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Streamflow, Water Quality, and Constituent Loads and Yields, Scituate Reservoir Drainage Area, Rhode Island, Water Year 2022

Data Report 1205

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

Cover. U.S. Geological Survey streamgage at Swamp Brook at Ponagansett Road near Clayville, Rhode Island; photograph by the U.S. Geological Survey.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
liter (L)	0.03531	cubic foot (ft^3)
	Discharge	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile ($[ft^3/s]/mi^2$)	0.01093	cubic meter per second per square kilometer ($[m^3/s]/km^2$)
liter per day (L/d)	0.03531	cubic foot per day (ft^3/d)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (t)	1.102	ton, short [2,000 lb]
	Load	
gram per day (g/d)	0.0022	pound per day (lb/d)
kilogram per day (kg/d)	2.205	pound per day (lb/d)
metric ton per year (t/yr)	2205	pound per year (lb/yr)
	Yield	
gram per day per square mile ($[g/d]/mi^2$)	0.0022	pound per day per square mile ($[lb/d]/m^2$)
kilogram per day per square mile ($[kg/d]/mi^2$)	2.590	kilogram per day per square kilometer ($[kg/d]/km^2$)
kilogram per day per square mile ($[kg/d]/mi^2$)	2.205	pound per day per square mile ($[lb/d]/mi^2$)
metric ton per year per square mile ($[t/yr]/mi^2$)	2.590	metric ton per year per square kilometer ($[t/yr]/mi^2$)
metric ton per year per square mile ($[t/yr]/mi^2$)	2205	pound per year per square mile ($[lb/yr]/mi^2$)

Datum

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

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

Supplemental Information

Concentrations of constituents in water are given in either milligrams per liter (mg/L) or colony forming units per 100 milliliters (CFU/100 mL).

Loads of bacteria in water are given in million colony forming units per day ([CFU×10^6]/d).

Yields of bacteria are given in million colony forming units per day per square mile ([(CFU×10^6)/d]/mi^2).

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

Color is given in platinum-cobalt units (PCU).

A water year is the period from October 1 to September 30 and is designated by the year in which it ends; for example, water year 2020 was from October 1, 2019, to September 30, 2020.

Abbreviations

E. coli	*Escherichia coli*
MOVE.1	Maintenance of Variance Extension type 1
NWIS	National Water Information System
PO_4	phosphate
PW	Providence Water
USGS	U.S. Geological Survey
WY	water year

Streamflow, Water Quality, and Constituent Loads and Yields, Scituate Reservoir Drainage Area, Rhode Island, Water Year 2022

By Kirk P. Smith and Alana B. Spaetzel

Abstract

As part of a long-term cooperative program to monitor water quality within the Scituate Reservoir drainage area, the U.S. Geological Survey, in cooperation with Providence Water (formerly the Providence Water Supply Board), collected streamflow and water-quality data in tributaries to the Scituate Reservoir, Rhode Island. Streamflow and concentrations of chloride and sodium estimated from records of specific conductance for 16 tributaries were used to calculate loads of chloride and sodium during water year 2022 (October 1, 2021, through September 30, 2022). Water-quality samples were collected by Providence Water at 37 sampling stations on tributaries to the Scituate Reservoir during water year 2022. These water-quality data are summarized by using values of central tendency and are used, in combination with measured (or estimated) streamflows, to calculate loads and yields of selected water-quality constituents for water year 2022.

Annual mean streamflows for monitoring stations in this study ranged from about 0.31 to 28.0 cubic feet per second during water year 2022. At the 16 continuous-record streamgages, tributaries transported about 2,600 metric tons of chloride and 1,600 metric tons of sodium to the Scituate Reservoir; annual chloride yields for the tributaries ranged from 15 to 100 metric tons per square mile, and annual sodium yields ranged from 10 to 59 metric tons per square mile. At the stations where water-quality samples were collected by Providence Water, the medians of the median daily loads were 55,000 million colony forming units per day for coliform bacteria, 1,300 million colony forming units per day for *Escherichia coli*, 230 kilograms per day for chloride, 11 grams per day as nitrogen for nitrite, 620 grams per day as nitrogen for nitrate, and 440 grams per day as orthophosphate for phosphate, The medians of the median yields were 25,000 million colony forming units per day per square mile for coliform bacteria, 810 million colony forming units per day per square mile for *Escherichia coli*, 110 kilograms per day per square mile for chloride, 5.1 grams per day per square mile as nitrogen for nitrite, less than 300 grams per day per square mile as nitrogen for nitrate, and 230 grams per day per square mile as orthophosphate for phosphate.

Introduction

The Scituate Reservoir is the primary source of drinking water for more than 60 percent of the population of Rhode Island. The Scituate Reservoir drainage area consists of six subbasins and covers an area of about 94 square miles (mi^2) in parts of the towns of Cranston, Foster, Glocester, Johnston, and Scituate, R.I. (fig. 1). The six subbasins are referred to in this report as the Barden Reservoir, "Direct runoff," Moswansicut Pond reservoir, Ponaganset Reservoir, "Regulating reservoir," and Westconnaug Reservoir subbasins (informal names are used for subbasins that do not have official names). Information about the water quality of the reservoir and its tributaries is important for management of the water supply and for the protection of human health. Providence Water (PW; formerly the Providence Water Supply Board) is the agency responsible for the management and distribution of the Scituate Reservoir water supply and has been monitoring and assessing water quality in the reservoir and reservoir drainage area for more than 60 years.

Since 1993, the U.S. Geological Survey (USGS) has been cooperating with PW and the Rhode Island Department of Environmental Management to measure streamflow in tributaries to the Scituate Reservoir. Streamflow has been continuously measured by the USGS at 10 streamgages in the drainage area (table 1) since 2009. Streamflow also was continuously measured at four streamgages from 2009 to 2014 and periodically measured at nine additional streamgages on tributaries in the drainage area. In October 2020, three streamgages began or resumed collection of continuous streamflow data (table 1). At 11 streamgages, daily mean streamflow was estimated for the period between October 1, 2021, and September 30, 2022, by using methods developed by the USGS (table 1; Hirsch, 1982). The USGS also has been continuously measuring specific conductance at 14 monitoring stations since 2009 and at two additional monitoring stations since 2020 (table 1). Equations that relate specific conductance to concentrations of chloride and sodium in stream water were developed as part of previous cooperative studies of the USGS and PW (Nimiroski and Waldron, 2002; Smith, 2015b, 2018a, 2022a; Spaetzel and

Smith, 2022a). These equations, used together with measured (or estimated) streamflows, allow for nearly continuous estimation of chloride and sodium loads to the reservoir.

In 2022, PW regularly, either monthly or quarterly, visited fixed sites on 38 tributaries within the Scituate Reservoir drainage area and collected water-quality samples; however, no samples were collected at the Toad Pond (PW station 31; USGS station 01115177) site because it was routinely dry. Therefore, a total of 37 sites were sampled by PW between October 1, 2021, and September 30, 2022, of which, eight were sampled fewer than three times. Compiled and tabulated streamflow (measured or estimated by the USGS) and water-quality data (collected by PW) have been published in Breault and others (2000), Nimiroski and others (2008), Breault (2010), Breault and Campbell (2010a–d), Breault and Smith (2010), Smith and Breault (2011), Smith (2013, 2014, 2015a, b, 2016, 2018a–d, 2019a, b, 2022a, b, 2024), Smith and Spaetzel (2021, 2024), and Spaetzel and Smith (2022a, b).

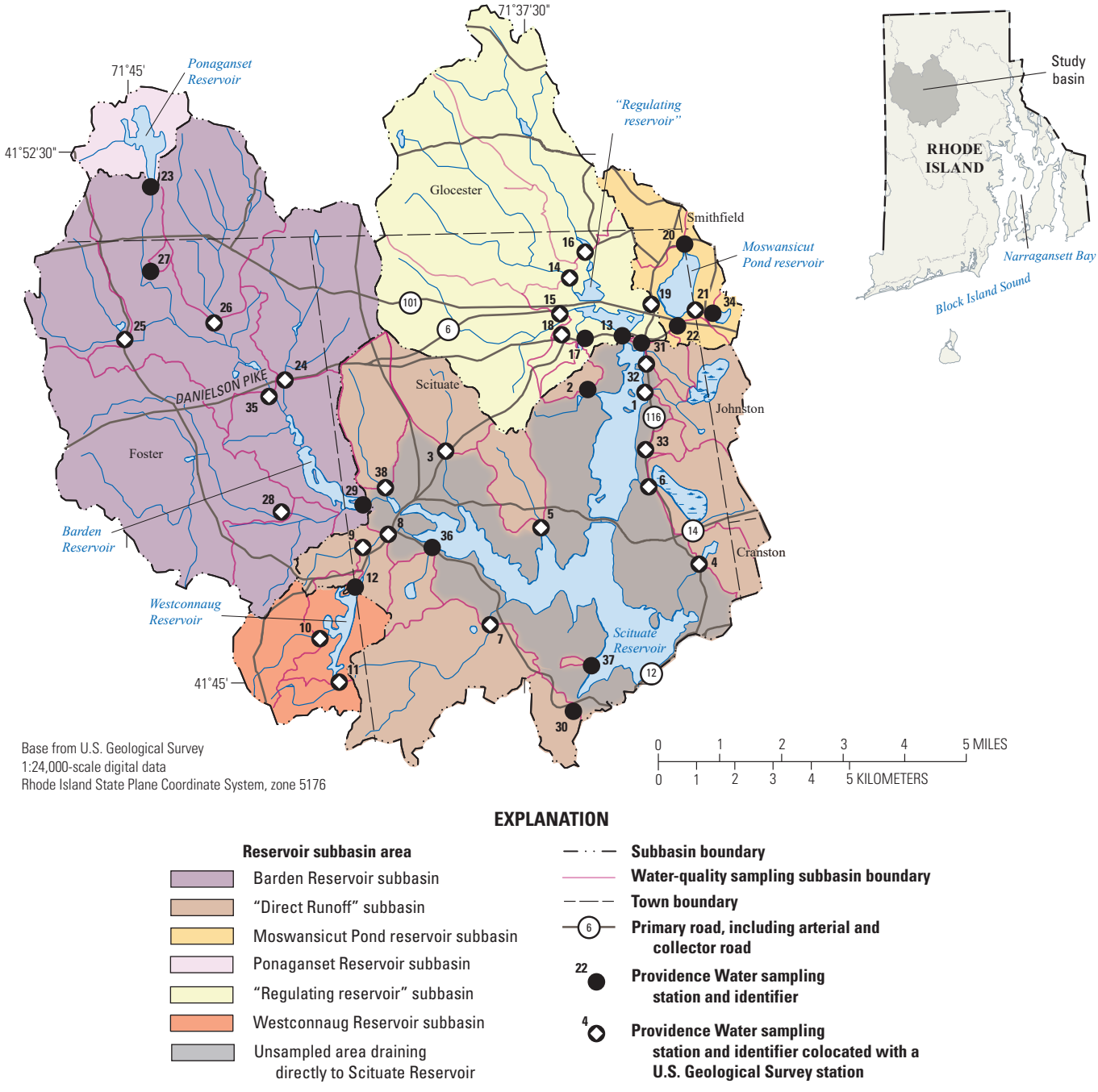

Figure 1. Map showing locations of tributary-reservoir subbasins and stations in the Scituate Reservoir drainage area, Rhode Island, October 1, 2021, through September 30, 2022. Modified from Breault (2010). Data are from Smith and Spaetzel (2021).

Table 1. Providence Water water-quality sampling stations and corresponding U.S. Geological Survey streamgages in the Scituate Reservoir drainage area, Rhode Island, and data collection and monitoring statistics from October 1, 2021, to September 30, 2022.

[Data are from Smith and Spaetzel (2021) and U.S. Geological Survey (2024). Alternate station names given for stations where different historical names were used for the same sampling location by Providence Water (PW). Locations of stations are shown on figure 1. USGS, U.S. Geological Survey; mi^2, square mile; WQ, water quality; Na, sodium; Cl, chloride; M, monthly; Q, quarterly; Y, yes; N, no; —, not applicable]

PW station number	USGS station number	USGS station short name	Alternate name	Drainage area (mi^2)	Frequency of WQ sample collection by PW	Number of samples collected by PW[1]	Daily estimated Na and Cl loads	Streamflow data availability	Specific conductance data availability
Barden Reservoir subbasin									
24	01115190	Dolly Cole Brook	—	4.9	M	11	Y	Continuous	Continuous
25	01115200	Shippee Brook	—	2.37	Q	2	N	Estimated	None
26	01115185	Winsor Brook	—	4.33	Q	4	Y	Continuous[2]	Continuous[2]
27	011151845	Unnamed tributary to Ponaganset River	Unnamed brook B, unnamed brook west of Winsor Brook	0.10	Q	3	N	None	None
28	01115265	Hemlock Brook	—	8.72	M	12	Y	Continuous	Continuous
29	01115271	Ponaganset River	Barden Stream	33.0	M	11	N	None	None
35	01115187	Ponaganset River	—	14.0	M	11	Y	Continuous	Continuous
Direct runoff subbasin									
1	01115180	Brandy Brook	—	1.57	M	9	N	Estimated	None
2	01115181	Unnamed tributary 2 to Scituate Reservoir	Unnamed brook north of Bullhead Brook	0.22	Q	2	N	None	None
3	01115280	Cork Brook	—	1.87	M	9	Y	Continuous	Continuous
4	01115400	Kent Brook	Betty Pond Stream	0.85	M	12	N	Estimated	None
5	01115184	Spruce Brook	—	1.26	Q	3	Y	Continuous[2]	Continuous
6	01115183	Quonopaug Brook	—	1.96	M	10	Y	Continuous	Continuous
7	01115297	Wilbur Hollow Brook	—	4.33	M	10	Y	Estimated	Continuous
8	01115276	Westconnaug Brook	Westconnaug Reservoir	5.18	M	12	Y	Continuous	Continuous
9	01115275	Bear Tree Brook	—	0.62	Q	3	Y	Estimated	Continuous
30	01115350	Coventry Brook	—	0.79	Q	2	N	None	None
31	01115177	Toad Pond	—	0.03	Q	0	N	None	None
32	01115178	Pine Swamp Brook	—	0.45	Q	3	N	Estimated	None
33	01115182	Halls Estate Brook	—	0.28	Q	2	N	Estimated	None
36	—	Not available	Outflow from King Pond	0.76	Q	3	N	None	None
37	—	Not available	Fire tower stream	0.03	Q	3	N	None	None
38	01115278	Swamp Brook	—	1.92	Q	2	Y	Continuous[2]	Continuous[2]

