Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2009

Massachusetts Water Resources Authority

Environmental Quality Department
Report 2010-11

Citation

Coughlin, K. 2010**. Summary of CSO receiving water quality monitoring in Upper Mystic River/Alewife Brook and Charles River, 2009.** Boston: Massachusetts Water Resources Authority. Report 2010-11. 46 pp.

Summary of CSO Receiving Water Quality Monitoring in Upper Mystic River/Alewife Brook and Charles River, 2009

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July 2010

Environmental Quality Department Technical Report 2010-11

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1 Introduction

This report summarizes data collected as part of Massachusetts Water Resources Authority's (MWRA's) 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 2009 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, Boston Water and Sewer Commission (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. In April 2010, MWRA requested three-year extensions to the Charles River and Alewife Brook/Upper Mystic River CSO variances, to October 1, 2013 and September 1, 2013, respectively.

Under the agreement on the Long Term Control Plan (the "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 Plan by 2015 and verify the predicted performance 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 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 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.

2009 CSO progress as it relates to the Charles River and Alewife Brook/Mystic River includes the following:

- On June 30, 2009, MWRA achieved substantial completion of the construction contract for the $3.3 million Cottage Farm Brookline Connection and Inflow Controls project. The project reduces treated CSO discharges from the Cottage Farm CSO Facility to the Charles River Basin by increasing the conveyance of wet weather flows to MWRA's Ward Street Headworks and Deer Island Wastewater Treatment Plant. The improvements optimize the combined conveyance capacity of the two MWRA sewers that carry flows across the Charles River and increase this capacity by bringing into service a previously unutilized 54-inch diameter sewer (the "Brookline Connection") constructed nearly 40 years ago by the Metropolitan District Commission.

- In September 2009, MWRA submitted findings from its $1.2 million Charles River Valley/South Charles River Relief Sewer gate controls and interceptor interconnections study to EPA and MADEP. The Charles River interceptor evaluations were proposed by MWRA in 2005 to ensure optimized allocation of flow among major interceptors related to the Cottage Farm CSO facility and other Charles River outfalls, with the goal of further controlling CSO discharges. CSO benefits achieved from any recommended optimization alternatives would improve upon the levels of CSO control for the Charles River in MWRA's approved Long-Term Control Plan (2006).

  MWRA and its study consultant performed extensive evaluations of existing system performance and examined alternatives to add interconnections between interceptors, modify existing interconnections and existing control gates. MWRA concluded that additional interceptor interconnections will not reduce CSO discharges and found no other feasible means to improve hydraulic performance of the interceptors without also increasing the risk of system flooding in very large storms. As a result of these findings, MWRA did not recommend system improvements beyond the measures in the approved long-term control plan, and MWRA proposed that related construction milestones be deleted from Schedule Seven of the Federal District Court Order in the Boston Harbor Case. MWRA has discussed this recommendation with EPA and DEP and has responded to comments from EPA on the technical documentation supporting the conclusion and recommendations.

- BWSC is on-schedule to complete the sole construction contract for the $9.6 million Bulfinch Triangle Sewer Separation project as of July 2010. The contractor has installed all 4,500 linear feet of new storm drain included in the contract and is continuing with sewer system work. This project is intended to minimize CSO discharges to the Charles River, especially at MWRA's Prison Point CSO facility and eliminates CSO discharges at outfall BOS049. It will discharge stormwater only.

- The Town of Brookline has achieved substantial completion of the first of two construction contracts for the $24 million Brookline Sewer Separation project. This project involves sewer separation in several areas of Brookline totaling 72 acres where there are remaining combined sewers tributary to MWRA's Charles River Valley Sewer. The project is intended to reduce discharges to the Charles River at MWRA's Cottage Farm facility. With the $1.4 million first contract, Brookline installed 6,800 linear feet of new storm drain in town streets along the north and south sides of Beacon Street. Brookline is completing final design for the second construction contract. Existing combined sewers will be converted to storm drains. MWRA is developing plans to rehabilitate outfall MWR010, which will convey the separated stormwater to Charles River.

- During 2009, the Alewife Brook Sewer Separation Plan moved forward after several years of delay due to project reassessment and a citizens' appeal of a wetlands permit. Cambridge made substantial final design progress 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.

As of the end of 2010, 28 CSOs have been permanently closed in Boston Harbor and its tributaries; 2 CSOs are tentatively closed (CAM009 and 011, pending the results of hydraulic evaluation); 54 CSOs remain active. In the Charles, ten CSOs remain active and nine have been closed (for purposes of this report, CAM009 and CAM011 are considered closed). In the Alewife Brook, eight CSOs remain active, five have been closed. In the Mystic River, one treated CSO (Somerville Marginal) remains active, 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. 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 2004 to the present is considered representative of current conditions.

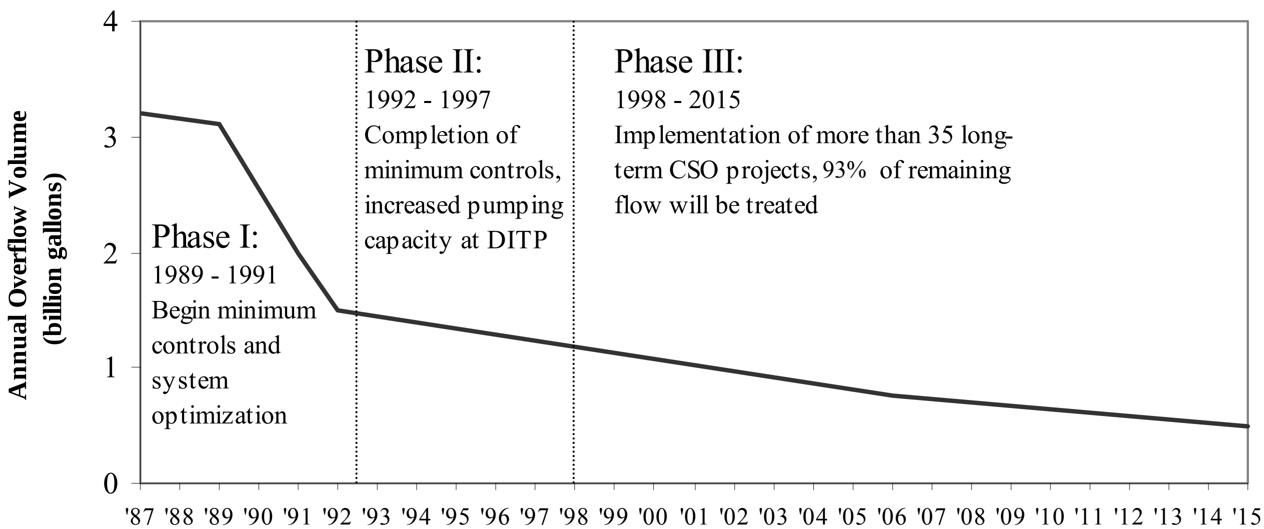

Figure 1-1. Estimated CSO flow reductions, 1987 – 2015.

