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Characterization of Water Quality in Bushy Park Reservoir, South Carolina, 2013–15

Scientific Investigations Report 2018–5010

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

Cover.

Front—U.S. Geological Survey (USGS) field crew near the Charleston Water System intake on Bushy Park Reservoir, August 2014. Photograph by Michael Hall, retired USGS.

Back—USGS field equipment, including autonomous underwater vehicle and multiparameter sonde, prior to deployment, August 2014. Photograph by Celeste Journey, USGS.

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By Paul A. Conrads, Celeste A. Journey, Matthew D. Petkewich, Timothy H. Lanier, and Jimmy M. Clark

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U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Deputy Director
exercising the authority of the Director

U.S. Geological Survey, Reston, Virginia: 2018

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"It is not length of life, but depth of life."
—Ralph Waldo Emerson

Paul A. Conrads, 1957–2017

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

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

$$°C = (°F - 32) / 1.8.$$

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

$$°F = (1.8 \times °C) + 32.$$

Datum

Vertical coordinate information is referenced to either the North American Vertical Datum of 1988 (NAVD 88) or the World Geodetic System of 1984 (WGS 84).

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

Altitude, as used in this report, refers to distance above the vertical datum.

Supplemental Information

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

Abbreviations

ADCP	acoustic Doppler current profiler
AIA	Actinomycete Isolation Agar
ANOSIM	analysis of similarity test
AUV	autonomous underwater vehicle
AVM	acoustic velocity meter
BGA	blue-green algae
cm/s	centimeter per second
CPW	Charleston Public Works
CRP	Cooper River Partners
CWS	Charleston Water System
DAL	double-agar layer
DO	dissolved oxygen
DOC	dissolved organic carbon
DVL	Doppler velocity lags
EFDC	Environmental Fluid Dynamics Code
EPA	U.S. Environmental Protection Agency
FNU	formazin nephelometric units
ft/s	foot per second
GPS	Global Positioning System
Hz	hertz
kHz	kilohertz
LRL	laboratory reporting level
mg/L	milligram per liter
MHz	megahertz
MIB	2-methylisoborneol
mL	milliliter
m/s	meter per second
ng/L	nanogram per liter
nMDS	nonmetric multidimensional scaling analysis
NTU	nephelometric turbidity units
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
PAC	powdered activated carbon
PAR	photosynthetically active radiation

RFU	relative fluorescence units
RPD	relative percent difference
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCE&G	South Carolina Electric and Gas
SPME	solid-phase microextraction
SRP	safe return path
SSC	suspended-sediment concentration
TN:TP	total nitrogen to total phosphorus ratio
T&O	taste and odor
TOC	total organic carbon
USGS	U.S. Geological Survey
UVA	ultraviolet absorbance
UVC	underwater vehicle console
UV-Vis	ultraviolet-visible spectrum
WHO	World Health Organization
YSI	Yellow Springs Instrument
µg/L	microgram per liter
$\mu m^3/mL$	cubic micrometer per milliliter
$\mu mol/s\text{-}m^2$	micromole per second per square meter

Characterization of Water Quality in Bushy Park Reservoir, South Carolina, 2013–15

By Paul A. Conrads, Celeste A. Journey, Matthew D. Petkewich, Timothy H. Lanier, and Jimmy M. Clark

Abstract

The Bushy Park Reservoir is the principal water supply for 400,000 people in the greater Charleston, South Carolina, area, which includes homes as well as businesses and industries in the Bushy Park Industrial Complex. Charleston Water System and the U.S. Geological Survey conducted a cooperative study during 2013–15 to assess the circulation of Bushy Park Reservoir and its effects on water-quality conditions, specifically, recurring taste-and-odor episodes. This report describes the water-quality data collected for the study that included a combination of discrete water-column sampling at seven locations in the reservoir and longitudinal water-quality profiling surveys of the reservoir and tributaries to characterize the temporal and spatial water-quality dynamics of Bushy Park Reservoir. Water-quality profiling surveys were conducted with an autonomous underwater vehicle equipped with a multiparameter water-quality-sonde bulkhead. Data collected by the autonomous underwater vehicle included water temperature, dissolved oxygen, pH, specific conductance, turbidity, total chlorophyll as fluorescence (estimate of algal biomass), and phycocyanin as fluorescence (estimate of cyanobacteria biomass) data.

Characterization of the water-quality conditions in the reservoir included comparison to established State nutrient guidelines, identification of any spatial and seasonal variation in water-quality conditions and phytoplankton community structures, and assessment of the degree of influence of water-quality conditions related to Foster Creek and Durham Canal inflows, especially during periods of elevated taste-and-odor concentrations. Depth-profile and autonomous underwater vehicle survey data were used to identify areas within the reservoir where greater phytoplankton and cyanobacteria densities were most likely occurring.

Water-quality survey results indicated that Bushy Park Reservoir tended to stratify thermally at a depth of about 20 feet from June to early October. The stratification was limited to the deeper portions of the reservoir near the dam and often dissipated within the reservoir near the CWS intake less than a mile upstream from the dam. Where thermally stratified, a corresponding depletion of dissolved oxygen also occurred at about the same depth and resulted in an anoxic hypolimnion below the 25-foot depth and an increase in specific conductance, likely due to re-mobilized metals and phosphorus under reducing conditions. In general, chlorophyll estimated from fluorescence exhibited some spatial variation, but no strong consistent pattern or “hot spot” was observed. Phycocyanin, estimated from relative fluorescence unit output as blue-green algae cell density, periodically seemed to be greater in the upper portion of the reservoir, but those differences may be attributed to increased turbidity and the potential change in phytoplankton community structure that affects fluorescence. Increased phycocyanin was observed at about the 10-foot depth during the summer months.

A constant production of 2-methylisoborneol (MIB) near the dam and geosmin in the middle and upper portions of the reservoir appears to be occurring during the summer and early fall in the reservoir, but concentrations of these compounds tend to be between 10 and 15 nanograms per liter, which is at the Charleston Water System treatment threshold. At the Bushy Park Reservoir intake, the dominant taste-and-odor compound tended to be MIB, measured at a 2- or 3-to-1 ratio with geosmin during the summer and fall. During springtime episodes, however, when taste-and-odor compound concentrations typically are elevated above the Charleston Water System treatment threshold, the spatial distribution of geosmin concentrations greater than 15 nanograms per liter (28 to 38 nanograms per liter) was best explained by in situ production in the lower portion of the Bushy Park Reservoir near the dam rather than transport from Foster Creek. This pattern seems to indicate a possible shift in phytoplankton communities (or, at least, cyanobacteria communities) from MIB producers to geosmin producers.

The spatial and seasonal assessment of water-quality conditions in Bushy Park Reservoir identified seasonal differences in water chemistry and spatial differences between the upper and lower portions of the reservoir that correspond to the location of elevated geosmin concentrations. On the basis of the spatial and seasonal assessment of actinomycetes concentrations compared to taste-and-odor compound concentrations, cyanobacteria production likely was the dominant source of the taste-and-odor episodes rather than actinomycetes. The lack of spatial and seasonal patterns in actinomycetes concentrations did not correspond to the springtime geosmin

concentrations that were elevated above the Charleston Water System treatment threshold in the lower portion of the reservoir. Additionally, actinomycetes concentrations, although ubiquitous, had a median of about 9 and maximum of about 20 colonies per milliliter, which can be considered low for elevated taste-and-odor compound production. Nonetheless, the potential exists for actinomycetes to be a secondary source of taste-and-odor production and could explain some of the ubiquitous occurrence of low-level taste-and-odor production, such as MIB concentrations, observed throughout the summer and early fall months.

When evaluated by biovolume, cyanobacteria were not the dominant phytoplankton group in Bushy Park Reservoir during the study period. *Dolichospermum planctonicum* (previously *Anabaena planktonica*) was the dominant genera of the cyanobacteria group during spring periods. The geosmin-producing genera that were identified in the 2014 and 2015 spring communities in Bushy Park Reservoir were not observed in the 1999 and 2000 algal taxonomic data.

A more robust examination of phytoplankton species was conducted by using a multivariate analysis that identified seasonal changes in phytoplankton community structure. These seasonal phytoplankton communities appeared to be explained by seasonal changes in water chemistry and may be responsible for episodes of taste-and-odor occurrence, especially geosmin. The most probable source of geosmin identified during the study was *D. planctonicum*.

In a synoptic sampling event during a taste-and-odor episode in April 2015, cyanobacteria, not acinomycetes, also was indicated to be the more prevalent source of the geosmin. Although the Edisto River intake and its associated supply tunnel to the treatment facility had relatively high actinomycetes concentrations (130 and 140 colonies per milliliter, respectively) compared to the Bushy Park intake and tunnel (2 colonies per milliliter), corresponding geosmin concentrations were below 5 nanograms per liter for source water from the Edisto River intake and tunnel. Elevated geosmin concentrations above the Charleston Water System treatment threshold were identified in source waters from the Bushy Park Reservoir. The cyanobacteria community at the sampled sites in April 2015 was statistically similar to the community in the Bushy Park Reservoir in April 2014, when geosmin concentrations also were elevated. The only geosmin-producing genus identified at the Bushy Park intake, however, was *D. planctonicum*.

Introduction

Currently (2017), the Bushy Park Reservoir is the principal water supply for 400,000 people in the greater Charleston, South Carolina, area, including homes as well as businesses and industries in the Bushy Park Industrial Complex (Charleston Water System, 2016). The Bushy Park Industrial Complex, located near Goose Creek and north of Charleston, was established in 1954 along the east bank of the Back River and the west bank of the Cooper River. To provide water to the industrial users, a freshwater reservoir was constructed by impounding the Back River at the southern end near the confluence with the Cooper River (fig. 1). Durham Canal was constructed as a conduit between the northern end of the reservoir and the freshwater reach of the West Branch of the Cooper River.

Bushy Park Reservoir is a relatively shallow impoundment with a subtropical climate, and, although there is an adequate supply of freshwater, there are water-quality concerns related to taste and odor (T&O). In general, T&O episodes are common in reservoirs used for drinking water throughout the United States (Paerl and others, 2001; Taylor and others, 2006; Jüttner and Watson, 2007). The occurrence of *trans*-1,10-dimethyl-*trans*-9-decalol (geosmin) and 2-methylisoborneol (MIB), which produce musty, earthy tastes and odors in drinking water, represents one of the primary causes of T&O episodes (Suffet and others, 1996). Although not a human health problem, geosmin and MIB are problematic in drinking water because the human detection threshold for these compounds is extremely low (10 nanograms per liter [ng/L]); Wnorowski, 1992; Young and others, 1996), and conventional water-treatment procedures (particle separation, oxidation, and adsorption) typically do not reduce concentrations below the threshold level (Suffet and others, 1996). The production and release of geosmin and MIB have been related to bacteria (actinomycetes) typically found in the soil and certain species of cyanobacteria (also known as blue-green algae [BGA]). Geosmin- and MIB-producing cyanobacterial blooms are attributed to a range of environmental factors, including nutrient concentrations and ratios, light availability, water temperatures, water-column stability, and flushing rates (Downing and others, 2001; Paerl and others, 2001; Mau and others, 2004; Dzialowski and others, 2009). The complex interaction among the physical, chemical, and biological processes within lakes and reservoirs often makes it difficult to identify primary environmental factors that cause the production and release of these cyanobacterial by-products. Nonetheless, an understanding of the environmental factors that control cyanobacteria dominance in reservoirs has allowed water-resource and watershed managers to apply management strategies to prevent conditions under which cyanobacteria dominate (Downing and others, 2001; Taylor and others, 2006). Remediation efforts of reservoir conditions where cyanobacteria dominance occurred has hinged upon a strong scientific understanding of the mechanisms controlling the algal community (Downing and others, 2001; Taylor and others, 2006).

As part of a long-range planning process, the Charleston Water System (CWS) requested assistance from the U.S. Geological Survey (USGS) in assessing the circulation of Bushy Park Reservoir and its effects on water quality. The South Carolina Surface Water Withdrawal, Permitting Use, and Reporting Act of 2011 (http://www.scstatehouse.gov/code/t49c004.php) has affected the permitting and operations of

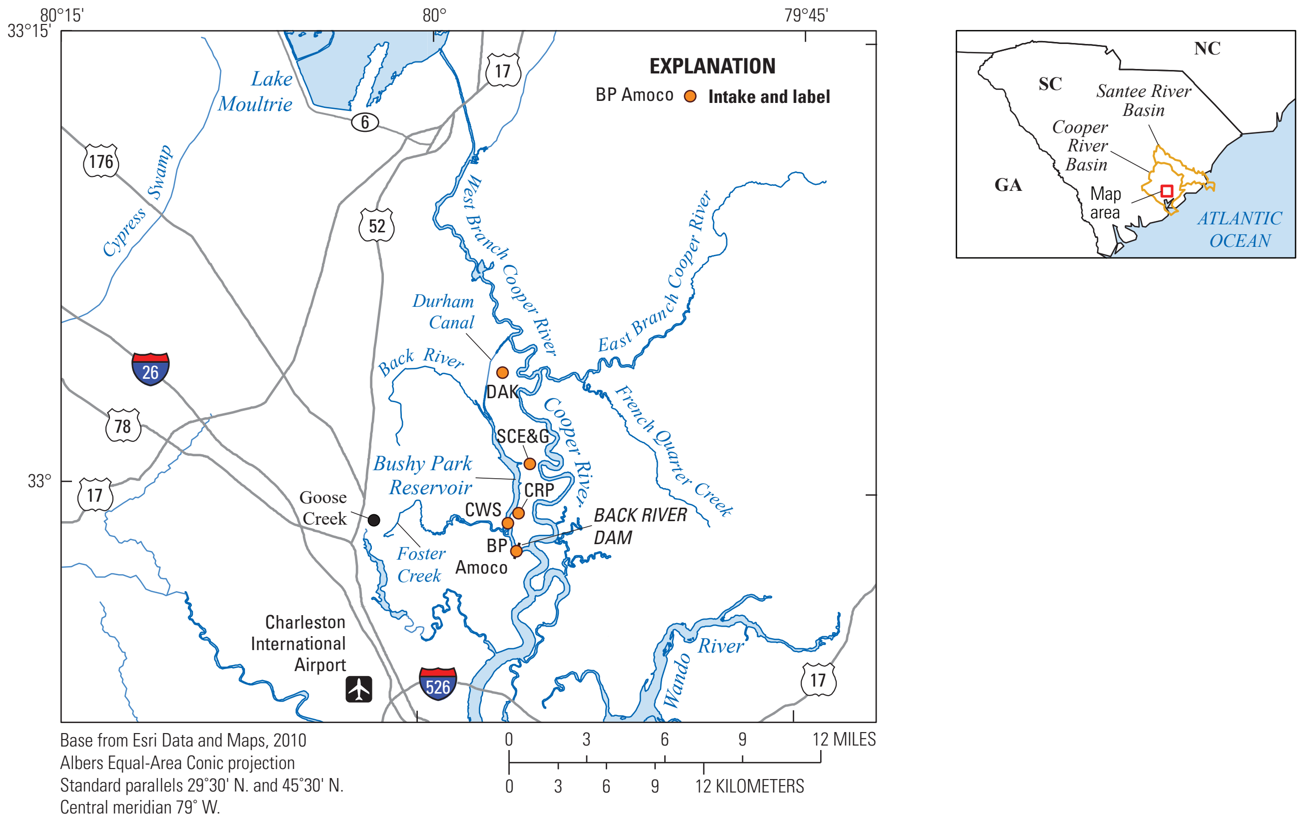

Figure 1. Bushy Park Reservoir, near Goose Creek, South Carolina, and location of industrial withdrawal intakes [BP Amoco, British Petroleum Amoco; DAK, DAK Americas; SCE&G, South Carolina Electric and Gas Williams Station; CRP, Cooper River Partners; CWS, Charleston Water System].

the Bushy Park Reservoir, and as a result, there has been an immediate need for hydrologic, hydrodynamic, and water-quality data and analysis to inform water-resource planning for the Charleston area. The USGS, in cooperation with the CWS, conducted a 21-month investigation to address five areas of interest for CWS in their long-range planning process:

1. Hydrologic monitoring of the reservoir to establish a water budget and document reservoir circulation dynamics;
2. Flow monitoring in the water-supply tunnel to compute flow from Bushy Park Reservoir;
3. Water-quality sampling, profiling, and continuous monitoring to understand the causes of T&O occurrence;
4. Technical evaluation of an existing hydrodynamic and water-quality simulation model for the reservoir; and
5. Preliminary evaluation of alternative reservoir operations scenarios.

Purpose and Scope

This report addresses the third area of concern in the study by describing the collection and analysis of data to characterize the water quality of the Bushy Park Reservoir from September 2013 to May 2015 (table 1). The first two areas of concern, hydrologic data, and reservoir circulation and flow monitoring of the water-supply tunnel, are addressed in Conrads and others (2017b). The water-quality data-collection network was designed to provide data that describe the chemical, physical, and biological processes that influence (1) geosmin and MIB occurrence in this source-water reservoir, (2) cyanobacterial abundance, and (3) occurrence of geosmin-producing and toxin-producing genera of cyano-bacteria. The possibility that actinomycetes may be a source of geosmin was also evaluated.

The water-quality data collection effort, which began in the fall of 2013 and ended in the spring of 2015, enhanced the existing continuous monitoring network by including spatial water-quality surveys that were conducted using an autonomous underwater vehicle (AUV), discrete sampling and profiling of water-quality conditions, and continuous flow monitoring in one of the water-supply tunnels. The spatial

Table 1. Timeline of U.S. Geological Survey water-quality data collection, surveys, and South Carolina Electric and Gas Company (SCE&G) monthly average withdrawal rates in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to May 2015.

[AUV, autonomous underwater vehicle; Mgal/d, million gallons per day]

Data collection	Sept. 2013	Oct. 2013	Nov. 2013	Dec. 2013	Jan. 2014	Feb. 2014	Mar. 2014	Apr. 2014	May 2014	June 2014	July 2014	Aug. 2014	Sept. 2014	Oct. 2014	Nov. 2014	Dec. 2014	Jan. 2015	Feb. 2015	Mar. 2015	Apr. 2015	May 2015
Discrete sampling events (water chemistry and algal taxonomy)	9/18, 9/19							4/16			7/23	8/26			11/6	12/16				4/30	
AUV water-quality and depth surveys	9/17,* 9/18,* 9/19*		11/19		1/13, 1/14		3/27	4/16		6/10	7/23	8/5, 8/26		10/2,* 10/29	11/5, 11/6	12/16	1/14		3/26	4/23	
Water-quality depth profile surveys	9/17		11/19		1/14		3/27	4/16		6/10	7/23	8/26		10/2, 10/29	11/5, 11/6	12/16	1/14		3/26	4/23	
SCE&G average monthly withdrawal rate, Mgal/d	416	518	554	554	554	403	149	523	554	554	533	525	554	368	201	376	376	376	252	297	376
SCE&G outages dates	9/25 to 10/2					2/22 to 3/19								10/24 to 11/15					3/22 to 4/6		

*Data were collected 9/17/13, 9/18/13, 9/19/13, and 10/2/14, but were not plotted because the data were collected at the water surface.

extent of the study was the Bushy Park Reservoir, from the Back River Dam to the confluence of Durham Canal and the West Branch of the Cooper River, and the two tributaries that form the reservoir—the Back River and Foster Creek (fig. 1).

Benefits of this investigation to the CWS and others include accurate data and analysis on the water quantity and water quality of Bushy Park Reservoir that will provide baseline conditions and an understanding of the available quantity of freshwater for the reservoir and the causes of T&O issues. An understanding of the environmental factors that control cyanobacteria dominance in Bushy Park Reservoir has the potential to allow water-resource managers to apply long-term management strategies to prevent conditions under which cyanobacteria dominate and to implement short-term treatment technologies to reduce or limit the development of T&O compounds.

Description of the Study Area

The Bushy Park Reservoir is located in the lower part of the Edisto-Santee River Basin (fig. 1). This basin covers 17,092 square miles (mi^2) and is the second largest drainage basin on the East Coast (Seaber and others, 1987). The climate of the Bushy Park Reservoir watershed is classified as humid subtropical (Pidwirny, 2011). Mean annual precipitation from 1981 to 2010 for the weather station located at the Charleston International Airport (Station USW00013880) was 51.03 inches, and the corresponding mean temperature was 65.9 degrees Fahrenheit (°F) (National Oceanic and Atmospheric Administration, undated).

The land cover of Bushy Park Reservoir, Foster Creek, and Back River drainage basin, which ends halfway up Durham Canal, is predominantly forest (36.2 percent), wetlands (35.5 percent), and developed (21.1 percent) (Homer and others, 2015; Conrads and others, 2017b). The remaining types of land cover are pasture, water, and barren land. The reservoir is mesotrophic to eutrophic and is heavily vegetated with aquatic plants that thrive only in freshwater, such as water hyacinth (*Eichhornia crassipes*), water primrose (*Ludwigia uruguayensis*), and hydrilla (*Hydrilla verticillata*) (South Carolina Department of Natural Resources, 2014). The South Carolina Department of Natural Resources (SCDNR) applies herbicides to the aquatic growth on an annual and as needed basis. Application rates do not require interruption of municipal and industrial withdrawals.

The construction of the Bushy Park Reservoir and Durham Canal is part of the long history of anthropogenic changes to the Santee and Cooper Rivers (Kjerfve and Magill, 1990). Rice plantations, with large diked fields along the banks of the Cooper and Wando Rivers, flourished in the 18th and 19th centuries. With the advent of mechanized rice harvesting, rice production diminished, because heavy machinery was unsuitable for the clayey soils of the area.

To provide a convenient freshwater reservoir for industrial and municipal water use for the 1954-created Bushy Park Industrial Complex, the Bushy Park Dam and Durham Canal were built in 1955 and 1956, respectively, by the Bushy Park Authority (a legislative committee of city and county government officials and area utilities) to form Bushy Park Reservoir. The Back River was dammed at the lower end near the confluence with the Cooper River to create the Bushy Park Reservoir, and Durham Canal was constructed as a conduit between the upper end of the reservoir and the freshwater reaches of the Cooper River (fig. 1). The Charleston Public Works (CPW) purchased the assets of the Bushy Park Authority in 1964 and controls use of the waters from the reservoir for municipal and industrial supply. Presently (2017), five facilities have water-withdrawal intakes on Bushy Park Reservoir—the South Carolina Electric and Gas Company (SCE&G) Williams Station, the CWS, DAK Americas, British Petroleum (BP) Amoco, and Cooper River Partners (CRP) (fig. 1).

In 1985, the U.S. Army Corps of Engineers rediverted flows from Lake Moultrie to the Santee River to alleviate a severe sedimentation problem in Charleston Harbor that had been created by the diversion of freshwater flows. After the rediversion project, the flows to the Cooper River were reduced from the annual mean flow of 15,600 cubic feet per second (ft^3/s) to a weekly mean flow of 3,000 ft^3/s—a level that would alleviate sedimentation in the harbor while ensuring an adequate freshwater source to the Bushy Park Reservoir at the mouth of the Durham Canal (South Carolina Water Resources Commission, 1979).

The flow and circulation dynamics of the Bushy Park Reservoir are quite complex. The water level, water velocity, and flow direction in the Bushy Park Reservoir are constantly changing due to the tides and flows from the Cooper River, industrial withdrawals, and meteorological conditions. The tidal effects on the reservoir are caused by orbital mechanics and are highly predictable. Historically, the Back River was a tidal slough (as was the Cooper River) with very little net flow. The Back River was dominated by the tidal exchange at the confluence with the Cooper River. After the construction of the Back River Dam and Durham Canal in the 1950s, the tidal exchange shifted to the confluence of the upper reaches of the Back River and Durham Canal, and net flow from the reservoir was through Durham Canal to the Cooper River. The Back River changed from a tidal brackish marsh to a freshwater tidal marsh. In 1973, SCE&G constructed the Williams Station, a coal-fired powerplant that withdraws water from the reservoir for cooling and returns the water to the Cooper River. The flow patterns of the Bushy Park Reservoir are dominated by the large withdrawal by SCE&G for cooling water for the Williams Station plant. The volume of the withdrawal, more than 500 million gallons per day (Mgal/d), is the dominant factor in the water budget and circulation pattern of the reservoir. When the plant is operating and withdrawing water, the net outflow from the reservoir is through the Williams Station and not through Durham Canal. Figure 2 shows daily precipitation, the tidally filtered daily flow for Durham Canal, the 7-day average flow in Durham Canal, and the withdrawal

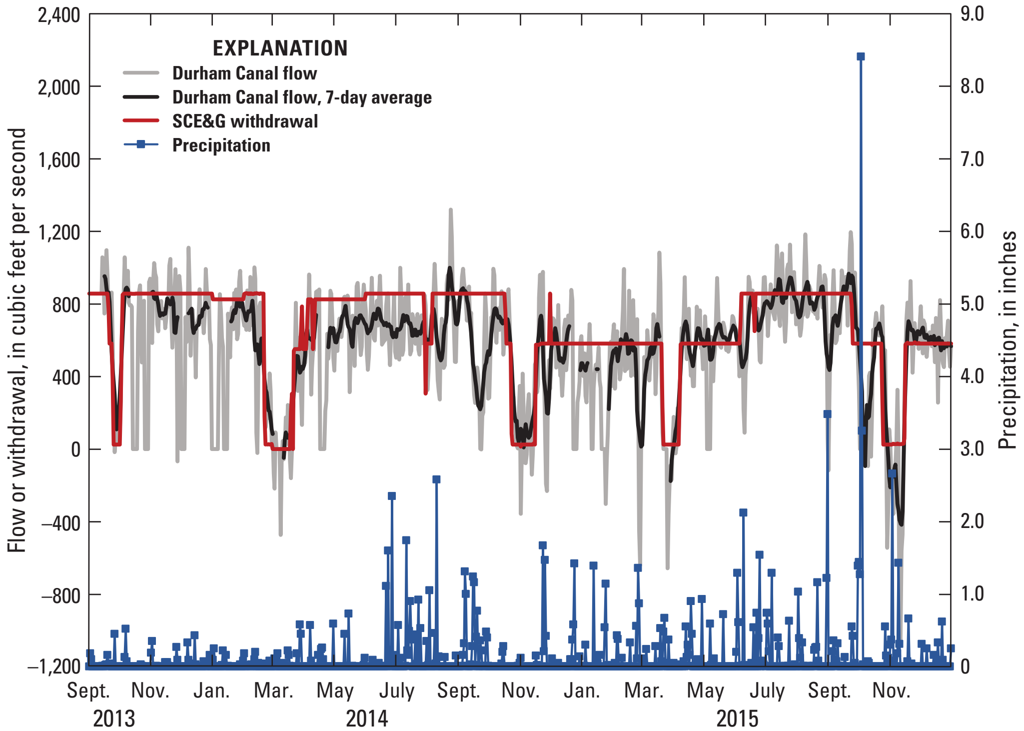

Figure 2. Precipitation at the Charleston Water System Intake (station 0217206110), daily flows and 7-day average flows in Durham Canal, and withdrawal rates by the Williams Station from Bushy Park Reservoir, near Goose Creek, South Carolina, for the period September 1, 2013, to December 31, 2015 (Conrads and others, 2017b). The sign of the Durham Canal flow was reversed (multiplied by negative one) for plotting purposes.

rates (in cubic feet per second) for the Williams Station for the period September 2013 to December 2015 (Conrads and others, 2017b). The flows in Durham Canal and the withdrawals are of similar magnitudes. When the Williams plant has an outage, the net flow in Durham Canal quickly changes from into the reservoir to a small net flow to the Cooper River. Periods of extended rainfall can cause the net flow in Durham Canal to either decrease into the reservoir or reverse to the Cooper River as in the case of the heavy rainfall in early October 2015.

Previous Studies

Over the years, a number of ecological and modeling studies of the Bushy Park Reservoir and its tributaries have been conducted. In the 1970s, 1980s, and 1990s, studies of Foster Creek were conducted to address the effect of runoff from military, commercial, and residential areas. A summary of these studies can be found in Campbell and Bower (1996). Highlights of other previous studies that are of interest to the current study are discussed in this section.

The water quality of Foster Creek and Bushy Park Reservoir has improved overall since the late 1970s, following elimination in 1983 of wastewater discharges into Foster Creek (South Carolina Department of Health and Environmental Control, 2004). Jordan, Jones & Goulding, Inc., (1988) investigated the cause of unpleasant T&O in municipal drinking water in the Charleston area and assessed the overall water quality in Foster Creek and Back River. The study arrived at four conclusions:

1. The entire Foster Creek, Bushy Park Reservoir, Durham Canal, and Back River system met South Carolina Department of Health and Environmental Control (SCDHEC) standards for Class B waters, with the exception of below standard dissolved-oxygen concentrations (DOC) in Foster Creek and Back River;

2. Bushy Park Reservoir and its tributaries (including Foster Creek) were eutrophic and supported large amounts of aquatic vegetation;

3. Naturally occurring T&O compounds were found throughout the system but were highest in Foster Creek and the Back River; and

4. Foster Creek samples had higher fecal coliform bacteria concentrations than Bushy Park Reservoir samples.

The SCDHEC monitors the water-quality conditions in Bushy Park Reservoir (referred to as Back River Reservoir [station CSTL-124] by SCDHEC) near the dam to determine if the water quality supports the designated aquatic life and recreational use. The SCDHEC has reported that Bushy Park Reservoir had total nitrogen, total phosphorus, and chlorophyll *a* concentrations that met established numeric nutrient criteria in 2004, 2010, and 2014, but dissolved-oxygen concentrations were not within required levels (South Carolina Department of Health and Environmental Control, 2004, 2010, 2014a, 2014b, 2014c). Low dissolved-oxygen concentrations also were reported as an impairment for Foster Creek, a tributary near the CWS intake.

The SCDNR manages the aquatic invasive and nuisance species of macrophytes in Bushy Park Reservoir. The SCDNR reported that, historically, the reservoir (referred to as Back River Reservoir in SCDNR reports) has been heavily vegetated with aquatic plants that thrive only in freshwater, including invasive species of water hyacinth (*Eichhornia crassipes*), water primrose (*Ludwigia hexapetala*), and hydrilla (*Hydrilla vertcillata*), and nuisance species of fanwort (*Cabomba caroliniana*), Frog's bit (*Limnobium spongia*) and giant cutgrass (*Zizaniopsis miliacea*) (South Carolina Department of Natural Resources, 2014). The SCDNR reported that macrophytes cover about 360 acres of the 850-acre surface area of the reservoir. As part of the management plan to control the aquatic growth, the SCDNR has applied herbicides seasonally over the past decades (South Carolina Department of Natural Resources, 2014).

Approach and Methods

Water-quality data were collected for this study to gain insight on the convergence of environmental factors that tend to occur between the physical, chemical, biological, and circulation processes within Bushy Park Reservoir that cause the production and release of cyanobacterial by-products of geosmin and MIB. A characterization of the hydrology and circulation of the reservoir is presented in Conrads and others (2017b).

The water-quality data collected for the study were a combination of discrete water-column sampling at seven locations in the reservoir (table 2; fig. 3) and longitudinal water-quality profiling surveys of the reservoir and tributaries, which were conducted to capture the temporal and spatial water-quality dynamics of Bushy Park Reservoir (Conrads and others, 2017a). The discrete water-column samples were collected near the surface (3.3-foot [ft; 1-meter {m}] depth) and analyzed for geosmin, MIB, chlorophyll *a*, pheophytin *a*, nutrient, major ions, trace metals, actinomycetes, and suspended-sediment concentrations, and for phytoplankton cell densities and biovolumes (table 3). Discrete sampling locations were assigned a site identification composed of "CWS" followed by a number from 1 to 7, with lower numbers in the upper portion of the reservoir and Durham Canal, increasing downstream toward the dam in the lower portion of the reservoir (table 2; fig. 3). Sites CWS-1 and CWS-2 represent contributions to the reservoir from Cooper River and Durham Canal, respectively. Sites CWS-3 and CWS-4 represent the middle portion of the reservoir and are near the SCE&G intake. Sites CWS-5 (CWS intake location) and CWS-7 at the dam represent the lower portion of the reservoir. Site CWS-6 is located on Foster Creek, which contributes inflow into Bushy Park Reservoir between sites CWS-5 and CWS-7.

Water-quality profiling surveys were conducted with an AUV equipped with a multiparameter water-quality-sonde bulkhead. Data collected by the AUV included water temperature, dissolved oxygen, pH, specific conductance, turbidity, total chlorophyll as fluorescence (estimate of algal biomass), and phycocyanin as fluorescence (estimate of cyanobacteria biomass) data (table 4; fig. 4). Although chlorophyll *a* is the dominant pigment in most phytoplankton, different phytoplankton groups contain other types of chlorophyll and accessory (carotenoids, phycobilins [for example, phycocyanin]) pigments. In addition to chlorophyll *a*, green algae also contain chlorophyll *b*, while diatoms, dinoflagellates, and brown algae contain chlorophyll *c*. The total chlorophyll present in the water was estimated based on in situ fluorescence of phytoplankton excited by a laser with a wavelength of 435–470 nanometers as recorded by the YSI 6025 probe (table 4). Cyanobacteria in freshwater systems contain the accessory pigment phycocyanin, and in situ fluorescence of cyanobacteria was measured by the YSI 6131 probe.

All data used in this study are available online. The data from the USGS gaging network and discrete water-quality sampling are available at the U.S. Geological Survey National Water Information System (NWIS) portal (U.S. Geological Survey, 2016). Phytoplankton taxonomic, vertical water-quality profile, and AUV survey data are available at Conrads and others (2017a).

The method used for planning the collection of water-quality data was to schedule bimonthly water-quality AUV surveys of large portions of the reservoir with periodic discrete sampling and additional surveys during potential T&O events ("on call" water-quality surveys). Many of these surveys coincided with velocity and flow data collection before and after withdrawal outages at the Williams Station.

Sixteen bimonthly water-quality AUV surveys of water temperature, dissolved oxygen, pH, specific conductance, turbidity, total chlorophyll fluorescence (estimate of algal biomass), and phycocyanin fluorescence (estimate of cyanobacteria biomass) were conducted (table 1). Total chlorophyll and phycocyanin measurements are expressed in relative fluorescence units (RFUs); however, an internal algorithm developed by the manufacturer can also provide a generalized estimate of chlorophyll, in micrograms per liter (µg/L), and cyanobacteria (BGA) density, in cells per milliliter, from the RFU output.

Table 2. Description of the selected reservoir locations for discrete sampling of water chemistry and algal taxonomy in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[USGS, U.S. Geological Survey; NWIS, National Water Information System; mi, mile; ft, foot; S, shallow; D, deep; —, no samples collected; F, field parameters collected; C, water chemistry samples collected including major ions, nutrients, organic carbon, and taste-and-odor compounds; A, algal taxonomy samples collected]

USGS NWIS station number	Station name	Estimated distance from dam (mi)	Depth of sample (ft)	Site identification (fig. 3)	Continuous streamflow	Discrete water-quality sampling events						
						9/18/2013	4/16/2014	7/23/2014	8/26/2014	11/6/2014	12/16/2014	4/30/2015
02172025	Cooper River at Inlet to Back River	8.84	3.3	CWS-1	No	—	—	F, C, A	F, C, A	F, C, A	F, C	—
02172060	Durham Canal at Bridge to Cypress Garden, SC	6.72	3.3	CWS-2	Yes	F, C, A	—	F, C, A	F, C, A	F, C, A	F, C	—
330139079570800	CWS-3 on Bushy Park Reservoir, Goose Creek, SC	4.50	3.3	CWS-3	No	F, C, A	F, C, A	F, C, A	F, C, A	F, C, A	F, C	—
330019079561500	CWS-4 on Bushy Park Reservoir, Goose Creek, SC	2.68	3.3	CWS-4S	No	F, C, A	—	F, C, A	F, C, A	F, C, A	F, C	—
330019079561500	CWS-4 On Bushy Park Reservoir, Goose Creek, SC	2.68	10	CWS-4D	No	—	—	F, C, A	F, C, A	F, C	F, C	—
0217206110	Bushy Park Reservoir above Foster Creek, Goose Creek, SC	0.84	3.3	CWS-5S	No	F, C, A	—	F, C, A	F, C, A	F, C, A	F, C	F, C, A
0217206110	Bushy Park Reservoir above Foster Creek, Goose Creek, SC	0.84	10	CWS-5D	No	F, C, A	F, C, A	F, C, A	F, C, A	F, C	F, C	—
0217206147	CWS-6 at Foster Creek, Goose Creek, SC	0.57	3.3	CWS-6	Yes	F, C, A	F, C, A	F, C, A	F, C, A	F, C, A	F, C	—
02172062	CWS-7 Back River below Foster Creek at Highway 5 (8-503)	0	3.3	CWS-7	No	F, C, A	F, C, A	F, C, A	F, C, A	F, C, A	F, C	—

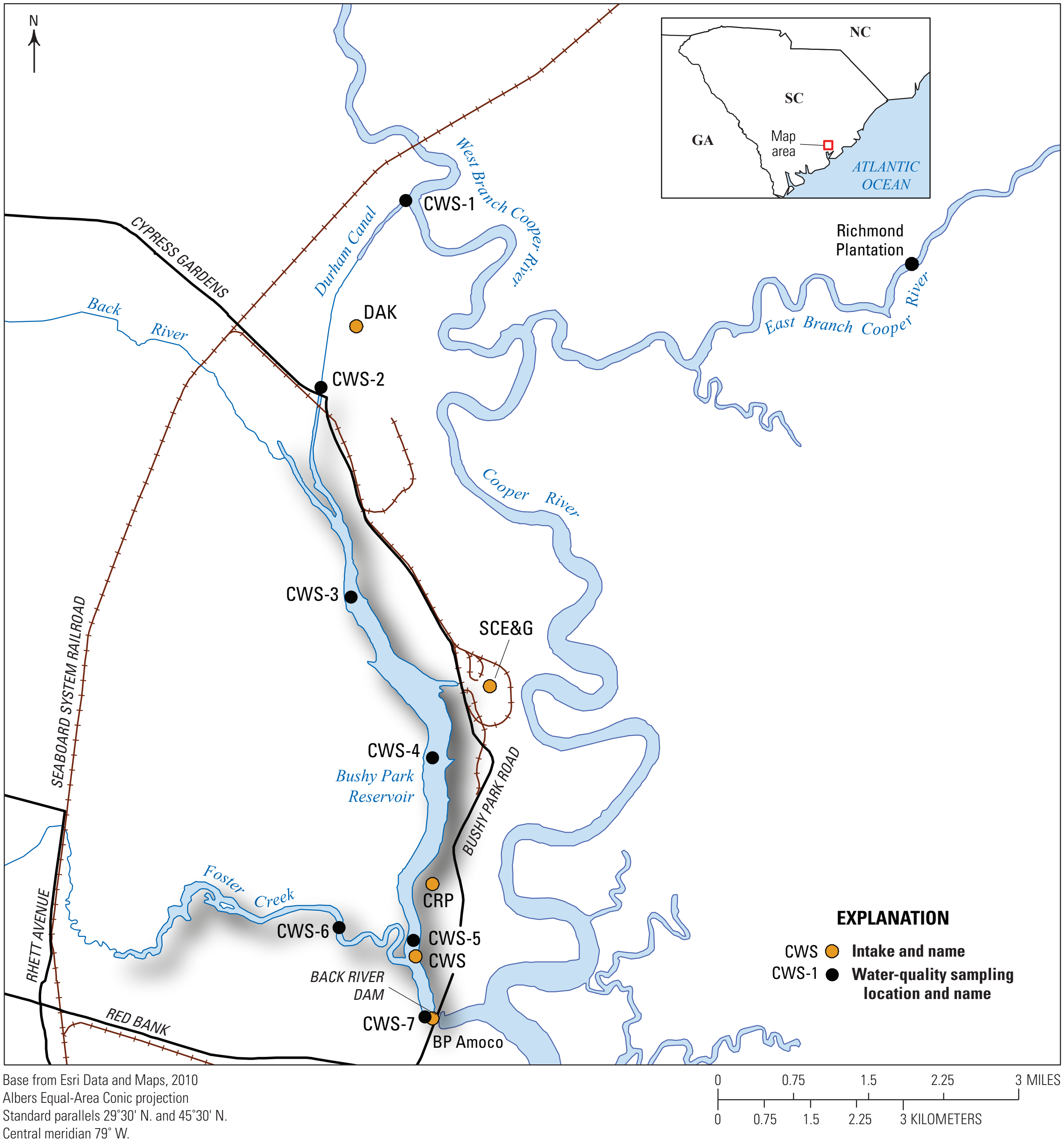

Figure 3. Locations and names of water-quality sampling sites and industrial withdrawal intakes in the Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015 [BP Amoco, British Petroleum Amoco; DAK, DAK Americas; SCE&G, South Carolina Electric and Gas Williams Station; CRP, Cooper River Partners; CWS, Charleston Water System].

Table 3. Description of the analytical tests performed by the U.S. Geological Survey National Water Quality Laboratory (NWQL) and National Environmental Laboratory Accreditation Program-certified contract laboratory on water samples from Bushy Park Reservoir, near Goose Creek, South Carolina, 2013 to 2015.

[Algal taxonomic analysis was performed by Linda C. Ehrlich, Ph.D., Spirogyra Diversified Environmental Services; taste-and-odor compound analysis was performed by Underwriter Laboratories/Eurofins Eaton Analytical, Inc. Abbreviations: —, not available; NWIS, U.S. Geological Survey National Water Information System; CAS, Chemical Abstracts Service; mg/L, milligram per liter; µg/L, microgram per liter; NH3, ammonia; NO2, nitrite; NO3, nitrate; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg Cel, degrees Celsius; μm^3/mL, cubic micrometer per milliliter; cells/mL, cells per milliliter; cm, centimeter; ng/L, nanogram per liter; EPA, U.S. Environmental Protection Agency; TSS, total suspended solids; TDS, total dissolved solids]

Analyte	Laboratory code	NWIS parameter code	NWIS method code	CAS number[1]	Laboratory reporting level	Unit	Method used
Dissolved ammonia, filtered	3116	00608	SHC02	7664-41-7	0.01	mg/L	Fishman, 1993
Dissolved nitrite, filtered	3117	00613	DZ001	14797-65-0	0.001	mg/L	Fishman, 1993
Dissolved nitrate plus nitrite, filtered	3156	00631	RED01	—	0.04	mg/L	Patton and Kryskalla, 2011
Total dissolved nitrogen (NH3+NO2+NO3+organic), filtered	2754	62854	CL063	17778-88-0	0.05	mg/L	Patton and Kryskalla, 2003
Total nitrogen (NH3+NO2+NO3+organic), unfiltered	2756	62855	AKP01	17778-88-0	0.05	mg/L	Patton and Kryskalla, 2003
Dissolved phosphorus, filtered	2757	00666	CL063	7723-14-0	0.01	mg/L	Patton and Kryskalla, 2003
Orthophosphate, filtered	3118	00671	PHM01	14265-44-2	0.004	mg/L	Fishman, 1993
Total phosphorus, unfiltered	2759	00665	AKP01	7723-14-0	0.01	mg/L	Patton and Kryskalla, 2003
Biomass, phytoplankton, ash free dry weight	2190	49953	93	—	0.1	mg/L	EPA Method 445.0; American Public Health Association, 1995b; Arar and Collins, 1997
Chlorophyll *a*, phytoplankton	3152	70953	50	479-61-8	0.1	µg/L	American Public Health Association, 1995b; Arar and Collins, 1997
Pheophytin *a*, phytoplankton	3152	62360	50	603-17-8	0.1	µg/L	American Public Health Association, 1995b; Arar and Collins, 1997
Phytoplankton, biomass, ash weight	2189	81353	GRV05	—	0.1	mg/L	American Public Health Association, 1995b; Arar and Collins, 1997
Phytoplankton, biomass, dry weight	2190	81354	GRV06	—	0.1	mg/L	American Public Health Association, 1995b; Arar and Collins, 1997
Calcium	659	00915	PLA11	7440-70-2	0.022	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Chloride	1571	00940	IC022	16887-00-6	0.02	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Fluoride	651	00950	IC003	16984-48-8	0.01	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998

Table 3. Description of the analytical tests performed by the U.S. Geological Survey National Water Quality Laboratory (NWQL) and National Environmental Laboratory Accreditation Program-certified contract laboratory on water samples from Bushy Park Reservoir, near Goose Creek, South Carolina, 2013 to 2015.—Continued

[Algal taxonomic analysis was performed by Linda C. Ehrlich, Ph.D., Spirogyra Diversified Environmental Services; taste-and-odor compound analysis was performed by Underwriter Laboratories/Eurofins Eaton Analytical, Inc. Abbreviations: —, not available; NWIS, U.S. Geological Survey National Water Information System; CAS, Chemical Abstracts Service; mg/L, milligram per liter; µg/L, microgram per liter; NH3, ammonia; NO2, nitrite; NO3, nitrate; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg Cel, degrees Celsius; μm^3/mL, cubic micrometer per milliliter; cells/mL, cells per milliliter; cm, centimeter; ng/L, nanogram per liter; EPA, U.S. Environmental Protection Agency; TSS, total suspended solids; TDS, total dissolved solids]

Analyte	Laboratory code	NWIS parameter code	NWIS method code	CAS number[1]	Laboratory reporting level	Unit	Method used
Iron	645	01046	PLA11	7439-89-6	5	µg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Magnesium	663	00925	PLA11	7439-95-4	0.011	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Manganese	648	01056	PLA11	7439-96-5	0.2	µg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
pH, laboratory	68	00403	EL006	—	0.1	standard units	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Potassium	2773	00935	PLO03	2023695	0.06	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Residue, 180 degrees Celsius (Total dissolved solids)	27	70300	ROE10	—	20	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Silica	3121	00955	CL151	7631-86-9	0.06	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Sodium	675	00930	PLA11	7440-23-5	0.1	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Specific conductance, laboratory	69	90095	WHT03	—	5	µS/cm	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Sulfate	1572	00945	IC022	14808-79-8	0.02	mg/L	Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998
Total organic carbon	3211	00680	COMB9	—	0.7	mg/L	Fishman and Friedman, 1989
Dissolved organic carbon	2612	00681	OX006	—	0.23	mg/L	Brenton and Arnett, 1993
Solids, Residue at 105 deg Cel, suspended, gravimetric (total suspended solids)	169	00530	SLD04	—	15	mg/L	Fishman and Friedman, 1989

Table 3. Description of the analytical tests performed by the U.S. Geological Survey National Water Quality Laboratory (NWQL) and National Environmental Laboratory Accreditation Program-certified contract laboratory on water samples from Bushy Park Reservoir, near Goose Creek, South Carolina, 2013 to 2015.—Continued

[Algal taxonomic analysis was performed by Linda C. Ehrlich, Ph.D., Spirogyra Diversified Environmental Services; taste-and-odor compound analysis was performed by Underwriter Laboratories/Eurofins Eaton Analytical, Inc. Abbreviations: —, not available; NWIS, U.S. Geological Survey National Water Information System; CAS, Chemical Abstracts Service; mg/L, milligram per liter; µg/L, microgram per liter; NH3, ammonia; NO2, nitrite; NO3, nitrate; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg Cel, degrees Celsius; μm^3/mL, cubic micrometer per milliliter; cells/mL, cells per milliliter; cm, centimeter; ng/L, nanogram per liter; EPA, U.S. Environmental Protection Agency; TSS, total suspended solids; TDS, total dissolved solids]

Analyte	Laboratory code	NWIS parameter code	NWIS method code	CAS number[1]	Laboratory reporting level	Unit	Method used
Ultraviolet absorbance at 254 nanometers	—	66700	—	—	0.01	cm^{-1}	American Public Health Association, 1995a
Ultraviolet absorbance at 280 nanometers	—	61726	—	—	0.01	cm^{-1}	American Public Health Association, 1995a
Actinomycetes	AIA	63688	—	—			American Public Health Association, 2005b
Geosmin, whole water	V210	68288	—	19700-21-1	2	ng/L	American Public Health Association, 2005a; modified EPA method 524.2; Standard Methods 6040C; Capillary Gas Chromatography/Mass Spectrometry/Selected Ion Storage
2-methylisoborneol (MIB), whole water	V210	68289	—	2371-42-8	2	ng/L	American Public Health Association, 2005a; modified EPA method 524.2; Standard Methods 6040C; Capillary Gas Chromatography/Mass Spectrometry/Selected Ion Storage
Isobutyl methoxy pryazine (IBMP), whole water	V210	—	—	24683-00-9	2	ng/L	American Public Health Association, 2005a; modified EPA method 524.2; Standard Methods 6040C; Capillary Gas Chromatography/Mass Spectrometry/Selected Ion Storage
Isopropyl methoxy pyrazine (IPMP), whole water	V210	—	—	25773-40-4	2	ng/L	American Public Health Association, 2005a; modified EPA method 524.2; Standard Methods 6040C; Capillary Gas Chromatography/Mass Spectrometry/Selected Ion Storage
2,4,6-Trichloroanisole (TCA), whole water	V210	—	—	87-40-1	2	ng/L	American Public Health Association, 2005a; modified EPA method 524.2; Standard Methods 6040C; Capillary Gas Chromatography/Mass Spectrometry/Selected Ion Storage
Phytoplankton taxonomic analysis	—	—	—	—	1	μm^3/mL; cells/mL	Ehrlich, 2010

[1]CAS Registry Number® is a Registered Trademark of the American Chemical Society. CAS recommends the verification of the CAS numbers through CAS Client Services.

Table 4. Manufacturer's specifications for the water-quality sensors in the handheld water-quality sondes and in the bulkhead sonde of the autonomous underwater vehicle.

[mS/cm, millisiemen per centimeter; ±, plus or minus; %, percent; °C, degrees Celsius; foot, ft; m, meter; ppt, part per thousand; mg/L, milligram per liter; NTU, nephelometric turbidity units; RFU, relative fluorescence units; µg/L, microgram per liter; cells/mL, cells per millliter; >, greater than; —, not specified; R^2, Pearson r-squared]

Sensor name	Sensor type	Range	Detection limit	Resolution	Accuracy	Linearity	Estimated lag, in seconds
Conductivity	6560	0 to 100 mS/cm	—	0.001 to 0.1 mS/cm	±0.5% +0.001 mS/cm	—	0.5
Temperature	6560	−5 to 50 °C	—	0.01 °C	±0.15 °C	—	2.1
Depth	NA	0 to 656 ft (200 m)	—	0.001 ft	±1 ft (±0.3 m)	—	—
Salinity	NA	0 to 70 ppt	—	0.01 ppt	±1% or 0.1 ppt	—	—
pH	FR6589; 6561	0 to 14 units	—	0.01 units	±0.2 units	—	7.1*
Optical dissolved oxygen	6150	0 to 50 mg/L	—	0.01 mg/L	±0.1 mg/L or 1%	—	5.5
Turbidity	6136	0 to 1,000 NTU	—	0.01 NTU	±2% or 0.3 NTU	—	2.1
Chlorophyll fluorescence (**estimated as concentration)	6025	0 to 400 µg/L; 0 to 100 RFU	0.1 µg/L	~ 0.1 µg/L	—	$R^2 > 0.9999$	2.1
Phycocyanin fluorescence (***estimated as blue-green algae cell density)	6131	0 to 280,000 cells/mL; 0 to 100 RFU	220 cells/mL	1 cell/mL; 0.1 RFU	—	$R^2 > 0.9999$	2.1

*Can vary with age of sensor.

**Determined from cultures of *Isochrysis* sp. and chlorophyll *a* concentration determined from extractions.

*** Estimated from cultures of *Microcystis aeruginosa*.

The discrete water-quality data collection was conducted concurrently with the water-quality surveys but at less frequent intervals. The discrete sampling occurred seven times during the study period, and samples were collected at the CWS intake and at as many as six other locations (fig. 3). Concurrent with the water-quality surveys and discrete sampling, vertical water-quality profiles of field properties were collected at a limited number of locations along the water-quality surveys or at the discrete sampling locations. Detailed descriptions of the data collection and analysis are provided below. Data-collection dates are listed in table 1.

Discrete Water-Quality Data Collection

In conjunction with 7 of the 16 AUV surveys, water-column samples were collected at 1 to 7 locations in Bushy Park Reservoir and major tributaries (Foster Creek and Durham Canal; table 2). The data were evaluated to describe the limnological conditions and phytoplankton community structure in the reservoir and to verify the AUV output in relation to in situ chlorophyll and phycocyanin fluorescence measurements (tables 1, 2; Conrads and others, 2017a). These discrete water-column samples, collected during

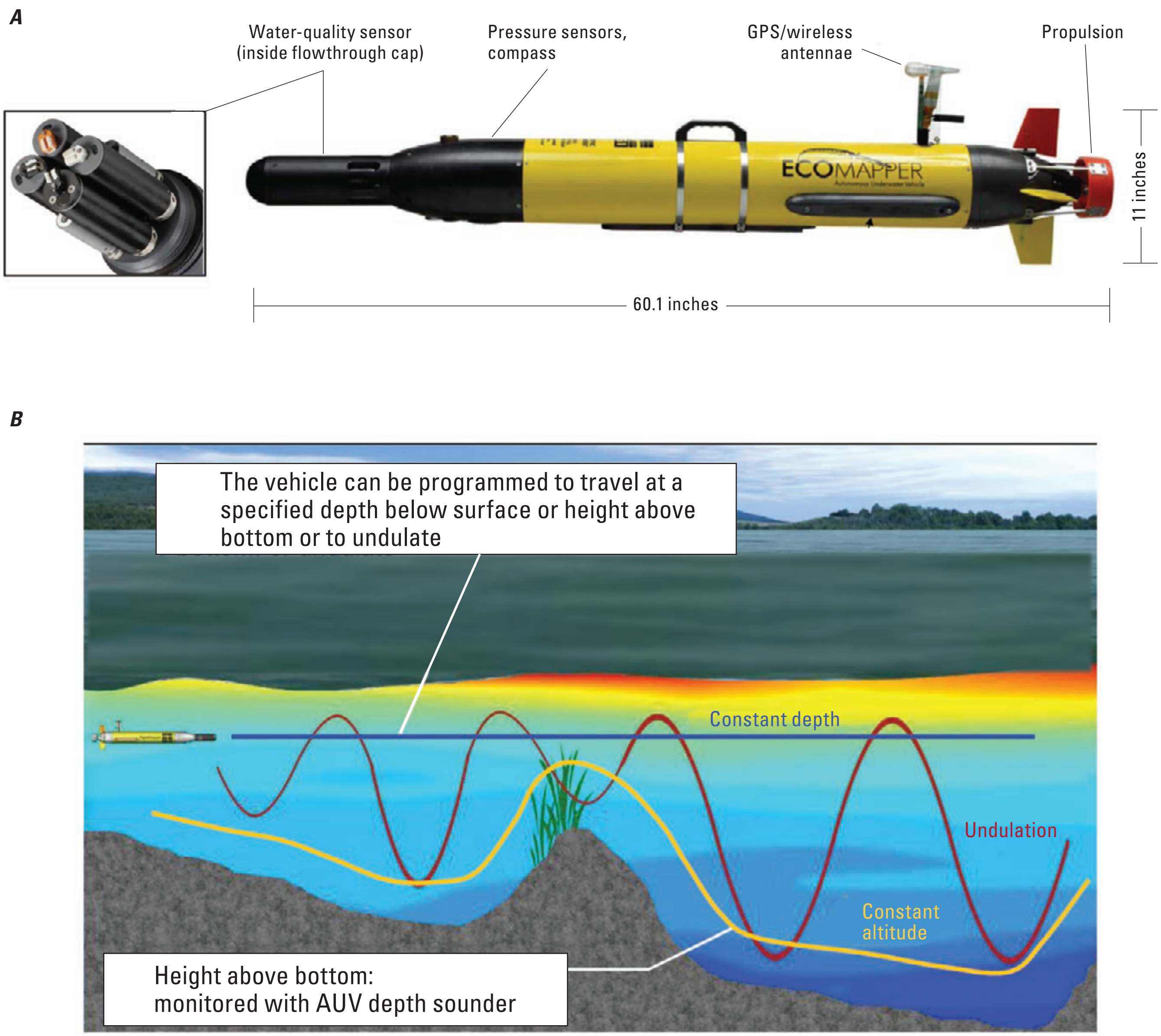

Figure 4. Diagrams of the autonomous underwater vehicle (AUV) used for water-quality surveys in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015: (*A*) major components, including a closeup of the water-quality sensors inside the flowthrough cap and (*B*) three survey modes (constant depth, constant altitude, and undulation). Surveys in Bushy Park Reservoir typically were run as undulations. Modified from YSI, Inc. (2008) and modified from Jackson (2013b).

September 2013 to April 2015, were analyzed for biological, physical, and chemical constituents.

Reservoir discrete sampling frequency varied seasonally and spatially with greater numbers of samples collected during the peak algal growth period (spring to late summer; table 2). In general, water samples at all sites were collected near the surface (3.3-ft [1-m] depth) within the photic zone to allow comparison among locations in the reservoir (the exception was site CWS-5 in April 2014). Additionally, concurrent water samples were collected at a 10-ft (3.3-m) depth at site CWS-5 to assess the environmental conditions at the intake depth (fig. 3). On the basis of the AUV survey output, a zone of greater chlorophyll and phycocyanin fluorescence periodically was observed near the 10-ft (3.3-m) depth in the middle portion of the reservoir, so a concurrent water sample at that depth was added to the site CWS-4 location during the July, August, November, and December 2014 sampling events (fig. 3).

Water-column samples were collected and processed according to USGS protocols and guidelines (U.S. Geological

Survey, variously dated; Graham and others, 2008, 2009). Because one of the main goals was to verify sonde measurements with laboratory-derived data, discrete-depth point samples were collected at one location in a cross section with a peristaltic pump sampler and tubing attached to a multiparameter sonde. Water was pumped from the selected depth directly into the sample bottle or filtration system during sample processing. The attached sonde provided Global Positioning System (GPS) location and field measurements of water temperature, dissolved oxygen, pH, specific conductance, turbidity, total chlorophyll as fluorescence (estimate of algal biomass), and phycocyanin as fluorescence (estimate of cyanobacteria biomass) during the exact same time, location, and depth of sampling as the water-column samples. At locations where water movement was negligible, transparency (Secchi disk depth) and light attenuation were measured at the time of sampling; however, increasing water movement due to changing tidal conditions in and near Durham Canal frequently prevented these properties from being measured.

Reservoir depth-profile measurements of pigment fluorescence (an estimate of chlorophyll and an estimate of phycocyanin), specific conductance, pH, dissolved-oxygen concentrations, and water temperature were made at 3.3- and 10-ft (1- to 3.3-m, respectively) depths along each transect using a field-calibrated multiparameter sonde (tables 2, 4). Photosynthetically active radiation (PAR) at the time of sampling was measured with a portable light meter that had an accuracy, for the 0 to 55 degrees Celsius (°C) range, of +/–0.6 percent of reading and +/–3 counts on the least significant digit displayed and linearity of +/–0.05 percent (user specifications found at https://www.licor.com/env/products/light/light_meter.html/). Measurements of PAR were made in the 0 to 1,999 range with a 0.1 micromole of photons per second per square meter (µmol/s-m^2) resolution.

Water-column samples were analyzed for total (dissolved and particulate) and dissolved nitrogen species of nitrate, nitrite, and ammonia and for total phosphorus and dissolved orthophosphate by the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado (Fishman, 1993; Patton and Kryskalla, 2003, 2011) (table 3). Additionally, water samples were analyzed for total and dissolved organic carbon (Fishman and Friedman, 1989; Brenton and Arnett, 1993, respectively), major ions, and trace metals (Fishman and Friedman, 1989; Fishman, 1993; American Public Health Association, 1998). Ultraviolet absorbance at 254 and 280 nanometers (estimate of the humic content or reactive fraction of organic carbon) was measured by using an ultraviolet-visible (UV-Vis) spectrum spectrophotometer at the USGS South Atlantic Water Science Center in Columbia, South Carolina (American Public Health Association, 1995a). Samples for chlorophyll *a*, pheophytin *a* (pigment degradation product of chlorophyll *a*), and phytoplankton ash-free dry mass were collected on 0.47-micron glass-fiber filters and analyzed according to standard methods and U.S. Environmental Protection Agency (EPA) method 445.0, respectively (American Public Health Association, 1995b; Arar and Collins, 1997) by the USGS NWQL. For analysis of total geosmin and MIB, samples were collected into 40-milliliter (mL) glass septum vials, and the whole-water samples were analyzed by a contract laboratory—Underwriter Laboratories/Eurofins (Eaton) in South Bend, Indiana—by solid-phase microextraction (SPME) using gas chromatograph and mass spectrometry according to Standard Method 6040D (American Public Health Association, 2005a). Samples for the determination of actinomycetes concentration were collected as raw water aliquots in sterile 1-liter plastic bottles and analyzed by the USGS Ohio Microbiology Laboratory in Columbus, Ohio. The double-agar layer (DAL) method with Actinomycete Isolation Agar (AIA) was used for enumeration of actinomycetes (American Public Health Association, 2005b). Whole-water samples were analyzed for total suspended solids as solids, residue at 105 °C, (Fishman and Friedman, 1989) and for suspended-sediment concentrations (SSCs) and sand/fine fraction at the USGS Kentucky Water Science Center Sediment Laboratory in Louisville, Kentucky. Methods for SSCs are described in Shreve and Downs (2005).

Additionally, water samples were used for taxonomic characterization and enumeration of phytoplankton by contract laboratories, Greenwater Laboratories (September 2013 sample and two duplicate quality-control samples in 2014) and Spirogyra Diversified Environmental Services (April 2014–April 2015). A 250-mL aliquot was collected and preserved in the field with 1 mL of Lugol's solution per 100 mL of sample (Ehrlich, 2010). Counts were conducted at multiple magnifications to include organism sizes spanning several orders of magnitude. A minimum of 400 natural units (single cells, colonies, or filaments) were counted for each sample to ensure a robust statistical enumeration of the phytoplankton community. Phytoplankton samples were classified at the genus and species level, when possible, with special consideration given to identification of potential geosmin-producing cyanobacteria. Phytoplankton data were analyzed to determine if the algal community structure was dominated by cyanobacteria at the time of sampling. Phytoplankton data were reported as cell density, in cells per milliliter (cells/mL), and as biovolume, in cubic micrometer per milliliter (µm^3/mL), for each species. Phytoplankton biovolume was calculated by multiplying cell density (the number of cells in a sample [cells/mL]) by the volume of each cell (µm^3). Plots showing the phytoplankton data can be found in the "Characterization of Reservoir Water Quality" section of this report.

Discrete Water-Quality Data Analysis

Water-quality data were censored below the laboratory reporting level (LRL) for several constituents, including geosmin (18 percent censored), MIB (24 percent), nitrate plus nitrite (88 percent), ammonia (37 percent), orthophosphate (18 percent), dissolved phosphorus (12 percent), and total phosphorus (10 percent). Therefore, a nonparametric statistical analysis on ranked data was used, in general, whereby censored values were given the same rank and were ranked below estimated and quantitative (detections above the LRL) values (Childress and others, 1999; Helsel, 2005). Estimated values that were semiquantitative detections below the LRL were given the same rank, that is, above censored values but below detected values (Childress and others, 1999; Helsel, 2005).

Several exploratory statistical data analyses were applied to the water-quality and phytoplankton data to evaluate the influence of environmental factors on T&O occurrence. For chemical, physical, and a subset of phytoplankton group data, a permutation test (number of replications = 5,000) was applied to the data to determine if a statistical difference existed (alpha level = 0.05) among groups of data, and the pairwise Wilcoxon multiple comparison test was used to identify which group or groups were different. Initially, water-quality data were evaluated by individual site and depth (3.3 ft and 10 ft [1 m and 3.3 m]) to determine if water quality differed significantly among sampling events and between depths by using a t-test (for normally distributed data) or Wilcoxon rank sum test (for non-normal data). Secondly, water-quality data were merged for all sites and depths and evaluated to determine if water quality differed significantly among sampling events and seasons (winter—January, February, March; spring—April, May, June; summer—July, August, September; fall—October, November, December). On the basis of findings from the permutations test, water-quality data from selected sites (CWS-5, CWS-7, CWS-4, CWS-2) were evaluated by the Spearman rho correlation procedure, a rank-based nonparametric method to measure the strength of the monotonic bivariate relation between the environmental factors and geosmin and MIB concentrations, actinomycetes concentrations, and cyanobacteria biomass metrics (Helsel and Hirsch, 1992). Strong relations between geosmin, MIB, and cyanobacteria metrics and a number of potential water-quality, hydrodynamic, and algal drivers were identified. Potential water-quality drivers included nutrients (total nitrogen, dissolved nitrate plus nitrite, dissolved ammonia, total phosphorus, total nitrogen to total phosphorus [TN:TP] ratio, silica, dissolved organic carbon, iron, manganese), basic water characteristics (major ions, water temperature, dissolved oxygen, transparency, pH), and potential sources of geosmin (chlorophyll *a*, actinomycetes concentration, total phytoplankton biovolume, cyanobacterial biovolume, cyanobacterial dominance, proportion of potential geosmin producers in the cyanobacteria group).

The presence of many species that compose the phytoplankton community in Bushy Park Reservoir requires the use of robust statistical methods to identify changes over time or distance. For this dataset, several routines in the PRIMER 7.0 multivariate statistical software program were used to evaluate seasonal and spatial changes in phytoplankton communities and assess relations between phytoplankton community structure and associated environmental variables (Clarke, 1993; Clarke and others, 2014; Clarke and Gorley, 2015). Specifically, the multivariate approach was used to determine if the seasonal and spatial pattern of phytoplankton species was statistically related to the chemical species at a range of sites and, if so, how strong was that relation. This approach uses nonparametric statistical tests, which is a good fit with the non-normal distribution of the chemical data. Initial data exploratory analyses were conducted using the resemblance matrices for the biweekly and median pharmaceutical datasets. A nonhierarchial cluster analysis (LINKTREE) with similarity profile tests (SIMPROF with 999 permutations) was performed to identify statistically significant groupings of sites with similar phytoplankton community patterns. The results of the cluster analysis were displayed in a heat map (or shade plot) that provides information about the phytoplankton species that may be driving the clustering. The next step was to project the resemblance matrices into 2- and 3-dimensional (2D and 3D) space by nonmetric multidimensional scaling (nMDS) analysis, which is permutated 50 times on the ranked distances, where the goodness of fit of the projection is measured by a sum-of-squares-derived stress coefficient. Samples that plot near each other in 2D nMDS space are more alike than samples that plot far away; however, to quantify that relation, further statistical analysis is needed.

Hypotheses of temporal (seasonal, annual) and spatial (depth, reservoir location) similarities in the taxonomic composition and biovolumes of phytoplankton communities were examined with a series of one-way analysis of similarity (ANOSIM) tests, which are multivariate, nonparametric analogs of analysis of variance (Clarke and others, 2014). The ANOSIM test results are given as a Global R test statistic, which is a measure, between 0 and 1, of the degree of separation of the groups in 2D space. Because Global R is a correlation-based coefficient, its value does not change with added samples, only the level of significance (p-value) is subject to change. The ANOSIM tests performed for this study used 100 permutations, producing a minimum p-value of 0.001 (Clarke and others, 2014). Four classes of samples for the ANOSIM tests were established: (1) sites; (2) location in the reservoir (upper, lower, middle); (3) season (winter, January–March; spring, April–June; summer, July–September; fall, October–December); and (4) sample depth (shallow at 3.3-ft depth, or deep at 10-ft depth).

Although ANOSIM compared grouping patterns in data to different categorical factors, it cannot account for gradient changes in environmental characteristics. Therefore, the RELATE statistical program in PRIMER was used to determine (1) if the grouping patterns of phytoplankton species (using the resemblance matrix) were related to the grouping pattern of environmental conditions (using the resemblance matrix) in the Bushy Park Reservoir and (2) if so, how strong was that relation. The BEST statistical routine in PRIMER was used to identify individual environmental characteristics that best explained the grouping pattern of phytoplankton species biovolumes (resemblance matrix). The BEST routine tests the null hypothesis that there is no relation or link between the two groups of data by using random permutation. Analyses were conducted on square-root transformed and standardized phytoplankton species biovolumes (in cubic micrometers per milliliter) and log-transformed and normalized environmental variables. Preliminary analyses of cell densities (cells per milliliter) yielded similar results but are not presented in this report. Additionally, phytoplankton taxonomy provided by the two separate contract laboratories were assessed separately to prevent any pattern due to potential analyst differences.

Spearman rho correlation analysis also was applied to water-quality data to evaluate the strength of association among T&O concentrations and environmental factors (Helsel and Hirsch, 1992). An alpha level of 0.05 (95-percent confidence) for significant correlations was selected for the analysis.

Water-Quality Spatial Surveys

Multiple water-quality surveys of Bushy Park Reservoir were completed by using the EcoMapper Iver2 AUV built by Yellow Springs Instrument (YSI), Inc., and OceanServer Technology, Inc. (fig. 4*A*; Conrads and others, 2017a). The AUV can cost-effectively collect spatially dense data by surveying large areas in minimal time compared to traditional, manned boat surveys and sampling. The description and operation of the AUV and the post-processing of the data are well documented in Jackson (2013a), and much of the information presented below and in appendix 1 comes from that report. The water-quality sensor suite is composed of a YSI 6600 V2–4 bulkhead equipped with a YSI 6560FR fast response temperature/conductivity probe, a YSI 6589FR fast response pH sensor, a YSI 6150FR fast response ROX optical dissolved-oxygen sensor, a YSI 6136 turbidity sensor, a YSI 6025 chlorophyll *a* sensor, and a YSI 6131 BGA-PC phycocyanin (BGA) sensor. Manufacturer's specifications for each of the probes are provided in table 4. All water-quality sensors made measurements at a rate of 1 hertz (Hz). The water-quality sensor was calibrated prior to deployment and after completing the survey.

The AUV performs autonomous surveys of water bodies and when properly programmed requires no assistance during execution of the survey. Programming a survey involves obtaining a high-resolution georeferenced aerial photograph of the water body (typically a USGS digital orthoquarter-quadrangle) and determining locations of any potential obstructions (from initial reconnaissance). The aerial imagery and obstructions information are then imported into Vector Map (Vector Map, 2015), the primary programming software for the AUV, and used as a background for survey planning. Within Vector Map, the user creates missions (surveys) by generating a field of numbered waypoints for the AUV to visit. The points are numbered sequentially, and the AUV will follow the set order, executing commands at each waypoint. Each waypoint has a set of associated commands, including dive mode, speed, dive angle, depth or height above bottom, sonar settings, and park commands. Dive mode options include (1) constant depth, where the AUV will achieve and maintain a specific depth below the surface by using its redundant-pressure sensors and vertical uplooking beam; (2) constant altitude (height) above bottom, where the AUV will maintain a specified height above the bottom by using its vertical downlooking beam; and (3) undulate, where the vehicle will undulate between two depths (or a combination of a depth and height above bottom) at a specified dive angle (fig. 4*B*).

For Bushy Park Reservoir, the missions included paths of centerline, "zigzag" (paths of a gradual back and forth while traveling up or down stream), or "lawnmower" (paths of bank to bank with designated longitudinal spacing) (fig. 5). Individual missions varied in spatial coverage. Overall missions covered the area from Back River Dam to the railroad bridge

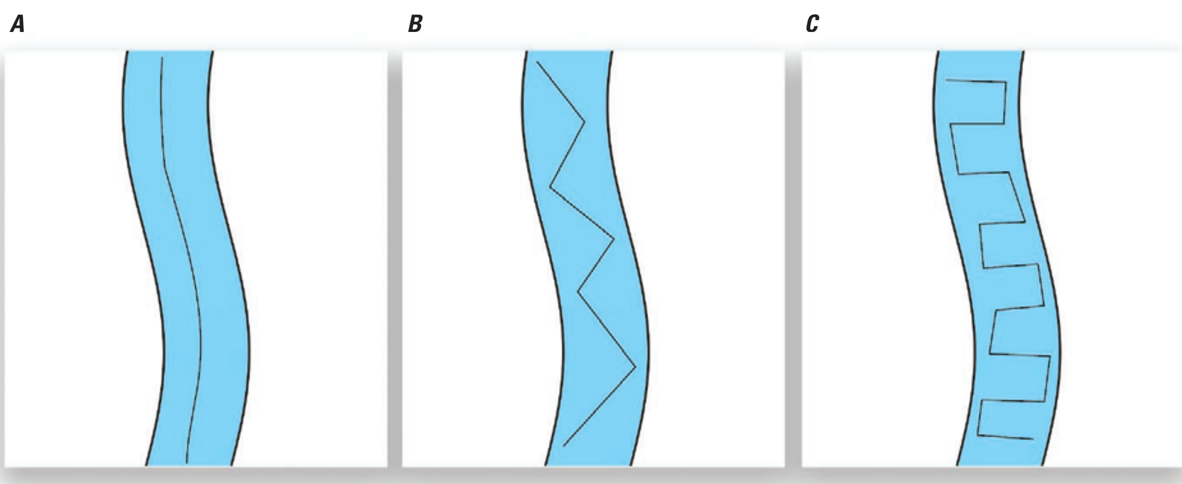

Figure 5. Examples of three mission routes used by the autonomous underwater vehicle during water-quality surveys on Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015: (*A*) centerline, (B) "zigzag," and (*C*) "lawnmower."

over Durham Canal (fig. 3). A few missions went upstream into Back River to the USGS streamgage 021720603 and up Foster Creek approximately 2 miles (near site CWS-6). During the initial runs, side-scan sonar was used to detect obstructions on the bottom that could present a problem if the AUV were to operate near the bottom of the reservoir. Figure 6 shows an image from the side-scan sonar (instrument settings were Gain–12, Range–50, and Frequency–low) in the lower reach of the reservoir between Back River Dam and the confluence with Foster Creek. The image is from initial AUV surface runs with the sonar collecting bathymetric data of the reservoir bottom. The image shows an abrupt change in depth that is probably a result of dredging the lower reach of the river to create the Back River Dam. Once the bottom features were determined, the emphasis of the missions switched from general reconnaissance to intense water-quality data collection.

To obtain data through a larger portion of the water column, undulating missions were used, consisting of dive patterns between at or near the water surface to a set distance

Figure 6. Side-scan sonar image from autonomous underwater vehicle of the lower reach of Bushy Park Reservoir, near Goose Creek, South Carolina, on September 17 and 18, 2013. Arrows pointing to dredging wall indicate an abrupt change in depth that is likely a result of dredging the lower reach of the river to create the Back River Dam.

above the bottom (fig. 4*B*). These undulating missions, combined with the lawnmower or zigzag patterns (fig. 5), were used to collect a detailed 3D dataset for each property measured. To understand the seasonal patterns occurring in the reservoir, missions were developed and reused several times with no change. During mission runs that coincided with intense sampling, the reusable mission was modified to collect additional data around the sampling points, enabling verification of sampling data to AUV data. Figure 7*A* shows the plan view of a lawnmower mission overlaid on the bathymetric data collected during the study. Undulating and zigzag missions showing chlorophyll data are provided in figure 7*B* and 7*C*. The zigzag mission is vertically offset for clarity of the visual presentation.

The 3D data from the AUV missions are collected at 1-second intervals and can be visualized by interpolating between the measured values and creating a longitudinal 2D plot showing the variability of the values from top to bottom of the water column and along the length of the AUV mission. An example of the 2D plot is provided in figure 8, which shows the vertical and longitudinal distribution of water temperature in June 2014 from the lower portion of the reservoir near the Back River Dam to the powerlines below the confluence with Durham Canal (fig. 7*A*). Depths at the lower reach of the reservoir were close to 40 ft and demonstrated relatively strong thermal stratification and an approximate 16 °C difference between the surface near site CWS-4 and bottom depths near the dam. Additionally, the longitudinal plot indicated about 2 °C cooler water temperature near the surface at site CWS-4 than elsewhere in the reservoir. Plots for seven physical properties (water temperature, specific conductance, dissolved oxygen, pH, turbidity, chlorophyll, and phycocyanin [estimated as BGA]) for the 16 AUV missions are shown in appendix 2.

