Nutrient Loading and Algal Response in West Thompson Lake, Thompson, Connecticut, 2003–2005

By Jonathan Morrison and Michael J. Colombo

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Conversion Factors and Abbreviations

[In this report, most values are in Inch/Pound units, with the exception of the discussion of the sediments in West Thompson Lake, which are in SI units.]

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
centimeter (cm)	0.3937	inch (in.)
foot (ft)	0.3048	meter (m)
meter (m)	3.281	foot (ft)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound per year, avoirdupois (lb)	0.4536	kilogram (kg)
	Yield	
pound per square mile per year ($lb/mi^2/yr$)	0.175	kilogram per square kilometer per year ($kg/km^2/yr$)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

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

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

WATER-QUALITY ABBREVIATIONS

mL	milliliters

OTHER ABBREVIATIONS USED IN REPORT

USEPA	U.S. Environmental Protection Agency
WWTP	wastewater-treatment plant
USACE	U.S. Army Corps of Engineers
CTDEP	Connecticut Department of Environmental Protection
EDTA	ethylenediaminetetraacetic acid
NWQL	National Water Quality Laboratory

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Abstract

Water quality and nutrient loads were characterized for parts of the Quinebaug River and West Thompson Lake in northeastern Connecticut during 2003 to 2005. The West Thompson Lake watershed is a mainly forested watershed that receives treated municipal wastewater from several point sources in Massachusetts. The lake is a flood-control reservoir formed in 1966 by impoundment of the Quinebaug River. Median concentrations of total phosphorus in two inflow (upstream) and one outflow (downstream) sampling stations on the Quinebaug River were higher than the nutrient criteria recommended by the U.S. Environmental Protection Agency (USEPA) for rivers and streams in aggregate Ecoregion XIV. In general, concentrations of total phosphorus in West Thompson Lake also were above the nutrient criteria recommended by USEPA for lakes and impoundments in aggregate Ecoregion XIV.

The trophic status of West Thompson Lake has changed since 1995 from a hypereutrophic lake to a eutrophic lake; however, the lake still has large algal blooms. These blooms are predominated by blue-green algae, with chlorophyll-*a* concentrations of more than 30 micrograms per liter and algal cell counts as high as 73,000 cells/mL. Water samples collected during the summer of 2005 identified phosphorus as the primary limiting nutrient early in the season, but algal growth is probably co-limited by phosphorus and nitrogen later in the season.

Lake-bottom sediments were collected from several areas throughout the lake and ranged in thickness from less than 1 foot (ft) to more than 3 ft. Concentrations of phosphorus in sediments differed throughout the lake; the highest values were found in the middle of the lake. Concentrations of total phosphorus also increased from an average 1,800 milligrams per kilogram (mg/kg) in the upper layers of sediment to more than 6,000 mg/kg at depth in the sediment.

Annual, seasonal, and monthly loads and yields of nutrients were calculated for the three sampling locations on the Quinebaug River to develop a nutrient mass-balance model (budget) for West Thompson Lake. The average annual yields of total phosphorus during 2000 to 2005 were 115 pounds per square mile per year (lb/mi^2/yr) at Quinebaug (inflow station), 116 lb/mi^2/yr at Red Bridge Road (inflow station), and 97.9 lb/mi^2/yr at West Thompson (outflow station). The 18-percent decrease in the average annual yield of total phosphorus between the inflow station at Red Bridge Road and the outlet of West Thompson Lake at West Thompson indicates that a significant part of the phosphorus load is retained in the lake. Annual yields of total phosphorus at Quinebaug have decreased significantly since the 1980s, from 362 lb/mi^2/yr (for 1981–1990) to 115 lb/mi^2/yr (1996–2005).

The annual net export of phosphorus in West Thompson Lake during water years 2000 to 2005 ranged from -36 percent (2005) to 1 percent (2002) of the incoming load. Seasonal mass-balance data for total phosphorus during the summers of 2000 to 2003, when streamflow was at or lower than normal, indicated a net export of phosphorus that ranged from 3.4 percent (2003) to 30.7 percent (2002) of the incoming load. During the summer of 2004, however, streamflows were much higher than normal, and there was a negative export of phosphorus in West Thompson Lake of -3.9 percent. The annual net export of nitrogen in West Thompson Lake during water years 2000 to 2005 ranged from -5 percent (2002) to 4 percent (2001) of the incoming load. No clear pattern was evident to relate total nitrogen export to seasonal variables or runoff.

Removal of phosphorus during the summer by wastewater-treatment plants (WWTPs) in Massachusetts reduces the concentration and load of total phosphorus entering West Thompson Lake in the summer; however, the large amount of phosphorus retained in the lake during the other seasons, in addition to the phosphorus stored in the lake-bottom sediments, may become available to fuel algal blooms in the lake and (or) in areas downstream from the lake during the critical summer growing season. The seasonal phosphorus removal at the WWTPs lowers the concentration of phosphorus entering the lake during the summer and probably reduces the magnitude and duration of algal blooms that occur in West Thompson Lake.

Introduction

West Thompson Lake is an impoundment of the Quinebaug River in the Thames River Basin in northeastern Connecticut. The U.S. Army Corps of Engineers (USACE) constructed the lake in 1965 as a flood-control reservoir and continues to manage it for flood control and for recreation. Beginning in the mid 1970s, nuisance algal blooms have occurred in West Thompson Lake as the result of excess nutrients. The USACE sampled the lake in the late 1970s, and again in the early 1980s, and found the lake to be eutrophic with high concentrations of total phosphorus and total nitrogen and persistent blue-green algal blooms (U.S. Army Corps of Engineers, written commun., 2005).

The primary sources of nutrients to West Thompson Lake are thought to be three municipal wastewater-treatment plants (WWTPs) in the upper part of the watershed in Massachusetts (fig. 1). Efforts to reduce nutrient concentrations and loads, primarily phosphorus, from the WWTPs in Massachusetts began in the mid to late 1980s and have been modified several times. Sampling at U.S. Geological Survey (USGS) water-quality station Quinebaug River at Quinebaug, Conn. (USGS Site ID 01124000), shows that annual loads of total nitrogen and phosphorus have decreased in the Quinebaug River upstream from West Thompson Lake since the improvements in municipal wastewater treatment were implemented (Trench, 2000). Despite these improvements, excessive loads of nitrogen and phosphorus are causing eutrophication of the lake with persistent seasonal algal blooms, adding to nutrient problems in the lower reaches of the Quinebaug and Thames Rivers (Connecticut Department of Environmental Protection, 2002). Data from a water-quality study (M.J. Colombo, U.S. Geological Survey, oral commun., 2002) indicate that West Thompson Lake is a sink for phosphorus. At times, however, the concentrations of phosphorus leaving the lake are higher than upstream concentrations, suggesting that phosphorus stored in the lake-bottom sediments is being released. In addition, West Thompson Lake stratifies during the summer, and dissolved oxygen concentrations approach 0 mg/L in sections of the lake deeper than 12 ft (Connecticut Department of Environmental Protection, 1998).

Resource managers in Massachusetts and Connecticut have tried to control external nutrient loading to West Thompson Lake. Questions remain over the role and timing of specific nutrient sources that contribute to nuisance algal blooms in the lake as well as other nutrient- and algae-related problems that exist in and near the lake. It is important to understand whether the primary cause of the algal blooms is the external load from upstream in the watershed or the internal load from within the lake, specifically the lake-bottom sediments. Related questions include (1) what is the effect of seasonal phosphorus removal at WWTPs in Massachusetts? (2) is the internal load of phosphorus sufficient to produce algal blooms in the lake even if the external load were managed? and (3) is the timing and duration of thermal stratification in the lake affecting the onset and duration of algal blooms?

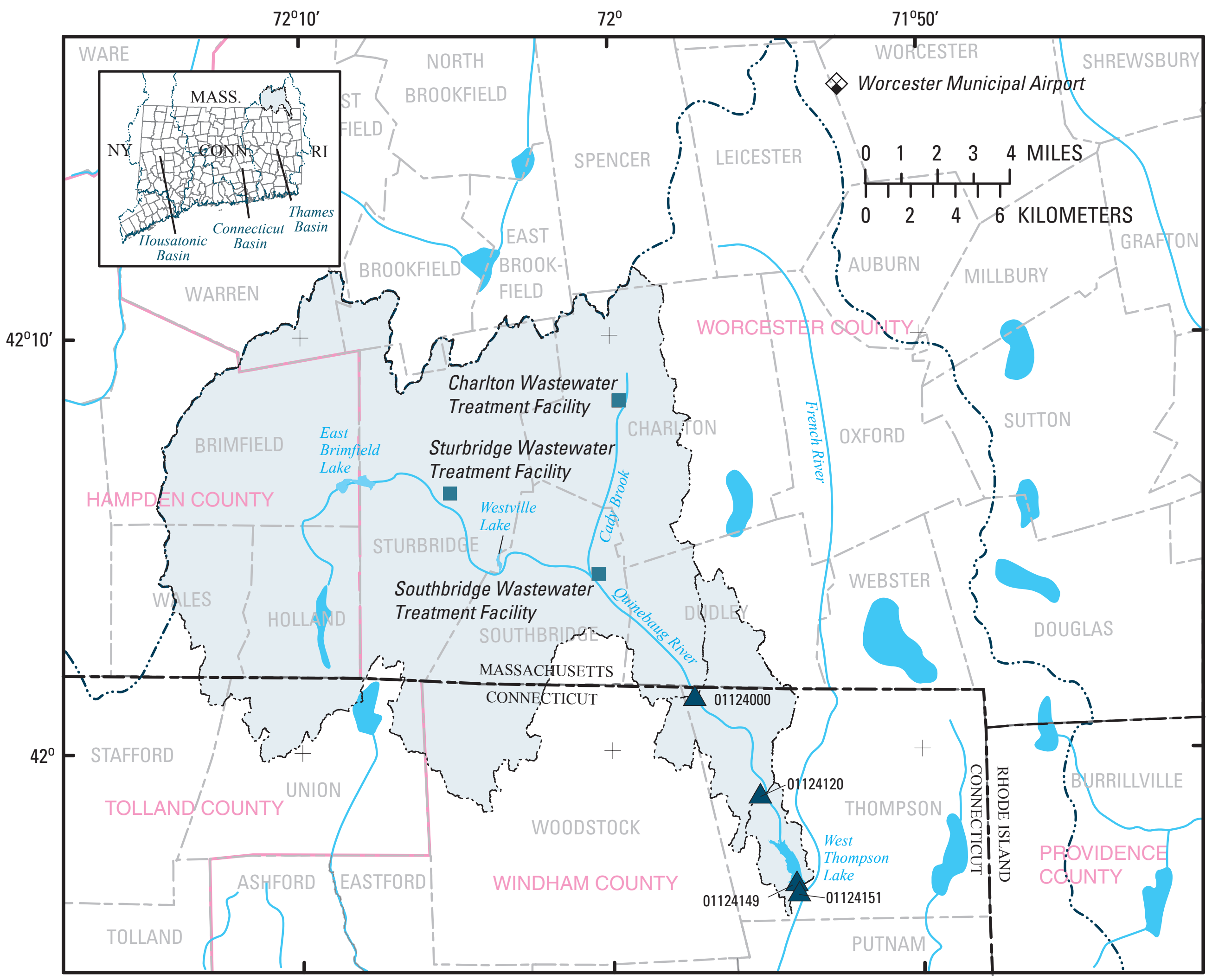
In 1999, USGS and the Connecticut Department of Environmental Protection (CTDEP) began an investigation of nutrient concentrations and eutrophication of the Quinebaug River watershed. Initial results indicate that loads of total phosphorus into and out of West Thompson Lake may vary seasonally (M.J. Colombo, U.S. Geological Survey, oral commun., 2002). As a result of those preliminary results, USGS and CTDEP began a cooperative study in 2003 to look at seasonal loads into and out of West Thompson Lake and the surrounding watershed, which will assist water-resource managers in developing a nutrient management plan for West Thompson Lake. CTDEP and U.S. Environmental Protection Agency (USEPA) can use the information from this study to develop a Total Maximum Daily Load for nutrients and excess algal growth in the Quinebaug River and the West Thompson Lake watershed.

Purpose and Scope

This report characterizes the surface-water hydrology and water quality of the Quinebaug River above and below West Thompson Lake; the water quality of the lake itself; and the type and distribution of algae found in the lake and the factors affecting their growth and abundance. In addition, the report describes the thickness and distribution of fine-grained sediments in the lake and the concentration of total phosphorus in the upper 2 in. of the sediment as well as at depth in two locations. This report also presents data on loads and yields of nutrients into and out of West Thompson Lake, a nutrient budget for the lake, and a conceptual model of nutrient cycling, including a determination of which nutrient is limiting algal growth. Data for this study were collected from 2003 to 2005; but historical data, as available, are used to extend the periods of record for sampling locations and to provide a context for the study data.

Description of the Study Area

West Thompson Lake is in northeastern Connecticut, in the town of Thompson in Windham County. The lake is an artificial impoundment on the Quinebaug River constructed and operated for flood control and recreation by the USACE. The dam was built in response to serious damage to the town of Putnam during a 1955 flood on the Quinebaug River. Construction of West Thompson Lake dam was started in 1964 and completed in 1965 at a cost of $6.7 million dollars. The dam is a rolled, earthen-filled dam 2,550 ft long and 69.5 ft above the elevation of the lakebed. A concrete gatehouse with three steel gates release flow. The primary releases are through a drop gate that allows water to spill from the lake surface and through two adjustable side gates located 12 ft below the surface (S.P. Simmer, U.S. Army Corps of Engineers,



Base from USGS, UCONN-MAGIC, and MassGIS sources

EXPLANATION

- West Thompson Lake Watershed
- Major basin boundary
- 01124151 Gaging station and number
- Wastewater treatment facility location
- Weather station location

Figure 1. Location of West Thompson Lake watershed in northeastern Connecticut and southern Massachusetts.

written commun., 2003). A spillway was constructed at an elevation of 342.5 ft above sea level, 37.5 ft above the normal pool elevation. Storage capacity of the lake is 25,600 acre-ft. Normal pool elevation is maintained for recreational purposes at 305 ft (13 ft of lake stage) with a normal surface area of 200 acres and a normal storage volume of 1,200 acre-ft.

West Thompson Lake is approximately 1.5 mi long and 1,500 ft wide throughout its length. The lake is bounded by West Thompson Lake dam on the southern edge, by woods and open fields along the eastern and western edges, and by the former river channel and flood plain on the northern edge. Several small unnamed tributaries flow directly into the western side of the lake. The confluence of the Quinebaug and French Rivers is approximately 0.25 mi downstream from West Thompson Lake dam.

The lake is relatively shallow with an average depth of approximately 7.7 ft (Kulp and Hunter, 1989) (fig. 2). Two relict stream channels are near the eastern and western banks with water depths of 15 ft. The maximum depth of the lake is 30 ft in an isolated hole on the southwestern side of the lake near an abandoned roadway that constricts the lake just above the dam. The northern third of the lake is shallower with a depth of approximately 5 ft. The eastern shore of the lake is mostly gravel with very little aquatic weed growth, most likely due to wind-driven wave action. The western shore is irregular with several small coves and rocky islands, and tends to have more aquatic weed growth in areas very close to the shoreline.

The drainage area to the lake is 172 mi^2. The Quinebaug River is highly regulated and is impounded in several locations above West Thompson Lake dam. The USACE operates two other flood-control impoundments on the Quinebaug River upstream from West Thompson Lake—East Brimfield Lake and Westville Lake. These two lakes control 99 of the 172 mi^2 draining to West Thompson Lake. Several other small impoundments upstream from West Thompson Lake on the Quinebaug River in Massachusetts are operated for hydroelectric-power generation. Streamflow regulation on the Quinebaug River is most significant during periods of low to medium streamflow. Streamflow can change rapidly from less than 100 to 500 ft^3/s.

The USACE owns and manages 1,700 acres adjacent to West Thompson Lake. The land is used for recreation and limited agriculture, primarily corn and hay. Land use in the watershed is primarily forested (80.5 percent) with lesser amounts of urban (9.5 percent) and agricultural (10 percent) land (K.J. Hitt, U.S. Geological Survey, written commun., 2006).

Previous Investigations

The USGS and CTDEP investigated the bathymetry and water quality of West Thompson Lake in 1989 and found it to be a eutrophic to highly eutrophic, productive warm-water fishery (Kulp and Hunter, 1989). Healy and Kulp (1995) classified the lake as highly eutrophic with maximum concentrations of 0.240 mg/L for total phosphorus, 2.7 mg/L for total nitrogen, and 690 µg/L for chlorophyll-*a*. In 1995, CTDEP classified the lake as eutrophic (Connecticut Department of Environmental Protection, 1996; 1998). Trench (2004) evaluated trends in total phosphorus concentrations in the Quinebaug River and documented a downward trend in concentrations of total phosphorus at the USGS sampling station on the Quinebaug River at Quinebaug, above West Thompson Lake.

Table 1. Annual precipitation at the National Weather Service station at Municipal Airport, Worcester, Massachusetts, water years 2000–2005 (National Oceanic and Atmospheric Administration, 1999–2005).

[Location shown on figure 1]

Water year	Total precipitation (inches)
2000	44.36
2001	36.77
2002	36.44
2003	48.55
2004	46.70
2005	46.27
Normal (1976–2005)	46.63

Hydrologic Conditions During the Study Period

Precipitation During 2000–2005

Precipitation records from the National Weather Service station at Worcester, Massachusetts, indicate that precipitation was within 2 in. of normal (46.63 in.) during water years[1] 2003, 2004, and 2005 (table 1) and within 2.27 in. of normal in 2000. During 2001 and 2002, however, precipitation was less than normal by 9.86 and 10.19 in., respectively. Precipitation during 2000 to 2005 was uniformly distributed throughout each year (National Oceanic and Atmospheric Administration, 1999–2005). Normal summer precipitation (June–September) is 15.57 in., but it was above normal in 2003 (19.02 in.) and 2004 (18.76 in.) and below normal in 2005 (12.36 in.) (table 2). Precipitation during the summer can come from either continental systems or coastal-frontal systems, which last from several hours to several days, or from local cyclonic storms (thunderstorms), which can be brief but intense and deposit large amounts of precipitation in a relatively short time. Generally, frontal systems are

[1] A water year is the 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends.

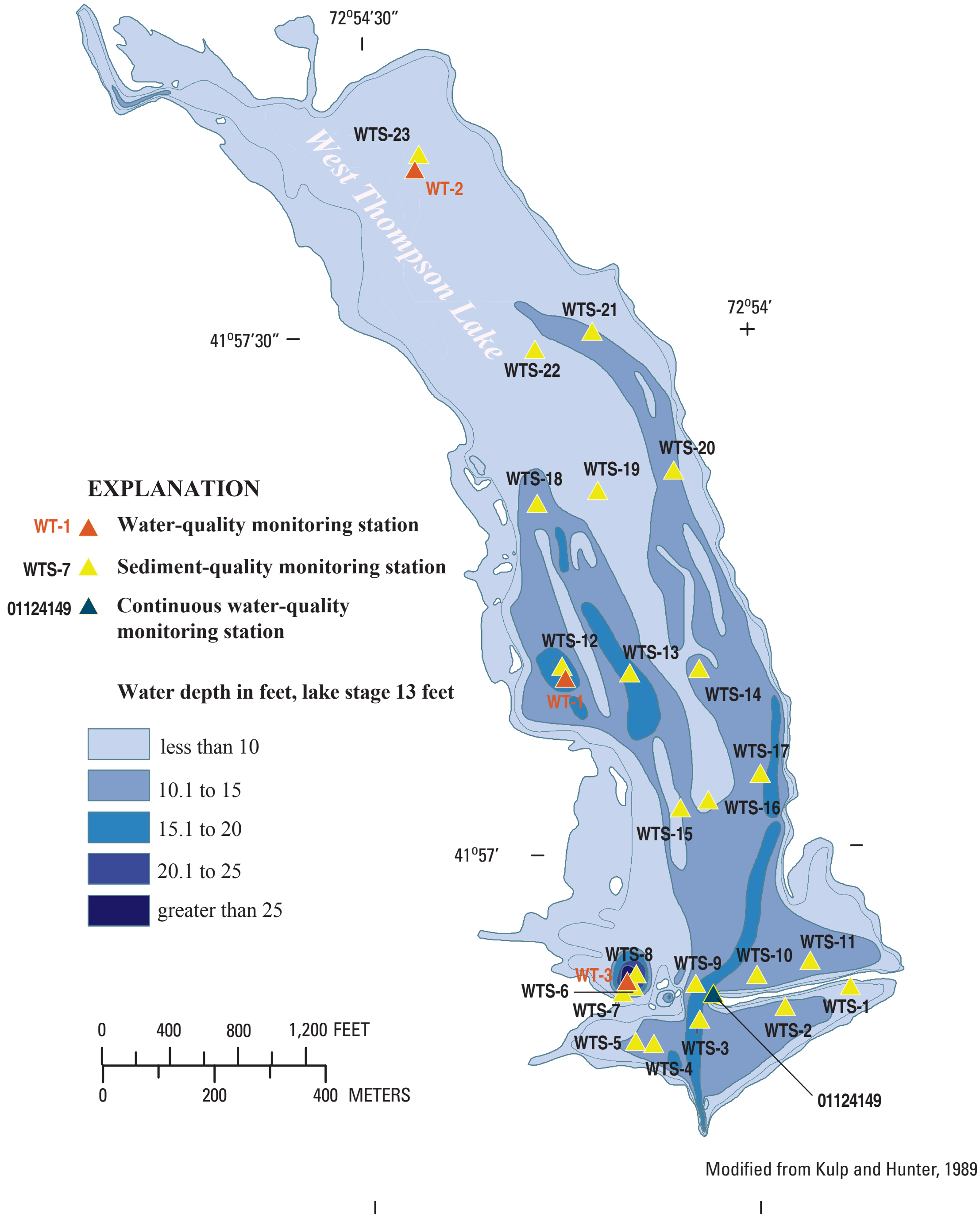


Figure 2. Bathymetric map of West Thompson Lake, Connecticut, with sampling locations.

Table 2. Monthly summer precipitation at the National Weather Service station at Municipal Airport, Worcester, Massachusetts, water years 2000–2005 (National Oceanic and Atmospheric Administration, 1999–2005).

[All values are in inches. Location shown on figure 1]

Water year	June	July	August	September	Total
2000	5.84	4.04	2.09	3.01	14.98
2001	6.27	1.91	2.31	3.42	13.91
2002	4.83	2.65	2.94	3.97	14.39
2003	6.16	3.05	5.54	4.27	19.02
2004	1.28	4.88	5.07	7.53	18.76
2005	1.81	5.05	2.65	2.85	12.36
Normal (1976–2005)	3.81	4.02	3.88	3.86	15.57

accompanied by prolonged strong winds and significant air temperature changes. Precipitation during the summer has a direct effect on streamflow entering West Thompson Lake and can cause changes in the temperature of the streamflow and the structure and distribution of temperature in the lake.

Streamflow

Continuous streamflow data for the Quinebaug River upstream from West Thompson Lake were collected at USGS continuous-record streamflow-gaging station Quinebaug River at Quinebaug, Conn. (USGS Site ID 01124000) (fig. 3A). This station measures 90 percent of the drainage area to West Thompson Lake. Continuous-streamflow data at the outlet of West Thompson Lake were collected at USGS streamflow-gaging station Quinebaug River at West Thompson (USGS site ID 01124151) (fig. 3B). Streamflow in the Quinebaug River during the 2000–2005 water years was relatively normal, except for the 2002 water year when the mean annual streamflow was less than half the normal amount (table 3). In 2002, the departure from the 30-year median annual streamflow was 159 ft^3/s at Quinebaug and 179 ft^3/s at West Thompson. Mean monthly streamflow deviated from normal during the summer months from 2000 to 2005, most notably during June in 2000–2003, when monthly mean streamflows were much lower than normal at both Quinebaug and West Thompson. During June 2004, monthly mean streamflows were more than three times normal at both stations. Mean monthly streamflows were consistently higher than normal for all of the summer months in 2003. In contrast, mean streamflows during August and September 2005 were nearly half of normal (table 4).

Hydraulic Residence Time

Hydraulic residence time is a theoretical value that represents the amount of time it takes to replace the volume of water in a lake. The average hydraulic residence time in West Thompson Lake, calculated for this study, ranged from 1.7 to 4.2 days. The long-term average-annual hydraulic residence time in West Thompson Lake is calculated to be 1.9 days based on the 30-year median annual daily streamflow. Hydraulic residence time can change significantly by season. During the summer months (June–September), hydraulic residence times can range from 1.1 to 22 days. With hydraulic residence times less than 30 days, West Thompson Lake would be considered a fast-flushing lake, which is typical of small, shallow lakes. The average hydraulic residence time does not account for water in the lake that may not circulate through as quickly, perhaps due to stratification.

Table 3. Annual mean streamflows and selected streamflow statistics for Quinebaug River at Quinebaug, Connecticut, (USGS Site ID 01124000) and Quinebaug River at West Thompson, Connecticut, (USGS Site ID 01124151), water years 2000–2005.

[Station locations shown on figure 1]

U.S. Geological Survey streamflow-gaging station	Annual mean streamflow (cubic feet per second)						Median annual mean streamflow for 30-year period (1976–2005) (cubic feet per second)	Average annual mean streamflow for period of record (cubic feet per second)
	Water year 2000	Water year 2001	Water year 2002	Water year 2003	Water year 2004	Water year 2005		
Quinebaug River at Quinebaug, Conn.	270	201	131	296	283	304	294	[1931–2005] 273
Quinebaug River at West Thompson, Conn.	278	238	145	322	326	360	324	[1966–1984; 1984–2005] 302

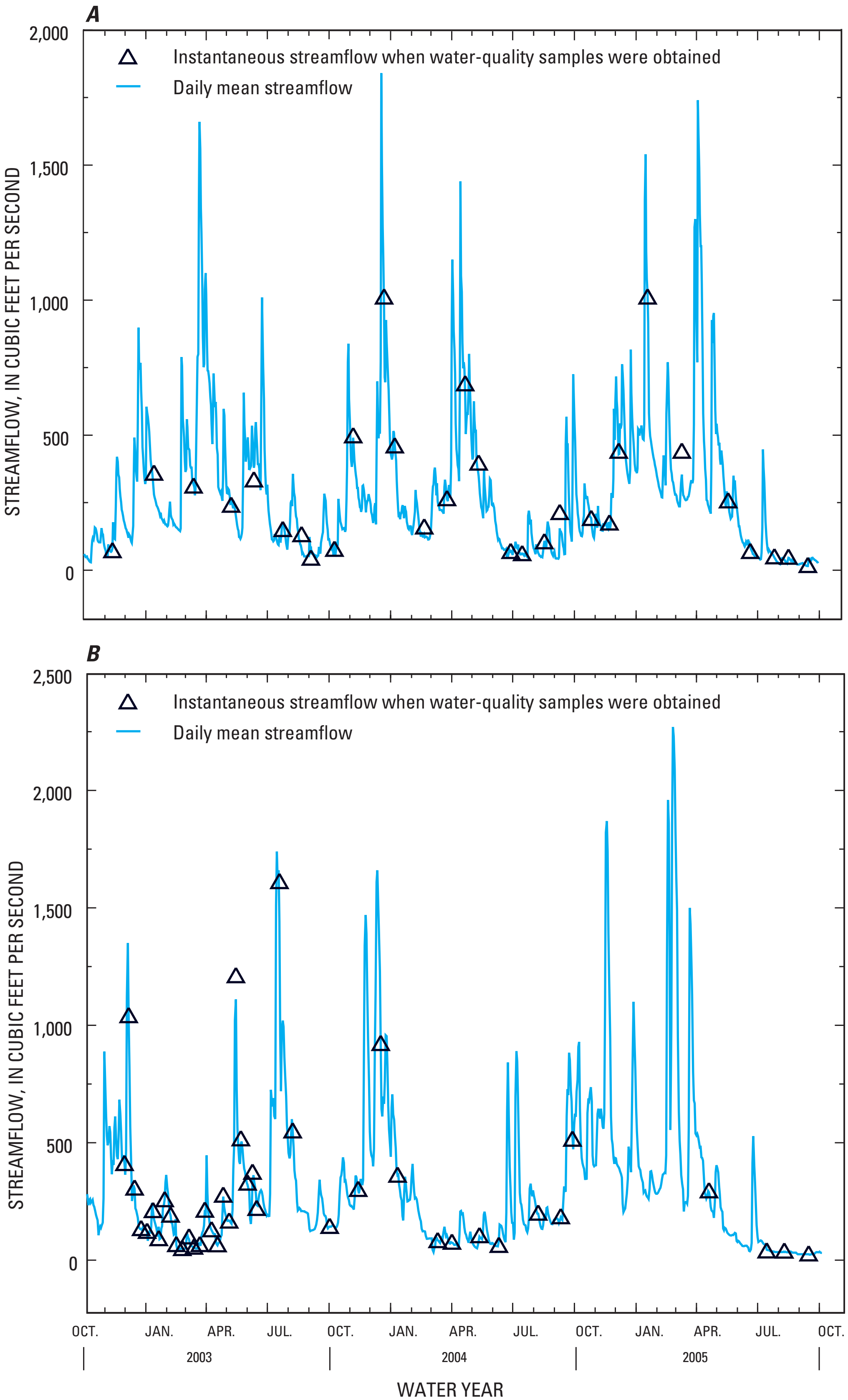


Figure 3. Streamflow at U.S. Geological Survey stations, indicating dates and flow conditions when water samples were collected, water years 2003–2005: *(A)* Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), and *(B)* Quinebaug River at West Thompson, Connecticut (USGS Site ID 01124151).

Table 4. Summer monthly mean streamflows for Quinebaug River at Quinebaug, Connecticut, (USGS Site ID 01124000) and Quinebaug River at West Thompson, Connecticut, (USGS Site ID 01124151), water years 2000–2005.

