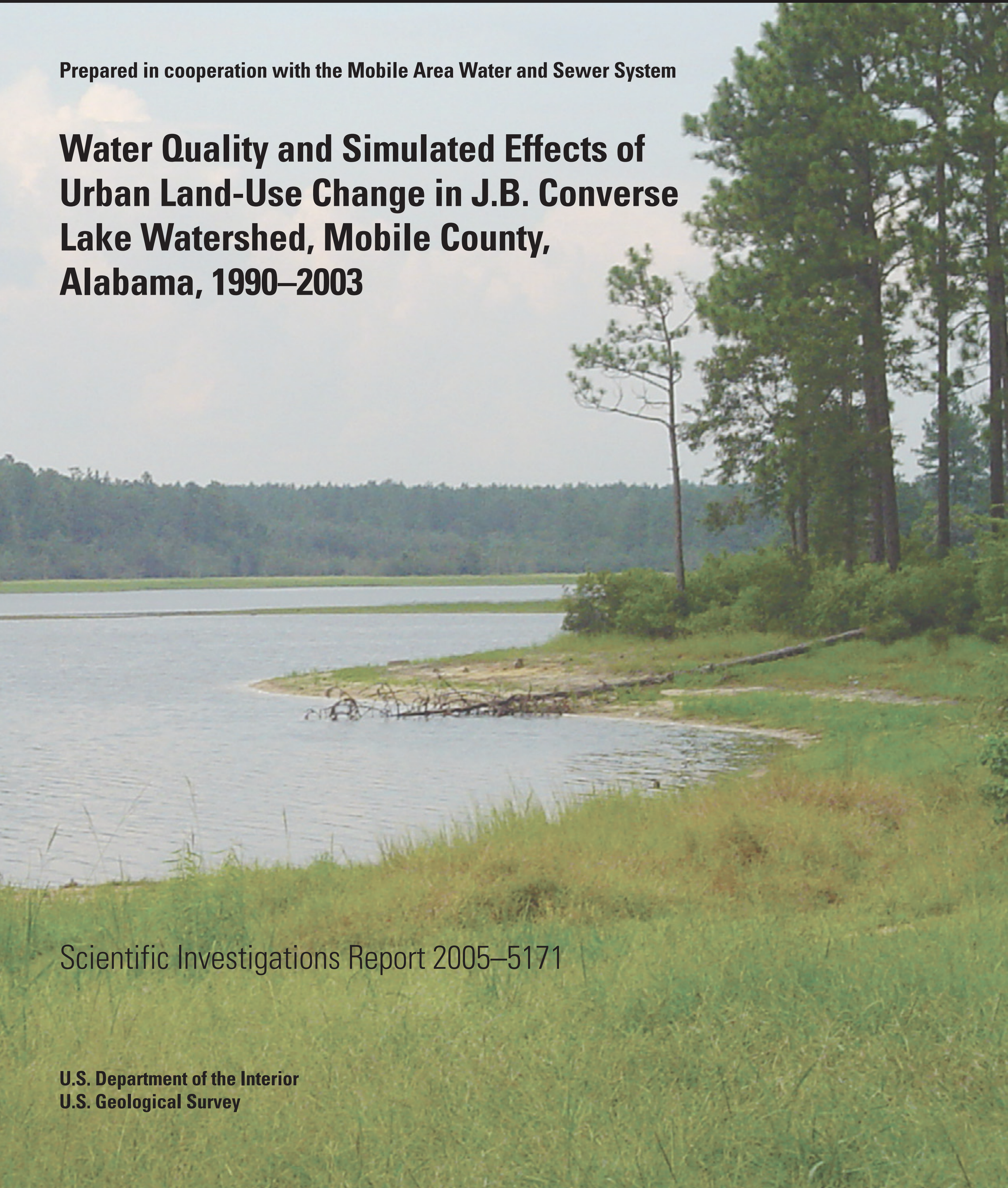

Prepared in cooperation with the Mobile Area Water and Sewer System

Water Quality and Simulated Effects of Urban Land-Use Change in J.B. Converse Lake Watershed, Mobile County, Alabama, 1990–2003

Scientific Investigations Report 2005–5171

U.S. Department of the Interior
U.S. Geological Survey

Cover. J.B. Converse Lake from the Howells Ferry Road boat landing, Mobile, Alabama.

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By Amy C. Gill, Ann K. McPherson, and Richard S. Moreland

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Conversion Factors, Datums, and Acronyms and Abbreviations

To convert Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

To convert SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
	Volume	
liter (L)	0.2642	gallon (gal)
cubic hectometer (hm^3)	810.7	acre-foot (acre-ft)
	Flow rate	
cubic hectometer per year (hm^3/yr)	811.03	acre-foot per year (acre-ft/yr)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
kilogram per year (kg/yr)	2.205	pound per year (lb/yr)
	Application rate	
kilogram per hectare per year [(kg/ha)/yr]	0.8921	pound per acre per year [(lb/acre)/yr]
kilogram per square kilometer per year [(kg/km^2)/yr]	0.00892	pound per acre per year [(lb/acre)/yr]

Temperature may be converted as follows:

$$°F = (1.8 \times °C) + 32$$

$$°C = (°F - 32) / 1.8$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Acronyms and Abbreviations

ADEM	Alabama Department of Environmental Management
AHTN	6-acetyl-1,1,2,4,4,7-hexamethyltetraline
AMLE	adjusted maximum likelihood estimator
ANOVA	analysis of variance
BHA	3-*tert*-butyl-4-hydroxyanisole
BHT	2-6-di-*tert*-butyl-*p*-cresol
col/100 mL	colonies per 100 milliliters
DEET	*N,N*-diethyl-*m*-toluamide
DBP	disinfection by-product
E. coli	*Escherichia coli*
GIS	geographic information system
HAL	lifetime health advisory
HHCB	1,3,4,6,7,8,-hexahydro-4,6,6,7,8,8-hexamethyl-cyclopenta(γ)-2-benzopyran
HTPL	high-performance liquid chromatography
LOWESS	locally weighted scatterplot smoothing
MADS	Mobile Atmospheric Deposition Station
MAWSS	Mobile Area Water and Sewer System
MCL	maximum contaminant level
MDL	minimum detection limit
mg/L	milligram per liter
MRL	minimum reporting level
MRLC	Multi-Resolution Land Characteristic
MVUE	minimum variance unbiased estimator
NP1EO	nonylphenol monoethoxylate
NP2EO	nonylphenol diethoxylate
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
OP1EO	octylphenol monoethoxylate
OP2EO	octylphenol diethoxylate
OWC	organic wastewater compound
OWQRL	Ocala Water Quality and Research Laboratory
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TSI	trophic state index
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
µg/L	microgram per liter

Water Quality and Simulated Effects of Urban Land-Use Change in J.B. Converse Lake Watershed, Mobile County, Alabama, 1990–2003

By Amy C. Gill, Ann K. McPherson, and Richard S. Moreland

Abstract

J.B. Converse Lake, a 3,600-acre manmade reservoir in western Mobile County, Alabama, is used as a source of drinking water for the city of Mobile, and for recreational fishing. The watershed of the lake is predominantly rural. Residential and commercial development is expanding westward from the city of Mobile, however, and the potential for water-quality changes as a result of land-use change is of concern in the J.B. Converse Lake watershed.

Tributary and lake water-quality data were collected during 1998–2003 and used with previously collected (October 1990–June 1998) data to assess water-quality conditions, identify temporal trends, and calibrate the BATHTUB reservoir water-quality model. Selected stream and lake samples were analyzed for concentrations of fecal-indicator bacteria and a group of wastewater-indicator compounds to aid in identifying sites receiving wastewater contamination. The calibrated BATHTUB model was used to predict lake response to changing land use in the watershed.

Median nutrient concentrations and trophic state indicators measured in the tributaries and lake in the study area during 1998–2003 were compared to U.S. Environmental Protection Agency criteria for streams and lakes, respectively, in the Southeastern Plains ecoregion. Tributary median concentrations exceeded the total Kjeldahl nitrogen criterion (300 micrograms per liter) at Jackson Branch, Crooked Creek at Wulff Road, and Hamilton Creek below Semmes; the nitrite plus nitrate criterion (95 micrograms per liter) at all sites except Jackson Branch; the total nitrogen criterion (395 micrograms per liter) at all sites except Collins Creek, Boggy Branch, and Hamilton Creek below Semmes; and the total phosphorus criterion (22.5 micrograms per liter) at Crooked Creek at Wulff Road and Juniper Creek at Coleman Dairy Road. Median nutrient concentrations exceeded the total nitrogen criterion (329 micrograms per liter), the total Kjeldahl criterion (320 micrograms per liter), and the nitrite plus nitrate method detection limit (20 micrograms per liter) at some lake sampling sites. Median total phosphorus concentrations, in contrast, were below the ecoregion criterion of 10 micrograms per liter at all lake sites. Median Secchi depths exceeded the criterion of 2.041 meters at all but one lake site, indicating good water clarity. Median chlorophyll *a* concentrations exceeded the fluorometric chlorophyll *a* criterion (5.125 micrograms per liter) at the intake to the water treatment system and at one other site in the lake.

The range of tributary total organic carbon concentrations, 0.4 to 13 milligrams per liter, was similar to the range of concentrations observed at the lake sites, 0.4 to 9.2 milligrams per liter. Tributary concentrations appeared to be greater in the predominantly forested watersheds of Big Creek and Jackson Branch, but no statistically significant correlation was found between forested land-use area and 1998–2003 organic carbon concentrations. Lake organic carbon concentrations and chlorophyll *a* concentrations were not significantly correlated, even though the occurrence of greater organic carbon concentrations during late summer indicated a potential algal source.

Trend analyses of nutrient concentrations in Big, Crooked, and Hamilton Creeks during 1990–2003 indicated only a few statistically significant changes in nutrient concentrations. Flow adjusted and unadjusted total and dissolved inorganic nitrogen concentrations exhibited significant decreasing long-term trends of about 0.01 milligram per liter per year at Crooked Creek near Fairview.

Annual nutrient loads and yields were calculated for Big, Crooked, and Hamilton Creeks. Mean annual instream nutrient loads were greater in Big Creek than in Crooked or Hamilton Creeks. Nutrient loads for all three creeks generally were influenced by nonpoint sources. Seasonal influences on nutrient loads were less apparent. In contrast, mean annual yields generally were greater for Crooked and Hamilton Creek watersheds than the Big Creek watershed, reflecting the greater prevalence of agricultural and urban land uses in the Crooked and Hamilton Creek watersheds.

Fecal coliform and *Escherichia coli* test results indicated smaller concentrations of fecal-indicator bacteria in the lake than in the tributaries. Maximum concentrations in the tributaries were well above the single-sample maximum criteria established by the Alabama Department of Environmental Management and U.S. Environmental Protection Agency for public water supplies and full-body contact. Median concentrations of fecal indicator bacteria were below these criteria at all tributary sites. Two lake sites each had elevated concentrations of fecal indicator bacteria in a single sample. Subsequent sampling at the two lake sites did not indicate recurring concentrations above criteria.

Eighty-six samples from throughout the J.B. Converse Lake watershed were analyzed for a group of organic wastewater compounds commonly found in wastewater and urban runoff. Twenty-nine of 87 compounds were detected in at least one sample in the J.B. Converse Lake watershed. Ten of the detected compounds have been identified as potential endocrine disruptors. Organic wastewater compounds were detected in 64 percent of the samples collected in the J.B. Converse Lake watershed; potential endocrine disruptors were detected in 29 percent of the samples. Organic wastewater compound detection frequencies from the J.B. Converse Lake watershed were lower than detection frequencies in the nearby Threemile Creek watershed and in a nationwide reconnaissance study.

The BATHTUB model was calibrated using tributary and lake water-quality data from the 2001–03 growing seasons (April–September). The calibrated model was used to predict changes in lake nutrient concentrations, trophic state, and frequency of algal blooms resulting from increases in urban land use. Based on estimated nutrient loading rates, total phosphorus and total nitrogen loads to the lake would be expected to increase by 156 and 39.1 percent, respectively, if 100 percent of the developable land in the watershed were urbanized. BATHTUB simulations indicated changes in trophic state and increases in algal bloom frequency in response to loading increases of this magnitude. Simulated trophic state indices calculated from phosphorus and chlorophyll *a* concentrations and from Secchi depths indicated increases in trophic state in shallower lake segments. Simulations indicated that moderate to severe algal blooms (defined by chlorophyll *a* concentrations greater than or equal to 30 micrograms per liter) can occur in some areas of the lake on as many as 8 days during the growing season.

Introduction

The Mobile Area Water and Sewer System (MAWSS) owns and operates J.B. Converse Lake, hereafter referred to as Converse Lake, as a drinking-water source for the city of Mobile and recreational fishing lake. A series of cooperative studies have been conducted from 1990 through June 1998 by the MAWSS and the U.S. Geological Survey (USGS) in the Converse Lake watershed to help ensure the continued supply of high quality water (Journey and others, 1995; Journey and Gill, 2001). Water-quality monitoring since June 1998 was designed to help in understanding the relation between tributary and lake water quality. As part of these studies, streamflow and concentrations of nitrogen and phosphorus have been monitored in selected tributaries to the lake, allowing the computation of nutrient loads and yields from each tributary. Observed spatial variation in nutrient yields has been attributed largely to local differences in land use.

Agricultural and urban land uses usually contribute greater nutrient loads to receiving streams than forested areas. Excessive loadings of nitrogen and phosphorus to lakes can trigger excessive algal growth, which can, in turn, cause other water-quality changes resulting in greater water treatment costs. When Big Creek was impounded to form Converse Lake in 1952, the 103-square mile (mi^2) watershed was predominantly rural and remains so today. Land-use data from 1992 indicate that the watershed was about 60 percent forested and only about 3 percent urbanized. Residential and commercial development is increasing in the watershed, however, and the potential for water-quality changes resulting from land-use changes is cause for concern in the Converse Lake watershed.

Eutrophication is a natural process of increasing nutrient enrichment and biological productivity that can be accelerated by anthropogenic land uses. The degree of eutrophication in a waterbody is referred to as the trophic state, which can be estimated from water-quality measures, such as total phosphorus, transparency or Secchi depth, and chlorophyll *a*. Eutrophication can cause water-quality problems of concern for drinking-water production.

Nutrient-enriched lake conditions can cause changes in the type and number of algal cells (U.S. Environmental Protection Agency, 2000c), and algal blooms, or excessive growth, can occur (Wehr and Sheath, 2003). Increases in algal growth tend to increase turbidity, particulate organic matter, dissolved organic compounds, and pH. As lake nutrient concentrations rise, natural algal populations tend to shift toward the cyanobacteria, or blue-green algae (Clark and others, 1977; Walker, 1983). Blue-green algae are undesirable in drinking-water supplies because some release compounds that can cause taste and odor problems in the finished water, and many have been shown to produce toxins (Walker, 1983; Wehr and Sheath, 2003). These changes in source-water quality can cause greater filtration and disinfection efforts and costs (Clark and others, 1977; Walker, 1983).

Greater in-lake biological productivity also can increase formation of disinfection by-products during treatment to produce drinking water. Disinfection by-products (DBPs) are compounds formed by the interaction of disinfectants with naturally occurring compounds. Studies have shown a link between the incidence of bladder, rectal, and colon cancers and exposure to DBPs (U.S. Environmental Protection Agency, 2001, 2003). Total organic carbon concentrations in source water are correlated to the formation of DBPs (Walker, 1983; Bayne and others, 1998; Journey and Gill, 2001), which prompted the U.S. Environmental Protection Agency (USEPA) to mandate the reduction of total organic carbon in source water (U.S. Environmental Protection Agency, 2001).

BATHTUB (Walker, 1999), an empirical reservoir water-quality model, was used to simulate current (2001–03) and future conditions in Converse Lake. Nitrogen and phosphorus export rates for various types of land use have been measured and were used to estimate future nutrient loads. Approximate changes in nutrient loads as a result of land-use changes were calculated and used in the calibrated BATHTUB model to predict corresponding changes in lake water quality. BATHTUB simulations can be used to assess the potential for deleterious water-quality changes in Converse Lake resulting from land-use change in the watershed.

Purpose and Scope

To address concerns over the effects of land-use change on lake water quality, the MAWSS and USGS began a new cooperative study in 1998 to better understand the effects of watershed loadings on water quality in Converse Lake. The goals of this study were to (1) monitor current (1998–2003) tributary and lake water quality, (2) assess changes and trends in water quality in the period 1990 through 2003, (3) use tributary water-quality data from the entire period (1990–2003) to calibrate a reservoir water-quality model to observed 2001–03 lake conditions, and (4) use the calibrated model to predict the effects of future land-use changes. This report presents a summary of water-quality monitoring data collected from July 1998 to September 2003, trend analyses of watershed nutrient and bacteria concentrations for 1990–2003, calibration of the empirical reservoir model (BATHTUB) to lake water-quality data collected in the growing seasons (April–September) of 2001–03, and projected water-quality changes based on predictive use of the BATHTUB model. Summaries of water-quality data used in the calibration of the BATHTUB model also include data from previous periods of monitoring (1990–98).

As part of the assessment of 1998–2003, water-quality samples collected throughout the watershed were analyzed for a suite of organic wastewater compounds. Many of these chemicals commonly are found in human sewage, and their presence in a waterbody indicates contamination from sewage effluent. Sources of other compounds include transportation, rubbish, industrial activities, and agricultural applications. Many of these compounds are of additional concern in a drinking-water supply because they are known to disrupt animal endocrine systems. The organic wastewater compound data are summarized in this report to aid in identifying areas of the watershed that may be receiving contamination from various human activities and to assess the levels of endocrine-disrupting compounds that were detected.

The results of the investigation presented herein advance the understanding of two high-priority science issues identified by the USGS—drinking-water quality and the effects of urbanization on water resources (U.S. Geological Survey, 1999). The results of this study can be used by local and State agencies to better protect and manage Converse Lake, the drinking-water supply for the city of Mobile. In addition, the data presented herein can be used to better define the range of water-quality changes that can result from increased urbanization in similar watersheds across the region and throughout the Nation. The organic wastewater compound results provide an important first look at the concentrations of these emerging contaminants not only in the Converse Lake watershed but also in rural areas of Alabama. Organic wastewater compound data collected during this study, in combination with results from other similar studies across the Nation, will provide a better understanding of the factors influencing the occurrence and concentrations of these compounds.

Description of the Study Area

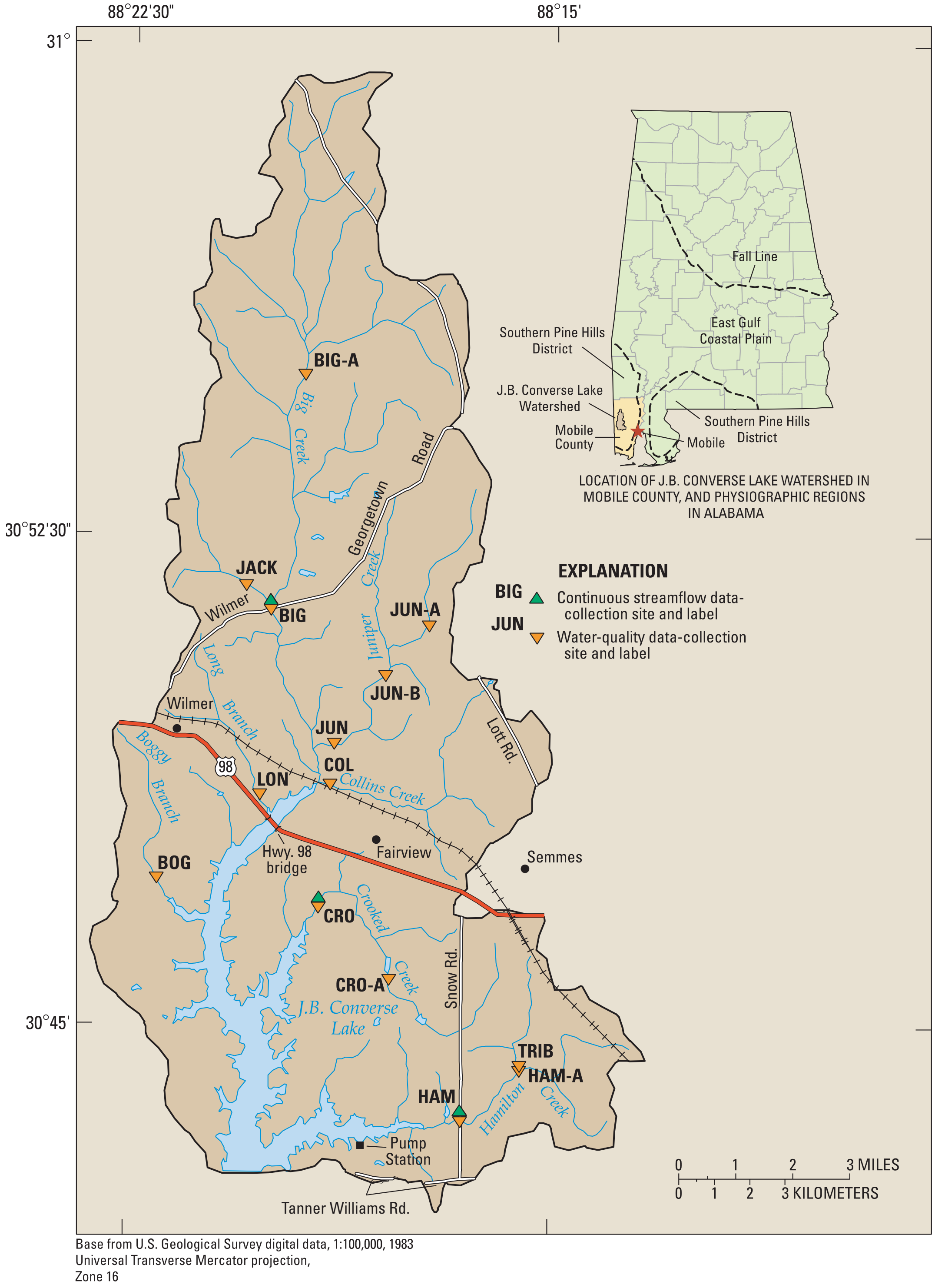
Converse Lake is a 3,600-acre manmade reservoir that serves as the primary source of drinking water for the city of Mobile. The lake and its 103-mi^2 watershed are located in western Mobile County in southwestern Alabama (fig. 1). Although a brief description of the watershed is given in this report, a more detailed description of the physical characteristics of the Converse Lake watershed is presented in Journey and Gill (2001). Sampling sites, sampled constituents, and numbers of samples for 1998–2003 are listed in table 1; and the locations of data-collection sites are shown in figures 1 and 2.

Converse Lake was created in 1952 by the impoundment of Big Creek, which is the major source of inflow. Other tributaries to the lake include Juniper, Collins, Crooked, and Hamilton Creeks and Boggy and Long Branches (fig. 1). Streamflow is an important component of load computation and has been monitored continuously at each of the major tributaries to Converse Lake during all or part of 1990–2003. Mean annual streamflow for each of the tributaries is presented in table 2. Big, Crooked, and Hamilton Creeks contributed about 70 percent of the measured inflow to the lake during the 1991 water year[1] (Journey and Gill, 2001), and streamflow in these three streams has been monitored continuously since 1990.

Streamflow-duration curves illustrate the frequency that a specific stream discharge is equaled or exceeded. Duration curves constructed for Big, Crooked, and Hamilton Creeks for the entire 1990–2003 period of record (fig. 3) show little change from the duration curves presented by Journey and Gill (2001, fig. 8) for 1990–98. Flow in Hamilton and Crooked Creeks is less variable than flow in Big Creek, and Hamilton Creek continues to have the greatest sustained flow. Instantaneous streamflow at sample-collection times can be compared to the duration curves to differentiate between high- and low-flow samples.

---

[1] Water year is the period October 1 through September 30 and is identified by the year in which the period ends. Thus, the 1991 water year began on October 1, 1990, and ended on September 30, 1991.



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection,
Zone 16

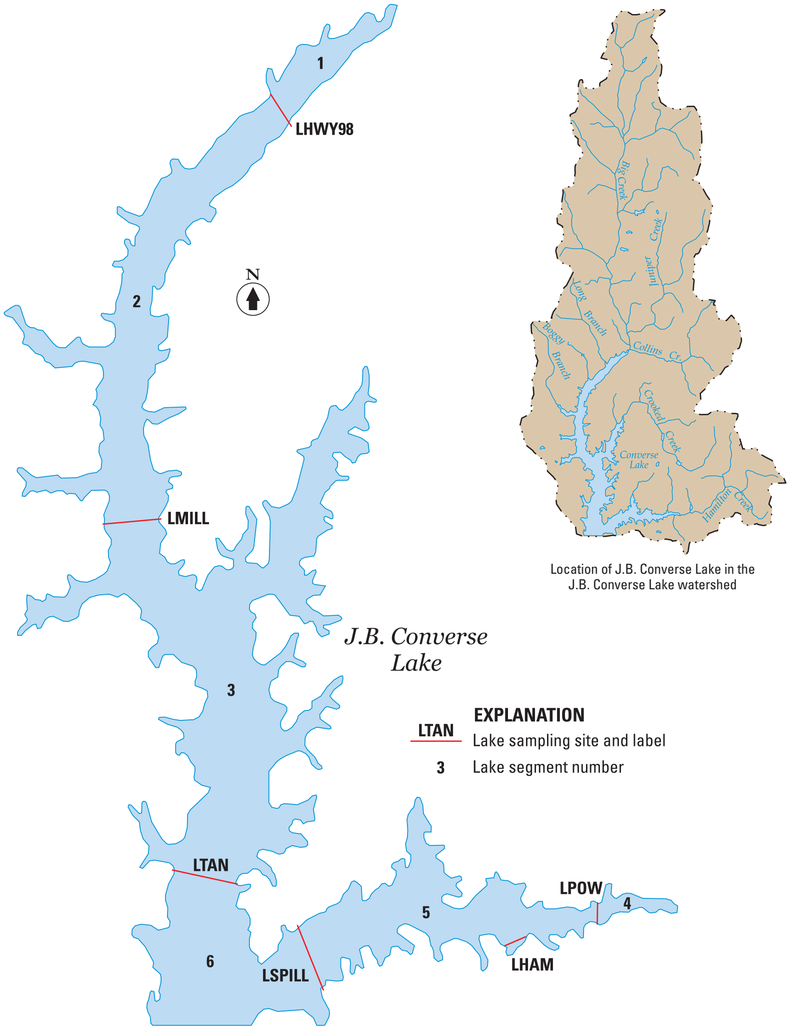
Figure 1. Locations of tributary data-collection sites in the J.B. Converse Lake watershed in Mobile County, Alabama, 1990–2003.

Table 1. Data-collection sites and number of samples in the Converse Lake watershed, Alabama, 1998–2003[a].

[USGS, U.S. Geological Survey; mi^2, square mile; S, stream site; L, lake cross section; —, not applicable]

Site label (figs. 1, 2)	USGS station number	Site name	Type of site	Used in model development	Latitude	Longitude	Drainage area (mi^2)	Number of samples		
								Nutrients and bacteria (1998–2003)	Organic carbon (1998–2003)	Wastewater indicators (1999–2002)
BIG-A	02479940	Big Creek at Mason Ferry Road	S	No	30°54'56"	88°19'27"	14.2	4	4	1
JACK	02479944	Jackson Branch at Howard Morris Road	S	No	30°51'43"	88°20'28"	3.41	11	7	1
BIG	02479945	Big Creek at County Road 63 near Wilmer	S	Yes	30°51'21"	88°20'02"	31.5	18	12	2
JUN-A	0247994650	Juniper Creek at Jack Williams Road near Georgetown	S	No	30°51'07"	88°17'14"	2.94	12	7	11
JUN-B	02479947	Juniper Creek at Coleman Dairy Road near Wilmer	S	No	30°50'20"	88°17'59"	7.02	12	7	11
JUN	02479948	Juniper Creek at Glenwood Road near Fairview	S	Yes	30°49'17"	88°18'53"	9.22	16	11	11
COL	02479950	Collins Creek at Glenwood Road near Fairview	S	Yes	30°48'40"	88°18'57"	8.54	11	11	7
LON	02479955	Long Branch near Wilmer	S	Yes	30°48'30"	88°20'12"	2.85	7	7	0
LHWY98	02479957	J.B. Converse Lake at U.S. Highway 98	L	Yes	30°48'05"	88°19'58"	—	20	9	1
BOG	02479960	Boggy Branch near Wilmer	S	Yes	30°47'13"	88°22'01"	3.17	11	11	1
LMILL	02479965	J.B. Converse Lake at Mill Branch	L	Yes	30°45'44"	88°20'52"	—	20	8	0
CRO-A	02479975	Crooked Creek at Wulff Road near Semmes	S	No	30°45'41"	88°17'52"	3.59	7	7	6
CRO	02479980	Crooked Creek near Fairview	S	Yes	30°46'48"	88°19'08"	8.08	19	12	7
LTAN	0248000010	J.B. Converse Lake at Old Tanner Williams Road	L	Yes	30°43'36"	88°20'23"	—	19	7	0
TRIB	0248000050	Unnamed tributary to Hamilton Creek at Firetower Road near Semmes	S	No	30°44'23"	88°15'33"	2.54	4	4	3
HAM-A	02480001	Hamilton Creek below Semmes	S	No	30°44'18"	88°15'33"	5.95	7	7	7
HAM	02480002	Hamilton Creek at Snow Road near Semmes	S	Yes	30°43'33"	88°16'35"	8.22	20	12	11
LPOW	02480003	J.B. Converse Lake—Hamilton Creek Embayment at powerline	L	Yes	30°43'25"	88°17'46"	—	19	8	1
LHAM	02480004	J.B. Converse Lake—Hamilton Creek Embayment at pumping station	L	Yes	30°43'15"	88°18'15"	—	20	17	5
LSPILL	02480009	J.B. Converse Lake—Hamilton Creek Embayment at Spillway	L	Yes	30°45'07"	88°19'41"	—	20	9	0

[a] For additional information, including period of record, see Psinakis and others, 2004.



Location of J.B. Converse Lake in the J.B. Converse Lake watershed

Figure 2. Converse Lake data-collection sites and segments used for the BATHTUB model in Mobile County, Alabama.

The climate in the study area is subtropical, with mild winters and hot, humid summers. Temperatures are usually above freezing even in winter. Most rainfall occurs in the summer months and is associated with tropical systems moving across the region. Climatological information for the lake-modeling period (2001–03 water years) is summarized in table 3. Mean annual precipitation for 1971–2000 at the Mobile Regional Airport was 66.29 inches (in.; fig. 4; Southeast Regional Climate Center, 2005a). Rainfall during the growing season (April–September) was extremely low in 2001, near average in 2002, and well above average in 2003. Higher rainfall amounts can cause higher rates of runoff and loading to streams from nonpoint sources. Annual and growing season departures from 30-year normals for the 3-year modeling period, 2001–03, are shown in figure 4 (Southeast Regional Climate Center, 2005b).

The most recent detailed land-use data available for this study were the 1992 Multi-Resolution Land Characteristics (MRLC) geographic information system (GIS) coverages (U.S. Environmental Protection Agency, 1992; fig. 5). Subwatershed land use is summarized by area (in hectares (ha), which are used to report nutrient yields) and percentages in table 4. Land use in the Converse Lake watershed is dominated by forest; but agricultural, especially plant nurseries and pasture, and residential land uses also are substantial, particularly in the tributary subwatersheds of Hamilton and Crooked Creeks. Much of the land surrounding Converse Lake is covered by a combination of evergreen and deciduous forest (Journey and Gill, 2001).

The S. Palmer Gaillard pumping station with lake site LHAM in the foreground.

Ann McPherson, USGS

Table 2. Streamflow conditions in selected tributaries to Converse Lake, Alabama, October 1990–September 2003.

[mi^2, square mile; ft^3/s, cubic foot per second; —, not applicable]

Site label (fig. 1)	Station number	Station name	Drainage area (mi^2)	Period of record (water years)	Streamflow characteristics (ft^3/s)				
					Mean annual	1991 water year	10-percent exceedance	50-percent exceedance	90-percent exceedance
BIG	02479945	Big Creek at County Road 63 near Wilmer	31.5	1991–2003	61.5[a]	94.1	129[a]	36[a]	15[a]
JUN	02479948	Juniper Creek at Glenwood Road near Fairview	9.22	1991–1992	17.7[b]	20.9	28[b]	14[b]	10[b]
COL	02479950	Collins Creek at Glenwood Road near Fairview	8.54	1991–1992	15.7[b]	18.1	24[b]	13[b]	9.2[b]
LON	02479955	Long Branch near Wilmer	2.85	1991	—	6.76[c]	—	—	—
BOG	02479960	Boggy Branch near Wilmer	3.17	1991	—	9.43[c]	—	—	—
CRO	02479980	Crooked Creek near Fairview	8.08	1991–2003	17.3[a]	21.8	26[a]	12[a]	7.3[a]
HAM	02480002	Hamilton Creek at Snow Road near Semmes	8.22	1991–2003	21.9[a]	24.5	29[a]	16[a]	11[a]
	Total		71.58	—	—	196	—	—	—

[a] Data published in Psinakis and others (2004).

[b] Data published in Pearman and others (1993).

[c] Data published in Pearman and others (1992).

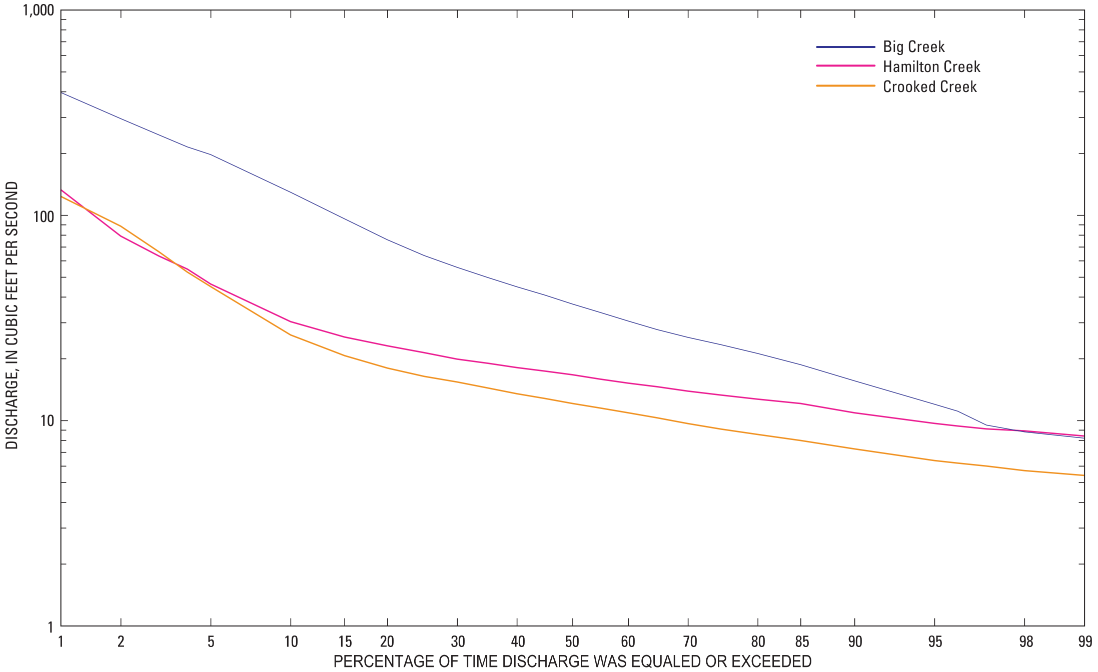


Figure 3. Streamflow duration curves for Big Creek, Crooked Creek, and Hamilton Creek in the Converse Lake watershed, 1990–2003.

Table 3. Climatological data for Mobile, Alabama.

[°F, degree Fahrenheit; in., inch; USGS, U.S. Geological Survey; —, not available]

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual total	Growing season total
Mean temperature (°F) (1971–2000)[a]	67.7	58.9	52.3	50.1	53.5	60.2	66.1	73.5	79.3	81.5	81.3	77.2	—	—
Mean precipitation (in.) (1971–2000)[a]	3.25	5.41	4.66	5.75	5.1	7.2	5.06	6.1	5.01	6.54	6.2	6.01	66.29	34.92
Monthly total precipitation (in.) for 2001 water year[a]	0.47	11.54	3.8	4.08	2.7	11.04	0.88	1.52	5.99	8.55	9.49	2.59	62.65	29.02
Monthly total precipitation (in.) for 2002 water year[a]	3.53	1.24	2.83	3.52	2.87	6.08	1.74	4.45	4.24	9.38	5.02	12.94	57.84	37.77
Monthly total precipitation (in.) for 2003 water year[a]	8.35	4.92	8.97	.55	5.57	4.3	3.59	9.51	20.66	9.48	5.17	1.57	82.64	49.98
2001 departure from mean (1971–2000)[a]	-2.78	6.13	-0.86	-1.67	-2.4	3.84	-4.18	-4.58	0.98	2.01	3.29	-3.42	-3.64	-5.9
2002 departure from mean (1971–2000)[a]	.28	-4.17	-1.83	-2.23	-2.23	-1.12	-3.32	-1.65	-.77	2.84	-1.18	6.93	-8.45	2.85
2003 departure from mean (1971–2000)[a]	5.1	-.49	4.31	-5.2	.47	-2.9	-1.47	3.41	15.65	2.94	-1.03	-4.44	16.35	15.06
USGS raingage monthly precipitation (in.) for 2002[b]	—	—	—	—	—	7.07	1.83	3.78	7.18	8.19	7.22	13.2	48.47	41.4
USGS raingage monthly precipitation (in.) for 2003[b]	10.84	4.51	9.61	0.26	5.96	4.69	3.36	7.45	18.47	7.55	9.24	2.21	84.15	48.28

[a] Data from Southeast Regional Climate Center.

[b] Data from U.S. Geological Survey National Water Information System database.

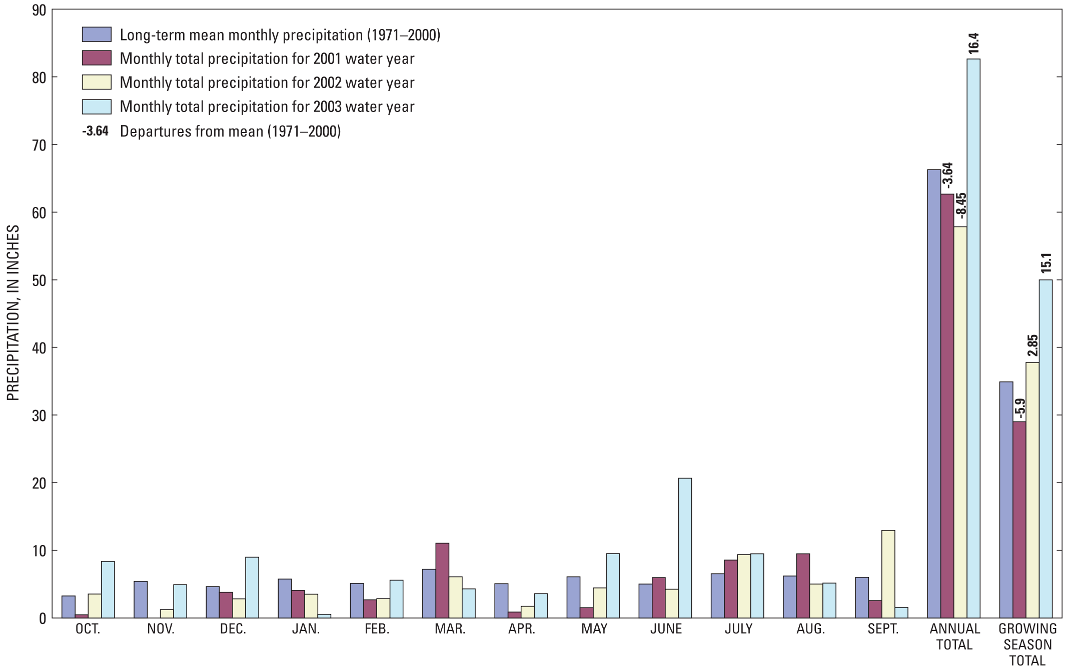


Figure 4. Monthly total precipitation (2001–03), long-term (1971–2000) mean monthly precipitation, and annual and growing-season departures (2001–03) from normal at the Mobile Regional Airport, Mobile, Alabama.

Will S. Mooty, USGS

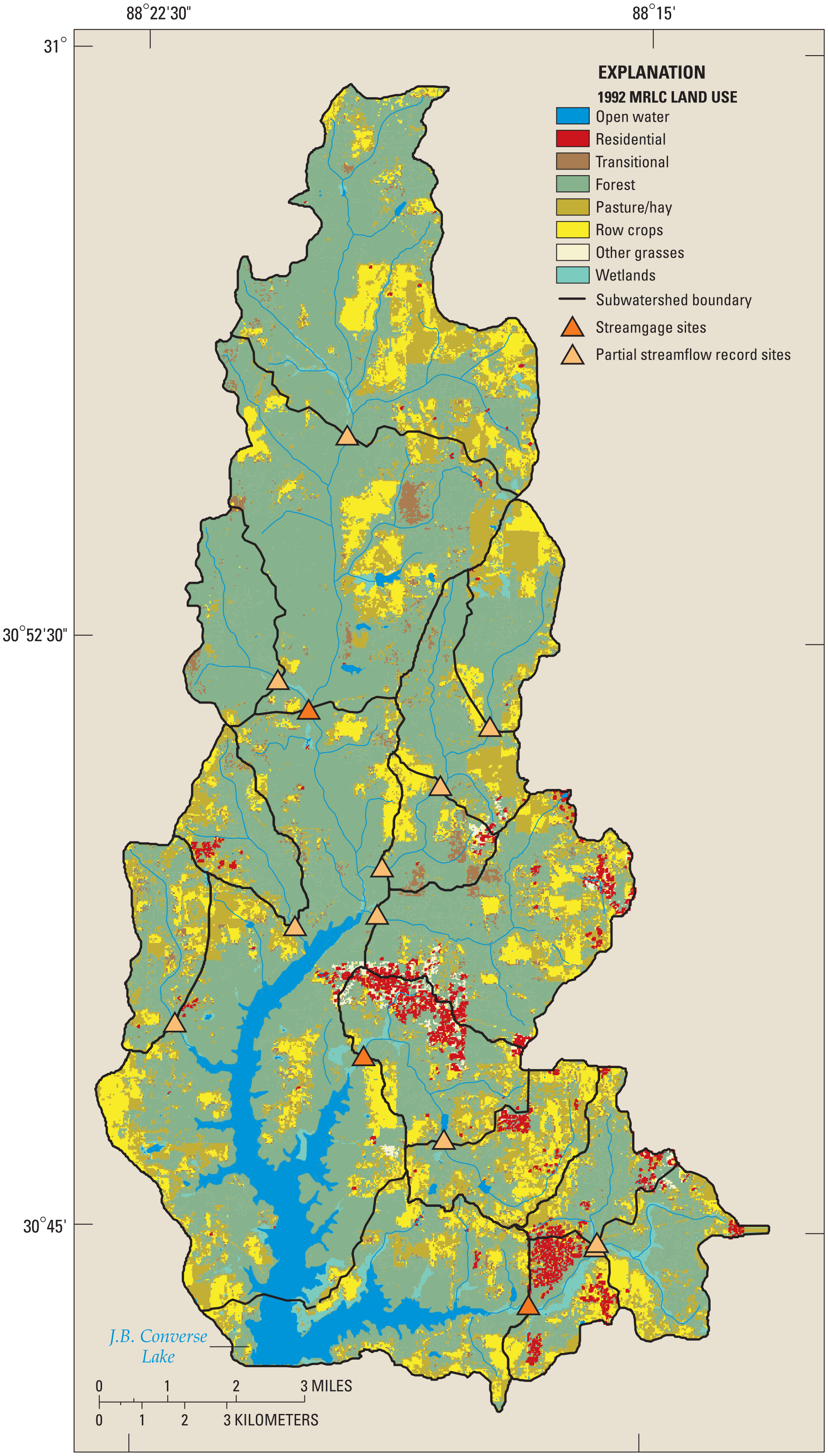
USGS stage recorder and raingage installation in the Hamilton Creek embayment of J.B. Converse Lake at the pumping station.

The MAWSS owns and maintains over 3,230 ha of land surrounding the reservoir (Mobile Area Water and Sewer System, 2004). In an effort to safeguard the reservoir and drinking water supply, the MAWSS has limited development in these areas, resulting in the creation of a protective buffer encircling the reservoir. The sampling site on Jackson Branch (JACK), a small tributary to Big Creek draining a predominantly forested subwatershed, was used as an indicator site of background conditions in the Converse Lake watershed because of limited anthropogenic effects in the subwatershed. Field observations indicate that residential land use has increased in the watershed since 1992, but more recent land-use data with resolution comparable to the MRLC are not yet available.

Loadings of nutrients and sediment are known to increase as land is converted from forest to more urban uses, and the increased nutrient loads often fuel excessive algal growth in receiving waterbodies. The population in unincorporated areas of Mobile County, which includes the majority of the Converse Lake watershed, increased by 3 percent between 2000 and 2002 (U.S. Census Bureau, 2002). As population growth continues, the conversion of forested and agricultural land to residential and commercial land uses is expected.

Previous Investigations

Nutrient export rates per unit area, or nutrient yields, were calculated previously for different land uses (Reckhow



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection,
Zone 16

Figure 5. General land uses in the Converse Lake watershed, Alabama, 1992.

Table 4. Areas of generalized land-use types in selected tributary subwatersheds of the Converse Lake watershed, Alabama.

[From 1992 Multi-Resolution Land Characteristics (MRLC) data; ha, hectare; U.S. Environmental Protection Agency (1992)]

Site	Open water (MRLC code 11)		Developed (MRLC codes 21,22,23,31,33)		Forest (MRLC codes 41,42,43)		Agricultural						Wetlands (MRLC codes 91,92)		Watershed total	
							Pasture (MRLC codes 81, 85)		Row crops (MRLC code 82)		Total					
	Area of sub-water-shed (ha[a,b])	Percent of sub-water-shed	Area of sub-water-shed (ha[a,b])	Percent of sub-water-shed	Area of sub-water-shed (ha[a,b])	Percent of sub-water-shed	Area of sub-water-shed (ha[a,b])	Percent of sub-water-shed	Area of sub-water-shed (ha[a,b])	Percent of sub-water-shed	Area of sub-water-shed (ha[a,b])	Percent of sub-water-shed	Area of sub-water-shed (ha[a,b])	Percent of sub-water-shed	Area of sub-water-shed (ha[a,b,c])	Percent of sub-water shed[d]
BIG-A	2.97	0.08	44.16	1.19	2,476.97	66.96	581.98	15.73	550.86	14.89	1,132.84	30.63	42.01	1.14	3,698.95	100
JACK	.27	.03	19.88	2.29	817.47	93.99	25.28	2.91	6.03	.69	31.31	3.60	.81	.09	869.74	100
BIG	19.07	.24	178.55	2.22	5,859.57	72.97	1,016.98	12.66	891.14	11.10	1,908.12	23.76	65.13	.81	8,030.43	100
JUN-A	.27	.03	5.94	.64	513.80	55.55	227.67	24.62	158.31	17.12	385.98	41.73	18.89	2.04	924.88	100
JUN-B	.27	.01	25.19	1.33	1,182.94	62.31	434.37	22.88	236.75	12.47	671.12	35.35	18.89	1.00	1,898.41	100
JUN	.54	.02	87.16	3.56	1,508.12	61.51	502.56	20.50	334.71	13.65	837.27	34.15	18.89	.77	2,451.98	100
COL	.81	.04	129.71	5.89	1,304.02	59.23	460.91	20.94	306.01	13.90	766.92	34.84	.00	.00	2,201.46	100
LON	.18	.02	22.93	3.07	499.95	67.00	163.35	21.89	58.11	7.79	221.46	29.68	1.62	.22	746.14	100
BOG	.54	.07	27.52	3.45	462.26	57.97	208.24	26.11	95.62	11.99	303.86	38.11	3.24	.41	797.41	100
CRO-A	3.15	.32	31.39	3.22	339.56	34.77	343.88	35.22	254.02	26.01	597.90	61.23	4.50	.46	976.51	100
CRO	4.23	.19	116.40	5.33	1,008.26	46.18	640.45	29.33	390.39	17.88	1,030.84	47.21	23.66	1.08	2,183.39	100
TRIB	.72	.11	33.01	4.97	385.26	58.00	159.39	24.00	81.58	12.28	240.97	36.28	4.32	.65	664.29	100
HAM-A	.18	.02	14.03	1.61	468.55	53.88	201.04	23.12	128.09	14.73	329.13	37.85	57.66	6.63	869.55	100
HAM	2.16	.10	110.37	5.17	1,107.39	51.90	469.45	22.00	331.47	15.54	800.92	37.54	112.80	5.29	2,133.64	100
Unmonitored areas	1,217.66	14.42	100.03	1.18	4,820.01	57.06	1,111.53	13.16	944.12	11.18	2,055.65	24.34	253.39	3.00	8,446.73	100
Converse Lake watershed[c]	1,245.19	4.61	772.67	2.86	16,569.55	61.39	4,573.46	16.94	3,351.56	12.42	7,925.02	29.36	478.72	1.77	26,991.15	100

[a] To convert hectares to square miles, multiply by 0.003861.

[b] To convert hectares to acres, multiply by 2.471.

[c] Total determined from geographic information system coverage. Due to rounding, total may not exactly equal the sum of individual component land-use areas reported.

[d] Due to rounding, total may not exactly equal 100.

and others, 1980). All 1991 total phosphorus yields in the Converse Lake watershed were within the observed range from Reckhow and others (1980) for forested land uses, although Hamilton, Crooked, and Juniper Creeks had greater total phosphorus yields than the other sites. Available land-use data indicate that greater areas of urban land use in Crooked and Hamilton Creeks may be responsible for elevated total phosphorus yields in these watersheds. Total nitrogen yields at all sites in the study area were within the range expected for predominantly forested watersheds with minor agricultural or urban influences (Journey and Gill, 2001).

Journey and Gill (2001) reported that nutrient concentrations remained stable at most tributary sites during the period 1990–98. Slight decreasing trends were identified for organic nitrogen at Crooked and Hamilton Creeks, total Kjeldahl nitrogen at Collins and Hamilton Creeks, and dissolved inorganic nitrogen at Crooked Creek. A slight upward trend in total phosphorus was also identified at Long Branch.

The Reservoir Water Quality Monitoring Program of the Alabama Department of Environmental Management (ADEM) uses the Carlson (1977) trophic state index (TSI), calculated from chlorophyll *a* concentrations, to evaluate the trophic state of 32 publicly accessible lakes and reservoirs across the State of Alabama (Alabama Department of Environmental Management, 2004). The majority of TSI values measured in Converse Lake by the ADEM from 1985 to 2001 indicated mesotrophic or eutrophic conditions. In 2002 and 2003, the ADEM ranked 23 lakes in Alabama, including Converse Lake, as eutrophic. The TSI values from Carlson (1977) related to particular trophic states are listed in table 5.

Previous studies of Converse Lake indicate that the dominant source of DBP precursors is terrestrial plants (Bayne and others, 1998; Journey and Gill, 2001). Bayne and others (1998) noted a significant correlation between chlorophyll *a* concentrations, used as a surrogate for algal biomass, and concentrations of total trihalomethanes in the finished water from Converse Lake during 1996 through 1998. As land-use changes continue to occur, increased algal growth may become another important source of disinfection by-product precursors and make compliance with the Stage 1 Disinfectants and Disinfection By-Products Rule (U.S. Environmental Protection Agency, 2001) more difficult.

Acknowledgments

The authors wish to thank MAWSS personnel Mr. Bennie White and the rest of the staff of the S. Palmer Gaillard Pumping Station for their assistance in providing lake access and data needed for calibrating and using the BATHTUB model. In addition, the authors greatly appreciate the assistance of Jerad Bales, of the USGS North Carolina Water Science Center, in developing and calibrating the model. Technical assistance provided by Celeste Journey, Callie Oblinger, and Dale Robertson, of the USGS also is appreciated.

Approach and Methods

Water-quality samples were collected during 1998–2003 at 20 sites in the Converse Lake watershed and analyzed for several constituents (table 1). Seven of these sites (BIG, JUN, COL, LON, BOG, CRO, and HAM) are on major tributaries to Converse Lake and have been sampled since 1990 by the USGS in cooperation with the MAWSS. Data from these seven sites and from six cross sections in the lake (LHWY98, LMILL, LTAN, LPOW, LHAM, and LSPILL) were used in developing the BATHTUB model. Data from seven additional sites along tributaries to Converse Lake (BIG-A, JACK, JUN-A, JUN-B, CRO-A, TRIB, and HAM-A) were included in the wastewater-indicator analysis (table 1). Streamflow and nutrient concentration data were collected to support the development and calibration of the BATHTUB reservoir water-quality model, extend the long-term

Table 5. Trophic state index values related to changes in lake water quality.