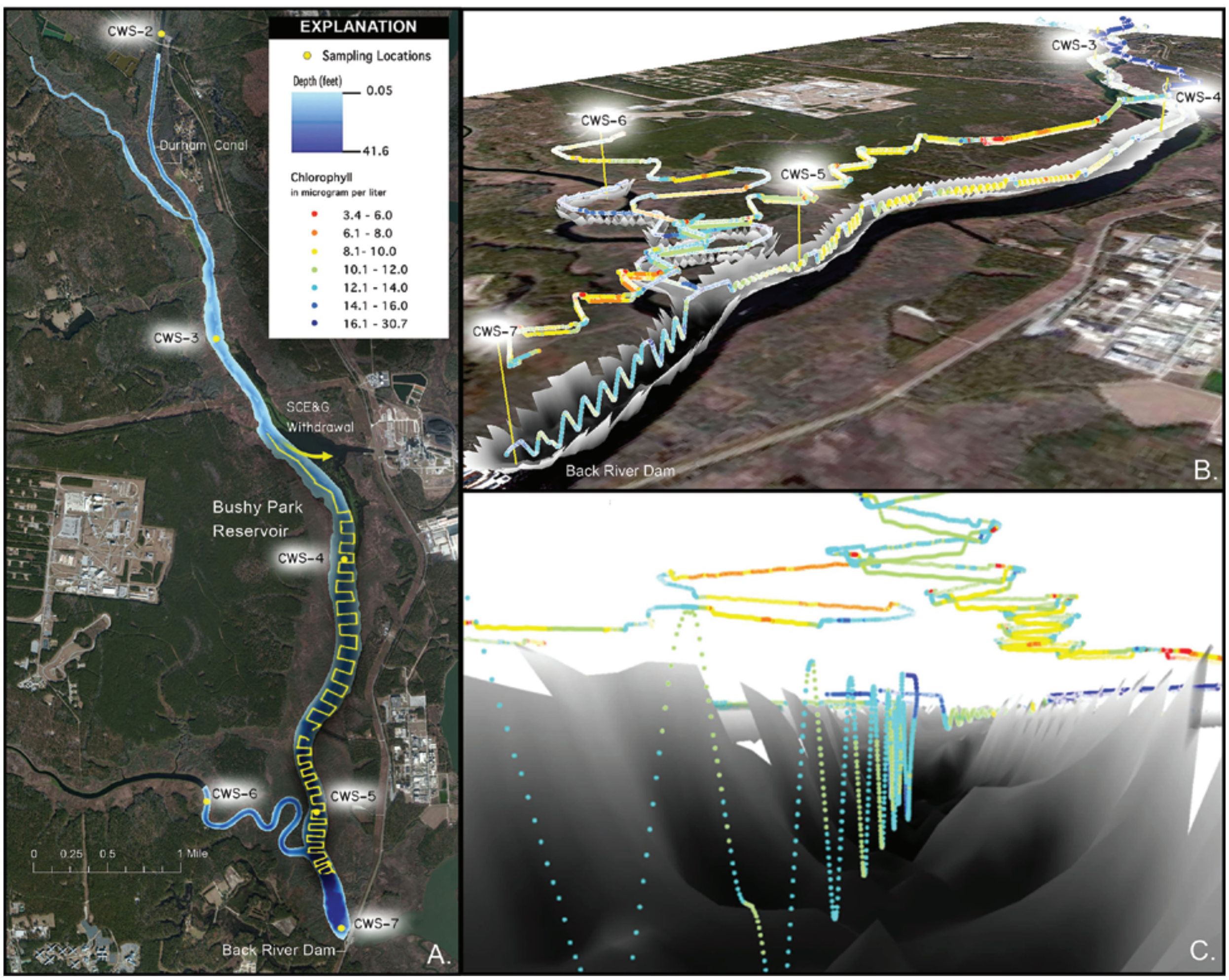

Figure 7. Examples of the autonomous underwater vehicle missions and data collection at Bushy Park Reservoir, near Goose Creek, South Carolina, on September 17 and 18, 2013: (*A*) plan view showing a “lawnmower” mission path and bathymetry depths, (*B*) side view showing chlorophyll data from a surface mission (elevation exaggerated to show both missions) and undulating mission, and (*C*) detail of the two missions looking upstream from the Back River Dam.

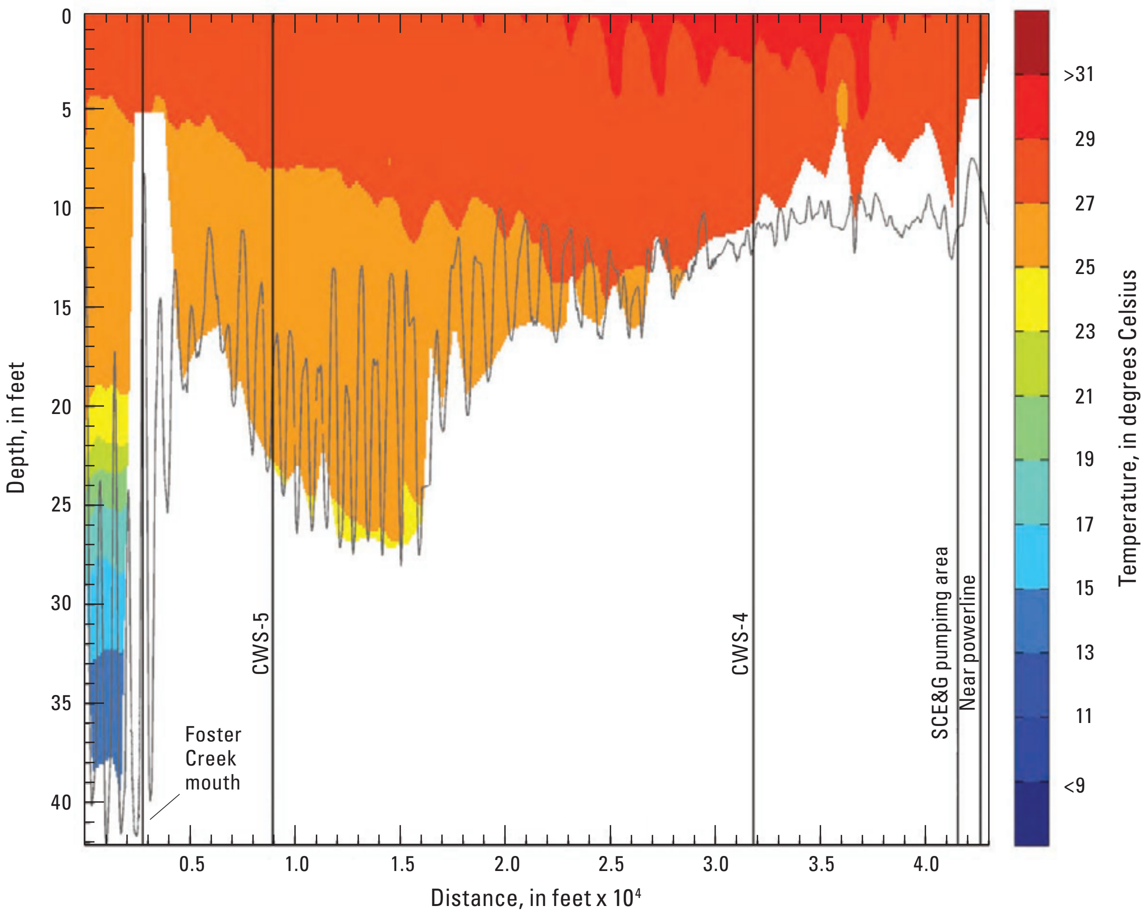

Figure 8. Longitudinal plot of water temperature depth profile from the autonomous underwater vehicle survey of the lower end of Bushy Park Reservoir near the Back River Dam to the powerlines near site CWS-3 and below the confluence with Durham Canal for June 10, 2014.

Verification of Physical Properties Measured by the Autonomous Underwater Vehicle

Water-quality profiles were collected with a hand-held calibrated sonde (field meter) in a manned boat concurrent with the AUV sonde to identify and verify diurnal- and depth-related changes during the AUV survey and water-quality sampling events and to make GPS-specific water-quality measurements in portions of the reservoir that were inaccessible to the AUV (Conrads and others, 2017a). Vertical reservoir profile measurements of water temperature, specific conductance, pH, dissolved-oxygen concentrations, turbidity, chlorophyll *a* fluorescence (estimate of phytoplankton biomass), and phycocyanin fluorescence (estimate of cyanobacteria or BGA biomass) were collected 1 ft below the water surface and at either 1-ft or 5-ft intervals, thereafter, to the bottom of the reservoir. Plots for these data are shown in appendix 3. In general, data collected with the field meter included the same properties as those collected by the AUV. Some exceptions occurred due to malfunctioning probes or probes not being available on the field meter sonde during the survey.

To verify the accuracy and performance of the AUV-acquired measurements, the performance of the AUV water-quality probes was checked before and after a sampling mission in certified standards and buffers according to manufacturer's and USGS protocols (Wagner and others, 2006; YSI, Inc., 2011). Ratings to define the accuracy of the AUV probes were similar to ratings applied to USGS continuous water-quality records (Wagner and others, 2006). Accuracy ratings assigned were excellent, good, fair, or poor based on differences between the probe measurements and the certified standards and buffers (table 5; Wagner and others, 2006). Calibration protocol and accuracy rating criteria were not established for chlorophyll and phycocyanin fluorescence measurements in Wagner and others (2006). Therefore, ratings were assigned for these properties on the basis of similar rating ranges for the turbidity measurements. For example, a chlorophyll fluorescence check measurement in chlorophyll-free water (deionized water) that is between –0.5 and 0.5 µg/L will be rated as excellent, between 0.5 and 1.0 µg/L will be rated as good, between 1.0 and 1.5 µg/L will be rated as fair, and greater than 1.5 µg/L will be rated

Table 5. Accuracy ratings of the autonomous underwater vehicle water-quality sensors and the surveys for the Bushy Park Reservoir water-quality study, near Goose Creek, South Carolina, September 2013 to April 2015.

[≤, less than or equal to; +/–, plus or minus; %, percent; >, greater than]

Rating	Water temperature,[1] in degrees Celsius	Specific conductance, in microsiemens per centimeter	pH, in standard units	Dissolved oxygen, in milligrams per liter	Turbidity	Chlorophyll,[2] in micrograms per liter	Blue-green algae,[2] in cells per milliliter
Excellent	≤ +/– 0.2	≤ +/– 3%	≤ +/– 0.2	≤ +/– 0.3 mg/L or ≤ +/– 5% (whichever is greater)	≤ +/– 0.5 mg/L or ≤ +/– 5% (whichever is greater)	≤ +/– 5%	≤ +/– 5%
Good	> +/– 0.2 to 0.5	> +/– 3 to 10%	> +/– 0.2 to 0.5	> +/– 0.3 to 0.5 mg/L or > +/– 5 to 10% (whichever is greater)	> +/– 0.5 to 1.0 mg/L or > +/– 5 to 10% (whichever is greater)	> +/– 5 to 10%	> +/– 5 to 10%
Fair	> +/– 0.5 to 0.8	> +/– 10 to 15%	> +/– 0.5 to 0.8	> +/– 0.5–0.8 mg/L or > +/– 10 to 15% (whichever is greater)	> +/– 1.0 to 1.5 mg/L or > +/– 10 to 15% (whichever is greater)	> +/– 10 to 15%	> +/– 10 to 15%
Poor	> +/– 0.8	> +/– 15%	> +/– 0.8	> +/– 0.8 mg/L or > +/– 15% (whichever is greater)	> +/– 1.5 mg/L or > +/– 15% (whichever is greater)	> +/– 15%	> +/– 15%
Survey date	**Rating**						
9/17/2013–9/19/2013	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
11/19/2013	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
1/13/2014–1/14/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
3/27/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
4/16/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
6/10/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
7/23/2014	Excellent	Good	Excellent	Good	Fair	Excellent	Excellent
8/5/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
8/26/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
10/2/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
10/29/2014	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
11/5/2014	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
11/6/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
12/16/2014	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
1/14/2015	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
3/26/2015	Good to excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
4/23/2015	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

[1]Due to the inability of inserting a thermistor in the closed calibration cup of the autonomous underwater vehicle, the temperature rating was based on a side-by-side field reading.

[2]Chlorophyll and blue-green algae concentrations were determined by internal algorithm estimated from chlorophyll and phycocyanin fluorescence. Because accuracy ratings were not established by the U.S. Geological Survey for chlorophyll or blue-green algae at the writing of this report, percentage ratings similar to dissolved oxygen and turbidity were used to rate these parameters.

as poor. Similarly, a phycocyanin fluorescence measurement in phycocyanin-free water (deionized water) that is between –1,000 and 1,000 cells/mL will be rated as excellent, between 1,000 and 2,000 cells/mL will be rated as good, between 2,000 and 3,000 cells/mL will be rated as fair, and greater than 3,000 cells/mL will be rated as poor. Drift corrections were applied to AUV field dissolved-oxygen and turbidity measurements made on July 23, 2014, on the basis of post-field data checks. Accuracy ratings for the AUV water-quality probes for 16 surveys (17 missions) ranged from fair to excellent (table 5) for this investigation.

Discrete Data Quality Assurance and Quality Control

Sample collection and processing were conducted according to water-quality sampling and biological assessment protocols documented in the USGS National Field Manual (U.S. Geological Survey, variously dated; Graham and others, 2008). A total of 65 water samples were collected for analysis. Six of the 65 samples were considered quality-control samples, including field blanks and sequential replicates. Two field blanks were collected and analyzed for geosmin, MIB, chlorophyll *a*, and major ion constituents, and four field blanks were collected and analyzed for nutrients and organic carbon constituents (appendix 4). Field blanks were used to test for bias due to contamination during cleaning, collection, processing, and analysis. Blank water was certified free of inorganic (major ions, nutrients, and trace elements) or organic (geosmin, MIB, and organic carbon) constituents. Constituent concentrations were below the LRL in all blanks except one for five constituents: chloride (0.02 milligram per liter [mg/L] in one of two blanks), manganese (0.3 µg/L in one of two blanks), total organic carbon (TOC; 1.3 mg/L in one of four blanks), chlorophyll *a* (0.02 and 0.03 µg/L in two of two blanks), and pheophytin *a* (0.02 and 0.03 µg/L in two of two blanks). Environmental concentrations for chloride, chlorophyll *a*, and pheophytin *a* were orders of magnitude above the field blank concentration and, therefore, considered free from bias by contamination. Only two of 47 environmental samples had manganese concentrations (0.9 µg/L and 1.1 µg/L) that were below 1.5 µg/L (five times the field blank concentration) that could potentially be influenced by some level of contamination. However, on the basis of the data quality objectives of the project (nonregulatory), the potential for that level of contamination (26 to 30 percent) was not considered problematic, and the data were used in the analysis. Three of the four blanks analyzed for TOC concentrations had nondetectable levels, and those blanks bracketed the period when the one-time detectable level was present; therefore, any potential contamination was considered limited to that August 2014 time period. During August 2014, the field blank TOC concentration of 1.3 mg/L was greater than 20 percent of five environmental TOC concentrations (range was 4.9 to 5.7 mg/L; 26 to 23 percent). Therefore, further evaluation of the environmental TOC concentrations was conducted by plotting the TOC concentrations against a surrogate for organic carbon, ultraviolet absorbance at 254 nanometers, to determine if significant deviations could be observed (fig. 9). Because

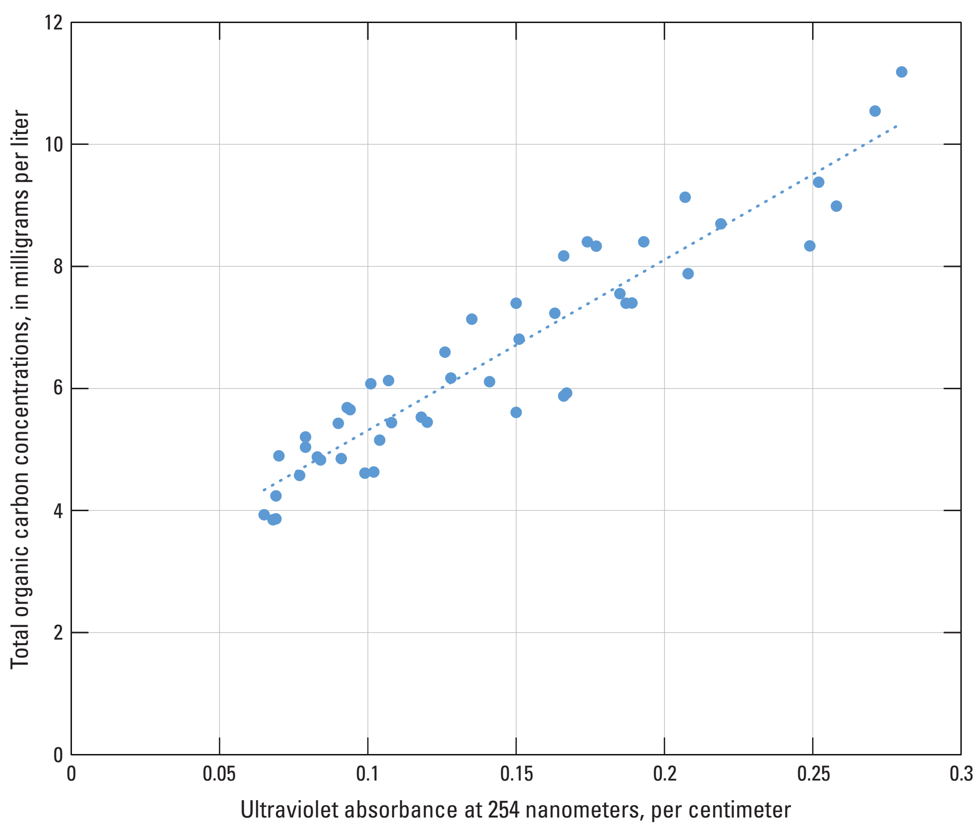

Figure 9. Scatterplot of total organic carbon concentrations and ultraviolet absorbance at 254 nanometers in water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, 2013 to 2015.

no observable deviations were identified compared to other sampling events, all TOC concentrations were considered reliable and were used in the assessment.

Comparison of the two environmental and replicate samples demonstrated good reproducibility for major ions, trace metals, and organic carbon (generally below 5 percent relative percent difference [RPD]) (appendix 4). Similar comparison among nutrient species indicated more bias than major ions, especially for ammonia (RPD of 26 and 18 percent) and nitrite (only one of two replicate samples with RPD of 102 percent). Ammonia was used in the data-analysis process even with the large RPD; however, nitrite was not used in the data analysis process, and nitrate plus nitrite was used instead.

Relation Between Sonde Measurements and Laboratory Analysis of Chlorophyll *a*

Estimated total chlorophyll measured in situ as fluorescence from the probe was compared to laboratory-derived chlorophyll *a* concentrations and to the sum of the laboratory-derived chlorophyll *a* and its degradate, pheophytin *a* concentrations. For all sites and all sampling events, in situ total chlorophyll was significantly correlated positively to the laboratory-derived chlorophyll *a* and pheophytin *a* concentrations (rho=0.484, p=0.0013 and rho=0.417, p=0.0062, respectively; fig. 10). However, the low correlation coefficients (rho of 1 indicates perfect correlation) between these compounds appear to indicate that some variability in in situ total chlorophyll is not reflected in the variability in the laboratory-derived concentrations. Plausible reasons for the poor agreement between in situ chlorophyll and laboratory-derived chlorophyll *a* values include variability in the in situ total chlorophyll attributed to spatial changes in phytoplankton species in the reservoir, water color (change from high DOC water near the dam to lower DOC water near Durham Canal), and turbidity during a sampling event and among the sampling events. All these environmental characteristics can affect the fluorescence measured by the probe and inaccurately attribute the change in fluorescence to increasing or decreasing chlorophyll *a*. Similar findings were observed when comparing the in situ estimated BGA cell count as fluorescence from the probe to the taxonomic-derived cyanobacteria cell densities,

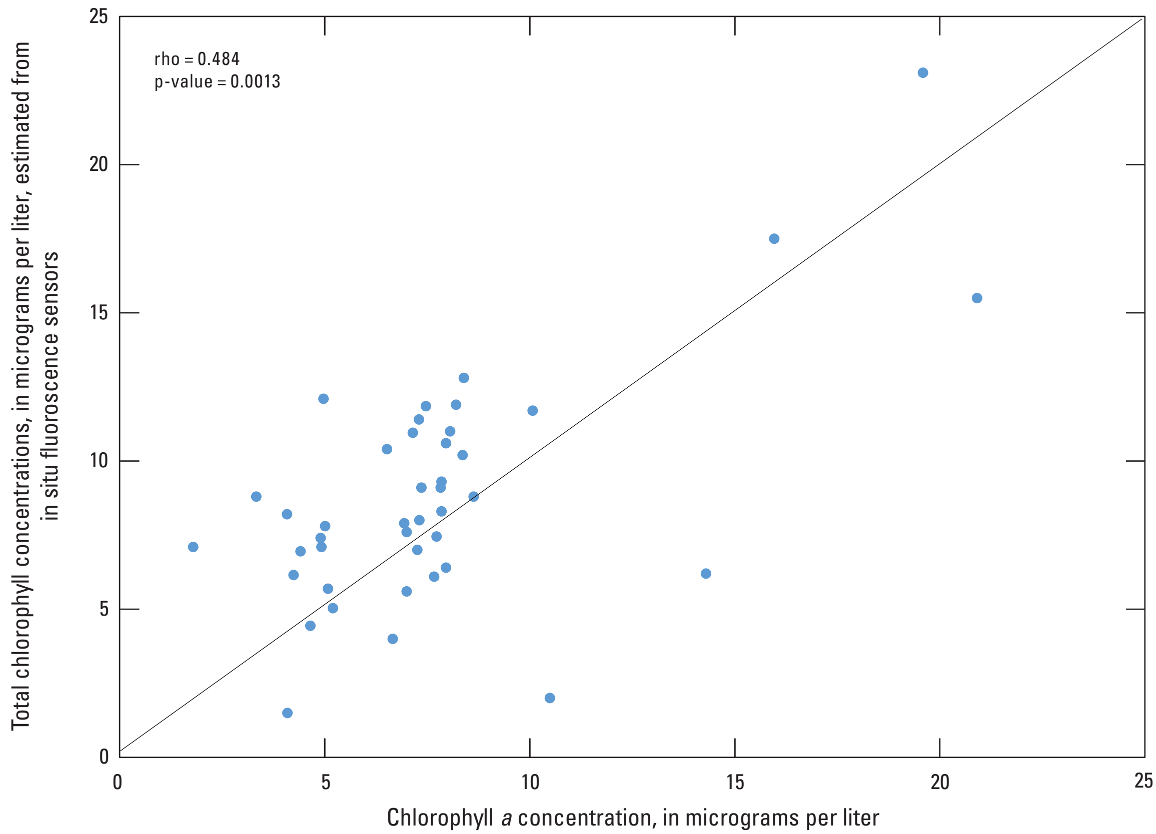

Figure 10. Scatterplot of laboratory-derived chlorophyll *a* concentrations and estimated total chlorophyll concentrations from in situ fluorescence measured with a YSI 6025 probe in Bushy Park Reservoir, near Goose Creek, South Carolina, 2013 to 2015. A one-to-one correspondence line is drawn for comparison purposes. Spearman rho correlation coefficient and associated probability value are provided.

and therefore, the in situ cell counts were used as a qualitative indicator of changes in cyanobacteria in the water column. Therefore, for this report, in situ total chlorophyll concentrations estimated from the AUV and field measurements were used as a qualitative, rather than quantitative, indicator of changes in chlorophyll *a* in the water column.

Characterization of Reservoir Water Quality

Taste-and-odor episodes are often sporadic, and intensities vary spatially (Peter and others, 2009). The production and release of geosmin and MIB have been related to cyanobacterial blooms or the presence of potential T&O-producing species of cyanobacteria. The presence and abundance of these species have been attributed to environmental factors, including nutrient concentrations and ratios, light availability, water temperatures, water column stability, and flushing rates (Izaguirre and others, 1982; Smith, 1983; Downing and McCauley, 1992; Smith and others, 1995; Smith and Bennett, 1999; Jacoby and others, 2000; Downing and others, 2001; Paerl and others, 2001; Havens and others, 2003; Graham and others, 2004; Dzialowski and others, 2009; Graham and Jones, 2009). Conversely, releases of geosmin and MIB from cyanobacteria in lakes that are not cyanobacteria-dominated also have been associated with periods of high transparency (clear-water phase) attributed to zooplankton grazing (Durrer and others, 1999; Scheffer, 2004; Jüttner and Watson, 2007). Therefore, the phytoplankton and water-quality data collected in Bushy Park Reservoir were assessed to identify environmental factors that may have contributed to the occurrence of T&O episodes. The complex interaction among the physical, chemical, and biological processes within lakes and reservoirs, however, often makes it difficult to identify the primary environmental factors that cause the production and release of these cyanobacterial by-products.

Phytoplankton taxonomic data were analyzed to determine if changes in the abundance and diversity of community occurred spatially and temporally. Additionally, genera within the cyanobacteria division were assessed for the presence of potential T&O-producing species. Genera of cyanobacteria, which contain known geosmin and MIB producers, include *Anabaena* (now referred to as *Dolichospermum*), *Planktothrix*, *Oscillatoria* (now referred to as *Jaaginema* or *Geitlerinema*), *Aphanizomenon, Lyngbya* (now referred to as *Planktolyngbya*), *Pseudanabaena, Symploca* (Izaguirre and others, 1982; Rashash and others, 1996; Jüttner and Watson, 2007) and *Synechococcus* (Taylor and others, 2006). Actinomycetes concentrations also were assessed to determine if elevated concentrations were present during T&O episodes.

The assessment was conducted in three steps. The first step was to characterize the water-quality conditions in the reservoir relative to established guidelines. The second step was to identify any spatial and seasonal variation in water-quality conditions and phytoplankton community structures throughout the reservoir. The second step was conducted to (1) identify the area of the reservoir that most influences the water-quality conditions at the intake (site CWS-5) (for example, Foster Creek inflows [site CWS-6] or Durham Canal inflows [sites CWS-1 and CWS-2]), especially during periods of elevated T&O concentrations, (2) determine if the T&O concentrations were produced in situ in the reservoir or delivered to the reservoir from either Foster Creek or Durham Canal, and (3) identify the most probable source of the T&O compounds (actinomycetes bacteria or cyanobacteria), and, if cyanobacteria, identify any phytoplankton species (or genus) that have the potential to produce T&O compounds during T&O episodes. The final step was to assess whether these spatial and seasonal changes in environmental factors correlate significantly with phytoplankton community structure and geosmin or MIB concentrations.

Reservoir Taste-and-Odor Occurrence

Discrete, AUV-acquired, and depth-profile water-quality data collected by the USGS in Bushy Park Reservoir from September 2013 to April 2015 were assessed in this report. Additionally, T&O concentrations from raw (untreated), blended water (Bushy Park Reservoir [dominant source] and Edisto River [secondary source]) and finished water collected by CWS in their distribution system as part of its treatment monitoring are reported but not included in the statistical assessment. The goal of the statistical assessment was to determine which, if any, environmental factors influence phytoplankton community structure and the occurrence of T&O compounds in CWS source water from Bushy Park Reservoir.

Seasonal Occurrence of Taste-and-Odor Compounds

Prior to this USGS investigation, internal monitoring by CWS had determined that spring and, less frequently, late summer periods tended to have the greatest potential for T&O occurrence (Rebecca Thames, Charleston Water System, written commun., March 26, 2015) (fig. 11). During these seasons and even with normal treatment techniques applied by CWS to reduce T&O compound concentrations in raw water, T&O occurrence tended to increase above the human detection level, as measured by customer complaints. The threshold level for T&O concentrations in raw water was between 15 and 20 ng/L. In the spring of 2013, raw water had total (geosmin plus MIB) T&O concentrations above 20 ng/L. During that spring T&O episode, CWS treated the raw water with powdered activated carbon (PAC) doses of between 8 and 10 parts per million and successfully reduced the T&O concentrations in the finished water to near 10 ng/L (fig. 11). T&O concentrations that were below 15 ng/L in finished water tended to reduce the customer complaints considerably.

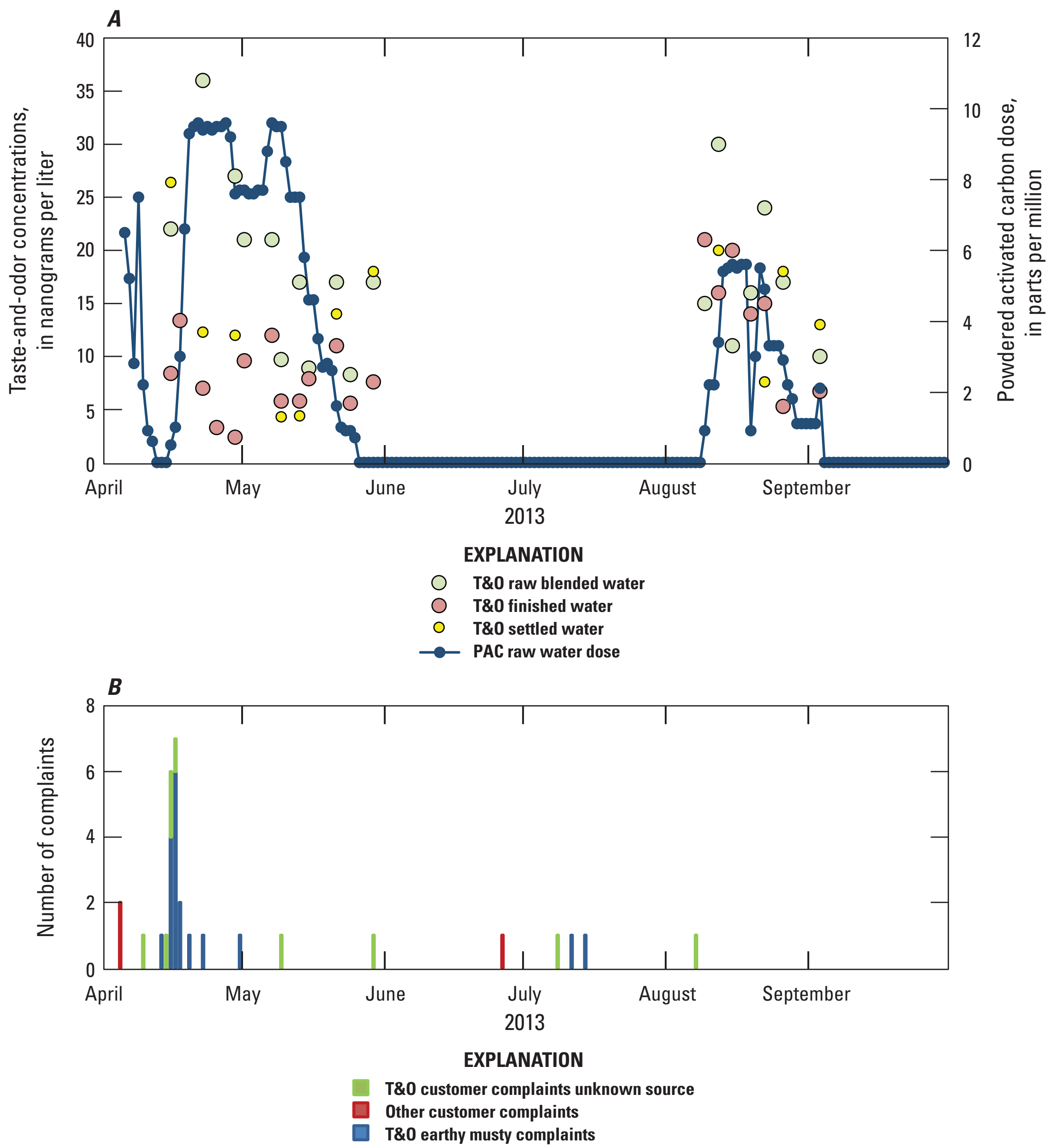

Figure 11. *A*, The temporal variability in taste-and-odor (T&O) concentrations as combined geosmin and 2-methylisoborneol concentrations in raw blended (Bushy Park Reservoir and Edisto River), settled, and finished water (colored circles) and the corresponding powdered activated carbon (PAC) doses used by Charleston Water Systems as a treatment technique (blue line) in the spring and fall of 2013. *B*, Associated temporal variability in number of complaints related to T&O problems by Charleston Water System customers.

Therefore, an assessment of the source water of Bushy Park Reservoir was needed to identify any changes in environmental conditions and phytoplankton community structure during these seasonal periods that may promote T&O production.

During the study period, T&O concentrations varied by dominant form of T&O constituent, sampling period, and location in the reservoir (fig. 12). Water-column samples had MIB concentrations consistently below 20 ng/L and only once exceeded 15 ng/L, which occurred at the CWS-6 (Foster Creek) site. Nonetheless, there was a general trend of greater MIB near the dam compared to the upper portion of the reservoir, including the September 2013, April 2014, and July 2014 sampling events. During the September and July sampling events, Foster Creek (at site CWS-6) had the greatest MIB concentrations compared to other sites in the reservoir, indicating the potential that Foster Creek may have served as a source of MIB to the reservoir during those periods. In this scenario, actinomycetes or cyanobacteria could be the producer of MIB. During the April sampling event, however, the MIB concentration in Foster Creek (site CWS-6) was lower

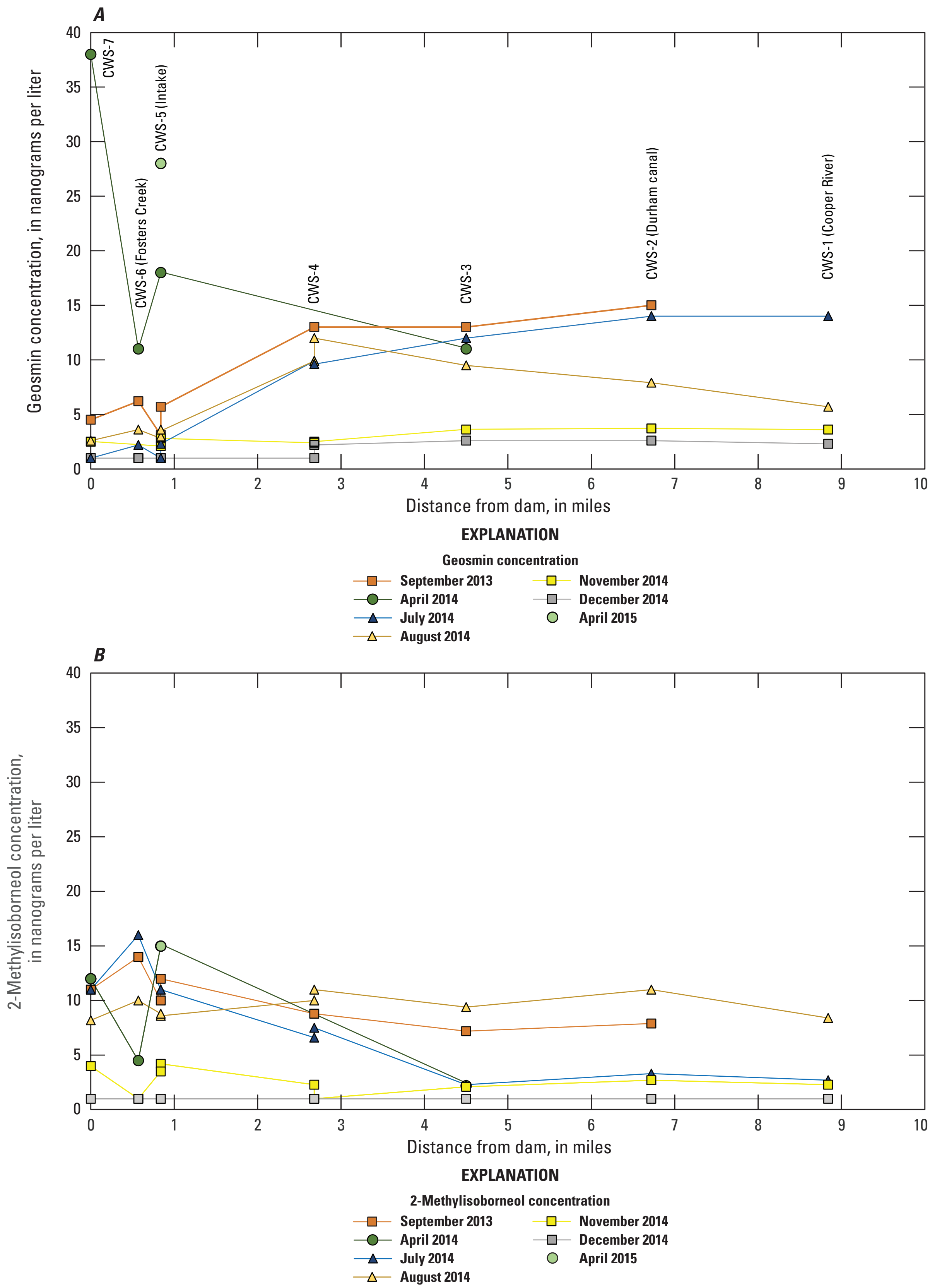

Figure 12. (*A*) Geosmin and (*B*) 2-methylisoborneol (MIB) concentrations at selected locations plotted by distance from Bushy Park Reservoir Dam, Goose Creek, South Carolina, for sampling events from September 2013 to April 2015.

than concentrations in the reservoir near the dam, indicating that the in situ production of MIB by cyanobacteria was more likely the dominant source.

In contrast to MIB, there was a general trend of increasing geosmin concentrations in the upper portion of the reservoir, especially near Cooper River and Durham Canal (sites CWS-1 and CWS-2, respectively) during the September 2013, July 2014, and August 2014 sampling events. However, geosmin concentrations never exceeded 15 ng/L in this portion of the reservoir. Water-column samples collected during the spring period exhibited increased geosmin concentrations at two locations in the reservoir near the dam (sites CWS-7 and CWS-5 [intake]), and unlike MIB, concentrations in Foster Creek (site CWS-6) were lower than in the reservoir, indicating a high probability of in situ production of geosmin in the reservoir by cyanobacteria.

During the study period, a constant production of MIB near the dam and geosmin in the middle and upper portions of the reservoir seemed to occur during the summer and early fall, but concentrations were relatively low, between 10 and 15 ng/L. At site CWS-5, the dominant T&O compound tended to be MIB at a 2- or 3-to-1 ratio with geosmin during the summer and fall. However, during springtime episodes in which T&O concentrations were elevated above the CWS treatment threshold, the spatial distribution of geosmin concentrations greater than 15 ng/L (28 to 38 ng/L) seems to be best explained by in situ production in the lower portion of the Bushy Park Reservoir near the dam rather than transport from Foster Creek or Durham Canal. This pattern seems to indicate a possible shift in phytoplankton communities, (or, at least, cyanobacteria communities) from MIB producers to geosmin producers. Therefore, identification of spatial and seasonal variation in water quality and phytoplankton community was evaluated to explain this shift in T&O occurrence.

Characterization of Water-Quality Conditions in Bushy Park Reservoir

Statistical summaries of field measurements (table 6), major ion, trace metal, and organic carbon concentrations (table 7), and nutrient, chlorophyll *a*, actinomycetes, and T&O concentrations (table 8) were produced in tabular format. Discrete water-quality data from each sampling event are provided in appendix 5. Chemical data are stored in the USGS National Water Information System and are publicly available through the NWISWeb database (U.S. Geological Survey, 2016). Water-quality profile and AUV-derived data were compiled in tabular and graphical formats (appendixes 2, 3) (Conrads and others, 2017a).

Depth profiles and AUV surveys of water temperature, pH, dissolved oxygen, and specific conductance were assessed to determine the degree and extent of thermal stratification during the study period (appendixes 2, 3). Additionally, the profile and survey data were used to identify areas within the reservoir where greater phytoplankton and cyanobacteria densities were most likely occurring. Bushy Park Reservoir tended to stratify thermally at a depth of about 20 ft from June to early October. The stratification was limited to the deeper portions of the reservoir near the dam and often dissipated within the reservoir near site CWS-5 (appendix 2, August 26, 2014, longitudinal survey, water temperature). Where thermally stratified, a corresponding depletion of dissolved oxygen also occurred at about the same depth and resulted in an anoxic hypolimnion below the 25-ft depth (appendix 2, August 26, 2014, longitudinal survey, dissolved oxygen) as well as an increase in specific conductance, likely due to remobilized metals and phosphorus under reducing conditions (appendix 2, August 26, 2014, longitudinal survey, specific conductance). In general, chlorophyll *a* exhibited some spatial variation, but no strong consistent pattern or “hot spot” was observed. Phycocyanin, estimated as BGA cell density, seemed to be greater in the upper portion of the reservoir, but those differences may be attributed to increased turbidity and potential change in phytoplankton community structure that may affect fluorescence. In cross section, at sites CWS-5 and CWS-4 for example, changes in phycocyanin levels were observed at about the 10-ft depth.

During the study period , field measurements of pH were consistently within the SCDHEC criterion range of 6 to 9 for freshwaters, with median pH ranging from 6.6 to 7.3 (table 6; South Carolina Department of Health and Environmental Control, 2014c). Greater transparency of the water column is beneficial to phytoplankton productivity because it allows for deeper penetration of photosynthetically available light to phytoplankton communities. Median transparencies (measured in the field as Secchi disk depths) ranged from 1.4 to 1.5 m at the seven sites. Related to transparency, the amount of particles in the water column that scatter light is measured in the field as turbidity. Turbidity at the time of sampling was below the SCDHEC criterion level of 25 nephelometric turbidity units (NTU) for freshwaters, and median turbidity measurements ranged from 1.3 to 5.0 formazin nephelometric units (FNU). Comparatively, the amount of suspended sediment in the water column was low at all sites, with median suspended-sediment concentrations ranging from 2 to 6 mg/L (table 7).

Dissolved ammonia nitrogen and dissolved nitrate plus nitrite species are the readily bioavailable forms of nitrogen for phytoplankton, especially for the noncyanobacteria groups (Wetzel, 2001). During the study period at all sites sampled in Bushy Park Reservoir, dissolved ammonia concentrations generally were above the LRL of 0.01 mg/L (35 percent censored at LRL), and median concentrations ranged from <0.010 to 0.016 mg/L (table 8). At all sites sampled, dissolved nitrate plus nitrite concentrations rarely were above the LRL of 0.04 mg/L (87.5 percent censored at LRL), and detectable concentrations typically were reported at only 1 of 5 sampling events at each site. Detectable dissolved nitrate plus nitrite concentrations at sites CWS-1 (0.05 mg/L), CWS-4S (0.05 mg/L), and CWS-5S (0.11 mg/L) were measured in December 2014 and at sites CWS-3 (0.29 mg/L), CWS-6 (0.08 mg/L), and CWS-7 (0.06 mg/L) in April 2014

Table 6. Statistical summary of the field measurements made during discrete water-column sampling at selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[n, number of samples; 25%, 25th percentile; 75%, 75th percentile; cm-1, per centimeter; mg/L, milligram per liter; %, percent; °C, degrees Celsius; m, meter; µmol/s-m², micromoles of photons per second per square meter; FNU, formazin nephelometric units]

Site	Ultraviolet absorbance at 254 nanometers (cm-1)				Dissolved oxygen (mg/L)				Dissolved oxygen (% saturation)			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	0.096	0.094	0.106	4	7.7	6.2	9.9	4	87.8	79.6	93.4
CWS-2	5	0.115	0.102	0.129	5	6.5	6.3	9.4	5	80.6	80.0	90.7
CWS-3	6	0.126	0.101	0.151	6	7.6	5.8	9.1	6	85.9	73.6	90.4
CWS-4	9	0.138	0.127	0.160	9	5.9	5.6	8.4	9	73.1	71.9	80.9
CWS-5	11	0.220	0.200	0.242	12	5.6	5.1	7.6	12	67.5	60.1	73.6
CWS-6	6	0.334	0.320	0.361	6	3.0	1.8	6.1	6	32.5	23.0	58.6
CWS-7	6	0.243	0.216	0.274	6	5.7	4.4	7.4	6	59.2	50.5	88.8

Site	pH (standard units)				Specific conductance (microsiemens per centimeter at 25 °C)				Water temperature (°C)			
	n	Median	25%	75%		Median	25%	75%	n	Median	25%	75%
CWS-1	4	7.2	7.1	7.4	4	128	103	157	4	22.9	12.8	28.6
CWS-2	5	7.2	7.1	7.3	5	106	103	122	5	26.0	14.2	28.4
CWS-3	6	7.3	7.0	7.4	6	108	103	113	6	22.0	15.6	28.0
CWS-4	9	6.8	6.7	6.9	9	113	112	120	9	26.4	14.2	28.2
CWS-5	11	6.8	6.6	6.9	12	119	116	124	12	23.9	16.9	28.3
CWS-6	6	6.6	6.5	7.0	6	132	128	140	6	23.9	15.0	28.2
CWS-7	6	6.8	6.6	7.3	6	122	118	126	6	23.4	15.7	28.7

Site	Transparency as secchi disk depth (m)				Photosynthetically active radiation (µmol/s-m²)				Turbidity (FNU)			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	2	1.4	1.3	1.5	1	1,200	1,200	1,200	4	5.0	3.2	7.4
CWS-2	2	1.4	1.0	1.7	4	978	269	1,813	5	3.2	3.1	6.9
CWS-3	5	1.5	1.1	1.7	5	1,875	1,133	2,050	5	3.4	3.0	6.7
CWS-4	7	1.5	1.4	3.2	7	1,120	694	1,770	9	2.9	1.9	5.7
CWS-5	9	1.5	1.3	2.3	8	1,090	491	1,748	11	2.5	1.8	4.6
CWS-6	6	1.4	1.3	2.7	6	1,346	594	1,943	5	1.3	0.8	5.3
CWS-7	5	1.4	1.2	2.3	5	1,008	640	1,335	5	2.9	1.5	5.0

(T&O response survey trip). The maximum concentration was measured at site CWS-3, April 16, 2014 (appendix 5). Dissolved forms of phosphorus, including orthophosphate, also are readily bioavailable forms of phosphorus for phytoplankton, especially for the noncyanobacteria groups (Wetzel, 2001). Dissolved orthophosphate and total phosphorus concentrations frequently were above the LRL of 0.004 mg/L (only 17 and 10 percent censored below LRL, respectively) (appendix 5). During the study period at all sites sampled in Bushy Park Reservoir, median dissolved orthophosphate concentrations ranged from <0.004 to 0.033 mg/L.

Unlike dissolved concentrations, total concentrations (which include dissolved and particulate forms and inorganic and organic forms) of nitrogen and phosphorus are used to assess the trophic state of a reservoir (Carlson, 1977; Wetzel, 2001), and numeric criteria have been established for lakes and reservoirs in South Carolina for the Middle Atlantic Coastal Plain ecoregion of the State where Bushy Park Reservoir is located (South Carolina Department of Health and Environmental Control, 2014c). The SCDHEC criterion for total nitrogen concentrations is 1.50 mg/L. At all sites sampled, total nitrogen concentrations did not exceed

Table 7. Statistical summary of major ion, trace metal, and organic carbon concentrations in discrete water-column samples collected at selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[n, number of samples; 25%, 25th percentile; 75%, 75th percentile; mg/L, milligram per liter; µg/L, microgram per liter]

Site	Hardness (mg/L)				Calcium (mg/L)				Magnesium (mg/L)			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	22.1	19.8	27.5	4	4.8	3.9	5.7	4	2.5	2.4	3.2
CWS-2	5	24.1	20.6	24.9	5	5.1	4.2	5.9	5	2.4	2.4	2.6
CWS-3	6	24.4	21.0	26.0	6	5.5	5.0	6.3	6	2.4	2.3	2.6
CWS-4	9	25.8	24.2	27.3	9	6.2	5.3	6.7	9	2.5	2.5	2.8
CWS-5	12	27.6	27.1	28.2	12	7.0	6.8	7.5	12	2.5	2.3	2.6
CWS-6	6	33.9	30.9	38.1	6	10.0	8.6	11.4	6	2.2	2.1	2.5
CWS-7	6	29.0	26.1	29.9	6	7.5	6.4	8.4	6	2.4	2.2	2.5
Site	**Potassium (mg/L)**				**Sodium (mg/L)**				**Silica (mg/L)**			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	2.7	2.4	2.7	4	10.7	8.9	15.8	4	8.6	8.3	8.7
CWS-2	5	2.6	2.4	2.7	5	10.9	9.4	11.2	5	8.4	8.3	8.7
CWS-3	6	2.6	2.2	2.9	6	10.4	8.4	11.8	6	8.2	7.5	8.9
CWS-4	9	2.6	2.4	3.2	9	11.9	10.2	12.3	9	8.4	7.8	8.7
CWS-5	12	2.4	2.0	3.3	12	11.5	10.1	12.0	12	8.0	7.7	8.7
CWS-6	6	2.3	1.6	3.0	6	11.1	10.6	11.3	6	7.8	5.8	8.4
CWS-7	6	2.4	2.1	2.9	6	10.8	10.1	11.6	6	8.1	6.3	8.5
Site	**Sulfate (mg/L)**				**Chloride (mg/L)**				**Iron (µg/L)**			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	9.6	8.2	10.2	4	10.0	9.9	20.5	4	22.7	12.7	26.3
CWS-2	5	8.5	7.2	9.5	5	10.5	10.1	12.7	5	46.2	32.0	46.4
CWS-3	6	8.1	7.5	8.9	6	11.7	9.8	14.0	6	59.5	37.7	199.7
CWS-4	9	8.2	7.2	9.2	9	13.1	12.3	14.6	9	88.7	32.2	179.2
CWS-5	12	7.0	6.5	8.1	12	12.6	11.3	15.1	12	97.9	70.6	180.8
CWS-6	6	5.3	4.4	7.6	6	13.3	12.5	14.4	6	181.9	161.3	252.2
CWS-7	6	6.7	6.0	8.3	6	12.4	10.7	15.1	6	101.6	66.1	159.3
Site	**Manganese (µg/L)**				**Suspended sediment (mg/L)**				**Total organic carbon (mg/L)**			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	3.3	1.4	4.3	4	5	3	7	4	4.6	3.9	5.1
CWS-2	5	4.1	2.5	14.5	5	4	3	8	5	4.9	4.3	5.6
CWS-3	6	15.4	5.0	17.4	6	6	2.5	19.5	6	5.0	4.4	6.4
CWS-4	9	14.1	12.0	23.4	9	3	2	4.75	9	5.4	5.0	5.7
CWS-5	12	10.9	2.4	20.7	12	3	2	3.25	12	7.3	6.2	7.5
CWS-6	6	15.4	13.8	18.4	6	2	2	3	6	9.2	8.6	10.7
CWS-7	6	4.3	2.7	17.9	6	2	1	4	6	8.1	6.6	8.6

Table 8. Statistical summary of the nutrient, chlorophyll *a*, actinomycetes, and taste-and-odor concentrations in discrete water-column samples collected at selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[n, number of samples; 25%, 25th percentile; 75%, 75th percentile; mg/L, milligram per liter; N, nitrogen; P, phosphorus; µg/L, microgram per liter; ng/L, nanogram per liter; col/100 mL, colonies per 100 milliliters; <, less than]

Site	Chlorophyll *a* (µg/L)				Ammonia (mg/L)				Nitrate plus nitrite (mg/L as N)			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	7.2	5.1	8.1	4	< 0.010	< 0.010	0.019	4	< 0.04	< 0.04	0.044
CWS-2	5	6.4	5.9	9.9	5	0.011	< 0.010	0.014	5	< 0.04	< 0.04	0.060
CWS-3	6	6.8	4.1	8.5	6	0.013	< 0.010	0.026	6	< 0.04	< 0.04	0.087
CWS-4	7	7.1	5.6	8.8	9	0.012	< 0.010	0.019	9	< 0.04	< 0.04	< 0.04
CWS-5	10	9.9	8.9	13.5	12	0.014	< 0.010	0.033	12	< 0.04	< 0.04	< 0.04
CWS-6	6	11.2	8.4	14.9	6	0.016	< 0.010	0.023	6	< 0.04	< 0.04	< 0.04
CWS-7	5	10.2	7.1	11.3	6	< 0.010	< 0.010	0.053	6	< 0.04	< 0.04	< 0.04

Site	Total organic nitrogen (mg/L as N)				Dissolved organic nitrogen (mg/L as N)				Total nitrogen (mg/L as N)			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	0.18	0.16	0.26	4	0.12	0.11	0.20	4	0.35	0.32	0.38
CWS-2	5	0.16	0.15	0.18	5	0.12	0.12	0.16	5	0.33	0.31	0.38
CWS-3	6	0.17	0.16	0.27	6	0.15	0.12	0.21	6	0.36	0.32	0.51
CWS-4	9	0.17	0.16	0.20	9	0.13	0.12	0.17	9	0.35	0.34	0.40
CWS-5	12	0.21	0.19	0.23	12	0.15	0.14	0.19	12	0.43	0.39	0.48
CWS-6	6	0.23	0.21	0.25	6	0.18	0.18	0.20	6	0.47	0.44	0.54
CWS-7	6	0.20	0.20	0.22	6	0.15	0.14	0.18	6	0.46	0.40	0.47

Site	Orthophosphate (mg/L as P)				Total phosphorus (mg/L as P)				2-methylisoborneol (ng/L)			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	< 0.004	< 0.004	0.005	4	0.030	0.014	0.034	4	2.5	1.3	7.0
CWS-2	5	0.004	< 0.004	0.006	5	0.025	0.016	0.028	5	3.3	1.9	9.5
CWS-3	6	0.004	0.004	0.006	6	0.026	0.025	0.039	6	2.3	1.8	7.8
CWS-4	9	0.006	0.005	0.007	9	0.027	0.024	0.037	9	6.6	1.0	9.4
CWS-5	12	0.011	0.006	0.014	12	0.041	0.040	0.046	12	9.4	3.7	11.8
CWS-6	6	0.033	0.027	0.041	6	0.065	0.044	0.074	6	7.3	1.0	14.5
CWS-7	6	0.010	0.007	0.015	6	0.041	0.034	0.047	6	9.6	3.3	11.3

Site	Geosmin (ng/L)				Actinomycetes (col/100 mL)				Biomass to chlorophyll *a* ratio (unitless)			
	n	Median	25%	75%	n	Median	25%	75%	n	Median	25%	75%
CWS-1	4	4.7	2.6	11.9	4	9	5	15	4	983	945	1,190
CWS-2	5	7.9	3.2	14.5	5	10	8	16	5	1,031	573	1,170
CWS-3	6	10.3	3.4	12.3	6	9	5	12	6	933	693	1,315
CWS-4	9	9.6	2.3	11.0	9	9	7	11	9	1,257	864	1,316
CWS-5	12	2.8	1.3	5.2	12	7	5	9	12	764	402	1,152
CWS-6	6	2.9	1.0	7.4	6	10	9	13	6	1,003	435	1,547
CWS-7	6	2.6	1.0	12.9	6	6	4	12	6	972	577	3,880

0.84 mg/L (this maximum concentration was measured at site CWS-3, April 16, 2014) and generally were near the study area-wide median of 0.40 mg/L and reservoir-wide (omit Foster Creek) median of 0.39 mg/L. Therefore, concentrations at sites located in Bushy Park Reservoir were well below the SCDHEC numeric total nitrogen criterion for lakes of 1.50 mg/L during the study period.

During the study period, total phosphorus concentrations at sites located in Bushy Park Reservoir were below the SCDHEC numeric total phosphorus criterion for lakes of 0.09 mg/L. Concentrations at sites within the reservoir generally were near the reservoir-wide median of 0.037 mg/L, and the maximum total phosphorus concentration was 0.067 mg/L. A maximum total phosphorus concentration of 0.095 mg/L, however, was measured at Foster Creek (site CWS-6), which is a tributary to the reservoir, on April 16, 2014.

Chlorophyll *a* is a pigment found in phytoplankton; therefore, chlorophyll *a* concentrations commonly are used to estimate the algal biomass present in a reservoir (Wetzel, 2001). Pheophytin *a* is the degraded form of the chlorophyll *a* pigment, resulting from the loss of a magnesium ion. Chlorophyll *a* concentrations are used to assess the trophic state of a reservoir (Carlson, 1977; Wetzel, 2001) and a numeric criterion of 40 µg/L has been established for lakes and reservoirs in the Middle Atlantic Coastal Plain ecoregion of South Carolina (South Carolina Department of Health and Environmental Control, 2014a). During the study period at all sites sampled in Bushy Park Reservoir, chlorophyll *a* concentrations did not exceed 20.9 µg/L (this maximum concentration was measured at site CWS-5, July 23, 2014), which is well below the SCDHEC chlorophyll *a* criterion level for reservoirs. However, chlorophyll *a* concentrations did fluctuate among sites and sample periods.

Spatial and Seasonal Changes in Water-Quality Conditions in Bushy Park Reservoir

Near-surface (about 3.3-ft depth) and deeper photic zone (about 10-ft depth, the location of the intake pipe) samples were collected at sites CWS-4 and CWS-5 periodically during the sampling events. A comparison between the mean concentrations of 3.3-ft and 10-ft depth samples indicated no difference in water chemistry at these sampling points. Nutrient, T&O, organic carbon, and chlorophyll *a* concentrations were statistically similar at the shallow and deep depth zones. Additionally, no differences were identified between phytoplankton biovolumes and cell densities with depth. Therefore, both deep and shallow samples were combined and included in the data analysis discussed in the section that follows (table 9).

Selected constituents were evaluated by using permutation one-factor tests to determine if spatial differences in water chemistry in Bushy Park Reservoir were present during the study period (table 10). Foster Creek (site CWS-6), one of the major tributaries to the lower portion of Bushy Park Reservoir near the dam, has classic "blackwater" (high humic content) stream water-quality characteristics. These characteristics include lower dissolved oxygen (DO) and higher total and dissolved organic carbon (TOC, DOC, respectively) and ultraviolet absorbance at 254 nanometers (UVA; an estimate of the humic content of the organic carbon) than the tributaries (Cooper River, site CWS-1; Durham Canal, site CWS-2) in the upper portion of the reservoir (table 10; fig. 13). This characteristic signature of high UVA and DOC can be observed at sites in the lower portion of the reservoir (CWS-7 and CWS-5), indicating dystrophic conditions for the reservoir in that region (table 10; fig. 13). The blackwater signature appears to dissipate in the water column near sites CWS-4 and CWS-3.

In general, Foster Creek (site CWS-6) had greater total phosphorus, dissolved orthophosphate, and total nitrogen concentrations and total hardness than sites on Cooper River (CWS-1) and Durham Canal (CWS-2) (table 10; figs. 14, 15). These signatures, however, are more indicative of the human development (residential and commercial) within the watershed rather than natural blackwater conditions. Dissolved iron concentrations were greater in the reservoir than in Cooper River and Durham Canal (sites CWS-1 and CWS-2, respectively; fig. 15). As was observed with the blackwater signature, nutrient levels at sites CWS-5 and CWS-7 also appeared to be influenced by contributions from Foster Creek (site CWS-6), whereby total phosphorus and total nitrogen concentrations in the lower portion of Bushy Park Reservoir generally were elevated relative to the upper portion of the reservoir (table 10; fig. 14). On the basis of chlorophyll *a* concentrations only, however, the elevated nutrient concentrations did not appear to influence algal productivity because no significant increase in chlorophyll *a* concentrations was identified in the lower portion of the reservoir (table 10; fig. 16). Additionally, no overall spatial differences in mean geosmin and MIB concentrations were identified among sites in the reservoir (table 10; fig. 16).

Statistically significant differences in water chemistry were identified among the three seasons during which samples were collected for the study (fall, spring, summer). A general springtime pattern of elevated geosmin concentrations occurred in Bushy Park Reservoir as observed by CWS monitoring of the raw blended water (table 11; fig. 17). In fact, geosmin concentrations had distinct differences among the seasons (spring > summer > fall). During the spring when geosmin concentrations were elevated, water chemistry of the reservoir also indicated higher levels of dissolved iron, dissolved nitrate plus nitrite, total nitrogen, and total phosphorus than during the fall and summer (table 11). Although geosmin concentrations were different among all three seasons, MIB concentrations were elevated similarly in the spring and summer seasons compared to concentrations in the fall. Correspondingly, chlorophyll *a* (estimate of total algal biomass) concentrations were higher during the spring and summer seasons compared to those in the fall. No seasonal differences were identified in actinomycetes, dissolved ammonia, dissolved orthophosphate, dissolved manganese, hardness, or total organic carbon concentrations or ultraviolet absorbance at 254 nanometers.

Table 9. Summary of the permutation one-factor test (t-test) and pairwise Wilcoxon multiple comparison tests (U) to identify differences in environmental conditions in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015, between shallow (1–3 feet) and deep (9–10 feet) samples.

[Depths that share the same letter are statistically similar, and sites that have different letters are statistically different, such that A > B > C, and so on. —, not determined]

Variable	T-test (t) or Wilcoxon rank sum (U)			Depth	
	Parametric	Nonparametric	p-value		
	t-statistic	U-statistic		Shallow	Deep
2-Methylisoborneol	–0.225	—	0.824	A	A
Geosmin	—	43.5	0.476	A	A
Actinomycetes	0.731	—	0.474	A	A
Ultraviolet absorbance at 254 nanometers	–0.925	—	0.367	A	A
Dissolved organic carbon	–0.268	—	0.791	A	A
Total organic carbon	–0.517	—	0.611	A	A
Total nitrogen	0.266	—	0.793	A	A
Total organic nitrogen	—	44	0.499	A	A
Dissolved organic nitrogen	–1.609	—	0.124	A	A
Dissolved ammonia	—	98.5	1.000	A	A
Dissolved nitrate plus nitrite	—	48	0.29	A	A
Dissolved orthophosphate	—	45.5	0.57	A	A
Total phosphorus	0.591	—	0.562	A	A
Dissolved iron	0.434	—	0.669	A	A
Dissolved manganese	—	48.5	0.722	A	A
Chlorophyll *a*	—	42	0.595	A	A
Total dissolved solids	0.698	—	0.498	A	A
Total hardness	—	39.5	0.319	A	A
Dissolved chloride	1.344	—	0.195	A	A
Dissolved oxygen	0.712	—	0.485	A	A
Dissolved oxygen as percent saturation	1.259	—	0.223	A	A
Cyanobacteria biovolumes	–0.102	—	0.92	A	A
Percent cyanobacteria of phytoplankton (biovolumes)	–0.189	—	0.853	A	A
Cyanobacteria cell density	—	27	0.953	A	A
Percent cyanobacteria of phytoplankton (cell density)	—	24	0.768	A	A
Phytoplankton biovolumes	—	21	0.517	A	A

Table 10. Summary of the permutation one-factor test and pairwise Wilcoxon multiple comparison tests to identify differences in environmental conditions in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015, among sites.

[Sites that share the same letter are statistically similar, and sites that have different letters are statistically different, such that A > B > C, and so on. n, number of samples; <, less than]

Variable	Permutation test (n = 5,000)		Pairwise Wilcoxon multiple comparison test						
	F-statistic	p-value	CWS-1	CWS-2	CWS-3	CWS-4	CWS-5	CWS-6	CWS-7
2-Methylisoborneol	1.19	0.328	A	A	A	A	A	A	A
Geosmin	0.29	0.94	A	A	A	A	A	A	A
Actinomycetes	0.77	0.594	A	A	A	A	A	A	A
Ultraviolet absorbance at 254 nanometers	75.23	< 0.001	D	D	CD	C	B	A	B
Dissolved organic carbon (DOC)	43.09	< 0.001	D	D	CD	C	B	A	B
Total organic carbon (TOC)	23.39	< 0.001	D	D	CD	C	B	A	B
DOC:TOC ratio	1.50	0.202	A	A	A	A	A	A	A
Total nitrogen	2.45	0.04	C	C	AB	BC	AB	A	AB
Total organic nitrogen	0.67	0.673	A	A	A	A	A	A	A
Dissolved organic nitrogen	1.41	0.234	A	A	A	A	A	A	A
Dissolved ammonia	0.64	0.699	A	A	A	A	A	A	A
Dissolved nitrate plus nitrite	0.68	0.667	A	A	A	A	A	A	A
Dissolved orthophosphate	27.75	< 0.001	B	B	B	B	B	A	B
Total phosphorus	8.70	< 0.001	C	C	BC	C	B	A	B
Dissolved iron	4.28	0.002	C	BC	B	AB	A	A	AB
Dissolved manganese	1.72	0.14	A	A	A	A	A	A	A
Chlorophyll *a*	0.58	0.745	A	A	A	A	A	A	A
Total dissolved solids	0.67	0.671	A	A	A	A	A	A	A
Total hardness	6.27	< 0.001	BC	D	C	C	B	A	BCD
Dissolved chloride	0.67	0.678	A	A	A	A	A	A	A
pH	2.08	0.077	A	A	A	A	A	A	A
Specific conductance	4.28	0.002	AB	AB	B	B	B	A	AB
Dissolved oxygen as percent saturation	7.44	< 0.001	A	A	A	AB	BC	C	ABC

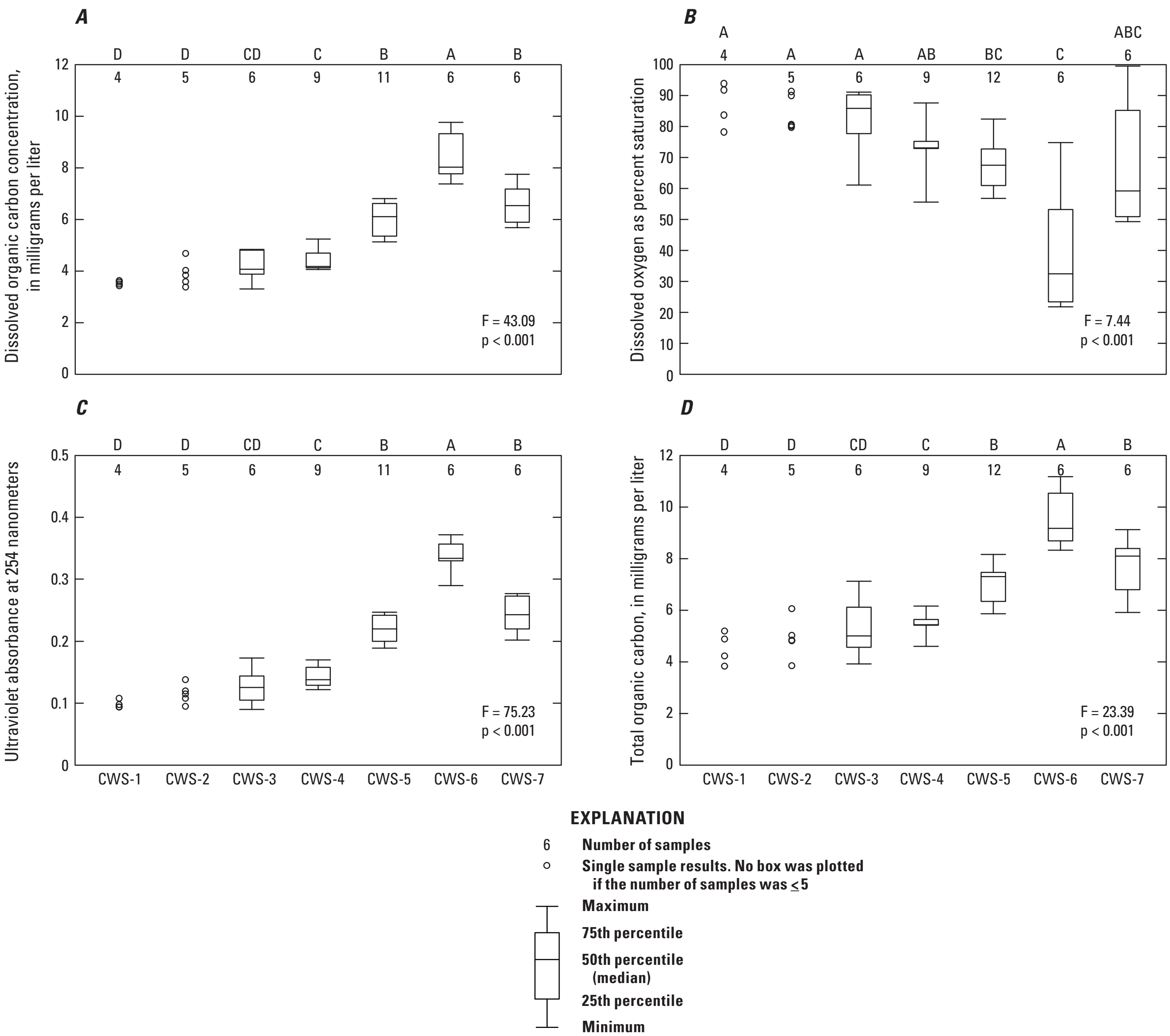

Figure 13. Boxplots of (*A*) dissolved organic carbon concentrations, (*B*) dissolved oxygen concentration as percent saturation, (*C*) ultraviolet absorbance at 254 nanometers, and (*D*) total organic carbon at seven locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015. F-statistic, probability value (p), and letters above each boxplot represent results of the permutation-based multiple comparison test whereby sites that share the same letters are statistically similar and sites that do not share the same letters are statistically different (A > B > C > D).

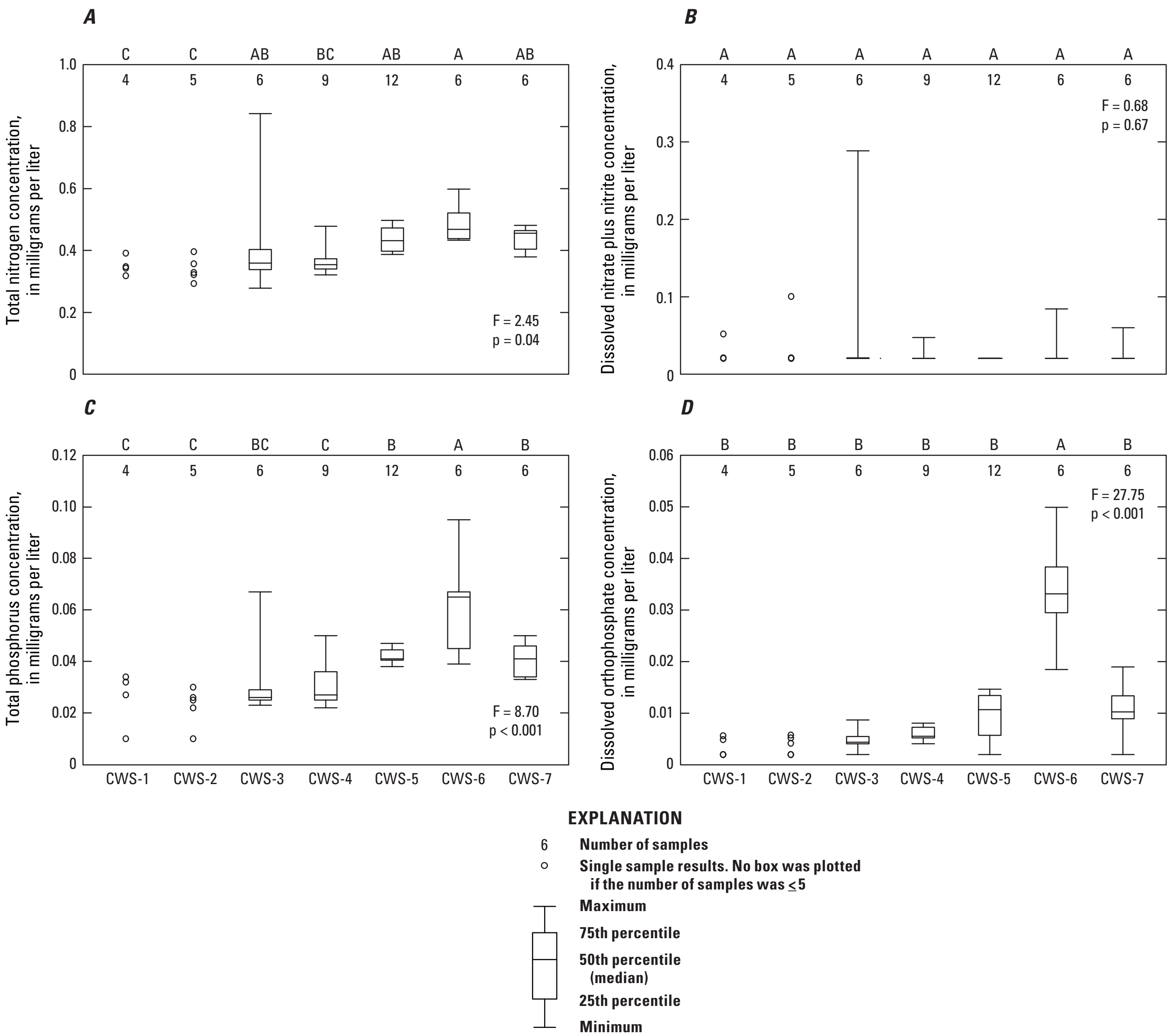

Figure 14. Boxplots of (*A*) total nitrogen, (*B*) dissolved nitrate plus nitrite, (*C*) total phosphorus, and (*D*) dissolved orthophosphate concentrations at seven locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015. F-statistic, probability value (p), and letters above each boxplot represent results of the permutation-based multiple comparison test whereby sites that share the same letters are statistically similar and sites that do not share the same letters are statistically different (A > B > C > D).

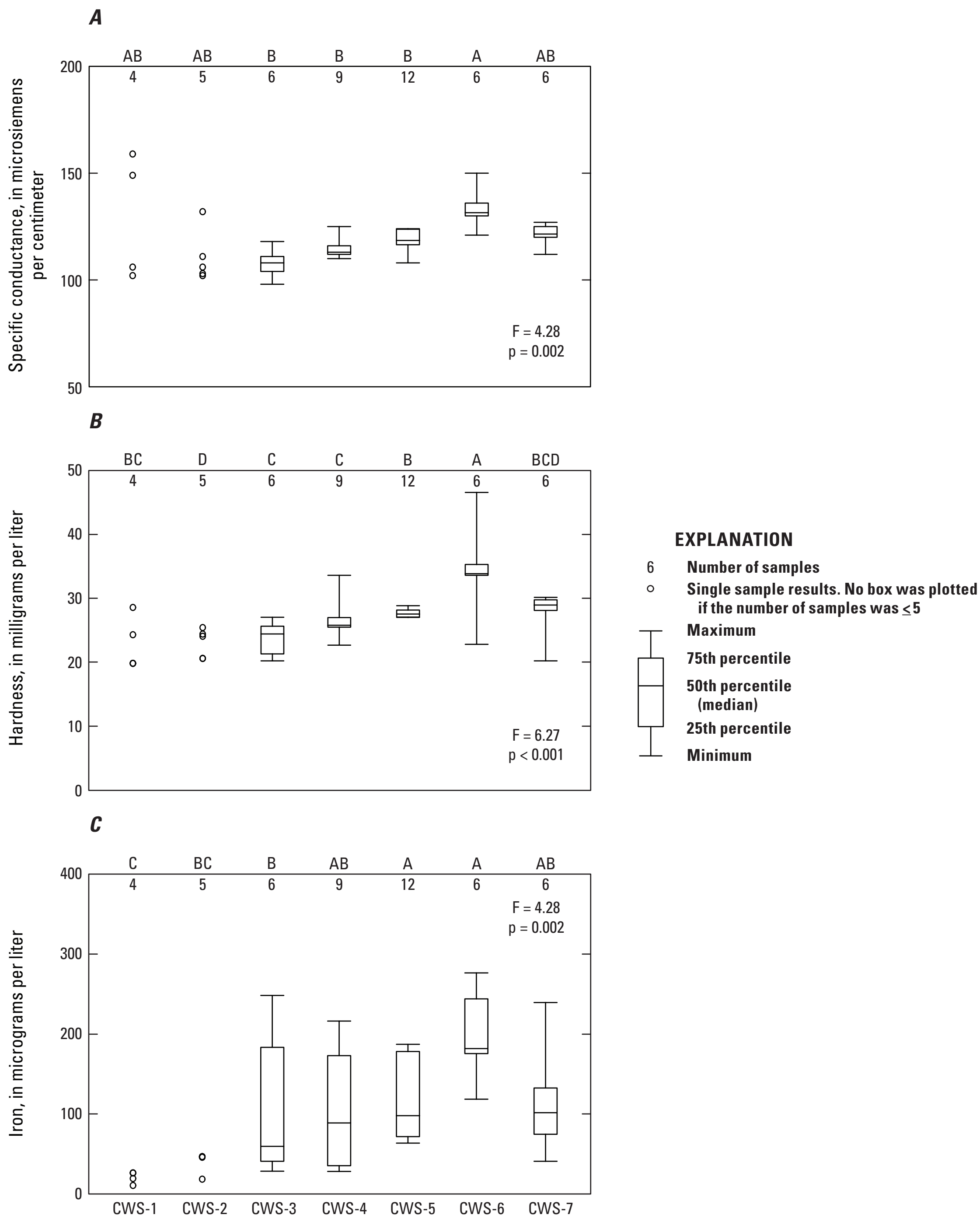

Figure 15. Boxplots of (*A*) specific conductance at 25 degrees Celsius, (*B*) total hardness concentration, and (*C*) dissolved iron concentration at seven locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015. F-statistic, probability value (p), and letters above each boxplot represent results of the permutation-based multiple comparison test whereby sites that share the same letters are statistically similar and sites that do not share the same letters are statistically different (A > B > C > D).

