Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2008

Massachusetts Water Resources Authority

Environmental Quality Department
Report ENQUAD 2009-09

Citation

Coughlin, Kelly. 2009**. Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2008.** Boston: Massachusetts Water Resources Authority. Report 2009-09. 42 pp.

Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2008

Prepared by:

Kelly Coughlin
Environmental Quality Department, Operations Division
Massachusetts Water Resources Authority
100 First Avenue, Boston, MA 02129

July 2009

Environmental Quality Department Technical Report 2009-09

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 OVERVIEW OF THE MONITORING PROGRAM 4
1.2 ORGANIZATION AND PURPOSE OF THE REPORT 4

2 MATERIALS AND METHODS 4

2.1 FIELD AND LABORATORY METHODS 4
2.1.1 Selection of sampling locations 4
2.1.2 Sampling schedule 4
2.1.3 Sample collection 4
2.1.4 Field measurements 5
2.1.5 Rainfall measurements 5
2.1.6 Laboratory analyses 5
2.2 DATA ANALYSIS 6
2.3 WATER QUALITY CRITERIA USED IN THIS REPORT 7

3 CHARLES RIVER 9

3.1 SAMPLING AREA 9
3.2 POLLUTION SOURCES 10
3.3 SUMMARY OF WATER QUALITY, 2003-2008 11
3.4 TRENDS IN WATER QUALITY, 2008 14
3.4.1 Physical measurements 14
3.4.2 Nutrients, TSS and chlorophyll 16
3.4.3 Bacterial water quality 18
3.5 SUMMARY OF CHARLES RIVER WATER QUALITY 24

4 MYSTIC RIVER AND ALEWIFE BROOK 25

4.1 SAMPLING AREA 25
4.2 POLLUTION SOURCES 25
4.3 SUMMARY OF WATER QUALITY, 2003-2008 27
4.4 TRENDS IN WATER QUALITY, 2008 30
4.4.1 Physical measurements 30
4.4.2 Nutrients, TSS and chlorophyll 32
4.4.3 Bacterial water quality 34
4.5 SUMMARY OF MYSTIC RIVER WATER QUALITY 42

REFERENCES 43

LIST OF TABLES

Table 2-1. Field measurements. 5
Table 2-2. Laboratory measurements..... 6
Table 2-3. Water quality criteria for Class B and Class SB waters. 8
Table 3-1. MWRA monitoring locations, lower Charles River. 10
Table 3-2. Charles River pollution sources. 11
Table 3-3. Charles River sample collection by rainfall condition. 11
Table 3-4. Summary of water quality, lower Charles River Basin 2004 – 2008. 12
Table 3-5. Geometric mean indicator bacteria, Charles River, 2003 – 2008. 21
Table 4-1. MWRA monitoring locations, Mystic River and Alewife Brook. 26
Table 4-2. Mystic River/Alewife Brook pollution sources. 27
Table 4-3. Mystic River/Alewife Brook sample collection by rainfall condition. 27
Table 4-4. Summary of water quality, Mystic River/Alewife Brook 2004 – 2008. 28
Table 4-5. Geometric mean indicator bacteria, Mystic River, 2003 – 2008. 39

LIST OF FIGURES

Figure 1-1. Estimated CSO flow reductions, 1987 – 2017 3
Figure 1-2. CSO Typical Year Discharge Volumes..... 3
Figure 2-1. Percentile distributions indicated on percentile plots 3
Figure 3-1. Map of MWRA Charles River sampling locations 9
Figure 3-2. Summer temperature,dissolved oxygen, and Secchi depth, Charles River Basin, 2008. 15
Figure 3-3. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Watertown Dam. 17
Figure 3-3. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Science Museum..... 18
Figure 3-5. Indicator bacteria concentrations, Charles River Basin, 2008. 20
Figure 3-6. *Enterococcus* by rainfall condition, Charles Basin, 2003 - 2008. 22
Figure 3-7. *Enterococcus* over time, Upper Charles Basin. 23
Figure 3-8. *Enterococcus* over time, Lower Charles Basin. 23
Figure 4-1. Map of Mystic River sampling locations 25
Figure 4-2. Summer temperature,dissolved oxygen, and Secchi depth, Lower Mystic, 2008. 31
Figure 4-3. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, upstream of Alewife Brook.. 33
Figure 4-4. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Boston Ave.. 33
Figure 4-5. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Amelia Earhart Dam..... 34
Figure 4-6. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Mystic River Mouth.. 35
Figure 4-7. *Enterococcus* by rainfall condition, Mystic River/Alewife Brook, 2003 - 2008. 40
Figure 4-8. *Enterococcus* over time, Upper Charles Basin. 40
Figure 4-9. *Enterococcus* over time, Lower Charles Basin. 40

1 Introduction

This report presents a summary of data collected as part of MWRA's ongoing combined sewer overflow (CSO) receiving water monitoring program. The goal of this monitoring is to identify the water quality impacts of CSO flows on water bodies.

During the 2008 calendar year, MWRA continued to implement its Long Term CSO Control Plan, which was developed to address CSO discharges from all CSOs hydraulically connected to the MWRA sewer system and its member communities. This monitoring summary provides an assessment of water quality in the Charles and Mystic Rivers, which are affected by CSO projects implemented as part of this plan.

In 2007, Massachusetts Department of Environmental Protection (MADEP) extended the CSO Variances for the Charles River issued to MWRA, BWSC and the City of Cambridge by three years, to October 1, 2010. MADEP also extended the CSO Variances for the Alewife Brook/Upper Mystic River issued to MWRA, the City of Cambridge and the City of Somerville by three years, to September 1, 2010.

Under the agreement on the Long-Term Control Plan reached by EPA, MADEP and MWRA in March 2006, MADEP agreed to issue a series of three-year variance extensions until 2020, and MWRA agreed to implement the revised Long-Term Control Plan by 2015 and verify the predicted performance of the plan at all CSO outfalls by 2020. At that time, DEP will consider issuing long-term water quality standards determinations, based on the verified performance of the Long-Term Control Plan and other conditions affecting the water quality and uses of these water bodies.

Conditions in the recent variance extensions require MWRA to implement the Long-Term Control Plan and require MWRA and the municipalities to continue to implement the Nine Minimum Controls of EPA's National CSO Control Policy. MWRA is also required to continue its ambient water quality sampling program, and all of the CSO permittees are required to report estimated CSO discharge frequency and volume from their respective outfalls to these receiving waters on an annual basis.

2008 CSO progress as it relates to the Alewife Brook/Mystic River and Charles River include the following:

- On June 30, 2008, MWRA issued the Notice to Proceed for the construction contract for the Cottage Farm Brookline Connection and Inflow Controls Project. The project will reduce treated CSO discharges from the Cottage Farm CSO Facility through improvements to the combined conveyance capacity of the two MWRA sewers that carry flows across the Charles River and installation of flow monitoring equipment that will allow operators to control the Cottage Farm Facility gates to maximize use of upstream storage.

- On April 23, 2008, MWRA sent a letter report to EPA and DEP confirming implementation of the procedures it had recommended in 2007 to minimize treated discharges from the Prison Point CSO facility to the Charles River mouth/Boston Inner Harbor. MWRA confirmed the improved hydraulic performance of the facility with the new procedures, which reduce long-

term treated discharges in a typically rainfall year from 30 activations and 335 million gallons to 17 activations and 243 million gallons.

- On July 16, 2008, MWRA's Board of Directors approved an amendment to the CSO Memorandum of Understanding and Financial Assistance Agreement with the City of Cambridge that increases the financial award amount from $21.6 million to $60 million, in addition to the $2.8 million that MWRA will spend to implement its MWR003 Gate and Rindge Avenue Siphon Relief project. The total cost of the Alewife Brook Sewer Separation plan, including MWRA and Cambridge cost shares, is $117.4 million.

- In July 2008, MWRA completed the Cummingsville Branch Sewer siphon modification in Winchester, which included cleaning and lining of the branch sewer, at a cost of $1.3 million.

- In October 2008, Cambridge resumed design work for three of the five projects that comprise the Alewife Brook plan: CAM004 Stormwater Outfall and Wetland Basin; CAM400 Manhole Separation; and Interceptor Connection Relief and Floatables Control at CAM002 and CAM401B and Floatables Control at CAM001. Due to citizens' appeals, the Alewife Brook projects are delayed at least 27 months beyond their respective design and construction milestones.

- In November 2008, a $1.6 million rehabilitation of 2 miles of the Mystic Valley Sewer in Winchester was completed.

As of the end of 2008, 27 CSOs have been closed in Boston Harbor and its tributaries since the early 1990s; 57 CSOs remain active. In the Charles, ten CSOs remain active and nine have been closed (most recently CAM009 and CAM011). In the Alewife Brook, eight CSOs remain active, five have been closed. In the Mystic River one treated CSO (Somerville Marginal) remains active in the Lower Mystic, discharging at two locations depending on tide (MWR205A upstream of the Amelia Earhart dam and MWR205 in the marine river mouth).

System-wide, average annual CSO discharge has been reduced by 2.7 billion gallons since 1988, an 82% reduction, with 73% of current discharge volume receiving treatment at MWRA's four CSO treatment facilities. Other system improvements since the 1990s have also reduced the frequency and volume of CSO flows over the period of the monitoring program and has resulted in increased treatment of remaining flows. These improvements include increased pumping capacity at Deer Island Treatment Plant; improvements to MWRA's pumping and interceptor systems; completion of nine minimum controls; and completion of system optimization projects. Figure 1-1 shows the estimated CSO flow reduction system-wide since 1987, and Figure 1-2 shows the CSO flow reduction by receiving water. For purposes of this report, receiving water quality data from 2003 to the present is considered representative of current conditions.

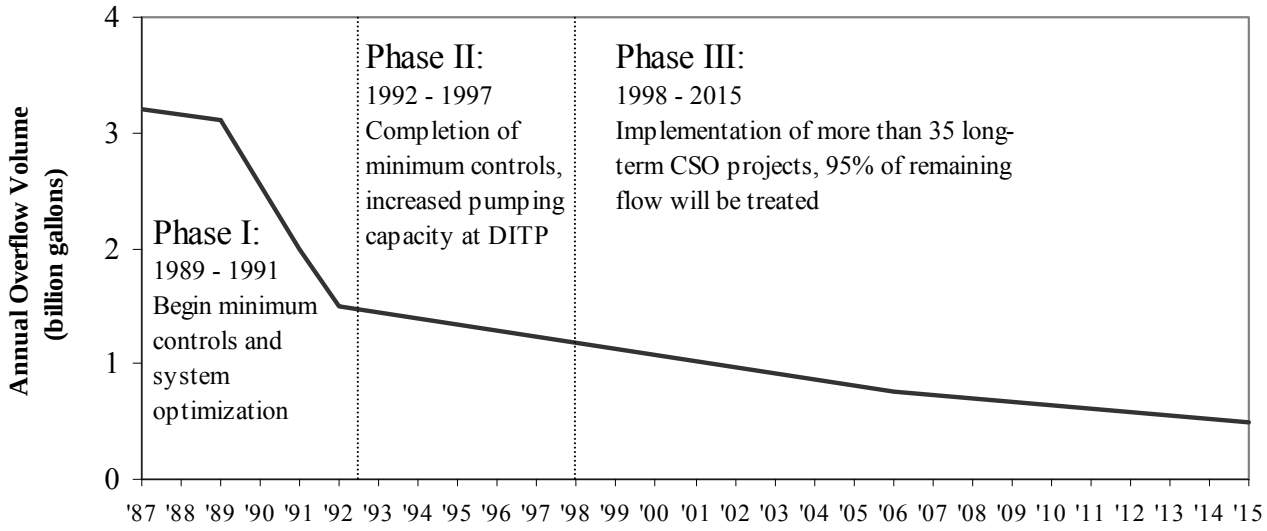


Figure 1-1. Estimated CSO flow reductions, 1987 – 2015.

Source: MWRA CSO Annual Progress Report 2008

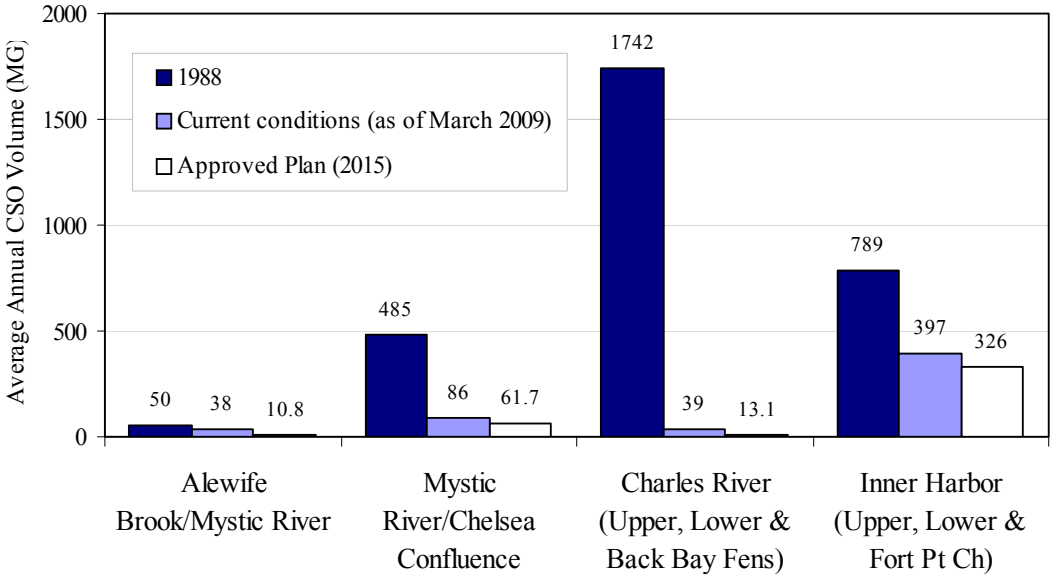


Figure 1-2. CSO Typical Year Discharge Volumes for 1988, Current, and Approved Long Term Control Plan model estimates

Source: MWRA CSO Annual Progress Report 2008

1.1 Overview of the monitoring program

MWRA's CSO receiving water quality monitoring program has been ongoing since 1989. All harbor and tributary areas impacted by CSOs in Boston, Chelsea, Cambridge, and Somerville are included in the monitoring program. For most sampling locations included in this report, at least 20 samples have been collected each year for at least seven years.

1.2 Organization and purpose of the report

Chapter 2 presents the materials and methods used in monitoring. Chapters 3 and 4 of this report discuss the results of the CSO receiving water quality monitoring program in the Charles River and Mystic River/Alewife Brook. Water quality parameters examined for each region include: bacterial indicators (*E. coli* and *Enterococcus*), dissolved oxygen, water clarity (Secchi depth, total suspended solids), nutrients (phosphate, ammonium, nitrate/nitrite) and chlorophyll.

The purpose of the report is to summarize water quality in the Charles and Alewife Brook/Mystic River. The report compares sampling results to water quality standards, and shows spatial and temporal variations in water quality, and differences between wet and dry weather. Data from 2003 – 2008 are analyzed together, and data for 2008 for bacterial and physical parameters are also shown separately.

2 Materials and Methods

2.1 Field and laboratory methods

2.1.1 Selection of sampling locations

Some sampling locations were chosen for their proximity to CSO discharges and others were chosen to provide representative water quality measurements for a given area. Complete lists of stations including descriptions for the Charles and Mystic River/Alewife Brook appear in Section 3.1 and 4.1, respectively.

2.1.2 Sampling schedules

Approximately 20 station visits or more were made to each location each year, with nutrient and chlorophyll samples collected once monthly year-round at a subset of river locations, and bacteria samples collected between April and December of each year in weekly rotations for each region. Sampling was random with respect to weather; however efforts were made to collect additional samples during wet weather, if an inadequate number of station visits occurred following rainfall events. In some cases, stations with known contamination problems were specifically targeted for wet weather sampling.

2.1.3 Sample collection

At all locations, water samples and water quality measurements were collected near-surface (approximately 0.1 meters below surface). Surface samples were collected by grab, directly into rinsed sample containers. Bottom samples were collected at locations with a water depth greater than 3 meters, using a Kemmerer sampler at 0.5 meters above the sediment surface. Beginning in 2000, bottom water quality measurements

(physical measurements such as dissolved oxygen, temperature, and salinity) were made at most locations regardless of depth. Separate sampling containers were used for bacteria, nutrient, and TSS analyses.

