

# **Hydrologic, Water-Quality, and Meteorological Data for the Cambridge, Massachusetts, Drinking-Water Source Area, Water Year 2006**

By Kirk P. Smith

Prepared in cooperation with the  
City of Cambridge, Massachusetts, Water Department

Open-File Report 2008–1175

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

**U.S. Department of the Interior**  
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Suggested citation:

Smith, K.P., 2008, Hydrologic, water-quality, and meteorological data for the Cambridge, Massachusetts, drinking-water source area, water year 2006: U.S. Geological Survey Open-File Report 2008-1175, 164 p.

# Contents

Abstract.....	1
Introduction.....	2
Purpose and Scope .....	2
Description of Monitoring Network.....	4
Continuous Data Collection and Computation .....	5
Hydrologic Data.....	5
Water-Quality Data .....	6
Meteorological Data.....	6
Sample Collection and Analysis.....	7
Presentation of Data .....	8
Station History.....	8
Streamflow Data .....	8
Daily Mean Values.....	8
Annual Summary Statistics.....	9
Reservoir Data.....	9
Meteorological Data and Physical Parameters .....	9
Water-Quality Data .....	9
Data for the Cambridge Drinking-Water Source Area .....	9
Surface-water data .....	9
Specific Conductance.....	11
Water-Quality Data .....	17
Quality-Control Samples.....	18
Meteorological data.....	19
References Cited.....	21
Tables 4–17.....	25
Glossary.....	161

## Figures

1. Map showing the monitoring network for Cambridge, Massachusetts, drinking-water source area for water year 2006, eastern Massachusetts.....3
- 2–8. Graphs showing:
  2. (A ) Discharge from the Hobbs Brook Reservoir as a percentage of water entering the Stony Brook Reservoir, and discharge from the Stony Brook Reservoir to the Charles River as a percentage of total inflow to the Stony Brook Reservoir for water year 2006; (B ) monthly precipitation totals at the Cambridge Reservoir, Stony Brook Reservoir, and Fresh Pond Reservoir in the Cambridge drinking-water source area, water year 2006.....10
  3. Monthly mean reservoir storage as a percentage of capacity for water year 2006 shown as percent capacity for the Cambridge Reservoir, Stony Brook Reservoir, and Fresh Pond Reservoir, near Cambridge, Massachusetts.....12

4. Monthly mean specific conductance for water year 2006 for U.S. Geological Survey station 01104415, Cambridge Reservoir, unnamed tributary 2, near Lexington, Massachusetts; period-of-record maximum and minimum monthly mean specific conductance; and median monthly specific conductance for water years 1997–98 and 2004–05.....	13
5. Monthly mean specific conductance for water year 2006 for U.S. Geological Survey station 01104430, Hobbs Brook below Cambridge Reservoir near Kendal Green, Massachusetts; period-of-record maximum and minimum monthly mean specific conductance; and the median, 25th percentile, and 75th percentile monthly specific conductance for water years 1998 through 2005.....	14
6. Monthly mean specific conductance for water year 2006 for U.S. Geological Survey station 01104460, Stony Brook at Route 20 at Waltham, Massachusetts; period-of-record maximum and minimum monthly mean specific conductance; and the median, 25th percentile, and 75th percentile monthly specific conductance for water years 1997–98 and 2002–05.....	15
7. Monthly mean specific conductance for water years 2005 and 2006 for U.S. Geological Survey station 422302071083801, Fresh Pond Reservoir at Cambridge, Massachusetts.....	16
8. Monthly mean air temperatures for water year 2006 for the Cambridge Reservoir, Massachusetts, period-of-record maximum and minimum monthly mean air temperatures, and the median monthly air temperatures for water years 2002–05.....	20

## Tables

1. Names, locations, drainage areas, and period of records for U.S. Geological Survey monitoring stations in the drinking-water source area for Cambridge, Massachusetts, water year 2006.....	4
2. Hydrologic, water-quality, and meteorological parameters measured at each continuous-monitoring station during water year 2006, in the drinking-water source area for Cambridge, Massachusetts, water year 2006.....	5
3. Rating classifications for continuous records of hydrologic, water quality, and meteorologic parameters.....	6
4. Daily, monthly, and annual statistics for discharge for U.S. Geological Survey stations in the drinking-water source area for Cambridge, Massachusetts, for water year 2006.....	26
5. Daily, monthly, and annual statistics for reservoir altitude for U.S. Geological Survey station numbers 01104430, Hobbs Brook below Cambridge Reservoir near Kendal Green, 01104480, Stony Brook Reservoir in Waltham, and 422302071083801, Fresh Pond Reservoir at Cambridge, for water year 2006.....	39
6. Daily, monthly, and annual statistics for reservoir capacity for U.S. Geological Survey station 01104430, Hobbs Brook below Cambridge Reservoir near Kendal Green; 01104480, Stony Brook Reservoir in Waltham; and 422302071083801, Fresh Pond Reservoir at Cambridge, Massachusetts, water year 2006.....	52
7. Daily, monthly, and annual statistics for precipitation for U.S. Geological Survey stations 01104430, Hobbs Brook below Cambridge Reservoir near Kendal Green; 01104480, Stony Brook Reservoir in Waltham; and 422302071083801, Fresh Pond Reservoir at Cambridge, Massachusetts, water year 2006.....	65

8. Daily, monthly, and annual statistics for air temperature for U.S. Geological Survey stations 01104430, Hobbs Brook below Cambridge Reservoir near Kendal Green; 01104480, Stony Brook Reservoir in Waltham; and 422302071083801, Fresh Pond Reservoir at Cambridge, Massachusetts, water year 2006.....	77
9. Daily, monthly, and annual statistics for water temperature for U.S. Geological Survey stations in the drinking-water source area for Cambridge, Massachusetts, for water year 2006 .....	89
10. Daily, monthly, and annual statistics for specific conductance for U.S. Geological Survey stations in the drinking-water source area for Cambridge, Massachusetts, for water year 2006.....	102
11. Extreme measurements of physical parameters for U.S. Geological Survey stations in the drinking-water source area for Cambridge, Massachusetts.....	116
12. Extreme and median constituent concentrations measured in water samples for each U.S. Geological Survey water-monitoring station in the drinking-water source area for Cambridge, Massachusetts, for the period of record .....	118
13. Physical properties and concentrations of calcium, sodium, chloride, sulfate, total nutrients, and polar pesticides and metabolites for base-flow and stormflow water samples collected in eleven subbasins and for water samples collected from the Fresh Pond intake structure in the Cambridge drinking-water source area in water year 2006 .....	120
14. Physical properties of and concentrations of dissolved calcium, sodium, chloride, sulfate, total nutrients, and polar pesticides and metabolites in quality-control samples collected in water year 2006.....	141
15. Characteristics of selected pesticides detected in base-flow and stormflow water samples collected in the Hobbs Brook and Stony Brook Basins, water year 2006 .....	155
16. Frequency of detection and maximum concentration of selected pesticides and caffeine in six samples of base-flow and seven samples of stormflow collected in the Hobbs Brook and Stony Brook Basins and collected in three samples of raw water collected from the intake of the water-treatment facility at Fresh Pond, Cambridge Massachusetts, water year 2006 .....	157
17. Analyte recovery statistics for field matrix spikes in environmental samples and the frequency of detection for available analytes in about 70 environmental samples collected in the Hobbs Brook and Stony Brook Basins, Massachusetts, for water year 2006 .....	158

## Conversion Factors, Datums, and Abbreviations

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
inch (in.)	25,400	micron ( $\mu$ )
inch (in.)	25,400,000	nanometer (nm)
mile (mi)	1.609	kilometer (km)
Area		
square inch (in <sup>2</sup> )	6.452	square centimeter (cm <sup>2</sup> )
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )
Volume		
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m <sup>3</sup> )
million gallons (Mgal)	3,785.4	cubic meter (m <sup>3</sup> )
Flow rate		
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m <sup>3</sup> /s)

Temperature in degrees Celsius ( $^{\circ}\text{C}$ ) may be converted to degrees Fahrenheit ( $^{\circ}\text{F}$ ) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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

Water- and sediment-quality constituents are expressed in milligrams per liter (mg/L), micrograms per liter ( $\mu\text{g/L}$ ), parts per million (ppm), and parts per billion (ppb). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand milligrams per liter is equivalent to one gram per liter. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in ppm.

Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius ( $\mu\text{S/cm}$  at  $25^{\circ}\text{C}$ ).

### ABBREVIATIONS USED IN REPORT

ASTM	American Society for Testing and Materials
COV	Coefficient of variation
CWD	City of Cambridge, Massachusetts, Water Department
HPLC	High-performance liquid chromatography
ISO	International Organization for Standardization
NIST	National Institute of Standards and Technology
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

# Hydrologic, Water-Quality, and Meteorological Data for the Cambridge, Massachusetts, Drinking-Water Source Area, Water Year 2006

By Kirk P. Smith

## Abstract

Records of water quantity, water quality, and meteorological parameters were continuously collected from three reservoirs, two primary streams, and four subbasin tributaries in the Cambridge, Massachusetts, drinking-water source area during water year 2006 (October 2005 through September 2006). Water samples were collected during base-flow conditions and storms in the subbasins of the Cambridge Reservoir and Stony Brook Reservoir drainage areas and analyzed for dissolved calcium, sodium, chloride, and sulfate; total nitrogen and phosphorus; and polar pesticides and metabolites. These data were collected to assist watershed administrators in managing the drinking-water source area and to identify potential sources of contaminants and trends in contaminant loading to the water supply.

Monthly reservoir contents for the Cambridge Reservoir varied from about 59 to 98 percent of capacity during water year 2006, while monthly reservoir contents for the Stony Brook Reservoir and the Fresh Pond Reservoir was maintained at greater than 83 and 94 percent of capacity, respectively. If water demand is assumed to be 15 million gallons per day by the city of Cambridge, the volume of water released from the Stony Brook Reservoir to the Charles River during the 2006 water year is equivalent to an annual water surplus of about 127 percent. Recorded precipitation in the source area was about 16 percent greater for the 2006 water year than for the previous water year and was between 12 and 73 percent greater than for any recorded amount since water year 2002.

The monthly mean specific-conductance values for all continuously monitored stations within the drinking-water source area were generally within the range of historical data collected since water year 1997, and in many cases were less than the historical medians. The annual mean specific conductance of 738  $\mu\text{S}/\text{cm}$  (microsiemens per centimeter) for water discharged from the Cambridge Reservoir was nearly identical to the annual mean specific conductance for water year 2005 which was 737  $\mu\text{S}/\text{cm}$ . However, the annual mean specific conductance at Stony Brook near Route 20 in

Waltham (U.S. Geological Survey (USGS) station 01104460), on the principal tributary to the Stony Brook Reservoir, and at USGS station 01104475 on a smaller tributary to the Stony Brook Reservoir were about 15 and 13 percent lower, respectively, than the previous annual mean specific conductances of 538 and 284  $\mu\text{S}/\text{cm}$ , respectively, for water year 2005. The annual mean specific conductance for Fresh Pond Reservoir decreased from 553  $\mu\text{S}/\text{cm}$  in the 2005 water year to 514  $\mu\text{S}/\text{cm}$  in the 2006 water year.