Source: MWRA CSO Annual Progress Report 2009

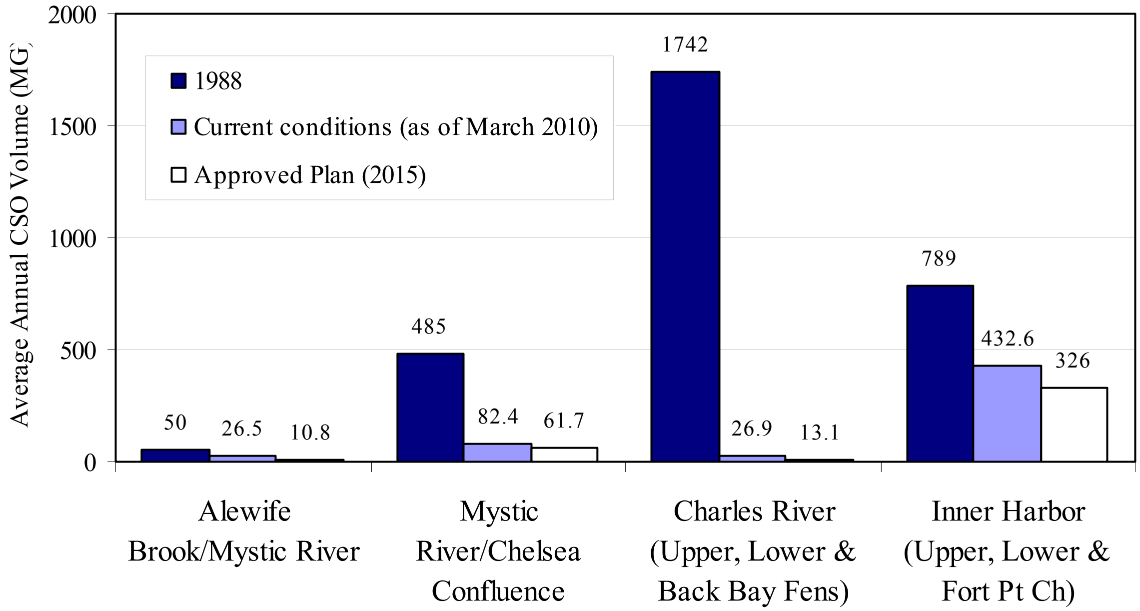

Figure 1-2. CSO Typical Year Discharge Volumes for 1988, Current, and Approved Long Term Control Plan model estimates

Source: MWRA CSO Annual Progress Report 2009

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 eight 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 the previous five monitoring years are analyzed together for representativeness, and data for 2009 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 into rinsed sample containers. Bottom samples were collected at locations with a water depth greater than 3 meters, using a Kemmerer sampler or alpha bottle at 0.5 meters above the sediment surface. 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 (2005 - 2009) YSI6600, YSI6820 (2009) YSI 600XL for temperature, conductivity, dissolved oxygen (1999 – 2009)
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 are followed.

Detailed laboratory methods with quality assurance and quality control procedures are described in the Central Laboratory Standard Operating Procedure (MWRA 2009).

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 2008-2009)
E. coli (measured from 2001 – 2009)	Modified EPA 1103.1, membrane filtration (for samples collected 2000–2006) Colilert (for samples collected 2009-2009)
Fecal coliform (limited measurements after 2001)	Standard Methods 9222D, membrane filtration
Total suspended solids	Clesceri et al. (1998, 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 (1998, 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 (1998, Method 4500-NH3 H), Skalar SAN^{plus} autoanalyzer, Whatman GF/F filters
Nitrate+nitrite	Bendshneider and Robinson (1952), modified as in Clesceri et al (1998, 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.

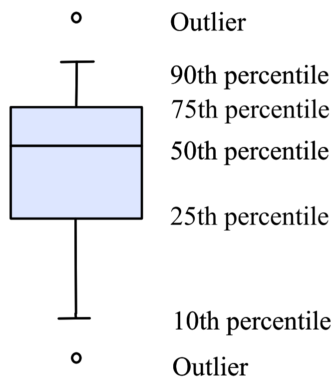

Figure 2-1. Percentile distributions indicated on percentile plots

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 10th, 25th, 50th, 75th, and 90th 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. The 50th percentile (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). 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	6.5 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 and further extension was requested by MWRA in April 2010). 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.