2.1.4 Field measurements

Field measurements were made with different instruments over the course of the monitoring program. Table 2-1 lists the instruments used and the variables measured.

Table 2-1. Field measurements.

Variable	Instruments used
Temperature, conductivity/salinity, dissolved oxygen, turbidity, pH	Hydrolab Datasonde 4 (1997-2008) Hydrolab Datasonde 5 (2003 - 2008) YSI 600XL for temperature, conductivity, dissolved oxygen (1999 – 2008)
Secchi Depth	Wildco 8-inch limnological secchi disk (upstream of dams) Wildco 8-inch oceanographic secchi disk (marine waters)

2.1.5 Rainfall measurements

Rainfall measurements were taken from the National Weather Service (NWS) rain gauge located at Logan Airport in East Boston, as this was considered the most representative location for the entire monitoring area. Results from the gauge are reported in one-day intervals. Data are downloaded from the NWS website and stored in MWRA's EM&MS database.

2.1.6 Laboratory analyses

Samples were analyzed at the MWRA Central Laboratory. For enumeration of bacteria, nutrients, and TSS, MWRA Department of Laboratory Services Standard Operating Procedures is followed.

Detailed laboratory methods with quality assurance and quality control procedures are described in the Central Laboratory Standard Operating Procedure (MWRA 2007).

Table 2-2 lists the analytes measured and methods used in the monitoring program.

Table 2-2. Laboratory measurements.

Analyte	Method
Enterococcus	Standard Methods 9230C 2c, membrane filtration (for samples collected 1996 – 2003) EPA Method 1600 (for samples collected 1999–2006, some 2008) Enterolert (for samples collected 2008)
E. coli (measured from 2001 – 2008)	Modified EPA 1103.1, membrane filtration (for samples collected 2000–2006) Colilert (for samples collected 2008)
Fecal coliform (limited measurements after 2001)	Standard Methods 9222D, membrane filtration
Total suspended solids	Clesceri et al. (2003, Method 2540D), using nucleopore filters
Total phosphorus	TP and/or TDP: Solarzano and Sharp (1980a); PP: Solarzano and Sharp (1980a), Whatman GF/F
Phosphate	Murphy and Riley (1962), modified as in Clesceri et al (2003, Method 4500-P F) Skalar SAN^{plus} autoanalyzer, Whatman GF/F filters
Total Nitrogen	TN and/or TDN: Solarzano and Sharp (1980b), Whatman G/F filters; PN: Perkin Elmer CHN analyzer, Whatman GF/F
Ammonium	Fiore and O'Brien (1962), modified as in Clesceri et al (2003, Method 4500-NH3 H), Skalar SAN^{plus} autoanalyzer, Whatman GF/F filters
Nitrate+nitrite	Bendshneider and Robinson (1952), modified as in Clesceri et al (2003, Method 4500-NO3 F), Skalar SAN^{plus} autoanalyzer, Whatman GF/F filters
Chlorophyll *a*	Acid-corrected (Holm Hansen 1965) as described in EPA (1992). Sequoia Turner Model 450 fluorometer, GF/F filters

2.2 Data analysis

Descriptive Analyses. Indicator bacteria counts are typically log-normally distributed, and therefore a proper measure of central tendency for these data is the geometric mean. Geometric means and their associated 95% confidence intervals were calculated for the measurements made at each station over the sampling period.

Many results are plotted as percentile plots, as shown in Figure 2-1.

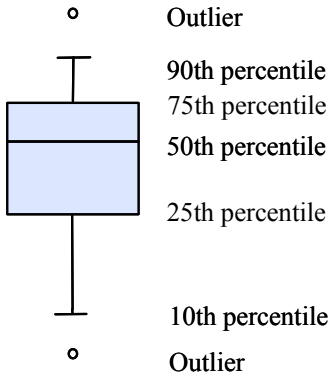


Figure 2-1. Percentile distributions indicated on percentile plots

These plots present a frequency distribution of a group of measurements. Each box comprises measurements from a single beach or sampling location. Values are shown in Figure 2-1 for the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles. Single measurements beyond these ranges (outliers) are displayed as dots.

The plots display the range and central tendencies of the data to be seen and allow for easy comparison of the results among stations. Since part of the Massachusetts standard is a percentile, these plots are particularly appropriate (see Section 2.3 for a description of these guidelines). The 50^{th} percentile or median is equivalent to the geometric mean, assuming the data are log-normally distributed.

2.3 Water Quality Standards used in this report

Standards are shown in Table 2-6, and include standards and guidelines from the Massachusetts Department of Environmental Protection (MADEP), Environmental Protection Agency (EPA), Massachusetts Department of Public Health (MADPH), and the Massachusetts Division of Marine Fisheries (MADMF). As of January 2007, the MADEP standard for Class SB waters (fishable swimmable) are based on *E. coli* and/or *Enterococcus* counts for freshwater, and *Enterococcus* counts for marine waters, following a USEPA recommendation for *Enterococcus* in marine waters (USEPA 1986). The Massachusetts Department of Public Health has issued regulations for beach management based on the USEPA criteria. The Massachusetts Division of Marine Fisheries continues to use fecal coliform counts to assess suitability for shellfish growing waters.

Table 2-3. Water quality standards for Class B and Class SB waters[1].

Designated Use/Standard	Parameter	Support
Inland waters, Class B, warm water fishery Massachusetts waters, MADEP	Dissolved Oxygen	≥ 5.0 mg/l ≥ 60% saturation unless background conditions lower
	Temperature	≤ 28.3ºC (83ºF)
	pH	6.0 to 8.3 S.U.
Coastal/marine waters, Class SB Massachusetts waters, MADEP	Dissolved Oxygen	≥ 5.0 mg/L ≥ 60% saturation unless background conditions lower
	Temperature	< 26.7ºC (80ºF)
	pH	6.5 to 8.5 S.U.
Primary contact recreation (designated swimming area), EPA and MADPH guidelines and, as of 2007, primary contact recreation, Massachusetts MADEP	*Enterococcus*	Single sample limit 61colonies/100 ml (freshwater), 104 colonies/100 ml (marine); geometric mean 33 colonies/100 ml (freshwater), 35 colonies/100 ml (marine)
Freshwater primary contact recreation (designated swimming area), EPA and MADPH guidelines; and, as of 2007, primary contact recreation, Massachusetts MADEP	*E. coli*	Single sample limit 235 colonies/100 ml (freshwater only); geometric mean 126 colonies/100 ml (freshwater only)
Prior to 2007, primary contact recreation, Massachusetts MADEP	Fecal coliform	Geometric mean ≤ 200 colonies/100 ml, no more than 10% of samples above 400 colonies/100 ml
Restricted shellfishing, Massachusetts MADMF	Fecal coliform	Geometric mean ≤ 88 colonies/100 ml

[1] All receiving water areas discussed in this report are either Class B or SB according to MADEP standards current as of January 2007 (except for Mystic River mouth, which is SB_{CSO}. SB_{CSO} has he same water quality standards as SB except CSOs are present).

From MADEP 1996:

Inland Water Class B: These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

Coastal and Marine Class SB: These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting with depuration (Restricted Shellfishing Areas). These waters shall have consistently good aesthetic value.

3 Charles River

3.1 Sampling area

MWRA's sampling area in the Charles River includes the river segment from the Watertown Dam in Watertown downstream to the New Charles River Dam in Boston, near the river mouth. This area, for purposes of this report called the Charles Basin, is freshwater and designated Class B with a variance for Combined Sewer Overflows by MADEP (the variance was extended in 2007). The river segment is approximately 10.3 km (8.6 mi) long. The New Charles Dam and locks limit river flow and tidal exchange at the river mouth. MWRA monitoring locations are primarily located midstream, bracketing CSO outfalls. Locations were also selected near to or downstream of outfalls where accessible by boat: at Stony Brook outlet and CSO (MWR023), Faneuil Brook outlet and CSO (BOS032, closed in 1997), and downstream of the Cottage Farm CSO outfall diffusers (MWR201).

For purposes of this report, MWRA's monitoring area in the lower Charles is divided into three smaller reaches. Table 3-1 describes the reaches, sampling locations and CSOs within each reach. Sampling locations and CSOs appear in Figure 3-1.

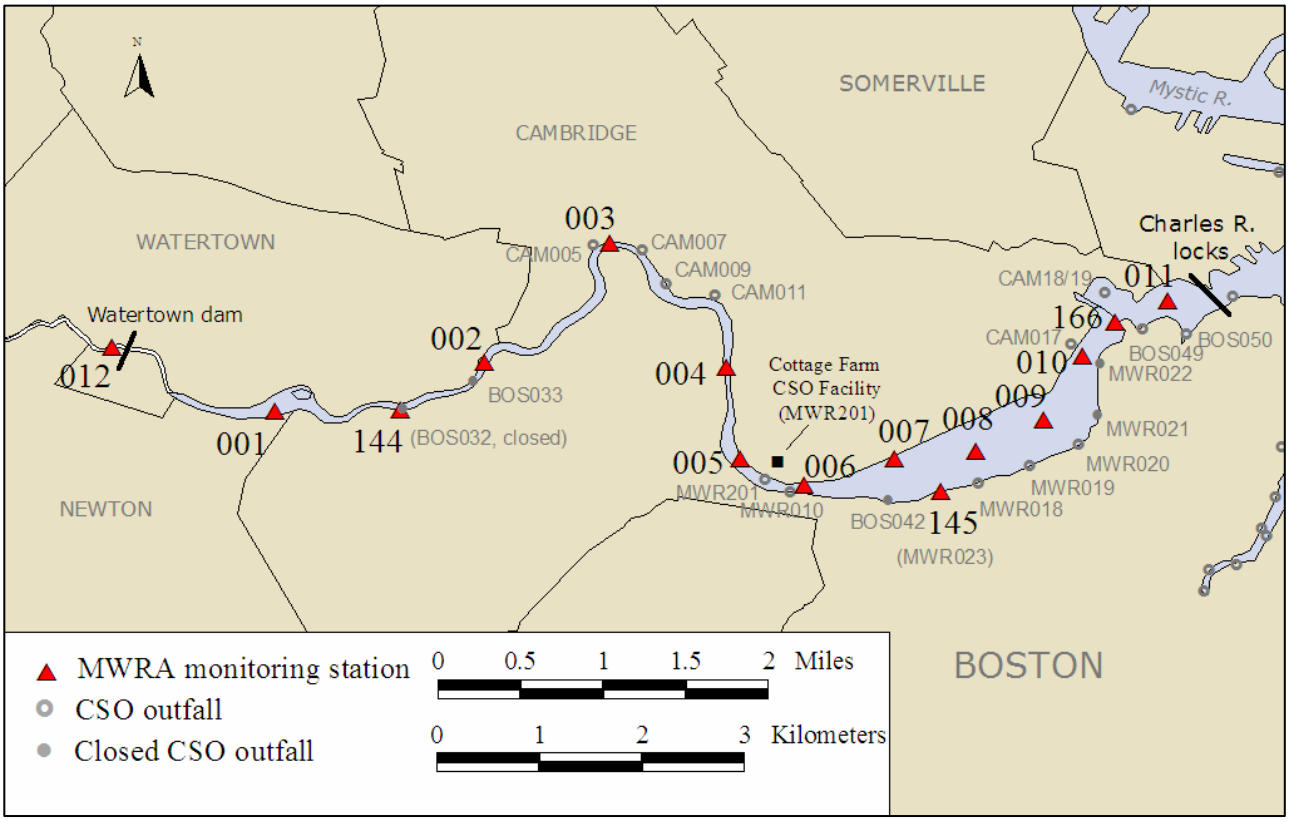


Figure 3-1. Map of MWRA Charles River sampling locations

Table 3-1. MWRA monitoring locations, Charles River Basin.

Reach	Description of Reach	Sampling location	Location Description
Upper Basin (Class B/ Variance, warm water fishery)	Watertown dam in Watertown, downstream to Magazine Beach (near BU Bridge) in Cambridge	012, Watertown	Watertown Dam at footbridge (upstream of all CSOs)
		001, Newton	Downstream of Newton Yacht Club (upstream of all CSOs)
		144, Allston	Faneuil Brook outlet (at BOS032, closed 11/97)
		002, Allston	Downstream of Beacon St. bridge (downstream of BOS033, closed 10/96)
		003, Cambridge	Downstream of Eliot Bridge, Cambridge side (at CAM005)
		004, Cambridge/Allston	Between River St. and Western Ave. bridges
		005, Cambridge	10 m off of Magazine Beach
Mid-Basin (Class B/Variance, warm water fishery)	BU Bridge on Boston/Cambridge line to downstream of Longfellow Bridge	006, Cambridge/Boston	BU Bridge, downstream side (downstream of MWR201)
		007, Cambridge	MIT Boathouse, Cambridge side
		145, Boston	Stony Brook outlet, Boston side (at MWR203)
		008, Cambridge/Boston	Mass. Ave bridge, downstream side (downstream of MWR203, MWR018)
		009, Cambridge/Boston	Longfellow Bridge, upstream side (downstream of MWR021, closed 3/00)
		010, Boston	Longfellow Bridge, downstream side (downstream of MWR022, closed 3/00)
Lower Basin (Class B/Variance, warm water fishery)	Science Museum to North Station railroad bridge, near Charlestown.	166, Boston	Science Museum, upstream of old dam (downstream of all lower basin CSOs)
		011, Boston	Between Science Museum and New Charles Dam/locks (downstream of all Charles CSOs)

Sampling locations are midstream unless otherwise noted.

3.2 Pollution sources

Known pollution sources to the Charles River are shown in Table 3-2. Contamination upstream of the Watertown Dam has been evident since MWRA's monitoring program began in 1989, though conditions have improved since the mid-1990s. MWRA's Cottage Farm CSO treatment facility, located upstream of the BU Bridge, screens, chlorinates and dechlorinates CSO flow before discharge and is the only source of treated CSO discharge to the river. With increases in sewer system capacity, the number of activations at Cottage Farm has decreased in recent years – from 26 activations in 1996 to 12 activations for calendar year 2008. The Stony Brook/Muddy River outlet near Kenmore Square is a source of contaminated brook flow and stormwater flows to the basin area. In 2006, Boston Water and Sewer Commission (BWSC) completed the Stony Brook sewer separation project at a cost of $45.1 million, reducing annual CSO discharge volumes to the Stony Brook by 99.7%. In November 2007, the City of Cambridge closed CAM009 and CAM011 (between monitoring stations 003 and 004).

The receiving water program is designed to capture water quality representative of all rainfall conditions. Table 3-3 summarizes the proportion of samples collected in dry, damp, and wet weather for 2003-2008.

Table 3-2. Charles River Basin pollution sources.

Source	Upper Basin	Mid-Basin	Lower Basin
CSOs (untreated)	2 active, 4 closed CAM005, CAM007 CAM009 closed 11/07 CAM011 closed 11/07 BOS032 closed 11/97 BOS033 closed 10/96	6 active, 3 closed MWR010, MWR023, MWR018, MWR019, MWR20, CAM017 BOS042 closed 5/96 MWR021 closed 3/00 MWR022 closed 3/00	1 active BOS049 (to be closed)
CSO treatment facility (settling and detention; screened, chlorinated and dechlorinated CSO discharge)	No	Yes Cottage Farm (MWR201) Activated 12 times in 2008	No
Storm drains	Yes	Yes	Yes
Upstream inputs (elevated bacteria counts upstream)	Yes	Yes	Yes
Dry weather inputs (elevated bacteria counts in dry weather)	Yes	Yes	Yes
Tributary brook or stream flow	Yes	Yes	Yes

Table 3-3. Charles River sample collection by rainfall condition.

Sampling period	Dry[1]	Damp[1]	Wet[1]	Total
2003 - 2007	26% 746 samples	34% 972 samples	40% 1178 samples	100% 2896 samples
2008	30% 184 samples	34% 214 samples	36% 225 samples	100% 623 samples

[1] Dry: no rainfall for previous 3 days; Wet: at least 0.5 inches in previous 2 days; damp is everything in between. Sampling is random with respect to weather, though if needed wet weather sampling is added late in the year to maintain a representative annual sample.

3.3 Summary of water quality, 2004-2008

A detailed summary of water quality results collected during the last five years is shown in Table 3-4.

Table 3-4. Summary of water quality, Charles River Basin 2004 – 2008.