Water samples were collected in nearly all of the subbasins in the Cambridge drinking-water source area and from Fresh Pond during water year 2006. Discrete water samples were collected during base-flow conditions with an antecedent dry period of at least 4 days. Composite samples, consisting of as many as 100 subsamples, were collected by automatic samplers during storms. Concentrations of most dissolved constituents were generally lower in samples of stormwater than in samples collected during base flow; however, the average concentration of total phosphorus in samples of stormwater were from 160 to 1,109 percent greater than the average concentration in water samples collected during base-flow conditions. Concentrations of total nitrogen in water samples collected during base-flow conditions and composite samples of stormwater at USGS stations 01104415, 01104460, and 01104475 were similar, but mean concentrations of total nitrogen in samples of stormwater differed by about 0.5 mg/L (milligrams per liter) from those in water samples collected during base-flow conditions at U.S. Geological Survey stations 01104433 and 01104455. In six water samples, measurements of pH were lower than the U.S. Environmental Protection Agency (USEPA) national recommended freshwater quality criteria and the USEPA secondary drinking water-standard of 6.5 pH units. Concentrations of dissolved chloride in all water samples collected during base-flow conditions from USGS stations 01104405, 01104415, 01104420, 01104433, and 01104455 exceeded the USEPA recommended freshwater quality criterion of 230 mg/L. With the exception of one sample collected during base-flow conditions at USGS station 01104455, chloride concentrations in all



of the respective samples also exceeded the USEPA secondary drinking-water standard of 250 mg/L. Concentrations of dissolved chloride in several composites of water collected during storms at USGS stations 01104415 and 01104433 also exceeded the USEPA recommended freshwater quality criterion and secondary drinking-water standard. Concentrations of dissolved sulfate in all water samples were below the USEPA secondary drinking-water standard of 250 mg/L.

Twenty pesticides and caffeine were detected in water samples collected from the primary streams and tributaries to the Cambridge Reservoir and Stony Brook Reservoir, and in raw water collected from the Cambridge water-treatment facility intake from the Fresh Pond Reservoir in water year 2006. Caffeine was detected in 77 percent of all water samples. Imidacloprid, siduron, and carbaryl were the most frequently detected pesticides. The compounds 2,4-D, MCPA, and triclopyr were detected only in samples of stormwater. Caffeine, metalaxyl, and siduron were detected more frequently in water samples collected during storms than in water samples collected during base-flow conditions. Caffeine, 2-hydroxy-4-isopropylamino-6-ethylamino-s-triazine, carbaryl, imidacloprid, norflurazon, and siduron also were detected in raw water from the Fresh Pond Reservoir.

## Introduction

Hydrologic and water-quality monitoring is important for the effective management and protection of drinking-water supplies. Both the quantity and the quality of water are monitored because these factors determine the physical, chemical, and biological state of the water supply. Without accurate information on the past and current condition of the water supply, effective preservation and remediation programs cannot be implemented or evaluated.

The U.S. Geological Survey (USGS) works closely with municipal water suppliers throughout the nation to address specific water problems by conducting hydrologic- and water-quality-monitoring programs and detailed investigations (Patterson, 1997). One such program, conducted during 1997–98 by the USGS in cooperation with the city of Cambridge, Massachusetts, Water Department (CWD), was designed to identify sources of contaminants in the drinking-water source area for the city (Waldron and Bent, 2001). Subsequently the USGS, in cooperation with the CWD, designed and implemented a water-monitoring network in the drinking-water source area. Data from this network have been published annually in various USGS reports (Smith, 2005 and 2007; Socolow and others, 1999, 2000, 2001, 2002, 2003, and 2004).

The CWD supplies approximately 15 Mgal/d (**millions of gallons per day**<sup>1</sup>) (Waldron and Bent, 2001) to more than 100,000 customers. Most of this water is obtained from three

primary storage reservoirs (Cambridge Reservoir (also known as the Hobbs Brook Reservoir), Stony Brook Reservoir, and Fresh Pond Reservoir), in parts of Lexington, Lincoln, Waltham, Weston, and Cambridge (fig. 1). The **drainage basin** for the Cambridge Reservoir includes Hobbs Brook and three unnamed tributaries that **discharge** directly into the reservoir. Water is discharged from the southern end of the Cambridge Reservoir into Hobbs Brook, which receives additional water from an unnamed tributary about 0.5 mi below the reservoir. Hobbs Brook joins with Stony Brook about 1.6 mi downstream from the reservoir and flows south to the Stony Brook Reservoir. Two unnamed tributaries flow into Stony Brook about a 0.25 mi north of the Stony Brook Reservoir. In addition to Stony Brook, an unnamed tributary flows directly into the Stony Brook Reservoir on the southwest side of the reservoir. Additional water enters both reservoirs from other minor tributaries and highway and parking-lot storm drains. Water from Stony Brook Reservoir is piped through an aqueduct by the CWD directly to Fresh Pond Reservoir, where it is stored prior to treatment. Overflow and controlled discharges from the Stony Brook Reservoir flow into the Charles River in Waltham.

The drainage basin contributing water to these reservoirs has undergone rapid development since the 1990s and encompasses major transportation corridors (Interstate 95, Routes 2, 2A, 20, and 117), as well as large areas of industrial, commercial, and high-density residential land use. Because the city of Cambridge owns less than 5 percent of the land in the basin contributing to its water supply, the CWD relies heavily on monitoring to provide information for optimizing the management of its reservoirs for water quality and quantity. The USGS monitoring network provides near-real-time information that assists the CWD in responding rapidly to water-quality changes caused by accidental or intentional contamination. This information also benefits the CWD, other municipalities, and state agencies involved with water-resource development and management in the Charles River Basin by enhancing their understanding of the relation between local drinking-water-management practices and regional issues of water supply and hydrologic-system response.

## Purpose and Scope

This report presents records of water quantity, water quality, and meteorological parameters collected in the Cambridge, Massachusetts, drinking-water source area during **water year 2006** (October 2005 through September 2006). It describes the monitoring network, data-collection methods for all types of data, and computation methods. It also describes the chemical characteristics of water samples collected during **base-flow** conditions and during storms from nearly all of the streams and tributaries to Hobbs Brook and Stony Brook in the Stony Brook Basin, and of water samples collected from the raw-water intake at the Cambridge water-treatment facility.

<sup>1</sup> Terms listed in the glossary at the back of this report are in bold type where first used in the text.





**Figure 1.** The monitoring network for Cambridge, Massachusetts, drinking-water source area for water year 2006, eastern Massachusetts.

## Description of Monitoring Network

Stations installed and operated by the USGS in the drinking-water source area continuously monitored various hydrologic, water-quality, and meteorological parameters including stream **stage**, stream-water temperature, stream **specific conductance**, reservoir altitude, air temperature, and **precipitation**. Stations were selected for continuous monitoring on the basis of the necessity for water-supply regulation by the CWD and of information gained in a previous USGS investigation (Waldron and Bent, 2001) that identified specific areas as potentially important sources of contaminants. Attributes of the monitoring stations are listed in table 1; locations of stations selected for continuous monitoring are shown in figure 1.

Stream-stage measurements were recorded at monitoring stations at the outlet of the Cambridge Reservoir, on an unnamed tributary to Stony Brook, on Stony Brook, and at the outlet of Stony Brook Reservoir (USGS stations 01104430, 01104453, 01104460, and 01104480, respectively). Equipment for the measurement of stream stage was installed at USGS station 01104453 late in the water year. Water-quality measurements were recorded at the outlet of the Cambridge Reservoir and at Stony Brook (USGS stations 01104430 and 01104460). Physical parameters monitored at these sites are listed in table 2. These data were recorded at a frequency of 15 minutes and, with the exception of data from USGS station 01104453, which was not equipped with telemetry, were uploaded to a USGS database hourly by phone modem. In addition to measurements made on these streams, stream-stage

**Table 1.** Names, locations, drainage areas, and period of records for U.S. Geological Survey monitoring stations in the drinking-water source area for Cambridge, Massachusetts, water year 2006.

[USGS, U.S. Geological Survey; mi<sup>2</sup>, square miles; latitude and longitude: In degrees, minutes, and seconds]

Station name	USGS station number	Latitude	Longitude	Drainage area (mi <sup>2</sup> )	Period of record
Stony Brook at Kendal Green	01104390	42 22 36	71 16 55	10.4	03/07/97–09/17/98
Hobbs Brook at Mill Street near Lincoln	01104405	42 26 11	71 16 12	2.16	03/05/97–09/16/98
Cambridge Reservoir, unnamed tributary 1, near Lexington	01104410	42 26 15	71 15 53	2.10	03/05/97–09/16/98
Cambridge Reservoir, unnamed tributary 2, near Lexington	01104415	42 26 09	71 15 38	0.41	10/22/97–09/22/98; 10/01/00–09/30/06
Cambridge Reservoir, unnamed tributary 3, near Lexington	01104420	42 25 11	71 15 29	0.73	04/09/97–09/16/98
Hobbs Brook below Cambridge Reservoir near Kendal Green	01104430	42 23 53	71 16 26	6.86	04/09/97–09/16/98
Hobbs Brook, unnamed tributary number 1 near Kendal Green	01104433	42 23 28	71 16 18	0.36	10/23/97–09/15/05; 06/28/04–09/30/06
Stony Brook, unnamed tributary number 2 near Weston Station	01104453	42 22 17	71 16 31	2.23	06/01/2006–09/30/06
Stony Brook, unnamed tributary number 1 near Waltham	01104455	42 22 21	71 16 15	0.48	10/22/97–09/22/98; 10/01/00–09/30/06
Stony Brook at Route 20 at Waltham	01104460	42 21 08	71 16 16	22.0	03/07/97–10/28/98; 05/14/02–09/30/06
Stony Brook Reservoir, unnamed tributary 1 near Weston	01104475	42 21 16	71 16 07	0.85	12/17/97–09/17/98; 08/26/04–09/30/06
Stony Brook Reservoir at dam near Waltham	01104480	42 21 20	71 15 56	23.7	03/1997–09/30/06
Fresh Pond in gate house at Cambridge	422302071083801	42 23 02	71 08 38	0.00	1998; 10/01/03–09/30/06

**Table 2.** Hydrologic, water-quality, and meteorological parameters measured at each continuous-monitoring station during water year 2006, in the drinking-water source area for Cambridge, Massachusetts, water year 2006.

[USGS, U.S. Geological Survey; X, indicates parameter is measured]

Parameter	USGS station number								
	01104415	01104430	01104433	01104453	01104455	01104460	01104475	01104480	422302071083801
Stream stage	X	X	X	X	X	X	X	X	
Reservoir altitude		X						X	X
Precipitation		X						X	X
Air temperature		X						X	X
Water temperature	X	X	X		X	X	X		X
Specific conductance	X	X	X		X	X	X		X

measurements and water-quality measurements were recorded at monitoring stations on four of the small tributaries (USGS stations 01104415, 01104433, 01104455, and 01104475). Because the **drainage areas** of these sites are small (less than 1 mi<sup>2</sup>) and contain many roadways, parking lots, and other impervious surfaces (Waldron and Bent, 2001), the hydrologic responses, and often the water-quality responses, change rapidly. To document these responses effectively, the monitoring stations recorded stream-stage and water-quality measurements at variable frequencies, as often as every minute. These data were uploaded to a USGS database hourly by digital cellular modem.

Measurements of reservoir altitude, precipitation, and air temperature were recorded at the Cambridge, Stony Brook, and Fresh Pond Reservoirs (USGS stations 01104430, 01104480, and 422302071083801). Measurements of reservoir water quality also were recorded at the Fresh Pond Reservoir. Physical parameters monitored at these sites are listed in table 2. These data were recorded at a frequency of 15 minutes and were uploaded to a USGS database on an hourly basis by phone modem.