[Median monthly mean value for 30-year period 1976–2005]

U.S. Geological Survey streamflow-gaging station	Monthly mean streamflow (cubic feet per second)				
	Water year	June	July	August	September
Quinebaug River at Quinebaug, Conn.	2000	367	103	83.8	45.3
	2001	251	74	37.6	46.9
	2002	285	51	31.6	28.5
	2003	474	140	146	111
	2004	110	93	84.5	202
	2005	100	103	31.8	29.6
	Median	124	73.5	67	59.6
Quinebaug River at West Thompson, Conn.	2000	368	110	99.6	99.6
	2001	263	80.7	46.0	46.0
	2002	303	61.7	32.9	32.9
	2003	552	159	145	114
	2004	126	106	97.6	229
	2005	110	116	34.6	27.5
	Median	130	83	62.5	54

Methods of Data Collection and Analysis

Stream Sampling

Samples of streamwater were collected and analyzed for selected nutrients at two locations upstream from West Thompson Lake (inflow stations) to characterize the concentrations and loads entering the lake (table 5). The first location was the continuous-record streamflow-gaging station Quinebaug River at Quinebaug, Conn. (USGS Site ID 01124000), chosen because the periods of record for water-quality and streamflow data were long enough to allow loads to be calculated. The second location was a partial-record station on the Quinebaug River at Red Bridge Road near North Grosvenordale, Conn. (USGS Site ID 01124120), which is just above the lake. This station was chosen to evaluate the differences in water quality between the station at Quinebaug and the lake. The approximate time of travel for water in the Quinebaug River to flow the 2.8 mi between the two locations is 20 hours (T. Bridges, U.S. Environmental Protection Agency, written commun., 2007). Samples of streamwater also were collected and analyzed for selected nutrients at a third station downstream from the lake, the continuous-record streamflow-gaging station Quinebaug River at West Thompson (USGS Site ID 01124151) (outflow station). This station is approximately 1,000 feet downstream of the West Thompson Lake dam and was chosen for sampling the outflow of the lake.

Water samples were collected from the two inflow stations and the outflow station using the equal-width increment method described by Edwards and Glysson (1988), Wilde and others (1998a, b, c), and Wilde and others (1999a, b). Samples from the Quinebaug station were collected monthly from May 2003 through October 2004. Samples from the Red Bridge Road station and the outflow of West Thompson Lake were collected weekly from May 2003 through November 2003 and monthly from December 2003 through October 2004. From December 2003 through October 2004, the sample at the Quinebaug station was collected on the same day as the samples from the other two locations. The number and type of samples collected for each location are shown in table 6.

Samples were analyzed for physical properties of water temperature, specific conductance, dissolved oxygen, and pH using methods described by Wilde and Radtke (1998). Samples also were analyzed for concentrations of the following constituents: filtered (dissolved) and unfiltered (total) Kjehldal nitrogen, filtered nitrate and nitrite, filtered ammonia, filtered orthophosphorus, filtered and unfiltered phosphorus, and chlorophyll-*a*.

All samples were analyzed by the USGS National Water-Quality Laboratory (NWQL) in Denver, Colo., using methods described by Fishman and Friedman (1989) and Patton and Truitt (1992), and results were published in the series of annual USGS water-data reports (Ranzau and others, 2001; Morrison and others, 2002–2006).

Lake Sampling

Water samples were collected at three locations in West Thompson Lake and analyzed for the same physical properties and constituent concentrations as the streamflow samples. The locations were selected on the basis of historical sampling data available for the locations and were named WT-1, WT-2, and WT-3, a naming convention established by CTDEP. WT-1 is in the middle of the lake with a water depth of approximately 15 ft. WT-2 is in the northern part of the lake with a water depth of approximately 5 ft. WT-3 is in a deep hole in the southwestern part of the lake with a water depth of approximately 30 ft (fig. 2).

Water samples and water-column profiles of physical and chemical parameters were collected at all three lake locations monthly from June to November 2003 and at WT-3 in June, July, and September 2004. Water samples were collected near the lake surface at all locations and analyzed for concentrations of selected nutrients and chlorophyll-*a*. Additional samples to characterize changes in concentrations and speciation of the selected nutrients with depth were collected at WT-1 (at 12 ft) and WT-3 (at 12 and 22 ft). All lake samples for nutrients were collected using a Van Dorn sampler described by Lind (1985). Chlorophyll-*a* samples were collected directly in glass sample bottles. Samples for algal cell count and algal identification were collected May to November 2003, and were analyzed by CTDEP staff. Samples for algal cell count were collected using a dipped sample bottle using methods described by Britton and Greeson (1989). Samples collected for qualitative algal identification were collected with a plankton tow net using methods described in Britton and Greeson (1989).

During July and August 2005, additional samples at each location were collected at WT-1 and WT-3 (near surface and at 12 ft) to determine algal-growth potential (AGP) and the limiting nutrient for algal growth. These analyses were performed at the Hydrosphere Research Laboratory in Gainesville, Fla. The AGP test compares a reference sample of

Table 5. U.S. Geological Survey sampling stations used for this study, West Thompson Lake watershed, Connecticut.

[Period of record is in water years; --, not available]

Sampling station		Drainage area (square miles)	Latitude	Longitude	Period of record for streamflow measurements	Period of record for water-quality samples	Number of samples	
Number	Name						Nutri-ents	Chloro-phyll-*a*
01124000	Quinebaug River at Quinebaug, Conn.	155	42°01'20"	71°57'22"	1931–2005	1980–2005	30	9
01124120	Quinebaug River at Red Bridge Road near North Grosve-nordale, Conn.	168	41°58'58"	71°55'17"	2003–2004	2003–2004	34	28
01124151	Quinebaug River at West Thompson, Conn.	172	41°56'29"	71°53'58"	1966–1984; 1984–2000 (unpublished); 2000–2005	1999–2000; 2003–2005	41	31
01124149	West Thompson Lake at Old Bridge, Thompson, Conn.	--	41°56'52"	71°54'08"	--	June 2003– November 2005	0	19
415701071540801	WT-1	--	41°57'01"	71°54'08"	--	June 2003– September 2005	11	10
415730071542301	WT-2	--	41°57'30"	71°54'23"	--	June 2003– November 2003	6	4
415652071540801	WT-3	--	41°56'52"	71°54'08"	--	June 2003– September 2005	15	13

Table 6. Water-quality sample types and collection frequency in the West Thompson Lake watershed, Connecticut.

[Grey shading indicates a sample was collected, boxes with numbers indicate multiple samples collected during that month; ft, feet]

Water year	2000												2001												2002											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
	Stream samples																																			
01124000 Quinebaug River at Quinebaug																																				
Nutrients										2	3	2						2		2	3	3	3	2												
Chlorophyll-*a*										2	3	2								2	2	2	2	2												
01124120 Quinebaug River at Red Bridge Road																																				
Nutrients																																				
Chlorophyll-*a*																																				
01124151 Quinebaug River at West Thompson																																				
Nutrients										2	2	2								2	2	2	2	2												
Chlorophyll-*a*										2	2	2								2	2	2	2	2												
	Lake samples																																			
WT-1																																				
Nutrients (near surface and 12 ft)																																				
Chlorophyll-*a* (near surface and 12 ft)																																				
Algal cell count and identification																																				
Algal growth potential and limiting nutrients																																				
WT-2 (near surface only)																																				
Nutrients																																				
Chlorophyll-*a*																																				
Algal cell count and identification																																				
Algal growth potential and limiting nutrients																																				
WT-3																																				
Nutrients (near surface, 12 ft, and 22 ft)																																				
Chlorophyll-*a* (near surface, 12 ft, and 22 ft)																																				
Algal cell count and identification																																				
Algal growth potential and limiting nutrients																																				
Continuous monitors (01124149)																																				

Table 6. Water-quality sample types and collection frequency in the West Thompson Lake watershed, Connecticut.—Continued

[Grey shading indicates a sample was collected, boxes with numbers indicate multiple samples collected during that month; ft, feet]

Water year	2003												2004												2005											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
	Stream samples																																			
01124000 Quinebaug River at Quinebaug																																				
Nutrients																																				
Chlorophyll-*a*																																				
01124120 Quinebaug River at Red Bridge Road																																				
Nutrients									2	5	4	4	5	4																						
Chlorophyll-*a*									2	5	4	4	5	3																						
01124151 Quinebaug River at West Thompson																																				
Nutrients									2	4	4	4	5	4																						
Chlorophyll-*a*									2	4	4	4	5	3																						
	Lake samples																																			
WT-1																																				
Nutrients (near surface and 12 ft)																																				
Chlorophyll-*a* (near surface and 12 ft)																																				
Algal cell count and identification																																				
Algal growth potential and limiting nutrients																																				
WT-2 (near surface only)																																				
Nutrients																																				
Chlorophyll-*a*																																				
Algal cell count and identification																																				
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WT-3																																				
Nutrients (near surface, 12 ft, and 22 ft)																																				
Chlorophyll-*a* (near surface, 12 ft, and 22 ft)																																				
Algal cell count and identification																																				
Algal growth potential and limiting nutrients																																				
Continuous monitors (01124149)																																				

freshwater algal-growth media to the test samples. All samples were treated with the algae *Selenestrum capricornutum,* incubated, and allowed to grow under ideal conditions for 2 weeks. At the end of the test, the samples were filtered, and the amount of algal growth from each sampled location was weighed and compared to that from other locations and to the growth in the reference sample. The limiting nutrient test is used to determine if the growth of algae in a sample is controlled by the amount of available phosphorus, nitrogen, or some other minor element in the sample, or if it is controlled by nutrient availability at all. The limiting nutrient test is performed by splitting each sample into seven treatment groups. Each treatment group is then spiked with the algae *Selenestrum capricornutum* and a specific dose of nitrogen, phosphorus, ethylenediaminetetraacetic acid (EDTA) (a chelating agent), or a combination of these treatments. The samples are incubated under ideal growing conditions for 2 weeks. At the end of the test, the samples are filtered and weighed, and the amount of algal growth from each treatment is calculated (American Public Health Association and others, 1992). The analyst then can determine which specific treatment caused the greatest amount of growth and if a specific nutrient source or combination of nutrients may be limiting algal growth in the water body tested.

Two continuous water-quality monitors were deployed in the southern part of the lake on the abandoned bridge abutment. These monitors were housed in vertical polyvinyl chloride pipes that had the bottom ends modified to allow water to flow through them. The monitors were located approximately 2.5 ft and approximately 12 ft below the average water surface. The monitors measured temperature, pH, specific conductance, and dissolved oxygen and were serviced and checked for accuracy every 2 weeks, using methods described by Wagner and others (2000). Chlorophyll-*a* also was sampled at this location every 2 weeks and analyzed using high-performance liquid chromatography methods as described by Britton and Greeson (1989).

Lake-Bottom Sediment Sampling

Lake-bottom sediment was sampled at 23 locations (WTS-1 to WTS-23) in the lake during August and September 2003 (fig. 2). Areas where water was deeper than 12 ft were targeted because there may be little or no oxygen at depth during periods of summer stratification. Sediment cores were collected for examination and chemical analysis using a universal piston corer. This corer uses a 2.2-in. lucite core sleeve that is pushed into the sediment using attached rods. A watertight piston in the core tube rests on the sediment. As the corer is advanced, the piston is retracted to maintain the vacuum in the tube and minimize sediment compaction. The core tube assembly is pulled straight out and the piston keeps the sediments in the core tube. The method works well in mucky (fine), cohesive sediments and generally is less effective in sediment with sand- or coarser-sized particles. The thickness of lake-bottom sediment was determined by the depth that the sediment corer was able to penetrate. The upper 2 in. of the sediment cores were analyzed by the NWQL for bulk total phosphorus concentrations. Several cores were subsampled at deeper depths to identify any vertical distribution in total phosphorus concentrations.

A second round of sediment coring was conducted in October 2004. Three cores were collected at two of the sites—stations WTS-12 and WTS-17. The cores were extruded from the lucite core tube using a hydraulic jack and subsampled every 1.2 in. Samples were analyzed for concentrations of total phosphorus and total carbon by the NWQL.

Nutrient Load Calculations

The stream load of a constituent is the amount of the constituent transported by the stream in a given length of time, such as the annual load for a water year or the instantaneous load during a storm. Annual loads of nitrogen and phosphorus for Quinebaug River at Quinebaug, Quinebaug River at Red Bridge Road, and Quinebaug River at West Thompson were estimated using daily mean streamflow and water-quality data collected during this study as well previously collected USGS data (Ranzau and others, 2001; Morrison and others, 2002, 2003). Nutrient loads were calculated using the USGS LOADEST program, which was described in detail by Runkel and others (2004). The LOADEST models with the best fit were used in the analysis. Load models were selected on the basis of the rank of the Akaike Information Criterion test statistic (Runkel and others, 2004, p. 7). Constituent loads based on monthly samples were estimated by the rating-curve (regression) method (Cohn and others, 1989; Crawford, 1991). Estimates of the uncertainty in the load estimates were determined using methods described by Likes (1980) and Gilroy and others (1990) for maximum-likelihood estimates and by the jackknife method (Efron, 1982) for linear-attribution estimates. A detailed description of these statistical methods may be found in Crawford (1996).

Estimates of mean daily loads with confidence intervals were selected from several regression models after first analyzing each regression for the best fit to the data using S-PLUS (Insightful, Inc., 2000). Estimated monthly, seasonal, and annual mean daily loads, in units of pounds per day, were calculated for each water year, along with the standard error and standard error of prediction for each mean daily load estimate. Estimated annual loads of total nitrogen and total phosphorus were used to compute the annual yields for each location. All data were analyzed for basic summary statistics using methods described by Helsel and Hirsch (2002) using statistical software by the Insightful Corporation (Insightful, Inc., 2000).

Physical Properties and Concentrations of Nutrients and Chlorophyll-*a* in Water

High concentrations of nutrients can cause large algal populations (blooms) in water bodies. These algal blooms can have harmful effects on water quality and the designated uses of the water body. Lakes and reservoirs tend to be more sensitive to algal blooms than rivers due to the longer hydraulic residence times, which allow algae to take up the nutrients, increase their numbers and biomass, and develop into algal blooms.

Quinebaug River

The concentrations of nutrients in the Quinebaug River upstream from West Thompson Lake are affected by WWTP effluent, as well as other point and nonpoint sources of nutrients, such as runoff from pavement and agricultural areas. WWTPs in Massachusetts are required to do seasonal removal of phosphorus from their effluent to reduce the amount of phosphorus in the receiving stream during the growing season (E.D. Thomas, Connecticut Department of Environmental Protection, oral commun., 2002). Trench (2004) reported a decreasing trend in concentrations of total phosphorus for the Quinebaug River at Quinebaug sampling station for the period 1980–2001.

Concentrations of total phosphorus from the two inflow stations were relatively consistent with each other and from year to year during 2003–2004. Concentrations of total phosphorus peaked during July, August, and September in the inflow to and the outflow from the lake. Concentrations of total phosphorus during the summer of 2003 were approximately 0.050 mg/L at the inflow to West Thompson Lake and 0.050 to 0.070 mg/L at the outflow of the lake. This difference may indicate an internal source of phosphorus in the lake.

Median summer (June–September) concentrations of total phosphorus for the two inflow stations were the same (0.043 mg/L) during 2003 and were slightly lower than the average concentration at the outflow station (0.056 mg/L). During the summer of 2004, the average summer concentration of total phosphorus at the Red Bridge Road (inflow) station was similar to the outflow station. Average summer concentration at the station at Quinebaug was slightly higher (0.058 mg/L) because of the high concentration (0.070 mg/L) in the September sample. Overall, the concentrations of phosphorus among the three stations were relatively uniform during the study period (fig. 4A).

Median concentrations of total phosphorus in the inflow stations (0.036 mg/L at Quinebaug and 0.044 mg/L at Red Bridge Road) and outflow station (0.042 mg/L at West Thompson) were higher than the 0.03125-mg/L nutrient criteria recommended by the USEPA for rivers and streams in the aggregate Ecoregion XIV (U.S. Environmental Protection Agency, 2000a, b).

The range and median concentrations of total nitrogen among all three stations during the study were very similar (fig. 4B); however, during the summer of 2004, the concentration of total nitrogen at the outflow station was 0.2 mg/L lower than the concentration at both inflow stations.

Chlorophyll-*a* is a photosynthetically active pigment found in algae and other green plants that is used as an indicator of biotic growth in water bodies. Concentrations of chlorophyll-*a* higher than 10 µg/L indicate eutrophic conditions, and concentrations higher than 20 to 30 µg/L generally are associated with algal blooms. Concentrations of chlorophyll-*a* ranged from 0.5 to 5.1 µg/L at the two inflow stations and from 1 to 32 µg/L at the outflow station. Based on a Tukeys's multiple comparison test (Helsel and Hirsch, 1992), chlorophyll-*a* concentrations at the outflow station were statistically different from the two upstream stations. Samples were not collected for chlorophyll-*a* at Quinebaug during 2003; however, the concentrations of chlorophyll-*a* at the two inflow stations were similar every time they were both sampled, so it is assumed they were similar during 2003. The chlorophyll-*a* concentration at the outflow station was significantly higher than the concentration at the inflow stations during the study (fig. 4C). The maximum concentration of chlorophyll-*a* at West Thompson was 34.4 µg/L in July 2003. This coincided with the highest concentration of chlorophyll-*a* in the lake (24.6 µg/L on July 31, 2003). The algal cell count in the lake was 73,000 cells/mL with the dominant algae taxa being the blue-green algae *Anacystis sp.* and *Anabaena* (G.F. Hoffman, Connecticut Department of Environmental Protection, written commun., 2006).

West Thompson Lake

Data for water temperature, specific conductance, pH, and dissolved oxygen from two continuous water-quality monitors (near-surface and deep) in West Thompson Lake during 2003 and 2005 are summarized in appendix 1. The pattern of water temperature in West Thompson Lake was consistent between 2003 and 2005 (figs. 5A and 5B). In general, water temperatures at both monitors increased during June to more than 20°C by the end of the month, at which time temperatures at the near-surface and deep monitors would begin to diverge. Water temperatures generally stayed above 20°C at both monitors until late August to mid-September, when temperatures would begin to drop to below 20°C and the difference between the near-surface and deep monitors would decrease. The maximum water temperature at the near-surface monitor was 29.5°C during 2003 and 31.3°C during 2005; the maximum water temperature at the deep monitor was 26.1°C during 2003 and 28.4°C during 2005. During the summer of 2003, daily mean water temperatures at the near-surface monitor were equal to or higher than 25°C for 33 days, and temperatures at the deep monitor were equal to or higher than

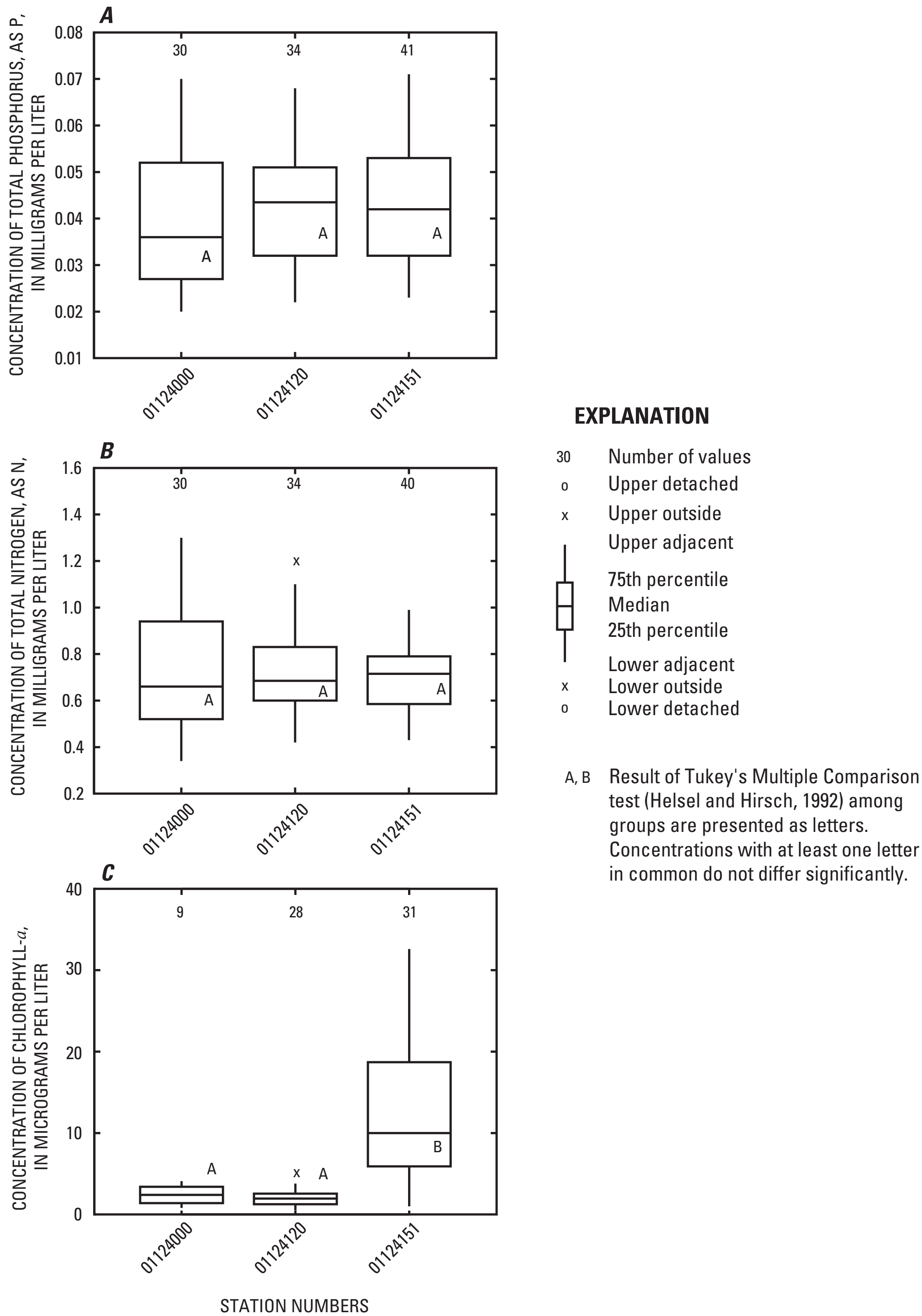


Figure 4. Distribution of concentrations of *(A)* total phosphorus, *(B)* total nitrogen, and *(C)* chlorophyll-*a* from Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), Quinebaug River at Red Bridge Road, Connecticut (USGS Site ID 01124120), and Quinebaug River at West Thompson, Connecticut (USGS Site ID 01124151).

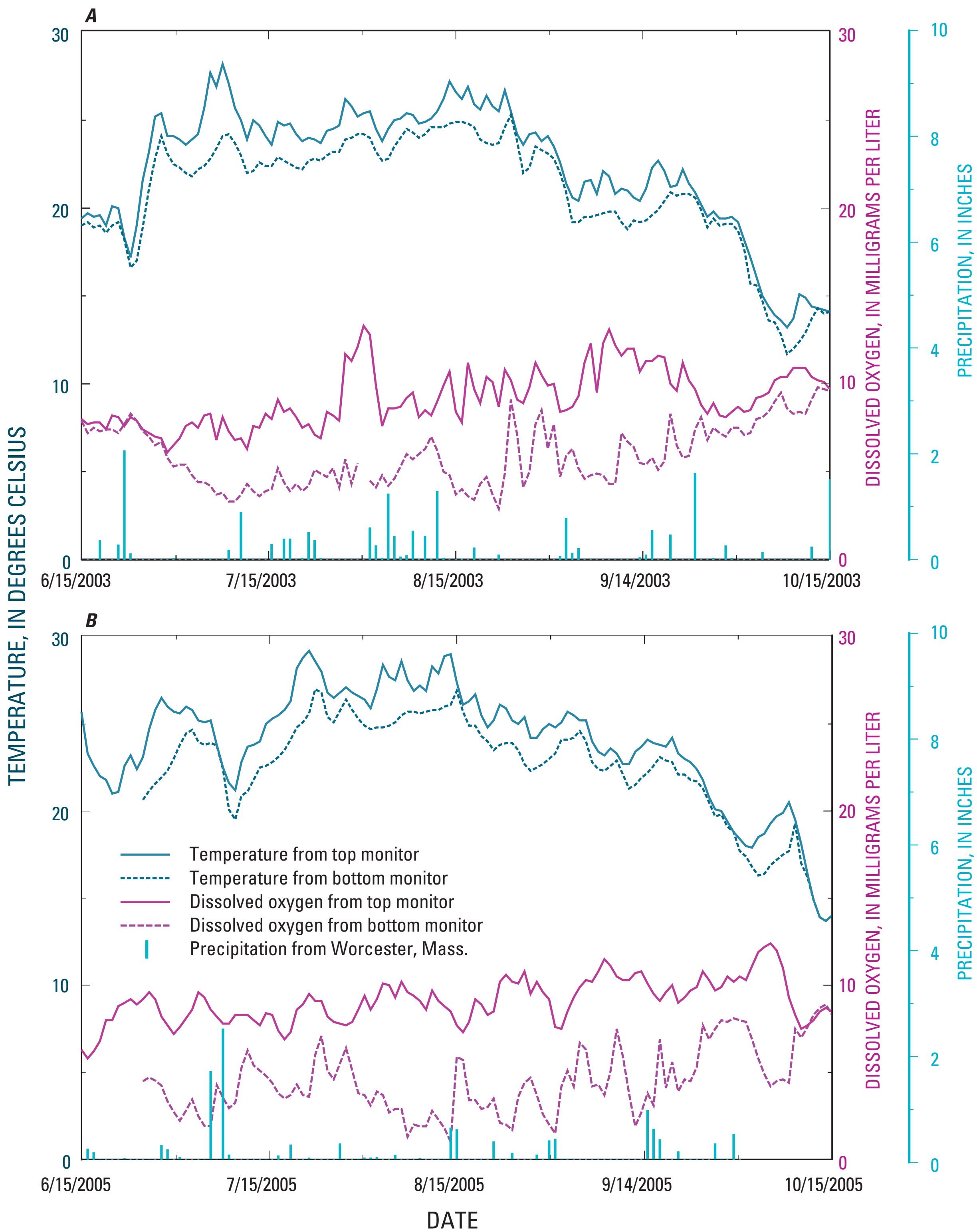


Figure 5. Continuous water-quality-monitoring data for water temperature and dissolved oxygen at the near-surface and deep monitors, West Thompson Lake at Old West Thompson Road near West Thompson (USGS Site ID 01124149) during *(A)* water year 2003 and *(B)* water year 2005.

25°C for 12 days. During the summer of 2005, daily mean water temperatures at the near-surface monitor were equal to or higher than 25°C for 59 days, and temperatures at the deep monitor were equal to or higher than 25°C for 23 days, indicating much warmer bottom water conditions during the summer of 2005.

Dissolved oxygen values changed significantly between the near-surface and deep monitors but showed similar patterns between 2003 and 2005. The water in the near surface was generally well oxygenated with values of dissolved oxygen higher than 5 mg/L; water near the deep monitor generally had lower dissolved oxygen than the surface with values ranging from almost 0 to values similar to those in the near surface. During the summer of 2003, the minimum concentration of dissolved oxygen at the near-surface monitor was 5.3 mg/L, and the daily mean concentration was 6 mg/L or higher for most of the summer (fig. 5A). The minimum concentration at the deep monitor was 0.4 mg/L, and the daily mean concentration of dissolved oxygen was below 5 mg/L for 23 days during July and 16 days in August. During the summer of 2005, the minimum concentration of dissolved oxygen at the near-surface monitor was 5.8 mg/L, and the daily mean concentration was higher than 7 mg/L on all but 7 days of the summer (fig. 5B). The minimum concentration of dissolved oxygen in the water at the deep monitor approached 0 mg/L on many days, and the daily mean concentration was below 5 mg/L on at least 6 days in June, 22 days in July, 29 days in August, and 12 days in September.

Specific conductance remained fairly stable during the summers of 2003 and 2005. In 2003, instantaneous specific conductance values ranged from 145 to 262 µS/cm at the near-surface monitor and from 162 to 267 µS/cm at the deep monitor. During 2005, specific conductance ranged from 206 to 327 µS/cm at the near-surface monitor and from 177 to 341 µS/cm at the deep monitor.

Values for pH showed some indications of diurnal changes in the near-surface water but were more stable at the bottom. During the summer of 2003, daily mean pH values ranged from 6.6 to 9.9 at the near-surface monitor, with the higher values in late August and September. Maximum pH values near the surface reached 10.2 on several days. At the deep monitor, daily mean pH values were near neutral, between 6.5 and 7.5, for most days; however, pH values ranged from 6.4 to 9.8. During the summer of 2005, daily mean pH values ranged from 6.7 to 9.8 at the near-surface monitor and reached a maximum value of 10.1, which was consistent with the values recorded during the summer of 2003. Daily mean values of pH at the deep monitor during 2005 were similar to 2003 and ranged from 6.5 to 7.8, with a maximum value of 9.0.

Concentrations of nitrogen and phosphorus in the West Thompson Lake change with depth and time of year. Typically, from June though September, West Thompson Lake stratifies thermally. Dead algae and other organic material settle into the hypolimnion (dense, lower layer) and decompose. This biochemical-oxygen demand and the sediment-oxygen demand result in the depletion of oxygen in the hypolimnion, which can cause changes in the concentration and speciation of nitrogen and phosphorus. In general, low levels of oxygen increase phosphorus solubility, and the dominant form of nitrogen becomes ammonia with low concentrations of nitrate and nitrite nitrogen.

The epilimnion (upper layer) had lower concentrations of phosphorus and ammonia nitrogen during the study than the lower layers of the lake, and the average concentration of total phosphorus in near-surface water ranged from 0.045 to 0.050 mg/L. Concentrations of nitrate and nitrite nitrogen in near-surface water averaged approximately 0.4 mg/L as nitrogen. Concentrations of dissolved phosphorus differed greatly throughout the season and with depth. Concentrations of orthophosphate were always below the detection limit (20 µg/L). Data from the lake sampling are summarized in table 7. In general, the concentrations of total phosphorus were well above than the 0.008-mg/L nutrient criteria recommended by USEPA for lakes and impoundments in aggregate Ecoregion XIV (U.S. Environmental Protection Agency, 2000c, d).

Concentrations of dissolved and total phosphorus and ammonia nitrogen increased in the hypolimnion during July, August, and September due to settling of senecing algae and phosphorus sorbed onto particles, as well as phosphorus being released from the sediments. Increases in ammonia nitrogen were due to the transformation of the oxidized form of nitrogen (nitrate and nitrite) to the more reduced form, ammonia, as well as direct release of ammonia from the sediments.

Concentrations of nitrogen and phosphorus in lake layers can change during partial or complete mixing events, typically caused by strong winds, when nutrients are redistributed through the water column. Examples of this can be seen in the changes in total phosphorus concentrations in the epilimnion, metalimnion (middle layer), and hypolimnion at sampling locations WT-1 and WT-3 during the summer of 2003 (table 7).