Table 1. Providence Water water-quality sampling stations and corresponding U.S. Geological Survey streamgages in the Scituate Reservoir drainage area, Rhode Island, and data collection and monitoring statistics from October 1, 2021, to September 30, 2022.—Continued

[Data are from Smith and Spaetzel (2021) and U.S. Geological Survey (2024). Alternate station names given for stations where different historical names were used for the same sampling location by Providence Water (PW). Locations of stations are shown on figure 1. USGS, U.S. Geological Survey; mi^2, square mile; WQ, water quality; Na, sodium; Cl, chloride; M, monthly; Q, quarterly; Y, yes; N, no; —, not applicable]

PW station number	USGS station number	USGS station short name	Alternate name	Drainage area (mi^2)	Frequency of WQ sample collection by PW	Number of samples collected by PW[1]	Daily estimated Na and Cl loads	Streamflow data availability	Specific conductance data availability
Moswansicut Pond reservoir subbasin									
19	01115170	Moswansicut Stream	—	3.25	M	11	Y	Continuous	Continuous
20	01115160	Blanchard Brook	—	1.18	M	8	N	None	None
21	01115165	Unnamed tributary 2 to Moswansicut Pond reservoir	Brook from Kimball Reservoir	0.30	Q	4	N	Estimated	None
22	01115167	Unnamed tributary 3 to Moswansicut Pond reservoir	—	0.10	M	7	N	None	None
34	01115164	Unnamed tributary from Kimball Reservoir	Kimball Stream	0.27	Q	4	N	None	None
Ponaganset Reservoir subbasin									
23	011151843	Ponaganset Reservoir	—	1.92	M	11	N	None	None
Regulating reservoir subbasin									
13	01115176	Regulating reservoir	—	22.1	M	10	N	None	None
14	01115110	Huntinghouse Brook	—	6.29	M	11	Y	Continuous	Continuous
15	01115114	Rush Brook	—	4.70	M	11	Y	Continuous	Continuous
16	01115098	Peeptoad Brook	Harrisdale Brook	4.97	M	9	Y	Continuous	Continuous
17	01115119	Dexter Pond	Paine Pond	0.22	Q	2	N	None	None
18	01115120	Unnamed tributary to Regulating reservoir	Unnamed brook A	0.28	Q	1	Y	Estimated	Continuous
Westconnaug Reservoir subbasin									
10	01115274	Westconnaug Brook	—	1.48	M	10	N	Estimated	None
11	01115273	Unnamed tributary to Westconnaug Reservoir	Unnamed brook south of Westconnaug Reservoir	0.72	Q	3	N	Estimated	None
12	011152745	Unnamed tributary to Westconnaug Brook	Unnamed brook north of Westconnaug Reservoir	0.16	Q	3	N	None	None

[1]Not all samples were analyzed for all water-quality properties or constituents.

[2]Continuous monitoring began or resumed in October 2020.

This report presents data on streamflow, water quality, and loads and yields of selected constituents for water year (WY) 2022 in the Scituate Reservoir drainage area. Data were collected in past studies by the USGS, in cooperation with PW and the Rhode Island Department of Environmental Management, and discrete sample data provided by PW (Smith and Spaetzel, 2021). This report summarizes measured and estimated streamflows presented for the 13 continuous-record and 11 partial-record streamgages (called estimated in table 1) in the drainage area. Estimated monthly and annual loads and yields of chloride and sodium are presented for the 16 streamgages at which specific conductance is continuously monitored by the USGS. Summary statistics for water-quality data collected by PW for 37 sampling stations (table 1) during WY 2022 also are presented. These data were used to calculate loads and yields of selected water-quality constituents where flow data were available. Water-quality data related to the Scituate Reservoir drainage area have been published serially by the USGS since 2000 (Breault and others, 2000). The presentation and content of this report has been replicated from Breault (2010), with annually updated methods, data, and interpretations (Breault and Campbell, 2010a–d; Breault and Smith, 2010; Smith and Breault, 2011; Smith 2013, 2014, 2015a, 2016, 2018a, b, 2019a, 2022a; Smith and Spaetzel, 2024).

Streamflow Data Collection and Estimation

Streamflow was measured or estimated by the USGS at 24 streamgages (table 1). Measured and estimated streamflows are necessary to estimate water volume and water-quality constituent loads and yields from tributary basins. Stream gage height was measured every 10 minutes at most continuous-record streamgages. Streamflow was computed with a gage height to discharge relation (known as a rating), which was developed on the basis of periodic manual measurements of streamflow. Daily mean streamflow at a streamgage was calculated by dividing the total volume of water that passed the streamgage each day by 86,400 (the number of seconds in a day). Periodic manual streamflow measurements at partial-record streamgages were used concurrently with continuous-record measurements from streamgages in nearby hydrologically similar drainage areas to estimate a continuous daily record at the partial-record streamgages. Specifically, daily streamflow records for the 11 partial-record sites in the Scituate Reservoir drainage area (table 1) were estimated by using the Maintenance of Variance Extension type 1 (MOVE.1) method, as described by Ries and Friesz (2000), Smith (2015b), and Spaetzel and Smith (2022a); data needed to estimate streamflows at partial-record sites were retrieved from the USGS National Water Information System (NWIS; USGS, 2024). The upper and lower 90-percent confidence limits for the estimated mean annual streamflows, as described by Tasker and Driver (1988), are listed in table 2. These USGS data indicate that there is a 90-percent chance that the estimated mean annual streamflow is between the upper and lower 90-percent confidence limits.

Continuous-record streamgages were operated and maintained by the USGS during WY 2022 (fig. 1; table 1). Streamflow data for these streamgages were collected at 10- or 15-minute intervals (near-real-time streamflow data), were updated at 1-hour intervals on the internet and are available through NWIS (USGS, 2024). Error associated with measured streamflows was generally within about 15 percent, as noted in the annual water year summary for each USGS streamgage (USGS, 2024).

Table 2. Measured or estimated annual mean streamflow for tributary streams in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.

[Data were collected by the U.S. Geological Survey (USGS; USGS, 2024). Locations of stations are shown on figure 1. PW, Providence Water; ft^3/s, cubic foot per second; $(ft^3/s)/mi^2$, cubic foot per second per square mile]

PW station number	USGS station number	Annual mean streamflow (ft^3/s)	Upper 90-percent confidence interval (ft^3/s)	Lower 90-percent confidence interval (ft^3/s)	Annual mean streamflow yield ($ft^3/s/mi^2$)
Barden Reservoir subbasin					
24	01115190	10.7	11.9	9.50	2.18
25	01115200	7.39	24.1	2.27	3.12
26	01115185	7.85	8.72	6.97	1.81
28	01115265	16.5	18.4	14.5	1.89
35	01115187	28.0	31.1	25.2	2.01
Direct Runoff subbasin					
1	01115180	2.94	6.23	1.39	1.87
3	01115280	3.42	3.86	2.98	1.83
4	01115400	1.54	6.94	0.34	1.81
5	01115184	2.10	2.30	1.89	1.66
6	01115183	3.55	3.95	3.16	1.81
7	01115297	7.39	15.2	3.59	1.71
8	01115276	8.06	8.58	7.53	1.56
9	01115275	1.42	2.43	0.83	2.29
32	01115178	0.61	1.14	0.33	1.36
33	01115182	0.31	0.71	0.13	1.10
38	01115278	3.27	3.65	2.88	1.70
Moswansicut Pond reservoir subbasin					
19	01115170	5.32	5.74	4.90	1.64
21	01115165	0.56	1.19	0.26	1.86
Regulating Reservoir subbasin					
14	01115110	10.1	11.4	8.88	1.61
15	01115114	8.23	9.40	7.06	1.75
16	01115098	7.92	8.73	7.10	1.59
18	01115120	0.49	2.14	0.11	1.75
Westconnaug Reservoir subbasin					
10	01115274	3.42	8.19	1.43	2.31
11	01115273	2.00	5.29	0.75	2.77

Water-Quality Data Collection and Analysis

Water-quality data were collected by the USGS and PW. Concentrations of sodium and chloride were estimated by the USGS from continuous records of specific conductance from 16 of the 24 streamgages. Water-quality samples were collected monthly or quarterly at 37 sampling stations in the Scituate Reservoir drainage area by PW during WY 2022 as part of a long-term sampling program table 1).

Data Collected by the U.S. Geological Survey

Three or more water-quality samples were collected by the USGS at each of the 16 streamgages equipped with continuous specific conductance monitors in the Scituate Reservoir drainage area during WY 2022 (table 1), except from the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120) and Cork Brook (PW station 3; USGS station 01115280), where samples could not be collected during the summer because the streambeds were dry. Samples were collected in the centroid of the streams during fall, winter, and summer. Water samples were

processed in the USGS New England Water Science Center laboratory in Northborough, Massachusetts, at the conclusion of scheduled sampling. After processing, the samples were packed in ice and shipped overnight to the USGS National Water Quality Laboratory in Lakewood, Colorado. Analytical results for the USGS water-quality samples are available through NWIS (USGS, 2024); these include specific conductance and dissolved concentrations of sodium and chloride.

The USGS collected and analyzed continuous-record specific conductance data at 16 streamgages (fig. 1; table 1). Measurements of specific conductance were recorded automatically at 10- or 15-minute intervals at each streamgage. Measurements were made by using an instream probe and standard USGS methods for continuous water-quality monitoring at streams (Wagner and others, 2006). The specific conductance measurement data are available through the NWIS web interface (USGS, 2024).

Concentrations of chloride and sodium were estimated from continuous measurements of specific conductance by using equations that were developed by the USGS to relate specific conductance to concentrations of chloride and sodium, as follows:

$$C_{Cl}=SPC^{m}\times b \text{ and} \quad (1)$$

$$C_{Na}=SPC^{m}\times b, \quad (2)$$

where

C_{Cl} is the chloride concentration, in milligrams per liter;

C_{Na} is the sodium concentration, in milligrams per liter;

SPC is the specific conductance, in microsiemens per centimeter;

m is the slope from the MOVE.1 analysis (table 3); and

b is the intercept from the MOVE.1 analysis (table 3).

These regression equations were developed by using the MOVE.1 method (also known as the line of organic correlation; Helsel and others, 2020) on the basis of concurrent measurements of specific conductance (USGS observed property "Specific conductance, water, unfiltered, normalized to 25 degrees Celsius, laboratory," formerly parameter code 90095) along with chloride (USGS observed property "Chloride, water filtered," formerly parameter code 00940) and sodium (USGS observed property "Sodium, water filtered," formerly parameter code 00930) concentrations measured in water-quality samples collected by the USGS from tributaries in the Scituate Reservoir drainage area during WY 2000, WY 2005, and WYs 2009–23 (table 3; USGS, 2024).

MOVE.1 was chosen for regression analysis to maintain variance (Hirsch and Gilroy, 1984). Under some circumstances, specific conductance records were unavailable, possibly because of the following reasons: a sensor malfunctioned; was affected by debris, fouling, or ice; or was not submerged during low flow. In these cases, values of specific conductance were estimated by proportional distribution between recorded values. In general, the period of specific conductance record when streamflow occurred that was unavailable for each USGS station represents a small fraction of the record period for WY 2022 (table 3).

Data Collected by Providence Water

Water-quality samples were collected by PW at 37 fixed stations on tributaries draining to the Scituate Reservoir during WY 2022. Samples were scheduled to be collected monthly at 19 stations and quarterly at another 18 stations (table 1). Water-quality samples were not collected according to specific weather conditions; instead, a periodic water-quality sampling schedule was followed so that water-quality samples would be representative of a variety of weather conditions. However, sometimes samples could not be collected because tributaries at the sampling stations were dry or frozen. When possible, water-quality samples were collected by dipping the sample bottle into the tributary at the center of flow (Richard Blodgett, PW, written commun., 2005). Samples were transported on ice to the PW water-quality laboratory at the P.J. Holton Water Purification Plant in Scituate, R.I. Water-quality properties and constituent concentrations were measured by using unfiltered water samples. These water-quality properties included pH, color, turbidity, and alkalinity; concentrations of chloride, nitrite, nitrate, orthophosphate; and *Escherichia coli* (*E. coli*) and total coliform bacteria. These data, collected by PW, are published in Smith and Spaetzel (2021). In this report, orthophosphate is the name for compounds with only one phosphate (PO_4) unit, whereas phosphate is used to name any compound having one or more PO_4 units. Analytical methods used to determine the values or concentrations of pH, color, turbidity, alkalinity, and chloride are documented by Baird and others (2018). Concentrations of nitrite were determined by U.S. Environmental Protection Agency method 353.2 (U.S. Environmental Protection Agency, 1993). Concentrations of nitrate were determined by Standard Method 4500–NO_3 (Holm and others, 2018). Concentrations of orthophosphate were determined by the Hach PhosVer Method (Hach Method 8048; Hach Company, 2000). Standard Method 9223 was used for the determination of concentrations of bacteria (Best and others, 2018).

Table 3. Regression equation coefficients used to estimate concentrations of chloride and sodium from values of specific conductance for U.S. Geological Survey streamgage stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.