## Continuous Data Collection and Computation

The monitoring network provides near-real-time information used to manage the quantity and quality of water in the CWD drinking-water source area. Data from each station are available to watershed managers through the USGS Massachusetts-Rhode Island Water Science Center on the World Wide Web (<http://ma.water.usgs.gov>).

## Hydrologic Data

Basic data collected at the monitoring stations include records of stream stage and measurements of discharge of streams, and water altitude and contents of reservoirs. In addition, observations of factors affecting the **stage-discharge relation** or the altitude-contents relation, weather records, and other information are used to supplement the basic data in determining the daily flow or water in storage. Measurements of discharge are made with a current meter or acoustic Doppler current profiler by standard USGS methods (Buchanan and Somers, 1968, 1969; Carter and Davidian, 1968; Rantz and others, 1982; Kennedy, 1983 and 1984; Oberg and others, 2005). The methods are consistent with the American Society for Testing and Materials (ASTM) standards and generally follow the standards of the International Organization for Standards (ISO).

To determine **streamflow** at each USGS monitoring station in the CWD drinking-water source area, discharge-rating tables for any stage are prepared from stage-discharge curves (Rantz and others, 1982). The daily **mean discharge** is computed from these stage and rating tables, and then the monthly and yearly mean discharges are computed from these daily values. If the stage-discharge relation for a station is changed temporarily by aquatic growth, scour, or debris in the **control** section, the daily mean discharge is computed by the shifting-control method (Rantz and others, 1982).

For the USGS monitoring stations on reservoirs in the CWD drinking-water source area, altitude-capacity tables giving the volume for any reservoir water altitude are prepared from water altitude-volume relation curves defined by surveys (Fugro East, Inc., 1996). From the altitude-capacity tables, the daily, monthly, or yearly changes in volume are computed.

For some stations, recorder or sensor malfunctions can cause gaps in the water-stage record or inaccurate readings, which cannot be used to compute daily discharge. For periods

of malfunction, the daily mean discharges are estimated on the basis of the recorded range in stage, prior and subsequent records, discharge measurements, weather records, and comparison with records from other stations in the same or nearby basins. Likewise, reservoir volumes may be estimated on the basis of operator's log, prior and subsequent records, and other information.

The accuracy of hydrologic data depends primarily on (1) the stability of the stage-discharge relation or, if the control is unstable, the frequency of discharge measurements, and (2) the accuracy of observations of stage, measurements of discharge, and interpretations of records. The degree of accuracy of the records is defined in table 3. Different accuracies may be attributed to different portions of a streamflow record.

## Water-Quality Data

Water-temperature and specific-conductance data were collected from continuous water-quality monitors in each stream, tributary, or reservoir except at USGS station 01104480. The accuracy of the water-quality records depends primarily on the rate of sensor drift, sensor fouling, and debris collection. Typically, sensors became fouled by aquatic growth more rapidly in the warmer months. In most cases, corrections for fouling and drift can be applied to the data to improve their accuracy (Wagner and others, 2006a). For parameters other than water temperature, such corrections were made on the basis of the performance of the sensor before and after sensor maintenance and by noting the response of the clean sensor after placing it in several standardized solutions. The accuracy of water-temperature data is determined by comparing measurements made by the monitoring system and by an independent probe calibrated against a National Institute of Standards and Technology (NIST) **traceable thermometer**. One of four accuracy classifications ranging from excellent to

poor is applied to physical properties measured at each station. The accuracy rating is based on data values recorded before any shifts or corrections are made for fouling and drift. The basis for each rating classification is listed in table 3.

## Meteorological Data

Precipitation data were collected with heated tipping-bucket precipitation gages that measure the volume of rain or melted snow in 0.01-in. increments. The precipitation gages at the Cambridge Reservoir and Stony Brook Reservoir include wind screens that reduce bias generated by precipitation missing the instrument. Precipitation data are summed for each day and then for each month. In general, the accuracy of precipitation data is assured by proper maintenance and calibration of the device. Precipitation measurements, especially when the precipitation is in the form of snow, are affected by strong winds and are subject to errors. These errors generally result in underestimating the total precipitation at a station.

Air-temperature data were collected with thermistors housed in **gill radiation shields**. The probes are installed approximately 8 ft above ground surface. The maximum, minimum, and mean temperature values are computed for each day. Monthly statistics are then computed from daily values. The accuracy of air-temperature data is determined by comparing measurements made by the monitoring system and by an independent probe calibrated against a NIST traceable thermometer.

Under rare circumstances, when no records of precipitation or air temperature were available, daily values were estimated on the basis of records from nearby stations. These circumstances may include a recorder malfunction, the plugging of the precipitation gage, or a malfunction of the heating element in the precipitation gage.

**Table 3.** Rating classifications for continuous records of hydrologic, water quality, and meteorologic parameters.

[Modified from Wagner and others, 2006a; and Socolow and others, 2003; ≤, less than or equal to; ±, plus or minus value shown; °C, degree Celsius; >, greater than; %, percent; ft, feet]

Parameter	Rating			
	Excellent	Good	Fair	Poor
Discharge	≤ ± 5%	> ±5 to 10%	> ±10 to 15%	> ±15%
Reservoir altitude	≤ ± 0.1 ft	> ±0.1 to 0.2 ft	> ±0.2 to 0.3 ft	> ±0.3 ft
Reservoir contents	≤ ± 1%	> ±1 to 2%	> ±2 to 4%	> ±4%
Precipitation	≤ ± 2%	> ±2 to 6%	> ±6 to 10%	> ±10%
Air temperature	≤ ± 0.4°C	> ±0.4 to 0.8°C	> ±0.8 to 2°C	> ±2°C
Water temperature	≤ ± 0.2°C	> ±0.2 to 0.5°C	> ±0.5 to 0.8°C	> ±0.8°C
Specific conductance	≤ ± 3%	> ±3 to 10%	> ±10 to 15%	> ±15%



## Sample Collection and Analysis

Water samples were collected during base-flow conditions and during rain and mixed-precipitation storms in selected streams in the Cambridge Reservoir and Stony Brook Reservoir basins throughout water year 2006. Samples of water from Fresh Pond also were collected from the raw-water intake at the Cambridge water-treatment plant. All water samples were analyzed for physical parameters; **dissolved** calcium, sodium, chloride, and sulfate; total nitrogen and total phosphorus; dissolved caffeine; and 60 **pesticides and metabolites**.

Water samples were collected during base-flow conditions and during storms at five continuously monitored stations in the Hobbs Brook and Stony Brook Basins—four on tributaries (USGS monitoring stations 01104415, 01104433, 01104455, and 01104475) and one on Stony Brook (USGS monitoring station 01104460) (fig. 1 and table 1). Water samples were collected during base-flow conditions on July 18 at several previously monitored USGS stations (Waldron and Bent, 2001) in the Cambridge Reservoir and Stony Brook Reservoir basins. These secondary sampling stations (fig. 1 and table 1) include Stony Brook above the confluence of Hobbs Brook, Hobbs Brook above the Cambridge Reservoir, two unnamed tributaries to the Cambridge Reservoir, Hobbs Brook below the Cambridge Reservoir, and an unnamed tributary to Stony Brook (USGS stations 01104390, 01104405, 01104410, 01104420, 01104430, and 01104453, respectively). Samples of stream water were collected manually (Wilde and others, 1999) under base-flow conditions with an antecedent dry period of at least 4 days. During storms, water samples for chemical analysis were collected with an automatic sampler controlled by a **datalogger**. The first sample was collected when flow exceeded a preset discharge threshold, and subsequent samples were collected at flow-proportional intervals. Each automatic sampler was configured to hold one 20-L glass bottle and fitted with a pre-cleaned 1/2-in. inner diameter Teflon intake and discharge tube, and a short piece of silicon pump-head tube.

A multi-step process was used to clean all wetted parts associated with the automatic sampler and the processing equipment before each sample collection. The initial cleaning consisted of washing the interior and exterior with a phosphate-free laboratory-grade soap and tap water, scrubbing surfaces with a plastic brush, and rinsing with tap water. Circulating the solution through the tubing cleaned the interior of the sampler tubing. Lint-free wipes were forced hydraulically through the tubing to remove internal deposits or films that were difficult to remove by circulating solution alone. After the components dried, they were placed in a large stainless-steel pan in a fume hood and immersed in Optima-grade methanol. A Teflon diaphragm pump was used to circulate the solution through the sampler tubing. The components were allowed to soak, with occasional agitation, for a minimum period of about 4 hours. After appropriately dispensing the

waste solution, all components except the tubing were rinsed with HPLC-grade methanol and air-dried in a fume hood over night. Because the rate of cleaning-solution volatilization was limited within the sampler tubing, the tubing was purged with purified air for approximately 20 minutes. All components were thoroughly rinsed with deionized water until the specific conductance of the waste rinse water was less than 1  $\mu\text{S}/\text{cm}$  (**microsiemen per centimeter**).

Water samples were processed in the Massachusetts Water Science Center laboratory in Northborough at the conclusion of each sampling round or storm. For water samples collected during base-flow conditions when the flow and depth of water in the streams were small, water samples generally were collected in separate bottles designated for whole water, dissolved constituents, and organic compounds; therefore, only limited splitting was necessary at the Water Science Center laboratory. For water samples collected during storms, subsamples to be analyzed for inorganic and organic constituents were split directly from the 20-L glass bottle by transferring the water with a Teflon-diaphragm pump while the contents of the sample bottle were homogenized with a stainless-steel laboratory mixer. Water to be analyzed for dissolved inorganic constituents was filtered through a 600- $\text{cm}^2$  capsule filter with a 0.45-micrometer pore size. Water to be analyzed for dissolved caffeine, pesticides, and pesticide metabolites was filtered through a 142-mm pre-combusted glass-fiber filter with a nominal 0.7-mm pore diameter to remove **suspended** particulate matter. After the samples were processed, they were packed in ice and shipped overnight to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, where they were analyzed for concentrations of dissolved calcium, sodium, chloride, sulfate, total nutrients, and **polar pesticides** and metabolites (Garbarino and others, 2006; Patton and Kryskalla, 2003; Furlong and others, 2001; American Public Health Association, 1998; Garbarino and Struzeski, 1998; Hoffman and others, 1996; Fishman, 1993; Fishman and Friedman, 1989).

The reliability of the chemical data was ensured by the preparation and analysis of several types of quality-control samples. These quality-control samples include two source-solution blanks, three field blanks, six replicate samples, and six field-matrix spike samples and replicate field-matrix spike samples. These analyses provided the basis for the interpretation of chemical data collected in the drinking-water source area.

Source-solution blanks were prepared from deionized water produced by a laboratory-grade water-purification system that uses ion-exchange packs and reverse osmosis. The source-solution water was stored in pre-cleaned glass bottles until it was subsequently used as blank water for the collection of field blanks.

A field blank is used to test for positive bias that can result from contamination at any stage of the sample-collection, -processing, or analysis process. One field blank was collected during sampling at base-flow conditions

in February 2006, and two additional field blanks were collected in preparation for the sampling of stormwater in December 2005 and July 2006. During collection of base-flow samples, the field blank was collected by transferring blank water from the holding bottle to the sample-collection bottles. It was then processed in a manner consistent with the collection of other environmental samples. The remaining field blanks were collected by the automatic sampler in preparation for storm sampling. These samples were collected by pumping blank water through the automatic sampler tubing and into the collection bottle, and processing it in a manner consistent with the collection of environmental samples of stormwater.