[From Carlson (1977) and modified from Journey and Gill (2001); <, less than; >, greater than]

Trophic state index values	Trophic state classification	Lake characteristics
<40	Oligotrophic	Clear water. Sparse macrophyte growth. Many algal species, but low algal biomass.
40–50	Mesotrophic	Moderately clear water. Water quality changes due to reduction of oxygen in unmixed layer of lake.
50–60	Eutrophic	Anoxic conditions in unmixed layer. Increased macrophyte growth. Algal species less diverse.
60–70		Dominant algal groups change from greens and diatoms to blue-greens. Increased algal and macrophyte biomass.
>70	Hypereutrophic	Dense algal and macrophyte growth.

monitoring dataset, and re-evaluate trends over time. Bacteria concentrations in samples were evaluated to monitor fecal contamination and assess trends in bacteria concentrations during 1990–2003 at selected sites. Total and dissolved organic carbon concentrations were measured to determine temporal and spatial patterns of occurrence in the watershed. Wastewater-indicator compound data were collected to provide information about contamination from human sources and to assess the occurrence of selected endocrine disruptors throughout the watershed.

Water-Quality Sampling

Fourteen stream sampling sites and six lake sampling sites were monitored during 1998–2003 (figs. 1, 2). The site locations and numbers and the types of samples collected at each site are summarized in table 1. Lake sampling was conducted primarily during the April–September growing seasons of 2001–03 to provide the trophic response data required for development of the BATHTUB model.

Sample-collection procedures varied based on the type of site and the constituent. Most of the water-quality samples were analyzed at the USGS Ocala Water Quality and Research Laboratory (OWQRL), in Ocala, Florida. Samples for organic wastewater compounds were analyzed by the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, using a method described below and in Brown and others (1999). Bacteria samples were processed by USGS Alabama Water Science Center personnel in the field using membrane filtration techniques outlined in Myers and Wilde (1999). Fecal coliform bacteria were cultured on m-FC media, and *Escherichia coli* (*E. coli*) were cultured on m-TEC media. Chlorophyll *a* concentrations were determined at the OWQRL by using standard method 10200H, a high-performance liquid chromatography (HPLC) method (American Public Health Association, 1995). All data collected during this investigation with the exception of the organic wastewater compound results are stored in the USGS National Water Information System (NWIS) and published in the USGS annual water-data reports for Alabama for water years 1998–2003 (Pearman and others, 1999, 2000, 2001, 2002, 2003; Psinakis and others, 2004).

Streamflow data also were collected at the 14 tributary sites. Streamflow was monitored continuously at gaging stations at sites BIG, CRO, and HAM, three tributaries to Converse Lake, during 1998–2003 (fig. 1; table 1). Instantaneous streamflow measurements were made at all other stream sites at the time of water-quality sampling.

Flow-weighted water samples from flowing stream sites were collected using equal-width increment methods and composited in a churn splitter as described in Wilde and others (1999a,b). Samples were analyzed for total and dissolved phosphorus, nitrite, nitrite plus nitrate, ammonia, ammonia plus organic nitrogen, and orthophosphate to estimate loadings to the lake. Additional samples were hand dipped at multiple points in the cross section and analyzed for concentrations of two types of fecal indicator bacteria—*E. coli* and fecal coliform—total and dissolved organic carbon, and organic wastewater compounds.

Six cross-section sites in the lake—LHWY98, LMILL, LTAN, LPOW, LHAM, and LSPILL (fig. 2)—were sampled for nutrient, bacteria, and organic carbon concentrations and trophic response. Lake samples were collected from at least three vertical sections of the water column (verticals) in each cross section. In-situ measurements of water temperature, dissolved oxygen concentration, specific conductance, and turbidity were made at multiple depths (usually at the surface and at 5-foot (ft) intervals) in each sampling vertical. A single Secchi-depth measurement was made at each cross section in the deepest vertical section.

Lake samples analyzed for total and dissolved phosphorus, nitrite, nitrite plus nitrate, ammonia, ammonia plus organic nitrogen, and orthophosphate were collected by dipping a weighted bottle sampler containing a 1-liter (L) polyethylene bottle. Samples were composited in a plastic churn splitter. Total and dissolved organic carbon concentrations and organic wastewater compound concentrations were assessed from samples collected and composited in 1-L baked-glass bottles from each of the verticals in the cross section. Chlorophyll *a*, *E. coli*, and fecal coliform concentrations at each lake cross-section site were determined from samples collected near the surface of the deepest vertical section.


Wyman Turner, USGS

USGS personnel collecting a sample at Converse Lake site LSPILL.

The method designed by the NWQL for organic wastewater compounds (OWCs) focuses on the determination of compounds that are indicators of wastewater or that have been chosen on the basis of their endocrine-disrupting potential or toxicity (Zaugg and others, 2002). OWCs were analyzed in unfiltered samples by continuous liquid-liquid extraction with methylene chloride and determined by capillary-column gas chromatography/mass spectrometry using selected-ion monitoring (Brown and others, 1999; Kolpin and others 2002). Information in Zaugg and others (2002) provides details about the specific wastewater-indicator compounds analyzed and their uses. The method designed by the NWQL for OWCs was under development during this investigation, and the final analysis of the associated method (lab code 8033) is pending (U.S. Geological Survey, 2003; S.D. Zaugg, U.S. Geological Survey, written commun., May 3, 2004).

Data Analysis and Review

Various graphical and statistical methods were used in this report to summarize data and facilitate comparisons between and among sites and criteria. Bar charts are used to compare rainfall amounts and constituent concentrations over time or between sites, and stacked bar charts also show the contributions of subgroups of constituents. Box plots show the distribution of the nutrient, organic carbon, chlorophyll *a*, and bacteria concentrations and Secchi depths in a graphical format that allows for easy comparison among sites. Watershed maps with graduated symbols illustrate the spatial variation of water-quality properties. Line plots, such as hydrographs, are used to show data variability over time or varying conditions. Scatterplots show the relation between two variables. Statistical analyses used in this report include (1) calculation of basic descriptive statistics, such as the minimum, maximum, median, and mean; (2) Kruskal-Wallis and Tukey multiple-comparison tests; (3) Spearman rho correlation; and (4) least-squares regression.

Statistical analyses of the nutrient and organic carbon data required that values be estimated below the detection limit. For load and trend computations, all nutrient concentrations reported below the detection limit were estimated at the detection limit. For all other statistical analyses, nutrient and organic carbon data reported below the detection limit were estimated to be one half the detection limit. Total nitrogen, total inorganic nitrogen, and total organic nitrogen concentrations were calculated from measured concentrations of appropriate constituent nitrogen species. When the necessary nitrogen species data were below detection limits, total nitrogen, total inorganic nitrogen, and total organic nitrogen concentrations were estimated using nitrogen species concentrations estimated to be one half the detection limit. Remark codes indicating non-ideal counts or problems with bacterial growth media or culture are stored with bacteria concentration data in the NWIS. In this report, remark codes for bacteria were ignored, and the reported bacteria concentrations were used for statistical analyses.

The Kruskal-Wallis test and the Tukey multiple-comparison test were used to evaluate whether nutrient loads and yields for each site were significantly different from nutrient loads and yields at other sites (SAS Institute, Inc., 1989). The Kruskal-Wallis test is a one-way nonparametric analysis of variance (ANOVA) that was used to determine whether significant differences in loads and yields existed between sites. The Tukey multiple-comparison test was then used to compare the differences in loads and yields between the individual sites. The simplest procedures for performing nonparametric multiple comparisons are rank transformation tests (Helsel and Hirsch, 1992). Ranks were substituted for the original data, and the Tukey multiple-comparison test was performed on the ranks. Groups of sites are indicated by letters—statistically similar sites are assigned the same letter, and statistically different sites are assigned different letters.

The Spearman rho correlation coefficient describes the linear relation between the ranks of two variables. Coefficients range from -1.0 to 1.0, and the closer the absolute value of the coefficient is to 1, the stronger the relation of the two variables. Negative coefficients indicate inverse relations, and positive coefficients indicate direct relations.

Linear regression was used to predict fecal coliform concentrations from *E. coli* concentrations. Least-squares estimation was used to find the straight line with the best fit. Bacteria concentrations were log-transformed to improve linearity before fitting the regression model. The *E. coli* are a subgroup of fecal coliform bacteria, so a relation between concentrations of the two bacteria is expected. The State bacteria criteria currently (2004) are based on the fecal coliform group, but the USEPA has recommended that criteria be based on concentrations of *E. coli* or enterococci, as these are more specific indicators of fecal contamination (U.S. Environmental Protection Agency, 2002b). A regression equation for fecal coliform and *E. coli* concentrations will aid in the study of trends in fecal indicator bacteria concentrations.

Median and maximum bacteria concentrations presented in this report were compared to criteria and standards developed by the ADEM and the USEPA for waters of various uses. The ADEM established a use-classification for State waters. Tributaries to Converse Lake are classified as suitable for fish and wildlife habitats, and the lake is classified as a public water supply. Bacterial standards for drinking water are enforceable and represent the maximum level of fecal indicator bacteria allowed in finished water. The criteria values for other water uses are suggested limits for fecal bacteria. All water-use classifications have fecal coliform criteria based on the maximum geometric mean bacterial density of five or more samples collected over 30 days at intervals of not less than 24 hours. Seasonal geometric mean criteria, which are effective June through September, apply to fish and wildlife and public water-supply uses. Geometric mean criteria are useful as benchmark indicators of water quality in the Converse Lake watershed even though samples for this study were not collected as frequently as required by the criteria. In addition, public water supply, fish and wildlife, and agricultural and industrial water-supply water-use classifications also have maximum single-sample fecal coliform concentrations.

Data from the Converse Lake watershed were compared to USEPA criteria to assess differences from background nutrient and trophic conditions. The USEPA has established criteria for nutrients in streams and for nutrients and trophic status indicators in lakes and reservoirs in the Southeastern Plains Level III ecoregion, which is part of nutrient ecoregion IX (U.S. Environmental Protection Agency, 2000a,b,c). These criteria are the 25th percentile of measured data in the ecoregion and are meant to serve as a starting point to define background conditions for waterbodies in the ecoregion. Criteria are available for (1) total Kjeldahl nitrogen concentrations, which are the sum of ammonia and organic nitrogen concentrations; (2) nitrite plus nitrate; (3) calculated total nitrogen; and (4) total phosphorus in lakes and streams, and for Secchi depth and chlorophyll *a* concentrations in lakes (U.S. Environmental Protection Agency, 2000a,b).

Criteria for chlorophyll *a* have been established by the USEPA for both fluorometric and spectrophotometric methods (U.S. Environmental Protection Agency, 2000a), but a criterion does not exist for the HPLC method (SM 10200 H. 4, American Public Health Association, 1995) used in this study. Results produced by the HPLC method have been shown to match spectrophotometric measurements within plus or minus 20 percent and agree well with fluorometric results (American Public Health Association, 1995). HPLC methods provide an accurate measurement of the chlorophyll *a* concentration. Many previously described relations between nutrient loading and chlorophyll *a* concentration, however, are based on data from the less accurate spectrophotometric methods, which are considered adequate for the estimation of algal biomass (U.S. Environmental Protection Agency, 2000c). In this report, chlorophyll *a* results from Converse Lake are compared to both of the existing chlorophyll *a* criteria.

The USEPA has established water-quality standards and guidelines for chemicals that can have adverse effects on human health, aquatic organisms, and wildlife (U.S. Environmental Protection Agency, 2002a). In this report, measured concentrations of organic wastewater compounds in the Converse Lake watershed are compared to drinking-water guidelines, drinking-water health advisories, or aquatic-life criteria. Many compounds, however, do not have established guidelines. Some compounds that are known to be toxic to aquatic life currently are unregulated, even though some are on the USEPA Toxic Substance Control Act Priority Testing List (U.S. Environmental Protection Agency, 1996; Zaugg and others, 2002).

Load Estimation and Analysis of Trends

Annual and monthly instream loads of total nitrogen and total phosphorus were calculated as the product of daily streamflow and estimated daily concentration using the ESTIMATOR model (Cohn and others, 1989; Gilroy and others, 1990; Cohn and others, 1992). This model includes a seven-parameter log-linear regression analysis of constituent concentrations against measured environmental variables:

$$\ln(C) = \beta_0 + \beta_1[\ln(Q - Q')] + \beta_2[\ln(Q - Q')]^2 + \beta_3 (t - t') + \beta_4(t - t')^2 + \beta_5 \sin(2\pi t) + \beta_6 \cos(2\pi t) + \varepsilon, \quad (1)$$

where

ln = natural logarithm function,
C = concentration (in milligrams per liter),
β_0 to β_6 = coefficients of the regression model,
Q = instantaneous discharge (in cubic feet per second),
Q' = centering variable defined so that β_1 and β_2 are statistically independent,
t = time (in decimal years),
t' = centering variable defined so that β_3 and β_4 are statistically independent
sin = sine function,
cos = cosine function,
π = 3.14159, and
ε = model errors.

The regression analysis assumes that model errors (ε) are independent and normally distributed, with zero mean and variance. The minimum variance unbiased estimator (MVUE; Bradu and Mundlak, 1970) was included in the model to correct for the retransformation bias associated with log-linear regression models; the model also employs the adjusted maximum likelihood estimator (AMLE; Cohn, 1988), which statistically adjusts for censored data and multiple reporting limits.

Equation 1 results in an estimate of the daily logarithmic constituent concentrations. The estimated daily constituent concentration then is multiplied by the daily mean discharge to produce a daily mean load by using the following equation:

$$\ln[L_i] = Q_i \times \ln[C_i], \quad (2)$$

where

ln = natural logarithm function,
L_i = daily mean load (in kilograms per day),
i = any interval,
Q_i = daily mean discharge for that interval (in cubic feet per second), and
C_i = mean concentration (in milligrams per liter).

Trend analyses were performed on concentrations adjusted for streamflow using a statistical technique known as locally weighted scatterplot smoothing (LOWESS; Cleveland, 1979; Helsel and Hirsch, 1992). The LOWESS trend lines illustrate relations between concentrations and streamflow that are difficult to discern in a simple scatterplot. The LOWESS trend line is computed by fitting a weighted least-squares equation to the concentration and streamflow data (Helsel and Hirsch, 1992). The smoothing technique used to calculate the LOWESS trend line is particularly useful because no assumptions regarding linearity of the data are required. The smoothing algorithm uses nearby data points to calculate a smoothed value for every data point. Each nearby data point is weighted so that the more distant points affect the smoothed value less than points that are close. A line is then drawn through the smoothed values. The number of nearby points used to calculate a smoothed value is controlled by the smoothness factor. A smoothness factor of 0.5 means that the closest 50 percent of the data points were used to calculate each smoothed value. Residuals (differences between the LOWESS-fitted concentrations and measured concentrations) were computed and referred to as flow-adjusted nutrient concentrations. Changes in the flow-adjusted concentrations indicate changes in concentration over time that are independent of changes in streamflow.

Time-series flow-adjusted concentration plots were tested by using the seasonal Kendall test to detect the presence of trends (Hirsch and others, 1982). The seasonal Kendall test can be used to detect long-term changes in concentration, which may indicate long-term improvement or deterioration in stream quality. The seasonal Kendall test is based on the nonparametric Kendall's tau test (Kendall, 1975), which compares the relative values of all data values in a time series. In the seasonal Kendall test, comparisons between data values are restricted to pairs of data that are from the same time period annually; this period is defined as a season. Schertz and others (1991) recommend that the number of seasons reflect the years with the least number of samples. Quarterly sampling was the minimum sampling frequency during a year, so four seasons were selected for the analysis.

The seasonal Kendall test also was used for testing a null hypothesis of no trend (the nutrient concentration and its date of observation are independent of one another). A statistically significant trend is indicated when the null hypothesis obtained from the seasonal Kendall test has a probability level (*p*-value) of 0.05 or less. For example, a *p*-value of 0.05 means that there is a 5-percent chance of making an error when rejecting the null hypothesis. In this report, *p*-values less than or equal to 0.05 were considered statistically significant in indicating increasing or decreasing trends in nutrient concentrations.

Modeling Approach

Converse Lake morphometric data, tributary and precipitation inflow and nutrient concentrations, and mean observed lake water quality for the 2001, 2002, and 2003 growing seasons (April–September) were used to develop and calibrate the BATHTUB water-quality model. Although most distance, area, streamflow, and rainfall data are presented in English units in this report, model development data are presented in the units required for input to the BATHTUB model. Conversion factors are supplied at the front of this report and in affected tables.

The BATHTUB model was developed by the U.S. Army Corps of Engineers (USACE) Waterways Experiment Station using a water-quality dataset from reservoirs operated by the USACE (Walker, 1999). Relations between nutrient loading and response in the modeled lake are assumed to be similar to the relations in the model development dataset. A mass-balance approach is used in the BATHTUB model to compute water and nutrient balances, and a set of empirically derived models is used to predict trophic response variables from in-lake nutrient concentrations. BATHTUB simulates steady-state mean growing-season conditions only.

For modeling purposes, Converse Lake was divided into six segments (fig. 2). Segments 1, 2, 3, and 4 were bounded on the downstream sides by lake-sampling stations LHWY98, LMILL, LTAN, and LPOW, respectively. Segment 5 extended from site LPOW to LSPILL, but water-quality data for the segment were based on data from LHAM. Segment 6 was bounded by LTAN and LSPILL, and water quality was assumed to be equal to water quality observed at LSPILL. Lake segment morphometry measures are listed in table 6. Segment surface area and length were determined from a GIS coverage of the lake. Mean depth was determined from data collected during a bathymetric survey of the lake in September 2003 and supplemented by depth observations made during

Table 6. Lake model segments and morphometric characteristics in Converse Lake, Mobile County, Alabama.

[km^2, square kilometer; km, kilometer; m, meter; hm^3, cubic hectometer]

Lake segment number	Lake segment name	Area (km^2)[a]	Length (km)[b]	Mean depth (m)[c]	Volume (hm^3)[d]	2002 residence time	
						Years	Days
1	Upper Lake	0.52	1.67	2	1.0	0.017	6
2	Mill Branch	3.03	5	5.4	16.4	.224	82
3	Crooked	5.7	5	6.4	36.5	.378	138
4	Upper Hamilton Arm	.15	.87	2	.3	.020	7
5	Pumping station	2.05	3.26	4.3	8.8	.110	40
6	Spillway	2.12	1.6	7.2	15.3	.152	55

[a] To convert square kilometers to square miles, multiply by 0.3861.

[b] To convert kilometers to miles, multiply by 0.6214.

[c] To convert meters to feet, multiply by 3.281.

[d] To convert cubic hectometers to acre-feet, multiply by 810.7.

routine water-quality sampling trips. Mixed-layer depth was determined from water-quality profile information collected at the time of sampling. Volumes were calculated from mean depth and area. Residence times were calculated in the BATHTUB model from growing season data.

Tributary inflows and nutrient loads for streamgaging stations were computed by dividing monthly load estimates from the ESTIMATOR program by mean monthly discharge. Mean nutrient concentrations for Juniper Creek were calculated from data collected during the water year. Mean nutrient concentrations for other ungaged sites were computed from period-of-record sampling data. Mean nutrient concentrations from the unmonitored areas adjacent to the lake were estimated to be equal to concentrations measured at the BIG site. The average streamflow rate per unit of drainage area at the three gaged streams—BIG, CRO, and HAM (fig. 1)—was used to calculate flow to the lake from the other stations and the unmonitored areas draining into the lake.

Nitrite plus nitrate, ammonia, and dissolved phosphorus concentrations in precipitation were measured from March 2001 to April 2002 at the Mobile Atmospheric Deposition Station (MADS), USGS site 304143088042200, located on the roof of the MAWSS offices in Mobile (Pearman and others, 2001, 2002). Concentrations of nitrite plus nitrate in precipitation ranged from the detection level 0.002 to 0.806 milligrams per liter (mg/L) with a median concentration of 0.23 mg/L. Ammonia concentrations ranged from 0.002 to 0.85 mg/L with a median concentration of 0.159 mg/L. Phosphorus concentrations in precipitation were generally low and ranged from 0.002 to 0.069 mg/L with a median concentration of 0.003 mg/L.

Concentrations of nutrients in rainwater reaching Converse Lake were estimated to be equal to mean concentrations for the entire period of record at the MADS. Precipitation amounts were assumed to be equal to recorded amounts at the Mobile Regional Airport (Southeast Regional Climate Center, 2005b). Atmospheric loads were obtained by multiplying mean concentrations by the volume of rainfall (table 7).

Ground water may be a substantial source of inflow to Converse Lake. A dedicated study has not been conducted to quantify the ground-water contribution to Converse Lake;

Table 7. Estimated annual atmospheric phosphorus and nitrogen loading to segments of Converse Lake, Alabama, 2001–03.

[km^2, square kilometer; (kg/km^2)/yr, kilogram per square kilometer per year; kg, kilogram]

		Phosphorus					
		2001		**2002**		**2003**	
Segment	**Area (km^2)[a]**	**Loading rate ([kg/km^2]/yr)**	**Annual atmospheric load (kg)**	**Loading rate ([kg/km^2]/yr)**	**Annual atmospheric load (kg)**	**Loading rate ([kg/km^2]/yr)**	**Annual atmospheric load (kg)**
1	0.52	8.9	2	8.2	4	11.8	6
2	3.03	8.9	27	8.2	25	11.8	36
3	5.7	8.9	51	8.2	47	11.8	67
4	.15	8.9	1	8.2	1	11.8	2
5	2.05	8.9	18	8.2	17	11.8	24
6	2.12	8.9	19	8.2	17	11.8	25
Total	13.57	8.9	121	8.2	111	11.8	160
		Nitrogen					
		2001		**2002**		**2003**	
Segment	**Area (km^2)[a]**	**Loading rate ([kg/km^2]/yr)**	**Annual atmospheric load (kg)**	**Loading rate ([kg/km^2]/yr)**	**Annual atmospheric load (kg)**	**Loading rate ([kg/km^2]/yr)**	**Annual atmospheric load (kg)**
1	0.52	766	398	708	368	1,012	526
2	3.03	766	2,321	708	2,145	1,012	3,066
3	5.7	766	4,366	708	4,036	1,012	5,768
4	.15	766	115	708	106	1,012	152
5	2.05	766	1,570	708	1,451	1,012	2,075
6	2.12	766	1,624	708	1,501	1,012	2,145
Total	13.57	766	10,395	708	9,608	1,012	13,733

[a] To convert square kilometers to square miles, multiply by 0.3861.

however, the RORA computer program (Rutledge, 1998) was used to estimate annual and quarterly ground-water contributions to streamflow in Big Creek (J.L. Robinson, U.S. Geological Survey, oral commun., 2004). RORA is based on the Rorabaugh-Daniel method of hydrograph separation and applies the recession-curve-displacement method to long-term streamflow record to estimate the mean rate of ground-water recharge (Rorabaugh, 1964; Daniel, 1976; Rutledge, 1998). The areal rate of ground-water discharge to Big Creek was assumed to be representative for the Converse Lake watershed and was used to approximate direct ground-water inflow to each lake segment. Because the BATHTUB model was calibrated for summer months, the April–June and July–September ground-water discharge estimates to Big Creek were used to calculate annual inflow rates for each year that was simulated (table 8). A rate of ground-water discharge was estimated for each year because ground-water inflow rates can vary from year to year based on rainfall variation. Estimated rates of inflow were entered into the BATHTUB model as flow into each lake segment.

Table 8. Rates of direct ground-water inflow to segments of Converse Lake, Alabama, 2001–03.

[km^2, square kilometer; hm^3/yr, cubic hectometer per year]

Lake segment	Area (km^2)[a]	Ground-water inflow rates 2001 (hm^3/yr)[b]	Ground-water inflow rates 2002 (hm^3/yr)[b]	Ground-water inflow rates 2003 (hm^3/yr)[b]
1	0.52	0.057	0.13	0.33
2	3.03	.33	.78	1.9
3	5.70	.63	1.5	3.6
4	.150	.17	.039	.095
5	2.05	.23	.53	1.3
6	2.12	.23	.54	1.3

[a] To convert square kilometers to square miles, multiply by 0.3861.

[b] To convert cubic hectometers per year to cubic feet per second, multiply by 1.12.

Mean nutrient and chlorophyll *a* concentrations for the lake were computed by using sampling data from April through September (growing season) of each year during 2001–03. Non-algal turbidity, a measure of the amount of turbidity from particulate matter other than algae, was estimated from measured Secchi depths and chlorophyll *a* concentrations by using the following equation:

$$(1/\ \mathrm{SD}) - 0.025 \times (\mathrm{Chl}\ a), \qquad (3)$$

where

SD = Secchi depth (in meters) and
Chl *a* = chlorophyll *a* concentration (in micrograms per liter).

Mean values of non-algal turbidity also were calculated for April through September of each simulated year. Coefficients of variation also were computed and used in the BATHTUB model to estimate the certainty of the observed water-quality measurements.

The calibrated model was used to assess the effects of nutrient loading reductions and increases caused by land-use changes in the Converse Lake watershed. Sampling data and literature values for nutrient loading from various land uses were used to estimate percentage changes in tributary nutrient loading resulting from various scenarios of land-use change in the Converse Lake watershed. Estimated percentage changes in loading were applied to the nutrient-concentration data for year 2002 and entered into the calibrated model. The model results indicated lake response to changes in loads.

Quality-Control Methods and Results

Quality-assurance and quality-control measures were practiced throughout the study in accordance with established USGS guidelines (Mueller and others, 1997; Wilde and others, 1999a,b). Laboratory and field blank samples were processed using water certified to contain undetectable concentrations of constituents to be analyzed. Data from blank samples were used to determine the extent of contamination potentially introduced during sampling, sample processing, shipping, or laboratory analyses.

Between July 1998 and September 2003, 49 blank samples were analyzed for this investigation, including 41 field blanks, 3 equipment blanks, and 5 blanks composed of de-ionized water from the USGS Alabama Water Science Center sample-processing area. De-ionized water is used for cleaning field collection and splitting equipment. Nutrient and most organic carbon field blank samples were analyzed by the OWQRL (appendix 1). Two equipment blanks and three de-ionized water blanks were analyzed by the NWQL. In all, 39 field blanks were analyzed for nutrient contamination, 22 field blanks were analyzed for organic carbon contamination, and 16 field blanks and 19 laboratory blanks associated with samples from this study were analyzed for organic wastewater compounds.

Environmental nutrient and organic carbon data were not censored on the basis of concentrations in blanks because the sources of contamination were unknown, contamination seemed to occur randomly, and environmental concentrations were small enough that censoring would have greatly reduced the information available for analysis. The occurrence of five nutrient species—total phosphorus, dissolved orthophosphorus, total nitrite plus nitrate, total Kjeldahl nitrogen, and total ammonia—and dissolved and total organic carbon in blank samples are summarized below.

Sixty-seven percent of nutrient field blank samples had no detectable levels of total phosphorus (appendix 1). The maximum detection of total phosphorus in a field blank was

0.02 mg/L in December 1998. Total phosphorus was detected at a level of 0.014 mg/L in one sample of de-ionized water during October 2002; however, subsequent sampling of the de-ionized water in December 2002 showed no evidence of phosphorus contamination.

Dissolved orthophosphorus was detected in three field blank samples. The maximum level of dissolved orthophosphorus contamination was 0.002 mg/L and was observed in July 2001. The two other dissolved orthophosphorus detections in field blank samples were at the minimum reporting level of 0.001 mg/L. Dissolved orthophosphorus was detected in the equipment blank and de-ionized water blank collected in July 2000. Both dissolved orthophosphorus concentrations were at the minimum reporting level.

Total nitrite plus nitrate was detected in only one field blank sample at a concentration of 0.16 mg/L in December 2000. Total Kjeldahl nitrogen was detected in 5 percent of the field blank samples, with a maximum concentration of 0.28 mg/L (in August 1999). Thirty-three percent of the field blank samples were contaminated with total ammonia; the maximum concentration was 0.07 mg/L in December 2000. There were no detections of total nitrite plus nitrate, total Kjeldahl nitrogen, or total ammonia in the equipment blanks or de-ionized water samples.

Total organic carbon was detected in over 50 percent of the blank samples, and the maximum concentration was 2.5 mg/L (in December 2000). Dissolved organic carbon also was detected in more than half of the blank samples, with a maximum detected concentration of 0.3 mg/L in blanks from June 2003 and August 2003.

The wastewater method is considered to be "information rich" (Childress and others, 1999) because compound identifications are determined by mass spectrometry; consequently, results are not censored at the minimum reporting level (MRL; Zaugg and others, 2002). The specific compounds included in the wastewater schedule and the MRLs varied among samples because of method refinement during the sampling period (1999–2002) and matrix interference. For compounds that meet qualitative criteria but whose concentrations are either less than the MRL or the lowest calibration standard (usually 0.05 microgram per liter (µg/L)), results are reported by using the "E" code to indicate that they have been estimated. All qualitatively identified compounds detected less than the MRL are reported as estimated (Zaugg and others, 2002).

The concentrations of 16 wastewater compounds (table 9) always are reported as estimated for one of three reasons: unacceptable low-biased recovery (less than 60 percent) or highly variable method performance (greater than 25-percent relative standard deviation), unstable instrument response, or reference standards prepared from technical mixtures (Zaugg and others, 2002). Four of these compounds—octylphenol monoethoxylate (OP1EO), *para*-nonylphenol total, *d*-limonene, and nonylphenol diethoxylate (NP2EO)—were detected in blank samples in this study (appendix 2); two compounds (OP1EO and *para*-nonylphenol total) were detected in stream or lake samples (appendix 3).

Wastewater-indicator data were censored according to the detection level of constituents found in laboratory and field blanks. If a constituent was detected at the same magnitude in either a laboratory blank or a field blank and also in a stream sample during the same sampling trip, the detection was not included. In addition, concentrations of phenol were censored at 1 µg/L because of documented problems associated with contamination (S.D. Zaugg, U.S. Geological Survey, written commun., June 8, 2004). The NWQL analyzed 16 field blanks and 19 laboratory blanks associated with samples from this study. Twenty-two compounds were detected in at least one blank sample (appendix 2). Twelve compounds were detected in at least 1 of the 16 field blanks; 17 compounds were detected in at least 1 of the 19 laboratory blanks (appendix 2). Seventeen of 40 detections in laboratory and field blanks were greater than the corresponding MRL associated with the sample (appendix 2). These low-level detections indicate some potential for contamination of stream samples, especially for compounds with documented problems, such as phenol.

Table 9. Wastewater compounds reported as estimated (E) because of low recovery, high variable recovery, unstable instrument response, or because the reference standard is from a technical mixture.

[Zaugg and others, 2002]

Compound
1,4-Dichlorobenzene[a]
17ß-Estradiol[a]
3-*tert*-Butyl-4-hydroxyanisole (BHA)[a]
Bromoform[a]
Carbaryl[b]
Dichlorvos[a]
d-Limonene[a]
Equilenin[a]
Estrone[a]
Isopropylbenzene (cumene)[a]
Nonylphenol diethoxylate (NP2EO)[c]
Octylphenol diethoxylate (OP2EO)[c]
Octylphenol monoethoxylate (OP1EO)[c]
para-Nonylphenol (total)[c]
Pentachlorophenol[b]
Tetrachloroethylene[a]

[a] Concentration is estimated because recovery is less than 60 percent or variability is greater than 25 percent relative standard deviation.

[b] Concentration is estimated because of unstable instrument response.

[c] Concentration is estimated because the reference standard is from a technical mixture.

Tributary Water Quality

Nutrient and organic carbon concentrations are summarized below for all tributary sites sampled from June 1998 through September 2003. Tributary sites BIG-A, JACK, JUN-A, JUN-B, CRO-A, TRIB, and HAM-A are located upstream from other monitoring sites (fig. 1) and were used only to assess spatial variability in constituent concentrations rather than to estimate loadings to the lake. Because continuous streamflow information is necessary for load computations, loads were calculated only for the BIG, CRO, and HAM sites (fig. 1).

Nutrient Concentrations

Nutrient concentrations in the tributaries to Converse Lake were compared to criteria established by the USEPA for waterbodies in the Southeastern Plains ecoregion (U.S. Environmental Protection Agency, 2000a,b; table 10). These criteria are guidelines meant to be indicative of background water quality and were established from sample data collected throughout the ecoregion. Criteria are available for four constituents collected in streams during this study: (1) total Kjeldahl nitrogen (TKN), which is the sum of ammonia and organic nitrogen; (2) nitrite plus nitrate; (3) calculated total nitrogen; and (4) total phosphorus. Total inorganic nitrogen and dissolved orthophosphate concentrations also are summarized because they were used in the BATHTUB model.

Water-quality samples collected at three sites in the Juniper Creek watershed (JUN-A, JUN-B, and JUN; fig. 1) during a March 2001 storm contained the highest concentrations of nutrients and bacteria measured at these sites. Sampling during similar storm events was not conducted at the other sites in the Converse Lake watershed. When a storm is represented in a small sampling dataset, the mean constituent concentrations may be positively skewed. For this reason, mean nutrient concentrations used in the BATHTUB model for Juniper Creek for 2001 were calculated without including the storm sample, because the Juniper Creek 2001 dataset was very small (three samples per site).

Median concentrations of TKN in tributaries to Converse Lake ranged from the detection limit of 200 to 400 µg/L (figs. 6, 7). Median concentrations of TKN exceeded the USEPA criterion of 300 µg/L at sites JACK, CRO-A, and HAM-A (fig. 6). Median concentrations of nitrite plus nitrate ranged from 20 µg/L at JACK to 830 µg/L at JUN-B. Median concentrations of nitrite plus nitrate at all sites except JACK, the most forested subwatershed, exceeded the USEPA criterion of 95 µg/L. Median concentrations of total nitrogen ranged from 320 µg/L at site COL to 1,020 µg/L at site JUN-B, and exceeded the USEPA criterion for total nitrogen at all sites except COL, BOG, and HAM-A. Median concentrations of total inorganic nitrogen ranged from 40 µg/L at JACK to 835 µg/L at JUN-B. Nitrogen concentrations at most locations in the Converse Lake watershed were elevated above the background concentrations estimated by the USEPA for the Southeastern Plains ecoregion. The forested subwatershed site (JACK) had the lowest nitrite plus nitrate concentrations but had organic nitrogen concentrations sufficient to make it similar to other sites in terms of total nitrogen.

Median values of total phosphorus in the watershed ranged from 3 µg/L at site HAM to 34 µg/L at site CRO-A and 30 µg/L at site JUN-B (figs. 8, 9). The minimum total phosphorus concentration at site CRO-A (24 µg/L) was greater than the median concentrations at all other sites except JUN-B, indicating that total phosphorus concentrations were elevated above background concentrations at site CRO-A. The greatest total phosphorus concentration measured in the Converse Lake watershed was 870 µg/L during the first flush runoff event at site JUN-B. Median total phosphorus concentrations exceeded the USEPA criterion of 22.5 µg/L at sites CRO-A and JUN-B (fig. 8).

Orthophosphate is the form of phosphorus most easily used as a nutrient by plants and, therefore, is a cause of nuisance algal growth. Dissolved orthophosphate concentrations in the watershed were frequently below the method reporting limit of 1 µg/L, and the only sites with minimum concentrations above the reporting limit were JUN-B and CRO-A (fig. 8). The two maximum dissolved orthophosphate concentrations observed were 170 µg/L during a storm and 104 µg/L during low flow at JUN-B.

Table 10. Nutrient criteria established by the U.S. Environmental Protection Agency for ambient water quality in the Southeastern Plains ecoregion.

[U.S. Environmental Protection Agency (2000a,b); µg/L, microgram per liter; m, meter; —, no criterion]

Site type	Total Kjeldahl nitrogen (µg/L)	Nitrite plus nitrate (µg/L)	Total nitrogen, calculated (µg/L)	Total phosphorus (µg/L)	Secchi depth (m)	Chlorophyll *a* (µg/L)
Streams and rivers	300	95	395	22.5	—	—
Lakes and reservoirs	320	9	329	10	2.041	5.125[a] 1.873[b]

[a] Fluorometric criterion.

[b] Spectrophotometric criterion.

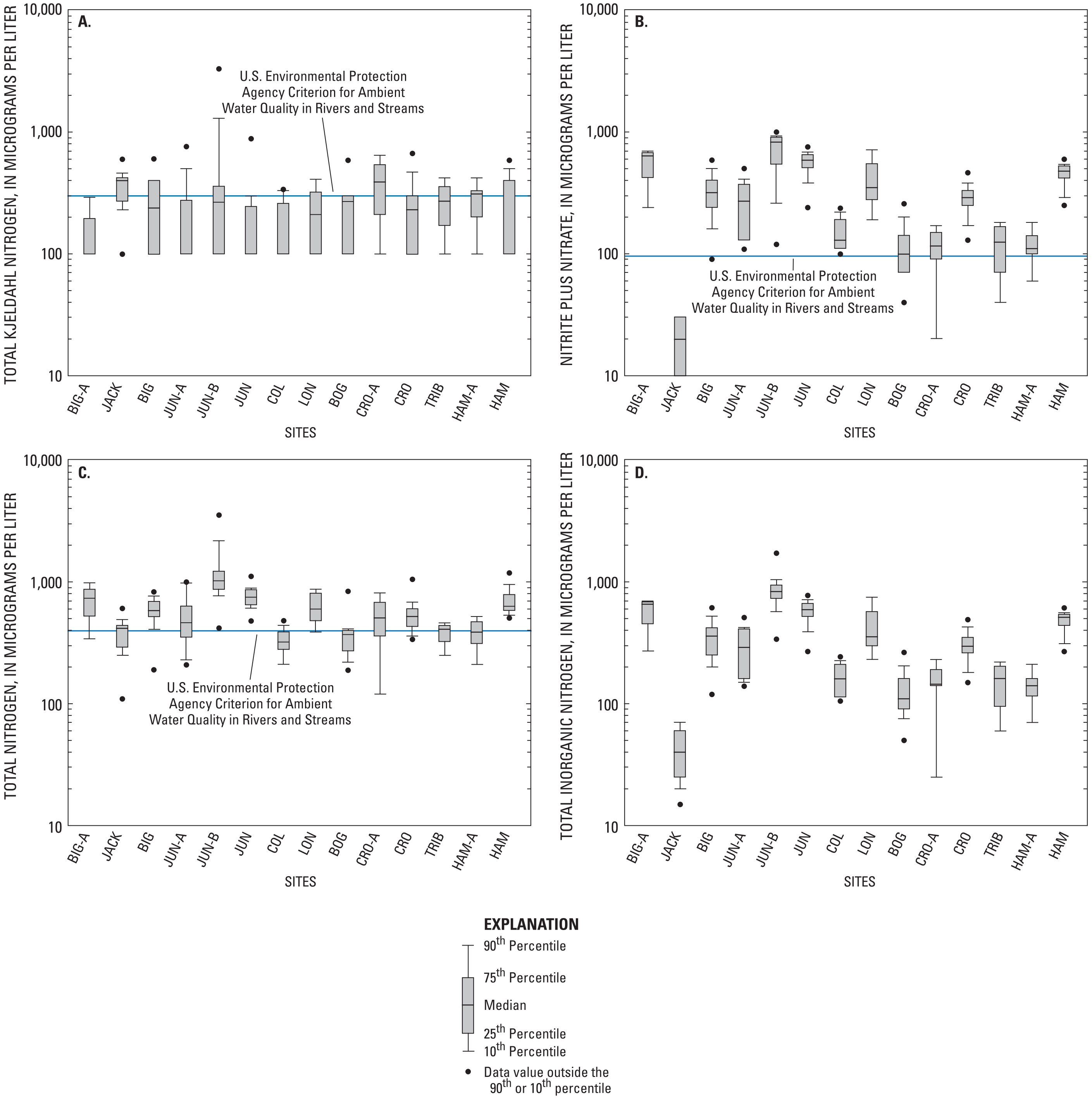
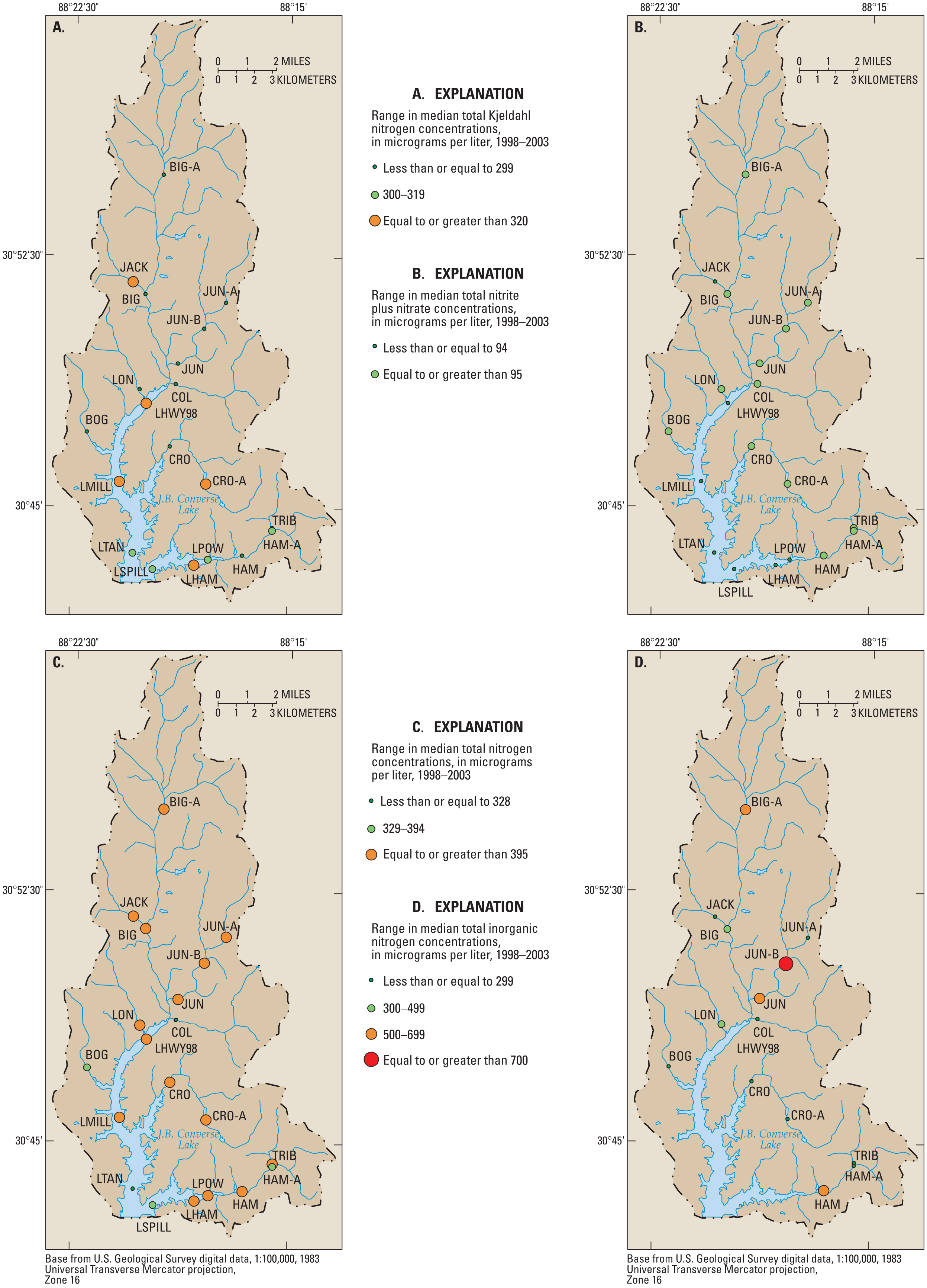


Figure 6. (A) Total Kjeldahl nitrogen, (B) nitrite plus nitrate, (C) total nitrogen, and (D) total inorganic nitrogen concentrations at selected tributary sites in the Converse Lake watershed, Alabama, 1998–2003.



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection,
Zone 16

Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection,
Zone 16

Figure 7. Median concentrations of (A) total Kjeldahl nitrogen, (B) nitrite plus nitrate, (C) total nitrogen, and (D) total inorganic nitrogen concentrations at selected sites in the Converse Lake watershed, Alabama, 1998–2003.

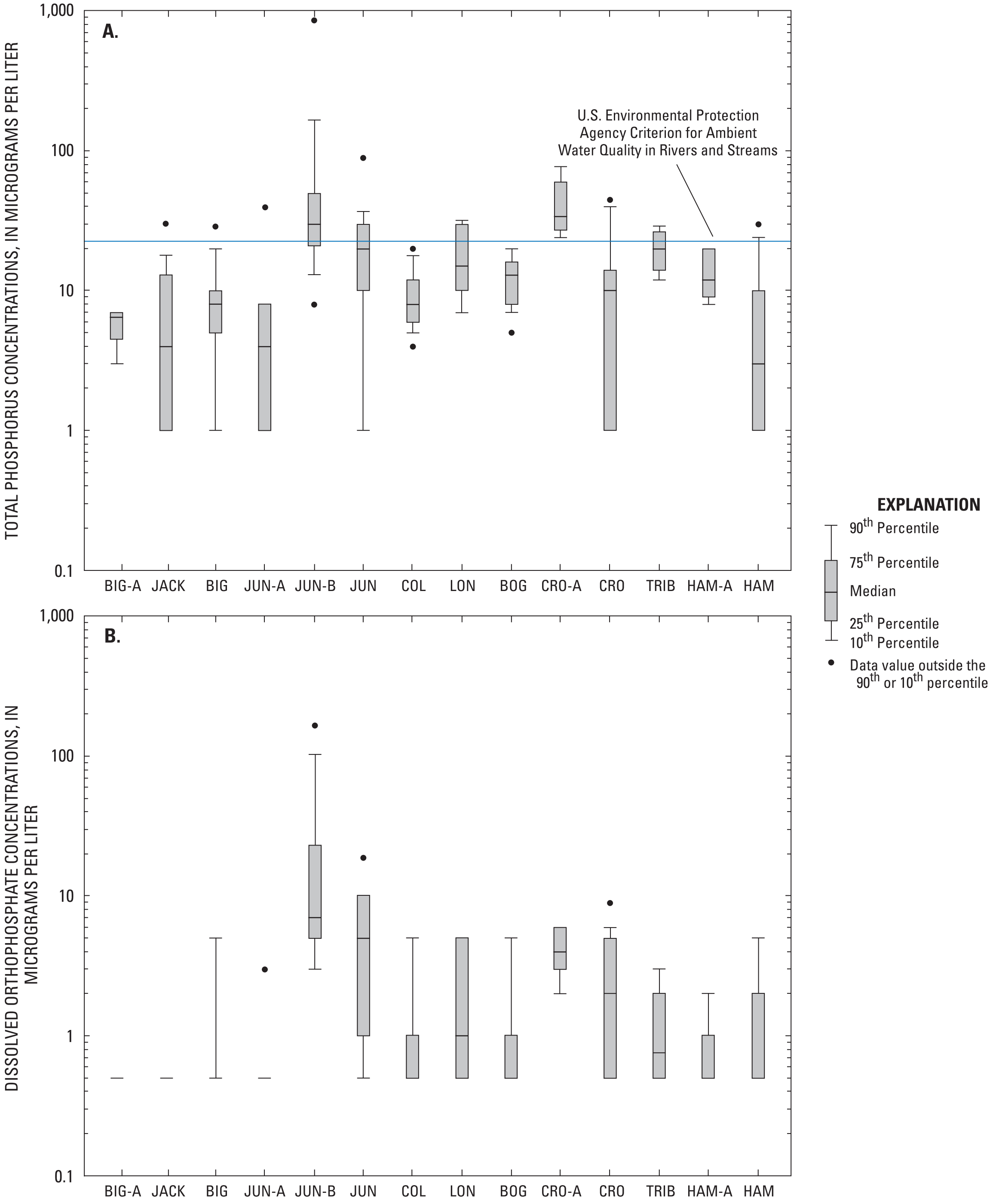


Figure 8. (A) Total phosphorus and (B) dissolved orthophosphate concentrations at selected tributary sites in the Converse Lake watershed, Alabama, 1998–2003.

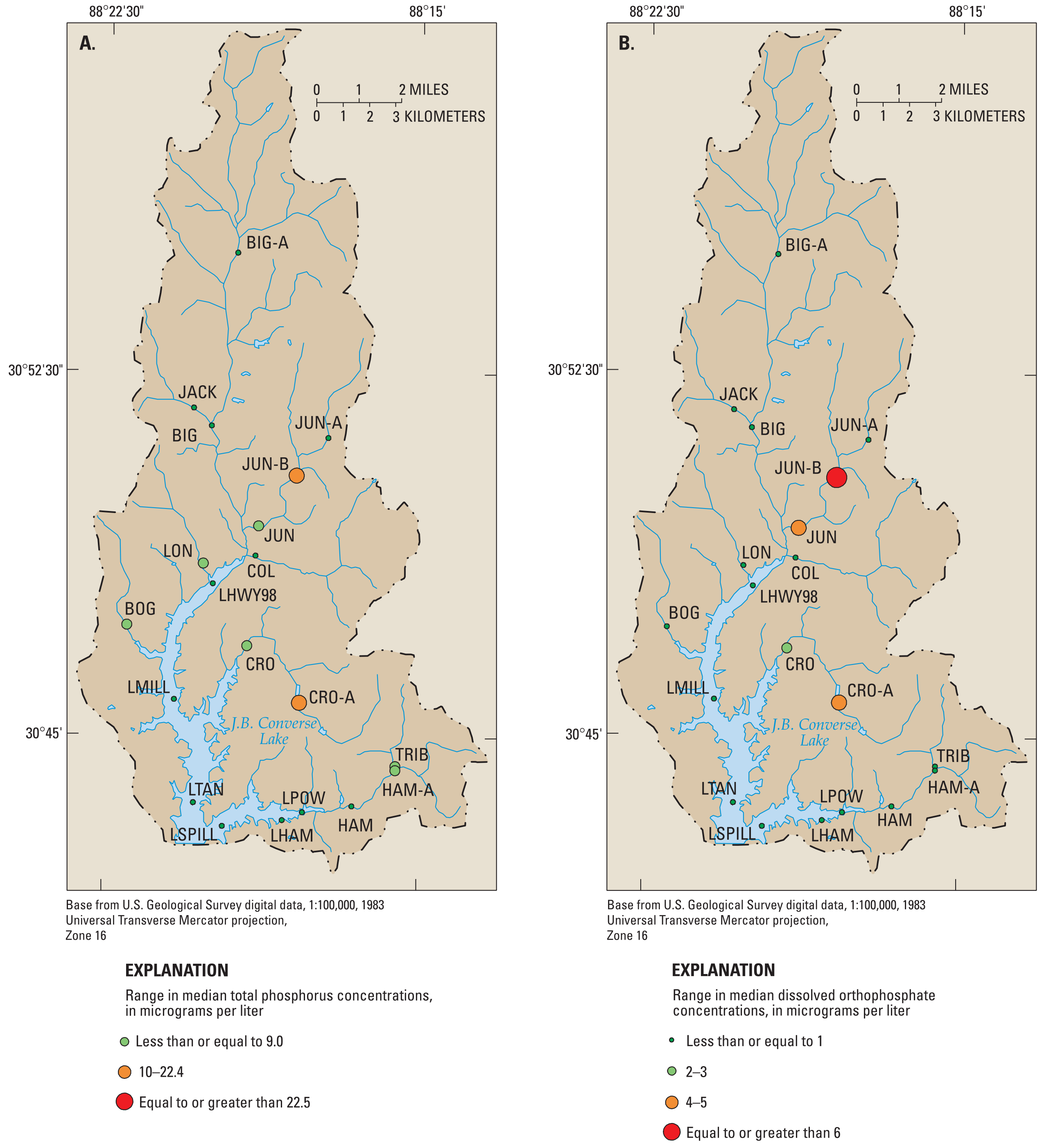


Figure 9. Median concentrations of (A) total phosphorus and (B) dissolved orthophosphate at selected sites in the Converse Lake watershed, Alabama, 1998–2003.

The presence of nutrient concentrations above background levels during the range of flow conditions sampled at JUN-B indicates that point sources of nitrate and orthophosphate are near the sampling site. A dairy farm is located between sites JUN-A and JUN-B and may be the source of some of the nutrients. Continued sampling in the Juniper Creek watershed will help to determine if newly implemented best-management practices have reduced the nutrient and bacteria concentrations in Juniper Creek. Elevated total phosphorus and dissolved orthophosphate concentrations at CRO-A also indicate a possible point source.

Mean tributary flow and nutrient concentrations used in the development of the BATHTUB model for the 2001–03 growing seasons are presented in table 11. In addition to the seven sampled tributaries, flows and mean nutrient concentrations were estimated for the unmonitored surface-water inputs to each lake segment, and ground-water flows were estimated to each lake segment. These inputs are labeled with the names used to distinguish them in the BATHTUB model. Unmonitored surface-water inputs are designated by the letters *Un* and a shorthand name for the receiving lake segment; whereas estimated ground-water inflow is indicated

Table 11. Total flow and mean concentrations of selected water-quality constituents in selected tributaries to Converse Lake, Alabama, during the 2001–03 growing seasons.