[Data were collected by the U.S. Geological Survey (USGS; USGS, 2024). Locations of stations are shown on figure 1. Constituent concentrations, continuous specific conductance, and parameter codes are available in National Water Information System (USGS, 2024). USGS parameter codes: specific conductance, 90095; chloride, 00940; sodium, 00930. USGS observed properties: "Chloride, water filtered" with units of mg/L; "Sodium, water filtered" with units of mg/L; "Specific conductance, water, unfiltered, normalized to 25 degrees Celsius, laboratory," with units of µS/cm. PW, Providence Water; ≥, greater than or equal to; ft^3/s, cubic foot per second]

PW station number	USGS station number	Samples used in analyses		Chloride			Sodium			Percentage of specific conductance record unavailable where streamflow is ≥0.01 ft^3/s
		Sample date range	Sample count	Slope	Intercept	Standard error of regressions (percent)	Slope	Intercept	Standard error of regressions (percent)	
Barden Reservoir subbasin										
24	01115190	03/08/2000; 03/29/2005; 01/22/2009–08/22/2023	44	1.1657	0.10659	3.2	1.1018	0.08995	5.0	9.0
26	01115185	01/22/2020–08/22/2023	12	1.1063	0.14054	6.3	0.9185	0.21066	2.9	0.3
28	01115265	03/28/2001; 03/30/2005; 01/22/2009–08/22/2023	44	1.1437	0.11781	3.8	1.0533	0.11041	5.3	1.3
35	01115187	03/28/2001; 03/29/2005; 01/22/2009–08/21/2023	44	1.1723	0.10101	4.0	1.0951	0.08976	5.2	2.8
Direct runoff subbasin										
3	01115280	03/08/2000; 03/30/2005; 01/22/2009–08/21/2023	42	1.2008	0.08650	3.1	1.0875	0.09106	4.8	1.9
5	01115184	03/05/2009–08/22/2023	41	1.2314	0.07031	3.8	1.0848	0.08551	4.8	2.6
6	01115183	03/08/2000; 03/30/2005; 01/22/2009–08/22/2023	55	1.1793	0.08437	4.6	1.1894	0.04825	6.2	3.2
7	01115297	03/28/2001; 03/30/2005; 01/22/2009–08/21/2023	43	1.0316	0.14569	4.4	0.8601	0.20013	5.3	19
8	01115276	01/22/2009–08/22/2023	41	1.0871	0.14598	2.6	1.0286	0.12185	3.5	0.27
9	01115275	03/08/2000; 03/30/2005; 01/22/2009–08/22/2023	43	1.0548	0.18169	2.2	1.0818	0.09317	3.0	1.4
38	01115278	01/22/2020–08/23/2023	12	1.4687	0.02243	11.2	1.2124	0.04999	7.6	0.00
Moswansicut Pond reservoir subbasin										
19	01115170	03/08/2000; 03/29/2005; 01/22/2009–08/21/2023	50	1.2118	0.07599	2.3	1.2127	0.04507	2.6	2.1
Regulating reservoir subbasin										
14	01115110	03/28/2001; 03/29/2005; 01/22/2009–08/22/2023	51	0.9935	0.18278	7.2	0.9335	0.14700	7.6	3.3
15	01115114	01/22/2009–08/22/2023	58	1.1372	0.11558	3.7	1.0679	0.10135	5.2	20
16	01115098	03/28/2001; 03/29/2005; 01/22/2009–08/22/2023	44	1.2439	0.06412	4.0	1.06100	0.09808	6.0	1.1
18	01115120	01/22/2009–08/21/2023	34	1.1610	0.09934	2.6	1.1454	0.06242	3.2	13

Water-quality samples were collected by PW during a wide range of flow conditions. During WY 2022, the measured or estimated daily mean flow-duration curves for the USGS streamgages at Dolly Cole Brook (PW station 24; USGS station 01115190) and the unnamed tributary 2 to Moswansicut Pond reservoir (PW station 21; USGS station 01115165) are shown in figure 2. The curves represent the percentage of time that each flow was equaled or exceeded at the respective stations; the flows at each station on days when water-quality samples were collected are represented by the plotted points superimposed on the curves. At Dolly Cole Brook, the 11 monthly samples were collected at flow rates that were exceeded between 9.7 and 91 percent of the time; this range indicates that the water-quality samples collected in WY 2022 represent a large range of the flow conditions representing flows between 0.38 and 28 ft^3/s. Samples collected on a quarterly schedule at the unnamed tributary 2 to Moswansicut Reservoir were collected at flow rates that were exceeded between 15 and 74 percent of the time; this range of flow rates excludes the flow conditions for both the lower and upper flow range at that station during WY 2022 (fig. 2).

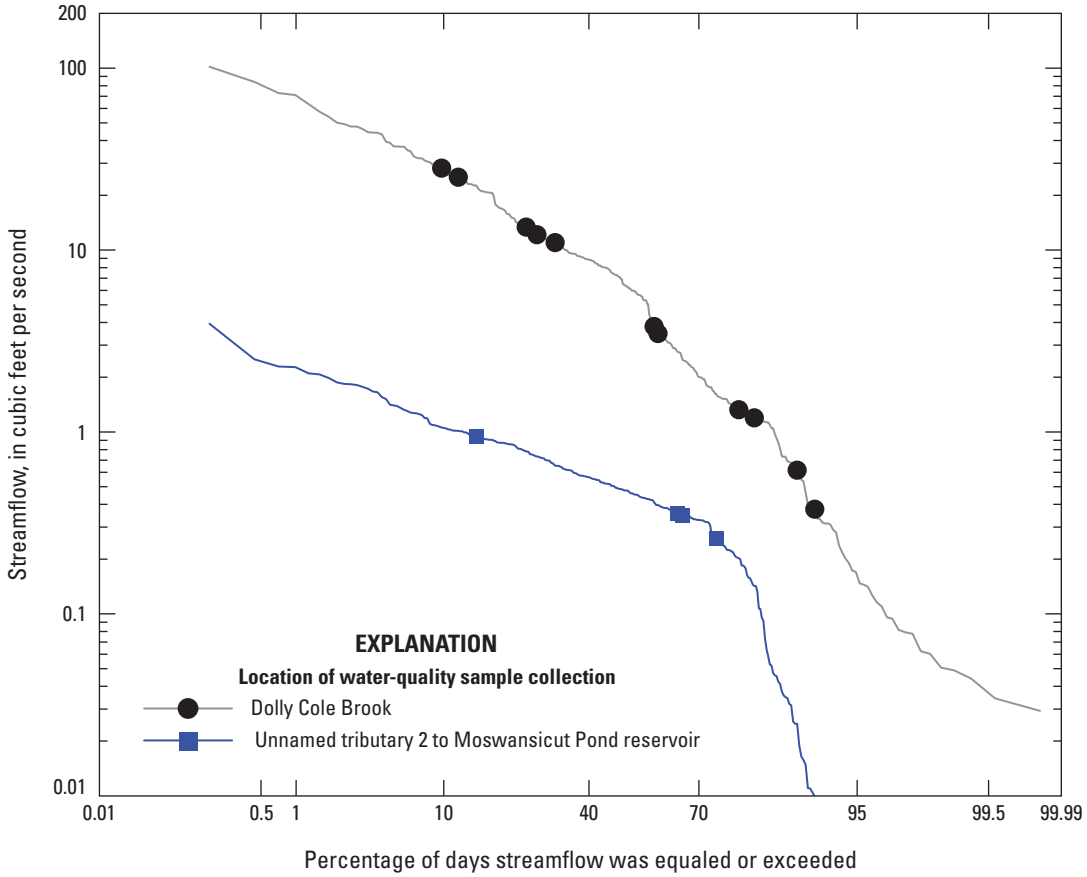

Figure 2. Graph showing flow-duration curves and streamflow on the dates (represented by points) when water-quality samples were collected by Providence Water at the U.S. Geological Survey (USGS) streamgages Dolly Cole Brook (station 01115190) in South Foster, Rhode Island, and the unnamed tributary 2 to Moswansicut Pond reservoir (station 01115165) in North Scituate, Rhode Island, from October 1, 2021, through September 30, 2022. Station information is shown in table 1. Modified from Breault (2010). Data are from Smith and Spaetzel (2021) and USGS (2024).

Estimating Daily, Monthly, and Annual Loads and Yields

Daily, monthly, and annual chloride and sodium loads (in kilograms) were estimated for all streamgages for which continuous streamflow and specific-conductance data were available for WY 2022. Daily flow-weighted concentrations of chloride and sodium were calculated by multiplying instantaneous flows by concurrent concentrations of chloride and sodium (estimated from measurements of specific conductance) for each day and dividing the sum by the total flow for that day. At the three instrumented monitoring stations, where continuous flow was unavailable (table 1), daily mean concentrations of chloride and sodium were calculated from the daily mean value of specific conductance for each day. The latter method may result in less accurate concentrations because instantaneous measurements of specific conductance may change (decrease or increase) with surface-water runoff; however, the variability of instantaneous measurements of specific conductance at these streamgages was generally small and daily mean values did not differ substantially from daily flow-weighted values estimated during prior water years when instantaneous flow data were available. Daily loads of chloride and sodium were estimated by multiplying daily flow-weighted concentrations of chloride and sodium (in milligrams per liter) by daily discharge (in liters per day). Daily data were summed to estimate monthly or annual loads (converted to metric tons).

Daily loads of water-quality constituents (in samples collected by PW) were calculated for all sampling dates during WY 2022 (table 4) for which periodic- or continuous-streamflow data were available (table 1). These loads were calculated by multiplying constituent concentrations (in milligrams per liter or colony forming units per liter) in individual samples by the daily discharge (in liters per day) for the day on which each sample was collected. The flows, which in some cases were estimates, were assumed to be representative of the flow at the time of the sample collection. Loads (in million colony forming units per day, kilograms per day, or grams per day) and yields (in million colony forming units per day per square mile, kilograms per day per square mile, or grams per day per square mile) were calculated for bacteria, chloride, nitrite, nitrate, and orthophosphate. Censored data (concentrations reported as less than method detection limits) were replaced with concentrations equal to one-half the method detection limit.

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.

[Data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d as N, gram per day as nitrogen; g/d as PO_4, gram per day as phosphate <, less than; >, greater than; NA, not available]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($CFUx10^6/d$)	*E. coli* (CFUx106/d)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as PO_4)
Barden Reservoir subbasin									
24	01115190	10/15/21	3.48	1,200,000	13,000	190	17	560	850
		11/23/21	12.1	160,000	<3,000	570	59	<1,500	6,500
		01/03/22	11.0	130,000	2,700	600	27	1,500	3,200
		02/17/22	28.2	330,000	<6,900	1,500	69	7,400	5,500
		03/04/22	25.1	140,000	<6,100	1,500	61	4,600	4,300
		04/12/22	13.4	850,000	<3,300	760	33	<1,600	1,300
		05/26/22	1.32	38,000	3,900	88	6.5	230	32
		06/03/22	1.19	100,000	3,700	79	5.8	260	87
		07/26/22	0.38	36,000	2,000	25	1.9	140	93
		08/25/22	0.62	100,000	5,700	42	1.5	290	46
		09/23/22	3.21	410,000	26,000	180	7.9	500	240
25	01115200	10/25/21	1.59	65,000	1,600	51	7.8	230	430
		04/28/22	6.01	110,000	2,900	170	15	<740	2,200
26	01115185	10/25/21	3.54	98,000	4,300	260	8.7	480	430
		01/28/22	3.61	21,000	880	220	8.8	870	350
		04/28/22	5.96	62,000	1,500	400	15	<730	1,600
		08/30/22	0.07	6,600	660	5.6	0.17	29	8.6
28	01115265	10/05/21	42.1	7,500,000	840,000	2,800	410	5,800	7,200
		11/04/21	19.3	260,000	4,700	910	140	2,500	4,700
		12/03/21	8.95	160,000	20,000	470	44	1,200	2,600
		01/18/22	33.6	1,000,000	99,000	1,400	160	<4,100	3,300
		02/08/22	98.9	4,000,000	150,000	5,300	480	17,000	17,000
		03/03/22	30.9	110,000	30,000	1,900	76	3,900	6,000
		04/05/22	17.1	170,000	13,000	1,100	42	<2,100	1,300
		05/12/22	7.32	180,000	1,800	470	36	<900	1,100
		06/09/22	9.19	1,400,000	130,000	720	67	1,500	670
		07/11/22	0.56	7,500	<140	46	4.1	230	55
		08/02/22	0.06	1,600	29	5.1	0.15	43	8.8
		09/08/22	21.5	3,400,000	440,000	1,300	160	<2,600	2,100
35	01115187	10/15/21	9.28	3,200,000	120,000	510	45	1,400	1,600
		11/23/21	42.7	470,000	10,000	1,800	100	<5,200	11,000
		01/03/22	37.7	350,000	<9,200	1,900	92	5,800	9,200
		02/17/22	62.9	1,300,000	15,000	2,700	150	17,000	7,700
		03/04/22	53.6	260,000	26,000	2,600	130	12,000	7,900
		04/12/22	39.6	1,400,000	19,000	1,900	97	<4,800	2,900
		05/26/22	5.01	300,000	16,000	280	25	960	370
		06/03/22	3.19	250,000	11,000	170	23	1,300	310
		07/26/22	0.53	50,000	1,100	34	2.6	170	65
		08/25/22	0.33	50,000	3,300	14	1.6	100	32
		09/23/22	38.5	9,900,000	1,000,000	2,000	190	6,200	940

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.—Continued

[Data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d as N, gram per day as nitrogen; g/d as PO_4, gram per day as phosphate <, less than; >, greater than; NA, not available]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($CFUx10^6/d$)	*E. coli* (CFUx106/d)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as PO_4)
Direct runoff subbasin									
1	01115180	10/01/21	1.14	9,200	<280	33	5.6	790	250
		11/01/21	7.13	240,000	1,700	260	70	1,400	1,700
		12/02/21	2.71	49,000	4,000	92	20	990	660
		01/06/22	4.13	45,000	1,000	140	40	2,200	1,200
		03/18/22	3.53	59,000	<860	130	17	1,000	350
		06/10/22	2.73	310,000	9,400	96	20	510	200
		07/15/22	0.64	NA	470	19	3.1	310	94
		08/29/22	0.12	7,300	380	3.7	0.29	95	26
		09/09/22	1.27	190,000	3,800	35	6.2	380	160
3	01115280	10/07/21	3.28	87,000	1,600	340	8.0	1,200	480
		11/02/21	5.55	160,000	4,100	450	27	<680	810
		12/07/21	4.78	86,000	1,200	400	23	1,200	1,100
		01/04/22	3.07	27,000	<750	290	7.5	1,300	380
		02/03/22	3.4	21,000	<830	290	8.3	2,300	830
		03/28/22	2.58	23,000	1,300	270	6.3	750	440
		04/15/22	3.37	48,000	3,300	320	8.2	830	490
		05/16/22	1.49	28,000	360	140	3.6	730	290
		06/07/22	0.52	28,000	<130	48	1.3	420	38
4	01115400	10/01/21	0.18	3,400	88	2.9	0.44	<22	92
		11/01/21	3.93	150,000	960	93	9.6	540	1,700
		12/02/21	0.54	4,200	<130	8.2	1.3	66	170
		01/06/22	1.26	13,000	<310	22	3.1	<150	340
		02/18/22	32.7	240,000	<8,000	420	80	<4,000	3,200
		03/07/22	6.64	39,000	<1,600	83	16	<810	810
		04/01/22	4.02	NA	<980	57	9.8	<490	300
		05/06/22	1.59	85,000	390	26	3.9	<190	120
		06/10/22	0.47	79,000	230	11	1.1	<57	11
		07/15/22	0.04	NA	88	0.53	0.20	<4.9	2.9
		08/29/22	0.02	2,800	<4.9	0.27	0.049	2.8	2.0
		09/09/22	0.16	5,900	<39	2.3	0.39	24	16
5	01115184	10/29/21	1.47	55,000	360	72	11	390	220
		03/18/22	3.12	87,000	760	150	7.6	2,200	530
		04/22/22	3.35	91,000	<820	150	16	1,400	330