Replicate samples are samples that are thought to be identical in composition to the environmental samples. Replicate samples provide a measure of bias and variability for the method of sample collection, sample processing (splitting, filtering, and preservation), and laboratory analysis, and for effects such as analyte degradation that can occur prior to laboratory analysis. A total of six replicate samples were collected during base-flow conditions and during storms. Three replicate samples were collected to test for potential differences between samples collected manually and samples collected concurrently by automatic samplers. These samples were collected during base-flow conditions. The remaining three replicates were collected during storms. These samples were collected by two independent automatic samplers that were triggered simultaneously. These replicates were used to test for potential differences between samples collected with the same method during periods of rapidly changing flow and water quality.

Field-matrix spikes are quality-control samples in which known amounts of target compounds are added to environmental replicate-split samples and then measured. The degree of recovery for each target analyte added to the environmental sample is used to determine the bias and variability attributed to the amount of degradation of target analytes during holding and shipment to the laboratory, the analytical method, and interferences contained in the environmental sample that mask or enhance determinations of the target analytes, or matrix effects. Replicate field-matrix spikes also were submitted to the NWQL for analysis. Similarly, known amounts of target compounds are added to replicate field-matrix spike samples. These samples are processed in the same manner as the field-matrix spike such that the samples are expected to be essentially identical in composition. Comparing the recovery of a field-matrix spike replicate to the recovery of the paired field-matrix spike provides a measure of the variability attributed to the aforementioned processes that can affect the concentration of each analyte.

In addition to the quality-assurance samples collected during this project, the NWQL routinely analyzes various quality-control samples including laboratory reagent blanks, interference check solutions, laboratory control samples, standard reference materials, laboratory reagent spike samples, and laboratory duplicate samples to test and track method performance (Garbarino and others, 2006, and Furlong and

others, 2001). The NWQL also adds surrogate compounds to all samples for determinations of pesticides and caffeine. Surrogate compounds, such as 2,4,5-T, caffeine-13C, and barban, are expected to perform similarly to the compounds being analyzed in the laboratory method. Because these compounds are not normally found in the environment, the recovery of the surrogate compounds can be used to qualify the performance of the analysis.

## Presentation of Data

Hydrologic, water-quality, and meteorological data collected at the USGS monitoring stations during water year 2006 are presented in tables 4–10 (tables 4–17 are in back of the report). Where available, each table includes a summary of daily values, monthly statistics, annual statistics, **gage datums**, and an accuracy rating for each station. The period of record and the period-of-record extremes for each physical parameter are presented in table 11 by USGS station number. The maximum, median, and minimum statistics for selected analytical results for the period of record for each USGS monitoring station are presented in table 12. Analytical results for all base-flow, stormflow, and raw-water samples are presented in table 13.

## Station History

The station history for each USGS monitoring station in the Cambridge drinking-water source area is presented in table 11. This table includes basic information about the period of record and the extremes for the period of record and for water year 2006 for each physical parameter for current USGS stations in the Cambridge drinking-water source area. The “period of record” is the time during which each type of data has been collected at the station. These data may have been collected manually on an intermittent basis or continuously with a monitoring system. The “extremes for the period of record” refer to the maximum and minimum values measured during the period of record.

## Streamflow Data

Streamflow data are presented in table 4. This table includes the daily mean values of discharge by USGS station number for the 2006 water year, monthly summary statistics, annual summary statistics, and data pertaining to **annual runoff** and flow duration.

## Daily Mean Values

The daily table of streamflow records (table 4) gives the **total discharge** for each day of the water year. In the monthly summary (at the bottom of the table), the line labeled **TOTAL**

gives the sum of the daily streamflows for each month; the line labeled MEAN gives the arithmetic average of the daily streamflows for the month; the lines labeled MAX and MIN give the maximum (**peak flow**) and minimum daily streamflows respectively, for each month; and the line labeled MED gives the median daily streamflow for each month. Discharge per unit area of the drainage basin for the month is expressed in **million gallons per day per square mile** (line labeled MGDSM); runoff is given in **inches** (line labeled IN.) of water over the drainage basin. Values for discharge per unit area and runoff in inches are not calculated for stations affected by reservoir regulation.

## Annual Summary Statistics

Annual summary statistics are presented at the end of table 4 following the daily mean values and monthly summaries. These statistics include the annual total, annual mean, annual runoff, and selected streamflow duration-curve statistics. In the annual summary for the table, the line labeled ANNUAL TOTAL gives the sum of all the daily discharges for the water year; the line labeled ANNUAL MEAN gives the arithmetic average of the daily discharges for the water year. Million gallons per day per square mile (ANNUAL MGDSM) is the average number of millions of gallons of water flowing per day from each square mile of area drained; the runoff is assumed to be distributed uniformly in time and area. Inches (ANNUAL IN.) indicates the depth to which the drainage area would be covered if all of the runoff for a given time period were uniformly distributed on it. Runoff data are omitted for stations affected by reservoir regulation. The line labeled 10 PERCENT EXCEEDS indicates that the discharge that was exceeded 10 percent of the time for the designated period (the 10-percent flow-duration discharge). The lines labeled 50 PERCENT EXCEEDS and 90 PERCENT EXCEEDS are similarly defined. The line labeled RECORD QUALITY indicates the accuracy of the records (table 3).

## Reservoir Data

Continuous records of reservoir altitude and contents for the Cambridge Reservoir, Stony Brook Reservoir, and Fresh Pond Reservoir are presented in tables 5 and 6 (tables are in back of the report), respectively. Data tables for each parameter consist of daily mean values; monthly and annual mean, maximum, and minimum values; a gage description; and an accuracy rating description. The line labeled GAGE indicates the value and definition of the datum used to monitor reservoir altitudes. The line labeled RECORD QUALITY indicates the accuracy of the records (table 3). The accuracy of reservoir contents is determined on the basis of the difference in contents associated with the error in the measurements of the reservoir altitude.

## Meteorological Data and Physical Parameters

Continuous records of meteorological and physical parameters are presented in tables 7 through 10. Data tables for precipitation (table 7) consist of daily totals, monthly and annual total and maximum values, and an accuracy rating description. Data tables for all other parameters (tables 8–10) consist of daily maximum, minimum, and mean values; monthly and annual maximum, minimum, and mean values; and an accuracy rating description. Extreme measurements of meteorological and physical parameters recorded during water year 2006 and for the period of record are presented in table 11 for each USGS station.

## Water-Quality Data

The maximum, median, and minimum statistics for concentrations of selected constituents in water samples collected during the period of record for each USGS station in the Cambridge drinking-water source area are presented in table 12. Detailed analytical results for water samples collected in water year 2006 are presented in table 13. Results for quality-control samples are presented in table 14.

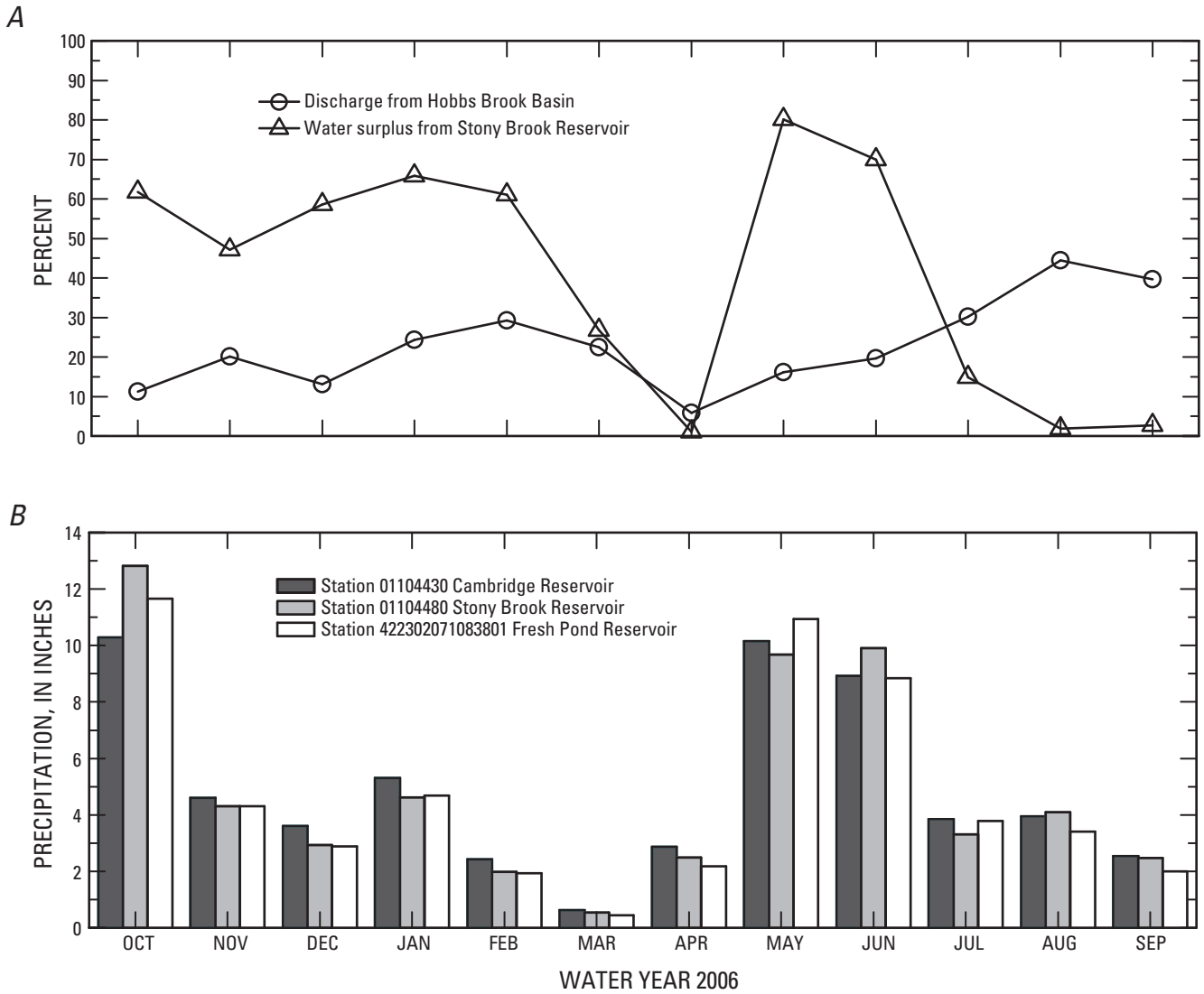
## Data for the Cambridge Drinking-Water Source Area

The data presented in this report can be used by the watershed managers in the city of Cambridge, Massachusetts, to optimize the management of the drinking-water-supply reservoirs for water quality and quantity. The data allow clarification of the relation of reservoir management practices and current conditions to trends in the quantity and quality of water in the subbasins of the hydrologic system.