[km^2, square kilometer; hm^3/yr, cubic hectometer per year; μg/L, microgram per liter; cv, coefficient of variation; *, indicates flow out of the lake from indicated segment]

Site label	Receiving lake segment	Drainage area (km^2)[a]	Flow (hm^3/yr)[b]	Total phosphorus (μg/L)		Total nitrogen (μg/L)		Dissolved orthophosphorus (μg/L)		Inorganic nitrogen (μg/L)	
				mean	cv	mean	cv	mean	cv	mean	cv
2001											
Monitored tributaries											
BIG	1	81.6	22.345	10.5	0.23	711	0.07	0.8	0.27	352	0.25
JUN	1	23.9	9.715	46	83	950	.16	7.7	.53	553	.46
COL	1	22.1	8.998	6.3	.33	370	.18	.5	0	127	.23
CRO	3	20.9	9.172	15.3	.56	681	.1	2.7	.18	310	.12
HAM	4	21.3	10.824	4.8	.17	822	.06	1	.13	475	.11
BOG	2	8.2	3.34	11.7	.65	497	.62	.5	0	143	.74
LON	1	7.4	3.003	19.1	.83	883	.44	5.4	.52	613	.5
Unmonitored surface-water inputs											
UnHwy98	1	15.91	6.475	10.5	0.21	711	0.07	0.8	0.27	352	0.25
UnMill	2	17.56	7.146	10.5	.21	711	.07	.8	.27	352	.25
UnCrook	3	18.2	7.403	10.5	.21	711	.07	.8	.27	352	.25
UnUpham	4	6.61	2.691	10.5	.21	711	.07	.8	.27	352	.25
UnPump	5	8.04	3.273	10.5	.21	711	.07	.8	.27	352	.25
UnSpill	6	1.67	.679	10.5	.21	711	.07	.8	.27	352	.25
Estimated ground-water inflow											
UpperGW	1	0.52	0.2	0	0	0	0	0	0	0	0
MillGW	2	3.03	1.17	0	0	0	0	0	0	0	0
CrookedGW	3	5.7	2.2	0	0	0	0	0	0	0	0
UphamGW	4	.15	.058	0	0	0	0	0	0	0	0
PumpStaGW	5	2.05	.79	0	0	0	0	0	0	0	0
SpillwayGW	6	2.12	.82	0	0	0	0	0	0	0	0
Lake outflow											
Pumpage	5*	267	83.33	6	0.76	423	0.23	0.5	0	30	0.73
Spillage	6*	267	25.61	5.7	.57	390	.19	.5	0	42	1.01

Table 11. Total flow and mean concentrations of selected water-quality constituents in selected tributaries to Converse Lake, Alabama, during the 2001–03 growing seasons.—Continued

[km^2, square kilometer; hm^3/yr, cubic hectometer per year; µg/L, microgram per liter; cv, coefficient of variation; *, indicates flow out of the lake from indicated segment]

Site label	Receiving lake segment	Drainage area (km^2)[a]	Flow (hm^3/yr)[b]	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Dissolved orthophosphorus (µg/L)		Inorganic nitrogen (µg/L)	
				mean	cv	mean	cv	mean	cv	mean	cv
2002											
Monitored tributaries											
BIG	1	81.6	25.659	7.8	0.25	766	0.1	0.4	0.32	365	0.39
JUN	1	23.9	11.72	4.2	1.11	682	.25	2.4	1.05	546	.2
COL	1	22.1	10.856	15.4	.69	362	.29	5.5	.64	178	.27
CRO	3	20.9	12.459	10.4	.52	650	.1	2.3	.17	277	.29
HAM	4	21.3	11.976	3	.33	826	.11	.7	.19	428	.24
BOG	2	8.2	4.03	15.8	.58	457	.52	5.5	.81	153	.39
LON	1	7.4	3.623	19.1	.83	883	.44	5.4	.52	613	.5
Unmonitored surface-water inputs											
UnHwy98	1	15.91	7.81	7.8	0.25	766	0.1	0.4	0.32	365	0.39
UnMill	2	17.56	8.62	7.8	.25	766	.1	.4	.32	365	.39
UnCrook	3	18.2	8.93	7.8	.25	766	.1	.4	.32	365	.39
UnUpham	4	6.61	3.25	7.8	.25	766	.1	.4	.32	365	.39
UnPump	5	8.04	3.95	7.8	.25	766	.1	.4	.32	365	.39
UnSpill	6	1.67	0.82	7.8	.25	766	.1	.4	.32	365	.39
Estimated ground-water inflow											
UpperGW	1	0.52	0.2	0	0	0	0	0	0	0	0
MillGW	2	3.03	1.17	0	0	0	0	0	0	0	0
CrookedGW	3	5.7	2.2	0	0	0	0	0	0	0	0
UphamGW	4	.15	.058	0	0	0	0	0	0	0	0
PumpStaGW	5	2.05	.79	0	0	0	0	0	0	0	0
SpillwayGW	6	2.12	.82	0	0	0	0	0	0	0	0
Lake outflow											
Pumpage	5*	267	90.251	4.9	1.18	411	0.44	0.5	0	34	0.99
Spillage	6*	267	40.49	6	1.58	365	.53	.5	0	99	1.02

Table 11. Total flow and mean concentrations of selected water-quality constituents in selected tributaries to Converse Lake, Alabama, during the 2001–03 growing seasons.—Continued

[km^2, square kilometer; hm^3/yr, cubic hectometer per year; μg/L, microgram per liter; cv, coefficient of variation; *, indicates flow out of the lake from indicated segment]

Site label	Receiving lake segment	Drainage area (km^2)[a]	Flow (hm^3/yr)[b]	Total phosphorus (μg/L)		Total nitrogen (μg/L)		Dissolved orthophosphorus (μg/L)		Inorganic nitrogen (μg/L)	
				mean	cv	mean	cv	mean	cv	mean	cv
2003											
Monitored tributaries											
BIG	1	81.6	88.98	8	0.1	725	0.08	0.4	0.08	175	0.22
JUN	1	23.9	23.219	36.8	3.04	699	.23	7	.54	492	.25
COL	1	22.1	21.507	15.4	.69	362	.29	5.5	.64	178	.27
CRO	3	20.9	16.362	7	.52	646	.09	2.8	.19	259	.13
HAM	4	21.3	22.238	2.5	.49	739	.13	.5	.22	332	.29
BOG	2	8.2	7.983	15.8	.58	457	.52	5.5	.81	153	.39
LON	1	7.4	7.177	19.1	.83	883	.44	5.4	.52	613	.5
Unmonitored surface-water inputs											
UnHwy98	1	15.91	15.474	8	0.1	725	0.08	0.4	0.08	175	0.22
UnMill	2	17.56	17.077	8	.1	725	.08	.4	.08	175	.22
UnCrook	3	18.2	17.693	8	.1	725	.08	.4	.08	175	.22
UnUpham	4	6.61	6.432	8	.1	725	.08	.4	.08	175	.22
UnPump	5	8.04	7.821	8	.1	725	.08	.4	.08	175	.22
UnSpill	6	1.67	1.622	8	.1	725	.08	.4	.08	175	.22
Estimated ground-water inflow											
UpperGW	1	0.52	0.2	0	0	0	0	0	0	0	0
MillGW	2	3.03	1.17	0	0	0	0	0	0	0	0
CrookedGW	3	5.7	2.2	0	0	0	0	0	0	0	0
UphamGW	4	.15	.058	0	0	0	0	0	0	0	0
PumpStaGW	5	2.05	.79	0	0	0	0	0	0	0	0
SpillwayGW	6	2.12	.82	0	0	0	0	0	0	0	0
Lake outflow											
Pumpage	5*	267	86.1	9	1.6	355	0.17	0.5	0	48.3	0.99
Spillage	6*	267	171.79	4.4	.84	411	.24	.5	0	47.5	.96

[a] To convert square kilometers to square miles, multiply by 0.3861.

[b] To convert cubic hectometers per year to cubic feet per second, multiply by 1.12.

by the shorthand name followed by the letters *GW*. Pumpage and spillage indicate measured outflow from the lake through the intake to the water treatment system and the spillway of the lake, respectively. Nutrient concentrations in the pumpage and spillage were estimated from mean nutrient concentrations at the nearest respective lake sites—LHAM for the pumpage and LSPILL for the spillage.

Nutrient Loads and Yields

Mean annual instream nutrient loads were calculated for the BIG, CRO, and HAM sites for water years 1991 through 2003. Summaries of regression coefficients and results of these calculations are shown in tables 12 and 13, respectively. Analyses of instream loads can provide insight into the relative influence of seasonal and temporal trends and point and nonpoint sources on nutrient loads (Journey and Gill, 2001), as well as the total volume of material being exported from a particular watershed. Instream yields are the loads normalized to watershed size, and provide a means of comparing nutrients at sites with different watershed sizes or streamflow magnitudes.

The ESTIMATOR model provides several diagnostic statistics for each constituent's load regression including the coefficient of determination (R^2), the variance (s), model variables, and the regression model coefficients (β_0–β_6).

Table 12. Regression summary for the seven-parameter, log-linear regression model used to estimate nutrient concentrations at selected tributary sites in the Converse Lake watershed, Alabama.

[s, standard deviation of the residuals from ordinary least squares fit, in log units; R^2, coefficient of determination; n, number of samples; β_0, constant; β_1, coefficient of natural logarithm of streamflow; β_2, coefficient of natural logarithm of streamflow, squared; β_3, coefficient of time; β_4, coefficient of time, squared; β_5, coefficient of sine (time); β_6, coefficient of cosine (time); **bold** indicates coefficients with an absolute T value greater than 2, which indicates statistical significance; —, no regression results because of insufficient data]

	s	R^2	n	β_0	β_1	β_2	β_3	β_4	β_5	β_6
BIG										
Total nitrogen	0.175	0.95	47	**4.3434**	**0.9578**	0.0462	**-0.0184**	**0.0049**	**-0.1016**	**-0.0756**
Total organic nitrogen	0.238	0.95	47	**3.4598**	**1.3224**	0.0782	**0.0214**	**0.0084**	**-0.1089**	**-0.2152**
Dissolved ammonia	0.447	0.77	46	**1.2049**	**0.7714**	**-0.229**	-0.0461	0.0014	-0.0729	-0.1258
Total ammonia	0.448	0.72	64	**0.9642**	**0.727**	-0.1719	**-0.0474**	**0.0079**	**0.0615**	**-0.0478**
Total Kjeldahl nitrogen plus ammonia	0.274	0.94	65	**3.224**	**1.313**	0.0525	-0.009	**0.0143**	-0.0938	**-0.1915**
Total inorganic nitrogen	0.592	0.47	65	**3.3189**	**0.4705**	0.0035	**-0.0639**	0.007	-0.0001	0.0954
Dissolved inorganic nitrogen	0.596	0.48	64	**3.3317**	**0.4542**	0.003	**-0.0707**	0.0062	0.0166	0.1165
Dissolved phosphorus	—	—	—	—	—	—	—	—	—	—
Total orthophosphorus	0.539	0.9	65	**-0.4414**	**1.4391**	-0.0948	**-0.2155**	**-0.017**	-0.1266	-0.147
Total phosphorus	0.832	0.64	64	**0.6006**	**1.2757**	-0.0135	-0.0502	-0.0157	-0.2077	-0.0583
HAM										
Total nitrogen	0.145	0.9	36	**3.8352**	**0.7887**	0.0333	-0.0096	0.0035	0.0022	0.042
Total organic nitrogen	0.339	0.79	35	**2.859**	**1.1922**	0.0861	0.0023	**0.0115**	-0.021	-0.0008
Dissolved ammonia	0.539	0.54	48	**0.6926**	**1.2996**	-0.0351	0.0166	-0.0088	0.1518	-0.115
Total ammonia	0.512	0.61	65	**0.4125**	**1.3776**	-0.2016	0.0197	-0.0023	**0.2047**	-0.169
Total Kjeldahl nitrogen plus ammonia	0.448	0.67	66	**2.4523**	**1.3504**	0.1206	-0.0149	**0.0133**	0.0126	**-0.2243**
Total inorganic nitrogen	0.098	0.88	66	**3.2647**	**0.4004**	**-0.2558**	**-0.0172**	**-0.0021**	0.0238	**0.088**
Dissolved inorganic nitrogen	0.098	0.88	66	**3.2492**	**0.361**	**-0.3127**	**-0.0166**	-0.0018	0.0218	**0.0912**
Dissolved phosphorus	0.642	0.79	64	**-1.4012**	**1.2209**	-0.0046	**-0.2204**	-0.0127	0.1489	0.042
Total orthophosphorus	0.661	0.76	66	**-0.7087**	**2.0347**	-0.1911	**-0.131**	0.0051	-0.0587	-0.2118
Total phosphorus	0.767	0.71	66	0.2313	**1.551**	0.1566	**-0.1678**	**-0.0363**	-0.033	**-0.3172**
CRO										
Total nitrogen	0.27	0.81	42	**3.4778**	**1.1243**	-0.0006	-0.0146	-0.0031	-0.0852	-0.0936
Total organic nitrogen	0.448	0.72	36	2.8404	**1.4694**	0.0617	-0.0016	0.0001	-0.2112	-0.204
Dissolved ammonia	0.668	0.56	48	-0.2216	**1.412**	0.1122	-0.0391	-0.0055	-0.0331	**-0.3377**
Total ammonia	0.548	0.61	65	**-0.3266**	**1.2835**	0.0968	**-0.0165**	**-0.0116**	**0.2031**	**-0.2357**
Total Kjeldahl nitrogen plus ammonia	0.488	0.69	66	**2.1404**	**1.5084**	0.1272	-0.0216	**0.0115**	0.0043	**-0.2758**
Total inorganic nitrogen	0.414	0.44	65	**2.422**	**0.7034**	-0.0425	**-0.0358**	0.0014	0.0486	-0.0343
Dissolved inorganic nitrogen	0.415	0.46	65	**2.4187**	**0.7306**	0.0126	**-0.0377**	0.0013	0.0534	-0.0332
Dissolved phosphorus	0.774	0.62	64	**-1.8681**	**1.4761**	0.0589	**-0.1677**	0.0094	0.0144	-0.0542
Total orthophosphorus	0.606	0.76	65	**-1.2449**	**2.0809**	0.2246	**-0.1246**	**0.0174**	-0.0809	-0.2536
Total phosphorus	0.881	0.56	65	-0.1636	**1.6575**	0.3488	**-0.1035**	**-0.0271**	0.1124	-0.129

Table 13. Annual and mean annual discharge, loads, and yields of selected nutrients at selected tributary sites in the Converse Lake watershed, Alabama.

[kg/yr, kilogram per year; ft^3/s, cubic foot per second; (kg/ha)/yr, kilogram per hectare per year; —, insufficient data]

BIG (station number 02479945)								
	Annual loads (kg/yr)							Mean annual discharge (ft^3/s)
Water year	Total organic nitrogen	Total inorganic nitrogen	Total ammonia	Total Kjeldahl nitrogen	Total nitrogen	Dissolved orthophosphate	Total phosphorus	
1991	53,700	24,700	2,010	58,800	67,400	—	1,750	94.1
1992	17,200	17,700	1,400	19,100	34,200	—	1,030	52.9
1993	35,100	19,200	1,800	34,300	52,400	—	1,900	83.7
1994	14,700	13,900	1,270	14,300	29,400	—	1,100	49.5
1995	22,500	13,400	1,290	20,100	35,400	—	1,380	61.6
1996	32,600	14,500	1,520	27,900	46,800	—	1,870	83.7
1997	19,800	12,100	1,300	17,100	33,300	—	1,280	60.8
1998	65,200	13,000	1,370	44,900	54,000	—	1,570	91.3
1999	14,900	10,300	1,040	12,800	26,700	—	828	49
2000	4,520	6,580	436	3,930	11,200	—	212	19.2
2001	10,600	7,930	638	9,420	18,200	—	333	31.8
2002	14,700	7,190	498	12,400	17,400	—	210	27.3
2003	60,100	13,500	1,340	56,300	58,300	—	718	94.7
Mean annual	28,125	13,385	1,224	25,488	37,285	—	1,091	61.5
	Annual yields ([kg/ha]/yr)							
Water year	Total organic nitrogen	Total inorganic nitrogen	Total ammonia	Total Kjeldahl nitrogen	Total nitrogen	Dissolved orthophosphate	Total phosphorus	
1991	6.58	3.03	0.25	7.21	8.26	—	0.21	
1992	2.11	2.17	0.17	2.34	4.19	—	0.13	
1993	4.30	2.35	0.22	4.20	6.42	—	0.23	
1994	1.80	1.70	0.16	1.75	3.60	—	0.13	
1995	2.76	1.64	0.16	2.46	4.34	—	0.17	
1996	4.00	1.78	0.19	3.42	5.74	—	0.23	
1997	2.43	1.48	0.16	2.10	4.08	—	0.16	
1998	7.99	1.59	0.17	5.50	6.62	—	0.19	
1999	1.83	1.26	0.13	1.57	3.27	—	0.10	
2000	0.55	0.81	0.05	0.48	1.37	—	0.03	
2001	1.30	0.97	0.08	1.15	2.23	—	0.04	
2002	1.80	0.88	0.06	1.52	2.13	—	0.03	
2003	7.37	1.65	0.16	6.90	7.15	—	0.09	
Mean annual	3.45	1.64	0.15	3.12	4.57	—	0.13	

Table 13. Annual and mean annual discharge, loads, and yields of selected nutrients at selected tributary sites in the Converse Lake watershed, Alabama.—Continued

[kg/yr, kilogram per year; ft^3/s, cubic foot per second; (kg/ha)/yr, kilogram per hectare per year; —, insufficient data]

CRO (station number 02479980)								
Annual loads (kg/yr)								Mean annual discharge (ft^3/s)
Water year	**Total organic nitrogen**	**Total inorganic nitrogen**	**Total ammonia**	**Total Kjeldahl nitrogen**	**Total nitrogen**	**Dissolved orthophosphate**	**Total phosphorus**	
1991	9,770	6,080	440	13,600	15,000	391	1,240	21.8
1992	5,020	4,520	253	5,300	9,460	173	635	14.2
1993	7,370	5,040	387	7,950	12,800	175	955	18.6
1994	4,700	3,780	259	4,040	8,590	91	651	12.5
1995	6,940	4,080	398	7,120	11,600	100	1,080	16.8
1996	8,480	4,560	451	7,330	14,000	106	1,240	20.4
1997	11,900	4,640	595	10,900	16,300	110	1,570	22.4
1998	12,600	4,920	588	11,500	18,900	109	1,390	28.9
1999	7,930	4,140	377	6,580	12,500	65.8	691	18.9
2000	3,490	2,670	161	2,660	6,230	27.5	191	10.3
2001	4,420	2,810	182	3,920	7,030	31.8	211	11.9
2002	4,420	2,500	140	5,050	6,320	22.6	103	11.2
2003	7,050	3,700	209	7,650	9,840	43.8	122	17.6
Mean annual	7,200	4,111	342	7,200	11,428	111	775	17.3

Annual yields ([kg/ha]/yr)							
Water year	**Total organic nitrogen**	**Total inorganic nitrogen**	**Total ammonia**	**Total Kjeldahl nitrogen**	**Total nitrogen**	**Dissolved orthophosphate**	**Total phosphorus**
1991	4.67	2.90	0.21	6.50	7.17	0.19	0.59
1992	2.40	2.16	0.12	2.53	4.52	0.08	0.30
1993	3.52	2.41	0.18	3.80	6.12	0.08	0.46
1994	2.25	1.81	0.12	1.93	4.10	0.04	0.31
1995	3.32	1.95	0.19	3.40	5.54	0.05	0.52
1996	4.05	2.18	0.22	3.50	6.69	0.05	0.59
1997	5.69	2.22	0.28	5.21	7.79	0.05	0.75
1998	6.02	2.35	0.28	5.49	9.03	0.05	0.66
1999	3.79	1.98	0.18	3.14	5.97	0.03	0.33
2000	1.67	1.28	0.08	1.27	2.98	0.01	0.09
2001	2.11	1.34	0.09	1.87	3.36	0.02	0.10
2002	2.11	1.19	0.07	2.41	3.02	0.01	0.05
2003	3.37	1.77	0.10	3.66	4.70	0.02	0.06
Mean annual	3.44	1.96	0.16	3.44	5.46	0.05	0.37

Table 13. Annual and mean annual discharge, loads, and yields of selected nutrients at selected tributary sites in the Converse Lake watershed, Alabama.—Continued

[kg/yr, kilogram per year; ft^3/s, cubic foot per second; (kg/ha)/yr, kilogram per hectare per year; —, insufficient data]

HAM (station number 02480002)								
	Annual loads (kg/yr)							Mean annual discharge (ft^3/s)
Water year	**Total organic nitrogen**	**Total inorganic nitrogen**	**Total ammonia**	**Total Kjeldahl nitrogen**	**Total nitrogen**	**Dissolved orthophos-phate**	**Total phosphorus**	
1991	8,250	8,630	497	9,280	17,300	239	666	24.9
1992	5,380	8,220	384	5,050	14,100	171	482	19.8
1993	6,110	8,270	444	6,200	14,700	162	696	22.5
1994	4,080	7,580	346	3,840	11,900	108	538	17.5
1995	5,740	7,800	460	6,230	13,800	113	779	22.7
1996	7,170	8,530	581	7,050	16,100	116	891	28
1997	6,700	8,270	611	7,180	15,300	88.5	772	26.7
1998	9,490	8,710	705	8,700	19,500	87.1	668	37.9
1999	5,560	7,640	482	4,740	13,500	47.4	314	21.9
2000	3,430	5,960	269	2,570	9,790	20.6	95.6	13.9
2001	3,600	5,420	247	2,680	9,540	13.8	55.5	13.2
2002	4,200	4,930	211	3,500	9,430	8.61	33	12.7
2003	9,270	6,390	522	8,860	14,900	12.1	49.21	22.6
Mean annual	6,075	7,412	443	5,837	13,835	91	465	21.9
	Annual yields ([kg/ha]/yr)							
Water year	**Total organic nitrogen**	**Total inorganic nitrogen**	**Total ammonia**	**Total Kjeldahl nitrogen**	**Total nitrogen**	**Dissolved orthophos-phate**	**Total phosphorus**	
1991	3.88	4.05	0.23	4.36	8.13	0.11	0.31	
1992	2.53	3.86	0.18	2.37	6.62	0.08	0.23	
1993	2.87	3.88	0.21	2.91	6.90	0.08	0.33	
1994	1.92	3.56	0.16	1.80	5.59	0.05	0.25	
1995	2.70	3.66	0.22	2.93	6.48	0.05	0.37	
1996	3.37	4.01	0.27	3.31	7.56	0.05	0.42	
1997	3.15	3.88	0.29	3.37	7.19	0.04	0.36	
1998	4.46	4.09	0.33	4.09	9.16	0.04	0.31	
1999	2.61	3.59	0.23	2.23	6.34	0.02	0.15	
2000	1.61	2.80	0.13	1.21	4.60	0.01	0.04	
2001	1.69	2.55	0.12	1.26	4.48	0.01	0.03	
2002	1.97	2.32	0.10	1.64	4.43	0.00	0.02	
2003	4.35	3.00	0.25	4.16	7.00	0.01	0.02	
Mean annual	2.85	3.48	0.21	2.74	6.50	0.04	0.22	

The R^2 values, expressed as percentages of the variation, indicate how well the regression model explains variability in the estimated concentrations. For example, an R^2 of 0.80 indicates that 80 percent of the variability is accounted for in the model. No load regressions were excluded because of low R^2 values. The ESTIMATOR model also provides T values for each regression coefficient; T values indicate whether the coefficient value is significantly different from 0 in the regression model (Cohn and others, 1992). Regression coefficients with T values greater than 2 were considered to be statistically significant and are shown in bold in table 12. Variables with coefficients that are statistically significant indicate a relation between the variable and the constituent concentration. For example, streamflow is a good predictor of total nitrogen concentration when the coefficient β_1 is statistically significant. Seasonal influences or variations are modeled by using a statistically significant sine coefficient (β_5) or cosine coefficient (β_6), which together represent seasonal fluctuation. If either coefficient was statistically significant, then both variables were considered to be significant.

Streams for which nutrient species have a significant positive discharge (β_1) coefficient most likely have nonpoint sources as their dominant input source; that is, nutrient concentrations increase when discharge increases. Discharge was a significant explanatory variable and had a positive coefficient for each nutrient species (table 12). Seasonal influences were more apparent with the nitrogen species than with the phosphorus species at all three sites. Total phosphorus at the HAM site was the only phosphorus species at any site that showed a seasonal influence.

Results of load calculations indicate that the mean annual phosphorus loads at site BIG were greater than those at the CRO and HAM sites (table 13). Mean annual loads of total nitrogen were about 37,300 kilogram per year (kg/yr) at BIG, 11,400 kg/yr at CRO, and 13,800 kg/yr at HAM. Because the magnitudes of nutrient loads are controlled by discharge and the nutrient concentrations in input sources, the distribution of mean annual loads is similar to the distribution of discharge among the three sites. Mean annual discharge for water years 1991–2003 for BIG, CRO, and HAM was 61.5, 17.3, and 21.9 cubic feet per second (ft^3/s), respectively (table 13; Pearman and others, 2003). The decreased loads for all nutrient species during water years 2000 and 2001 coincide with a period of severe drought in the study area.

Kruskal-Wallis test results for load estimations indicate a statistically significant ($p < 0.05$) difference for all nutrient load estimates at each site except dissolved orthophosphate (table 14). Multiple comparison tests indicate two significantly different groups for estimated loads of total organic nitrogen, ammonia, and total Kjeldahl nitrogen—A for site BIG and B for sites CRO and HAM (table 14). Three multiple comparison groups were indicated for estimated loads of total inorganic nitrogen—A for site BIG, B for site CRO, and C for site HAM. Multiple comparison groups for total phosphorus were A for site BIG, AB for site CRO, and B for site HAM (table 14).

Table 14. Results of statistical tests for load and yield estimates at selected tributary sites in the Converse Lake watershed, Alabama.

[<, less than; —, no distinct Tukey groupings]

Nutrient	Kruskal-Wallis *p*-value	Tukey grouping		
		BIG	CRO	HAM
Loads				
Total organic nitrogen	< 0.0001	A	B	B
Total inorganic nitrogen	< .0001	A	B	C
Ammonia	< .0001	A	B	B
Total Kjeldahl nitrogen	< .0001	A	B	B
Total nitrogen	< .0001	A	B	B
Dissolved orthophosphate	.5903	—	—	—
Total phosphorus	.0122	A	AB	B
Yields				
Total organic nitrogen	0.5972	—	—	—
Total inorganic nitrogen	< .0001	B	B	A
Ammonia	.1012	—	—	—
Total Kjeldahl nitrogen	.4725	—	—	—
Total nitrogen	.0381	B	AB	A
Dissolved orthophosphate	.5903	—	—	—
Total phosphorus	.0271	B	A	AB

Mean annual nutrient yields were computed by dividing the mean annual load for each site by the drainage area of the site; the results are summarized in table 13 and figure 10. Nutrient yields allow for the comparison of loads among sites with varying drainage areas by eliminating the effect of watershed size. Although nutrient loads generally were higher at site BIG, the distribution of nutrient yields had a different pattern (fig. 10) than that of loads. Mean annual yields of total nitrogen, total inorganic nitrogen, and total ammonia were highest at HAM followed by CRO and BIG. Yields of total phosphorus and dissolved orthophosphate were highest at CRO. Total phosphorus yields at CRO were 75 to 100 percent higher than at sites HAM and BIG. The difference in the distribution of loads and yields is attributable to land-use differences in each watershed. Land use in the Big Creek (BIG) watershed is about 73 percent forested, 24 percent agricultural, and 3 percent urban, wetlands, and transitional land (table 4). Land use in the Crooked Creek (CRO) and Hamilton Creek (HAM) watersheds is less forested, about 46 and 52 percent, respectively, and more agricultural, about 47 and 38 percent, respectively. Urban land use also is higher in the CRO and HAM watersheds with about 5 percent in each watershed, whereas the BIG watershed has less than 2.5 percent.

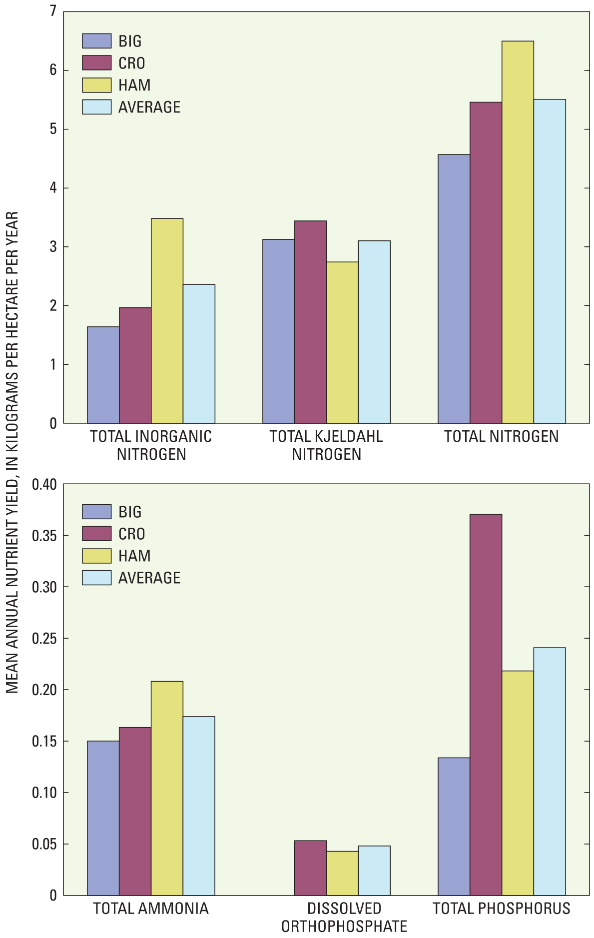


Figure 10. Mean annual nutrient yields at selected sites in the Converse Lake watershed, Alabama, 1991–2003.

Nutrient export coefficients for total nitrogen and total phosphorus developed by Reckhow and others (1980; table 15) are smallest for forested land and greatest for agricultural and urban land-use categories. Mean annual total nitrogen yield at HAM (6.5 kilograms per hectare per year ((kg/ha)/yr), table 13) is greater than the maximum yield for forested land (6.26 (kg/ha)/yr) and falls within the range of nonrow crops (0.97 to 7.82 (kg/ha)/yr, table 15). Mean annual total nitrogen yields at sites CRO and BIG, 5.46 and 4.57 (kg/ha)/yr, respectively (table 13), fall within the range of forested land use (1.38 to 6.26 (kg/ha)/yr, table 15). Mean annual yields of total phosphorus for sites BIG, CRO, and HAM (table 13) are within the range of export coefficients for forested land (0.02 to 0.83 (kg/ha)/yr, table 15).

Results of the Kruskal-Wallis test had fewer statistically significant ($p < 0.05$) differences among the sites for yields compared to loads. Significant differences were indicated by the Kruskal-Wallis test for yields of total inorganic nitrogen, total nitrogen, and total phosphorus (table 14). Tukey's multiple comparison test results for total inorganic nitrogen yield indicated two groups—A for site HAM and B for sites BIG and CRO. Multiple comparison groups for total nitrogen were A for site HAM, AB for site CRO, and B for site BIG.

Table 15. Range in nutrient yields from nonpoint sources.

[Modified from Reckhow and others, 1980]

Dominant land use	Nutrient yields, in kilograms per hectare per year			
	Mean	Minimum	Median	Maximum
	Total phosphorus export			
Forest	0.24	0.02	0.21	0.83
Row crops	4.46	.26	2.24	18.6
Nonrow crops	1.08	.1	.76	2.9
Pasture	1.5	.14	.81	4.9
Feedlots	301	21.3	224	795
Mixed agriculture	1.13	.08	.91	3.25
Urban	1.91	.19	1.1	6.23
	Total nitrogen export			
Forest	2.86	1.38	2.46	6.26
Row crops	16.1	2.1	9	79.6
Nonrow crops	5.19	.97	6.08	7.82
Pasture	8.65	1.48	5.19	30.9
Feedlots	3,110	681	2,920	7,980
Mixed agriculture	16.5	2.82	14.3	41.5
Urban	9.97	1.48	5.5	38.5

Total phosphorus multiple comparison groups were A for site CRO, AB for site HAM, and B for site BIG.

Organic Carbon Concentrations

Trihalomethanes, a class of disinfection by-products, are formed by the chlorination of naturally occurring organic carbon compounds. During 1996–98, Journey and Gill (2001) measured total and dissolved organic carbon concentrations in the tributaries to Converse Lake and found the concentrations to be positively correlated with deciduous forest and negatively correlated with residential land use. During 1998–2003, additional water samples were analyzed for total and dissolved organic carbon concentrations to further assess temporal and spatial variability in the watershed.

Total organic carbon concentrations in the tributaries ranged from 0.4 mg/L at HAM to 13 mg/L at JUN-A, which occurred during a storm (fig. 11). Excluding the storm samples collected at the Juniper Creek sites, the maximum concentration of total organic carbon was 10 mg/L at site BIG.

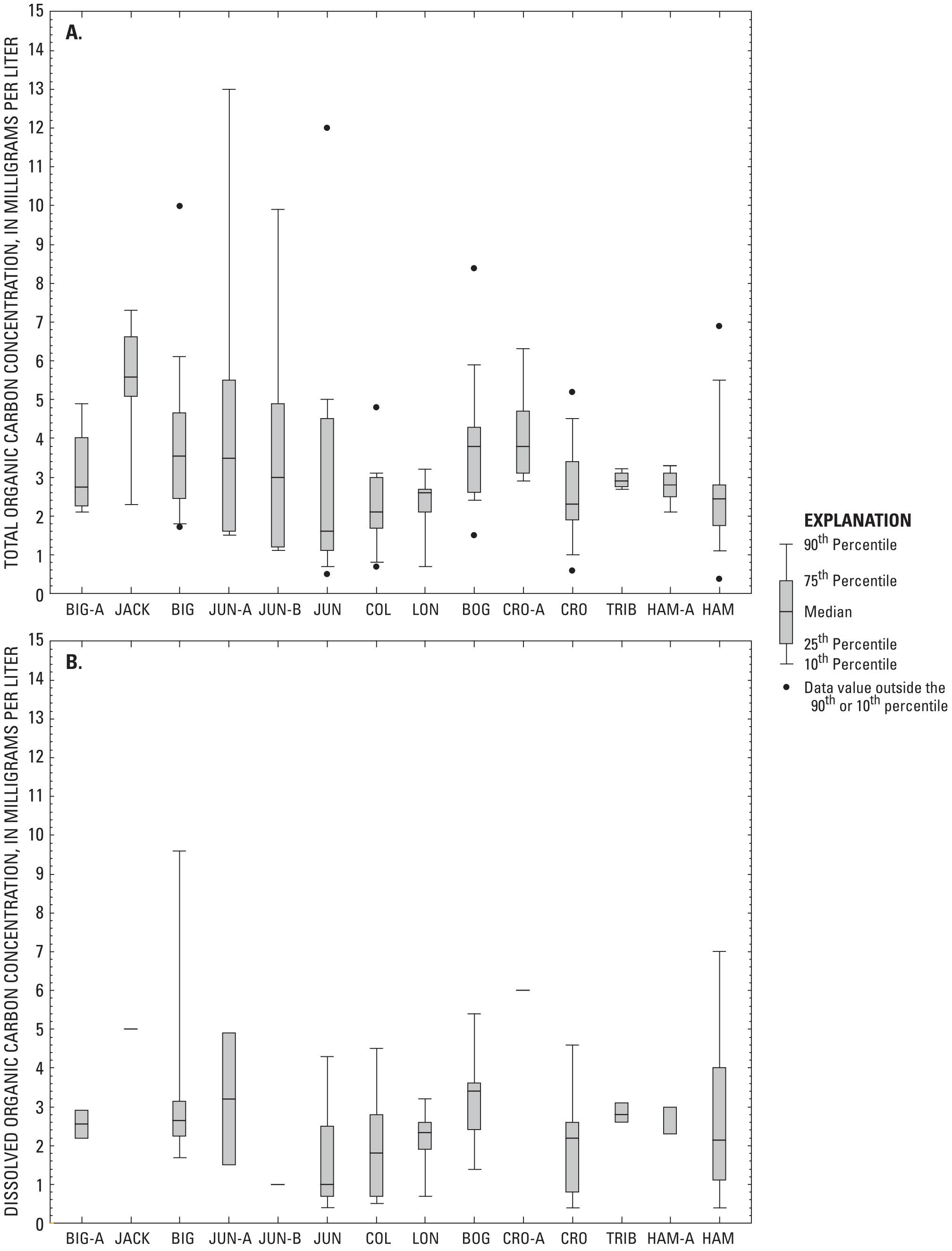


Figure 11. Concentrations of (A) total organic carbon and (B) dissolved organic carbon at selected tributary sites in the Converse Lake watershed, Alabama, 1998–2003.

Excluding the storm samples, median concentrations of total organic carbon ranged from 1.55 mg/L at site JUN to 5.6 mg/L at site JACK. Dissolved organic carbon concentrations ranged from 0.4 mg/L at sites JUN, CRO, and HAM to 9.6 mg/L at site BIG. Median dissolved organic carbon concentrations were unchanged by the exclusion of the storm samples.

Sites BIG and JACK, which had the greatest concentrations of total and dissolved organic carbon and the greatest median total organic carbon concentration, respectively (figs. 11, 12), are also the two subwatersheds with the greatest percentages of forested land use (table 4; fig. 5). Although this indicates a link between forested land use and organic carbon concentrations, no significant ($p < 0.05$) Spearman rho correlations were found between median organic carbon concentrations and percentages of each of the three major land-use categories (agricultural, forested, and urban) in the sampling data for 1998–2003.

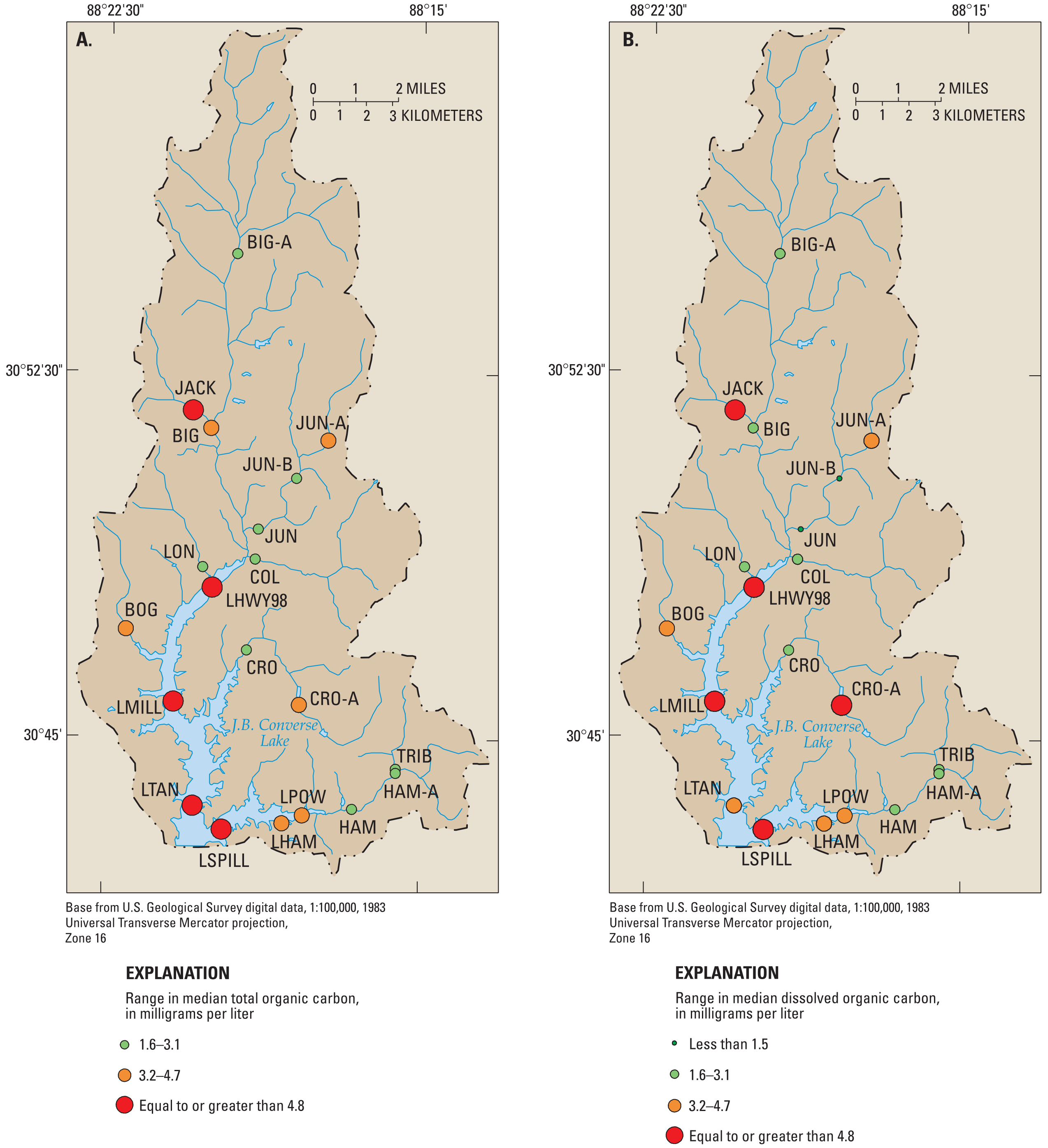


Figure 12. Median concentrations of (A) total and (B) dissolved organic carbon at selected sites in the Converse Lake watershed, Alabama, 1998–2003.

Lake Water Quality

Measurements of lake water-quality constituents and properties were made to better understand the spatial and temporal variability in physical properties, nutrient concentrations, and trophic response variables. Physical properties measured during sample collection were summarized to describe general lake water quality and to better define the mixing of lake water. Nutrient, chlorophyll *a*, and organic carbon concentrations and Secchi depth data from 2001 to 2003 were summarized for all six lake sites. Nutrient and chlorophyll *a* concentrations from the epilimnion, or mixed upper layer of the lake, and Secchi depths were compared to Southeastern Plains ecoregion criteria established by the USEPA for lakes and reservoirs (table 10). Mean nutrient and chlorophyll *a* concentrations and Secchi depths were calculated for use as input data for the BATHTUB models and are presented in table 16. Organic carbon data were examined for spatial and temporal patterns and for relation to algal biomass.

Field Properties

Two multiparameter water-quality instruments were deployed in the main channel at site LSPILL during the summer of 2002 to better define the duration of thermal stratification. One instrument was suspended at 10 ft below the lake surface, and the other was suspended at 25 ft below the lake surface. Data collected from these two instruments are shown in figure 13. Beginning in mid-April 2002, water temperature began to increase more rapidly in the surface layer than in the bottom layer of water. An apparent brief mixing period occurred in mid-May, and then water temperatures at the 10- and 25-ft depths were consistently different for the remainder of the summer months until mid-September. Because cool water is more dense than warm water, the temperature gradient results in less frequent mixing until mixing ceases to occur altogether.

A rapid decline in dissolved oxygen coincided with the onset of thermal stratification in early June (fig.13 A, B). Because the density difference between the top and bottom layers of lake water prohibits mixing, dissolved oxygen concentrations in the bottom layer are not replenished from wind action at the surface. Ongoing decomposition at the water and sediment interface continues to deplete oxygen until anoxic, or oxygen-free, conditions develop, as occurred in July and August 2002 (fig. 13B). Small increases in dissolved oxygen concentrations occurred in the bottom waters during the

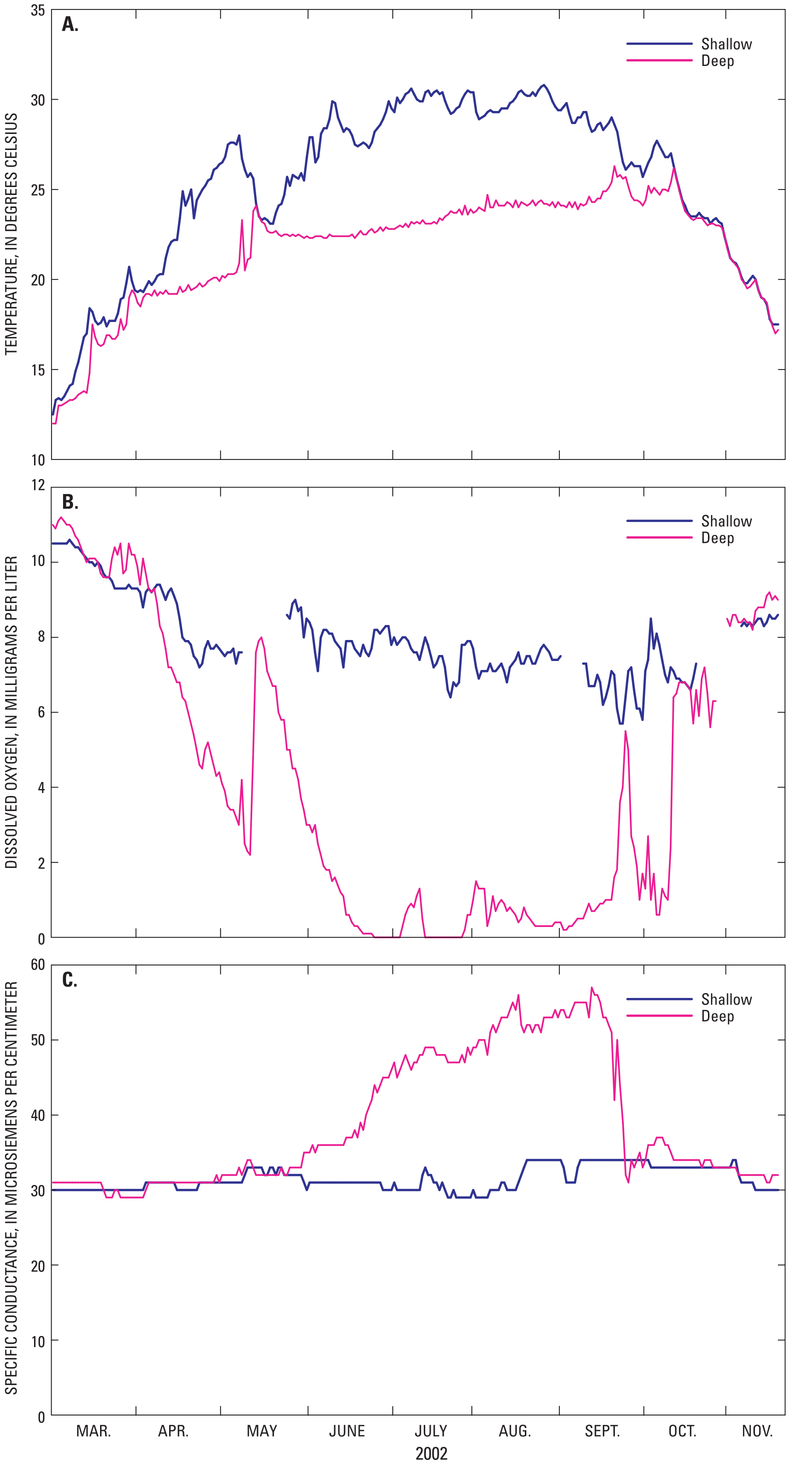


Figure 13. Continuous (A) water temperature, (B) dissolved oxygen, and (C) specific conductance data from USGS streamgaging station 02480009 (LSPILL, fig. 2) in Converse Lake, Alabama, during March–November, 2002.

Table 16. Mean observed water quality in the epilimnion at selected sites in Converse Lake, Alabama, during the 2001–03 growing seasons (April–September).

[USGS, U.S. Geological Survey; 1/m, reciprocal meter; N, nitrogen; µg/L, microgram per liter; P, phosphorus; TP-orthoP, total phosphorus minus dissolved orthophosphorus; Dissolved orthoP, dissolved orthophosphorus; N:P, nitrogen to phosphorus; m, meter; cv, coefficient of variation; e, estimated; —, not measured]

Segment	USGS downstream order number	Site name		Non-algal turbidity (1/m)	Total N (µg/L)	Total P (µg/L)	Organic nitrogen (µg/L)	TP-orthoP (µg/L)	Dissolved orthoP (µg/L)	N:P ratio	Chlorophyll *a* (µg/L)	Secchi (m)
					2001							
1	02479957	Converse Lake at U.S. Highway 98	Average	0.34e	430	5.7	377	4.7	1	200	1.47	—
			cv	.28e	.02	1.13	.04	1.5	.87	.99	1.67	—
2	02479965	Converse Lake below Mill Branch	Average	0	413	6.6	370	6.2	.5	63	18.8	2
			cv	-4.1	.25	.31	.22	.34	0	.08	1.49	.04
3	0248000010	Converse Lake at Old Tanner Williams Road	Average	.34	390	6.7	335	6.2	.5	84	2.1	2.5
			cv	.28	.22	.62	.14	.68	0	.74	1.69	.12
4	02480003	Hamilton Creek Arm at powerline	Average	.41	433	7.3	402.5	6.8	.5	165	3.7	2
			cv	.46	.05	.75	.08	.8	0	1.29	1.71	.08
5	02480004	Hamilton Creek Arm at pumping station	Average	.36	423	6	393	5.5	.5	142	3.8	2.2
			cv	.27	.23	.76	.23	.83	0	1.02	.86	.06
6	02480009	Hamilton Creek Arm at spillway	Average	.37	390	5.7	348	5.2	.5	90	2.2	2.4
			cv	.25	.19	.57	.15	.62	0	.63	1.69	.09
					2002							
1	02479957	Converse Lake at U.S. Highway 98	Average	0.36e	504	10.8	369	10.2	0.5	196	4	—
			cv	.24e	.42	1.27	.46	1.34	.3	1	1.62	—
2	02479965	Converse Lake below Mill Branch	Average	.36	342	8.9	313	8.4	.5	152	7.7	1.9
			cv	.24	.3	1.26	.39	1.34	0	.93	.55	.1
3	0248000010	Converse Lake at Old Tanner Williams Road	Average	.39	313	5.1	271	4.6	.5	156	2.8	2.2
			cv	.35	.58	1.01	.69	1.12	0	1.27	1.26	.13
4	02480003	Hamilton Creek Arm at powerline	Average	.5	402	5.9	351	5.4	.5	261	.99	2.1
			cv	.29	.37	1.31	.48	1.43	0	.84	1.88	.36
5	02480004	Hamilton Creek Arm at pumping station	Average	.42	411	4.9	377	4.4	.5	241	4.1	2
			cv	.18	.44	1.18	.51	1.32	0	1.06	1.19	.16
6	02480009	Hamilton Creek Arm at spillway	Average	.45	279	8.1	241	7.6	.5	110	1.2	2.1
			cv	.2	.43	1.44	.51	1.53	0	1.28	2.1	.11

Table 16. Mean observed water quality in the epilimnion at selected sites in Converse Lake, Alabama, during the 2001–03 growing seasons (April–September).—Continued

[USGS, U.S. Geological Survey; 1/m, reciprocol meter; N, nitrogen; µg/L, microgram per liter; P, phosphorus; TP-orthoP, total phosphorus minus dissolved orthophosphorus; Dissolved orthoP, dissolved orthophosphorus; N:P, nitrogen to phosphorus; m, meter; cv, coefficient of variation; e, estimated; —, not measured]

Segment	USGS downstream order number	Site name		Non-algal turbidity (1/m)	Total N (µg/L)	Total P (µg/L)	Organic nitrogen (µg/L)	TP-orthoP (µg/L)	Dissolved orthoP (µg/L)	N:P ratio	Chlorophyll *a* (µg/L)	Secchi (m)
2003												
1	02479957	Converse Lake at U.S. Highway 98	Average	0.39	480	2.2	371	1.8	.5	384	11.9	2.5
			cv	—	.12	1.03	.22	1.32	0	.52	1.35	—
2	02479965	Converse Lake below Mill Branch	Average	.36	381	5.4	326	4.9	.5	238	8.3	1.8
			cv	.49	.26	1.12	.32	1.23	0	.89	1.01	.22
3	0248000010	Converse Lake at Old Tanner Williams Road	Average	.31	338	4.4	284	3.9	.5	146	5.7	2.1
			cv	.42	.18	.84	.2	.95	0	.8	1.25	.17
4	02480003	Hamilton Creek Arm at powerline	Average	.34	333	2.3	270	1.8	.5	256	2.9	2.4
			cv	.3	.22	1.03	.26	1.32	0	.59	1.34	.14
5	02480004	Hamilton Creek Arm at pumping station	Average	.27	355	9	307	8.5	.5	160	5.6	2.2
			cv	.18	.17	1.6	.24	1.69	0	.95	.88	.11
6	02480009	Hamilton Creek Arm at spillway	Average	.33	411	4.4	364	3.9	.5	235	6.3	2
			cv	.36	.24	.84	.24	.96	0	.98	.94	.15

summer of 2002, which may indicate that slight mixing occurs occasionally. Extremely low dissolved oxygen concentrations (below 2 mg/L) were sustained at the deeper measuring point from June 12, 2002, through September 25, 2002.