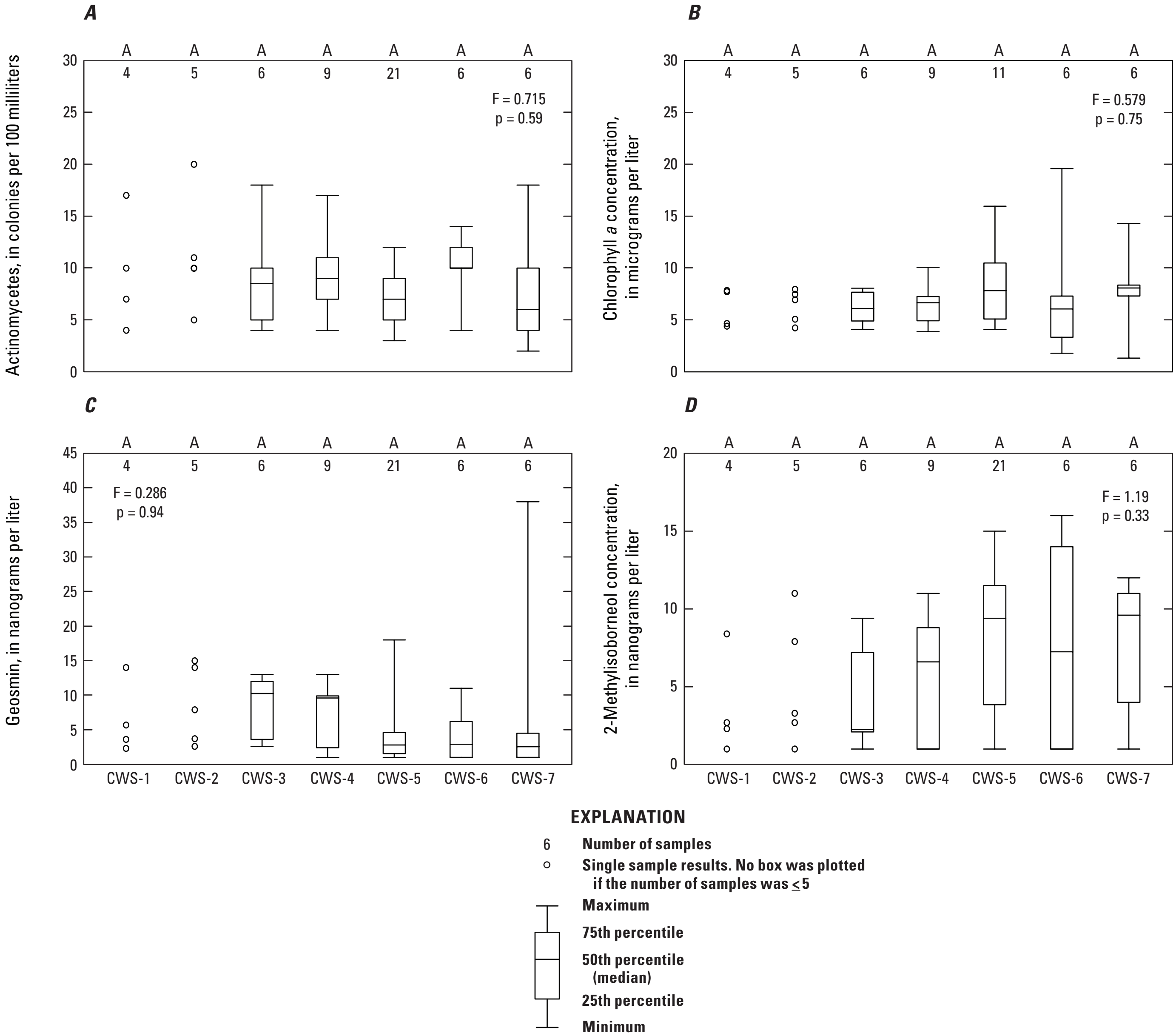

Figure 16. Boxplots of (*A*) actinomycetes, (*B*) chlorophyll *a*, (*C*) geosmin, and (*D*) 2-methylisoborneol (MIB) concentrations at seven locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015. F-statistic, probability value (p), and letters above each boxplot represent results of the permutation-based multiple comparison test whereby sites that share the same letters are statistically similar and sites that do not share the same letters are statistically different (A > B > C > D).

Table 11. Summary of the permutation one-factor test and pairwise Wilcoxon multiple comparison tests to identify differences in environmental conditions in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015, among seasons.

[Seasons that share the same letter are statistically similar, and sites that have different letters are statistically different, such that A > B > C, and so forth. n, number of samples; <, less than]

Variable	Permutation test (n = 5,000)		Pairwise Wilcoxon multiple comparison test		
	F-statistic	p-value	Spring	Summer	Fall
2-Methylisoborneol	8.48	< 0.001	A	A	B
Geosmin	21.847	< 0.001	A	B	C
Actinomycetes	0.583	0.562	A	A	A
Ultraviolet absorbance at 254 nanometers	2.249	0.117	A	A	A
Dissolved organic carbon (DOC)	3.846	0.029	A	B	AB
Total organic carbon (TOC)	2.646	0.082	A	A	A
DOC:TOC ratio	13.67	< 0.001	A	B	A
Total nitrogen	14.24	< 0.001	A	B	B
Total organic nitrogen	6.278	0.004	A	B	B
Dissolved organic nitrogen	3.205	0.05	A	A	A
Dissolved ammonia	2.999	0.06	A	A	A
Dissolved nitrate plus nitrite	7.84	0.001	A	B	B
Dissolved orthophosphate	0.207	0.814	A	A	A
Total phosphorus	4.337	0.019	A	B	B
Dissolved iron	3.426	0.041	A	B	B
Dissolved manganese	0.155	0.857	A	A	A
Chlorophyll *a*	18.32	< 0.001	A	A	B
Total dissolved solids	0.669	0.517	A	A	A
Total hardness	3.114	0.054	A	A	A
Dissolved chloride	1.599	0.213	A	A	A
pH	19.92	< 0.001	A	B	B
Specific conductance	0.894	0.416	A	A	A
Dissolved oxygen as percent saturation	2.854	0.068	A	A	A

In summary, the spatial and seasonal assessment of water-quality conditions in Bushy Park Reservoir identified differences in water chemistry between the upper and lower portions of the reservoir that correspond to the season and location of elevated geosmin concentrations. The assessment determined that higher levels of dissolved iron, dissolved nitrate plus nitrite, total nitrogen, and total phosphorus were present in the reservoir during the spring compared to levels during the fall and summer. With the exception of dissolved nitrate plus nitrite concentrations, these constituents also were elevated in concentration in the lower portion of the reservoir, where geosmin was determined to reach concentrations above the CWS treatment threshold. On the basis of the spatial and seasonal assessment of actinomycetes concentrations compared to T&O concentrations, there appears to be a greater likelihood of cyanobacteria production as the dominant source of the T&O episodes rather than actinomycetes. The absence of spatial and seasonal patterns in actinomycetes concentrations does not correspond to the springtime geosmin concentrations that were elevated above the CWS threshold in the lower portion of the reservoir. Additionally, actinomycetes concentrations, although ubiquitous, had a median of about 9 and maximum of about 20 colonies per milliliter, which could be considered low for elevated T&O production. Nonetheless, the potential exists for actinomycetes to be a secondary source of T&O production and could explain some of the ubiquitous occurrence of low-level T&O concentrations observed throughout the summer and early fall months.

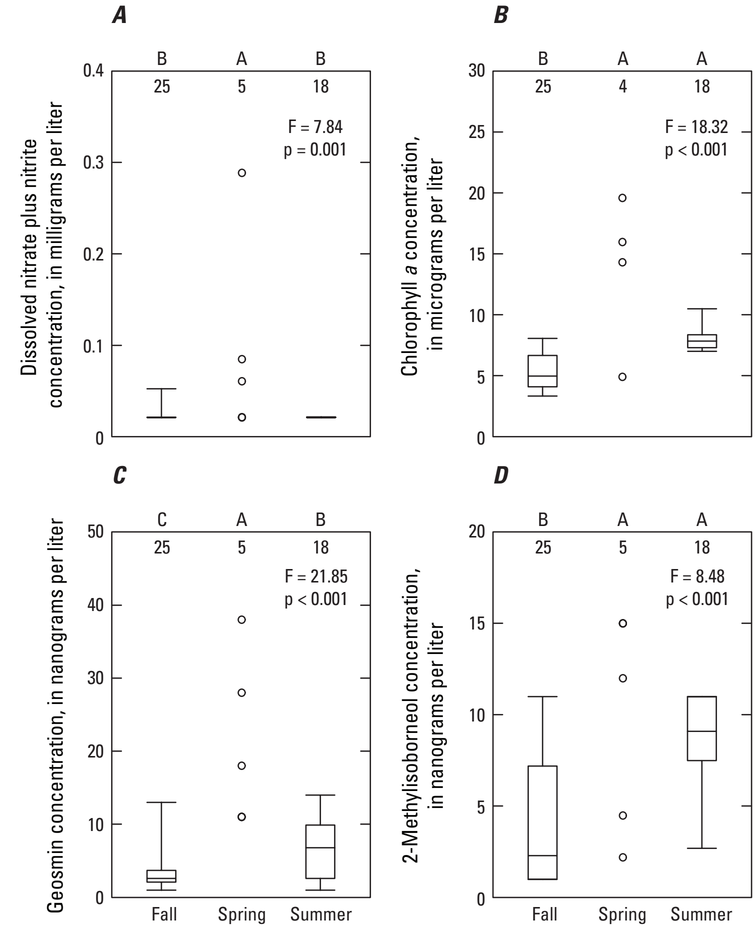

Figure 17. Boxplots of (*A*) dissolved nitrate plus nitrite, (*B*) chlorophyll *a*, (*C*) geosmin, and (*D*) 2-methylisoborneol (MIB) concentrations at all seven locations by season in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

Spatial and Seasonal Variation in Phytoplankton Community Structure in Bushy Park Reservoir

The phytoplankton taxonomic data were summarized by major group (table 12, p. 56). The cell density of phytoplankton was quantified by microscopic cell counts found in 1 milliliter of sample (cells per milliliter). Biovolumes also were computed by using the cell density and the cell volume of the phytoplankton cell, the morphology of which varied by species and species variants. Explicitly, two species of phytoplankton that have different morphologies but the same cell density can have orders of magnitude different biovolumes. The cell density was used as an estimate of the abundance of a species while biovolume was used as an estimate of the biomass present.

In Bushy Park Reservoir, total phytoplankton biovolumes ranged from 748,223 (site CWS-2, July 2014) to 41,701,849 (site CWS-7, November 2014) cubic micrometers per milliliter (table 12). The percentage of the total phytoplankton biovolume that was represented by the cyanobacteria major group ranged from less than 1 to 32.5 percent; therefore, cyanobacteria did not dominate the phytoplankton in relation to overall biomass. Diatom and green algae major groups tended to dominate total phytoplankton biovolume in Bushy Park Reservoir with the exception of the yellow-green algae group during the July, August, and November 2014 sampling periods in the lower portion of the reservoir. These extremely high biovolumes were due to the presence of large-celled *Gonyostomum semen* that tends to be found in acidic waters and prefers a pH range of 4.4 to 6.6 and a water temperature range of 11 to 29 °C.

During the sampling period, total phytoplankton cell densities ranged from 1,810 (site CWS-3, April 2014) to 74,544 (site CWS-2, September 2013) cells per milliliter (cells/mL) (table 12). For recreational waters, the World Health Organization (WHO) has established recommended harmful algal bloom response guidelines that stipulate a range of cyanobacteria cell densities and chlorophyll *a* concentrations that indicate the relative probability of acute health effects attributed to the likely presence of cyanotoxins (Chorus and Bartram, 1999). The application of those guidelines to the cyanobacteria cell densities and chlorophyll *a* concentrations observed in Bushy Park Reservoir would place the reservoir in the moderate probability of acute health effects. The percentage of the total phytoplankton cell density represented by the cyanobacteria major group ranged from 13 to 95.5 percent, and at most sites, cyanobacteria seasonally dominated the phytoplankton in relation to abundance of cells. On the basis of cell density, green algae and diatoms were the other predominate groups in the phytoplankton community structure when cyanobacteria were not dominating.

Phytoplankton biovolumes and cell densities were compared by using permutation tests among sites and among seasons to identify differences, if present. No differences among sites were identified during the study period (table 13). These results were similar to the comparison of chlorophyll *a* concentrations among sites in which no differences were identified (table 10) probably because total phytoplankton biovolumes and chlorophyll *a* concentrations represent similar bulk measures of the overall phytoplankton community. When these bulk measures of phytoplankton community were compared among seasons, no differences in biovolumes were indicated (table 13); however, cell densities of total phytoplankton, cyanobacteria, percentage of cyanobacteria in total phytoplankton, and number of total cyanobacteria species all were found to be greatest in the fall, intermediate in the summer, and least in the spring.

On the basis of biovolume, cyanobacteria were not the dominant phytoplankton group in Bushy Park Reservoir during the study period. “Bloom” forming levels of *G. semen* were identified in the reservoir during the summer months;

Table 13. Summary of the permutation one-factor test and pairwise Wilcoxon multiple comparison tests to identify differences in phytoplankton and cyanobacteria biovolume and cell density in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015, among sites and seasons.

[Sites or seasons that share the same letter are statistically similar, and sites that have different letters are statistically different, such that A > B > C, and so on. n, number of samples; <, less than]

Variable	Permutation test (n = 5,000)		Pairwise Wilcoxon multiple comparison test						
	F -statistic	p-value	CWS-1	CWS-2	CWS-3	CWS-4	CWS-5	CWS-6	CWS-7
Total phytoplankton biovolume	1.69	0.157	A	A	A	A	A	A	A
Total cyanobacteria biovolume	0.267	0.948	A	A	A	A	A	A	A
Percent cyanobacteria in total phytoplankton biovolume	1.61	0.175	A	A	A	A	A	A	A
Total phytoplankton cell density	1.55	0.195	A	A	A	A	A	A	A
Total cyanobacteria cell density	1.62	0.175	A	A	A	A	A	A	A
Percent cyanobacteria in total phytoplankton cell density	1.92	0.110	A	A	A	A	A	A	A
Number of total cyanobacteria species	1.01	0.439	A	A	A	A	A	A	A

Variable	Permutation test (n = 5,000)		Pairwise Wilcoxon multiple comparison test		
	F -statistic	p-value	Spring	Summer	Fall
Total phytoplankton biovolume	0.333	0.719	A	A	A
Total cyanobacteria biovolume	0.116	0.891	A	A	A
Percent cyanobacteria in total phytoplankton biovolume	0.713	0.497	A	A	A
Total phytoplankton cell density	8.79	< 0.001	C	B	A
Total cyanobacteria cell density	9.57	< 0.001	C	B	A
Percent cyanobacteria in total phytoplankton cell density	17.136	< 0.001	C	B	A
Number of total cyanobacteria species	34.62	< 0.001	C	B	A

however, the genus *Gonyostomum* was present in historic algal taxonomic data for the reservoir (Andy Fairey, Charleston Water System, written commun., June 1999 and March 2000). *Dolichospermum planctonicum* was the dominant genera of the cyanobacteria group during spring periods. Geosmin-producing genera that were identified in the 2014 and 2015 spring community were not observed in the 1999 and 2000 algal taxonomic data (Andy Fairey, Charleston Water System, written commun., June 1999 and March 2000).

Potential toxin-producing species within the cyanobacteria group were present in the summer of 2014, including *Cylindrospermopsis raciborskii* (less than 2,000 cells/mL) and *Microcystis* sp. (less than 1,000 cells/mL). The phytoplankton community, including the cyanobacteria group, had a greater number of cells during the fall and least during the spring when geosmin episodes tended to occur. On the basis of the cyanobacteria cell densities and chlorophyll *a* concentrations observed in Bushy Park Reservoir, the WHO recreational guidelines indicate a moderate probability of acute health effects attributed to cyanotoxins. Nonetheless, these bulk measures of phytoplankton community were not able to effectively determine if distinct differences in community structure could explain the springtime geosmin episodes. Therefore, a more robust examination of phytoplankton species was conducted by using multivariate analysis.

Results of the cluster analysis on the potential T&O-producing species of cyanobacteria were provided in a heat map plot (fig. 18). The heat map is a graphical representation of cyanobacteria data that uses color to indicate the species abundance of the genera. Light blue colors indicate low abundance, shading to darker blue for intermediate abundance, and dark red and black colors for high abundance; no color indicates absence of that species. Six statistically different cluster groups were identified. From left to right, the first group was composed of samples collected in April 2014 and 2015 for all sites. In this group, fewer genera were present, but

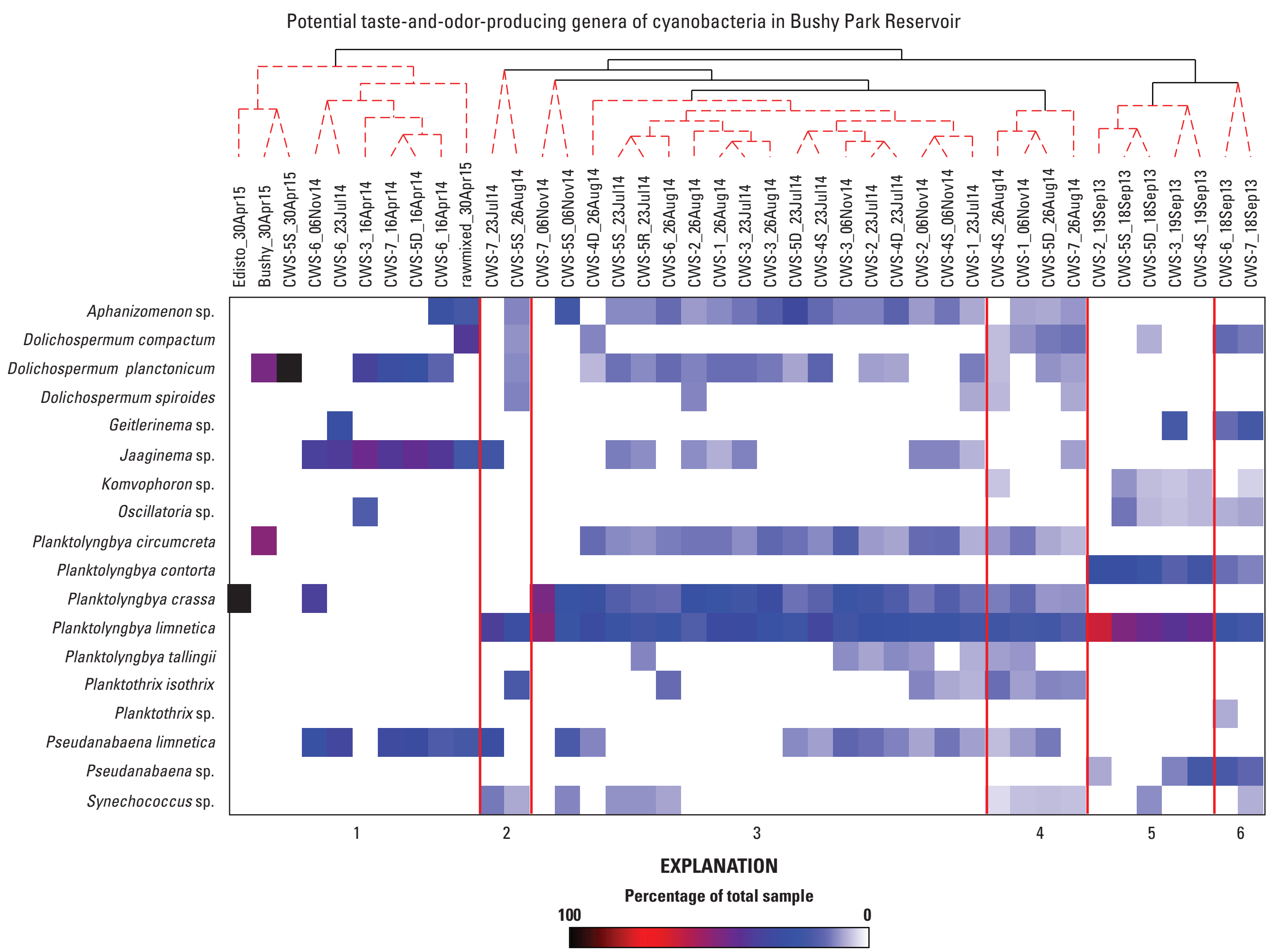

Figure 18. Heat map of standardized cyanobacteria cell densities, reported as percentage of total sample, for potential taste-and-odor (T&O)-producing genera in Bushy Park Reservoir, reordered by results of the hierarchical cluster analysis similarity profile results. Samples within the cluster dendogram of red dashed lines grouped by solid black lines are statistically similar, and samples grouped by different solid black lines are statistically different. Vertical red lines mark cluster groups 1–6.

at relatively higher abundance than other groups (*D. planctonica, Jaaginema* sp., and *Pseudanabaena limnetica* were most abundant). The next group contained only two samples (site CWS-7 in July 2014 and site CWS-5 at 3.3-ft depth in August 2014) where *Planktolyngbya limnetica* was the most abundant species. The next two groups represent samples collected in July, August, and November 2014 at a variety of locations that had many more species and the most abundant species from the *Planktolyngbya* genera. The last two groups represent samples collected and analyzed in September 2013 by a different contract laboratory and taxonomist. Nonetheless, within the September 2013 samples, differences in cyanobacteria species were present between sites CWS-6 and CWS-7 and sites located in the upper and middle portions of the reservoir. In summary, there appeared to be seasonal and locational changes in the cyanobacteria community that warranted further analysis.

The multivariate analysis, conducted by using analysis of similarity (ANOSIM), identified statistically different phytoplankton communities among sites (global R=0.207, p-value=0.014; table 14; fig. 18); however, these differences appear to be mainly attributed to location in the reservoir. Sites near the lower and middle portion of the reservoir had statistically different phytoplankton communities than those in the upper portion of the reservoir (global R=0.385, p=0.001). But the greatest difference in phytoplankton community structure was among the seasons, whereby summer communities were different from spring communities, which were, in turn, different from fall communities (global R=0.495, p=0.001) (fig. 19). No difference between communities at shallow (3.3-ft) depths and deeper (10-ft) depths was identified. These community patterns among sites, location, and seasons were similar to patterns in environmental conditions identified previously; therefore, the next test was to determine if the environmental pattern was statistically related to the phytoplankton community pattern.

The RELATE statistical program that correlates similarity matrices for phytoplankton and for environmental variables was applied to the dataset. The routine determined that the environmental variables were correlated to the phytoplankton community. Because a significant relation was identified, the BEST statistical program was used to determine which environmental variables best explained the changes in phytoplankton community, and those best variables included ultraviolet absorbance at 254 nanometers, field pH, potassium, silica, and total nitrogen (and water temperature during the September 2013 sampling event). The algal taxonomy for the September 2013 sampling event was conducted by a different contract laboratory, and inherent differences in the taxonomic evaluation did not allow the September algal data to be combined with the other data and thus were analyzed separately. Therefore, during this study, seasonal changes in the phytoplankton community structure appear to be explained by seasonal changes in water chemistry and may be responsible for episodes of T&O occurrence, especially geosmin.

Table 14. Summary of the multivariate statistical tests on phytoplankton community data as biovolumes in Bushy Park Reservoir, near Goose Creek, South Carolina, 2013 to 2014.

[≠, not equal to; =, equal to; UVA, ultraviolet absorbance; nm, nanometer]

Analysis of similarity (ANOSIM) in phytoplankton community structure (biovolume)	Global R	p-value	Comments
Among sites	0.207	0.014	CWS-7, CWS-6 ≠ CWS-1, CWS-2, CWS-3
Among locations	0.385	0.001	Upper ≠ Lower, Middle
Among seasons	0.495	0.001	Summer ≠ Spring ≠ Fall
Between depths	–0.052	0.623	Shallow = Deep
RELATE test	**rho**	**p-value**	**Comments**
September 2013	0.599	0.009	Environmental variables with phytoplankton community
April 2014 to November 2014	0.697	0.001	Environmental variables with phytoplankton community
April 2014 to November 2014	0.444	0.001	Environmental variables with cyanobacteria potential taste-and-odor producers
BEST subset	**rho**	**p-value**	**Selected variables that best explain phytoplankton**
September 2013	0.773	0.001	Water temperature, potassium, silica
April 2014 to November 2014	0.743	0.001	UVA at 254 nm, field pH, potassium, silica, total nitrogen
BEST subset	**rho**	**p-value**	**Selected variables that best explain cyanobacteria potential taste-and-odor producers**
April 2014 to November 2014	0.646	0.001	UVA at 254 nm, potassium, silica, total nitrogen

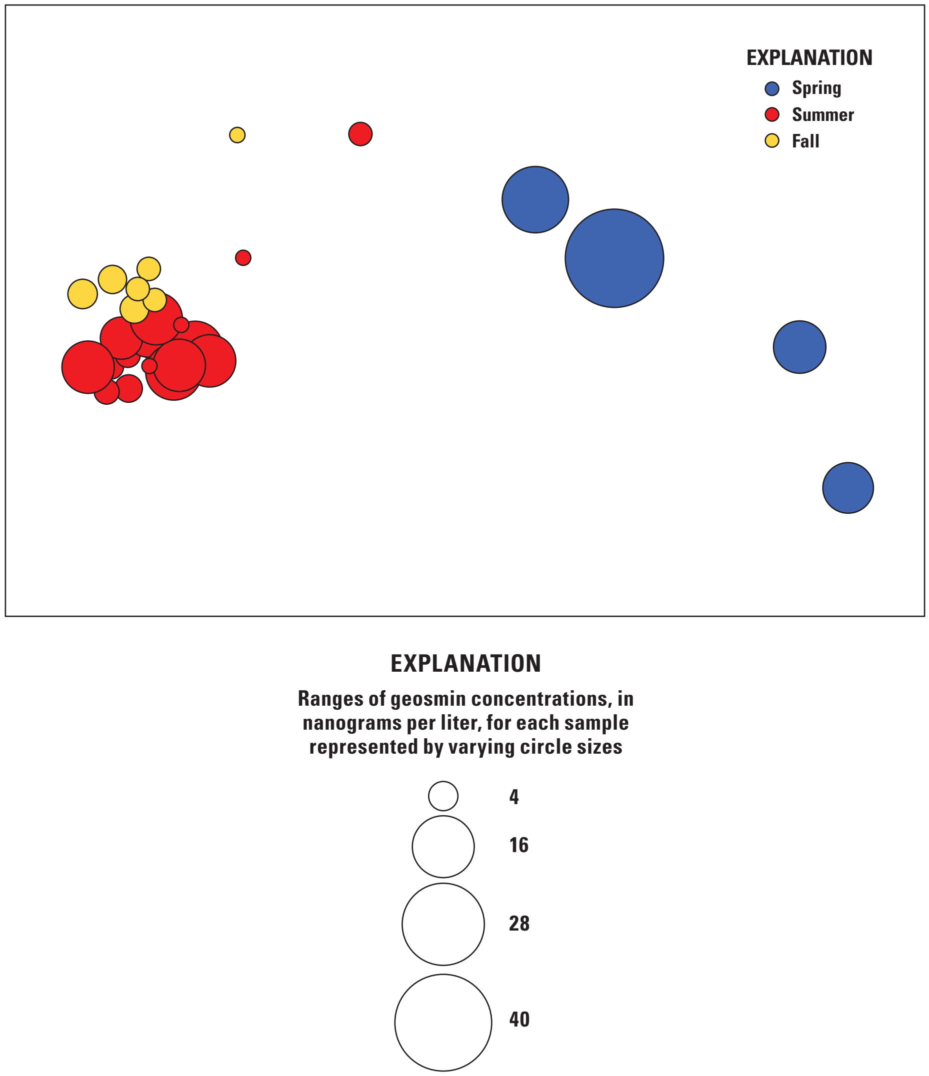

Figure 19. Two-dimensional nonmetric scaling graph of the pattern of fourth-root transformed cyanobacteria cell densities, standardized as percentage of total sample, in Bushy Park Reservoir for selected seasons in 2014. Symbols that plot close to each other are more similar than symbols that plot farther apart. Symbols are color-coded by season. Ranges of geosmin concentrations, in nanograms per liter, for each sample are represented by varying circle sizes, indicating that spring and summer have greater geosmin levels than fall.

Relation of Environmental Conditions to Taste-and-Odor Occurrence

Geosmin and MIB concentrations in Bushy Park Reservoir were correlated significantly to several environmental variables during the study period. To evaluate the relation between temporally changing environmental variables and T&O occurrence, a Spearman rho correlation analysis was performed for all samples at one site—the CWS-5 intake location. At this site, increased geosmin concentrations coincided with increased calcium concentrations, *Dolichospermum* biovolumes, and field pH. Conversely, increased geosmin concentrations coincided with decreased dissolved orthophosphate concentrations and field specific conductance (table 15). Increased MIB concentrations also coincided with increased field pH and decreased dissolved orthophosphate, as well as increased chlorophyll *a* concentrations and decreased transparency and dissolved potassium (table 15). Although correlation does not indicate causation, these environmental conditions of greater chlorophyll *a* and pH may be indicative of greater algal production. In addition, water with lower dissolved orthophosphate and specific conductance was identified within the Bushy Park Reservoir compared to Foster Creek and may indicate periods of less influence by the tributary (site CWS-5) when geosmin was elevated (figs. 14, 15).

To evaluate the relation between temporally and spatially changing environmental variables and T&O occurrence, a Spearman rho correlation analysis was performed for samples at all sites and depths for the study period. In the previous sections, geosmin concentrations were observed to increase in the upper portion of the reservoir near the Durham Canal during the summer months, but, during the spring, problematic levels of geosmin tended to occur near the dam (fig. 12*A*). Increased MIB concentrations tended to be greater near the dam during the same time period, including during the spring geosmin events (fig. 12*B*). In the correlation analysis, increased geosmin concentrations correlated with environmental conditions that included greater suspended sediment, field pH, PAR, water temperature, dissolved-oxygen percentage of saturation, and concentrations of chlorophyll *a* (estimated from sonde-derived fluorescence) and pheophytin *a*, which would also be an indication of algal growth. At the same time, elevated geosmin correlated with periods of reduced transparency, specific conductance, and concentrations of major ions (dissolved potassium, chloride, and sodium) and nutrients (dissolved orthophosphate, total phosphorus, and dissolved ammonia) (table 16). These correlations seem to reflect both temporal and spatial changes as seen previously at site CWS-5 whereby lower nutrient and major ion concentrations were identified within the Bushy Park Reservoir compared to Foster Creek (site CWS-6; figs. 14, 15). Increased MIB concentrations correlated with environmental conditions indicative of the "blackwater signature" of Foster Creek (increased organic carbon and decreased dissolved oxygen) and increased algal production (increased chlorophyll *a*, water temperature, PAR) as well as decreased concentrations of major ions, transparency, and inorganic nitrogen (table 16).

Table 15. Spearman correlation coefficients (rho) and probability values (p-value) between two taste-and-odor compounds, geosmin and 2-methylisoborneol (MIB), algal pigments, and associated environmental factors in Bushy Park Reservoir near the Charleston Water Intake (site CWS-5), near Goose Creek, South Carolina, September 2013 to April 2015.

[alpha value = 0.05; bold and italicized values represent statistically signficant relations; —, left blank because of redundancy; < , less than]

Selected environmental variables	Geosmin		MIB		Chlorophyll *a*	
	rho	p-value	rho	p-value	rho	p-value
Dissolved orthophosphate	***–0.721***	***0.007***	–0.838	***< 0.001***	–0.427	0.178
Field specific conductance	***–0.665***	***0.017***	–0.366	0.233	–0.226	0.484
Dissolved potassium	–0.448	0.136	***–0.794***	***< 0.001***	***–0.864***	***< 0.001***
Transparency	–0.379	0.285	***–0.718***	***0.025***	***–0.720***	***0.025***
Actinomycetes	–0.176	0.572	–0.441	0.143	–0.246	0.450
Water temperature	0.296	0.340	0.503	0.089	***0.745***	***0.007***
Chlorophyll (total from sensor)	0.483	0.110	***0.824***	***< 0.001***	0.484	0.006
Chlorophyll *a*	0.510	0.102	***0.694***	***0.017***	—	—
Photosynthetically active radiation (PAR)	0.533	0.160	0.549	0.164	0.660	0.264
Dolichospermum biovolume	***0.767***	***0.012***	0.319	0.381	0.190	0.619
Dissolved calcium	***0.811***	***< 0.001***	0.496	0.094	0.264	0.416
Field pH	***0.954***	***< 0.001***	***0.600***	***0.047***	0.571	0.074

Table 16. Spearman correlation coefficients (rho) and probability values (p-value) between two taste-and-odor compounds, geosmin and 2-methylisoborneol (MIB), algal pigments, and associated environmental factors at all locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[alpha value = 0.05; bold and italicized values represent statistically signficant relations; < , less than]

Variable	Geosmin			Variable	2-Methylisoborneol		
	rho	p-value	number		rho	p-value	number
Dissolved orthophosphate	***–0.644***	***< 0.001***	48	Dissolved potassium	***–0.692***	***< 0.001***	48
Transparency	***–0.617***	***< 0.001***	36	Dissolved sulfate	***–0.593***	***< 0.001***	48
Dissolved sodium	***–0.508***	***< 0.001***	48	Dissolved oxygen as concentration	***–0.551***	***< 0.001***	48
Phytoplankton biomass to chlorophyll *a* ratio	***–0.448***	***0.002***	47	Transparency	***–0.543***	***0.001***	36
Dissolved potassium	***–0.444***	***0.002***	48	Phytoplankton biomass to chlorophyll *a* ratio	***–0.495***	***< 0.001***	47
Dissolved chloride	***–0.400***	***0.005***	48	Dissolved manganese	***–0.329***	***0.023***	48
Total phosphorus	***–0.338***	***0.019***	48	Dissolved ammonia	***–0.314***	***0.030***	48
Field specific conductance	***–0.294***	***0.043***	48	Dissolved oxygen as percent saturation	***–0.310***	***0.032***	48
Dissolved ammonia	–0.280	0.054	48	Dissolved nitrate plus nitrite	***–0.294***	***0.043***	48
Dissolved oxygen as percent saturation	***0.333***	***0.021***	48	Dissolved organic carbon	***0.309***	***0.030***	48
Water temperature	***0.410***	***0.004***	48	Total organic carbon	***0.421***	***0.003***	48
MIB	***0.437***	***0.002***	48	Geosmin	***0.437***	***0.002***	48
Total chlorophyll (sonde-derived fluorescence)	***0.478***	***< 0.001***	47	Dissolved calcium	***0.445***	***0.002***	48
Pheophytin *a*	***0.550***	***< 0.001***	47	Hardness	***0.457***	***0.001***	48
Photosynthetically active radiation (PAR)	***0.554***	***< 0.001***	36	Photosynthetically active radiation (PAR)	***0.482***	***0.003***	36
Field pH	***0.600***	***< 0.001***	47	Pheophytin *a*	***0.648***	***< 0.001***	47
Suspended sediment	***0.630***	***< 0.001***	43	Chlorophyll *a*	***0.655***	***< 0.001***	47
				Water temperature	***0.660***	***< 0.001***	48

Synoptic Assessment of Taste-and-Odor Occurrence in the Bushy Park Reservoir by the Charleston Water System Treatment Plant

Source water from Bushy Park Reservoir is blended with Edisto River water by the CWS to produce the raw water that is treated and distributed as finished water. Source water from Bushy Park Reservoir is the major component of the raw water, with Edisto River source water typically representing less than 20 percent of the blended raw water. Source water is transported to the Hanahan Water Treatment Plant through two water-supply tunnels, one from each source (fig. 20; Conrads and others, 2017b).

In April 2015, CWS experienced two elevated T&O events when temperatures in the source water rose above 21 °C (Rebecca Thames, Charleston Water System, written commun., March 26, 2015) (fig. 21). At the beginning of the event during the first part of the month, CWS analyzed raw water in the Bushy Park tunnel and raw blended and treated water from supply lines in the plant and identified that raw blended and treated water had high concentrations of geosmin that were not observed in the Bushy Park tunnel raw water. That finding suggests that the Edisto River may have contributed to the T&O event. The most probable T&O source in a free-flowing river would be actinomycetes or cyanobacteria that form mats on the streambed or are attached to debris or vegetation.

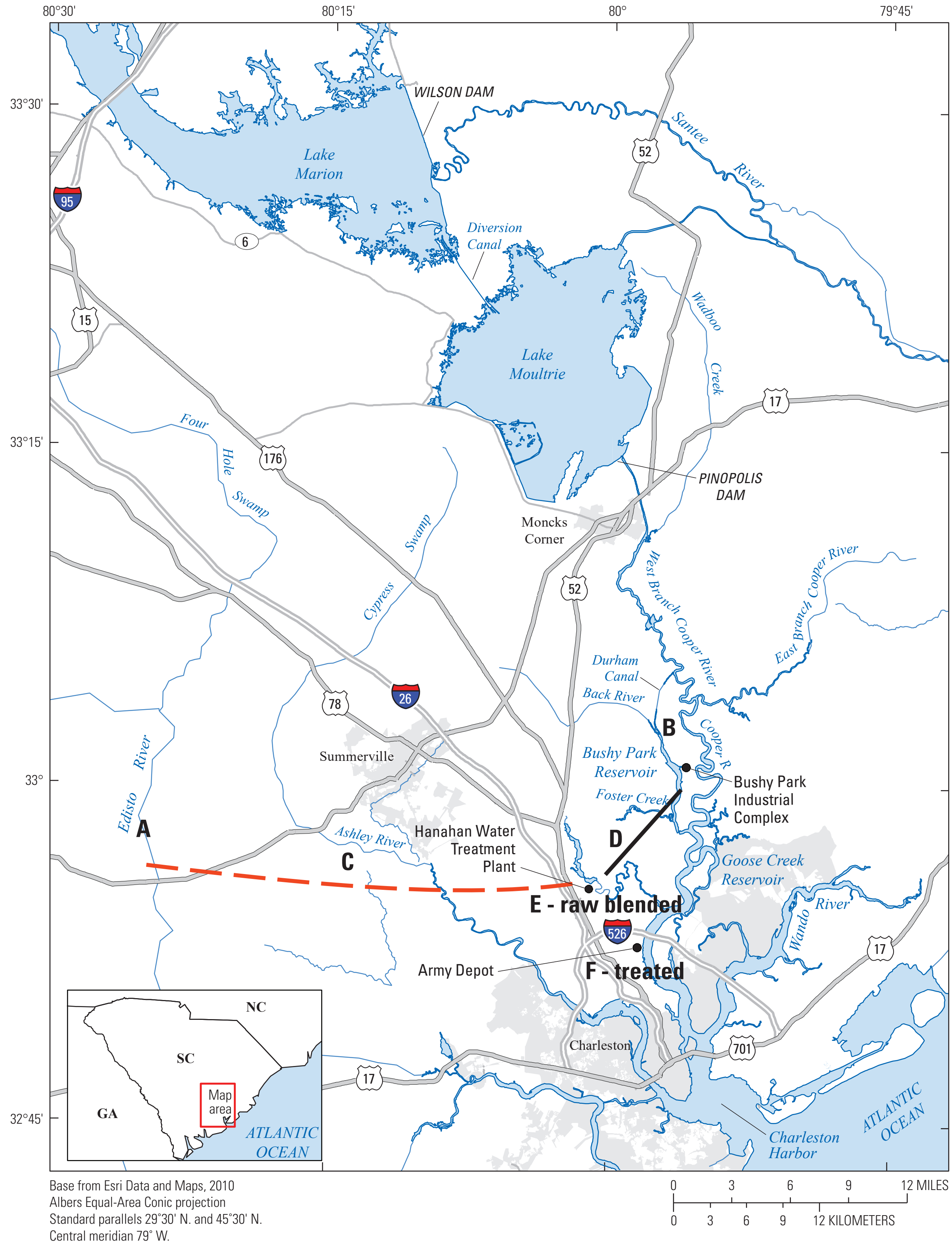

Figure 20. Area of the synoptic assessment of taste-and-odor occurrence in Edisto River [A] and Bushy Park Reservoir [B], April 2015. Source water flows through supply tunnels [C and D, respectively] into the Hanahan Water Treatment Plant where it is blended [E] and treated [F]. The red dashed line indicates the general area of the Edisto River tunnel, and the solid black line indicates the general area of the Bushy Park tunnel.

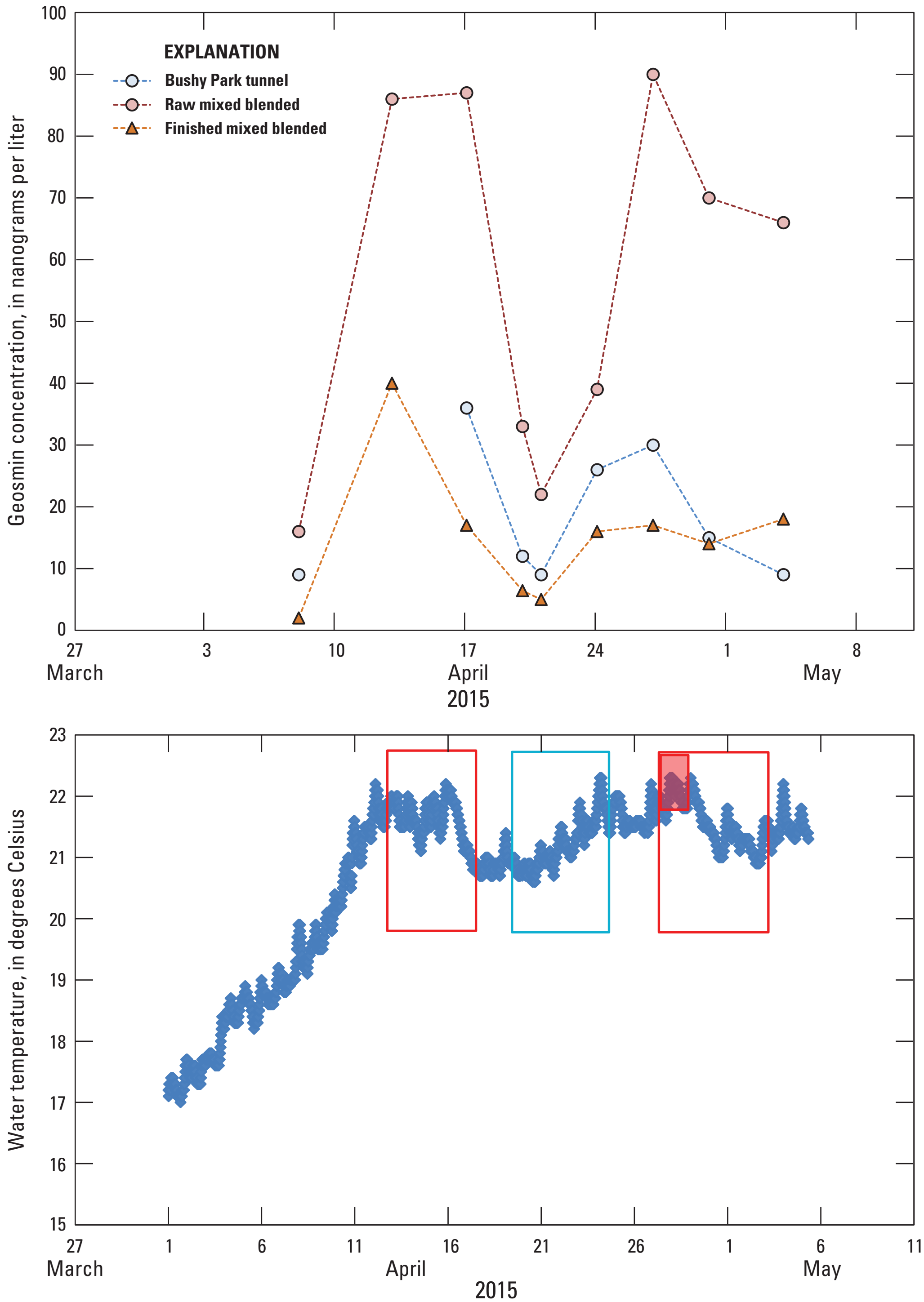

Figure 21. Temporal variability in geosmin concentrations in Bushy Park tunnel, raw blended (Bushy Park Reservoir and Edisto River), and finished water (top graph) and corresponding water temperatures in Bushy Park tunnel (bottom graph) in April 2015. In the bottom plot, red open boxes indicate periods of elevated geosmin, the red shaded box indicates the period of USGS sampling, and the blue open box indicates a period of low geosmin concentrations.

When the second April T&O event began, CWS requested the USGS participate in a synoptic sampling of both raw water sources at the intakes and in the tunnels, raw blended, and treated water to evaluate the degree of influence of T&O from the Edisto River. The CWS provided the USGS with estimated travel times for source water in the tunnel to reach the intake, and those times were used to coordinate the synoptic sampling. The Edisto River intake was sampled on the morning of April 29, the Bushy Park Reservoir intake was sampled about 24 hours later on the morning of April 30, and the Edisto River tunnel and supply lines for Bushy Park tunnel, raw blended, and treated water were sampled 6 hours later during the afternoon of April 30 (table 17). Field properties of pH, dissolved oxygen, water temperature, and specific conductance as well as chlorophyll *a* and phycocyanin fluorescence were measured at the time of sampling. Samples were analyzed for dissolved organic carbon, ultraviolet absorbance at 254 nanometers, geosmin, MIB, and actinomycetes concentrations. Samples from the Bushy Park intake (site CWS-5) also were analyzed for major ions and nutrients, and these data were also included in the previous assessments. Phytoplankton enumeration and identification were performed on water samples.

The Edisto River is a free-flowing, blackwater stream that has dissolved organic carbon with high humic content, as reflected in elevated ultraviolet absorbance at 254 nanometers, compared to Bushy Park Reservoir (0.876 and 0.263, respectively; table 17). Additionally, at the time of the synoptic sampling, the Edisto River had relatively lower specific conductance than Bushy Park Reservoir (73 and 123 microsiemens per centimeter at 25 °C, respectively). Therefore, scatterplots of these two constituents were used to evaluate the mixing relation between dissolved organic and inorganic constituents in the two source waters (Edisto River, Bushy Park Reservoir at the CWS intake), source water in the supply tunnels, and raw mixed or blended water at the Hanahan Water Treatment Plant near Goose Creek (fig. 22, top graph). Although there appeared to be minor changes in the chemistry of the source water from the intakes to the tunnels, the raw mixed (blended) water seemed to be a product of simple mixing of the two tunnel waters, with greater contribution from the Bushy Park source than Edisto River (as would be expected). However, a scatterplot of geosmin concentrations and specific conductance identified a discrepancy in the relation between the two tunnel source waters and the raw mixed water. As was observed by CWS during the first April T&O event, the Bushy Park tunnel water had significantly lower geosmin concentrations than Bushy Park intake water (15 and 28 ng/L, respectively; table 17). Additionally, source water from the Bushy Park intake and tunnel had less geosmin than required to explain the simple theoretical mixing relation of the two source waters to produce geosmin concentrations in the raw mixed water (fig. 22, bottom graph). The scope of the synoptic sampling did not provide sufficient data to identify definitively the reason for the apparent discrepancy between the expected and actual geosmin concentrations in the Bushy Park Reservoir source waters. However, one possible explanation could be that the sampling lines in the Bushy Park tunnel or point samples at the intake may not have adequately captured a representative sample of the source water that was used in the blending of the raw water. In the case of the measured geosmin concentrations in the Bushy Park tunnel compared to the intake, geosmin still in the cellular (particulate) phase could possibly be distributed lower in the tunnel than the dissolved released phase; therefore, geosmin concentrations from the sample lines may only represent the dissolved or released phase of geosmin. Additionally, the travel times of the water in the tunnels for blending may have been incorrectly estimated; therefore, the temporal pulse of water sampled in the Bushy Park intake and tunnel may not adequately reflect the same pulse of water that was blended to form the raw mixed water.

Nonetheless, as determined in the water-quality characterization at sites within the Bushy Park Reservoir, cyanobacteria were indicated to be the more significant source of the geosmin, not actinomycetes, in the April 2015 sampling event. Although the Edisto River intake and tunnel water had relatively high actinomycetes concentrations (130 and 140 colonies per milliliter, respectively) compared to the Bushy Park intake and tunnel (2 colonies per milliliter), corresponding geosmin concentrations were below 4 ng/L for source water from the Edisto River intake and tunnel (table 17). Elevated geosmin concentrations above the CWS treatment threshold were identified in source waters from the Bushy Park Reservoir. The cyanobacteria community at the sampled sites in April 2015 was statistically similar to the community in Bushy Park Reservoir in April 2014 (fig. 18), when geosmin concentrations also were elevated above the human detection threshold (fig. 19). However, the only geosmin-producing genus identified at the Bushy Park intake (site CWS-5) was *Dolichospermum planctonicum*, which also was observed with *Planktolyngbya compactum* in the Bushy Park tunnel. Although statistically similar on the basis of cluster analysis, the cyanobacteria community appeared to be somewhat more diverse and varied in the raw mixed sample and contained species, including *Dolichospermum compactum* (rather than *planctonicum*), *Jaaginema* sp., *Aphanizomenon* sp., and *Pseudanabaena limnectica*, not identified at the other sampled locations.

This finding appears to support the hypothesis that a different pulse of water was sampled in the source water of Bushy Park Reservoir than was sampled in the raw mixed or blended water at the treatment plant. Further investigation may be required to determine if the uneven mixing of water in the tunnel may produce uneven vertical distribution of geosmin concentrations within the Bushy Park tunnel and if predicted travel times of the source water to the treatment plant need to be adjusted.

Table 17. Measurements of selected properties in water from Bushy Park Reservoir, near Goose Creek, South Carolina, during the second taste-and-odor event sampling of the U.S. Geological Survey investgation in April 2015.

Station number	Station name	Date	Time	Barometric pressure, millimeters of mercury	Dissolved oxygen, milligrams per liter	Dissolved oxygen, percent of saturation	pH, field, standard units	Specific conductance, microsiemens per centimeter at 25 degrees Celsius	Temperature, water, degrees Celsius	Turbidity, formazin nephelometric units (FNU)	Chlorophyll, total, in situ sensor, micrograms per liter	Actinomycetes, colonies per milliliter	2-Methylisoborneol, unfiltered, nanograms per liter	Geosmin, unfiltered, nanograms per liter	Ultraviolet absorbance at 254 nanometers, filtered, absorbance units per centimeter	Ultraviolet absorbance at 280 nanometers, filtered, absorbance units per centimeter
02172061139	140B-002 (Bushy Park Tunnel)	Apr. 30, 2015	1400	756	6.6	75	7.7	127	21.3	6.1	3.59	2	<2.0	15	0.268	0.208
0217206110	Bushy Park Reservoir above Foster Creek, Goose Creek, SC	Apr. 30, 2015	0800	756	7.3	82	7.1	123	20.8	1.8	11.6	2	15	28	0.263	0.2
021749992	140B-001 (Edisto River Tunnel)	Apr. 30, 2015	1400	755	7.7	82	7.4	94	18.4	5	8.49	140	<2.0	2.1	0.868	0.673
02175000	Edisto River near Givhans, SC	Apr. 29, 2015	1030	755	6.8	72	6.7	73	17.8	4.5	7.88	130	<2.0	3.6	0.876	0.678
325530908001049	Finished water at Hanahan Water Treatment Plant, Hanahan, SC	Apr. 30, 2015	1400	755	5.5	62	7.2	124	21	1.6	5.23	14	9.2	58	0.346	0.264

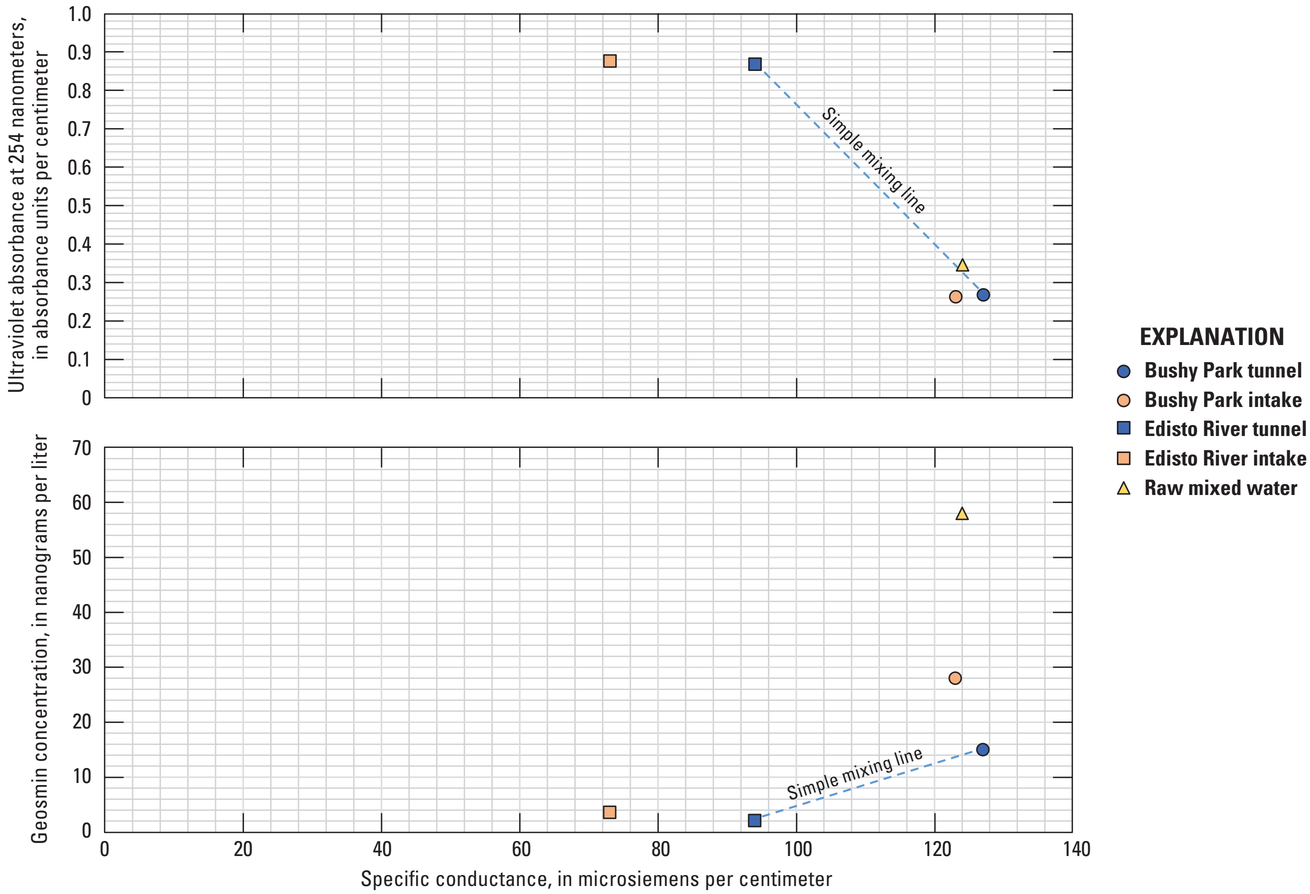

Figure 22. Scatterplots of ultraviolet absorbance at 254 nanometers (top graph) and geosmin concentrations, in nanograms per liter (bottom graph), against conservative tracer of specific conductance, in microsiemens per centimeter at 25 degrees Celsius, to support the evaluation of mixing relations between two source waters (Edisto River, Bushy Park Reservoir at the Charleston Water Intake), source water in the supply tunnels, and raw mixed or blended water at the Hanahan Water Treatment Plant near Goose Creek, South Carolina. The simple mixing line represents the mixed water, falling along a line between the two source waters.

Summary

The Bushy Park Reservoir is the principal water supply for 400,000 people in the greater Charleston, South Carolina, area, which includes homes as well as businesses and industries in the Bushy Park Industrial Complex. As part of a long-range planning process, Charleston Water System approached the U.S. Geological Survey for assistance in understanding the circulation of Bushy Park Reservoir and its effects on water-quality conditions, specifically, taste-and-odor (T&O) episodes. The water-quality data collected for the study included a combination of discrete water-column sampling at seven locations in the reservoir and longitudinal water-quality profiling surveys of the reservoir and tributaries to capture the temporal and spatial water-quality dynamics of Bushy Park Reservoir. The discrete water-column samples were analyzed for geosmin, 2-methylisoborneol (MIB), chlorophyll *a*, pheophytin *a*, nutrient, major ions, trace metals, actinomycetes, and suspended-sediment concentrations, and for phytoplankton cell densities and biovolumes. Water-quality profiling surveys were conducted with an autonomous underwater vehicle equipped with a multiparameter water-quality-sonde bulkhead. Properties measured by the autonomous underwater vehicle included water temperature, dissolved oxygen, pH, specific conductance, turbidity, total chlorophyll as fluorescence (estimate of algal biomass), and phycocyanin as fluorescence (estimate of cyanobacteria biomass).

The data assessment was conducted in three steps. The first step was to characterize the water-quality conditions in the reservoir relative to established guidelines. The second step was to identify any spatial and seasonal variation in water-quality conditions and phytoplankton community structures throughout the reservoir. The second step was conducted to (1) identify the area of the reservoir that most influences the water-quality conditions at the intake (site CWS-5) (for example, Foster Creek inflows [site CWS-6] or Durham Canal inflows [sites CWS-1 and CWS-2]), especially during

periods of elevated T&O concentrations, (2) determine if the T&O concentrations are produced in situ in the reservoir or delivered to the reservoir from either Foster Creek or Durham Canal, and (3) identify the most probable source of the T&O compounds (actinomycetes bacteria or cyanobacteria), and, if cyanobacteria, identify any phytoplankton species (or genus) that have the potential to produce T&O compounds during T&O episodes. The final step was to assess whether these spatial and seasonal changes in environmental factors correlate significantly with phytoplankton community structure and geosmin or MIB concentrations.

Additionally, the profile and survey data were used to identify areas within the reservoir where greater phytoplankton and cyanobacteria densities were most likely occurring. Bushy Park Reservoir tended to stratify thermally at a depth of about 20 feet from June to early October. The stratification was limited to the deeper portions of the reservoir near the dam and often dissipated within the reservoir near the site CWS-5 location. Where thermally stratified, a corresponding depletion of dissolved oxygen also occurred at about the same depth and resulted in an anoxic hypolimnion below the 25-foot depth and an increase in specific conductance, likely due to re-mobilized metals and phosphorus under reducing conditions. In general, chlorophyll *a* exhibited some spatial variation, but no strong consistent pattern or "hot spot" was observed. Phycocyanin, estimated as blue-green algae cell density, seemed to be greater in the upper portion of the reservoir periodically, but those differences may be attributed to increased turbidity and the potential change in phytoplankton community structure that affects fluorescence. In cross section, at sites CWS-5 and CWS-4, for example, changes with depth of phycocyanin were observed at about the 10-foot depth.

A constant production of MIB near the dam and geosmin in the middle and upper portions of the reservoir appears to be occurring during the summer and early fall in the reservoir, but concentrations of these compounds tend to be between 10 and 15 nanograms per liter. At site CWS-5, the dominant T&O compound tended to be MIB at a 2- or 3-to-1 ratio with geosmin during the summer and fall. During springtime episodes, however, when T&O concentrations typically are elevated above the Charleston Water System treatment threshold, the spatial distribution of geosmin concentrations greater than 15 nanograms per liter (28 to 38 nanograms per liter) was best explained by in situ production in the lower portion of the Bushy Park Reservoir near the dam rather than transport from Foster Creek. This pattern seems to indicate a possible shift in phytoplankton communities (or, at least, cyanobacteria communities) from MIB producers to geosmin producers. An identification of spatial and seasonal variation in water quality and phytoplankton community was completed to explain this shift.

The spatial and seasonal assessment of water-quality conditions in Bushy Park Reservoir identified seasonal differences in water chemistry between the upper and lower portions of the reservoir that correspond to the location of elevated geosmin concentrations. The assessment determined that higher levels of dissolved iron, dissolved nitrate plus nitrite, total nitrogen, and total phosphorus were present in the reservoir during the spring compared to concentrations during the fall and summer. With the exception of dissolved nitrate plus nitrite concentrations, these constituents also were elevated in concentration in the lower portion of the reservoir where geosmin concentrations were elevated above the Charleston Water System treatment threshold. On the basis of the spatial and seasonal assessment of actinomycetes concentrations compared to T&O concentrations, cyanobacteria production likely was the dominant source of the T&O episodes rather than actinomycetes. The lack of spatial and seasonal patterns in actinomycetes concentrations does not correspond to the springtime geosmin concentrations that were elevated above Charleston Water System threshold in the lower portion of the reservoir. Additionally, actinomycetes concentrations, although ubiquitous, have a median of about 9 and maximum of about 20 colonies per milliliter, which can be considered low for elevated T&O production. Nonetheless, the potential exists for actinomycetes to be a secondary source of T&O production and could explain some of the ubiquitous occurrence of low-level T&O production, such as MIB, observed throughout the summer and early fall months.

When evaluated by biovolume, cyanobacteria were not the dominant phytoplankton group in Bushy Park Reservoir during the study period. "Bloom-" forming levels of *Gonyostomum semen* were identified in the reservoir during the summer months; however, the genus *Gonyostomum* was present in historic algal taxonomic data for the reservoir. *Dolichospermum planctonicum* (previously *Anabaena planktonica*) was the dominant genera of the cyanobacteria group during spring periods. The geosmin-producing genera that were identified in the 2014 and 2015 spring community in Bushy Park Reservoir were not observed in the 1999 and 2000 algal taxonomic data.

Potential toxin-producing species within the cyanobacteria group were present in the summer of 2014, including *Cylindrospermopsis raciborskii* (less than 2,000 cells per milliliter) and *Microcystis* sp. (less than 1,000 cells per milliliter). The phytoplankton community, including the cyanobacteria group, had a greater number of cells during the fall and least during the spring when geosmin episodes tended to occur. On the basis of the cyanobacteria cell densities and chlorophyll *a* concentrations observed in Bushy Park Reservoir, the World Health Organization recreational guidelines indicate a moderate probability of acute health effects attributed to cyanotoxins. Nonetheless, these bulk measures of phytoplankton community were not able to effectively determine if distinct differences in community structure could explain the springtime geosmin episodes. Therefore, a more robust examination of phytoplankton species was conducted using a multivariate analysis that identified seasonal changes in phytoplankton community structure. These seasonal phytoplankton communities appeared to be explained by seasonal changes in water chemistry and may be responsible for episodes of T&O occurrence, especially geosmin. The most probable source of geosmin identified during the study was *D. planctonicum*.

Nonetheless, as determined in the water-quality characterization at sites within the Bushy Park Reservoir, cyanobacteria was indicated to be the more significant source of the geosmin, not actinomycetes, in the April 2015 sampling event. Although the Edisto River intake and tunnel water had relatively high actinomycetes concentrations (130 and 140 colonies per milliliter, respectively) compared to the Bushy Park intake and tunnel (2 colonies per milliliter), corresponding geosmin concentrations were below 5 nanograms per liter for source water from the Edisto River intake and tunnel. Elevated geosmin concentrations above the Charleston Water System treatment threshold were identified in source waters from the Bushy Park Reservoir. The cyanobacteria community at the sampled sites in April 2015 was statistically similar to the community in the Bushy Park Reservoir in April 2014, when geosmin concentrations also were elevated. The only geosmin-producing genus identified at the Bushy Park intake (site CWS-5), however, was *D. planctonicum,* which also was observed with *Planktolyngbya compactum* in the Bushy Park tunnel. Although statistically similar on the basis of cluster analysis, the cyanobacteria community appeared to be somewhat more diverse and varied in the raw mixed sample and contained species, including *Dolichospermum compactum* (rather than *planctonicum*), *Jaaginema* sp., *Aphanizomenon* sp., and *Pseudanabaena limnectica*, not identified at the other sampled locations. This finding appears to support the hypothesis that a different pulse of water was sampled in the source water of Bushy Park Reservoir than what was sampled in the raw mixed or blended water at the treatment plant.