Parameter		MA DEP Water Quality Guideline or Standard	Upper Basin				Mid-Basin				Lower Basin			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Surface Temperature (°C)[1]	Summer	<28.3	20.9 ± 4.6	98.7	9.3 - 29.3	672	20.6 ± 4.4	98.0	8.8 - 29.8	859	21.9 ± 4.7	88.8	11.2 - 30.2	258
	Winter		3.1 ± 2.8	100.0	0.1 - 10.1	53	ND	ND	ND	0	4.1 ± 2.3	100.0	0.7 - 10.6	64
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	7.2 ± 1.7	93.0	0.6 - 13.3	670	5.6 ± 3.2	67.9	0.1 - 12.7	859	6.9 ± 2.4	79.5	0.3 - 13.1	258
	Winter	5.0	13.5 ± 1	100.0	11.7 - 14.9	53	ND	ND	ND	0	12.9 ± 0.7	100.0	11.2 - 14.2	64
pH (S.U.)		6.5-8.3	7.3 ± 0.3	97.7	6.2 - 9	1092	7.3 ± 0.6	92.1	6.3 - 9.5	1248	7.5 ± 0.5	90.7	6.4 - 9.4	497
Water clarity	Total Suspended Solids (mg/L)	NS	4 ± 2.7	-	0.5 - 17.2	125	ND	-	ND	0	4 ± 2.5	-	0.7 - 14.4	120
	Secchi depth (m)	NS	1 ± 0.3	-	0.5 - 2.1	316	1 ± 0.3	-	0.3 - 1.7	651	1.2 ± 0.3	-	0.4 - 2.2	115
	Turbidity (NTU)	NS	6.7 ± 4.1	-	0.2 - 32.5	501	7.3 ± 4.9	-	0.1 - 52.5	998	5.5 ± 4.8	-	0.5 - 26.5	178

Table 3-4. Summary of water quality, Charles River Basin 2004 – 2008, continued.

Parameter		MA DEP Water Quality Guideline or Standard	Upper Basin				Mid- Basin				Lower Basin			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Bacteria (col/100mL)[2]	*E. coli*	126 / 235[3,4]	179 (158-202)	58.9	0 - 13000	681	81 (72-92)	72.3	0 - 24700	1081	61 (51-72)	79.7	0 - 10500	365
	Enterococcus	33 / 61[3]	40 (33-47)	58.5	0 - 17600	682	13 (11-15)	73.1	0 - 9200	1080	9 (7-11)	80.3	0 - 8900	365
Nutrients (µmol/L)	Phosphate	NS	0.71 ± 0.4	-	0.13 - 2.67	125	ND	-	ND	0	0.66 ± 0.46	-	0.04 - 2.76	120
	Ammonium	NS	4.6 ± 3	-	0.2 - 14.4	125	ND	-	ND	0	6.7 ± 5.5	-	0 - 23.3	120
	Nitrate+nitrite	NS	44.5 ± 20.5	-	0 - 116	125	ND	-	ND	0	41.2 ± 28	-	0 - 202	120
Algae (µg/L)	Chlorophyll	25[5]	5 ± 5.3	98.4	0.5 - 32.2	126	ND	ND	ND	0	16.3 ± 21.1	80.8	0.8 - 112	120

NS: no standard or guideline. ND: No data. [1]: Summer (June-September), Winter (December-March).

[2]For bacterial data, 95% confidence intervals are provided in lieu of standard deviations. Fecal coliform is no longer used as an indicator of suitability for primary recreation. Most recent results for 2000-2001 are shown for comparison. "Mean" = geometric mean for bacteria data.

[3]First number is the all samples geometric mean limit - compare to the "Mean±SD" column; the second number is the single sample limit - compare to the "% meeting guideline" column.

[4]*E. coli* or *Enterococcus* is an acceptable indicator for Massachusetts Department of Public Health, EPA, and MADEP to assess suitability for swimming in freshwater.

[5]NOAA guideline.

3.4 Trends in water quality, 2008

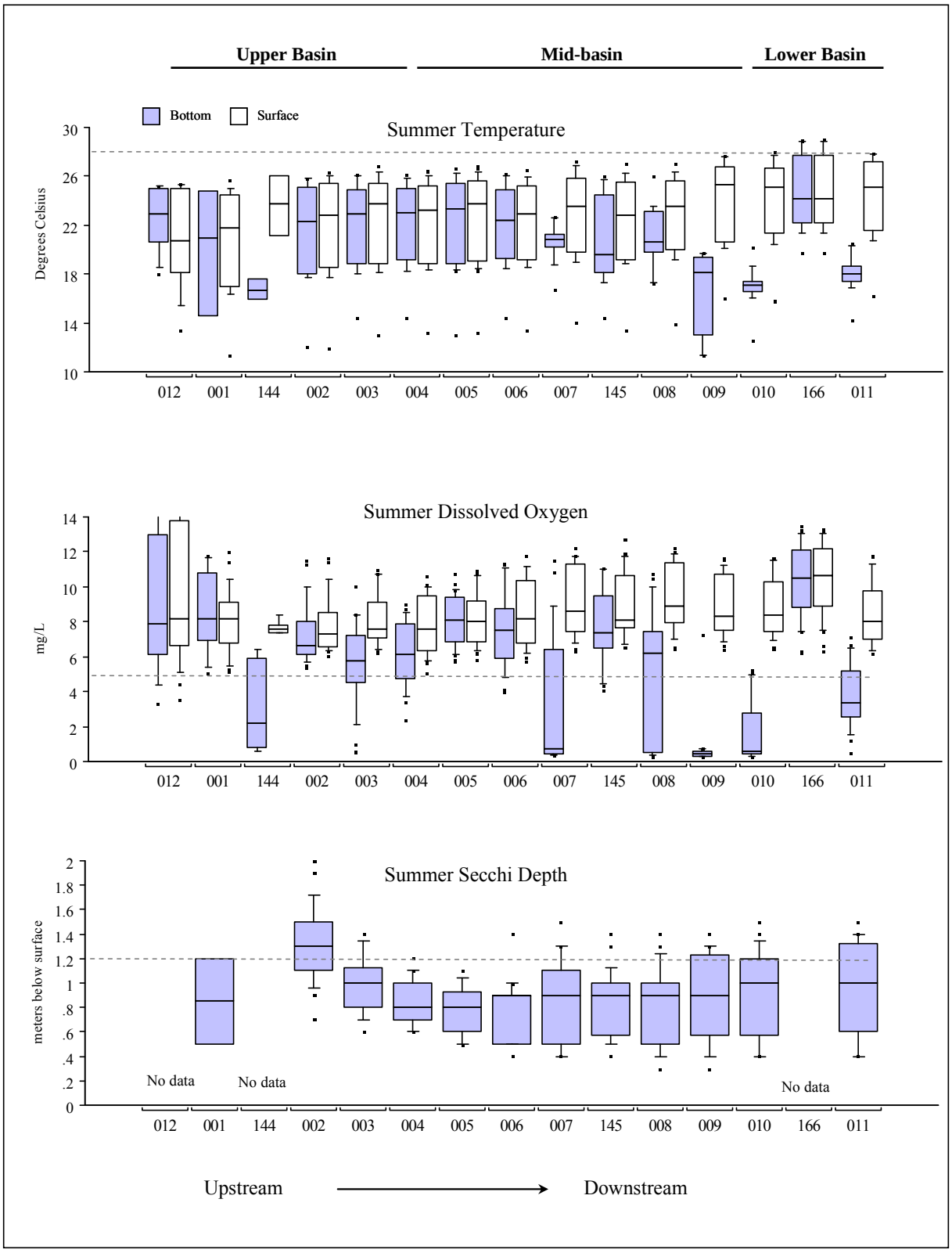
This section provides an analysis of trends for water quality parameters measured in the lower Charles in the 2008 monitoring year.

3.4.1 Physical measurements

Temperature. Summer mean temperatures for 2008 are shown for each sampling location in the top graph in Figure 3-2. Temperature profiles are relatively consistent upstream to downstream, with bottom-water temperatures relatively low in the deepest stations, 009 and 010, where depths average 6 to 7 meters (20 to 23 feet). Station 166 is collected in a shallow location in the basin near the Science Museum where differences in surface and bottom temperatures are slight.

Dissolved Oxygen. The spatial trend in dissolved oxygen (DO) in the Charles Basin differs for surface and bottom waters, shown in the center graph of Figure 3-2. Mean surface DO meets the State standard of 5.0 mg/L at all locations at the surface, but mean bottom water DO consistently fails to meet meets the standard at most Mid- and Lower-Basin locations. Stratification (due to salt water intrusion through the river locks during the summer months, as well as cooler bottom temperatures) results in extremely low bottom-water dissolved oxygen in the lower basin area near the Longfellow Bridge (Stations 009 and 010). Station 166, downstream of the lower basin, is collected at a relatively shallow near-shore location and does not reflect the low levels of deeper water. Station 011 has the highest bottom water salinity of any of the locations (data not shown), but does have slightly higher dissolved oxygen levels than basin locations located further upstream – likely reflecting the influence of more highly oxygenated ocean water infiltrating the New Charles Dam.

Water clarity. Water clarity is indicated by Secchi disk depth. Summer (June through September) Secchi results shown for individual sampling locations in the bottom graph in Figure 3-2. (Because of its shoreline location, Secchi disk depths are not measured at Station 166). In general, there is a pattern of increasing water clarity from upstream to downstream. Most Secchi depths average approximately 1.0 meter in the summer months, which fails to meet the State guideline of 1.2 meters.



0

Figure 3-2. Summer temperature, dissolved oxygen, and Secchi depth, Charles River Basin, 2008.

Dashed lines are State standards (maximum for temperature, minima for DO and Secchi).
No Secchi data is available for Station 012 because of its shallow depth; it is visible to bottom.

3.4.2 Nutrients, TSS and chlorophyll

Monthly averages for total nitrogen, ammonium, nitrate/nitrite, total phosphorus, phosphate, total suspended solids, and chlorophyll *a* at the upstream (012) and downstream (166) locations in the lower Charles are shown in Figure 3-3 and Figure 3-4, respectively. Nutrient monitoring began in 1997, immediately-+- prior to the latest phase of the CSO plan used in this report. There is no evidence of a trend in nutrient or clarity measures since monitoring began.

However, in the shorter term, results do show strong seasonal trends. Seasonal signals are most evident with nitrate+nitrite, total phosphorus/phosphate, and chlorophyll *a*. While the two locations show similar concentrations for most parameters, there are marked differences between the two stations for ammonium, total suspended solids and chlorophyll *a*. Total suspended solids increases in the spring months at Station 012, but there is a less dramatic increase downstream of the lower basin at Station 166.

Trends for the 2008 monitoring year are similar to the 2003-2006 averages, although chlorophyll *a* and total suspended solids at Watertown Dam (Station 012) were lower than average. The Science Museum location (Station 166) had below average concentrations for ammonium for the year, but an increase in total phosphorus, total nitrogen, and total suspended solids in early autumn.

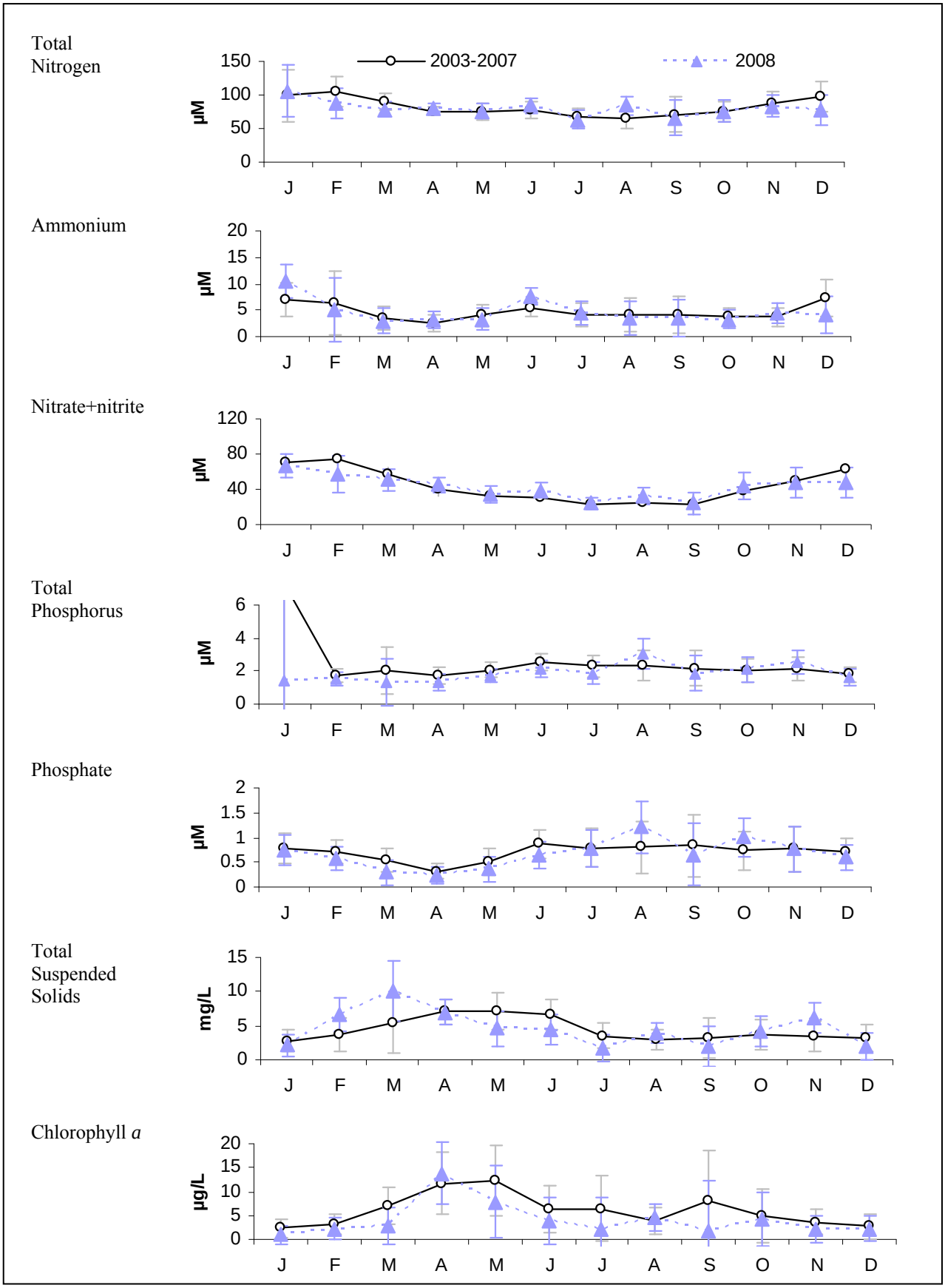


Figure 3-3. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Station 012, Watertown Dam.

Error bars are ± 1 SD.