Stratification and Mixing in West Thompson Lake

West Thompson Lake is a shallow river impoundment that develops a weak thermal stratification (thermocline) that begins in mid-June and typically ends in mid- to late September, with a change in temperature between the upper layer and lower layer of 6 to 10°C. The weak thermal stratification can break down partially or completely, allowing water from different lake layers to mix thermally and chemically. In a typical dimictic lake, this mixing takes place two times per year—once at spring overturn and again at fall overturn. Lakes that mix more than twice a year are referred to as polymictic lakes. Based on data from the continuous water-quality monitors in West Thompson Lake, it appears that, depending on climatic conditions, the lake can develop a weak thermocline and

Table 7. Statistical summary of water-quality sampling data in West Thompson Lake, Connecticut, for water years 2003–2005.

[mg/L, milligrams per liter; µg/L, micrograms per liter; N, nitrogen; P, phosphorus; Min, minimum; Max, maximum; --, no data]

Sampling station	Year	Water-quality constituent (units)											
		Nitrate + nitrite, dissolved (mg/L as N)			Ammonia, dissolved (mg/L as N)			Nitrogen, ammonia + organic, total (mg/L as N)			Nitrogen, total (mg/L as N)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
WT-1-top	2003	<0.06	0.102	0.15	<0.04	<0.04	<0.04	0.42	0.62	0.89	0.56	0.69	0.89
WT-1-middle	2003	<0.06	0.12	0.13	<0.04	0.12	0.19	0.5	0.68	0.97	0.66	0.78	0.97
WT-1-bottom	2003	<0.06	0.09	0.12	0.46	1.01	2.28	0.82	1.61	3.1	0.95	1.68	3.1
WT-2	2003	<0.06	0.12	0.21	<0.04	0.0375	E.04	0.42	0.61	0.78	0.57	0.7	0.8
WT-3-top	2003	<0.06	0.095	0.14	<0.04	<0.04	<0.04	0.44	0.62	0.85	0.57	0.68	0.8
WT-3-middle	2003	<0.06	0.06	0.07	<0.04	<0.04	<0.04	0.47	0.65	0.84	0.54	0.67	1.1
WT-3-bottom	2003	<0.06	0.08	0.15	0.04	1.56	3.15	0.44	2.11	3.8	0.6	2.15	3.8
WT-3-top	2004	0.11	0.15	0.23	<0.04	<0.04	<0.04	0.53	0.54	0.66	0.56	0.69	0.77
WT-3-middle	2004	<0.06	0.16	0.24	0.07	0.17	0.29	0.53	0.73	1.1	0.74	0.87	1.1
WT-3-bottom	2004	<0.06	<0.06	<0.06	0.83	2.74	4.47	1.1	3.1	4.9	1.1	3.13	4.9
WT-1-top	2005	E.04	0.135	0.28	E.02	0.03	<0.04	0.44	0.62	0.88	0.66	0.73	0.88
WT-1-middle	2005	E.04	0.105	0.17	E.02	0.025	E.03	0.61	0.635	0.66	0.66	0.725	0.79
WT-1-bottom	2005	<0.06	0.1	0.22	0.08	0.725	1.13	0.47	1.34	1.9	0.69	1.4	1.9
WT-3-top	2005	<0.06	0.12	0.23	<0.04	<0.04	<0.04	0.52	0.64	0.75	0.65	0.73	0.78
WT-3-middle	2005	<0.06	0.15	0.24	E.02	0.175	0.4	0.4	0.68	0.94	0.63	0.8	0.94
WT-3-bottom	2005	<0.06	0.1	0.22	0.24	1.47	2.69	0.57	1.94	3.3	0.79	2	3.3

Sampling station	Year	Water-quality constituent (units)											
		Orthophosphate, dissolved, (mg/L as P)			Phosphorus, dissolved (mg/L as P)			Phosphorus, total (mg/L as P)			Chlorophyll-*a*, phytoplankton (µg/L)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
WT-1-top	2003	<0.02	<0.02	<0.02	0.011	0.016	0.019	0.04	0.05	0.062	6.9	15.2	26.5
WT-1-middle	2003	<0.02	<0.02	<0.02	0.01	0.015	0.16	0.047	0.06	0.074	--	--	--
WT-1-bottom	2003	<0.02	0.06	0.13	0.016	0.047	0.106	0.066	0.108	0.189	--	--	--
WT-2	2003	<0.02	<0.02	<0.02	0.012	0.017	0.022	0.04	0.051	0.061	2.3	12.9	26.5
WT-3-top	2003	<0.02	<0.02	E.01	0.013	0.016	0.018	0.037	0.051	0.064	7.7	15.2	24.6
WT-3-middle	2003	<0.02	<0.02	E.01	0.008	0.012	0.016	0.03	0.046	0.066	--	--	--
WT-3-bottom	2003	<0.02	0.02	0.03	0.02	0.029	0.039	0.041	0.058	0.075	--	--	--
WT-3-top	2004	<0.02	<0.02	<0.02	0.018	0.019	0.021	0.037	0.041	0.05	5.8	10	15.6
WT-3-middle	2004	<0.02	<0.02	<0.02	0.013	0.013	0.014	0.044	0.062	0.084	--	--	--
WT-3-bottom	2004	<0.02	<0.02	<0.02	0.01	0.022	0.039	0.036	0.056	0.079	--	--	--
WT-1-top	2005	<0.02	<0.02	<0.02	0.008	0.014	0.018	0.039	0.042	0.045	7.1	17.1	30.2
WT-1-middle	2005	<0.02	<0.02	<0.02	0.011	0.014	0.017	0.025	0.041	0.057	--	--	--
WT-1-bottom	2005	<0.02	<0.02	E.01	E.004	0.018	0.032	0.038	0.068	0.094	--	--	--
WT-3-top	2005	<0.02	<0.02	<0.02	0.011	0.015	0.019	0.028	0.04	0.05	9.9	18.3	32.6
WT-3-middle	2005	<0.02	<0.02	<0.02	0.005	0.01	0.013	0.027	0.037	0.045	--	--	--
WT-3-bottom	2005	<0.02	<0.02	<0.02	0.005	0.014	0.021	0.028	0.041	0.049	--	--	--

stratify for most of the summer or may stratify and mix several times during the summer.

Periods of thermal and dissolved oxygen stratification can be seen in the continuous water-quality-monitor data for West Thompson Lake in both the 2003 and 2005 water years (figs. 5A and 5B). In May and early June, water temperature and dissolved oxygen data, collected at 15-minute intervals, are similar near the surface and at a depth of 12 ft. The values then gradually diverge: water temperature increases rapidly near the surface and stays warmer than the temperature at depth, and concentrations of dissolved oxygen increase near the surface and decrease, approaching zero, at depth. In September, the concentrations of dissolved oxygen become similar again.

During 2003 and 2005, the water temperatures and dissolved oxygen concentrations were similar for several brief periods during the summer, indicating a breakdown in the thermal and chemical stratification, and mixing of the lake layers. During summer 2003, water temperature and dissolved oxygen concentrations appear to have been similar several times, indicating possible mixing events—June 22 and 28, August 24 and 28, and September 19 and 23. During summer 2005, potential mixing events took place on July 24 and 28, and August 15.

The pattern of thermal and chemical stratification also is apparent from the water-temperature and dissolved oxygen profiles collected on sampling days throughout the study (figs. 6, 7, and 8). Thermal and chemical stratification based on dissolved oxygen concentrations, intensifies throughout the summer season until the fall overturn, after which the lake is completely mixed. Concentrations of total phosphorus increased in the lower layer of the lake throughout the summer of 2003 at the WT-1 and WT-3 sampling locations (fig. 6). At these locations, the concentration of total phosphorus in the upper and middle layers can increase or decrease throughout the summer. In summer 2004, the concentration of total phosphorus increased steadily in the middle and lower layers at WT-3 (fig. 7). In the summer of 2005, the same pattern was evident—increasing concentration of total phosphorus in the lower layer of the lake throughout the summer, as well as the variable pattern of increasing and decreasing concentrations of total phosphorus in the middle and upper layers (fig. 8). The largest and most consistent pattern of increasing total phosphorus concentration in the lower layer of the lake was observed during the summers of 2003 and 2004 at WT-1. A persistent anoxic layer at 12 ft typically forms here during the summer, which may contribute to the increasing concentration of total phosphorus in this layer. Because of the shallow water depths in the area near WT-1 and its location in the middle of the lake, the potential for water with higher concentrations of total phosphorus from the lower and middle layers mixing with the upper layer is high. As can be seen on figures 6–8, total phosphorus can accumulate in the lower and middle layers of the lake during stratification, probably due to release of the phosphorus from sediments under anoxic conditions and a lack of uptake. Then, during a complete or partial lake-mixing event, this total phosphorus (and possibly nitrogen in the form of ammonia) may be redistributed to the upper layer of the lake and become available for uptake and growth of algae. Also, in areas of the lake where water depths range from 10–12 ft (WT-1) the middle layer of the lake is in contact with the sediment. This could allow phosphorus and nitrogen to diffuse from the lake-bottom sediments directly into the middle layer of the lake when there are anoxic conditions in the overlying waters.

Algal Dynamics in West Thompson Lake

Many studies have been done relating water quality, nutrient concentrations, and chlorophyll-*a* concentrations with algal productivity and trophic classification (Vollenweider, 1968; Dillon and Rigler, 1974; and Carlson, 1977). These studies indicate that algal productivity, typically measured as chlorophyll-*a* concentration, are directly related to, and often controlled or limited by, the concentrations of phosphorus and nitrogen in the water column.

Chlorophyll-*a* and Algal Cell Density and Community Composition

Chlorophyll-*a* samples were collected during lake-sampling events and periodically during visits to inspect the continuous water-quality monitors (fig. 9). A continuous chlorophyll-*a* sensor was deployed with the near-surface continuous water-quality monitor during the summer of 2005 to augment the periodic sampling. Results from the continuous chlorophyll-*a* sensor are shown in figure 10. During the early part of the summer, the daily mean value of chlorophyll-*a* from the sensor closely matched the concentration of chlorophyll-*a* collected as a grab sample. By approximately halfway through the summer, the daily mean value from the monitor was much lower than the concentration of chlorophyll-*a* collected as a grab sample, and the daily maximum value for the sensor matched the concentration of chlorophyll-*a* collected as a grab sample. This change could be related to a shift in the composition of the algal community. During this period, the daily maximum value is thought to give a better estimate of the trend in concentrations of chlorophyll-*a* in the lake.

Algal cell counts and community composition were analyzed in samples collected during 2003 and 2005 by Guy Hoffman of the CTDEP, and results are shown in figure 6. Algal cell counts ranged from less than 1,000 to 73,000 (July 2003); large algal cell counts were typically dominated by the blue-green algae *Anacystis sp.* and *Anabaena sp*. Algal cell counts typically are lowest in the beginning of the summer and increase as a result of algal blooms through the summer growing period; the population of algae in the lake may

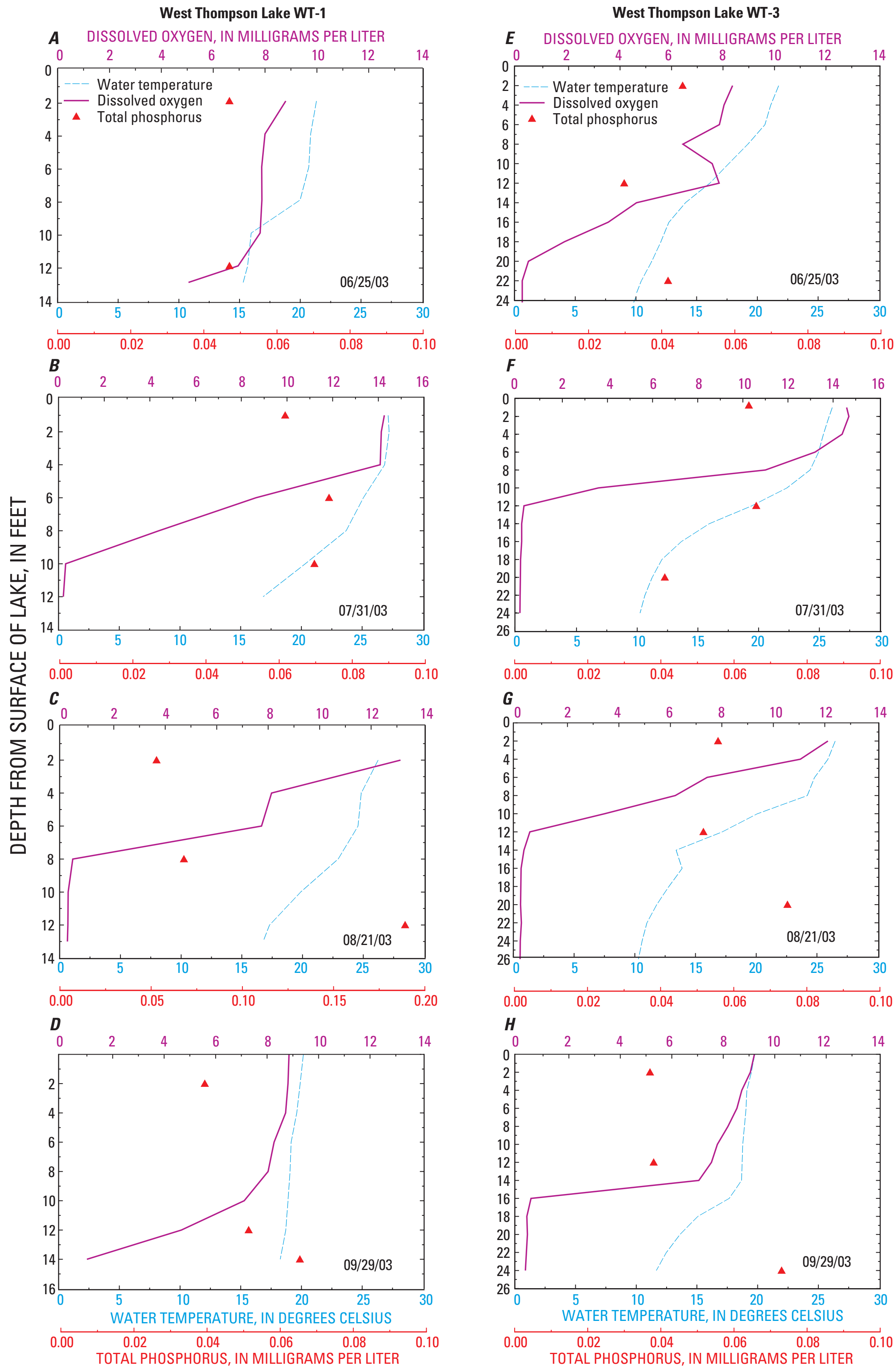


Figure 6. Profiles of water temperature data and concentrations of dissolved oxygen and total phosphorus from stations WT-1 and WT-3, West Thompson Lake, Connecticut, summer 2003.

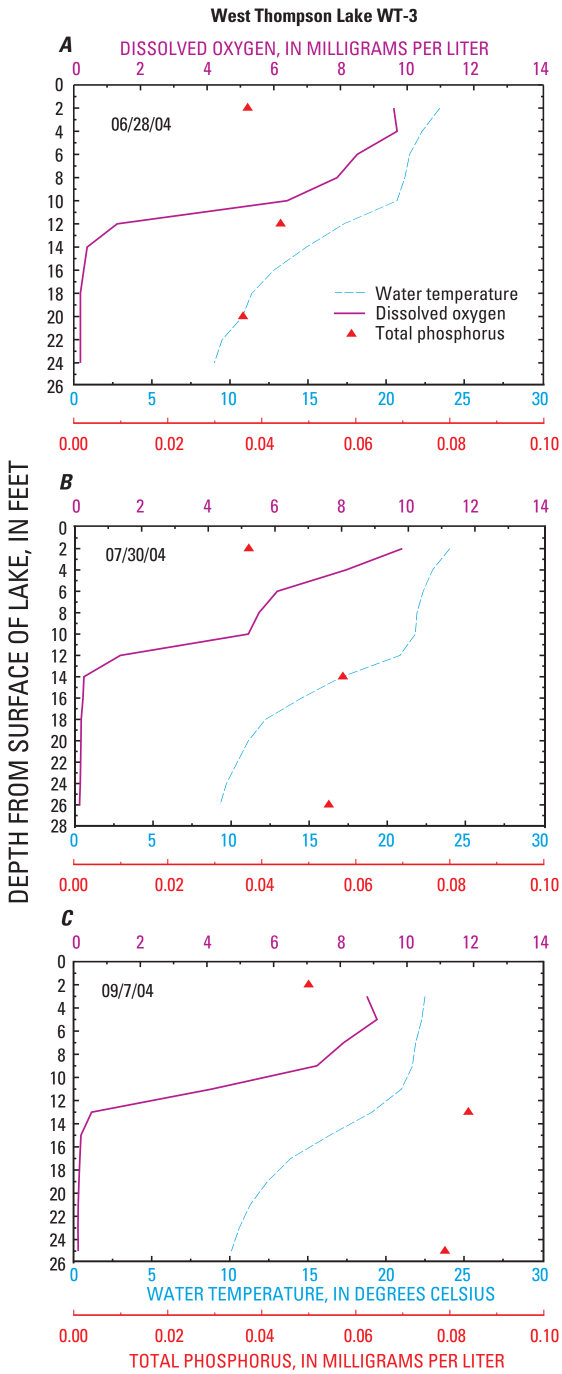


Figure 7. Profiles of water temperature data and concentrations of dissolved oxygen and total phosphorus from station WT-3, West Thompson Lake, Connecticut, summer 2004.

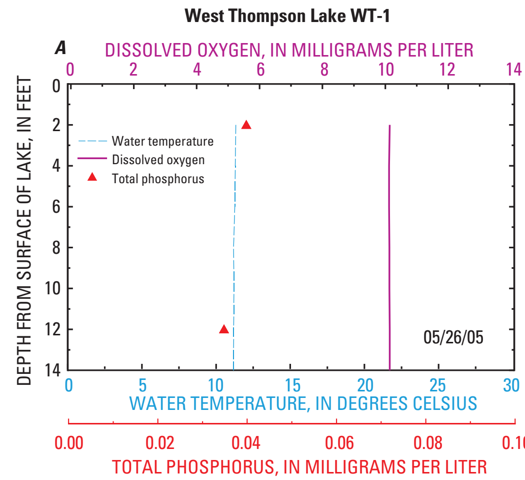


Figure 8. Profiles of water temperature data and concentrations of dissolved oxygen and total phosphorus from stations WT-1 and WT-3, West Thompson Lake, Connecticut, summer 2005.

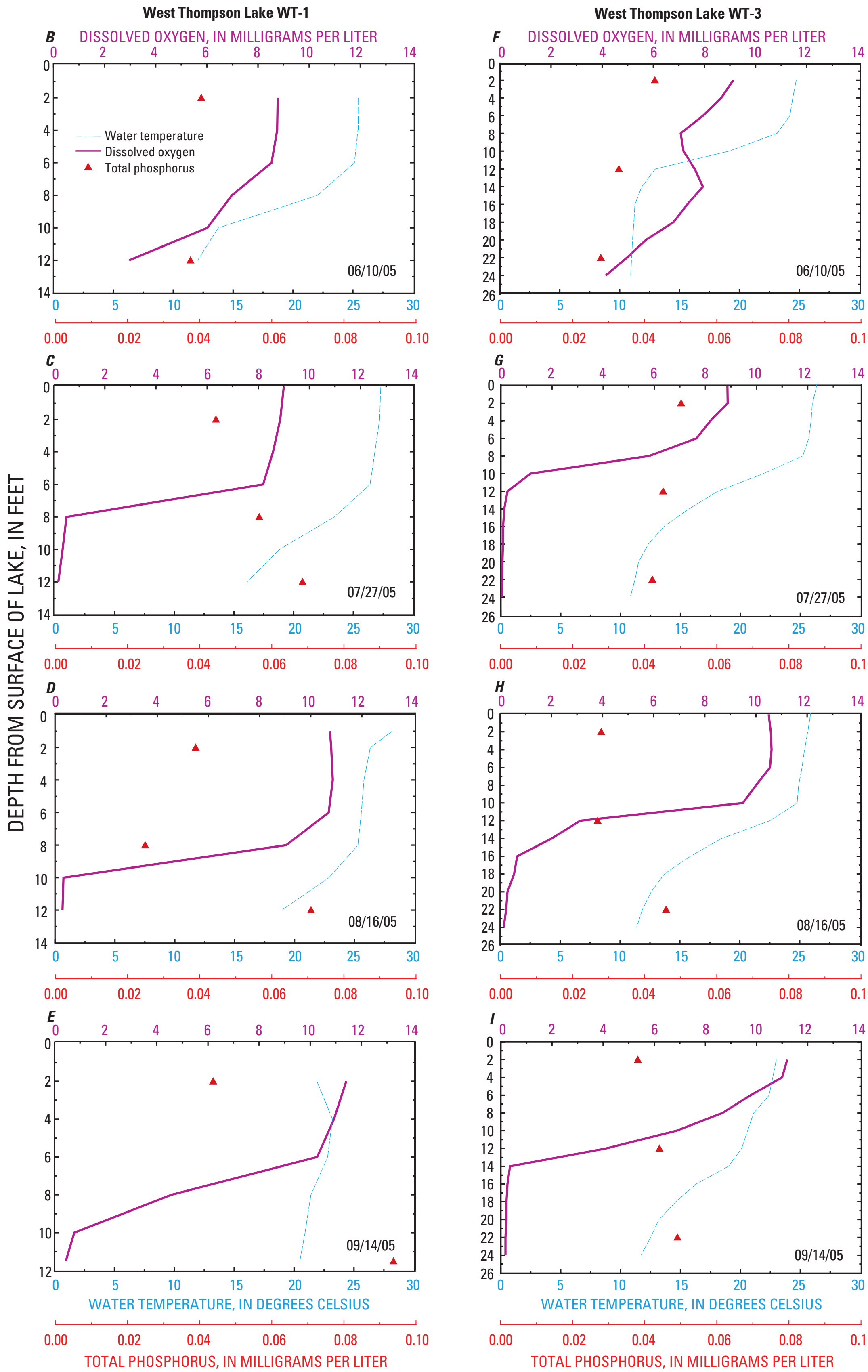


Figure 8. Profiles of water temperature data and concentrations of dissolved oxygen and total phosphorus from stations WT-1 and WT-3, West Thompson Lake, Connecticut, summer 2005.—Continued

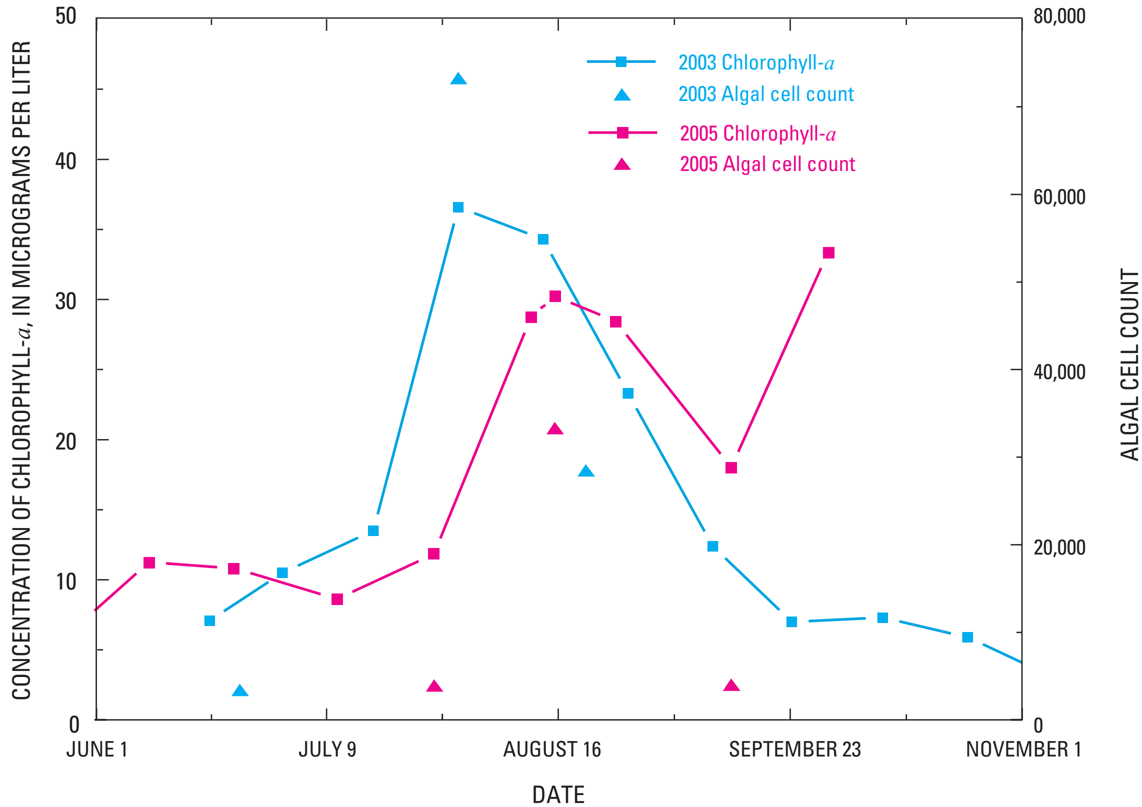


Figure 9. Concentrations of chlorophyll-*a* and algal cell counts in West Thompson Lake, June to September 2003 and 2005.

increase, peak (bloom), and decrease (crash) more than once during the summer and fall growing seasons based on climatic conditions. Blooms and crashes are the result of changes in nutrient levels (including nutrient limitation), mixing from storms and runoff events in the upstream watershed, and changes in the algal community.

Carlson Trophic-State Index

The Carlson Trophic-State Index (TSI) is a commonly used index of productivity or trophic status in lakes (Carlson, 1977). This index is based on Secchi depth and indicators of productivity calculated from concentrations of total phosphorus and chlorophyll-*a* from the near surface of a lake. The TSI scores are calculated using the following formulas:

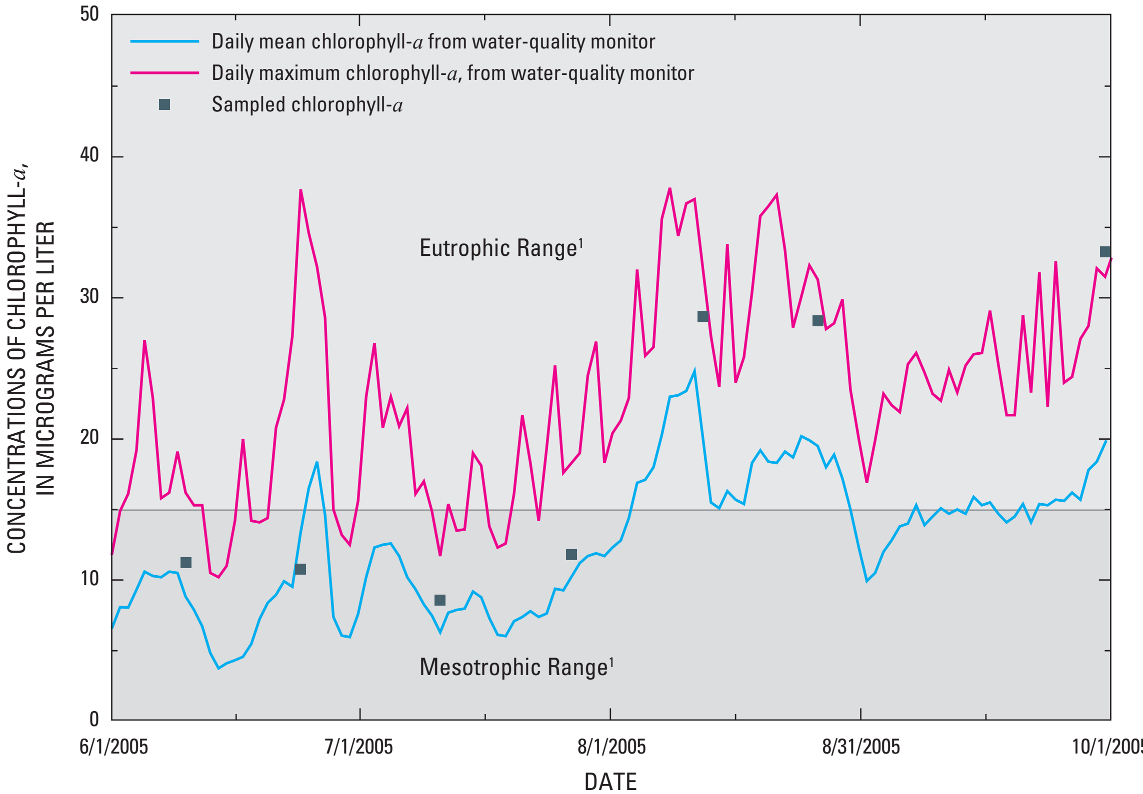
TSI Secchi depth = 60–14.41 ln Secchi depth (in m),
TSI total phosphorus = 14.42 ln total phosphorus (in µg/L) + 4.15, and
TSI chlorophyll-*a* = 9.81 ln chlorophyll-*a* (in µg/L) + 30.6,

where
TSI is the Carlson Trophic-State Index, and
ln is the natural logarithm.

The TSI scores calculated for each variable are plotted on the same scale to determine if each TSI score is giving the same result. Ranges of TSI scores are grouped into trophic-state classifications:

0–40: generally low nutrients, oligotrophic (minimally productive)
40–50: moderate nutrients, mesotrophic (moderately productive)
50–60: high nutrients, eutrophic (productive)
> 60: high nutrients, hypereutrophic (highly productive)

TSI scores for West Thompson Lake at station WT-3 were at or above 70 (hypereutrophic) in 1990 and in the 50 to 70 range (eutrophic–hypereutrophic) in samples collected during 2003 and 2005 (fig. 11). This indicates that the trophic status of the lake has decreased since the early 1990s suggesting that its nutrient supply and productivity have decreased; however, it is still in the eutrophic range.



[1] Water-quality standard, Connecticut Department of Environmental Protection, 1996.

Figure 10. Continuous chlorophyll-*a* sensor data from West Thompson Lake at Old West Thompson Road near West Thompson, Connecticut (USGS Site ID 01124149), June 2005–September 2005.