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Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	September 2013 sampling event						
		CWS-2	CWS-3	CWS-4S	CWS-5S	CWS-5D	CWS-6	CWS-7
All	**Total biovolume (μm^3/mL)**	**1,957,108**	**2,100,544**	**2,043,734**	**3,502,282**	**3,376,657**	**3,191,239**	**1,690,094**
Cyanobacteria	Total cyanobacteria biovolume (μm^3/mL)	330,536	370,292	298,719	454,277	431,092	566,433	140,543
	Total cyanobacteria - Percent of total biovolume	16.9	17.6	14.6	13.0	12.8	17.7	8.3
Green algae	Total chlorophyta biovolume (μm^3/mL)	309,579	449,600	269,026	612,776	313,176	347,418	258,802
	Total chlorophyta - Percent of total biovolume	15.8	21.4	13.2	17.5	9.3	10.9	15.3
Diatoms	Total bacillariophyta biovolume (μm^3/mL)	1,211,609	1,166,690	1,321,031	1,519,499	1,925,960	1,552,778	367,383
	Total bacillariophyta - Percent of total biovolume	61.9	55.5	64.6	43.4	57.0	48.7	21.7
Euglenoids	Total euglenophyta biovolume (μm^3/mL)	21,124	4,243	4,308	571,397	372,696	253,143	323,016
	Total euglenophyta - Percent of total biovolume	1.1	0.2	0.2	16.3	11.0	7.9	19.1
Dinoflagellates	Total pyrrhophyta biovolume (μm^3/mL)	13,818	12,287	21,529	125,234	159,594	342,536	444,358
	Total pyrrhophyta - Percent of total biovolume	0.7	0.6	1.1	3.6	4.7	10.7	26.3
Cryptomonads	Total cryptophyta biovolume (μm^3/mL)	25,100	48,057	53,211	82,707	25,996	24,071	99,220
	Total cryptophyta - Percent of total biovolume	1.3	2.3	2.6	2.4	0.8	0.8	5.9
Yellow-green algae	Total xanthophyta biovolume (μm^3/mL)	718	34,551	17,542	2,948	11,268	14,812	12,299
	Total xanthophyta - Percent of total biovolume	0.0	1.6	0.9	0.1	0.3	0.5	0.7
Golden-brown algae	Total chrysophyta biovolume (μm^3/mL)	34,362	2,935	15,463	68,942	26,979	13,430	29,505
	Total chrysophyta - Percent of total biovolume	1.8	0.1	0.8	2.0	0.8	0.4	1.7
All	**Total cell density (cell/mL)**	**74,544**	**72,245**	**70,026**	**42,391**	**71,248**	**37,520**	**21,892**
Cyanobacteria	Total cyanobacteria cell density (cell/mL)	68,449	66,513	64,231	33,897	63,309	30,144	16,005
	Total cyanobacteria - Percent of total cell density	91.8	92.1	91.7	80.0	88.9	80.3	73.1
	Number of cyanobacteria species	24	26	25	21	26	23	24
Green algae	Total chlorophyta cell density (cell/mL)	4,374	4,377	4,382	5,662	5,161	4,455	4,045
	Total chlorophyta - Percent of total cell density	5.9	6.1	6.3	13.4	7.2	11.9	18.5
	Total chlorophyta species	50	55	44	55	53	52	47
Diatoms	Total bacillariophyta cell density (cell/mL)	1,393	1,185	931	1,680	1,865	2,083	589
	Total bacillariophyta - Percent of total cell density	1.9	1.6	1.3	4.0	2.6	5.6	2.7
	Total bacillariophyta species	14	14	14	16	14	13	12

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	September 2013 sampling event—Continued						
		CWS-2	CWS-3	CWS-4S	CWS-5S	CWS-5D	CWS-6	CWS-7
Euglenoids	Total euglenophyta cell density (cell/mL)	9	1	1	168	116	95	96
	Total euglenophyta - Percent of total cell density	0.0	0.0	0.0	0.4	0.2	0.3	0.4
	Total euglenophyta species	1	0	0	3	5	3	5
Dinoflagellates	Total pyrrhophyta cell density (cell/mL)	1	1	3	24	32	120	71
	Total pyrrhophyta - Percent of total cell density	0.0	0.0	0.0	0.1	0.0	0.3	0.3
	Total pyrrhophyta species	0	0	1	2	2	3	2
Cryptomonads	Total cryptophyta cell density (cell/mL)	212	47	230	473	157	50	322
	Total cryptophyta - Percent of total cell density	0.3	0.1	0.3	1.1	0.2	0.1	1.5
	Total cryptophyta species	2	2	3	1	1	2	2
Yellow-green algae	Total xanthophyta cell density (cell/mL)	0	61	53	52	53	47	39
	Total xanthophyta - Percent of total cell density	0.0	0.1	0.1	0.1	0.1	0.1	0.2
	Total xanthophyta species	0	2	2	1	1	2	2
Golden-brown algae	Total chyrsophyta cell density (cell/mL)	35	45	16	209	165	259	197
	Total chyrsophyta - Percent of total cell density	0.0	0.1	0.0	0.5	0.2	0.7	0.9
	Total chyrsophyta species	1	1	1	3	3	3	2

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	April 2014 sampling event			
		CWS-3	CWS-5D	CWS-6	CWS-7
All	**Total biovolume (μm^3/mL)**	**885,919**	**7,424,206**	**4,125,843**	**8,156,678**
Cyanobacteria	Total cyanobacteria biovolume (μm^3/mL)	18,799	87,038	101,324	52,093
	Total cyanobacteria - Percent of total biovolume	2.1	1.2	2.5	0.6
Green algae	Total chlorophyta biovolume (μm^3/mL)	42,823	206,129	352,542	116,811
	Total chlorophyta - Percent of total biovolume	4.8	2.8	8.5	1.4
Diatoms	Total bacillariophyta biovolume (μm^3/mL)	814,454	5,154,117	2,445,264	1,092,476
	Total bacillariophyta - Percent of total biovolume	91.9	69.4	59.3	13.4
Euglenoids	Total euglenophyta biovolume (μm^3/mL)	0	42,966	21,470	32,088
	Total euglenophyta - Percent of total biovolume	0.0	0.6	0.5	0.4
Dinoflagellates	Total pyrrhophyta biovolume (μm^3/mL)	504	459,551	20,521	37,537
	Total pyrrhophyta - Percent of total biovolume	0.1	6.2	0.5	0.5
Cryptomonads	Total cryptophyta biovolume (μm^3/mL)	1,890	753,726	603,087	2,384,404
	Total cryptophyta - Percent of total biovolume	0.2	10.2	14.6	29.2
Yellow-green algae	Total xanthophyta biovolume (μm^3/mL)	0	523,041	523,041	4,184,323
	Total xanthophyta - Percent of total biovolume	0.0	7.0	12.7	51.3
Golden-brown algae	Total chrysophyta biovolume (μm^3/mL)	7,449	111,678	29,940	253,762
	Total chrysophyta - Percent of total biovolume	0.8	1.5	0.7	3.1
All	**Total cell density (cell/mL)**	**1,810**	**11,416**	**9,340**	**6,460**
Cyanobacteria	Total cyanobacteria cell density (cell/mL)	238	4,632	3,584	1,208
	Total cyanobacteria - Percent of total cell density	13.1	40.6	38.4	18.7
	Number of cyanobacteria species	3	8	4	6
Green algae	Total chlorophyta cell density (cell/mL)	319	1,688	2,852	840
	Total chlorophyta - Percent of total cell density	17.6	14.8	30.5	13.0
	Total chlorophyta species	9	21	28	12
Diatoms	Total bacillariophyta cell density (cell/mL)	1,235	4,332	2,184	1,128
	Total bacillariophyta - Percent of total cell density	68.2	37.9	23.4	17.5
	Total bacillariophyta species	15	14	13	13

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[µm³/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	April 2014 sampling event—Continued			
		CWS-3	CWS-5D	CWS-6	CWS-7
Euglenoids	Total euglenophyta cell density (cell/mL)	0	16	8	12
	Total euglenophyta - Percent of total cell density	0.0	0.1	0.1	0.2
	Total euglenophyta species	0	2	2	2
Dinoflagellates	Total pyrrhophyta cell density (cell/mL)	2	28	8	32
	Total pyrrhophyta - Percent of total cell density	0.1	0.2	0.1	0.5
	Total pyrrhophyta species	1	3	1	3
Cryptomonads	Total cryptophyta cell density (cell/mL)	12	492	584	2,840
	Total cryptophyta - Percent of total cell density	0.7	4.3	6.3	44.0
	Total cryptophyta species	1	2	2	2
Yellow-green algae	Total xanthophyta cell density (cell/mL)	0	4	4	32
	Total xanthophyta - Percent of total cell density	0.0	0.0	0.0	0.5
	Total xanthophyta species	0	1	1	1
Golden-brown algae	Total chyrsophyta cell density (cell/mL)	4	116	80	364
	Total chyrsophyta - Percent of total cell density	0.2	1.0	0.9	5.6
	Total chyrsophyta species	2	2	3	5

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	July 2014 sampling event								
		CWS-3	CWS-5D	CWS-6	CWS-7	CWS-5S	CWS-1	CWS-4D	CWS-4S	CWS-2
All	**Total biovolume (μm^3/mL)**	**1,263,174**	**2,759,849**	**5,952,451**	**4,304,629**	**39,122,165**	**2,653,481**	**2,358,829**	**2,878,666**	**748,223**
Cyanobacteria	Total cyanobacteria biovolume (μm^3/mL)	163,377	156,853	15,225	39,352	69,033	443,290	171,377	224,760	66,010
	Total cyanobacteria - Percent of total biovolume	12.9	5.7	0.3	0.9	0.2	16.7	7.3	7.8	8.8
Green algae	Total chlorophyta biovolume (μm^3/mL)	249,587	357,308	261,055	347,628	342,813	543,321	557,334	511,960	163,338
	Total chlorophyta - Percent of total biovolume	19.8	12.9	4.4	8.1	0.9	20.5	23.6	17.8	21.8
Diatoms	Total bacillariophyta biovolume (μm^3/mL)	624,853	244,586	463,688	467,947	391,514	1,223,490	1,161,717	415,121	358,675
	Total bacillariophyta - Percent of total biovolume	49.5	8.9	7.8	10.9	1.0	46.1	49.2	14.4	47.9
Euglenoids	Total euglenophyta biovolume (μm^3/mL)	3,618	275,292	125,824	207,372	155,607	25,087	28,090	29,494	11,641
	Total euglenophyta - Percent of total biovolume	0.3	10.0	2.1	4.8	0.4	0.9	1.2	1.0	1.6
Dinoflagellates	Total pyrrhophyta biovolume (μm^3/mL)	14,935	123,370	522,037	207,372	304,683	18,835	92,795	39,018	0
	Total pyrrhophyta - Percent of total biovolume	1.2	4.5	8.8	4.8	0.8	0.7	3.9	1.4	0.0
Cryptomonads	Total cryptophyta biovolume (μm^3/mL)	206,229	545,473	344,844	658,902	1,822,427	398,883	337,282	1,124,729	144,579
	Total cryptophyta - Percent of total biovolume	16.3	19.8	5.8	15.3	4.7	15.0	14.3	39.1	19.3
Yellow-green algae	Total xanthophyta biovolume (μm^3/mL)	0	1,046,081	4,184,323	2,092,162	35,566,890	0	0	523,041	0
	Total xanthophyta - Percent of total biovolume	0.0	37.9	70.3	48.6	90.9	0.0	0.0	18.2	0.0
Golden-brown algae	Total chrysophyta biovolume (μm^3/mL)	575	10,886	14,825	197,934	134,909	575	7,050	4,175	0
	Total chrysophyta - Percent of total biovolume	0.0	0.4	0.2	4.6	0.3	0.0	0.3	0.1	0.0
All	**Total cell density (cell/mL)**	**15,972**	**5,101**	**5,572**	**8,312**	**13,992**	**33,696**	**25,452**	**23,064**	**11,458**
Cyanobacteria	Total cyanobacteria cell density (cell/mL)	12,748	1,333	2,804	4,640	8,084	27,276	19,652	17,152	9,715
	Total cyanobacteria - Percent of total cell density	79.8	26.1	50.3	55.8	57.8	80.9	77.2	74.4	84.8
	Number of cyanobacteria species	14	18	13	13	18	23	19	17	15
Green algae	Total chlorophyta cell density (cell/mL)	2,536	2,976	1,860	2,476	3,208	4,888	4,404	3,284	1,296
	Total chlorophyta - Percent of total cell density	15.9	58.3	33.4	29.8	22.9	14.5	17.3	14.2	11.3
	Total chlorophyta species	23	30	24	32	38	32	36	37	32
Diatoms	Total bacillariophyta cell density (cell/mL)	492	272	324	412	436	1,080	1,100	512	314
	Total bacillariophyta - Percent of total cell density	3.1	5.3	5.8	5.0	3.1	3.2	4.3	2.2	2.7
	Total bacillariophyta species	13	10	11	13	12	14	16	10	11

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[µm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	July 2014 sampling event—Continued								
		CWS-3	CWS-5D	CWS-6	CWS-7	CWS-5S	CWS-1	CWS-4D	CWS-4S	CWS-2
Euglenoids	Total euglenophyta cell density (cell/mL)	4	140	52	28	168	16	24	28	17
	Total euglenophyta - Percent of total cell density	0.0	2.7	0.9	0.3	1.2	0.0	0.1	0.1	0.1
	Total euglenophyta species	1	8	7	3	6	2	4	4	3
Dinoflagellates	Total pyrrhophyta cell density (cell/mL)	8	68	216	244	328	12	32	20	0
	Total pyrrhophyta - Percent of total cell density	0.1	1.3	3.9	2.9	2.3	0.0	0.1	0.1	0.0
	Total pyrrhophyta species	2	2	2	3	2	2	4	3	0
Cryptomonads	Total cryptophyta cell density (cell/mL)	180	296	216	356	964	420	212	1,528	111
	Total cryptophyta - Percent of total cell density	1.1	5.8	3.9	4.3	6.9	1.2	0.8	6.6	1.0
	Total cryptophyta species	2	2	2	2	1	2	2	2	2
Yellow-green algae	Total xanthophyta cell density (cell/mL)	0	8	32	16	276	0	0	4	0
	Total xanthophyta - Percent of total cell density	0.0	0.2	0.6	0.2	2.0	0.0	0.0	0.0	0.0
	Total xanthophyta species	0	1	1	1	2	0	0	1	0
Golden-brown algae	Total chyrsophyta cell density (cell/mL)	4	8	28	136	108	4	24	528	0
	Total chyrsophyta - Percent of total cell density	0.0	0.2	0.5	1.6	0.8	0.0	0.1	2.3	0.0
	Total chyrsophyta species	1	1	2	3	3	1	2	1	0

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm³/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	August 2014 sampling event								
		CWS-3	CWS-5S	CWS-6	CWS-7	CWS-5D	CWS-1	CWS-4S	CWS-4D	CWS-2
All	**Total biovolume (μm³/mL)**	**2,091,805**	**9,893,294**	**6,444,635**	**20,327,422**	**4,453,772**	**2,504,429**	**3,745,980**	**2,866,705**	**1,918,486**
Cyanobacteria	Total cyanobacteria biovolume (μm³/mL)	240,319	214,111	132,016	913,077	444,153	238,293	383,908	156,151	329,879
	Total cyanobacteria - Percent of total biovolume	11.5	2.2	2.0	4.5	10.0	9.5	10.2	5.4	17.2
Green algae	Total chlorophyta biovolume (μm³/mL)	474,601	447,860	234,648	4,877,496	2,192,074	620,292	765,666	644,792	595,472
	Total chlorophyta - Percent of total biovolume	22.7	4.5	3.6	24.0	49.2	24.8	20.4	22.5	31.0
Diatoms	Total bacillariophyta biovolume (μm³/mL)	891,749	212,043	309,034	406,657	174,567	1,078,340	547,010	1,417,386	575,707
	Total bacillariophyta - Percent of total biovolume	42.6	2.1	4.8	2.0	3.9	43.1	14.6	49.4	30.0
Euglenoids	Total euglenophyta biovolume (μm³/mL)	43,572	298,114	212,573	110,185	133,613	28,813	103,371	23,564	44,893
	Total euglenophyta - Percent of total biovolume	2.1	3.0	3.3	0.5	3.0	1.2	2.8	0.8	2.3
Dinoflagellates	Total pyrrhophyta biovolume (μm³/mL)	14,935	133,957	319,415	87,404	145,521	48,037	33,768	5,915	4,893
	Total pyrrhophyta - Percent of total biovolume	0.7	1.4	5.0	0.4	3.3	1.9	0.9	0.2	0.3
Cryptomonads	Total cryptophyta biovolume (μm³/mL)	406,127	624,129	1,006,245	94,289	623,179	454,029	799,284	596,218	346,674
	Total cryptophyta - Percent of total biovolume	19.4	6.3	15.6	0.5	14.0	18.1	21.3	20.8	18.1
Yellow-green algae	Total xanthophyta biovolume (μm³/mL)	0	7,845,604	4,184,323	13,602,897	523,041	0	1,049,495	0	0
	Total xanthophyta - Percent of total biovolume	0.0	79.3	64.9	66.9	11.7	0.0	28.0	0.0	0.0
Golden-brown algae	Total chrysophyta biovolume (μm³/mL)	12,607	66,536	30,462	159,879	61,854	36,625	52,224	17,968	14,600
	Total chrysophyta - Percent of total biovolume	0.6	0.7	0.5	0.8	1.4	1.5	1.4	0.6	0.8
All	**Total cell density (cell/mL)**	**24,360**	**17,864**	**7,752**	**26,372**	**25,364**	**31,692**	**40,728**	**28,436**	**34,732**
Cyanobacteria	Total cyanobacteria cell density (cell/mL)	18,208	13,468	4,772	20,636	20,800	25,476	32,076	22,544	27,432
	Total cyanobacteria - Percent of total cell density	74.7	75.4	61.6	78.2	82.0	80.4	78.8	79.3	79.0
	Number of cyanobacteria species	17	19	20	25	22	20	23	18	19
Green algae	Total chlorophyta cell density (cell/mL)	4,548	3,312	1,848	4,636	3,400	4,208	7,008	4,464	6,028
	Total chlorophyta - Percent of total cell density	18.7	18.5	23.8	17.6	13.4	13.3	17.2	15.7	17.4
	Total chlorophyta species	46	36	36	60	44	42	39	40	45
Diatoms	Total bacillariophyta cell density (cell/mL)	772	292	292	456	216	1,156	496	432	416
	Total bacillariophyta - Percent of total cell density	3.2	1.6	3.8	1.7	0.9	3.6	1.2	1.5	1.2
	Total bacillariophyta species	17	10	13	19	9	18	17	13	14

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	August 2014 sampling event—Continued								
		CWS-3	CWS-5S	CWS-6	CWS-7	CWS-5D	CWS-1	CWS-4S	CWS-4D	CWS-2
Euglenoids	Total euglenophyta cell density (cell/mL)	28	132	60	60	116	16	92	44	40
	Total euglenophyta - Percent of total cell density	0.1	0.7	0.8	0.2	0.5	0.1	0.2	0.2	0.1
	Total euglenophyta species	4	8	7	7	4	2	6	3	4
Dinoflagellates	Total pyrrhophyta cell density (cell/mL)	8	112	152	84	116	20	20	8	12
	Total pyrrhophyta - Percent of total cell density	0.0	0.6	2.0	0.3	0.5	0.1	0.0	0.0	0.0
	Total pyrrhophyta species	2	3	2	4	4	2	2	2	3
Cryptomonads	Total cryptophyta cell density (cell/mL)	756	360	536	76	464	800	852	920	788
	Total cryptophyta - Percent of total cell density	3.1	2.0	6.9	0.3	1.8	2.5	2.1	3.2	2.3
	Total cryptophyta species	2	2	2	3	2	2	2	2	2
Yellow-green algae	Total xanthophyta cell density (cell/mL)	0	60	32	132	4	0	28	0	0
	Total xanthophyta - Percent of total cell density	0.0	0.3	0.4	0.5	0.0	0.0	0.1	0.0	0.0
	Total xanthophyta species	0	1	1	4	1	0	2	0	0
Golden-brown algae	Total chyrsophyta cell density (cell/mL)	28	64	40	132	56	16	44	16	8
	Total chyrsophyta - Percent of total cell density	0.1	0.4	0.5	0.5	0.2	0.1	0.1	0.1	0.0
	Total chyrsophyta species	2	4	3	5	3	1	3	2	2

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	November 2014 sampling event						
		CWS-3	CWS-5S	CWS-6	CWS-7	CWS-1	CWS-4S	CWS-2
All	**Total biovolume (μm^3/mL)**	**3,005,689**	**10,067,049**	**4,832,269**	**41,701,849**	**2,180,416**	**3,588,782**	**1,730,482**
Cyanobacteria	Total cyanobacteria biovolume (μm^3/mL)	323,916	66,476	3,135	33,225	221,649	94,592	267,447
	Total cyanobacteria - Percent of total biovolume	10.8	0.7	0.1	0.1	10.2	2.6	15.5
Green algae	Total chlorophyta biovolume (μm^3/mL)	1,021,254	453,660	110,352	351,832	453,740	1,490,249	516,295
	Total chlorophyta - Percent of total biovolume	34.0	4.5	2.3	0.8	20.8	41.5	29.8
Diatoms	Total bacillariophyta biovolume (μm^3/mL)	765,042	377,652	193,402	654,593	965,142	450,341	798,486
	Total bacillariophyta - Percent of total biovolume	25.5	3.8	4.0	1.6	44.3	12.5	46.1
Euglenoids	Total euglenophyta biovolume (μm^3/mL)	52,872	123,701	26,678	81,657	42,571	14,732	7,235
	Total euglenophyta - Percent of total biovolume	1.8	1.2	0.6	0.2	2.0	0.4	0.4
Dinoflagellates	Total pyrrhophyta biovolume (μm^3/mL)	819,939	460,964	19,875	70,137	398,935	9,945	16,385
	Total pyrrhophyta - Percent of total biovolume	27.3	4.6	0.4	0.2	18.3	0.3	0.9
Cryptomonads	Total cryptophyta biovolume (μm^3/mL)	11,071	683,768	284,732	598,258	35,022	432,987	109,949
	Total cryptophyta - Percent of total biovolume	0.4	6.8	5.9	1.4	1.6	12.1	6.4
Yellow-green algae	Total xanthophyta biovolume (μm^3/mL)	0	7,845,755	4,184,323	39,755,749	2,344	1,046,764	2,344
	Total xanthophyta - Percent of total biovolume	0.0	77.9	86.6	95.3	0.1	29.2	0.1
Golden-brown algae	Total chrysophyta biovolume (μm^3/mL)	1,150	47,920	5,219	137,344	53,118	39,620	9,157
	Total chrysophyta - Percent of total biovolume	0.0	0.5	0.1	0.3	2.4	1.1	0.5
All	**Total cell density (cell/mL)**	**36,625**	**11,188**	**2,785**	**11,564**	**47,164**	**22,288**	**41,090**
Cyanobacteria	Total cyanobacteria cell density (cell/mL)	34,984	6,868	1,557	6,568	42,200	17,380	35,252
	Total cyanobacteria - Percent of total cell density	95.5	61.4	55.9	56.8	89.5	78.0	85.8
	Number of cyanobacteria species	20	21	10	14	26	20	23
Green algae	Total chlorophyta cell density (cell/mL)	1,340	3,012	661	3,348	4,300	3,336	5,032
	Total chlorophyta - Percent of total cell density	3.7	26.9	23.7	29.0	9.1	15.0	12.2
	Total chlorophyta species	35	45	30	35	40	34	42
Diatoms	Total bacillariophyta cell density (cell/mL)	157	340	220	688	496	448	640
	Total bacillariophyta - Percent of total cell density	0.4	3.0	7.9	5.9	1.1	2.0	1.6
	Total bacillariophyta species	15	11	11	12	15	20	15

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	November 2014 sampling event—Continued						
		CWS-3	CWS-5S	CWS-6	CWS-7	CWS-1	CWS-4S	CWS-2
Euglenoids	Total euglenophyta cell density (cell/mL)	40	72	20	56	64	20	2
	Total euglenophyta - Percent of total cell density	0.1	0.6	0.7	0.5	0.1	0.1	0.0
	Total euglenophyta species	4	6	4	5	4	2	1
Dinoflagellates	Total pyrrhophyta cell density (cell/mL)	24	48	15	44	8	16	8
	Total pyrrhophyta - Percent of total cell density	0.1	0.4	0.5	0.4	0.0	0.1	0
	Total pyrrhophyta species	3	4	3	3	2	2	2
Cryptomonads	Total cryptophyta cell density (cell/mL)	36	664	259	448	56	1,024	144
	Total cryptophyta - Percent of total cell density	0.1	5.9	9.3	3.9	0.1	4.6	0.4
	Total cryptophyta species	3	2	4	4	3	3	2
Yellow-green algae	Total xanthophyta cell density (cell/mL)	0	128	26	312	4	12	4
	Total xanthophyta - Percent of total cell density	0.0	1.1	0.9	2.7	0.0	0.1	0
	Total xanthophyta species	0	2	1	2	1	2	1
Golden-brown algae	Total chyrsophyta cell density (cell/mL)	8	36	18	60	24	40	4
	Total chyrsophyta - Percent of total cell density	0.0	0.3	0.6	0.5	0.1	0.2	0.0
	Total chyrsophyta species	1	4	2	1	4	3	1

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[$\mu m^3/mL$, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	December 2014 sampling event					
		CWS-3	CWS-5	CWS-6	CWS-7	CWS-1	CWS-4
All	**Total biovolume ($\mu m^3/mL$)**	**1,791,153**	**1,492,494**	**1,155,746**	**1,011,972**	**1,098,670**	**1,606,522**
Cyanobacteria	Total cyanobacteria biovolume ($\mu m^3/mL$)	23,527	146,979	7,161	15,786	29,765	7,610
	Total cyanobacteria - Percent of total biovolume	1.3	9.8	0.6	1.6	2.7	0.5
Green algae	Total chlorophyta biovolume ($\mu m^3/mL$)	511,526	100,201	110,972	53,445	300,747	405,035
	Total chlorophyta - Percent of total biovolume	28.6	6.7	9.6	5.3	27.4	25.2
Diatoms	Total bacillariophyta biovolume ($\mu m^3/mL$)	904,702	246,773	172,544	324,137	453,017	450,341
	Total bacillariophyta - Percent of total biovolume	50.5	16.5	14.9	32.0	41.2	28.0
Euglenoids	Total euglenophyta biovolume ($\mu m^3/mL$)	17,853	40,190	0	9,597	0	8,060
	Total euglenophyta - Percent of total biovolume	1.0	2.7	0	0.9	0	32.3
Dinoflagellates	Total pyrrhophyta biovolume ($\mu m^3/mL$)	9,815	12,145	13,050	0	2,015	18,903
	Total pyrrhophyta - Percent of total biovolume	0.5	0.8	1.1	0	0.2	1.2
Cryptomonads	Total cryptophyta biovolume ($\mu m^3/mL$)	310,986	927,631	827,934	598,258	307,273	518,184
	Total cryptophyta - Percent of total biovolume	17.4	62.2	71.6	59.1	28.0	32.3
Yellow-green algae	Total xanthophyta biovolume ($\mu m^3/mL$)	0	0	0	0	0	0
	Total xanthophyta - Percent of total biovolume	0	0	0	0	0	0
Golden-brown algae	Total chrysophyta biovolume ($\mu m^3/mL$)	12,482	18,313	24,085	9,157	5,853	23,166
	Total chrysophyta - Percent of total biovolume	0.7	1.2	2.1	0.9	0.5	1.4
All	**Total cell density (cell/mL)**	**34,396**	**4,484**	**3,260**	**2,006**	**43,336**	**13,856**
Cyanobacteria	Total cyanobacteria cell density (cell/mL)	29,116	1,040	392	1,002	39,748	9,360
	Total cyanobacteria - Percent of total cell density	84.6	23.2	12.0	50.0	91.7	67.6
	Number of cyanobacteria species	10	8	3	8	11	7
Green algae	Total chlorophyta cell density (cell/mL)	3,784	556	752	478	2,548	2,412
	Total chlorophyta - Percent of total cell density	11.0	12.4	23.1	23.8	1.2	17.4
	Total chlorophyta species	32	30	29	25	37	32
Diatoms	Total bacillariophyta cell density (cell/mL)	832	228	204	290	528	560
	Total bacillariophyta - Percent of total cell density	2.4	5.1	6.3	14.5	1.2	4.0
	Total bacillariophyta species	14	10	11	12	14	16

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	December 2014 sampling event—Continued					
		CWS-3	CWS-5	CWS-6	CWS-7	CWS-1	CWS-4
Euglenoids	Total euglenophyta cell density (cell/mL)	8	12	0	8	0	4
	Total euglenophyta - Percent of total cell density	0	0.3	0	0.4	0	0
	Total euglenophyta species	2	2	0	4	0	1
Dinoflagellates	Total pyrrhophyta cell density (cell/mL)	12	4	8	0	4	16
	Total pyrrhophyta - Percent of total cell density	0	0.1	0.2	0	0	0.1
	Total pyrrhophyta species	2	1	2	0	1	4
Cryptomonads	Total cryptophyta cell density (cell/mL)	624	2,632	1,884	222	504	1,480
	Total cryptophyta - Percent of total cell density	1.8	58.7	57.8	11.1	1.2	10.7
	Total cryptophyta species	4	4	4	4	4	4
Yellow-green algae	Total xanthophyta cell density (cell/mL)	0	0	0	0	0	0
	Total xanthophyta - Percent of total cell density	0	0	0	0	0	0
	Total xanthophyta species	0	0	0	0	0	0
Golden-brown algae	Total chyrsophyta cell density (cell/mL)	16	8	20	4	4	20
	Total chyrsophyta - Percent of total cell density	0.0	0.2	0.6	0.2	0	0.1
	Total chyrsophyta species	3	1	3	1	1	3

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[$\mu m^3/mL$, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	April 2015 sampling event			
		CWS-5S	Edisto River	Bushy Park Tunnel	Charleston Water System raw blended water
All	**Total biovolume ($\mu m^3/mL$)**	**3,778,786**	**128,031**	**363,270**	**764,031**
Cyanobacteria	Total cyanobacteria biovolume ($\mu m^3/mL$)	1,226,257	423	42,352	101,403
	Total cyanobacteria - Percent of total biovolume	32.5	0.3	11.7	13.3
Green algae	Total chlorophyta biovolume ($\mu m^3/mL$)	293,966	2,862	92,440	75,104
	Total chlorophyta - Percent of total biovolume	7.8	2.2	25.4	9.8
Diatoms	Total bacillariophyta biovolume ($\mu m^3/mL$)	1,221,272	93,583	174,278	318,386
	Total bacillariophyta - Percent of total biovolume	32.3	73.1	48.0	41.7
Euglenoids	Total euglenophyta biovolume ($\mu m^3/mL$)	22,852	2,348	3,232	0
	Total euglenophyta - Percent of total biovolume	0.6	1.8	0.9	0.0
Dinoflagellates	Total pyrrhophyta biovolume ($\mu m^3/mL$)	35,988	21,253	12,145	12,124
	Total pyrrhophyta - Percent of total biovolume	1.0	16.6	3.3	1.6
Cryptomonads	Total cryptophyta biovolume ($\mu m^3/mL$)	637,736	7,562	38,823	197,118
	Total cryptophyta - Percent of total biovolume	16.9	5.9	10.7	25.8
Yellow-green algae	Total xanthophyta biovolume ($\mu m^3/mL$)	1,366	0	0	1,366
	Total xanthophyta - Percent of total biovolume	0.0	0.0	0.0	0.2
Golden-brown algae	Total chrysophyta biovolume ($\mu m^3/mL$)	114,657	0	0	58,530
	Total chrysophyta - Percent of total biovolume	3.0	0.0	0.0	7.7
All	**Total cell density (cell/mL)**	**9,504**	**188**	**1,844**	**1,942**
Cyanobacteria	Total cyanobacteria cell density (cell/mL)	5,912	143	816	836
	Total cyanobacteria - Percent of total cell density	62.2	76.1	44.3	43.0
	Number of cyanobacteria species	6	2	4	8
Green algae	Total chlorophyta cell density (cell/mL)	1,692	22	708	683
	Total chlorophyta - Percent of total cell density	17.8	11.7	38.4	35.2
	Total chlorophyta species	22	3	10	21
Diatoms	Total bacillariophyta cell density (cell/mL)	1,008	8	276	263
	Total bacillariophyta - Percent of total cell density	10.6	4.3	15.0	13.5
	Total bacillariophyta species	11	4	7	6

Table 12. Summary of phytoplankton taxonomic data by major algal group as biovolume and cell density for selected locations in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[μm^3/mL, cubic micrometer per milliliter; cell/mL, cells per milliliter)

Algal group	Phytoplankton metric	April 2015 sampling event—Continued			
		CWS-5S	Edisto River	Bushy Park Tunnel	Charleston Water System raw blended water
Euglenoids	Total euglenophyta cell density (cell/mL)	36	4	12	0
	Total euglenophyta - Percent of total cell density	0.4	2.1	0.7	0.0
	Total euglenophyta species	2	2	1	0
Dinoflagellates	Total pyrrhophyta cell density (cell/mL)	20	7	4	4
	Total pyrrhophyta - Percent of total cell density	0.2	3.7	0.2	0.2
	Total pyrrhophyta species	2	1	1	1
Cryptomonads	Total cryptophyta cell density (cell/mL)	356	4	28	108
	Total cryptophyta - Percent of total cell density	3.7	2.1	1.5	5.6
	Total cryptophyta species	3	2	3	2
Yellow-green algae	Total xanthophyta cell density (cell/mL)	8	0	0	8
	Total xanthophyta - Percent of total cell density	0.1	0	0	0.4
	Total xanthophyta species	1	0	0	1
Golden-brown algae	Total chyrsophyta cell density (cell/mL)	100	0	0	40
	Total chyrsophyta - Percent of total cell density	1.1	0.0	0.0	2.1
	Total chyrsophyta species	2	0	0	1

Appendixes 1–5

Appendix 1. Operation and data processing of the EcoMapper Iver2 autonomous underwater vehicle

Multiple water-quality surveys of Bushy Park Reservoir were completed using the EcoMapper Iver2 autonomous underwater vehicle (AUV) built by Yellow Springs Instrument (YSI), Inc., and OceanServer Technology, Inc. (fig. 1–1). The AUV can cost-effectively collect spatially dense water-quality, bathymetric, and side-scan sonar data by surveying large areas in minimal time compared to traditional, manned boat surveys and sampling. The description and operation of the AUV and the post-processing of the data are well documented in Jackson (2013a), and much of the information presented in this appendix comes from that report.

Description of the EcoMapper Iver2

The AUV is composed of an aluminum hull with carbon-fiber nose and tail sections (fig. 1–1). The nose of the AUV houses a V2-4 YSI sonde bulkhead with four optical ports and temperature/conductivity and pH ports. A pressure sensor also is integrated into the sonde bulkhead for measurement of the sample depth. Aft of the sensor suite on the nose of the vehicle is the Doppler velocimetry log (DVL) instrument. The DVL is a six-beam system for underwater navigation (bottom tracking) and includes vertical beams (uplooking and downlooking) for altitude and depth measurement. Additionally, the DVL provides current-profiling capabilities below the instrument. The tail is composed of four independent control fins and a three-blade propeller. Atop the vehicle near the tail section is the antennae mast, which houses a differential Global Positioning System (GPS) antenna (Wide Area Augmentation System corrected), a wireless radio antenna that operates with a 802.11g wireless networking standard at 2.4 gigahertz, the navigation lights, and an external power plug for vehicle charging. All communication with the vehicle is through the wireless Ethernet radio link. Onboard electronics include an embedded computer running Windows XP and an 80 gigabyte hard drive for data storage. The aft section of the body also houses the integrated Imagenex side-scan sonar transducers, mounted on the port and starboard sides of the vehicle just forward of the tail section.

The water-quality sensor suite is composed of a YSI 6600 V2-4 bulkhead equipped with a YSI 6560FR fast response temperature/conductivity probe, a YSI 6589FR fast response pH sensor, a YSI 6150FR fast response ROX optical dissolved-oxygen sensor, a YSI 6136 turbidity sensor, a YSI 6025 chlorophyll sensor, and a YSI 6131 BGA-PC phycocyanin (blue-green algae) sensor. Manufacturer's specifications for each of the probes are given in table 4 (main text of report). All water-quality sensors are sampled at a rate of 1 hertz (Hz).

The six-beam DVL system aboard the AUV is composed of four 1-megahertz (MHz) beams oriented vertically at a 25-degree angle with acoustic beam widths of 3.5 degrees (YSI, Inc., 2011). The additional two 500-kilohertz (kHz) beams are oriented vertically, one uplooking and one downlooking, for range-to-surface and range-to-bed measurements, respectively. The vertical beams have a beam width of 5 degrees, a range of 0.82 foot (ft; 0.25 meter [m]) to 262 ft (80 m), an accuracy of 1 percent of measured range, and a resolution of 0.01 m. The DVL has an internal sampling

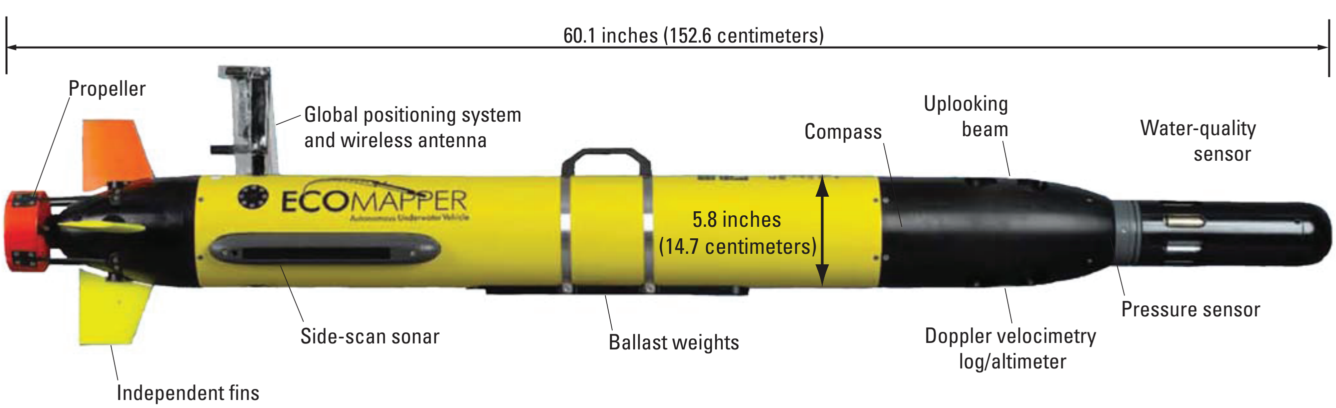

Figure 1–1. Diagram of the EcoMapper Iver2 with components labeled (modified from YSI, Inc., 2010; modified from Jackson, 2013a, b).

rate of up to 70 Hz depending on the configuration, but DVL data are averaged and reported at 1 Hz to the AUV onboard computer. Manufacturer's specifications report the bottom-tracking range of the DVL to be 0.16 ft (0.05 m) to 98 ft (30 m), the current profiling velocity range of ±32.8 feet per second (ft/s) (±10 meters per second [m/s]) with an accuracy of ±0.0066 ft/s (±0.2 centimeter per second [cm/s]) or 0.25 percent of measured profile velocity, and a resolution of 0.032 ft/s (0.01 m/s). The minimum cell size for the DVL profiling is 0.82 ft (0.25 m), and the maximum number of cells is 128.

In addition to the DVL, the AUV has several other integrated sensors to aid in navigation. A three-axis digital compass is integrated into the vehicle as is a second pressure sensor. The compass is required for underwater navigation with the DVL and when using dead reckoning. Additionally, the compass is required for proper alignment of velocity data from the DVL. The second pressure sensor is used for navigation of the vehicle and provides depth measurements redundant to the YSI bulkhead pressure sensor and the uplooking vertical beam. According to the manufacturer, the vehicle pressure sensor has a range of 200 ft (61 m), accuracy of ±0.02 ft (0.006 m), and resolution of 0.001 ft. Finally, the AUV is equipped with a 75-kHz acoustic pinger for location of the vehicle by using a hydrophone from a manned boat. Acoustic images of the bed are obtained by using the integrated Imagenex 330/800 kHz side-scan sonar. Two dual-frequency transducers are mounted on the vehicle near the tail (one on each side) and are angled down at 20 degrees. The range of the sonar is 49 ft (15 m) to 394 ft (120 m) and is user configurable. Resolution of the sonar is computed as the range scale divided by 250 (or 500 if only operating one transducer).

Pre-Deployment Planning

The EcoMapper AUV performs autonomous surveys of water bodies and when properly programmed requires no assistance during execution of the survey. Programming a survey involves obtaining a high-resolution georeferenced aerial photograph of the water body and determining locations of any potential obstructions (from initial reconnaissance). The aerial imagery and obstructions information are then imported into Vector Map (Vector Map, 2015), the primary programming software for the AUV, and used as a background for survey planning. Within Vector Map, the user creates missions (surveys) by generating a field of numbered waypoints for the AUV to visit. The points are numbered sequentially, and the AUV will follow the set order, executing commands at each waypoint. Each waypoint has a set of associated commands, including dive mode, speed, dive angle, depth or height above bottom, sonar settings, and park commands. Dive mode options include (1) constant depth, where the AUV will achieve and maintain a specific depth below the surface by using its redundant-pressure sensors and vertical uplooking beam; (2) constant height above bottom, where the AUV will maintain a specified height above the bed by using its vertical downlooking beam; and (3) undulate, where the vehicle will undulate between two depths (or a combination of a depth and height above bottom) at a specified dive angle (fig. 1–2). The speed command sets the speed over ground of the AUV and is limited to 2.5 knots at the surface and 4 knots underwater. Sonar settings can be adjusted for each waypoint and include the range, gain, frequency, and transducer configuration (single-side or both sides). Lastly, park commands can be issued at any waypoint to force the vehicle to park on the surface at a waypoint and actively maintain that position for a specified period of time. Park commands generally are issued at the end of a mission, at a specified meeting point with the manned boat, for recovery of the AUV. The AUV executes the waypoint commands of the destination waypoint and transitions to the next set of commands after entering the waypoint success radius (user defined) of the destination waypoint. Once the mission is programmed in Vector Map, the mission is transferred to the AUV via the wireless connection as a text-based mission file (*.mis).

Execution of an EcoMapper survey begins with the loading of a mission into the underwater vehicle console (UVC), the onboard control program of the AUV. The UVC decodes the mission command file and controls the AUV sensors, navigation, and propulsion to execute each of the sequential commands. Prior to deployment, the user sets the safety settings within the UVC (settings that allow the AUV to abort a mission if necessary) and loads a safe return path (SRP) file if necessary. (The SRP is a mission file that will execute only upon abortion of the survey mission.) The goal of the SRP is to bring the AUV back to land safely in the event of a system malfunction.

The AUV is placed in the water and checked for proper ballasting (adjustments are made if necessary), and the pressure sensors are zeroed. Internal checks of the GPS receiver, altimeter, and compass also are completed in addition to response checks of all water-quality sensors, DVL system, and the navigation and propulsion systems. If all systems are functional, the mission is started by the UVC, via the wireless connection, with a remote computer aboard the manned boat. The AUV then begins to navigate to each of the programmed waypoints, in sequential order, executing the waypoint commands along the way. All data are recorded to files and stored on the internal hard drive aboard the AUV. Upon completing the mission, the AUV is retrieved at the meeting point, disabled remotely, and recovered by hand. Once onboard, data files are recovered via the wireless network connection, and a new mission is loaded (if necessary). Should the AUV fail to arrive at the meeting point at the scheduled time, the operators should check the beaching point in the SRP to determine if the AUV aborted the mission and returned to shore. If the AUV aborts the mission for any reason, the data files contain a set of error codes that explain the reason.

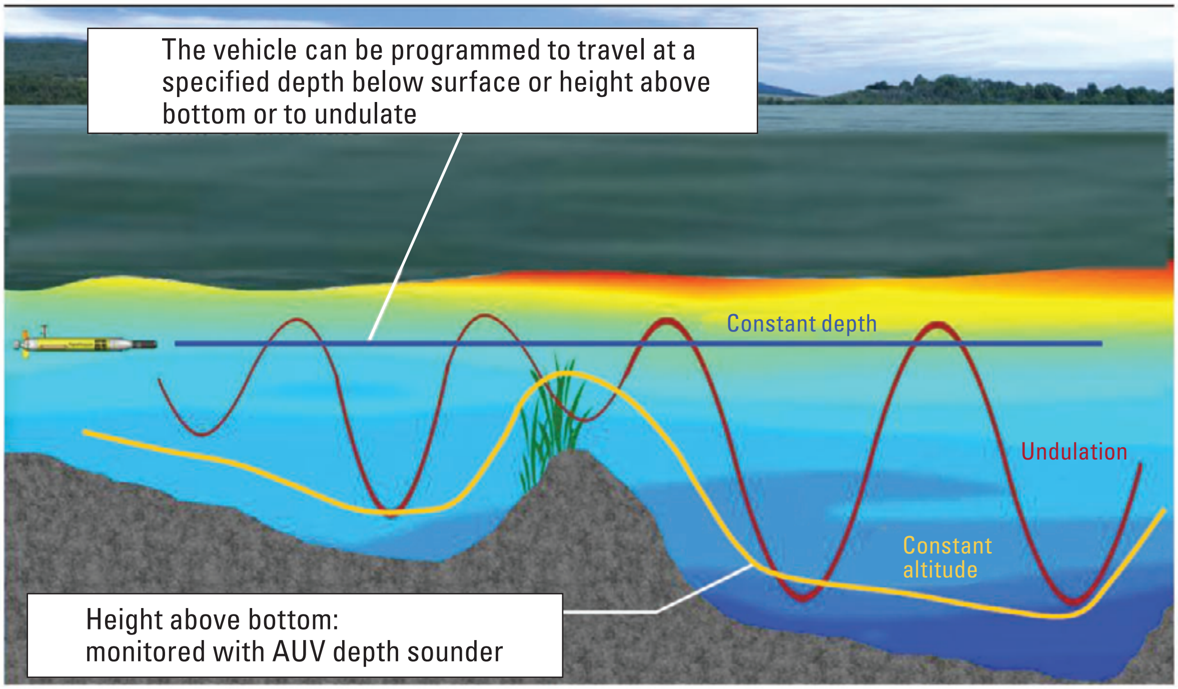

Figure 1–2. Schematic showing three survey modes (constant depth, constant altitude, and undulation) for the autonomous underwater vehicle. Modified from Jackson, 2013b).

Calibration of the EcoMapper Sensors

Calibration check and re-calibration procedures were conducted on all water-quality sensors prior to and after deployment according to procedures outlined by YSI and the U.S. Geological Survey (USGS) National Field Manual (YSI, Inc., 2011; Wilde, variously dated; respectively). When possible, calibrations were done in the controlled environment of a laboratory. The AUV thermistor is not user calibrated, but rather is periodically checked for accuracy against a National Institute of Standards and Technology-certified thermometer in a thermal bath over a range of temperatures. Typically, the chlorophyll and blue-green algae sensors are calibrated (zeroed) in deionized water by using a one-point calibration method. The one-point calibration method results in relative chlorophyll and blue-green algae distributions rather than absolute concentrations. If absolute concentrations are required by the project, the sensors are post-calibrated with a second point by using samples collected in the field in close proximity to the AUV during data collection and analyzed by a qualified laboratory.

Calibration of the vehicle compass was achieved by running an in-water compass calibration mission composed of four survey sweeps. Each sweep consisted of six 400-ft underwater legs (three in each direction) at a depth of 7 ft below the surface. Each of the four sweeps was run at a different orientation (north-south, east-west, northeast-southwest, and northwest-southeast). Navigational errors between the actual and computed position of the vehicle were monitored and used to generate a compass-deviation table. The deviation table is composed of compass errors at different headings and was used in real time during subsequent missions to correct the compass heading on the fly. According to the manufacturer, a properly calibrated compass can reduce underwater offline drift (drift equals accumulated error) to 0.5 percent of the underwater run length (5 ft drift for 1,000 ft underwater run). Based on past experience, field calibrations have produced underwater drift errors of approximately 1 percent of the underwater run. Because the underwater mission paths were shorter than what the manufacturer recommended, mission underwater run lengths were reduced to keep drift low. Following USGS calibration guidelines, within 24 hours after the deployment, the water-quality sensors on the AUV were rechecked for fouling and electronic drift. Sensor drift due to fouling was not an issue because of the short period of time the AUV was submerged.

EcoMapper Post-Deployment Data Processing

Raw data files from the AUV include a LOG file (*.log) consisting of georeferenced and time-stamped data from the AUV and onboard sensors in a semicolon-delimited data format. Data include navigation data (waypoint number, speed, heading, depth, altitude, latitude, longitude), vehicle data (pitch, roll, yaw, prop speed, fin settings, dive angle), bathymetry data (water-column depth), and water-quality data (temperature, specific conductance, pH, dissolved oxygen, turbidity) from the installed sensors. All data in the LOG file are recorded at a sampling rate of 1 Hz.

In addition to the LOG file, the AUV creates DVL (*.dvl) and PFD (*.pfd) data files. The DVL file contains time-stamped series of vehicle position and DVL output. The DVL outputs in this file are related to distance traveled, speed, and range to bottom. In addition, this file contains bottom-track quality indicators to assess quality of the bottom-track data. The PFD data files contain water-velocity profile data as measured by the DVL below the instrument. The velocities contained in this file are organized by cell, or range from the transducers, and have not been corrected for depth or speed of the instrument, heading, pitch, or roll. Therefore, these files contain a very basic form of the velocity-profile data and must be post-processed to obtain meaningful, georeferenced, water-velocity data.

All data are post-processed by using a suite of custom Matlab scripts. This process is detailed in figure 1–3. The processing begins with applying corrections to position and depth. Corrections to the positional data include correction of the vehicle track for underwater drift during dives. Drift generally is induced by compass error or improper calibration and is identified by screening the vehicle track for jumps in position greater than 5 m in 1 second. Jumps generally will occur when the vehicle surfaces and corrects its position on the basis of GPS data in its track log. Any identified underwater drift is corrected by applying a linear correction between the dive point and the surface point assuming a constant heading and speed. Following the drift correction, a depth correction is applied to the total water column depth to account for the offset of the downlooking vertical beam from the water surface. The time-series data are plotted and then screened manually to identify outliers and remove them from the dataset (fig. 1–4*A* and 1–4*B*). Outliers are identified as individual measurements made at a 1-second interval that have large deviations from the surrounding points (spikes) that are uncharacteristic of a natural system in which shape gradients are normally smoothed by turbulence and diffusion. Once all outliers have been removed, the user has the option to smooth the time-series data for each variable independently (fig. 1–4*C*). This process generally is applied only to turbidity,

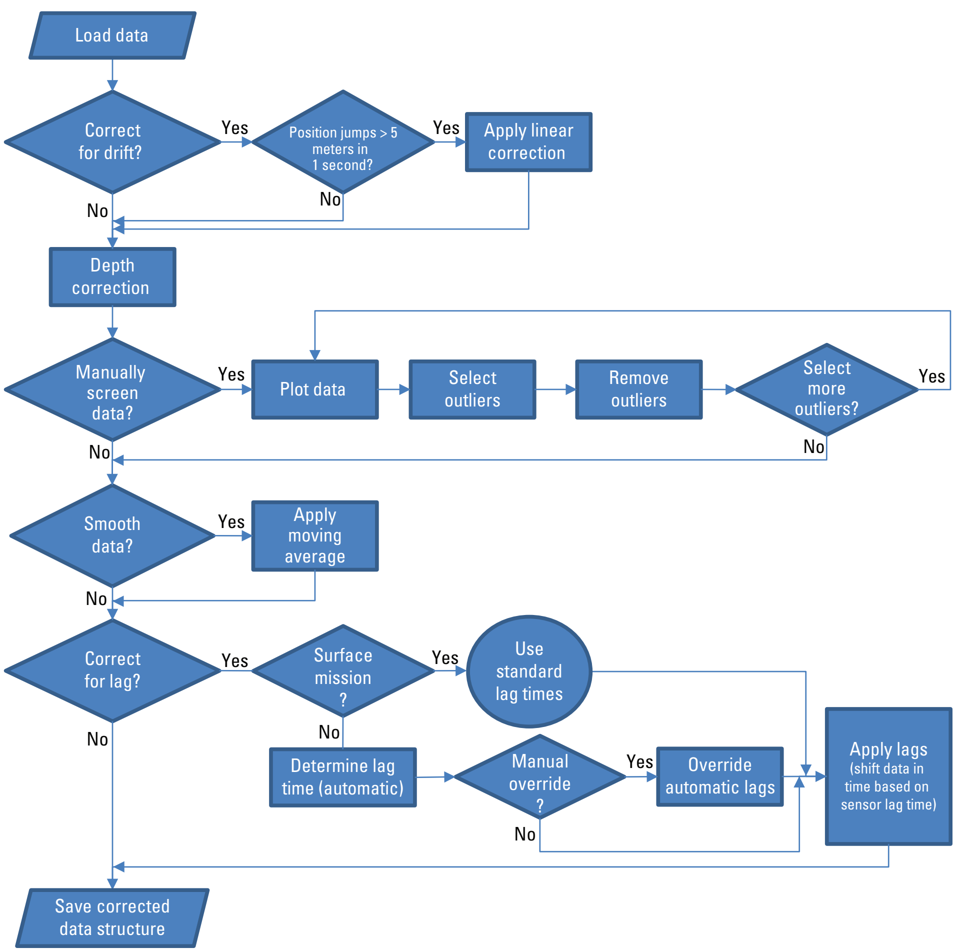

Figure 1–3. Data processing algorithm for LOG files from the autonomous underwater vehicle From Jackson (2013a). [>, greater than]

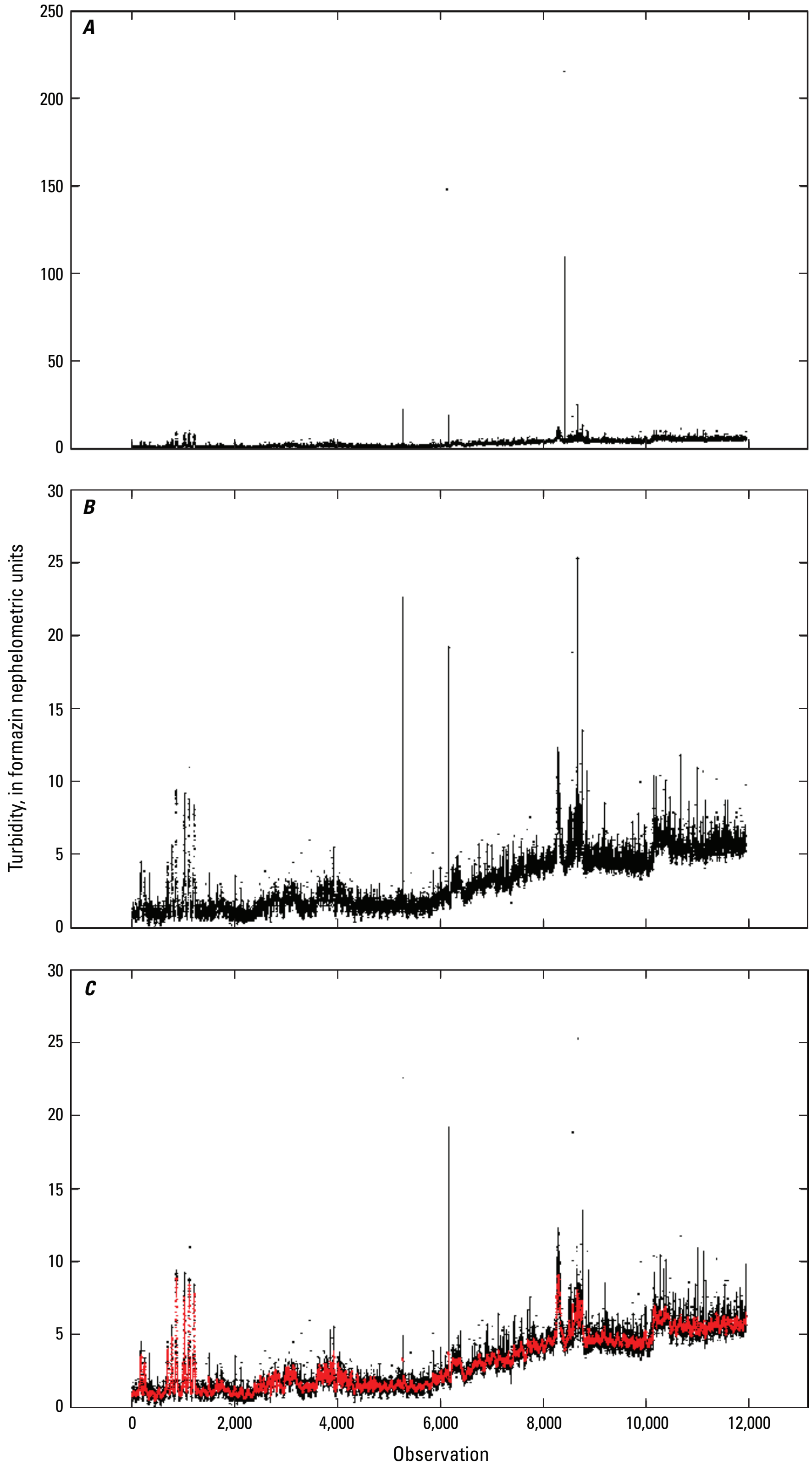

Figure 1–4. Data processing steps: (*A*) original data, (*B*) outliers removed, and (*C*) smoothed time-series data. Note scale change between plots *A* and *B*.

chlorophyll, and blue-green algae data, as these data tend to be noisy. During smoothing, a moving average is applied to the data with a user-defined window size. The user, through an iterative process, chooses the window size such that noise is minimized, yet true oscillations of the dataset are maintained.

The final step, if required, in this processing routine is to apply temporal lags to measurements made by each water-quality sensor to account for lags in the sensor response time. Standard lag times have been provided by YSI on the basis of laboratory tests of response time; however, the processing code also determines an empirical lag for each sensor when vertical profile data are available from diving missions. To determine these lag constants, the data for each sensor are plotted as a function of depth, and the variance of the data cloud is computed. Because a lag in the sensor response time will lead to larger variance in a sensor for a given depth, the code seeks to minimize the variance in the sensor by applying a range of lag times to the data and recomputing the variance at each step. The lag time that produces the minimum variance in the vertical profile of each sensor is chosen as the suggested lag time. The user can then override the computed lag times with manual entries of standard values. Once lag times are determined, each sensor is shifted in time by the appropriate lag time. Standard lag times for each of the sensors are given in table 4 (main text of report). The corrected dataset is then saved as a Matlab data structure, which can be used as input for additional processing and visualization scripts.

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Appendix 2. Plots showing 2D longitudinal profiles for seven parameters for 16 autonomous underwater vehicle water-quality surveys

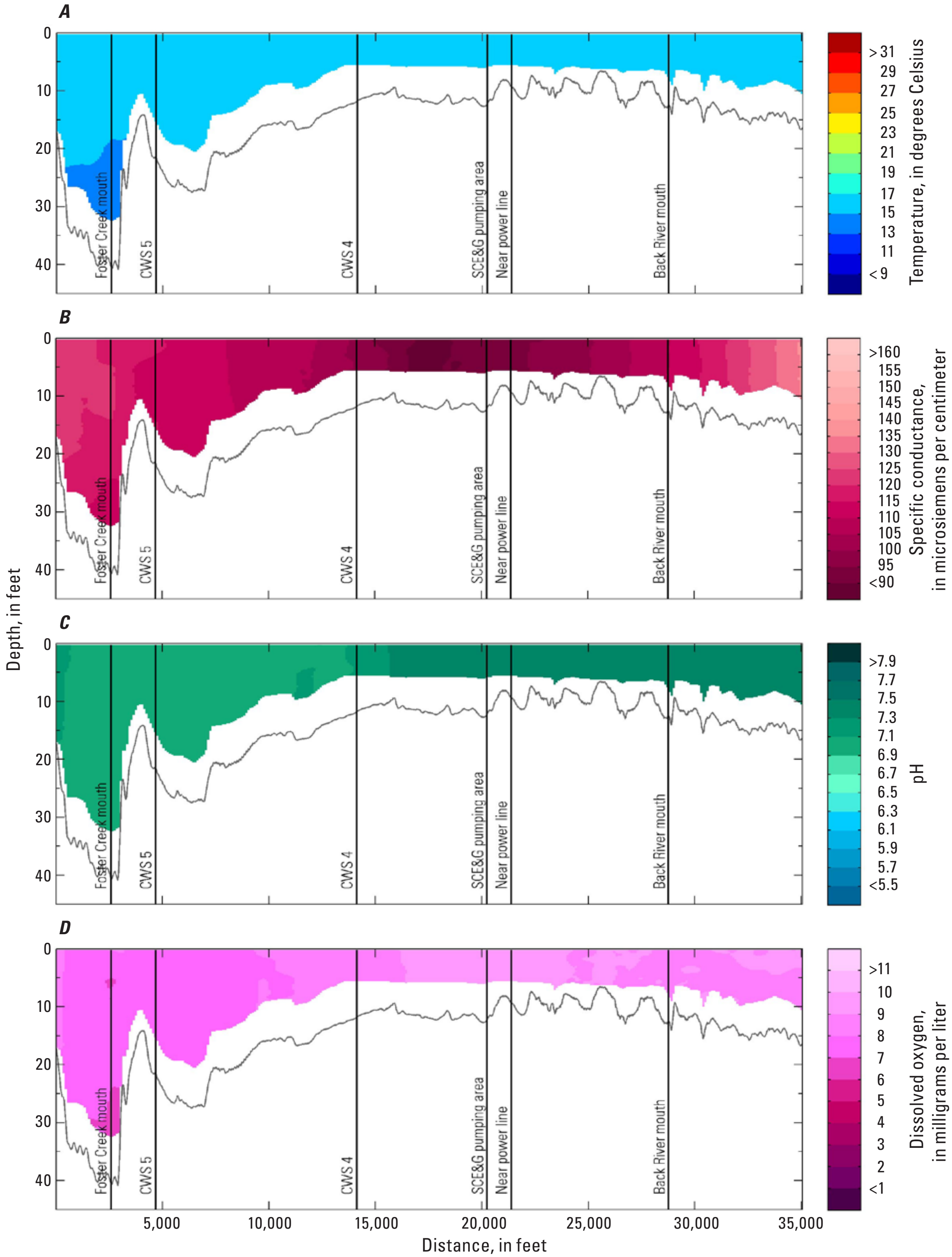

Figure 2–1. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, November 11, 2013.

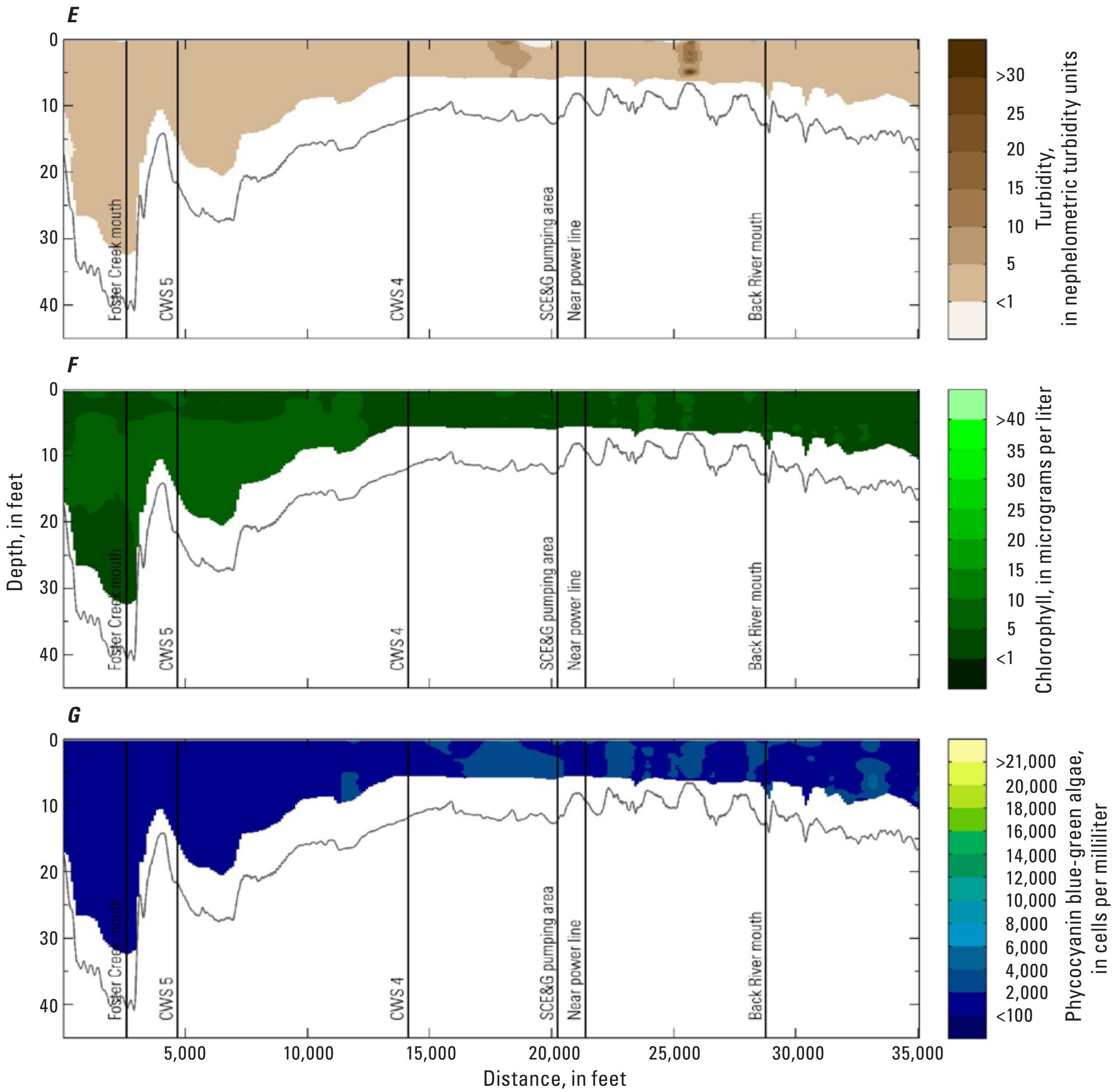

Figure 2–1. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, November 11, 2013.

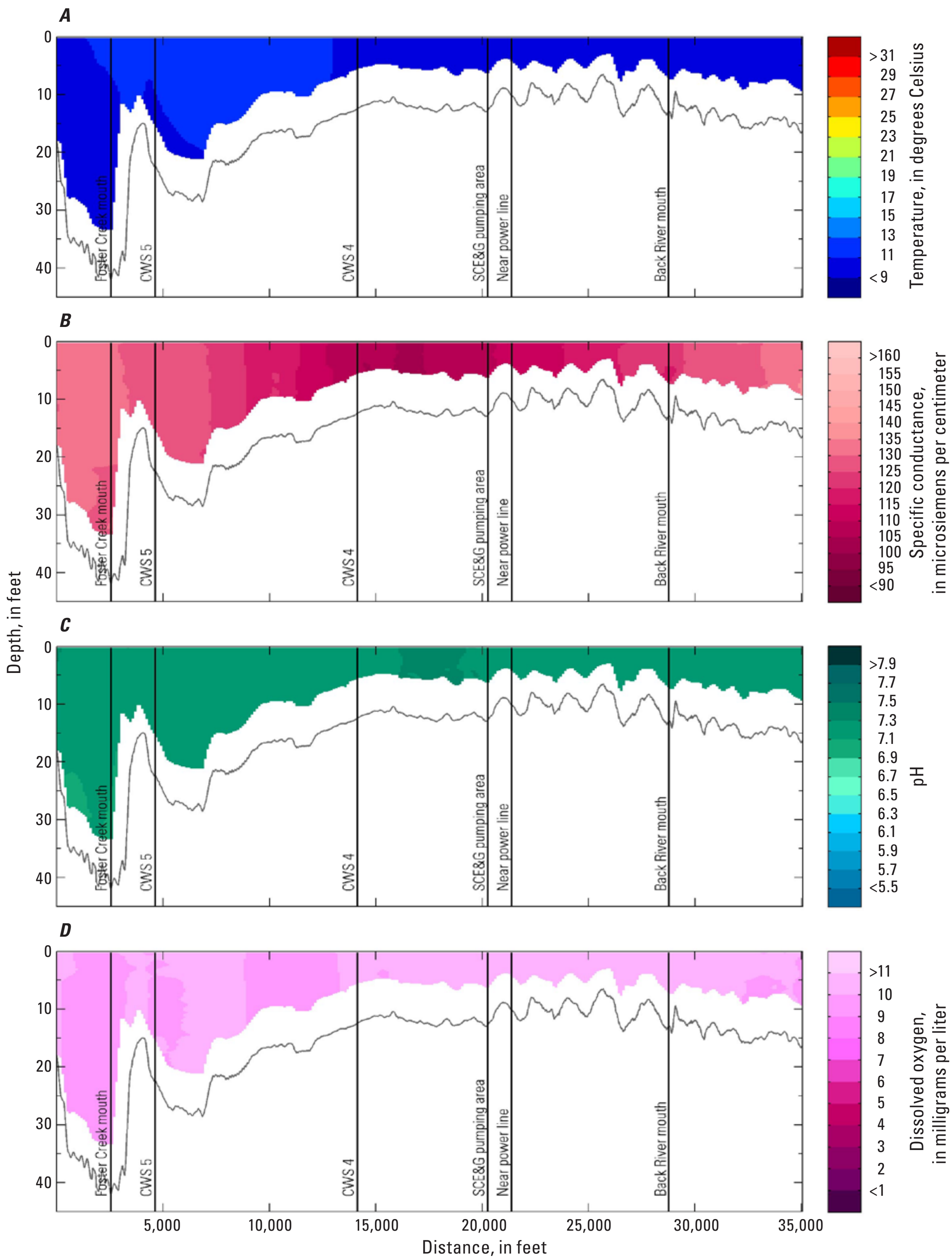

Figure 2–2. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, January 14, 2014.

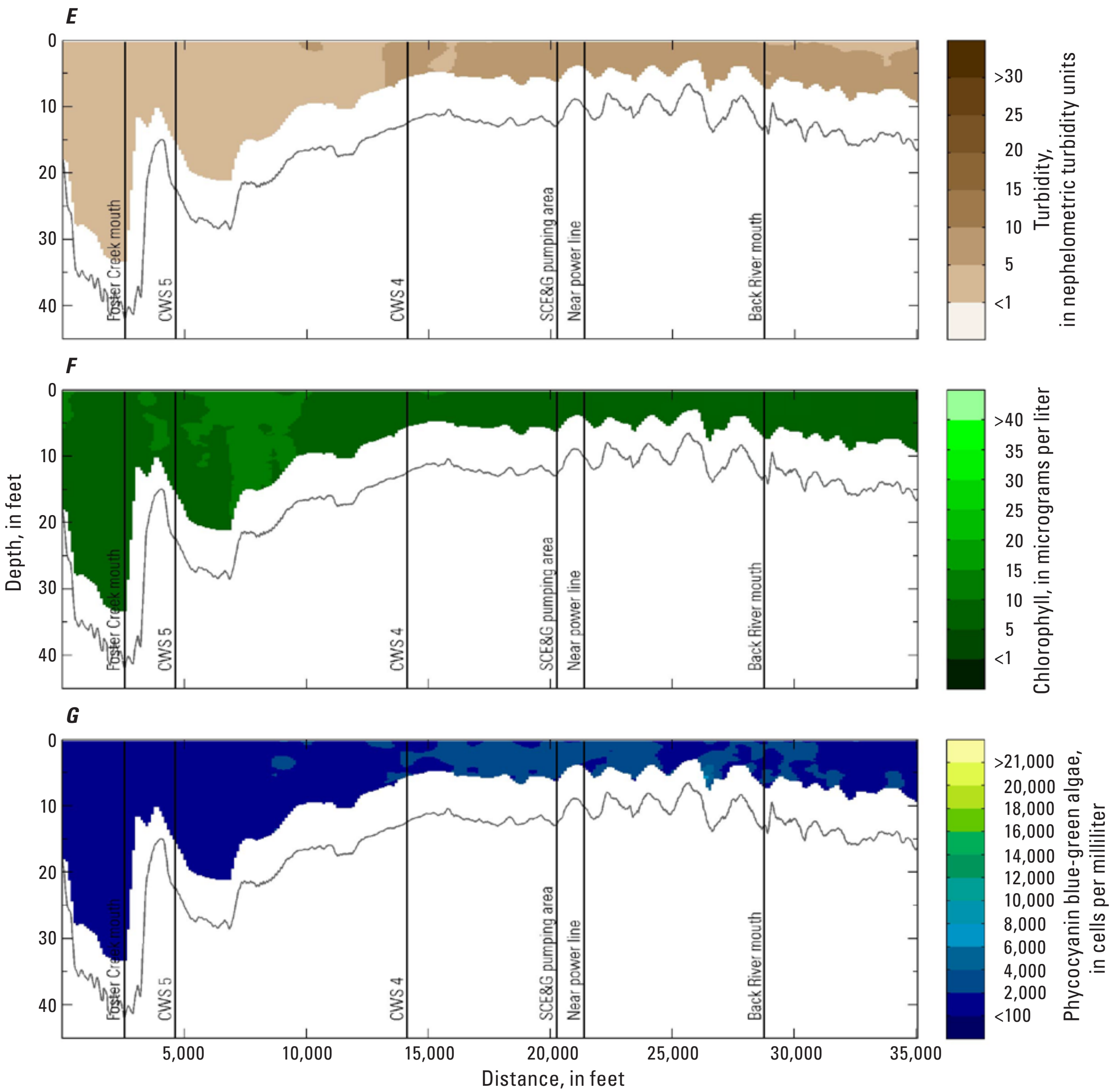

Figure 2–2. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, January 14, 2014.

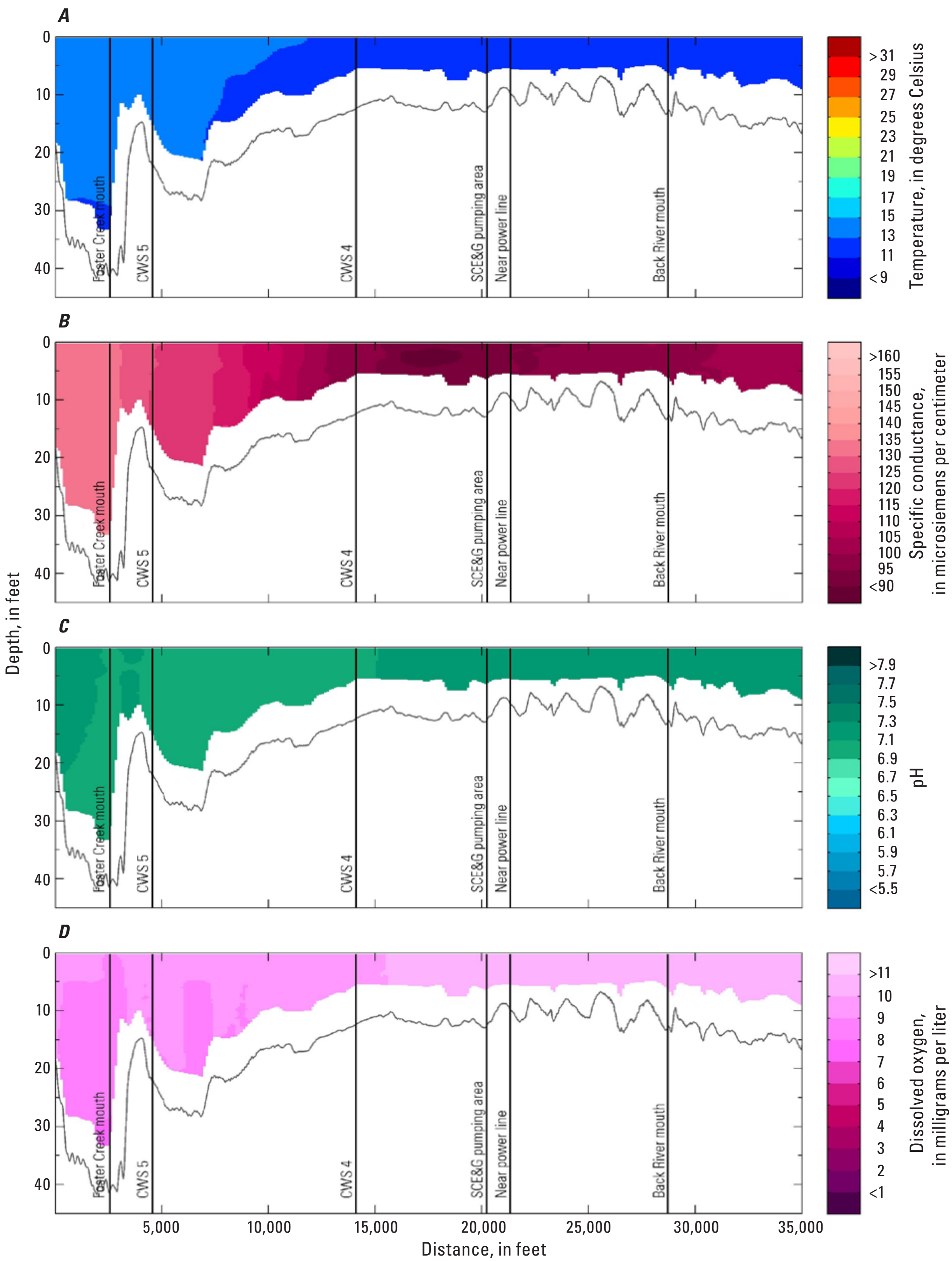

Figure 2–3. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, March 27, 2014.

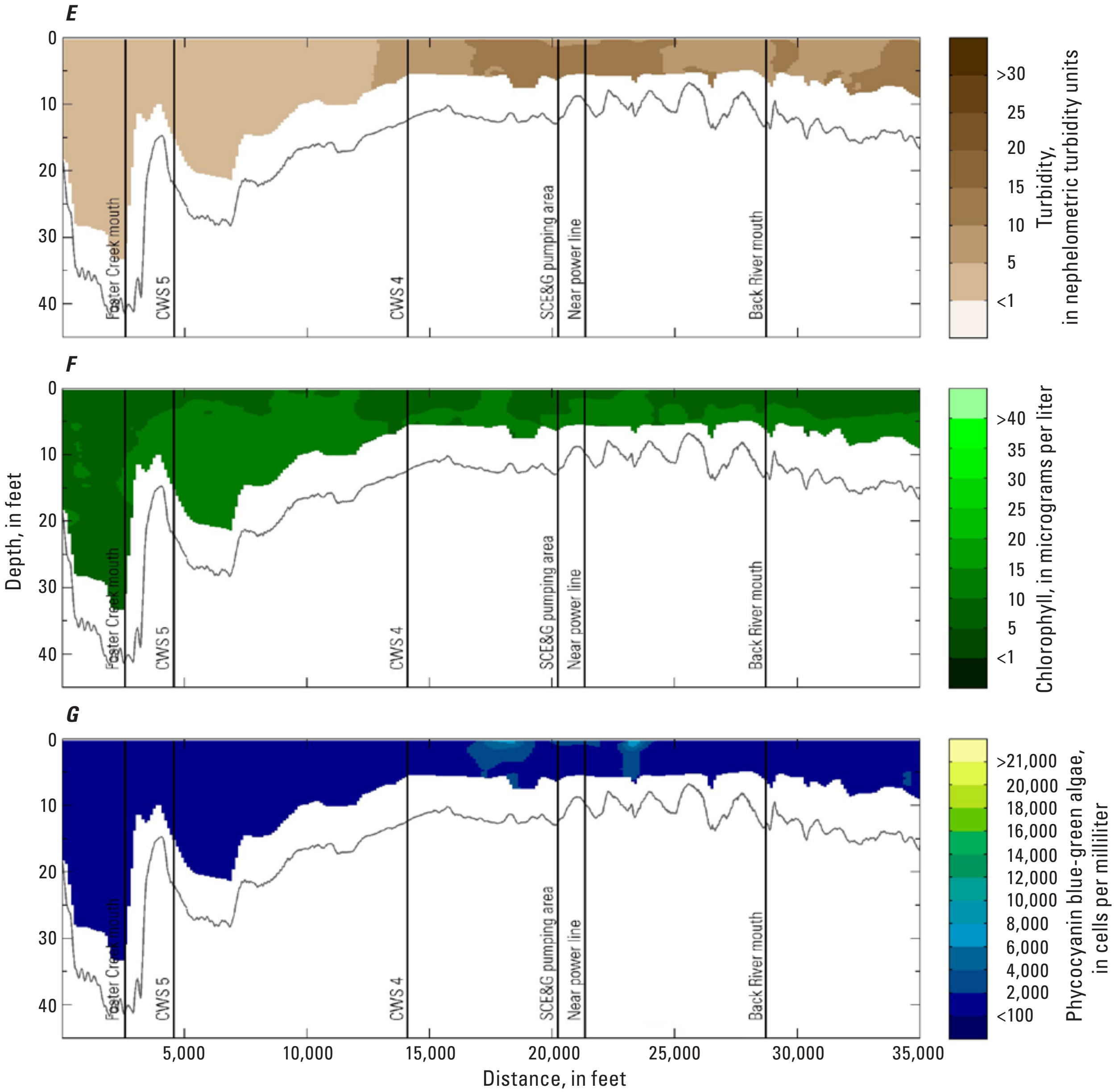

Figure 2–3. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, March 27, 2014.

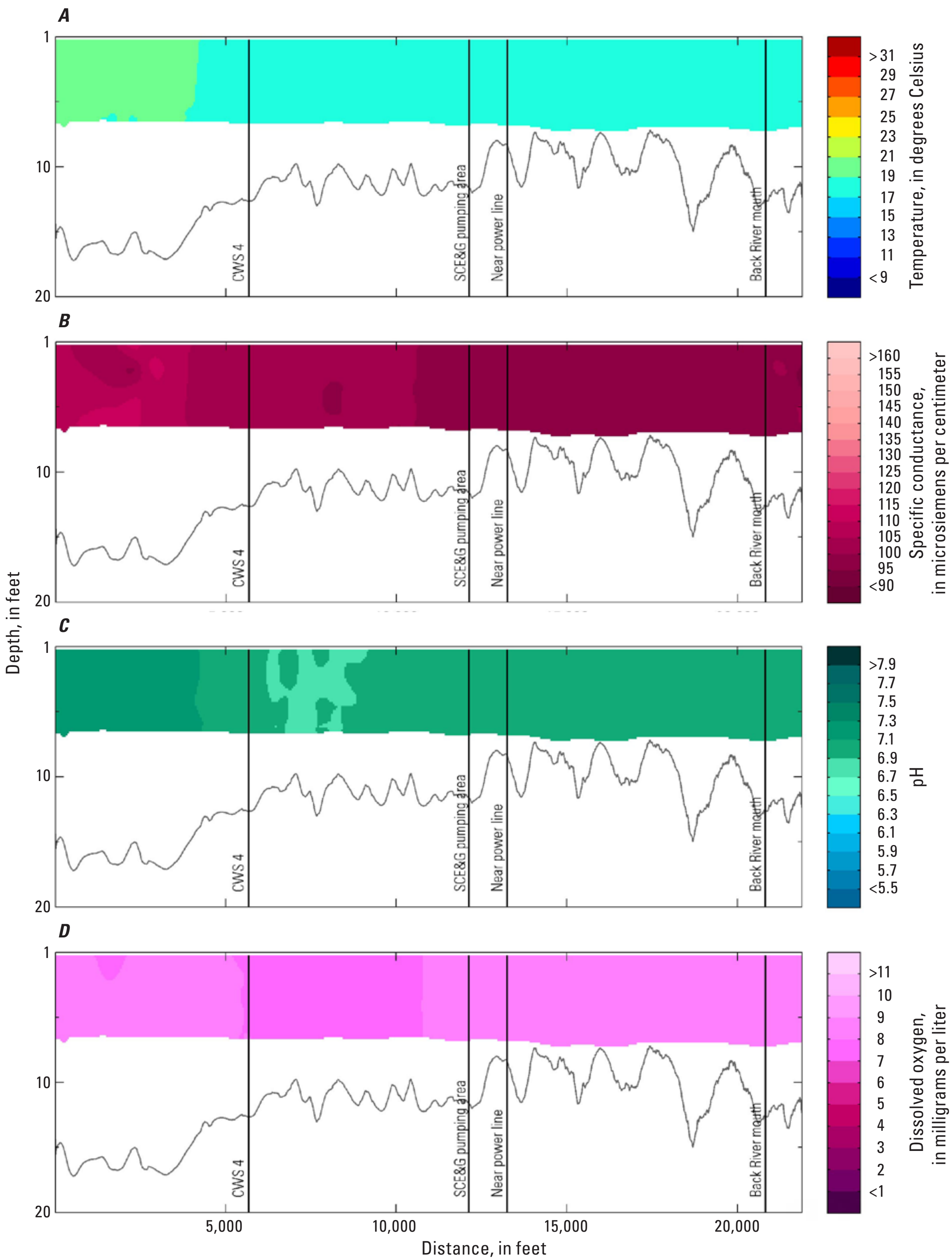

Figure 2–4. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, April 16, 2014.

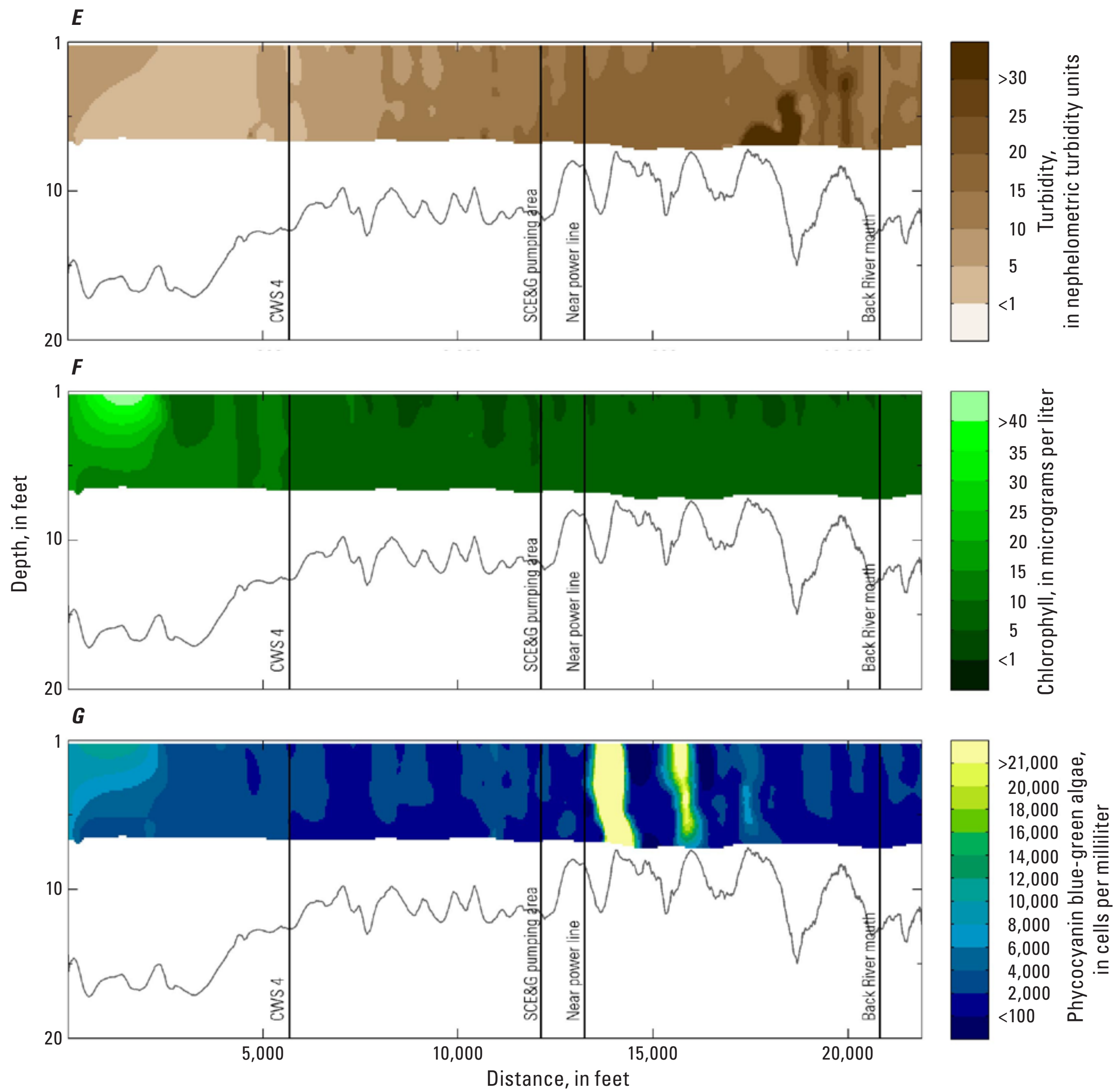

Figure 2–4. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, April 16, 2014.