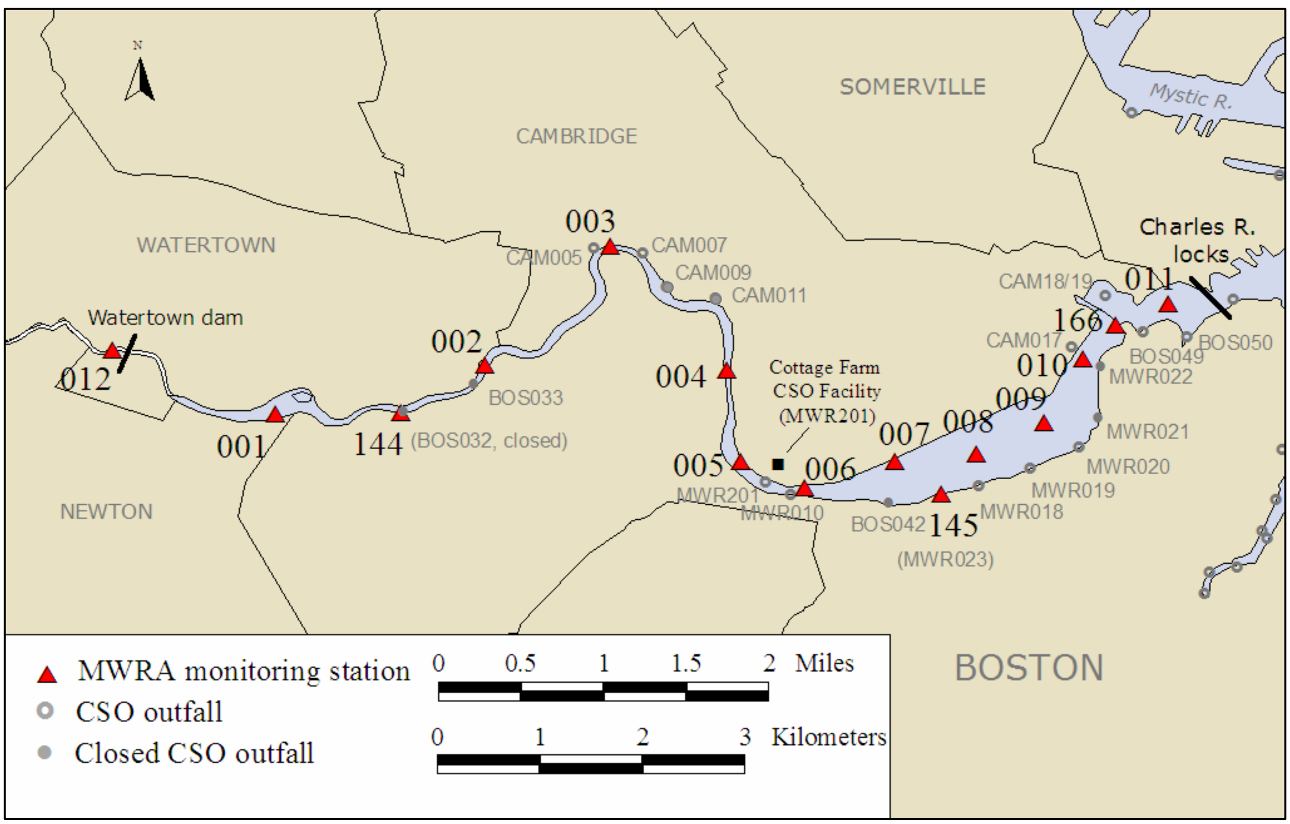

Figure 3-1. Map of MWRA Charles River sampling locations

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. 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. (MWRA's Prison Point CSO facility, located near the Charles River mouth, has its discharge point on the Boston Harbor side of the New Charles Dam.) With increases in sewer system capacity, the number of activations at Cottage Farm has decreased in recent years – from 24 activations in 1999 to 4 activations in 2009. The Stony Brook/Muddy River outlet near Kenmore Square is a source of contaminated brook flow and stormwater flows to the basin area, however CSO discharge volumes to the Stony Brook have been reduced in recent years due to sewer separation by Boston Water and Sewer Commission (BWSC) in the mid-2000s.

Table 3-3 shows the MWRA model simulation results for CSOs affecting the Charles River Basin in calendar year 2009. Actual CSO volumes and activation frequency are available for the Cottage Farm CSO facility, while the remaining results are estimated using model data. According to the simulation using 2009 conditions, untreated CSOs discharged approximately one or two times during 2009, indicating that CSOs had a relatively minor impact on wet weather water quality in the Basin for this year.

The receiving water program is designed to capture water quality in all weather conditions. Table 3-4 summarizes the proportion of samples collected in dry, damp, and wet weather, which indicate an even distribution of sampling events across all weather conditions.

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 4 times in 2009	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 Basin CSO activations, results of MWRA model simulations for 2009 system conditions and 2009 rainfall.[1]

CSO Outfall	Activation Frequency	Total Discharge Duration (hr)	Total Discharge Volume (million gallons)
Upper Charles			
CAM005	1	0.70	0.03
CAM007	1	0.66	0.01
TOTAL		1.36	0.04
Back Bay Fens (Muddy River)			
BOS046	0	0.00	0.00
TOTAL	0	0.00	0.00
Lower Charles			
BOS049	0	0.00	0.00
CAM017	0	0.00	0.00
MWR010	0	0.00	0.00
MWR018	2	2.72	1.13
MWR019	1	0.98	0.14
MWR020	1	0.66	0.02
MWR201 (Cottage Farm Facility) [2]	4	23.27	57.50
MWR023 (Stony Brook)	0	0.00	0.00
TOTAL		27.63	58.79[3]

[1]Activation frequency and volume are from MWRA model results, except where noted.
[2]Activation frequency and volume are from MWRA facility records (measurements).
[3]57.5 million gallons of a total annual discharge of 58.79 million gallons in the Lower Charles is treated at the Cottage Farm Facility.

Table 3-4. Charles River sample collection by rainfall condition.

Sampling period	Dry[1]	Damp[1]	Wet[1]	Total
2004 - 2008	26% 774 samples	34% 1006 samples	40% 1200 samples	100% 2980 samples
2009	40% 253 samples	24% 154 samples	36% 223 samples	100% 630 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, 2005-2009*

A detailed summary of water quality results collected during the last five years is shown in Table 3-5.

Table 3-5. Summary of water quality, Charles River Basin 2005 – 2009.

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	20.6 ± 4.6	99.0	8.9 - 29.3	884	20.4 ± 4.5	98.2	8.8 - 29.8	1051	21.7 ± 4.6	89.9	11.2 - 30.2	316
	Winter		3 ± 2.8	100.0	-0.1 - 10.1	67	ND	ND	ND	0	3.9 ± 2.3	100.0	0.7 - 10.6	76
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	7.6 ± 1.8	94.6	0.6 - 14.5	871	5.7 ± 3.2	69.2	0.1 - 12.7	1040	7 ± 2.3	80.6	0.3 - 13.8	315
	Winter	5.0	13.8 ± 1.2	100.0	11.7 - 15.8	67	ND	ND	ND	0	13.1 ± 0.9	100.0	11.2 - 15.8	76
pH[6] (S.U.)		6.5-8.3	7.2 ± 0.4	98.2	6.2 - 9	1386	7.2 ± 0.6	93.3	6.3 - 9.5	1488	7.4 ± 0.6	92.0	6.4 - 9.4	587
Water clarity	Total Suspended Solids (mg/L)	NS	4.2 ± 3.9	-	0.5 - 36.1	151	ND	-	ND	0	4.1 ± 3.5	-	0.7 - 34.6	143
	Secchi depth (m)	NS	1.1 ± 0.3	-	0.5 - 2.1	401	1.1 ± 0.3	-	0.3 - 1.7	771	1.2 ± 0.3	-	0.4 - 2.2	137
	Turbidity (NTU)	NS	6.8 ± 3.9	-	0.2 - 32.5	758	7.2 ± 4.6	-	0.1 - 52.5	1236	5.6 ± 4.5	-	0.5 - 26.5	251