## Surface-Water Data

From October 2005 through July 2006, mean monthly discharge from the Hobbs Brook Reservoir accounted for less than 30 percent (estimated by dividing the monthly discharges measured at USGS station 01104430 by the sum of monthly discharges measured at USGS stations 01104460 and 01104475) of the water entering the downstream Stony Brook Reservoir (fig. 2A). During the remainder of the water year (August through September 2006), the amount of water released from the Cambridge Reservoir, increased to about 43 percent of the total inflow to the Stony Brook Reservoir. This represents a substantial decrease in the amount of water released from the Cambridge Reservoir compared to the same period in water year 2005, when nearly 99 percent of the water entering the downstream Stony Brook Reservoir was released from the Cambridge Reservoir (Smith, 2007). This difference was the result of the local basins receiving nearly 19 in. of





**Figure 2.** (A) Discharge from the Hobbs Brook Reservoir as a percentage of water entering the Stony Brook Reservoir, and discharge from the Stony Brook Reservoir to the Charles River as a percentage of total inflow to the Stony Brook Reservoir for water year 2006; (B) monthly precipitation totals at the Cambridge Reservoir, Stony Brook Reservoir, and Fresh Pond Reservoir in the Cambridge drinking-water source area, Massachusetts, water year 2006.

rain during the months of May and June and an additional 10 in. of rain distributed during the remainder of the water year (fig. 2B). From October 2005 through February 2006, and during May and June, about 47 percent of all water entering the Stony Brook Reservoir (estimated by dividing the sum of monthly reservoir outflows measured at USGS station 01104480 by the sum of monthly discharges measured at USGS stations 01104460 and 01104475) was diverted to the Charles River (fig. 2A). The volume of water released from the Stony Brook Reservoir to the Charles River during water year 2006 represents an annual surplus of about 127 percent of the total annual water demand by the city of Cambridge. During 1999–2005, this surplus has ranged from 29 to 155 percent if average demand is assumed to be 15 Mgal/d.

The annual runoff for USGS stations 01104415, 01104455, and 01104475 ranged from 1.38 to 1.70 MGDSM (table 4). However, the annual runoff for USGS station 01104433 was 0.82 MGDSM or about half that of the other stations (table 4). The low yield at USGS station 01104433 may be the result of high flows diverted to a neighboring intermittent stream caused by a back-water condition from a drainage pipe upstream of the monitoring station that limits the rate of flow.

Monthly reservoir contents for the Cambridge Reservoir varied from about 59 to 98 percent of capacity during water year 2006 (fig. 3). The reservoir storage was at its lowest during the month of October. The reservoir storage was near capacity in the spring but was subsequently drawn down to about 84 percent of its capacity as additional water was needed to supplement the city of Cambridge water supply when the yield from the Stony Brook Basin diminished. Monthly reservoir storage values for the Stony Brook and Fresh Pond Reservoirs were maintained at greater than 83 and 94 percent of capacity, respectively, during water year 2006 (fig. 3).

## Specific Conductance

Monthly mean specific-conductance values for USGS station 01104415 for water year 2006 generally were lower than the median of monthly specific-conductance values for available data for the period from water year 1997 to water year 2005 (Smith, 2005 and 2007; Socolow and others, 1999, 2000, 2001, 2002, 2003, and 2004) (fig. 4). The monthly mean specific conductances for streamflow for Hobbs Brook below the Cambridge Reservoir (USGS station 01104430) were within the interquartile range of the monthly mean specific conductances for the same period (fig. 5). The annual mean specific conductance of 738  $\mu\text{S}/\text{cm}$  (table 10) was nearly identical to the annual mean specific conductance for water 2005 which was 737  $\mu\text{S}/\text{cm}$  (Smith, 2007). Monthly mean specific-conductance values for USGS station 01104433 for water year 2006 were consistently lower than those for water year 2005 (Smith, 2007), differing by -11 percent to -49 percent.

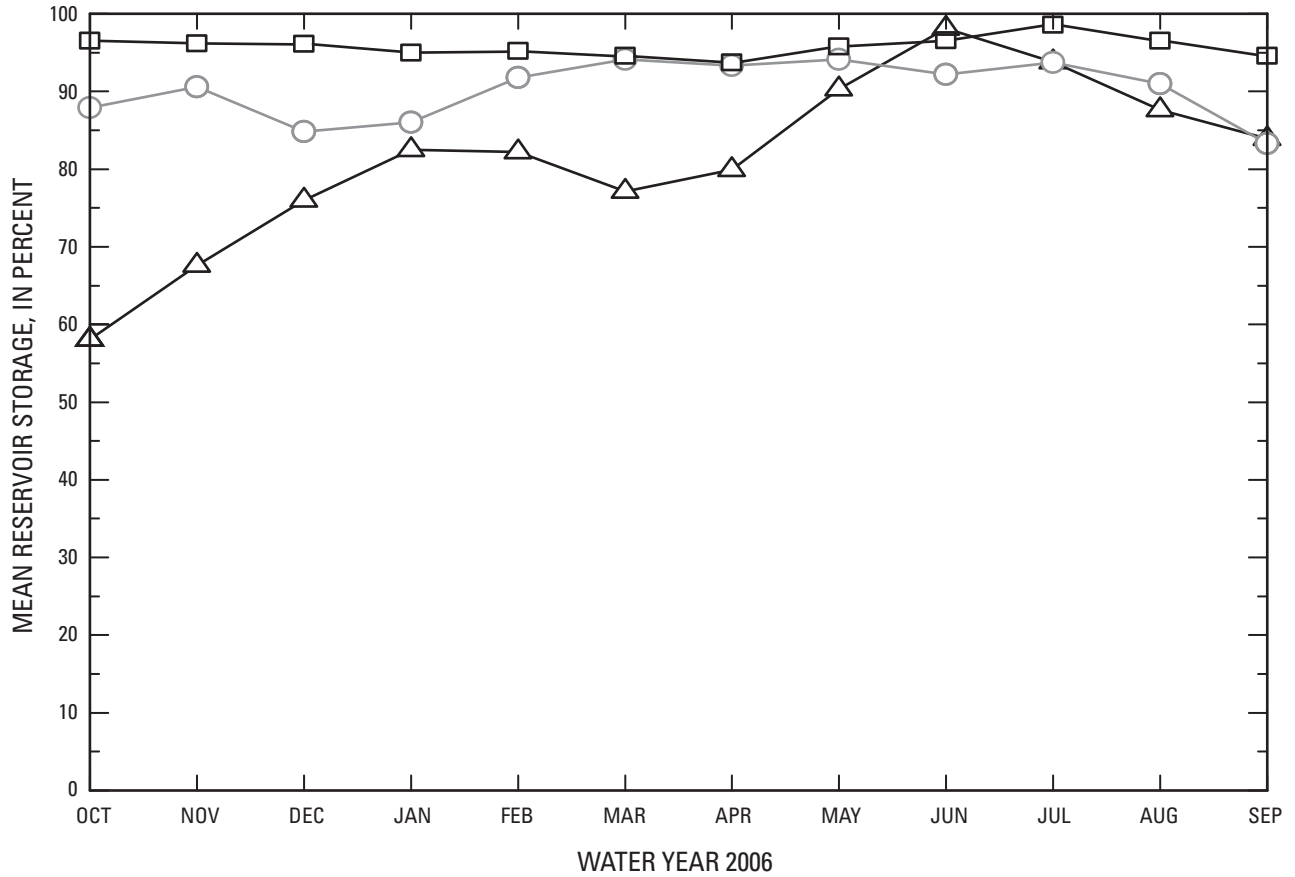
Because of construction activities near USGS station 01104455, the site was temporarily decommissioned from August 2005 through April 2006. As a result, no records of

water quality are available for the period from October through April, except for values estimated from data collected during field visits. Monthly mean specific-conductance values during the remainder of water year 2006 were consistently lower than those for water year 2005 (Smith, 2007), differing by -8 percent to -44 percent. For the months of April, June, August, and September, the monthly mean conductance values were similar to monthly means values for the period from water year 1998 to 2005 (Smith, 2005 and 2007; Socolow and others, 2000, 2001, 2002, 2003, and 2004). The monthly mean conductance for May was less than the 25th-percentile value (964  $\mu\text{S}/\text{cm}$ ), and the monthly mean conductance for July was greater than the 75th-percentile value (1,260  $\mu\text{S}/\text{cm}$ ) for the same period. The interquartile ranges for these months were 263 and 120  $\mu\text{S}/\text{cm}$ , respectively.

New maximum values for monthly mean specific conductances for Stony Brook at USGS station 01104460 were calculated for the months of December and January. For all other months, the monthly mean specific conductances were within the established maximum and minimum values for the period 1997 through 1998 and 2002 through 2005 (fig. 6). For USGS station 01104475, monthly mean conductance values for water year 2006 were consistently lower than those for the previous 2 water years (Smith, 2005 and 2007), differing by -2 percent to -32 percent. The annual mean specific conductances for USGS stations 01104460 and 01104475 were about 15 and 13 percent lower, respectively, than the annual mean specific conductances for water year 2005, which were 538 and 284  $\mu\text{S}/\text{cm}$ , respectively (Smith, 2007).

Many of the small tributaries to the reservoirs differ from the primary streams in that both the quantity and quality of water in the tributaries respond more rapidly to stormwater runoff. The daily mean specific-conductance values for USGS stations 01104415, 01104433, and 01104455 differed by as much as 826 percent from the annual mean values during water year 2006. Daily mean specific-conductance values for USGS station 01104475 differed by about 578  $\mu\text{S}/\text{cm}$ , or about 233 percent of the mean annual value during water year 2006. The coefficient of variation (COV) (the standard deviation divided by the mean) for monthly mean specific-conductance values ranged from about 5 percent to about 36 percent (01104433>01104455>01104415>01104475).