Specific conductance in the bottom waters of Converse Lake increased during summer stratification (fig. 13C). When low dissolved oxygen concentrations occur, a reducing chemical environment develops, and metal ions that have sorbed to the sediments are resuspended as they are reduced to more easily dissolved forms (Drever, 1988; Hem, 1992; Krauskopf and Bird, 1995). The release of ions from the bottom sediments to the water column increases the electrical conductance of the water.

Vertical profiles of water quality in Converse Lake were used to better define the extent of thermal stratification. At the time of sampling, measurements of temperature, turbidity, dissolved oxygen, and specific conductance were made at depth intervals of 5 ft at all sampling sites. Data collected at USGS streamgaging station 02480009 (LSPILL, fig. 2) during April and August 2002 were compared (fig. 14). In April, the relatively constant values of temperature, dissolved oxygen, and specific conductance throughout the water column indicated well-mixed conditions. During August, profile data clearly illustrate the occurrence of thermal stratification and the development of discrete unmixed layers of lake water. Water temperature began to decrease between 10 and 15 ft. Dissolved oxygen concentrations began decreasing at the same depth and were near zero at depths of 25 ft or greater. Specific conductance increased with depth below 15 ft. Based on profile data collected during this investigation, the mean depth of the epilimnion, or upper mixed layer, was estimated to be 13 ft.

Nutrient Concentrations

Nutrient and chlorophyll *a* concentrations and Secchi depths were compared among three stations in the main body of Converse Lake (LHWY98, LMILL, and LTAN, fig. 2) and three stations in the Hamilton Creek embayment (LPOW, LHAM, and LSPILL, fig. 2; figs. 15, 16). Stream hydrographs of the major tributaries to these respective lake sections, Big and Hamilton Creeks, were included to determine relations between tributary inflow and lake water quality. Comparison of lake water quality to the Big Creek

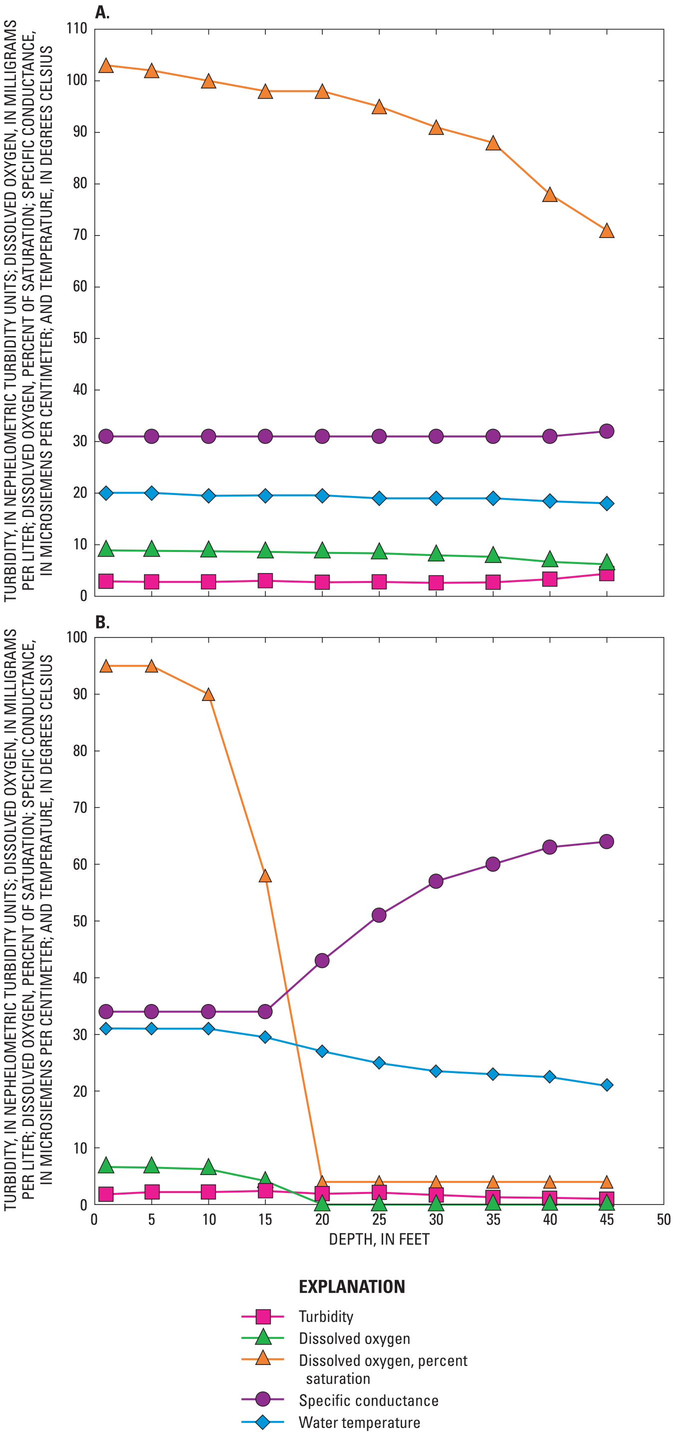
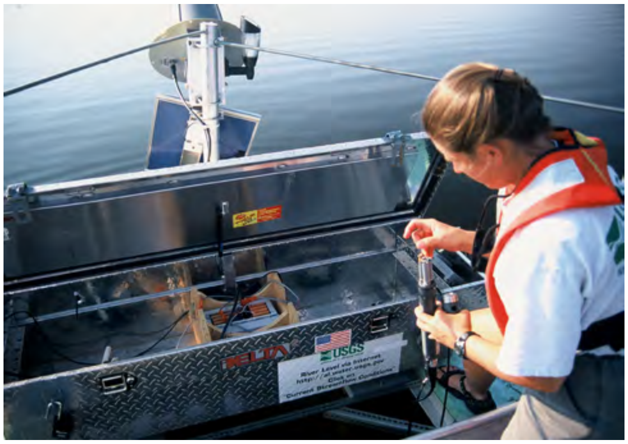


Figure 14. Water-quality profiles at USGS streamgaging station 02480009 (LSPILL, fig. 2) on (A) April 10, 2002, and (B) August 21, 2002, in Converse Lake, Alabama.



Ann McPherson, USGS

Sue Hartley, USGS, servicing the continuous water-quality monitor station at site LSPILL.

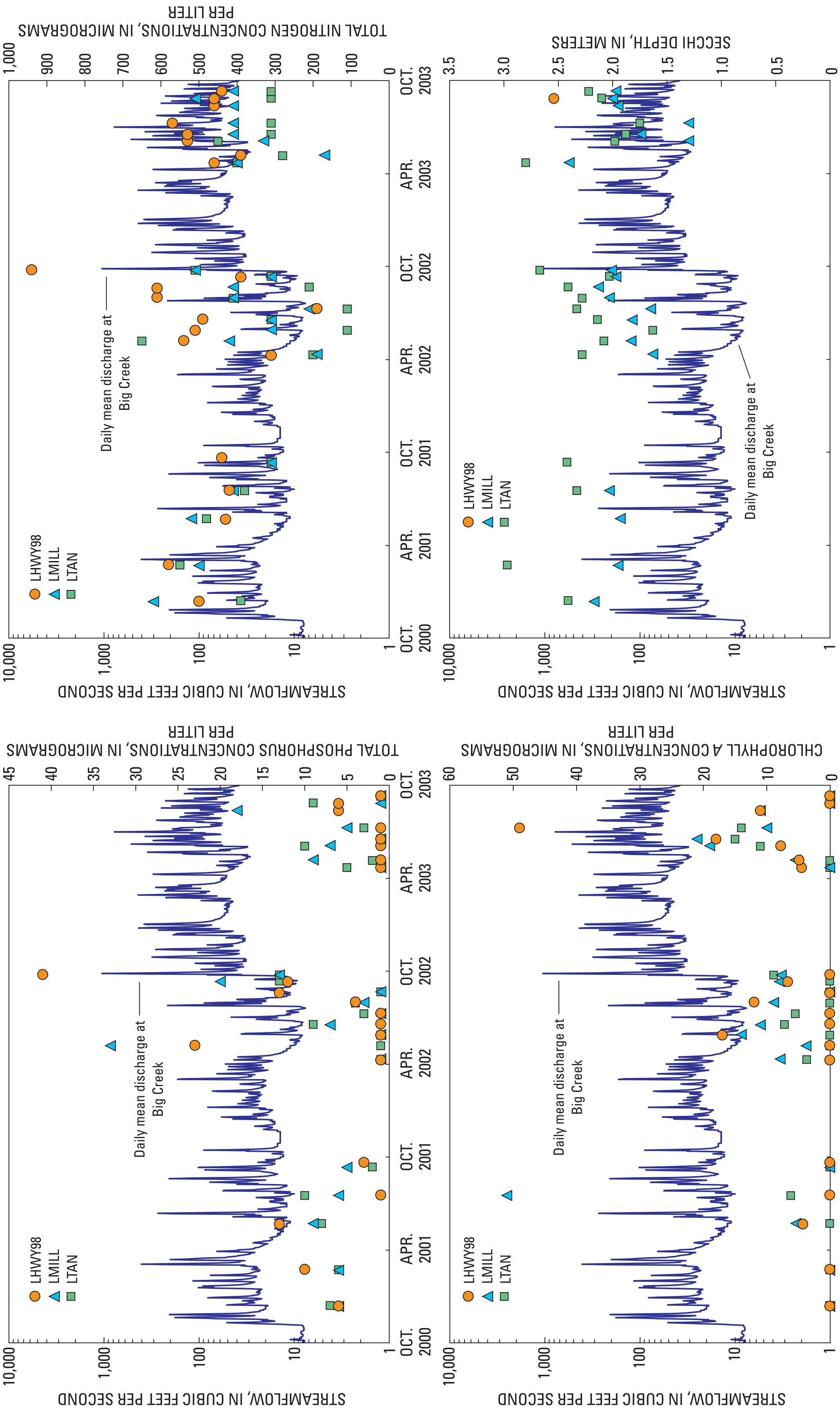


Figure 15. Water-quality at three sampling sites (LHWY98, LMILL, and LTAN) in Converse Lake, Alabama, during water years 2001–03.

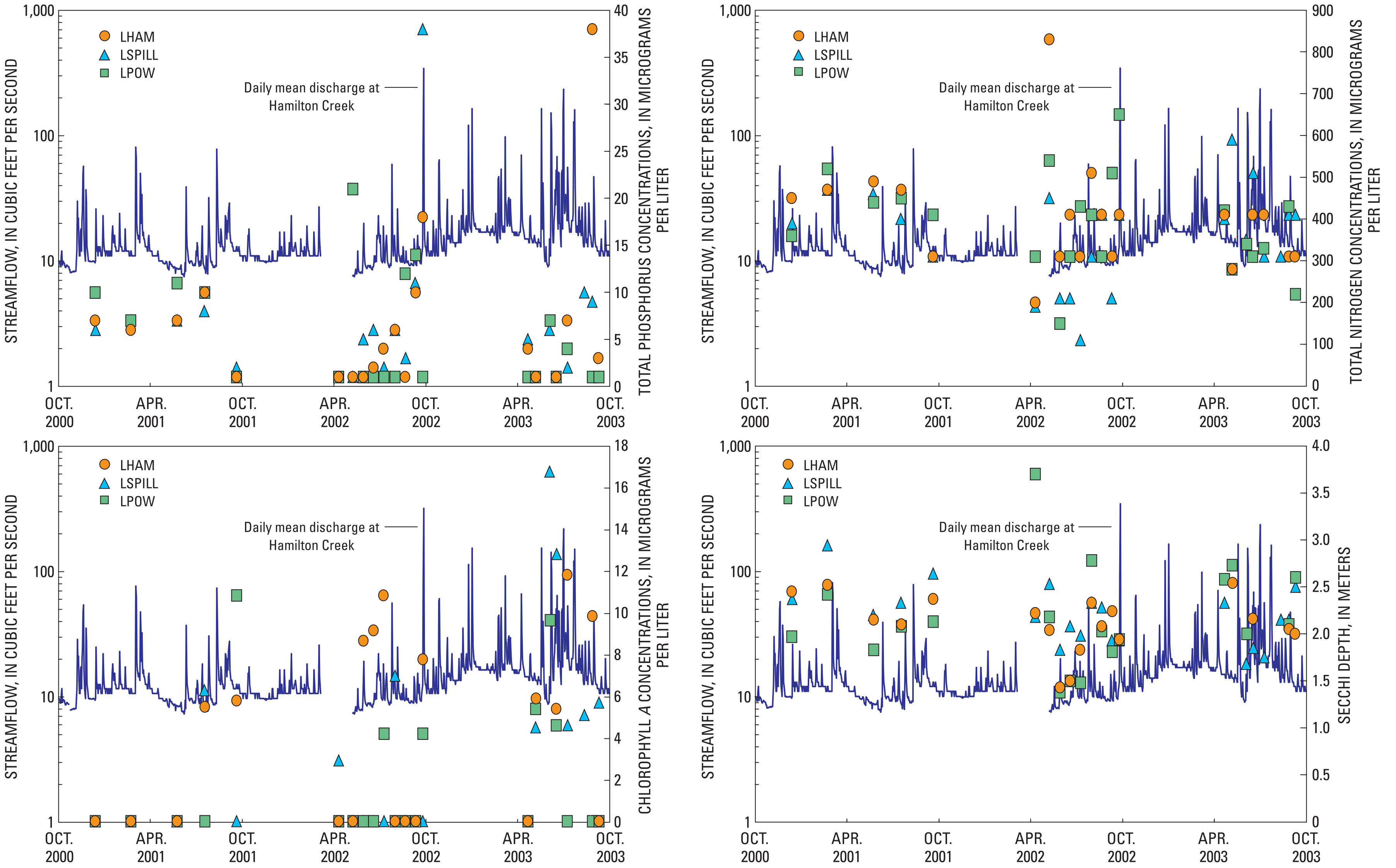


Figure 16. Water-quality at three sampling sites (LHAM, LSPILL, and LPOW) in the Hamilton Creek embayment of Converse Lake, Alabama, during water years 2001–03.

daily mean discharge indicated no distinct relation between increased streamflow and increased nutrient concentrations at the lake sites in the main body of the lake (fig. 15). Likewise, no consistent relation could be established between water quality in the Hamilton Creek embayment and streamflow in Hamilton Creek (fig. 16).

The distributions of growing season concentrations of selected nutrients and chlorophyll *a*, and Secchi depth were compared among the lake sites (fig. 17). Where Tukey multiple-comparison tests indicated distinct groups of lake sites based on median concentrations of total nitrogen and chlorophyll *a*, the groupings are indicated by a letter

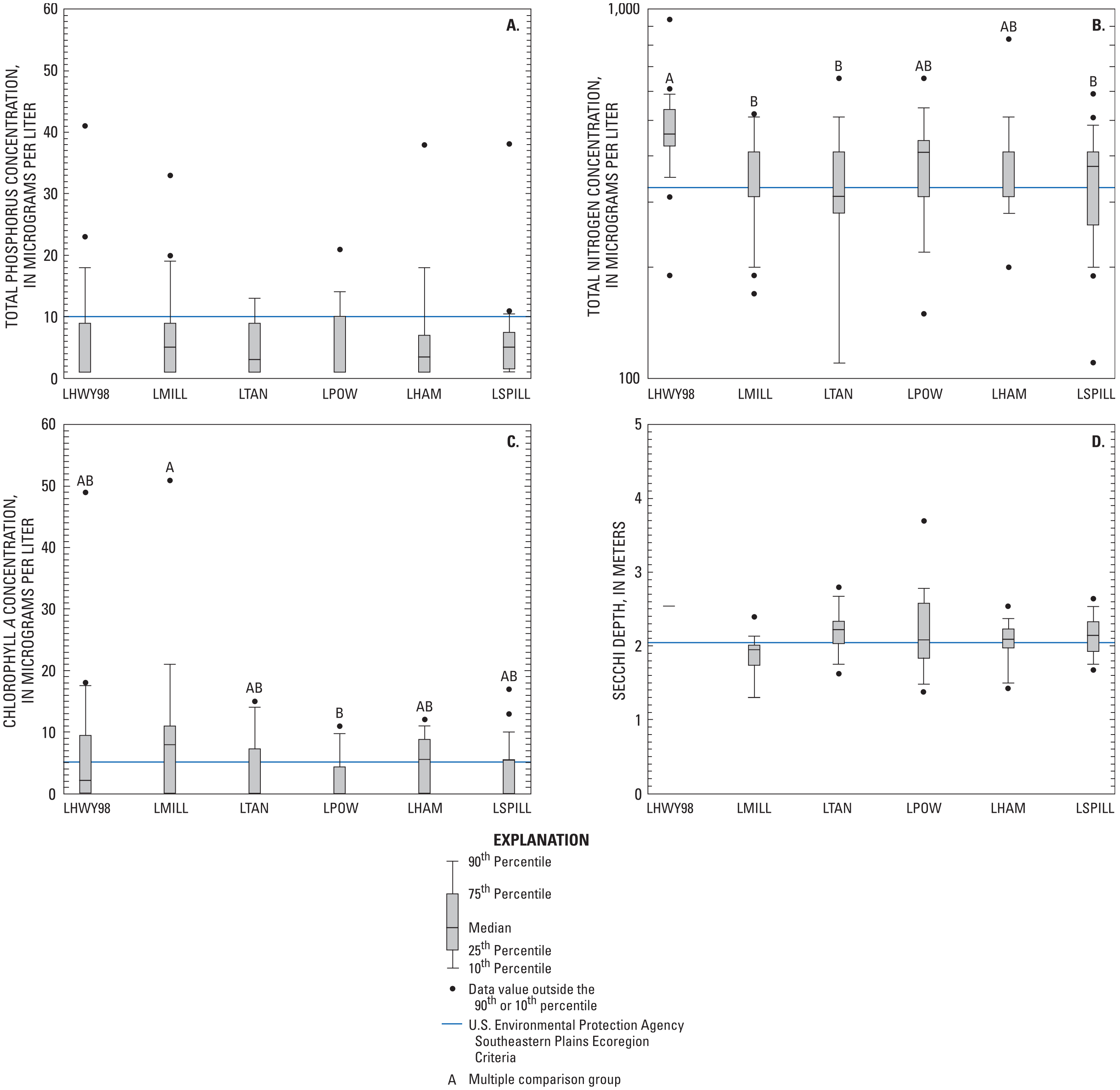


Figure 17. Distributions of measured water-quality properties at selected sites in Converse Lake, Alabama, during the growing seasons (April–September) of 2001–03.

designation beside each of the boxes in the appropriate box plots in figure 17.

Total phosphorus concentrations in the lake generally were low during 2001 through 2003 (fig. 17A). About 38 percent of the lake epilimnion samples contained levels of total phosphorus below the method detection limit of 1 g/L, and median concentrations in all lake segments were below the USEPA criterion of 10 µg/L for the Southeastern Plains ecoregion. The highest median total phosphorus concentration of 5 µg/L occurred at sites LMILL and LSPILL (figs. 9A, 17A). The greatest total phosphorus concentration, 41 µg/L, was measured at site LHWY98 in September 2002. A Kruskal-Wallis test indicated no significant ($p < 0.05$) differences in median total phosphorus concentration among the lake sites.

Total nitrogen concentrations at the Converse Lake sites ranged from 110 to 940 µg/L during the study period (fig. 17B). The maximum total nitrogen concentration occurred at site LHWY98 during September 2002, and the minimum concentration occurred at site LTAN in May and July 2002 and at site LSPILL in July 2002. Median total nitrogen concentrations at all sites except LTAN were greater than the USEPA ambient water-quality criterion of 329 µg/L for lakes and reservoirs (figs. 7C,17B). Total nitrogen concentrations at site LHWY98 were significantly ($p < 0.05$) higher than at sites LMILL, LTAN, and LSPILL according to the Tukey multiple-comparison test. Median total Kjeldahl nitrogen concentrations were below the criterion of 320 µg/L at three of the lake sites—LTAN, LPOW, and LSPILL (fig. 7A). The ecoregion criterion for nitrite plus nitrate was below the method detection level used in this study. The only nitrite plus nitrate median concentrations measured above the method detection level were at sites LHWY98 and LPOW, which had median nitrite plus nitrate concentrations of 65 and 30 µg/L, respectively; these two sites are closest to the mouths of tributaries. Kruskal-Wallis tests indicated no significant ($p < 0.05$) differences in total Kjeldahl nitrogen or nitrite plus nitrate concentrations among the lake sites.

LOCATION OF J.B. CONVERSE LAKE
IN THE J.B. CONVERSE LAKE WATERSHED

Chlorophyll *a* concentration is a surrogate measure for algal biomass. Chlorophyll *a* concentrations were variable at the study sites. In about 50 percent of all lake samples, chlorophyll *a* concentrations were below the method detection limit of 0.1 µg/L, and maximum concentrations of 51 and 49 µg/L occurred at LMILL during July 2001 and at LHWY98 during July 2003, respectively (fig. 17C). Median concentrations of chlorophyll *a* exceeded the ecoregion spectrophotometric criterion of 1.873 µg/L at LHWY98, LMILL, and LHAM, and the ecoregion fluorometric criterion of 5.125 µg/L at LMILL and LHAM (figs. 17C, 18A). A Tukey multiple-comparison test indicated site LMILL had significantly ($p < 0.05$) higher chlorophyll *a* concentrations than site LPOW, which placed the two sites into multiple-

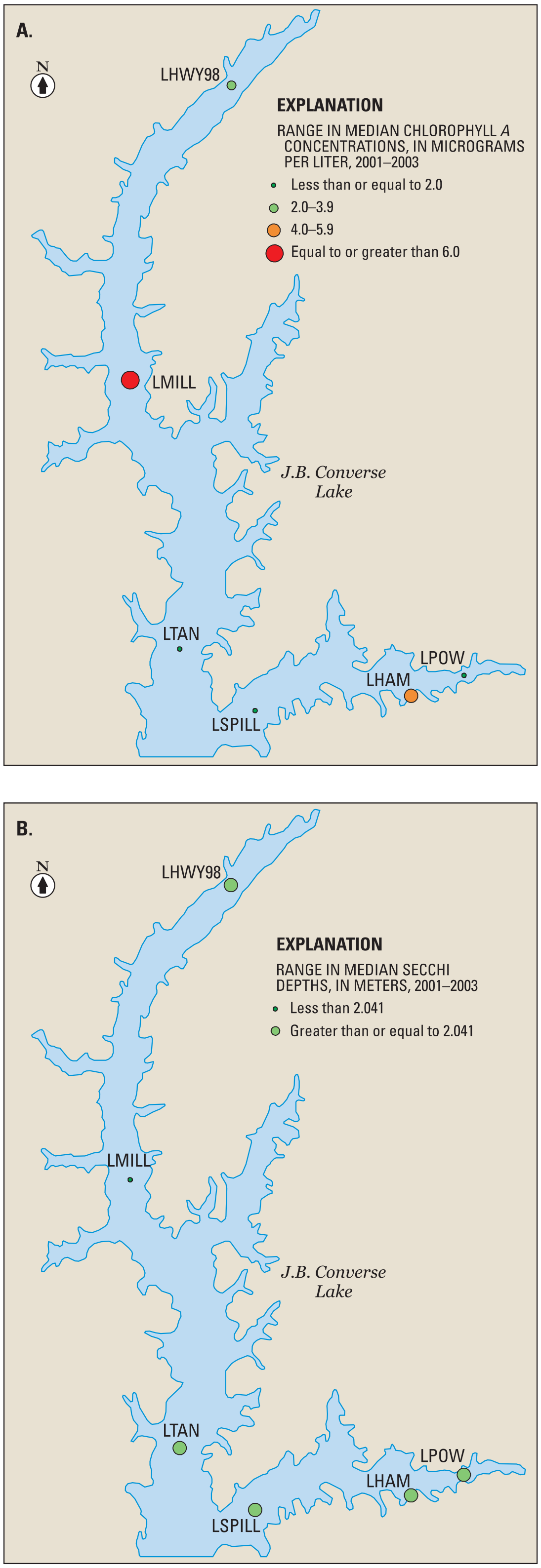


Figure 18. Median (A) chlorophyll *a* concentrations and (B) Secchi depths at selected sites in Converse Lake, Alabama, during the growing seasons (April–September) of 2001–03.

comparison groups A and B, respectively. All other lake sites were in the intermediate grouping, AB. Greater chlorophyll *a* concentrations and shorter Secchi depths at site LMILL indicated that algal biomass was greater at this site than in other areas of the lake, perhaps because of the greater total phosphorus concentrations.

Secchi depth provides a quick measure of water transparency, with greater depths indicating greater transparency (figs. 17D, 18B). The minimum Secchi depth criterion indicated for the Southeastern Plains ecoregion is 2.041 meters (m). Secchi depths in Converse Lake were fairly constant from site to site throughout the growing season, with median values ranging from 1.95 to 2.54 m. Median Secchi depth was greater than the criterion at all sites except LMILL (figs. 17D, 18B). The Kruskal-Wallis test indicated significant ($p < 0.05$) differences among the sites, but a Tukey multiple-comparison test of the data failed to identify distinct groups.

Organic Carbon Concentrations

Total organic carbon concentrations in Converse Lake generally were similar to total organic carbon concentrations in the tributaries, and ranged from 0.4 mg/L at LHAM to 9.2 mg/L at site LTAN (fig. 19A). Median concentrations of total organic carbon were slightly greater in the lake than in the tributaries, ranging from 3.6 mg/L at site LHAM to 6.2 mg/L at site LHWY98 (figs. 12A, 19A). Dissolved organic carbon concentrations ranged from the minimum detection level of 0.1 mg/L at site LHAM to 8.4 mg/L at site LHWY98 (fig. 19B). Kruskal-Wallis tests indicated no significant ($p < 0.05$) differences in total or dissolved organic carbon concentrations among the lake sites.

Increases in algal biomass can cause increases in organic carbon. To assess the current relation between algal biomass and organic carbon concentrations in Converse Lake, temporal changes in organic carbon throughout the 2003 growing season and correlations between chlorophyll *a* and organic carbon were evaluated. Algal biomass in the study area is expected to peak in mid to late summer because stable temperatures and low-flow conditions allow algal colonies to become better established. Organic carbon concentrations generally increased during the mid to late growing season of 2003 (fig. 20), as would be expected of algal biomass. Spearman rho correlations between chlorophyll *a* and organic carbon, however, were not found to be significant. Chlorophyll *a* to biomass ratios can vary with the type of algae. Therefore, more direct measures of algal biomass could better identify algal contributions to total organic carbon concentrations in Converse Lake.

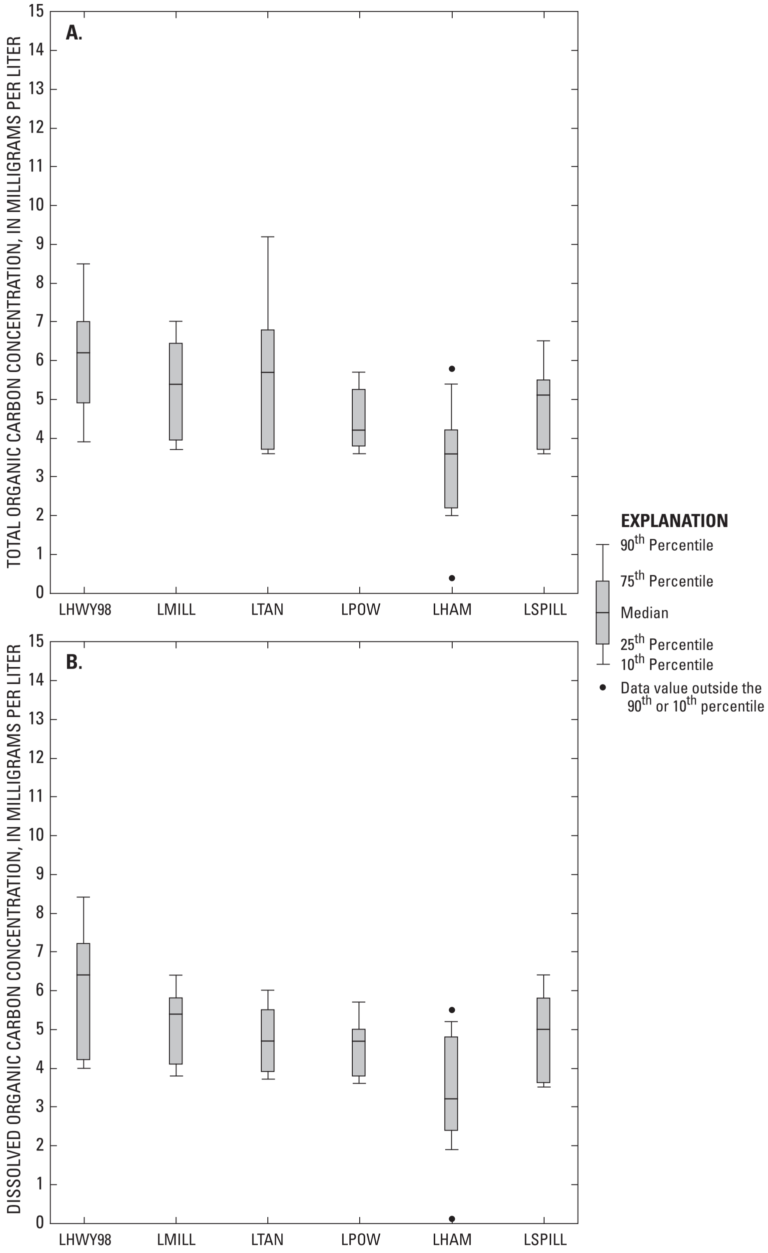


Figure 19. (A) Total and (B) dissolved organic carbon concentrations at selected sites in Converse Lake, Alabama, 1998–2003.

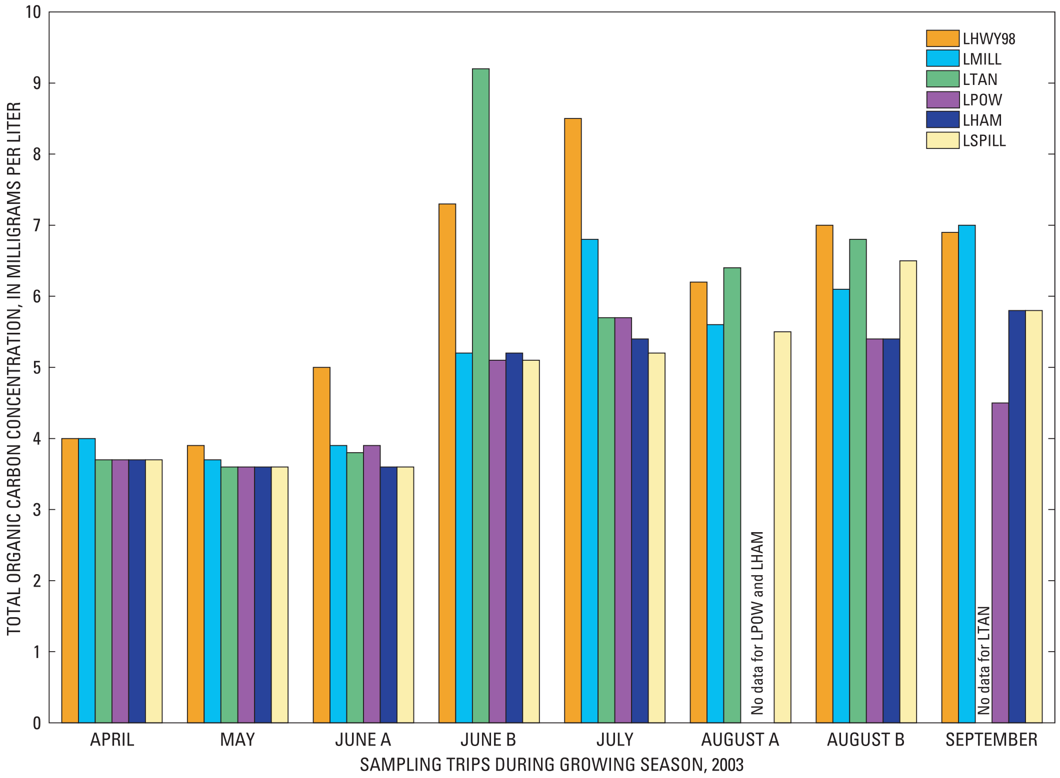


Figure 20. Total organic carbon concentrations at selected sites in Converse Lake, Alabama, summer 2003.

The USEPA has guidelines for removal percentages of total organic carbon (U.S. Environmental Protection Agency, 2001) to aid in reducing the formation of DBPs in finished drinking water. The removal percentages required for various concentrations of total organic carbon based on alkalinities in raw water are summarized in table 17. Median concentrations of total organic carbon at all of the lake sites except LHAM indicate a required reduction of 45 percent to produce finished water. Median total organic carbon concentrations at LHAM, located just upstream from the drinking-water intakes, indicated that only a 35-percent reduction in total organic carbon was necessary for finished water production.

Table 17. Required removal percentages of total organic carbon based on source-water alkalinities less than 60, under the Stage 1 Disinfectants and Disinfection By-Products Rule.

[Modified from U.S. Environmental Protection Agency (2001); TOC, total organic carbon; mg/L, milligram per liter; >, greater than]

TOC in source water (mg/L)	Required TOC removal (percent)
>2.0 to 4.0	35.0
>4.0 to 8.0	45.0
>8.0	50.0

Trophic Status

A trophic state index (TSI) was calculated from Converse Lake data (fig. 21), using the following equations from Carlson, 1977:

$$TSI\ (TP) = 14.42\ \ln(TP) + 4.15, \tag{4}$$

$$TSI\ (chl) = 9.81\ \ln(chl) + 30.6, \tag{5}$$

and

$$TSI\ (sd) = 60 - 14.41\ \ln(sd), \tag{6}$$

where

TSI = trophic state index (Carlson, 1977),
TP = total phosphorus concentration (in micrograms per liter),
ln = natural logarithm function,
chl = chlorophyll *a* concentration (in micrograms per liter), and
sd = Secchi depth (in meters).

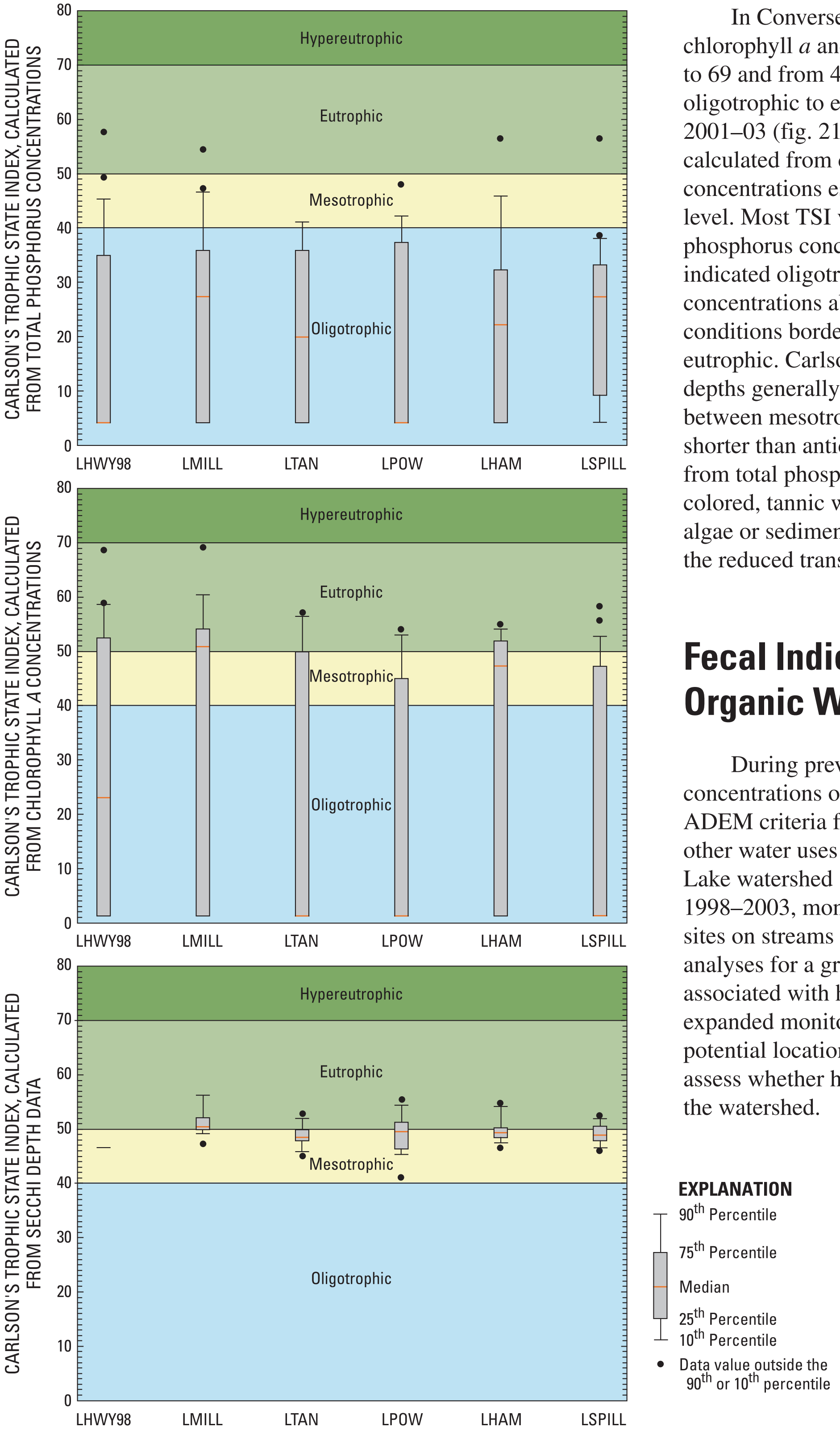


Figure 21. Trophic state index values for selected sites in Converse Lake for the 2001–03 growing seasons (April–September).

In Converse Lake, TSI values calculated from chlorophyll *a* and total phosphorus ranged from 1.2 to 69 and from 4.2 to 58, respectively, indicating oligotrophic to eutrophic conditions in the lake during 2001–03 (fig. 21). Many oligotrophic values were calculated from chlorophyll *a* and total phosphorus concentrations estimated below the method detection level. Most TSI values calculated from total phosphorus concentrations above the detection level indicated oligotrophic conditions, but chlorophyll *a* concentrations above the detection level indicated conditions bordering between mesotrophic and eutrophic. Carlson's TSI values calculated from Secchi depths generally indicated borderline conditions between mesotrophic and eutrophic. Secchi depths were shorter than anticipated from the TSI values calculated from total phosphorus concentrations. The highly colored, tannic waters of the lake rather than elevated algae or sediment concentrations probably account for the reduced transparency.

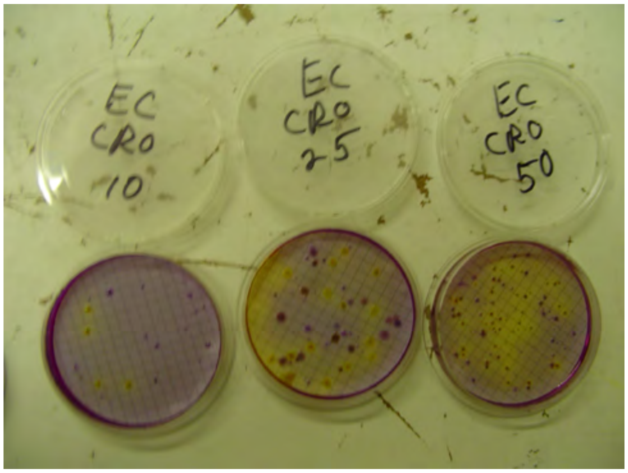
Fecal Indicator Bacteria and Organic Wastewater Compounds

During previous monitoring of the watershed, concentrations of fecal indicator bacteria exceeded ADEM criteria for swimming (full-body contact) and other water uses in several locations in the Converse Lake watershed (Journey and Gill, 2001). During 1998–2003, monitoring was expanded to include more sites on streams of particular interest and to include analyses for a group of organic compounds that are associated with human wastewater. The results of this expanded monitoring can be used to further pinpoint potential locations of wastewater contamination and assess whether human wastewater is reaching streams in the watershed.

Occurrence and Distribution of Fecal Indicator Bacteria

Samples were analyzed for fecal coliform and *E. coli*, two types of bacteria that are indicative of fecal contamination. Criteria for concentrations of fecal-indicator bacteria in water intended for various uses have been established by the ADEM and USEPA (table 18). Many of these criteria are designed to be compared to the geometric mean of five or more samples collected within 30 days. Sampling frequency during this study did not meet this requirement, so comparisons between the criteria and median, maximum, and geometric mean concentrations of bacteria were used to identify potential areas where exceedance of criteria may occur. The drinking-water standard of zero colonies per 100 milliliters (col/100 mL) is enforceable but applies only to finished drinking water. All other criteria in table 18 are suggested limits for bacteria concentrations in water intended for various uses.

Fecal coliform concentrations in the tributaries to Converse Lake ranged from 28 col/100 mL at site BIG to a storm concentration of 75,000 col/100mL at site JUN-B (fig. 22A). When the storm concentration was excluded from the data set, the maximum fecal coliform concentration of 9,400 col/100 mL still occurred at site JUN-B. Median fecal coliform concentrations at all sites were less than 1,000 col/100 mL, the geometric mean criterion for public water-supply use (fig. 22A). Median fecal coliform concentrations at all sites except BIG, BOG, HAM-A, and HAM exceeded the seasonal geometric mean criterion for whole-body contact of 200 col/100 mL. Geometric mean fecal coliform concentrations exceeded the geometric mean criterion for public water-supply use at one site, JUN-B. Geometric mean fecal coliform concentrations exceeded the seasonal geometric mean criterion for public water-supply use at all sites except BIG.



Amy C. Gill, USGS

Growth of bacterial colonies, including *Escherichia coli*, on membrane filters processed at site CRO.

E. coli concentrations ranged from 30 col/100 mL at site BIG to a storm concentration of 190,000 col/100 mL at site JUN-B (fig. 22B). The maximum *E. coli* concentration during normal flow (excluding the storm sample) was 10,000 col/100 mL, which also occurred at site JUN-B. During normal flow conditions, median *E. coli* concentrations at all sites were below 576 col/100 mL, the USEPA single-sample maximum criterion for waters infrequently used

Table 18. Standards and criteria for concentrations of fecal bacteria for different water-use classifications.

[Alabama Department of Environmental Management (2000); U.S. Environmental Protection Agency (1986); —, not applicable]

Type of bacteria	Drinking-water standard	Fecal bacterial concentrations by water-use classification (colonies per 100 milliliters)				
		Outstanding Alabama water	Public water supply	Swimming and other whole-body contact water sports	Fish and wildlife	Agricultural and industrial water supply
Fecal coliform	0	[a]200	[a]1,000 [b](200) [c]2,000	[a]200	[a]1,000 [b](200) [c]2,000	[a]2,000 [c]4,000
Escherichia coli	0	—	—	[a]126 [d]235 to 576	—	—

[a] Bacteria shall not exceed a geometric mean of this value. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours.

[b] Values in parentheses are seasonal geometric mean limits effective during June through September to account for incidental water contact and recreational uses.

[c] Maximum bacterial concentration that is not to be exceeded in any sample.

[d] Range in single-sample maximum concentrations allowed for full-body contact in recreational waters for different frequencies of use, from designated beaches to infrequently used full-body contact recreation areas.

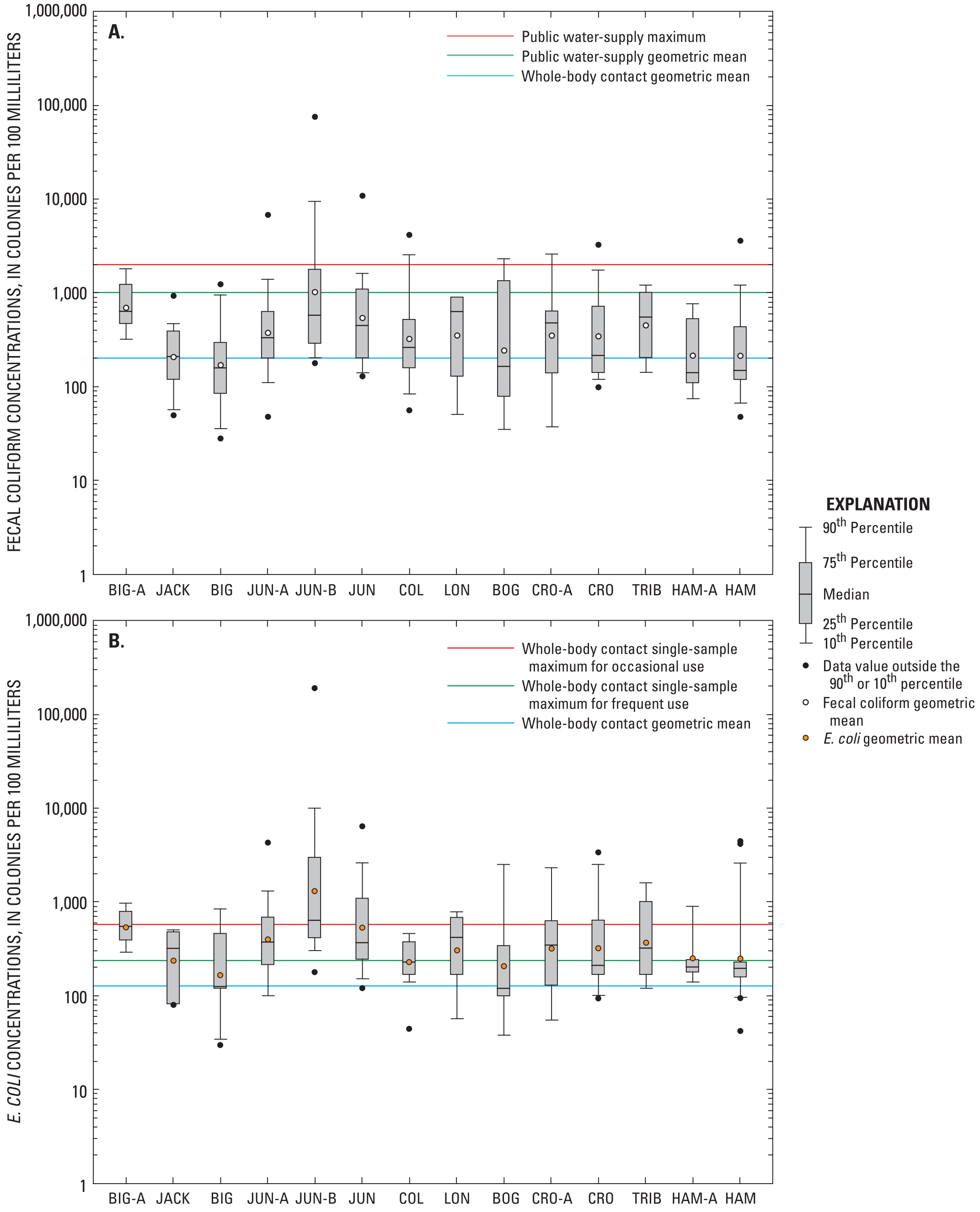


Figure 22. (A) Fecal coliform and (B) *Escherichia coli* (*E. coli*) concentrations at selected tributary sites in the Converse Lake watershed, Alabama, 1998–2003.

for whole-body contact recreation. Geometric mean *E. coli* concentrations exceeded the geometric mean criterion for whole-body contact recreation at all sites, and geometric mean *E. coli* concentrations at JUN-B exceeded the single-sample criterion for waters infrequently used for whole-body contact recreation.

Spearman rho correlation coefficients were calculated between fecal-indicator bacteria concentrations and streamflow for each tributary site for 1998–2003. As with other constituents, the relation between concentrations of fecal-indicator bacteria and streamflow can provide information about the probable source(s) of contamination. If bacteria concentrations increase with streamflow, then the contamination is most likely from nonpoint or diffuse sources related to land use. If bacteria concentrations decrease as streamflow increases, then the contamination is probably from a point source, such as a sewer outfall, and is being diluted by the increased flow. Homes and businesses in the Converse

Lake watershed have septic systems rather than a centralized sewage disposal system, so bacteria concentrations in the watershed are likely to increase with increases in streamflow.

Only five significant ($p < 0.05$) correlations between fecal-indicator bacteria concentrations and streamflow were detected, and all were weakly positive, indicating that nonpoint sources are the likely sources for the bacteria contamination. Both fecal coliform and *E. coli* were significantly correlated with streamflow at site JUN (fecal coliform rho = 0.38; *E. coli* rho = 0.68) and site BOG (fecal coliform rho = 0.38; *E. coli* rho = 0.49). Fecal coliform and streamflow were significantly correlated (rho = 0.31) at site HAM.

Concentrations of fecal indicator bacteria were much lower in Converse Lake than in the tributaries (figs. 22, 23, 24). Median and geometric mean concentrations of fecal coliform and *E. coli* were well below all criteria at all six lake sampling sites (fig. 23). In fact, only two lake samples had fecal-indicator bacteria concentrations that exceeded criteria during 2001–03. Extremely high concentrations of fecal coliform and *E. coli* were measured during September 2003 at site LSPILL, but such high concentrations were not observed during subsequent sampling. Because other samples at LSPILL had very low bacteria concentrations, this occurrence seems to be an isolated incident. Because the sampling location at the LSPILL site is in the center of a cross section of the lake in an area where fishing and boating are prohibited, the most likely source of the high concentrations of bacteria in this sample was birds. The September 2002 sample at LHWY98 also had high fecal bacteria concentrations that exceeded criteria—fecal coliform concentrations of 630 col/100 mL and *E. coli* concentrations of 1,100 col/100 mL. The high concentrations at LHWY98 may have been related to a small increase in flow from rain in the upper watershed during the previous days.