Table 3-5. Summary of water quality, Charles River Basin 2005 – 2009, 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]	3188 (939-10821)	14.3	220 - 20000	7	1177 (629-2203)	16.7	160 - 17200	18	71 (1-2684)	50.0	0 - 2200	4
	Enterococcus	33 / 61[3]	177 (160-196)	59.9	0 - 13000	848	79 (71-88)	74.0	0 - 24700	1281	59 (51-70)	80.6	0 - 10500	432
Nutrients (µmol/L)	Phosphate	NS	33 (28-39)	61.5	0 - 17600	849	12 (10-13)	75.4	0 - 15500	1280	9 (7-10)	81.7	0 - 8900	432
	Ammonium	NS	0.73 ± 0.43	-	0.13 - 2.67	151	ND	-	ND	0	0.67 ± 0.46	-	0.02 - 2.76	143
	Nitrate+nitrite	NS	4.4 ± 2.9	-	0.2 - 14.4	151	ND	-	ND	0	6.5 ± 5.3	-	0 - 23.3	143
Algae (µg/L)	Chlorophyll	25[5]	43.9 ± 19.5	-	0 - 116	151	ND	-	ND	0	40.7 ± 26.1	-	0 - 202	143

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. "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.

[6] Median and standard error of the median are shown for pH, not arithmetic mean and standard deviation.

3.4 Trends in water quality, 2009

This section provides an analysis of trends for water quality parameters measured in the lower Charles in the 2009 monitoring year.

3.4.1 Physical measurements

Temperature. Summer water temperatures for 2009 are shown for each sampling location in the top graph in Figure 3-2. Temperature profiles are relatively consistent upstream to downstream. Bottom-water temperatures are 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. Average 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 upstream of the Longfellow Bridge (Station 009). Station 166, downstream of the lower basin, is collected at a relatively shallow near-shore location and does not reflect the low DO levels of deeper water.

Water clarity. Water clarity is indicated by Secchi disk depth. Summer Secchi results (collected June through September) are shown for individual sampling locations in the bottom graph in Figure 3-2. In general, there is a pattern of increasing water clarity from upstream to downstream. Clarity was slightly improved at lower basin locations in 2009, with areas downstream of Station 006 (BU Bridge) meeting the State guideline.

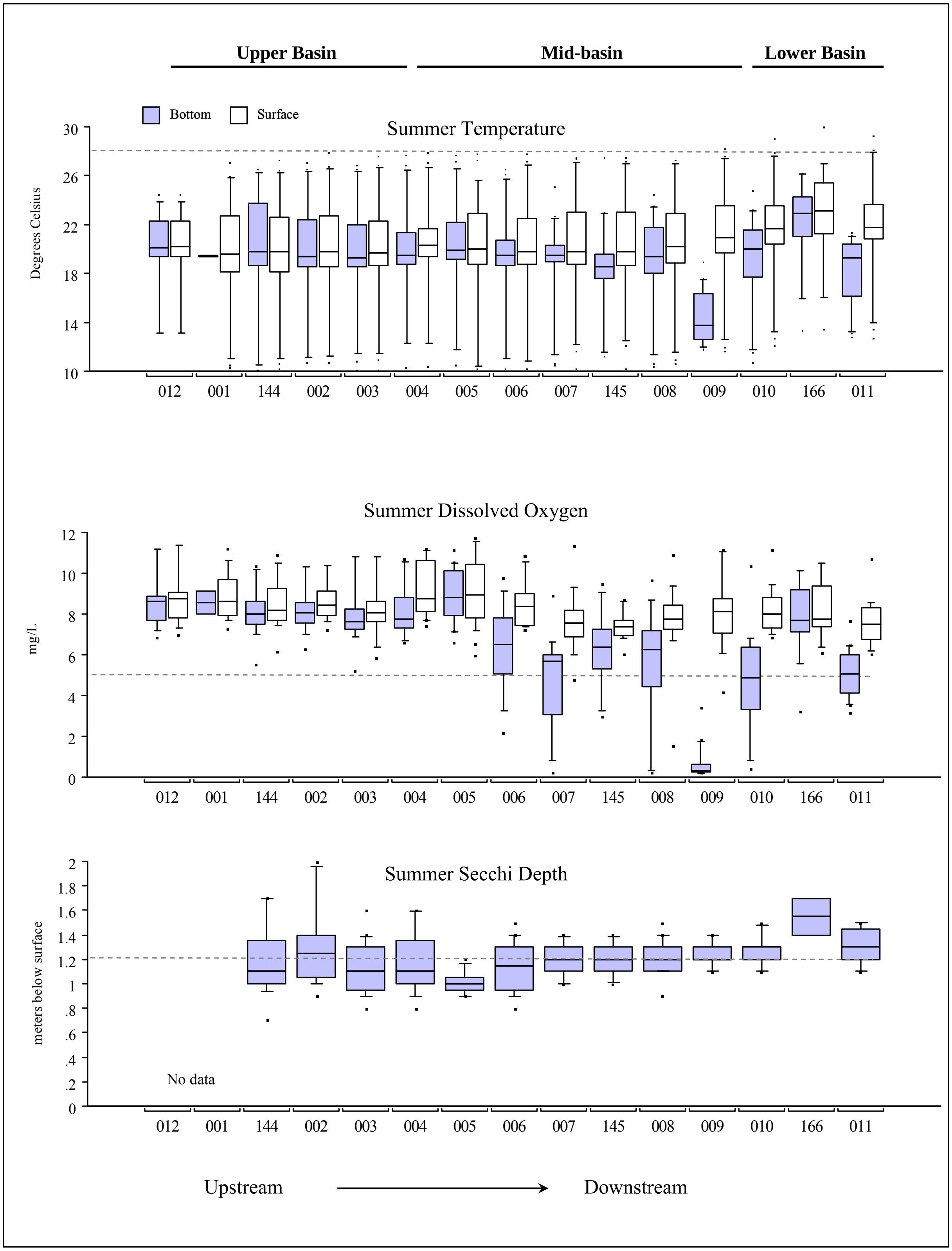

Figure 3-2. Summer temperature, dissolved oxygen, and Secchi depth, Charles River Basin, 2009.

Dashed lines are State standards (maximum for temperature, minima for DO and Secchi).

No Secchi data are available for Station 012 and 001 because of shallow depth; they are typically 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, so historical data is not available for the period spanning Phase I and Phase II of the CSO plan. There is no evidence of a long term trend in nutrient or clarity measures since monitoring began, so 2009 averages are plotted with the average of the previous five years (2004 – 2008) for comparison.