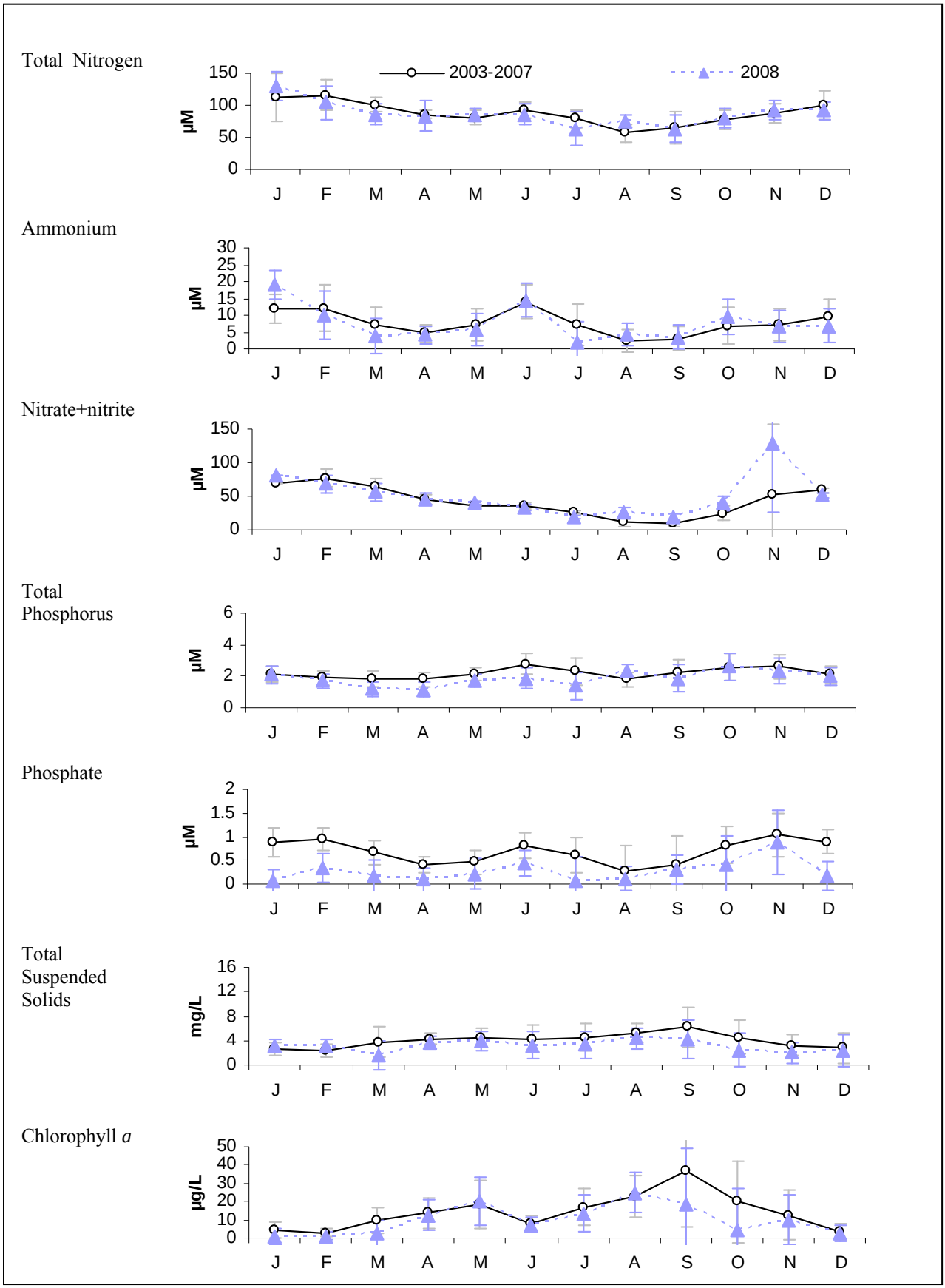


Figure 3-4. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Station 166, Science Museum.

Error bars are ± 1 SD.

3.4.3 Bacterial water quality

Figure 3-5 shows the current bacterial water quality at each location sampled in the Charles for 2008. Bacterial water quality in the Charles varies upstream to downstream, with upstream reaches generally having more elevated bacteria counts than downstream locations.

Geometric means for each location for 2003 – 2008 appear in Table 3-5. Geometric means for 2008 are shown in a separate column from 2003-2007 results. If confidence intervals for the two periods overlap, this indicates no statistically significant difference between the two means ($\alpha = 0.95$).

Enterococcus. The uppermost graph in Figure 3-5 shows percentile plots of *Enterococcus* counts arranged from upstream to downstream locations for 2008. Figure 3-6 shows the impact of rainfall on the three river reaches on *Enterococcus* densities, along with the change at locations near CSO outfalls. All reaches show a similar pattern, with wet weather mean counts generally higher than in dry weather.

The change in *Enterococcus* concentrations since 1989 in the Upper Charles Basin (upstream of CSO influences) and the lower Charles (including the Mid- and Lower-Basin locations) appear in Figure 3-7 and Figure 3-8. Results are grouped by phases of the Long Term CSO Plan improvements and include the geometric mean counts in each rainfall condition. These figures show change over time in both regions, with statistically significant improvement in water quality, particularly in the latest phase (2000 – 2008, $F = 219.5$, d.f. 2 , $p < 0.0001$, ANOVA). The Upper Basin shows improvement in both dry and wet conditions but does not yet consistently meet the geometric mean swimming standard. The most pronounced change is in the lower Charles, which meets the geometric mean swimming standard in all but heavy rain. Since the mid-1990s, the greatest improvement in bacterial water quality was in heavy rain, with less improvement in other conditions.

E. coli. The bottom graph in Figure 3-5 shows percentile plots of *E. coli* counts arranged from upstream to downstream locations for 2008. Generally, *E. coli* shows the same spatial trend as *Enterococcus*, with more elevated bacteria counts upstream relative to downstream locations. However, except for the lower basin, locations failed to meet the geometric mean of 126 colonies/100 mL, in contrast to *Enterococcus* geometric means, which are well within the swimming standard for *Enterococcus*. *E. coli* counts were more elevated at several locations in 2008 because of a large number of rain events compared to previous years; there was an 80% increase in rainstorms exceeding 0.5 inches in 2008 compared to 2007 (National Weather Service daily rain data).

Fecal coliform. Fecal coliform monitoring was replaced with *E. coli* beginning in mid-2001. No fecal coliform samples were collected in the Charles River in 2008.

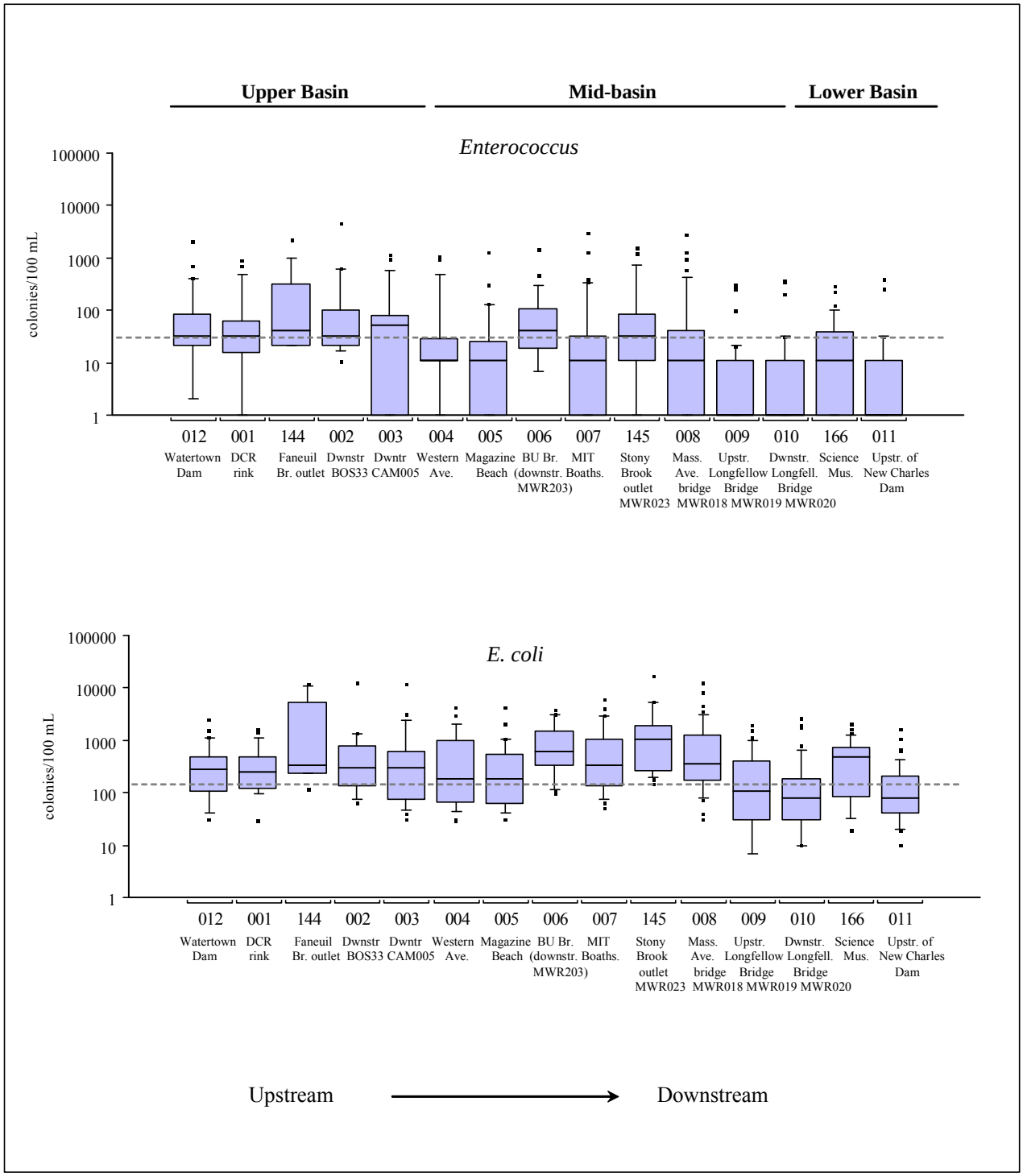


Figure 3-5. Indicator bacteria concentrations, Charles River Basin, 2008.

Dotted lines show MADEP *Enterococcus* and *E. coli* standard.

Table 3-5. Geometric mean indicator bacteria, Charles River Basin, 2003 – 2008.

Station	Location	Surface or Bottom	Number of samples[1]	*Enterococcus* (95% CI)		*E. coli* (95% CI)	
				2003 – 2007	2008	2003 – 2007	2008
012	Newtown/Watertown, footbridge upstream of Watertown Dam	S	160/26 160/29	92 68-124)	33 (16-68)	182 (147-224)	235 (150-370)
001	Newton, near Nonantum Rd., rear of DCR skating rink	S	79/20 79/21	85 (47-154)	28 (12-66)	281 (199-396)	266 (173-408)
144	Brighton, downstream of N. Beacon St. bridge, Faneuil Brook outlet, BOS-032 (closed 1999)	S	37/15 37/6	195 (90-423)	76 (27-210)	315 (134-741)	943 (409-2172)
002	Allston, downstream of Arsenal Street bridge, BOS-033	S	47/21 47/21	26 (13-52)	49 (23-104)	196 (142-271)	341 (198-587)
003	Allston/Cambridge, midstream, near Mt. Auburn Street, between CAM-005 and CAM-006	S	47/21 47/21	25 (12-48)	20 (6-57)	137 (95-198)	301 (158-573)
004	Allston/Cambridge, midstream, between River Street and Western Avenue bridges	S	47/21 47/21	16 (8-31)	16 (6-37)	60 (33-109)	241 (127-455)
005	Cambridge, near Magazine Beach, upstream of Cottage Farm	S	159/28 159/21	29 (21-41)	10 (4-21)	132 (105-166)	186 (113-304)
006	Cambridge/Boston, midstream, downstream of Cottage Farm, BU bridge	S	109/21 109/21	44 (29-65)	37 (17-79)	196 (155-249)	646 (405-1029)
007	Cambridge, near Memorial Dr., MIT Boathouse	S	107/21/107/21	17 (11-25)	9 (3-23)	95 (69-131)	278 (130-595)
		B	106/21/106/21	34 (22-51)	20 (8-50)	159 (123-207)	506 (284-901)
145	Boston (Charlesgate), Muddy River/Stony Brook outlet	S	107/21/107/21	46 (30-70)	26 (10-66)	214 (154-298)	926 (523-1640)
008	Cambridge/Boston, midstream, downstream of Harvard Bridge	S	107/21/107/21	14 (9-21)	11 (4-31)	73 (52-102)	396 (213-737)
		B	106/21/106/21	23 (14-35)	11 (3-34)	117 (85-161)	477 (251-909)
009	Cambridge/Boston, midstream, upstream of Longfellow Bridge near Community Sailing	S	108/21/108/21	10 (6-15)	5 (1-12)	51 (37-71)	197 (96-405)
		B	106/21/106/21	7 (5-11)	0 (0-1)	13 (9-19)	34 (14-81)
010	Boston, downstream of Longfellow Bridge, MWR-022	S	107/21/106/21	7 (4-10)	3 (1-7)	38 (27-54)	110 (53-228)
		B	107/21/107/21	5 (3-7)	2 (1-6)	10 (7-14)	55 (27-110)
166	Boston, old Charles River dam, rear of Science Museum	S	159/31/159/31	11 (7-16)	6 (2-13)	65 (49-87)	242 (135-435)
011	Boston, upstream of river locks (New Charles River Dam) and I-93, near Nashua St.	S	109/21/109/21	9 (6-13)	2 (0-4)	40 (31-51)	87 (45-166)
		B	108/21/108/21	16 (12-21)	5 (2-13)	34 (26-45)	90 (55-145)

[1]N values for *Enterococcus* and *E. coli* for the 2003-2007 and 2008 periods, respectively.

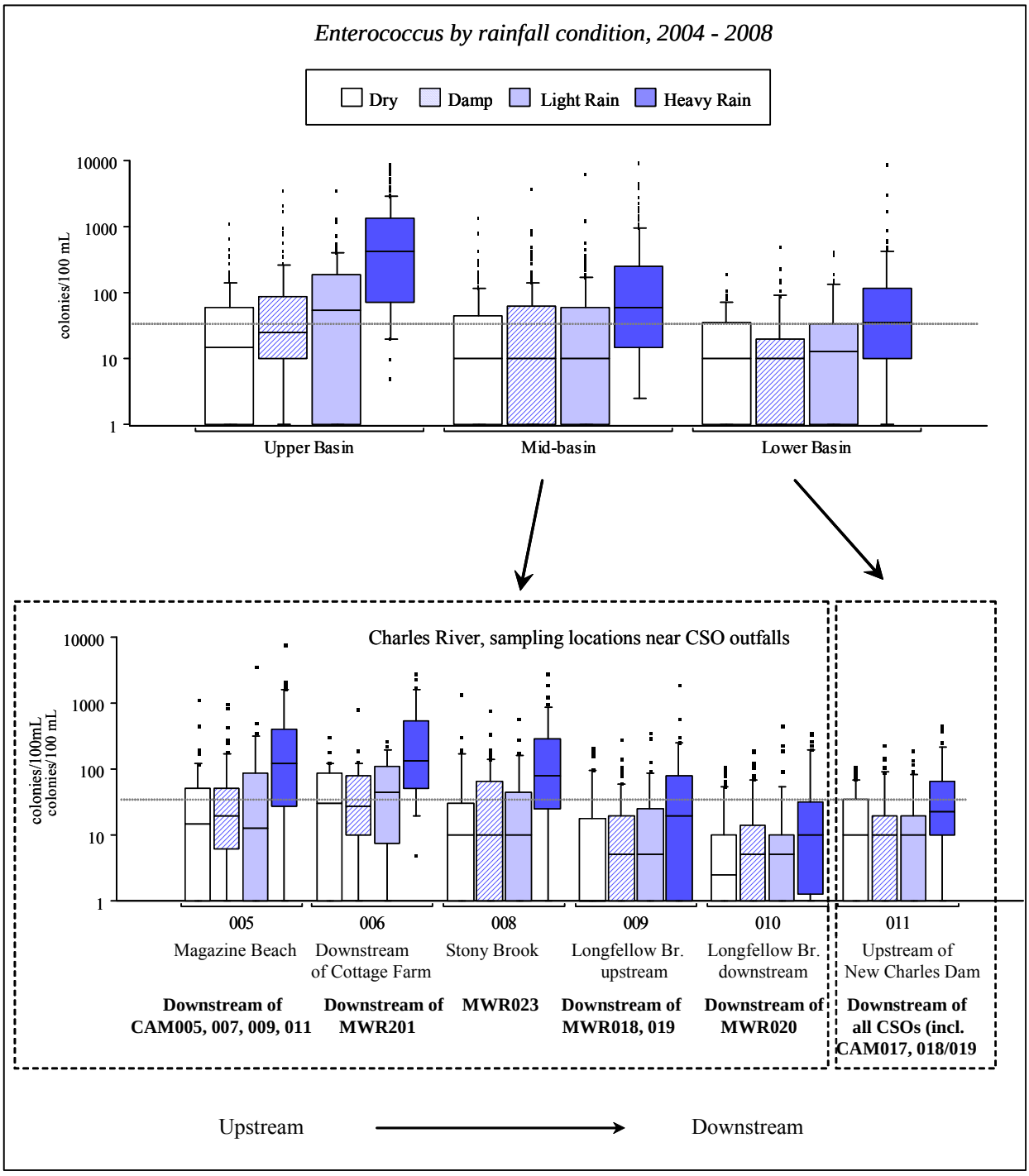


Figure 3-6. *Enterococcus* by rainfall condition, Charles Basin, 2003 - 2008.