The USEPA recommends that States replace fecal coliform concentration criteria with *E. coli* or enterococci criteria, because these organisms are considered to be more specific indicators of fecal contamination as a result of their enteric origin (U.S. Environmental Protection Agency, 2002b). As the criteria change to new fecal-indicator bacteria, a relation between historical fecal coliform data and new indicator data is needed for use in analyzing trends in fecal-indicator bacteria concentrations. In this study, samples for both fecal coliform and *E. coli* concentrations were collected, and the relation between tributary concentrations of these two indicator bacteria was examined. Prior to fitting the regression model, concentrations of both types of bacteria were log-transformed to improve the linearity of the relation. The following linear

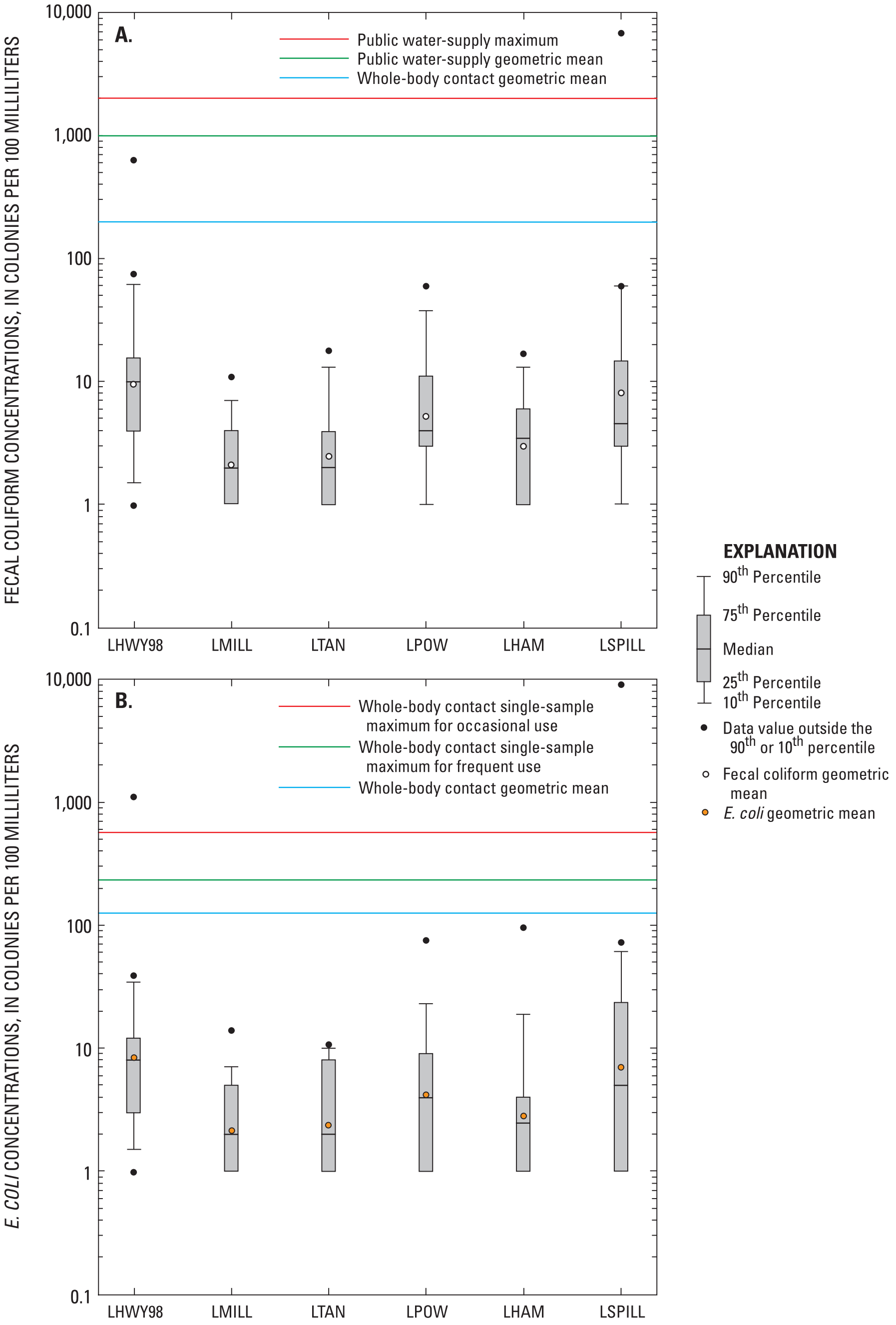
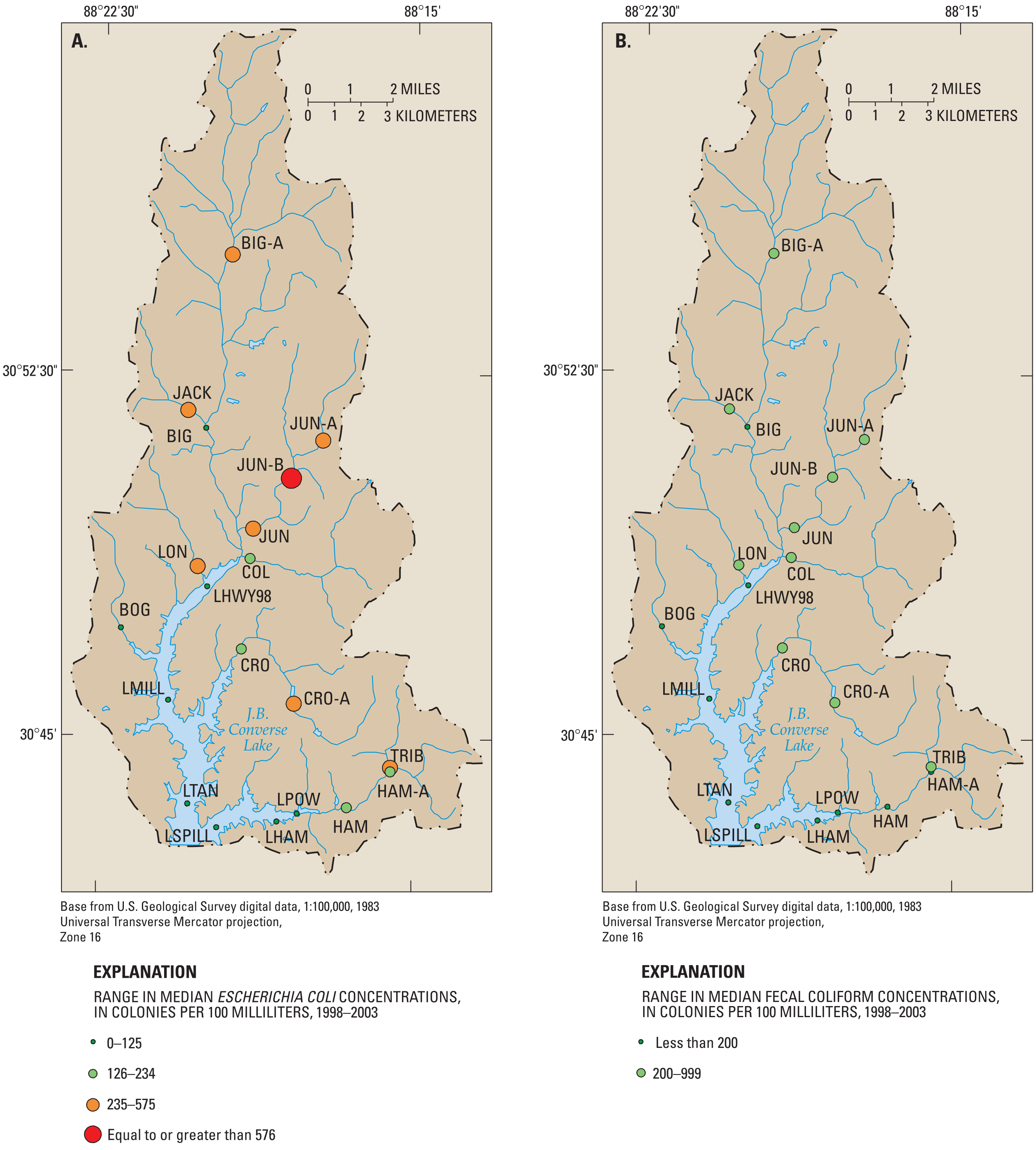


Figure 23. (A) Fecal coliform and (B) *Escherichia coli* (*E. coli*) concentrations at selected sites in Converse Lake, Alabama, 2001–03.



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection,
Zone 16

Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator projection,
Zone 16

Figure 24. Median concentrations of (A) *Escherichia coli* (*E. coli*) and (B) fecal coliform at selected sites in the Converse Lake watershed, Alabama, 1998–2003.

regression model was fit to measured concentrations of fecal coliform and *E. coli:*

$$\ln(\mathrm{FC}) = 0.7947 + 0.8565 \times (\ln(\mathrm{EC})), \qquad (7)$$

where

ln = the natural logarithm,
FC = fecal coliform concentration (in colonies per 100 mL) and
EC = *E. coli* concentration (in colonies per 100 mL).

Measured *E. coli* concentrations in relation to measured and regression-estimated fecal coliform concentrations are shown in figure 25. The uncertainty in the predicted concentrations is graphically displayed by the 95-percent prediction interval. Given an *E. coli* concentration within the range of plotted data, there is a 95-percent chance that the estimated fecal coliform concentration will be within the prediction interval shown. The R^2 value indicates that approximately 77 percent of the variability in fecal coliform concentrations is explained by *E. coli* concentrations, and the regression equation should reasonably estimate concentrations of one type of indicator bacteria from concentrations of the other type for the Converse Lake watershed.

Occurrence and Distribution of Organic Wastewater Compounds

Organic wastewater compounds (OWCs), also referred to as wastewater indicators, are chemical compounds commonly found in wastewater and urban runoff that may indicate contamination associated with human sources. OWCs can originate from a variety of natural and anthropogenic sources in a watershed, including wastewater-treatment facilities. Household chemicals, pharmaceuticals, and other consumables can be released to the environment after passing through wastewater-treatment processes or domestic septic systems, which often are not designed to remove them from the effluent. Most compounds are from anthropogenic sources although a few compounds, such as cholesterol and coprostanol, can occur naturally. Comparative analysis of detection frequency and concentrations provides clues as to the sources and origins of these compounds.

The method used by the NWQL to identify OWCs was developed in response to increasing concern over the effects of endocrine-disrupting chemicals in wastewater on aquatic organisms (Zaugg and others, 2002). This method focuses on identifying the compounds that are either an indicator of wastewater or that have been selected on the basis of their

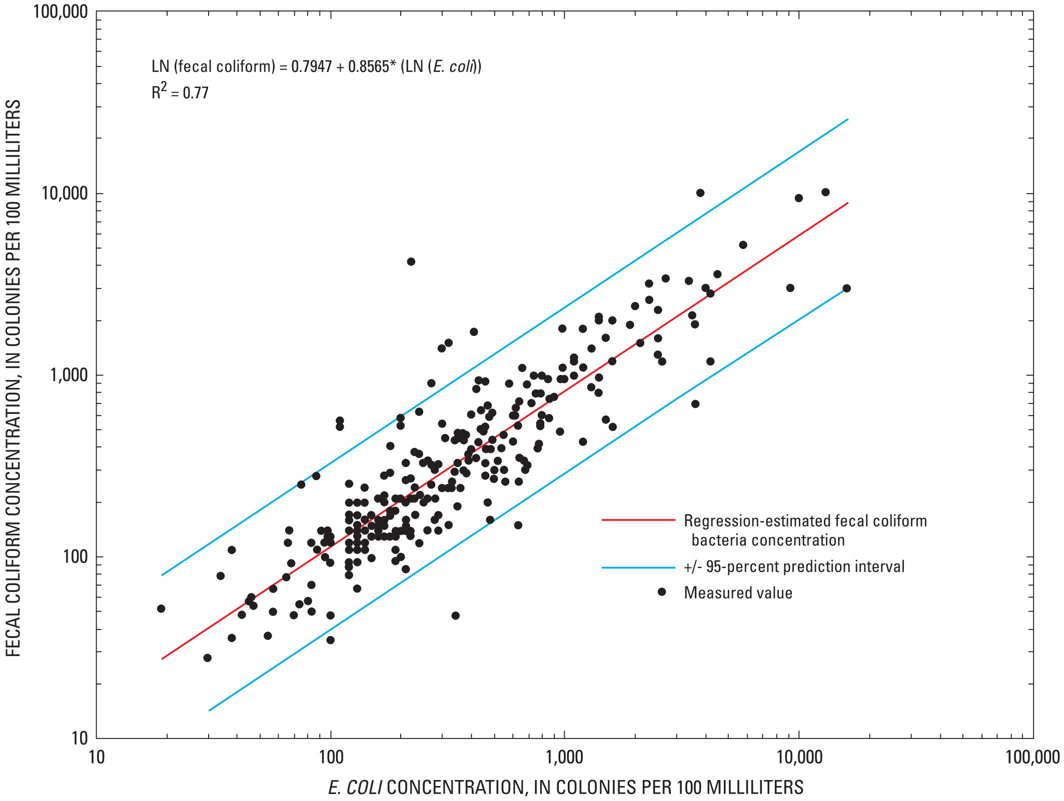


Figure 25. Measured fecal coliform and *Escherichia coli* (*E. coli*) bacteria concentrations, regression-estimated fecal coliform concentrations, and prediction intervals for tributaries of Converse Lake, Alabama, 1998–2003.

endocrine-disrupting potential or general toxicity (Zaugg and others, 2002). The NWQL method included 87 compounds between 1999 and 2002 (table 19); 48 of these compounds were selected for analysis in the stream samples collected from the Threemile Creek basin (McPherson and others, 2005) and will be discussed later in this report (see Comparison of Wastewater-Indictor Groups in the Threemile Creek and Converse Lake Watersheds).

Of the 87 compounds analyzed in this study, 29 were detected in at least one sample in the Converse Lake watershed (table 19; fig. 26; appendix 3). The most frequently detected OWCs included metolachlor (herbicide), atrazine (herbicide), caffeine (stimulant), β-sitosterol (plant steroid), bromacil (herbicide), metalaxyl (fungicide), prometon (herbicide), NP1EO (detergent metabolite), cholesterol (plant and animal steroid), OP1EO (detergent metabolite), and triclosan (disinfectant) (fig. 26; table 20). The frequent detection of several of these compounds in a national reconnaissance of 139 streams indicates that their environmental occurrence is widespread (Kolpin and others, 2002).

Wastewater indicators were detected in 55 of 86 samples (64 percent) collected at 16 sites in the Converse Lake watershed in 1999–2002 (appendixes 3, 4). The number of samples collected at each of the 16 sites ranged from 1 to 11, with the greatest number of samples collected in the Juniper Creek and Hamilton Creek basins (table 1). The number of wastewater-indicator compounds detected in an individual sample ranged from zero (BIG-A, BIG, JUN-A, JUN-B, JUN, COL, CRO-A, CRO, HAM-A, and HAM) to seven (HAM; appendix 4). The number of OWCs detected at individual sites throughout the study ranged from 0 to 13, with the highest number found at HAM (appendix 3). Mixtures of chemicals were common but only 15 of 86 samples (17 percent) contained total concentrations of OWCs exceeding 1 μg/L (appendix 4). Total concentrations of OWCs were greatest at JUN-A (6.32 μg/L) and HAM (5.79 μg/L). The highest concentrations of 10 different OWCs (caffeine, cholesterol, 3β-coprostanol, NP1EO, *para*-nonylphenol, *para*-cresol, diethylphthalate, tri(2-chloroethyl)phosphate, atrazine, and metolachlor) occurred at site HAM; the highest concentrations of 4 OWCs (2-butoxyethanol phosphate, bromacil, prometon, and metalaxyl) occurred at site CRO-A (table 20).

The 29 detected compounds represent a wide variety of uses and origins, including residential, industrial, and agricultural sources. To obtain a broader view of the results of this study, the 29 detected compounds were divided into the following 10 groups based on their general use and(or) origins: (1) prescription and nonprescription drugs, (2) steroids, (3) detergent metabolites, (4) disinfectants, (5) plasticizers/flame retardants, (6) insect repellent, (7) insecticides, (8) herbicides and fungicides, (9) polycyclic aromatic hydrocarbons, and (10) fragrances (table 20). The prevalence of these different groups of compounds with respect to each sample collected in the Converse Lake watershed is shown in figure 27. The greatest concentrations of OWCs are from three groups: steroids, disinfectants, and plasticizers/flame retardants (fig. 27A). The diversity among the compound groups detected in the Converse Lake watershed indicates that although concentrations of some groups of compounds, such as herbicides and prescription/nonprescription drugs, were inherently low, these compounds were detected frequently in the Converse Lake watershed (fig. 27B).

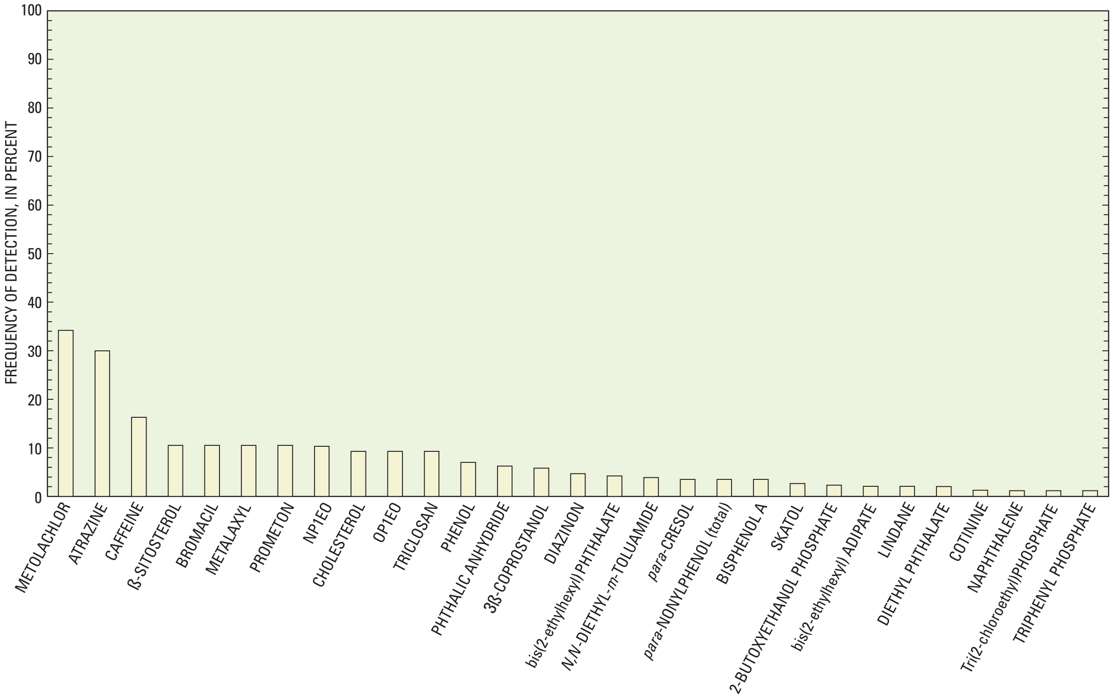


Figure 26. Frequencies of detection of organic wastewater compounds in water samples from the Converse Lake watershed, Alabama, 1999–2002.

Table 19. Organic wastewater compounds sampled in the Converse Lake watershed, Alabama, 1999–2002.

[Compounds in **bold** were detected in the Converse Lake watershed; AHTN, 6-acetyl-1,1,2,4,4,7-hexamethyltetraline; BHA, 3-*tert*-butyl-4-hydroxyanisole; BHT, 2-6-di-*tert*-butyl-*p*-cresol; HHCB, 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl-cyclopenta(γ)-2-benzopyran; NP1EO, nonylphenol monoethoxylate; NP2EO, nonylphenol diethoxylate; OP1EO, octylphenol monoethoxylate; OP2EO, octylphenol diethoxylate]

Compound	Included in 48-compound group (McPherson and others, 2005)	Compound	Included in 48-compound group (McPherson and others, 2005)
1,2-dichlorobenzene		**Diazinon**	X
1,3-dichlorobenzene		Dichlorvos	
1,4-dichlorobenzene		Dieldrin	X
17-alpha-ethynyl estradiol		Diethylhexyl phthalate	
17ß-estradiol	X	**Diethyl phthalate**	
1-methylnaphthalene	X	*d*-limonene	
2(2-butoxyethoxy) ethyl acetate		Equilenin	
2,6-dimethylnaphthalene	X	Estrone	
2,6-di-*tert*-butylphenol	X	Ethyl citrate	
2,6-di-*tert*-butyl-1,4-benzoquinone	X	Fluoranthene	X
2-butoxyethanol phosphate	X	HHCB	X
2-methylnaphthalene	X	Indole	
3,4-dichlorophenyl isocyanate		Isoborneol	
3ß-coprostanol	X	Isophorone	
4-cumylphenol		Isoquinoline	
4-n-octylphenol		**Lindane**	X
4-*tert*-octylphenol		Menthol	
5-methyl-1*H*-benzotriazole	X	**Metalaxyl**	X
Acetophenone	X	Methyl parathion	X
AHTN	X	Methyl salicylate	
Anthracene	X	**Metolachlor**	X
Anthraquinone		***N,N*-diethyl-*m*-toluamide**	X
Atrazine	X	**Naphthalene**	X
Benzaldehyde		**NP1EO**	X
Benzo[*a*]pyrene	X	NP2EO	X
Benzophenone		**OP1EO**	X
BHA	X	OP2EO	X
BHT	X	***para*-cresol**	X
bis(2-ethylhexyl) adipate		***para*-nonylphenol**	X
bis(2-ethylhexyl) phthalate		Pentachlorophenol	
bisphenol A		Phenanthrene	X
Bromacil	X	**Phenol**	
bromoform		**Phthalic anhydride**	
ß-sitosterol	X	**Prometon**	X
Caffeine	X	Pyrene	X
Camphor		**Skatol**	
Carbaryl	X	Stigmastanol	X
Carbazole		Tetrachloroethylene	
cis-chlordane	X	**tri(2-chloroethyl)phosphate**	X
Chlorpyrifos	X	tri(2-chloroisopropyl)phosphate	X
Cholesterol	X	Tributylphosphate	
Codeine		**Triclosan**	X
Cotinine	X	**Triphenyl phosphate**	X
Cumene			

Table 20. Summary of organic wastewater compounds detected in water samples in the Converse Lake watershed, Alabama, 1999–2002.

[µg/L, microgram per liter; E, estimated; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Compounds that are potential endocrine disruptors are in **bold**]

Compound	Maximum concentration (µg/L)	Number of detections	Sample size	Detection frequency	Site with the highest concentration
Prescription and non-prescription drugs					
Caffeine	0.72	14	86	16.3	HAM
Cotinine	E .015	1	77	1.3	JUN-B
Steroids					
Cholesterol	E 2.00	8	86	9.3	HAM
3ß-coprostanol	E 1.60	5	86	5.8	HAM
ß-sitosterol	E 1.10	4	38	10.5	JUN
Detergent metabolites					
NP1EO	E 0.670	6	58	10.3	HAM
OP1EO	E .103	8	86	9.3	LHAM
***para*-nonylphenol (total)**	E .670	3	86	3.5	HAM
Disinfectants					
para-cresol	0.053	3	86	3.5	HAM
Phenol	2.42	6	86	7.0	LHWY98
Triclosan	.37	8	86	9.3	COL
Plasticizers/flame retardants					
2-Butoxyethanol phosphate	0.143	2	86	2.3	CR0-A
bisphenol A	.12	3	86	3.5	JUN-A
bis(2-ethylhexyl) adipate	1.4	1	48	2.1	TRIB
bis(2-ethylhexyl) phthalate	6.2	2	48	4.2	JUN-A
diethyl phthalate	E .290	1	49	2.0	HAM
Phthalic anhydride	.582	3	48	6.3	JUN
Triphenyl phosphate	E .007	1	86	1.2	CRO
Tri(2-chloroethyl)phosphate	.043	1	86	1.2	HAM
Insect repellent					
N,N-diethyl-*m*-toluamide	E 0.062	3	77	3.9	LHAM
Insecticides					
Diazinon	E 0.047	4	86	4.7	TRIB
Lindane	E .030	1	48	2.1	CRO
Herbicides and fungicides					
Atrazine	E 0.019	3	10	30.0	HAM
Bromacil	E .340	4	38	10.5	CRO-A
Metolachlor	E .067	13	38	34.2	HAM
Prometon	E .035	4	38	10.5	CRO-A
Metalaxyl	E .037	4	38	10.5	CR0-A
Polycyclic aromatic hydrocarbons					
Naphthalene	0.052	1	86	1.2	LHAM
Fragrances					
Skatol	E 0.120	1	38	2.6	JUN-B

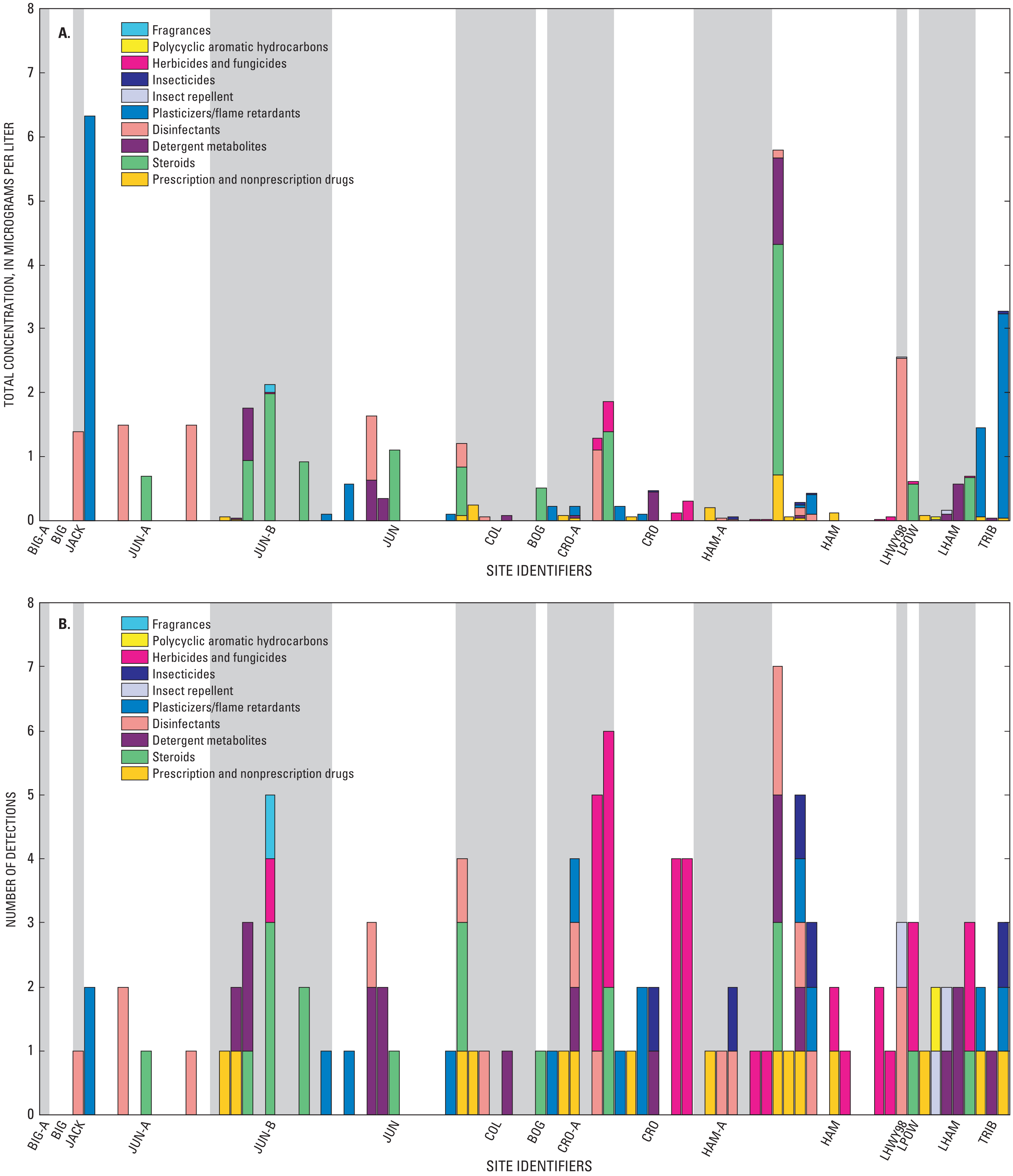


Figure 27. Summary of the types of organic wastewater compounds detected per sample for (A) total concentration and (B) number of detections in the Converse Lake watershed, Alabama, 1999–2002.

Some groups of compounds were detected exclusively in certain areas of the watershed. Herbicides, fungicides, and insecticides were found predominantly in Crooked Creek, the Hamilton Creek basin, and in Converse Lake. A single detection of metolachlor was detected at another site (JUN-B, fig. 27; appendix 3). The insect repellent DEET (*N*, *N*-diethyl-*m*-toluamide) was detected only in Converse Lake (fig. 27; appendix 3).

Detection of caffeine can be an important indicator of wastewater contamination in surface-water samples even though caffeine is not persistent in the environment (Zaugg and others, 2002). Caffeine was detected in the lower reaches of Hamilton Creek (HAM) four times and at seven other sites in the basin (JUN-B, COL, CRO-A, CRO, HAM-A, LHAM, and TRIB; appendix 3). 3-β coprostanol is a traditional indicator of sewage contamination because it is produced almost exclusively in the digestive tract of higher mammals (humans, pigs, cats) and often correlates with the presence of other sewage-derived pollutants (Zaugg and others, 2002). 3-β coprostanol was detected three times at JUN-B, and once at COL and HAM (appendix 3). Cotinine, a metabolic by-product produced by the human body in processing nicotine, and skatol, a constituent of human feces, were detected only at JUN-B (appendix 3).

Detection of detergents or detergent metabolites also can be indicative of wastewater contamination. Detergent metabolites were detected most frequently in the lower reaches of Juniper Creek (JUN-B, JUN) and in the lower reaches of Hamilton Creek (HAM; fig. 27). Triclosan, an antimicrobial agent found in soaps, deodorants, lotions, and creams, was detected in Collins Creek (COL), Hamilton Creek (HAM-A, HAM), and in one sample from Converse Lake (LHWY98; appendix 3).

Little is known about the potential interactive effects (synergistic or antagonistic toxicity) that may occur from complex mixtures of OWCs in the environment. Research has shown that select chemical combinations can exhibit additive or synergistic toxic effects (Kolpin and others, 2002). Much is yet to be learned pertaining to the effects (particularly chronic effects) on humans, plants, and animals exposed to low-level concentrations of pharmaceuticals and other OWCs that were detected in this study.

Organic Wastewater Compounds as Endocrine Disruptors

An endocrine disruptor is a natural or synthetic chemical that, when absorbed into the body, either mimics or blocks hormones and disrupts the body's normal functions. Exposure to endocrine disruptors can occur through direct contact with chemicals or through intake of contaminated water, food, or air. Chemicals suspected of acting as endocrine disruptors are found in detergents, resins, plasticizers, insecticides, herbicides, fumigants, fungicides, industrial chemicals, and heavy metals. Of the 29 compounds detected in the Converse Lake watershed, 10 are known or suspected to exhibit at least weak hormonal activity, with the potential to disrupt endocrine function (table 20; Kolpin and others, 2002). These 10 compounds can be divided into five groups based on general use and(or) origin, including detergent metabolites (NP1EO, OP1EO, and *para*-nonylphenol); disinfectants (triclosan); plasticizers/flame retardants (bisphenol A, bis(2-ethylhexyl) phthalate, and diethylphthalate); insecticides (diazinon and lindane); and herbicides (atrazine).

Research has shown that even low-level exposure (less than 0.001 μg/L) to select hormones can elicit deleterious effects in aquatic species (Kolpin and others, 2002). In the Converse Lake watershed, potential endocrine disruptors were detected in 25 of 86 samples (29 percent), and the total concentration of potential endocrine disruptors detected in a single sample ranged from 0 to 6.32 μg/L, with the highest concentration detected at JUN-A (appendix 4). The total concentration of potential endocrine disruptors exceeded 1 μg/L in 3 of 86 samples (3.5 percent) collected in the Converse Lake watershed (appendix 4). The number of potential endocrine disruptors detected in a single sample ranged from zero to three, with the highest number detected at HAM (appendix 4).

Comparison of Wastewater-Indicator Groups in the Threemile Creek and Converse Lake Watersheds

The occurrence and distribution of wastewater-indicator groups in the Converse Lake watershed was compared to data collected in the adjacent Threemile Creek watershed in Mobile, Alabama. Threemile Creek is approximately 15 miles (mi) in length and drains densely urbanized areas. Land use in the Threemile Creek watershed consists of highly intensive residential areas, interspersed with grass, forest, and wetlands (McPherson and others, 2005). Both the Converse Lake watershed and the Threemile Creek watershed are located in close proximity to each other in Mobile County; however, the Converse Lake watershed is less developed and less urbanized than the Threemile Creek watershed. Comparative analysis of wastewater-indicator groups in the two watersheds is interesting because of the proximity of the two basins and because of the differences in land use. A total of 86 OWC samples were collected in the J.B. Converse Lake watershed (1999–2002); 63 OWC samples were collected in the Threemile Creek watershed (2000–2003).

In the Threemile Creek study, 48 OWCs were selected for detailed analysis in the stream samples collected from the Threemile Creek watershed (McPherson and others, 2005). The 48 OWCs were broadly characterized into 11 wastewater-indicator groups: (1) prescription and nonprescription drugs, (2) herbicides and fungicides, (3) plasticizers/flame retardants, (4) steroids, (5) insecticides, (6) polycyclic aromatic hydrocarbons, (7) antimicrobials, (8) detergent metabolites, (9) insect repellent, (10) antioxidants, and (11) fragrances.

In the Threemile Creek basin, 37 of the 48 compounds were detected in at least one sample—9 compounds were detected in at least 50 percent of the samples (McPherson and others, 2005). In contrast, only 22 of the 48 selected OWCs were detected in the Converse Lake watershed (table 19), and none of the compounds were detected in more than 50 percent of the samples. In the Threemile Creek basin, 50 of 63 samples (79 percent) contained total concentrations of the 48 selected OWCs exceeding 1 µg/L. In the Converse Lake watershed, only 6 of 86 samples (7 percent) contained total concentrations of the 48 selected OWCs exceeding 1 µg/L.

Different groups of compounds were prevalent in the Converse Lake watershed compared to the Threemile Creek basin (fig. 28). In the Threemile Creek data set, 9 of the 11 groups of OWCs were found in more than 50 percent of the samples, whereas none of the groups of OWCs were found in 50 percent or more of the samples in the Converse Lake watershed (fig. 28A). With regard to percentages of total measured concentration, a similar pattern was exhibited in both the Converse Lake and Threemile Creek watersheds. The four most prevalent groups in the Converse Lake watershed included: steroids, detergent metabolites, prescription and nonprescription drugs, and herbicides and fungicides; the four most prevalent groups in the Threemile Creek watershed included: steroids, detergent metabolites, plasticizers and flame retardants, and prescription and nonprescription drugs. With regard to percentages of total measured concentration for each group, however, four groups (steroids, detergent metabolites, plasticizers/flame retardants, and prescription and nonprescription drugs) contributed almost 88 percent of the total measured concentration in all samples from both the Converse Lake watershed and the Threemile Creek watershed (fig. 28B).

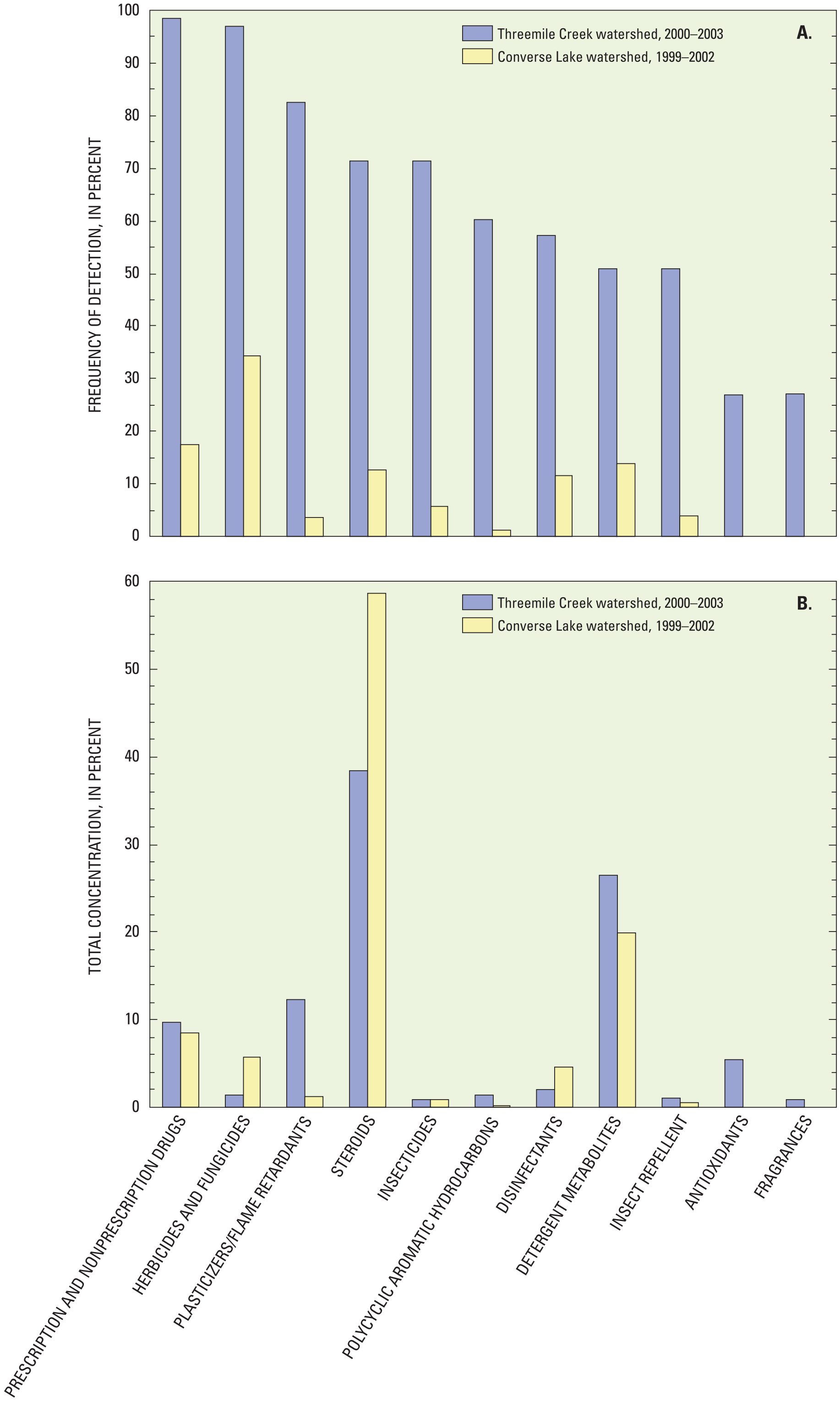


Figure 28. (A) Frequency of detection and (B) percentages of total measured concentrations of 48 organic wastewater compounds, by general use category, in the Threemile Creek and Converse Lake watersheds, Alabama.

The occurrence and distribution of the 48 selected OWCs were less frequent in the Converse Lake watershed than in the more urbanized Threemile Creek watershed (fig. 28A).

Total concentrations of the OWCs in the Converse Lake watershed were substantially lower than total concentrations in the Threemile Creek watershed (fig. 27A; fig. 25A, p. 56 in McPherson and others, 2005). The lack of development in the watershed and the protective buffer encircling Converse Lake serve to safeguard the reservoir and likely contribute to the low concentrations and low detection frequencies found in the Converse Lake watershed. Striking similarities were observed, however, between the groups of compounds detected (in relation to percentage of total measured concentration) in both watersheds (fig. 28B).

Comparison of Organic Wastewater Compounds in the Converse Lake and Threemile Creek Watersheds with Nationwide Results

Organic wastewater compounds detected in the Converse Lake and Threemile Creek watersheds were compared with data collected in the first nationwide reconnaissance of the occurrence of pharmaceuticals, hormones, and other OWCs in water resources (fig. 29; table 21). In the nationwide reconnaissance, the USGS used five analytical methods to measure concentrations of 95 OWCs in water samples from 139 streams in 30 states during 1999 and 2000 (Kolpin and others, 2002). The selection of sites in the nationwide reconnaissance was biased toward streams susceptible to contamination (for example, downstream from intense urbanization or livestock production). OWCs were detected in 80 percent of the streams sampled and represented a wide range of origins and uses, including residential, industrial, and agricultural. Of the 95 OWCs investigated, 82 were detected during the nationwide study (Kolpin and others, 2002).

Detection frequencies for 35 selected OWCs included in the nationwide reconnaissance were compared with detection frequencies in the Converse Lake and Threemile Creek watersheds (fig. 29). Detection frequencies for some compounds commonly found in the Converse Lake watershed, such as metolachlor and atrazine, are not shown in figure 29 because they were not included in the nationwide sampling schedule. In the nationwide reconnaissance (1999–2000), 85 samples were collected; 86 samples were collected in the Converse Lake watershed (1999–2002); and 63 samples were collected in the Threemile Creek watershed (2000–2003). Samples for all three studies were processed by the NWQL using the same method. Of 35 selected compounds detected nationwide, 15 were detected in the Converse Lake watershed and 28 were detected in the Threemile Creek watershed (fig. 29).

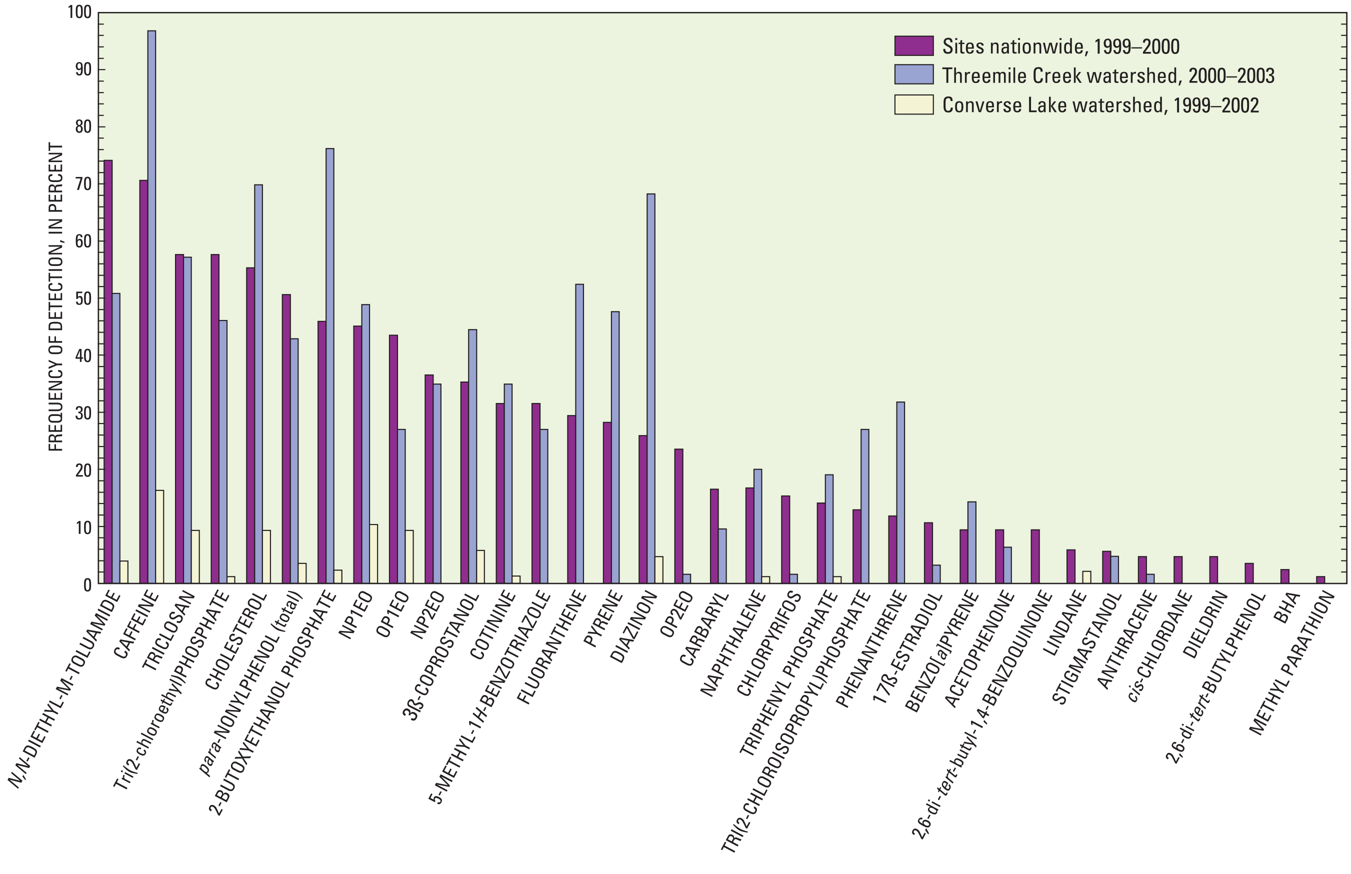


Figure 29. Frequencies of detection of 35 selected organic wastewater compounds in water samples from the Converse Lake and Threemile Creek watersheds, Alabama, and from sites nationwide.

Table 21. Detection frequencies and concentrations of selected organic wastewater compounds in water samples from the Threemile Creek watershed (2000–2003) and Converse Lake watershed (1999–2002), Alabama, and from sites nationwide (1999–2000).

[µg/L, microgram per liter; MCL, maximum contaminant level; HAL, lifetime health advisory; ND, not detected; —, no data; E, estimated; BHA, 3-*tert*-butyl-4-hydroxyanisole; NP1EO, nonylphenol monoethoxylate; NP2EO, nonylphenol diethoxylate; OP1EO, octylphenol monoethoxylate; OP2EO, octylphenol diethoxylate; compounds in **bold** are potential endocrine disruptors]

Compound	Detection frequency (percent)			Maximum (µg/L)			Median of detected values (µg/L)			MCL[a] (µg/L)	HAL[a] (µg/L)
	Threemile Creek watershed	Converse Lake watershed	Sites nationwide	Threemile Creek watershed	Converse Lake watershed	Sites nationwide	Threemile Creek watershed	Converse Lake watershed	Sites nationwide		
2-Butoxyethanol phosphate	76.2	2.3	45.9	12.0	0.143	6.7	0.51	0.119	0.51	—	—
2,6-di-*tert*-butyl-1,4-benzoquinone	0	0	9.4	ND	ND	.46	ND	ND	.13	—	—
2,6-di-*tert*-butylphenol	0	0	3.5	ND	ND	.11[b]	ND	ND	.06[b]	—	—
2,6-dimethyl-naphthalene	3	0	—	E .086	ND	—	.086	ND	—	—	—
3ß-coprostanol	44.4	5.8	35.3	5.86	E 1.6	9.8[b]	1.33	.34	.7[b]	—	—
5-methyl-1H-benzo-triazole	27	0	31.5	21.4	ND	2.4	.19	ND	.39	—	—
17ß-Estradiol	3.2	0	10.6	E .636	ND	.2[b]	.48	ND	.16[b]	—	—
Acetophenone	6.3	0	9.4	.236	ND	.41	.124	ND	.15	—	—
Anthracene	1.6	0	4.7	E .16	ND	.11	.16	ND	.07	—	—
Atrazine	100	30	—	.64	E .019	—	.063	.008	—	3	200
Benzo[*a*]pyrene	14.3	0	9.4	E .15	ND	.24	.056	ND	.04	.2	—
BHA	0	0	2.4	ND	ND	.2[b]	ND	ND	.1[b]	—	—
bis(2-ethylhexyl) adipate	0	2.1	3.5	ND	1.4	10[c]	ND	1.4	3[c]	400	400
bis(2-ethylhexyl) phthalate	11.6	4.2	10.6	E 8.4	6.2	20[c]	4	4.69	7[c]	6	—
bisphenol A	30.2	3.5	41.2	2.29	.12	12	.111	.11	.14	—	—
Bromacil	66.7	10.5	—	E .340	E .34	—	.165	.165	—	—	90
Caffeine	96.8	16.3	70.6	9.8	.72	5.7	.143	.070	.1	—	—
Carbaryl	9.5	0	16.5	E .062	ND	.1[b]	.046	ND	.04[b]	—	700
cis-Chlordane	0	0	4.7	ND	ND	.1	ND	ND	.02	2	—
Chlorpyrifos	1.6	0	15.3	.036	ND	.31	.036	ND	.06	—	20
Cholesterol	69.8	9.3	55.3	E 7	E 2	10[b]	1.26	.615	1[b]	—	—
Cotinine	34.9	1.3	31.5	E .469	E .015	.57	.10	.015	.05	—	—
para-cresol	25.4	3.5	—	1.4	.05	—	.088	.039	—	—	—
Diazinon	68.3	4.7	25.9	.307	.047	.35	.066	.039	.07	—	.6
Dieldrin	0	0	4.7	ND	ND	.21	ND	ND	.18	—	—
Diethyl phthalate	9.3	2.0	11.1	.375	E .29	.42	.241	.29	.2	—	—
Fluoranthene	52.4	0	29.4	.287	ND	1.2	.055	ND	.04	—	—
Lindane	0	2.1	5.9	ND	E .03	.11	ND	.03	.02	.2	.2

Table 21. Detection frequencies and concentrations of selected organic wastewater compounds in water samples from the Threemile Creek watershed (2000–2003) and Converse Lake watershed (1999–2002), Alabama, and from sites nationwide (1999–2000).—Continued

[µg/L, microgram per liter; MCL, maximum contaminant level; HAL, lifetime health advisory; ND, not detected; —, no data; E, estimated; BHA, 3-*tert*-butyl-4-hydroxyanisole; NP1EO, nonylphenol monoethoxylate; NP2EO, nonylphenol diethoxylate; OP1EO, octylphenol monoethoxylate; OP2EO, octylphenol diethoxylate; compounds in **bold** are potential endocrine disruptors]

Compound	Detection frequency (percent)			Maximum (µg/L)			Median of detected values (µg/L)			MCL[a] (µg/L)	HAL[a] (µg/L)
	Threemile Creek watershed	Converse Lake watershed	Sites nationwide	Threemile Creek watershed	Converse Lake watershed	Sites nationwide	Threemile Creek watershed	Converse Lake watershed	Sites nationwide		
Metalaxyl	0	10.5	—	ND	E .037	—	ND	.0285	—	—	—
Methyl parathion	0	0	1.2	ND	ND	0.01	ND	ND	0.01	—	2
Metolachlor	9.1	34.2	—	E 0.3	E 0.067	—	0.020	0.013	—	—	100
Naphthalene	20	1.2	16.5	E .12	.052	.08	.03	.052	.02	—	100
N,*N*-diethyl-*m*-toluamide	50.8	3.9	74.1	1.89	E .062	1.1	.061	.021	.06	—	—
***para*-nonylphenol-total**	42.9	3.5	50.6	E 3.33	E .67	40[d]	.92	.233	.8[d]	—	—
NP1EO	48.8	10.3	45.9	E 4.91	E .67	20[d]	1.15	.457	1[d]	—	—
NP2EO	34.9	0	36.5	E 5.97	ND	9[d]	2.47	ND	1[d]	—	—
OP1EO	27	9.3	43.5	E .76	E .103	2[d]	.11	.068	.2[d]	—	—
OP2EO	1.6	0	23.5	E .13	ND	1[d]	.13	ND	.1[d]	—	—
Phenanthrene	31.7	0	11.8	E .15	ND	.53	.033	ND	.04	—	—
Phenol	42.9	7.0	8.2	E 1.5	2.42	1.3[c]	.461	1.425	.7[c]	—	—
Phthalic anhydride	76.7	6.3	17.6	E .984	.582	1[c]	.52	.23	.7[c]	—	—
Prometon	27.3	10.5	—	E .059	E .035	—	.021	.0295	—	—	100
Pyrene	47.6	0	28.2	.217	ND	.84	.041	ND	.05	—	—
ß-sitosterol	45.5	10.5	—	E 3.80	E 1.1	—	1.40	.855	—	—	—
Skatol	20	2.6	—	E .24	E .12	—	.076	.12	—	—	—
Stigmastanol	4.8	0	5.6	E 1.1	ND	4[b]	.80	ND	2[b]	—	—
Triclosan	57.1	9.3	57.6	.894	.37	2.3	.098	.092	.14	—	—
Tri(2-chloroethyl)phosphate	46	1.2	57.6	.31	.043	.54	.06	.043	.1	—	—
Tri(2-chloroisopropyl)phosphate	27	0	12.9	.214	ND	.16	.077	ND	.1	—	—
Triphenyl phosphate	19	1.2	14.1	E .085	E .007	.22	.054	.007	.04	—	—

[a] U.S. Environmental Protection Agency, 2002a.

[b] Concentration estimated—average recovery less than 60 percent.

[c] Concentration estimated—compound routinely detected in laboratory blanks.

[d] Concentration estimated—reference standard prepared from a technical mixture.

Of 50 selected constituents, 29 were detected in the Converse Lake watershed, 41 were detected in the Threemile Creek watershed, and 41 were detected at sites nationwide (table 21). Median concentrations of 4 compounds in the Converse Lake watershed and 18 compounds in the Threemile Creek watershed met or exceeded median concentrations of detected compounds in the nationwide reconnaissance (table 21). Maximum concentrations of nine compounds in the Threemile Creek watershed exceeded maximum concentrations detected in the nationwide reconnaissance (table 21).

Detection frequencies in the Converse Lake watershed were much lower than detection frequencies in the Threemile Creek watershed or in the nationwide reconnaissance (fig. 29; table 21). Median and maximum concentrations also were lower in the Converse Lake watershed. The protective buffer encircling Converse Lake and the lack of development in the watershed likely contribute to the lower concentrations and lower detection frequencies.

Relations Between Bacterial and Chemical Wastewater Indicators

Detections of certain OWCs (detergents, dyes, caffeine, or 3-β coprostanol) can strongly indicate human sewage as the source of fecal contamination in a watershed (U.S. Environmental Protection Agency, 2002a). Detections of these OWCs, in conjunction with high levels of nutrients or fecal-indicator bacteria, likely would further implicate human sewage as the source of fecal contamination. Concentrations of fecal-indicator bacteria, however, were not significantly correlated with concentrations nor with the number of OWCs detected in a sample. Nitrogen and phosphorus concentrations also were not correlated with OWCs, except in two instances. At site HAM, total phosphorus was positively correlated with the number of OWC detections (rho = 0.769; $p = 0.0092$); at site LHAM, total phosphorus was negatively correlated with the total concentration of OWCs (rho = -0.97468; $p = 0.0048$).

Organic wastewater compounds were detected infrequently in the Converse Lake watershed, making it difficult to evaluate occurrence and distribution between sites statistically. The lack of correlations between OWCs, fecal indicator bacteria, and nutrients may indicate that the sources of fecal contamination are different or that chemical and biological processes, such as survival times of indicator organisms and degradation of organic compounds, differ between these types of constituents. Other factors, such as pH, also may affect the degradation of organic compounds or the survival times of indicator organisms.

Trends in Nutrient and Bacteria Concentrations

Trend analyses were conducted for total ammonia, dissolved inorganic nitrogen, total inorganic nitrogen, total Kjeldahl nitrogen, total nitrogen, total phosphorus, and fecal coliform bacteria at the BIG, CRO, HAM, and LHAM sites for water years 1991 through 2003 (table 22). Both flow-adjusted and unadjusted trend tests were conducted at all sites except LHAM. Because LHAM is a lake site, there is no discharge associated with the samples and, therefore, no requirement to adjust for flow. Total nitrogen values are calculated as the sum of total Kjeldahl nitrogen and total nitrite plus nitrate nitrogen. In cases where either of these constituents was missing, a total concentration was not computed. When either constituent was censored, the censored value was set at the detection level and the total concentration was calculated from this value.

Results of trend analyses indicated very few long-term trends for most constituents at most sites. The only significant ($p < 0.05$) trend detected was an approximately 0.01-mg/L downward trend for total inorganic nitrogen and dissolved inorganic nitrogen at site CRO for both flow-adjusted and unadjusted concentrations. The absence of increasing trends indicates that land-use changes during 1990–2003 have not had an effect on stream nutrient and bacteria concentrations at the three monitored streams.