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.—Continued

[Data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d as N, gram per day as nitrogen; g/d as PO_4, gram per day as phosphate <, less than; >, greater than; NA, not available]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($CFUx10^6/d$)	*E. coli* (CFUx106/d)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as PO_4)
Direct runoff subbasin—Continued									
6	01115183	10/01/21	0.59	18,000	1,000	15	4.3	180	250
		11/01/21	9.97	250,000	4,900	720	120	<1,200	3,200
		12/02/21	2.16	21,000	2,100	160	11	1,200	530
		01/06/22	4.03	39,000	4,900	340	20	2,300	690
		02/18/22	18.2	1,300,000	27,000	1,200	130	7,700	2,200
		03/07/22	9.58	26,000	2,300	840	47	5,800	1,200
		04/01/22	7.01	NA	27,000	560	34	3,200	510
		05/06/22	3.38	79,000	6,600	260	17	1,000	330
		06/10/22	4.50	510,000	45,000	180	66	1,400	770
		09/09/22	3.35	860,000	67,000	250	16	1,200	250
7	01115297	10/07/21	5.99	430,000	16,000	170	44	1,100	880
		11/02/21	11.7	440,000	42,000	250	110	<1,400	2,000
		12/07/21	8.75	96,000	6,400	300	43	2,000	1,500
		01/04/22	4.61	66,000	4,600	120	23	1,500	790
		02/03/22	4.66	19,000	<1,100	160	11	2,500	1,100
		03/28/22	7.52	140,000	1,800	180	37	1,200	1,100
		04/15/22	11.8	410,000	5,800	290	58	<1,400	1,400
		05/16/22	6.99	500,000	120,000	290	51	1,000	860
		06/07/22	1.87	110,000	3,400	56	9.2	<230	140
		07/01/22	1.07	75,000	3,400	25	7.9	180	180
8	01115276	10/19/21	4.05	76,000	<990	120	9.9	640	790
		11/16/21	11.7	140,000	<2,900	350	29	<1,400	4,000
		12/21/21	6.64	6,700	<1,600	300	32	1,600	320
		01/21/22	11.2	8,200	<2,700	360	27	<1,400	1,400
		02/22/22	20.7	32,000	<5,100	720	51	<2,500	1,500
		03/08/22	17.3	13,000	<4,200	660	42	<2,100	2,500
		04/18/22	10.5	25,000	<2,600	410	26	<1,300	510
		05/20/22	5.78	34,000	<1,400	200	14	<710	710
		06/30/22	2.58	270,000	<630	84	6.3	<320	440
		07/28/22	1.74	83,000	<430	60	4.3	<210	85
		08/10/22	1.41	33,000	<340	50	3.4	<170	140
		09/30/22	2.69	120,000	660	93	6.6	<330	200
9	01115275	03/18/22	2.63	55,000	<640	320	6.4	2,500	320
		04/22/22	2.99	83,000	<730	380	7.3	230	220
		08/19/22	0.23	10,000	56	41	0.56	420	73
32	01115178	10/22/21	0.36	11,000	440	13	1.8	76	35
		02/24/22	1.50	22,000	<370	47	7.3	1,400	37
		06/24/22	0.125	7,600	230	4.3	0.92	160	40

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.—Continued

[Data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d as N, gram per day as nitrogen; g/d as PO_4, gram per day as phosphate <, less than; >, greater than; NA, not available]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($CFUx10^6/d$)	*E. coli* (CFUx106/d)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as PO_4)
Direct runoff subbasin—Continued									
33	01115182	11/29/21	0.14	990	<34	5.3	0.34	38	27
		06/16/22	0.05	1,200	<12	2.5	0.24	30	15
38	01115278	02/24/22	8.06	40,000	<2,000	910	20	<990	590
		09/30/22	0.52	7,200	<130	37	<1.3	<64	51
Moswansicut Pond reservoir subbasin									
19	01115170	10/18/21	2.03	3,300,000	5,100	270	5	370	150
		11/15/21	8.92	44,000	6,500	2,300	44	1,500	2,000
		12/14/21	5.21	3,800	1,300	670	25	1,900	250
		01/13/22	4.16	3,100	2,000	510	20	1,200	710
		03/22/22	6.25	<1,500	<1,500	800	31	2,400	460
		04/14/22	8.21	8,000	<2,000	1,100	40	3,000	1,200
		05/23/22	2.48	70,000	<610	320	12	540	120
		06/17/22	0.96	180,000	190	130	4.7	<120	190
		07/25/22	0.16	11,000	<39	22	0.39	20	7.8
		08/18/22	0.15	5,100	<37	21	0.37	<18	33
		09/26/22	2.48	170,000	<610	320	6.1	410	180
21	01115165	10/21/21	0.35	15,000	340	35	1.7	170	34
		03/11/22	0.94	9,700	230	81	6.9	1,100	160
		05/27/22	0.26	15,000	380	33	3.8	370	38
		09/15/22	0.35	37,000	1,500	37	1.7	240	94
Regulating Reservoir subbasin									
14	01115110	10/04/21	12.2	>7,200,000	180,000	430	90	4,500	2,100
		11/10/21	5.94	120,000	16,000	210	15	<730	1,000
		12/17/21	8.85	130,000	6,500	340	22	1,800	1,900
		01/10/22	17.1	200,000	8,400	780	42	4,300	4,200
		02/11/22	32.3	760,000	16,000	1,100	79	8,200	7,100
		03/29/22	10.4	79,000	<2,500	340	25	1,900	2,300
		04/07/22	23.0	460,000	34,000	920	56	3,100	2,800
		05/13/22	4.93	130,000	4,800	150	12	600	1,100
		06/17/22	0.90	57,000	1,400	30	8.8	490	130
		07/14/22	0.16	18,000	3,600	4.3	0.78	72	20
		09/23/22	4.38	1,900,000	140,000	200	21	1,200	320

Table 4. Daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.—Continued

[Data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; $CFU \times 10^6/d$; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d as N, gram per day as nitrogen; g/d as PO_4, gram per day as phosphate <, less than; >, greater than; NA, not available]

PW station number	USGS station number	Date	Daily mean streamflow (ft^3/s)	Total coliform bacteria ($CFUx10^6/d$)	*E. coli* (CFUx106/d)	Chloride (kg/d)	Nitrite (g/d as N)	Nitrate (g/d as N)	Orthophosphate (g/d as PO_4)
Regulating Reservoir subbasin—Continued									
15	01115114	10/04/21	13.9	>8,200,000	200,000	1,600	240	5,100	3,400
		11/10/21	3.83	54,000	5,600	370	9.4	<470	840
		12/17/21	7.46	110,000	5,500	650	18	<910	1,100
		01/10/22	14.5	200,000	11,000	1,700	35	3,200	2,500
		02/11/22	20.9	190,000	15,000	1,800	51	6,500	4,600
		03/29/22	6.82	25,000	<1,700	800	17	1,500	1,200
		04/07/22	16.7	120,000	8,200	1,800	41	22,000	1,200
		05/13/22	2.19	110,000	4,600	270	5.4	<270	210
		06/17/22	0.50	1,600	98	59	2.4	240	110
		07/14/22	0.14	25,000	830	29	0.69	24	31
		09/23/22	5.94	1,700,000	210,000	630	29	1,600	440
16	01115098	10/04/21	11.3	480,000	5,500	1,000	55	2,100	1,700
		11/10/21	15.8	220,000	12,000	1,500	39	3,100	1,500
		12/17/21	7.19	58,000	1,800	920	35	2,300	350
		01/10/22	7.66	36,000	1,900	710	37	3,200	1,300
		02/11/22	8.42	110,000	8,200	790	21	4,200	1,900
		03/29/22	11.6	88,000	<2,800	1,200	28	3,300	2,000
		04/07/22	16.7	290,000	12,000	1,700	41	4,500	1,600
		05/13/22	4.83	250,000	1,200	460	12	<590	350
		06/17/22	1.00	320,000	49	100	4.9	<120	98
18	01115120	03/11/22	0.91	6,100	1,300	130	4.5	620	200
Westconnaug Reservoir subbasin									
10	01115274	10/05/21	11.2	1,200,000	79,000	820	55	1,400	2,500
		11/04/21	3.02	73,000	3,000	190	7.4	<370	440
		12/03/21	1.99	48,000	<490	130	4.9	<240	390
		01/18/22	11.9	370,000	71,000	650	29	<1,500	4,400
		02/08/22	15.1	430,000	11,000	940	37	2,000	1,800
		03/03/22	7.54	85,000	3,700	500	18	<920	1,300
		04/05/22	3.47	180,000	<850	240	8.5	<420	510
		05/12/22	1.39	110,000	<340	95	<3.4	<170	170
		06/09/22	2.58	820,000	62,000	190	6.3	<320	320
		09/08/22	1.76	300,000	14,000	110	4.3	<220	220
11	01115273	03/10/22	3.82	42,000	<930	56	9.3	<470	750
		05/31/22	0.25	14,000	120	4.3	2.4	<31	49
		07/29/22	0.02	2,500	25	0.48	0.24	3.3	6.4

Streamflow

Monitoring streamflow is a necessary step for computing the volume of water and estimating constituent loads to the Scituate Reservoir. The Ponaganset River is the largest monitored tributary to the Scituate Reservoir. Mean annual streamflow at the streamgage on the Ponaganset River (PW station 35; USGS station 01115187) for the entire period of its operation (mean of the annual mean streamflows for the period of record, WYs 1995–2021) before WY 2022 was 29.1 cubic feet per second (ft^3/s; USGS, 2024). During WY 2022, the annual mean streamflow of 28.0 ft^3/s was just below the median for the period of record (fig. 3). Daily mean streamflows were commonly within the 10th and 90th percentile of all mean daily streamflows for WYs 1995–2021; however, daily streamflows from the fall, early winter, and late summer exceeded the 90th percentile on many occasions. Daily mean streamflows in WY 2022 fell below the 10th percentile values for periods from May through August (fig. 3). The other long-term continuous-record streamgage in the Scituate Reservoir drainage area is the Peeptoad Brook streamgage (PW station 16; USGS station 01115098). The mean annual streamflow at the Peeptoad Brook streamgage for the period of record (WYs 1995–2021), before WY 2022, was 10.6 ft^3/s (USGS, 2024). The annual mean streamflow at the Peeptoad Brook streamgage during WY 2022 (7.9 ft^3/s) also was lower than the median annual streamflow for its period of record (11 ft^3/s). The annual mean measured or estimated streamflows for the other monitoring stations in this study ranged from about 0.31 to 16.5 ft^3/s (table 2).

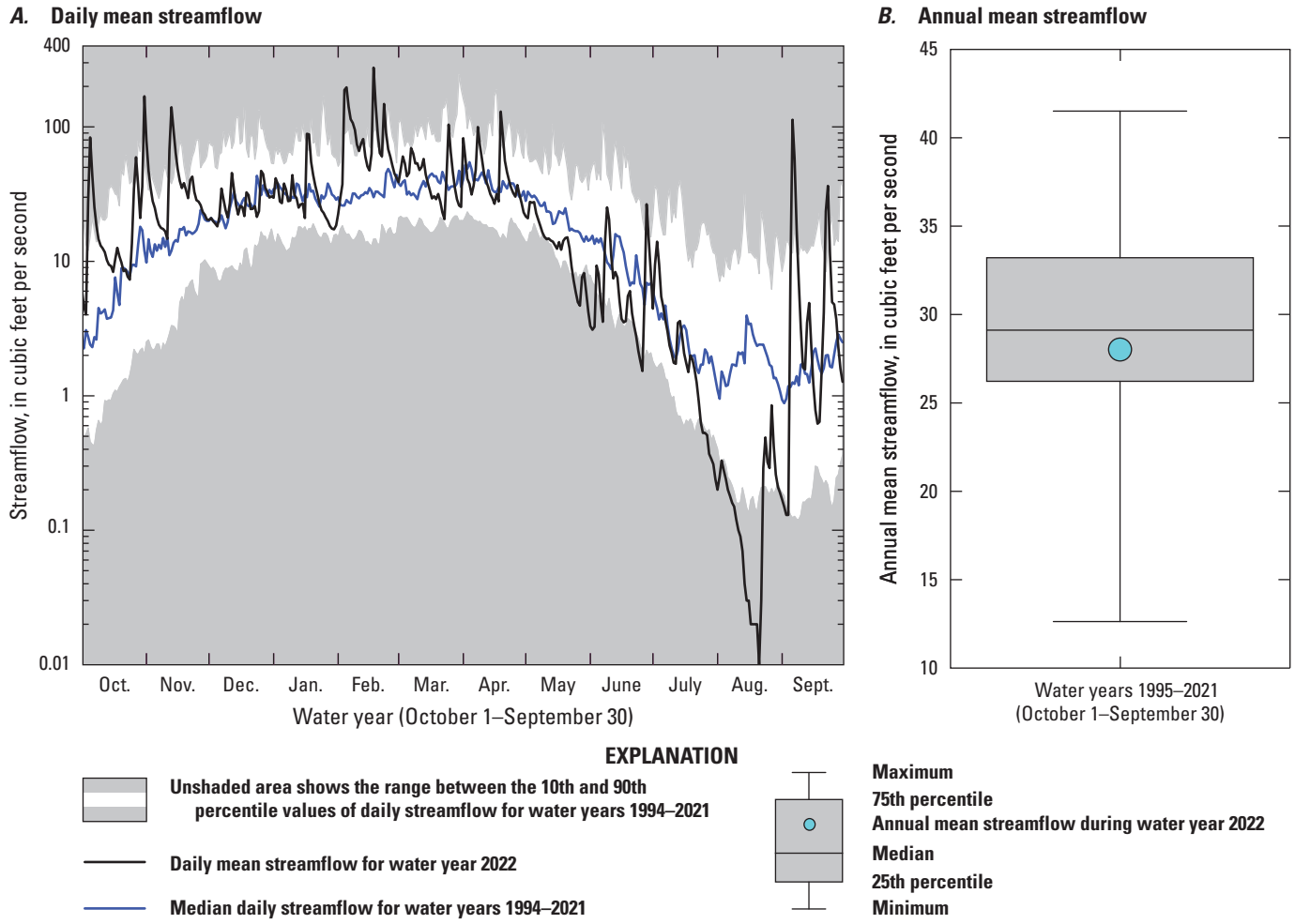

Figure 3. Hydrologic data taken at the Providence Water station 35 (U.S. Geological Survey [USGS] station 01115187 on the Ponaganset River in South Foster, Rhode Island); *A*, Graph showing measured daily mean streamflow for water year 2022 (October 1, 2021, through September 30, 2022), and the 10th percentile, median, and 90th percentile values of daily streamflow from October 1, 1994, through September 30, 2021; and *B*, Boxplot showing annual mean streamflow during water year 2022 and the distribution of mean annual streamflows for water years 1995–2021. Location of station is shown on figure 1. Modified from Breault (2010). Data are from USGS (2024).