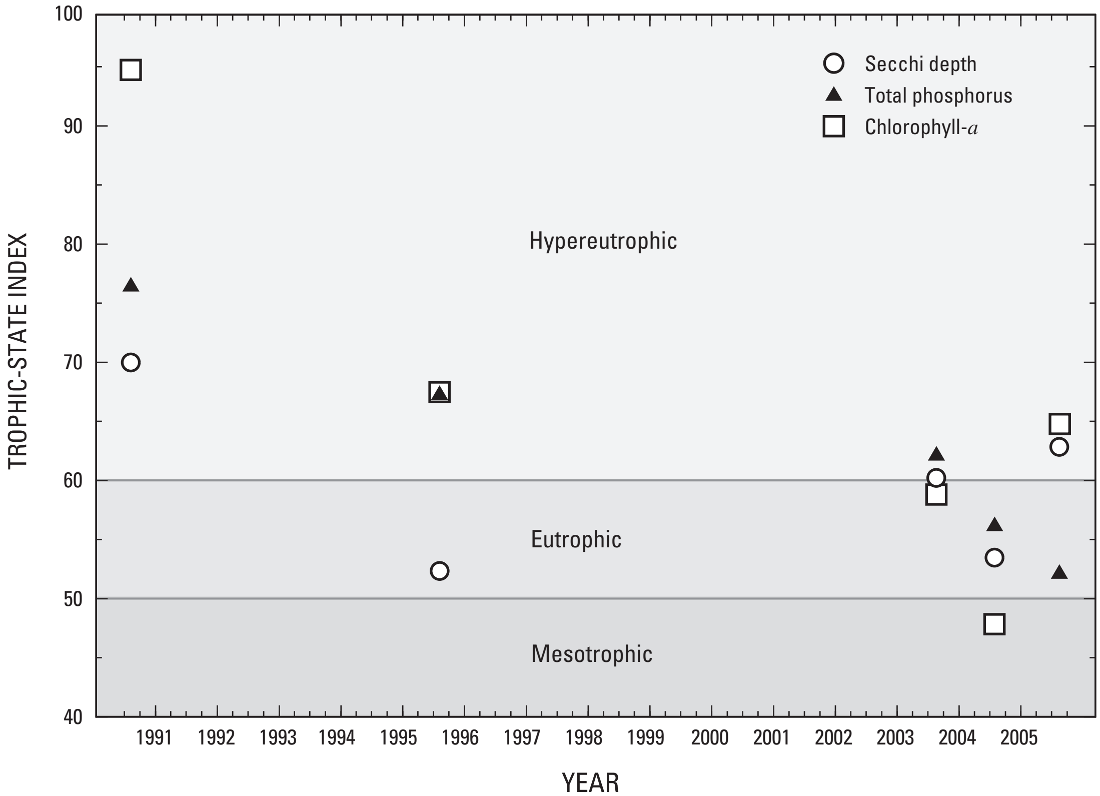


Figure 11. Carlson trophic-state indexes for samples collected near the deep hole sampling station (WT-3) from West Thompson Lake, Connecticut, 1990 to 2005.

Redfield Ratios

The ratio of nitrogen to phosphorus, called the Redfield ratio (Redfield, 1958), can indicate which nutrient limits algal growth in a water body. Redfield ratios are based on the stochiometric elemental composition of freshwater algae and the 16:1 molar ratio of nitrogen to phosphorus, which converts to a ratio of 7.5:1 mg/L. Redfield ratios of nitrogen to phosphorus less than 16:1 in water may indicate that nitrogen is limiting the growth of algae; assuming no other limitations, Redfield ratios higher than 16:1 in water may indicate that phosphorus is the limiting nutrient (Cook and others, 2005).

In West Thompson Lake, Redfield ratios of total nitrogen to total phosphorus from the near-surface water at WT-3 ranged from 25:1 to 139:1, indicating phosphorus is the limiting nutrient for algal growth in the majority of the samples taken. At WT-1, however, the sample collected on August 16, 2005, indicated it may have been co-limited by nitrogen.

Most Redfield ratios of dissolved nutrients in West Thompson Lake indicated even more strongly that phosphorus is limiting algal growth. In addition to the Redfield ratios, concentrations of orthophosphate in the water column were generally less than 0.02 mg/L, indicating that the most bioavailable form of phosphorus was unavailable.

Algal Growth Potential and Limiting Nutrient Analysis

Results of the Algal Growth Potential (AGP) test and limiting nutrient tests from July and August 2005 are shown in table 8. All samples collected on July 27 and August 16 had similar AGP and were all much less than the reference sample for freshwater algal-growth media. Samples collected on July 27 that were spiked with phosphorus or combinations of phosphorus and other nutrients had increased growth relative to the other treatments. This indicates that, at the time these samples were collected, algal growth was limited by phosphorus. The limiting nutrient tests performed on the sample collected on August 16, 2005, indicate that the sample from WT-1 at 12 ft was probably phosphorus limited, but samples from the other three locations were probably co-limited by phosphorus and nitrogen. The water-chemistry data collected on that day also show very little inorganic nitrogen was available (non-detects in the near-surface samples for nitrate and nitrite and dissolved ammonia). The Redfield ratios are fairly low, in the nitrogen-limited range, indicating the samples are possibly co-limited. The continuous chlorophyll-*a* data from the lake indicated that August 16, 2005, samples were collected at the end of what appeared to be the largest algal bloom of the summer (fig. 10).

Table 8. Results of algal limiting-growth analysis and nutrient concentrations from West Thompson Lake, summer 2005.

[Numbers in parentheses indicate control samples with no additional nutrients added; TN, total nitrogen; DN, dissolved nitrogen; TP, total phosphorus; DP, dissolved phosphorus; ft, feet; <, less than; --, no data]

July 27, 2005

Treatment (nutrient additions)	Control sample	Lake sampling station			
		WT-1 at 2 ft	WT-1 at 12 ft	WT-3 at 2 ft	WT-3 at 12 ft
Algal growth potential	88.3	2.6	3.1	1.1	1.8
Nitrogen (N)[1]	(5.2) 47.5	2.7	2.1	1.5	3.7
Phosphorus (P)[2]	(0.3) 55.6	11.6	6.9	2.8	9.8
EDTA (E)	(98.7) 91.8	0	2.6	0	2.7
N and P	--	13.1	17	10.5	8.2
N and E	--	0.2	1.7	2.5	2.8
P and E	--	14.2	20.1	11.5	21.3
N, P, and E	--	52.5	46.8	52.2	50.8
Water-sample concentration data					
Nitrite + nitrate, dissolved (mg/L as N)		0.16	<0.06	0.15	<0.06
Nitrogen, ammonia dissolved (mg/L as N)		0.02	1.07	<0.04	1.18
Nitrogen, ammonia + organic, total (mg/L as N)		0.51	1.7	0.63	1.6
Nitrogen, total (mg/L as N)		0.67	[3]1.7	0.78	[3]1.6
Phosphorus, ortho, dissolved (mg/L as P)		<0.02	<0.02	<0.02	<0.02
Phosphorus, dissolved (mg/L as P)		0.018	0.013	0.019	0.012
Phosphorus, total (mg/L as P)		0.045	0.069	0.050	0.042
Chlorophyll-*a* (µg/L)		13	--	12.4	--
Ratio TN/TP (mg/L/mg/L)		14.9	459.4	15.6	752.4
Ratio DN/DP (mg/L/mg/L)		10.0	86.9	10.0	103.3

August 16, 2005

Treatment	Control sample	Lake sampling station			
		WT-1 at 2 ft	WT-1 at 12 ft	WT-3 at 2 ft	WT-3 at 12 ft
Algal growth potential	94.4	6.4	1.6	7.6	6.8
Nitrogen (N)[1]	(8.9) 51.7	3	2.3	6.5	6.2
Phosphorus (P)[2]	(5.6) 52.2	10.7	20.2	9.7	8
EDTA (E)	(114) 126	5.2	1.1	8.1	6.3
N and P	--	26	8.8	17.6	25.9
N and E	--	8.8	1.3	5.1	6.2
P and E	--	8.7	61	9	10.6
N, P, and E	--	52.9	66.7	56.8	49.3
Water-sample concentration data					
Nitrite + nitrate, dissolved (mg/L as N)		E0.04	<0.06	<0.06	<0.06
Nitrogen, ammonia dissolved (mg/L as N)		E0.03	1.13	<0.04	1.76
Nitrogen, ammonia + organic, total (mg/L as N)		0.88	1.9	0.75	2.3
Nitrogen, total (mg/L as N)		[3]0.88	[3]1.9	[3]0.75	[3]2.3
Phosphorus, ortho, dissolved (mg/L as P)		<0.02	E.01	<0.02	<0.18
Phosphorus, dissolved (mg/L as P)		0.014	0.032	0.014	0.021
Phosphorus, total (mg/L as P)		0.039	0.071	0.028	0.046
Chlorophyll-*a* (µg/L)		30.2	--	32.6	--
Ratio TN/TP (mg/L/mg/L)		22.6	26.8	26.8	50.0
Ratio DN/DP (mg/L/mg/L)		5.0	37.2	7.1	86.7

[1] 1.0 mg/L N, as nitrogen.

[2] 0.05 mg/L P, as phosphorus, and 1.0 mg/L EDTA.

[3] Calculated by method described by Mullaney and Zimmerman, 1997.

Characteristics of Lake-Bottom Sediments

In general, phosphorus can settle out of the water column of a lake and be stored in the lake-bottom sediment that is deposited over time. This stored phosphorus can continue to accumulate in the sediment for many years and be removed from the water or under certain conditions it can be re-released back into the water column of the lake. Soft sediment has accumulated on what was once the land surface before the West Thompson Lake dam was constructed. In some parts of the lake, these soft sediments may be exposed to hypoxic conditions and subsequently release phosphorus to the water column.

Sediment Thickness and Distribution

The soil and fluvial sediment underlying the lake sediment is much more compact than the lake sediment, so the thickness of the lake sediment can be determined by probing with a fixed rod. Lake sediment thickness in the areas where samples were collected ranged from 0.3 ft in the southern part of the lake to 3.5 ft in the middle (table 9; fig. 12). Most sediment samples were from areas where water was deeper than or equal to 10 ft. Some shallower areas were sampled; however, the probing technique used generally gave poor results in shallow areas, probably because the sediment was coarser in those areas. The thickest sediments were found in four areas: (1) the pre-lake river channel, (2) the northeastern part of the lake, (3) the southern part of the lake, (4) a deep hole in the southwestern part of the lake. These areas were expected to have the thickest accumulations because they are the deeper sections of the lake and are not subject to reworking. Cores from areas 1, 2, and 3 were very similar, with little visible layering or structure in the dark brown, cohesive, and very-fine-grained samples. A particle-size analysis from the cores indicated that 42 to 97 percent of the sediment was in the silt- or finer-size range and 22 to 56 percent of the sediment was in the clay-size range.

The sediment thickness in the deep hole in the southwestern part of the lake (area 4) was 2.85 ft, with the top 0.6 ft being modern or post dam construction. Below this was 1.3 ft of disturbed material with angular rock chunks, probably deposited during the construction of the dam. This was underlain by 0.95 ft of denser, slightly lighter-colored sediment that is thought to be from a pre-lake pond that existed at this location.

There are several age-dating techniques using isotopes of lead (Pb 210) and cesium that are currently available for age-dating modern sediment; however, they were outside the scope of this project. Therefore, sediment accumulation rates were calculated assuming a constant rate, by dividing sediment thickness by 39, the number of years since the construction of the impoundment. Sediment accumulation rates ranged from 0.008 to 0.090 ft/yr. This method for determining accumulation rate and relative age of sediment layers is for use as a general indicator and may be subject to errors. The largest potential source of error is associated with sediment focusing in the deeper portions of the lake. This occurs when sediments are re-suspended from shallow areas within the lake and accumulate in the deeper portions of the lake.

Concentrations of Phosphorus in Lake-Bottom Sediments

Most phosphorus entering a lake is in particulate form, and it generally settles to the bottom and becomes associated with the lake-bottom sediments. The phosphorus is not irreversibly bound to the sediments, however, and can be mobilized by chemical reactions or transformations. In well-oxygenated water, phosphorus can bond with ferric iron and settle out of the water; it is considered to be insoluble. Over time this phosphorus accumulates in the sediments. In water with little to no oxygen, phosphorus can bond with ferrous iron and remain soluble. Other cations, principally calcium and aluminum, can bond with phosphorus and form insoluble particulate forms of phosphorus. During seasonal stratification in lakes and ponds, oxygenated water at depth is replaced with water with little or no oxygen. Under this condition, iron-bound phosphorus in the sediments can convert from the insoluble form to the soluble form and be released from the sediments. This source of phosphorus from sediment is commonly referred to as “internal load,” and, in some lakes, can be a significant source of phosphorus during the summer and fall algal growing seasons.

Prior to this study, little information was available about whether phosphorus concentrations in the sediments in West Thompson Lake were high enough to contribute a significant internal load to the lake. Concentrations of total phosphorus from the initial round of sediment coring in 2003 ranged from 1,100 to 3,200 mg/kg in the upper 2 in. of the sediments. Total phosphorus concentrations were sampled at deeper sections in three cores—WTS-6B, WTS-12, and WTS-21. The phosphorus concentrations in cores WTS-12 and WTS-21 (at depths of approximately 7.9 to 11.8 in.) were 5,100 mg/kg and 3,400 mg/kg, respectively; these values were higher than the concentrations at the top of the cores. The core from WTS-6B had the lowest concentration of total phosphorus, 860 mg/kg, at approximately 23.6 in. This is thought to be from a small pond that existed in the area before West Thompson Lake. The mean concentration of total phosphorus (1,980 mg/kg) in the upper layer of sediment from West Thompson Lake is somewhat higher than the mean concentrations in the Assabet River outside of Boston, Mass. (1,600 mg/kg), which has received wastewater for many years (Zimmerman and Sorenson, 2005). The mean concentration of total phosphorus in West Thompson Lake sediments also is comparable to results reported by Robertson for several embayments in Lake Geneva,

Table 9. Sampling locations, sediment thickness, sediment recovery, and concentrations of total phosphorus from sediment cores collected in West Thompson Lake, Connecticut, 2003.

[mg/kg, milligram per kilogram; --, not available]

Sediment collection identifier	Date	Time	Water depth (feet)	Sediment thickness (feet)	Sediment core recovery (feet)	Sampling interval analyzed (inches)	Concentration of total phosphorus dry weight (mg/kg)	Moisture (percent by weight)
WTS-1	8/19/03	10:00	10.0	1.35	0.90	0–2.0	1,600	50
WTS-2	8/19/03	10:45	11.0	0.95	0.55	0–2.0	1,200	41
WTS-3	8/19/03	11:30	20.5	2.00	1.65	0–2.0	1,500	56
WTS-4	8/19/03	12:10	14.5	1.55	1.65	0–2.0	2,200	74
WTS-5	8/19/03	12:45	10.0	0.30	0.00	0–2.0	--	--
WTS-6A	8/19/03	13:15	22.0	2.85	2.30	0–2.0	2,800	74
WTS-6B	8/19/03	13:16	22.0	2.85	2.30	21.6–23.6	860	--
WTS-7	8/20/03	09:30	10.5	0.80	0.00	0–2.0	--	--
WTS-8	8/20/03	09:51	26.0	1.30	1.25	0–2.0	2,400	78
WTS-9	8/20/03	10:30	14.0	2.50	2.20	0–2.0	1,100	54
WTS-10	8/20/03	11:30	10.0	0.80	0.75	0–2.0	2,300	60
WTS-11	8/20/03	12:05	9.5	1.40	1.30	0–2.0	2,700	81
WTS-12A	8/20/03	12:45	13.5	3.15	3.00	0–2.0	3,200	78
WTS-12B	8/20/03	12:46	13.5	3.15	3.00	9.8–11.8	5,100	78
WTS-13	8/20/03	13:15	13.0	1.90	1.75	0–2.0	3,100	82
WTS-14	8/20/03	13:30	10.5	2.20	2.40	0–2.0	1,800	67
WTS-15	9/15/03	09:45	10.5	1.70	1.40	0–2.0	1,100	39
WTS-16	9/15/03	10:05	10.0	0.60	0.45	0–2.0	1,400	47
WTS-17	9/15/03	10:25	14.5	1.10	0.55	0–2.0	3,100	77
WTS-18	9/15/03	11:15	11.0	0.80	0.65	0–2.0	1,700	54
WTS-19	9/15/03	11:30	7.0	0.55	0.55	0–2.0	1,400	45
WTS-20	9/15/03	11:45	11.5	1.30	1.20	0–2.0	1,100	51
WTS-21A	9/15/03	12:00	9.5	3.50	3.40	0–2.0	2,500	73
WTS-21B	9/15/03	12:01	9.5	3.50	3.40	9.8–11.8	3,400	73
WTS-22	9/15/03	12:25	7.0	0.70	0.70	0–2.0	1,800	63
WTS-23	9/15/03	12:45	5.5	1.10	1.10	0–2.0	1,500	61

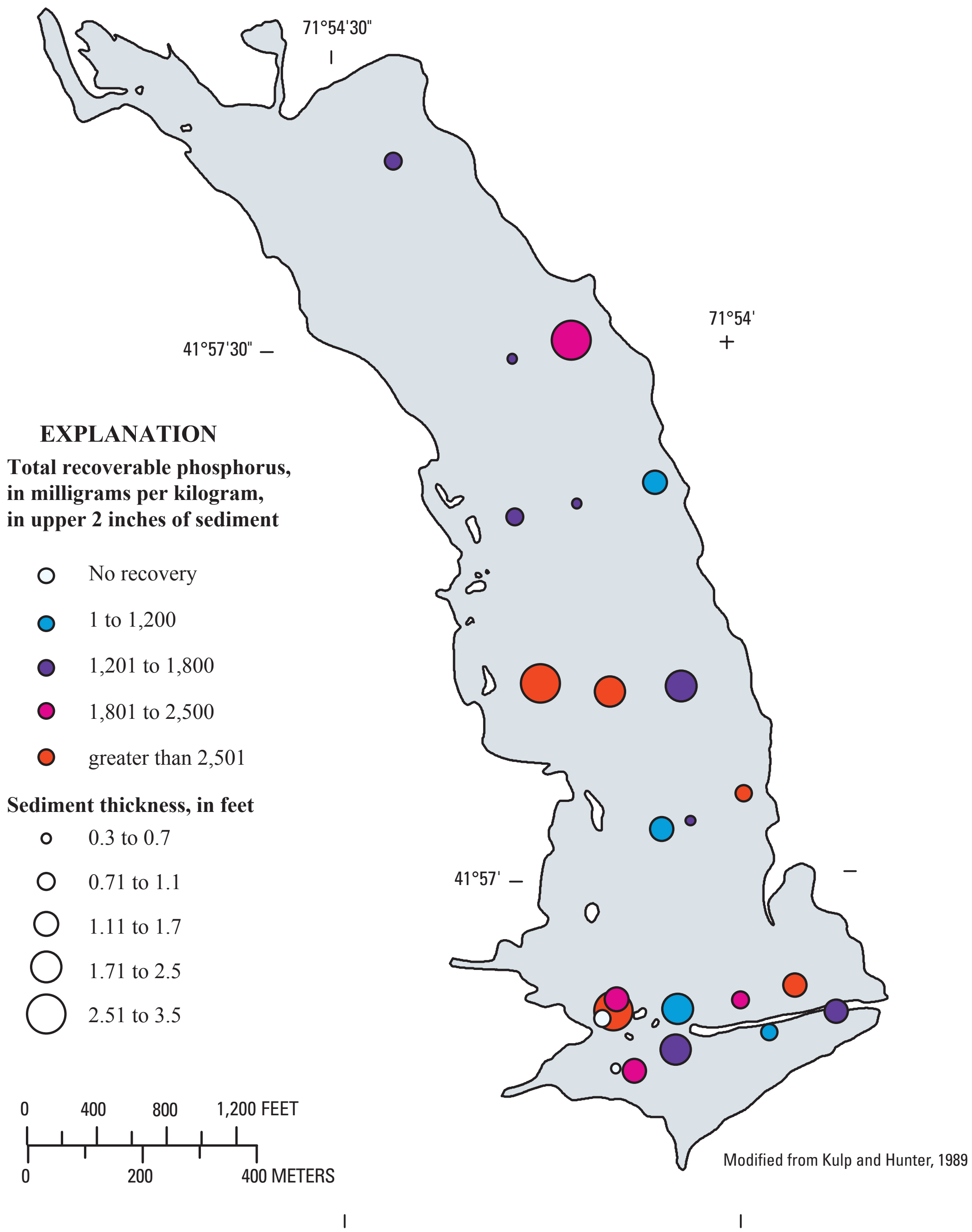


Figure 12. Sediment thicknesses and total phosphorus concentrations from upper 2 inches of sediment cores collected in West Thompson Lake, Connecticut, water year 2003.

Wisconsin, which has had increased urban inputs (780–1,610 mg/kg) (Elder and others, 2000).

Additional sediment cores were collected in 2004 from two different locations, WTS-12 and WTS-17 (table 10). These areas had the thickest sediment accumulation and provided the greatest sample mass per year for analysis. The potential for sediment disturbance also was lowest in these areas. Subsamples of these cores, taken every 1.2 in., were analyzed for concentrations of total phosphorus. A replicate core was collected and analyzed from WTS-12 to determine variability at one location. The results from the detailed core sampling indicate that phosphorus concentrations increased gradually from 0 to 5.9 in. Below 5.9 in., concentrations of phosphorus in the cores increased dramatically, by almost a factor of 2 (fig. 13). The concentrations from the two cores from WTS-12 matched closely to a depth of about 17.7 in. where the concentrations began to show variation. The pattern of increasing concentration at depth was also evident in the core from WTS-17 (table 10).

Results from a study by Søndergaard and others (1999) of Lake Søbygaard in Denmark indicate a pattern of phosphorus accumulations in sediment similar to that in West Thompson Lake. The Danish study examined the concentrations of phosphorus in sediment cores three times after external loads to the lake were reduced. In each sampling round, concentrations of phosphorus in the sediments throughout the entire 11.8 in. core were less than concentrations in the previous round. The concentration of phosphorus was reduced by half to depths of 9.8 in. during the 13-year period. This indicates that phosphorus stored in the lake-bottom sediments was being mobilized to a depth of 9.8 in., contradicting the common belief that only phosphorus in the near-surface sediments, less than 3.8 in. deep, interacts with the lake water. It is possible that the high concentrations of phosphorus stored in West Thompson Lake sediments as deep as 9.8 in. could be mobilized through the sediments and into the water column.

Nutrient Loads and Yields in West Thompson Lake and Surrounding Watershed

Annual loads of total phosphorus and total nitrogen were calculated for the three Quinebaug River sampling locations: Quinebaug River at Quinebaug (water years 1996–2005), Quinebaug River at Red Bridge Road (water years 2000–2005), and Quinebaug River at West Thompson (water years 2000–2005). A regression model was developed for each constituent at each sampling location; explanatory variables, term coefficients, and coefficients of determination for the models are shown in table 11. Annual loads for each constituent differed between years and between the inflow stations and the outflow station (table 12).

Table 10. Sample depth, moisture content, and concentrations of total phosphorus and organic carbon in sediment cores collected in West Thompson Lake, Connecticut, 2004.

[mg/kg, milligram per kilogram; g/kg, gram per kilogram]

Sampling location	Sampling interval depth, in inches	Moisture content, in percent	Total phosphorus concentration, in mg/kg	Organic carbon content, in g/kg
WTS-12A1	0–1.2	81	3,900	100
WTS-12A1	1.2–2.4	80	4,100	100
WTS-12A1	2.4–3.5	76	4,000	99
WTS-12A1	3.5–4.7	78	4,500	97
WTS-12A1	4.7–5.9	78	4,600	97
WTS-12A1	5.9–7.1	77	3,900	95
WTS-12A1	7.1–8.3	82	6,200	95
WTS-12A1	8.3–9.4	77	5,800	97
WTS-12A1	9.4–10.6	77	5,900	96
WTS-12A1	10.6–11.8	77	6,100	96
WTS-12A1	11.8–13.0	77	6,100	99
WTS-12A1	13.0–14.2	78	5,600	97
WTS-12A1	14.2–15.4	78	6,400	96
WTS-12A1	15.4–16.5	77	6,100	100
WTS-12A1	16.5–17.7	76	6,400	98
WTS-12A1	17.7–18.9	77	6,200	97
WTS-12A1	18.9–20.1	80	7,400	100
WTS-12A1	20.1–21.3	75	5,700	97
WTS-12A1	21.3–22.4	76	4,900	94
WTS-12A1	22.4–23.6	75	5,300	91
WTS-12A2	0–1.2	81	3,700	99
WTS-12A2	1.2–2.4	81	4,100	97
WTS-12A2	2.4–3.5	78	4,200	97
WTS-12A2	3.5–4.7	76	4,400	96
WTS-12A2	4.7–5.9	77	4,600	95
WTS-12A2	5.9–7.1	76	5,300	96
WTS-12A2	7.1–8.3	80	6,200	96
WTS-12A2	8.3–9.4	77	5,800	95
WTS-12A2	9.4–10.6	78	6,300	97
WTS-12A2	10.6–11.8	77	6,600	98
WTS-12A2	11.8–13.0	78	5,800	97
WTS-12A2	13.0–14.2	77	5,700	100
WTS-12A2	14.2–15.4	77	5,500	98
WTS-12A2	15.4–16.5	79	6,100	120
WTS-12A2	16.5–17.7	77	4,900	98
WTS-12A2	17.7–18.9	76	3,400	90
WTS-12A2	18.9–20.1	73	4,500	89
WTS-12A2	20.1–21.3	69	4,300	81
WTS-12A2	21.3–22.4	68	4,300	70
WTS-12A2	22.4–23.6	35	1,800	21
WTS-17B1	0–1.2	78	2,700	81
WTS-17B1	2.4–3.5	75	2,700	82
WTS-17B1	4.7–5.9	69	2,400	69
WTS-17B1	7.1–8.3	69	2,900	71
WTS-17B1	9.4–10.6	72	4,400	80
WTS-17B1	11.8–13.0	74	5,000	91
WTS-17B1	14.2–15.4	75	4,700	89
WTS-17B1	16.5–17.7	72	5,200	88
WTS-17B1	18.9–20.1	72	5,000	87

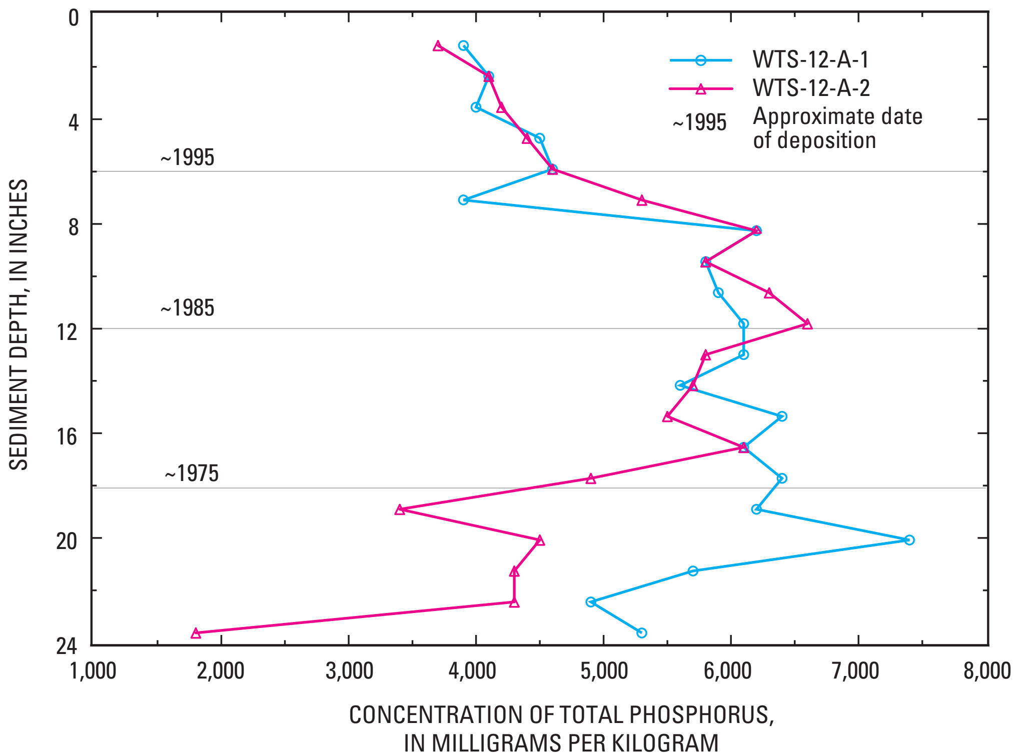


Figure 13. Total phosphorus concentrations from two cores collected at sampling station WTS-12, West Thompson Lake, Connecticut.

Table 11. Explanatory variable terms, term coefficients, and coefficients of determination used in estimates of nutrient loads for inflow and outflow stations, West Thompson Lake, Connecticut.

[Ln, natural logarithm; Q, streamflow; T, decimal time in years; r^2, coefficient of determination; --, no data]

U.S. Geological Survey station	Regression intercept	Ln (Q)	Ln (Q^2)	T	$(T)^2$	Sine (T)	Cosine (T)	Coefficient of determination (r^2)
				Total nitrogen				
01124000	6.2414	0.7944	--	0.163	--	--	--	94.6
01124120	6.2414	0.7944	--	0.163	--	--	--	94.6
01124151	6.4591	0.9102	--	--	--	-0.0942	-0.1178	95.1
				Total phosphorus				
01124000	3.2315	0.9725	0.0131	0.70	0.0168	-0.1646	-0.2003	83.3
01124120	3.2315	0.9725	0.0131	0.070	0.0168	-0.0168	-0.2003	83.3
01124151	3.6550	0.9086	0.0289	-0.0133	-0.0584	-0.2540	-0.2912	92.6

Table 12. Annual loads and yields of total nitrogen and total phosphorus for U.S. Geological Survey sampling stations in the West Thompson Lake Watershed, Connecticut.