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 2009 monitoring year are similar to the 2004-2008 averages for most parameters, though phosphate, TSS, and chlorophyll showed some marked differences for 2009. The June and July averages are likely elevated because of several large rainstorms during these months (June had 3 large rainstorms of 0.5 inch or greater, July had two rainstorms of 1 inch or greater). Chlorophyll was unusually low in September at both locations. Both locations had below average ammonium concentrations for most of the year.

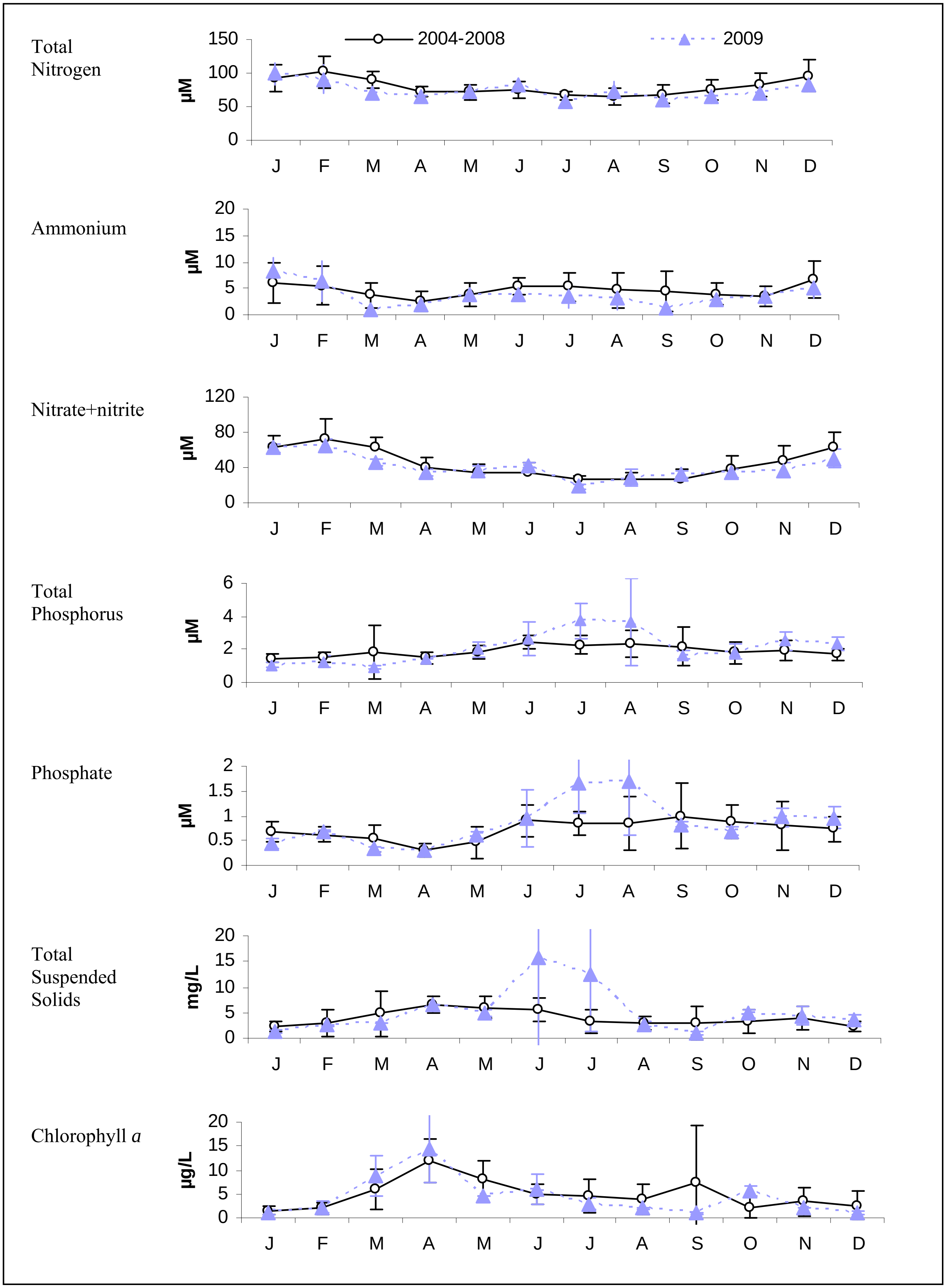

Figure 3-3. Monthly average nutrients, TSS and Chlorophyll 2005 – 2009, Station 012, Watertown Dam.
Error bars are ± 1 SD.