Water Quality and Constituent Loads and Yields

Water-quality conditions in the Scituate Reservoir drainage area are described by summary statistics for water-quality properties, constituent concentrations, and estimated constituent loads and yields. Loads and yields measure the rates at which masses of constituents are transferred to the reservoir by tributaries. Tributaries with high flows tend to have high loads because the greater volume of water can carry more of the constituent to the reservoir per unit time than tributaries with low flows. Yield represents the constituent load per unit of drainage area and is calculated by dividing the load estimated for a streamgage by the drainage area for the monitoring station. Yields are useful for comparison among streamgages that have different drainage areas because each basin size and therefore total streamflow volume is normalized. Yields also are useful for examining potential differences among basin properties that may contribute to water quality in the reservoir.

Summary statistics include means and medians. For some purposes, median values are more appropriate because they are less likely to be affected by high or low concentrations (outliers). Medians are especially important to use for summarizing a relatively limited number of values. In contrast, datasets that include a large number of values, such as continuously monitored streamflow and loads of chloride and sodium (estimated from measurements of specific conductance), are better summarized in terms of means because large datasets are more resistant to the effects of outliers than small datasets. Mean values also are particularly appropriate for measuring loads because outlier values, which typically represent large flows, are important to include in estimates of constituent masses delivered to receiving waters.

Uncertainties associated with measuring streamflow and specific conductance and with chloride and sodium sample collection, preservation, and analysis produce uncertainties in load and yield estimates. The load and yield estimates presented in the text and tables are the most likely values for chloride and sodium inputs from tributaries or their drainage basins, based on the available data and analysis methods. It may be best to discuss loads and yields in terms of a range within which the true values lie; however, the most likely values of loads and yields are presented for ease of discussion and presentation. The range within which the true values lie also depends on the uncertainties in individual measurements of streamflow and concentration, which are difficult to quantify with the available information. The uncertainties associated with streamflow are commonly assumed to have a larger effect on load and yield calculations than the errors associated with measuring specific conductance or chemical analysis. The uncertainties associated with estimated streamflow are greater than those associated with measured streamflow. The most likely values of loads and yields presented in the tables and text are sufficient for planning-level analysis of water quality in tributaries and their drainage basins.

Chloride and Sodium Loads and Yields Estimated From Specific-Conductance Monitoring Data

Chloride and sodium are constituents of special concern in the Scituate Reservoir drainage area; chloride is difficult to remove from finished drinking water and can affect the taste; and sodium is a constituent of potential concern for human health; some people on restricted diets might need to limit their sodium intake. Chloride and sodium are major constituents of road salt used for deicing, and several major roadways cross the Scituate Reservoir drainage area. State Routes 12 and 14 cut across the main body of the reservoir, and Route 116 parallels the eastern limb of the reservoir (fig. 1). Nimiroski and Waldron (2002) indicated that tributaries in basins with State-maintained roads had substantially higher concentrations of chloride and sodium than tributaries in basins with low road density, presumably because of deicing activities. Smith (2015b) indicated relations between concentrations of chloride collected from the tributaries to the Scituate Reservoir and total impervious area of the respective subbasins were significant; and Spaetzel and Smith (2022a) found 32 significant upward trends in tributary chloride concentrations at the 37 stations during WYs 1983–2019.

Monthly mean concentrations were calculated by dividing the total monthly load by the total discharge for the month. Estimated monthly mean chloride concentrations in tributaries of the Scituate Reservoir drainage area ranged from 8.6 to 80 milligrams per liter (mg/L), and estimated monthly mean sodium concentrations ranged from 6.0 to 48 mg/L (table 5). Both highest monthly mean concentrations of chloride and sodium (80 and 48 mg/L, respectively) were recorded at Quonopaug Brook (PW station 6; USGS station 01115183) in August 2022. The estimated monthly mean concentrations of chloride and sodium were greatest in July, August, and September 2022 at most stations, compared with the estimated monthly mean concentrations during the winter months. Monthly estimated chloride and sodium mean concentrations were either highest or tied for highest in August for 11 of the 16 stations. Monthly estimated mean concentrations were highest in January for the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120) and highest in March for Swamp Brook (PW station 38; USGS station 01115278). The estimated monthly mean concentrations of chloride and sodium in Dolly Cole Brook (PW station 24; USGS station 01115190), Cork Brook (PW station 3; USGS station 01115290), Wilbur Hollow Brook (PW station 7; USGS station 01115297) and Moswansicut Stream (PW station 19; USGS station 01115170) remained consistent throughout the water year, ranging only

Table 5. Monthly mean concentrations of chloride and sodium estimated from continuous measurements of specific conductance in the Scituate Reservoir drainage area, Rhode Island, October 1, 2021, through September 30, 2022.

[Data were collected by the U.S. Geological Survey (USGS; USGS, 2024). Locations of stations are shown on figure 1. Monthly mean concentrations were calculated by dividing the monthly load by the total discharge for the month. All units in milligrams per liter. PW, Providence Water; Cl, chloride; Na, sodium; —, not applicable]

PW station number	USGS station number	October 2021		November 2021		December 2021		January 2022		February 2022		March 2022	
		Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na
Barden Reservoir subbasin													
24	01115190	21	13	19	12	21	14	23	15	23	14	24	15
26	01115185	22	14	19	12	22	14	22	14	19	12	23	14
28	01115265	23	14	18	11	21	13	22	14	18	11	21	13
35	01115187	18	11	15	9.9	17	11	17	11	15	9.7	17	11
Direct runoff subbasin													
3	01115280	31	19	28	17	34	20	34	20	30	18	34	20
5	01115184	23	14	19	12	21	13	19	12	17	11	17	11
6	01115183	32	20	28	17	31	19	31	19	28	17	29	18
7	01115297	10	6.9	8.6	6.0	12	7.9	12	7.9	9.1	6.3	9.1	6.3
8	01115276	23	15	20	13	22	14	21	14	19	12	20	13
9	01115275	53	31	52	31	53	31	55	32	42	25	45	27
38	01115278	27	17	21	14	26	17	35	22	44	26	53	30
Moswansicut Pond reservoir subbasin													
19	01115170	49	29	48	29	49	29	51	31	50	30	50	30
Regulating reservoir subbasin													
14	01115110	12	7.6	11	7.2	13	8.0	13	8.2	10	6.4	11	7.2
15	01115114	29	18	26	16	27	17	47	29	52	31	27	17
16	01115098	35	21	33	20	32	20	36	22	33	20	33	20
18	01115120	41	24	49	29	61	35	68	39	51	30	53	30
Scituate Reservoir drainage area													
Mean	—	28	17	26	16	29	18	32	19	29	17	29	18

by less than 7.1 mg/L and less than 4.1 mg/L, respectively. The greatest variation of estimated monthly mean concentrations of chloride and sodium was for Quonopaug Brook (PW station 6; USGS station 01115183), Swamp Brook (PW station 38; USGS station 01115278), and the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120).

Annual mean concentrations were calculated by dividing the total annual load by the total discharge for the year. The highest annual mean concentrations of chloride and sodium were estimated to be 52 and 30 mg/L, respectively (table 6), in the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120) and 50 and 30 mg/L, respectively, in Moswansicut Stream (PW station 19; USGS station 01115170). The stations on the Moswansicut Pond reservoir basin and the unnamed tributary to Regulating reservoir are in the more developed, northeastern part of the Scituate Reservoir drainage area (fig. 1). The similarly high annual mean concentrations of 49 mg/L of chloride and 29 mg/L of sodium in Bear Tree Brook (PW station 9; USGS station 01115275) are the result of residual chloride and sodium leaching to groundwater from a formerly uncovered salt storage pile (Nimiroski and Waldron, 2002).

During WY 2022, the Scituate Reservoir received about 2,600 metric tons (t) of chloride and 1,600 t of sodium from tributaries that are equipped with instrumentation capable of continuously monitoring specific conductance (table 6). The highest annual chloride and sodium loads in the Scituate Reservoir drainage area during WY 2022 were estimated to be 430 and 270 t, respectively, at the Ponaganset River station (PW station 35; USGS station 01115187; table 6). Monthly estimated chloride and sodium loads tended to be lowest in August at each station, except at Spruce Brook (PW station 5; USGS station 01115184) and Cork Brook (PW station 3; USGS station 01115280) where the loads were slightly lower in July (fig. 4). Monthly estimated chloride and sodium loads were highest in February at all stations; however, loads tended to remain relatively high through April at each station before diminishing through the summer months (fig. 4). From January through April, the sums of the monthly estimated

Table 5. Monthly mean concentrations of chloride and sodium estimated from continuous measurements of specific conductance in the Scituate Reservoir drainage area, Rhode Island, October 1, 2021, through September 30, 2022. —Continued

[Data were collected by the U.S. Geological Survey (USGS; USGS, 2024). Locations of stations are shown on figure 1. Monthly mean concentrations were calculated by dividing the monthly load by the total discharge for the month. All units in milligrams per liter. PW, Providence Water; Cl, chloride; Na, sodium; —, not applicable]

PW station number	USGS station number	April 2022		May 2022		June 2022		July 2022		August 2022		September 2022	
		Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na
Barden Reservoir subbasin													
24	01115190	23	14	24	15	26	16	24	15	26	16	26	16
26	01115185	21	14	27	16	32	19	33	20	28	17	32	19
28	01115265	20	12	26	16	31	19	32	19	33	20	33	20
35	01115187	17	11	20	12	22	14	23	14	24	15	23	14
Direct runoff subbasin													
3	01115280	34	20	33	20	31	18	34	21	34	21	32	19
5	01115184	16	10	19	12	20	12	27	16	32	18	16	10
6	01115183	27	16	32	19	35	21	50	30	80	48	37	22
7	01115297	8.9	6.2	11	7.2	11	7.2	11	7.2	16	9.9	14	9.1
8	01115276	20	13	23	15	26	17	26	17	25	16	27	17
9	01115275	47	28	54	32	56	34	65	39	66	39	47	28
38	01115278	38	23	28	18	32	20	22	15	12	8.9	40	24
Moswansicut Pond reservoir subbasin													
19	01115170	50	30	51	31	52	31	53	32	55	33	53	32
Regulating reservoir subbasin													
14	01115110	11	7.1	13	8.1	14	8.8	15	9.1	18	11	16	9.6
15	01115114	32	20	45	27	50	30	52	31	48	29	43	26
16	01115098	36	22	38	23	41	24	42	25	44	26	41	24
18	01115120	48	28	61	35	60	34	52	30	33	19	36	21
Scituate Reservoir drainage area													
Mean	—	28	17	31	19	34	20	35	21	36	22	32	19

loads of chloride and sodium for the respective drainage areas upstream from each streamgage accounted for about 53 to 76 percent of the annual loads of chloride and sodium.

During WY 2022, estimated annual loads of chloride and sodium at the continuous streamgage stations were greater than the median estimated annual loads for WYs 2009–21 for 8 of the 16 USGS stations (fig. 5; note that two stations do not have estimates for WYs 2009–20). The sums of annual loads of chloride and sodium during WY 2022 for 14 stations with continuous monitoring in WYs 2009–21 (2,300 and 1,400 t, respectively) were about 12 percent lower than the average sums of loads of chloride (2,600 t) and sodium (1,600 t) during WYs 2009–21 (fig. 6). Annual loads from Swamp Brook (PW station 38; USGS station 01115278) and Winsor Brook (PW station 26; USGS station 01115185), which were incorporated into the monitoring network in 2021, represented about 10 percent of the sum of annual loads of chloride and sodium (fig. 6) in WY 2022. The annual mean discharge yield in cubic feet per second per square mile for WY 2022 was lower (by 0.17 cubic foot per second per square mile) than the WY 2009–21 average (table 2).

Watershed yields ranged from 15 to 100 metric tons per year per square mile ([t/yr]/mi^2) for estimated chloride and from 10 to 59 (t/yr)/mi^2 for estimated sodium. The lowest yields for estimated chloride and sodium were 15 and 10 (t/yr)/mi^2, respectively, for Wilbur Hollow Brook (PW station 7; USGS Station 01115297) and 17 and 10 (t/yr)/mi^2, respectively, for Huntinghouse Brook (PW station 14; USGS station 01115110). The highest yields for chloride and sodium among the 16 USGS stations, 100 and 59 (t/yr)/mi^2, respectively, were in Bear Tree Brook (PW station 9; USGS station 01115275), which is downstream from a formerly uncovered salt storage pile. The second highest chloride and sodium yields, 80 and 46 (t/yr)/mi^2, respectively, were in the small watershed for the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120; table 6). Chloride and sodium yields for Ponaganset River (PW station 35; USGS station 01115187), the largest

Table 6. Estimated annual mean chloride and sodium concentrations, loads, and yields at streamgage stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.