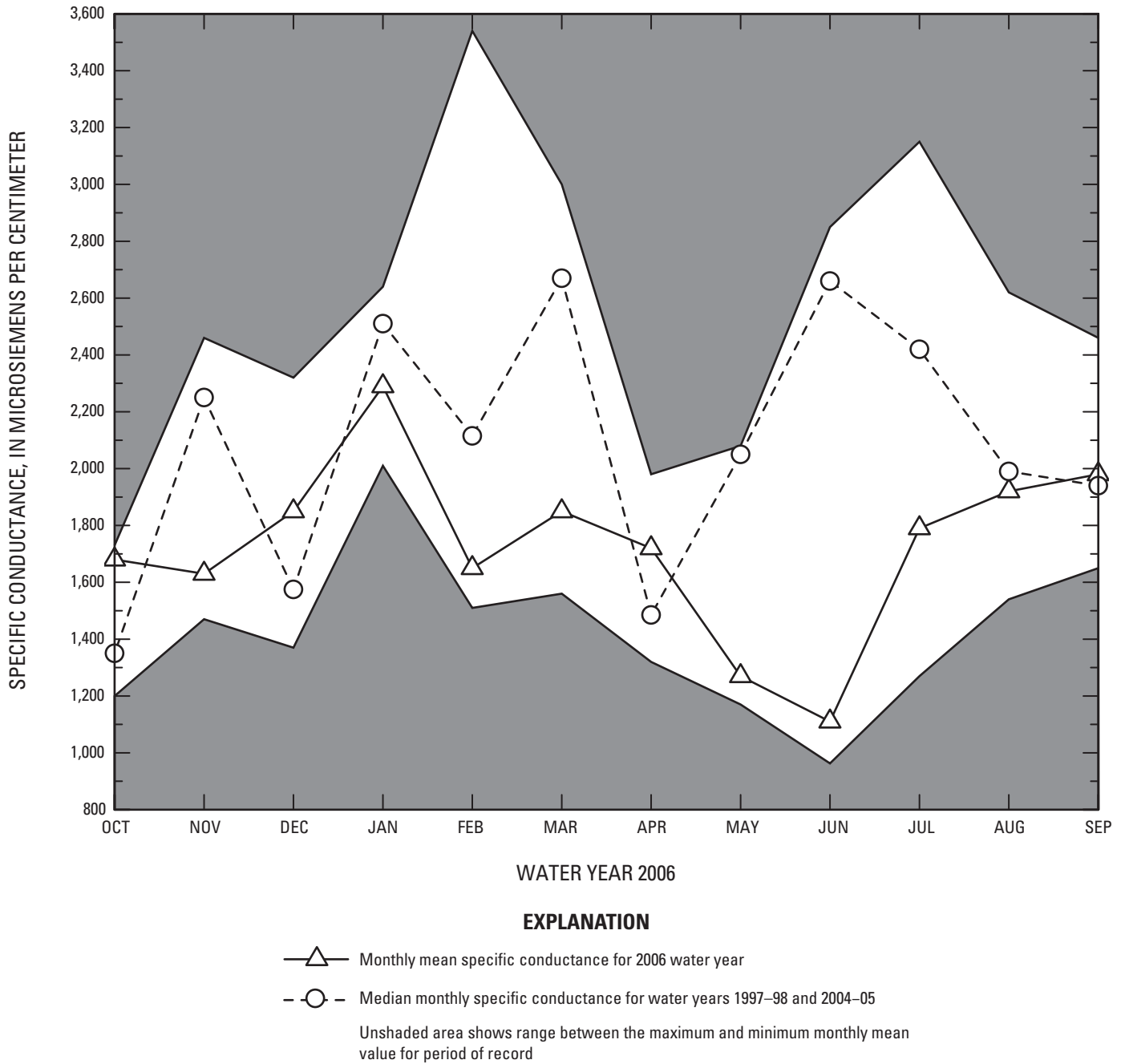
The annual mean specific conductance for Fresh Pond Reservoir decreased from 553  $\mu\text{S}/\text{cm}$  in the 2005 water year (Smith, 2007) to 514  $\mu\text{S}/\text{cm}$  in the 2006 water year (table 10 and fig. 7). The monthly mean specific conductance remained between 515  $\mu\text{S}/\text{cm}$  and 450  $\mu\text{S}/\text{cm}$  from December 2005 through September 2006. In water year 2005, the specific conductance increased during the summer months as a result of the increasing influx of water from the Cambridge Reservoir (fig. 2A), which had a greater specific conductance than water from the primary stream in the Stony Brook Basin (table 10). As a result of large amounts of rainfall during the spring and throughout the summer of 2006, lower conductance water was available from the Stony Brook Basin to buffer the higher conductance water from the Cambridge Reservoir.



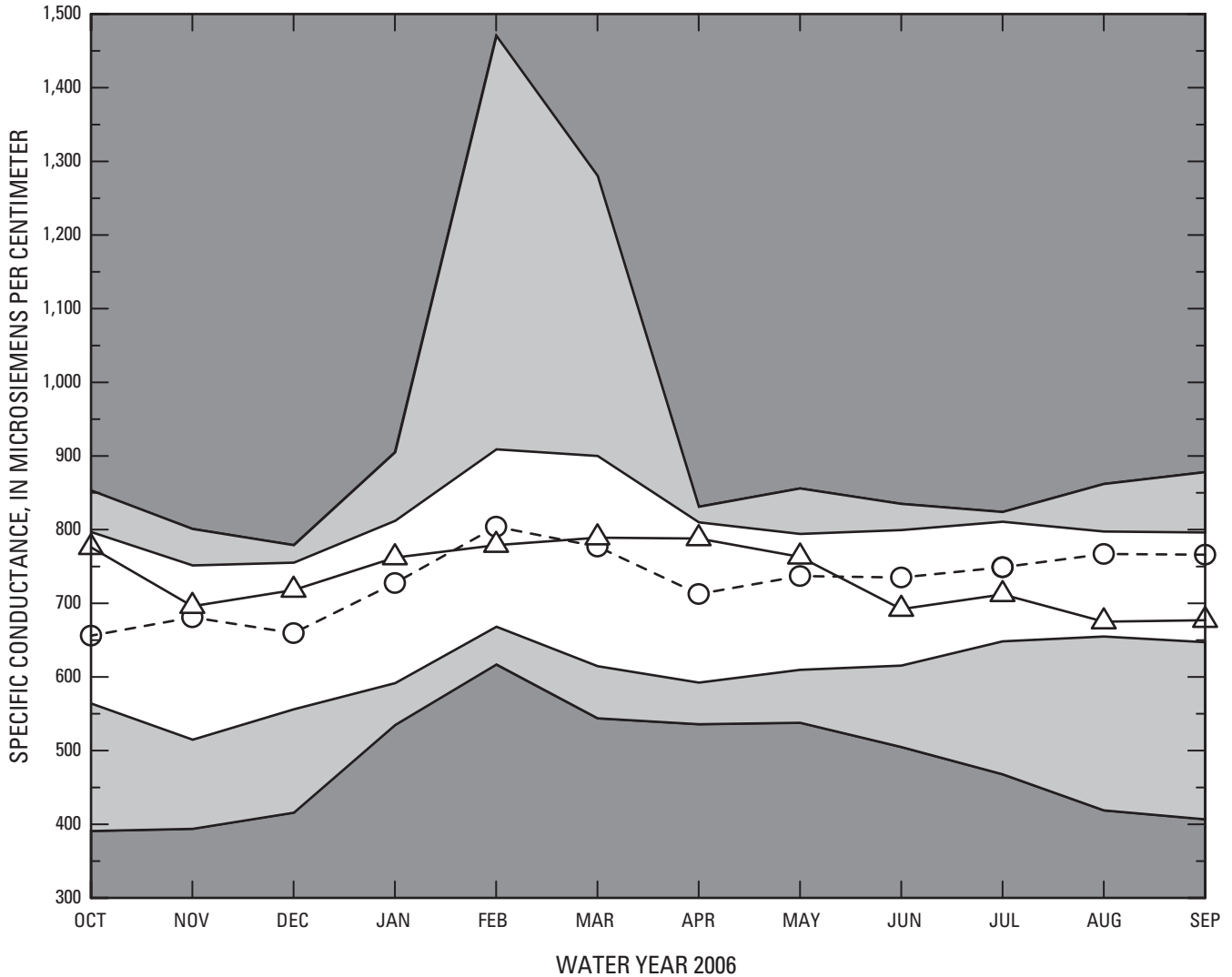
**EXPLANATION**

- △— Station 01104430 Cambridge Reservoir
- Station 01104480 Stony Brook Reservoir
- Station 422302071083801 Fresh Pond Reservoir

**Figure 3.** Monthly mean reservoir storage as a percentage of capacity for water year 2006 shown as percent capacity for the Cambridge Reservoir, Stony Brook Reservoir, and Fresh Pond Reservoir, near Cambridge, Massachusetts.



**Figure 4.** Monthly mean specific conductance for water year 2006 for U.S. Geological Survey station 01104415, Cambridge Reservoir, unnamed tributary 2, near Lexington, Massachusetts; period-of-record maximum and minimum monthly mean specific conductance; and median monthly specific conductance for water years 1997-98 and 2004-05.