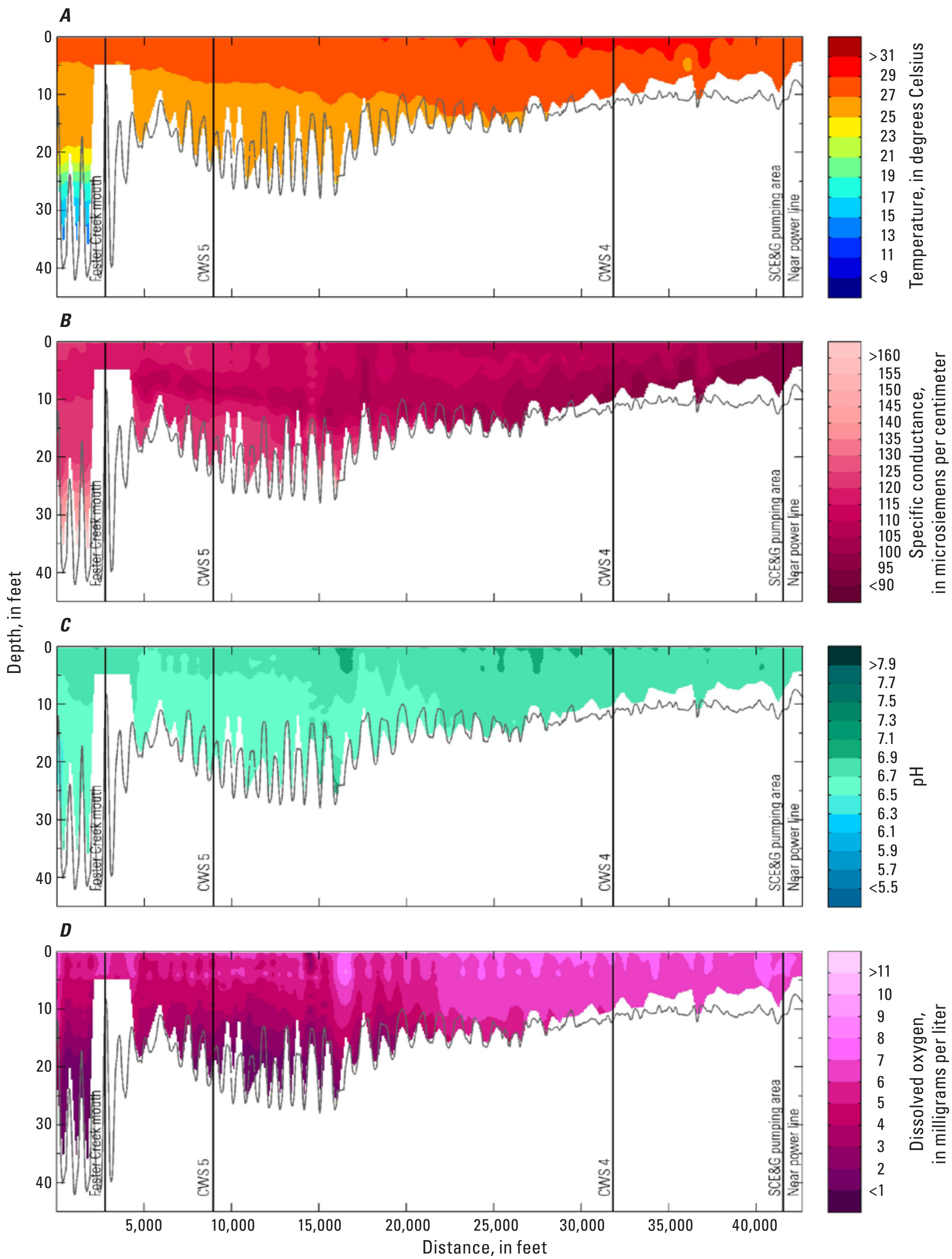

Figure 2–5. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, June 10, 2014.

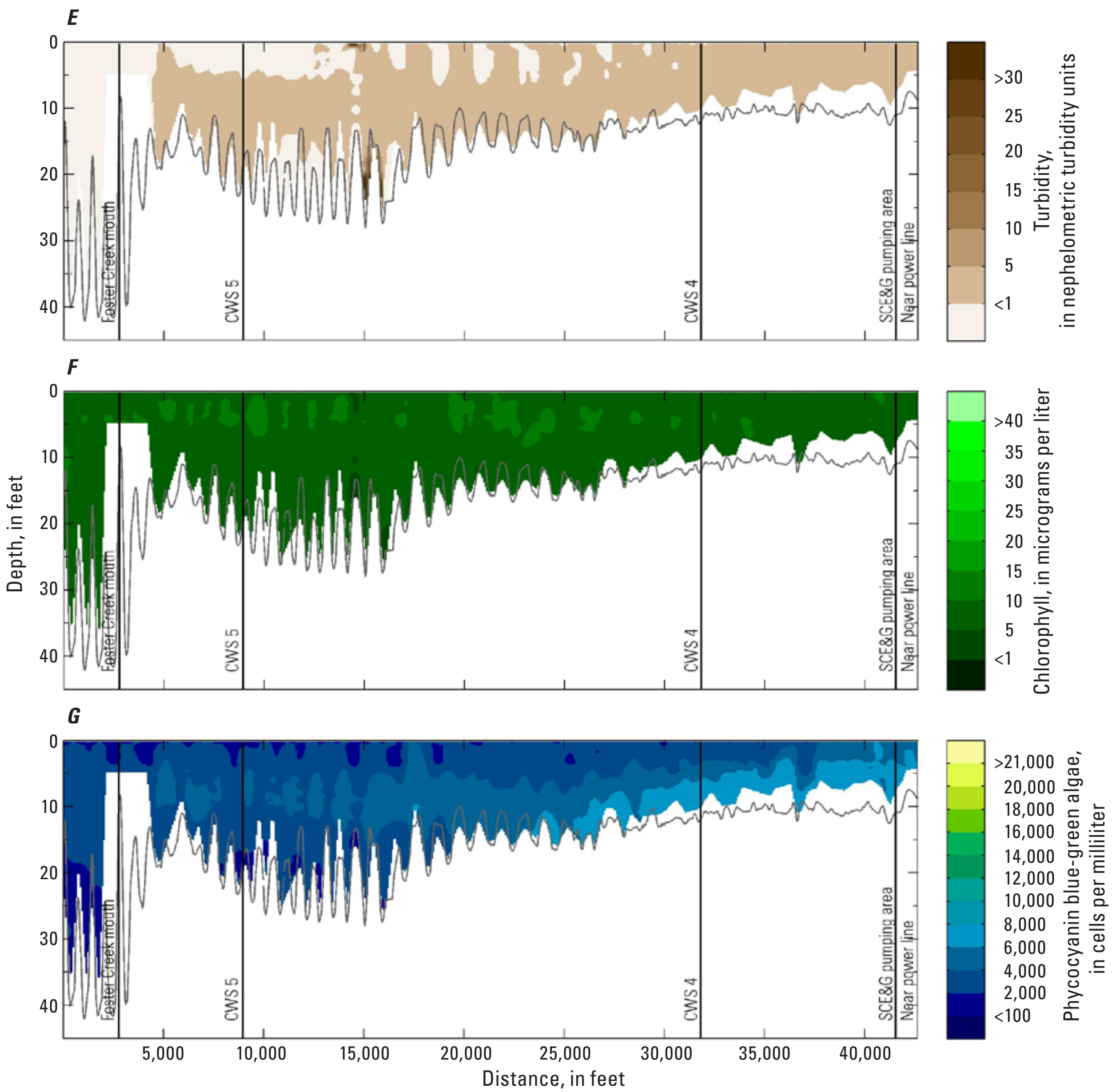

Figure 2–5. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, June 10, 2014.

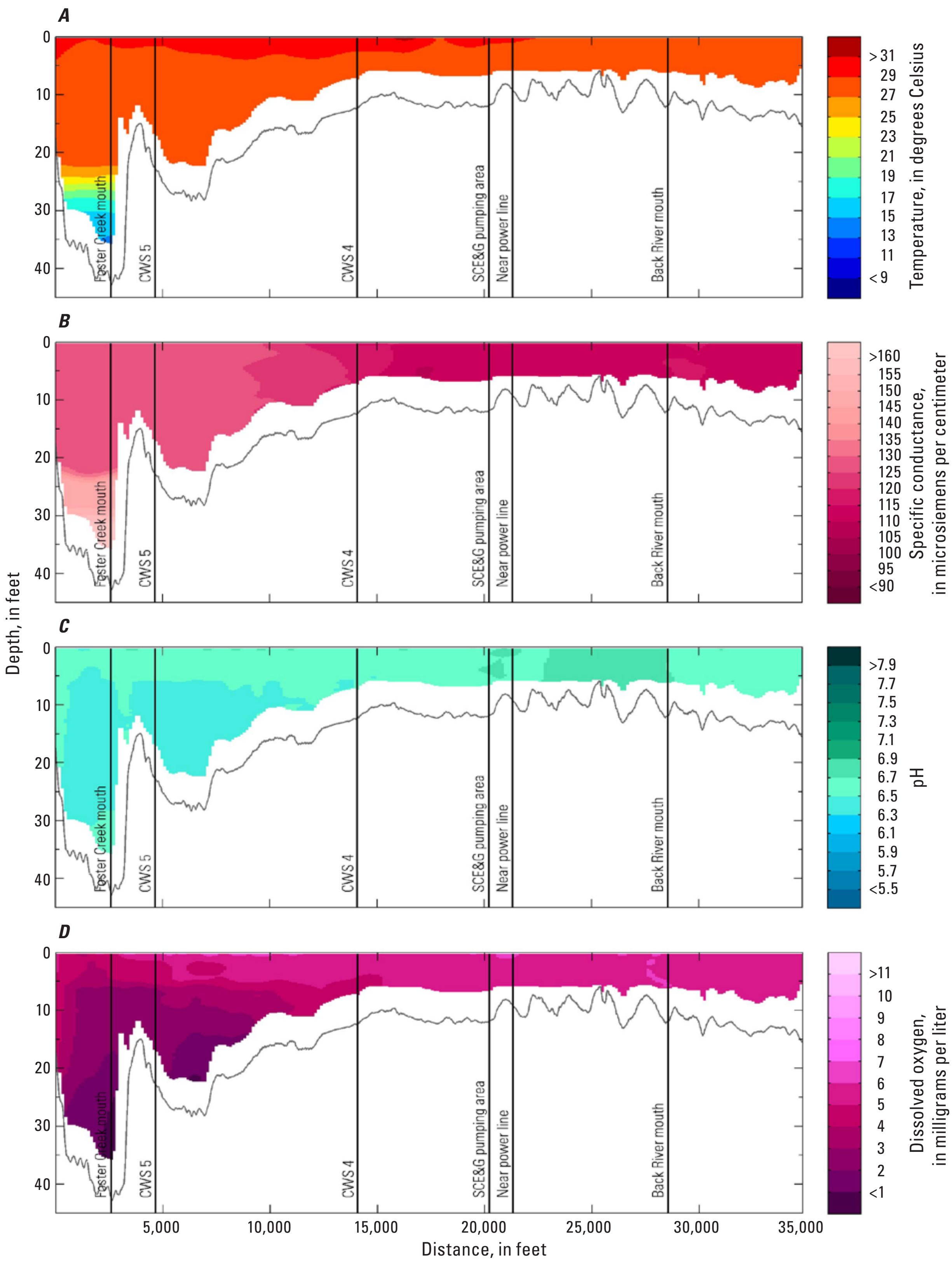

Figure 2–6. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, July 23, 2014.

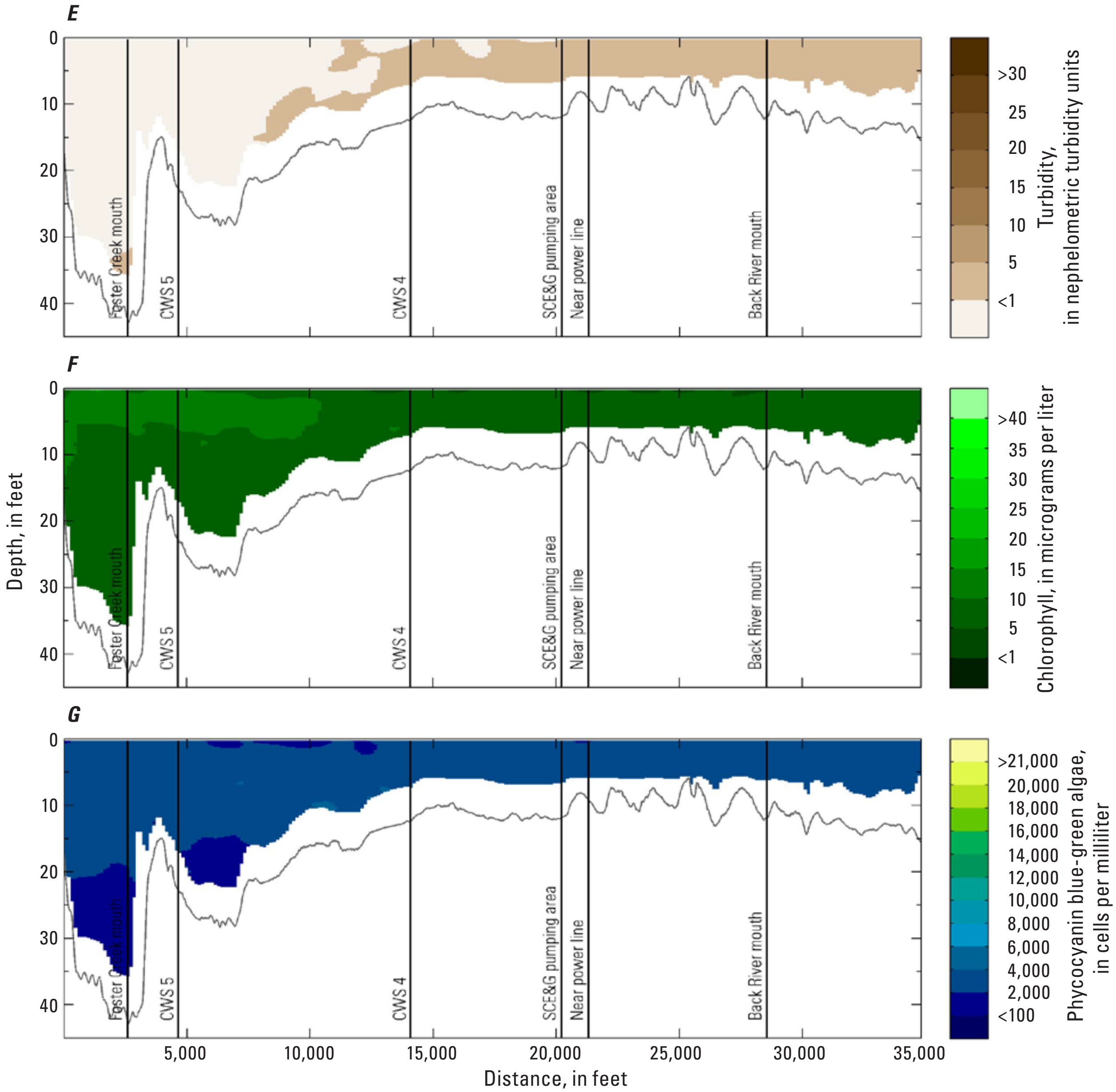

Figure 2–6. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, July 23, 2014.

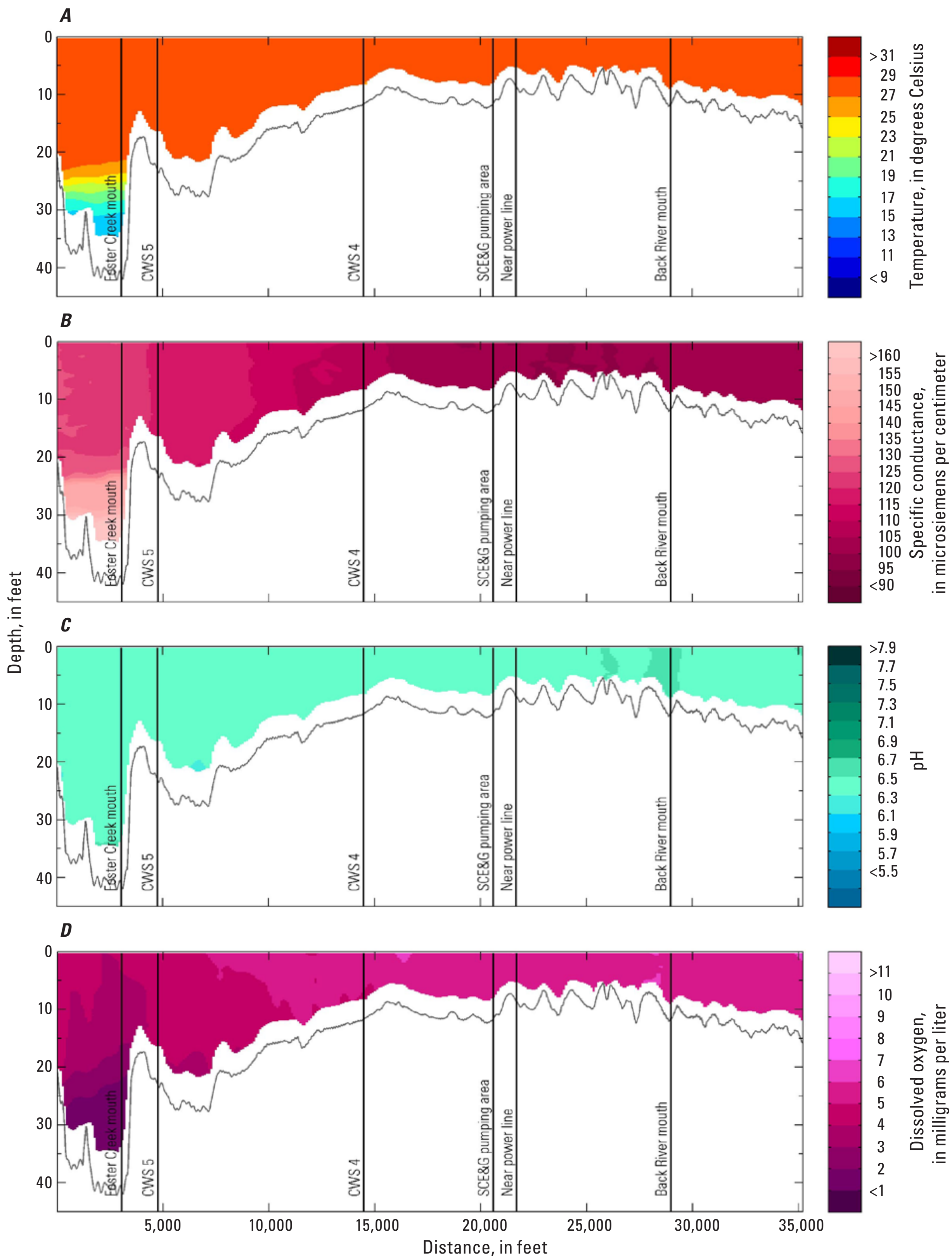

Figure 2–7. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, August 5, 2014.

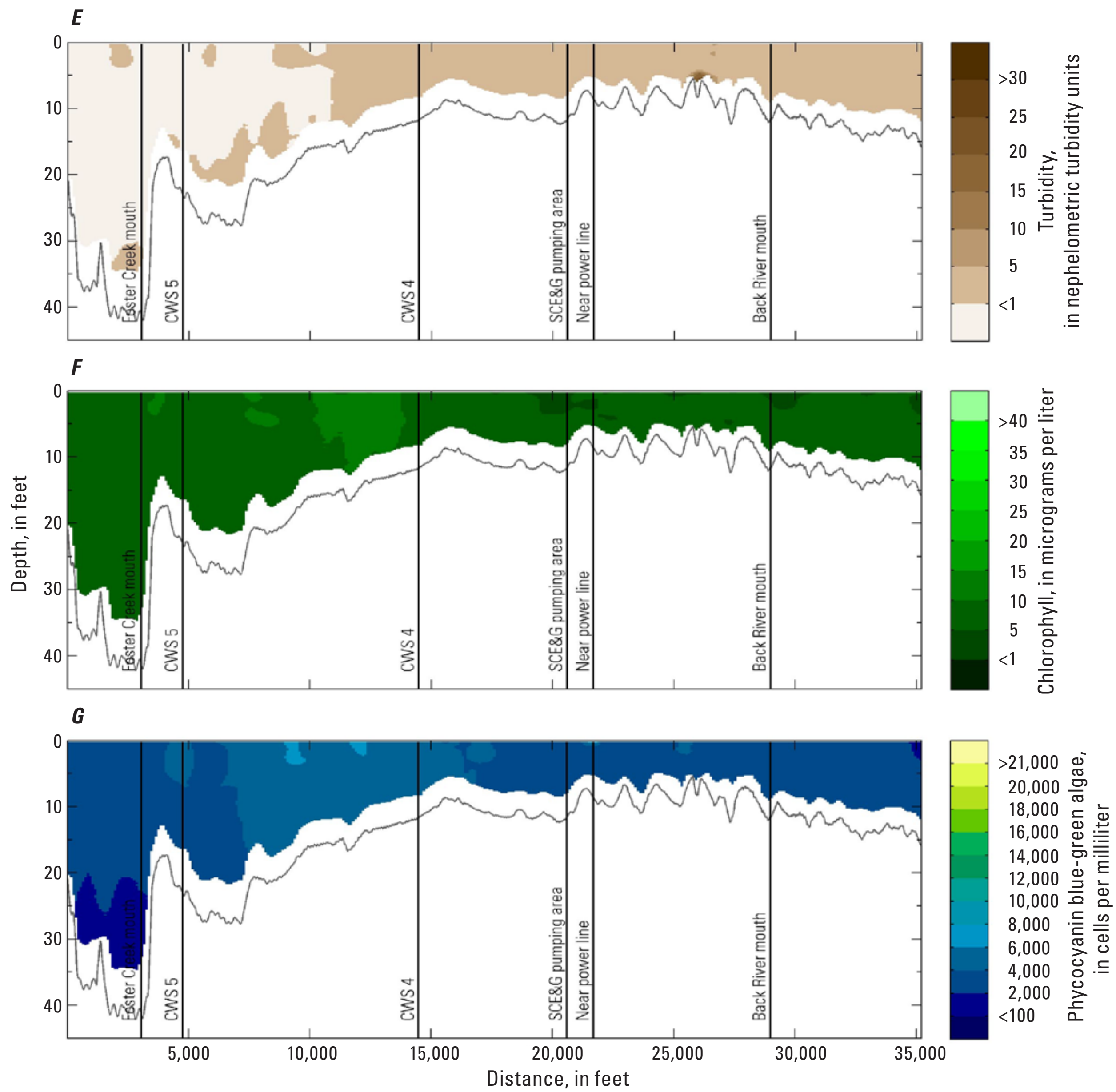

Figure 2–7. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, August 5, 2014.

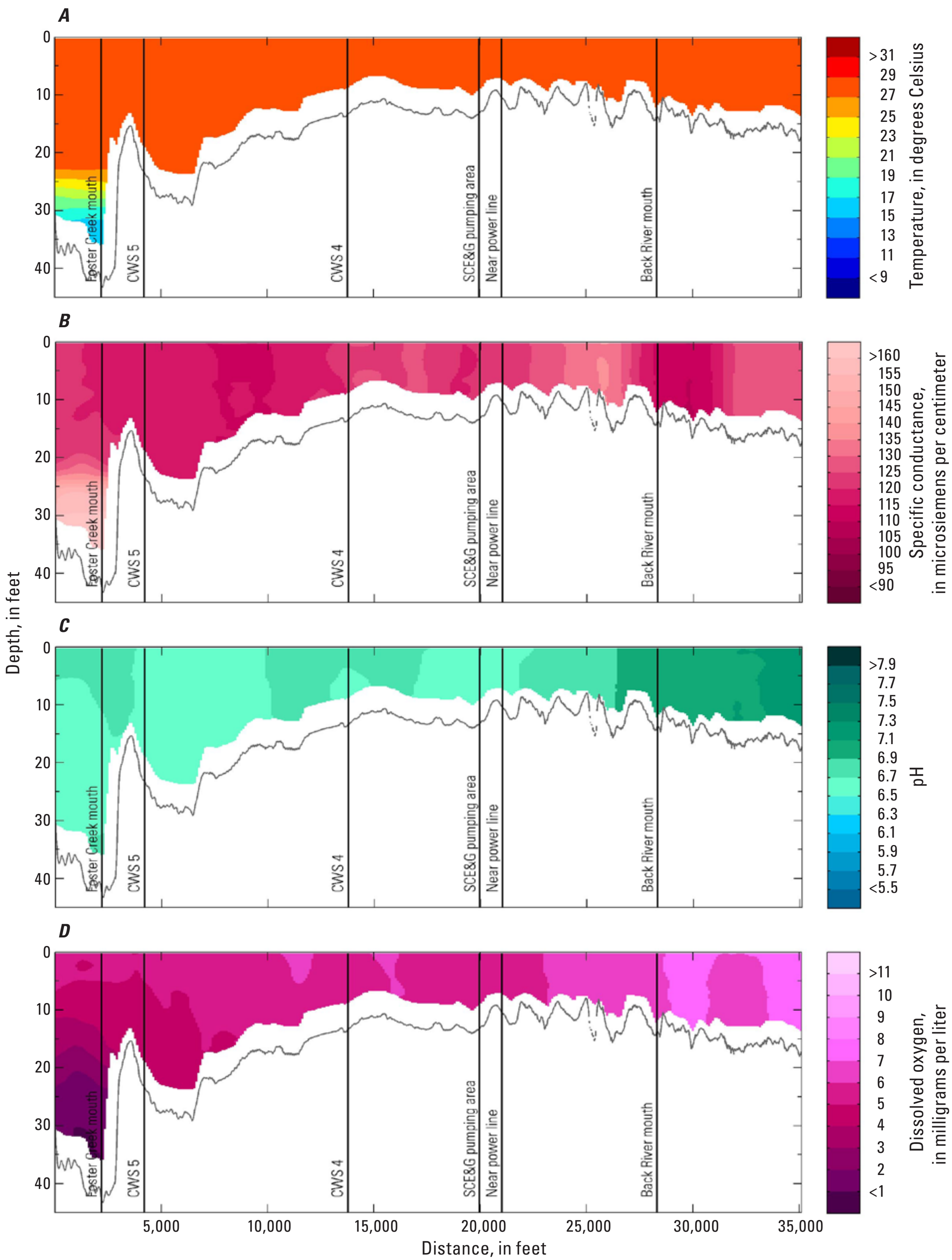

Figure 2–8. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, August 26, 2014.

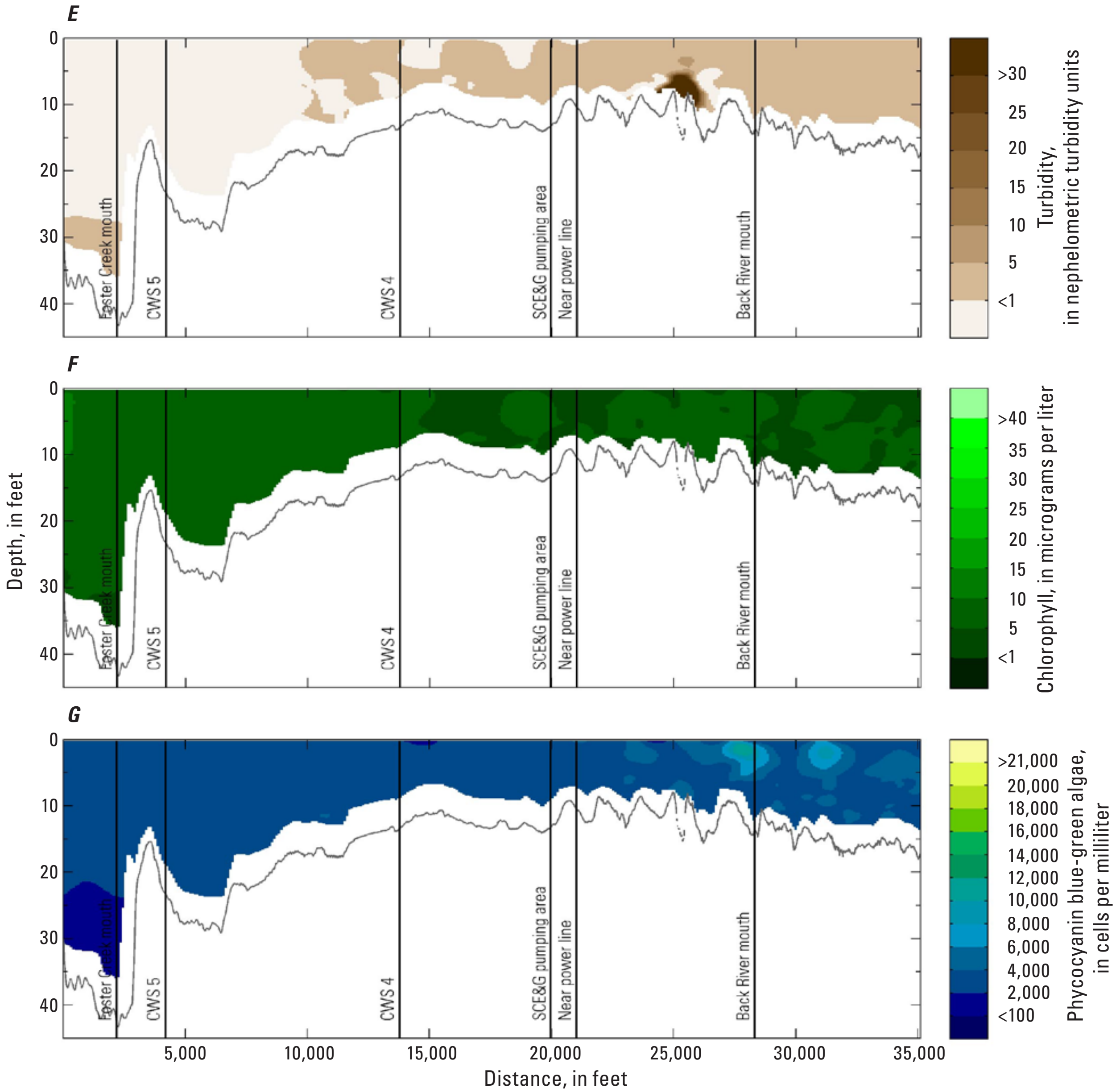

Figure 2–8. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, August 26, 2014.

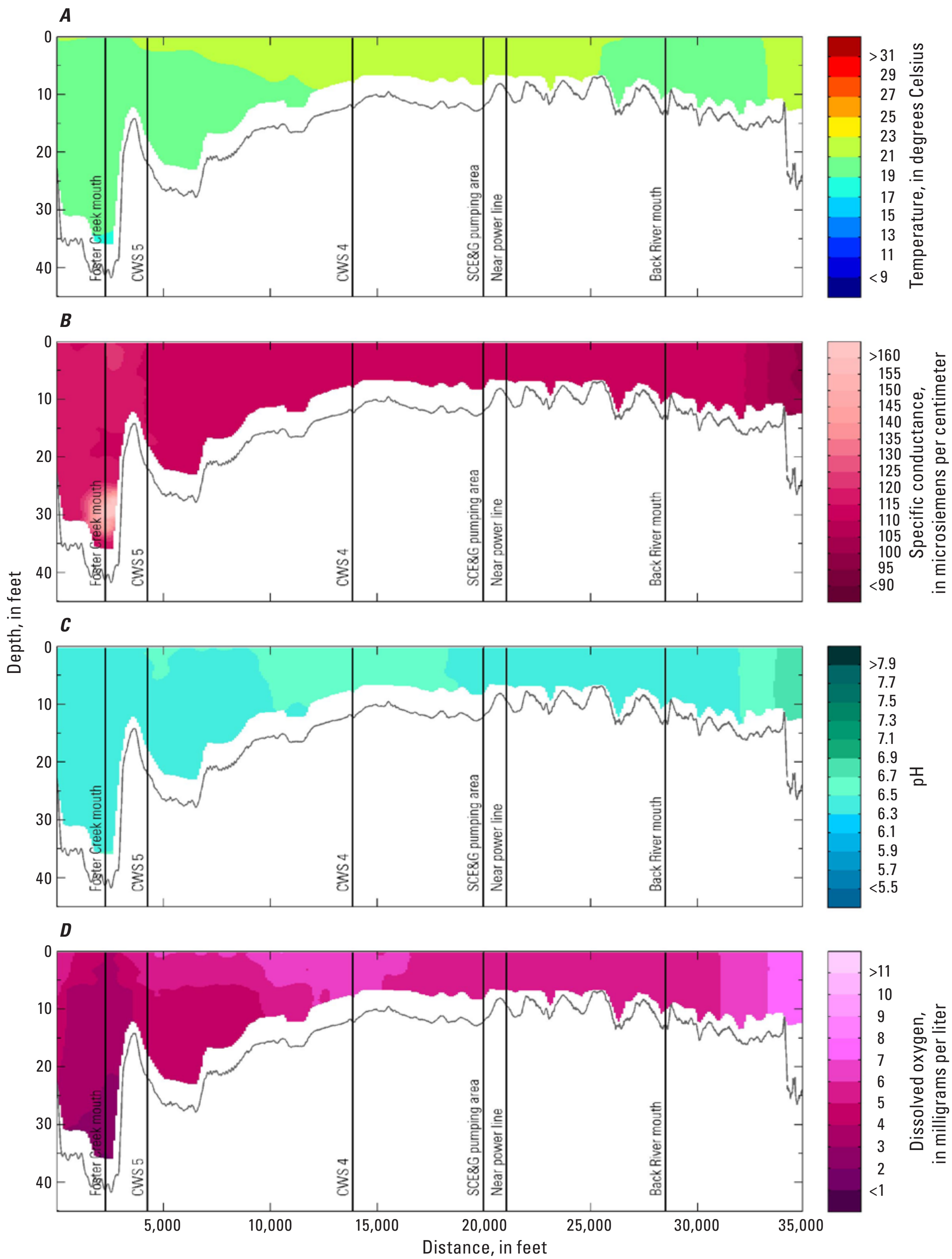

Figure 2–9. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, October 29, 2014.

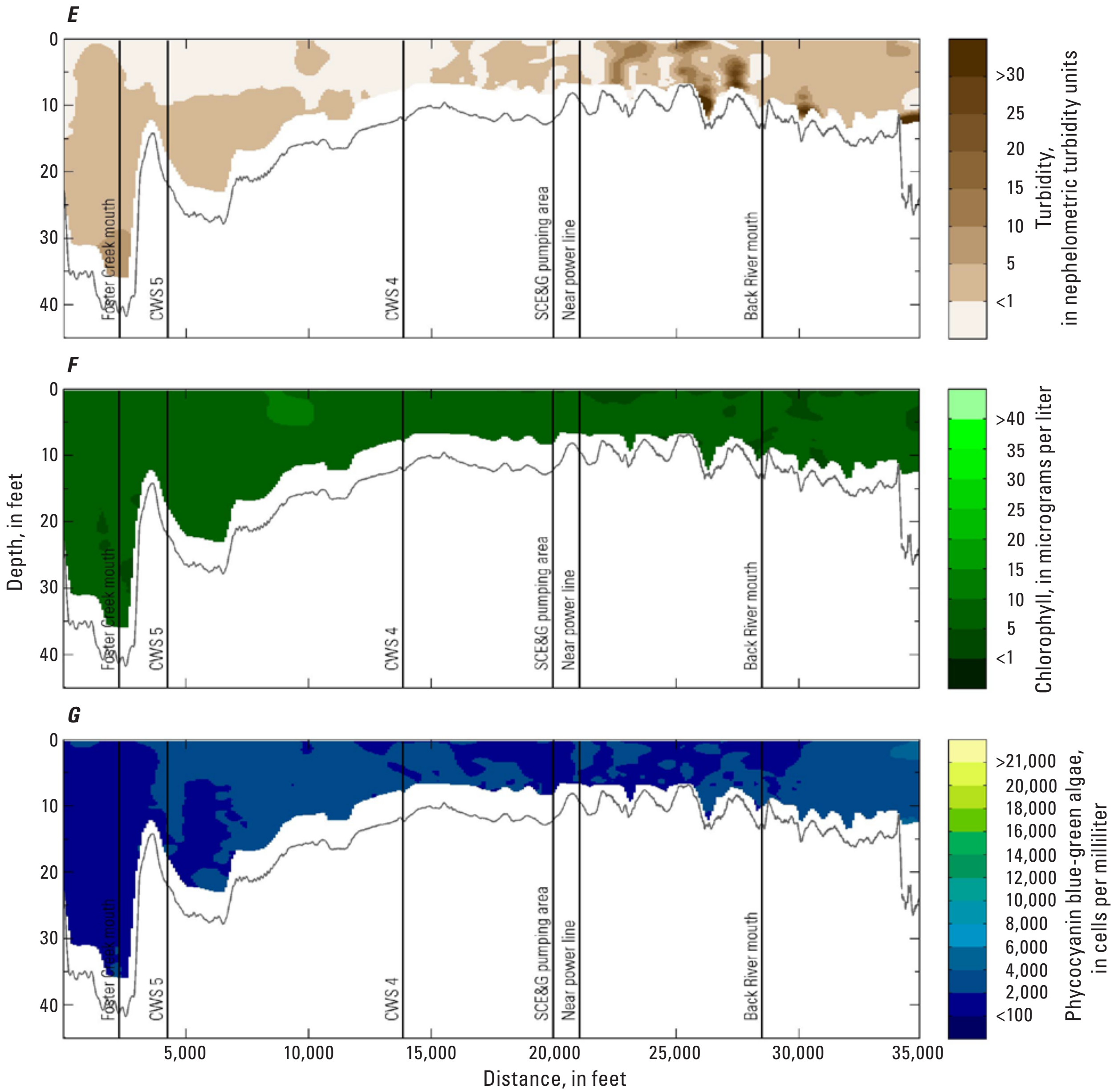

Figure 2–9. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, October 29, 2014.

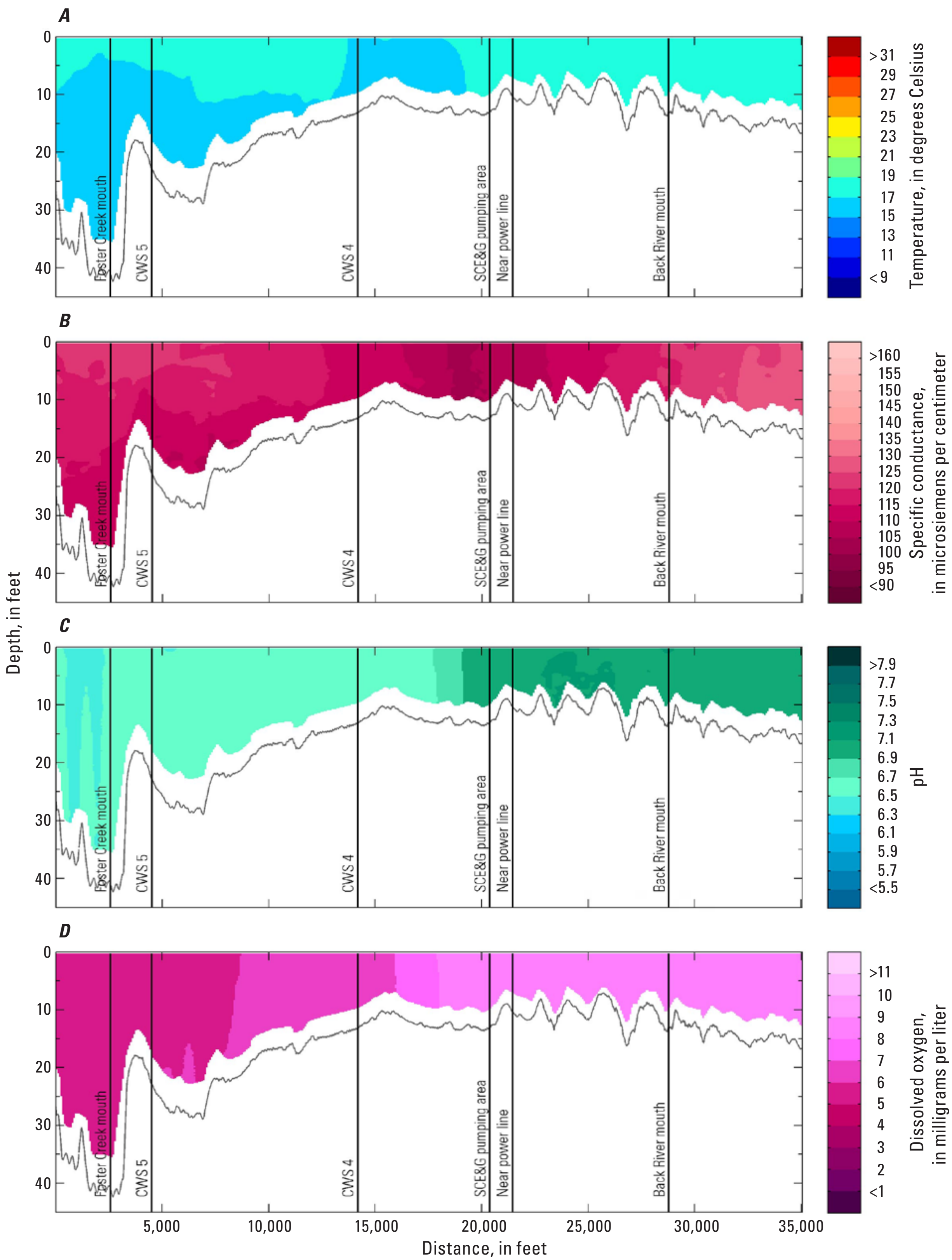

Figure 2–10. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, November 5, 2014.

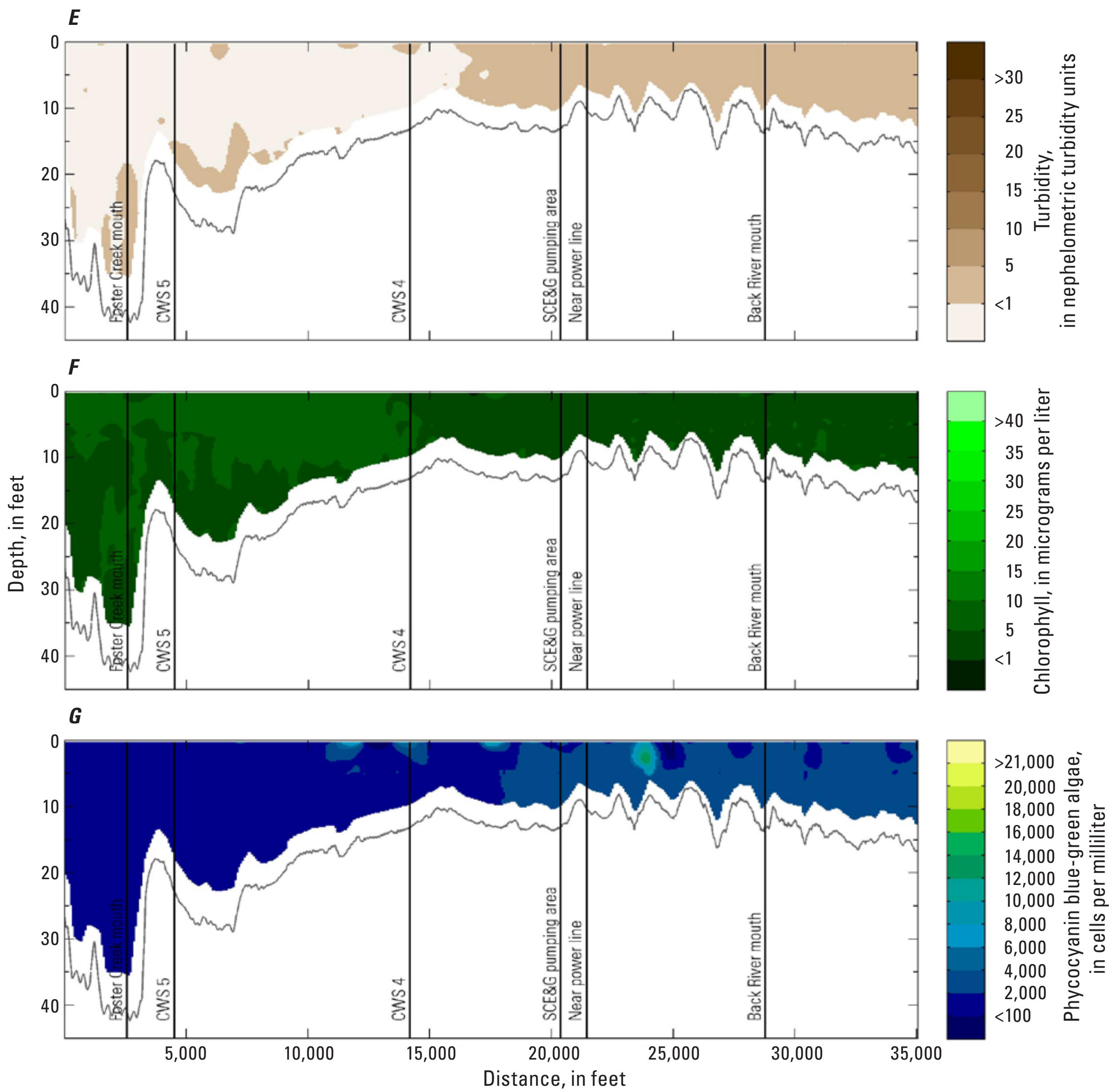

Figure 2–10. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, November 5, 2014.

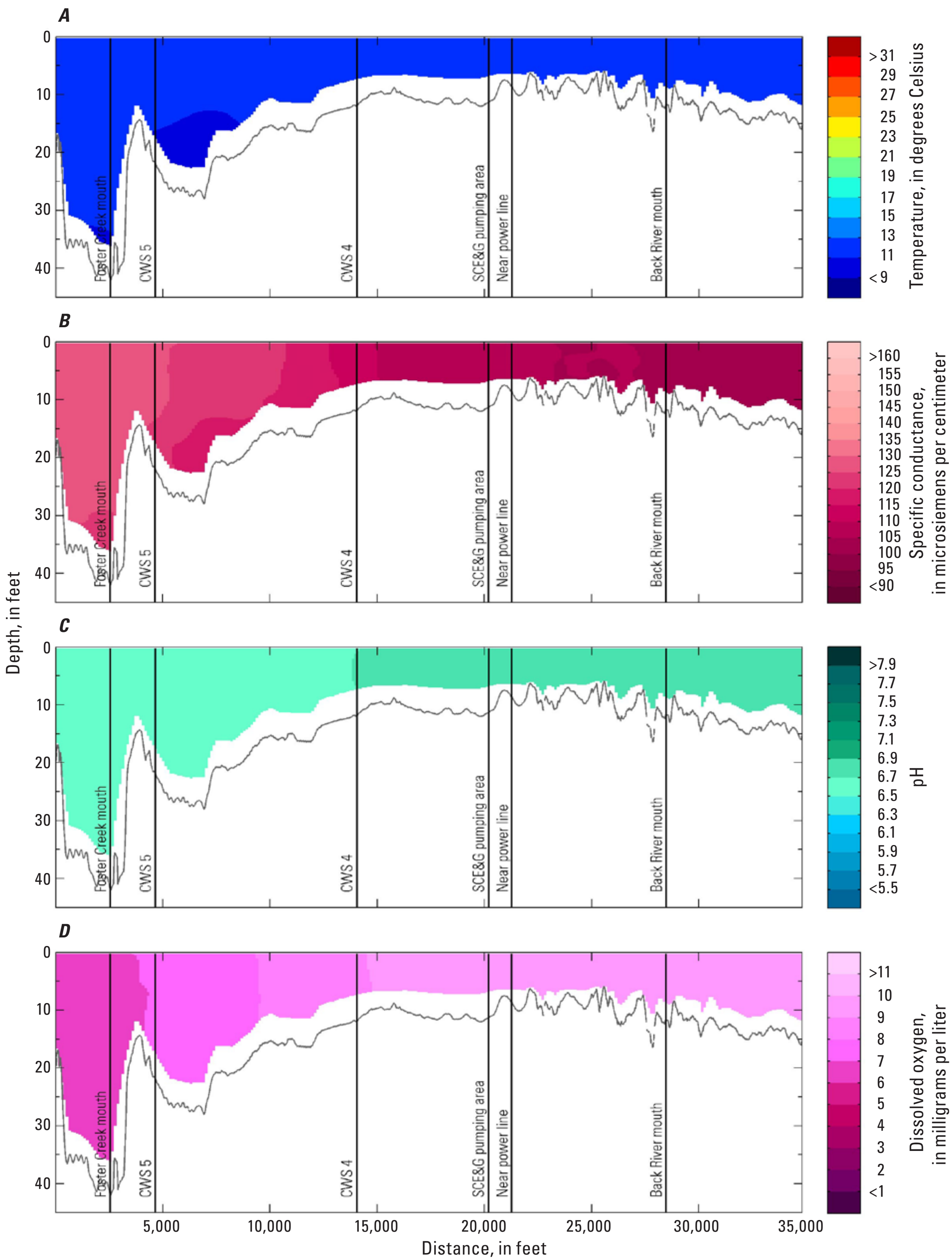

Figure 2–11. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, December 16, 2014.

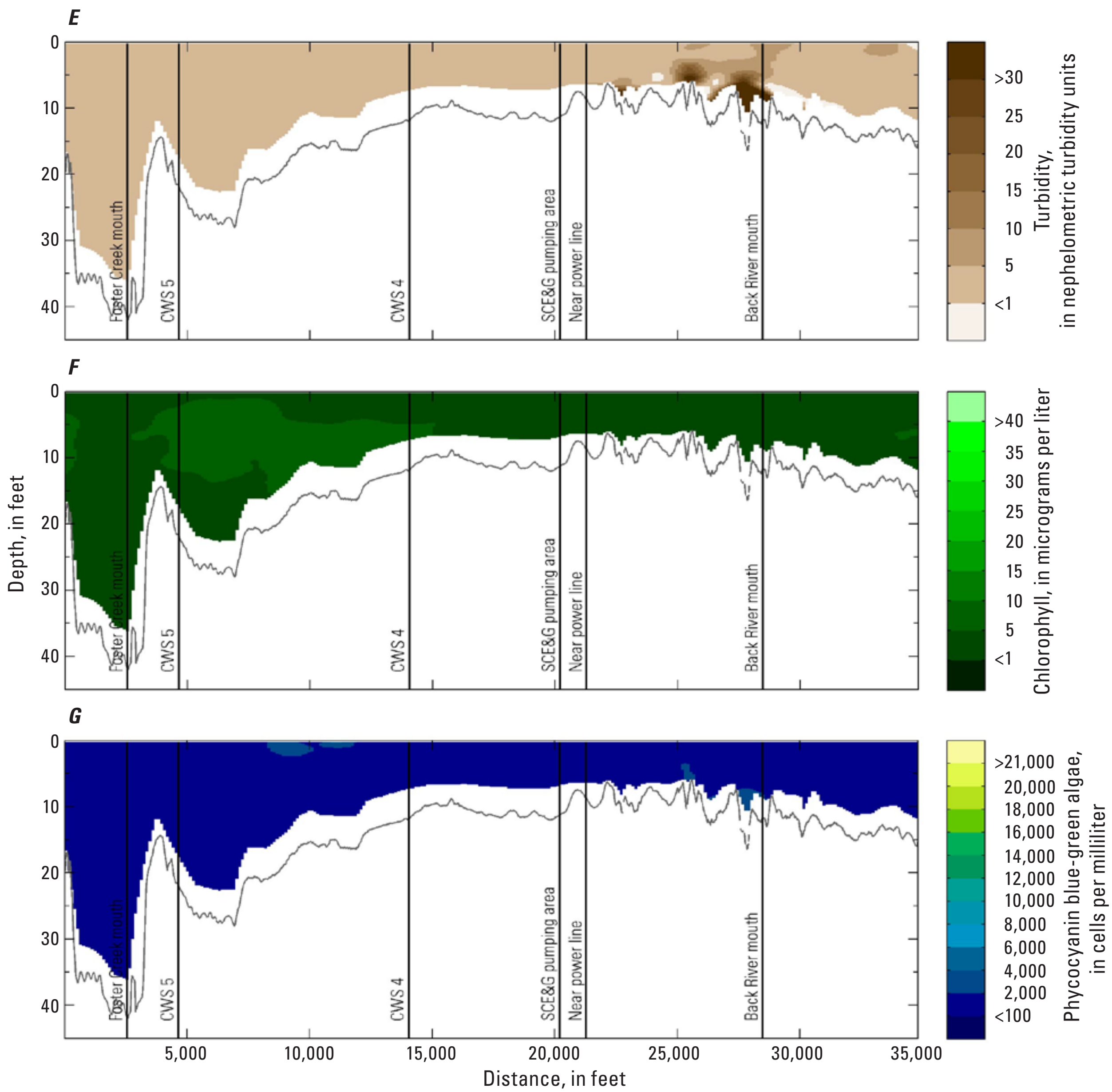

Figure 2–11. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, December 16, 2014.

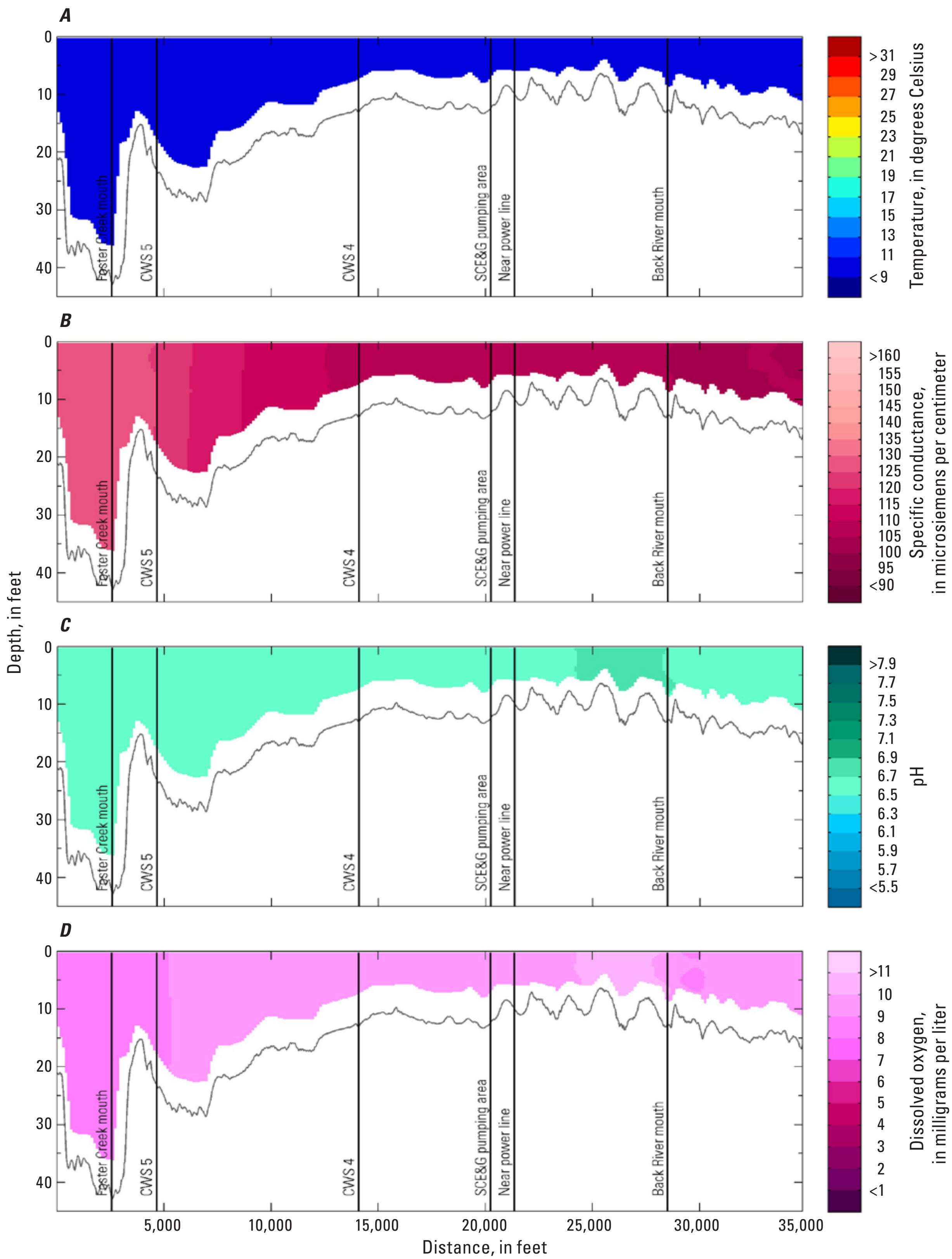

Figure 2–12. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, January 14, 2015.

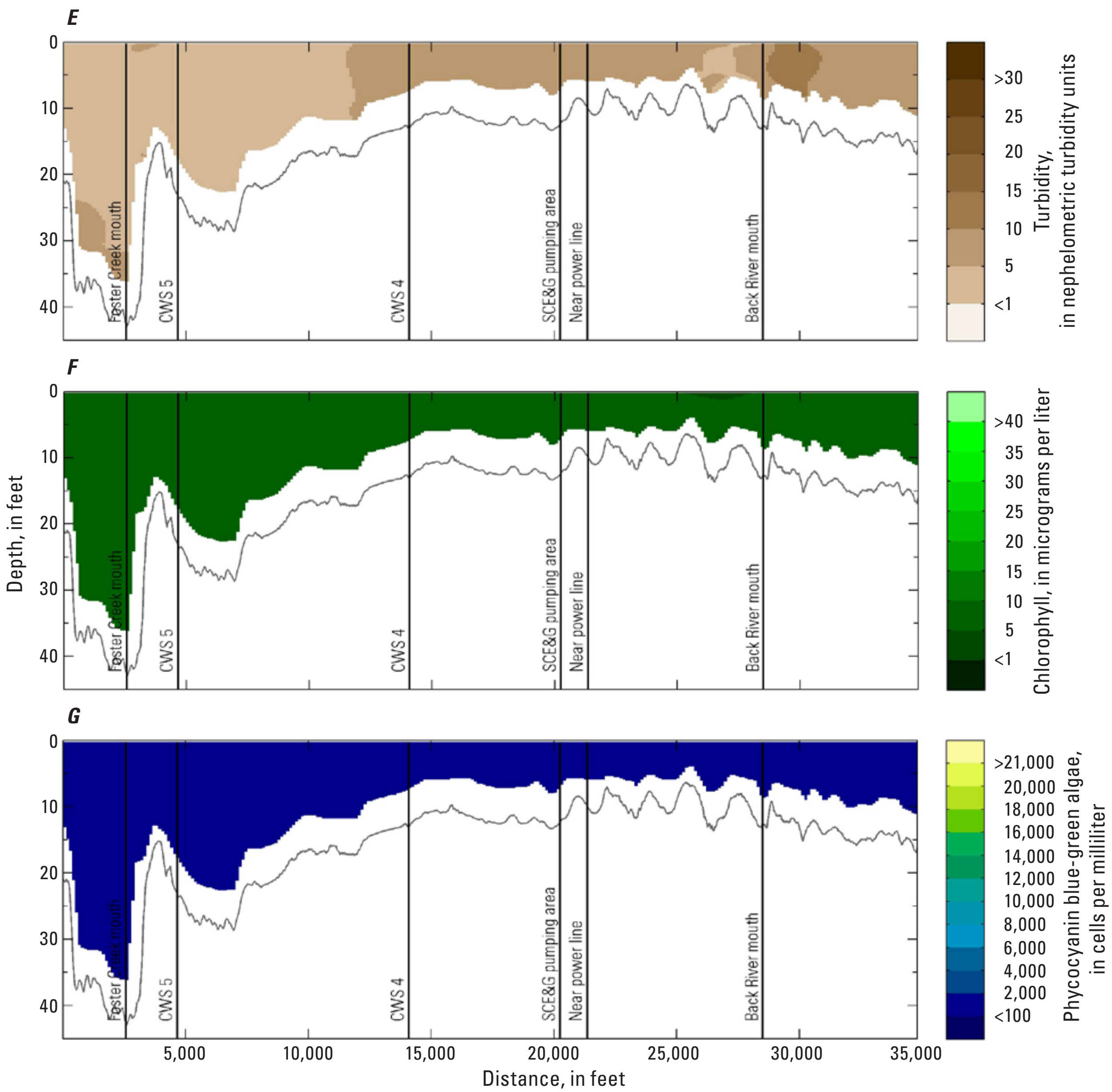

Figure 2–12. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, January 14, 2015.

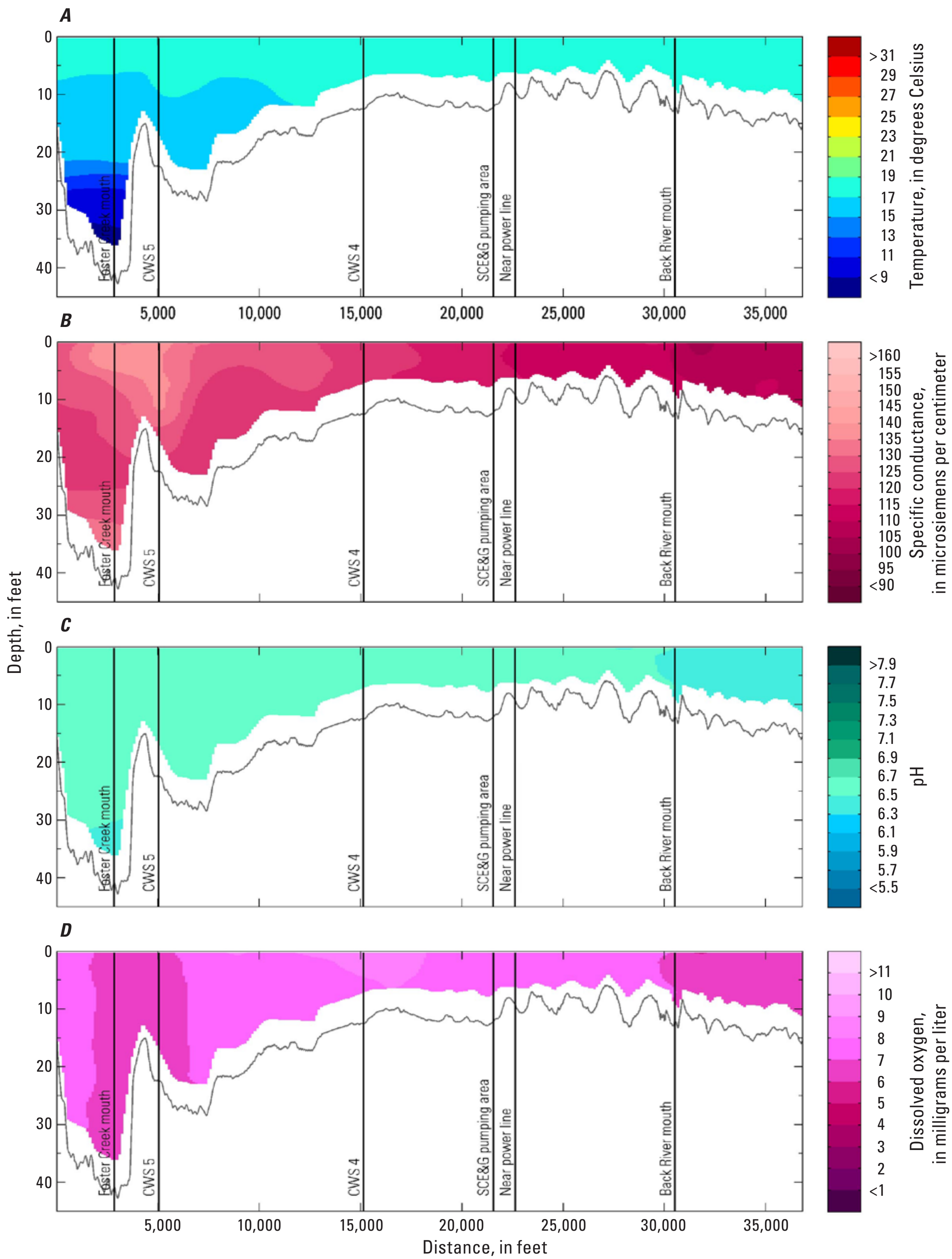

Figure 2–13. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, March 26, 2015.

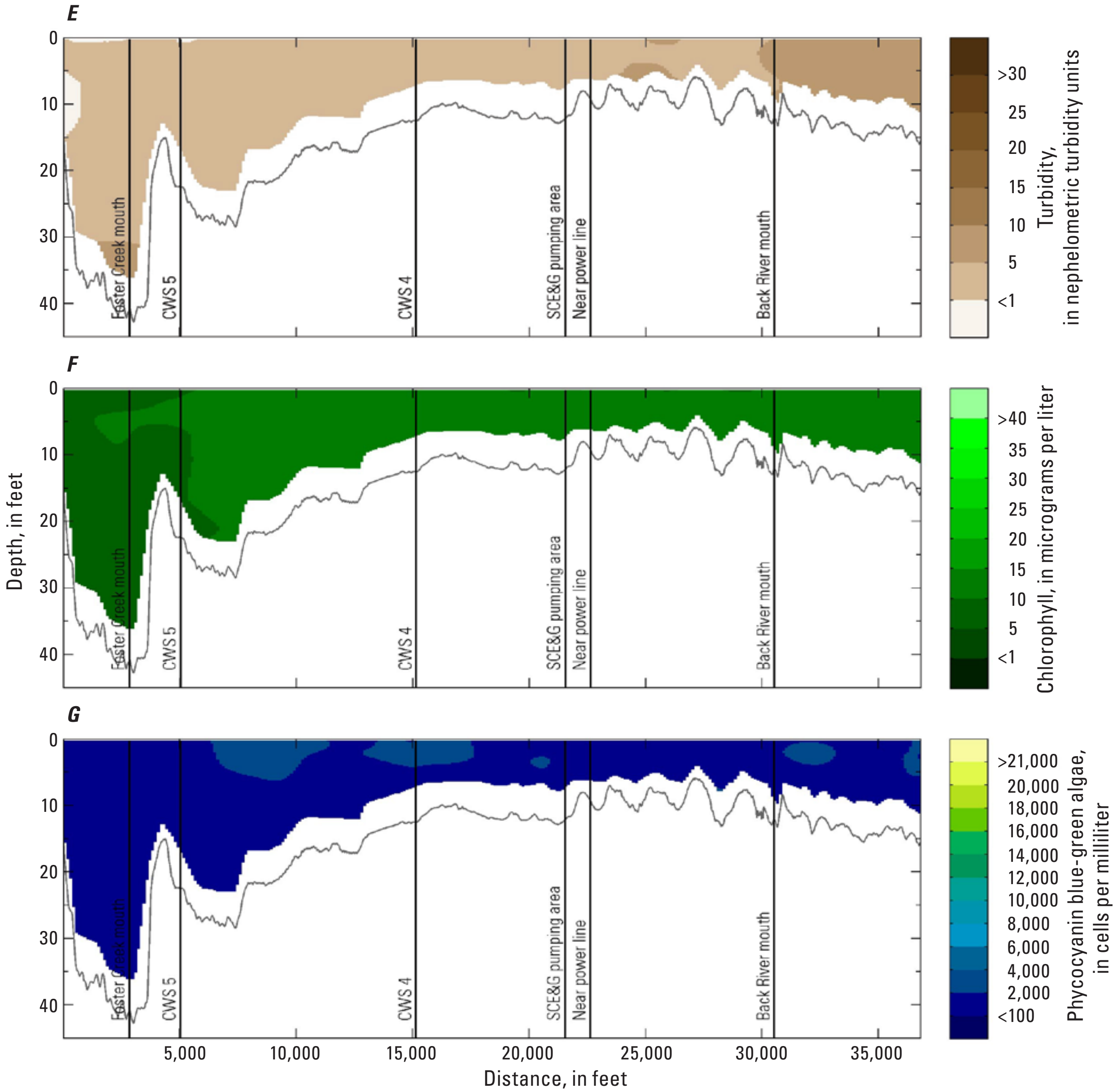

Figure 2–13. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, March 26, 2015.

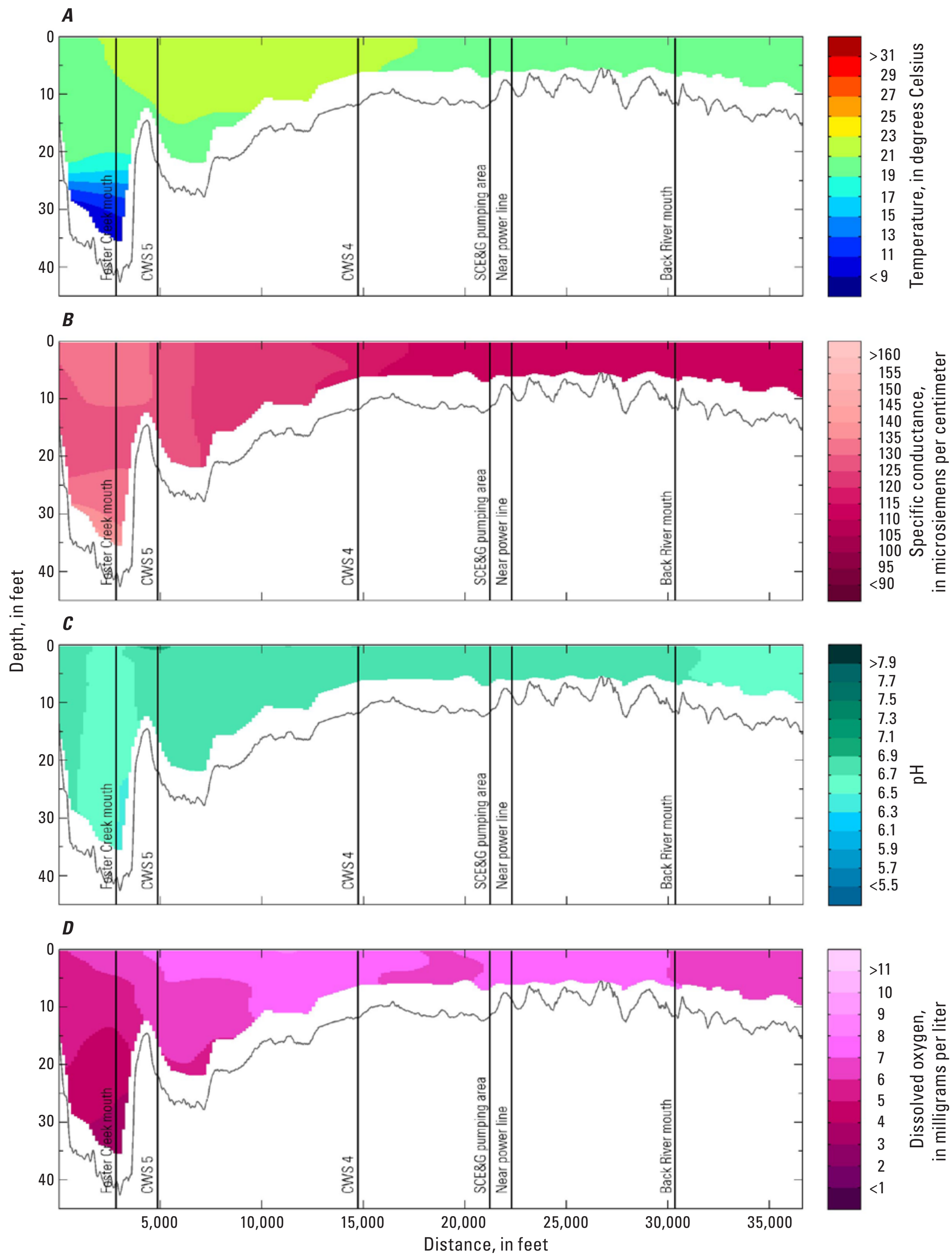

Figure 2–14. Longitudinal plots of (*A*) water temperature, (*B*) specific conductance, (*C*) pH, and (*D*) dissolved oxygen at Bushy Park Reservoir, April 23, 2015.

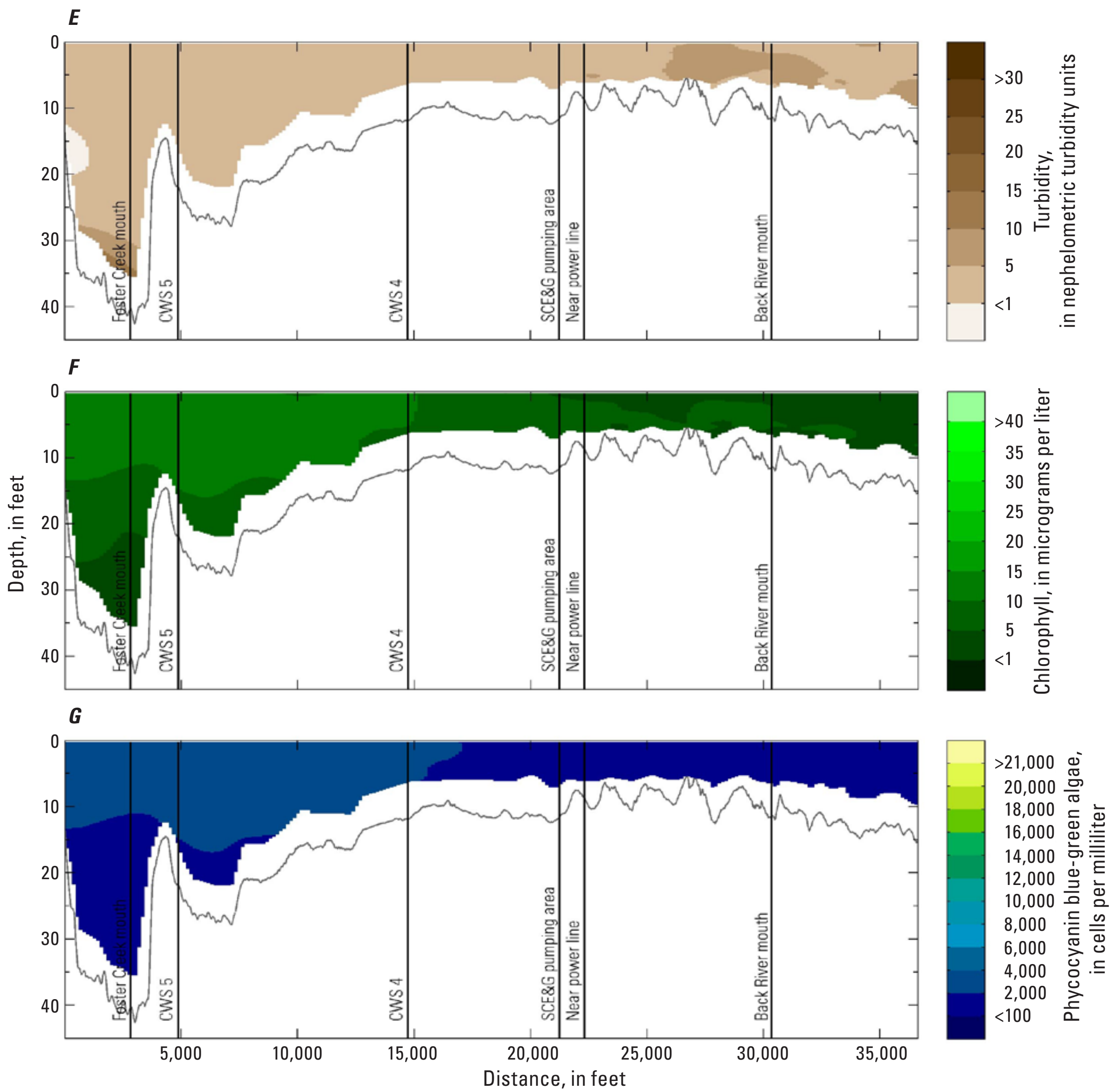

Figure 2–14. (Continued) Longitudinal plots of (*E*) turbidity, (*F*) total chlorophyll fluorescence estimated as micrograms per liter, and (*G*) phycocyanin fluorescence, estimated as blue-green algae, in cells per milliliter at Bushy Park Reservoir, April 23, 2015.