[Data were collected by the U.S. Geological Survey (USGS; USGS, 2024). Locations of stations are shown on figure 1. Annual mean concentrations were calculated by dividing the annual load by the total discharge for the year; annual mean yields were calculated by dividing the sum of individual loads by the sum of the drainage area. PW, Providence Water; Cl, chloride; mg/L, milligram per liter; Na, sodium; t/yr, metric ton per year; (t/yr)/mi^2, metric ton per year per square mile; —, not applicable]

PW station number	USGS station number	Concentration		Load		Yield	
		Cl (mg/L)	Na (mg/L)	Cl (t/yr)	Na (t/yr)	Cl ([t/yr]/mi^2)	Na ([t/yr]/mi^2)
Barden Reservoir subbasin							
24	01115190	22	14	210	130	43	27
26	01115185	22	14	150	96	35	22
28	01115265	20	13	300	190	34	21
35	01115187	17	11	430	270	30	19
Direct Runoff subbasin							
3	01115280	32	19	97	58	52	31
5	01115184	18	11	34	21	27	17
6	01115183	30	18	95	57	49	29
7	01115297	10	6.9	67	45	15	10
8	01115276	21	14	150	97	29	19
9	01115275	49	29	62	37	100	59
38	01115278	37	22	110	65	56	34
Moswansicut Pond reservoir subbasin							
19	01115170	50	30	240	140	73	44
Regulating reservoir subbasin							
14	01115110	12	7.3	110	66	17	10
15	01115114	38	23	280	170	59	36
16	01115098	35	21	250	150	49	30
18	01115120	52	30	23	13	80	46
Scituate Reservoir drainage area							
Mean concentration or yield		29	18	—	—	38	23
Total load		—	—	2,600	1,600	—	—

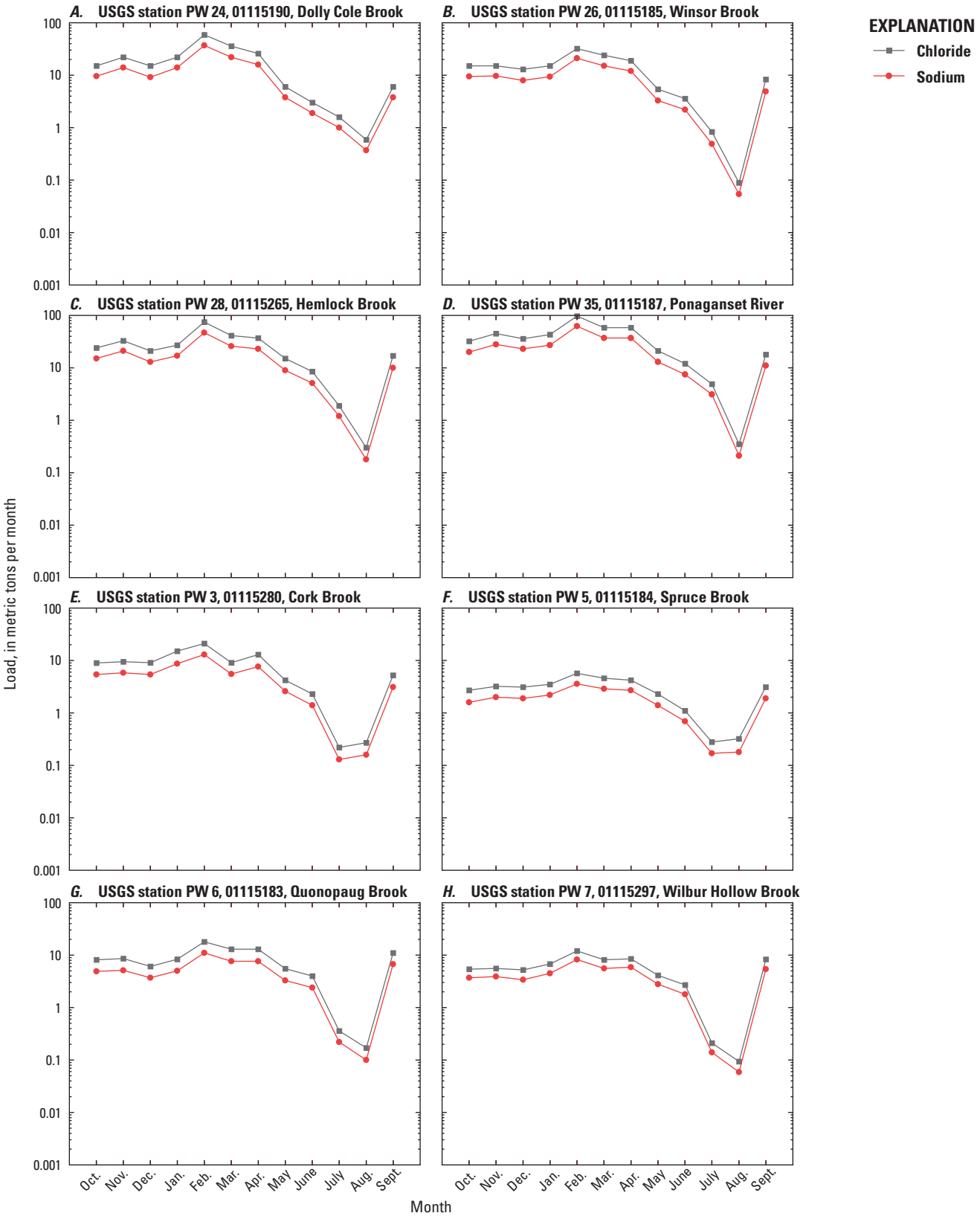

Figure 4. Graphs showing monthly loads of chloride and sodium estimated from streamflow and specific conductance data and annual mean discharge for October 1, 2021, through September 30, 2022, at 16 Providence Water (PW) sampling stations with continuous-record U.S. Geological Survey (USGS) water-quality data in the Scituate Reservoir drainage area, Rhode Island. Locations of stations are shown on figure 1; station information is shown in table 1. Data are from USGS (2024).

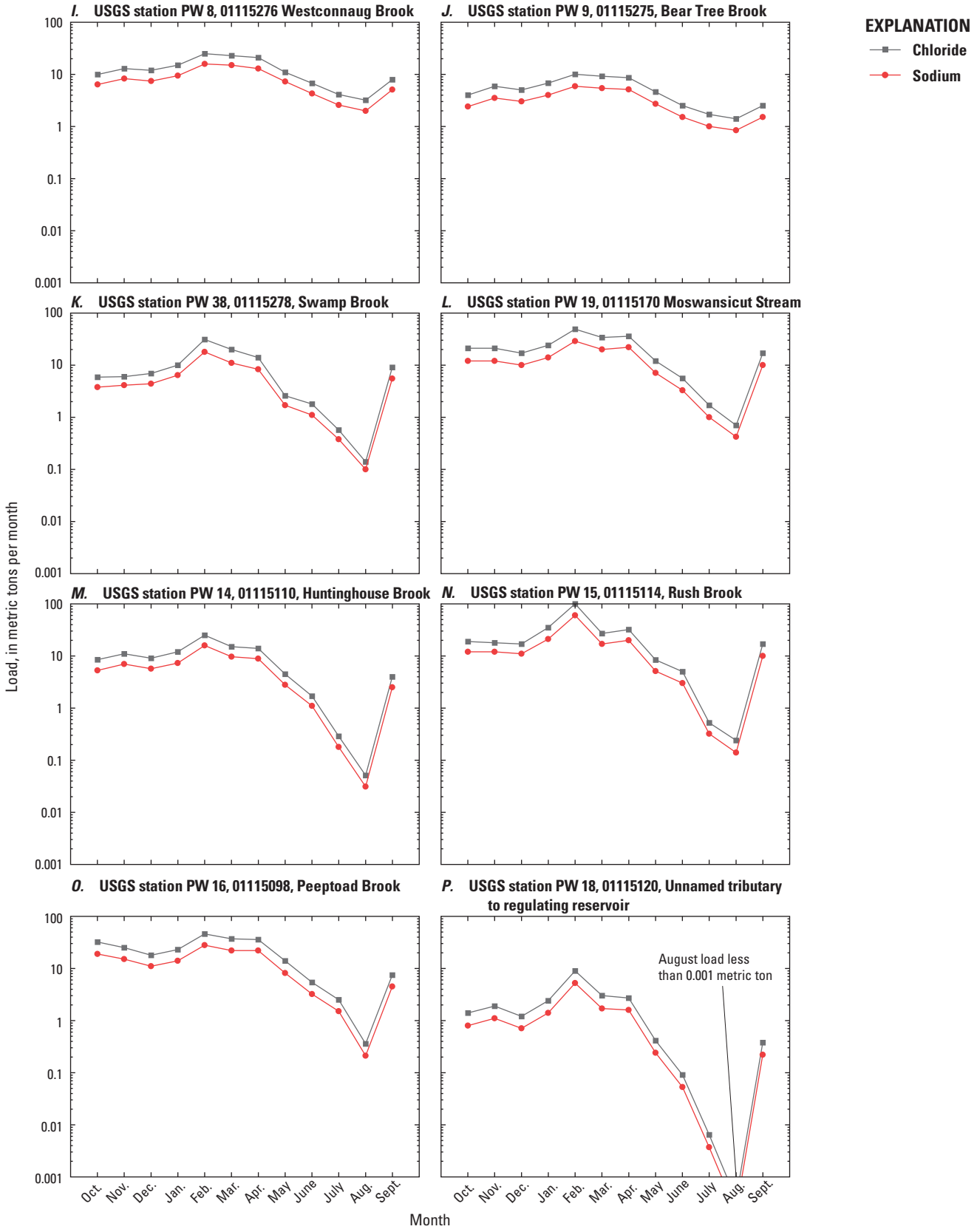

Figure 4.—Continued

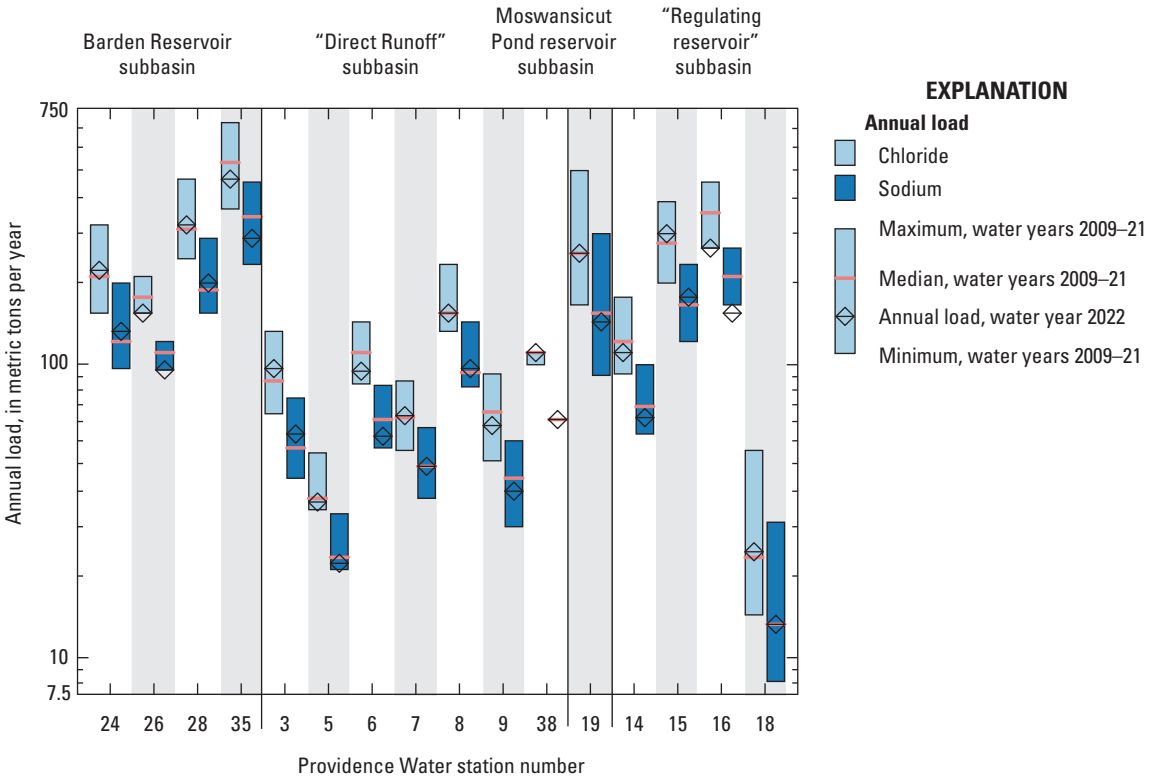

Figure 5. Graph showing annual loads of chloride and sodium estimated from streamflow and specific conductance data for October 1, 2021, through September 30, 2022, and associated minimum, maximum, and median annual loads for October 1, 2008, through September 30, 2021, at 16 Providence Water sampling stations with continuous-record U.S. Geological Survey water quality data in the Scituate Reservoir drainage area, Rhode Island. Locations of stations are shown on figure 1; only 2 years of available data are available for PW stations 26 and 38. Station information is shown in table 1. Modified from Smith (2016).

subbasin in the Scituate Reservoir watershed, were more than three times lower at 30 and 19 (t/yr)/mi^2, respectively, than the yields for Bear Tree Brook. The estimated annual mean yields of chloride and sodium for the drainage area upstream from the 16 USGS streamgage stations were 38 and 23 (t/yr)/mi^2, (table 6), respectively. These estimated annual mean yields of chloride and sodium for WY 2022 were lower than estimated annual mean yields of chloride and sodium in the prior water year by about 27 percent (Smith, 2024).

Physical and Chemical Properties and Daily Loads and Yields Estimated From Data Collected by Providence Water

PW routinely measured four water-quality properties (pH, color, turbidity, and alkalinity), and concentrations of chloride, nitrite, nitrate, orthophosphate, total coliform bacteria, and *E. coli* bacteria in monthly or quarterly samples of tributary water. These data are general indicators of water-quality conditions in the Scituate Reservoir drainage area.

Physical and Chemical Properties

Physical and chemical properties including pH, color, turbidity, and alkalinity were routinely measured to determine water quality in each of the six subbasins in the Scituate Reservoir drainage area (table 7) by PW. Specifically, pH is a measure of the effective hydrogen-ion concentration (USGS, 2021) representing the negative base-10 logarithm of hydrogen-ion activity of a solution, in moles per liter; color can be an indirect measure of the amount of organic carbon dissolved in the water column; turbidity is an indirect measure of suspended particles; and alkalinity is a measure of the buffer capacity of water.