Estimation of Increased Nutrient Loading as a Result of Land-Use Change

A method proposed by Reckhow and others (1980) was used to estimate annual nutrient loading to Converse Lake. Nutrient export coefficients were estimated for land-use types in the Converse Lake watershed and used with available land-use information to estimate nutrient loading to the lake from the tributaries. The approach presented was then modified to reflect future land-use scenarios and to estimate associated changes in nutrient loading.

Reckhow and others (1980) summarized results of several nutrient runoff studies and proposed a method for using published nutrient export coefficients to estimate annual nutrient (especially phosphorus) loading to lakes. Reckhow and others (1980) suggested the following equation for estimating phosphorus inputs:

$$\begin{aligned}&\text{Mass loading in kilograms per year} = (Ec_f \times \text{Area}_f) + \\ &(Ec_{ag} \times \text{Area}_{ag}) + (Ec_u \times \text{Area}_u) + (Ec_a \times A_o) + \\ &(Ec_{st} \times \text{number of capita-years} \times (1 - SR)) + PSI,\end{aligned} \qquad (8)$$

where

Ec_f = export coefficient for forest land (in kilograms per hectare per year),
Ec_{ag} = export coefficient for agricultural land (in kilograms per hectare per year),
Ec_u = export coefficient for urban area (in kilograms per hectare per year),
Ec_a = export coefficient for atmospheric input,
Ec_{st} = export coefficient for septic tank systems affecting the lake, (in kilograms per capita per year),
$Area_f$ = area of forested land (in hectares),
$Area_{ag}$ = area of agricultural land (in hectares),
$Area_u$ = area of urban land (in hectares),
A_o = area of lake (in hectares),
Number of capita-years = number of capita-years of septic tank/tile field systems use affecting the lake (one capita-year of septic tank use is the equivalent of one person using a septic system for one full year),
SR = soil retention coefficient (dimensionless), and
PSI = point-source input (in kilograms per year).

Table 22. Results of the seasonal Kendall tau test for trends in unadjusted and flow-adjusted nutrient and bacteria concentrations at selected tributary sites in the Converse Lake watershed, Alabama, 1990–2003.

[Trends reported in units of milligrams per liter per year; **bold** values represent significant trends with *p*-value less than or equal to 0.05; —, not applicable]

Constituent	Unadjusted			Adjusted		
	Trend	Tau	*p*-value	Trend	Tau	*p*-value
BIG						
Total ammonia	0	-0.196	0.17	0	-0.176	0.226
Total inorganic nitrogen	-.012	-.127	.27	-.01	-.127	.464
Dissolved inorganic nitrogen	-.012	-.186	.271	-.012	-.186	.271
Total Kjeldahl nitrogen	0	-.02	.923	0	.014	.948
Total nitrogen	-.007	-.088	.565	-.025	-.186	.227
Total phosphorus	0	-.211	.199	0	.054	.681
Fecal coliform bacteria	.905	.016	.603	.905	.016	.603
CRO						
Total ammonia	0	0	1	0	-0.104	0.395
Total inorganic nitrogen	**-.01**	**-.342**	**.013**	**-.009**	**-.342**	**.022**
Dissolved inorganic nitrogen	**-.01**	**-.371**	**.014**	**-.01**	**-.371**	**.014**
Total Kjeldahl nitrogen	0	.059	.678	0	.099	.443
Total nitrogen	-.007	-.208	.151	-.02	-.188	.158
Total phosphorus	0	-.11	.349	0	.04	.8
Fecal coliform bacteria	.285	.033	.132	.286	.033	.133
HAM						
Total ammonia	0	0.024	0.86	0	-0.033	0.803
Total inorganic nitrogen	-.008	-.297	.054	-.008	-.297	.073
Dissolved inorganic nitrogen	-.008	-.33	.054	-.008	-.33	.014
Total Kjeldahl nitrogen	0	-.071	.431	0	-.056	.551
Total nitrogen	-.007	-.193	.177	-.023	-.203	.094
Total phosphorus	0	-.142	.31	0	-.118	.46
Fecal coliform bacteria	5	.153	3.3333	5	.153	3.33
LHAM						
Total ammonia	0	0.128	0.959	—	—	—
Total inorganic nitrogen	0	.128	.252	—	—	—
Dissolved inorganic nitrogen	0	.074	.644	—	—	—
Total Kjeldahl nitrogen	0	.023	.448	—	—	—
Total nitrogen	.002	.023	.959	—	—	—
Total phosphorus	0	-.025	.932	—	—	—
Fecal coliform bacteria	0	-.055	.806	—	—	—

The atmospheric, septic system, and point-source input terms were removed from the general mass loading equation before it was used to simulate nutrient loading to Converse Lake under various land-use scenarios. The atmospheric input term was removed because it is incorporated in the BATHTUB lake model. The septic system term is included in tributary load estimates; however, septic tanks near the lake shore may affect lake water directly. Residential development around the Converse Lake perimeter is limited. Inspection of USGS 7.5-minute topographic maps of the lake (U.S. Geological Survey, 1982a,b) indicated only 37 structures within 0.1 mi of the lake shoreline. Because of the scarcity of homes near the shoreline, nutrient loading from septic tanks to the lake was assumed to be adequately represented in the estimated tributary loads. Because no known point-source nutrient inputs are located in the Converse Lake watershed, point-source loading was assumed to be zero.

Nutrient-export coefficients for specific land uses in the Converse Lake watershed (table 23) were estimated for use in equation 8 within the ranges previously reported by Reckhow and others (1980) and near the range of mixed land-use yields observed for the Converse Lake watershed during 1991 (Journey and Gill, 2001). Extensive loading data for Converse Lake were available from the long-term water-quality monitoring program; however, loads and yields were calculated for watersheds with mixed land use. Export coefficients determined for single land-use types have been summarized and published in previous reports (Reckhow and others, 1980; Beaulac and Reckhow, 1982; Line and others, 2002). Most published export coefficients come from edge-of-field studies, which measure direct runoff from small areas of each land-use type and do not account for attenuation of nutrient loads in relation to distance of the land use from the receiving waterbody, uptake by terrestrial processes, and instream losses. Extrapolation of yields derived from edge-of-field studies to larger watersheds may cause significant error in the final loading prediction. To adjust for these limitations, Converse Lake watershed monitoring data were used to identify local patterns in loadings from various land uses and, in turn, the relative magnitudes of local land-use-specific nutrient-export coefficients.

Table 23. Nutrient-export coefficients used to predict loadings from future land-use scenarios in the Converse Lake watershed, Alabama.

[(kg/ha)/yr, kilogram per hectare per year]

Land use	Total phosphorus—Adjusted to predict 1991 watershed loadings ([kg/ha]/yr)	Total nitrogen—Adjusted to predict 1991 watershed loadings ([kg/ha]/yr)
Forest	0.020	4
Agricultural		
Pasture	.800	7
Row crops	.300	7
Urban	.55	7

Nutrient-export coefficients for the Converse Lake watershed were adjusted within the published range to achieve a statistically significant positive correlation between predicted and calculated nutrient yields for water year 1991, the only year for which nutrient loads and yields from all seven major tributaries to Converse Lake were calculated (table 24). Calculated loads for JUN, COL, LON, and BOG have greater uncertainty than loads for BIG, CRO, and HAM because data were insufficient to meet the requirements of the ESTIMATOR program. Loads for all seven tributaries were used in the correlation analysis to allow for a more robust statistical comparison with nutrient loads estimated using the nutrient export coefficients.

Table 24. Annual total phosphorus and total nitrogen yields for water year 1991 for selected tributary sites in the Converse Lake watershed, Alabama.

[From Journey and Gill (2001); kg/yr, kilogram per year; (kg/ha)/yr, kilogram per hectare per year; —, no data]

Site label (fig. 1)	Total phosphorus		Total nitrogen	
	Load (kg/yr)	Yield ([kg/ha]/yr)	Load (kg/yr)	Yield ([kg/ha]/yr)
BIG	1,750	0.21	67,400	8.26
JUN	1,080	.45	13,300	5.57
COL	272	.12	8,480	3.83
LON	86.0	.12	5,430	7.36
BOG	77.9	.11	—	—
CRO	1,240	.59	15,000	7.17
HAM	666	.31	17,300	8.13

Phosphorus concentrations and calculated phosphorus yields in the more heavily forested subwatersheds of the Converse Lake watershed (BIG, JACK) indicate that forested land use does not supply as much phosphorus to receiving streams as more developed land uses. Previously published studies also indicate that this is often the case (Beaulac and Reckhow, 1982; Line and others, 2002). Based on site-specific data for forested land use and the results of published studies, the phosphorus export coefficient for forested land use was set lower than coefficients for more developed land uses.

The relation between predicted and calculated total phosphorus yields in the Converse Lake watershed was improved by distinguishing between two agricultural land-use types—pasture (MRLC codes 81 and 85) and row crops (MRLC code 82). Predicted total yields followed the pattern of observed total yields better when pasture yields were slightly higher than row crop yields. Ornamental plant nurseries are very common in the Converse Lake watershed and appear to account for the majority of land designated as row crops by the MRLC coverage. A cooperative effort began in the 1990s to encourage the adoption of best-management practices at southeastern plant nurseries, and many nurseries in the area have implemented practices to reduce nutrient loading to streams (Fain and others, 1999). The use of best-management practices at plant nurseries in the watershed may explain the apparent difference in phosphorus yields between the two agricultural land uses.

Phosphorus yields from urban land uses were estimated to be similar to the average yield from the two agricultural land uses. A wide range of phosphorus yields from urban land uses has been reported in previous studies (Reckhow and others, 1980). Urban land use in the Converse Lake watershed is scarce, however, and urban export coefficients have very little effect on the total predicted load for the current land use. Continued monitoring of nutrient loading in the watershed, especially in rapidly urbanizing areas and in more urbanized neighboring watersheds, is needed to refine the urban export coefficients.

Nitrogen export coefficients from the main land-use types were chosen to represent the approximate observed range in nitrogen yields in the Converse Lake watershed and to reflect the pattern of increased nitrogen yields with the increased development observed in previous studies (table 23). Previously published values of nitrogen export indicated greater yields of nitrogen from agricultural and urban watersheds than from forested watersheds (Reckhow and others, 1980; Line and others, 2002; U.S. Environmental Protection Agency, 2002c), but calculated yields of total nitrogen in the Converse Lake watershed in 1991 did not follow the usual pattern—the greatest yield of total nitrogen (8.26 (kg/ha)/yr) was in the most forested subwatershed, Big Creek (table 24).

The estimation of greater nitrogen loads at Big Creek during 1991 probably was related to the greater numbers of high-flow samples collected at site BIG than at the other monitoring sites. Samples were collected at relatively high flows more often from Big Creek than from Crooked (CRO) or Hamilton (HAM) Creeks. When sampling flows are compared to flow-duration curves constructed from 1990–2003 data for the three streamgaging stations (fig. 3), one-half of the samples collected at BIG in 1991 were in the upper 20 percent of measured flows, and one-fourth of the samples were collected in the upper 10 percent of flows. In contrast, only one-third of the samples at CRO were collected at flows in the upper 20 percent, and no samples were collected in the upper 10 percent. One-sixth of the samples at HAM were collected in the upper 20 percent of flows, and one of these was also in the upper 10 percent.

In contrast to nitrogen loads calculated for 1991, long-term (1990–2003) median yields of total nitrogen at site BIG were significantly lower than median yields at sites HAM and CRO, indicating that increased agricultural and urban development may increase nitrogen loading. Beaulac and Reckhow (1982) also noted higher nitrogen export from developed land than from forested land. Because the sample collection at site BIG during 1991 was skewed toward higher flows, the long-term medians were considered to be more representative of average loading conditions in the Converse Lake watershed. Nitrogen export coefficients used to estimate future loadings from agricultural and urban land uses for the BATHTUB model were set slightly higher than forested export coefficients to reflect the observed long-term pattern of increased nitrogen loading in more developed subwatersheds.

Spearman rho correlations were run between the nutrient yields predicted (hereafter referred to as predicted yields) from the nutrient export coefficients in table 23 and the nutrient yields calculated by using the ESTIMATOR program (hereafter referred to as calculated yields; table 24). The Spearman rho correlation coefficient is calculated from the ranks of the original data, and Spearman rho correlations improve as the pattern of high and low values in the predicted yields more closely mimics the pattern of calculated yields among sites. A significant correlation between these two yield computations indicates that the most likely export coefficients followed the observed pattern of nutrient yields in the watershed—the coefficients predicted high nutrient yields where high nutrient yields were observed, and low nutrient yields where low nutrient yields were observed.

Using the nutrient export coefficients in table 23, the predicted median total phosphorus yield followed the general pattern of 1991 phosphorus yields, but nitrogen yields were less predictable (fig. 30). Predicted and calculated phosphorus yields for 1991 were significantly correlated (rho = 0.86, $p < 0.05$) using the phosphorus export coefficients in table 23. Calculated nitrogen yields for 1991 in the Converse Lake watershed showed no clear relation to land-use type; therefore, yields predicted from land-use export coefficients and calculated nitrogen yields were not significantly correlated. The nitrogen export coefficients used for predictions of future loads were assumed to be reasonable because predicted nitrogen yields appear to be similar to the calculated long-term median nitrogen yields for the BIG, CRO, and HAM sites.

The nutrient export coefficients used in the BATHTUB model are not a unique fit to the Converse Lake watershed data and do not provide an exact estimate of the yields observed in the Converse Lake watershed. The percentage differences between the predicted and calculated yields may be quite high (table 25) even though the Spearman rho correlation coefficients indicate a strong relation. The export coefficients simulated a pattern of loading among the tributary subwatersheds similar to the observed pattern for 1991; therefore, they can be used to predict the magnitude of changes in nutrient loading resulting from land-use changes in the watershed. Percentage changes in nutrient loading from each tributary to the lake (table 26) were calculated from the application of these export coefficients to estimated future land use, and percentage changes were then applied to tributary nutrient concentration data that were used in the BATHTUB model for water year 2002. This approach directly relates simulated increases or decreases in nutrient loads to measured water-quality data from the Converse Lake watershed, so the effects of nutrient loading changes on lake water quality can be simulated.

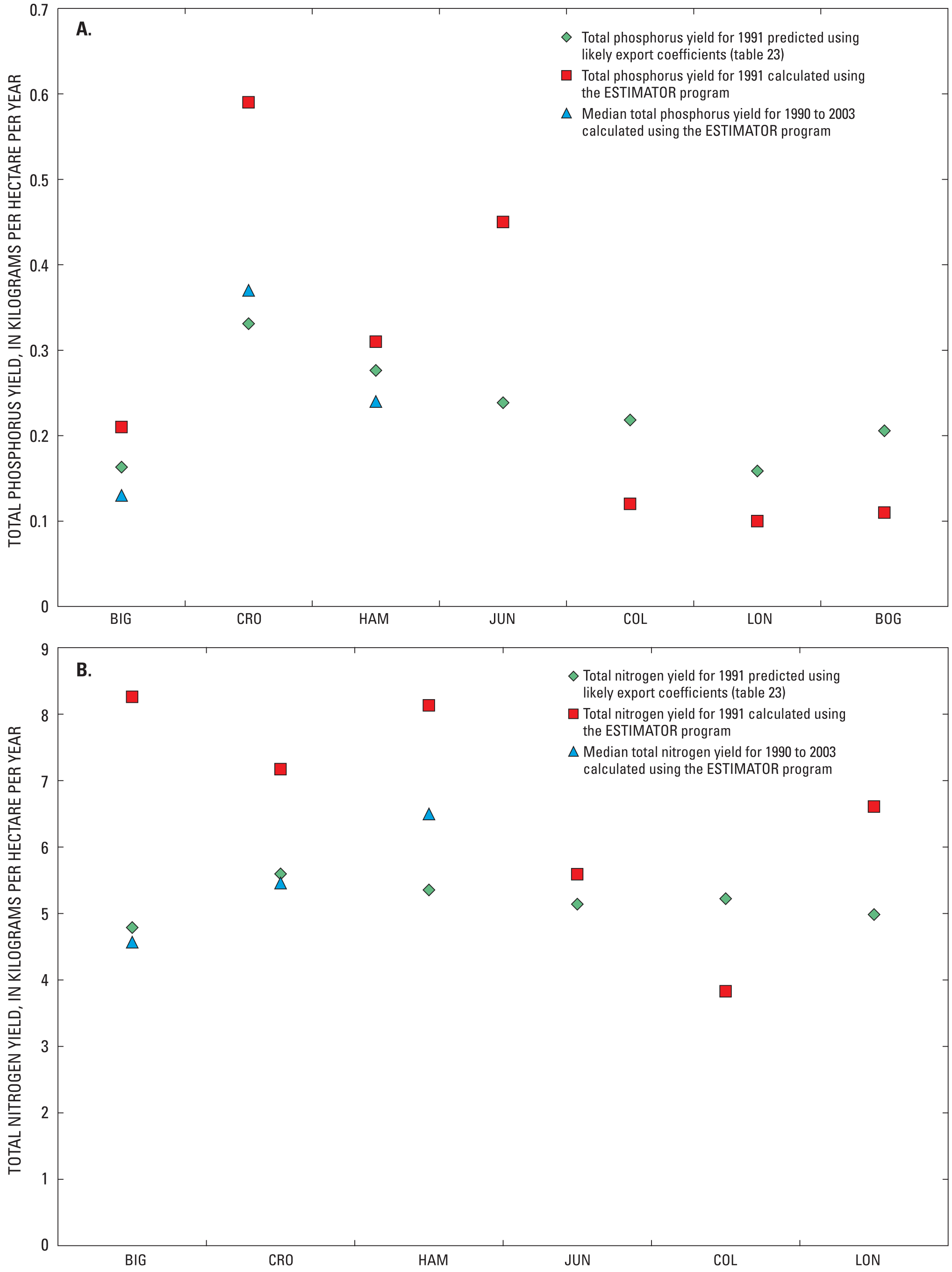


Figure 30. Total (A) phosphorus and (B) nitrogen yields for selected tributary sites in the Converse Lake watershed, Alabama.

Table 25. Total phosphorus and total nitrogen loads and yields predicted by using nutrient export coefficients in table 23, and percentage differences between total phosphorus and total nitrogen yields predicted using export coefficients and yields calculated by the ESTIMATOR program for selected sites in the Converse Lake watershed, water year 1991.

[—, calculated load not available]

Site label (fig. 1)	Total phosphorus			Total nitrogen		
	Predicted load	Predicted yield	Difference between predicted and calculated yields (in percent)	Predicted load	Predicted yield	Difference between predicted and calculated yields (in percent)
BIG	1,300	0.16	-22.3	38,000	4.79	-42.0
CRO	714	.33	-43.9	12,100	5.60	-21.9
HAM	558	.28	-10.9	10,800	5.35	-34.1
JUN	581	.24	-47.0	12,500	5.14	-8.05
COL	481	.22	82.0	11,500	5.22	36.4
LON	118	.16	58.7	3,710	4.98	-24.6
BOG	163	.21	87.1	4,170	5.25	—

Selected phosphorus and nitrogen loading coefficients (table 23) also were used to calculate current and future total phosphorus and total nitrogen loads for the entire watershed. The total area of the Converse Lake watershed is approximately 27,000 ha, or 270 square kilometers (km^2). The area of the lake and the area of all wetlands were subtracted from the total area to estimate the area available for development. Areas of the watershed in each of the major land-use categories—forest, row crop, pasture, and urban—were calculated based on 1992 land-use information (table 4). Current loading from these areas was estimated using equation 8 (Reckhow and others, 1980) with the agricultural category split into separate categories for pasture and row crops. Future loadings from the increasing conversion of areas of forested and agricultural land to urban uses were calculated using the selected coefficients and adjusted areas of land use. To account for the gain in urban land uses, losses of agricultural and forested land were applied in proportion to percentages of these land uses present in 1992. The range in expected percentage increases of total phosphorus and total nitrogen loading from various increases in urban land use is presented in table 27. A 50-percent increase over current area of urban land use results in an estimated phosphorus loading increase of about 2.5 percent and an estimated nitrogen loading increase of 0.62 percent. At current estimated loading rates for urban land use, if all of the developable land in the watershed were to be converted to urban uses, corresponding percentage increases in phosphorus and nitrogen loading would be 156 and 39.1 percent, respectively (table 27).

Table 26. Estimated percent change in tributary nutrient loading at selected sites in the Converse Lake watershed resulting from changes in areas of urban land use.

[TP, total phosphorus; TN, total nitrogen]

Percent change in area of urban land	Estimated percent change in tributary loading resulting from land-use change															
	BIG		**JUN**		**COL**		**LON**		**BOG**		**CRO**		**HAM**		**Unmonitored drainage**	
	TP	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**
-25	-1.36	-0.266	-1.21	-0.336	-1.83	-0.533	-1.11	-0.321	-.887	-0.299	-0.944	-0.358	-1.43	-0.444	-0.690	-0.153
50	2.73	.531	2.42	.672	3.66	1.07	2.22	.642	1.77	.597	1.89	.716	2.86	.889	1.38	.306
100	5.45	1.06	4.85	1.34	7.32	2.13	4.44	1.28	3.55	1.19	3.77	1.43	5.73	1.78	2.76	.612
500	27.3	5.31	24.2	6.72	36.6	10.7	22.2	6.42	17.7	5.97	18.9	7.16	28.6	8.89	13.8	3.06
Scenario A[a]	116	22.6	62.8	17.4	54.8	16.0	67.7	19.6	47.6	16.0	31.2	11.8	46.6	14.5	93.5	20.7
Scenario B[a]	176	34.4	96.6	26.8	85.9	25.0	104	30.0	73.2	24.7	48.6	18.4	72.8	22.6	142	31.4
Scenario C[a]	237	46.2	130	36.2	117	34.0	140	40.4	98.7	33.3	66.1	25.1	99.0	30.7	190	42.1

[a] Scenarios A, B, and C represent 50, 75, and 100 percent of developable land, respectively, used for urban purposes.

Table 27. Estimated increases in nutrient loading in the Converse Lake watershed resulting from changes in urban land use.

[ha, hectare; kg, kilogram; %, percent]

Land use	Area (ha)	Percent of developable land	Total phosphorus load (kg)	Total nitrogen load (kg)	Percent increase in phosphorus loading	Percent increase in nitrogen loading
Current land use						
Forest	16,569.55	65.58	331	66,300		
Agricultural	7,925.02					
Pasture	4,573.45	18.10	3,660	32,000		
Row crops	3,351.56	13.26	1,010	23,500		
Urban	772.67	3.06	425	5,410		
Total	25,267.23	1	5,420	127,000		
25% decrease of urban from current levels						
Forest	16,700.22	66.09	334	66,800		
Agricultural	7,987.52					
Pasture	4,609.52	18.24	3,690	32,300		
Row crops	3,377.99	13.37	1,010	23,600		
Urban	579.50	2.29	319	4,060		
Total	25,267.23	1	5,350	127,000	-1.23	-0.31
50% increase of urban over current levels						
Forest	16,308.21	64.54	326	65,200		
Agricultural	7,800.02					
Pasture	4,501.32	17.81	3,600	31,500		
Row crops	3,298.70	13.06	990	23,100		
Urban	1,159.00	4.59	637	8,110		
Total	25,267.23	1	5,550	128,000	2.47	0.62
100% increase of urban over current levels						
Forest	16,046.87	63.51	321	64,200		
Agricultural	7,675.03					
Pasture	4,429.18	17.53	3,540	31,000		
Row crops	3,245.84	12.85	974	22,700		
Urban	1,545.34	6.12	850	10,800		
Total	25,267.23	1	5,690	129,000	4.93	1.23
500% increase of urban over current levels						
Forest	13,956.16	55.23	279	55,800		
Agricultural	6,675.06					
Pasture	3,852.11	15.25	3,080	27,000		
Row crops	2,822.94	11.17	847	19,800		
Urban	4,636.02	18.35	2,550	32,500		
Total	25,267.23	1	6,760	135,000	24.7	6.17

Table 27. Estimated increases in nutrient loading in the Converse Lake watershed resulting from changes in urban land use.—Continued

[ha, hectare; kg, kilogram; %, percent]

Land use	Area (ha)	Percent of developable land	Total phosphorus load (kg)	Total nitrogen load (kg)	Percent increase in phosphorus loading	Percent increase in nitrogen loading
Scenario A – 50% of developable land is urban						
Forest	8,546.12	33.82	171	34,184.46		
Agricultural	4,087.51					
Pasture	2,358.86	9.34	1,890	16,512.01		
Row crops	1,728.64	6.84	519	12,100.49		
Urban	12,633.61	50.00	6,950	88,435.31		
Total	25,267.23	1	9,530	151,232.27	75.72	18.93
Scenario B – 75% of developable land is urban						
Forest	4,273.06	16.91	85.5	17,100		
Agricultural	2,043.75					
Pasture	1,179.43	4.67	944	8,260		
Row crops	864.32	3.42	259	6,050		
Urban	18,950.42	75.00	10,400	133,000		
Total	25,267.23	1	11,700	164,000	116	29.0
Scenario C – 100% of developable land is urban						
Forest	0	0.00	0	0		
Agricultural	0					
Pasture	0	0.00	0	0		
Row crops	0	0.00	0	0		
Urban	25,267.23	100.00	13,900	177,000		
Total	25,267.23	1	13,900	177,000	156	39.1

Simulation of Lake Water Quality and Trophic Status

The BATHTUB model simulates average lake water-quality conditions from average tributary loads for a given time period, known as the averaging period (Walker, 1999). In reservoirs with a short hydraulic residence time, the averaging period usually is set as the growing season, April through September. For reservoirs with a longer hydraulic residence time, the averaging period can be extended. Hydraulic residence time in Converse Lake has been reported as 0.44 year (Journey and Gill, 2001). A growing season (April–September) averaging period was chosen for the application of the BATHTUB model to Converse Lake. Phosphorus and nitrogen turnover ratios were calculated by the BATHTUB model and indicated the approximate number of times that the mass of phosphorus or nitrogen was displaced. The appropriate averaging period should allow for about two complete displacements of the limiting nutrient, or a nutrient turnover ratio greater than 2 (Walker, 1999). Turnover ratios for phosphorus, the limiting nutrient in Converse Lake, ranged from 1.6 in 2001, a time of severe drought, to 4.1 in 2003, a summer with above-average rainfall. Average rainfall conditions resulted in a phosphorus turnover ratio of 1.9 for 2002. A growing season averaging period was deemed appropriate for Converse Lake because most water-quality data were collected in the growing season months, and the total phosphorus turnover ratio was near 2 for an average-rainfall year.

The BATHTUB model was simultaneously calibrated to growing season (April–September) data from Converse Lake for 2001, 2002, and 2003. Several algorithms are available within the BATHTUB model to simulate nutrient and chlorophyll *a* concentrations and Secchi depth. Calibration factors also can be applied globally or to the data from each segment to better simulate concentrations and Secchi depth. Algorithms were chosen and calibration coefficients refined by an iterative process of running the models for all years until a reasonable calibration was achieved for all 3 years. Algorithms chosen to predict lake conditions are summarized in table 28.

Table 28. Algorithms used in the BATHTUB model to simulate water quality in Converse Lake, Alabama.

Process	Algorithm number	Algorithm description
Phosphorus balance	1	Second order, available phosphorus
Nitrogen balance	1	Second order, available nitrogen
Chlorophyll *a* concentration	1	Function of phosphorus, nitrogen, light, and temperature
Secchi depth	1	Function of chlorophyll *a* and turbidity
Dispersion	3	Input exchange rate
Phosphorus calibration	2	Concentrations
Nitrogen calibration	2	Concentrations

Calibration factors used for the model simulations of Converse Lake are listed in table 29.

Nutrient concentrations in many samples from Converse Lake were below detection limits, and even most detections were near the lower extreme of the BATHTUB model development data set (table 30). In Converse Lake, chlorophyll *a* concentrations, Secchi depth, and non-algal turbidity appeared to be less responsive to changes in total phosphorus concentrations than in reservoirs operated and maintained by the USACE. Despite observed differences in water quality between Converse Lake and the model-development data set, however, the calibrated BATHTUB model appeared to predict Converse Lake trophic response variables reasonably well for the summers of 2001–03.

Measured and simulated values for growing-season mean concentrations of total phosphorus, total nitrogen, and chlorophyll *a* concentrations, and mean Secchi depths were compared among lake segments and years (figs. 31–34). Error bars around measured mean values indicate plus and minus one standard deviation of the measured values. Simulated mean total phosphorus concentrations were within one standard deviation of the measured mean for all segments in all years except segment 1 in 2003. Simulated area-weighted mean phosphorus concentrations were within 2 µg/L of the area-weighted mean calculated from measured phosphorus concentrations for all 3 years (fig. 31). Total nitrogen concentrations were simulated within one standard deviation of the observed mean in all segments except segment 1 in 2001 and segment 6 in 2003. Area-weighted mean total nitrogen concentrations were within 23 µg/L, or about 7 percent, of calculated area-weighted means for all 3 years (fig. 32). Simulated mean chlorophyll *a* concentrations were more than one standard deviation away from the observed mean concentration at segments 1 and 2 in 2001 and segment 4 in 2002. Measured and simulated area-weighted mean chlorophyll *a* concentrations were no more than 2.5 µg/L apart in each year (fig. 33). Measured Secchi depths had relatively low variability in most segments during all years. Simulated mean Secchi depths were within 0.7 m of measured means in all segments for all 3 years, but differed from the observed mean Secchi depth by more than one standard deviation in segments 2 and 6 in 2001 and in segments 3 and 5 in 2003 (fig. 34).

The calibrated BATHTUB model was used to simulate potential water-quality changes in response to seven scenarios of future changes in urban land use. Predictive simulations were run using the calibrated BATHTUB model for 2002 because growing-season rainfall in 2002 was closer to

Table 29. Calibration coefficients used in the BATHTUB model simulations of Converse Lake, Alabama.

Lake segment number	Lake segment name	Total phosphorus	Total nitrogen	Chlorophyll *a*	Secchi depth
Global coefficients (applied to all lake segments)					
All	Converse Lake	0.5	0.75	1.4	1
Segment-specific coefficients					
1	Upper Lake	1	1	1	1
2	Mill Branch	1	1	2	1
3	Crooked	1	1	1	1
4	Upper Hamilton	1.5	.75	1.5	1
5	Pumping station	1	1	1.5	1
6	Spillway	1	1	1.5	1

Table 30. Geometric mean values and ranges of measured water-quality constituents and properties in the BATHTUB model development data set and measured in Converse Lake, Alabama, during 2001–03.

[μg/L, microgram per liter; m, meter; 1/m, reciprocal meter; <, less than; >, greater than]

Lake water-quality constituent or property	Description[a]	Model development data set			Converse Lake data set		
		Geometric mean	Minimum	Maximum	Geometric mean	Minimum	Maximum
Total phosphorus, in μg/L	Growing season, mixed-layer total phosphorus concentration.	47.9	9.9	274	3.16	1	41
Total nitrogen, in μg/L	Growing season, mixed-layer total nitrogen concentration.	1,002	243	4,306	362	110	940
Chlorophyll *a*, in μg/L	Growing season, mixed-layer chlorophyll *a* concentration. Measure of algal standing crop based on photosynthetic pigment.	9.39	2	63.6	.631	.05	51
Secchi depth, in m	Growing season, mean secchi depth. Measure of water transparency as influenced by algae and non-algal turbidity.	1.08	.19	4.6	2.06	1.3	3.7
Organic nitrogen, in μg/L	Growing season, mixed-layer organic nitrogen concentration. Portion of nitrogen pool in organic forms; generally correlated with chlorophyll *a* concentration.	474	186	1,510	297	40	790
Total phosphorus minus orthophosphorus, in μg/L	Growing season, mixed-layer concentration of non-orthophosphorus.	30	4.3	148	2.3	0	40.5
Non-algal turbidity, in 1/m	Non-algal turbidity approximated by the following equation: 1/(secchi depth)-0.025*(chlorophyll *a* concentration). Indicates importance of color and inorganic suspended solids.	.61	.13	5.15	.36	-.78	.723
	Low: Turbidity < 0.4 allochthonous / non-algal particulates unimportant high algal response to nutrients likely						
	High: Turbidity > 1 allochthonous particulates possibly important algal response to nutrients may be suppressed by light limitation and(or) nutrient bioavailability						

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[a] Adapted from Walker (1999).

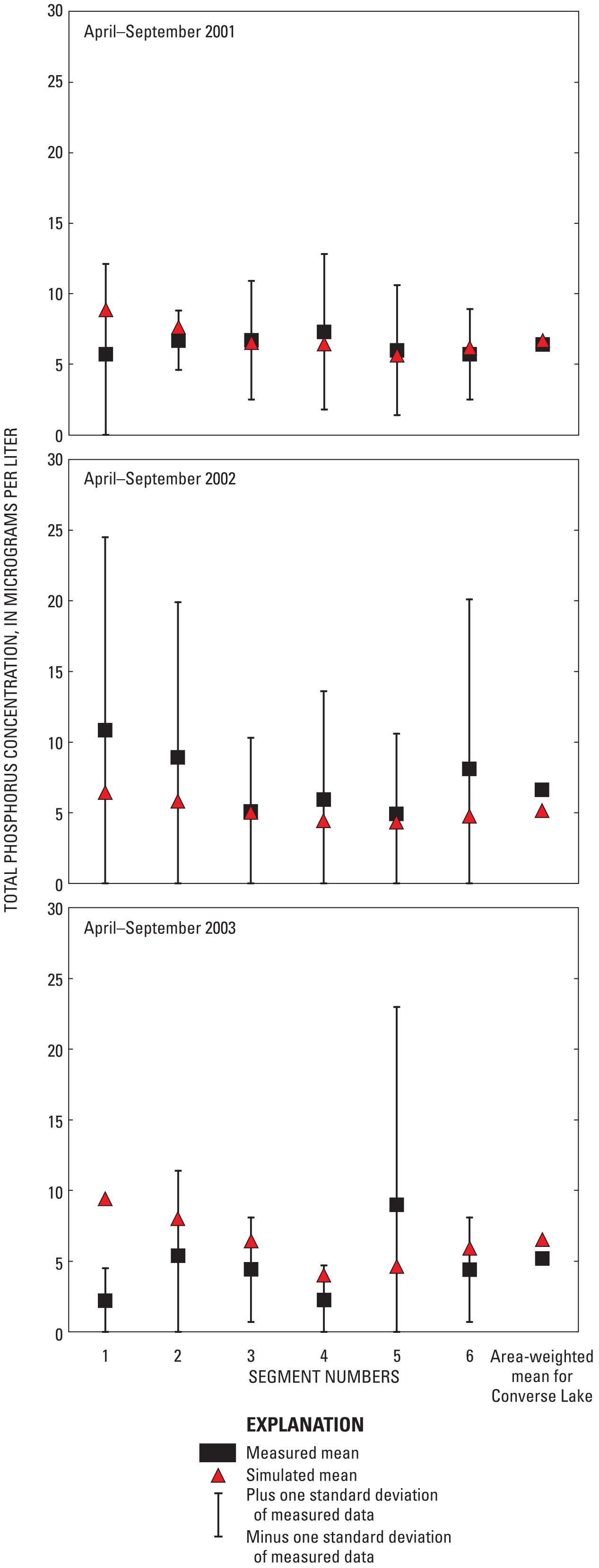

Figure 31. Measured and simulated (from BATHTUB) growing-season mean total phosphorus concentrations for selected sites in Converse Lake, Alabama, 2001–03.

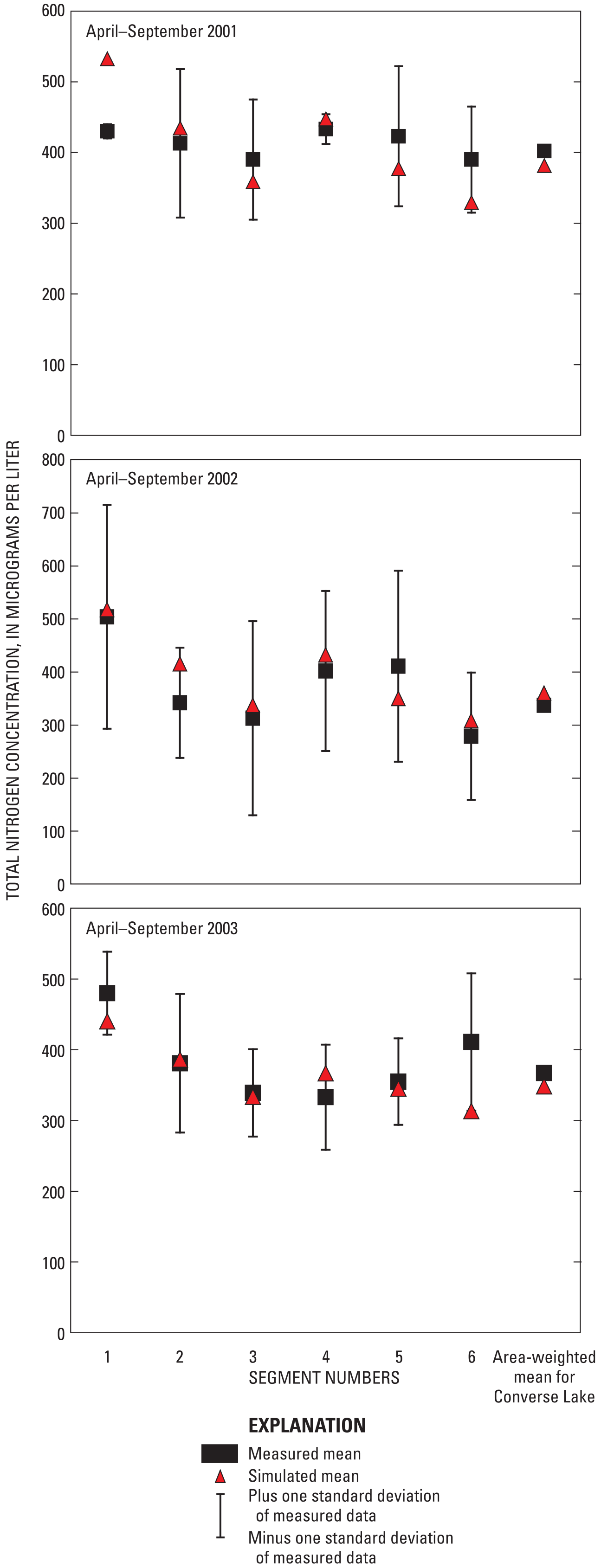

Figure 32. Measured and simulated (from BATHTUB) growing-season mean total nitrogen concentrations for selected sites in Converse Lake, Alabama, 2001–03.

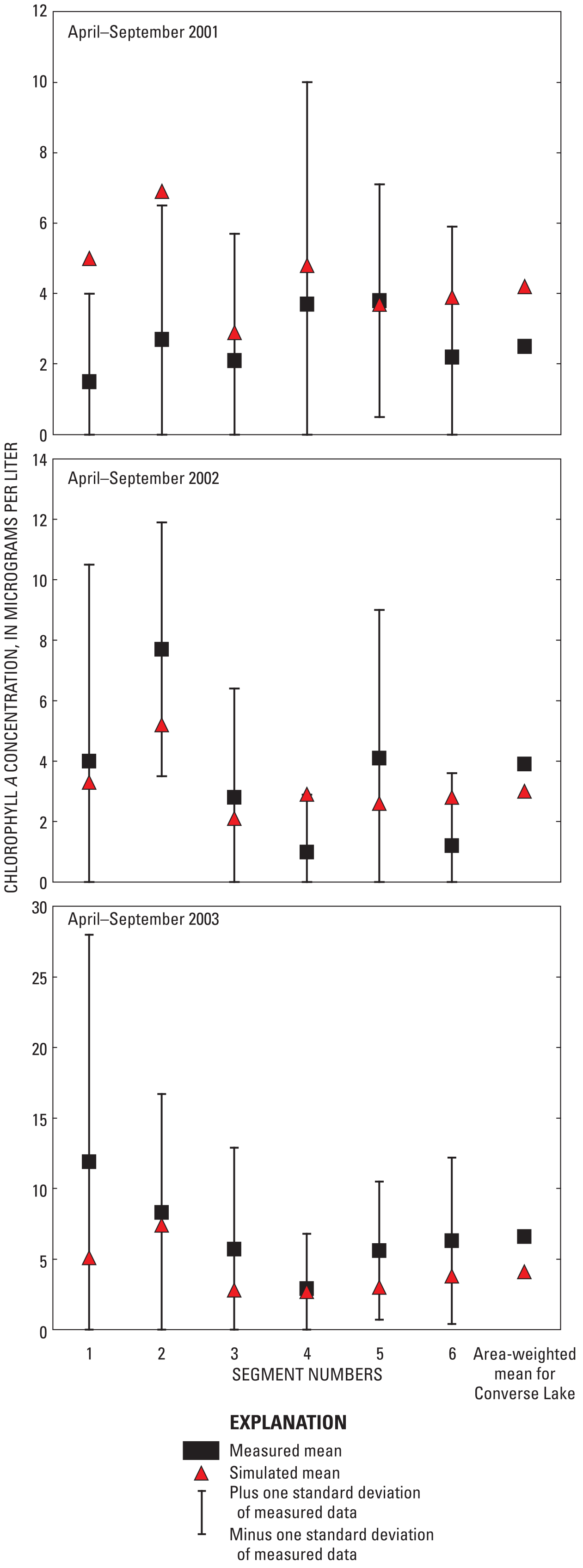

Figure 33. Measured and simulated (from BATHTUB) growing-season mean chlorophyll *a* concentrations for selected sites in Converse Lake, Alabama, 2001–03.

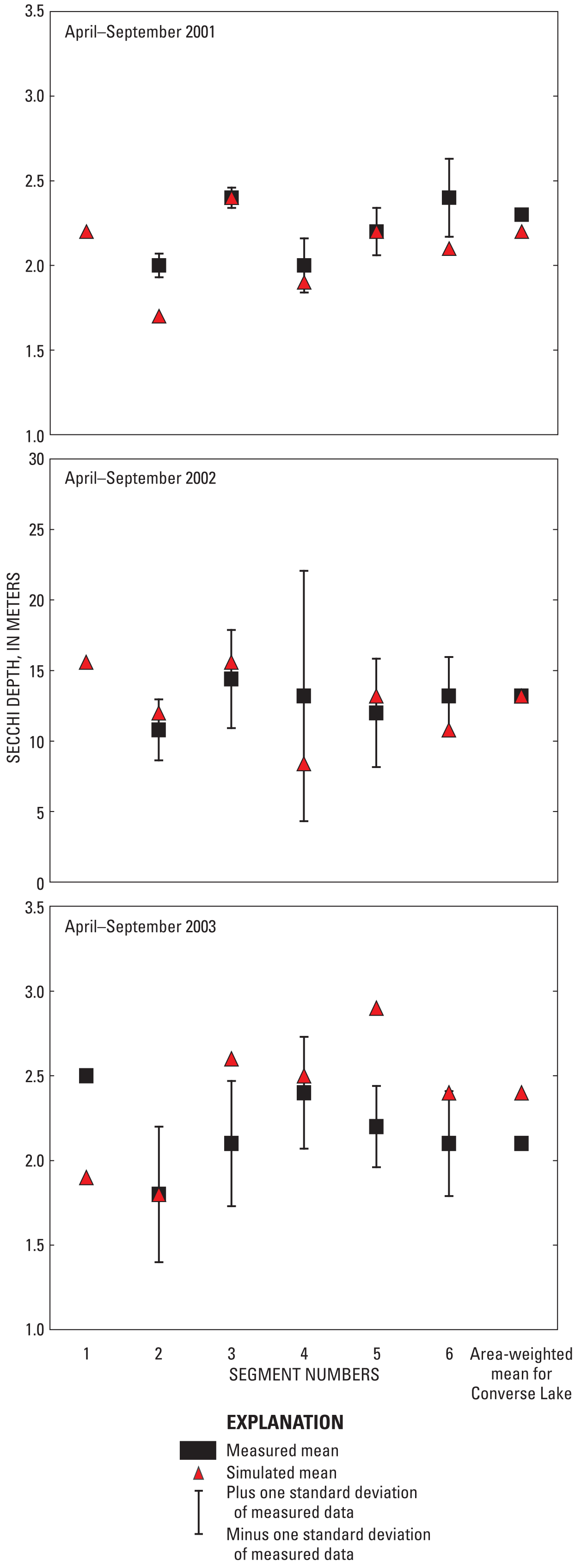

Figure 34. Measured and simulated (from BATHTUB) growing-season mean Secchi depths for selected sites in Converse Lake, Alabama, 2001–03.

long-term normals than in the other 2 years. Once calibrated across all 3 years, the BATHTUB model predicted mean total phosphorus concentrations within 4.5 µg/L, mean total nitrogen concentrations within 75 µg/L, mean chlorophyll *a* concentrations within 2.5 µg/L, and mean Secchi depths within 0.4 m of the measured values in all segments for year 2002 (figs. 31–34). Four future land-use scenarios were created by applying a set percentage of change in urban land use to all individual subwatersheds. These four scenarios included the simulation of lake water quality for a 25-percent decrease and 50-, 100-, 500-percent increases in urban land in all individual subwatersheds. Because these percentage changes do not alter the current relative proportional distribution of urban land among the subwatersheds, three additional scenarios were simulated to assess the effects of nutrient loads from various fixed percentages of urban land, representing more diffuse development throughout the watershed. These three scenarios, labeled A, B, and C, represent urban land use in 50, 75, and 100 percent of the developable land in each subwatershed, respectively. Increases in urban land use were assumed to mirror decreases in forested and agricultural land use in proportion to the 1992 percentages of these land uses (table 27; fig. 35).

Tributary loads for future land-use scenarios were calculated in the BATHTUB model using adjusted nutrient concentrations and tributary streamflow amounts for 2002. Atmospheric loads, tributary streamflow, and nutrient transport out of the lake were assumed to remain constant and were not changed from observed values for 2002. Percentage changes in nutrient loading to the entire watershed, in response to various changes in land-use areas, are shown in figure 35. Percentage changes for the entire watershed and for individual tributaries were estimated using export coefficients (table 23) and equation 8 (p. 61). Percentage changes for each tributary were applied to the tributary nutrient concentrations to create BATHTUB input files for each land-use scenario. The BATHTUB model then computed tributary nutrient loads under each scenario. These conditions were chosen to demonstrate the utility of the model, but more localized land-use changes could be simulated if detailed locations of future development were known.

Changes in Nutrient Concentrations

The BATHTUB model simulations indicated that nutrient concentrations and percentage changes in nutrient concentrations in all lake segments tended to show a relatively linear response to linear increases in urban land use (figs. 36, 37). Greater rates of response of total phosphorus and total nitrogen concentrations were seen in segments 1, 2, and 4 of Converse Lake, perhaps because of shallow depths and the proximity of tributary mouths. Percentage increases in phosphorus concentrations in response to a 100-percent increase in urban land use were less than 5 percent for all segments. At six times the current urban land use, mean total

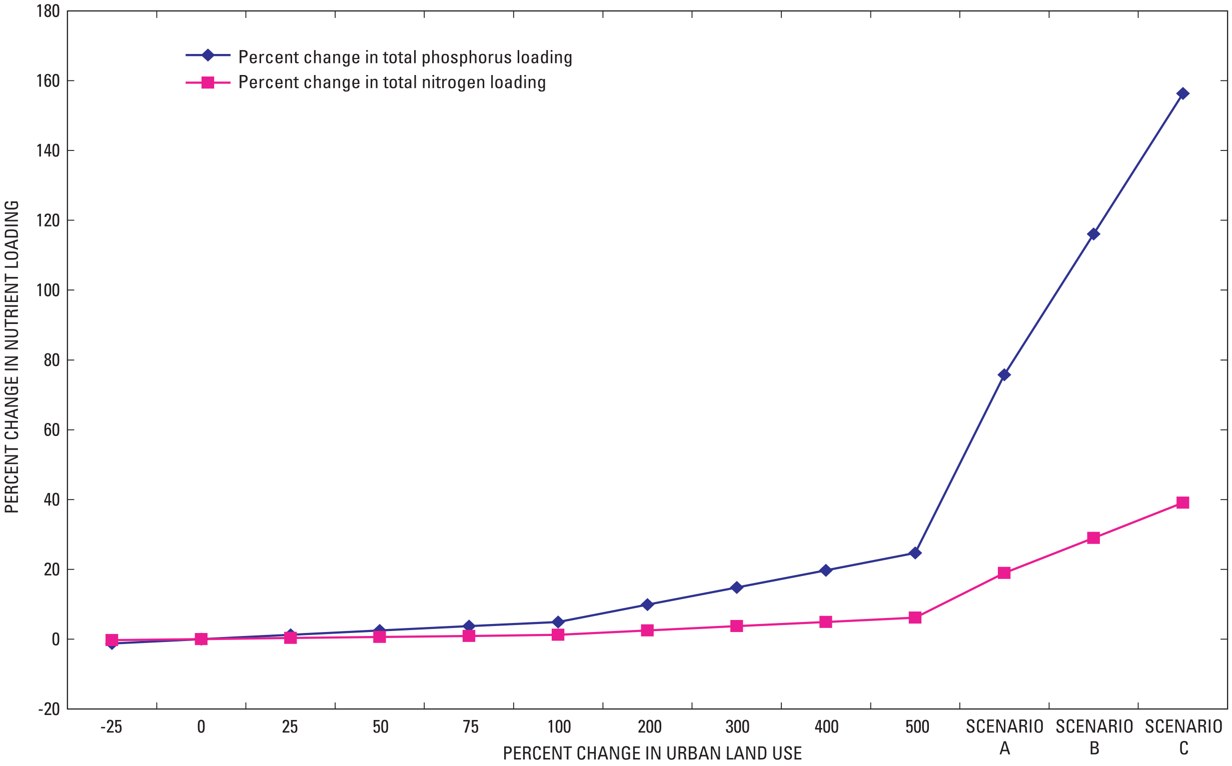

Figure 35. Percent changes in nutrient loading to Converse Lake, Alabama, in response to various land-use scenarios.