Dotted line shows MADEP standard of 33 colonies/100 mL. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

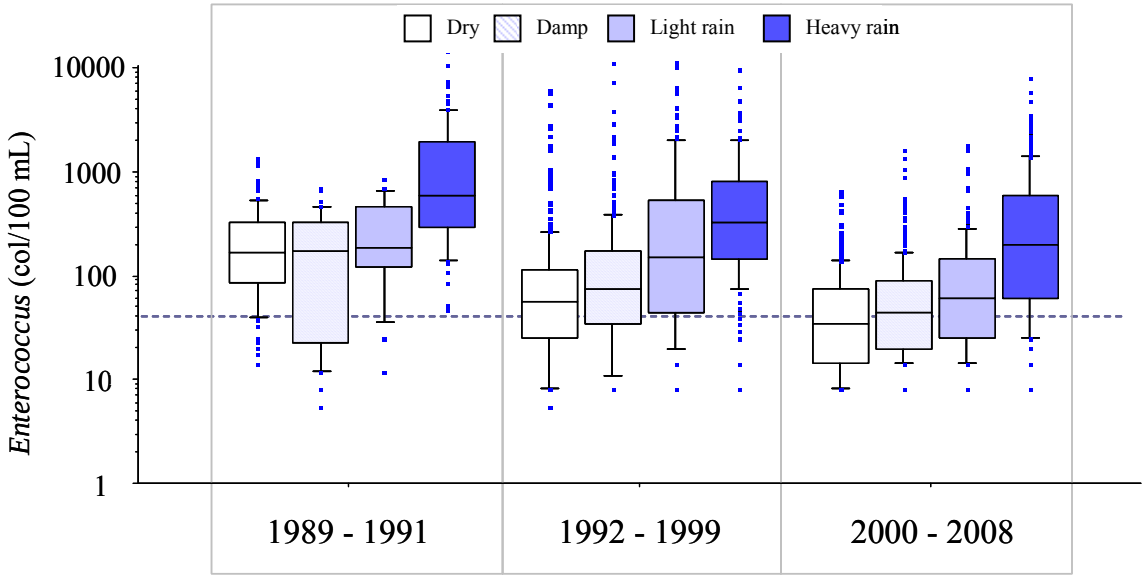


Figure 3-7. *Enterococcus* over time, Upper Charles Basin (upstream of CSOs) by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for stations 012, 001, 002, 003. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

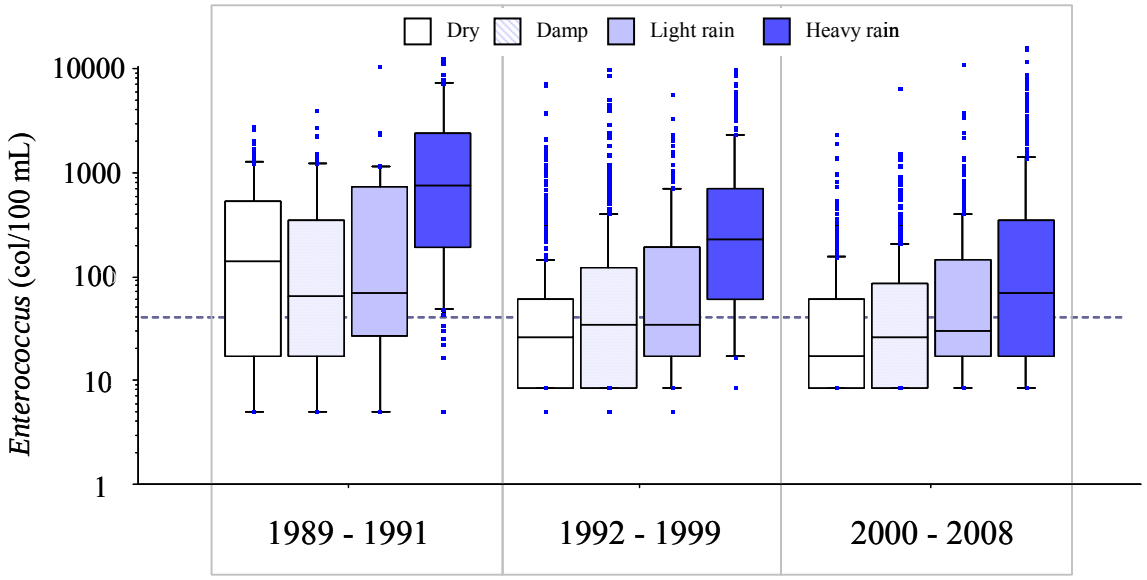


Figure 3-8. *Enterococcus* over time, Lower Charles Basin by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for all stations downstream of Western Ave (Station 004). Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

3.5 Summary of Charles River Water Quality

2008 was a particularly wet year; 2008 rainfall was significantly greater than Typical Year estimates (according to MWRA's CSO Control Plan Model Simulation results), and greater than 2007. The bacterial water quality reflects this, with a decline in bacterial water quality for 2008 at all but one location in the monitoring area for *E. coli*. Consistent with previous years, bacterial water quality in the Charles is poorer at upstream locations, and improves as the river widens and slows in the Lower Basin and approaches the New Charles Dam. The lower basin locations were stratified in summer, resulting in relatively low bottom water temperatures and extremely low bottom water dissolved oxygen. Seawater continues to enter through the Charles locks in summer, contributing to stratification of the basin, limiting exchange with surface waters.

Nutrients and chlorophyll exhibited strong seasonal and spatial signals, with chlorophyll *a* and ammonium more elevated downstream than upstream in summer months, and total suspended solids more elevated upstream than downstream in spring months. Total nitrogen and total phosphorus are similar in both upstream and downstream locations. Nutrient parameters were largely consistent with long-term averages at both locations in 2008.

4 Mystic River and Alewife Brook

4.1 Sampling area

Monitoring results of the Mystic River are divided into four reaches. Table 4-1 describes the reaches and the sampling locations within each reach. Locations are shown on the map in Figure 4-1.

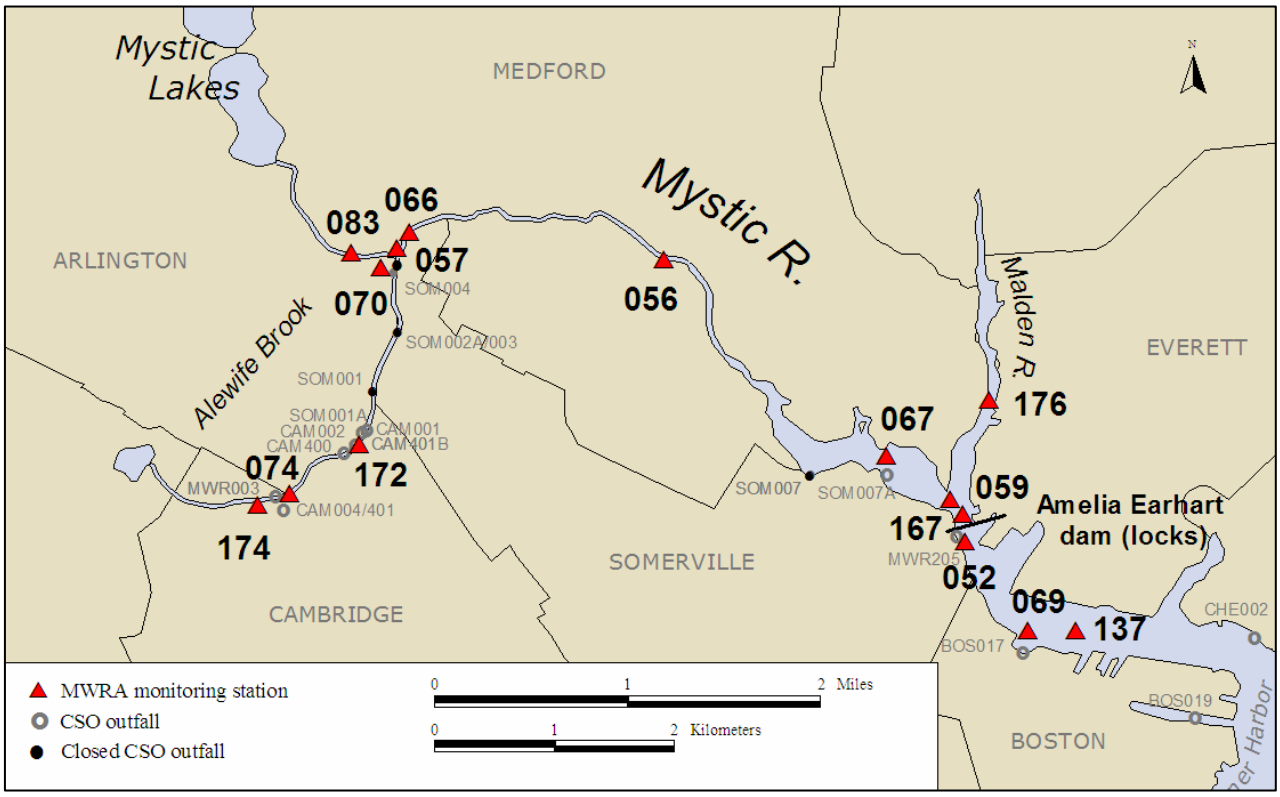


Figure 4-1. Map of Mystic River sampling locations.

4.2 Pollution sources

Known pollution sources to the Mystic River/Alewife Brook are shown in Table 4-2 and consist of stormwater, upstream inputs and CSOs. Nine CSOs are located in Cambridge and Somerville, including eight active CSOs in Alewife Brook, and one treated CSO in the Lower Mystic basin (Somerville Marginal CSO, MWR205A/SOM007A), which discharges only during an activation at high tide. At low tide, the Somerville Marginal CSO (MWR205) discharges downstream of the Amelia Earhart dam, screening and chlorinating CSO flow before discharge. It is the only source of treated CSO discharge to the Mystic River. For calendar year 2008, Somerville Marginal 205A/SOM007A had six discharge events, and Somerville Marginal 205 had 27 activations resulting in discharge. The Alewife Brook is the primary source of contaminated flow to the lower Mystic River, in both dry and wet weather.

Table 4-3 summarizes the proportion of samples collected in dry, damp, and wet weather between 2003 and 2008.

Table 4-1. MWRA monitoring locations, Mystic River and Alewife Brook.

Reach	Description of Reach	Sampling location	Location Description
Alewife Brook (Class B/Variance, warm water fishery)	Tributary to Mystic River. From confluence at Little River in Cambridge/Arlington to confluence with Mystic River in Arlington/Somerville	174, Cambridge/Arlington	Little River, upstream of Rt. 2 and off ramp to Alewife T station. Upstream of all CSOs.
		074, Cambridge/Arlington	Downstream of CAM001A, CAM004, MWR003
		172, Cambridge/Arlington	Downstream of CAM001, CAM002, CAM400, CAM401B, SOM001A
		070, Arlington/Somerville	Mystic Valley Parkway bridge. Downstream of all Alewife CSOs
Upper Mystic River (Class B/Variance, warm water fishery)	Downstream of Lower Mystic Lake in Arlington/Medford to Route 28 bridge in Medford	083, Arlington/Medford	Upstream of confluence of Mystic River and Alewife Brook
		057, Medford	Confluence of Mystic River and Alewife Brook
		066, Medford	Boston Ave bridge, downstream side
		056, Medford	Upstream of I-93 bridge, near Medford Square off ramp
Lower Mystic River basin (Class B/Variance, warm water fishery)	Route 28 bridge in Medford to Amelia Earhart Dam in Somerville/Everett	177, Medford	Downstream of Rt. 16 bridge
		067, Medford	Rt. 28 bridge, downstream side, near Somerville Marginal MWR205A outfall
		176, Medford/Everett	Malden River, upstream of Rt. 16 bridge
		059, Somerville/Everett	Confluence of Mystic and Malden Rivers
		167, Somerville/Everett	Amelia Earhart Dam, upstream side
Mystic River mouth (Class SB/CSO, marine)	Downstream of Amelia Earhart Dam in Somerville/Everett to Tobin Bridge, Chelsea R. confluence in Chelsea/East Boston	052, Somerville	Downstream of Amelia Earhart dam, near Somerville Marginal CSO facility outfall (MWR205)
		137, Charlestown/Everett	Upstream of Tobin Bridge near confluence of Mystic, Chelsea Rivers and upper inner harbor

Sampling locations are midstream unless otherwise noted.

Table 4-2. Mystic River/Alewife Brook pollution sources.

Source	Alewife Brook	Upper Mystic River	Lower Mystic Basin	Mystic River mouth
CSOs (untreated)	8 active, 5 closed CAM401A, MWR003, CAM001, CAM401B, CAM002, SOM001A *CAM004, CAM400 to be closed* SOM001 closed 12/96 SOM002 closed 1994 SOM002A closed 8/95 SOM003 closed 8/95 SOM004 closed 12/95	2 closed SOM006 closed 12/96 SOM007 closed 12/96	None	1 active BOS017
CSO treatment facility (screened, chlorinated and dechlorinated CSO discharge)	No	No	Yes Somerville Marginal (MWR205A/SOM007A, high tide only) Activated 6 times in 2008	Yes Somerville Marginal (MWR205) Activated 27 times in 2008
Storm drains	Yes	Yes	Yes	Yes
Upstream inputs (elevated bacteria counts upstream)	Yes	Yes	Yes	Yes
Dry weather inputs (elevated bacteria counts in dry weather)	Yes	Yes	Yes	Yes
Tributary brook or stream flow	Yes	Yes	Yes	Yes

Table 4-3. Mystic River/Alewife Brook sample collection by rainfall condition.

Sampling period	Dry[1]	Damp[1]	Wet[1]	Total
2003-2007	37% 1079 samples	32% 926 samples	41% 1181 samples	100% 3186 samples
2008	32% 200 samples	39% 240 samples	29% 183 samples	100% 623 samples

[1] Dry: no rainfall for previous 3 days; Wet: at least 0.5 inches in previous 2 days; Damp is everything in between. Sampling is random with respect to weather, though if needed wet weather sampling is added late in the year to maintain a representative annual sample of wet weather.

4.3 Summary of water quality, 2004-2008

A detailed summary of water quality results collected from the last five years is shown in Table 4-4.

Table 4-4. Summary of water quality, Mystic River/Alewife Brook 2004 – 2008.

Parameter		Water Quality Guideline or Standard	Alewife Brook				Upper Mystic				Lower Mystic Basin				Malden River				Mystic Mouth			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Surface Temperature (°C)[1]	Summer	<28.3	18.3 ± 4.1	100.0	7.3 - 25.9	349	20.5 ± 4.2	99.5	9.3 - 28.4	629	20.5 ± 4.3	100.0	8.8 - 27.8	546	20.2 ± 4.1	99.0	9 - 29.5	193	16.9 ± 2.7	100.0	10.4 - 23.1	209
	Winter		5.8 ± 1.5	100.0	3.8 - 8.1	14	3.1 ± 1.8	100.0	-0.6 - 7.6	60	3.9 ± 1.8	100.0	0.7 - 8.4	81	ND	ND	ND	0	3 ± 1.6	100.0	-0.7 - 6	43
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	4.5 ± 1.9	37.8	1.1 - 10.2	347	6.7 ± 1.5	87.0	0.1 - 11.7	630	7.6 ± 2.6	85.7	0.1 - 14.7	545	5.4 ± 3.9	59.8	0 - 14.1	189	6.5 ± 1.3	89.4	3.5 - 10.7	207
	Winter	5.0	10 ± 0.7	100.0	8.2 - 11.2	14	11.6 ± 1.1	100.0	8 - 13.5	60	11.7 ± 1.2	100.0	5.9 - 13.6	81	ND	ND	ND	0	10.2 ± 0.8	100.0	8.6 - 11.9	43
pH (S.U.)		6.5-8.3 (8.5 marine)	7.1 ± 0.3	7.1 ± 0.2	98.9	6.4 - 8.3	531	7.5 ± 0.3	97.8	6 - 8.8	942	7.7 ± 0.6	84.8	6.2 - 10	880	7.5 ± 0.7	86.1	6 - 9.7	245	7.8 ± 0.2	98.6	7.1 - 9.4
Water clarity	Total Suspended Solids (mg/L)	NS	ND	-	ND	0	4.6 ± 2.8	-	0.2 - 15.2	236	7 ± 2.9	-	0.9 - 16.7	107	ND	-	ND	0	3 ± 1.4	-	0.2 - 9.9	186
	Secchi depth (m)	NS	0.5 ± 0.1	-	0.3 - 0.7	21	1.4 ± 0.7	-	0.1 - 4	197	0.8 ± 0.2	-	0.3 - 1.5	239	0.8 ± 0.2	-	0.4 - 1.8	110	2.4 ± 0.9	-	0.5 - 5.5	169
	Turbidity (NTU)	NS	14.4 ± 8.9	-	2.4 - 58.5	65	6.4 ± 4.8	-	0.8 - 42	523	11.9 ± 5.7	-	0.8 - 31.3	391	10.5 ± 6.3	-	0.4 - 49	188	4.5 ± 3.9	-	0 - 26.1	254

Table 4-4. Summary of water quality, Mystic River/Alewife Brook 2004 – 2008, continued.