The median pH in tributaries in the Scituate Reservoir drainage area ranged from 5.7 to 7.2; the median of the medians for all stations with more than two samples was 6.5. Median values of color ranged from 18 to 135 platinum-cobalt units; the median for all stations was 35 platinum-cobalt units. Median values of turbidity ranged from 0.21 to 2.1 nephelometric turbidity units; the median for all stations was 0.80 nephelometric turbidity unit. Median alkalinity values in tributaries were low, ranging from 4.0 to 23 mg/L as calcium carbonate; the median for all stations was 8.5 mg/L alkalinity as calcium carbonate (table 7).

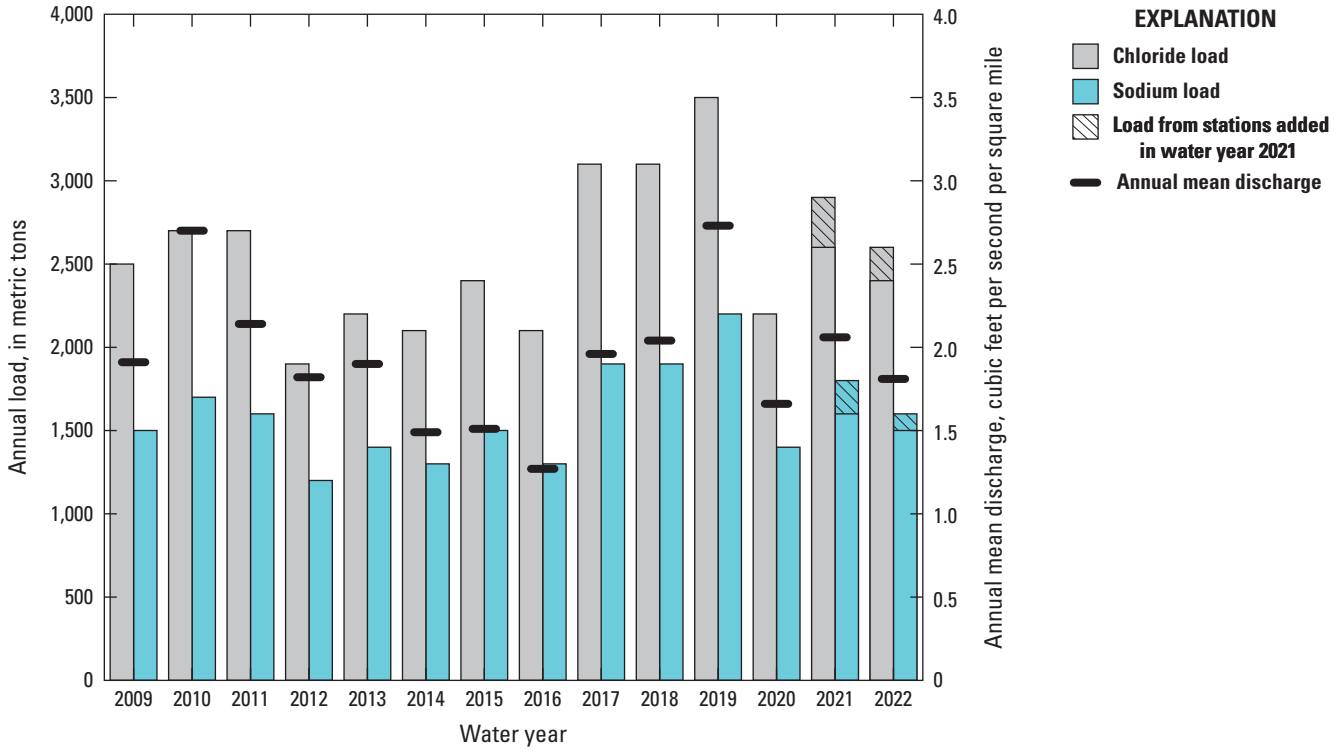

Figure 6. Bar chart showing all available estimated annual loads of chloride and sodium estimated from continuous measurements of streamflow and specific conductance from water years 2009–22 (October 1, 2008, through September 30, 2022), for the area upstream from 16 Providence Water sampling stations in the Scituate Reservoir drainage area, Rhode Island. Modified from Smith (2019a). Note: there were no data available to show chloride and sodium loads associated with Providence Water stations 26 and 38 prior to water year 2021.

Constituent Concentrations and Daily Loads and Yields

Fecal indicator bacteria, chloride, and nutrients such as nitrogen and phosphorus are commonly detected in natural water; at elevated concentrations, these constituents can cause or contribute to water-quality impairments. Fecal indicator bacteria, which are found in the intestines of warm-blooded animals, may indicate impairment from sewage contamination or from livestock or wildlife that defecate in or near the stream margin. Chloride originates in tributary stream water from precipitation, weathering, or human activities such as waste disposal, use of septic systems, and road deicing. Sources of nutrients in tributary stream water include atmospheric deposition, leaching of naturally occurring organic material, discharge of groundwater that is enriched with nutrients from septic-system leachate, and runoff contaminated with fertilizer or animal waste. The ultimate intended use of water in the tributaries is drinking water, which must meet specific water-quality standards. For this reason, PW closely monitors concentrations of these constituents in tributaries. Median concentrations, loads, and yields of water-quality constituents are listed in tables 7, 8, and 9.

Table 7. Median values for water-quality data collected at Providence Water stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.

[Data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations are shown on figure 1. If fewer than three samples were collected, the sample values are reported instead of a median. Minimum, median, and maximum values of station medians are based on stations with more than two samples. USGS, U.S. Geological Survey; PCU, platinum-cobalt units; NTU, nephelometric turbidity unit; CFU/100 mL, colony forming unit per 100 milliliters; *E. coli*., *Escherichia coli*; mg/L, milligram per liter ; $CaCO_3$, calcium carbonate; N, nitrogen; PO_4, phosphate; <, less than; —, no data; shaded rows, also indicated by footnotes, show actual values where less than three samples were collected]

PW station number	USGS station number	Properties			Constituents						
		pH	Color (PCU)	Turbidity (NTU)	Total coliform bacteria (CFU/100 mL)	*E. coli* (CFU/100 mL)	Alkalinity (mg/L as $CaCO_3$)	Chloride (mg/L)	Nitrite (mg/L as N)	Nitrate (mg/L as N)	Orthophosphate (mg/L as PO_4)
Barden Reservoir subbasin											
24	01115190	6.5	45	0.60	2,600	121	7.4	23.3	0.001	0.07	0.07
[1]25	01115200	6.3; 6.5	70; 60	0.93; 0.64	1,660; 776	40; 20	7.9; 5.4	13; 11.7	0.002; 0.001	0.06; <0.05	0.11; 0.15
26	01115185	6.4	30	0.28	778	30	7.2	28.8	0.001	0.08	0.05
27	011151845	6.0	20	0.21	637	<10	4.8	11.8	0.001	<0.05	0.10
28	01115265	6.1	70	0.78	1,070	50	6.6	25.6	0.002	0.05	0.06
29	01115271	6.5	40	0.75	384	<10	5.6	21	0.001	0.05	0.04
[1]35	01115187	6.4	35	0.83	2,480	83	6.1	20.4	0.002	0.08	0.05
Direct Runoff subbasin											
1	01115180	7.0	125	2.0	1,060	30	16	13.9	0.002	0.15	0.09
[1]2	01115181	6.5; 6.5	65; 8	1.1; 0.21	24,200; 310	<10; 2,600	9.2,7.7	54.9; 66.5	0.002; 0.001	0.06; 0.27	0.03; 0.07
3	01115280	6.5	37	0.34	738	<10	7.8	37.9	0.001	0.15	0.06
4	01115400	6.3	30	0.47	1,140	10	8.5	6.1	0.001	<0.05	0.04
5	01115184	6.2	85	0.34	1,140	10	5.3	19.1	0.002	0.18	0.06
6	01115183	6.4	125	1.0	1,020	65	13	30.8	0.002	0.16	0.06
7	01115297	6.4	110	0.81	1,470	58	8.6	11	0.002	0.07	0.07
8	01115276	6.5	18	0.48	374	<10	5.2	14.2	0.001	<0.05	0.05
9	01115275	6.6	35	0.38	1,140	<10	9.0	51.3	0.001	0.39	0.05
[1]30	01115350	5.7; 5.9	40; 62	0.48; 0.43	464; 738	<10; 10	4.9; 5.9	32.8; 23.5	0.001; 0.002	0.08; 0.05	0.08; 0.05
32	01115178	6.6	85	0.93	1,290	50	12	14.1	0.002	0.38	0.04
[1]33	01115182	6.2; 6.5	25; 40	0.22; 0.43	290; 988	<10; <10	9.8; 11.8	15.6; 20.2	0.001; 0.002	0.11; 0.25	0.08; 0.12
36	—	6.8	30	0.33	730	<10	6.4	4.9	0.001	<0.05	0.08
37	—	5.8	25	0.21	630	<10	5.1	6.6	0.001	<0.05	0.06
[1]38	01115278	6.3; 6.6	25; 20	0.19; 0.13	201; 563	<10; <10	4; 7.4	46.3; 29.2	0.001; <0.001	<0.05; <0.05	0.03; 0.04

Table 7. Median values for water-quality data collected at Providence Water stations in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.—Continued

[Data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations are shown on figure 1. If fewer than three samples were collected, the sample values are reported instead of a median. Minimum, median, and maximum values of station medians are based on stations with more than two samples. USGS, U.S. Geological Survey; PCU, platinum-cobalt units; NTU, nephelometric turbidity unit; CFU/100 mL, colony forming unit per 100 milliliters; *E. coli*., *Escherichia coli*; mg/L, milligram per liter ; $CaCO_3$, calcium carbonate; N, nitrogen; PO_4, phosphate; <, less than; —, no data; shaded rows, also indicated by footnotes, show actual values where less than three samples were collected]

PW station number	USGS station number	Properties			Constituents						
		pH	Color (PCU)	Turbidity (NTU)	Total coliform bacteria (CFU/100 mL)	*E. coli* (CFU/100 mL)	Alkalinity (mg/L as $CaCO_3$)	Chloride (mg/L)	Nitrite (mg/L as N)	Nitrate (mg/L as N)	Orthophosphate (mg/L as PO_4)
Moswansicut Pond reservoir subbasin											
19	01115170	7.2	25	0.76	1,150	<10	13	53.5	0.002	0.07	0.03
20	01115160	6.3	135	0.98	516	10	8.9	66.4	0.003	0.07	0.08
21	01115165	6.5	45	2.1	2,000	50	17	42.2	0.003	0.39	0.07
22	01115167	6.7	35	1.7	4,610	130	23	50.2	0.010	0.98	0.07
34	01115164	6.4	83	0.82	690	25	18	37.4	0.003	<0.05	0.08
Ponaganset Reservoir subbasin											
23	011151843	6.2	20	0.51	749	<10	4.2	19	0.001	0.06	0.03
Regulating reservoir subbasin											
13	01115176	7.0	35	1.0	670	<10	12	39.1	0.001	<0.05	0.05
14	01115110	6.6	35	0.81	960	60	11	14.3	0.001	0.10	0.07
15	01115114	6.9	50	0.83	573	30	12	45.7	0.001	0.09	0.07
16	01115098	6.7	35	0.98	576	10	14	38.9	0.001	0.11	0.04
[1]17	01115119	6.4; 5.9	32; 250	0.54; 1.0	684; 8,160	<10; 70	8.6; 12.9	26.6; 55.4	0.001; 0.005	<0.05; 0.06	0.07; 0.13
18	01115120	6.5	42	0.90	275	60	9.6	58.6	0.002	0.28	0.09
Westconnaug Reservoir subbasin											
10	01115274	5.7	30	0.27	1,710	35	4.0	26.6	0.001	<0.05	0.06
11	01115273	5.9	90	1.2	2,360	20	7.6	7.1	0.004	<0.05	0.08
12	011152745	6.2	25	0.87	4,880	30	7.0	13.6	0.001	<0.05	0.03
Scituate Reservoir drainage area											
Minimum median		5.7	18	0.21	275	<10	4.0	4.9	0.001	<0.05	0.03
Median median		6.5	35	0.81	1,020	25	8.5	23.3	0.001	0.10	0.06
Maximum median		7.2	135	2.1	4,880	130	23	66.4	0.010	0.98	0.10

[1]Less than three samples were collected at this station; actual values rather than medians are listed.

Table 8. Median daily loads of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.

[Concentration data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations are shown on figure 1. USGS, U.S. Geological Survey; (CFU×10^6)/d; millions of colony forming units per day; *E. coli*, *Escherichia coli*; kg/d, kilogram per day; g/d, gram per day; N, nitrogen; PO_4, phosphate; —, not applicable]

PW station number	USGS station number	Total coliform bacteria ([CFUx10^6]/d)	*E. coli* ([CFUx10^6]/d)	Chloride (kg/d)	Nitrite (as N) (g/d)	Nitrate (as N) (g/d)	Orthophosphate (as PO_4) (g/d)
Barden Reservoir subbasin							
24	01115190	140,000	3,900	190	17	560	850
25	01115200	88,000	2,300	110	11	<490	1,300
26	01115185	42,000	1,200	240	8.8	<610	390
28	01115265	220,000	25,000	1,000	72	<2,300	2,400
35	01115187	350,000	15,000	1,800	92	<4,800	1,600
Direct Runoff subbasin							
1	01115180	54,000	1,000	92	17	790	250
3	01115280	28,000	1,200	290	8.0	830	480
4	01115400	26,000	<270	17	2.2	<110	145
5	01115184	87,000	<760	150	11	1,400	330
6	01115183	79,000	5,800	300	27	1,300	610
7	01115297	130,000	5,200	180	40	<1,300	990
8	01115276	33,500	<1,500	250	20	<1,000	610
9	01115275	55,000	<640	320	6.4	420	220
32	01115178	11,000	<370	13	1.8	160	37
33	01115182	1,100	<23	3.9	0.29	34	21
38	01115278	24,000	<1,100	470	<11	<530	320
Moswansicut Pond reservoir subbasin							
19	01115170	11,000	1,300	320	12	540	190
21	01115165	15,000	360	36	2.8	310	66
Regulating reservoir subbasin							
14	01115110	130,000	8,400	340	22	1,800	1,900
15	01115114	110,000	5,600	650	18	1,500	1,100
16	01115098	220,000	<2,800	920	35	3,100	1,500
18	01115120	6,100	1,300	130	4.5	620	200
Westconnaug Reservoir subbasin							
10	01115274	240,000	7,400	220	8.0	<400	480
11	01115273	14,000	120	4.3	2.4	<31	49
Scituate Reservoir drainage area							
Minimum median		1,100	<23	3.9	0.29	<31	21
Median median		55,000	1,300	230	11	620	440
Maximum median		350,000	25,000	1,800	92	<4,800	2,400

Table 9. Median daily yields of bacteria, chloride, nitrite, nitrate, and orthophosphate in the Scituate Reservoir drainage area, Rhode Island, from October 1, 2021, through September 30, 2022.