[lb, pound; lb/mi², pounds per square mile]

U.S. Geological Survey station	Water year	Total phosphorus				Total nitrogen			
		Load (lb)	95-percent confidence limit for load		Yield (lb/mi²)	Load (lb)	95-percent confidence limit for load		Yield (lb/mi²)
			Lower	Upper			Lower	Upper	
Quinebaug River at Quinebaug (01124000)	1996	12,800	9,070	17,400	82.6	380,000	339,000	425,000	2,450
	1997	14,200	10,900	18,300	91.6	365,000	330,000	403,000	2,360
	1998	15,300	12,000	19,300	98.7	328,000	301,000	358,000	2,120
	1999	10,700	8,440	13,400	69.0	227,000	211,000	244,000	1,460
	2000	18,200	14,200	23,000	117	317,000	297,000	338,000	2,040
	2001	14,400	11,000	18,500	92.9	245,000	230,000	260,000	1,580
	2002	10,400	8,260	13,000	67.1	179,000	169,000	189,000	1,160
	2003	22,700	17,400	29,100	146	359,000	333,000	386,000	2,320
	2004	21,100	15,700	27,800	136	351,000	323,000	380,000	2,260
	2005	20,400	13,900	28,900	132	371,000	338,000	407,000	2,390
Average					**115**				**2,010**
Quinebaug River at Red Bridge Road (01124120)	2000	19,900	15,300	25,500	118	341,000	318,000	365,000	2,030
	2001	15,700	11,900	20,400	93.5	263,000	247,000	280,000	1,560
	2002	11,400	9,000	14,300	67.9	193,000	182,000	204,000	1,150
	2003	24,900	18,800	32,300	148	386,000	358,000	416,000	2,300
	2004	23,100	17,000	30,700	138	377,000	347,000	409,000	2,240
	2005	22,400	15,100	31,900	133	399,000	363,000	439,000	2,380
Average					**116**				**1,940**
Quinebaug River at West Thompson (01124151)	2000	14,800	12,300	17,600	86.0	332,000	308,000	357,000	1,930
	2001	15,100	13,300	17,100	87.8	274,000	252,000	298,000	1,590
	2002	11,500	10,100	13,000	66.9	183,000	170,000	198,000	1,060
	2003	22,900	20,300	25,800	133	377,000	349,000	407,000	2,190
	2004	20,300	18,200	22,600	118	380,000	352,000	410,000	2,210
	2005	16,400	13,800	19,400	95.3	400,000	367,000	435,000	2,330
Average					**97.7**				**1,880**

Annual Loads and Yields of Total Phosphorus

Annual loads of total phosphorus were lowest during water year 2002 (a relatively dry year) with values of 10,400 lb/yr at Quinebaug, 11,400 lb/yr at Red Bridge Road, and 11,500 lb/yr at West Thompson. The highest annual loads of total phosphorus were during 2003, with values of 22,700 lb/yr at Quinebaug, 24,900 lb/yr at Red Bridge Road, and 22,900 lb/yr at West Thompson. Average annual yields of total phosphorus differed between the two inflow sites and the outflow site and among the years of the study, and ranged from 67.1 (2002) to 146 lb/mi^2/yr (2003) at Quinebaug; 67.9 (2002) to 148 lb/mi^2/yr (2003) at Red Bridge Road; and 66.9 (2002) to 133 lb/mi^2/yr (2003) at West Thompson. The average annual yields of total phosphorus among the three sites during the study ranged from 97.9 to 116 lb/mi^2/yr. The 18-percent decrease in the average annual phosphorus yield between Red Bridge Road (116 lb/mi^2/yr) and the outlet of West Thompson Lake (97.9 lb/mi^2/yr) for water years 2000 to 2005, indicates that in some years a substantial part of the phosphorus load is retained in the lake.

Annual yields of total phosphorus at Quinebaug have decreased significantly since the 1980s (fig. 14). Based on loads and yields reported by Trench (2000), the average yield of total phosphorus for the Quinebaug River was 362 lb/mi^2/yr for the period 1981–1990, and decreased to 110 lb/mi^2/yr for the period 1991–1995. This value is close to the average annual yield of total phosphorus of 115 lb/mi^2/yr reported for this study (1996–2005).

The range of annual yields of total phosphorus from the Quinebaug River at Quinebaug, Red Bridge Road, and West Thompson was less than that reported for the Nepaug River (162 to 228 lb/mi^2/yr for 1999–2001), a primarily forested watershed in north-central Connecticut without point sources of treated wastewater (Morrison and Colombo, 2006). Average annual yields of total phosphorus for the three sites on the Quinebaug River in this study also tended to be much less than those reported for Broad Brook (932 lb/mi^2/yr for 2000–2004), a predominantly agricultural watershed in north-central Connecticut with no treated wastewater sources (Mullaney, 2007). Average annual yields of total phosphorus were within the range of Sasco Brook (47.7 to 267 lb/mi^2/yr for 1995–1997), a small forested watershed in southwestern Connecticut (Morrison, 2002).

Annual Loads and Yields of Total Nitrogen

Annual loads and yields of total nitrogen differed between years as much as annual loads and yields of total phosphorus because of variations in runoff. The annual load of total nitrogen at Quinebaug was the highest during 1996 (380,000 lb/yr). During water years 2000 to 2005 (the focus of this study), annual loads of total nitrogen were the highest in water year 2005 for all three stations, with the maximum annual load at West Thompson (400,000 lb/yr). Annual loads of total nitrogen from the three stations ranged from a minimum of 179,000 lb/yr at Quinebaug (2002, a relatively dry year) to 400,000 lb/yr at West Thompson (2005, a wet year).

Average annual yields of total nitrogen for the Quinebaug River during 2000 to 2005 were 1,960 lb/mi^2/yr at Quinebaug, 1,940 lb/mi^2/yr at Red Bridge Road, and 1,880 lb/mi^2/yr at West Thompson. Annual yields of total nitrogen for the Quinebaug River at Quinebaug have decreased significantly since the 1980s (fig. 15). Based on loads and yields reported by Trench (2000), the average yield for total nitrogen for the Quinebaug River was 3,300 lb/mi^2/yr for the period 1981–1990 and decreased to 2,000 lb/mi^2/yr for the period 1991–1995. This value is close to the average annual yield of total nitrogen of 2,010 lb/mi^2/yr reported for this study (1996–2005).

Average annual yields of total nitrogen reported above from the three stations were slightly larger than the average annual yield of total nitrogen reported for the Nepaug River, a primarily forested watershed in north-central Connecticut without point sources of treated wastewater (1,550 lb/mi^2/yr for 1999–2001) (Morrison and Colombo, 2006). Average annual yields of total nitrogen for the three sites on the Quinebaug River in this study were much less than those reported for Broad Brook, a predominantly agricultural watershed in north-central Connecticut with no treated wastewater sources (13,000 lb/mi^2/yr for 2000–2004) (Mullaney, 2007). Average annual yields of total nitrogen for the Quinebaug River were much less than reported for Sasco Brook (4,430 lb/mi^2/yr for 1995–1997), a small forested watershed in southwestern Connecticut (Morrison, 2002).

Seasonal Loads

Loads of total phosphorus and total nitrogen were computed for each month from October 1999 through September 2005 at Quinebaug, Red Bridge Road, and West Thompson. Monthly loads and 95-percent confidence intervals of total phosphorus and total nitrogen are listed in appendix 2. Loads of total phosphorus and total nitrogen also were computed for each season from October 1999 through September 2005 at the same three stations. Seasonal loads, based on the computed monthly loads, were defined in the following way: fall—October 1 to December 31, winter—January 1 to March 31, spring—April 1 to June 30, and summer—July 1 to September 30.

In general, seasonal loads of total phosphorus at all three stations were largest during spring, which has the highest streamflow, and smallest during summer and fall (table 13). The largest seasonal loads of total phosphorus during the study period were in spring 2003—8,570 lb at Quinebaug, 9,390 lb at Red Bridge Road, and 9,060 lb at West Thompson. The smallest seasonal loads of total phosphorus during the study period were in fall 2001—969 lb at Quinebaug and 1,060 lb at Red Bridge Road—and summer 2005—1,140 lb at West Thompson.

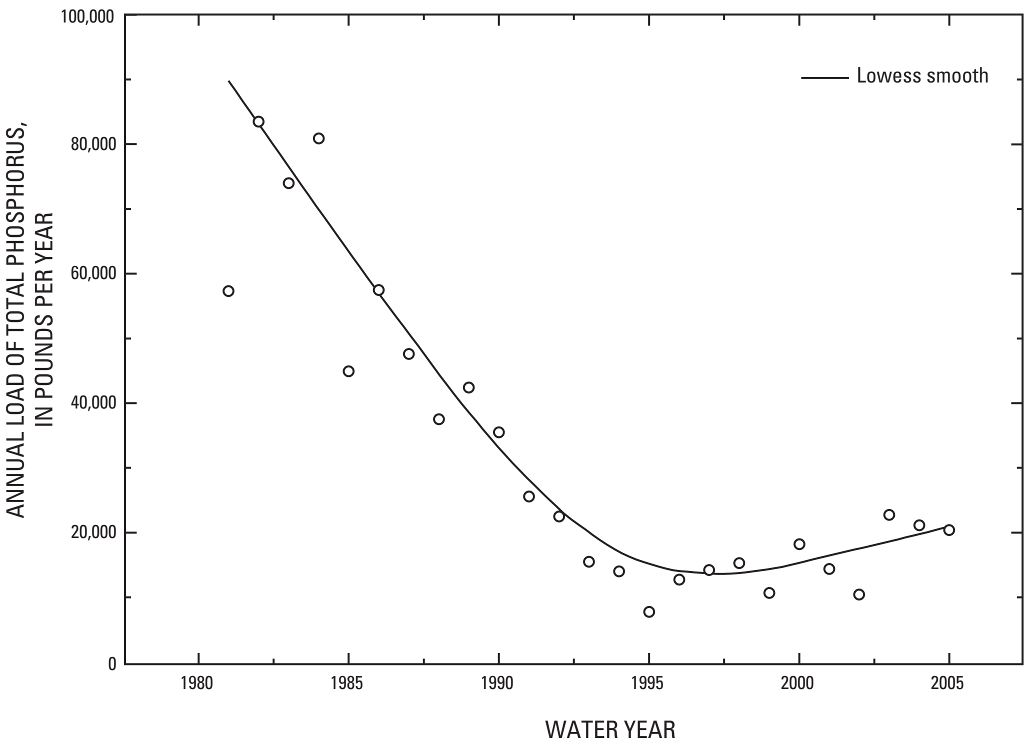


Figure 14. Annual loads of total phosphorus for Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), water years 1980–2005.

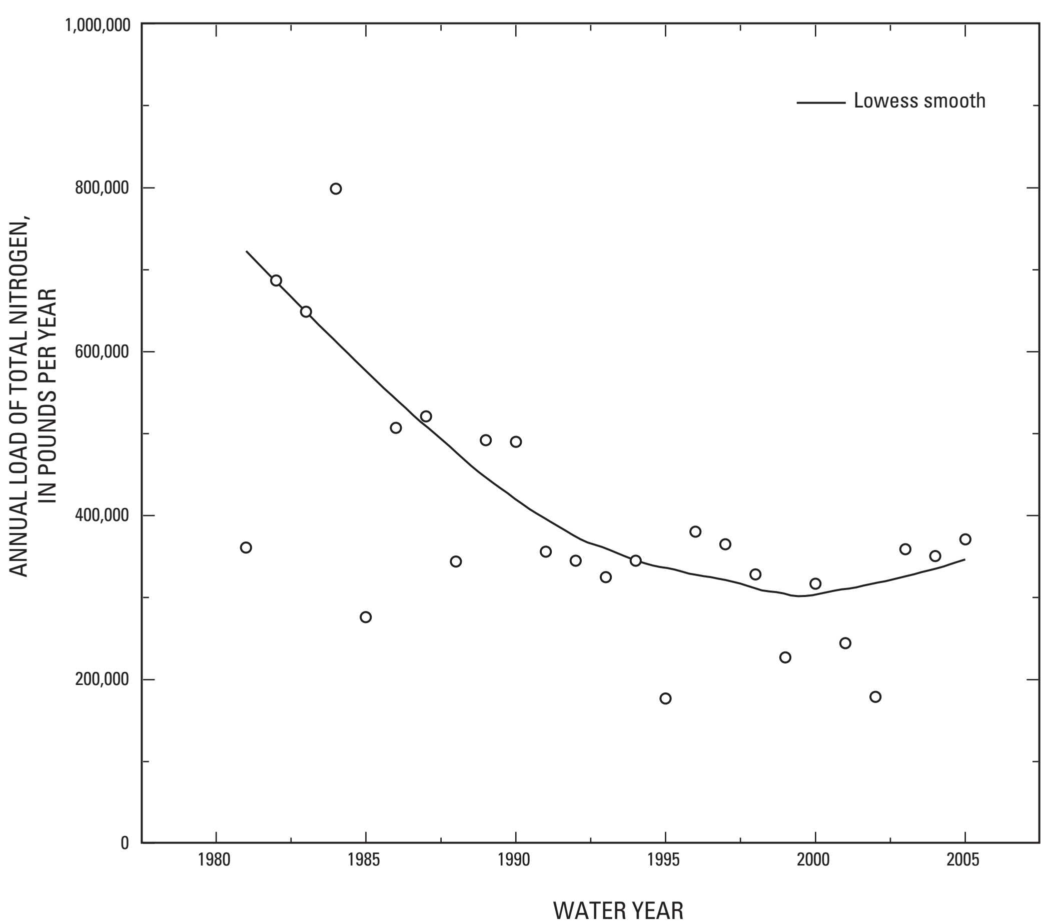


Figure 15. Annual loads of total nitrogen for Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), water years 1980–2005.

Table 13. Seasonal loads of total phosphorus for U.S. Geological Survey sampling stations above and below West Thompson Lake, Connecticut.

[lb, pound]

Begin date	End date	Quinebaug River at Quinebaug: Load (lb)	Quinebaug River at Quinebaug: 95-percent confidence limit for load (lb), Lower	Quinebaug River at Quinebaug: 95-percent confidence limit for load (lb), Upper	Quinebaug River at Red Bridge Road: Load (lb)	Quinebaug River at Red Bridge Road: 95-percent confidence limit for load (lb), Lower	Quinebaug River at Red Bridge Road: 95-percent confidence limit for load (lb), Upper	Quinebaug River at West Thompson: Load (lb)	Quinebaug River at West Thompson: 95-percent confidence limit for load (lb), Lower	Quinebaug River at West Thompson: 95-percent confidence limit for load (lb), Upper
10/1/1999	12/31/1999	3,290	2,380	4,440	3,600	2,600	4,870	2,580	1,930	3,380
1/1/2000	3/31/2000	4,860	3,510	6,550	5,330	3,850	7,190	3,390	2,740	4,150
4/1/2000	6/30/2000	8,150	5,700	11,300	8,930	6,110	12,600	6,630	5,410	8,030
7/1/2000	9/30/2000	1,880	1,450	2,400	2,060	1,570	2,640	2,190	1,860	2,560
10/1/2000	12/31/2000	2,170	1,570	2,930	2,380	1,710	3,210	2,090	1,780	2,440
1/1/2001	3/31/2001	4,010	2,770	5,630	4,400	3,000	6,220	4,130	3,440	4,930
4/1/2001	6/30/2001	6,810	4,790	9,390	7,460	5,140	10,500	7,080	5,960	8,360
7/1/2001	9/30/2001	1,370	1,100	1,680	1,500	1,200	1,840	1,800	1,600	2,020
10/1/2001	12/31/2001	969	706	1,300	1,060	772	1,420	1,240	1,050	1,460
1/1/2002	3/31/2002	1,930	1,280	2,800	2,110	1,410	3,040	1,980	1,600	2,420
4/1/2002	6/30/2002	6,510	4,850	8,560	7,140	5,270	9,460	6,810	5,870	7,870
7/1/2002	9/30/2002	1,020	823	1,250	1,110	901	1,360	1,460	1,230	1,710
10/1/2002	12/31/2002	3,920	2,810	5,320	4,290	3,060	5,850	3,970	3,420	4,590
1/1/2003	3/31/2003	6,810	4,700	9,560	7,460	5,080	10,600	6,000	4,930	7,240
4/1/2003	6/30/2003	8,570	6,180	11,600	9,390	6,660	12,900	9,060	7,740	10,500
7/1/2003	9/30/2003	3,430	2,570	4,480	3,750	2,790	4,940	3,880	3,440	4,350
10/1/2003	12/31/2003	7,120	4,800	10,200	7,800	5,170	11,300	6,910	5,950	7,980
1/1/2004	3/31/2004	3,720	2,500	5,330	4,080	2,770	5,810	3,140	2,630	3,730
4/1/2004	6/30/2004	7,180	4,950	10,100	7,870	5,360	11,200	7,020	5,900	8,270
7/1/2004	9/30/2004	3,090	2,180	4,260	3,380	2,360	4,690	3,250	2,820	3,720
10/1/2004	12/31/2004	5,770	3,910	8,210	6,320	4,260	9,040	4,900	4,160	5,740
1/1/2005	3/31/2005	6,740	4,320	10,000	7,390	4,710	11,100	5,050	4,120	6,130
4/1/2005	6/30/2005	6,610	4,140	10,000	7,240	4,470	11,100	5,350	4,240	6,680
7/1/2005	9/30/2005	1,300	850	1,910	1,420	929	2,080	1,140	907	1,410

Seasonal loads of total nitrogen at all three stations also were generally the largest during the high-flow seasons of winter and spring and smallest during the summer (table 14). The highest seasonal loads of total nitrogen during the study period were in winter 2005—134,000 lb at Quinebaug and 144,000 lb at Red Bridge Road—and in spring 2003—144,000 lb at West Thompson. The smallest seasonal loads of total nitrogen during the study period were in summer 2002, a dry year—17,700 lb at Quinebaug, 19,100 lb at Red Bridge Road, and 17,900 at West Thompson.

Water and Nutrient Budgets for West Thompson Lake

A budget for a lake (whether for water or for nutrients) balances the inputs to the lake, the losses from the lake, and the change in storage in the lake.

Water Budget

The following equation is typically used for water budgets.

$$\Delta S = P + SI + GI - E - SO - GO \,, \tag{1}$$

where

ΔS is the change in storage volume of the lake,
P is direct precipitation on the lake,
SI is the surface-water inflow,
GI is the ground-water inflow,
E is evaporation from the lake surface,
SO is the surface-water outflow from the lake, and
GO is the ground-water outflow from the lake.

A water budget should be calculated using input data that come from as close as possible to the lake. In developing a water budget for West Thompson Lake, streamflow and nutrient concentration data were collected from the Red Bridge Road site; however, variable backwater conditions precluded installing a continuous-record streamflow-gaging station at this location. Therefore, the streamflow at Red Bridge Road was calculated using a drainage-area correction to the flow at Quinebaug of 1.08 (drainage area ratio of 168 to 155 mi^2). The calculated annual flow at Red Bridge Road accounted for approximately 99 percent of the streamflow at West Thompson. Therefore, for West Thompson Lake, only the surface-water inflow and outflow terms and the change in storage term in the water-budget equation are significant, probably because the drainage area is very large relative to the surface area and volume of the lake.

Nutrient Budgets

There was no statistical difference between nutrient-concentration data from the Quinebaug and Red Bridge Road sites during the study. In order to use the longest possible period of record for a nutrient budget for West Thompson Lake, the concentration data set at Quinebaug was used with the drainage-area-corrected flow at Red Bridge Road in the LOADEST model to calculate the inflow nutrient loads for water years 2000 to 2005.

Phosphorus and nitrogen budgets for West Thompson Lake were calculated using annual and seasonal loads. The phosphorus and nitrogen loads out of the lake were subtracted from the load into the lake to calculate the net exports. Results of the nutrient budget indicate that the export of phosphorus and nitrogen in West Thompson Lake can change annually, seasonally, and monthly.

The annual net export of phosphorus in West Thompson Lake during water years 2000 to 2005 ranged from -36 percent (2005) to 1 percent (2002) of the incoming load. A negative export means less phosphorus comes out of the lake than came into the lake from upstream, and phosphorus is stored in the lake. A positive export indicates more phosphorus is released from the lake to the river downstream than is coming into the lake from upstream. This could be the result of an internal load of phosphorus, which most likely is being released from the lake-bottom sediments. The magnitude of this internal load may be small relative to the annual incoming load; however; the timing of the load may be critical in supplying phosphorus to the lake when conditions are present to cause an algal bloom.

Phosphorus is exported from the lake in years with below-normal runoff and is retained in years with above-normal runoff. This pattern appears to be present seasonally as well (fig. 16). Phosphorus may be exported from the lake during the summer and fall. This was particularly evident during the summers of 2000 to 2003. Seasonal mass-balance data for total phosphorus shows that during the summers of 2000 to 2003, the net export of phosphorus ranged from 3.4 percent (2003) to 30.7 percent (2002) of the incoming load. Streamflow during these summers was at or less than normal. During the summer of 2004, however, streamflows were much higher than normal, and there was a negative export of phosphorus in West Thompson Lake of -3.9 percent. West Thompson Lake retains as much as 30 percent of the incoming phosphorus load during the fall, winter, and spring.

The annual net export of nitrogen in West Thompson Lake during water years 2000 to 2005 ranged from -5 percent (2002) to 4 percent (2001) of the incoming load. No clear pattern was evident in relating the total nitrogen export to climatic variables or runoff.

Confidence intervals around the loads into and out of the lake generally overlap, indicating that the true difference between the nutrient loads into and out of the lake could be within the error of the load estimation (figs. 17 and 18). For nitrogen, this overlap is even more pronounced (figs. 19

Table 14. Seasonal loads of total nitrogen for U.S. Geological Survey sampling stations above and below West Thompson Lake, Connecticut.

[lb, pound]

Begin date	End date	U.S. Geological Survey station: Quinebaug River at Quinebaug			Quinebaug River at Red Bridge Road			Quinebaug River at West Thompson		
		Load (lb)	95-percent confidence limit for load (lb)		Load (lb)	95-percent confidence limit for load (lb)		Load (lb)	95-percent confidence limit for load (lb)	
			Lower	Upper		Lower	Upper		Lower	Upper
10/1/1999	12/31/1999	64,300	59,800	68,900	69,200	64,300	74,300	65,300	59,300	71,700
1/1/2000	3/31/2000	99,100	91,200	107,000	107,000	98,000	116,000	93,600	83,000	105,000
4/1/2000	6/30/2000	123,000	113,000	134,000	132,000	121,000	145,000	138,000	123,000	153,000
7/1/2000	9/30/2000	30,500	28,500	32,700	32,900	30,700	35,200	35,100	32,500	37,900
10/1/2000	12/31/2000	43,200	40,300	46,200	46,400	43,400	49,700	40,500	36,500	44,800
1/1/2001	3/31/2001	76,100	69,800	82,700	81,800	75,000	89,200	86,400	76,300	97,600
4/1/2001	6/30/2001	102,000	93,700	112,000	110,000	101,000	120,000	123,000	110,000	138,000
7/1/2001	9/30/2001	23,000	21,400	24,700	24,700	23,000	26,500	24,100	22,200	26,000
10/1/2001	12/31/2001	20,900	19,400	22,500	22,500	20,900	24,200	19,600	17,500	21,900
1/1/2002	3/31/2002	43,600	40,600	46,700	46,900	43,700	50,300	39,200	34,100	44,900
4/1/2002	6/30/2002	96,700	89,300	104,000	104,000	96,000	113,000	107,000	96,300	118,000
7/1/2002	9/30/2002	17,700	16,300	19,200	19,100	17,600	20,600	17,900	16,400	19,500
10/1/2002	12/31/2002	67,700	62,400	73,200	72,800	67,100	78,900	66,300	59,700	73,500
1/1/2003	3/31/2003	119,000	109,000	131,000	128,000	117,000	141,000	114,000	101,000	128,000
4/1/2003	6/30/2003	122,000	112,000	134,000	132,000	120,000	144,000	144,000	129,000	159,000
7/1/2003	9/30/2003	49,300	45,600	53,200	53,100	49,100	57,300	53,200	48,900	57,700
10/1/2003	12/31/2003	112,000	102,000	123,000	121,000	109,000	133,000	122,000	109,000	137,000
1/1/2004	3/31/2004	79,100	72,600	86,000	85,100	78,100	92,700	70,500	62,400	79,400
4/1/2004	6/30/2004	113,000	102,000	124,000	121,000	109,000	134,000	134,000	120,000	150,000
7/1/2004	9/30/2004	46,700	42,600	51,100	50,300	45,900	55,100	53,200	48,500	58,300
10/1/2004	12/31/2004	101,000	91,200	111,000	108,000	98,000	119,000	107,000	96,000	118,000
1/1/2005	3/31/2005	134,000	120,000	149,000	144,000	129,000	160,000	137,000	121,000	154,000
4/1/2005	6/30/2005	112,000	100,000	125,000	121,000	108,000	135,000	132,000	117,000	148,000
7/1/2005	9/30/2005	24,200	21,700	26,900	26,000	23,400	28,900	23,900	21,800	26,000

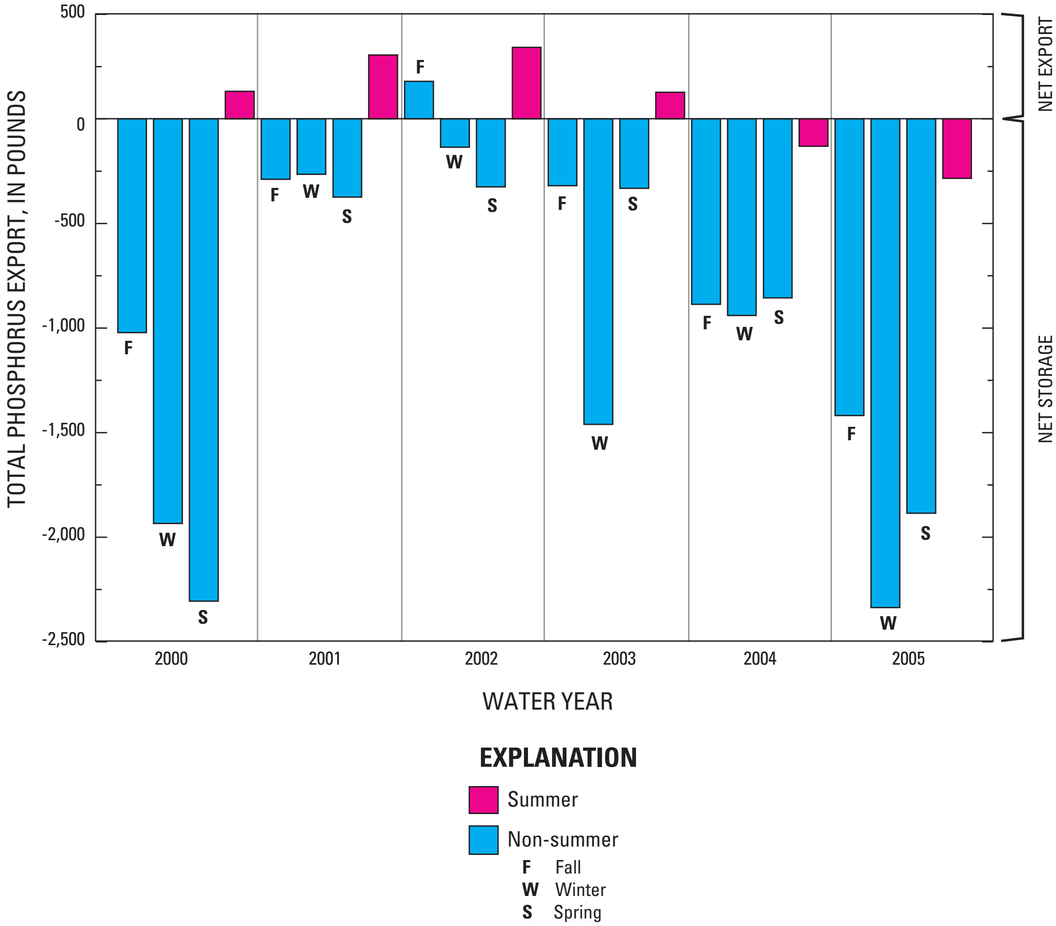


Figure 16. Seasonal loads of total phosphorus exported from West Thompson Lake, Connecticut, water years 2000–2005.

and 20). Because the data for the phosphorus budget are based on frequent measurements and a well fitted regression model, the apparent pattern is believed to represent processes taking place in the lake. In phosphorus budgets used for other water bodies, assumptions and data may have larger sources of uncertainty than those used in this report. Labaugh and Winter (1984) documented uncertainty in some lake phosphorus budgets to be as high as 50 percent, as a result of error in water input and output terms and assumptions regarding phosphorus concentrations. Based on the repeatability of the pattern of phosphorus retention and export associated with streamflow patterns and other lines of evidence, the phosphorus budget for West Thompson Lake is believed to be fairly accurate. Therefore, it is reasonable to propose that the lake retains a large amount of phosphorus during the fall, winter, and spring and that the lake may release phosphorus from an internal load during the summer stratification period. Phosphorus removal during the summer by upstream WWTPs in Massachusetts reduces the concentration and load of phosphorus entering the lake in the summer; however, the large amount of phosphorus retained in the lake during other seasons may become available to promote algal blooms in the lake and (or) in areas downstream from the lake during the critical summer growing season.

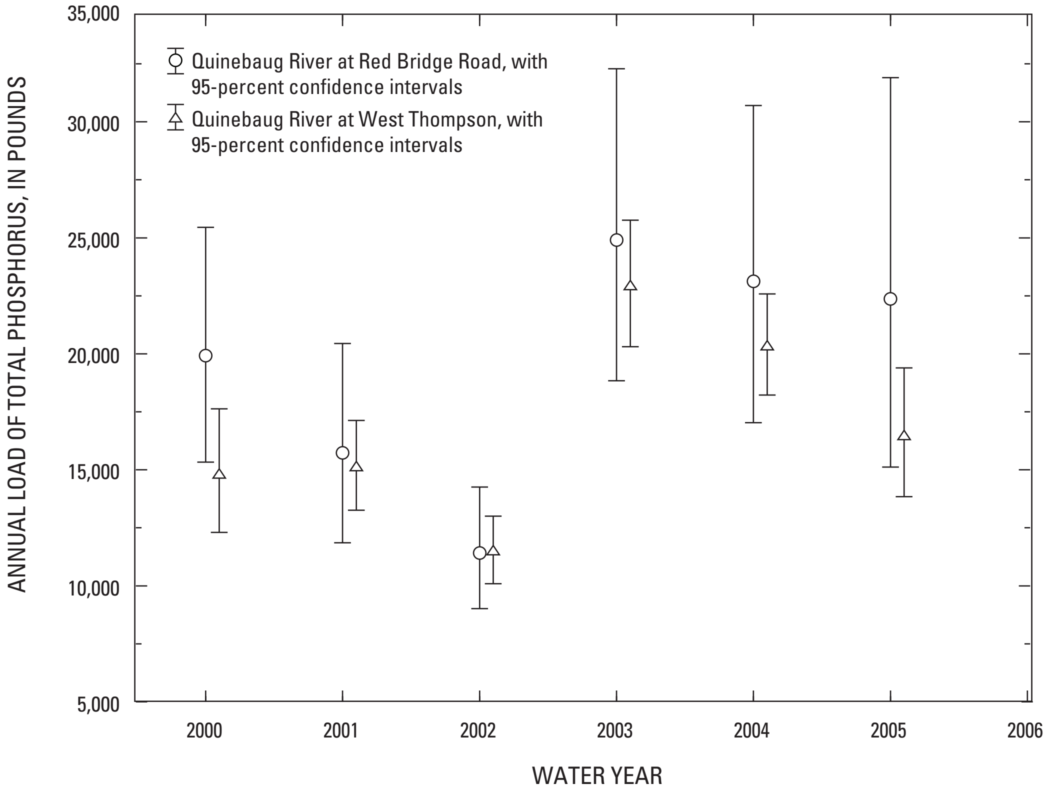


Figure 17. Annual loads of total phosphorus from Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), and Quinebaug River at West Thompson, Connecticut (USGS Site ID 01124151).