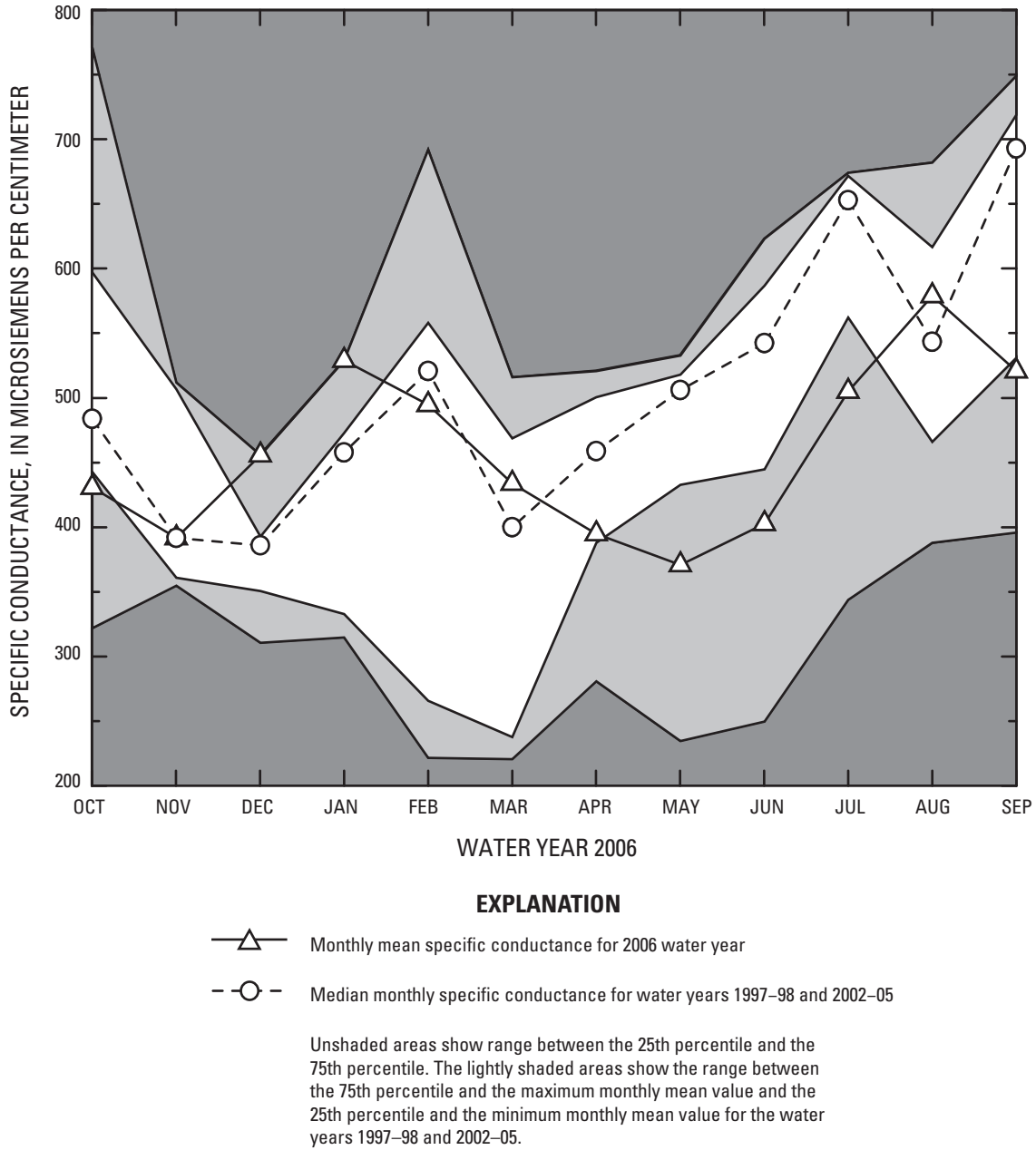


**EXPLANATION**

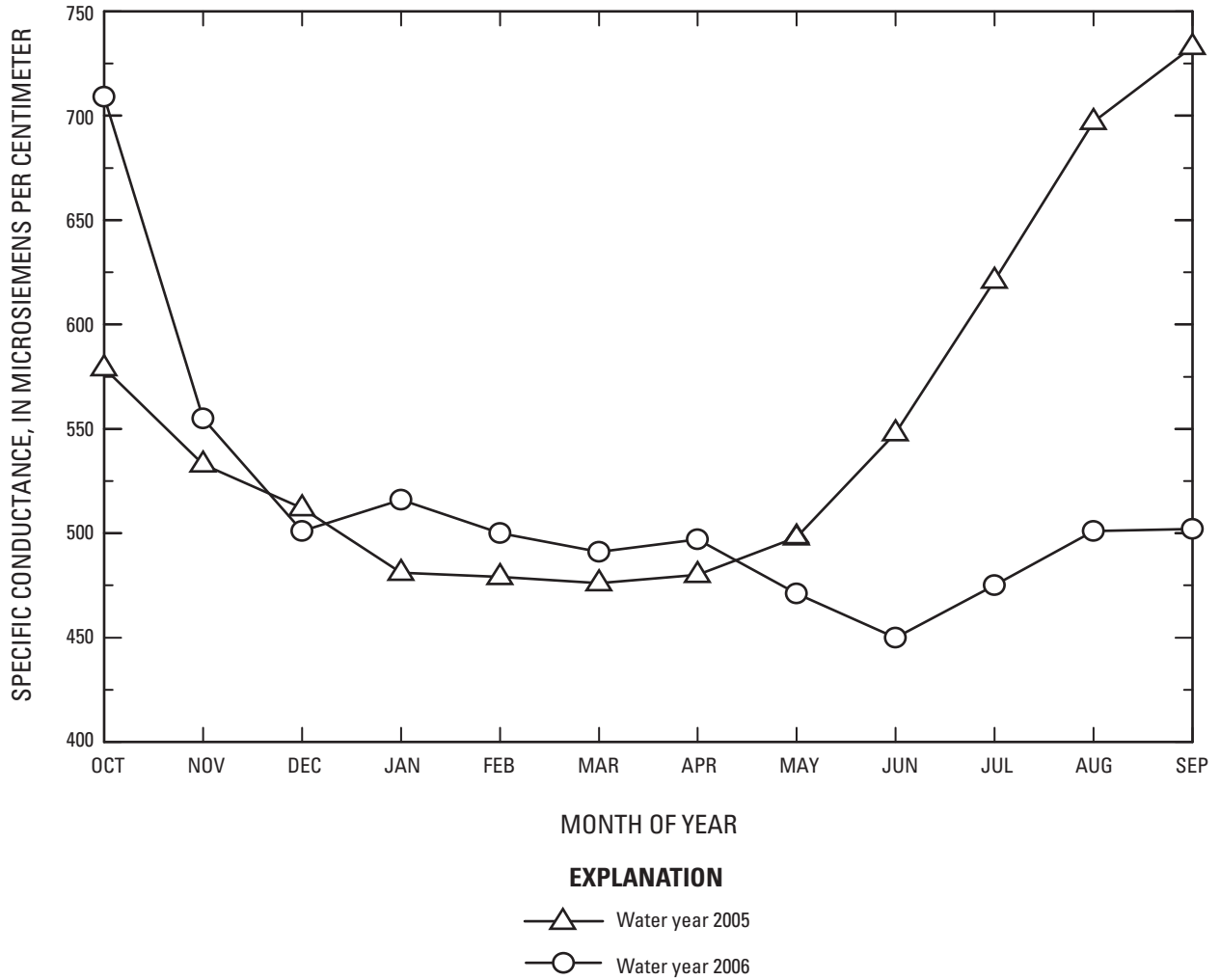
- △— Monthly mean specific conductance for 2006 water year
- Median monthly specific conductance for water years 1998–2005

Unshaded areas show range between the 25th percentile and the 75th percentile. The lightly shaded areas show the range between the 75th percentile and the maximum monthly mean value and the 25th percentile and the minimum monthly mean value for the water years 1998–2005.

**Figure 5.** Monthly mean specific conductance for water year 2006 for U.S. Geological Survey station 01104430, Hobbs Brook below Cambridge Reservoir near Kendal Green, Massachusetts; period-of-record maximum and minimum monthly mean specific conductance; and the median, 25th percentile, and 75th percentile monthly specific conductance for water years 1998 through 2005.



**Figure 6.** Monthly mean specific conductance for water year 2006 for U.S. Geological Survey station 01104460, Stony Brook at Route 20 at Waltham, Massachusetts; period-of-record maximum and minimum monthly mean specific conductance; and the median, 25th percentile, and 75th percentile monthly specific conductance for water years 1997-98 and 2002-05.



**Figure 7.** Monthly mean specific conductance for water years 2005 and 2006 for U.S. Geological Survey station 422302071083801, Fresh Pond Reservoir at Cambridge, Massachusetts.



## Water-Quality Data

Water samples were collected in nearly all of the subbasins in the Cambridge drinking-water source area and from Fresh Pond during water year 2006. Six water samples were collected manually during base-flow conditions and seven composites of stormwater were collected with automatic samplers at the primary sampling sites (USGS stations 01104415, 01104433, 01104455, 01104460, and 01104475). Three samples of water from Fresh Pond were collected from the raw-water intake at the Cambridge water treatment plant. A single water sample also was collected from secondary sampling sites (USGS stations 01104390, 01104405, 01104410, 01104420, 01104430, and 01104453) during a synchronous sampling round on July 18 when samples of water were collected at most of the subbasins within the Hobbs Brook and Stony Brook basin during the same day. Various quality-assurance samples also were collected to determine bias and precision associated with the sample data. All samples were analyzed for physical properties and concentrations of dissolved calcium, sodium, chloride, sulfate, total nutrients, and polar pesticides and metabolites.

The physical properties and chemical concentrations for water samples were compared to the U.S. Environmental Protection Agency (USEPA) recommended freshwater-quality criterion and the USEPA secondary drinking-water standards, where available. Secondary drinking-water regulations are non-mandatory water-quality standards established by the USEPA. They are guidelines designed to assist public water suppliers in managing their drinking water for aesthetic considerations, such as taste, odor, color, foaming, corrosivity, staining, scaling, and **sedimentation**. These constituents do not present a risk to human health at the secondary maximum contaminant level (U.S. Environmental Protection Agency, 2007). Although these standards typically are applied to finished water, the presence of these constituents in concentrations that exceed the respective standards can damage water equipment or reduce the effectiveness of treatment for other contaminants. Some constituents, such as chloride, sodium, and nitrogen, cannot be effectively removed or reduced during the water-treatment process (Smith, 2007).

In 6 of 71 water samples, measurements of **pH** were less than the USEPA recommended freshwater-quality criterion and the USEPA secondary drinking-water standard of 6.5 pH units. Concentrations of dissolved chloride in all water samples collected during base-flow conditions from USGS stations 01104405, 01104415, 01104420, 01104433, and 01104455 exceeded the USEPA national recommended freshwater-quality criterion of 230 mg/L (**milligrams per liter**). With the exception of one of six samples collected during base-flow conditions at USGS station 01104455, chloride concentrations in all of the respective samples also exceeded the USEPA secondary drinking-water standard of 250 mg/L. Concentrations of dissolved chloride in three out of seven and three out of eight composites of water collected during storms at USGS stations 01104415 and 01104433, respectively, also

exceeded the USEPA recommended freshwater-quality criterion and secondary drinking-water standard. Concentrations of dissolved sulfate in all 71 water samples were below the USEPA secondary drinking-water standard of 250 mg/L.

Concentrations of dissolved calcium, sodium, chloride, and sulfate in water samples collected in the drinking-water source area varied from 6.55 to 112, 19.6 to 449, 31.1 to 793, and 5.78 to 57.6 mg/L, respectively (table 13). The average concentrations of dissolved calcium and sulfate in water samples collected during storms were lower than the average concentrations observed in water samples collected during base-flow conditions at the primary sampling stations. With the exception of USGS station 01104475, the average concentrations of dissolved sodium and chloride in water samples collected during storms also were lower than the average concentrations observed in water samples collected during base-flow conditions at the primary sampling stations. The highest concentrations of dissolved sodium, chloride, and sulfate were found in a water sample collected on March 13, 2006, during a winter storm at USGS station 01104415. The highest concentration of dissolved calcium was found in a water sample collected on April 21, 2006, at USGS station 01104433. Concentrations of dissolved calcium in water samples collected at USGS stations 01104405, 01104430, 01104433, and 01104460 in water year 2006 were the highest measured by the USGS for water years 1997 to 2006 (table 12). Similarly, concentrations of dissolved sodium and chloride in water samples collected at USGS stations 01104390, 01104430, 01104433, 01104460, and 01104475 in water year 2006 were greater than the previous maximum concentration recorded by the USGS since water year 1997 (table 12).

The concentration of total nitrogen in water samples for all subbasins ranged from 0.55 to 3.12 mg/L. Average nitrogen concentrations in water samples for the tributaries at the primary sampling sites ranged from 1.41 to 1.77 mg/L. The average concentration of nitrogen in water samples collected during base-flow conditions was not substantially different from the average concentration of nitrogen in composite samples of stormwater at USGS stations 01104415, 01104460, and 01104475. The difference between average concentrations of total nitrogen in samples of base flow and stormwater was about 0.5 mg/L at USGS stations 01104433 and 01104455. The highest concentration of total nitrogen (3.12 mg/L) was observed in a sample of water collected on December 12, 2005, during base-flow conditions at USGS station 01104433. Concentrations of total nitrogen in water samples collected in water year 2006 at USGS stations 01104410, 01104430, 01104433, and 01104460 were greater than the previous maximum concentrations of total nitrogen recorded by the USGS since water year 1997 (table 12).

Concentrations of total phosphorus were similar in water samples collected during base-flow conditions for all subbasins; however, the average concentration of total phosphorus in samples of stormwater at the primary sampling stations were from 160 to 1,109 percent greater than the average concentration in water samples collected during base-flow conditions

at the same stations. Concentrations of total phosphorus in water samples collected in water year 2006 were greater than the previous maximum concentrations of total phosphorus recorded by the USGS since water year 1997 for USGS stations 01104390 and 01104420 (table 12).

Twenty pesticides and caffeine were detected in water samples collected in the primary streams and tributaries to the Cambridge Reservoir and Stony Brook Reservoir, and in raw water collected from the Cambridge water-treatment facility intake from the Fresh Pond Reservoir in water year 2006. Most of these pesticides are found in over-the-counter products used for turf management and the treatment of ornamental shrubs (table 15). Caffeine was detected in 77 percent of 70 water samples at concentrations ranging from 0.003 to 1.82 µg/L (**micrograms per liter**). Imidacloprid, siduron, and carbaryl were the most frequently detected pesticides (table 16). The compounds 2,4-D, MCPA, and triclopyr were detected only in samples of stormwater runoff. Caffeine, metalaxyl, and siduron were more frequently detected in water samples collected during storms than in water samples collected during base-flow conditions. Imazaquin, imidacloprid, and siduron were the only widespread pesticides detected in water samples collected at USGS stations 01104415, 01104433, 01104455, 01104460, and 01104475. The herbicide norflurazon was detected in all water samples collected at USGS station 01104455. The insecticide imidacloprid and the fungicides benomyl, metalaxyl, and propiconazole were detected in water samples collected at USGS station 01104475 at a frequency equal to or greater than about 85 percent. With the exception of USGS stations 01104405 (in the Hobbs Brook Basin) and 01104453 (in the Stony Brook Basin), neither caffeine nor any pesticides listed in table 13 were detected in water samples collected at any of the secondary sampling sites. Caffeine, 2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine, carbaryl, imidacloprid, norflurazon, and siduron also were detected in water from the Fresh Pond Reservoir.