Parameter		Water Quality Guideline or Standard	Alewife Brook				Upper Mystic				Lower Mystic Basin				Malden River				Mystic Mouth			
			Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n	Mean ± SD	% meeting guideline	Range	n
Bacteria (col/100mL)[2]	Fecal coliform	200 / 400[3]																	558 (79-3896)		0 - 23000	80
	E. coli	126 / 235[3,4]	512 (458-572)	25.6	10 - 36000	507	86 (75-99)	74.2	0 - 27000	631	48 (40-57)	81.3	0 - 12400	459	63 (44-88)	74.6	0 - 10800	138	29 (21-38)	84.1	0 - 19900	276
	Enterococcus	33 / 61[3]	257 (219-301)	17.9	0 - 22000	503	35 (30-41)	62.4	0 - 18500	628	10 (8-12)	80.5	0 - 4800	461	20 (13-29)	72.7	0 - 9000	139	6 (5-8)	83.7	0 - 4500	355
Nutrients (µmol/L)	Phosphate	NS	ND	-	ND	0	0.47 ± 0.34	-	0.01 - 2.51	236	0.36 ± 0.29	-	0.01 - 1.53	106	ND	-	ND	0	0.81 ± 0.38	-	0 - 2.45	184
	Ammonium	NS	ND	-	ND	0	12.8 ± 11.7	-	0 - 48	236	10.7 ± 10.7	-	0.1 - 40.7	106	ND	-	ND	0	4.2 ± 3.9	-	0 - 19.1	184
	Nitrate+nitrite	NS	ND	-	ND	0	48.4 ± 27	-	0.3 - 90.7	236	38.3 ± 25.6	-	0 - 77.8	106	ND	-	ND	0	8.2 ± 8.5	-	0.1 - 47.4	184
Algae (µg/L)	Chlorophyll *a*	25[5]	ND	ND	ND	0	8.6 ± 6	98.7	0.2 - 30	236	25 ± 19.4	58.9	2 - 107	107	ND	ND	ND	0	3.4 ± 4.2	100.0	0.3 - 22.1	188

NS: no standard or guideline. ND: No data. [1]: Summer (June-September), Winter (December-March).

[2]For bacterial data, 95% confidence intervals are provided in lieu of standard deviations.

[3]First number is the all samples geometric mean limit - compare to the "Mean±SD" column; the second number is the single sample limit - compare to the "% meeting guideline" column. For marine locations, fecal coliform replaced *E. Coli* in marine waters in 2008 for methodological reasons.

[4]*E. coli* or *Enterococcus* are acceptable indicators for Massachusetts Department of Public Health and MADEP to assess suitability for swimming in fresh water.

[5]NOAA guideline.

4.4 Trends in water quality, 2008

This section reports spatial trends for water quality parameters measured in the Mystic River in the 2008 monitoring year.

4.4.1 Physical measurements

Temperature. Summer mean temperatures for 2008 are shown for each sampling location in the top graph of Figure 4-2. Temperatures are lowest in the Alewife Brook and at the river mouth, where the river meets Boston Harbor. Surface and bottom temperatures are similar, except in the downstream reach near the dam where the river deepens, with depths averaging more than 6 meters (19 feet).

Dissolved Oxygen. The spatial trend in dissolved oxygen in the Mystic Basin is similar for surface and bottom waters, except in the most downstream Lower Basin/Malden River locations, shown in the center graph of Figure 4-2. Mean surface and bottom dissolved oxygen are well above the State standard of 5.0 mg/L in much of the river, but fail to meet the standard in the downstream bottom-water portions of Alewife Brook, Malden River, and upstream of the Amelia Earhart dam. Bottom-water dissolved oxygen is lowest at the Malden River location, Station 176.

Unlike the Charles River, there is little evidence of stratification in the lower portion of the Mystic due to saltwater intrusion. The elevated summer surface DO values indicate eutrophic conditions in this area of the river. MWRA sampling crews routinely report significant algae blooms in this area in midsummer. The relatively good DO values (and lower chlorophyll *a* values, see Figure 4-3) at nearby upstream locations in the Mystic Basin implicate the Malden River as a source of eutrophication in the area immediately upstream of the Amelia Earhart Dam (station 059 is at the confluence of the Malden and Mystic Rivers and conditions show the influence of both tributaries).

Water clarity. Water clarity is indicated by Secchi disk depth; shown for individual sampling locations in the bottom graph of Figure 4-2. In general water clarity is poor, with nearly all stations failing to meet the guideline of 1.2 meters. (Alewife Brook is too shallow to collect Secchi depth readings.) Clarity downstream of the Amelia Earhart dam improves markedly as the river flows are diluted by Boston Harbor water.

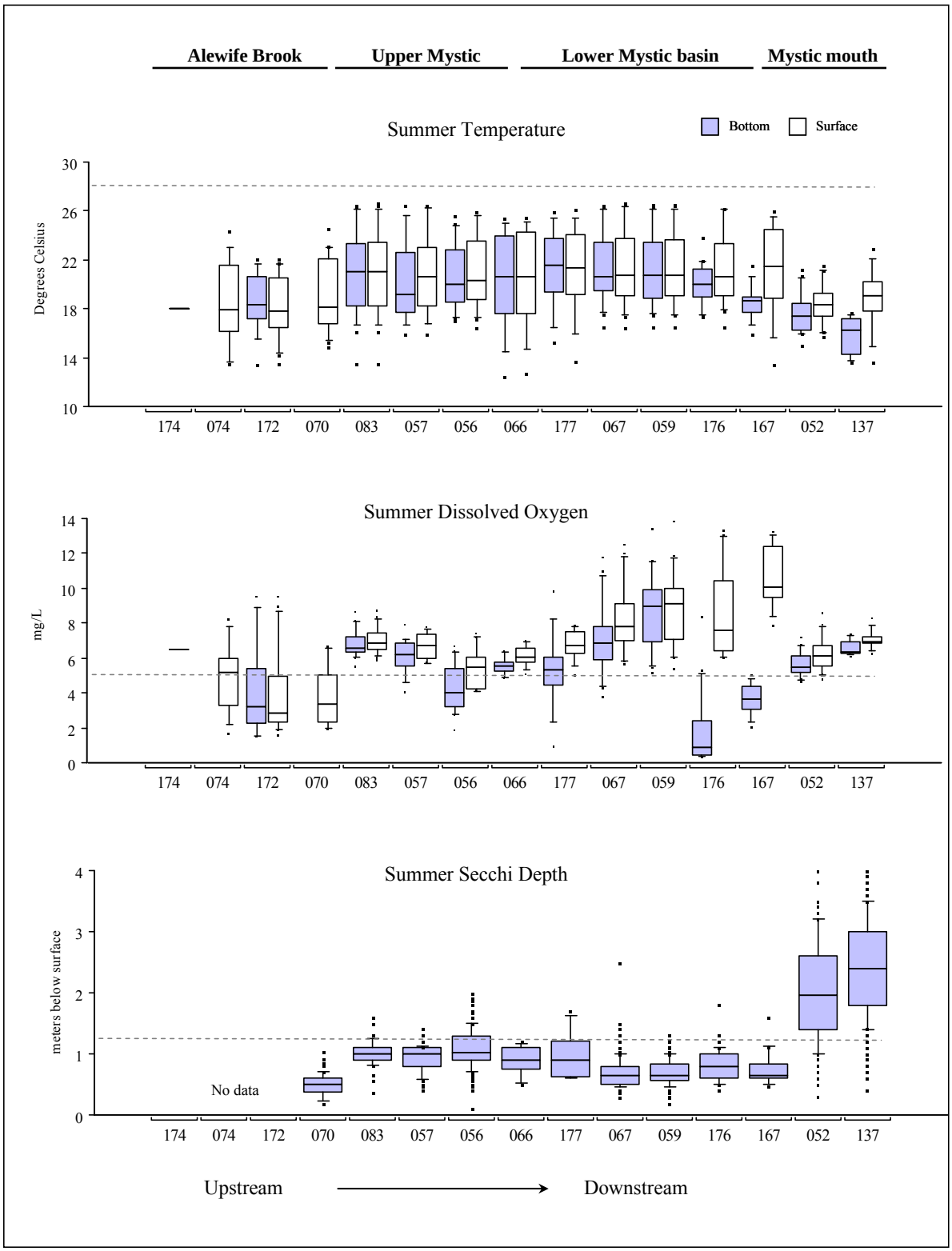


Figure 4-2. Summer temperature, dissolved oxygen, and Secchi depth, Lower Mystic, 2008.

Dashed lines are State standards. Fewer results are available for the upper Alewife Brook because upstream locations are often too shallow for measurements in the summer months.

4.4.2 Nutrients, TSS and chlorophyll

Monthly average total nitrogen, ammonium, nitrate/nitrite, total phosphorus, orthophosphate, total suspended solids, and chlorophyll *a* at the upstream locations (083 upstream of Alewife Brook and 066 at Boston Ave.), downstream (167 at Amelia Earhart Dam) and river mouth (137) locations are shown in Figure 4-3 through Figure 4-6. These results show strong seasonal trends. The nitrogen parameters drop substantially in summer months, and chlorophyll *a* and TSS increase. Station 167, immediately upstream of the dam, is more eutrophic than either upstream or at the mouth of the river, with increases in chlorophyll *a* in the warm weather months. 2008 results were near 2003-2007 averages for most nutrient parameters, with the exception of below-average TSS and chlorophyll *a* at the upstream locations.

In the cold weather months, when biological nutrient uptake is low, ammonium concentrations in the Mystic are more than twice as high in the Upper Mystic as in the Charles Basin. Nutrient concentrations on the marine side of the dam are generally much lower than upstream, particularly for nitrogen, chlorophyll, and total suspended solids. Increased ammonium concentrations for the last half of 2008 at the river mouth may reflect increased wet weather runoff, originating from upstream sources.

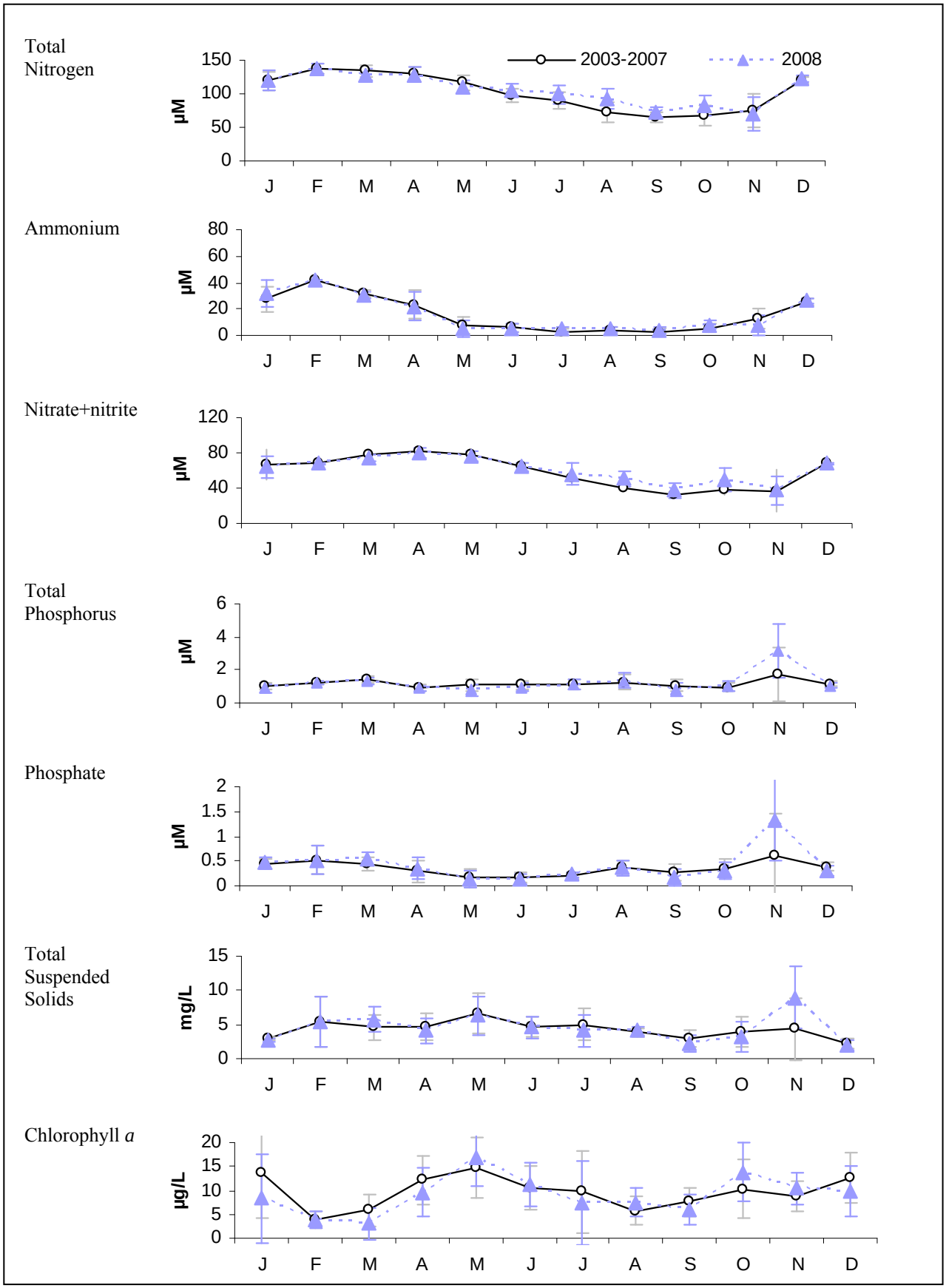


Figure 4-3. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Station 083 (upstream of Alewife Brook)

Error bars are ± 1 SD.

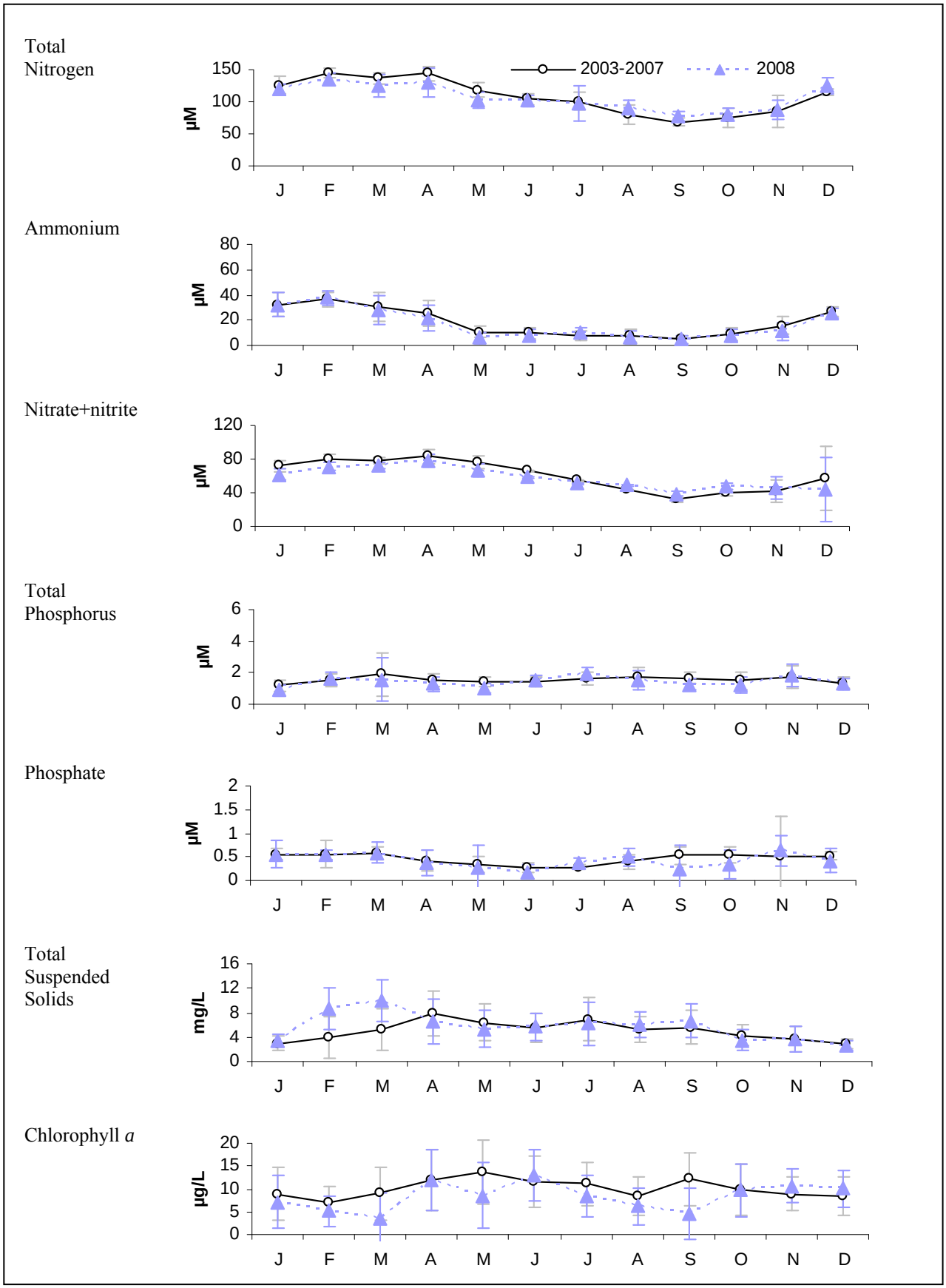


Figure 4-4. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Station 066 (Boston Ave.)