Appendix 3. Water-quality profile data collected from the Bushy Park Reservoir, near Goose Creek, South Carolina, between September 2013 and April 2015

[Latitude and longitude coordinates are referenced to the World Geodetic System of 1984 (WGS84). Profiles located at sampling locations include site names and latitude and longitude coordinates. If a profile is not located at a sampling location, no site name is included with the coordinates. Graphs are empty for locations at which the specific water-quality sensor was not available or was malfunctioning. Chlorophyll and blue-green algae concentrations were determined by internal algorithm estimated from chlorophyll and phycocyanin fluorescence]

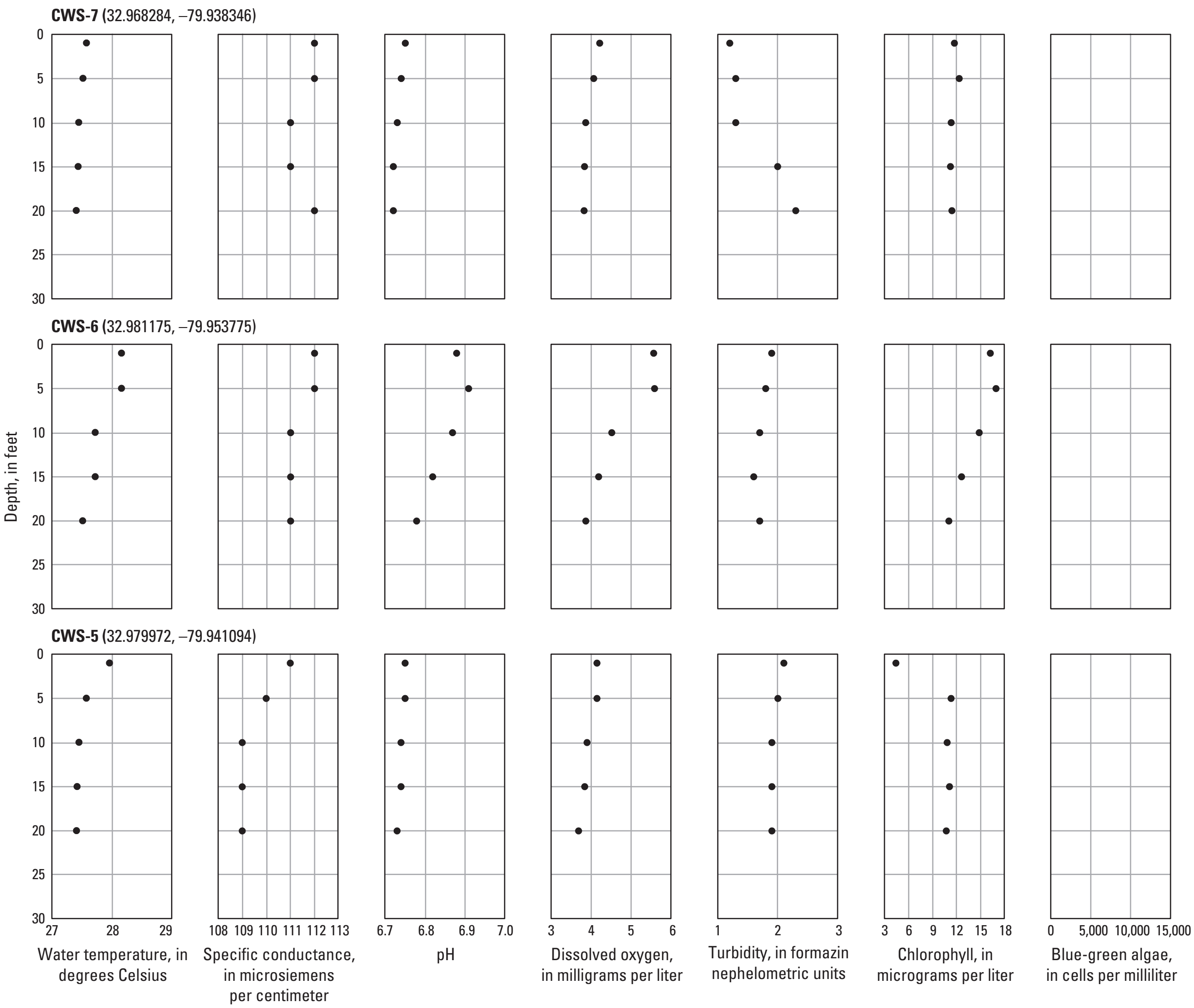

Figure 3–1. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, September 17, 2013.

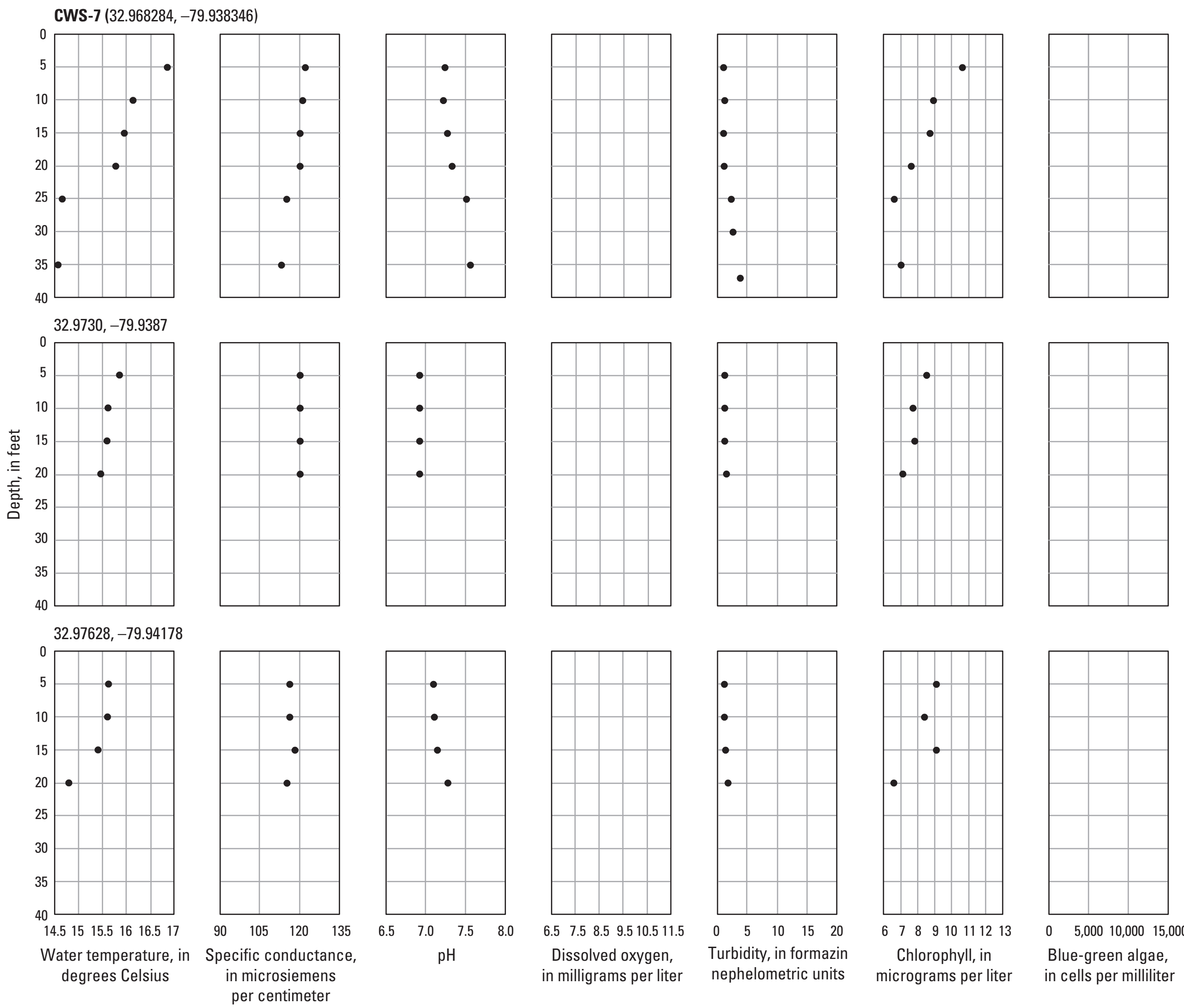

Figure 3–2. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 19, 2013.

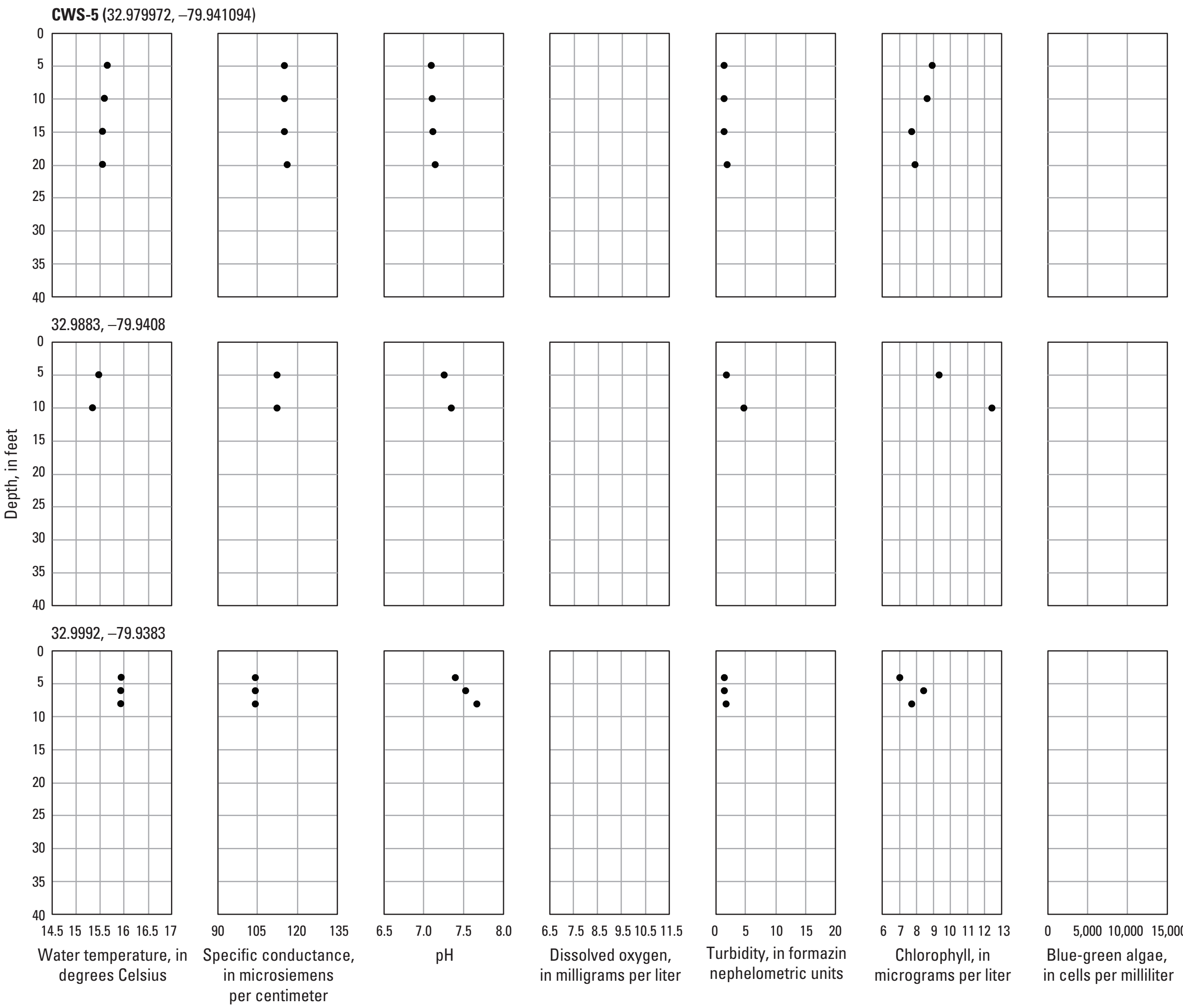

Figure 3–2. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 19, 2013.

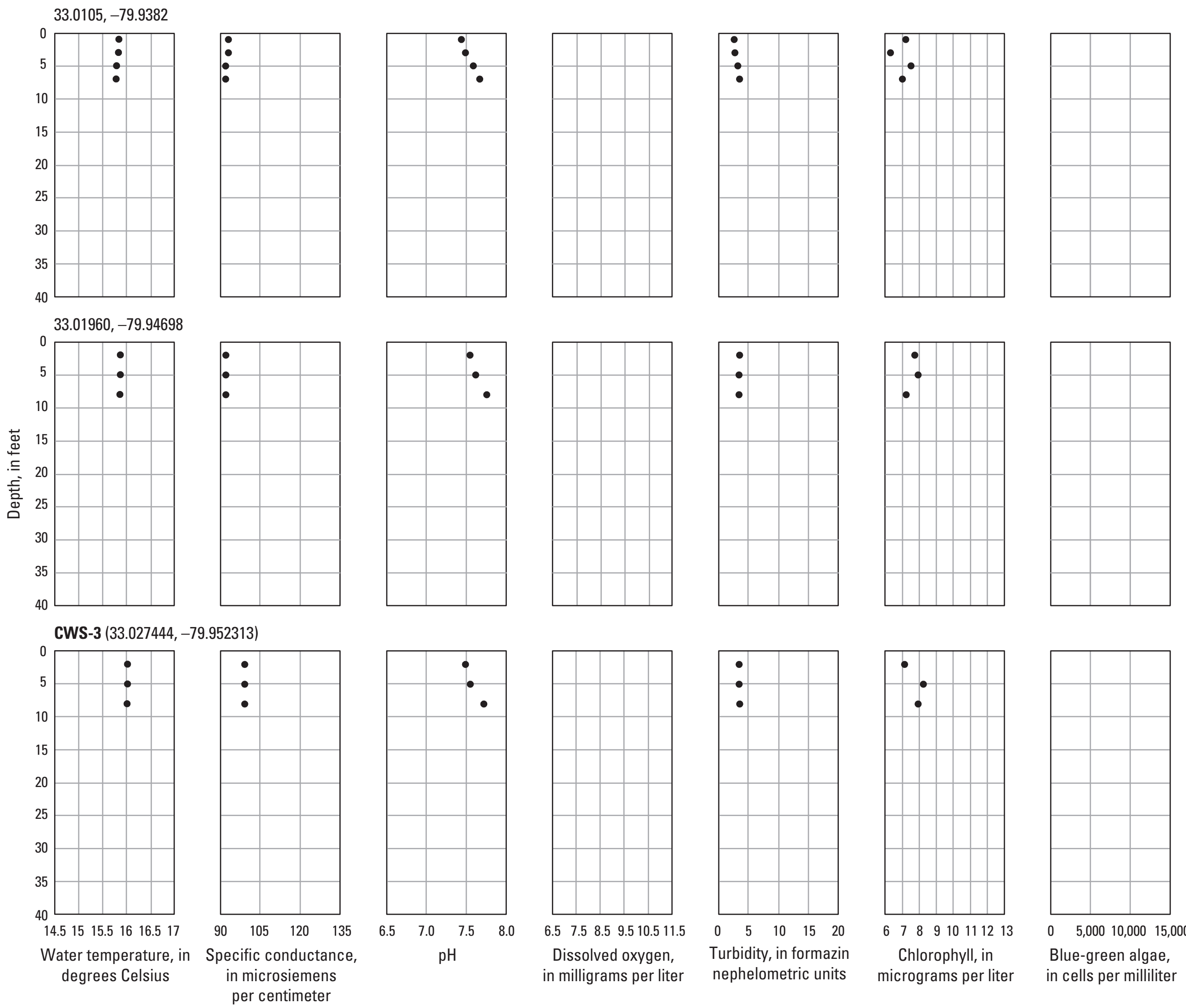

Figure 3–2. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 19, 2013.

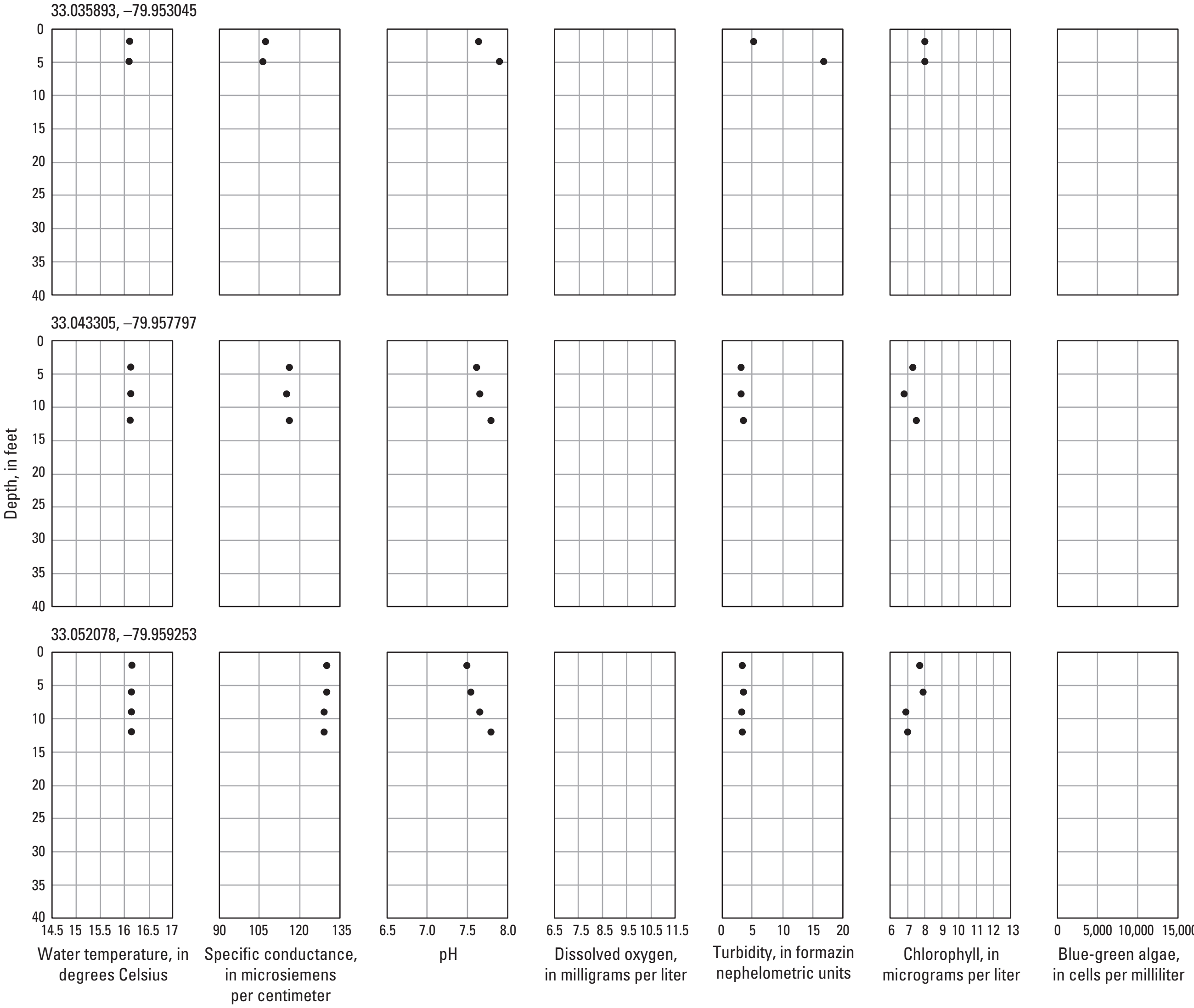

Figure 3–2. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 19, 2013.

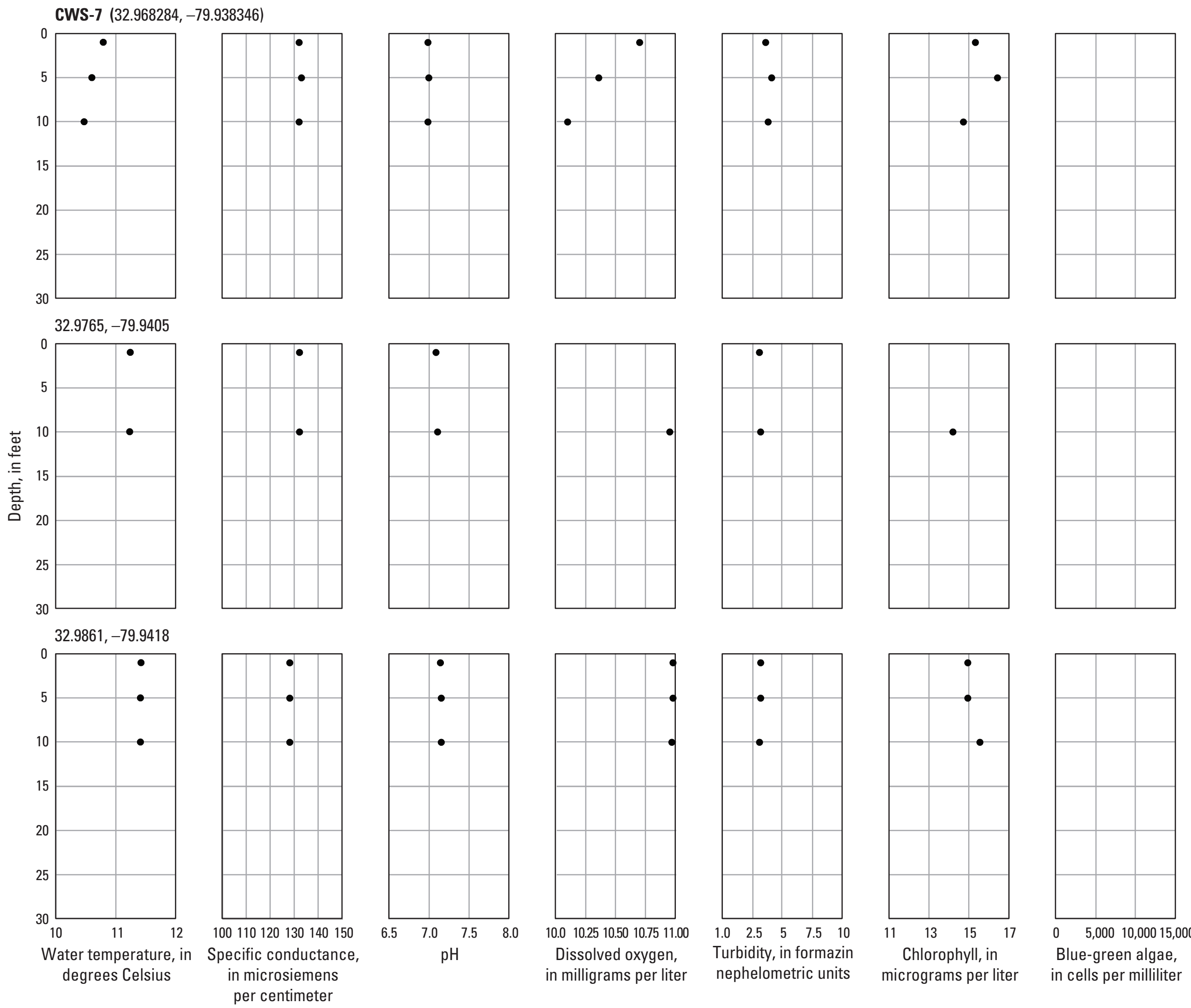

Figure 3–3. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, January 14, 2014.

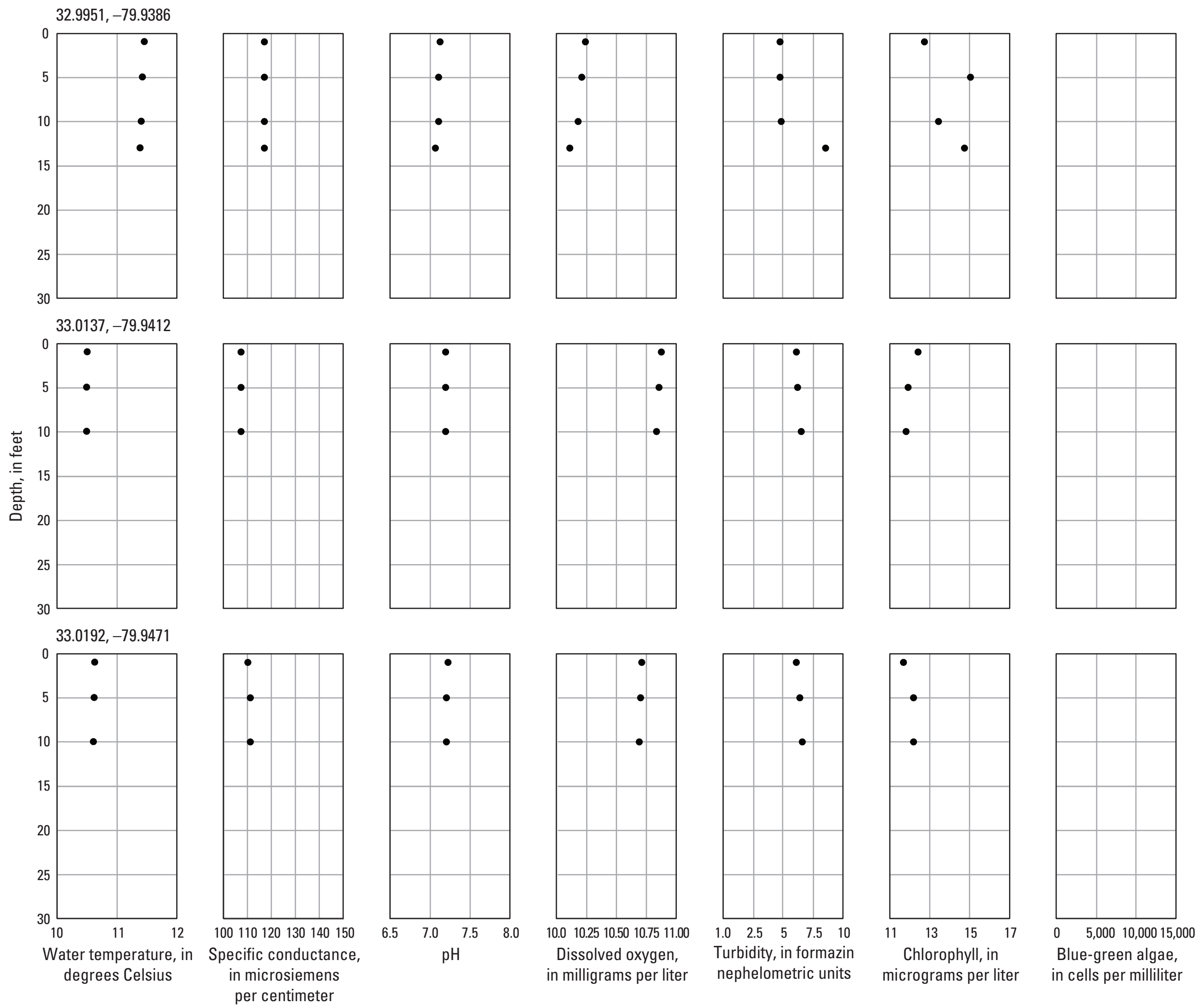

Figure 3–3. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, January 14, 2014.

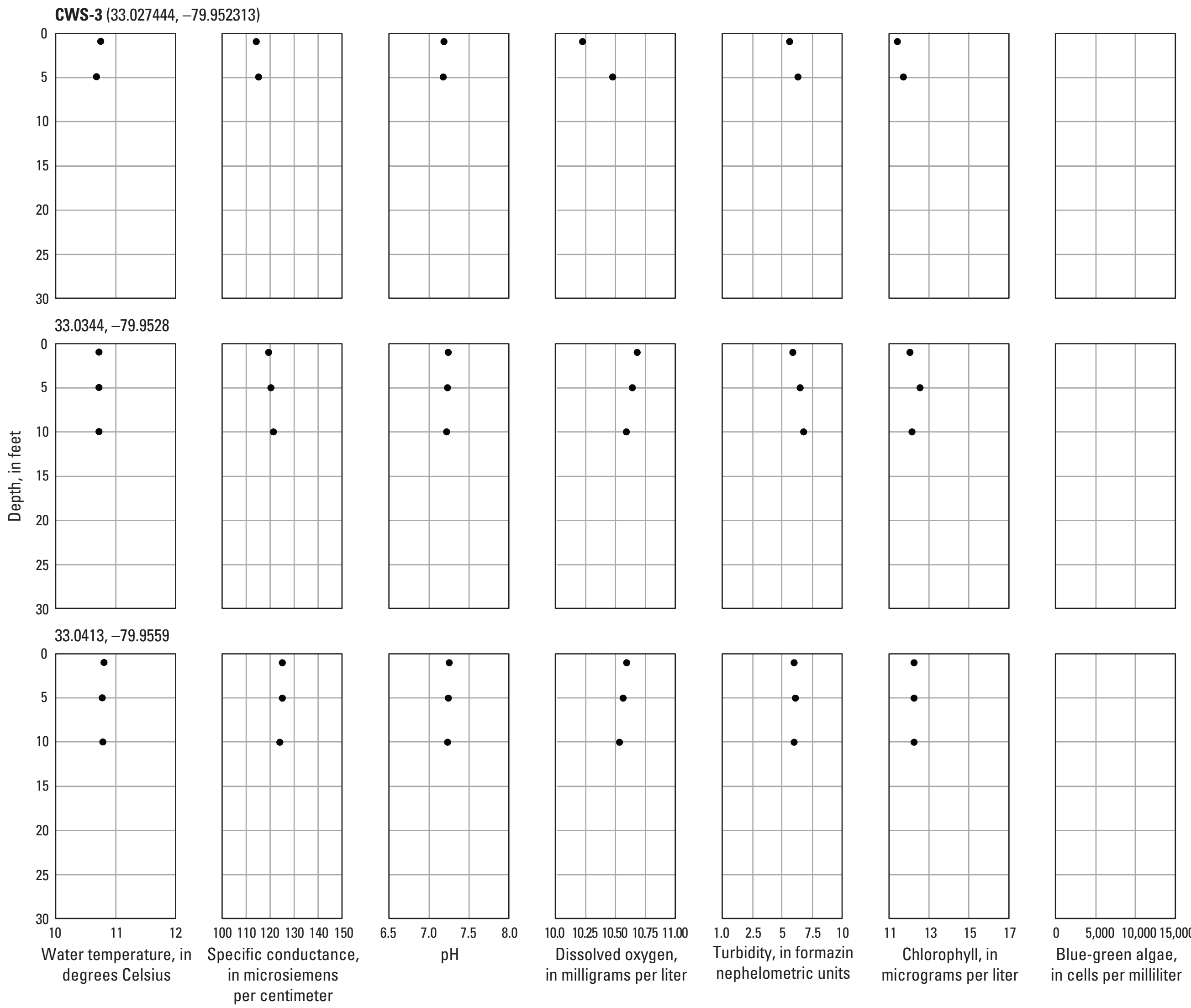

Figure 3–3. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, January 14, 2014.

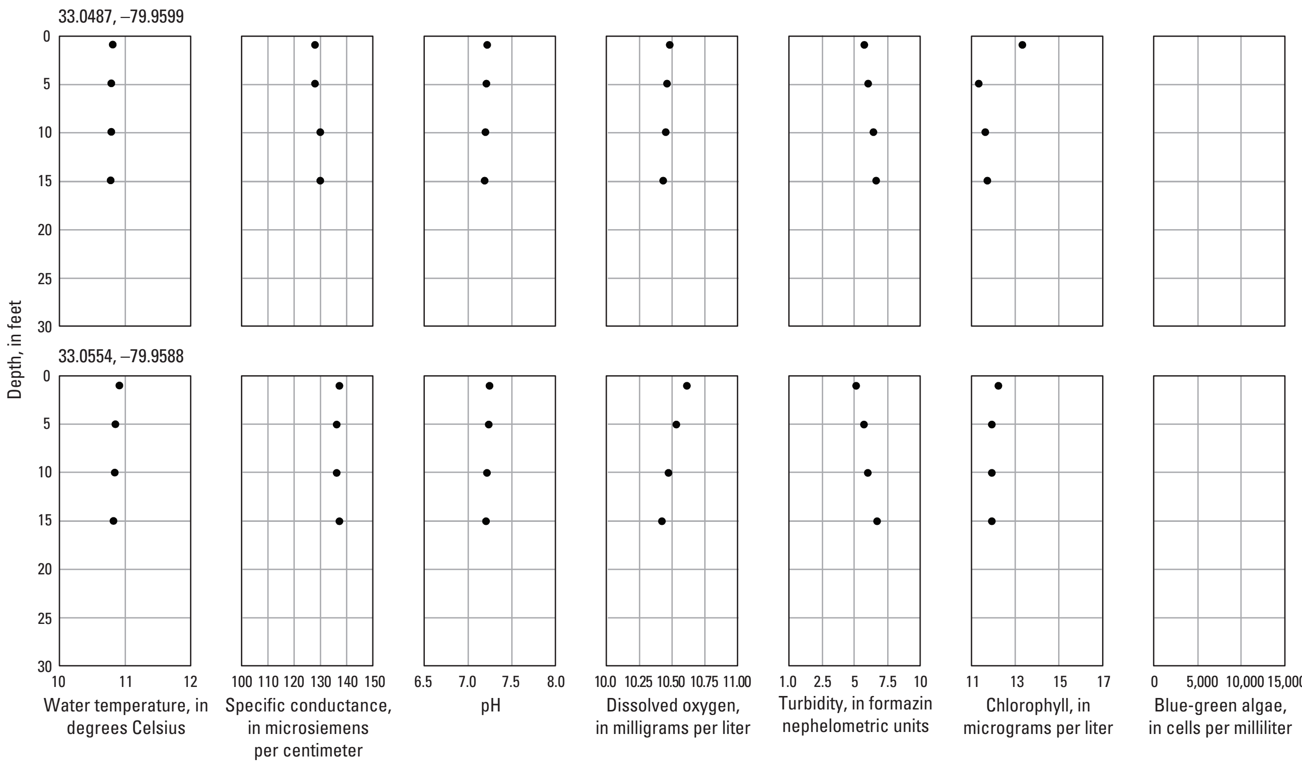

Figure 3–3. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, January 14, 2014.

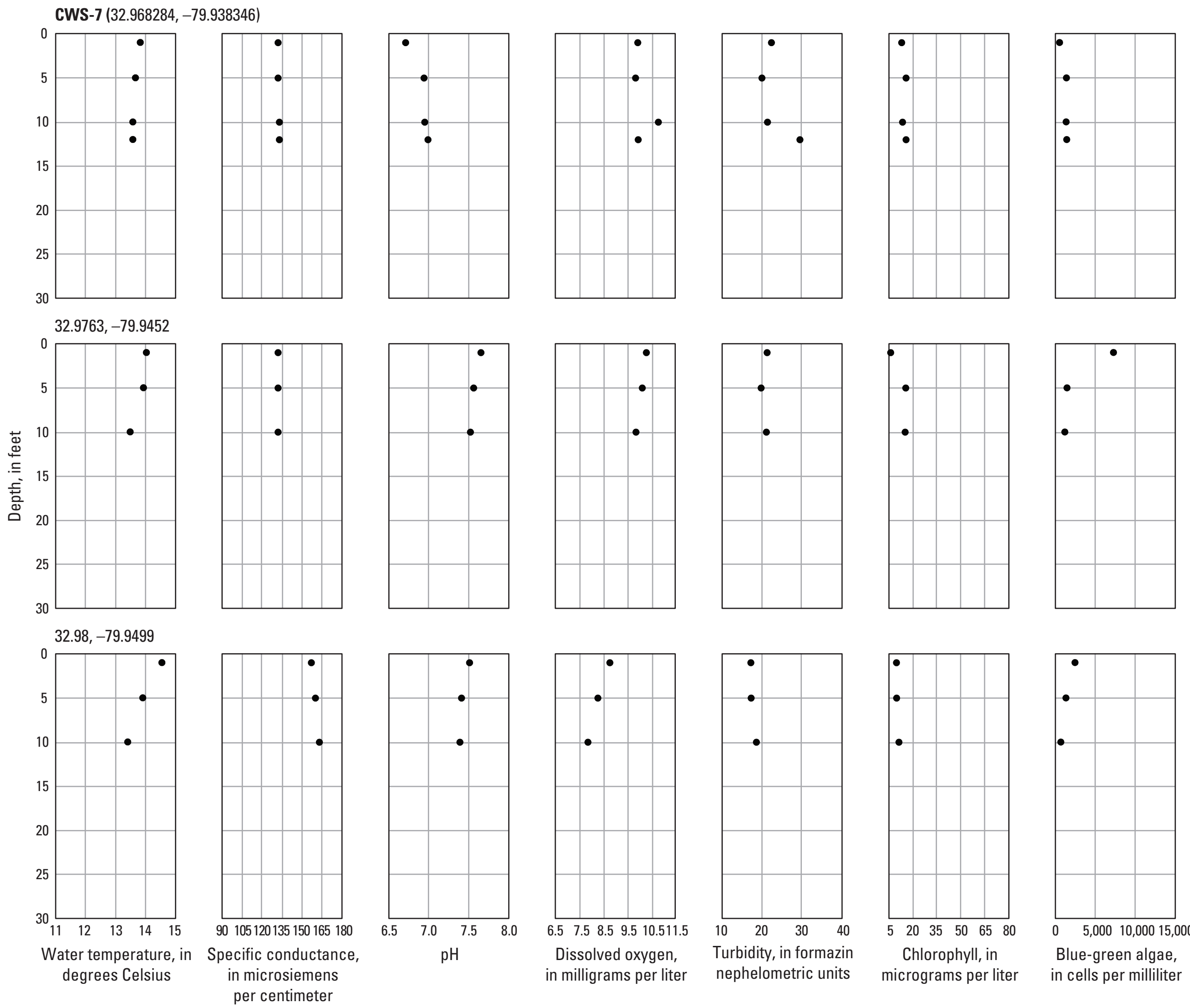

Figure 3–4. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 27, 2014.

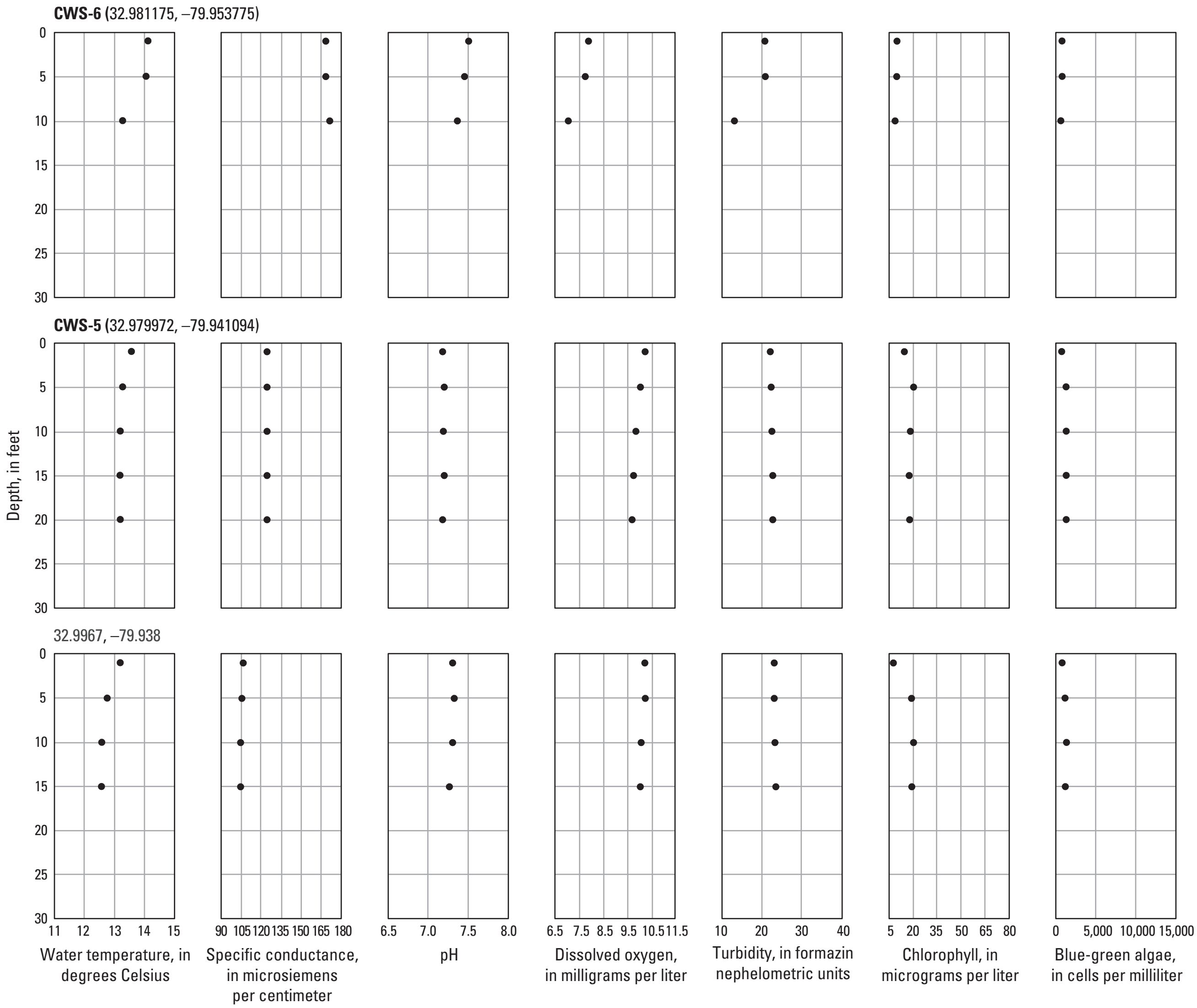

Figure 3–4. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 27, 2014.

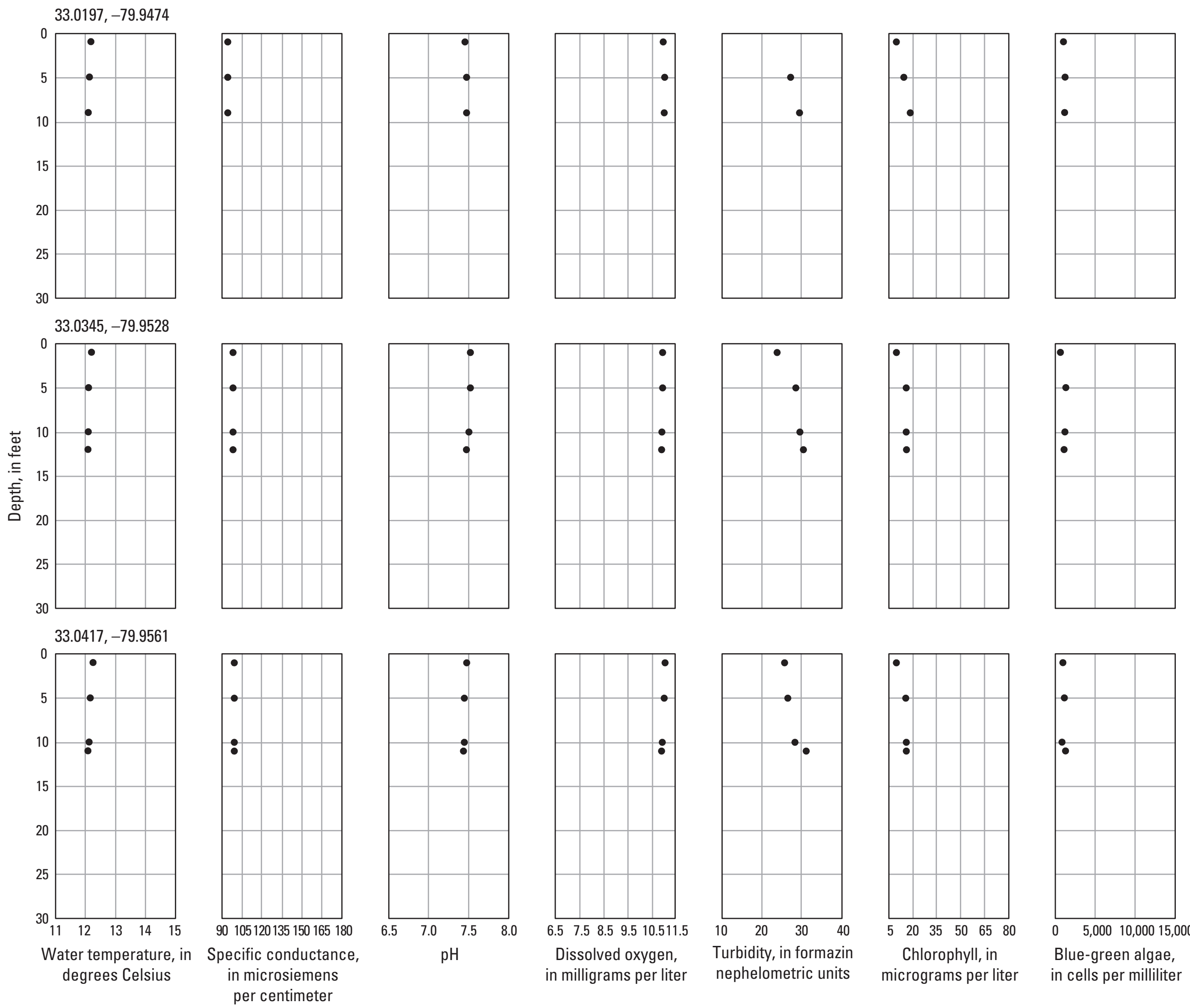

Figure 3–4. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 27, 2014.

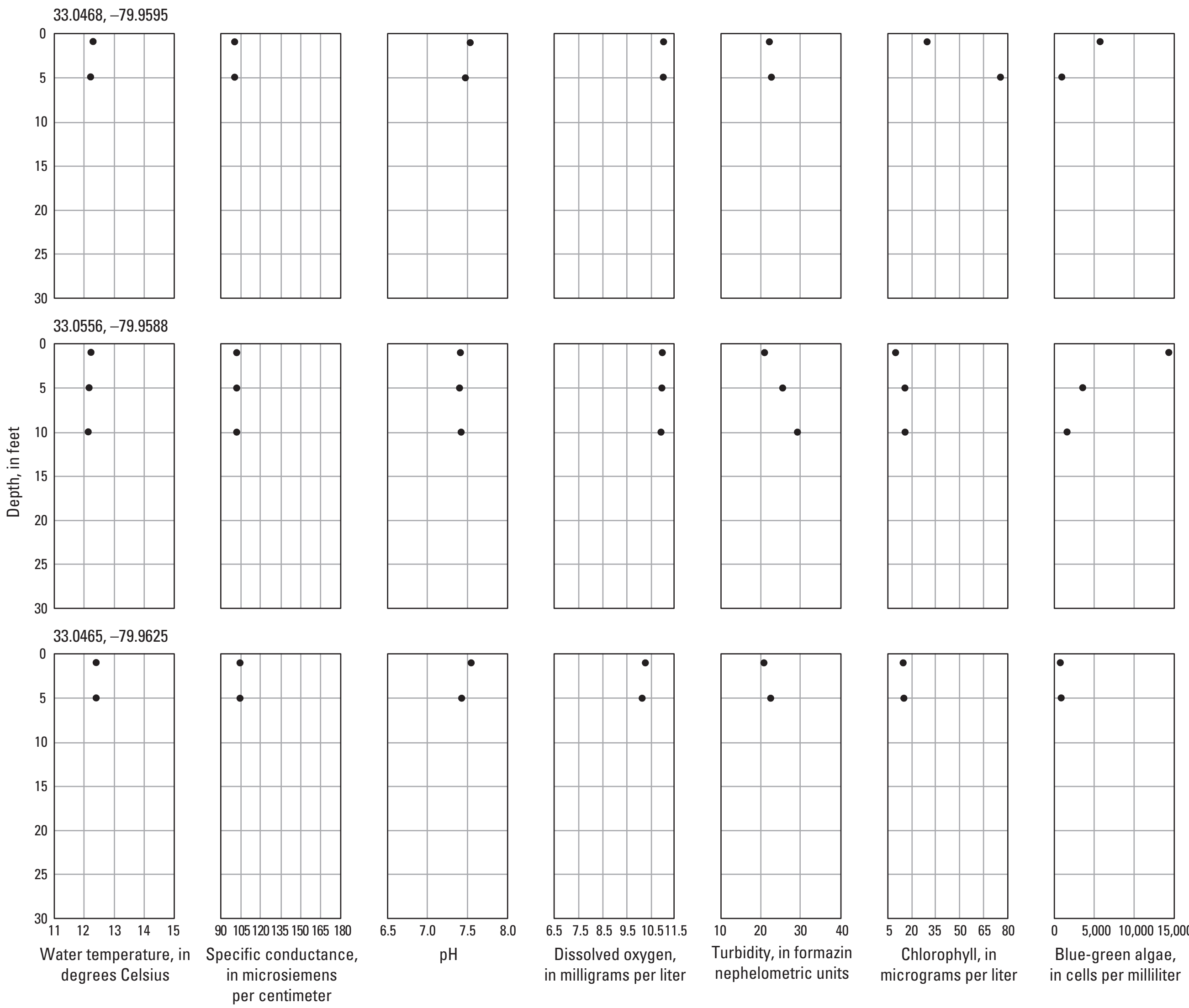

Figure 3–4. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 27, 2014.

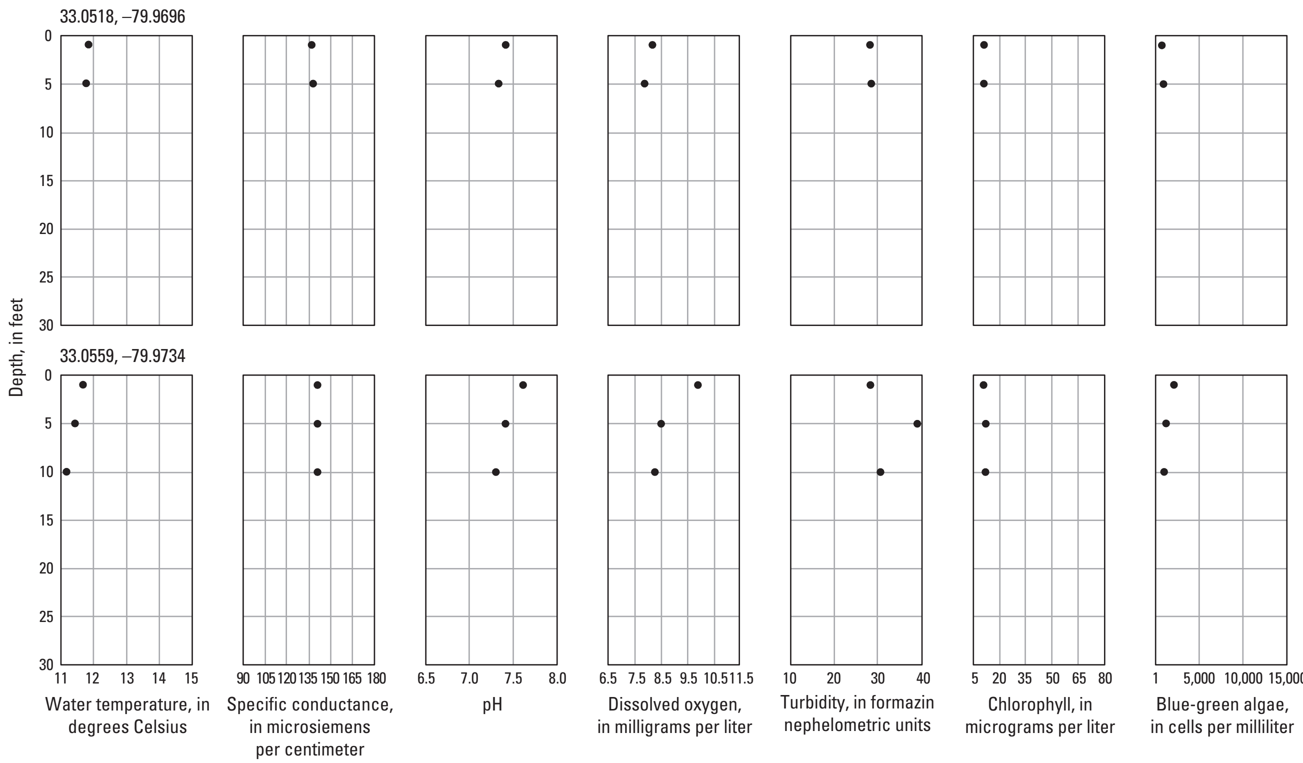

Figure 3–4. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 27, 2014.

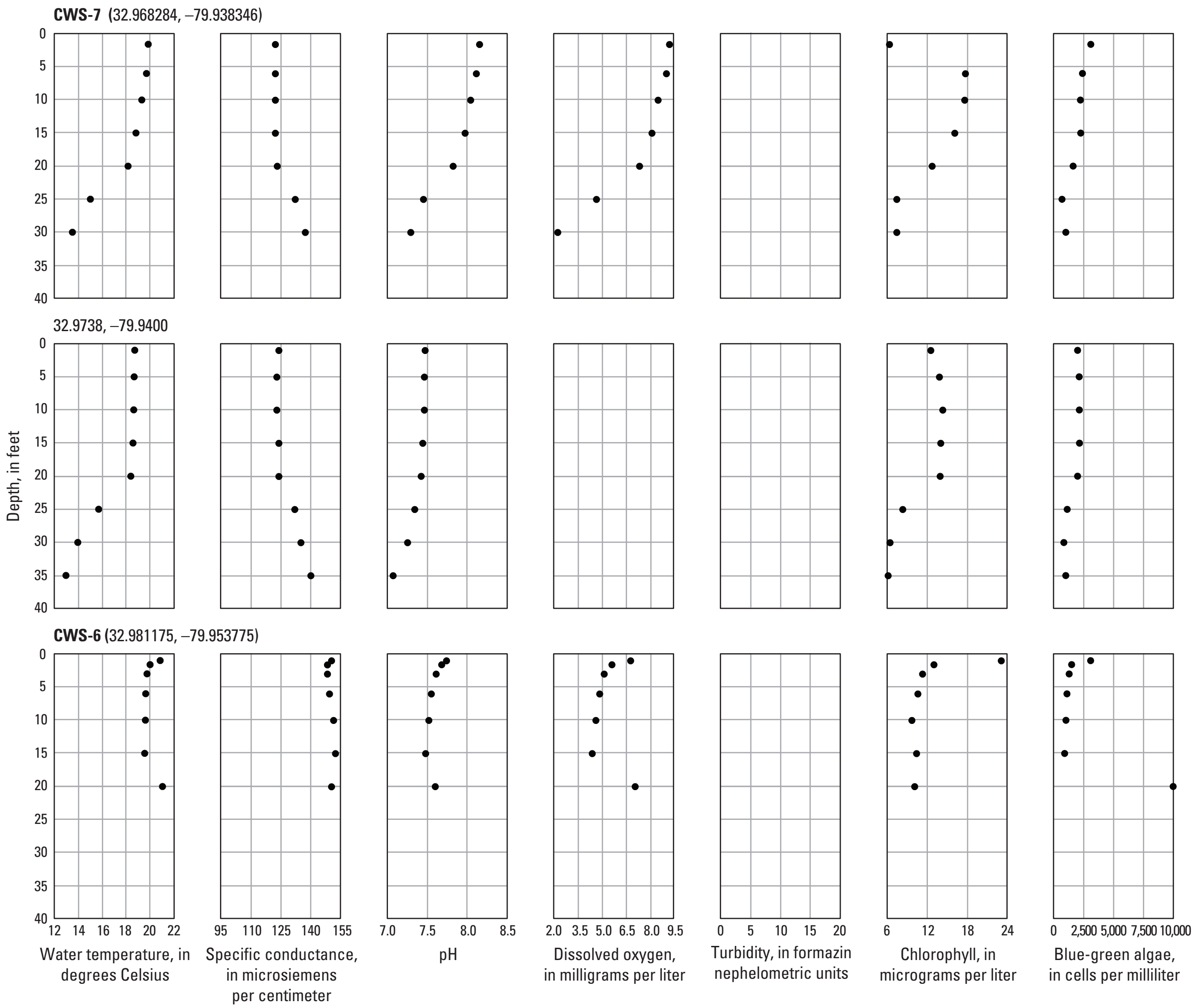

Figure 3–5. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 16, 2014.

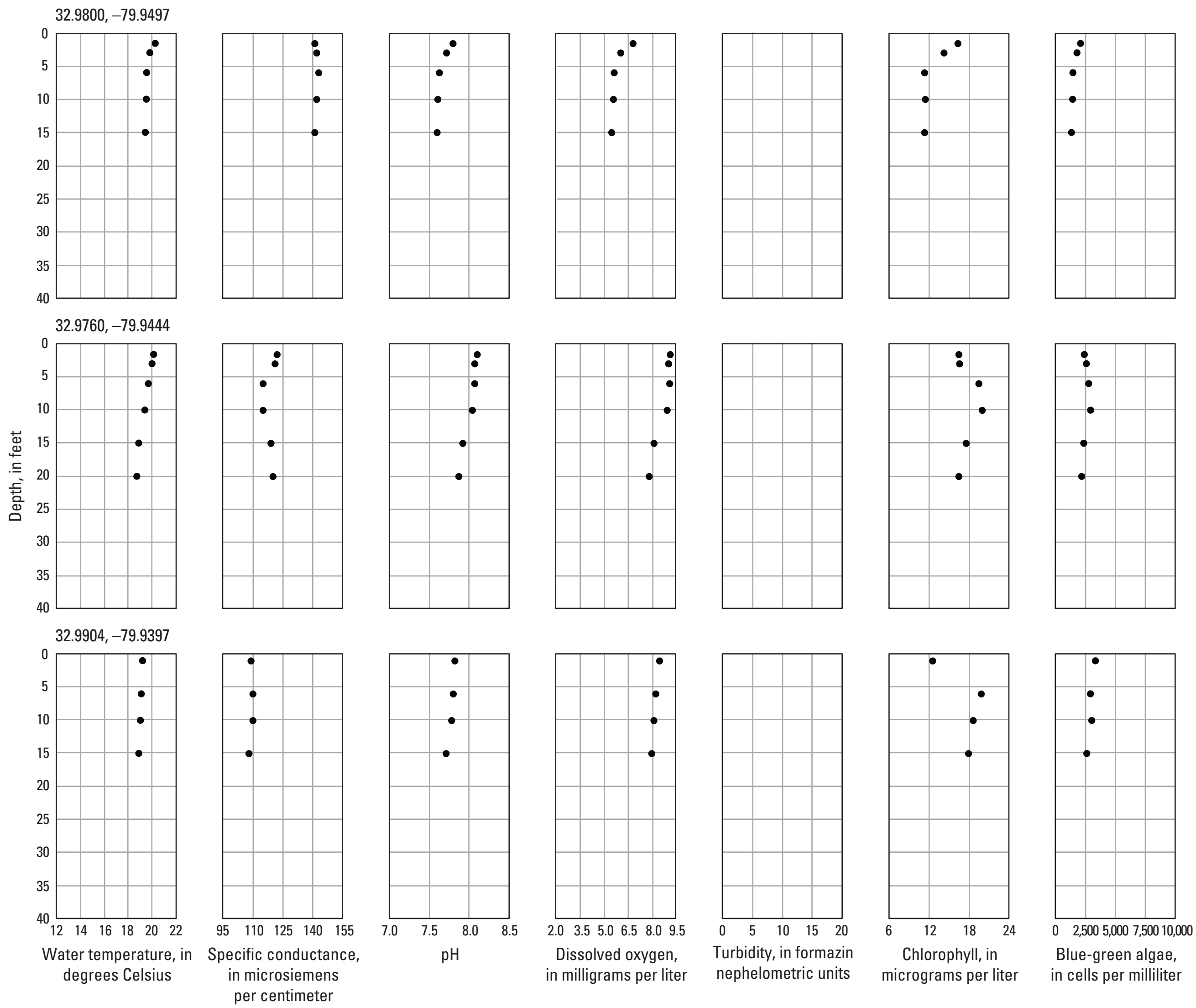

Figure 3–5. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 16, 2014.

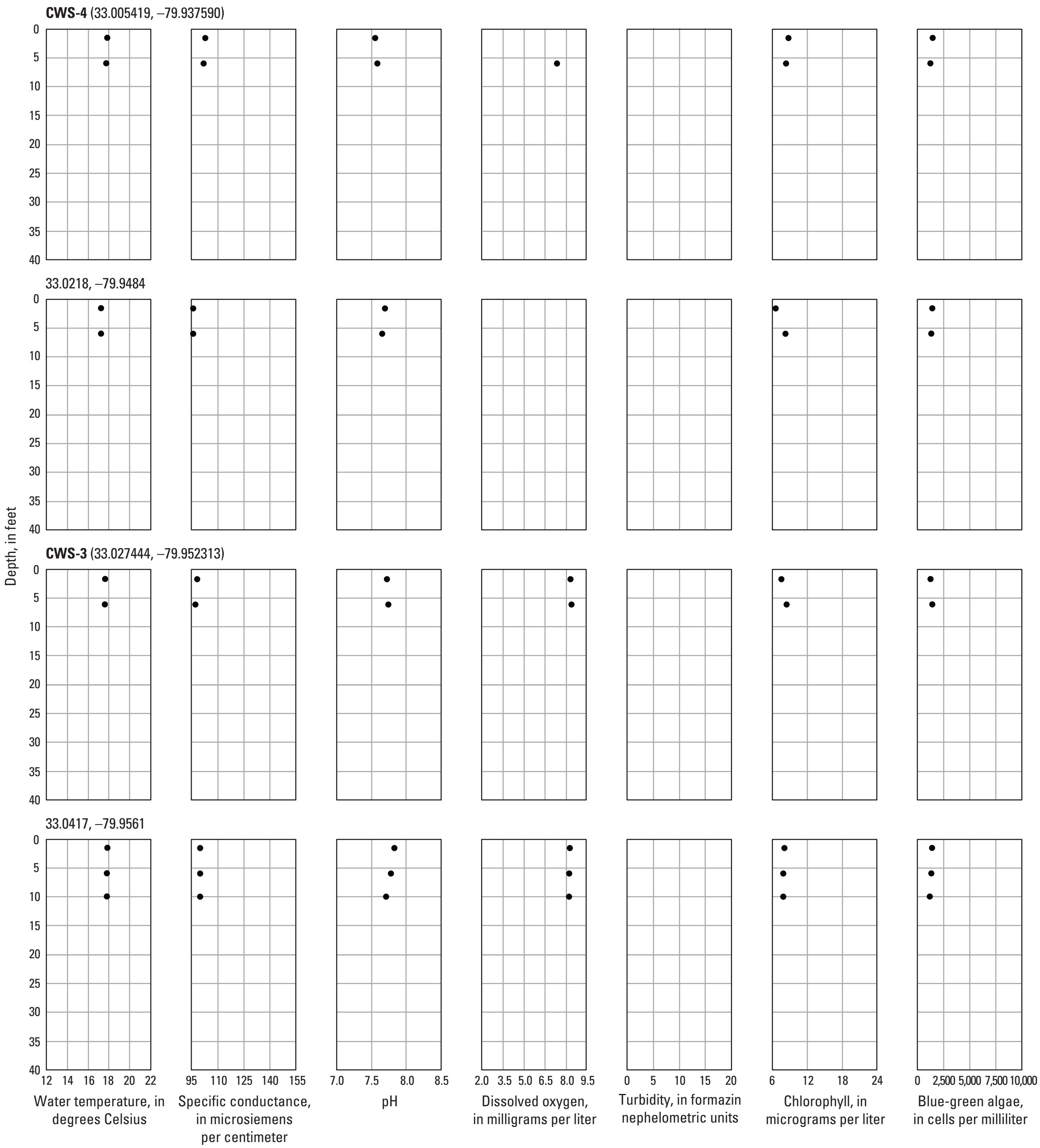

Figure 3–5. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 16, 2014.

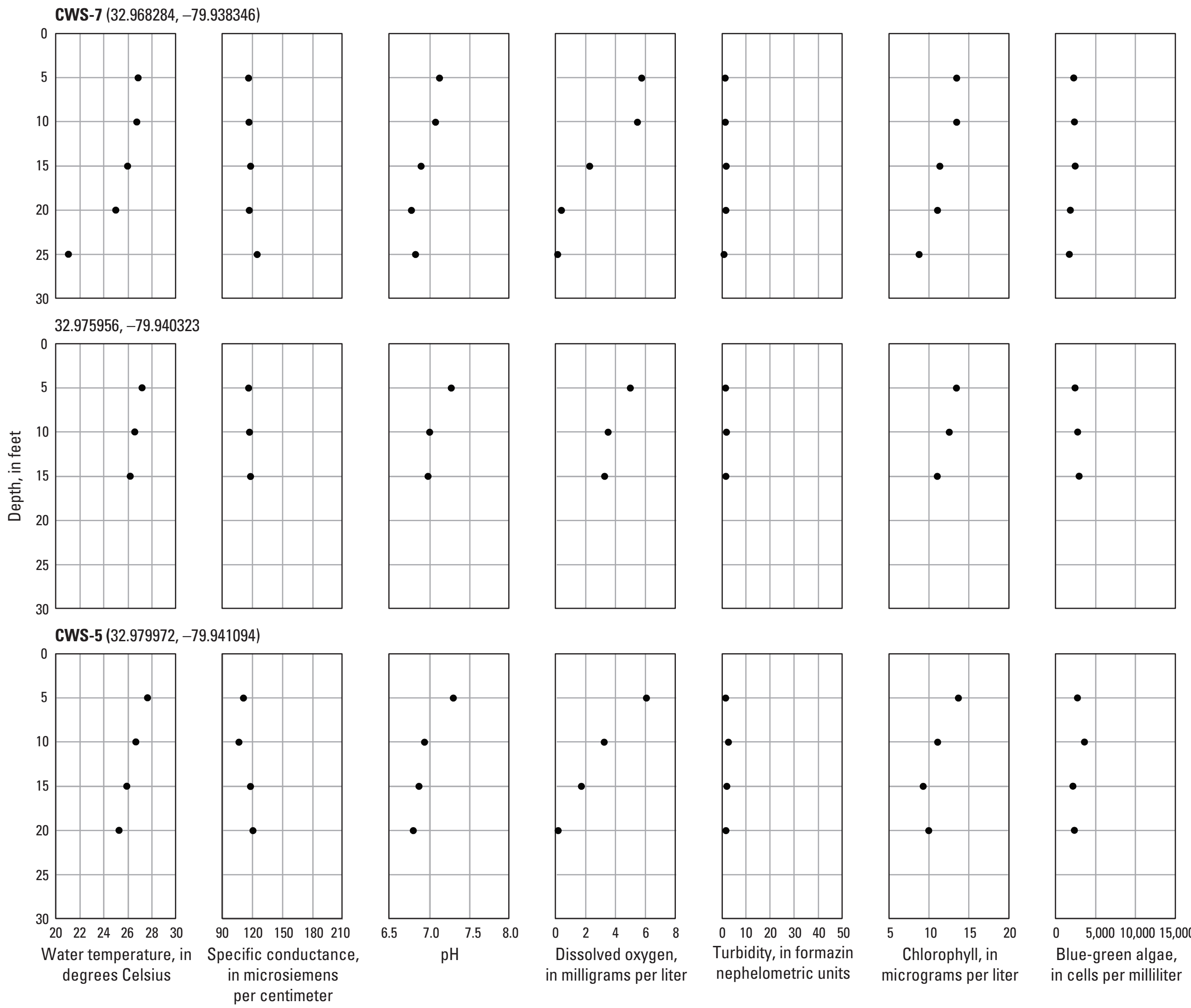

Figure 3–6. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, June 10, 2014.

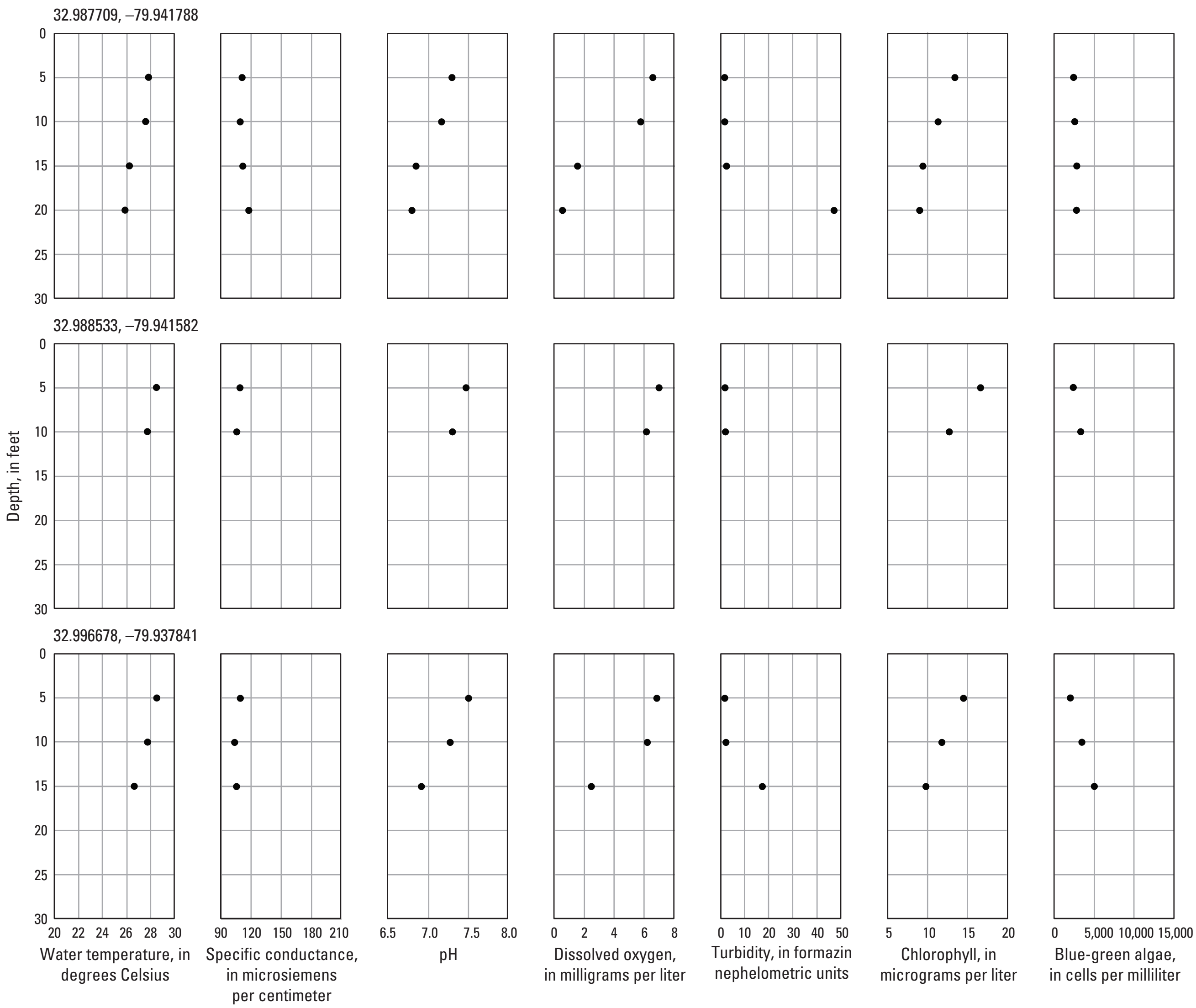

Figure 3–6. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, June 10, 2014.

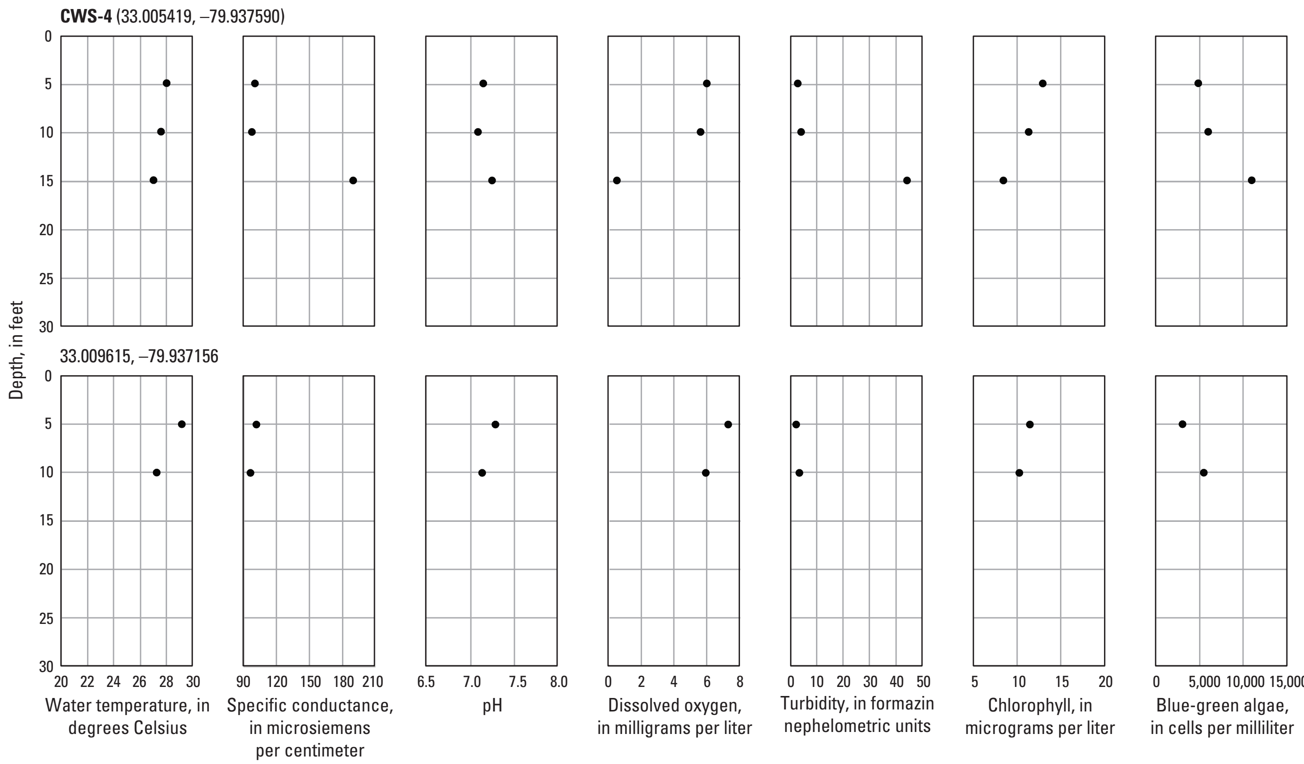

Figure 3–6. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, June 10, 2014.