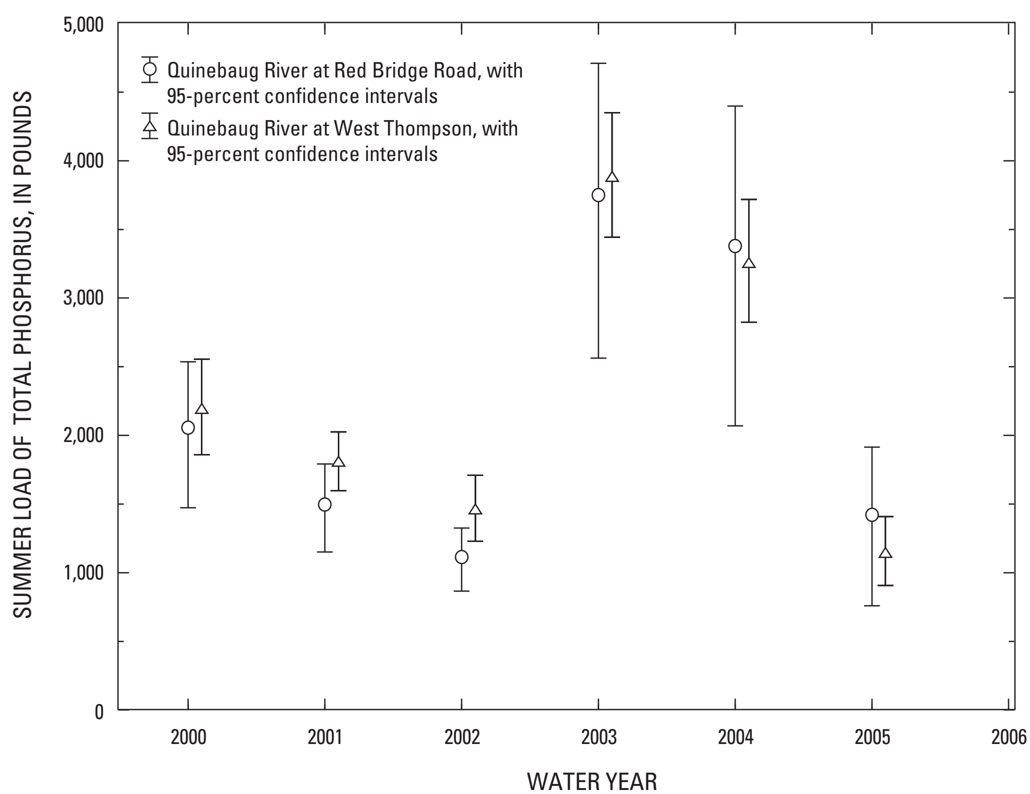


Figure 18. Summer loads of total phosphorus from Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), and Quinebaug River at West Thompson, Connecticut (USGS Site ID 01124151).

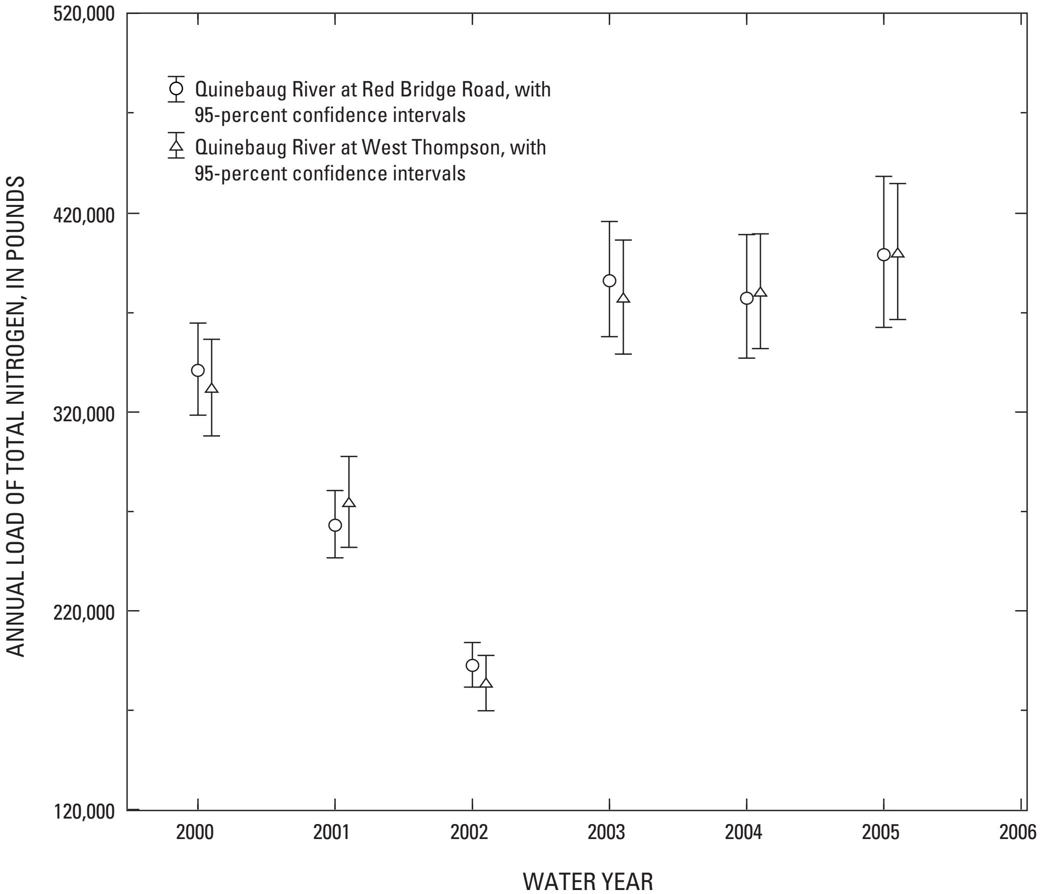


Figure 19. Annual loads of total nitrogen from Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), and Quinebaug River at West Thompson, Connecticut (USGS Site ID 01124151).

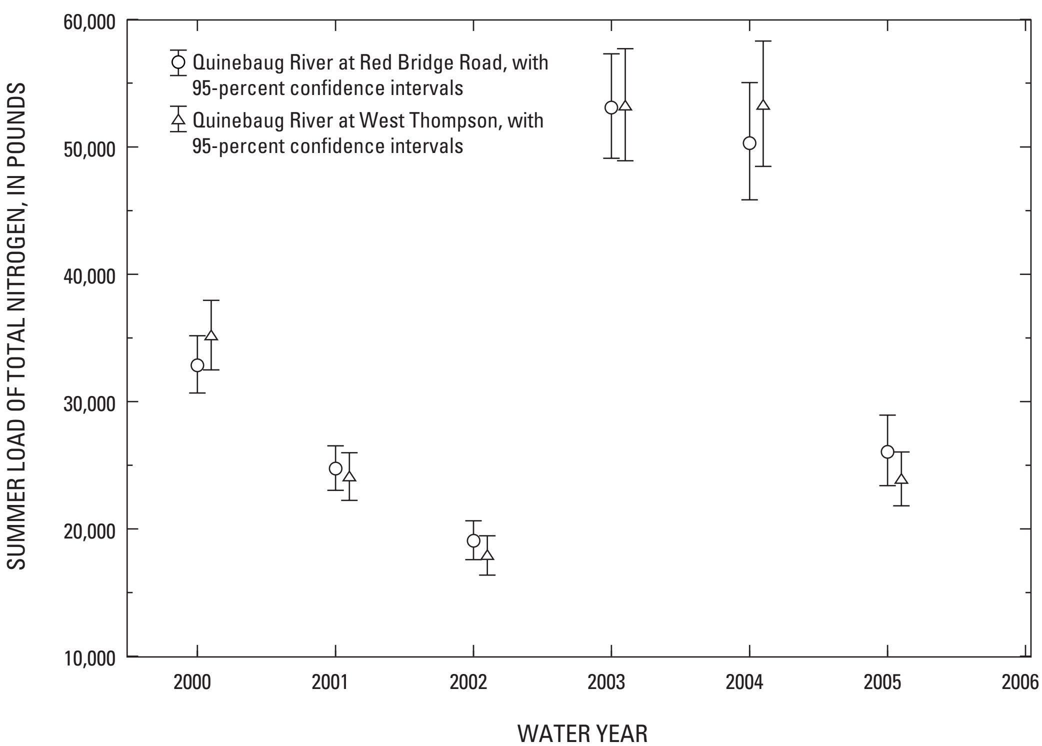


Figure 20. Summer loads of total nitrogen from Quinebaug River at Quinebaug, Connecticut (USGS Site ID 01124000), and Quinebaug River at West Thompson, Connecticut (USGS Site ID 01124151).

Summary and Conclusions

A 3-year study (2003–2005) to evaluate the effects of nutrient loading to West Thompson Lake in northeastern Connecticut, a U.S. Army Corps of Engineers flood-control reservoir on the Quinebaug River, was conducted by the U.S. Geological Survey in cooperation with the Connecticut Department of Environmental Protection. Water-quality data from this and previous studies were used to compute a budget for total phosphorus and total nitrogen for West Thompson Lake. In addition, the lake-bottom sediments were sampled to evaluate concentrations and distribution of total phosphorus stored in the sediments. Data also were collected to examine the timing, duration, and magnitude of algal blooms and determine if nutrient concentrations may limit algal growth.

Median concentrations of total phosphorus were determined at two inflow sampling stations (0.036 milligrams per liter (mg/L) at Quinebaug River at Quinebaug, Conn. (USGS Site ID 01124000), and 0.044 mg/L at Quinebaug River at Red Bridge Road, Conn. (USGS Site ID 01124120)), and at one outflow sampling station (0.042 mg/L at Quinebaug River at West Thompson, Conn. (USGS Site ID 01124151)). Median concentrations were not significantly different from each other but were higher than the 0.03125 mg/L nutrient criteria recommended by the U.S. Environmental Protection Agency (USEPA) for rivers and streams in the aggregate Ecoregion XIV. Median concentrations of total nitrogen also were not significantly different between the two inflow stations and the outflow station. Concentrations of chlorophyll-*a* at the outflow station were significantly higher than those at the inflow stations.

The average concentration of total phosphorus in the near-surface water in West Thompson Lake ranged from 0.045 to 0.050 mg/L during the study. In general, the epilimnion had lower concentrations of phosphorus and ammonia nitrogen than the hypolimnion. Concentrations of nitrate and nitrite nitrogen in the near-surface water averaged approximately 0.4 mg/L as nitrogen. Concentrations of dissolved phosphorus differed greatly through the season and with depth. Concentrations of orthophosphate always were below the detection limit (20 micrograms per liter). In general, concentrations of total phosphorus in West Thompson Lake were higher than the 0.008 mg/L nutrient criteria recommended by the USEPA for lakes and impoundments in aggregate Ecoregion XIV.

During the study, two rounds of limiting nutrient analysis were performed on samples from two locations in the lake. Samples collected on July 27, 2005, identified phosphorus as the primary limiting nutrient. Samples collected on August 17, 2005, indicated that the sample from WT-1 at a depth of 12 feet (ft) probably was phosphorus limited, but samples from three other locations were probably co-limited by phosphorus and nitrogen. Algal cell counts ranged from less than 1,000 to a maximum of 73,000 (July 2003); large algal cell counts were typically dominated by the blue-green algae *Anacystis sp.* and *Anabaena sp.*

Measurements were made of the thickness of lake-bottom sediments and concentration of total phosphorus in the sediments. Sediment thickness ranged from 0.3 to 3.5 ft. Concentrations of total phosphorus from the initial round of sediment coring in 2003 ranged from 1,100 to 3,200 milligrams per kilograms (mg/kg) in the upper 2 inches (in.) of the sediment. Additional sediment cores were collected in 2004. Subsamples of cores from locations WTS-12 and WTS-17, taken every 1.2 in., were analyzed for total phosphorus. The results from the detailed core sampling indicate that phosphorus concentrations increased gradually from 0 to 5.9 in., then increased dramatically below 5.9 in., almost doubling to a maximum of 7,400 mg/kg, indicating a large amount of total phosphorus stored in the lake-bottom sediments.

Annual loads of total phosphorus ranged from 10,400 to 22,700 pounds per year (lb/yr) at Quinebaug, 11,400 to 24,900 lb/yr at Red Bridge Road, and 11,500 to 22,900 lb/yr at West Thompson. Average annual yields of total phosphorus at the three stations during 2000–2005 were 115 pounds per square mile per year (lb/mi^2/yr) at Quinebaug, 116 lb/mi^2/yr at Red Bridge Road, and 97.9 lb/mi^2/yr at West Thompson. The 18-percent decrease in the average annual yield of phosphorus between the Red Bridge Road and the outlet of West Thompson Lake (West Thompson) indicates that a significant part of the phosphorus load is retained in the lake.

Annual loads of total nitrogen ranged from 179,000 to 371,000 lb/yr at Quinebaug, 193,000 to 399,000 lb/yr at Red Bridge Road, and 183,000 to 400,000 lb/yr at West Thompson. Average annual yields of total nitrogen at the three stations were 1,960 lb/mi^2/yr at Quinebaug, 1,940 lb/mi^2/yr at Red Bridge Road, and 1,880 lb/mi^2/yr at West Thompson.

Seasonal loads and yields of total phosphorus and total nitrogen also were estimated during the study. In general, loads and yields are the smallest during summer, due to lower streamflows; loads and yields are largest during the spring when streamflows are the highest.

A phosphorus budget was developed for West Thompson Lake. The annual net export of phosphorus during water years 2000 to 2005 ranged from -36 percent (2005) to 1 percent (2002) in excess of the incoming load. In general, phosphorus was exported from the lake in years with below-normal runoff and was retained in years with above-normal runoff. This pattern appears to be present seasonally as well—phosphorus is exported during the summer and fall and retained during fall, winter, and spring. Seasonal mass-balance data for total phosphorus shows that during the summers of 2000 to 2003, when streamflow was at or lower than normal, the net export of phosphorus ranged from 3.4 percent (2003) to 30.7 percent (2002) of the incoming load. This could be attributed to an internal load of phosphorus being released from the lake-bottom sediments. The magnitude of this internal load may be small relative to the annual incoming load; however, the timing of this load may be critical for supplying phosphorus to the lake when conditions are present to cause an algal bloom. This also may result in the export of total phosphorus from West Thompson Lake, potentially exacerbating algal blooms in areas downstream from the lake. During the summer of 2004, however, streamflow was much higher than normal and there was a negative export of phosphorus in West Thompson Lake of -3.9 percent.

Based on the repeatability of the pattern of phosphorus retention and export associated with streamflow patterns and other lines of evidence, the phosphorus budget for West Thompson Lake is believed to be fairly accurate and demonstrates that the lake stores a large amount of phosphorus during fall, winter, and spring and that the lake may release phosphorus from an internal load during the summer growing season. Summer seasonal thermal and chemical stratification in West Thompson Lake may cause phosphorus and possibly nitrogen to be released from the sediments and accumulate in the lower layer of the lake. During the stratification period large runoff events possibly in conjunction with windy conditions can cause the thermal and chemical stratification of West Thompson Lake to breakdown, causing partial or complete mixing of the lake layers. These mixing events can redistribute phosphorus and nitrogen released from the sediment to the upper layers of the lake promoting algal growth and contributing to nutrient and algae problems downstream of West Thompson Lake.

Phosphorus removal during the summer by wastewater-treatment plants (WWTPs) in Massachusetts reduces the concentration and load of phosphorus entering the lake in the summer; however, the large amount of phosphorus retained in the lake during the other seasons, in addition to the phosphorus stored in the lake-bottom sediments, may become available to promote algal blooms in the lake and (or) in areas downstream from the lake during the critical summer growing season. The seasonal phosphorus removal at the WWTPs lowers the concentration of phosphorus entering the lake during the summer and probably reduces the magnitude and duration of algal blooms that occur in West Thompson Lake; however, the trophic status of the lake remains in the eutrophic range.

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Appendix 1. Daily Maximum, Minimum, and Mean Values of Water Temperature for USGS Station 01124149 at Top and Bottom Locations for Water Years 2003 and 2005

Tables

1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005 46

1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005..54

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.

[--, not available; Max, maximum; Min, minimum]

Top water temperature, water year 2003												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	24.6	23.3	23.9	26	25.1	25.5	23.4	22.1	22.6
2	--	--	--	24.1	23.1	23.6	25.1	23.4	24.5	22.1	21	21.4
3	--	--	--	24.6	23.1	23.9	24.8	23.3	23.8	21	19.8	20.6
4	--	--	--	25.8	23.6	24.2	25.3	23.9	24.5	20.7	20.1	20.4
5	--	--	--	28.8	23.9	25.7	25.4	24.5	25	22.9	20.3	21.5
6	--	--	--	29.2	25.2	27.7	25.6	24.7	25.1	23	20.9	21.6
7	18.4	17.5	17.8	27.9	26	26.9	25.6	25.1	25.4	23.6	20.3	20.8
8	18.1	16.6	17.4	29.5	26.8	28.2	25.8	24.6	25.3	23.9	20.3	22.1
9	17.6	16.5	16.8	27.6	26.3	27.1	25.4	24.2	24.8	22.6	21.1	21.8
10	20.6	16.9	18.6	26.6	24.9	25.7	25.3	24.5	24.9	22.1	19.9	20.8
11	19.2	18.3	18.9	25.6	24.5	25	25.4	24.8	25.1	23	20	21.1
12	19.9	18.7	19.2	24.6	22.9	23.9	26	25.1	25.5	22.1	20.2	21
13	19.2	18.3	18.9	26.6	24.1	25	27.2	25.8	26.2	20.9	20.2	20.6
14	19.6	17.7	18.6	26.1	23.8	24.7	28.2	26	27.2	21	19.8	20.4
15	20.6	18.2	19.4	24.8	23.1	24.1	27.2	26	26.6	21.5	20.7	21.1
16	20.7	19.2	19.7	23.8	23.3	23.6	27.2	25.9	26.2	23.3	21.2	22.3
17	20.2	19	19.5	26.6	23.5	24.9	27.4	26.2	26.9	23.7	21.9	22.7
18	20	19.2	19.6	25.7	24	24.7	26.8	25.1	25.9	22.5	21.5	22.1
19	19.7	18.5	19	26.4	23.6	24.8	27.9	24.7	25.6	21.5	21.1	21.2
20	21	19.5	20.1	25.4	23.7	24.2	28.6	24.7	26.4	23	21.1	21.3
21	20.3	19.4	20	24.3	23.2	23.8	26.4	25	25.8	23	21.6	22.2
22	19.4	17.5	18.3	24.8	23.8	24	27.4	24.8	25.5	21.8	20.9	21.4
23	18.2	16.3	17.2	24.4	23.3	23.9	27.2	26.1	26.7	21.1	20.7	20.9
24	20.6	17.8	19	24.2	23.3	23.7	26.1	25	25.5	20.7	19.8	20.2
25	23.9	20.5	21.6	25.6	23.9	24.4	25	23.8	24.2	19.8	19	19.5
26	25.1	22.1	23.2	25.4	24	24.5	24	23.3	23.6	20.1	19.4	19.8
27	28.2	23.8	25.2	25.7	23.9	24.7	25.1	23.2	24.2	19.8	19	19.4
28	27.1	24.5	25.4	27.1	25.4	26.2	24.8	23.7	24.3	19.5	19.2	19.4
29	24.7	23.4	24.1	26.6	25.1	25.8	24.2	23.4	23.8	20.2	19	19.5
30	25.2	23.3	24.1	25.8	24.8	25.2	24.7	23.8	24.1	19.8	18.6	19.2
31	--	--	--	26.1	24.9	25.4	24.2	22.8	23.5	--	--	--
Monthly average	--	--	--	29.5	22.9	24.9	28.6	22.8	25.2	23.9	18.6	21

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Top water temperature, water year 2005												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	18.8	17.9	18.3	26.1	25.3	25.6	26.3	25.6	25.9	25.8	24.4	25.1
2	19	17.6	18.2	26.9	25.1	26	28.6	25.3	27	27.1	24.5	25.7
3	21.1	18.6	19.5	26.5	25.2	25.8	30.2	26.9	28.4	26.2	24.8	25.5
4	22.6	20.1	21	26.2	24.6	25.2	29	26.6	27.7	25.7	24.5	25.2
5	23.4	21.8	22.5	25.9	24.7	25.1	28.9	26.5	27.5	26.4	24.3	25.2
6	24.1	21.4	23.1	25.4	24.6	25.2	30.3	27.1	28.6	24.9	23.4	24
7	24.8	22.4	23.4	24.6	23.3	23.8	28.5	27	27.5	24.5	22.8	23.4
8	26	23.5	24.5	23.3	21.6	22.5	27.5	26.6	26.9	23.8	22.8	23.2
9	25.9	24.6	25	22.4	20.9	21.6	27.9	26.9	27.2	24.1	23	23.6
10	25.6	24.3	25.1	22.2	19.8	21.2	27.8	26.4	26.9	23.8	22.7	23.3
11	25.5	24.6	24.9	24.7	21.2	22.8	29.8	26.7	28.3	23.9	22.1	22.7
12	27	25.1	25.7	24.5	23.2	23.7	--	--	--	24.1	21.6	22.7
13	26.8	25.6	26.1	24.1	23.5	23.8	30.5	27.2	28.9	24.3	22.8	23.4
14	29.6	26.2	28.1	25.4	23.8	24	29.7	28.4	29	25	23	23.7
15	27.9	24.1	25.7	26.4	23.8	25	28.5	26.5	27.4	24.4	23.8	24.1
16	24.1	22.4	23.3	25.6	24.8	25.3	26.8	25.8	26.1	24.1	23.6	23.9
17	23.9	21.9	22.6	25.9	25.2	25.5	27.4	25.2	26.3	25.1	23.1	23.8
18	22.5	21.8	22	26	25.7	25.8	27.8	25.7	26.7	24.1	23.1	23.7
19	22.3	21.4	21.8	27.6	25.7	26.3	26.5	25	25.5	25.8	23	24.2
20	21.6	20.6	21	29.4	26.9	28.2	25.2	24.6	24.8	24.7	22.7	23.3
21	23.4	20.1	21.1	30.4	27.8	28.8	26.3	24.5	25.2	23.8	22.2	23
22	23.4	21.9	22.6	31.3	27.9	29.2	27.2	25.1	26.1	23.8	22.3	22.8
23	25.4	22	23.2	29.5	28.2	28.6	26.4	25.1	25.9	22.9	22	22.4
24	23.3	21.9	22.4	29.3	27.1	28	25.7	24.8	25.2	22.6	21.2	21.8
25	24	22.5	23.1	27.7	26.4	26.8	26.1	23.9	25	21.5	20.2	20.8
26	25.8	24	24.7	28	26	26.5	26.7	24	25.4	20.2	19.9	20.1
27	26.8	24.9	25.8	--	--	--	25.6	23.3	24.2	20.3	19.6	20
28	26.7	26	26.5	27.7	26.5	27.1	24.8	23.8	24.2	20	19	19.4
29	26.8	25.7	26	27.8	26.1	26.8	25.2	24.4	24.7	19.1	18.4	18.8
30	26	25.4	25.7	27.7	26	26.6	25.2	24.9	25	19.2	17.7	18.5
31	--	--	--	26.8	25.9	26.4	25	24.7	24.8	--	--	--
Monthly average	29.6	17.6	23.4	--	--	--	--	--	--	27.1	17.7	22.9

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Top specific conductance, water year 2003												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	178	167	172	240	231	235	241	233	236
2	--	--	--	188	175	181	231	224	227	239	232	235
3	--	--	--	199	185	192	227	214	221	251	233	237
4	--	--	--	200	191	196	223	218	220	248	239	241
5	--	--	--	199	195	198	235	222	226	246	238	242
6	--	--	--	203	198	200	230	226	227	248	238	242
7	162	157	159	208	201	204	232	226	229	256	234	239
8	164	158	162	207	203	204	230	218	226	259	234	245
9	170	159	163	212	204	209	219	197	207	253	237	246
10	168	165	167	213	207	210	206	199	204	245	237	242
11	167	165	166	212	209	210	206	203	204	249	237	243
12	165	162	163	222	210	215	204	201	202	248	238	245
13	166	161	164	221	215	216	208	202	203	250	246	248
14	170	159	163	224	216	219	213	201	206	254	243	247
15	174	166	172	231	219	220	206	201	203	252	247	249
16	177	173	175	236	221	223	203	202	202	254	249	251
17	176	175	176	234	220	222	212	203	208	257	251	254
18	175	171	174	221	218	219	211	203	206	256	252	255
19	172	163	169	219	216	218	216	204	208	255	253	254
20	174	167	170	218	217	217	222	207	213	257	253	254
21	178	174	176	218	215	216	222	207	211	259	254	255
22	179	171	177	217	211	215	226	220	223	256	254	255
23	171	145	153	218	189	209	227	220	223	262	254	257
24	159	156	158	203	189	195	226	222	224	256	241	250
25	160	152	157	198	195	197	224	222	223	242	204	228
26	152	148	150	198	195	196	225	222	223	225	211	220
27	151	147	148	203	198	201	233	223	227	218	193	204
28	159	150	154	220	200	210	237	227	233	193	183	189
29	170	156	164	217	210	213	235	231	233	188	183	185
30	173	165	168	238	211	220	236	232	234	183	177	180
31	--	--	--	249	215	231	239	232	235	--	--	--
Monthly average	--	--	--	249	167	208	240	197	218	262	177	238

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Top specific conductance, water year 2005												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	214	211	212	252	251	251	267	263	264	300	299	300
2	214	212	213	253	251	252	273	266	269	305	299	301
3	217	213	214	253	251	252	277	268	272	302	299	301
4	220	215	216	254	251	252	283	271	273	303	299	301
5	221	215	218	258	252	254	301	273	275	306	299	302
6	223	219	221	257	252	255	289	273	279	307	300	303
7	225	220	222	256	253	254	311	276	279	310	304	306
8	225	222	223	258	255	256	287	278	282	312	306	309
9	229	225	227	260	251	257	287	281	284	319	310	315
10	239	228	233	258	216	232	287	281	284	321	315	317
11	244	234	239	228	224	226	296	283	289	319	316	317
12	243	238	241	226	220	224	--	--	--	321	316	319
13	245	240	242	222	217	219	295	286	289	324	318	321
14	248	242	246	219	206	214	292	276	288	327	321	324
15	249	246	247	214	206	210	283	278	282	325	317	321
16	263	248	249	211	207	209	286	280	283	320	318	319
17	265	247	250	210	208	209	292	283	288	320	317	319
18	273	247	249	219	209	212	294	287	290	319	315	317
19	248	246	247	219	213	215	294	288	290	319	314	316
20	247	243	245	222	216	219	293	288	291	317	306	312
21	245	243	244	227	220	222	293	288	291	307	301	305
22	248	245	246	234	221	226	299	289	293	307	304	306
23	251	246	249	239	226	232	299	292	296	307	305	306
24	250	247	248	242	233	238	299	293	296	308	305	307
25	250	248	249	248	239	244	296	292	294	307	305	306
26	251	249	250	253	247	249	307	293	299	306	302	305
27	253	250	252	--	--	--	303	299	300	303	301	302
28	253	251	252	258	255	257	303	299	301	302	300	301
29	253	250	252	261	257	259	301	300	301	300	295	298
30	253	251	252	264	259	261	301	299	300	300	296	298
31	--	--	--	267	261	264	300	299	299	--	--	--
Monthly average	273	211	238	--	--	--	--	--	--	327	295	309

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Top pH, water year 2003								
Day	June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min
1	--	--	6.8	6.5	10.1	9.9	9.5	7.9
2	--	--	7.1	6.5	10	7.2	9	8
3	--	--	7.2	6.6	9.1	7	9	7.7
4	--	--	7.2	6.6	9.5	7.2	9	7.6
5	--	--	8	6.6	9.4	7.2	9.9	7.8
6	--	--	8.3	6.8	9.4	7.5	10	8.8
7	6.6	6.6	7.2	6.6	9.5	7.4	10.2	7.2
8	6.7	6.5	7.6	6.7	9.7	7.1	10.2	7.3
9	6.7	6.5	7	6.6	9	7	10.2	9
10	6.8	6.5	6.9	6.6	8.8	7.1	10	8.7
11	6.7	6.6	6.8	6.6	8.3	7.3	10	7.7
12	6.8	6.6	6.8	6.6	9.1	7	9.9	8.6
13	6.7	6.5	7.1	6.7	9.5	7.7	9.9	9.7
14	6.7	6.5	7	6.6	9.8	7.3	9.8	7.6
15	6.7	6.6	7.2	6.6	9.5	7	9.7	9.2
16	6.7	6.6	7	6.6	9	7	9.8	9.2
17	6.8	6.6	8.3	6.9	9.8	8.8	9.8	9.5
18	6.8	6.6	7.9	6.8	9.6	6.9	9.8	9.5
19	6.7	6.6	8.1	6.8	9.8	6.9	9.6	8.8
20	7	6.6	8.1	6.7	9.9	7.1	9.4	8.4
21	6.9	6.7	7	6.6	9.8	7.3	9.7	9.1
22	6.7	6.7	7.2	6.8	9.6	7.2	9.4	7.5
23	6.7	6.6	7	6.7	9.8	9.5	9.1	7.5
24	6.6	6.6	6.9	6.6	9.7	9.3	8.5	7.5
25	6.7	6.6	7.7	6.8	9.5	8.1	8	7.1
26	6.8	6.5	7.4	6.8	9.5	8.2	8.6	7.3
27	7.1	6.6	7.6	6.6	9.7	8.3	7.8	7
28	7.1	6.6	9.7	7.2	9.9	9.3	7.2	7.1
29	6.7	6.4	9.5	7.9	9.8	9.3	7.5	7.1
30	6.9	6.4	9.9	8.3	9.7	9.2	7.8	7.1
31	--	--	10.2	8.9	9.8	9.3	--	--
Monthly average	--	--	10.2	6.5	10.1	6.9	10.2	7