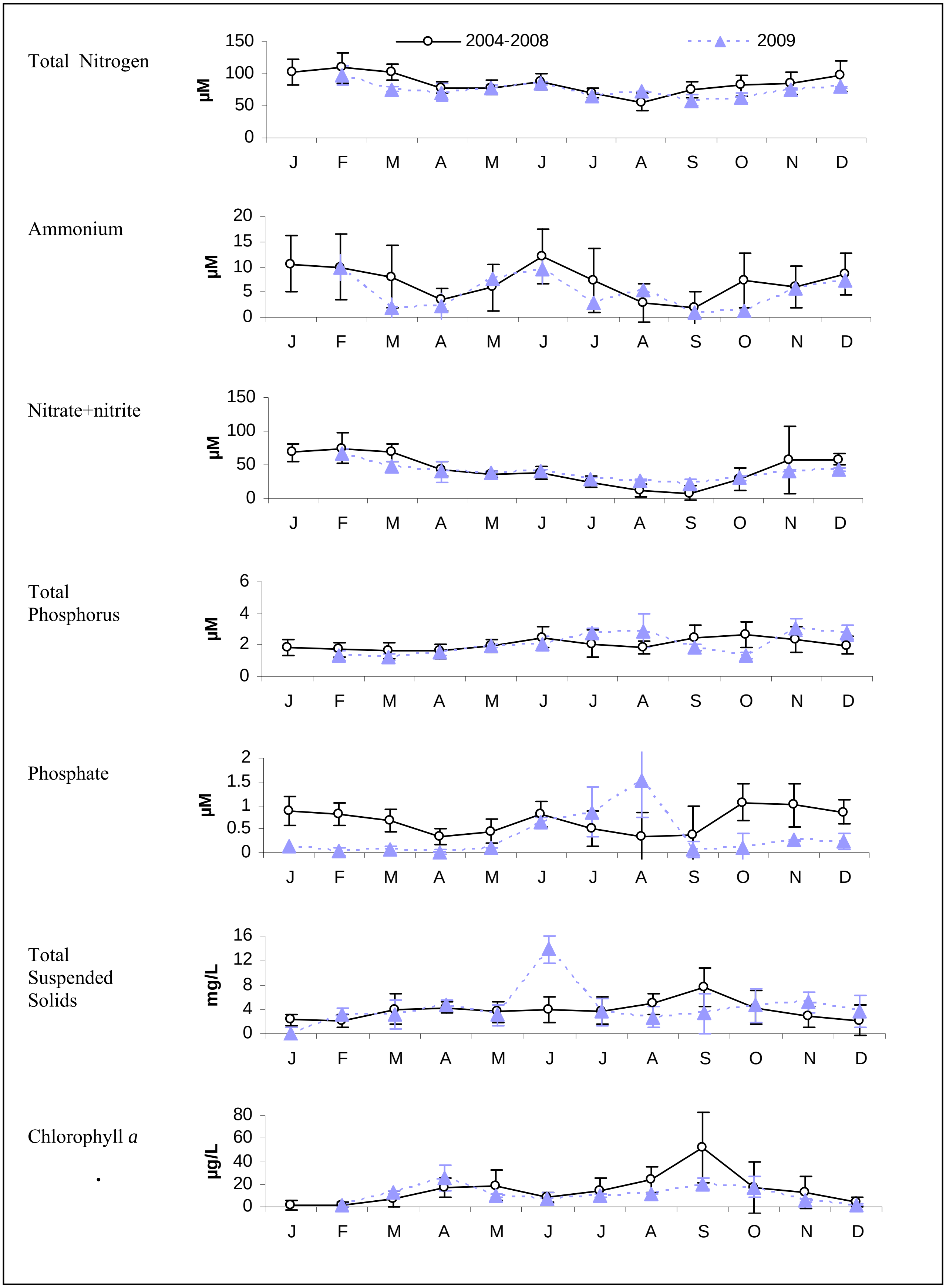

Figure 3-4. Monthly average nutrients, TSS and Chlorophyll 2005 – 2009, Station 166, Science Museum.

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 2009. 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 2005 – 2009 appear in Table 3-6. Geometric means for 2009 are shown in a separate column from 2004-2008 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 2009. 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 – 2009, $F = 219.5$, 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.

For 2009, all locations downstream of the Eliot Bridge in Cambridge meet geometric mean standards for both bacterial indicators except station 007, at the MIT Boathouse. Station 007 has for the last several years had median bacteria counts slightly more elevated than the Stony Brook outlet, located on the opposite bank. This is in increasing contrast with historical conditions (1990s and early 2000s), when the Stony Brook location was typically the most contaminated location in the Mid-Basin.

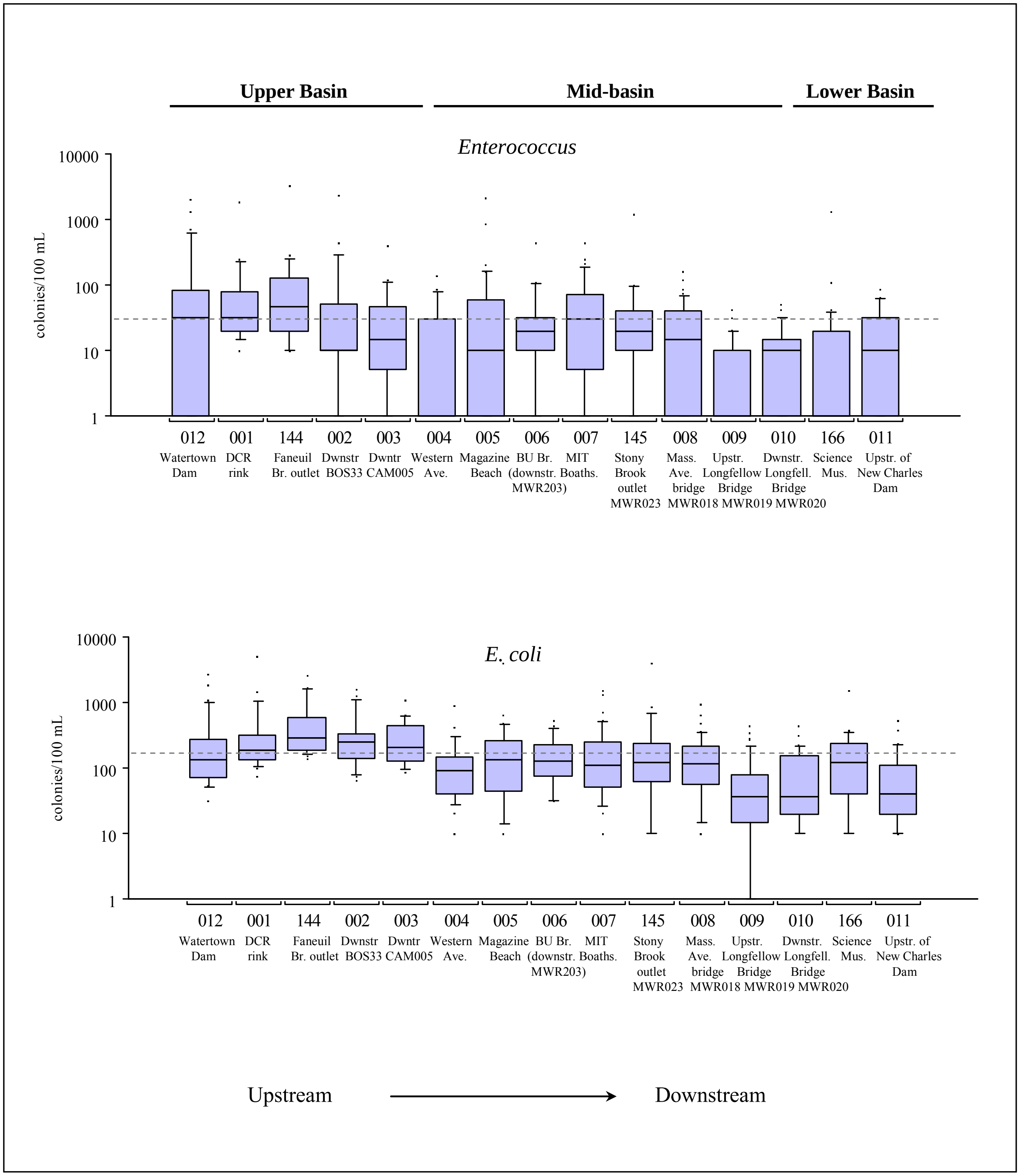

Figure 3-5. Indicator bacteria concentrations, Charles River Basin, 2009.
Dotted lines show MADEP *Enterococcus* and *E. coli* standard.