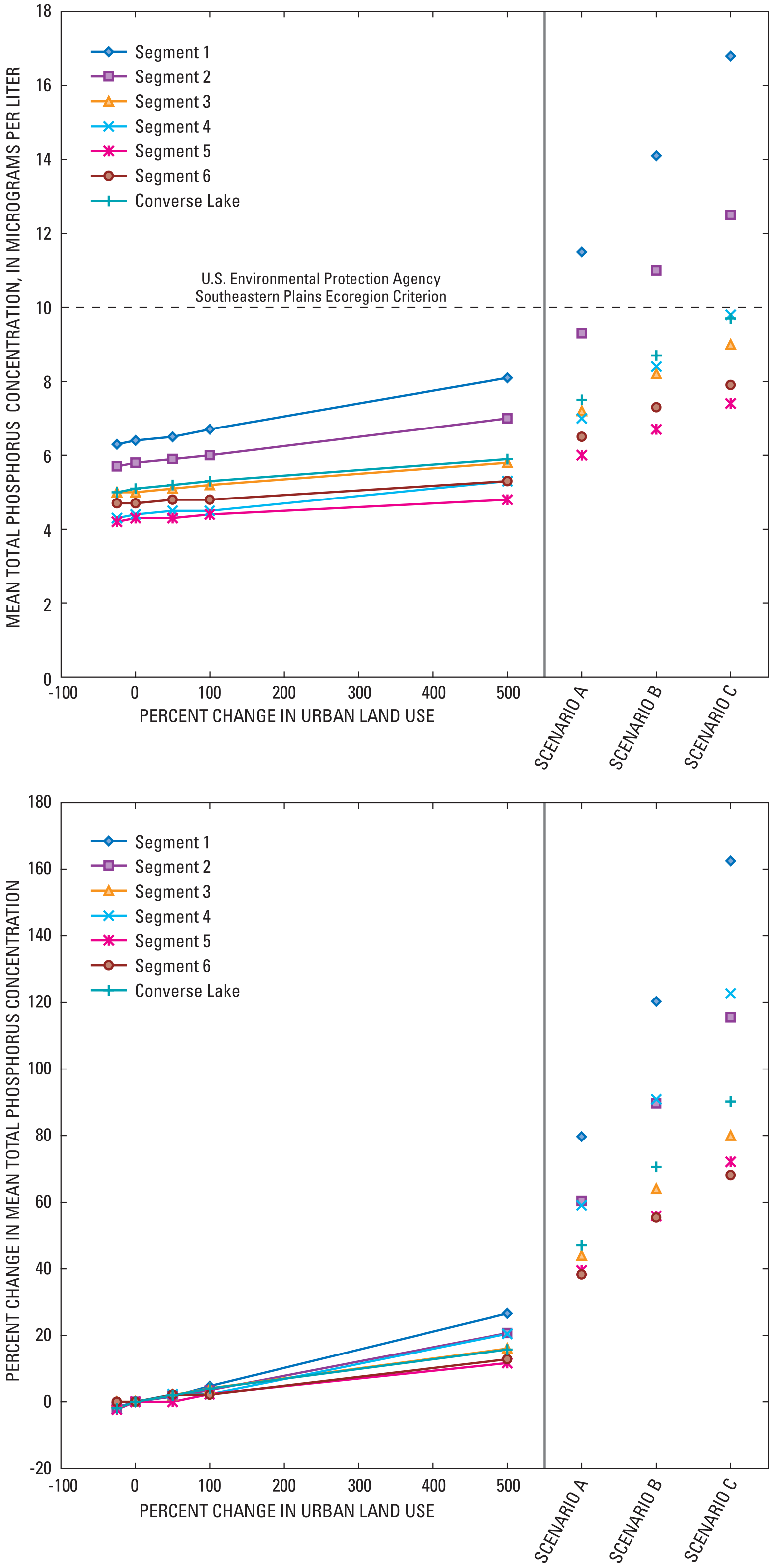

Figure 36. Simulated changes in mean total phosphorus concentrations in Converse Lake, Alabama, in response to various land-use scenarios from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

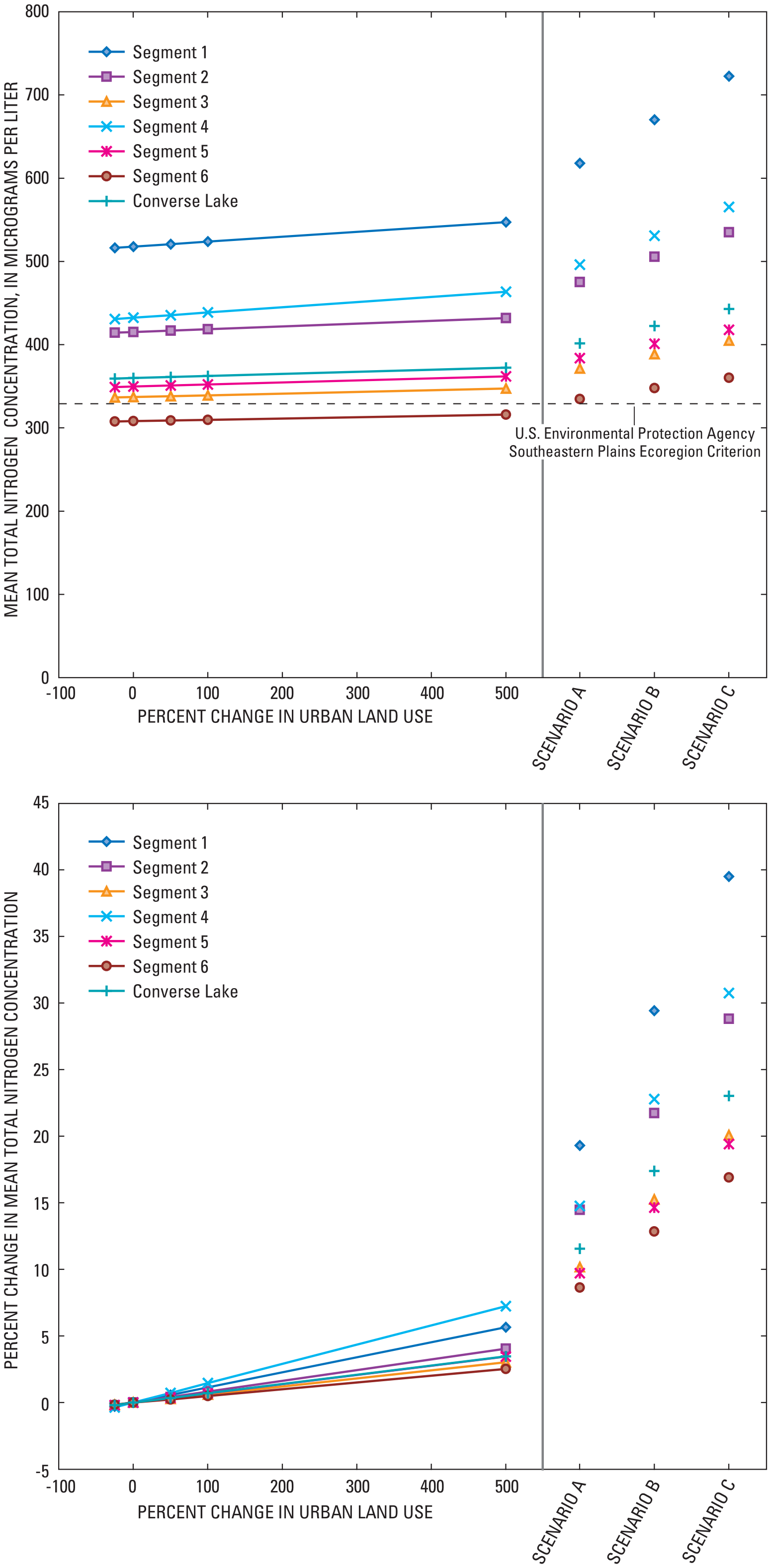

Figure 37. Simulated changes in mean total nitrogen concentrations in Converse Lake, Alabama, in response to various land-use scenarios from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

phosphorus concentrations could increase about 20–25 percent in the relatively shallow segments 1, 2, and 4, but only about 16 percent in the entire lake. Percentage increases in mean total nitrogen concentrations were very small (less than (<) 2 percent) in all segments even with doubling the current area of urban land use. When urban land use increases to six times the current area, mean total nitrogen concentrations in the lake increase by no more than 7.5 percent in all lake segments.

To simulate the effects of more extreme urbanization in the Converse Lake watershed, three scenarios of increased urban land were evaluated using the BATHTUB model. Rates of change in lake response were different in each segment because of differences in beginning land-use distributions. Results for segment 5 are discussed in detail because the drinking-water intake for the city of Mobile is located in segment 5. Results for scenario A (50 percent of developable land is urbanized) indicated a summer mean total phosphorus concentration of 6.0 µg/L and a mean total nitrogen concentration of 384 µg/L, or about 40 and 9.7 percent increases, respectively, from 2002 concentrations in segment 5. Results for scenario B (75 percent of developable land is urbanized) indicated approximate increases in summer mean total phosphorus and mean total nitrogen concentrations to 6.7 and 401 µg/L, respectively, in segment 5. These concentrations represent increases of about 56 percent for total phosphorus and 15 percent for total nitrogen. Results for scenario C (100 percent of developable land is urbanized) indicated increases to 7.4 µg/L in mean total phosphorus and 418 µg/L in mean total nitrogen in segment 5, representing increases of 72.1 and 19.4 percent, respectively. Simulated mean concentrations for the entire lake are slightly higher than those for segment 5 because of the greater response in shallow segments 1 and 4.

Simulated nutrient concentrations were compared to USEPA criteria for lakes and reservoirs in the Southeastern Plains ecoregion. In all lake segments, simulated phosphorus concentrations for a 500-percent increase in urban land use were below the USEPA criterion for lakes and reservoirs in the Southeastern Plains ecoregion. If 50 percent of the developable land becomes urbanized (scenario A), phosphorus concentrations in segment 1 can be expected to exceed the USEPA phosphorus criterion. Both segment 1 and segment 2 could exceed the criterion if urban land use increases to 75 percent, but even if 100 percent of developable land were urbanized, no more lake segments would exceed the USEPA phosphorus criterion. In contrast, simulated total nitrogen concentrations for a 25-percent decrease in the amount of urban land were greater than the total nitrogen ecoregion criterion (329 µg/L) in all segments except segment 6. The mean total nitrogen concentration in segment 6 did not exceed the USEPA criterion after a 500-percent increase in urban land but exceeded the criterion for scenarios A, B, and C. Under scenario C, nitrogen concentrations were 1.1 to 2.2 times the USEPA criterion, with the greatest concentrations occurring in segment 1.

Changes in Chlorophyll *a* Concentrations

Simulated mean chlorophyll *a* concentrations and percentage changes in chlorophyll *a* concentrations had relatively linear patterns of increase in each lake segment in response to increases in urban land use (fig. 38). The greatest absolute increases in mean chlorophyll *a* concentrations in response to increases in urban land-use area occurred in shallow segments 1, 2, and 4. Simulated percentage increases over observed mean chlorophyll *a* concentrations for 2002 were greatest in segments 1 and 4, indicating that these segments will have the greatest response to nutrient loading changes associated with increases in urban land use. Decreases of 25 percent in urban land-use area produced reductions in chlorophyll *a* concentrations of less than 5 percent in all lake segments.

Simulated growing-season mean chlorophyll *a* concentrations were compared to USEPA chlorophyll *a* criteria for fluorometric and spectrophotometric methods. At six times the current amount of urban land-use area, mean chlorophyll *a* concentrations in all segments, except segment 2, were below the fluorometric method criterion. If urban land encompasses half of the developable land in the watershed, mean chlorophyll *a* concentrations will exceed the fluorometric criterion in the shallow segments 1, 2, and 4. Simulated concentrations remained below the fluorometric criterion in segments 3 and 5, even with 100-percent urbanization of developable land (scenario C). Mean chlorophyll *a* concentrations exceeded the spectrophotometric criterion in all segments, even with a 25-percent decrease in urban land. Land-use scenario C would result in mean chlorophyll *a* concentrations ranging from about 2.6 to 7.0 times greater than the spectrophotometric criterion.

Simulated mean chlorophyll *a* concentrations in segment 5, the location of drinking-water intakes, were examined further. The rates of increase in mean chlorophyll *a* concentrations in segment 5 with increases in urban land use were among the lowest observed in Converse Lake. The mean growing-season chlorophyll *a* concentration in segment 5 predicted under scenario A (50 percent of developable land urbanized) was 3.9 µg/L, or about 1.5 times the concentration for 2002. The increase in urban land use under scenario B (75 percent of developable land urbanized) would increase mean chlorophyll *a* concentration to 4.5 µg/L. If 100 percent of developable land were converted to urban land uses, then the mean chlorophyll *a* concentration in segment 5 would increase to 5.0 µg/L, or about twice the mean concentration measured in 2002. Mean chlorophyll *a* concentrations were still below the USEPA fluorometric chlorophyll *a* criterion in segment 5, indicating relatively unimpaired water quality in terms of algal biomass.

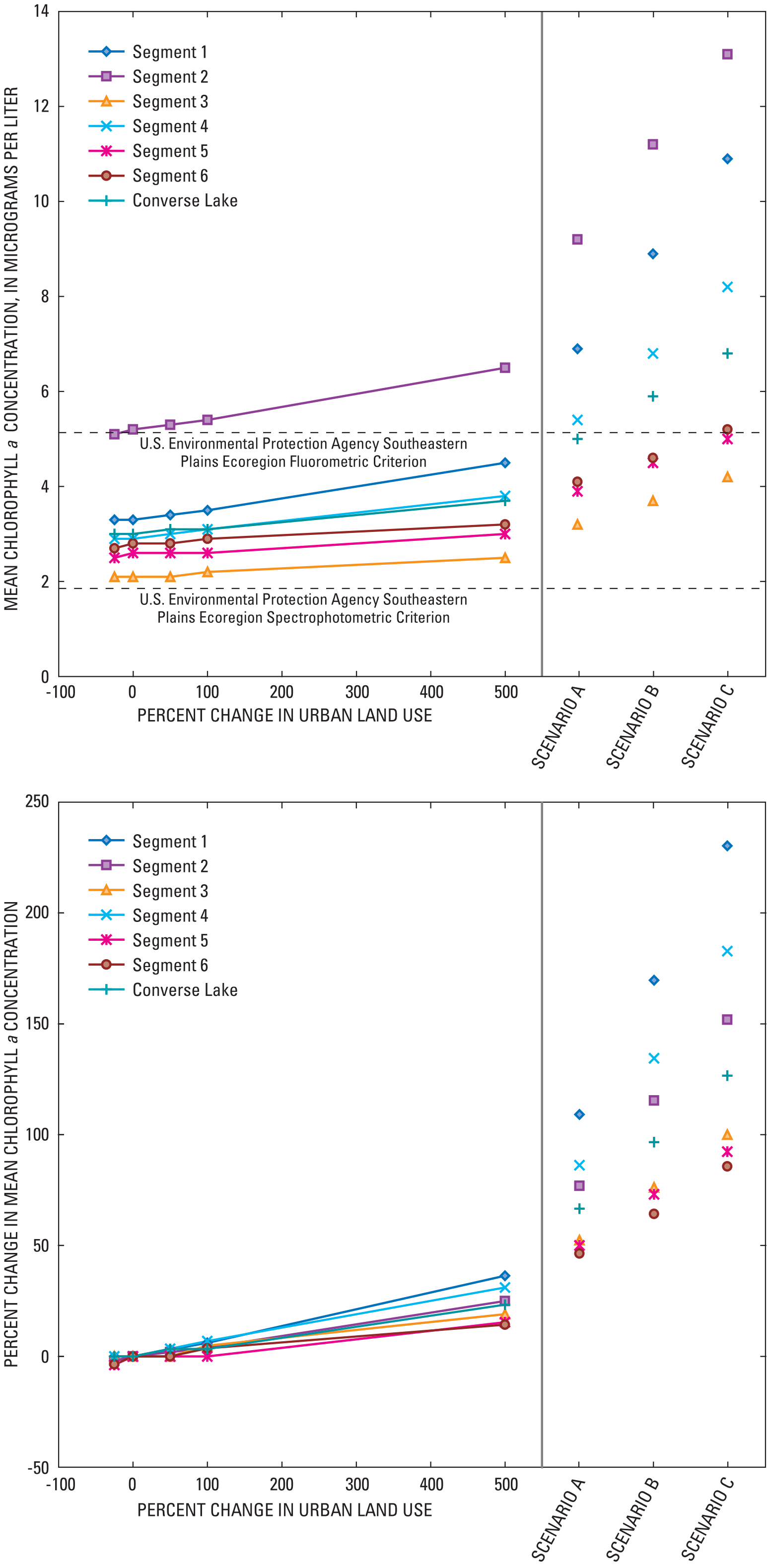

Figure 38. Simulated changes in mean chlorophyll *a* concentrations in Converse Lake, Alabama, in response to various land-use scenarios from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

Changes in Secchi Depths

Mean Secchi depths decreased with increasing areas of urban land use in all segments, but large changes in land use were necessary to cause measurable changes in segments 4 and 6 and in mean conditions for the lake (fig. 39). With six times the current area of urban land use, no measurable changes in mean Secchi depth were simulated in segments 4, 6, or in the entire lake, and decreases in mean Secchi depths in the other segments were less than 10 percent of measured values for 2002. Under scenario C, mean Secchi depths in segments 1 and 2 decreased by 25–30 percent, or about 0.5 to 0.7 m, from 2002 depths. Percentage decreases in mean Secchi depth with increasing urban land use were greater in segments 1 and 2 and least in segment 6.

Mean Secchi depths must be greater than 2.041 m to comply with the USEPA criterion. Secchi depths in segments 4 and 6 were less than the criterion, even with a 25-percent decrease in urban land-use area. Secchi depths were below the criterion for all segments except segment 3, if 50 percent of the developable land were urbanized. Simulated Secchi depths remained above the criterion in segment 3, if 75 percent of developable land were urbanized, but was simulated slightly below the criterion if all available land were converted to urban uses.

Changes in Trophic Status

Trophic state index (TSI) values calculated by the BATHTUB model indicate mean growing-season conditions. For 2002, oligotrophic conditions occurred in all lake segments based on total phosphorus concentrations, oligotrophic to mesotrophic conditions occurred based on chlorophyll *a* concentrations, and mesotrophic to eutrophic conditions occurred based on Secchi depths (fig. 40). The presence of highly colored, tannic waters may inflate the current TSI calculated from Secchi depths and dampen the simulated pattern of response in TSI to increased urban land use. Increases in urban land use caused linear increases in TSIs, but the rate of increase was different for each type of water-quality measurement used to evaluate trophic condition. A 25-percent decrease in urban land use caused no change in trophic state classification in all lake segments.

The TSIs calculated from total phosphorus and chlorophyll *a* concentrations are more responsive to increases in urban land use than the TSI calculated from Secchi depth. Simulated TSIs calculated from total phosphorus concentrations increase linearly with increases in urban land use, but only segments 1 and 2 become classified as mesotrophic in response to increased phosphorus loads associated with 100 percent of developable land becoming urbanized. The response in simulated TSIs calculated from chlorophyll *a* concentrations to increases in urban land use is less rapid than with TSIs calculated from total phosphorus concentrations. When 50 percent of the developable land in the watershed was urbanized, only segment 2 was classified as eutrophic on the basis of chlorophyll *a* concentrations; all other sites remained mesotrophic. An increase to 75-percent urbanization causes segment 1 to be classified as eutrophic as well. When all available land is used for urban uses, all of the shallow lake segments, 1, 2, and 4, exhibit eutrophic conditions as indicated by the TSI for chlorophyll *a*. The TSIs calculated from Secchi depths increased only slightly in all lake segments with a 500-percent increase in urban land use. When 50 percent of available land was urbanized, TSIs calculated from Secchi depth indicated eutrophic conditions in all lake segments except segment 3. Even when all available land was urbanized, segment 3 remained classified as mesotrophic.

Changes in Algal Bloom Frequency

Increased nutrient loadings may cause extreme growth in algal biomass or algal blooms. These blooms may be of short duration, however, because algal life cycles are relatively short; as excess nutrients are consumed, fewer replacement algal cells are produced. Even though blooms may last only a few days, they can have serious water-treatment implications because of taste and odor problems, possible release of algal toxins, and the release of DBP precursors into the lake. In addition, the decomposition of algal blooms can cause low dissolved oxygen levels, which are detrimental to aquatic biota, including fish (Clark and others, 1977). Chlorophyll *a* concentrations are used as a surrogate for algal biomass and can be used to define the presence and severity of algal blooms. Chlorophyll *a* concentrations of 30–40 µg/L or more

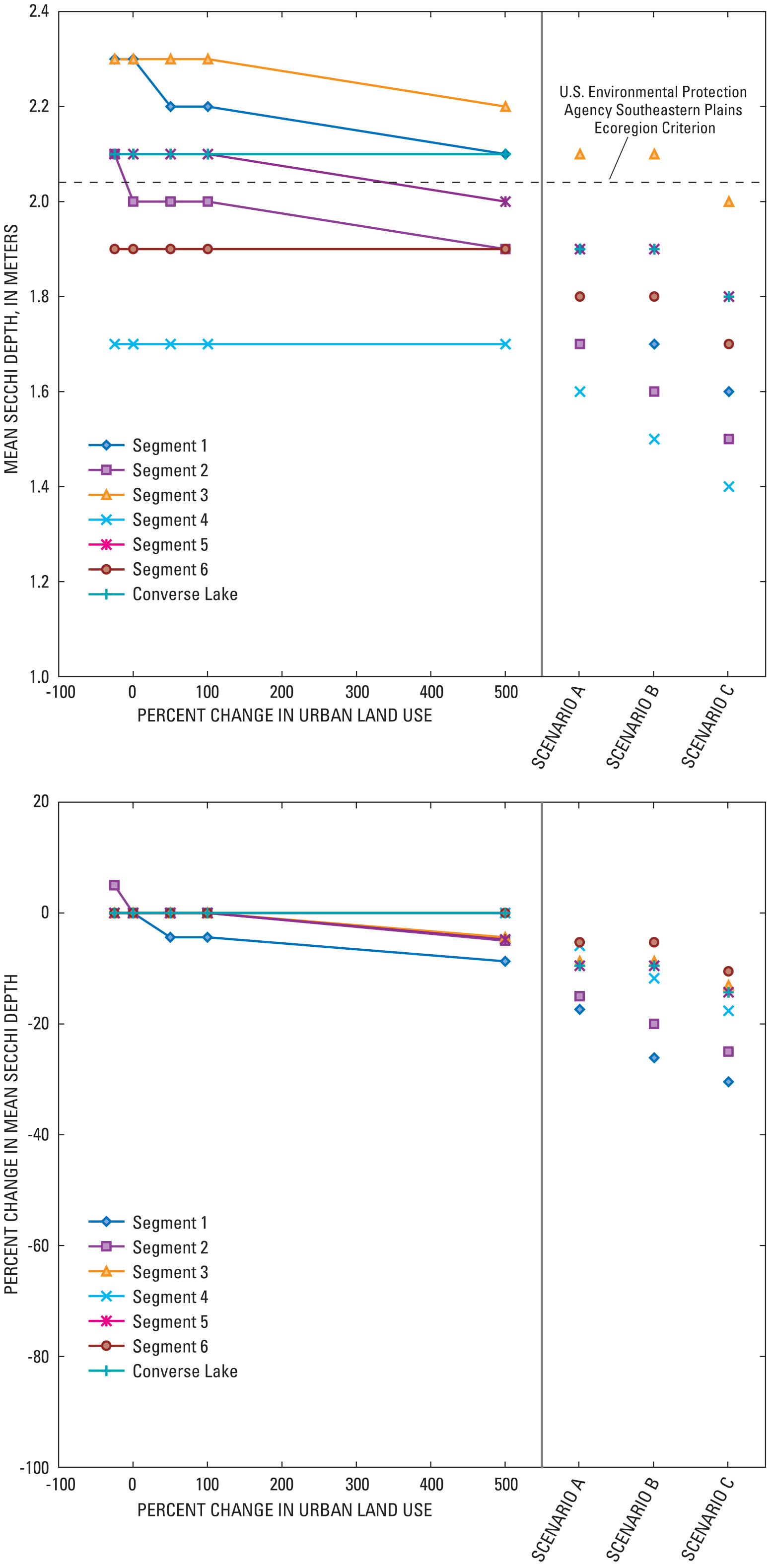

Figure 39. Simulated changes in mean Secchi depth in Converse Lake, Alabama, in response to various land-use scenarios from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

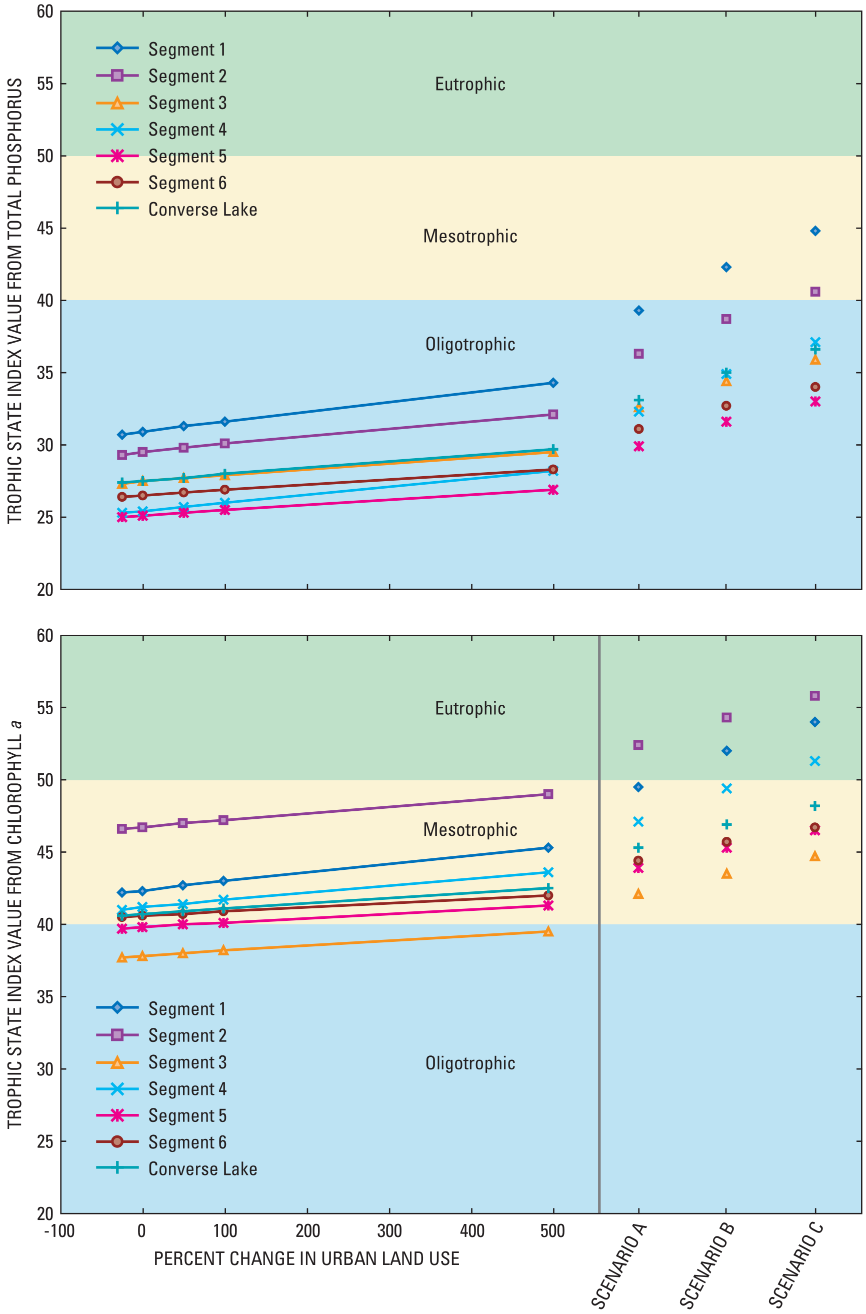

Figure 40. Simulated changes in trophic status in Converse Lake, Alabama, in response to various land-use scenarios from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

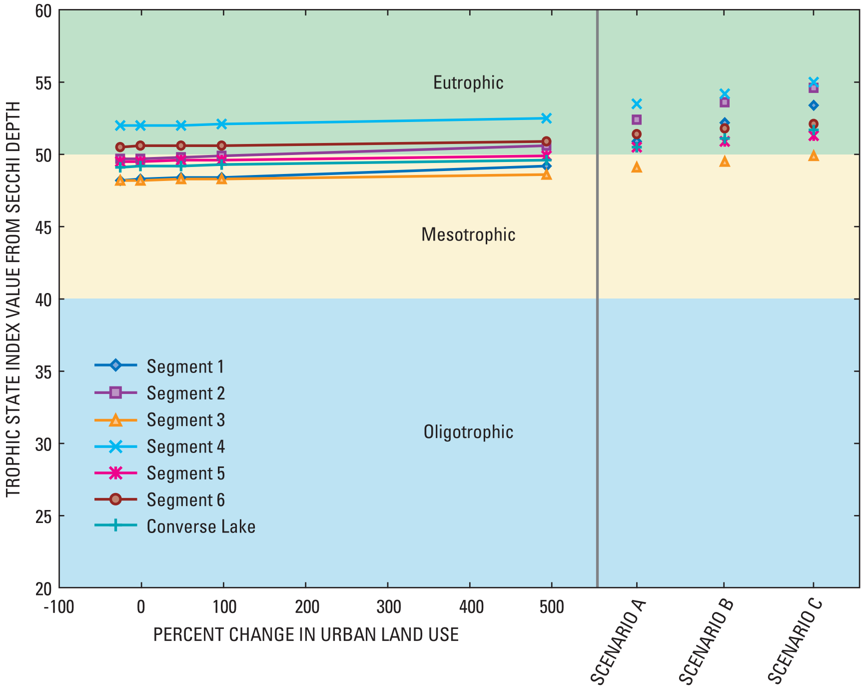

Figure 40 (Continued). Simulated changes in trophic status in Converse Lake, Alabama, in response to various land-use scenarios from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

generally are considered to indicate algal bloom conditions (Walker, 1999).

The BATHTUB model predicts the percentage of days during May–September that concentrations of chlorophyll *a* exceed 10, 20, 30, 40, 50, and 60 µg/L (figs. 41, 42). Based on simulations of 2002 data, algal blooms of 30 µg/L do not currently occur in Converse Lake, except for blooms of less than 1 day's duration in segment 2. If urban land use increases by six times, chlorophyll *a* concentrations in segment 4 also may exceed 30 µg/L for durations of less than 1 day. As simulated urban land use increases to 50, 75, and 100 percent of developable land, algal blooms become more likely in shallow lake segments, 1, 2, and 4. Under these simulated conditions, segment 2 has the greatest number of days with moderate bloom (chlorophyll *a* greater than 30 µg/L) conditions. Chlorophyll *a* concentrations greater than 30 µg/L did not occur in segment 3, and occurred for less than 1 day in segments 5 and 6 when 100 percent of available land was urbanized.

Chlorophyll *a* concentrations predicted by the BATHTUB model for the entire lake reflect the average of conditions in the individual lake segments (fig. 42). Chlorophyll *a* concentrations greater than 30 µg/L are not expected to occur throughout the entire lake for periods greater than 1 day until 75 percent of developable land in the watershed is urbanized. Under scenario C (100 percent of developable land is urbanized) chlorophyll *a* concentrations of 30 µg/L and 40 µg/L are expected to occur for durations of about 2 days and 1 day, respectively, during the growing season. Chlorophyll *a* concentrations of 50 µg/L or more are not expected to occur in the entire lake in response to increased urban development.

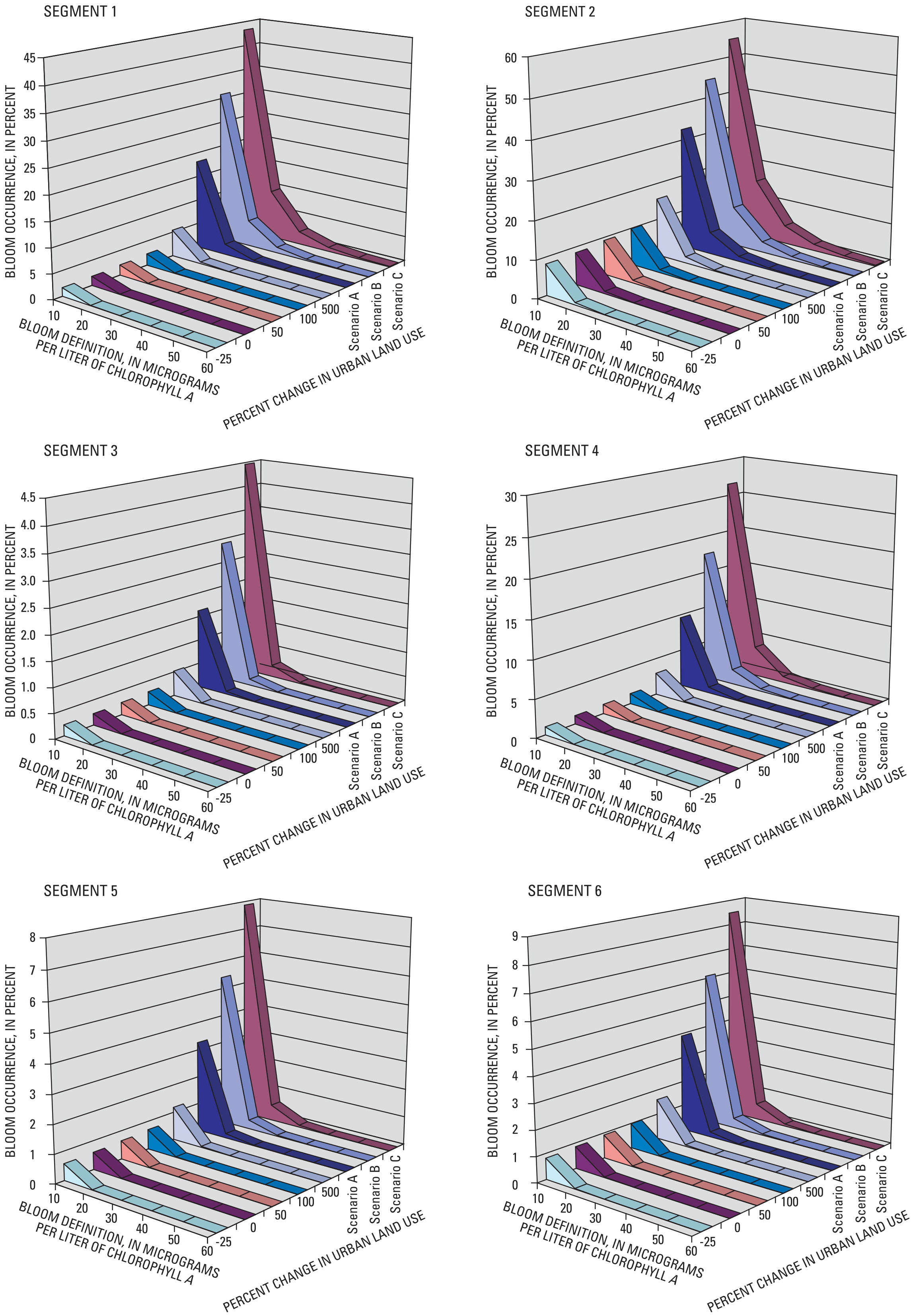

Figure 41. Simulated changes in frequency (percentage of days May through September) of algal blooms (defined by chlorophyll *a* concentrations) in selected segments of Converse Lake, Alabama, in response to various land-use scenarios, from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

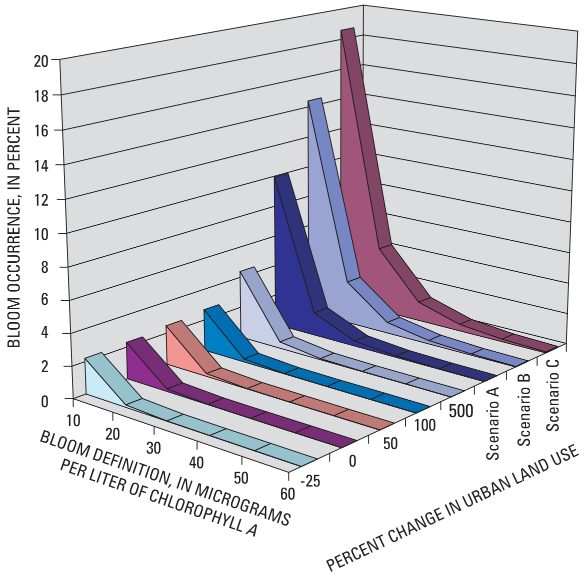

Figure 42. Simulated changes in frequency (percentage of days May through September) of algal blooms (defined by chlorophyll a concentrations) in Converse Lake, Alabama, in response to various land-use scenarios from BATHTUB model output. Scenarios A, B, and C represent urban land use in 50, 75, and 100 percent of developable land in the watershed, respectively.

Summary and Conclusions

J.B. Converse Lake (Converse Lake) is a 3,600-acre manmade reservoir formed in 1952 by the impoundment of Big Creek. The lake and its 103-square mile (mi^{2}) watershed are located in western Mobile County, Alabama. The Mobile Area Water and Sewer System manages the lake as the primary source of drinking water for the city of Mobile and as a recreational fishing lake. Previous sampling of the lake by the Alabama Department of Environmental Management (ADEM) indicated that the lake is mesotrophic to eutrophic, based on Carlson's trophic state index.

Land use in the Converse Lake watershed is predominantly rural, and urban land use accounts for only about 3 percent of the watershed. Previous studies indicate that runoff from different land uses contributes different nutrient loads to streams, and that changes in land use potentially affect water quality. Increases in residential development have been observed in the Converse Lake watershed during routine field trips between 1990 and 2003, and U.S. Census Bureau data show a slight population increase in unincorporated areas of Mobile County, which includes the majority of the Converse Lake watershed.

Water quality was evaluated in the watershed of Converse Lake during 1990–2003, and data were used to calibrate the BATHTUB lake water-quality model, which was used as a predictive tool to better understand lake water-quality response to changes in watershed loading. Tributary and lake water-quality data were collected during 1998–2003 and used with previously collected data (1990–98) to assess current water-quality conditions, identify temporal trends, and calibrate the BATHTUB model. Selected stream and lake samples also were analyzed for fecal indicator bacteria and a group of compounds commonly found in wastewater and urban runoff to aid in identifying sites receiving wastewater contamination. Finally, the calibrated BATHTUB model was used to predict lake water-quality changes as a result of potential future changes in urban land use.

Tributary nutrient and organic carbon concentrations were monitored during 1998–2003 to quantify inputs to the lake, to identify areas with concentrations elevated above background (estimated by U.S. Environmental Protection Agency (USEPA) criteria for streams in the Southeastern Plains ecoregion), and to evaluate long-term trends in concentrations. Median concentrations of total Kjeldahl nitrogen exceeded the ecoregion criterion of 300 micrograms per liter (µg/L) at sites JACK, CRO-A, and HAM-A. Median nitrite plus nitrate concentrations exceeded the criterion of 95 µg/L at all sites except JACK. Median total nitrogen concentrations exceeded the criterion at all sites except COL, BOG, and HAM-A. Median total phosphorus concentrations exceeded the criterion at sites CRO-A and JUN-B. Organic carbon concentrations ranged from 0.4 to 13 milligrams per liter (mg/L) at the tributary sites. Concentrations appeared to be greater in the heavily forested watersheds of BIG and JACK, but no statistically significant ($p < 0.05$) relation was noted between forested land use and 1998–2003 organic carbon concentrations.

Only a few statistically significant changes in nutrient concentrations were observed in the watersheds of sites BIG, CRO, and HAM during 1990–2003. The only significant ($p < 0.05$) trends detected were approximate 0.01-(mg/L)/yr downward trends for both flow-adjusted and unadjusted total and dissolved inorganic nitrogen concentrations at CRO.

Annual loads and yields were calculated for BIG, CRO, and HAM, the three sites with continuous streamflow record. Mean annual instream loads of all species of nutrients were generally higher at site BIG than at sites CRO and HAM, a reflection of the larger drainage area and associated discharge at site BIG. With the exception of dissolved inorganic nitrogen at site BIG, all nutrient species had significant ($p < 0.05$) positive streamflow influences on nutrient concentrations. Seasonal influences on nutrient concentrations were more apparent with the nitrogen species than with the phosphorus species, with total phosphorus concentrations at site HAM being the only phosphorus species influenced seasonally.

Mean annual nutrient yields had a different distribution than mean annual nutrient loads, with higher nutrient yields for all species generally occurring at sites CRO and HAM rather than at site BIG. Agricultural and urban land-use categories make up approximately 42 and 50 percent, respectively, of the watersheds for sites HAM and CRO compared with 24 percent of the watershed for site BIG. This difference in land-use distribution is reflected in the higher nutrient yields in the more developed watersheds.

Lake water quality was evaluated from samples collected from six lake cross sections. Data indicated a range from oligotrophic to eutrophic conditions in the lake during the summer months of 2001–03. Nutrient concentrations and trophic state indicators were compared to reference-condition criteria defined by the USEPA for lakes and reservoirs in the Southeastern Plains ecoregion. Median total nitrogen concentrations in the lake exceeded the ecoregion criterion of 329 µg/L at all sites except LTAN. Median total Kjeldahl nitrogen concentrations were below the ecoregion criterion of 320 µg/L at sites LTAN, LPOW, and LSPILL. The ecoregion nitrite plus nitrate criterion was below the method detection level of 20 µg/L used in this study, and only sites LHWY98 and LPOW had median nitrite plus nitrate concentrations greater than the method detection level. Median total phosphorus concentrations at all lake sites were below the ecoregion criterion of 10 µg/L. Median Secchi depths were greater than the criterion of 2.041 meters at all lake sites except LMILL, indicating good water clarity. The fluorometric chlorophyll *a* criterion of 5.125 µg/L was exceeded at sites LMILL and LHAM.

Organic carbon concentrations were similar in the lake and tributaries, ranging from 0.4 to 9.2 mg/L at the lake sites. Lake concentrations of total organic carbon tended to be greater in mid to late summer than in early summer, indicating a possible algal source for part of the carbon. No statistically significant ($p < 0.05$) correlation was found, however, between chlorophyll *a* and total or dissolved organic carbon concentrations.

Concentrations of fecal coliform and *Escherichia coli* (*E. coli)* were smaller in the lake than in the tributaries. Maximum observed concentrations of fecal indicator bacteria in the tributaries were well above criteria set by the ADEM and USEPA for public water supply and infrequently used full-body contact. Median tributary bacterial concentrations were below these criteria. In contrast, only two lake sites (LHWY98 and LSPILL) had elevated concentrations of fecal indicator bacteria, and elevated concentrations were not observed during subsequent sampling of these sites.

Stream and lake samples were analyzed for 87 chemical compounds that are commonly found in wastewater and urban runoff—29 of these compounds were detected in at least one sample in the Converse Lake watershed. Ten of the detected compounds are known or suspected to exhibit at least weak hormonal activity, with the potential to disrupt endocrine function. Organic wastewater compounds were detected in 55 of 86 samples (64 percent) collected at 16 sites in the Converse Lake watershed; potential endocrine disruptors were detected in 25 of 86 samples (29 percent). The most frequently detected compounds were metolachlor (herbicide), atrazine (herbicide), caffeine (stimulant), β-sitosterol (plant steroid), bromacil (herbicide), metalaxyl (fungicide), prometon (herbicide), and NP1EO (detergent metabolite).

Mixtures of chemicals were common but concentrations generally were low—only 17 percent of the samples contained total concentrations of organic wastewater contaminants exceeding 1 µg/L. The 29 detected compounds were divided into the following 10 wastewater-indicator groups based on their general use and(or) origins: (1) prescription and nonprescription drugs, (2) steroids, (3) detergent metabolites, (4) disinfectants, (5) plasticizers/flame retardants, (6) insect repellent, (7) insecticides, (8) herbicides and fungicides, (9) polycyclic aromatic hydrocarbons, and (10) fragrances. The greatest concentrations of organic wastewater compounds came from three groups of compounds: steroids, disinfectants, and plasticizers/flame retardants. Some groups of compounds were detected exclusively in certain areas of the watershed. Detergent metabolites were detected most frequently in the lower reaches of Juniper Creek and Hamilton Creek. Triclosan, a disinfectant, was detected in Collins Creek, Hamilton Creek, and in one sample from Converse Lake. Herbicides, fungicides, and insecticides were found predominantly in Crooked Creek, the Hamilton Creek basin, and in Converse Lake. The insect repellent DEET was detected only in Converse Lake.

Organic wastewater data from the Converse Lake watershed were compared with data collected in the Threemile Creek watershed and with data collected in the first nationwide reconnaissance of the occurrence of pharmaceuticals, hormones, and other OWCs in water resources. In the nationwide reconnaissance, the selection of sites was biased toward streams susceptible to contamination. Of 50 selected constituents, 29 were detected in the Converse Lake watershed, 41 were detected in the Threemile Creek watershed, and 41 were detected at sites nationwide. Detection frequencies in the Converse Lake watershed were much lower than detection frequencies in the Threemile Creek watershed or in the nationwide reconnaissance. Total concentrations of OWCs found in the Converse Lake watershed also were less than concentrations found in the Threemile Creek watershed.

The empirical lake model BATHTUB was developed and calibrated using data from the 2001–03 growing seasons (April–September). Calibration resulted in predictions of 2002 growing-season mean concentrations of total phosphorus within 4.5 µg/L, total nitrogen within 75 µg/L, chlorophyll *a* within 2.5 µg/L, and Secchi depths within 0.4 meters of 2002 observed means. Predictive use of the model allows the estimation of changes in nutrient concentrations and trophic state of the lake resulting from continued residential and commercial development in the Converse Lake watershed.

Nutrient export rates from each of four general land-use categories—forest, row crop, pasture, and urban—in the Converse Lake watershed were approximated from yields observed in the watershed and previously published yields from other study areas. These approximate nutrient yields were used to estimate expected changes in nutrient loading to the lake from various land-use scenarios. If 100 percent of developable land in the watershed were converted to urban uses, then total phosphorus loads would be expected to increase by 156 percent and total nitrogen loads by 39.1 percent.

The effects of various land-use changes on lake water quality were evaluated by adjusting tributary nutrient concentrations in the BATHTUB model according to estimated percentage changes in loading. In each of the six lake segments, mean nutrient concentrations had a relatively linear response to linear increases in urban land use. Greater rates of response were seen in the shallow segments 1, 2, and 4. Mean chlorophyll *a* concentrations in all segments increased with increasing urban land use, but the rate of increase was greatest in segments 1 and 4. Mean Secchi depths decreased slowly in response to increases in urban land use, with the greatest decreases in segments 1 and 2.

The BATHTUB model simulations indicated relatively minor changes in lake water quality in response to changes in urban land use. Simulated trophic state index values for 2002 indicated oligotrophic conditions based on total phosphorus concentrations, oligotrophic to mesotrophic conditions for chlorophyll *a* concentrations, and mesotrophic to eutrophic conditions for Secchi depths. A simulated 25-percent reduction in urban land use caused no change in trophic state classification in any segment. If 100 percent of developable land in the Converse Lake watershed were urbanized, then trophic state indices calculated from total phosphorus indicate mesotrophic conditions in segments 1 and 2. Under this same land-use scenario, trophic state index values based on chlorophyll *a* concentrations indicate eutrophic conditions in segments 1, 2, and 4, and trophic state index values based on Secchi depths indicate eutrophic conditions in all segments except segment 3.

Model simulations indicated that moderate to severe algal blooms (defined by chlorophyll *a* concentrations greater than or equal to 30 μg/L) do not currently occur in Converse Lake. Increases in urban land use cause more frequent algal blooms, with a maximum number of days of bloom conditions occurring in segment 2.

Water quality in the Converse Lake watershed appears to be minimally affected by changes in land use occurring during 1990–2003. Trend analyses indicated that observed changes in land use in the Converse Lake watershed have had little effect on stream nutrient concentrations during 1990–2003. Tributary phosphorus concentrations were similar to background levels at most sites. Organic wastewater compounds are present in the Converse Lake and in the surrounding watershed; however, concentrations and detection frequencies are low when compared with data from other studies. The protective buffer encircling Converse Lake and the lack of development in the watershed likely contribute to the low concentrations and low detection frequencies found in the Converse Lake watershed.

The BATHTUB model simulations of future lake water quality indicate relatively minor lake water-quality changes in response to more widespread urban land-use changes. Continued monitoring of nutrient export from specific land uses would be needed to refine tributary inputs to the BATHTUB model and improve predictions. In particular, more data would be needed from rapidly urbanizing areas of the Converse Lake watershed, or in adjacent, more urbanized watersheds.

Literature Cited

Alabama Department of Environmental Management, 2000, Water quality criteria: Alabama Department of Environmental Management Administrative Code, chaps. 335–6–10 and 335–6–11.

Alabama Department of Environmental Management, 2004, Alabama's 2004 integrated water quality monitoring and assessment report: Alabama Department of Environmental Management, 159 p.; accessed June 17, 2004, at *http://www.adem.state.al.us/WaterDivision/WQuality/305b/WQ305bReport.htm*

American Public Health Association, 1995, Standard methods for the examination of water and wastewater: Washington, D.C., United Book Press [variously paged].

Bayne, D.R., Seesock, W.C., and Reutebuch, E.M., 1998, Limnological study of Big Creek Lake: Auburn University, Department of Fisheries and Allied Aquaculture, Alabama Agricultural Experiment Station, 74 p.

Beaulac, M.N., and Reckhow, K.H., 1982, An examination of land use—Nutrient export relationships: Water Resources Bulletin, v. 18, no. 6, p. 1013–1024.

Bradu, D., and Mundlak, Y., 1970, Estimation in lognormal linear models: Journal of the American Statistical Association, v. 65, no. 329, p. 198–211.

Brown, G.K., Zaugg, S.D., and Barber, L.B., 1999, Wastewater analysis by gas chromatography/mass spectrometry, *in* Morganwalp, D.W., and Buxton, H.T., eds., U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the technical meeting, Charleston, South Carolina, March 8–12, 1999: U.S. Geological Survey Water-Resources Investigations Report 99–4018–B, v. 2, p. 431–436.

Carlson, R.E., 1977, A trophic state index for lakes: Limnology and Oceanography, v. 22, p. 361–369.

Childress, C.J.O., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99–193, 19 p.

Clark, J.W., Viessman, Warren, Jr., and Hammer, M.J., 1977, Water supply and pollution control: New York, Harper and Row, 857 p.

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots: Journal of American Statistics Association, v. 74, p. 829–836.

Cohn, T.A., 1988, Adjusted maximum likelihood estimation of the moments of lognormal populations from type 1 censored samples: U.S. Geological Survey Open-File Report 88–350, 34 p.

Cohn, T.A., Caulder, D.L., Gilroy, E.J., Zynjuk, L.D., and Summers, R.M., 1992, The validity of a simple statistical model for estimating fluvial constituent loads—An empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, no. 5, p. 2353–2363.

Cohn, T.A., DeLong, L.L., Gilroy, E.J., Hirsch, R.M., and Wells, D.K., 1989, Estimating constituent loads: Water Resources Research, v. 25, no. 5, p. 937–942.

Daniel, J.F., 1976, Estimating groundwater evapotranspiration from streamflow records: Water Resources Research, v. 12, no. 3, p. 360–364.

Drever, J.I., 1988, The geochemistry of natural waters: Englewood Cliffs, New Jersey, Prentice Hall, Inc., 437 p.

Fain, G.B., Gilliam, C.H., Tilt, K.M., and Wallace, Beth, 1999, Alabama nurseries implement best management practices: Southern Nursery Association Research Conference, v. 44, p. 533–535; accessed January 3, 2005, at *http://www.sna.org/research*

Gilroy, E.J., Hirsch, R.M., and Cohn, T.A., 1990, Mean square error of regression-based constituent transport estimates: Water Resources Research, v. 26, no. 9, p. 2069–2077.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: New York, Elsevier Science Publishers, 522 p.

Hem, J.D., 1992, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hirsch, R.M., Slack, J.R., and Smith, R.A., 1982, Techniques of trend analysis for monthly water quality data: Water Resources Research, v. 20, p. 727–732.

Journey, C.A., and Gill, A.C., 2001, Assessment of water-quality conditions in the J.B. Converse Lake watershed, Mobile County, Alabama, 1990–98: U.S. Geological Survey Water-Resources Investigations Report 01–4225, 131 p.

Journey, C.A., Psinakis, W.L., and Atkins, J.B., 1995, Streamflow in and water quality and bottom material analyses of the J.B. Converse Lake basin, Mobile County, Alabama, 1990–92: U.S. Geological Survey Water-Resources Investigations Report 95–4106, 69 p.

Kendall, M.G., 1975, Rank correlation methods (4th ed.): London, UK, Charles Griffin, 202 p.

Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., and Buxton, H.T., 2002, Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000—A national reconnaissance: Environmental Science and Technology, v. 36, no. 6, p. 1202–1211.

Krauskopf, K.B., and Bird, D.K., 1995, Introduction to geochemistry: New York, McGraw-Hill, Inc., 647 p.

Line, D.E., White, N.M., Osmond, D.L., Jennings, G.D., and Mojonnier, C.B., 2002, Pollutant export from various land uses in the Upper Neuse River basin: Water Environment Research, v. 74, no. 1, p. 100–108.

McPherson, A.K., Gill, A.C., and Moreland, R.S., 2005, Assessment of water quality, benthic invertebrates, and periphyton in the Threemile Creek basin, Mobile, Alabama, 1999–2003: U.S. Geological Survey Scientific Investigations Report 2004–5302, 153 p.

Mobile Area Water and Sewer System, 2004, Drinking water quality 2004 report: Mobile, Alabama, Mobile Area Water and Sewer System, 6 p.

Mueller, D.K., Martin, J.D., and Lopes, T.J., 1997, Quality-control design for surface-water sampling in the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 97–223, 17 p.

Myers, D.N., and Wilde, F.D., eds., 2003 (3d ed.), Biological indicators—National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, Chap. A7, 163 p.

Pearman, J.L., Sedberry, F.C., Stricklin, V.E., and Cole, P.W., 1992, Water resources data, Alabama, water year 1991: U.S. Geological Survey Water-Data Report AL–91–1, 475 p.

Pearman, J.L., Sedberry, F.C., Stricklin, V.E., and Cole, P.W., 1993, Water resources data, Alabama, water year 1992: U.S. Geological Survey Water-Data Report AL–92–1, 457 p.

Pearman, J.L., Stricklin, V.E., and Psinakis, W.L., 1999, Water resources data, Alabama, water year 1998: U.S. Geological Survey Water-Data Report AL–98–1, 444 p.

Pearman, J.L., Stricklin, V.E., and Psinakis, W.L., 2000, Water resources data, Alabama, water year 1999: U.S. Geological Survey Water-Data Report AL–99–1, 594 p.

Pearman, J.L., Stricklin, V.E., and Psinakis, W.L., 2001, Water resources data, Alabama, water year 2000: U.S. Geological Survey Water-Data Report AL–00–1, 712 p.

Pearman, J.L., Stricklin, V.E., and Psinakis, W.L., 2002, Water resources data, Alabama, water year 2001: U.S. Geological Survey Water-Data Report AL–01–1, 669 p.

Pearman, J.L., Stricklin, V.E., and Psinakis, W.L., 2003, Water resources data, Alabama, water year 2002: U.S. Geological Survey Water-Data Report AL–02–1, 511 p.

Psinakis, W.L., Lambeth, D.S., Stricklin, V.E., and Treece, M.W., Jr., 2004, Water resources data, Alabama, water year 2003: U.S. Geological Survey Water-Data Report AL–03–1, 634 p.