## Quality-Control Samples

Trace amounts of calcium, sodium, total nitrogen, phosphorus, and caffeine were detected in one or more field blanks (table 14). The maximum concentration of calcium, sodium, and total nitrogen measured in field blanks was one or more orders of magnitude less than the lowest concentration found in all environmental samples and was within the precision of the laboratory methods (Patton and Kryskalla, 2003; Fishman and Friedman, 1989). Although the concentrations of total phosphorus and caffeine measured in a single field blank were low, the results for several environmental samples (particularly those samples collected during base-flow conditions

and analyzed for total phosphorus) also were low and should be viewed with caution. If it is assumed that the amount of phosphorus and caffeine measured in the field-blank water represents the maximum amount of contamination present in any given sample, the potential positive bias for concentrations of total phosphorus and caffeine compared to the average concentrations in all samples collected during the 2006 water year is 11 and 2 percent, respectively.

Field and laboratory concurrent replicate sets were analyzed by comparing the relative percent differences (RPDs) of the results for each pair of samples where the same analyte was detected in both samples. The maximum RPD for measurements of **turbidity** for replicate sets was less than about 14 percent, or 2 NTRUs. Measurements of pH for replicate sets were within 0.1 pH unit of each other. The maximum RPD for both field and laboratory measurements of specific conductance was less than about 5 percent. The RPDs for calcium, sodium, chloride, sulfate, total nitrogen, and total phosphorus were also precise and varied by no more than about 6 percent, except the RPD for total phosphorus in a single replicate set, which was about 10 percent, or 0.01 mg/L. Total phosphorus was inconsistently detected in replicate pairs collected during base-flow conditions, and as a result, fewer observations were available to determine the RPD for that constituent. Similarly, norflurazon and triclopyr were detected only in the environmental samples and not in the replicate samples. The RPDs for 2,4-D, metalaxyl, propiconazole, and siduron were less than 8 percent. The RPDs for benomyl, caffeine, carbaryl, and imidacloprid ranged from 0 to 50 percent; however, the RPDs for replicate pairs in composites of stormwater were less than 8 percent. The concentrations of these compounds in replicate sets collected during base-flow conditions were generally low and were **estimated** by the NWQL. As a result, the uncertainty in these measurements is greater than the uncertainty in measurements made at higher concentrations and above the **laboratory reporting level**. Therefore, the difference in the variability associated with the replicate sets collected during different flow conditions is more likely attributed to the precision of the analytical method than to any potential bias associated with the sample-collection method.

Polar pesticides and metabolites are detected, identified, and quantified under different ionization modes. Some compounds preferentially form positive ions during the analytical method, while other compounds form negative ions (Furlong and others, 2001). Because field-matrix spike and field-matrix spike replicate samples were fortified with either compounds determined under positive ionization conditions or with compounds determined under negative ionization conditions, the RPD for background concentrations of non-fortified compounds was determined for each pair of samples where

the same analyte was detected in both samples. The RPD for concentrations of benomyl, carbaryl, metalaxyl, imidacloprid, propiconazole, and siduron in environmental samples and paired field-matrix spike and field-matrix spike replicate samples that were not fortified was less than 9 percent. Caffeine and propoxur were not consistently detected in either the environmental sample or the non-fortified samples, and therefore, RPDs were not computed.

The average recovery for all compounds determined under positive ionization conditions in spiked deionized water was about 83 percent. Individual recoveries for these compounds ranged from about 10 percent to 140 percent. Spike recoveries for analytes detected in environmental samples and determined under positive ionization conditions ranged from 43 to 140. The RPDs for all analyte recoveries in the pair of spike samples ranged from about -30 percent to 13 percent. The RPDs for all analyte recoveries for those compounds detected in environmental samples and in the pair of spike samples were less than 6 percent. These recoveries represent variability associated with sample processing, spiking technique, sample degradation, and laboratory method performance in the absence of any environmental matrix effect. Spike recoveries for compounds determined under negative ionization conditions in the sample of deionized water were not available.

The average of the mean recoveries for all compounds except 2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine and chlorodiamino-s-triazine, which were not included in the spike solutions, in spiked environmental samples was about 87 percent with a relative standard deviation of about 37 percent. Recoveries for these analytes ranged from about 20 to 202 percent (table 17). The average of the mean recoveries for all compounds determined under positive ionization conditions was about 76 percent, and the average of the mean recoveries for all compounds determined under negative ionization conditions was about 124 percent. Spike recoveries for analytes detected in environmental samples ranged from about 80 to 107 percent, except for 2-Chloro-6-ethylamino-4-amino-s-triazine, benomyl, caffeine, and imazaquin, which had mean recoveries of 35, 49, 61, and 66 percent, respectively. The RPD for all replicate spike recoveries ranged from about -35 percent to 13 percent. The RPDs for analyte recoveries between paired spike samples for compounds that were detected in environmental samples were within about 30 percent. These recoveries represent variability associated with sample splitting and processing, spiking technique, sample degradation, laboratory method performance, and potential matrix effects.

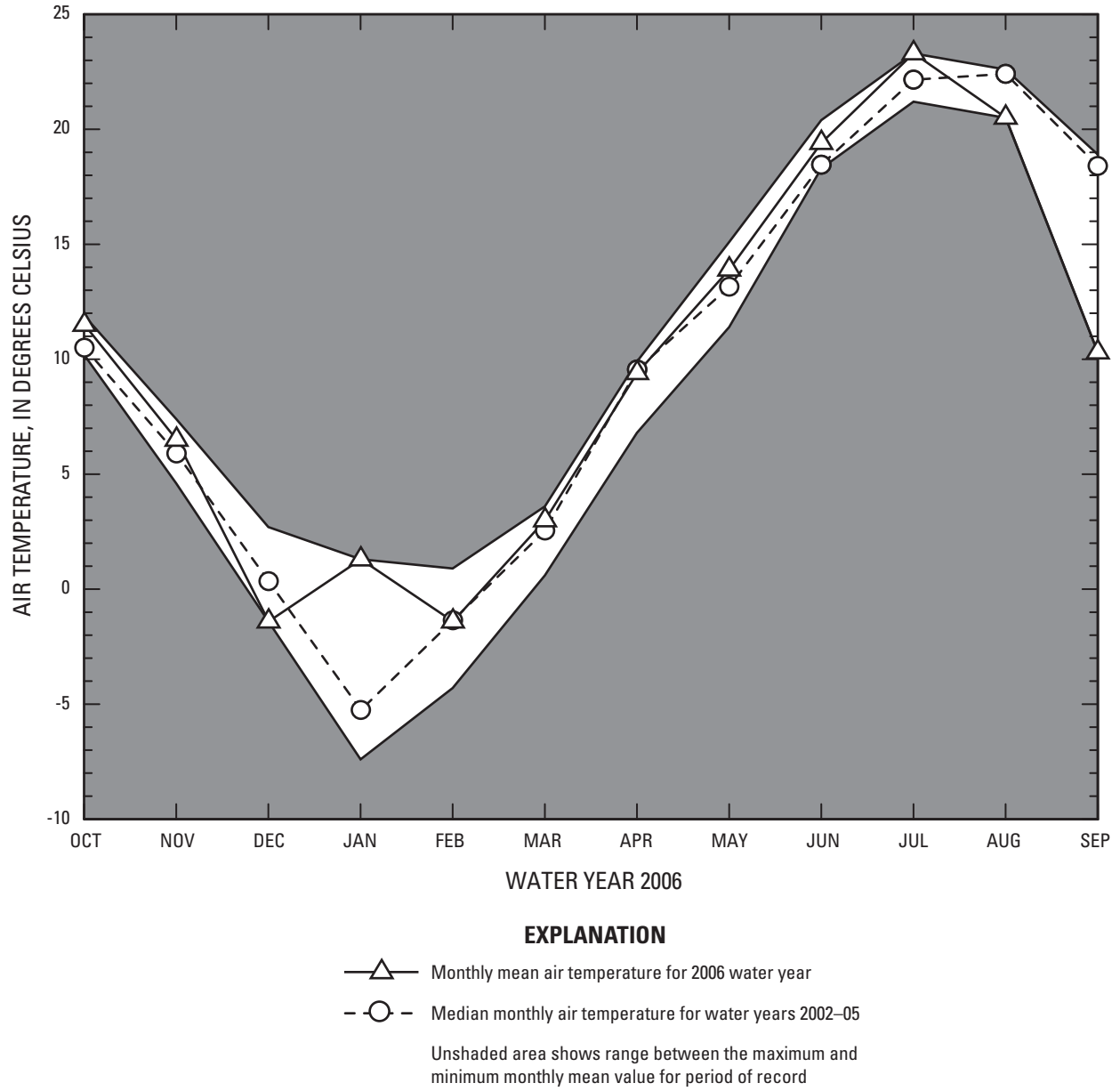
The average recovery for the surrogate compounds 2,4,5-T, barban, and caffeine-13C for all environmental

samples was 119, 103, and 77 percent, respectively. The COV for these compounds was 62, 49, and 30 percent, respectively. Surrogate recoveries provide a measure of method performance for each individual sample. When the difference between surrogate recoveries is outside acceptable control limits (usually low) as a result of an identified process failure, the results for the associated analytes are usually flagged by the NWQL with the "E" code (estimated value), or even deleted, if the recovery is poor. Reporting levels may also be adjusted accordingly under some circumstances.

## Meteorological Data

Monthly precipitation totals for the Cambridge drinking-water source area varied from about 0.5 in. to more than 12 in. during water year 2006 (fig. 2B and table 7). The COVs for monthly precipitation totals for each site were similar, ranging from about 65 to 78 percent. Monthly precipitation totals for USGS stations 01104480 and 422302071083801 differed from those for USGS station 01104430 by -25 to 27 percent with average differences of about 5 and 11 percent, respectively. In general, variability between monthly precipitation totals for all stations is attributed to differences in storm tracks, storm-intensity patterns, and storm wind intensity. Additionally, variability between monthly precipitation totals during the winter months is compounded by a change in precipitation type—that is, snow is less dense than rain and, therefore, is affected more strongly by wind. The precipitation gages at USGS stations 01104480 and 422302071083801 are more susceptible to wind bias than the gage at USGS station 01104430, and therefore, the totals are generally lower (fig. 2B and table 7). The annual precipitation total recorded at station 01104430 during water year 2006 was about 16 percent greater than the total for water year 2005 and was from 12 and 73 percent greater than any amount recorded since water year 2002 (Smith, 2005 and 2007; Socolow and others, 2003 and 2004).

Mean monthly air-temperature values were generally similar from site to site, differing by no more than about 1.6°C. Mean monthly air-temperature values varied most in January, February, and September. During water year 2006, mean monthly air-temperature values were within 2°C of the median values for water years 2002 through 2005 (fig. 8), except for the months of January and September 2006 when they were about 6.5 and -8.1°C from the median values for water years 2002 through 2005 (Smith, 2005 and 2007; Socolow and others, 2002 and 2003).



**Figure 8.** Monthly mean air temperatures for water year 2006 for the Cambridge Reservoir, Massachusetts, period-of-record maximum and minimum monthly mean air temperatures, and the median monthly air temperatures for water years 2002-05.



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