Error bars are ± 1 SD.

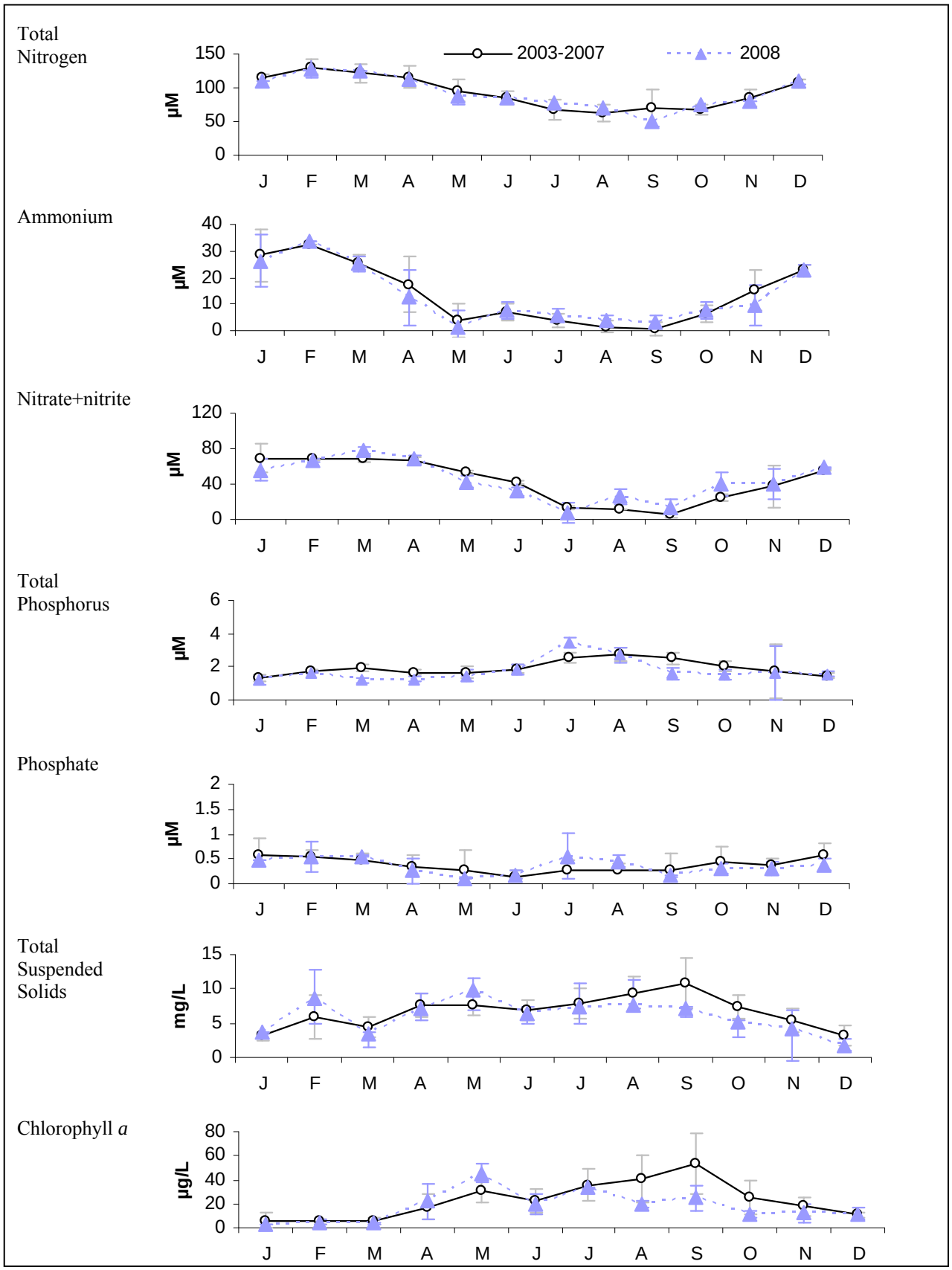


Figure 4-5. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Station 167 (Amelia Earhart Dam (upstream/freshwater)).

Error bars are ± 1 SD.

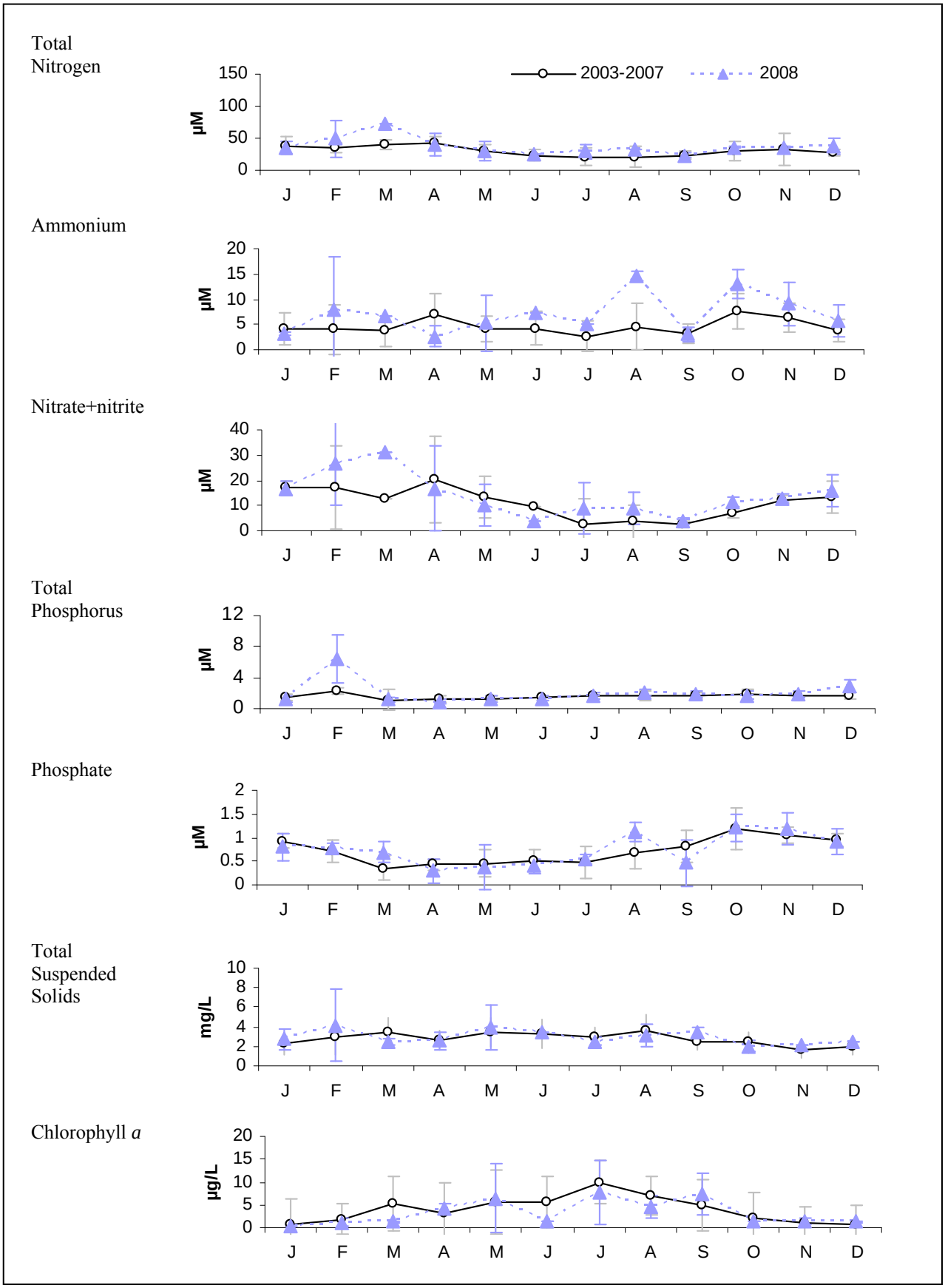


Figure 4-6. Monthly average nutrients, TSS and Chlorophyll 2003 – 2008, Station 137 Mystic River mouth (marine).

Error bars are ± 1 SD.

4.4.3 Bacterial water quality

Figure 4-7 shows the current bacterial water quality at each location sampled in the Mystic River and Alewife Brook for 2008. Alewife Brook has the highest bacteria counts, and counts gradually decrease downstream to the river mouth.

Geometric means for each indicator for all locations for 2003 – 2008 appear in Table 4-5.

Enterococcus. The uppermost graph in Figure 4-7 shows percentile plots of *Enterococcus* counts for each location, arranged from upstream to downstream for 2008. Figure 4-8 shows the impact of rainfall on the three river reaches on *Enterococcus* densities, along with the change at locations near CSO outfalls. For the 2003-2008 period (with results for all years combined), Alewife Brook locations consistently fail to meet standards, in both dry and wet weather, though conditions improve dramatically moving downstream to the river mouth. However, 2008 geometric means for the Alewife decreased significantly, and most Mystic River locations met *Enterococcus* swimming standards.

Figure 4-8 indicates little change in water quality from the most upstream location in the Alewife (upstream of all CSOs) to the most downstream location near Mystic Valley Parkway in both wet and dry weather.

The change in *Enterococcus* concentrations since 1989 in Alewife Brook and the Mystic River appear in Figure 4-8 and Figure 4-9. Results are grouped by phases of the Long Term CSO Plan improvements and include the geometric mean counts in each rainfall condition. These figures show little change over time in either the Alewife or the Mystic River in dry and wet weather since the early 1990's. However, Mystic River locations do generally meet geometric mean limits in dry and light rainfall conditions.

E. coli. The center graph in Figure 4-7 shows percentile plots of *Enterococcus* counts arranged from upstream to downstream locations for 2008. *E. coli* shows a similar trend to *Enterococcus*, with basin locations generally meeting the geometric mean limit of 126 colonies/100 mL. While not meeting standards, Alewife Brook showed a marked improvement, with geometric means falling dramatically compared to the previous five years. This is particularly noteworthy considering the relatively wet year, where other downstream locations had similar or slightly higher geometric mean concentrations compared to previous years.

Fecal coliform. Fecal coliform monitoring replaced *E. coli* in marine waters in 2008, due to methodological reasons. Fecal coliform is shown for the two marine locations, 052 and 137, which meet the former state geometric mean standard of 200 colonies/100 mL. Fecal coliform appears in the bottom graph in Figure 4-7. Station 052, at the Somerville Marginal outfall (205) has continued to show occasional impairment in a variety weather conditions; in July 2008, a count of 23,000 colonies/100 mL fecal coliform was measured during dry weather.

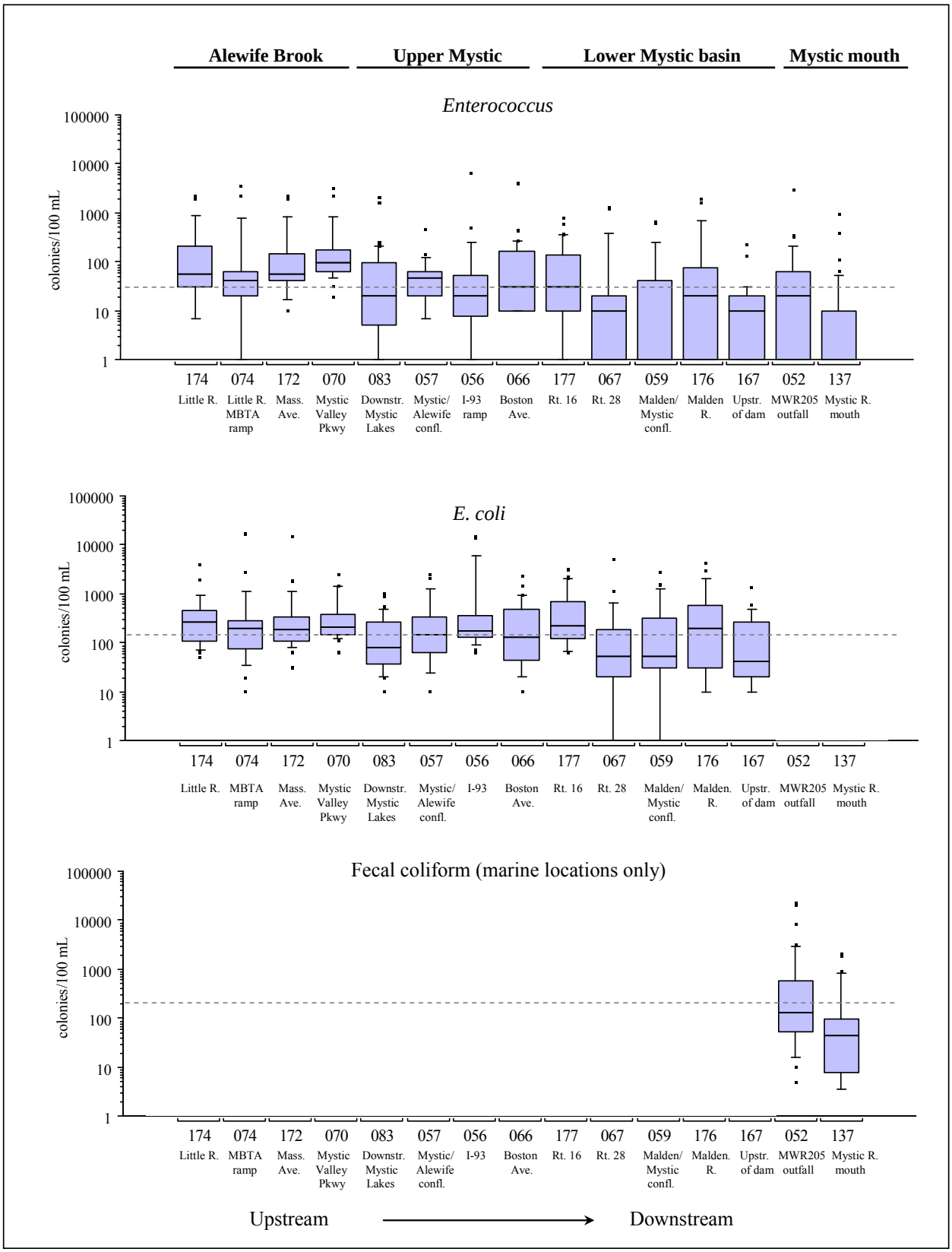


Figure 4-7. Indicator bacteria concentrations, Mystic River/Alewife Brook, 2008.

Dotted lines show MADEP *Enterococcus* and *E. coli* standard and former fecal coliform standard. *E. coli* testing was discontinued in 2008 in marine waters for methodological reasons.