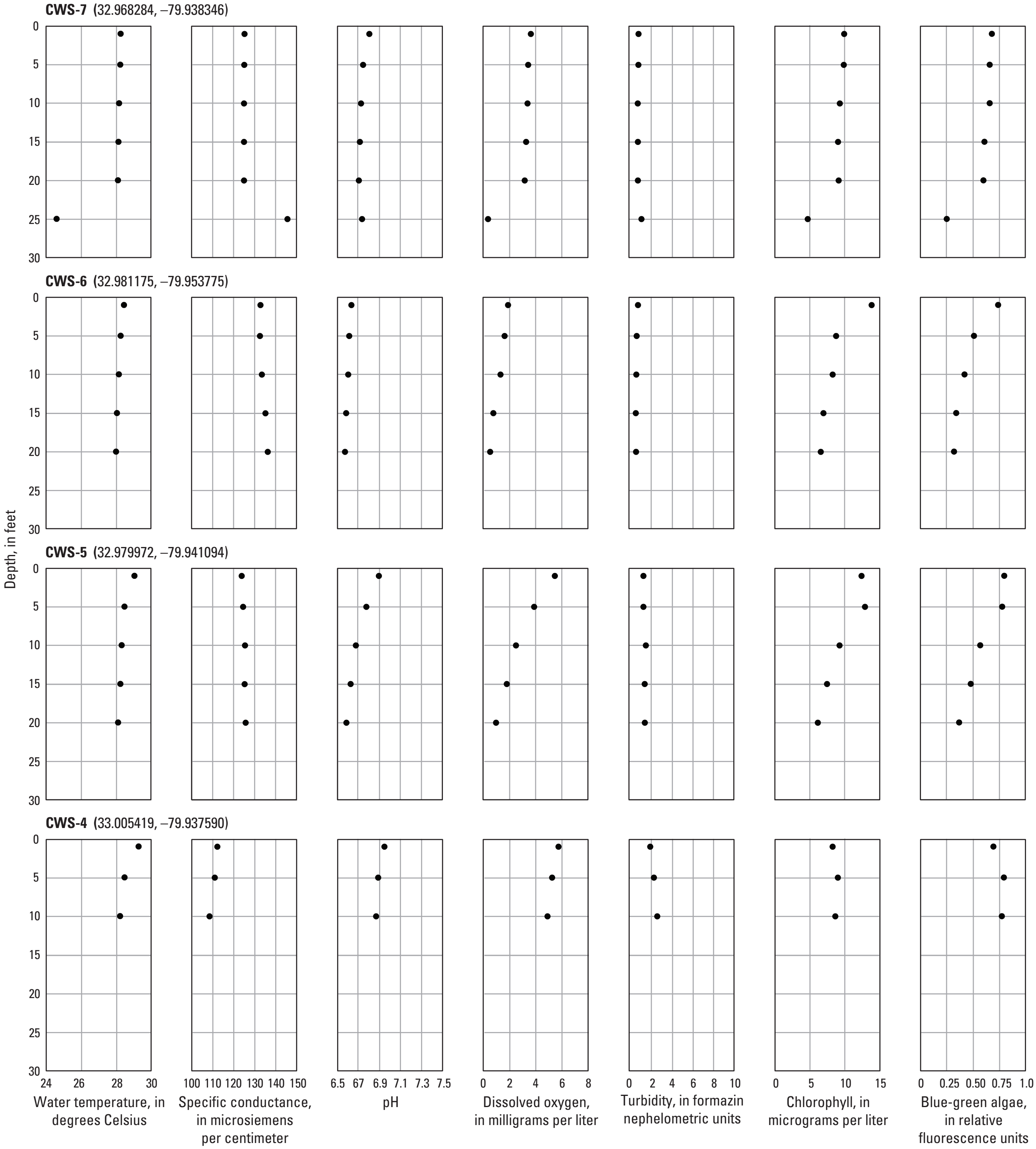

Figure 3–7. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, July 23, 2014.

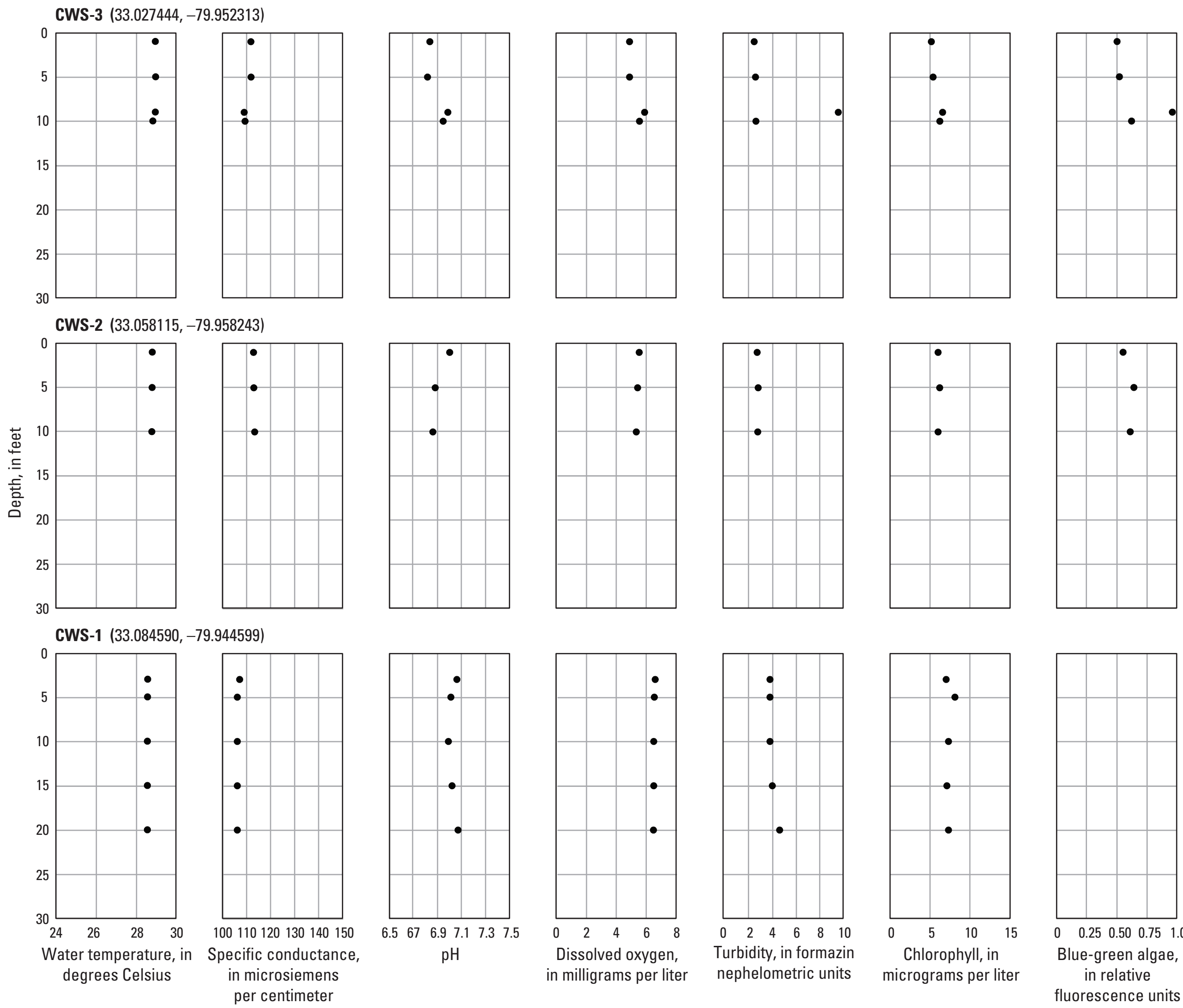

Figure 3–7. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, July 23, 2014.

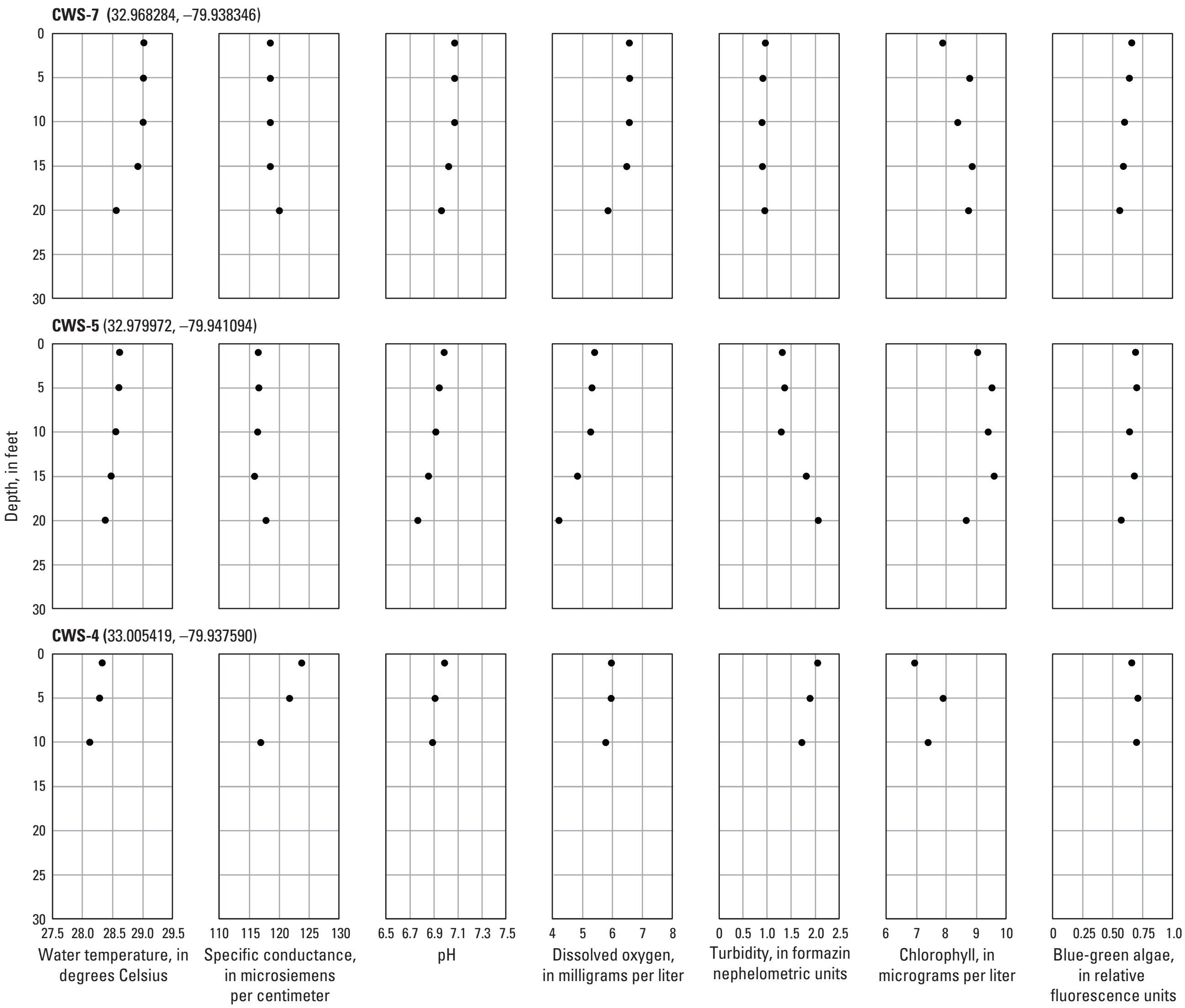

Figure 3–8. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, August 26, 2014.

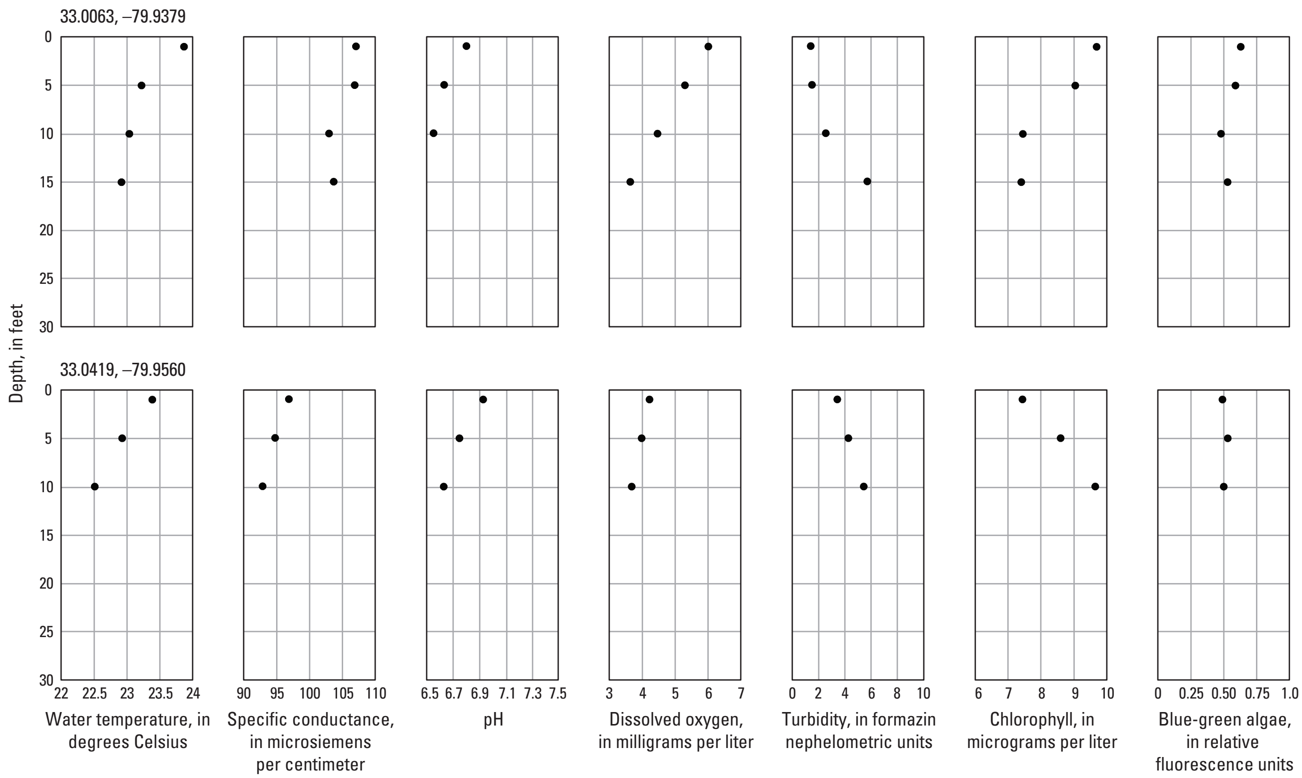

Figure 3–9. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, October 2, 2014.

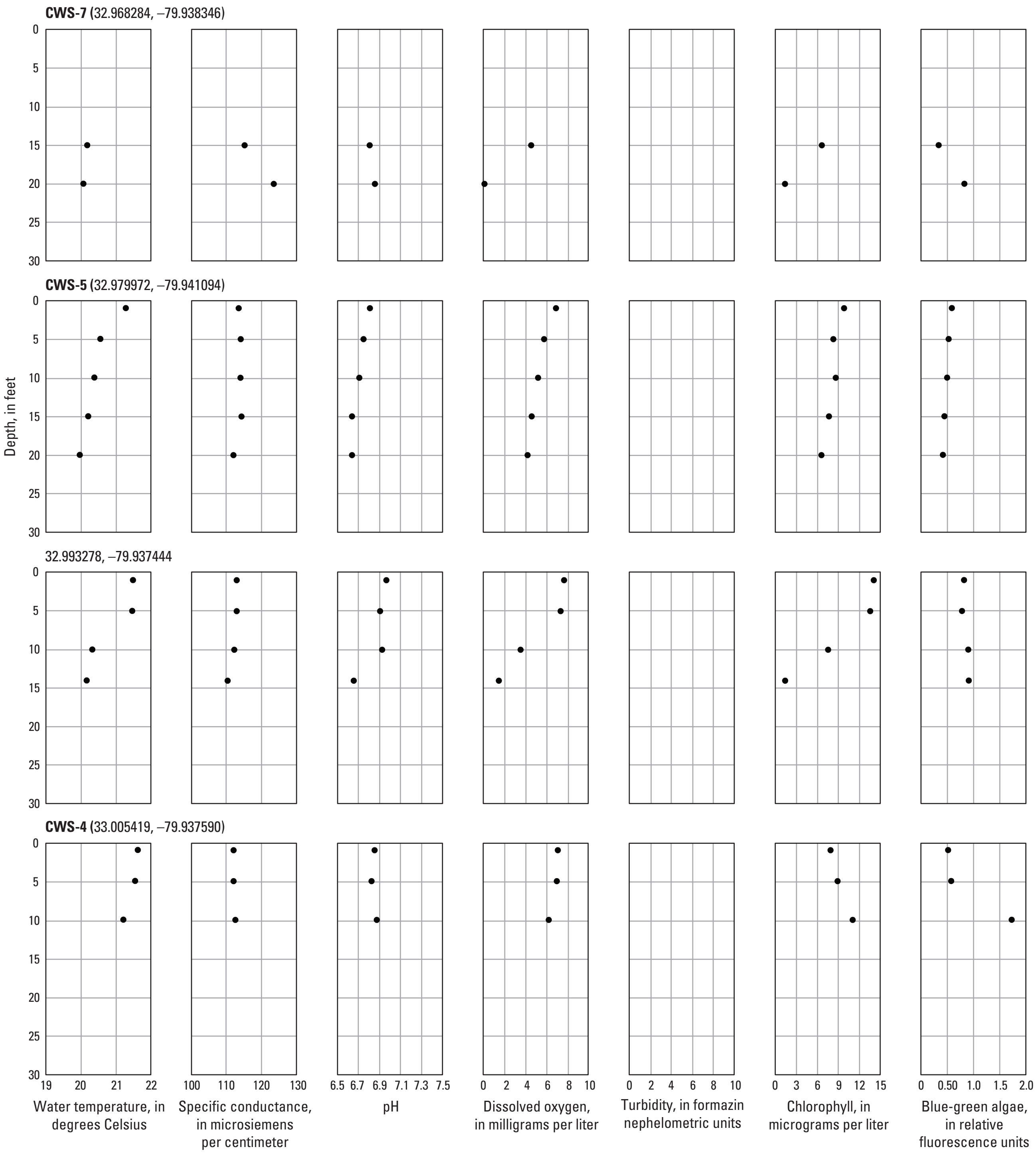

Figure 3–10. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, October 29, 2014.

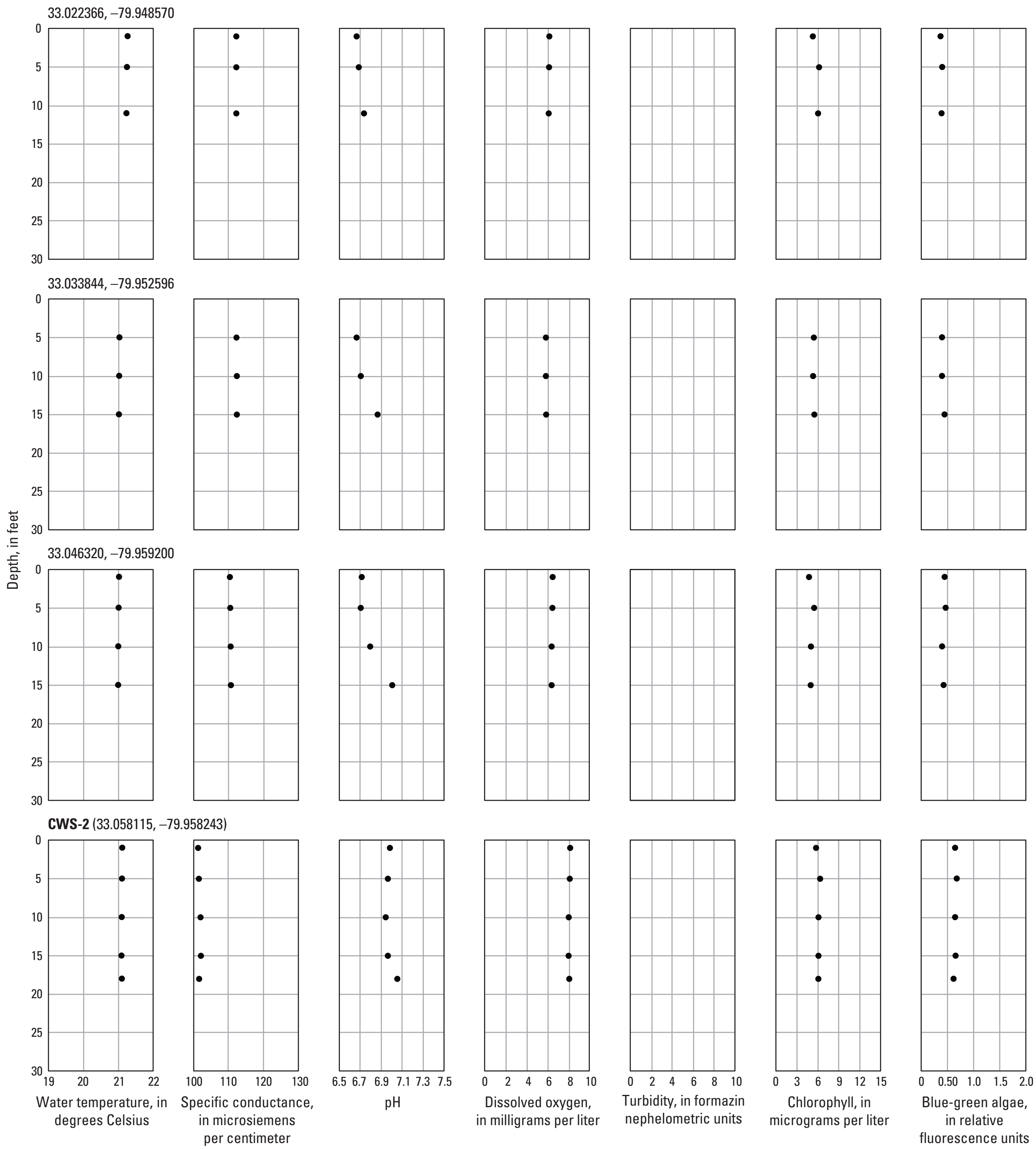

Figure 3–10. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, October 29, 2014.

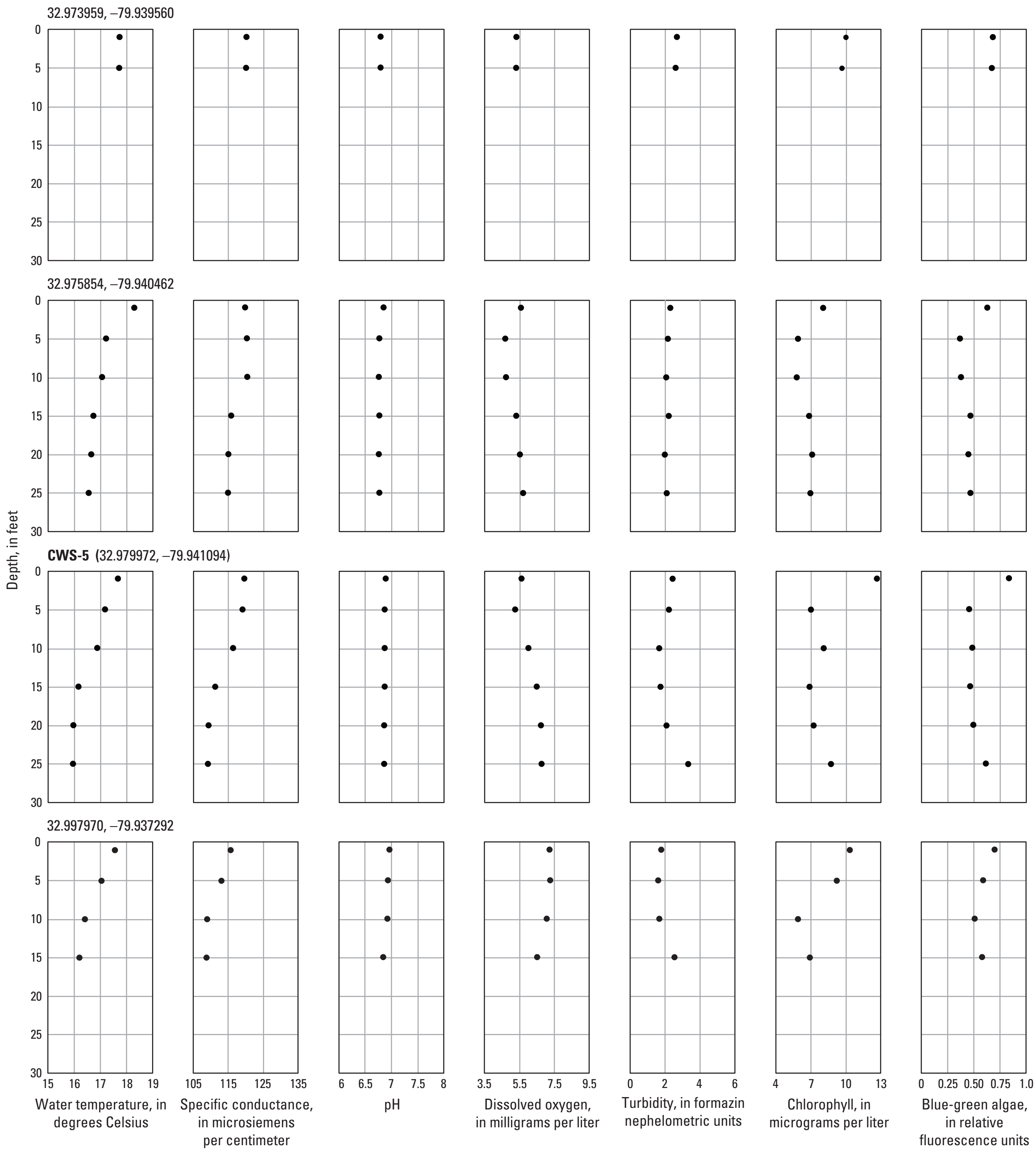

Figure 3–11. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 5, 2014.

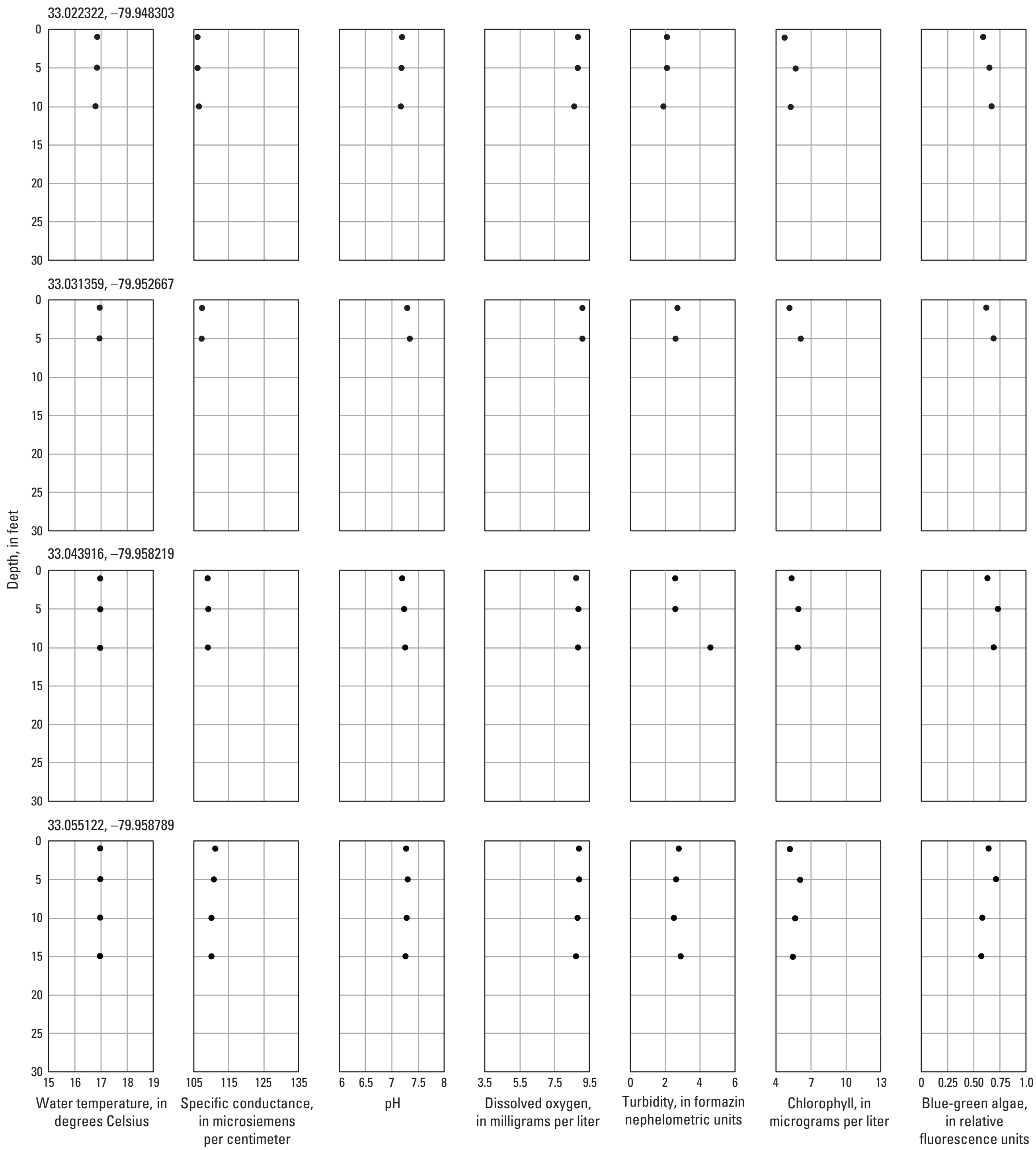

Figure 3–11. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 5, 2014.

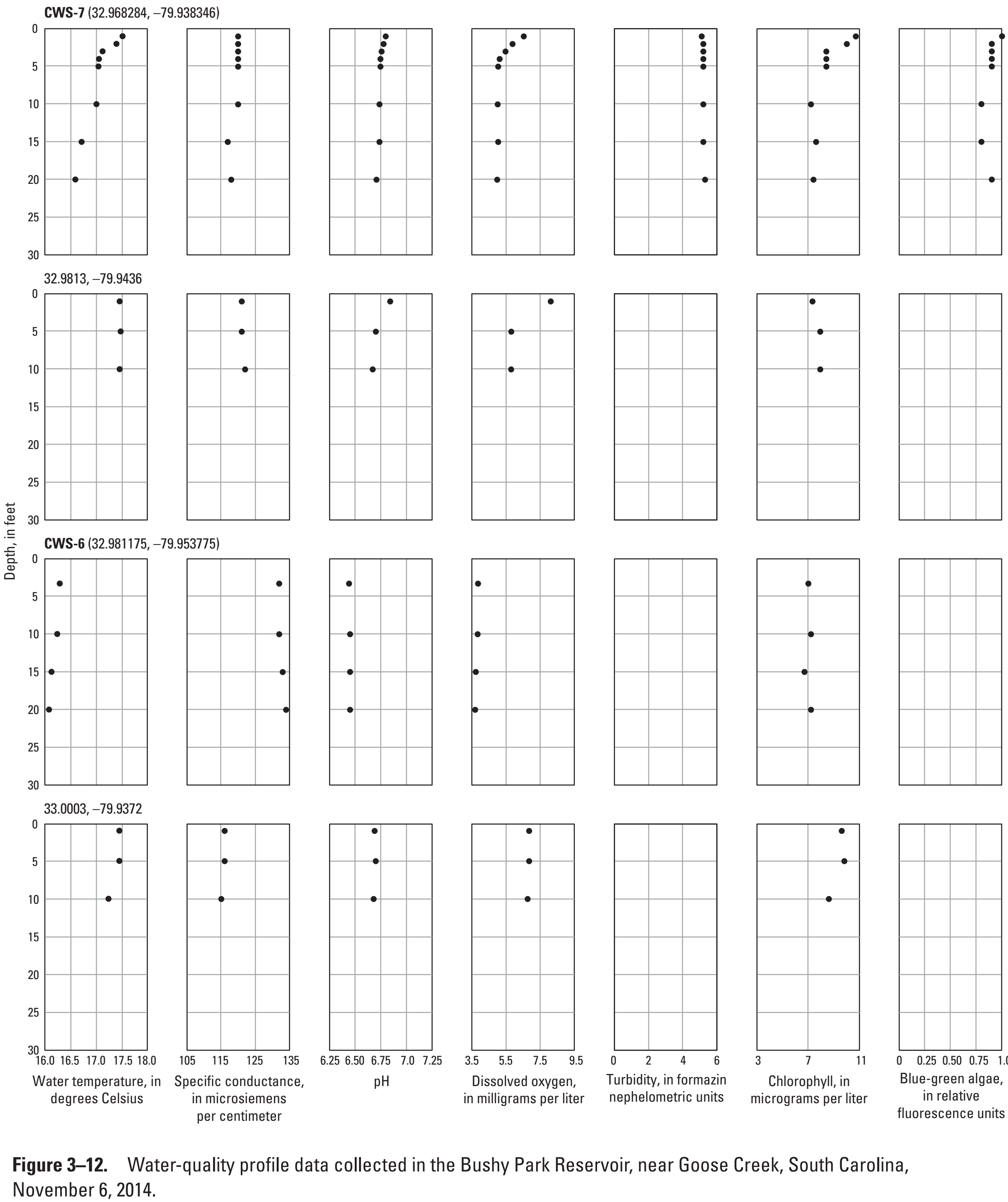

Figure 3–12. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 6, 2014.

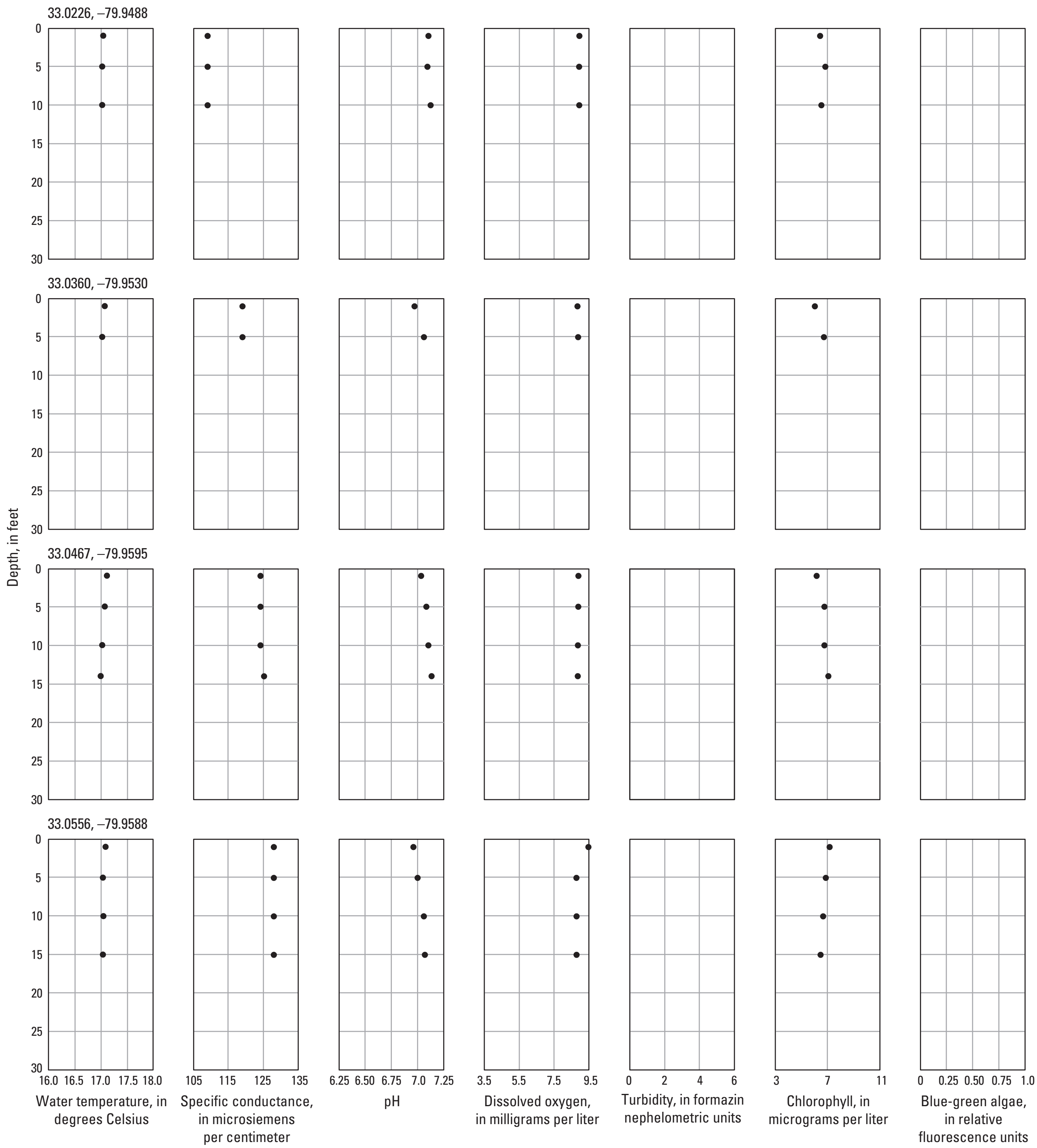

Figure 3–12. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, November 6, 2014.

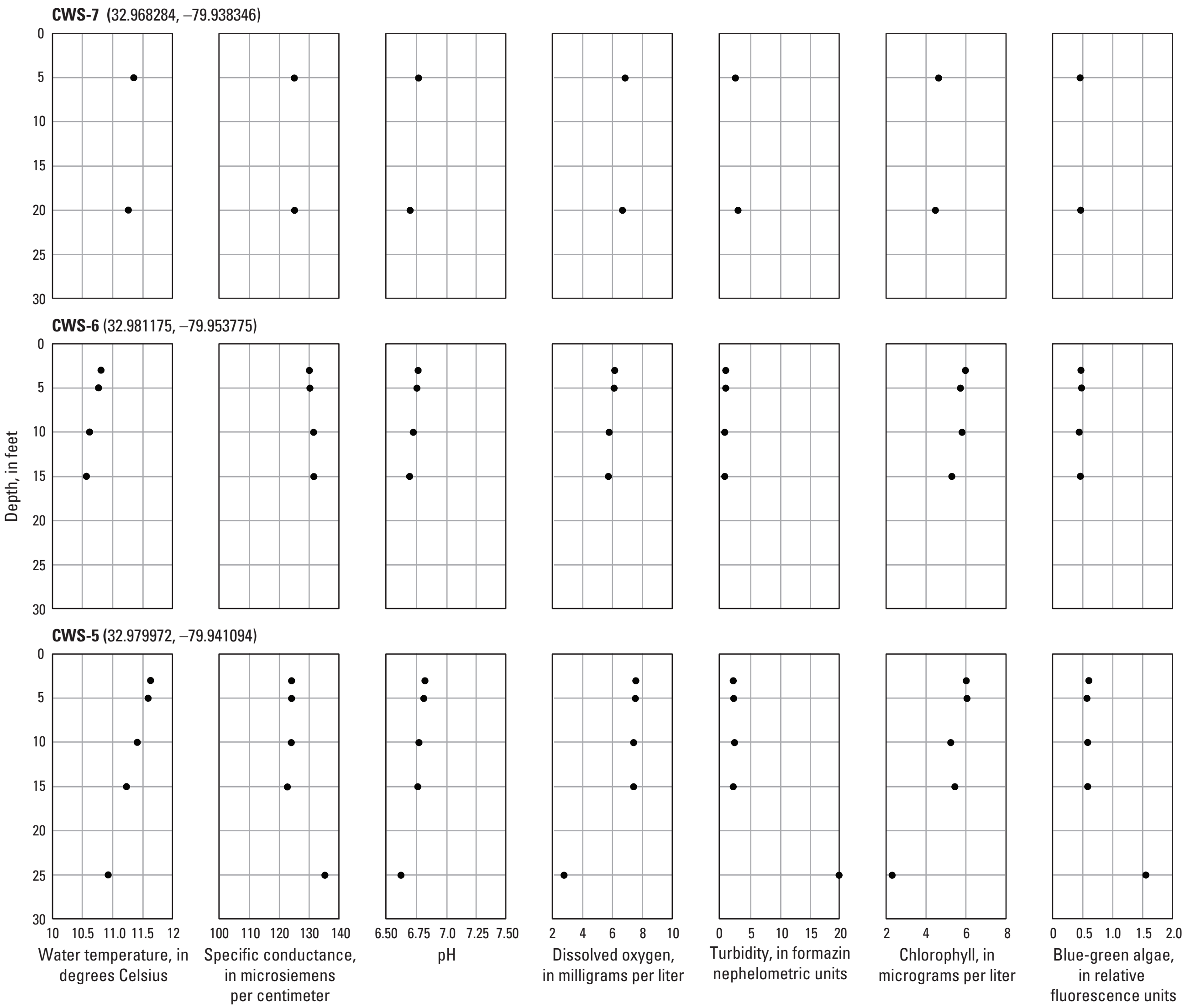

Figure 3–13. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, December 16, 2014.

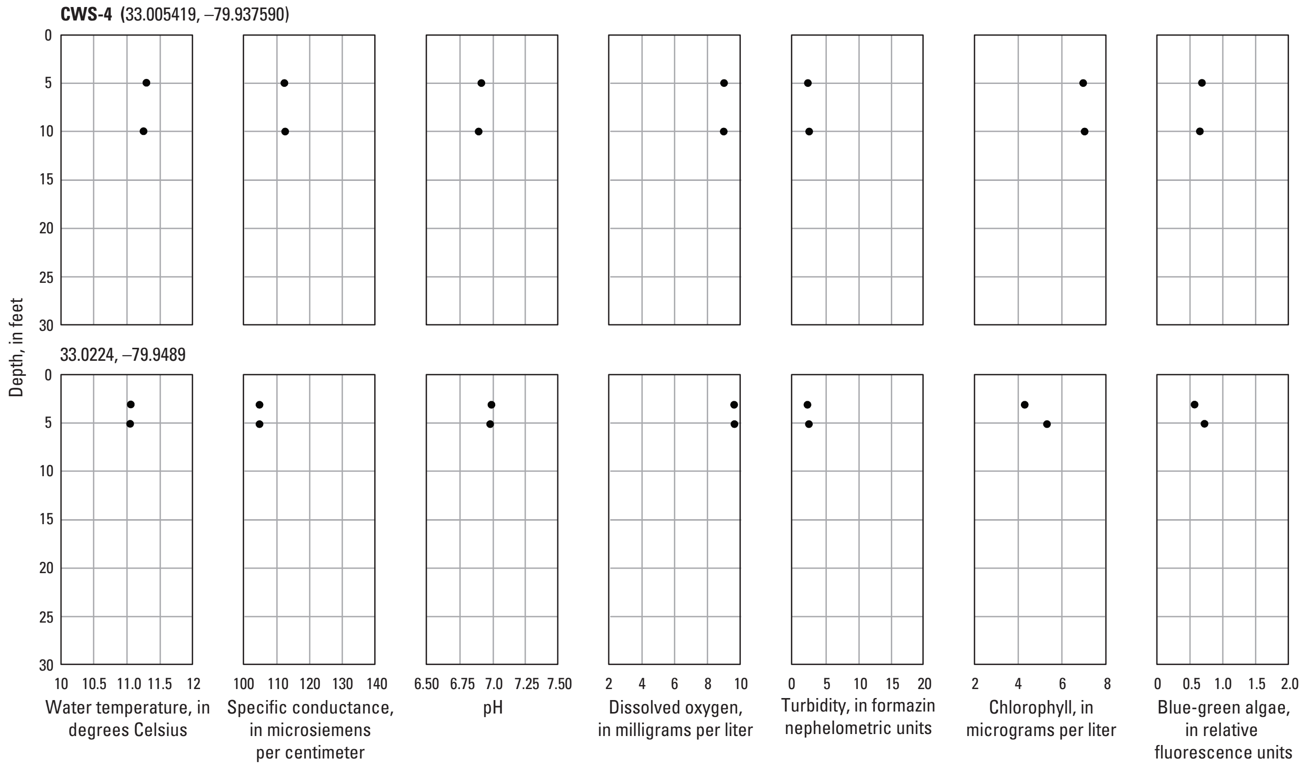

Figure 3–13. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, December 16, 2014.

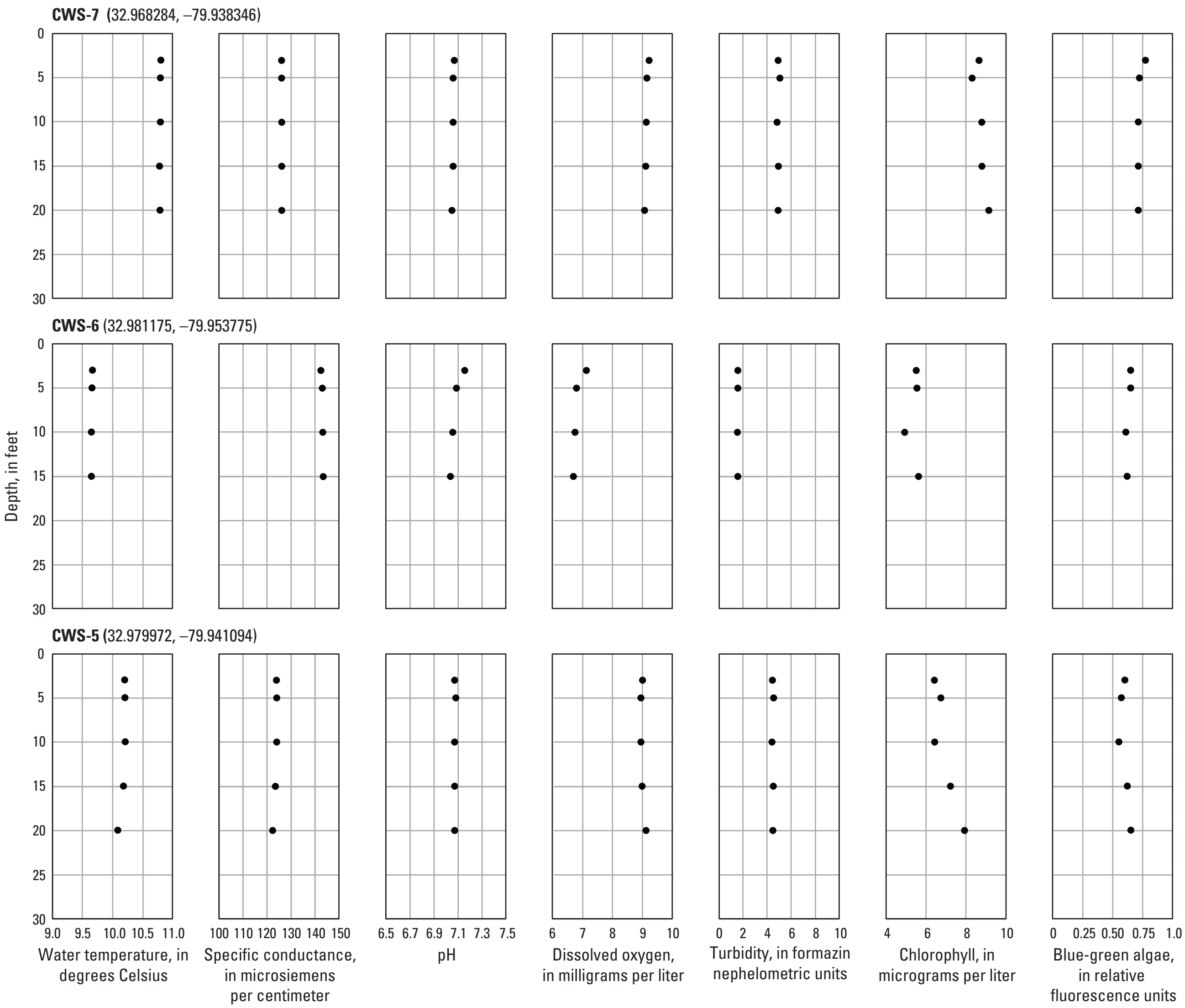

Figure 3–14. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, January 14, 2015.

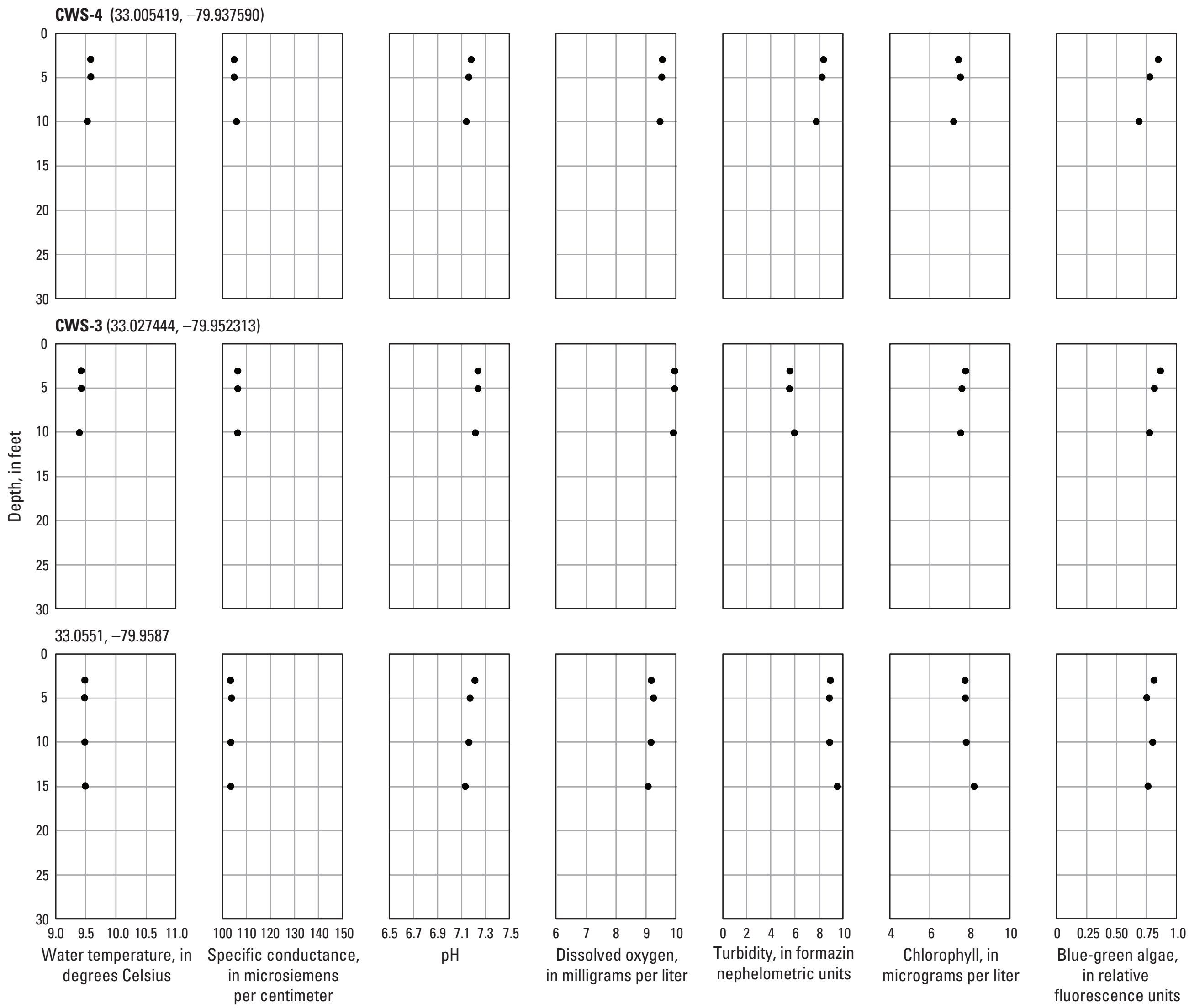

Figure 3–14. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, January 14, 2015.

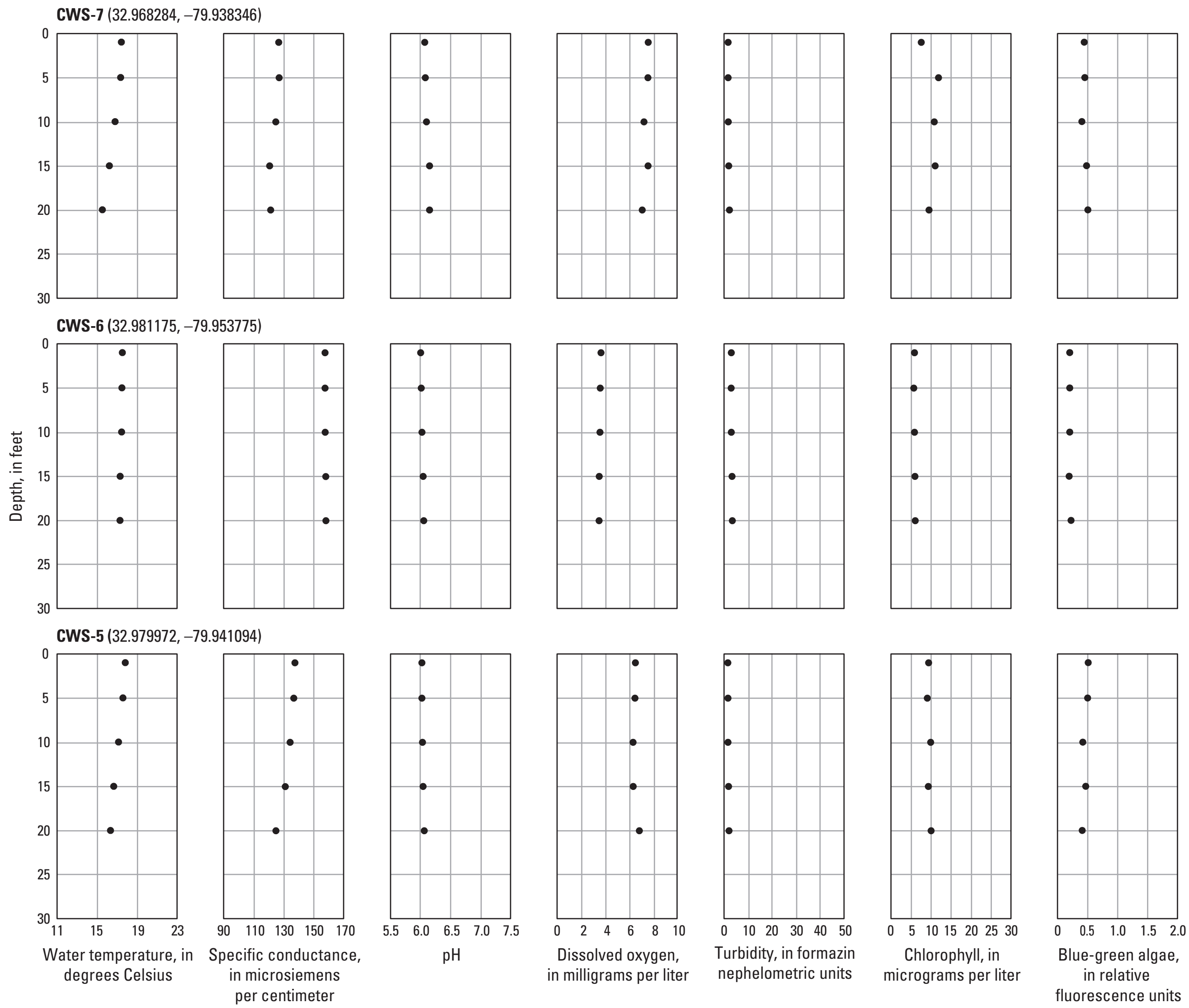

Figure 3–15. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 26, 2015 (morning survey).

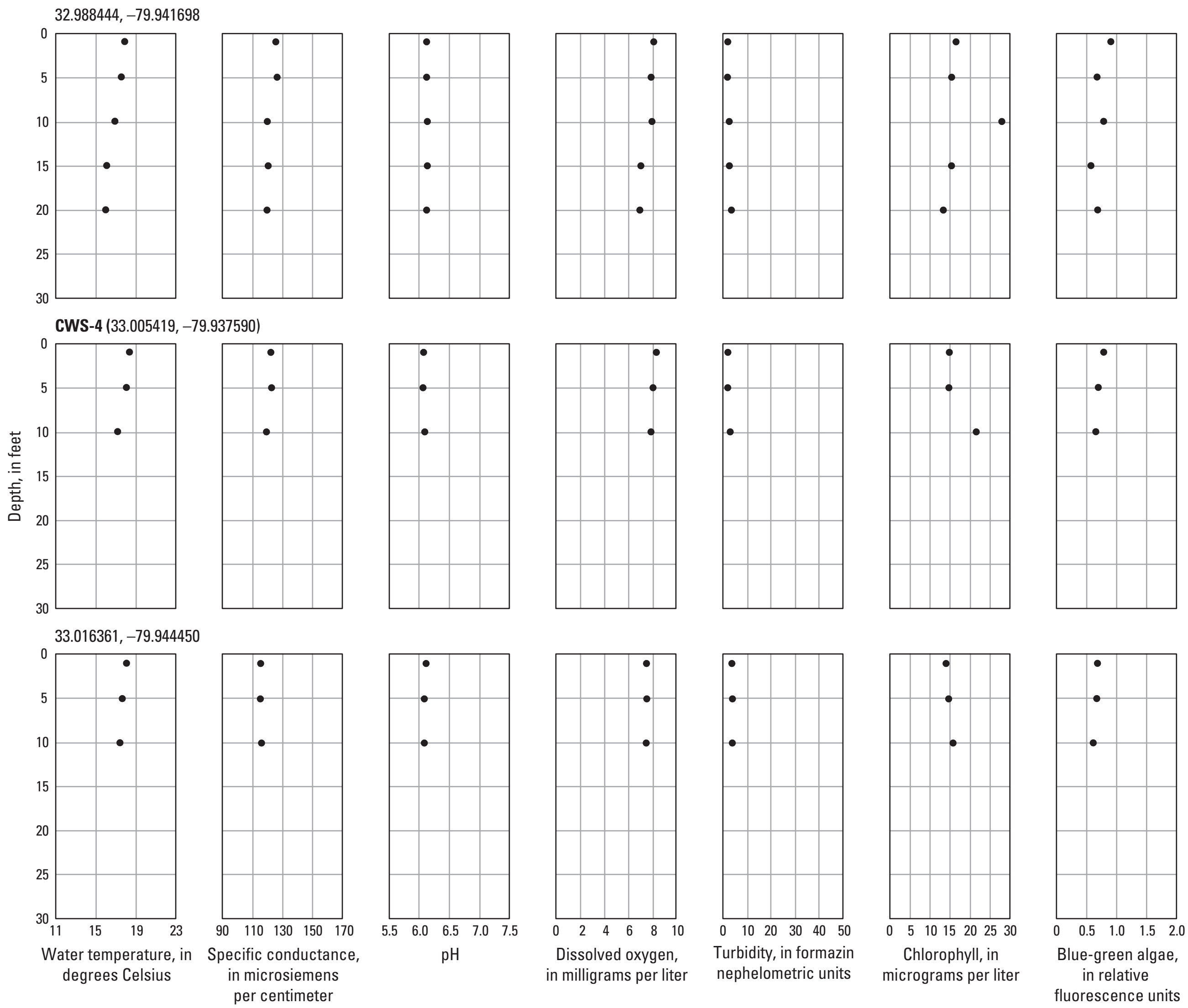

Figure 3–15. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 26, 2015 (morning survey).

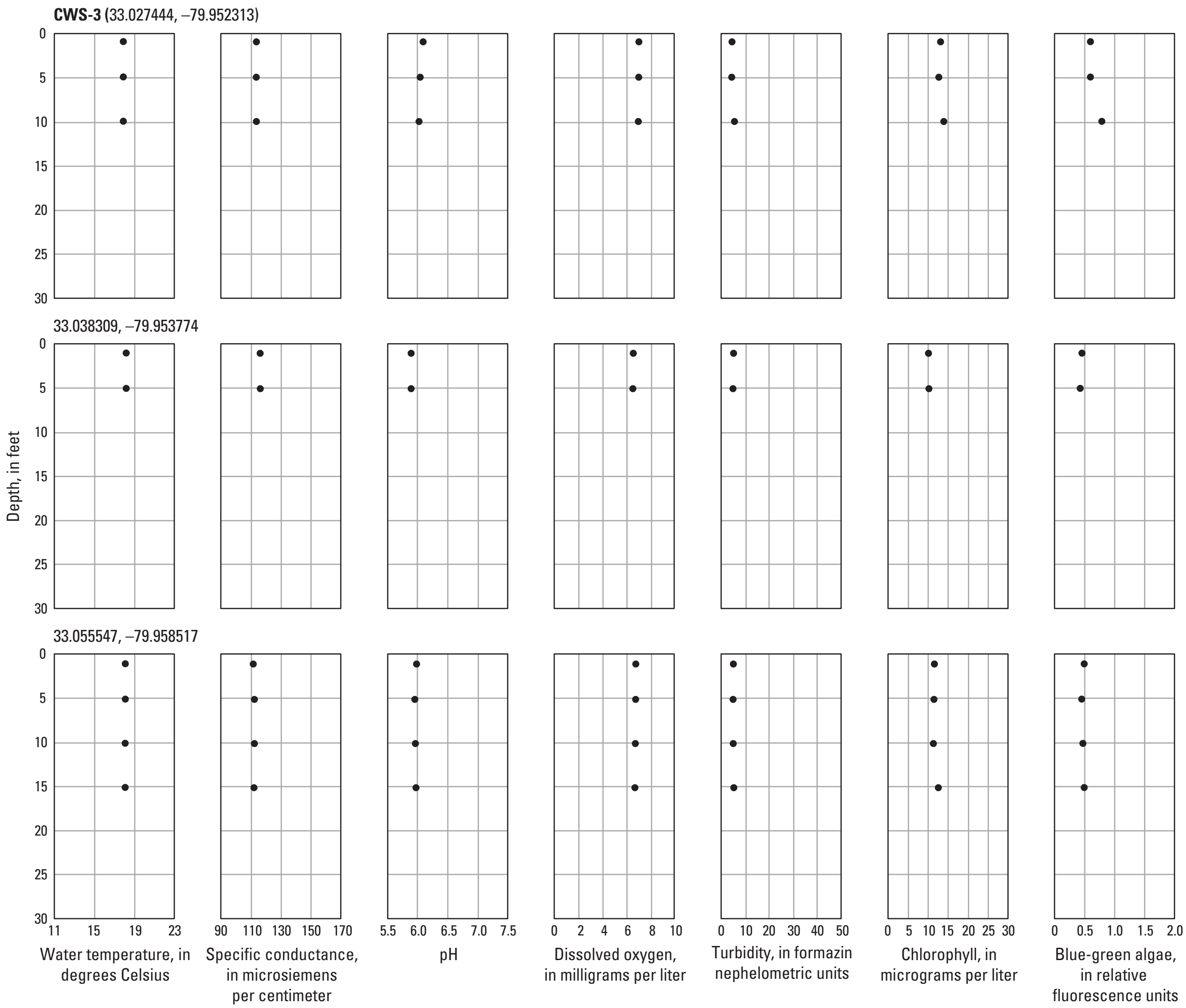

Figure 3–15. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 26, 2015 (morning survey).

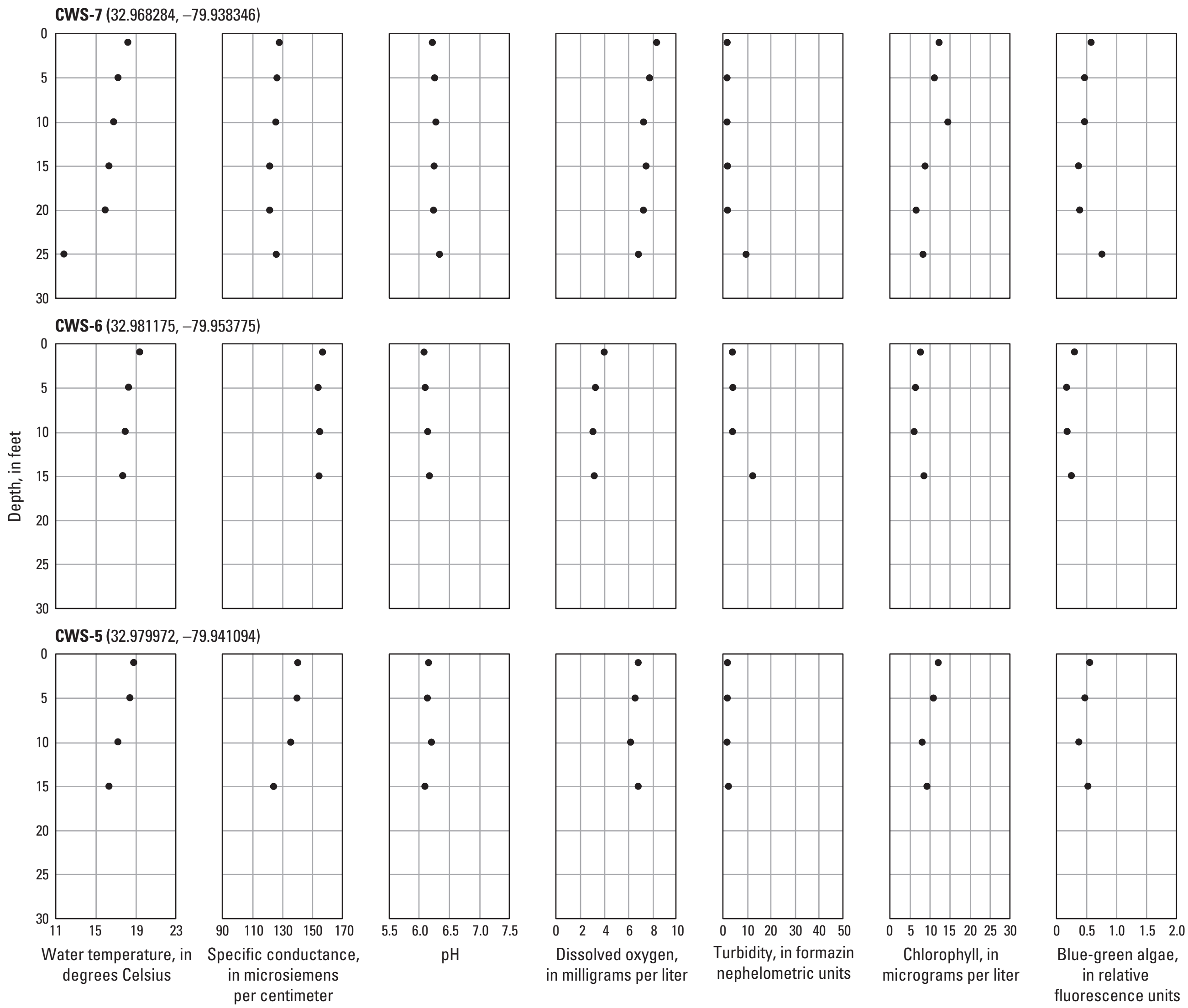

Figure 3–15. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 26, 2015 (afternoon survey).

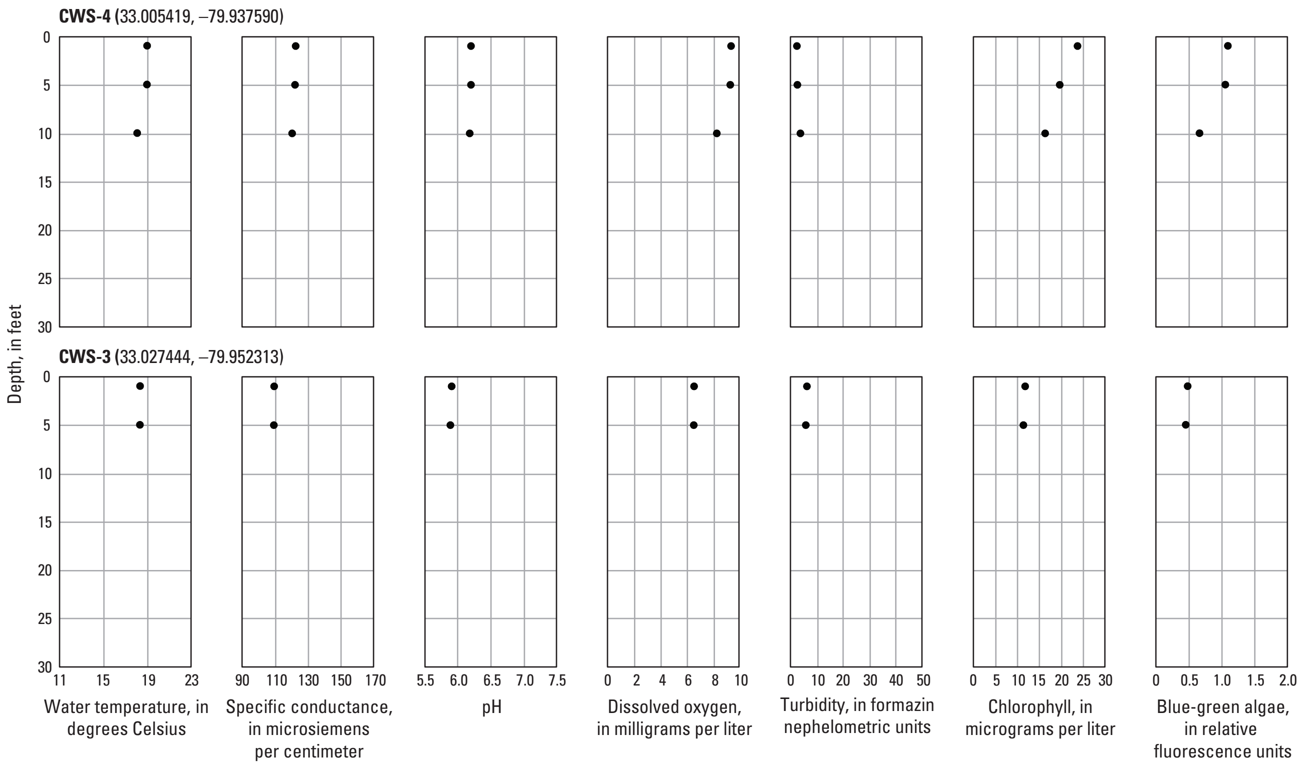

Figure 3–15. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, March 26, 2015 (afternoon survey).

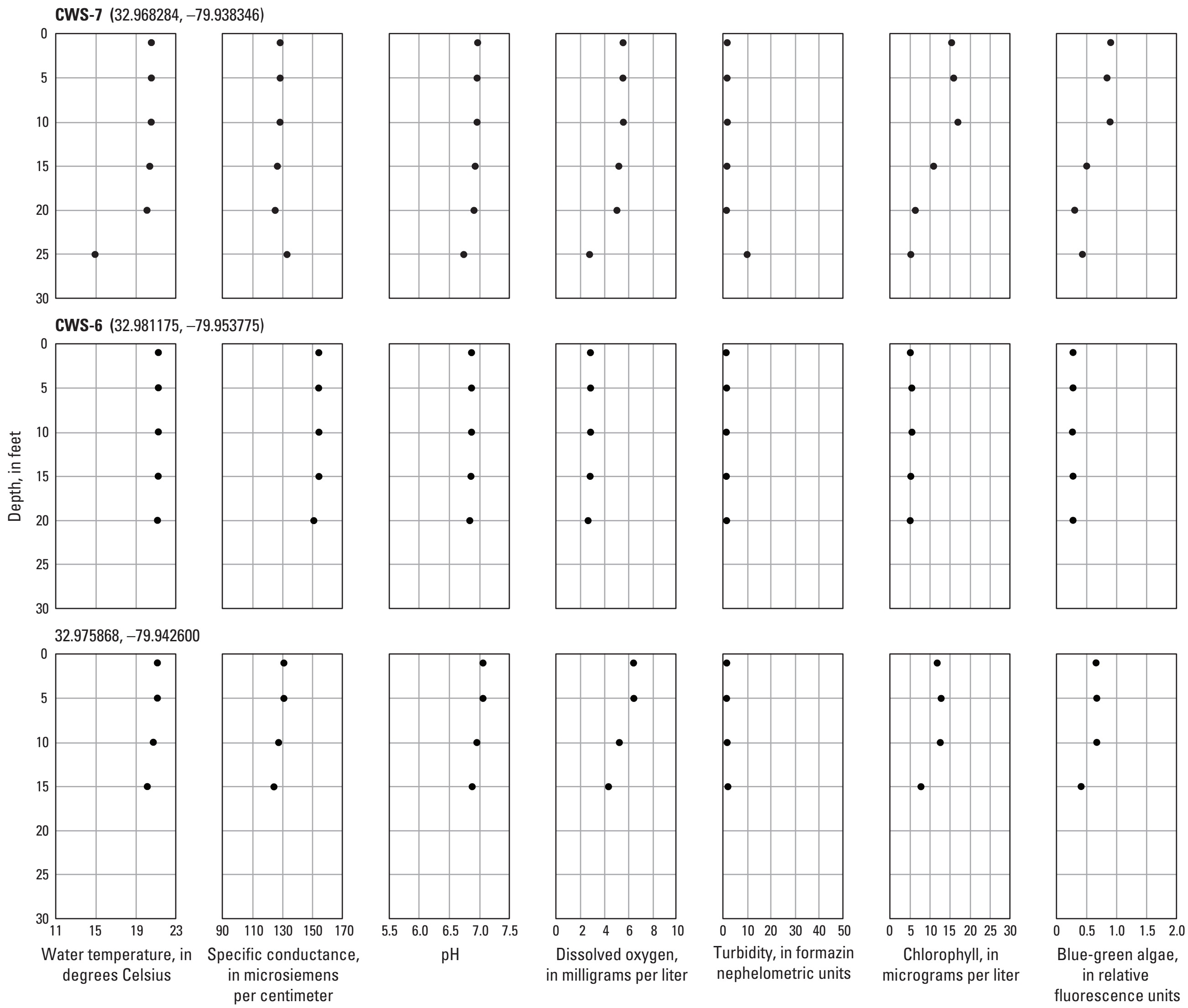

Figure 3–16. Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 23, 2015 (morning survey).

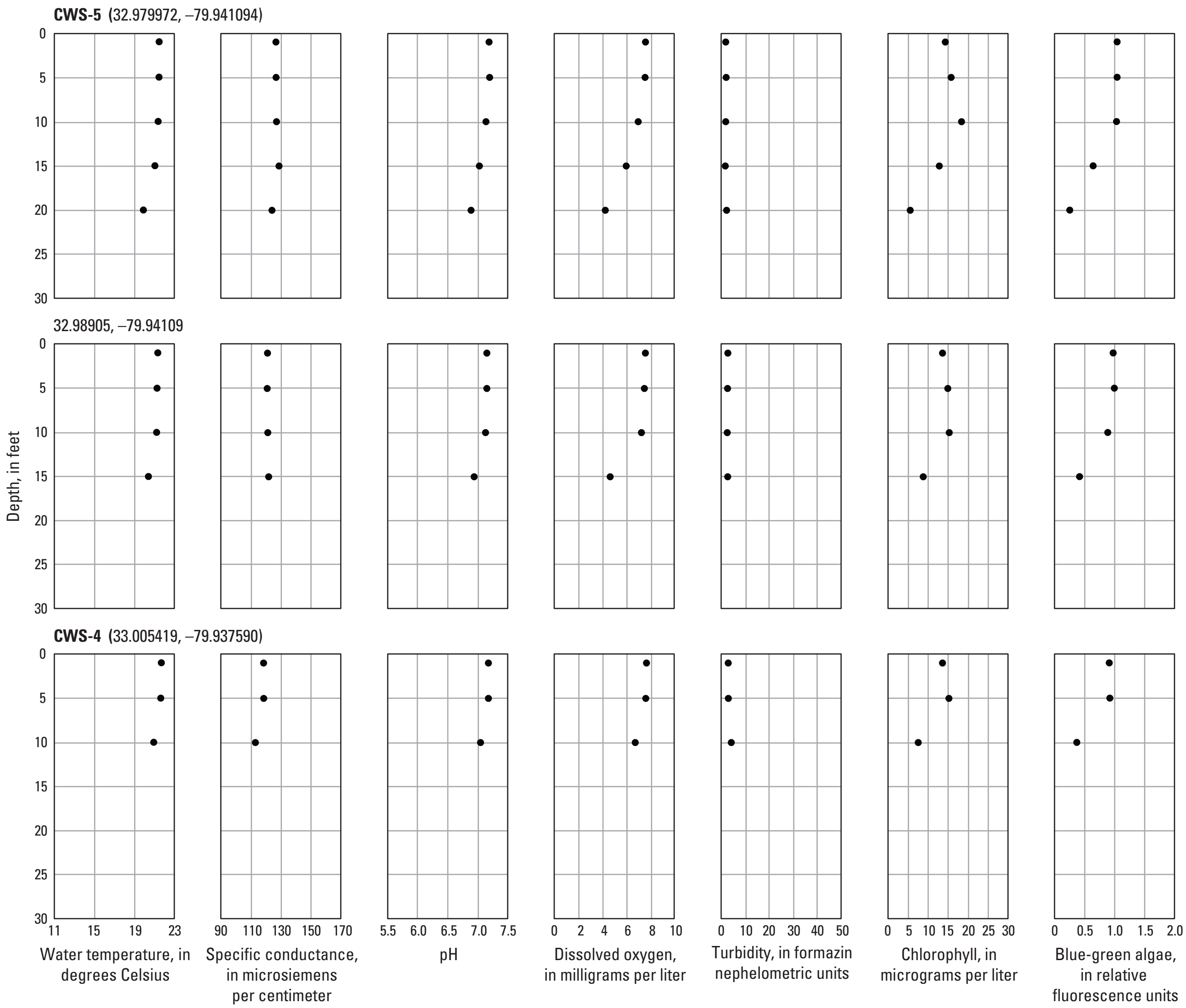

Figure 3–16. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 23, 2015 (morning survey).