[Concentration data from Smith and Spaetzel (2021). Water-quality data are from samples collected and analyzed by Providence Water (PW). Locations of stations shown on figure 1. USGS, U.S. Geological Survey; ([CFU×10^6]/d)/mi^2; millions of colony forming units per day per square mile; *E. coli*, *Escherichia coli*; N, nitrogen; PO_4, phosphate; (kg/d)/mi^2, kilogram per day per square mile; (g/d)/mi^2, gram per day per square mile; —, none]

PW station number	USGS station number	Total coliform bacteria ([CFUx10^6]/mi^2)	*E. coli* ([CFUx10^6]/mi^2)	Chloride ([kg/d]/mi^2)	Nitrite (as N) ([g/d]/mi^2)	Nitrate (as N) ([g/d]/mi^2)	Orthophosphate (as PO_4) ([g/d]/mi^2)
Barden Reservoir subbasin							
24	01115190	29,000	800	39	3.5	110	170
25	01115200	37,000	950	47	4.8	<200	550
26	01115185	10,000	270	55	2.0	<140	90
28	01115265	25,000	2,900	120	8.2	<260	270
35	01115187	25,000	1,100	130	6.6	<340	110
Direct Runoff subbasin							
1	01115180	34,000	640	59	11	500	160
3	01115280	15,000	640	160	4.3	440	260
4	01115400	31,000	<320	19	2.6	<130	170
5	01115184	69,000	<600	120	8.7	1,100	260
6	01115183	40,000	2,900	150	14	660	310
7	01115297	29,000	1,200	40	9.2	<300	230
8	01115276	6,500	<290	48	3.9	<190	120
9	01115275	89,000	<1,000	520	10	680	350
32	01115178	24,000	<820	29	4.0	360	82
33	01115182	3,900	<82	14	1.0	120	75
38	01115278	12,000	<550	250	<5.5	<270	170
Moswansicut Pond reservoir subbasin							
19	01115170	3,400	400	100	3.7	170	58
21	01115165	50,000	1,200	120	9.2	1,000	220
Regulating reservoir subbasin							
14	01115110	21,000	1,300	54	3.5	290	300
15	01115114	23,000	1,200	140	3.8	320	230
16	01115098	44,000	<560	190	7.0	620	300
18	01115120	22,000	4,600	460	16	2,200	710
Westconnaug Reservoir subbasin							
10	01115274	160,000	5,000	150	5.4	<270	320
11	01115273	19,000	170	6.0	3.3	<43	68
Scituate Reservoir drainage area							
Minimum median		3,400	<82	6.0	1.0	<43	58
Median median		25,000	810	110	5.1	<300	230
Maximum median		160,000	5,000	520	16	2,200	710

Bacteria

Median concentrations of total coliform bacteria were above the detection limit (1 colony forming unit per 100 milliliters [CFU/100 mL]) at all sites (table 7). Median concentrations of *E. coli* were censored below the detection limit of 10 CFU/100 mL at 10 of the 37 stations that had more than two samples collected in WY 2022. Median concentrations of *E. coli* were uncensored for 22 stations, and these concentrations ranged from 10 to 130 CFU/100 mL. For seven stations, medians were not determined because fewer than three samples were collected, and these concentrations ranged from less than 10 to 2,600 CFU/100 mL. Total coliform bacteria concentrations were greater than *E. coli* concentrations (as expected because total coliform is a more inclusive measure than *E. coli*); the medians of median concentrations for all sites in the drainage area were 1,020 CFU/100 mL for total coliform bacteria and 25 CFU/100 mL for *E. coli* (table 7). The highest median concentration of total coliform bacteria, 4,880 CFU/100 mL, was at the unnamed tributary to Westconnaug Brook (PW station 12; USGS station 011152745), which drains directly to the Scituate Reservoir (table 1). Median concentrations of total coliform bacteria were equal to or exceeded 2,000 CFU/100 mL at five other stations, including Dolly Cole Brook (PW station 24; USGS station 01115190), Ponaganset River (PW station 35; USGS station 01115187), unnamed tributary 2 to Moswansicut Pond reservoir (PW station 21; USGS station 011151650, unnamed tributary 3 to Moswansicut Pond reservoir (PW station 22; USGS station 01115167), and unnamed tributary to Westconnaug Reservoir (PW station 11; USGS station 01115273). Median concentrations of total coliform bacteria were lowest at the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120). The highest median concentration of *E. coli*, 130 CFU/100 mL (table 7), was at the unnamed tributary 3 to Moswansicut Pond Reservoir (PW station 22; USGS station 1115167).

Median daily loads and yields of total coliform bacteria and *E. coli* varied by two orders of magnitude or more (tables 8 and 9). The median daily loads of total coliform bacteria for all subbasins in the Scituate Reservoir drainage area ranged from 1,100 to 350,000 million colony forming units per day ([CFU×10^6]/d), and yields ranged from 3,400 to 160,000 million colony forming units per day per square mile ([(CFU×10^6)/d]/mi^2); *E. coli* loads ranged from less than 23 to 25,000 (CFU×10^6)/d, and yields ranged from less than 82 to 5,000 ([CFU×10^6]/d)/mi^2 (tables 8 and 9). The highest median daily yield of total coliform bacteria at 160,000 ([CFU×10^6]/d)/mi^2 was at Westconnaug Brook (PW station 10; USGS station 01115274), and the *E. coli* median yield at this station was 5,000 ([CFU×10^6]/d)/mi^2 (table 9). Although relatively high for sampling stations in the Scituate Reservoir subbasin, median daily bacteria yields at these stations were low to moderate for yields of indicator bacteria in sewage-contaminated stream water or stream water affected by stormwater runoff in an urban environment (Breault and others, 2002).

Chloride

Median chloride concentrations among the PW stations ranged from 4.9 to 66.4 mg/L. The highest median concentration was collected at the unnamed tributary 1 to Moswansicut Pond reservoir (PW station 20; USGS station 01115160; table 7). The median of median concentrations for all sites in the drainage area was 23.3 mg/L (table 7), which is similar to the median of median concentrations in WY 2020 and 2021 (24.8 and 23.7 mg/L, respectively; Smith, 2024, Smith and Spaetzel 2024). Median daily chloride loads and yields estimated from samples collected by PW varied among monitoring stations in the drainage area (tables 8 and 9). Ponaganset River (PW station 35; USGS station 01115187) had the largest median daily chloride load at 1,800 kilograms per day (kg/d), followed by Hemlock Brook (PW station 28; USGS station 01115265) and Peeptoad Brook (PW station 16; USGS station 01115098; table 8). Bear Tree Brook (PW station 9; USGS station 01115275) had the largest median yield at 520 kilograms per day per square mile ([kg/d]/mi^2). Median chloride yields ranged from 6 to 250 (kg/d)/mi^2at the other streamgages, except for the small drainage area above the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120), which was 460 (kg/d)/mi^2 (table 9). The median daily chloride yield for monitored areas within the drainage area was 110 (kg/d)/mi^2.

Nutrients

Median concentrations of nitrite and nitrate (table 7) were 0.001 and 0.10 mg/L as nitrogen, respectively. The highest median concentrations of nitrite (0.010 mg/L as nitrogen) and nitrate (0.98 mg/L as nitrogen) were at the unnamed tributary 3 to Moswansicut Pond reservoir (PW station 22; USGS station 01115167). The median concentration of orthophosphate for the entire study area (table 7) was 0.06 mg/L as phosphate. The maximum median concentration of orthophosphate was 0.10 mg/L as phosphate, measured in a sample collected at the unnamed tributary to Ponaganset River (PW station 27; USGS station 011151845).

Median daily nitrite and nitrate loads were largest at Ponaganset River (PW station 35; USGS station 01115187) at 92 grams per day (g/d) and less than 4,800 g/d (table 8). The largest uncensored median daily nitrate load was at Peeptoad Brook (PW station 16; USGS station 01115098) at 3,100 g/d as nitrogen. Median daily orthophosphate loads were largest (2,400 g/d The medians of median daily loads were 11 g/d for nitrite as nitrogen, 620 g/d for nitrate as nitrogen, and 440 g/d for orthophosphate as phosphate as phosphate) at Hemlock Brook (PW station 28; USGS station 01115265; table 8).

The maximum median daily yields for nitrite and nitrate were 16 grams per day per square mile ([g/d]/mi^2) as nitrogen and 2,200 (g/d)/mi^2 as nitrogen, respectively, at the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120; table 9). These maximum daily yields were more than three and seven times greater, respectively, than the median yields among all stations (5.1 and less than 300 (g/d)/mi^2, respectively). For orthophosphate, the maximum median daily yield was 710 (g/d)/mi^2 as phosphate at the unnamed tributary to Regulating reservoir. This maximum median daily yield of orthophosphate was about three times greater than the median among all station medians (230 [g/d]/mi^2 as phosphate).

Summary

Since 1993, the U.S. Geological Survey (USGS), in cooperation with Providence Water (PW; formerly the Providence Water Supply Board), has maintained a long-term cooperative water-quality monitoring program within the Scituate Reservoir drainage area. PW also has been independently monitoring and assessing water quality in the reservoir and reservoir drainage area for more than 60 years. Together, the data collected by the USGS and PW are used to calculate concentrations, loads, and yields of chloride, sodium, nutrients, and bacteria for tributaries within Scituate Reservoir drainage area on an annual basis.

During water year (WY) 2022, the USGS measured or estimated streamflow at 24 streamgages; 16 of these streamgages are equipped with instrumentation capable of continuously monitoring water level, specific conductance, and water temperature. Prior to WY 2021, 14 streamgages were equipped with continuous-monitoring instrumentation; therefore, for annual comparisons of total chloride and sodium loads measured in the drainage area over the WY 2009–21 period, loads from the two streamgages added in WY 2022 were omitted. Water-quality samples were periodically collected by the USGS at each of the 16 streamgages and analyzed for dissolved concentrations chloride and sodium. Concentrations of chloride and sodium collected during WY 2022 were combined with data collected in previous WYs to support and refine relations between each ion and specific conductance. Monthly and annual concentrations, loads, and yields were estimated for the 16 streamgages by using equations to relate specific conductance to concentrations of chloride and sodium and measured or estimated streamflow data.

At 16 of the 24 USGS streamgages, where both streamflow and continuous specific conductance data were available, estimated monthly mean chloride concentrations ranged from 8.6 to 80 milligrams per liter (mg/L) and estimated monthly mean sodium concentrations ranged from 6.0 to 48 mg/L in tributaries of the Scituate Reservoir drainage area. The highest annual mean concentrations of chloride and sodium in the more developed, northeastern part of the Scituate Reservoir drainage area were estimated to be 52 and 30 mg/L, respectively, in the unnamed tributary to Regulating reservoir (PW station 18; USGS station 01115120) and 50 and 30 mg/L, respectively, in Moswansicut Stream (PW station 19; USGS station 01115170). Estimated loads of 2,600 metric tons of chloride and 1,600 metric tons of sodium were transported to the Scituate Reservoir during WY 2022 from the 16 tributaries equipped with instrumentation. Annual chloride yields for tributaries in the drainage area ranged from 15 to 100 metric tons per square mile, and annual sodium yields ranged from 10 to 59 metric tons per square mile. The sum of estimated chloride and sodium annual loads during WY 2022 for 14 stations with continuous monitoring in WYs 2009–21 was about 12 percent lower than the sum of annual loads estimated during the previous water year and less than the average annual load for WYs 2009–21 for the same stations.

PW collected at least one water-quality sample at 37 of 38 sampling stations in WY 2022, including at the 16 USGS continuous-record streamgages, as part of their long-term sampling program in the Scituate Reservoir drainage area. In WY 2022, only Toad Pond (PW station 31; USGS station 01115177) was not sampled. Water-quality samples are analyzed by PW for pH, color, turbidity, alkalinity, and concentrations of chloride, nutrients, and bacteria. Water-quality data collected by PW are summarized by using values of central tendency and are used in combination with periodic- or continuous-streamflow data available at 24 of the 37 stations sampled in WY 2022 to calculate loads and yields of chloride, nutrients, and bacteria.

For water samples collected by PW, the median of the median pH values for samples from all stations on tributaries in the Scituate Reservoir drainage area was 6.5; the median value for color was 35 platinum-cobalt units; the median value for turbidity was 0.80 nephelometric turbidity unit; and the median concentration for alkalinity was 8.5 mg/L as calcium carbonate. The medians of the median concentrations for water samples from all stations were 1,020 colony forming units per 100 milliliters for total coliform bacteria, 25 colony forming units per 100 milliliters for *Escherichia coli,* 23.3 milligrams per liter for chloride, 0.001 milligram per liter as nitrogen for nitrite, 0.07 milligram per liter as nitrogen for nitrate, and 0.06 milligram per liter as phosphate for orthophosphate. The medians of the median daily loads were 55,000 million colony forming units per day for coliform bacteria, 1,300 million colony forming units per day for *Escherichia coli,* 230 kilograms per day for chloride, 11 grams per day as nitrogen for nitrite, 620 grams per day as nitrogen for nitrate, and 440 grams per day as orthophosphate for phosphate. The medians of the median yields were 110 kilograms per day per square mile for chloride, 5.1 grams as nitrogen per day per square mile for nitrite, less than 300 grams as nitrogen per day per square mile for nitrate, 230 grams as orthophosphate per day per square mile for phosphate, 25,000 million colony forming units per day per square mile for coliform bacteria, and 810 million colony forming units per day per square mile for *Escherichia coli*.

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