Table 4-5. Geometric mean indicator bacteria, Mystic River, 2003 – 2008.

Station	Location	Surface or Bottom	Number of samples[1]	*Enterococcus* (95% CI)		*E. coli* (95% CI)	
				2003 - 2007	2008	2003 – 2007	2008
174	Cambridge, Little River, upstream of Rt. 2 and offramp to Alewife T station	S	111/22 112/22	337 (252-450)	63 (28-142)	643 (520-795)	258 (164-406)
074	Cambridge, Little River, at offramp to Alewife T station	S	133/22 134/22	345 (258-462)	29 (11-72)	709 (585-860)	184 (97-346)
172	Arlington, Alewife Brook, upstream of Massachusetts Ave bridge, midchannel	S	118/22 119/22	417 (323-538)	82 (47-145)	694 (561-858)	236 (137-407)
070	Arlington, Alewife Brook, off Mystic Valley Parkway bridge	S	134/48 136/48	456 (332-626)	127 (78-208)	591 (474-736)	274 (187-403)
083	Medford, upstream of confluence of Mystic River and Alewife Brook	S	148/48 149/48	40 (29-55)	19 (10-36)	62 (49-79)	89 (60-131)
057	Medford, confluence of Mystic River and Alewife Brook	S	108/22 108/22	62 (44-88)	31 (17-58)	88 (66-116)	138 (68-280)
056	Medford, Mystic River, upstream of I-93 bridge	S	98/21 98/21	72 (50-103)	20 (7-52)	281 (215-366)	290 (155-539)
066	Medford, Mystic River, Boston Ave bridge	S	149/26 150/26	86 (63-118)	35 (17-73)	124 (97-159)	132 (76-231)
177	Medford, Downstream of Rt. 16 bridge, mid-channel	S	128/22 127/27	28 (19-39)	26 (11-57)	100 (77-132)	292 (186-459)
067	Medford, Mystic River, Rt. 28 bridge	S	99/22 99/22	7 (5-11)	8 (3-21)	28 (19-40)	55 (22-137)
059	Everett, confluence of Mystic and Malden Rivers	S	99/22 99/22	6 (4-8)	4 (1-13)	23 (16-34)	56 (20-152)
176	Malden River, upstream of Rt. 16 bridge	S	101/22 101/22	21 (13-33)	14 (4-41)	56 (38-84)	135 (56-327)
167	Medford, Mystic River, upstream side of Amelia Earhart Dam	S	133/25 132/25	10 (6-15)	5 (2-10)	27 (19-39)	57 (28-118)
052[2]	Somerville, Mystic River, near Somerville Marginal CSO facility (MWR205)	S	126/21 126/21	37 (23-59)	25 (10-63)	182 (112-296)	*339* *(131-874)*
		B	94/17 95/17	14 (9-20)	4 (1-11)	36 (24-52)	*47 (26-87)*
137[2]	Mystic River, upstream of Tobin Bridge	S	122/18 122/18	8 (6-11)	6 (2-18)	34 (24-48)	*103* *(51-208)*
		B	120/18 122/18	2 (1-3)	1 (0-3)	3 (2-4)	*7 (3-13)*

[1]N values for *Enterococcus* and *E. coli* for the 2003-2007 and 2008 periods, respectively. [2]Results in italics are fecal coliform, not *E. coli. E. coli* testing was discontinued in 2008 in marine waters for methodological reasons.

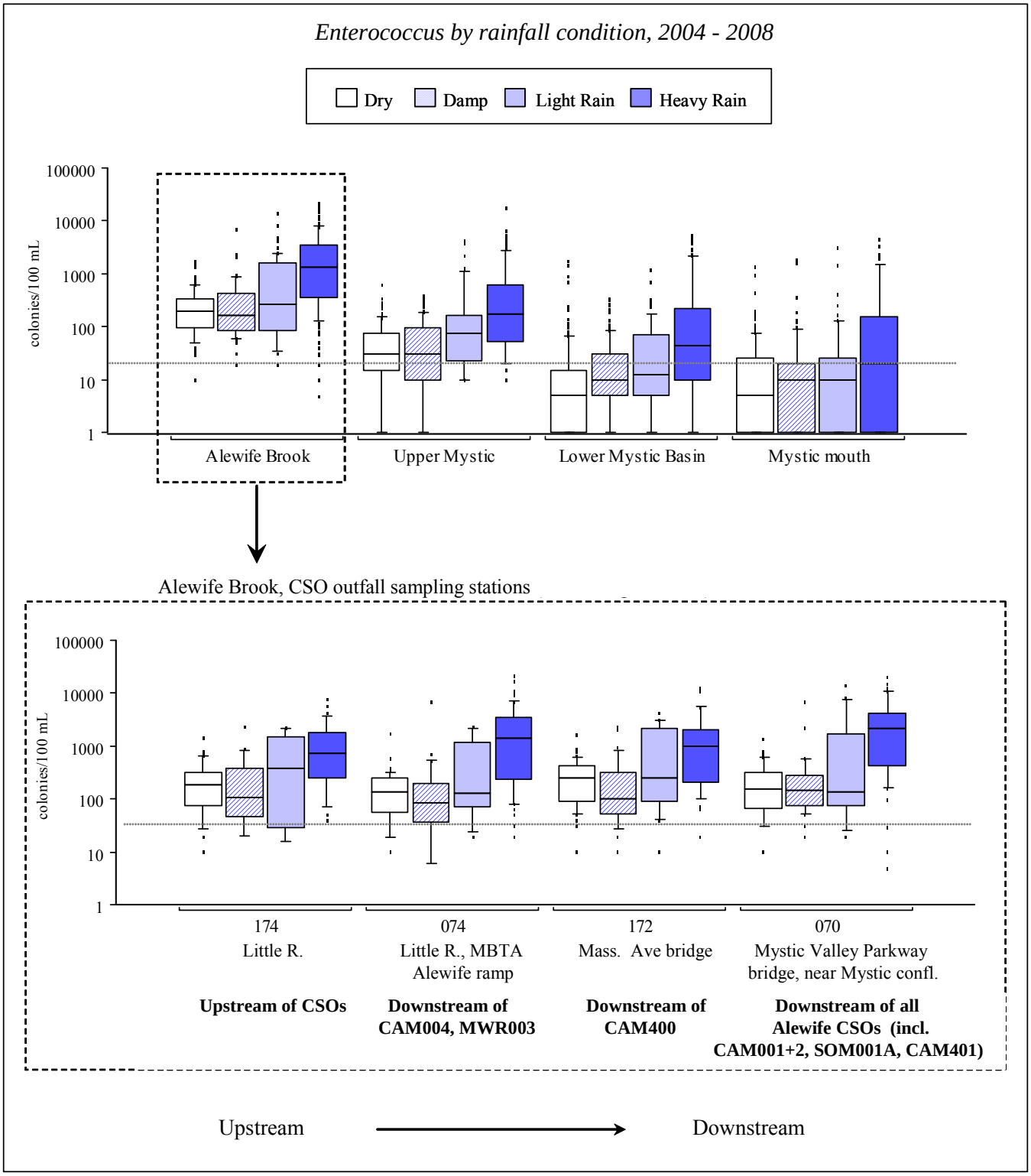


Figure 4-8. *Enterococcus* by rainfall condition, Mystic River/Alewife Brook, 2004 - 2008.

Dotted line shows State standard. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

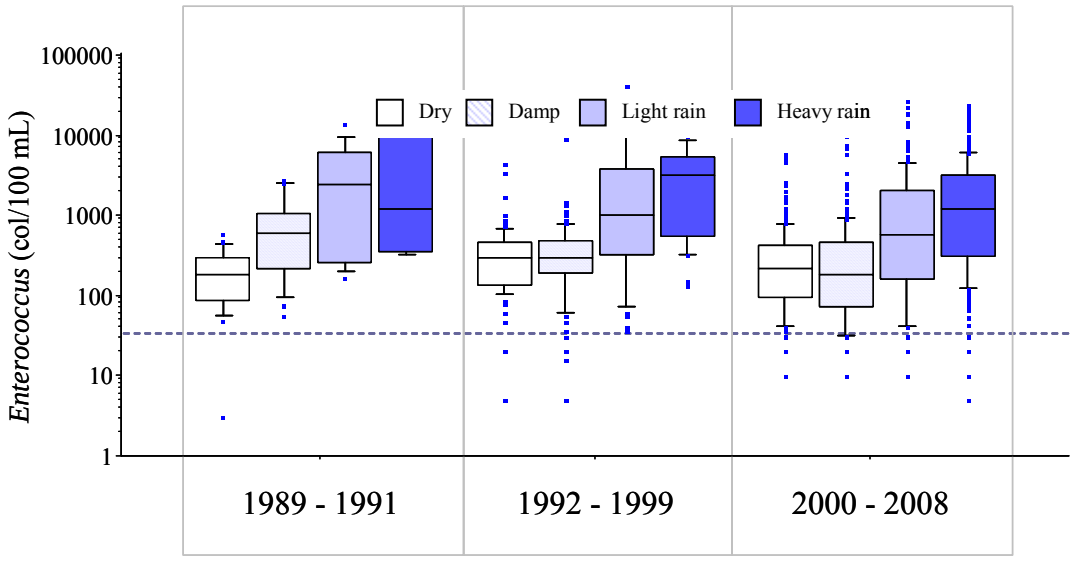


Figure 4-9. *Enterococcus* over time, Alewife Brook by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for stations 174, 172, 074 and 070. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

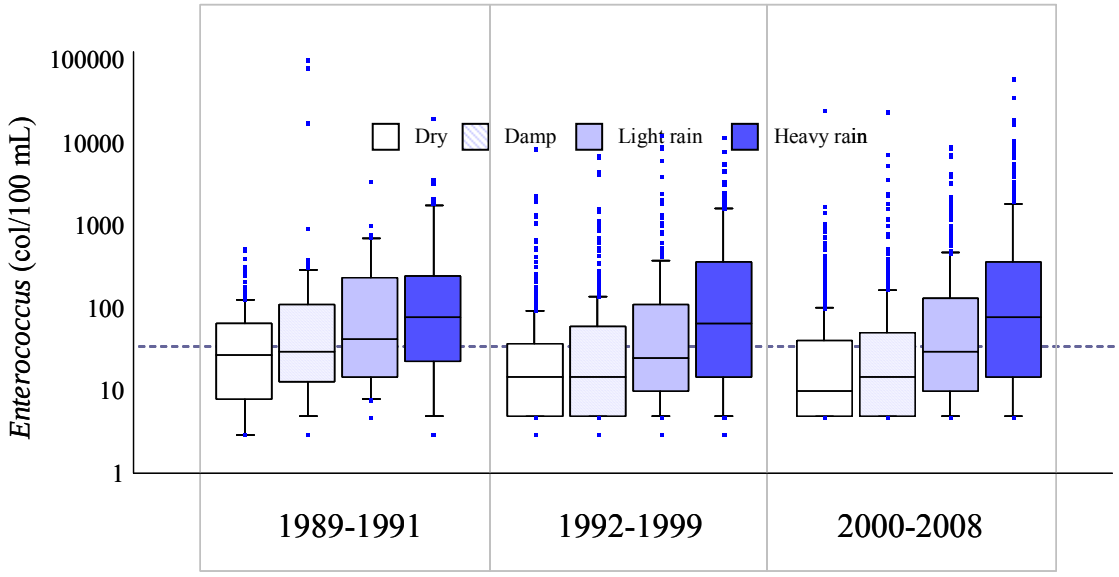


Figure 4-9. *Enterococcus* over time, Mystic River by phase of Long Term CSO Plan and rainfall condition.

Dotted line shows State standard. Data includes results for all Mystic River stations excepting Alewife Brook. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any rain < 0.15 inches at least two or three days previous to sampling and/or 0.1 inches in previous day; "Light rain": between 0.1 and 0.5 inches in previous day and/or between 0.15 and 0.5 in two previous days.

4.5 Summary of Mystic River/Alewife Brook water quality

Given that 2008 rainfall was significantly greater than Typical Year estimates (according to MWRA's CSO Control Plan Model Simulation results), and greater than 2007, water quality in the Mystic River was generally good, meeting water quality standards for much of the Lower Mystic Basin and Mystic River mouth, but failing to meet limits in the Upper Mystic, Alewife Brook and Malden River. Bacterial counts in the Alewife for the 2003-2008 period fail to meet standards, even in dry weather, and water clarity and dissolved oxygen also remain poor in this area. However, 2008 results indicate significant improvement in bacterial water quality in the Alewife compared to the previous five years. Geometric mean limits were still not met in the Alewife but all locations in the Mystic River did meet *Enterococcus* geometric mean limits, and most locations met *E. coli* geometric mean limits. This is in contrast to the Charles River which failed to meet *E. coli* limits at most locations. Both rivers met *Enterococcus* geometric limits at all but a few locations.

Wet weather continues to adversely impact all locations in the Mystic River and Alewife Brook, with the highest bacteria counts occurring after heavy rain. However, in the lower portion of the River geometric mean bacteria counts are well within standards; in 2008, all locations met the *Enterococcus* single sample limit of 104 colonies/100 mL downstream of Alewife Brook. While *E. coli* monitoring was discontinued in the marine area of the river mouth, fecal coliform concentrations at the Somerville Marginal outfall location (205) were inconsistent, with elevated counts occurring at similar frequencies in dry and weather wet weather.

Like the Charles River, nutrients and chlorophyll show strong seasonal fluctuations. 2008 nutrient results were similar to previous years, with monthly concentrations near long term averages. Locations near the Amelia Earhart dam and Malden River confluence were the most eutrophic, having the highest chlorophyll *a* and lowest dissolved oxygen, and pronounced changes in seasonal nitrogen concentrations – with markedly elevated concentrations during the cold weather months, when biological activity is reduced.

REFERENCES

Bendschneider, K. and Robinson, R. J. 1952. A new spectrophotometric determination of nitrate in seawater. Journal of Marine Research 11: 87-96.

Clesceri, L. S., A. E. Greenberg, and A. D. Eaton. 2003. Standard Methods for the Examination of Water and Wastewater. 20th Edition. American Public Health Association, American Water Works Association, Water Environment Federation.

Ellis B., Rosen J. 2001. Statistical Analysis of Combined Sewer Overflow Receiving Water Data, 1989 – 1999. Massachusetts Water Resources Authority. Report ENQUAD 2001-06.

Fiore, J. and O'Brien, J. E. 1962. Ammonia determination by automatic analysis. Wastes Engineering. 33: 352.

Gong G., Lieberman J., D. McLaughlin. 2003. Statistcal analysis of combined sewer overflow receiving water data, 1989-1996. Boston: Massachusetts Water Resources Authority. Report ENQUAD 98-09.

Holm-Hanson. O, Lorenzen, C. J, Holmes, R. W, and Strickland, J. D. H. 1965. Fluorometric determination of chlorophyll. J. Cons. Int. Explor. Mer. 30: 3-15.

Murphy, J. and Riley, J. 1962. A modified single solution for the determination of phosphate in natural waters. Anal. Chim. Acta. 27:31.

MADEP. 1996. Massachusetts surface water quality standards. Massachusetts Department of Environmental Protection, Division of Water Pollution Control, Technical Services Branch. Westborough, MA (Revision of 314 CMR 4.00, effective January, 2008).

MADEP. 2002. Boston Harbor 1999 Water Quality Assessment Report. Massachusetts Department of Environmental Protection, Division of Watershed Management. Worcester, MA. Report 70-AC-1.

MWRA. 2007. (DCN 5000.0). Department of Laboratory Services Quality Assurance Management Plan, Revision 2.0. Massachusetts Water Resources Authority, Boston, MA.

MWRA. 2009. Combined Sewer Overflow Control Plan, Annual Progress Report 2008. Massachusetts Water Resources Authority, Boston, MA.

Solarzano, L, and Sharp, J. H. 1980a. Determination of total dissolved phosphorus and particulate phosphorus in natural waters. Limnology and Oceanography, 25, 754-758.

Solarzano, L, and Sharp, J. H. 1980b. Determination of total dissolved nitrogen in natural waters. Limnology and Oceanography, 25, 750-754.

USEPA, Office of Water. 1986. Ambient Water Quality for Bacteria – 1986. Washington, D.C. Office of Water. EPA 440/5-84-002.

Wu D. 2008. NPDES compliance summary report, fiscal year 2008. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2008-04.

Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129
(617) 242-6000
http://www.mwra.state.ma.us