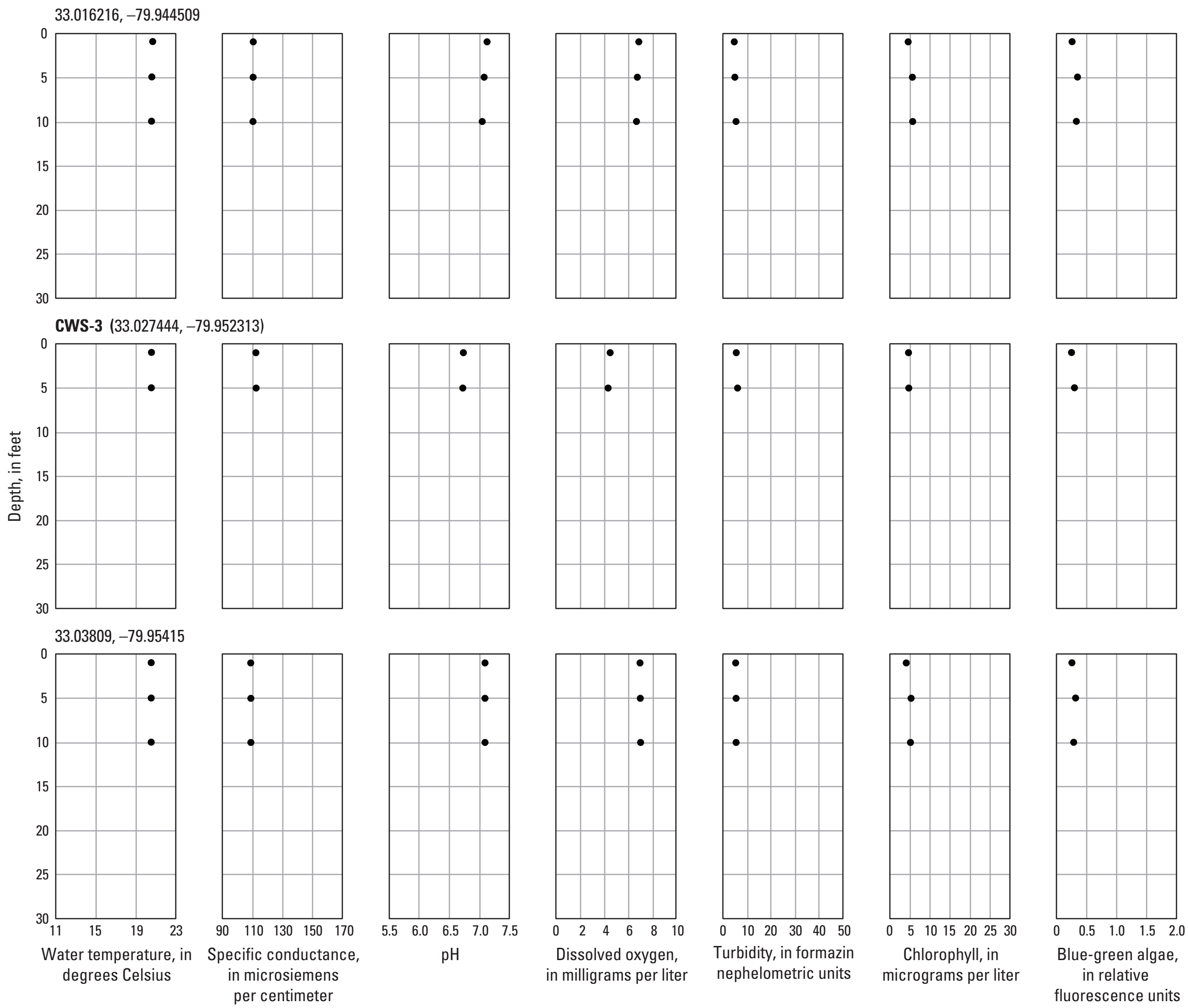

Figure 3–16. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 23, 2015 (morning survey).

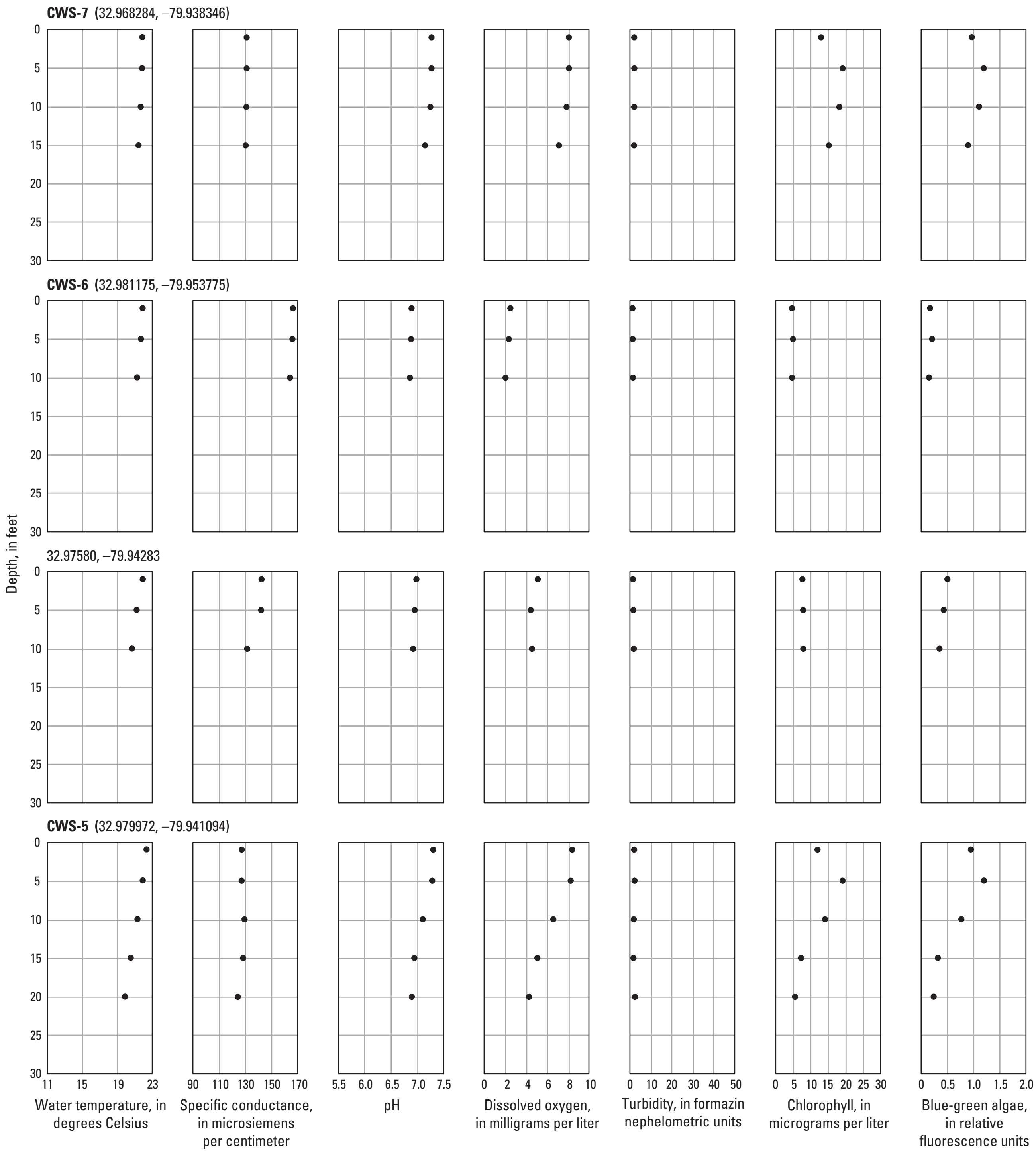

Figure 3–16. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 23, 2015 (afternoon survey).

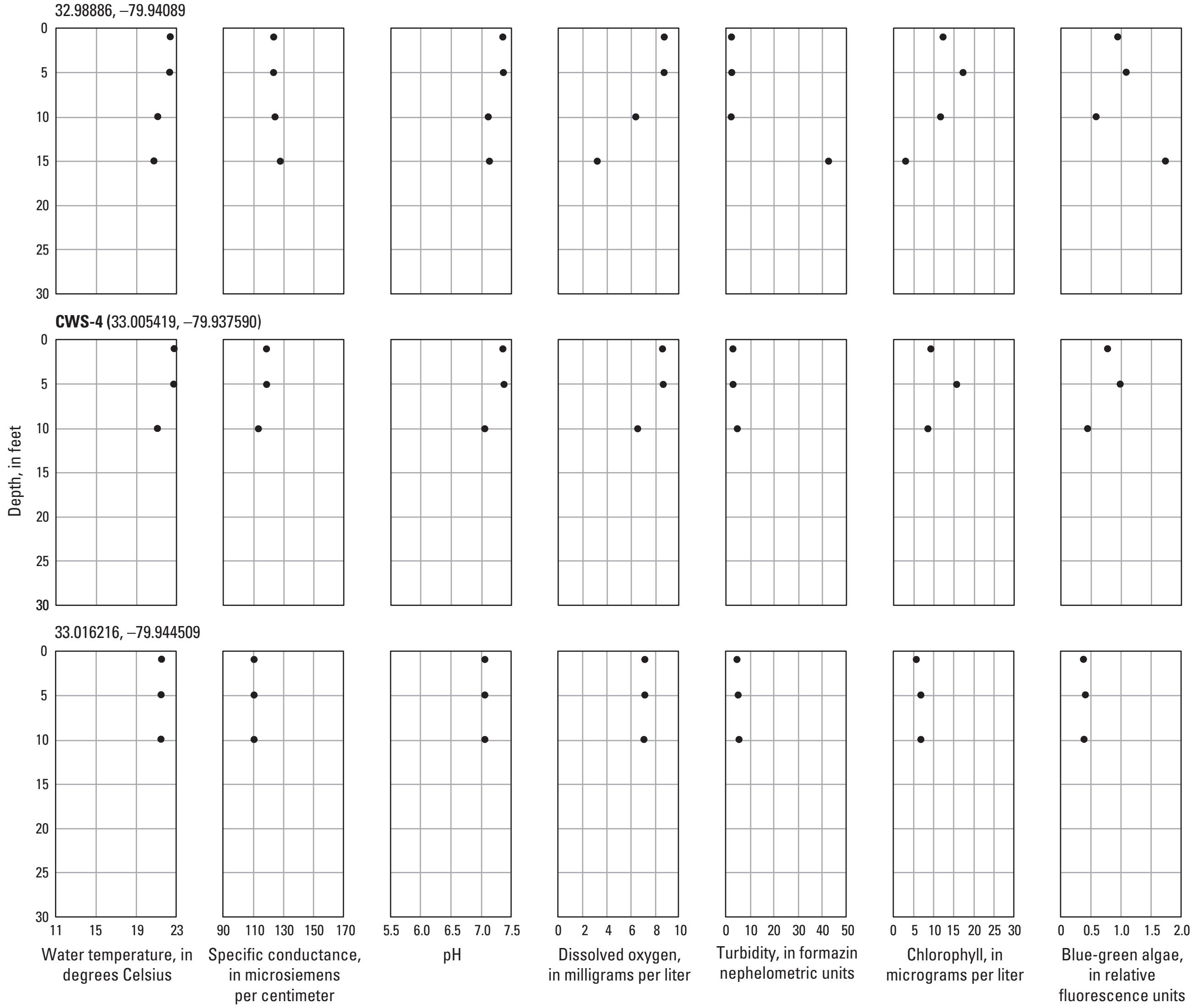

Figure 3–16. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 23, 2015 (afternoon survey).

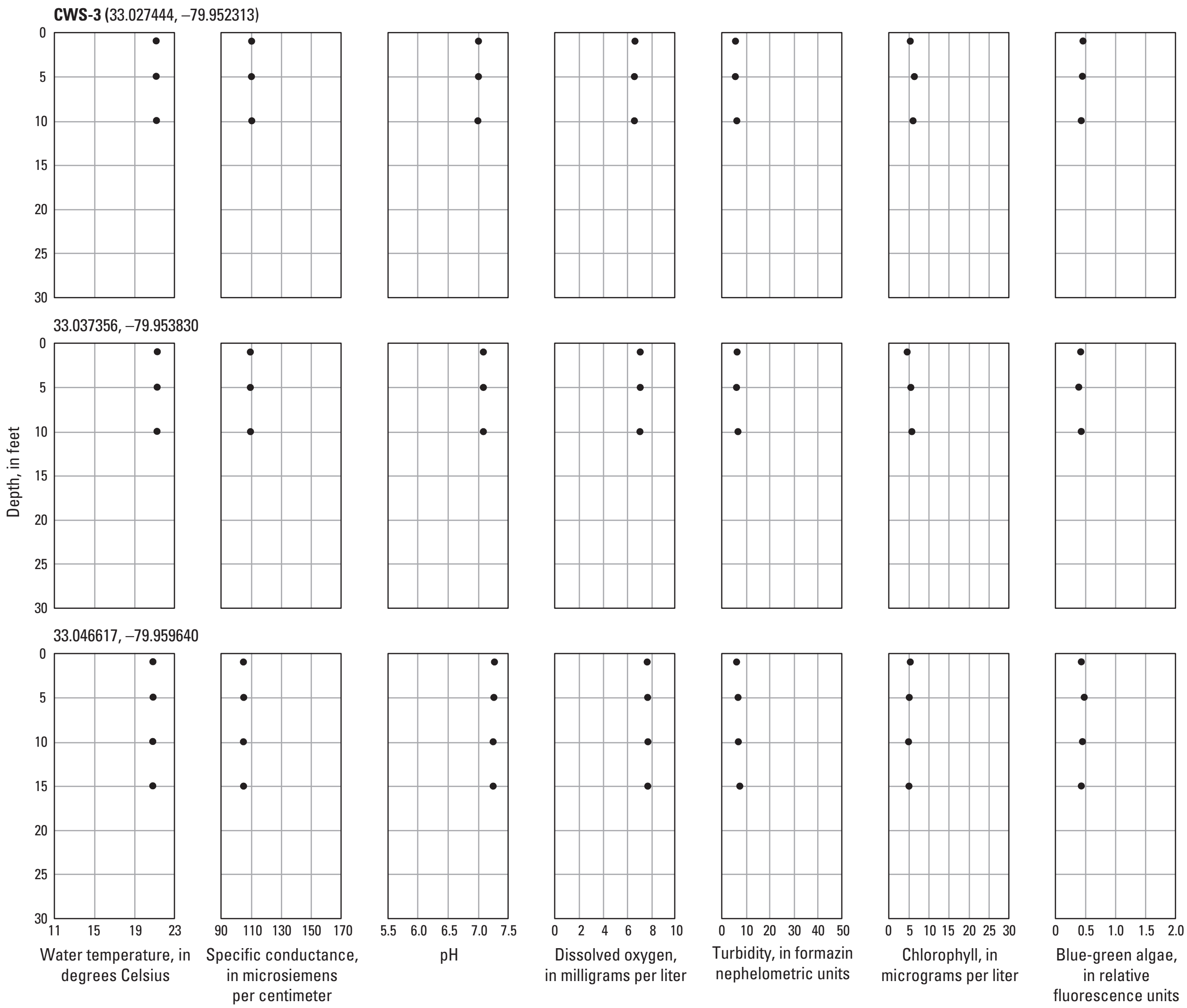

Figure 3–16. (Continued) Water-quality profile data collected in the Bushy Park Reservoir, near Goose Creek, South Carolina, April 23, 2015 (afternoon survey).

Appendix 4. Summary of the quality assurance and quality control data collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[MIB, 2-methyisoborneol; Mn, manganese; Cl, chloride; mg/L, milligram per liter; µg/L, microgram per liter; TOC, total organic carbon]

Quality control	Trace metals	Major ions	Ammonia	Total dissolved nitrogen	Total nitrogen	Nitrate plus nitrite	Nitrite	Phosphorus species	Organic carbon	Chlorophyll	Geosmin/MIB	Actinomycetes
Field blank												
Number	2	2	4	4	4	4	4	4	4	2	2	1
Detections	1 (Mn, 0.3 µg/L)	1 (Cl at 0.02 mg/L)	0	0	0	0	0	0	1 (TOC, 1.3 mg/L)	2 (0.02 and 0.03 µg/L)	0	0
Sequential replicates												
Number	2	2	2	2	2	2	2	2	2	2	2	2
Relative percent difference range	3.3–24.3	0–3.2	18–26	4.1–8.0	2.5–10.4	0	0–102	0–14.4	1.6–4.1	4.9–7.8	0	35–75

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00025 Barometric pressure, millimeters of mercury	P00020 Temperature, air, degrees Celsius	P50624 Absorbance, 254 nm, water, filtered, absorbance units per centimeter	P61726 Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter	P00300 Dissolved oxygen, water, unfiltered, milligrams per liter	P00301 Dissolved oxygen, water, unfiltered, percent of saturation	P00400 pH, water, unfiltered, field, standard units	P99988 Photosynthetically active radiation (average flux density on a horizontal surface during measurement interval), micromoles of photons per square meter per second	P00095 Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	P00010 Temperature, water, degrees Celsius	P00078 Transparency, water, in situ, Secchi disk, meters	P63676 Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 +/–30 degrees, ratiometric correction, NTRU	P63680 Turbidity, water, unfiltered, monochrome near infrared LED light, 780–900 nm, detection angle 90 +/–2.5 degrees, formazin nephelometric units (FNU)	P85328 Depth to 1 percent of surface light, meters	P00198 Depth to 10 percent of surface light, feet	P00003 Sampling depth, feet
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	09/18/13	1245	770	--	0.223	0.166	5.1	62.7	6.8	2,100	108	27.04	1.75	--	1.9	--	2.3	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	09/18/13	1430	768	--	0.233	0.174	5.2	64.5	6.8	551	108	26.91	1.75	--	2.7	--	4.59	10
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	09/18/13	1130	770	--	0.372	0.28	2.1	25.6	6.6	1,950	121	27.02	1.25	--	1.3	--	2.95	3
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	09/18/13	0930	770	--	0.277	0.207	4.6	56.8	6.8	1,100	112	27	1.05	--	1.7	--	2.95	3
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	09/19/13	0930	768	--	0.138	0.101	6.5	79.8	7.2	1,250	102	26.02	--	--	3.2	--		3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	09/19/13	1145	767	--	0.17	0.128	5.9	72.9	7.0	1,900	110	26.39	1.5	--	1.4	--	4.26	3
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK, SC	09/19/13	1245	766	--	0.144	0.107	6.9	85.2	7.3	2,000	111	26.39		--	3.4	--	4.92	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	04/16/14	1200	772	14.6	0.242	0.185	8.1	85.8	7.6	1,820	116	18.76	1.25	--	--	2.5	6.56	10
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	04/16/14	1500	770	16.1	0.357	0.271	6.8	74.8	7.7	1,372	150	20.8	1.25	--	--	2.3	3.28	3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00025 Barometric pressure, millimeters of mercury	P00020 Temperature, air, degrees Celsius	P50624 Absorbance, 254 nm, water, filtered, absorbance units per centimeter	P61726 Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter	P00300 Dissolved oxygen, water, unfiltered, milligrams per liter	P00301 Dissolved oxygen, water, unfiltered, percent of saturation	P00400 pH, water, unfiltered, field, standard units	P99988 Photosynthetically active radiation (average flux density on a horizontal surface during measurement interval), micromoles of photons per square meter per second	P00095 Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	P00010 Temperature, water, degrees Celsius	P00078 Transparency, water, in situ, Secchi disk, meters	P63676 Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 +/−30 degrees, ratiometric correction, NTRU	P63680 Turbidity, water, unfiltered, monochrome near infrared LED light, 780–900 nm, detection angle 90 +/−2.5 degrees, formazin nephelometric units (FNU)	P85328 Depth to 1 percent of surface light, meters	P00198 Depth to 10 percent of surface light, feet	P00003 Sampling depth, feet
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/16/14	1700	770	13.2	0.254	0.193	9.2	99.5	8.2	820	122	19.81	1.25	--	--	2.3	3.28	3
330139079570800	CWS-3 ON BUSHY PARK RES, GOOSE CREEK, SC	04/16/14	1300	770	16.1	0.173	0.135	8.4	86.5	7.7	1,875	98	17.54	0.75	--	--	--	2.62	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	06/10/14	0914	--	--	0.191	0.143	--	--	--	--	--	--	--	--	--	--	--	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	06/10/14	0919	--	--	0.154	0.116	--	--	--	--	--	--	--	--	--	--	--	10
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	06/10/14	0735	--	--	0.186	0.139	--	--	--	--	--	--	--	--	--	--	--	3
02172025	COOPER RIVER AT IN-LET TO BACK RIVER	07/23/14	1330	764	27.2	0.098	0.07	6.5	83.7	7.0	--	106	28.58	1.3	--	3.9	--	--	3
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	07/23/14	1215	765	27.2	0.108	0.079	6.3	80.2	7.0	>2,000	106	28.44	1	--	3.2	--	--	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	07/23/14	1100	766	27.2	0.17	0.126	5.8	74.4	6.8	--	123.5	28.81	1.3	--	5.15	--	--	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	07/23/14	1130	766	27.2	0.189	0.141	2.3	28.6	6.5	--	124	28.25	1.3	--	5.4	--	--	10
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	07/23/14	0845	764	27.2	0.29	0.219	1.7	21.8	6.6	1,940	136	28.14	1.4	--	0.9	--	--	3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00025 Barometric pressure, millimeters of mercury	P00020 Temperature, air, degrees Celsius	P50624 Absorbance, 254 nm, water, filtered, absorbance units per centimeter	P61726 Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter	P00300 Dissolved oxygen, water, unfiltered, milligrams per liter	P00301 Dissolved oxygen, water, unfiltered, percent of saturation	P00400 pH, water, unfiltered, field, standard units	P99988 Photosynthetically active radiation (average flux density on a horizontal surface during measurement interval), micromoles of photons per square meter per second	P00095 Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	P00010 Temperature, water, degrees Celsius	P00078 Transparency, water, in situ, Secchi disk, meters	P63676 Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 +/–30 degrees, ratiometric correction, NTRU	P63680 Turbidity, water, unfiltered, monochrome near infrared LED light, 780–900 nm, detection angle 90 +/–2.5 degrees, formazin nephelometric units (FNU)	P85328 Depth to 1 percent of surface light, meters	P00198 Depth to 10 percent of surface light, feet	P00003 Sampling depth, feet
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	07/23/14	0830	766	27.2	0.202	0.151	3.9	49.3	6.6	1,570	125	28.32	1.7	--	4.8	--	--	3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	07/23/14	1215	766	27.2	0.129	0.094	5.7	73.1	6.7	1,770	116	28.84	1.5	--	6.5	--	--	3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	07/23/14	1245	766	27.2	0.144	0.108	4.4	55.6	6.6	1,770	114	28.21	1.5	--	8.4	--	--	10
330139079570800	CWS-3 ON BUSHY PARK RES, GOOSE CREEK, SC	07/23/14	1015	765	27.2	0.113	0.083	6.1	77.7	7.1	>2,000	108	28.18	1.4	--	3.1	--	--	3
02172025	COOPER RIVER AT IN-LET TO BACK RIVER	08/26/14	1300	764	31.1	0.108	0.079	6.1	78.2	7.1	--	159	28.52	--	--	6.1	--	--	3.3
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	08/26/14	1145	764	30	0.12	0.091	6.3	80.6	7.1	--	111	28.31	--	--	6	--	--	3.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	08/26/14	0900	763	26.1	0.215	0.163	5.4	69.4	6.9	--	118	28.58	--	1.7	--	--	--	3.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	08/26/14	1000	763	27.8	0.2	0.15	5.1	65.6	6.8	--	118	28.38	--	1.6	--	--	--	10
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	08/26/14	0900	764	26.1	0.33	0.252	1.8	23.4	6.5	1,320	130	28.38	1.4	--	4.7	--	--	3.3
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	0800	764	23.9	0.232	0.177	6.5	85.2	7.1	--	121	29.65	--	1.3	--	--	--	3.3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00025 Barometric pressure, millimeters of mercury	P00020 Temperature, air, degrees Celsius	P50624 Absorbance, 254 nm, water, filtered, absorbance units per centimeter	P61726 Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter	P00300 Dissolved oxygen, water, unfiltered, milligrams per liter	P00301 Dissolved oxygen, water, unfiltered, percent of saturation	P00400 pH, water, unfiltered, field, standard units	P99988 Photosynthetically active radiation (average flux density on a horizontal surface during measurement interval), micromoles of photons per square meter per second	P00095 Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	P00010 Temperature, water, degrees Celsius	P00078 Transparency, water, in situ, Secchi disk, meters	P63676 Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 +/–30 degrees, ratiometric correction, NTRU	P63680 Turbidity, water, unfiltered, monochrome near infrared LED light, 780–900 nm, detection angle 90 +–2.5 degrees, formazin nephelometric units (FNU)	P85328 Depth to 1 percent of surface light, meters	P00198 Depth to 10 percent of surface light, feet	P00003 Sampling depth, feet
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	1300	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.5
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	08/26/14	1130	764	30	0.125	0.093	5.6	70.9	6.8	--	125	28.23	--	2.2	--	--	--	3.3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	08/26/14	1200	763	30	0.122	0.09	5.7	73	6.9	--	124	28.19	--	1.6	--	--	--	10
330139079570800	CWS-3 ON BUSHY PARK RES, GOOSE CREEK, SC	08/26/14	1015	764	27.8	0.138	0.104	4.8	61.1	6.7	--	118	27.94	1.5	--	5.7	--	--	3.3
02172025	COOPER RIVER AT IN-LET TO BACK RIVER	11/06/14	1452	760	--	0.094	0.068	8.8	91.8	7.3	1,200	149	17.32	--	--	2.99	--	--	3.3
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	11/06/14	1357	762	--	0.095	0.069	8.8	91.3	7.3	705	132	17.18	--	--	2.97	--	--	3.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	11/06/14	1130	765	--	0.22	0.166	5.5	56.8	--	471	119	17.15	1.45	--	4.6	--	4.6	3.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	11/06/14	1230	764	--	0.2	0.15	5.8	59.2	6.8	471	117	16.88	1.45	--	4.6	--	4.6	10
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	11/06/14	1015	763	22.8	0.33	0.249	3.9	39.3	6.4	440	132	16.27	2.4	--	0.76	--	--	3.3
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	11/06/14	1030	766	--	0.22	0.167	5.0	50.9	6.7	460	120	17.09	1.4	--	5.2	--	--	3.3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00025 Barometric pressure, millimeters of mercury	P00020 Temperature, air, degrees Celsius	P50624 Absorbance, 254 nm, water, filtered, absorbance units per centimeter	P61726 Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter	P00300 Dissolved oxygen, water, unfiltered, milligrams per liter	P00301 Dissolved oxygen, water, unfiltered, percent of saturation	P00400 pH, water, unfiltered, field, standard units	P99988 Photosynthetically active radiation (average flux density on a horizontal surface during measurement interval), micromoles of photons per square meter per second	P00095 Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	P00010 Temperature, water, degrees Celsius	P00078 Transparency, water, in situ, Secchi disk, meters	P63676 Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 +/−30 degrees, ratiometric correction, NTRU	P63680 Turbidity, water, unfiltered, monochrome near infrared LED light, 780–900 nm, detection angle 90 +/−2.5 degrees, formazin nephelometric units (FNU)	P85328 Depth to 1 percent of surface light, meters	P00198 Depth to 10 percent of surface light, feet	P00003 Sampling depth, feet
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	11/06/14	1400	763	--	0.133	0.099	7.2	73.9	6.8	694	111	16.98	1.4	--	4.8	--	--	3.3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	11/06/14	1430	762	--	0.138	0.102	7.3	75.2	6.8	694	112	17.18	1.4	--	4.6	--	4.9	10
330139079570800	CWS-3 ON BUSHY PARK RES, GOOSE CREEK, SC	11/06/14	1153	763	23.9	0.09	0.065	8.8	91.1	7.3	1,265	108	17.11	1.7	--	2.82	--	--	3.3
02172025	COOPER RIVER AT IN-LET TO BACK RIVER	12/16/14	1430	760	--	0.094	0.069	10.3	93.9	7.4	--	102	11.26	1.5	--	7.8	1.2	--	3.3
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	12/16/14	1335	761	--	0.115	0.084	9.9	90	7.2	124	103	11.17	1.7	--	7.7	4	--	3.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	12/16/14	1130	763	--	0.247	0.187	7.8	71.1	6.6	1,090	124	11.53	2.8	--	2.5	--	--	3.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	12/16/14	1200	763	--	0.249	0.189	7.6	69.9	6.6	1,090	124	11.54	2.8	--	2.5	--	--	10
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	12/16/14	1010	763	--	0.338	0.258	5.9	53.2	6.8	645	131	10.99	3.4	--	5.9	2	--	3.3
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	12/16/14	1030	764	--	0.273	0.208	6.8	61.6	6.6	1,008	127	11.34	2.8	--	2.9	--	--	3.3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	12/16/14	1330	761	--	0.158	0.118	9.6	87.6	6.8	1,120	112	11.34	3.2	--	2.7	--	--	3.3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00025 Barometric pressure, millimeters of mercury	P00020 Temperature, air, degrees Celsius	P50624 Absorbance, 254 nm, water, filtered, absorbance units per centimeter	P61726 Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter	P00300 Dissolved oxygen, water, unfiltered, milligrams per liter	P00301 Dissolved oxygen, water, unfiltered, percent of saturation	P00400 pH, water, unfiltered, field, standard units	P99988 Photosynthetically active radiation (average flux density on a horizontal surface during measurement interval), micromoles of photons per square meter per second	P00095 Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	P00010 Temperature, water, degrees Celsius	P00078 Transparency, water, in situ, Secchi disk, meters	P63676 Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 +/–30 degrees, ratiometric correction, NTRU	P63680 Turbidity, water, unfiltered, monochrome near infrared LED light, 780–900 nm, detection angle 90 +/–2.5 degrees, formazin nephelometric units (FNU)	P85328 Depth to 1 percent of surface light, meters	P00198 Depth to 10 percent of surface light, feet	P00003 Sampling depth, feet
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	12/16/14	1400	761	--	0.161	0.12	9.5	86.5	6.8	1,120	113	11.4	3.2	--	2.9	--	--	10
330139079570800	CWS-3 ON BUSHY PARK RES, GOOSE CREEK, SC	12/16/14	1215	763	--	0.105	0.077	10.0	90.2	7.2	1,000	104	11.01	1.7	--	7.6	--	--	3.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	03/26/15	1035	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	03/26/15	1530	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	03/26/15	0845	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	03/26/15	0930	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	03/26/15	1130	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK, SC	04/30/15	0800	756	--	--	--	7.3	82.4	7.1	1,533	122.6	20.8	--	--	1.79	--	--	3
0217206147	CWS-6 AT FOSTER CREEK, GOOSE CREEK, SC	04/30/15	0730	756	--	--	--	7.2	80.9	7.2	--	123.3	20.73	--	--	1.74	--	--	--

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00025 Barometric pressure, millimeters of mercury	P00020 Temperature, air, degrees Celsius	P50624 Absorbance, 254 nm, water, filtered, absorbance units per centimeter	P61726 Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter	P00300 Dissolved oxygen, water, unfiltered, milligrams per liter	P00301 Dissolved oxygen, water, unfiltered, percent of saturation	P00400 pH, water, unfiltered, field, standard units	P99988 Photosynthetically active radiation (average flux density on a horizontal surface during measurement interval), micromoles of photons per square meter per second	P00095 Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	P00010 Temperature, water, degrees Celsius	P00078 Transparency, water, in situ, Secchi disk, meters	P63676 Turbidity, water, unfiltered, broad band light source (400–680 nm), detectors at multiple angles including 90 +/–30 degrees, ratiometric correction, NTRU	P63680 Turbidity, water, unfiltered, monochrome near infrared LED light, 780–900 nm, detection angle 90 +–2.5 degrees, formazin nephelometric units (FNU)	P85328 Depth to 1 percent of surface light, meters	P00198 Depth to 10 percent of surface light, feet	P00003 Sampling depth, feet
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/30/15	0715	756	--	--	--	7.4	83	7.2	--	125.2	20.69	--	--	1.63	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK, SC	04/30/15	0900	756	--	--	--	7.1	78.8	7.1	--	106.7	19.93	--	--	2.79	--	--	3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70300 Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter	P00900 Hardness, water, milligrams per liter as calcium carbonate	P00530 Suspended solids, water, unfiltered, milligrams per liter	P00915 Calcium, water, filtered, milligrams per liter	P00925 Magnesium, water, filtered, milligrams per liter	P00935 Potassium, water, filtered, milligrams per liter	P00931 Sodium adsorption ratio, water, number	P00932 Sodium fraction of cations, water, percent in equivalents of major cations	P00930 Sodium, water, filtered, milligrams per liter	P00940 Chloride, water, filtered, milligrams per liter	P00950 Fluoride, water, filtered, milligrams per liter	P00191 Hydrogen ion, water, unfiltered, calculated, milligrams per liter	P00955 Silica, water, filtered, milligrams per liter as SiO2	P00945 Sulfate, water, filtered, milligrams per liter	P00608 Ammonia, water, filtered, milligrams per liter as nitrogen	P00631 Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	09/18/13	1245	75	27.03	<15	7.15	2.23	2.64	0.72	38.2	8.63	10.45	0.11	0.000	8.19	5.65	0.010	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	09/18/13	1430	71	27.51	<15	7.30	2.25	2.59	0.76	39.2	9.12	10.50	0.11	0.000	8.11	5.62	0.011	<0.04
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	09/18/13	1130	78	33.79	<15	10.02	2.13	2.67	0.71	35.8	9.54	11.67	0.13	0.000	7.80	4.27	0.033	<0.04
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	09/18/13	0930	71	29.78	<15	8.28	2.21	2.56	0.72	37.3	9.03	10.72	0.12	0.000	7.72	5.14	0.011	<0.04
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	09/19/13	0930	68	25.45	<15	6.10	2.48	2.57	0.87	43.2	10.04	12.11	0.10	0.000	8.68	6.65	0.011	<0.04
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	09/19/13	1145	66	25.50	<15	6.17	2.45	2.56	0.86	43	9.98	11.72	0.10	0.000	9.75	6.68	0.012	<0.04
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	09/19/13	1245	71	25.65	<15	6.10	2.53	2.58	0.87	43.2	10.10	12.93	0.10	0.000	9.81	6.80	0.011	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	04/16/14	1200	66	27.94	<15	7.68	2.13	2.10	0.82	41.3	9.89	11.09	0.11	0.000	3.20	7.34	0.015	<0.04
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	04/16/14	1500	85	46.60	<15	15.16	2.12	1.72	0.71	33.2	11.14	13.69	0.14	0.000	2.50	5.73	<0.010	0.084

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70300 Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter	P00900 Hardness, water, milligrams per liter as calcium carbonate	P00530 Suspended solids, water, unfiltered, milligrams per liter	P00915 Calcium, water, filtered, milligrams per liter	P00925 Magnesium, water, filtered, milligrams per liter	P00935 Potassium, water, filtered, milligrams per liter	P00931 Sodium adsorption ratio, water, number	P00932 Sodium fraction of cations, water, percent in equivalents of major cations	P00930 Sodium, water, filtered, milligrams per liter	P00940 Chloride, water, filtered, milligrams per liter	P00950 Fluoride, water, filtered, milligrams per liter	P00191 Hydrogen ion, water, unfiltered, calculated, milligrams per liter	P00955 Silica, water, filtered, milligrams per liter as SiO2	P00945 Sulfate, water, filtered, milligrams per liter	P00608 Ammonia, water, filtered, milligrams per liter as nitrogen	P00631 Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/16/14	1700	68	30.17	<21.45	8.59	2.12	2.18	0.83	40.9	10.48	12.35	0.12	0.000	1.88	7.19	<0.010	0.06
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	04/16/14	1300	64	21.31	<30	5.38	1.92	2.23	0.78	42.8	8.31	8.72	0.07	0.000	6.90	7.75	0.050	0.289
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	06/10/14	0914	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	06/10/14	0919	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	06/10/14	0735	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
02172025	COOPER RIVER AT INLET TO BACK RIVER	07/23/14	1330	74	24.32	<15	5.66	2.48	2.28	0.73	39.7	8.25	9.91	0.10	0.000	8.22	7.76	0.010	<0.04
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	07/23/14	1215	71	24.06	<15	5.62	2.44	2.21	0.78	41.6	8.81	9.72	0.10	0.000	8.19	7.72	0.011	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	07/23/14	1100	75	27.09	<15	6.54	2.61	1.91	0.96	45.9	11.53	14.90	0.11	0.000	8.63	6.81	0.018	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	07/23/14	1130	74	27.38	<15	6.81	2.52	1.91	0.96	45.7	11.54	15.03	0.11	0.000	8.69	6.52	<0.010	<0.04

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70300 Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter	P00900 Hardness, water, milligrams per liter as calcium carbonate	P00530 Suspended solids, water, unfiltered, milligrams per liter	P00915 Calcium, water, filtered, milligrams per liter	P00925 Magnesium, water, filtered, milligrams per liter	P00935 Potassium, water, filtered, milligrams per liter	P00931 Sodium adsorption ratio, water, number	P00932 Sodium fraction of cations, water, percent in equivalents of major cations	P00930 Sodium, water, filtered, milligrams per liter	P00940 Chloride, water, filtered, milligrams per liter	P00950 Fluoride, water, filtered, milligrams per liter	P00191 Hydrogen ion, water, unfiltered, calculated, milligrams per liter	P00955 Silica, water, filtered, milligrams per liter as SiO2	P00945 Sulfate, water, filtered, milligrams per liter	P00608 Ammonia, water, filtered, milligrams per liter as nitrogen	P00631 Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	07/23/14	0845	89	33.96	<15	10.02	2.17	1.36	0.82	40	10.92	14.88	0.14	0.000	7.71	4.43	0.019	<0.04
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	07/23/14	0830	82	28.12	<15	7.10	2.52	1.83	0.94	44.9	11.39	15.05	0.11	0.000	8.52	6.24	<0.010	<0.04
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	07/23/14	1215	67	27.00	<15	6.36	2.70	2.31	0.85	42.4	10.15	13.05	0.13	0.000	8.54	7.50	0.013	<0.04
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	07/23/14	1245	79	26.64	<15	6.28	2.66	2.31	0.86	42.9	10.23	11.89	0.12	0.000	8.38	7.62	0.031	<0.04
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	07/23/14	1015	65	24.13	<15	5.63	2.45	2.23	0.74	40.3	8.38	10.20	0.10	0.000	8.11	7.87	0.014	<0.04
02172025	COOPER RIVER AT INLET TO BACK RIVER	08/26/14	1300	94	28.60	<15	5.69	3.49	2.74	1.43	54.3	17.52	23.97	0.11	0.000	8.56	10.43	<0.010	<0.04
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	08/26/14	1145	66	24.41	<15	5.13	2.82	2.52	1.01	47.4	11.45	13.38	0.10	0.000	8.63	8.51	<0.010	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	08/26/14	0900	72	28.24	<15	7.06	2.58	2.19	0.88	43	10.76	12.03	0.13	0.000	8.70	6.60	<0.010	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	08/26/14	1000	69	28.12	<15	7.03	2.57	2.20	0.88	43	10.71	11.99	0.13	0.000	8.69	6.57	<0.010	<0.04

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70300 Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter	P00900 Hardness, water, milligrams per liter as calcium carbonate	P00530 Suspended solids, water, unfiltered, milligrams per liter	P00915 Calcium, water, filtered, milligrams per liter	P00925 Magnesium, water, filtered, milligrams per liter	P00935 Potassium, water, filtered, milligrams per liter	P00931 Sodium adsorption ratio, water, number	P00932 Sodium fraction of cations, water, percent in equivalents of major cations	P00930 Sodium, water, filtered, milligrams per liter	P00940 Chloride, water, filtered, milligrams per liter	P00950 Fluoride, water, filtered, milligrams per liter	P00191 Hydrogen ion, water, unfiltered, calculated, milligrams per liter	P00955 Silica, water, filtered, milligrams per liter as SiO2	P00945 Sulfate, water, filtered, milligrams per liter	P00608 Ammonia, water, filtered, milligrams per liter as nitrogen	P00631 Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	08/26/14	0900	73	35.32	<15	10.11	2.45	1.91	0.82	39.1	11.13	12.92	0.12	0.000	8.51	4.84	0.013	<0.04
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	0800	73	29.07	<15	7.39	2.58	2.15	0.89	42.9	10.99	12.53	0.13	0.000	8.51	6.29	<0.010	<0.04
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	1300	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	08/26/14	1130	70	25.59	<15	5.57	2.84	2.53	1.05	48	12.21	14.65	0.11	0.000	8.76	8.84	<0.010	<0.04
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	08/26/14	1200	72	25.80	<15	5.58	2.88	2.51	1.05	48	12.29	14.51	0.11	0.000	8.67	8.88	<0.010	<0.04
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	08/26/14	1015	63	24.74	<15	5.31	2.79	2.54	1.03	47.7	11.73	13.65	0.10	0.000	8.53	8.71	<0.010	<0.04
02172025	COOPER RIVER AT INLET TO BACK RIVER	11/06/14	1452	86	24.14	<15	4.43	3.18	2.82	1.59	58.4	17.90	22.71	0.11	0.000	9.66	11.78	<0.010	<0.04
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	11/06/14	1357	85	22.74	<15	4.34	2.89	2.71	1.42	56.3	15.51	17.84	0.11	0.000	9.94	10.90	<0.010	<0.04

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70300 Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter	P00900 Hardness, water, milligrams per liter as calcium carbonate	P00530 Suspended solids, water, unfiltered, milligrams per liter	P00915 Calcium, water, filtered, milligrams per liter	P00925 Magnesium, water, filtered, milligrams per liter	P00935 Potassium, water, filtered, milligrams per liter	P00931 Sodium adsorption ratio, water, number	P00932 Sodium fraction of cations, water, percent in equivalents of major cations	P00930 Sodium, water, filtered, milligrams per liter	P00940 Chloride, water, filtered, milligrams per liter	P00950 Fluoride, water, filtered, milligrams per liter	P00191 Hydrogen ion, water, unfiltered, calculated, milligrams per liter	P00955 Silica, water, filtered, milligrams per liter as SiO2	P00945 Sulfate, water, filtered, milligrams per liter	P00608 Ammonia, water, filtered, milligrams per liter as nitrogen	P00631 Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	11/06/14	1130	75	27.93	<15	6.86	2.62	2.84	1.03	46.3	12.52	13.59	0.13		9.24	7.72	0.036	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	11/06/14	1230	82	26.85	<15	6.38	2.65	2.85	1.01	46.2	12.03	13.18	0.12	0.000	9.13	8.01	0.024	<0.04
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	11/06/14	1015	92	33.40	<15	9.48	2.37	3.02	0.92	41.7	12.23	14.97	0.13	0.000	8.99	6.11	0.011	<0.04
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	11/06/14	1030	79	27.47	<15	6.69	2.62	2.85	1.00	45.8	12.07	13.58	0.12	0.000	9.53	7.69	0.054	<0.04
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	11/06/14	1400	75	23.25	<15	4.95	2.64	2.90	1.11	49.8	12.29	12.47	0.12	0.000	8.98	9.02	<0.010	<0.04
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	11/06/14	1430	80	23.47	<15	5.02	2.66	2.92	1.10	49.5	12.26	12.54	0.12	0.000	8.83	9.00	<0.010	<0.04
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	11/06/14	1153	73	20.40	<15	3.98	2.54	2.50	1.11	51.6	11.56	12.09	0.11	0.000	9.82	9.52	<0.010	<0.04
02172025	COOPER RIVER AT INLET TO BACK RIVER	12/16/14	1430	67	19.82	<15	3.91	2.44	2.71	1.04	49.9	10.67	10.02	0.10	0.000	8.68	9.60	0.021	0.051
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	12/16/14	1335	81	20.60	<15	4.22	2.45	2.73	1.05	49.7	10.92	10.46	0.11	0.000	8.36	9.55	0.017	<0.20

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70300 Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter	P00900 Hardness, water, milligrams per liter as calcium carbonate	P00530 Suspended solids, water, unfiltered, milligrams per liter	P00915 Calcium, water, filtered, milligrams per liter	P00925 Magnesium, water, filtered, milligrams per liter	P00935 Potassium, water, filtered, milligrams per liter	P00931 Sodium adsorption ratio, water, number	P00932 Sodium fraction of cations, water, percent in equivalents of major cations	P00930 Sodium, water, filtered, milligrams per liter	P00940 Chloride, water, filtered, milligrams per liter	P00950 Fluoride, water, filtered, milligrams per liter	P00191 Hydrogen ion, water, unfiltered, calculated, milligrams per liter	P00955 Silica, water, filtered, milligrams per liter as SiO2	P00945 Sulfate, water, filtered, milligrams per liter	P00608 Ammonia, water, filtered, milligrams per liter as nitrogen	P00631 Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	12/16/14	1130	88	27.05	<15	6.81	2.44	3.37	1.01	45.6	12.10	15.11	0.13	0.000	7.67	8.32	0.037	0.109
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	12/16/14	1200	75	27.60	<15	6.99	2.46	3.51	1.05	46.2	12.68	15.11	0.13	0.000	7.83	8.22	0.037	<0.04
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	12/16/14	1010	81	33.62	<15	9.84	2.20	3.42	0.83	38.8	11.08	14.24	0.13	0.000	6.87	6.99	0.018	<0.04
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	12/16/14	1030	79	28.86	<15	7.62	2.39	3.47	0.98	44	12.03	15.12	0.13	0.000	7.78	7.80	0.052	<0.04
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	12/16/14	1330	73	22.68	<15	4.95	2.51	2.99	1.10	49.6	11.98	12.64	0.12	0.000	7.86	9.44	0.018	0.047
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	12/16/14	1400	72	22.81	19	4.96	2.53	2.85	1.08	49.4	11.88	12.82	0.11	0.000	8.30	9.43	0.020	<0.04
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	12/16/14	1215	84	20.22	<15	4.13	2.40	2.72	1.03	49.4	10.64	10.46	0.10	0.000	8.36	9.66	0.017	<0.04
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	03/26/15	1035	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70300 Dissolved solids dried at 180 degrees Celsius, water, filtered, milligrams per liter	P00900 Hardness, water, milligrams per liter as calcium carbonate	P00530 Suspended solids, water, unfiltered, milligrams per liter	P00915 Calcium, water, filtered, milligrams per liter	P00925 Magnesium, water, filtered, milligrams per liter	P00935 Potassium, water, filtered, milligrams per liter	P00931 Sodium adsorption ratio, water, number	P00932 Sodium fraction of cations, water, percent in equivalents of major cations	P00930 Sodium, water, filtered, milligrams per liter	P00940 Chloride, water, filtered, milligrams per liter	P00950 Fluoride, water, filtered, milligrams per liter	P00191 Hydrogen ion, water, unfiltered, calculated, milligrams per liter	P00955 Silica, water, filtered, milligrams per liter as SiO2	P00945 Sulfate, water, filtered, milligrams per liter	P00608 Ammonia, water, filtered, milligrams per liter as nitrogen	P00631 Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	03/26/15	1530	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	03/26/15	0845	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	03/26/15	0930	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	03/26/15	1130	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	04/30/15	0800	82	29.90	<15	8.21	2.28	1.90	0.91	43.6	11.48	12.64	0.11	0.000	3.49	7.19	0.013	<0.04
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	04/30/15	0730	--	--	--	--	--	--	--	--	--	--	--	0.000	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/30/15	0715	--	--	--	--	--	--	--	--	--	--	--	0.000	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	04/30/15	0900	--	--	--	--	--	--	--	--	--	--	--	0.000	--	--	--	--

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00618 Nitrate, water, filtered, milligrams per liter as nitrogen	P00613 Nitrite, water, filtered, milligrams per liter as nitrogen	P00607 Organic nitrogen, water, filtered, milligrams per liter as nitrogen	P00605 Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	P00671 Orthophosphate, water, filtered, milligrams per liter as phosphorus	P00666 Phosphorus, water, filtered, milligrams per liter as phosphorus	P00665 Phosphorus, water, unfiltered, milligrams per liter as phosphorus	P62854 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	P62855 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	P63688 Actinomycetes, standard plate count, double agar layer, water, colonies per milliliter	P70949 Biomass/chlorophyll ratio, plankton, number	P49953 Biomass, phytoplankton, ash free dry mass, milligrams per liter	P81353 Biomass, plankton, ash weight, milligrams per liter	P81354 Biomass, plankton, dry weight, milligrams per liter
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	09/18/13	1245	<0.0400	<0.0010	<0.283	<0.412	0.006	0.015	0.041	0.293	0.422	7	567.5	<7.5	326.5	330.2
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	09/18/13	1430	<0.0400	<0.0010	<0.304	<0.430	0.007	0.011	0.041	0.315	0.441	5	47.68	<8.6	376	376.4
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	09/18/13	1130	<0.0400	<0.0010	<0.359	<0.488	0.033	0.031		0.392	0.521	10	462.8	<7.5	331	333.3
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	09/18/13	0930	<0.0400	<0.0010	<0.307	<0.453	0.009	0.015	0.046	0.318	0.464	10	5293	<8.6	337.7	381.1
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	09/19/13	0930	<0.0388	0.001	<0.232	<0.385	0.004	0.02	<0.050	0.243	0.396	E 20	259.4	<7.5	336.5	338.3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	09/19/13	1145	<0.0400	<0.0010	<0.328	<0.358	0.005	0.035	0.023	0.34	0.37	E 9	375.4	<7.5	334.5	337
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	09/19/13	1245	<0.0389	0.001	<0.252	<0.392	0.005	0.03	<0.050	0.263	0.403	10	347.4	<7.5	332.5	335.3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	04/16/14	1200	<0.0388	0.001	<0.424	<0.486	<0.004	0.028	0.041	0.439	0.501	7	200.5	<7.5	332	335.2
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	04/16/14	1500	0.084	<0.0010	<0.351	<0.514	0.050	0.068		0.435	0.598	4	352.2	<9.4	396.2	403.1
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/16/14	1700	0.058	0.002	<0.263	<0.394	<0.004	0.011	0.034	0.323	0.454	6	440.6	<8.6	360	366.3
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	04/16/14	1300	0.284	0.005	0.301	0.503	0.009	0.027	0.067	0.64	0.842	18	1,000	<8.6	395.7	400.6
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	06/10/14	0914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	06/10/14	0919	--	--	--	--	--	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	06/10/14	0735	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00618 Nitrate, water, filtered, milligrams per liter as nitrogen	P00613 Nitrite, water, filtered, milligrams per liter as nitrogen	P00607 Organic nitrogen, water, filtered, milligrams per liter as nitrogen	P00605 Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	P00671 Orthophosphate, water, filtered, milligrams per liter as phosphorus	P00666 Phosphorus, water, filtered, milligrams per liter as phosphorus	P00665 Phosphorus, water, unfiltered, milligrams per liter as phosphorus	P62854 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	P62855 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	P63688 Actinomycetes, standard plate count, double agar layer, water, colonies per milliliter	P70949 Biomass/chlorophyll ratio, plankton, number	P49953 Biomass, phytoplankton, ash free dry mass, milligrams per liter	P81353 Biomass, plankton, ash weight, milligrams per liter	P81354 Biomass, plankton, dry weight, milligrams per liter
02172025	COOPER RIVER AT INLET TO BACK RIVER	07/23/14	1330	<0.0378	0.002	<0.239	<0.333	<0.004	<0.010	0.027	0.249	0.343	10	944.4	<10.0	432.7	440
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	07/23/14	1215	<0.0378	0.002	<0.291	<0.318	<0.004	0.015	0.022	0.302	0.329	10	1,043	<10.0	433	441.3
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	07/23/14	1100	<0.0400	<0.0010	<0.241	<0.424	0.006	<0.010	0.042	0.259	0.442	5	401.7	<10.0	416.3	424.7
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	07/23/14	1130	<0.0400	<0.0010	<0.275	<0.390	0.013	0.015	0.04	0.275	0.39	5	764.3	<7.5	309.2	315.2
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	07/23/14	0845	<0.0400	<0.0010	<0.358	<0.439	0.038	0.04		0.377	0.458	12	937.1	<10.0	423	429.7
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	07/23/14	0830	<0.0400	<0.0010	<0.278	<0.379	0.011	0.012	0.033	0.278	0.379	2	622	<7.5	312.3	317.5
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	07/23/14	1215	<0.0400	<0.0010	<0.216	<0.327	0.005	<0.010	0.022	0.229	0.34	11	754.7	<10.0	416.7	424.3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	07/23/14	1245	<0.0388	0.001	<0.355	<0.342	0.008	0.034	0.036	0.386	0.373	8	973.3	<10.0	417.3	425.7
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	07/23/14	1015	<0.0379	0.002	<0.352	<0.347	0.004	0.017	0.026	0.366	0.361	8	808.3	<7.5	328.8	335
02172025	COOPER RIVER AT INLET TO BACK RIVER	08/26/14	1300	<0.0400	<0.0010	<0.237	<0.391	<0.004	0.01	0.032	0.237	0.391	7	1,019	<8.6	370.3	378.3
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	08/26/14	1145	<0.0400	<0.0010	<0.335	<0.322	<0.004	0.023	0.026	0.335	0.322	11	1,031	<8.6	366.9	374.6
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	08/26/14	0900	<0.0400	<0.0010	<0.389	<0.405	0.014	0.041	0.047	0.389	0.405	13	981.9	10.3	406.7	417
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	08/26/14	1000	<0.0400	<0.0010	<0.286	<0.387	0.011	0.02	0.041	0.286	0.387	12	1,111	<10.0	416	424.7
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	08/26/14	0900	<0.0400	<0.0010	<0.476	<0.465	0.033	0.061		0.489	0.478	14	1,068	7.7	318.5	326.3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00618 Nitrate, water, filtered, milligrams per liter as nitrogen	P00613 Nitrite, water, filtered, milligrams per liter as nitrogen	P00607 Organic nitrogen, water, filtered, milligrams per liter as nitrogen	P00605 Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	P00671 Orthophosphate, water, filtered, milligrams per liter as phosphorus	P00666 Phosphorus, water, filtered, milligrams per liter as phosphorus	P00665 Phosphorus, water, unfiltered, milligrams per liter as phosphorus	P62854 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	P62855 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	P63688 Actinomycetes, standard plate count, double agar layer, water, colonies per milliliter	P70949 Biomass/chlorophyll ratio, plankton, number	P49953 Biomass, phytoplankton, ash free dry mass, milligrams per liter	P81353 Biomass, plankton, ash weight, milligrams per liter	P81354 Biomass, plankton, dry weight, milligrams per liter
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	0800	<0.0400	<0.0010	<0.381	<0.404	0.009	0.033	0.04	0.381	0.404	18	1,219	<10.0	411	420.7
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	1300	--	--	--	--	--	--	--	--	--	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	08/26/14	1130	<0.0400	<0.0010	<0.248	<0.354	0.005	0.013	0.029	0.248	0.354	17	1,286	<10.0	418	427
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	08/26/14	1200	<0.0400	<0.0010	<0.241	<0.344	0.004	0.012	0.027	0.241	0.344	4	3,030	22	412	434
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	08/26/14	1015	<0.0400	<0.0010	<0.316	<0.338	<0.004	0.023	0.029	0.316	0.338	5	1,371	<10.0	430.7	440.3
02172025	COOPER RIVER AT INLET TO BACK RIVER	11/06/14	1452	<0.0400	<0.0010	<0.215	<0.318	0.006	0.012	<0.020	0.215	0.318	17	946.2	<7.5	329.8	334.2
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	11/06/14	1357	<0.0400	<0.0010	<0.235	<0.293	0.005	<0.010	<0.020	0.235	0.293	10	885.8	<7.5	322	326.5
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	11/06/14	1130	<0.0400	<0.0010	<0.286	<0.380	0.012	0.019	0.038	0.322	0.416	3	638.6	<10	416.3	421
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	11/06/14	1230	<0.0400	<0.0010	<0.287	<0.349	0.010	0.023	0.036	0.311	0.373	9	1,152	<10.0	418	422.7
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	11/06/14	1015	<0.0400	<0.0010	<0.375	<0.422	0.018	0.02		0.386	0.433	10	1,955	<7.5	323.5	327
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	11/06/14	1030	<0.0400	<0.0010	<0.298	<0.403	0.013	0.017	0.042	0.352	0.457	4	725	<10	414	419.3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	11/06/14	1400	<0.0400	<0.0010	<0.236	<0.321	0.006	0.011	0.025	0.236	0.321	11	1,292	<10.0	415	420
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	11/06/14	1430	<0.0400	<0.0010	<0.257	<0.329	0.006	0.012	0.026	0.257	0.329	10	1,340	<10	419.7	425.3
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	11/06/14	1153	<0.0400	<0.0010	<0.219	<0.278	0.004	<0.010	0.023	0.219	0.278	9	865.4	<7.5	325.5	330

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00618 Nitrate, water, filtered, milligrams per liter as nitrogen	P00613 Nitrite, water, filtered, milligrams per liter as nitrogen	P00607 Organic nitrogen, water, filtered, milligrams per liter as nitrogen	P00605 Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	P00671 Orthophosphate, water, filtered, milligrams per liter as phosphorus	P00666 Phosphorus, water, filtered, milligrams per liter as phosphorus	P00665 Phosphorus, water, unfiltered, milligrams per liter as phosphorus	P62854 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	P62855 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	P63688 Actinomycetes, standard plate count, double agar layer, water, colonies per milliliter	P70949 Biomass/chlorophyll ratio, plankton, number	P49953 Biomass, phytoplankton, ash free dry mass, milligrams per liter	P81353 Biomass, plankton, ash weight, milligrams per liter	P81354 Biomass, plankton, dry weight, milligrams per liter
02172025	COOPER RIVER AT INLET TO BACK RIVER	12/16/14	1430	0.051	<0.0010	0.223	0.275	0.005	0.013	0.034	0.296	0.348	4	1,247	<7.5	324.5	330
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	12/16/14	1335	<0.1989	0.001	<0.245	<0.340	0.006	0.014	0.03	0.262	0.357	5	1,297	<7.5	325	330.5
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	12/16/14	1130	0.107	0.001	0.199	0.352	0.015	0.024	0.047	0.344	0.497	7	1,238	<10.0	420.7	427
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	12/16/14	1200	<0.0389	0.001	<0.312	<0.429	0.015	0.023	0.047	0.349	0.466	9	1,796	<10.0	416.7	422.7
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	12/16/14	1010	<0.0400	<0.0010	<0.373	<0.420	0.029	0.041		0.391	0.438	10	1,411	<7.5	322	326.7
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	12/16/14	1030	<0.0390	0.001	<0.343	<0.429	0.019	0.026	0.05	0.395	0.481	6	3,409	<7.5	307.7	312.2
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	12/16/14	1330	0.047	<0.0010	0.226	0.364	0.007	0.017	0.037	0.291	0.429	7	1,220	<10.0	414.7	420.7
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	12/16/14	1400	<0.0389	0.001	<0.286	<0.458	0.007	0.018	0.05	0.306	0.478	7	1,257	<10.0	412.7	419
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	12/16/14	1215	<0.0400	<0.0010	<0.269	<0.340	0.005	0.015	0.026	0.286	0.357	4	1,296	<7.5	326.5	331.8
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	03/26/15	1035	--	--	--	--	--	--	--	--	--	--	744.2	<7.5	318.7	324.2
0217206110	BUSHY PARK RES. ABOVE FOS-TER CRK, GOOSE CREEK,SC	03/26/15	1530	--	--	--	--	--	--	--	--	--	--	301	<7.5	324.2	328.7
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	03/26/15	0845	--	--	--	--	--	--	--	--	--	--	4,343	<7.5	320.5	324.8
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	03/26/15	0930	--	--	--	--	--	--	--	--	--	--	795.1	<7.5	327	332.2
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	03/26/15	1130	--	--	--	--	--	--	--	--	--	--	361.9	<8.6	374	380

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P00618 Nitrate, water, filtered, milligrams per liter as nitrogen	P00613 Nitrite, water, filtered, milligrams per liter as nitrogen	P00607 Organic nitrogen, water, filtered, milligrams per liter as nitrogen	P00605 Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	P00671 Orthophosphate, water, filtered, milligrams per liter as phosphorus	P00666 Phosphorus, water, filtered, milligrams per liter as phosphorus	P00665 Phosphorus, water, unfiltered, milligrams per liter as phosphorus	P62854 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	P62855 Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	P63688 Actinomycetes, standard plate count, double agar layer, water, colonies per milliliter	P70949 Biomass/chlorophyll ratio, plankton, number	P49953 Biomass, phytoplankton, ash free dry mass, milligrams per liter	P81353 Biomass, plankton, ash weight, milligrams per liter	P81354 Biomass, plankton, dry weight, milligrams per liter
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	04/30/15	0800	<0.0386	0.001	<0.334	<0.466	<0.004	0.017	0.042	0.347	0.479	2	--	--	--	--
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	04/30/15	0730	--	--	--	--	--	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/30/15	0715	--	--	--	--	--	--	--	--	--	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	04/30/15	0900	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70953 Chlorophyll *a*, phytoplankton, chromatographic-fluorometric method, micrograms per liter	P62361 Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor, micrograms per liter	P95202 Cyanobacteria (blue-green algae), YSI in vivo fluorescence of phycocyanin, excitation at 595, emission at 650 nm, cells per milliliter	P62360 Pheophytin *a*, phytoplankton, micrograms per liter	P01046 Iron, water, filtered, micrograms per liter	P01056 Manganese, water, filtered, micrograms per liter	P68289 2-Methylisoborneol, water, unfiltered, recoverable, nanograms per liter	P68288 Geosmin, water, unfiltered, recoverable, nanograms per liter	P00681 Organic carbon, water, filtered, milligrams per liter	P00680 Organic carbon, water, unfiltered, milligrams per liter	P63162 Specific UV Absorbance, 254 nm, water, filtered, 1 cm path length, calculated, liter per (milligram of dissolved organic carbon * meter)	P70331 Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter	P80154 Suspended sediment concentration, milligrams per liter
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	09/18/13	1245	6.5	10.4	--	4.5	63.5	5.2	12	5.7	6.4	8.2	3.47	87	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	09/18/13	1430	8.4	12.8	--	5.3	83.4	7.7	10	3.1	6.6	8.4	3.52	94	4
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	09/18/13	1130	5.0	12.1	--	3.5	178.4	16.4	14	6.2	9.3	11.2	3.99	92	2
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	09/18/13	0930	8.2	11.9	--	6.2	84.5	3.2	11	4.5	7.8	9.1	3.57	100	1
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	09/19/13	0930	6.9	7.9	--	4.4	18.3	0.9	7.9	15	4.7	6.1	2.95	77	10
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	09/19/13	1145	6.7	4.0	--	3.7	83.4	16.8	8.8	13	5.2	6.2	3.24	91	5
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	09/19/13	1245	8.1	11.0	--	4.7	28.3	3.9	7.2	13	4.8	6.1	2.99	91	9
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	04/16/14	1200	16.0	17.5	2,635	7.5	187.2	14.1	15	18	6.6	7.6	3.66	86	6
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	04/16/14	1500	19.6	23.1	3,087	5.1	244.1	15.3	4.5	11	9.8	10.5	3.66	89	3
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/16/14	1700	14.3	6.2	3,086	5.4	118.7	2.9	12	38	7.2	8.4	3.54	91	5
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	04/16/14	1300	4.9	7.4	1,227	6.6	248.4	16.0	2.2	11	4.8	7.1	3.57	93	30
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	06/10/14	0914	--	--	--	--	--	--	--	--	--	--	--	--	--

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70953 Chlorophyll *a*, phytoplankton, chromatographic-fluorometric method, micrograms per liter	P62361 Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor, micrograms per liter	P95202 Cyanobacteria (blue-green algae), YSI in vivo fluorescence of phycocyanin, excitation at 595, emission at 650 nm, cells per milliliter	P62360 Pheophytin *a*, phytoplankton, micrograms per liter	P01046 Iron, water, filtered, micrograms per liter	P01056 Manganese, water, filtered, micrograms per liter	P68289 2-Methylisoborneol, water, unfiltered, recoverable, nanograms per liter	P68288 Geosmin, water, unfiltered, recoverable, nanograms per liter	P00681 Organic carbon, water, filtered, milligrams per liter	P00680 Organic carbon, water, unfiltered, milligrams per liter	P63162 Specific UV Absorbance, 254 nm, water, filtered, 1 cm path length, calculated, liter per (milligram of dissolved organic carbon * meter)	P70331 Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter	P80154 Suspended sediment concentration, milligrams per liter
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	06/10/14	0919	--	--	--	--	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	06/10/14	0735	--	--	--	--	--	--	--	--	--	--	--	--	--
02172025	COOPER RIVER AT INLET TO BACK RIVER	07/23/14	1330	7.7	7.5	--	4.8	19.1	2.3	2.7	14	3.6	4.9	2.74	87	7
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	07/23/14	1215	8.0	6.4	--	5.4	45.8	12.9	3.3	14	3.6	5.0	3.01	95	6
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	07/23/14	1100	20.9	15.5	--	7.7	45.7	1.8	11	2.3	4.9	6.6	3.49	89	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	07/23/14	1130	7.9	9.3	--	5.2	69.5	2.9	11	<2	5.1	6.1	3.68	89	3
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	07/23/14	0845	7.2	11.0	--	4.3	175.6	14.8	16	2.2	7.4	8.7	3.93	100	2
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	07/23/14	0830	8.4	10.2	--	4.7	74.6	2.2	11	<2	5.7	6.8	3.55	100	1
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	07/23/14	1215	10.1	11.7	--	3.8	35.2	5.3	7.5	9.6	4.1	5.7	3.17	95	3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	07/23/14	1245	8.6	8.8	--	5.2	216.3	73.5	6.6	9.9	4.1	5.4	3.49	98	8
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	07/23/14	1015	7.7	6.1	--	4.7	51.1	15.3	2.3	12	3.9	4.9	2.91	100	6
02172025	COOPER RIVER AT INLET TO BACK RIVER	08/26/14	1300	7.9	8.3	3,262	3.6	10.5	1.1	8.4	5.7	3.6	5.2	2.97	95	7

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70953 Chlorophyll *a*, phytoplankton, chromatographic-fluorometric method, micrograms per liter	P62361 Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor, micrograms per liter	P95202 Cyanobacteria (blue-green algae), YSI in vivo fluorescence of phycocyanin, excitation at 595, emission at 650 nm, cells per milliliter	P62360 Pheophytin *a*, phytoplankton, micrograms per liter	P01046 Iron, water, filtered, micrograms per liter	P01056 Manganese, water, filtered, micrograms per liter	P68289 2-Methylisoborneol, water, unfiltered, recoverable, nanograms per liter	P68288 Geosmin, water, unfiltered, recoverable, nanograms per liter	P00681 Organic carbon, water, filtered, milligrams per liter	P00680 Organic carbon, water, unfiltered, milligrams per liter	P63162 Specific UV Absorbance, 254 nm, water, filtered, 1 cm path length, calculated, liter per (milligram of dissolved organic carbon * meter)	P70331 Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter	P80154 Suspended sediment concentration, milligrams per liter
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	08/26/14	1145	7.5	11.9	8,642	3.5	46.6	16.2	11	7.9	3.8	4.9	3.12	100	4
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	08/26/14	0900	10.5	2.0	[a]0.64	4.5	152.3	18.1	8.6	3.5	6.0	7.2	3.61	100	2
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	08/26/14	1000	7.8	9.1	[a]0.63	4.0	73.7	2.3	8.8	2.8	5.6	7.4	3.58	100	1
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	08/26/14	0900	7.3	11.4	[a]1	4.3	276.6	15.4	10	3.6	7.8	9.4	4.25	100	2
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	0800	8.0	10.6	[a]0.65	4.1	132.5	14.0	8.2	2.6	6.4	8.3	3.65	100	2
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	08/26/14	1300	--	--	--	--	--	--	7.5	4.2	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	08/26/14	1130	7.0	5.6	[a]0.62	3.5	29.2	13.3	11	12	4.2	5.7	3	100	2
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	08/26/14	1200	7.3	7.0	[a]0.66	3.8	28.0	14.1	10	9.9	4.1	5.4	2.99	100	4
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	08/26/14	1015	7.0	7.6	2,809	3.3	67.8	15.5	9.4	9.5	4.1	5.2	3.33	80	3
02172025	COOPER RIVER AT INLET TO BACK RIVER	11/06/14	1452	4.7	4.4	--	2.9	18.8	1.3	2.3	3.6	3.4	3.8	2.74	100	5
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	11/06/14	1357	5.1	5.7	--	3.3	16.7	1.1	2.7	3.7	3.4	3.9	2.81	100	5
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	11/06/14	1130	7.4	9.1	2,107	3.4	275.0	8.6	4.2	2.6	5.6	5.9	3.95	95	3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70953 Chlorophyll *a*, phytoplankton, chromatographic-fluorometric method, micrograms per liter	P62361 Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor, micrograms per liter	P95202 Cyanobacteria (blue-green algae), YSI in vivo fluorescence of phycocyanin, excitation at 595, emission at 650 nm, cells per milliliter	P62360 Pheophytin *a*, phytoplankton, micrograms per liter	P01046 Iron, water, filtered, micrograms per liter	P01056 Manganese, water, filtered, micrograms per liter	P68289 2-Methylisoborneol, water, unfiltered, recoverable, nanograms per liter	P68288 Geosmin, water, unfiltered, recoverable, nanograms per liter	P00681 Organic carbon, water, filtered, milligrams per liter	P00680 Organic carbon, water, unfiltered, milligrams per liter	P63162 Specific UV Absorbance, 254 nm, water, filtered, 1 cm path length, calculated, liter per (milligram of dissolved organic carbon * meter)	P70331 Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter	P80154 Suspended sediment concentration, milligrams per liter
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	11/06/14	1230	4.1	8.2	2,999	3.6	243.4	2.9	3.5	2.1	5.1	5.6	3.89	22	10
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	11/06/14	1015	1.8	7.1	--	1.6	244.8	9.1	<2	<2	8.0	8.3	4.1	82	2
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	11/06/14	1030	7.3	8.0	1,940	4.3	287.4	6.6	4	2.5	5.9	5.9	3.73	100	3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	11/06/14	1400	3.9	--	4,535	2.1	60.9	6.7	<2	2.5	4.2	4.6	3.18	100	3
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	11/06/14	1430	4.2	--	11,114	2.5	68.1	7.1	2.3	2.4	4.2	4.6	3.27	100	2
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	11/06/14	1153	5.2	5.0	--	3.5	14.0	0.8	2.1	3.6	3.3	3.9	2.72	88	6
02172025	COOPER RIVER AT INLET TO BACK RIVER	12/16/14	1430	4.4	7.0	2,360	3.3	26.3	4.3	<2	2.3	3.5	4.2	2.69	100	3
02172060	DURHAM CANAL AT BRIDGE TO CYPRESS GARDEN, SC	12/16/14	1335	4.2	6.2	1,935	2.9	46.2	4.1	<2	2.6	4.0	4.8	2.85	100	3
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	12/16/14	1130	5.1	--	--	2.3	183.4	21.5	<2	<2	6.3	7.4	3.94	100	2
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	12/16/14	1200	3.3	--	--	2.2	173.0	22.3	<2	<2	6.9	7.4	3.58	100	2
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	12/16/14	1010	3.3	8.8	1,615	1.7	185.3	10.7	<2	<2	8.0	9.0	4.22	88	2
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	12/16/14	1030	1.3	--	--	2.1	239.5	29.7	<2	<2	6.7	7.9	4.06	93	3

Appendix 5. Analytical results for water-column samples collected in Bushy Park Reservoir, near Goose Creek, South Carolina, September 2013 to April 2015.—Continued

[P, parameter code; --, no data; E, estimated; <, less than; >, greater than; nm, nanometer]

Station number	Station name	Date	Sample start time	P70953 Chlorophyll *a*, phytoplankton, chromatographic-fluorometric method, micrograms per liter	P62361 Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor, micrograms per liter	P95202 Cyanobacteria (blue-green algae), YSI in vivo fluorescence of phycocyanin, excitation at 595, emission at 650 nm, cells per milliliter	P62360 Pheophytin *a*, phytoplankton, micrograms per liter	P01046 Iron, water, filtered, micrograms per liter	P01056 Manganese, water, filtered, micrograms per liter	P68289 2-Methylisoborneol, water, unfiltered, recoverable, nanograms per liter	P68288 Geosmin, water, unfiltered, recoverable, nanograms per liter	P00681 Organic carbon, water, filtered, milligrams per liter	P00680 Organic carbon, water, unfiltered, milligrams per liter	P63162 Specific UV Absorbance, 254 nm, water, filtered, 1 cm path length, calculated, liter per (milligram of dissolved organic carbon * meter)	P70331 Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeter	P80154 Suspended sediment concentration, milligrams per liter
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	12/16/14	1330	4.9	7.1	--	2.4	88.7	14.0	<2	2.2	4.8	5.5	3.26	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	12/16/14	1400	5.0	7.8	--	2.8	118.5	24.5	<2	<2	4.7	5.4	3.43	100	3
330139079570800	CWS-3 ON BUSHY PARK RES,GOOSE CREEK SC	12/16/14	1215	4.1	1.5	6,108	3.1	40.8	5.3	<2	2.6	4.0	4.6	2.63		
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	03/26/15	1035	7.4	--	--	4.9	--	--	--	--	--	--	--	--	--
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	03/26/15	1530	15.0	--	--	7.2	--	--	--	--	--	--	--	--	--
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	03/26/15	0845	1.0	--	--	1.1	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	03/26/15	0930	6.5	--	--	5.3	--	--	--	--	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	03/26/15	1130	16.6	--	--	10.9	--	--	--	--	--	--	--	--	--
0217206110	BUSHY PARK RES. ABOVE FOSTER CRK, GOOSE CREEK,SC	04/30/15	0800	--	11.6	--	--	107.0	1.9	15	28	6.8	7.2	--	--	--
0217206147	CWS-6 @ FOSTER CREEK, GOOSE CREEK SC	04/30/15	0730	--	10.9	--	--	--	--	--	--	--	--	--	--	--
02172062	CW-7 BACK R BELOW FOSTER CK AT HWY5(8-503)	04/30/15	0715	--	10.6	--	--	--	--	--	--	--	--	--	--	--
330019079561500	CWS-4 ON BUSHY PARK RES, GOOSE CREEK SC	04/30/15	0900	--	6.2	--	--	--	--	--	--	--	--	--	--	--

[a]Cyanobacteria values reported are in relative fluorescence units from a YSI EXO algal probe, not cells per milliliter from YSI 6600 phycoyanin probe.

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