Table 3-6. Geometric mean indicator bacteria, Charles River Basin, 2005 – 2009.

Station	Location	Surface or Bottom	Number of samples[1] 2004 –08	Number of samples[1] 2009	*Enterococcus* (95% CI) colonies/100 mL 2004 – 2008	*Enterococcus* (95% CI) colonies/100 mL 2009	*E. coli* (95% CI) colonies/100 mL 2004 – 2008	*E. coli* (95% CI) colonies/100 mL 2009
012	Newtown/Watertown, footbridge upstream of Watertown Dam	S	143	26	67 (48-95)	21 (8-52)	191 (151-240)	161 (105-247)
001	Newton, near Nonantum Rd., rear of DCR skating rink	S	96	20	62 (37-104)	46 (26-79)	258 (195-341)	244 (157-378)
144	Brighton, downstream of N. Beacon St. bridge, Faneuil Brook outlet, BOS-032 (closed 1999)	S	48	20	118 (63-222)	60 (32-113)	371 (184-745)	374 (255-549)
002	Allston, downstream of Arsenal Street bridge, BOS-033	S	68	20	32 (19-54)	18 (7-46)	233 (176-309)	248 (169-363)
003	Allston/Cambridge, midstream, near Mt. Auburn Street, between CAM-005 and CAM-006	S	68	20	23 (13-41)	12 (5-28)	175 (125-244)	230 (167-318)
004	Allston/Cambridge, midstream, between River Street and Western Avenue bridges	S	68	22	16 (9-27)	3 (1-7)	93 (57-149)	88 (58-134)
005	Cambridge, near Magazine Beach, upstream of Cottage Farm	S	138	39	15 (11-22)	9 (4-19)	103 (82-130)	101 (63-161)
006	Cambridge/Boston, midstream, downstream of Cottage Farm, BU bridge	S	110	20	34 (23-51)	14 (6-30)	209 (162-268)	119 (82-173)
007	Cambridge, near Memorial Dr., MIT Boathouse	S	108	20	13 (8-20)	10 (4-24)	108 (76-153)	92 (57-150)
		B	107	20	28 (18-43)	36 (13-96)	195 (148-259)	149 (86-256)
145	Boston (Charlesgate), Muddy River/Stony Brook outlet	S	108	20	39 (25-60)	18 (8-39)	278 (196-394)	106 (49-229)
008	Cambridge/Boston, midstream, downstream of Harvard Bridge	S	108	20	13 (8-19)	7 (3-16)	98 (69-139)	65 (36-119)
		B	107	20	18 (11-28)	12 (5-29)	152 (108-213)	118 (60-229)
009	Cambridge/Boston, midstream, upstream of Longfellow Bridge near Community Sailing	S	109	20	8 (5-12)	4 (1-8)	67 (48-93)	63 (34-114)
		B	107	20	4 (3-7)	0 (0-0)	15 (10-22)	13 (6-27)
010	Boston, downstream of Longfellow Bridge, MWR-022	S	109	20	5 (3-8)	3 (1-5)	47 (33-67)	54 (29-99)
		B	108	20	4 (3-6)	6 (3-13)	13 (9-20)	32 (15-68)
166	Boston, old Charles River dam, rear of Science Museum	S	148	27	9 (6-14)	3 (1-8)	94 (69-129)	75 (39-142)
011	Boston, upstream of river locks (New Charles River Dam) and I-93, near Nashua St.	S	109	20	6 (4-9)	4 (1-9)	47 (36-61)	45 (25-81)
		B	108	20	13 (9-18)	17 (9-31)	43 (32-57)	40 (21-74)

[1]N values for *Enterococcus* and *E. coli* for the 2004-2008 and 2009 periods, respectively.