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Day	June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min
	Top pH, water year 2005							
1	7	6.7	7.8	7	9.2	8.1	8.2	7
2	7.3	6.8	8.4	7	9.7	7.4	9.1	7.2
3	7.5	6.9	8.9	7.4	9.9	9	9.2	7.5
4	8.3	7.1	9.1	7.5	9.8	8.4	9.3	7.9
5	8.8	7.2	8.7	7.4	9.8	8.5	9.4	8.2
6	8	6.8	8	7.4	10.1	9.2	9.3	7.8
7	7.8	6.8	7.7	7.3	9.9	8.9	9.5	7.4
8	8.3	7	7.4	7	9.9	8.6	9.6	8.8
9	8.2	7.2	7.4	6.9	9.7	8.5	9.4	9
10	7.7	7	7.3	6.8	9.8	8	9.3	8.6
11	7.5	6.9	7.3	6.9	10	8.8	9.3	8.6
12	7.7	7	7.7	6.8	--	--	9.4	8.1
13	7.5	6.9	7.1	6.8	9.6	7.7	9.6	8.7
14	7.5	6.9	7.7	6.7	9.4	8.8	9.5	9
15	7	6.8	8.3	6.7	9.1	8	9.4	8.9
16	6.9	6.7	7.9	6.7	9.2	7.3	9.1	8.7
17	7	6.7	7.1	6.7	9.3	7	9.1	7.7
18	7.1	6.8	6.9	6.7	9.4	7.6	9.2	7.6
19	7.5	7	7.3	6.7	9.2	7.8	9.3	7.9
20	7.5	7	8.6	7.1	8.8	7.2	9.1	7.3
21	8.1	6.9	9	7.3	9.2	7.1	9.1	6.9
22	8.2	7.3	9.1	7.6	9.6	8.4	9	7.6
23	8.5	7.4	8.8	7.8	9.6	8.9	9.2	7.4
24	8.2	7.2	8.9	7.3	9.5	8.7	9.5	8.2
25	8.8	7.4	8.3	7.1	9.4	8	9.2	8.3
26	9	7.7	7.7	7	9.8	8.3	8.6	7.7
27	8.8	7.9	--	--	9.5	7.1	8.9	7.5
28	8.1	7.3	8.8	7.4	9.4	8.2	9.4	7.7
29	7.5	7.1	9.3	7.4	9.3	8.4	8.9	7.6
30	7.3	7	9.5	7.5	9.1	8.4	9.2	7.8
31	--	--	9.6	8.4	8.7	7.2	--	--
Monthly average	9	6.7	--	--	--	--	9.6	6.9

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Top dissolved oxygen, water year 2003												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	8.3	5.7	6.9	13.7	12	12.8	10.1	7.3	8.4
2	--	--	--	9.2	6.2	7.6	12.1	6.8	9.9	9.1	7.5	8.5
3	--	--	--	8.8	6.5	7.8	9.6	6.4	7.6	9.7	7.6	8.7
4	--	--	--	9.3	6.7	7.5	10.6	7.2	8.6	10.1	8.3	9.3
5	--	--	--	9.4	6.8	8.2	10.3	7.2	8.6	13.3	8.2	11.2
6	--	--	--	9.1	7	8.3	10.5	7.7	8.7	13.9	9.5	12.3
7	9	8.5	8.7	8.2	5.6	6.8	10.6	7.7	9.2	15.7	6.8	9.5
8	8.9	7.9	8.5	9	6.5	8.1	12	6.9	9.5	15.3	8	12.3
9	8.9	7.7	8.3	7.8	6.2	7.3	9.4	6.7	8.1	14.2	9.8	13.1
10	9.3	8.4	8.9	7.4	6	6.8	9.8	7.6	8.5	13.5	9.4	12.2
11	8.8	8.2	8.5	7.2	5.9	6.9	8.9	7.6	8.2	13.5	8.3	11.6
12	8.8	7.6	8.2	7	5.3	6.3	10.6	6.8	9	12.9	9.1	12
13	8.2	7.2	7.8	8.7	6.8	7.6	12.6	8.5	9.9	12.6	11.4	12
14	8.2	7	7.7	8.4	6.6	7.5	12.9	7.5	10.7	12	8.9	10.7
15	8.2	7.6	8	9.7	6.1	8.3	11.7	6.5	8.4	12.3	10.6	11.3
16	8.1	7.4	7.7	8.9	6.5	8	9.6	6.6	7.8	12.1	10.3	11.3
17	8.4	7.2	7.8	10.3	8.3	9.1	12.5	9.4	11.2	12.5	10.7	11.6
18	8.4	7	7.8	9.5	7	8.4	12.3	6.1	9.7	12	10.6	11.5
19	7.9	7.1	7.4	9.7	7.3	8.6	12.3	5.9	8.9	10.8	9.2	10
20	9.3	7.3	8.2	10.2	6.7	8.1	13.4	6.2	10.4	11.1	8.4	9.6
21	8.5	7.6	8.1	8.5	6.3	7.5	12.9	8	10.1	13	10.4	11.2
22	7.7	7.4	7.6	8.6	7.2	7.7	10.9	7.4	8.7	11.4	8.6	10.2
23	8.4	7.6	8.1	7.8	6.4	7.1	11.5	9.8	10.8	10.7	8.8	9.7
24	8.3	7.6	7.9	7.7	6.1	6.9	11	9.3	10.2	9.5	7.9	8.8
25	7.9	7.1	7.4	9.8	7.1	8.4	9.9	7.6	9.1	8.9	7.5	8.3
26	8.2	6.7	7.2	9.3	7.4	8.2	10.9	7.2	8.9	9.8	7.9	8.9
27	8.2	6.2	7	9.7	6.5	7.9	11.3	7.5	9.8	9.1	7.6	8.2
28	7.4	6.2	6.9	14.2	8.6	11.7	11.8	9.8	11.2	8.5	7.7	8.1
29	7.1	4.8	6.1	12.8	8.5	11.3	11.3	9.1	10.5	9	8	8.4
30	8.1	5.5	6.5	16.6	9	12.1	11	8.9	9.9	9.5	8.1	8.7
31	--	--	--	15.7	10.3	13.3	11.4	9	10	--	--	--
Monthly average	--	--	--	16.6	5.3	8.3	13.7	5.9	9.5	15.7	6.8	10.3

Table 1–1. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149, at top location for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Top dissolved oxygen, water year 2005												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	9.5	8.6	9.1	8.8	6.8	7.6	9.2	8	8.6	8.6	6	7.5
2	9.9	8.7	9	8.9	7	8.1	10.6	7.5	9.2	10.3	6.7	8.5
3	9.4	8	9.1	9.8	7.9	8.6	11.4	8.9	10.1	10.5	7.7	9.3
4	10.6	8.7	9.8	10.9	8	9.6	11.1	8.9	10	11.1	8.4	9.9
5	10.6	8.4	9.6	10.2	7.7	9.3	10.2	8.6	9.3	11.6	8.8	10.3
6	9.7	7.8	8.4	8.9	7.9	8.6	11.5	8.8	10.2	11.8	7.7	10.2
7	8.3	6.7	7.9	8.6	7.7	8.2	10.5	8.6	9.6	12.5	7.9	10.8
8	9.8	7.6	8.5	8.2	7.3	7.8	11.1	7.6	9.4	13	10	11.5
9	10.4	8.3	9.3	8.5	6.9	7.8	10.2	7.3	9.1	11.9	10.5	11.1
10	8.9	7.6	8.3	9.2	7.2	8.3	10.3	6.8	8.6	11.2	9.2	10.5
11	8	6.4	7.2	8.9	7.8	8.3	11.2	7.5	9.7	11.6	9.2	10.3
12	8	7	7.6	9.4	7.7	8.3	--	--	--	11.5	8.9	10.3
13	7.9	6.4	7.1	8.4	7	8	10.1	6.7	8.8	12.4	9.6	10.7
14	7.6	6	6.9	9.1	6.8	7.7	9.2	7.3	8.5	11.7	10.2	10.8
15	6.8	5.6	6.3	9.8	6.7	8.4	8.4	6.8	7.7	11.1	9.5	10.1
16	6.2	5.4	5.8	9.3	6.8	8.3	9.1	6	7.3	10	8.9	9.5
17	6.8	5.4	6.2	8	6.9	7.4	9.8	5.8	7.9	10.2	8.1	9.1
18	7.5	6	6.8	7.5	6.1	6.9	10.5	7.4	9.2	10.8	7.8	9.6
19	8.7	7.3	8	8.3	6.2	7.3	10.2	7.7	8.9	11.3	8.5	10
20	9	6.7	8	9.6	7.5	8.6	9.6	7	8.3	10.5	7.8	9
21	9.7	7.6	8.8	10.9	7.9	8.9	10.3	6.7	8.5	10.8	6.5	9.3
22	9.6	8.6	9	11	8.2	9.5	11.8	8.7	10.2	10.7	7.8	9.7
23	10	8.5	9.2	9.6	8.4	9.1	11.5	9.3	10.6	11.4	8.4	9.9
24	9.6	8	8.9	10.2	8.1	9.1	11.2	9.1	10.2	12.3	9.3	10.8
25	10.2	8.5	9.2	9	7.4	8.2	11.5	8.3	10.1	11.2	9.7	10.3
26	10.4	8.8	9.6	9	6.6	7.9	12.2	8.9	10.8	10.3	9	9.7
27	9.8	8.5	9.2	--	--	--	11.2	7.3	9.5	10.8	8.7	9.9
28	8.6	7.8	8.2	8.4	6.9	7.7	11.3	8.4	10.2	12.6	9.3	10.5
29	8.1	7.1	7.7	9.1	6.9	7.9	10.5	8.3	9.6	10.9	9.3	10.2
30	7.7	6.4	7.2	10	7	8.6	9.7	8.2	9.2	11.6	9.3	10.5
31	--	--	--	10	8.3	9.4	8.9	6.8	7.6	--	--	--
Monthly average	10.6	5.4	8.2	--	--	--	--	--	--	13	6	10

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.

[--, not available; Max, maximum; Min, minimum]

Bottom water temperature, for water year 2003												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	22.8	22	22.3	24.3	23.8	24	22.3	21.4	22
2	--	--	--	22.6	21.7	22	24	22.5	23.2	21.5	19.6	20.9
3	--	--	--	22.3	21.5	21.8	23.2	22.4	22.7	19.8	19	19.2
4	--	--	--	23	21.8	22.2	23.4	22.6	22.8	19.3	19.1	19.2
5	--	--	--	22.8	22	22.4	24	22.9	23.5	20.4	19.2	19.5
6	--	--	--	23.5	22.4	22.8	24.6	23.4	24	19.7	19.4	19.5
7	17.6	15.8	16.5	24.1	23	23.4	25.1	24	24.5	19.8	19.5	19.6
8	17.5	16.4	16.9	24.5	23.6	24.1	24.5	23.9	24.3	19.9	19.6	19.7
9	16.6	16.3	16.5	24.6	23.8	24.2	24.3	23.8	24	19.9	19.7	19.8
10	18.7	16.4	17.1	24.4	22.9	23.7	24.6	23.8	24.2	19.9	19.7	19.8
11	18.6	16.8	17.5	23.2	22.5	23	24.9	24.2	24.6	19.7	18.5	19.2
12	19	18.3	18.7	22.6	21.8	22	25	24.3	24.6	19.1	18.6	18.8
13	18.9	18.3	18.6	22.8	21.9	22.1	25	24.4	24.6	19.7	18.9	19.3
14	19.2	17.3	17.9	22.8	22.3	22.6	25.3	24.5	24.8	19.3	19.1	19.2
15	20.6	17.2	19	22.6	22.1	22.4	25.2	24.5	24.9	19.6	19.2	19.3
16	19.9	18.7	19.2	23	22	22.4	25.3	24.7	24.9	20.3	19.3	19.6
17	19.6	18.2	18.9	23.6	22.5	22.9	25	24.6	24.8	20.3	19.6	19.9
18	19.6	18.6	19	23.3	22.4	22.7	24.9	24.1	24.6	21.9	19.9	20.4
19	19	18.2	18.6	22.9	22	22.5	24.5	23.5	23.9	21.3	20.6	20.9
20	20	18.2	19	22.7	22	22.3	24.6	23.5	23.7	21.1	20.6	20.7
21	19.9	18.4	19.2	22.5	22	22.2	23.8	23.4	23.6	21.2	20.5	20.8
22	19.2	17.4	18.2	23.5	22.2	22.7	24.2	23.4	23.7	20.9	20.6	20.8
23	17.4	16.1	16.6	23.2	22.5	22.8	26.1	23.8	24.6	21	20	20.6
24	18.1	16.1	17	23.1	22.4	22.7	26.1	24.7	25.3	20.7	18.9	19.9
25	20.5	16.9	18.9	23.5	22.7	23	25	22.8	23.8	19.2	18.7	18.9
26	22	19.5	21.1	23.7	22.8	23.2	22.8	21.5	22	20	18.8	19.4
27	24.3	21.4	22.8	23.5	22.9	23.2	23.2	21.7	22.3	19.3	18.7	19
28	25	22.7	24.1	25	23.1	23.9	24.6	22.4	23.5	19.3	18.9	19.1
29	23.9	22.2	23.1	24.6	23.5	24	24.1	22.8	23.3	19.5	18.9	19.1
30	23.1	22.3	22.5	24.7	23.8	24.2	23.6	22.8	23.1	19.2	18.3	18.7
31	--	--	--	24.6	23.9	24.2	23.7	22.2	22.8	--	--	--
Monthly average	--	--	--	25	21.5	22.9	26.1	21.5	23.9	22.3	18.3	19.8

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Bottom water temperature, for water year 2005												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	24.1	23.5	23.8	25	24.4	24.7	24.8	23.7	24.1
2	--	--	--	25.9	23.6	24.5	25.4	24.3	24.8	24.4	24	24.1
3	--	--	--	25.7	23.9	24.7	25.4	24.6	24.8	25	23.7	24.2
4	--	--	--	24.5	23.5	24	25.1	24.6	24.9	25.4	24	24.6
5	--	--	--	24	23.4	23.8	26.2	24.7	25.1	24.5	23.2	24
6	--	--	--	24.8	23.6	23.9	26.3	25.2	25.5	23.3	22.5	22.8
7	--	--	--	24.5	23.2	23.8	25.9	25.5	25.7	22.6	21.9	22.4
8	--	--	--	23.2	21.5	22.4	26	25.5	25.7	22.5	22.1	22.3
9	--	--	--	21.5	18.7	20.1	25.9	25.3	25.6	22.9	22.3	22.6
10	--	--	--	21.3	18.4	19.5	26	25.5	25.7	23.6	22.4	22.9
11	--	--	--	22	20.2	20.9	26.4	25.5	25.8	23.1	21.3	22.1
12	--	--	--	22.5	20.2	21.1	26	25.2	25.8	21.6	21	21.3
13	--	--	--	22.7	21	21.8	26.3	25.8	26	21.8	21.2	21.5
14	--	--	--	22.9	22.2	22.5	26.7	25.9	26.1	26	21.5	21.9
15	--	--	--	22.9	22.3	22.6	27.5	25.8	26.9	22.5	21.7	22.2
16	--	--	--	23.1	22.4	22.8	26.4	24.7	25.7	22.8	22.4	22.6
17	--	--	--	23.3	22.7	23.1	25.5	24.4	24.9	23.5	22.8	23.1
18	--	--	--	23.9	23.2	23.5	25.2	24.5	24.9	23.1	22.7	22.9
19	--	--	--	25.1	23.7	24.1	24.6	24.1	24.3	23.1	22.4	22.8
20	--	--	--	26	24.2	24.8	24.2	23.6	24	22.4	21.8	22.1
21	--	--	--	25.6	24.5	25.1	24.7	23.3	23.5	22.4	21.9	22.1
22	--	--	--	26.6	25.2	25.6	24.3	23.5	23.8	22.2	21.4	21.8
23	--	--	--	28.4	25.3	27	24.4	23.7	23.9	22.3	21.5	21.7
24	--	--	--	27.6	25.8	26.8	24.8	23.6	23.9	22	20.8	21.3
25	21	20.3	20.6	25.8	25.1	25.4	23.9	23	23.5	20.9	20.2	20.5
26	21.8	20.8	21.2	25.6	24.6	25.1	23.8	22.2	22.7	20.2	18.9	19.7
27	22.1	21.2	21.6	--	--	--	22.5	22	22.3	20.3	19.4	19.8
28	22.4	21.5	21.9	27	25.2	26.4	22.7	22.3	22.5	19.9	18.7	19.1
29	23	21.7	22.3	26.3	25.5	25.8	22.9	22.5	22.7	19.1	18.4	18.8
30	23.7	22.6	23	25.9	24.4	25.3	23.2	22.7	23	18.4	17.3	17.7
31	--	--	--	25.3	24.5	24.9	23.9	23	23.3	--	--	--
Monthly average	--	--	--	--	--	--	27.5	22	24.6	26	17.3	22

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Bottom specific conductance, for water year 2003												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	182	175	179	223	217	221	255	233	241
2	--	--	--	193	181	186	228	219	224	267	226	248
3	--	--	--	200	191	197	223	213	221	262	252	257
4	--	--	--	202	198	200	221	213	217	255	251	253
5	--	--	--	202	200	201	230	215	221	254	234	248
6	--	--	--	203	200	201	227	220	224	243	230	238
7	171	165	167	206	202	203	225	219	222	232	228	230
8	173	167	170	211	204	208	225	202	219	231	228	229
9	179	167	172	214	210	212	207	186	195	231	228	229
10	179	174	177	220	212	216	198	189	194	234	228	230
11	180	172	177	219	212	214	199	196	198	261	233	244
12	173	169	170	230	219	226	199	194	196	259	248	255
13	174	171	172	227	222	225	197	195	196	254	238	246
14	177	166	170	225	223	224	199	197	198	260	249	253
15	183	174	178	231	225	228	201	198	199	255	251	253
16	192	179	181	230	223	227	202	198	199	253	242	249
17	185	181	182	227	221	223	202	198	200	250	245	248
18	184	178	181	222	218	220	209	201	205	250	242	247
19	178	168	173	221	218	220	216	206	210	248	243	246
20	177	170	173	222	220	221	219	204	215	249	245	247
21	179	172	176	221	212	216	220	215	217	248	245	247
22	180	171	177	218	213	216	224	217	220	253	246	248
23	171	145	150	222	177	205	221	210	215	264	246	252
24	156	148	152	190	180	185	218	213	215	248	205	234
25	159	152	157	195	185	191	232	214	220	213	185	194
26	157	152	154	201	193	197	240	229	235	214	188	203
27	155	150	152	207	199	202	239	219	231	203	178	189
28	164	152	157	205	200	202	231	219	225	188	177	181
29	173	162	167	219	203	210	228	219	224	184	178	181
30	189	172	174	226	209	219	226	222	224	182	171	176
31	--	--	--	225	212	217	237	223	226	--	--	--
Monthly average	--	--	--	231	175	209	240	186	214	267	171	233

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Bottom specific conductance, for water year 2005												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	254	251	253	276	267	273	296	291	293
2	--	--	--	254	249	251	274	256	266	294	292	293
3	--	--	--	253	250	251	267	260	264	296	291	294
4	--	--	--	258	248	251	272	264	266	296	292	294
5	--	--	--	263	251	256	272	265	268	301	292	295
6	--	--	--	260	251	256	270	264	267	325	300	311
7	--	--	--	254	251	253	281	269	274	341	301	317
8	--	--	--	257	253	255	295	275	281	335	305	321
9	--	--	--	267	203	244	289	281	283	318	302	308
10	--	--	--	227	177	202	281	273	279	311	303	308
11	--	--	--	224	215	221	280	271	276	318	308	311
12	--	--	--	224	215	220	290	275	278	320	314	317
13	--	--	--	223	220	221	282	278	280	321	313	317
14	--	--	--	223	203	215	287	280	283	324	317	320
15	--	--	--	214	202	206	282	270	276	322	316	318
16	--	--	--	210	204	206	286	273	276	318	315	317
17	--	--	--	208	205	206	287	278	283	316	310	311
18	--	--	--	215	205	208	290	279	283	315	308	311
19	--	--	--	222	210	215	295	286	290	312	297	307
20	--	--	--	224	213	219	301	289	293	300	278	287
21	--	--	--	228	221	225	308	284	302	302	283	293
22	--	--	--	255	228	234	313	289	300	304	296	299
23	--	--	--	252	231	240	311	293	303	302	296	300
24	--	--	--	250	234	239	310	292	303	301	297	298
25	249	246	246	277	250	266	304	289	298	302	297	299
26	248	246	247	277	260	269	298	290	295	299	294	297
27	249	247	247	--	--	--	293	288	291	297	294	295
28	251	247	248	259	249	250	293	290	291	296	289	294
29	253	248	250	254	249	251	295	292	293	293	289	292
30	255	250	251	277	250	260	297	293	295	293	291	291
31	--	--	--	276	259	269	298	295	296	--	--	--
Monthly average	--	--	--	--	--	--	313	256	284	341	278	304

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Bottom pH, for water year 2003								
Day	June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min
1	--	--	6.6	6.4	7.3	6.8	7.2	6.8
2	--	--	6.6	6.5	7	6.6	8.5	6.8
3	--	--	6.6	6.5	6.9	6.7	7.2	6.9
4	--	--	6.6	6.4	6.9	6.7	7.1	6.9
5	--	--	6.5	6.4	7.2	6.8	8	6.7
6	--	--	6.6	6.4	7.4	6.8	7	6.8
7	6.7	6.5	6.5	6.4	8.3	6.9	7	6.7
8	6.7	6.5	6.6	6.5	7.1	6.8	6.9	6.7
9	6.7	6.5	6.6	6.4	7.1	6.8	6.8	6.7
10	6.8	6.5	6.6	6.4	7.3	6.8	7.4	6.7
11	6.7	6.5	6.6	6.5	7.3	7	7.5	6.8
12	6.7	6.6	6.6	6.5	7.3	6.8	7.1	6.8
13	6.7	6.5	6.6	6.5	7	6.7	7.7	6.8
14	6.7	6.6	6.5	6.5	7	6.6	7	6.7
15	6.8	6.6	6.6	6.4	6.8	6.6	7.1	6.7
16	6.7	6.5	6.6	6.4	6.8	6.7	7.8	6.8
17	6.7	6.6	7	6.5	6.8	6.6	7.2	6.8
18	6.7	6.6	6.7	6.5	6.8	6.6	9.7	6.8
19	6.7	6.5	6.6	6.5	6.9	6.7	9.4	7.2
20	6.9	6.5	6.6	6.5	7.2	6.7	8.3	7.1
21	6.8	6.5	6.6	6.5	6.8	6.7	8.5	6.9
22	6.8	6.7	6.8	6.5	6.8	6.6	7.6	6.9
23	6.8	6.7	6.7	6.6	9.5	6.6	8.6	6.9
24	6.7	6.6	6.6	6.5	9.7	8.1	8.5	7
25	6.6	6.5	6.7	6.4	9.5	6.9	7.2	6.9
26	6.6	6.5	6.8	6.5	7.1	6.6	8.3	6.8
27	6.7	6.4	6.6	6.5	7.9	6.8	7.2	6.9
28	6.8	6.5	7.2	6.5	9.8	6.7	7.1	6.8
29	6.6	6.4	6.8	6.5	9.7	7.7	7.2	7
30	6.6	6.4	7.9	6.5	9.1	7.2	7.3	6.9
31	--	--	--	--	9.4	7	--	--
Monthly average	--	--	--	--	9.8	6.6	9.7	6.7

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Bottom pH, for water year 2005								
Day	June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min
1	--	--	7	6.8	6.7	6.6	7.1	6.6
2	--	--	7.6	6.8	7.4	6.6	7	6.7
3	--	--	7.5	6.9	6.8	6.6	7.7	6.6
4	--	--	7.4	6.6	6.7	6.5	9	6.8
5	--	--	6.9	6.6	7.2	6.6	8	6.7
6	--	--	7.5	6.6	6.9	6.5	6.8	6.6
7	--	--	7.6	7.3	6.7	6.5	7.2	6.6
8	--	--	7.4	7.2	6.6	6.5	6.9	6.6
9	--	--	7.3	7.1	6.6	6.5	8.1	6.7
10	--	--	7.4	7.2	6.8	6.5	9	7
11	--	--	7.4	6.9	7.6	6.5	9	6.9
12	--	--	7	6.8	6.8	6.6	7.1	6.7
13	--	--	6.8	6.7	6.7	6.6	6.9	6.6
14	--	--	6.8	6.7	6.7	6.5	6.8	6.6
15	--	--	6.8	6.6	9	6.5	6.9	6.6
16	--	--	6.7	6.5	8.3	6.7	6.8	6.6
17	--	--	6.6	6.4	7	6.6	8.3	6.7
18	--	--	6.6	6.4	7.4	6.6	7.1	6.7
19	--	--	6.7	6.5	6.8	6.6	7.4	6.7
20	--	--	6.8	6.5	6.7	6.5	6.7	6.6
21	--	--	6.6	6.3	7.2	6.5	7.1	6.6
22	--	--	6.7	6.4	6.8	6.5	7.1	6.7
23	--	--	8.6	6.5	6.8	6.5	8.1	6.7
24	--	--	7.5	6.7	7.1	6.5	8.2	6.9
25	7.3	7.2	6.7	6.6	7.4	6.5	7.8	6.8
26	7.3	7.1	6.7	6.5	6.8	6.6	7.4	6.9
27	7.2	7.1	--	--	6.8	6.6	7.8	6.8
28	7.4	7.1	7.7	6.7	6.7	6.5	7.3	6.9
29	7.2	7.1	7.2	6.7	6.6	6.5	8.1	6.8
30	7.1	6.9	7.3	6.6	6.6	6.5	7.8	7.1
31	--	--	6.8	6.6	6.6	6.5	--	--
Monthly average	--	--	--	--	9	6.5	9	6.6

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Day	Bottom dissolved oxygen, for water year 2003											
	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	6.2	4.5	5.4	6.9	2.7	4.5	5.9	2.9	4.7
2	--	--	--	6.5	4.4	5.4	5.8	1.5	4.1	8.5	3.7	5.9
3	--	--	--	5.7	3.9	4.8	6	0.4	4.8	7.9	3.9	6.3
4	--	--	--	5.8	3.4	4.4	5.2	2.7	4.2	7.4	2.8	5.2
5	--	--	--	5.1	3.6	4.4	6.2	3.1	4.6	7.9	1.6	4.6
6	--	--	--	5.2	3.1	4.2	7.3	3.9	5.3	6.1	3.3	4.8
7	8.2	6.7	7.4	4.7	2.6	3.7	8.1	4.5	6	6.6	2.9	4.9
8	8.4	6.6	7.6	4.4	3	3.8	6.8	3.8	5.7	6.9	2.5	4.8
9	8.3	6.9	7.7	4.3	2.5	3.3	6.8	3.5	6	5.8	2.8	4.3
10	8.9	7	7.9	4.7	2.1	3.3	7.8	4.7	6.3	7.8	2.6	4.3
11	7.7	6.4	7.1	4.5	2.7	3.7	8.1	6	7	8.6	4.6	7.2
12	8	6.6	7.4	5.1	2.8	4.3	7.3	5	6.2	7.8	5.8	6.7
13	7.8	5.8	7.1	4.4	3	3.9	6.2	3.7	5	7.6	4.3	6.4
14	8.3	7.3	7.7	4.3	2.9	3.6	6.3	3.2	4.8	6.7	3.8	5.5
15	8.3	7	7.9	4.7	2.4	3.9	5	2.5	3.7	7.2	4.3	5.4
16	7.8	5.8	7.2	4.8	3	4	5	3	4	8.3	4.3	5.8
17	8.2	6.6	7.5	7.8	3.5	5.2	4.3	2.7	3.6	6.9	4.2	5.1
18	8.1	6.6	7.3	6	3.6	4.4	5.5	1.8	3.4	11.4	3.7	5.6
19	7.7	6.1	7.4	5	2.7	3.9	5.3	3.1	4.3	9.6	6.5	8.3
20	9	5.6	7.4	5.4	3.7	4.3	7.2	3.2	4.7	8.4	4.3	6.5
21	8.2	5.8	7.2	4.7	2.8	3.9	5	2.4	3.7	8.7	3.8	5.8
22	8	7.3	7.7	6.4	2.9	4.2	4.9	1.4	2.9	8.6	4.1	5.9
23	8.6	7.9	8.3	6	3.9	5.1	10.2	2.4	4.9	9.6	4.9	7.4
24	8.3	7.4	7.9	5.7	4.1	4.9	10.9	6.6	9.1	9.2	7	8.1
25	7.7	6.8	7.3	6.2	3.3	4.7	9.4	4.2	7.1	7.7	5.9	6.8
26	7.4	6.1	7	6.8	3.6	5.2	5.9	2.6	4.1	9.6	5.2	7.5
27	7.6	5.9	6.5	5.5	3.1	4.1	7.4	3.4	5	7.7	6.7	7.2
28	7.7	5.3	6.7	8.5	3.5	5.7	11.4	3.4	7.7	7.8	6.3	7
29	6.9	4.2	5.8	6.6	2.8	4.3	10.6	6.1	8.5	8.5	6.5	7.5
30	6.4	4.1	5.3	9.7	3	5.5	8.1	5.3	6.3	8.3	6.5	7.5
31	--	--	--	--	--	--	9.5	4.9	7.7	--	--	--
Monthly average	--	--	--	--	--	--	11.4	0.4	5.3	11.4	1.6	6.1

Table 1–2. Daily maximum, minimum, and mean values of water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter; pH (maximum and minimum only); and dissolved oxygen, in milligrams per liter, for USGS station 01124149 at location 12 feet below surface (near bottom) for water years 2003 and 2005.—Continued

[--, not available; Max, maximum; Min, minimum]

Bottom dissolved oxygen, for water year 2005												
Day	June			July			August			September		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	--	--	--	3.4	1.5	2.2	4.5	2.2	3.3	6.7	2	4.2
2	--	--	--	5.6	1.2	2.8	7.7	2.3	4.1	6.6	3.6	5.1
3	--	--	--	5.2	1.8	3.5	5.9	3	4	8.9	1.1	4.2
4	--	--	--	4.9	1.1	2.5	4.4	1.6	3	10.9	3.8	6.7
5	--	--	--	3.5	0.3	1.9	7.6	1	3.2	8.6	3.9	6.3
6	--	--	--	4.8	0.4	1.9	6.1	2.2	3.3	6	1.7	4.2
7	--	--	--	4.7	3.5	4.3	3.5	1	1.7	8.7	1.6	4.3
8	--	--	--	4.2	2.7	3.5	3.7	1.4	2.5	5.9	1.9	3.7
9	--	--	--	3.5	1.7	2.9	3.6	1.5	2.4	9.2	1.2	5.1
10	--	--	--	3.7	2.4	3.3	5.4	1.4	2.4	11	3.5	7.5
11	--	--	--	8.2	2.4	5.2	7.4	1.4	3.4	10.4	2.3	5.9
12	--	--	--	7.3	5.5	6.3	4.1	1.3	2.5	7	0.2	3.8
13	--	--	--	6.4	4.7	5.4	3.2	0.4	1.7	4.4	0.1	1.9
14	--	--	--	5.8	4.2	5.1	2.8	0.2	0.8	5	0.1	2.6
15	--	--	--	5.3	3.7	4.8	8	0	5.6	5.7	2.6	3.9
16	--	--	--	5.4	3	4.4	7	1.7	5.3	4.5	2.5	3.3
17	--	--	--	4.8	3	3.8	4.4	1.6	2.9	8.7	3.2	7.4
18	--	--	--	4.4	2.8	3.5	6.4	0.2	2.8	6.8	3	4.7
19	--	--	--	5.7	2.3	3.7	4	0.3	2.2	8.4	3.5	6.3
20	--	--	--	7	2.8	4.3	3.3	0.4	2.2	6.1	3.4	4.7
21	--	--	--	4.6	2.7	3.7	5.9	1.1	2.6	7.5	3.5	5.6
22	--	--	--	5.7	2.8	3.6	3	0	1.1	8.8	3.4	5.6
23	--	--	--	9.4	2.6	6	3	0	0.9	10.4	3.9	6.6
24	--	--	--	8.4	4.5	7.1	5.8	0	0.5	11	5.9	9.1
25	5.3	3.6	4.5	5.9	4.4	5.1	6.6	0	2.3	10.8	5.2	8.3
26	5.7	3.6	4.7	5.7	3.3	4.6	5.9	1.4	3.6	10.7	6.6	9.1
27	5.4	3.4	4.5	--	--	--	5.6	3.2	4.7	11.6	6.8	9.8
28	5.7	2.5	4.2	7.6	3.5	6.4	5.1	2.2	3.7	10.9	7.6	9.8
29	4.7	1.4	3.3	7.1	3.8	5.2	3.6	1.2	2.6	11.9	5.9	10.1
30	3.6	1.4	2.7	7.9	2.7	3.9	3.4	0.9	2	11	6.7	8.9
31	--	--	--	4.9	3.1	3.9	2.8	0.6	1.5	--	--	--
Monthly average	--	--	--	--	--	--	8	0	2.7	11.9	0.1	6

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Appendix 2. Total Phosphorus and Nitrogen for the Quinebaug River Sites

Table

2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites....64

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.