Reckhow, K.H., Beaulac, M.N., and Simpson, J.T., 1980, Modeling phosphorus loading and lake response under uncertainty—A manual and compilation of export coefficients: U.S. Environmental Protection Agency, Office of Water Regulations and Standards, EPA 440/5–80–011, 214 p.

Rorabaugh, M.I., 1964, Estimating changes in bank storage and ground-water contribution to streamflow: International Association of Scientific Hydrology, Publication 63, p. 432–441.

Rutledge, A.T., 1998, Computer programs for describing the recession of ground-water discharge and for estimating mean ground-water recharge and discharge from streamflow records: U.S. Geological Survey Water-Resources Investigations Report 98–4148; accessed November 9, 2004, at *http://water.usgs.gov/ogw/rora/*

SAS Institute, Inc., 1989, SAS/STAT User's guide, version 6 (4th ed.), v. 2: Cary, North Carolina, SAS Institute, Inc., 943 p.

Schertz, T.L., Alexander, R.B., and Ohe, D.J., 1991, The computer program EStimate TREND (ESTREND), a system for the detection of trends in water-quality data: U.S. Geological Survey Water-Resources Investigations Report 91–4040, 63 p.

Southeast Regional Climate Center, 2005a, National Climatic Data Center 1971–2000 monthly normals for the Mobile Regional Airport; accessed April 25, 2004, at *http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliNORMNCDC2000.pl?al5478*

Southeast Regional Climate Center, 2005b, National Climatic Data Center monthly total precipitation for the Mobile Regional Airport; accessed April 25, 2004, at *http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMONtpre.pl?al5478*

U.S. Census Bureau, 2002, Table 10. Alabama incorporated place population estimates, sorted within county—April 1, 2000, to July 1, 2002; accessed July 22, 2004, at *http://eire.census.gov/popest/data/cities/tables/SUB-EST2002-10-01.pdf*

U.S. Environmental Protection Agency, 1986, Ambient water quality criteria for bacteria—1986: U. S. Environmental Protection Agency, EPA 440/5–84–002.

U.S. Environmental Protection Agency, 1992, Multi-Resolution Land Characteristics Consortium, National Land Cover Data; accessed July 31, 2001, at *http://www.epa.gov/mrlc/nlcd.html*

U.S. Environmental Protection Agency, 1996, Thirty-seventh report of the Toxic Substances Control Act Interagency Testing Committee to the administrator: Federal Register, v. 61, no. 23, February 2, 1996, p. 4188–4196.

U.S. Environmental Protection Agency, 2000a, Ambient water quality criteria recommendations—Lakes and reservoirs in nutrient ecoregion IX: Washington, DC, Office of Water, EPA–822–B–00–011, December 2000.

U.S. Environmental Protection Agency, 2000b, Ambient water quality criteria recommendations—Rivers and streams in nutrient ecoregion IX: Washington, DC, Office of Water, EPA–822–B–00–019, December 2000.

U.S. Environmental Protection Agency, 2000c, Nutrient criteria technical guidance manual—Lakes and reservoirs: Washington, DC, Office of Water, EPA–822–B–00–001, April 2000; accessed March 31, 2005, at *http://www.epa.gov/waterscience/standards/nutrients/lakes/index.html*

U.S. Environmental Protection Agency, 2001, Stage 1 Disinfectants and disinfection by-products rule: U.S. Environmental Protection Agency, EPA 816–F–01–010.

U.S. Environmental Protection Agency, 2002a, Drinking water standards and health advisories (2002 ed.): U.S. Environmental Protection Agency, Office of Water, EPA 822–R–02–038, 19 p.

U.S. Environmental Protection Agency, 2002b, Implementation guidance for ambient water quality criteria for bacteria, May 2002 draft: Washington, DC, U.S. Environmental Protection Agency, Office of Water, EPA–823–B–02–003, May 2002, 90 p.; accessed May 7, 2003, at *http://www.epa.gov/ost/standards/bacteria/bacteria.pdf*

U.S. Environmental Protection Agency, 2002c, Methods for evaluating wetland condition—Land-use characterization for nutrient and sediment risk assessment: Washington, DC, Office of Water, EPA–822–R–02–025.

U.S. Environmental Protection Agency, 2003, Stage 2 Disinfectants and disinfection by-products rule: U.S. Environmental Protection Agency, EPA 815–F–03–006.

U.S. Geological Survey, 1982a, Topographic map of Semmes, Alabama: U.S. Geological Survey Quadrangle Map, 7.5-minute series, scale 1:24,000.

U.S. Geological Survey, 1982b, Topographic map of Tanner Williams, Alabama: U.S. Geological Survey Quadrangle Map, 7.5-minute series, scale 1:24,000.

U.S. Geological Survey, 1999, Strategic directions for the Water Resources Division, 1998–2008: U.S. Geological Survey Open-File Report 99-249, 19 p.

U.S. Geological Survey, 2003, Rapi-Note 03–018, Subject: Reporting of hormones in lab schedule 2433 and lab code 8043; accessed May 4, 2004, at *http://wwwnwql.cr.usgs.gov/USGS/rapi-note/03-018.html*

Walker, W.W., Jr., 1983, Significance of eutrophication in water supply reservoirs: Journal of American Water Works Association, v. 75, no. 1, p. 38–42.

Walker, W.W., Jr., 1999 [updated from 1996], Simplified procedures for eutrophication assessment and prediction: U.S. Army Corps of Engineers, Instruction Report W–96–2 [variously paged].

Wehr, J.D., and Sheath, R.G., eds., 2003, Freshwater algae of North America—Ecology and classification: San Diego, CA, Academic Press, 918 p.

Wilde, F.D., Radtke, D.B., Gibs, Jacob, and Iwatsubo, R.T., eds., 1999a, Collection of water samples—National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4 [variously paged]; accessed October 5, 2004, at *http://water.usgs.gov/owq/FieldManual/chapter4/html/Ch4_contents.html*

Wilde, F.D., Radtke, D.B., Gibs, Jacob, and Iwatsubo, R.T., eds., 1999b, Processing of water samples—National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A5 [variously paged]; accessed October 5, 2004, at *http://water.usgs.gov/owq/FieldManual/chapter5/html/Ch5_contents.html*

Zaugg, S.D., Smith, S.G., Shroeder, M.P., Barber, L.B., and Burkhardt, M.R., 2002, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of wastewater compounds by polystyrene-divinylbenzene solid-phase extraction and capillary-column gas chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01–4186, p. 37.

Appendixes

1. Concentrations of nutrients and organic carbon detected in blank samples in the Converse Lake watershed, Mobile County, Alabama, June 1998–September 2003.

2. Concentrations of organic wastewater compounds detected in blank samples in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.

3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.

4. Summary of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.

Appendix 1. Concentrations of nutrients and organic carbon detected in blank samples in the Converse Lake watershed, Mobile County, Alabama, June 1998–September 2003.

[<, less than; MDL, minimum detection limit; TKN, total Kjeldahl nitrogen]

Constituent	Blank type	Number of detections	Sample size	Reporting level	Reporting level type	Detected concentration
Phosphorus, total	Field blank	13	39	< 0.002	MDL	0.002
	Field blank			< 0.002	MDL	0.002
	Field blank			< 0.002	MDL	0.003
	Field blank			< 0.002	MDL	0.002
	Field blank			< 0.002	MDL	0.002
	Field blank			< 0.002	MDL	0.004
	Field blank			< 0.02	MDL	0.02
	Field blank			< 0.002	MDL	0.004
	Field blank			< 0.002	MDL	0.003
	Field blank			< 0.002	MDL	0.009
	Field blank			< 0.002	MDL	0.003
	Field blank			< 0.002	MDL	0.003
	Field blank			< 0.002	MDL	0.003
	Deionized water blank	1	4	< 0.002	MDL	0.014
Nitrite plus nitrate, total	Field blank	1	39	< 0.02	MDL	0.16
Ammonia plus organic nitrogen, total (TKN)	Field blank	2	39	< 0.2	MDL	0.28
	Field blank			< 0.2	MDL	0.21
Phosphorus, ortho, dissolved	Field blank	3	39	< 0.001	MDL	0.001
	Field blank			< 0.001	MDL	0.001
	Field blank			< 0.001	MDL	0.002
Ammonia, total	Field blank	13	39	< 0.01	MDL	0.01
	Field blank			< 0.01	MDL	0.02
	Field blank			< 0.01	MDL	0.03
	Field blank			< 0.01	MDL	0.02
	Field blank			< 0.01	MDL	0.02
	Field blank			< 0.01	MDL	0.03
	Field blank			< 0.01	MDL	0.01
	Field blank			< 0.01	MDL	0.02
	Field blank			< 0.01	MDL	0.07
	Field blank			< 0.01	MDL	0.01
	Field blank			< 0.01	MDL	0.01
	Field blank			< 0.01	MDL	0.01
	Field blank			< 0.01	MDL	0.01

Appendix 1. Concentrations of nutrients and organic carbon detected in blank samples in the Converse Lake watershed, Mobile County, Alabama, June 1998–September 2003.—Continued

[<, less than; MDL, minimum detection limit; TKN, total Kjeldahl nitrogen]

Constituent	Blank type	Number of detections	Sample size	Reporting level	Reporting level type	Detected concentration
Organic carbon, total	Field blank	12	22	< 0.1	MDL	1.8
	Field blank			< 0.1	MDL	0.1
	Field blank			< 0.1	MDL	0.3
	Field blank			< 0.1	MDL	0.2
	Field blank			< 0.1	MDL	0.5
	Field blank			< 0.1	MDL	1.1
	Field blank			< 0.1	MDL	0.4
	Field blank			< 0.1	MDL	2.5
	Field blank			< 0.1	MDL	0.1
	Field blank			< 0.1	MDL	0.1
	Field blank			< 0.1	MDL	0.2
	Field blank			< 0.1	MDL	0.2
Organic carbon, dissolved	Field blank	7	13	< 0.1	MDL	0.1
	Field blank			< 0.1	MDL	0.2
	Field blank			< 0.1	MDL	0.2
	Field blank			< 0.1	MDL	0.3
	Field blank			< 0.1	MDL	0.1
	Field blank			< 0.1	MDL	0.3
	Field blank			< 0.1	MDL	0.3

Appendix 2. Concentrations of organic wastewater compounds detected in blank samples in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.

[µg/L, microgram per liter; E, estimated; <, less than; MRL, minimum reporting level; *, Concentrations of these compounds are always reported as estimated; NP1EO, nonylphenol monoethoxylate; NP2EO, nonylphenol diethoxylate; OP1EO, octylphenol monoethoxylate]

Constituent	Number of blanks with no detection	Number of blanks	Concentration (µg/L)	Minimim reporting level (µg/L)	Type of blank
ß-sitosterol	9	10	E 0.041	< 2.000	Lab
bis(2-ethylhexyl) adipate	8	9	E 0.150	< 0.900	Lab
bis(2-ethylhexyl) phthalate	9	11	E 3.770	< 2.500	Field
bis(2-ethylhexyl) phthalate	9	11	E 3.740	< 2.500	Field
bis(2-ethylhexyl) phthalate	7	9	E 0.400	< 1.500	Lab
bis(2-ethylhexyl) phthalate	7	9	2.13	< 1.800	Lab
2-Butoxyethanol phosphate	15	16	E 0.240	< 0.500	Field
2-Butoxyethanol phosphate	18	19	1.3	< 0.500	Lab
Caffeine	14	16	E 0.053	< 0.060	Field
Caffeine	14	16	E 0.069	< 0.080	Field
2,6-di-*tert*-butyl-1,4-benzoquinone	8	9	E 0.048	< 0.070	Lab
Diethyl phthalate	9	10	0.53	< 0.500	Field
Diethyl phthalate	10	11	E 2.350	< 0.350	Lab
Fluoranthene	15	16	0.036	< 0.030	Field
Fluoranthene	18	19	0.536	< 0.030	Lab
d-Limonene *	9	10	E 0.081	< 0.500	Lab
Naphthalene	18	19	0.039	< 0.030	Lab
N,N-diethyl-*m*-toluamide	13	14	E 0.081	< 0.500	Field
NP1EO	10	12	E 0.412	< 1.000	Field
NP1EO	10	12	E 0.356	< 1.000	Field
NP1EO	11	12	E 0.302	< 1.000	Lab
NP2EO *	18	19	E 0.490	< 5.000	Lab
OP1EO *	14	16	E 0.114	< 0.100	Field
OP1EO *	14	16	E 0.088	< 0.120	Field
OP1EO *	17	19	E 2.720	< 0.120	Lab
OP1EO *	17	19	E 0.250	< 1.000	Lab
para-nonylphenol (total)*	18	19	E 8.000	< 5.000	Lab
Phenanthrene	18	19	1.23	< 0.050	Lab

Appendix 2. Concentrations of organic wastewater compounds detected in blank samples in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[µg/L, microgram per liter; E, estimated; <, less than; MRL, minimum reporting level; *, Concentrations of these compounds are always reported as estimated; NP1EO, nonylphenol monoethoxylate; NP2EO, nonylphenol diethoxylate; OP1EO, octylphenol monoethoxylate]

Constituent	Number of blanks with no detection	Number of blanks	Concentration (µg/L)	Minimim reporting level (µg/L)	Type of blank
Phenol	11	16	1.0	< 0.150	Field
Phenol	11	16	0.26	< 0.150	Field
Phenol	11	16	E 0.205	< 0.450	Field
Phenol	11	16	E 0.250	< 0.500	Field
Phenol	11	16	E 0.320	< 0.500	Field
Phenol	17	19	E 0.020	< 0.150	Lab
Phenol	17	19	E 0.250	< 0.500	Lab
Phthalic anhydride	8	9	0.474	< 0.300	Lab
Pyrene	18	19	0.482	< 0.030	Lab
Tributyl phosphate	6	7	E 0.130	< 0.500	Field
Tri(2-chloroisopropyl)phosphate	15	16	E 0.054	< 0.500	Field
Triphenyl phosphate	15	16	E 0.067	< 0.500	Field

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Atrazine	ß-Sitosterol	bis(2-ethylhexyl) adipate	bis(2-ethylhexyl) phthalate	Bisphenol A	Bromacil	2-Butoxyethanol phosphate
BIG-A	02479940	1/11/2000	900	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
BIG	02479945	4/3/2001	750	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
BIG	02479945	6/4/2001	1340	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JACK	02479944	4/2/2001	1810	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	8/25/1999	945	—	—	< 0.900	6.2	0.12	—	< 0.070
JUN-A	0247994650	1/12/2000	900	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
JUN-A	0247994650	6/7/2000	840	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
JUN-A	0247994650	8/8/2000	850	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
JUN-A	0247994650	10/17/2000	1505	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
JUN-A	0247994650	3/3/2001	1315	—	E 0.700	—	—	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	6/7/2001	810	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	12/12/2001	800	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	2/6/2002	1540	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	3/5/2002	830	< 0.500	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	7/10/2002	830	< 0.500	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-B	02479947	8/25/1999	1015	—	—	< 0.900	< 1.500	< 0.090	-	< 0.070
JUN-B	02479947	1/12/2000	1145	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
JUN-B	02479947	6/7/2000	1140	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
JUN-B	02479947	8/8/2000	1230	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
JUN-B	02479947	10/17/2000	1135	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
JUN-B	02479947	3/3/2001	1625	—	E 0.960	—	—	< 1.000	< 0.500	< 0.500
JUN-B	02479947	6/7/2001	1105	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-B	02479947	12/12/2001	1040	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-B	02479947	2/7/2002	910	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-B	02479947	3/5/2002	1040	< 0.500	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN-B	02479947	7/10/2002	1030	< 0.500	< 2.000	—	—	E 0.100	< 0.500	< 0.500
JUN	02479948	8/25/1999	1530	—	—	< 0.900	< 1.500	< 0.090	—	< 0.070
JUN	02479948	1/12/2000	1545	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
JUN	02479948	6/7/2000	1445	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
JUN	02479948	8/8/2000	1615	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
JUN	02479948	10/17/2000	925	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Atrazine	ß-Sitosterol	bis(2-ethylhexyl) adipate	bis(2-ethylhexyl) phthalate	Bisphenol A	Bromacil	2-Butoxyethanol phosphate
JUN	02479948	3/4/2001	910	—	E 1.100	—	—	< 1.000	< 0.500	< 0.500
JUN	02479948	6/7/2001	1520	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN	02479948	12/12/2001	1445	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN	02479948	2/7/2002	1245	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN	02479948	3/5/2002	1325	< 0.500	< 2.000	—	—	< 1.000	< 0.500	< 0.500
JUN	02479948	7/10/2002	1430	< 0.500	< 2.000	—	—	E 0.110	< 0.500	< 0.500
COL	02479950	8/25/1999	1450	—	—	< 0.900	< 1.500	< 0.090	—	< 0.070
COL	02479950	1/14/2000	850	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
COL	02479950	6/8/2000	1235	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
COL	02479950	8/10/2000	1415	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
COL	02479950	10/19/2000	1210	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
COL	02479950	3/1/2001	925	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
COL	02479950	6/8/2001	920	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
BOG	02479960	2/28/2001	1535	—	< 2.000	-		< 1.000	< 0.500	< 0.500
CRO-A	02479975	9/2/1999	1530	—	—	**	**	< 0.090	—	< 0.070
CRO-A	02479975	1/10/2000	1630	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
CRO-A	02479975	6/5/2000	1630	—	—	< 1.500	< 2.000	< 0.090	—	0.143
CRO-A	02479975	8/7/2000	1730	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
CRO-A	02479975	4/3/2001	1300	—	< 2.000	—	—	< 1.000	E 0.120	< 0.500
CRO-A	02479975	6/5/2001	1125	—	E 0.750	—	—	< 1.000	E 0.340	< 0.500
CRO	02479980	9/1/1999	1300	—	—	< 0.900	< 1.500	< 0.090	—	< 0.070
CRO	02479980	1/10/2000	1300	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
CRO	02479980	6/5/2000	1330	—	—	< 1.500	< 2.000	< 0.090	—	0.094
CRO	02479980	8/7/2000	1313	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
CRO	02479980	10/18/2000	1120	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
CRO	02479980	4/3/2001	1015	—	< 2.000	—	—	< 1.000	E 0.073	< 0.500
CRO	02479980	6/5/2001	850	—	< 2.000	—	—	< 1.000	E 0.210	**
HAM-A	02480001	8/26/1999	1330	—	—	< 0.900	< 1.500	< 0.090	—	< 0.070
HAM-A	02480001	1/13/2000	1325	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
HAM-A	02480001	6/15/2000	1805	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
HAM-A	02480001	8/2/2000	1130	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Atrazine	ß-Sitosterol	bis(2-ethylhexyl) adipate	bis(2-ethylhexyl) phthalate	Bisphenol A	Bromacil	2-Butoxyethanol phosphate
HAM-A	02480001	10/19/2000	815	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
HAM-A	02480001	4/3/2001	1820	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
HAM-A	02480001	6/6/2001	1625	—	< 2.000	—	—	< 1.000	< 0.500	**
HAM	02480002	8/26/1999	1025	—	—	< 0.900	< 1.500	< 0.090	—	< 0.070
HAM	02480002	1/13/2000	1600	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
HAM	02480002	6/15/2000	1330	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
HAM	02480002	8/2/2000	1500	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
HAM	02480002	10/19/2000	825	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
HAM	02480002	4/3/2001	1545	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
HAM	02480002	6/6/2001	1345	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
HAM	02480002	12/11/2001	1400	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
HAM	02480002	2/6/2002	1200	—	< 2.000	—	—	< 1.000	< 0.500	< 0.500
HAM	02480002	3/4/2002	1430	E 0.019	< 2.000	—	—	< 1.000	< 0.500	< 0.500
HAM	02480002	8/19/2002	1200	< 0.500	< 2.000	—	—	< 1.000	< 0.500	< 0.500
LHWY98	02479957	6/13/2000	1500	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
LPOW	02480003	8/20/2002	1515	E 0.006	< 2.000	-	—	< 1.000	< 0.500	< 0.500
LHAM	02480004	1/18/2000	1645	—	—	< 0.900	< 1.800	< 0.090	—	< 0.070
LHAM	02480004	6/14/2000	1115	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
LHAM	02480004	8/30/2000	950	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
LHAM	02480004	12/12/2000	1015	—	—	< 2.000	< 2.500	< 0.090	—	< 0.200
LHAM	02480004	8/20/2002	1615	E 0.008	< 2.000	—	—	< 1.000	< 0.500	< 0.500
TRIB	0248000050	8/26/1999	900	—	—	1.4	< 1.500	< 0.090	—	< 0.070
TRIB	0248000050	6/15/2000	1630	—	—	< 1.500	< 2.000	< 0.090	—	< 0.070
TRIB	0248000050	8/2/2000	830	—	—	< 2.000	E 3.180	< 0.090	—	< 0.200

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Caffeine	Cholesterol	3ß-Coprostanol	Cotinine	Diazinon	*N,N*-diethyl-*m*-toluamide	Diethylphthalate
BIG-A	02479940	1/11/2000	900	< 0.060	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
BIG	02479945	4/3/2001	750	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
BIG	02479945	6/4/2001	1340	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JACK	02479944	4/2/2001	1810	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN-A	0247994650	8/25/1999	945	< 0.060	< 1.000	< 0.600	—	< 0.030	—	—
JUN-A	0247994650	1/12/2000	900	< 0.060	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
JUN-A	0247994650	6/7/2000	840	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	< 0.040	< 0.250
JUN-A	0247994650	8/8/2000	850	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
JUN-A	0247994650	10/17/2000	1505	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
JUN-A	0247994650	3/3/2001	1315	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN-A	0247994650	6/7/2001	810	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN-A	0247994650	12/12/2001	800	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN-A	0247994650	2/6/2002	1540	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN-A	0247994650	3/5/2002	830	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
JUN-A	0247994650	7/10/2002	830	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
JUN-B	02479947	8/25/1999	1015	< 0.060	< 1.000	< 0.600	—	< 0.030	—	—
JUN-B	02479947	1/12/2000	1145	E 0.059	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
JUN-B	02479947	6/7/2000	1140	< 0.080	< 1.500	< 0.600	E 0.015	< 0.030	< 0.040	< 0.250
JUN-B	02479947	8/8/2000	1230	< 0.080	< 1.500	E 0.941	< 0.080	< 0.030	< 0.080	< 0.350
JUN-B	02479947	10/17/2000	1135	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
JUN-B	02479947	3/3/2001	1625	< 0.500	E 0.760	E 0.270	< 1.000	< 0.500	< 0.500	—
JUN-B	02479947	6/7/2001	1105	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN-B	02479947	12/12/2001	1040	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN-B	02479947	2/7/2002	910	< 0.500	E 0.580	E 0.340	< 1.000	< 0.500	< 0.500	—
JUN-B	02479947	3/5/2002	1040	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
JUN-B	02479947	7/10/2002	1030	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
JUN	02479948	8/25/1999	1530	< 0.060	< 1.000	< 0.600	—	< 0.030	—	—
JUN	02479948	1/12/2000	1545	**	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
JUN	02479948	6/7/2000	1445	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	< 0.040	< 0.250
JUN	02479948	8/8/2000	1615	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
JUN	02479948	10/17/2000	925	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Caffeine	Cholesterol	3ß-Coprostanol	Cotinine	Diazinon	*N,N*-diethyl-*m*-toluamide	Diethylphthalate
JUN	02479948	3/4/2001	910	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN	02479948	6/7/2001	1520	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN	02479948	12/12/2001	1445	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN	02479948	2/7/2002	1245	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
JUN	02479948	3/5/2002	1325	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
JUN	02479948	7/10/2002	1430	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
COL	02479950	8/25/1999	1450	0.087	E 0.530	E 0.230	—	< 0.030	—	—
COL	02479950	1/14/2000	850	0.246	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
COL	02479950	6/8/2000	1235	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	< 0.040	< 0.250
COL	02479950	8/10/2000	1415	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
COL	02479950	10/19/2000	1210	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
COL	02479950	3/1/2001	925	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
COL	02479950	6/8/2001	920	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
BOG	02479960	2/28/2001	1535	< 0.500	E 0.520	< 2.000	< 1.000	< 0.500	< 0.500	—
CRO-A	02479975	9/2/1999	1530	< 0.060	< 1.000	< 0.600	—	< 0.030	—	—
CRO-A	02479975	1/10/2000	1630	0.072	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
CRO-A	02479975	6/5/2000	1630	E 0.033	< 1.500	< 0.600	< 0.040	< 0.030	< 0.040	< 0.250
CRO-A	02479975	8/7/2000	1730	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
CRO-A	02479975	4/3/2001	1300	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
CRO-A	02479975	6/5/2001	1125	< 0.500	E 0.650	< 2.000	< 1.000	< 0.500	< 0.500	—
CRO	02479980	9/1/1999	1300	< 0.060	< 1.000	< 0.600	—	< 0.030	—	—
CRO	02479980	1/10/2000	1300	0.067	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
CRO	02479980	6/5/2000	1330	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	< 0.040	< 0.250
CRO	02479980	8/7/2000	1313	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
CRO	02479980	10/18/2000	1120	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
CRO	02479980	4/3/2001	1015	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
CRO	02479980	6/5/2001	850	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
HAM-A	02480001	8/26/1999	1330	< 0.060	< 1.000	< 0.600	—	< 0.030	—	—
HAM-A	02480001	1/13/2000	1325	0.199	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
HAM-A	02480001	6/15/2000	1805	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	< 0.040	< 0.250
HAM-A	02480001	8/2/2000	1130	< 0.080	< 1.500	< 0.600	< 0.040	0.038	< 0.040	< 0.250

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Caffeine	Cholesterol	3ß-Coprostanol	Cotinine	Diazinon	*N,N*-diethyl-*m*-toluamide	Diethylphthalate
HAM-A	02480001	10/19/2000	815	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
HAM-A	02480001	4/3/2001	1820	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
HAM-A	02480001	6/6/2001	1625	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
HAM	02480002	8/26/1999	1025	0.72	E 2.000	E 1.600	—	< 0.030	—	—
HAM	02480002	1/13/2000	1600	0.062	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
HAM	02480002	6/15/2000	1330	E 0.034	< 1.500	< 0.600	< 0.040	0.04	< 0.040	< 0.250
HAM	02480002	8/2/2000	1500	< 0.080	< 1.500	< 0.600	< 0.040	0.031	< 0.040	E 0.290
HAM	02480002	10/19/2000	825	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
HAM	02480002	4/3/2001	1545	E 0.120	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
HAM	02480002	6/6/2001	1345	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
HAM	02480002	12/11/2001	1400	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
HAM	02480002	2/6/2002	1200	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	—
HAM	02480002	3/4/2002	1430	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
HAM	02480002	8/19/2002	1200	< 0.500	< 2.000	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
LHWY98	02479957	6/13/2000	1500	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	E 0.021	< 0.250
LPOW	02480003	8/20/2002	1515	< 0.500	E 0.580	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
LHAM	02480004	1/18/2000	1645	0.088	< 2.000	< 0.600	< 0.030	< 0.030	< 0.040	< 0.300
LHAM	02480004	6/14/2000	1115	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	E 0.016	< 0.250
LHAM	02480004	8/30/2000	950	**	< 1.500	< 0.600	< 0.080	< 0.030	E 0.062	< 0.350
LHAM	02480004	12/12/2000	1015	< 0.080	< 1.500	< 0.600	< 0.080	< 0.030	< 0.080	< 0.350
LHAM	02480004	8/20/2002	1615	< 0.500	E 0.680	< 2.000	< 1.000	< 0.500	< 0.500	< 0.500
TRIB	0248000050	8/26/1999	900	E 0.055	< 1.000	< 0.600	—	< 0.030	—	—
TRIB	0248000050	6/15/2000	1630	< 0.080	< 1.500	< 0.600	< 0.040	< 0.030	< 0.040	< 0.250
TRIB	0248000050	8/2/2000	830	E 0.047	< 1.500	< 0.600	< 0.040	0.047	< 0.040	< 0.250

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Lindane	Metalaxyl	Metolachlor	Naphthalene	*para*-Nonylphenol-total	NP1EO	OP1EO
BIG-A	02479940	1/11/2000	900	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
BIG	02479945	4/3/2001	750	-	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
BIG	02479945	6/4/2001	1340	-	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JACK	02479944	4/2/2001	1810	-	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-A	0247994650	8/25/1999	945	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
JUN-A	0247994650	1/12/2000	900	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
JUN-A	0247994650	6/7/2000	840	< 0.050	—	—	< 0.030	< 0.500	< 1.000	< 0.100
JUN-A	0247994650	8/8/2000	850	< 0.050	—	—	< 0.025	< 0.700	< 1.000	< 0.120
JUN-A	0247994650	10/17/2000	1505	< 0.050	—	—	< 0.025	< 0.700	< 1.000	< 0.120
JUN-A	0247994650	3/3/2001	1315	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-A	0247994650	6/7/2001	810	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-A	0247994650	12/12/2001	800	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-A	0247994650	2/6/2002	1540	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-A	0247994650	3/5/2002	830	—	< 0.500	< 0.500	< 0.500	**	< 5.000	< 1.000
JUN-A	0247994650	7/10/2002	830	-	< 0.500	< 0.500	< 0.500	< 5.000	< 5.000	< 1.000
JUN-B	02479947	8/25/1999	1015	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
JUN-B	02479947	1/12/2000	1145	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
JUN-B	02479947	6/7/2000	1140	< 0.050	—	—	< 0.030	< 0.500	< 1.000	E 0.018
JUN-B	02479947	8/8/2000	1230	< 0.050	—	—	< 0.025	E 0.233	E 0.592	**
JUN-B	02479947	10/17/2000	1135	< 0.050	—	—	< 0.025	< 0.700	< 1.000	< 0.120
JUN-B	02479947	3/3/2001	1625	—	< 0.500	E 0.011	< 0.500	< 5.000	—	< 1.000
JUN-B	02479947	6/7/2001	1105	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-B	02479947	12/12/2001	1040	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-B	02479947	2/7/2002	910	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN-B	02479947	3/5/2002	1040	—	< 0.500	< 0.500	< 0.500	< 5.000	< 5.000	< 1.000
JUN-B	02479947	7/10/2002	1030	—	< 0.500	< 0.500	< 0.500	< 5.000	< 5.000	< 1.000
JUN	02479948	8/25/1999	1530	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
JUN	02479948	1/12/2000	1545	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
JUN	02479948	6/7/2000	1445	< 0.050	—	—	< 0.030	< 0.500	< 1.000	< 0.100
JUN	02479948	8/8/2000	1615	< 0.050	—	—	< 0.025	E 0.226	E 0.402	**
JUN	02479948	10/17/2000	925	< 0.050	—	—	< 0.025	< 0.700	E 0.269	E 0.086

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Lindane	Metalaxyl	Metolachlor	Naphthalene	*para*-Nonylphenol-total	NP1EO	OP1EO
JUN	02479948	3/4/2001	910	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN	02479948	6/7/2001	1520	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN	02479948	12/12/2001	1445	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN	02479948	2/7/2002	1245	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
JUN	02479948	3/5/2002	1325	—	< 0.500	< 0.500	< 0.500	< 9.800	< 5.000	< 1.000
JUN	02479948	7/10/2002	1430	—	< 0.500	< 0.500	< 0.500	< 5.000	< 5.000	< 1.000
COL	02479950	8/25/1999	1450	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
COL	02479950	1/14/2000	850	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
COL	02479950	6/8/2000	1235	< 0.050	—	—	< 0.030	< 0.500	< 1.000	< 0.100
COL	02479950	8/10/2000	1415	< 0.050	—	—	< 0.025	< 0.700	< 1.000	< 0.120
COL	02479950	10/19/2000	1210	< 0.050	—	—	< 0.025	< 0.700	< 1.000	E 0.081
COL	02479950	3/1/2001	925	-	< 0.500	< 0.500	< 0.500	< 5.000	-	< 1.000
COL	02479950	6/8/2001	920	-	< 0.500	< 0.500	< 0.500	< 5.000	-	< 1.000
BOG	02479960	2/28/2001	1535	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
CRO-A	02479975	9/2/1999	1530	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
CRO-A	02479975	1/10/2000	1630	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
CRO-A	02479975	6/5/2000	1630	< 0.050	—	—	< 0.030	< 0.500	< 1.000	E 0.039
CRO-A	02479975	8/7/2000	1730	< 0.050	—	—	< 0.025	< 0.700	**	< 0.120
CRO-A	02479975	4/3/2001	1300	—	E 0.022	E 0.013	< 0.500	< 5.000	—	< 1.000
CRO-A	02479975	6/5/2001	1125	—	E 0.037	E 0.058	< 0.500	< 5.000	—	< 1.000
CRO	02479980	9/1/1999	1300	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
CRO	02479980	1/10/2000	1300	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
CRO	02479980	6/5/2000	1330	< 0.050	—	—	< 0.030	< 0.500	< 1.000	< 0.100
CRO	02479980	8/7/2000	1313	E 0.030	—	—	< 0.025	< 0.700	E 0.440	**
CRO	02479980	10/18/2000	1120	< 0.050	—	—	< 0.025	< 0.700	< 1.000	< 0.120
CRO	02479980	4/3/2001	1015	—	E 0.032	E 0.007	< 0.500	< 5.000	—	< 1.000
CRO	02479980	6/5/2001	850	—	E 0.025	E 0.038	< 0.500	< 5.000	—	< 1.000
HAM-A	02480001	8/26/1999	1330	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
HAM-A	02480001	1/13/2000	1325	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
HAM-A	02480001	6/15/2000	1805	< 0.050	—	—	< 0.030	< 0.500	< 1.000	< 0.100
HAM-A	02480001	8/2/2000	1130	< 0.050	—	—	< 0.020	< 0.500	< 1.000	**

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	Lindane	Metalaxyl	Metolachlor	Naphthalene	*para*-Nonylphenol-total	NP1EO	OP1EO
HAM-A	02480001	10/19/2000	815	< 0.050	—	—	< 0.025	< 0.700	< 1.000	< 0.120
HAM-A	02480001	4/3/2001	1820	—	< 0.500	E 0.018	< 0.500	< 5.000	—	< 1.000
HAM-A	02480001	6/6/2001	1625	—	< 0.500	E 0.021	< 0.500	< 5.000	—	< 1.000
HAM	02480002	8/26/1999	1025	< 0.050	-	—	< 0.030	E 0.670	E 0.670	< 0.100
HAM	02480002	1/13/2000	1600	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
HAM	02480002	6/15/2000	1330	< 0.050	—	—	< 0.030	< 0.500	< 1.000	E 0.055
HAM	02480002	8/2/2000	1500	< 0.050	—	—	< 0.020	< 0.500	< 1.000	**
HAM	02480002	10/19/2000	825	< 0.050	—	—	< 0.025	< 0.700	< 1.000	< 0.120
HAM	02480002	4/3/2001	1545	—	< 0.500	E 0.007	< 0.500	< 5.000	—	< 1.000
HAM	02480002	6/6/2001	1345	—	< 0.500	E 0.009	< 0.500	< 5.000	—	< 1.000
HAM	02480002	12/11/2001	1400	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
HAM	02480002	2/6/2002	1200	—	< 0.500	< 0.500	< 0.500	< 5.000	—	< 1.000
HAM	02480002	3/4/2002	1430	—	< 0.500	E 0.007	< 0.500	< 5.000	< 5.000	< 1.000
HAM	02480002	8/19/2002	1200	—	< 0.500	E 0.067	< 0.500	< 5.000	< 5.000	< 1.000
LHWY98	02479957	6/13/2000	1500	< 0.050	—	—	< 0.030	< 0.500	< 1.000	< 0.100
LPOW	02480003	8/20/2002	1515	—	< 0.500	E 0.018	< 0.500	< 5.000	< 5.000	< 1.000
LHAM	02480004	1/18/2000	1645	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
LHAM	02480004	6/14/2000	1115	< 0.050	—	—	0.052	< 0.500	< 1.000	< 0.100
LHAM	02480004	8/30/2000	950	< 0.050	—	—	< 0.025	< 0.700	< 1.000	E 0.095
LHAM	02480004	12/12/2000	1015	< 0.050	—	—	< 0.025	< 0.700	E 0.474	E 0.103
LHAM	02480004	8/20/2002	1615	—	< 0.500	E 0.006	< 0.500	< 5.000	< 5.000	< 1.000
TRIB	0248000050	8/26/1999	900	< 0.050	—	—	< 0.030	< 0.500	< 0.800	< 0.100
TRIB	0248000050	6/15/2000	1630	< 0.050	—	—	< 0.030	< 0.500	< 1.000	E 0.036
TRIB	0248000050	8/2/2000	830	< 0.050	—	—	< 0.030	< 0.500	< 1.000	< 0.100

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	*para*-Cresol	Phenol	Phthalic anhydride	Prometon	Skatol	Triclosan	Tri(2-chloro-ethyl) phosphate	Triphenyl phosphate
BIG-A	02479940	1/11/2000	900	< 0.030	< 0.200	< 0.300	—	—	< 0.080	< 0.040	< 0.100
BIG	02479945	4/3/2001	750	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
BIG	02479945	6/4/2001	1340	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JACK	02479944	4/2/2001	1810	< 1.000	E 1.400	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	8/25/1999	945	< 0.030	**	< 0.200	—	—	< 0.040	< 0.040	< 0.100
JUN-A	0247994650	1/12/2000	900	< 0.030	**	< 0.300	—	—	< 0.080	< 0.040	< 0.100
JUN-A	0247994650	6/7/2000	840	< 0.030	< 0.080	< 0.150	—	—	< 0.040	< 0.040	< 0.100
JUN-A	0247994650	8/8/2000	850	E 0.039	E 1.450	< 0.350	—	—	< 0.050	< 0.040	< 0.100
JUN-A	0247994650	10/17/2000	1505	< 0.060	< 0.450	< 0.350	—	—	< 0.050	< 0.040	< 0.100
JUN-A	0247994650	3/3/2001	1315	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	6/7/2001	810	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	12/12/2001	800	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	2/6/2002	1540	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	3/5/2002	830	< 1.000	E 1.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-A	0247994650	7/10/2002	830	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-B	02479947	8/25/1999	1015	< 0.030	< 0.150	< 0.200	—	—	< 0.040	< 0.040	< 0.100
JUN-B	02479947	1/12/2000	1145	< 0.030	< 0.200	< 0.300	—	—	< 0.080	< 0.040	< 0.100
JUN-B	02479947	6/7/2000	1140	< 0.030	< 0.080	< 0.150	—	—	< 0.040	< 0.040	< 0.100
JUN-B	02479947	8/8/2000	1230	< 0.060	**	< 0.350	—	—	< 0.050	< 0.040	< 0.100
JUN-B	02479947	10/17/2000	1135	< 0.060	< 0.450	< 0.350	—	—	< 0.050	< 0.040	< 0.100
JUN-B	02479947	3/3/2001	1625	< 1.000	< 0.500	—	< 0.500	E 0.120	< 1.000	< 0.500	< 0.500
JUN-B	02479947	6/7/2001	1105	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-B	02479947	12/12/2001	1040	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-B	02479947	2/7/2002	910	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-B	02479947	3/5/2002	1040	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN-B	02479947	7/10/2002	1030	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN	02479948	8/25/1999	1530	< 0.030	< 0.150	< 0.200	—	—	< 0.040	< 0.040	< 0.100
JUN	02479948	1/12/2000	1545	< 0.030	< 0.200	0.582	—	—	< 0.080	< 0.040	< 0.100
JUN	02479948	6/7/2000	1445	< 0.030	< 0.080	< 0.150	—	—	< 0.040	< 0.040	< 0.100
JUN	02479948	8/8/2000	1615	< 0.060	E 1.000	< 0.350	—	—	< 0.050	< 0.040	< 0.100
JUN	02479948	10/17/2000	925	< 0.060	< 0.450	< 0.350	—	—	< 0.050	< 0.040	< 0.100

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	*para*-Cresol	Phenol	Phthalic anhydride	Prometon	Skatol	Triclosan	Tri(2-chloro-ethyl) phosphate	Triphenyl phosphate
JUN	02479948	3/4/2001	910	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN	02479948	6/7/2001	1520	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN	02479948	12/12/2001	1445	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN	02479948	2/7/2002	1245	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN	02479948	3/5/2002	1325	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
JUN	02479948	7/10/2002	1430	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
COL	02479950	8/25/1999	1450	< 0.030	< 0.150	< 0.200	—	—	0.37	< 0.040	< 0.100
COL	02479950	1/14/2000	850	< 0.030	< 0.200	< 0.300	—	—	< 0.080	< 0.040	< 0.100
COL	02479950	6/8/2000	1235	< 0.030	< 0.080	< 0.150	—	—	0.064	< 0.040	< 0.100
COL	02479950	8/10/2000	1415	< 0.060	**	< 0.350	—	—	< 0.050	< 0.040	< 0.100
COL	02479950	10/19/2000	1210	< 0.060	< 0.450	< 0.350	—	—	< 0.050	< 0.040	< 0.100
COL	02479950	3/1/2001	925	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
COL	02479950	6/8/2001	920	< 1.000	< 0.500	-	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
BOG	02479960	2/28/2001	1535	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
CRO-A	02479975	9/2/1999	1530	< 0.030	< 0.150	0.23	—	—	< 0.040	< 0.040	< 0.100
CRO-A	02479975	1/10/2000	1630	< 0.030	< 0.200	< 0.300	—	—	< 0.080	< 0.040	< 0.100
CRO-A	02479975	6/5/2000	1630	E 0.012	< 0.080	< 0.150	—	—	< 0.040	< 0.040	< 0.100
CRO-A	02479975	8/7/2000	1730	< 0.060	< 0.450	< 0.350	—	—	< 0.050	< 0.040	< 0.100
CRO-A	02479975	4/3/2001	1300	< 1.000	E 1.100	—	E 0.025	< 1.000	< 1.000	< 0.500	< 0.500
CRO-A	02479975	6/5/2001	1125	< 1.000	< 0.500	—	E 0.035	< 1.000	< 1.000	< 0.500	< 0.500
CRO	02479980	9/1/1999	1300	< 0.030	**	0.22	—	—	< 0.040	< 0.040	< 0.100
CRO	02479980	1/10/2000	1300	< 0.030	< 0.200	< 0.300	—	—	< 0.080	< 0.040	< 0.100
CRO	02479980	6/5/2000	1330	< 0.030	< 0.080	< 0.150	—	—	< 0.040	< 0.040	E 0.007
CRO	02479980	8/7/2000	1313	< 0.060	**	< 0.350	—	—	< 0.050	< 0.040	< 0.100
CRO	02479980	10/18/2000	1120	< 0.060	**	< 0.350	—	—	< 0.050	< 0.040	< 0.100
CRO	02479980	4/3/2001	1015	< 1.000	**	—	E 0.019	< 1.000	< 1.000	< 0.500	< 0.500
CRO	02479980	6/5/2001	850	< 1.000	< 0.500	—	E 0.034	< 1.000	< 1.000	< 0.500	< 0.500
HAM-A	02480001	8/26/1999	1330	< 0.030	< 0.150	< 0.200	—	—	< 0.040	< 0.040	< 0.100
HAM-A	02480001	1/13/2000	1325	< 0.030	< 0.200	< 0.300	—	—	< 0.080	< 0.040	< 0.100
HAM-A	02480001	6/15/2000	1805	< 0.030	< 0.080	< 0.150	—	—	0.051	< 0.040	< 0.100
HAM-A	02480001	8/2/2000	1130	< 0.060	**	< 0.290	—	—	E 0.022	< 0.040	< 0.100

Appendix 3. Concentrations of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; —, no data; <, less than; E, estimated; **, censored; NP1EO, nonylphenol monoethoxylate; OP1EO, octylphenol monoethoxylate. Concentrations are in micrograms per liter. Shaded values indicate detected values]

Site label (fig. 1)	USGS station number	Date	Time	*para*-Cresol	Phenol	Phthalic anhydride	Prometon	Skatol	Triclosan	Tri(2-chloro-ethyl) phosphate	Triphenyl phosphate
HAM-A	02480001	10/19/2000	815	< 0.060	**	< 0.350	—	—	< 0.050	< 0.040	< 0.100
HAM-A	02480001	4/3/2001	1820	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
HAM-A	02480001	6/6/2001	1625	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
HAM	02480002	8/26/1999	1025	0.053	**	< 0.200	—	—	0.077	< 0.040	< 0.100
HAM	02480002	1/13/2000	1600	< 0.030	0.391	< 0.300	—	—	< 0.080	< 0.040	< 0.100
HAM	02480002	6/15/2000	1330	< 0.030	< 0.080	< 0.150	—	—	0.106	0.043	< 0.100
HAM	02480002	8/2/2000	1500	< 0.060	**	< 0.290	—	—	0.111	< 0.040	< 0.100
HAM	02480002	10/19/2000	825	< 0.060	**	< 0.350	—	—	< 0.050	< 0.040	< 0.100
HAM	02480002	4/3/2001	1545	< 1.000	**	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
HAM	02480002	6/6/2001	1345	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
HAM	02480002	12/11/2001	1400	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
HAM	02480002	2/6/2002	1200	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
HAM	02480002	3/4/2002	1430	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
HAM	02480002	8/19/2002	1200	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
LHWY98	02479957	6/13/2000	1500	< 0.030	2.42	< 0.150	—	—	0.107	< 0.040	< 0.100
LPOW	02480003	8/20/2002	1515	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
LHAM	02480004	1/18/2000	1645	< 0.030	**	< 0.300	—	—	< 0.080	< 0.040	< 0.100
LHAM	02480004	6/14/2000	1115	< 0.030	< 0.080	< 0.150	—	—	< 0.040	< 0.040	< 0.100
LHAM	02480004	8/30/2000	950	< 0.060	**	< 0.350	—	—	< 0.050	< 0.040	< 0.100
LHAM	02480004	12/12/2000	1015	< 0.060	< 0.450	< 0.350	—	—	< 0.050	< 0.040	< 0.100
LHAM	02480004	8/20/2002	1615	< 1.000	< 0.500	—	< 0.500	< 1.000	< 1.000	< 0.500	< 0.500
TRIB	0248000050	8/26/1999	900	< 0.030	< 0.150	< 0.200	—	—	< 0.040	< 0.040	< 0.100
TRIB	0248000050	6/15/2000	1630	< 0.030	< 0.080	< 0.150	—	—	< 0.040	< 0.040	< 0.100
TRIB	0248000050	8/2/2000	830	< 0.060	< 0.250	< 0.290	—	—	< 0.050	< 0.040	< 0.100

Appendix 4. Summary of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.

[USGS, U.S. Geological Survey; OWCs, organic wastewater compounds; µg/L, micrograms per liter]

Site label (fig. 1)	USGS station number	Date	Time	Total concentration of OWCs (µg/L)	Total number of OWCs detected	Total concentration of endocrine disruptors (µg/L)	Total number of endocrine disruptors detected
BIG-A	02479940	1/11/2000	900	0	0	0	0
BIG	02479945	4/3/2001	750	0	0	0	0
BIG	02479945	6/4/2001	1340	0	0	0	0
JACK	02479944	4/2/2001	1810	1.4	1	0	0
JUN-A	0247994650	8/25/1999	945	6.32	2	6.32	2
JUN-A	0247994650	1/12/2000	900	0	0	0	0
JUN-A	0247994650	6/7/2000	840	0	0	0	0
JUN-A	0247994650	8/8/2000	850	1.489	2	0	0
JUN-A	0247994650	10/17/2000	1505	0	0	0	0
JUN-A	0247994650	3/3/2001	1315	0.7	1	0	0
JUN-A	0247994650	6/7/2001	810	0	0	0	0
JUN-A	0247994650	12/12/2001	800	0	0	0	0
JUN-A	0247994650	2/6/2002	1540	0	0	0	0
JUN-A	0247994650	3/5/2002	830	1.5	1	0	0
JUN-A	0247994650	7/10/2002	830	0	0	0	0
JUN-B	02479947	8/25/1999	1015	0	0	0	0
JUN-B	02479947	1/12/2000	1145	0.059	1	0	0
JUN-B	02479947	6/7/2000	1140	0.033	2	0.018	1
JUN-B	02479947	8/8/2000	1230	1.766	3	0.825	2
JUN-B	02479947	10/17/2000	1135	0	0	0	0
JUN-B	02479947	3/3/2001	1625	2.121	5	0	0
JUN-B	02479947	6/7/2001	1105	0	0	0	0
JUN-B	02479947	12/12/2001	1040	0	0	0	0
JUN-B	02479947	2/7/2002	910	0.92	2	0	0
JUN-B	02479947	3/5/2002	1040	0	0	0	0
JUN-B	02479947	7/10/2002	1030	0.1	1	0.1	1
JUN	02479948	8/25/1999	1530	0	0	0	0
JUN	02479948	1/12/2000	1545	0.582	1	0	0
JUN	02479948	6/7/2000	1445	0	0	0	0
JUN	02479948	8/8/2000	1615	1.628	3	0.628	2
JUN	02479948	10/17/2000	925	0.355	2	0.355	2
JUN	02479948	3/4/2001	910	1.1	1	0	0
JUN	02479948	6/7/2001	1520	0	0	0	0
JUN	02479948	12/12/2001	1445	0	0	0	0
JUN	02479948	2/7/2002	1245	0	0	0	0
JUN	02479948	3/5/2002	1325	0	0	0	0
JUN	02479948	7/10/2002	1430	0.11	1	0.11	1
COL	02479950	8/25/1999	1450	1.217	4	0.37	1
COL	02479950	1/14/2000	850	0.246	1	0	0
COL	02479950	6/8/2000	1235	0.064	1	0.064	1
COL	02479950	8/10/2000	1415	0	0	0	0
COL	02479950	10/19/2000	1210	0.081	1	0.081	1
COL	02479950	3/1/2001	925	0	0	0	0
COL	02479950	6/8/2001	920	0	0	0	0
BOG	02479960	2/28/2001	1535	0.52	1	0	0

Appendix 4. Summary of organic wastewater compounds detected at sites in the Converse Lake watershed, Mobile County, Alabama, 1999–2002.—Continued

[USGS, U.S. Geological Survey; OWCs, organic wastewater compounds; µg/L, micrograms per liter]

Site label (fig. 1)	USGS station number	Date	Time	Total concentration of OWCs (µg/L)	Total number of OWCs detected	Total concentration of endocrine disruptors (µg/L)	Total number of endocrine disruptors detected
CRO-A	02479975	9/2/1999	1530	0.23	1	0	0
CRO-A	02479975	1/10/2000	1630	0.072	1	0	0
CRO-A	02479975	6/5/2000	1630	0.227	4	0.039	1
CRO-A	02479975	8/7/2000	1730	0	0	0	0
CRO-A	02479975	4/3/2001	1300	1.28	5	0	0
CRO-A	02479975	6/5/2001	1125	1.87	6	0	0
CRO	02479980	9/1/1999	1300	0.22	1	0	0
CRO	02479980	1/10/2000	1300	0.067	1	0	0
CRO	02479980	6/5/2000	1330	0.101	2	0	0
CRO	02479980	8/7/2000	1313	0.47	2	0.47	2
CRO	02479980	10/18/2000	1120	0	0	0	0
CRO	02479980	4/3/2001	1015	0.131	4	0	0
CRO	02479980	6/5/2001	850	0.307	4	0	0
HAM-A	02480001	8/26/1999	1330	0	0	0	0
HAM-A	02480001	1/13/2000	1325	0.199	1	0	0
HAM-A	02480001	6/15/2000	1805	0.051	1	0.051	1
HAM-A	02480001	8/2/2000	1130	0.06	2	0.06	2
HAM-A	02480001	10/19/2000	815	0	0	0	0
HAM-A	02480001	4/3/2001	1820	0.018	1	0	0
HAM-A	02480001	6/6/2001	1625	0.021	1	0	0
HAM	02480002	8/26/1999	1025	5.79	7	1.417	3
HAM	02480002	1/13/2000	1600	0.062	1	0	0
HAM	02480002	6/15/2000	1330	0.278	5	0.201	3
HAM	02480002	8/2/2000	1500	0.432	3	0.432	3
HAM	02480002	10/19/2000	825	0	0	0	0
HAM	02480002	4/3/2001	1545	0.127	2	0	0
HAM	02480002	6/6/2001	1345	0.009	1	0	0
HAM	02480002	12/11/2001	1400	0	0	0	0
HAM	02480002	2/6/2002	1200	0	0	0	0
HAM	02480002	3/4/2002	1430	0.026	2	0.019	1
HAM	02480002	8/19/2002	1200	0.067	1	0	0
LHWY98	02479957	6/13/2000	1500	2.548	3	0.107	1
LPOW	02480003	8/20/2002	1515	0.604	3	0.006	1
LHAM	02480004	1/18/2000	1645	0.088	1	0	0
LHAM	02480004	6/14/2000	1115	0.068	2	0	0
LHAM	02480004	8/30/2000	950	0.157	2	0.095	1
LHAM	02480004	12/12/2000	1015	0.577	2	0.577	2
LHAM	02480004	8/20/2002	1615	0.694	3	0.008	1
TRIB	0248000050	8/26/1999	900	1.455	2	0	0
TRIB	0248000050	6/15/2000	1630	0.036	1	0.036	1
TRIB	0248000050	8/2/2000	830	3.274	3	3.227	2

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