[lb, pound; lb/mi^2, pounds per square mile]

Quinebaug River at Quinebaug, Conn., water years 1996–2005								
	Total phosphorus				Total nitrogen			
Date	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)
		Lower	Upper			Lower	Upper	
October 1995	921	563	1,420	5.94	27,300	23,700	31,400	176
November 1995	1,440	893	2,190	9.29	42,900	37,100	49,300	277
December 1995	614	398	908	3.96	24,000	21,000	27,200	155
January 1996	1,630	898	2,720	10.5	50,500	42,700	59,300	326
February 1996	1,420	936	2,080	9.16	48,400	41,800	55,700	312
March 1996	1,090	730	1,550	7.03	38,200	33,400	43,500	246
April 1996	2,230	1,300	3,580	14.4	58,700	50,300	68,100	379
May 1996	1,310	893	1,860	8.45	36,000	31,500	41,000	232
June 1996	427	289	610	2.76	12,900	11,400	14,500	83.2
July 1996	724	470	1,070	4.67	17,400	15,200	19,800	112
August 1996	337	233	472	2.18	9,360	8,290	10,500	60.4
September 1996	614	396	909	3.96	14,800	13,000	16,900	95.5
October 1996	1,480	936	2,230	9.55	34,000	29,700	38,700	219
November 1996	1,510	1,020	2,150	9.74	38,000	33,300	43,100	245
December 1996	3,200	1,930	5,020	20.6	75,800	65,600	87,200	489
January 1997	1,430	1,020	1,940	9.23	42,100	37,000	47,700	272
February 1997	1,090	772	1,500	7.03	33,700	29,700	38,200	217
March 1997	1,230	877	1,670	7.94	36,100	31,900	40,600	233
April 1997	2,260	1,570	3,140	14.6	53,200	46,600	60,500	343
May 1997	1,110	811	1,480	7.16	27,200	24,100	30,400	175
June 1997	353	256	476	2.28	9,470	8,460	10,600	61.1
July 1997	219	162	290	1.41	5,840	5,190	6,550	37.7
August 1997	221	166	288	1.42	5,690	5,060	6,370	36.7
September 1997	141	102	190	0.91	3,990	3,530	4,490	25.7
October 1997	299	217	402	1.93	8,080	7,210	9,020	52.1
November 1997	749	531	1,030	4.83	18,900	17,000	21,000	122
December 1997	491	337	693	3.17	14,700	13,200	16,300	94.8
January 1998	1,670	1,190	2,300	10.8	41,500	36,700	46,700	268
February 1998	1,650	1,170	2,260	10.6	40,600	35,800	45,800	262
March 1998	3,510	2,140	5,440	22.6	72,000	62,800	82,300	465
April 1998	1,620	1,190	2,150	10.5	36,100	32,200	40,400	233
May 1998	1,640	1,180	2,210	10.6	32,200	28,600	36,100	208
June 1998	1,820	1,230	2,580	11.7	30,600	27,200	34,400	197
July 1998	1,310	857	1,920	8.45	21,600	19,100	24,400	139
August 1998	318	245	407	2.05	6,840	6,160	7,590	44.1
September 1998	231	174	299	1.49	5,320	4,760	5,930	34.3
October 1998	729	509	1,010	4.70	14,600	13,100	16,300	94.2
November 1998	401	282	554	2.59	10,200	9,210	11,300	65.8
December 1998	414	277	595	2.67	11,600	10,500	12,700	74.8

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi^2, pounds per square mile]

Quinebaug River at Quinebaug, Conn., water years 1996–2005—Continued								
	Total phosphorus				Total nitrogen			
Date	Load (lbs)	95-percent confidence interval Lower	95-percent confidence interval Upper	Yield (lb/mi^2)	Load (lbs)	95-percent confidence interval Lower	95-percent confidence interval Upper	Yield (lb/mi^2)
January 1999	1,740	1,190	2,460	11.2	37,900	33,600	42,600	245
February 1999	1,650	1,150	2,310	10.6	36,800	32,700	41,200	237
March 1999	2,840	1,940	4,030	18.3	55,700	49,400	62,600	359
April 1999	899	633	1,240	5.80	20,400	18,400	22,600	132
May 1999	813	593	1,090	5.24	16,800	15,200	18,400	108
June 1999	217	155	295	1.40	5,020	4,490	5,590	32.4
July 1999	201	148	266	1.30	4,350	3,890	4,850	28.1
August 1999	151	106	210	0.98	3,320	2,950	3,730	21.4
September 1999	627	418	905	4.05	10,500	9,320	11,800	67.7
October 1999	942	658	1,310	6.08	17,200	15,600	18,800	111
November 1999	1,100	760	1,550	7.10	21,100	19,100	23,200	136
December 1999	1,250	861	1,750	8.06	26,000	23,600	28,600	168
January 2000	1,100	741	1,560	7.10	24,900	22,500	27,400	161
February 2000	1,230	833	1,760	7.94	26,700	23,900	29,700	172
March 2000	2,530	1,760	3,530	16.3	47,500	42,500	52,800	306
April 2000	3,350	2,100	5,080	21.6	52,500	46,400	59,100	339
May 2000	2,310	1,660	3,140	14.9	36,500	33,000	40,400	235
June 2000	2,490	1,650	3,610	16.1	34,100	30,500	37,900	220
July 2000	826	593	1,120	5.33	12,800	11,500	14,100	82.6
August 2000	694	510	922	4.48	11,100	10,100	12,200	71.6
September 2000	360	271	469	2.32	6,660	6,020	7,340	43.0
October 2000	493	356	665	3.18	9,490	8,640	10,400	61.2
November 2000	743	513	1,040	4.79	14,600	13,300	16,000	94.2
December 2000	936	628	1,340	6.04	19,000	17,100	21,000	123
January 2001	494	308	754	3.19	12,600	11,500	13,800	81.3
February 2001	733	465	1,100	4.73	17,300	15,700	19,000	112
March 2001	2,790	1,760	4,210	18.0	46,100	40,800	52,000	297
April 2001	3,830	2,360	5,890	24.7	57,000	50,400	64,300	368
May 2001	1,130	822	1,530	7.29	19,400	17,600	21,300	125
June 2001	1,850	1,310	2,530	11.9	25,900	23,400	28,600	167
July 2001	634	481	820	4.09	10,200	9,290	11,200	65.8
August 2001	346	267	443	2.24	6,010	5,430	6,640	38.8
September 2001	389	288	516	2.51	6,760	6,080	7,490	43.6
October 2001	459	334	617	2.96	8,530	7,740	9,390	55.0
November 2001	201	135	289	1.30	4,750	4,260	5,280	30.6
December 2001	309	196	463	1.99	7,660	6,920	8,460	49.4

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi², pounds per square mile]

Quinebaug River at Quinebaug, Conn., water years 1996–2005—Continued								
	Total phosphorus				Total nitrogen			
Date	Load (lbs)	95-percent confidence interval		Yield (lb/mi²)	Load (lbs)	95-percent confidence interval		Yield (lb/mi²)
		Lower	Upper			Lower	Upper	
January 2002	286	169	454	1.85	7,840	7,110	8,620	50.6
February 2002	479	289	749	3.09	12,000	10,900	13,200	77.4
March 2002	1,160	776	1,680	7.48	23,700	21,500	26,100	153
April 2002	1,550	1,090	2,140	10.0	27,600	24,900	30,500	178
May 2002	2,800	1,960	3,880	18.1	39,900	35,900	44,300	257
June 2002	2,160	1,520	2,970	13.9	29,100	26,200	32,200	188
July 2002	466	359	595	3.01	7,820	7,080	8,620	50.4
August 2002	301	226	393	1.94	5,190	4,640	5,800	33.5
September 2002	253	187	336	1.63	4,710	4,200	5,260	30.4
October 2002	723	517	985	4.67	12,500	11,300	13,700	80.6
November 2002	1,140	785	1,610	7.35	19,900	17,900	22,000	128
December 2002	2,050	1,380	2,940	13.2	35,300	31,500	39,400	228
January 2003	1,670	1,130	2,380	10.8	32,300	29,100	35,800	208
February 2003	1,260	825	1,840	8.13	25,400	22,700	28,400	164
March 2003	3,880	2,430	5,890	25.0	61,600	54,400	69,500	397
April 2003	3,120	2,130	4,410	20.1	48,900	43,500	54,700	315
May 2003	1,850	1,330	2,520	11.9	28,800	25,900	31,900	186
June 2003	3,600	2,370	5,240	23.2	44,800	39,900	50,000	289
July 2003	1,220	889	1,620	7.87	17,600	15,900	19,400	114
August 2003	1,300	908	1,800	8.39	17,800	16,000	19,700	115
September 2003	914	645	1,260	5.89	14,000	12,500	15,500	90.3
October 2003	1,490	980	2,160	9.61	22,400	19,900	25,100	145
November 2003	2,080	1,410	2,960	13.4	33,200	29,800	37,000	214
December 2003	3,560	2,180	5,490	23.0	56,400	49,600	63,800	364
January 2004	1,480	976	2,150	9.55	30,300	27,100	33,700	195
February 2004	761	462	1,180	4.91	18,200	16,400	20,200	117
March 2004	1,490	968	2,180	9.61	30,600	27,500	34,000	197
April 2004	4,120	2,610	6,200	26.6	63,000	55,500	71,200	406
May 2004	2,240	1,550	3,130	14.5	35,500	31,700	39,600	229
June 2004	821	574	1,140	5.30	14,100	12,700	15,800	91.0
July 2004	799	565	1,100	5.15	12,800	11,500	14,300	82.6
August 2004	736	520	1,010	4.75	11,900	10,700	13,300	76.8
September 2004	1,560	972	2,360	10.1	22,000	19,300	24,900	142
October 2004	1,630	1,080	2,380	10.5	25,900	23,100	29,000	167
November 2004	1,290	845	1,880	8.32	24,000	21,400	26,900	155
December 2004	2,850	1,820	4,250	18.4	50,700	44,800	57,200	327

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi^2, pounds per square mile]

Quinebaug River at Quinebaug, Conn., water years 1996–2005—Continued								
	Total phosphorus				Total nitrogen			
Date	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)
		Lower	Upper			Lower	Upper	
January 2005	3,030	1,860	4,670	19.5	57,000	50,000	64,700	368
February 2005	1,740	1,080	2,680	11.2	37,200	32,900	42,000	240
March 2005	1,960	1,190	3,050	12.6	39,500	34,800	44,800	255
April 2005	3,880	2,210	6,340	25.0	63,500	55,200	72,700	410
May 2005	2,030	1,300	3,040	13.1	35,400	31,400	39,800	228
June 2005	697	440	1,050	4.50	13,400	11,900	15,100	86.5
July 2005	802	501	1,220	5.17	13,500	11,800	15,300	87.1
August 2005	269	169	408	1.74	5,620	4,940	6,380	36.3
September 2005	230	141	354	1.48	5,130	4,490	5,830	33.1

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi², pounds per square mile]

Quinebaug River at Red Bridge Road, Conn., water-years 1996–2005								
Date	Total phosphorus				Total nitrogen			
	Load (lbs)	95-percent confidence interval		Yield (lb/mi²)	Load (lbs)	95-percent confidence interval		Yield (lb/mi²)
		Lower	Upper			Lower	Upper	
October 1995	1,010	611	1,570	6.00	29,400	25,500	33,800	175
November 1995	1,570	966	2,430	9.35	46,200	39,900	53,100	275
December 1995	674	439	990	4.01	25,800	22,600	29,300	153
January 1996	1,780	948	3,060	10.6	54,300	45,800	63,900	323
February 1996	1,560	1,020	2,300	9.29	52,000	44,800	60,000	310
March 1996	1,190	804	1,700	7.08	41,100	35,900	46,800	245
April 1996	2,440	1,380	4,020	14.5	63,200	54,100	73,400	376
May 1996	1,440	974	2,050	8.57	38,700	33,800	44,200	230
June 1996	467	316	666	2.78	13,800	12,200	15,600	82.1
July 1996	793	510	1,180	4.72	18,700	16,300	21,300	111
August 1996	368	254	518	2.19	10,100	8,920	11,300	60.1
September 1996	672	430	1,000	4.00	16,000	13,900	18,200	95.2
October 1996	1,620	1,010	2,470	9.64	36,600	31,900	41,600	218
November 1996	1,650	1,100	2,380	9.82	40,800	35,800	46,400	243
December 1996	3,510	2,040	5,640	20.9	81,600	70,400	94,000	486
January 1997	1,560	1,110	2,140	9.29	45,300	39,800	51,400	270
February 1997	1,200	851	1,650	7.14	36,300	31,900	41,100	216
March 1997	1,350	967	1,830	8.04	38,800	34,300	43,800	231
April 1997	2,480	1,690	3,500	14.8	57,200	50,000	65,200	340
May 1997	1,220	889	1,630	7.26	29,200	25,900	32,800	174
June 1997	386	280	520	2.30	10,200	9,110	11,400	60.7
July 1997	239	177	316	1.42	6,290	5,600	7,040	37.4
August 1997	241	181	314	1.43	6,120	5,450	6,840	36.4
September 1997	154	113	206	0.920	4,290	3,800	4,830	25.5
October 1997	327	237	440	1.94	8,690	7,760	9,700	51.7
November 1997	820	581	1,120	4.88	20,400	18,300	22,700	121
December 1997	538	371	755	3.20	15,800	14,200	17,500	94.0
January 1998	1,840	1,290	2,530	11.0	44,600	39,400	50,400	265
February 1998	1,810	1,270	2,500	10.8	43,700	38,500	49,400	260
March 1998	3,840	2,260	6,130	22.9	77,500	67,400	88,800	461
April 1998	1,780	1,300	2,370	10.6	38,800	34,500	43,500	231
May 1998	1,790	1,280	2,440	10.6	34,600	30,700	38,900	206
June 1998	1,990	1,330	2,870	11.8	33,000	29,200	37,000	196
July 1998	1,440	922	2,130	8.57	23,200	20,500	26,200	138
August 1998	347	267	445	2.07	7,370	6,630	8,160	43.9
September 1998	252	191	326	1.50	5,730	5,130	6,370	34.1
October 1998	798	554	1,110	4.75	15,800	14,100	17,500	94.0
November 1998	438	308	606	2.61	11,000	9,910	12,100	65.5
December 1998	452	304	648	2.69	12,400	11,300	13,700	73.8

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi^2, pounds per square mile]

Date	Total phosphorus Load (lbs)	Total phosphorus 95-percent confidence interval Lower	Total phosphorus 95-percent confidence interval Upper	Total phosphorus Yield (lb/mi^2)	Total nitrogen Load (lbs)	Total nitrogen 95-percent confidence interval Lower	Total nitrogen 95-percent confidence interval Upper	Total nitrogen Yield (lb/mi^2)
Quinebaug River at Red Bridge Road, Conn., water-years 1996–2005—Continued								
January 1999	1,910	1,300	2,720	11.4	40,800	36,100	46,000	243
February 1999	1,810	1,250	2,540	10.8	39,600	35,100	44,400	236
March 1999	3,120	2,080	4,480	18.57	60,000	53,100	67,500	357
April 1999	985	698	1,350	5.86	22,000	19,800	24,300	131
May 1999	890	652	1,190	5.30	18,000	16,400	19,900	107
June 1999	237	171	320	1.41	5,400	4,800	6,010	32.1
July 1999	219	164	287	1.30	4,680	4,200	5,210	27.9
August 1999	165	118	225	0.984	3,580	3,190	4,000	21.3
September 1999	686	453	997	4.08	11,300	10,000	12,700	67.3
October 1999	1,030	716	1,440	6.13	18,500	16,800	20,300	110
November 1999	1,210	830	1,700	7.20	22,700	20,600	25,000	135
December 1999	1,370	945	1,910	8.15	28,000	25,300	30,800	167
January 2000	1,200	817	1,700	7.14	26,800	24,200	29,500	160
February 2000	1,350	916	1,920	8.04	28,700	25,700	32,000	171
March 2000	2,780	1,920	3,900	16.6	51,100	45,700	56,900	304
April 2000	3,670	2,240	5,690	21.8	56,500	49,900	63,700	336
May 2000	2,540	1,800	3,470	15.1	39,300	35,400	43,500	234
June 2000	2,730	1,770	4,010	16.2	36,600	32,800	40,900	218
July 2000	903	643	1,240	5.38	13,700	12,400	15,200	81.6
August 2000	758	553	1,020	4.51	12,000	10,900	13,100	71.4
September 2000	393	295	513	2.34	7,160	6,490	7,890	42.6
October 2000	538	387	729	3.20	10,200	9,300	11,200	60.7
November 2000	812	561	1,140	4.84	15,800	14,400	17,200	94.0
December 2000	1,020	689	1,470	6.07	20,500	18,400	22,700	122
January 2001	541	339	820	3.22	13,600	12,400	14,800	81.0
February 2001	803	515	1,200	4.78	18,600	16,900	20,400	111
March 2001	3,050	1,880	4,700	18.2	49,600	43,800	56,000	295
April 2001	4,190	2,500	6,600	24.9	61,400	54,100	69,400	365
May 2001	1,240	900	1,670	7.38	20,800	18,900	22,900	124
June 2001	2,020	1,420	2,800	12.0	28,000	25,200	30,800	167
July 2001	693	523	900	4.12	11,000	10,000	12,000	65.5
August 2001	378	291	483	2.25	6,470	5,850	7,140	38.5
September 2001	425	313	565	2.53	7,280	6,550	8,060	43.3
October 2001	502	363	675	2.99	9,180	8,340	10,100	54.6
November 2001	220	148	313	1.31	5,110	4,590	5,670	30.4
December 2001	337	216	504	2.01	8,240	7,450	9,090	49.0

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi², pounds per square mile]

Quinebaug River at Red Bridge Road, Conn., water-years 1996–2005—Continued								
Date	Total phosphorus				Total nitrogen			
	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)
		Lower	Upper			Lower	Upper	
January 2002	312	186	494	1.86	8,440	7,660	9,270	50.2
February 2002	524	318	814	3.12	12,900	11,700	14,200	76.8
March 2002	1,270	857	1,820	7.56	25,600	23,200	28,100	152
April 2002	1,700	1,200	2,340	10.1	29,700	26,800	32,800	177
May 2002	3,070	2,120	4,300	18.3	43,000	38,600	47,800	256
June 2002	2,360	1,650	3,280	14.0	31,300	28,200	34,700	186
July 2002	509	392	650	3.03	8,420	7,620	9,270	50.1
August 2002	329	248	427	1.96	5,590	5,000	6,230	33.3
September 2002	276	206	364	1.64	5,070	4,530	5,650	30.2
October 2002	790	563	1,080	4.71	13,400	12,200	14,800	79.8
November 2002	1,250	858	1,770	7.44	21,400	19,200	23,700	127
December 2002	2,250	1,500	3,250	13.4	38,000	33,900	42,400	226
January 2003	1,830	1,240	2,610	10.9	34,800	31,300	38,600	207
February 2003	1,380	909	2,010	8.21	27,400	24,400	30,600	163
March 2003	4,260	2,600	6,580	25.4	66,300	58,500	75,000	395
April 2003	3,420	2,310	4,890	20.4	52,600	46,800	58,900	313
May 2003	2,030	1,450	2,770	12.1	31,000	27,800	34,400	185
June 2003	3,940	2,550	5,840	23.4	48,200	42,900	53,900	287
July 2003	1,330	967	1,780	7.92	18,900	17,100	20,900	113
August 2003	1,420	984	1,990	8.45	19,200	17,200	21,200	114
September 2003	999	700	1,380	5.95	15,000	13,500	16,700	89.3
October 2003	1,620	1,060	2,380	9.64	24,100	21,400	27,100	143
November 2003	2,280	1,530	3,260	13.6	35,800	32,000	39,800	213
December 2003	3,900	2,330	6,130	23.2	60,700	53,300	68,800	361
January 2004	1,620	1,080	2,350	9.64	32,600	29,200	36,300	194
February 2004	834	512	1,290	4.96	19,600	17,600	21,800	117
March 2004	1,630	1,070	2,380	9.70	32,900	29,500	36,600	196
April 2004	4,520	2,800	6,910	26.9	67,800	59,600	76,800	404
May 2004	2,450	1,690	3,440	14.6	38,200	34,100	42,700	227
June 2004	899	628	1,250	5.35	15,200	13,600	17,000	90.5
July 2004	873	616	1,200	5.20	13,800	12,400	15,400	82.1
August 2004	804	566	1,110	4.79	12,800	11,500	14,300	76.2
September 2004	1,700	1,050	2,610	10.1	23,600	20,800	26,800	140
October 2004	1,790	1,170	2,620	10.6	27,900	24,900	31,200	166
November 2004	1,410	925	2,050	8.39	25,900	23,000	29,000	154
December 2004	3,120	1,980	4,700	18.6	54,600	48,200	61,600	325

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi^2, pounds per square mile]

Quinebaug River at Red Bridge Road, Conn., water-years 1996–2005—Continued								
Date	Total phosphorus				Total nitrogen			
	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)	Load (lbs)	95-percent confidence interval		Yield (lb/mi^2)
		Lower	Upper			Lower	Upper	
January 2005	3,320	2,010	5,170	19.8	61,300	53,700	69,700	365
February 2005	1,910	1,180	2,930	11.4	40,100	35,300	45,300	239
March 2005	2,150	1,300	3,360	12.8	42,600	37,400	48,300	254
April 2005	4,250	2,360	7,080	25.3	68,300	59,300	78,400	407
May 2005	2,230	1,420	3,340	13.3	38,100	33,700	42,900	227
June 2005	762	483	1,150	4.54	14,400	12,800	16,200	85.7
July 2005	877	546	1,340	5.22	14,500	12,700	16,400	86.3
August 2005	294	186	443	1.75	6,050	5,320	6,850	36.0
September 2005	250	155	384	1.49	5,520	4,840	6,270	32.9

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi^2, pounds per square mile]

Quinebaug River at West Thompson, Conn., water years 2000–2005								
Date	Total phosphorus				Total nitrogen			
	Load (lbs)	95-percent confidence interval Lower	95-percent confidence interval Upper	Yield (lb/mi^2)	Load (lbs)	95-percent confidence interval Lower	95-percent confidence interval Upper	Yield (lb/mi^2)
October 1999	800	577	1,080	4.65	18,500	16,600	20,600	108
November 1999	849	623	1,130	4.94	21,200	18,900	23,800	123
December 1999	933	705	1,210	5.43	25,500	22,500	28,800	148
January 2000	752	583	955	4.37	21,700	18,900	24,900	126
February 2000	886	700	1,110	5.15	25,200	21,800	29,000	147
March 2000	1,760	1,410	2,170	10.2	46,700	40,800	53,100	271
April 2000	2,680	2,080	3,400	15.6	60,400	52,400	69,200	351
May 2000	1,780	1,460	2,150	10.3	37,700	33,500	42,200	219
June 2000	2,160	1,730	2,680	12.6	39,600	34,800	44,900	230
July 2000	874	719	1,050	5.08	14,400	12,900	16,000	83.8
August 2000	847	700	1,020	4.92	13,400	12,100	14,800	78.2
September 2000	467	394	548	2.71	7,280	6,560	8,060	42.3
October 2000	485	407	574	2.82	8,190	7,300	9,150	47.6
November 2000	681	566	813	3.96	13,100	11,600	14,600	76.0
December 2000	921	756	1,110	5.35	19,200	16,700	22,000	112
January 2001	545	444	662	3.17	12,400	10,600	14,400	72.0
February 2001	783	642	946	4.55	18,100	15,600	20,900	105
March 2001	2,800	2,220	3,500	16.3	56,000	48,300	64,500	325
April 2001	4,080	3,180	5,150	23.7	75,300	65,000	86,800	438
May 2001	1,070	910	1,250	6.21	18,600	16,500	20,800	108
June 2001	1,930	1,640	2,270	11.2	29,300	25,900	33,000	170
July 2001	789	685	904	4.59	10,900	9,840	12,100	63.4
August 2001	522	447	607	3.04	6,660	6,000	7,380	38.7
September 2001	491	417	574	2.85	6,490	5,800	7,230	37.7
October 2001	562	477	656	3.27	8,060	7,180	9,010	46.9
November 2001	287	227	358	1.67	4,440	3,820	5,140	25.8
December 2001	390	311	483	2.27	7,090	6,050	8,250	41.2
January 2002	352	271	450	2.05	6,910	5,780	8,200	40.2
February 2002	506	395	640	2.94	10,400	8,780	12,200	60.4
March 2002	1,120	902	1,360	6.49	21,900	19,000	25,200	127
April 2002	1,540	1,270	1,860	8.98	27,800	24,400	31,500	161
May 2002	2,910	2,430	3,450	16.9	45,400	40,000	51,300	264
June 2002	2,360	2,000	2,760	13.7	33,400	29,600	37,500	194
July 2002	676	573	792	3.93	8,600	7,750	9,520	50.0
August 2002	418	338	511	2.43	4,910	4,390	5,480	28.6
September 2002	361	289	445	2.10	4,360	3,870	4,890	25.4
October 2002	804	686	936	4.67	11,500	10,300	12,800	66.9
November 2002	1,170	982	1,380	6.78	19,000	16,800	21,400	111
December 2002	2,000	1,660	2,390	11.6	35,800	31,300	40,800	208

Table 2–1. Monthly loads, 95-percent confidence intervals, and yields of total phosphorus and total nitrogen for the Quinebaug River sites.—Continued

[lb, pound; lb/mi², pounds per square mile]

Quinebaug River at West Thompson, Conn., water years 2000–2005—Continued								
	Total phosphorus				Total nitrogen			
Date	Load (lbs)	95-percent confidence interval		Yield (lb/mi²)	Load (lbs)	95-percent confidence interval		Yield (lb/mi²)
		Lower	Upper			Lower	Upper	
January 2003	1,410	1,160	1,700	8.22	27,500	24,000	31,400	160
February 2003	984	785	1,220	5.72	20,100	17,300	23,200	117
March 2003	3,610	2,830	4,530	21.0	66,400	57,500	76,200	386
April 2003	3,030	2,480	3,660	17.6	53,900	47,300	61,300	314
May 2003	1,950	1,640	2,320	11.4	31,600	28,000	35,600	184
June 2003	4,080	3,390	4,870	23.7	58,000	50,600	66,300	337
July 2003	1,470	1,270	1,700	8.55	20,300	18,300	22,500	118
August 2003	1,400	1,200	1,620	8.15	18,700	16,700	21,000	109
September 2003	1,000	866	1,160	5.84	14,100	12,600	15,800	82.1
October 2003	1,580	1,340	1,860	9.21	24,500	21,400	27,900	143
November 2003	2,040	1,740	2,390	11.9	35,300	31,200	39,900	205
December 2003	3,280	2,660	3,990	19.1	62,200	53,800	71,600	362
January 2004	1,210	1,000	1,450	7.05	26,400	23,000	30,200	154
February 2004	692	552	857	4.02	16,100	13,800	18,600	93.5
March 2004	1,240	1,010	1,500	7.20	28,100	24,400	32,000	163
April 2004	4,090	3,270	5,070	23.8	80,100	69,600	91,700	466
May 2004	2,060	1,740	2,420	12.0	39,100	34,700	44,000	228
June 2004	857	726	1,000	4.98	14,900	13,400	16,700	86.9
July 2004	870	747	1,010	5.06	14,000	12,700	15,500	81.5
August 2004	826	711	954	4.80	13,200	11,900	14,600	76.7
September 2004	1,550	1,270	1,890	9.03	26,000	22,500	29,900	151
October 2004	1,550	1,280	1,860	8.99	28,700	25,300	32,400	167
November 2004	1,050	870	1,250	6.09	22,900	20,300	25,800	133
December 2004	2,310	1,900	2,780	13.4	55,200	48,300	62,700	321
January 2005	2,320	1,850	2,870	13.5	60,400	52,400	69,300	351
February 2005	1,270	1,020	1,560	7.38	36,200	31,400	41,500	210
March 2005	1,470	1,150	1,840	8.53	40,400	34,900	46,400	235
April 2005	3,250	2,430	4,250	18.9	80,800	69,600	93,300	470
May 2005	1,530	1,220	1,900	8.90	38,100	33,800	42,700	221
June 2005	577	458	717	3.36	13,300	11,900	14,800	77.0
July 2005	693	538	879	4.03	14,800	13,000	16,600	85.8
August 2005	257	201	324	1.49	5,170	4,630	5,750	30.0
September 2005	187	142	242	1.09	3,940	3,480	4,430	22.9