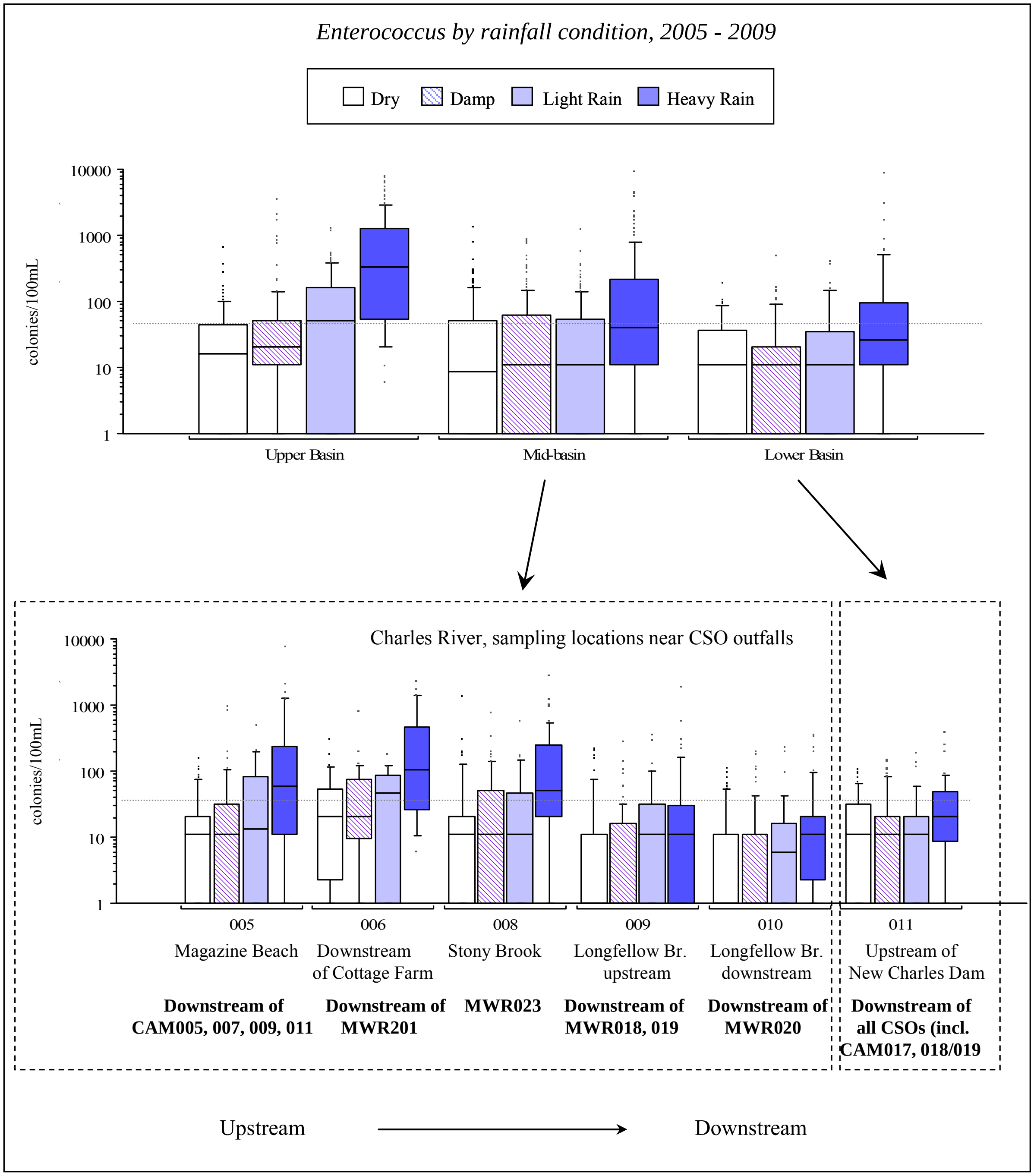

Figure 3-6. *Enterococcus* by rainfall condition, Charles Basin, 2005 - 2009.

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.

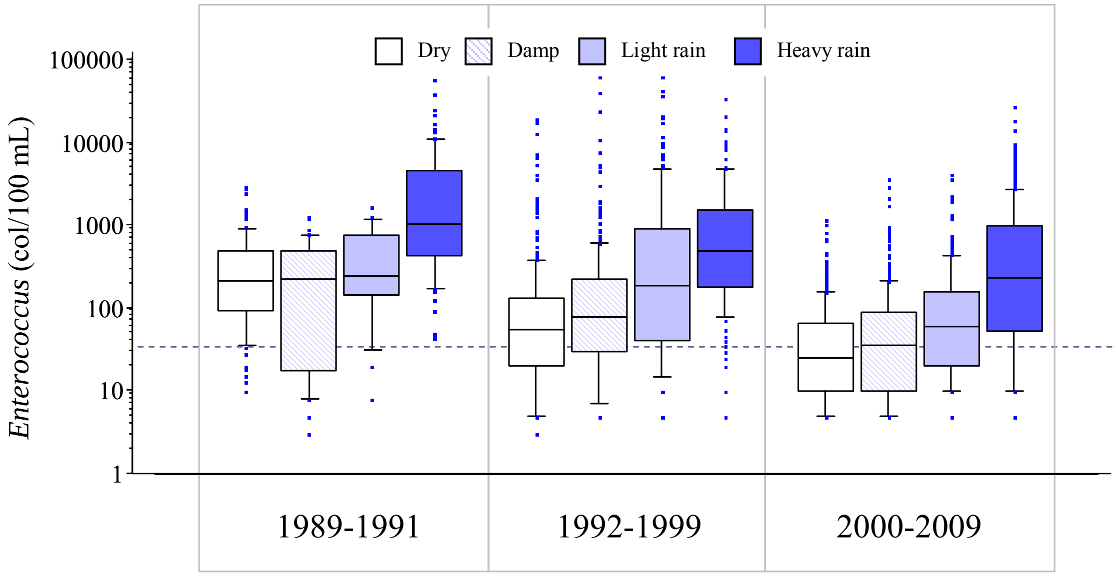

Figure 3-7. *Enterococcus* over time, Upper Charles Basin (upstream of CSOs) by phase of Long Term CSO Plan and rainfall condition.

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.

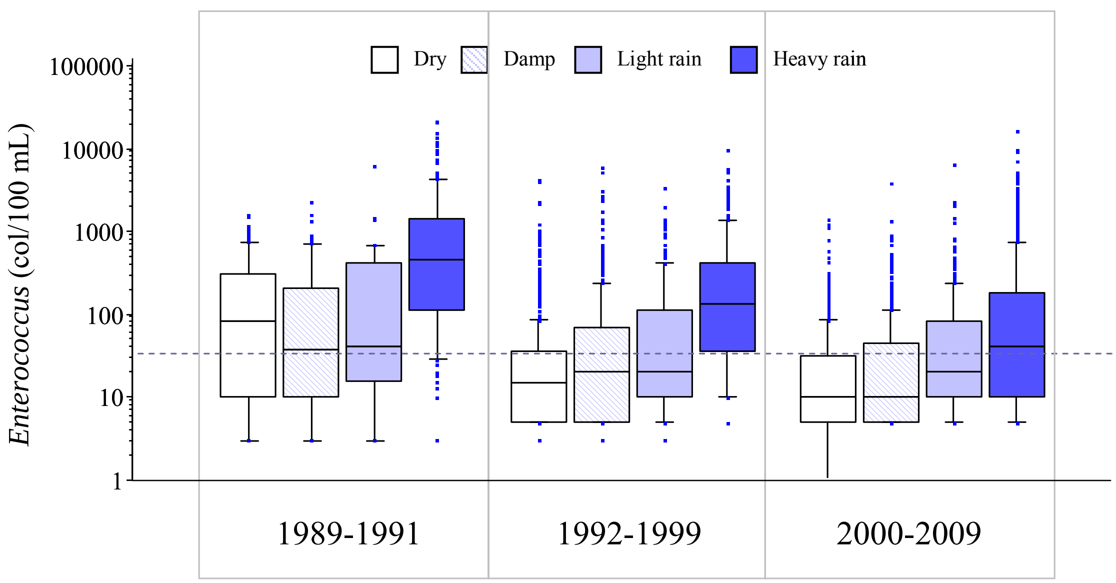

Figure 3-8. *Enterococcus* over time, Lower Charles Basin by phase of Long Term CSO Plan and rainfall condition.

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

2009 was a moderately wet year, with 2009 rainfall greater than Typical Year estimates (according to MWRA's CSO Control Plan Model Simulation results). Bacterial water quality is improved for 2009 compared with 2008, with all Mid- and Lower-Basin locations meeting bacterial geometric mean limits except for Station 007 (MIT boathouse). Consistent with previous years, bacterial water quality in the Charles is poorer at upstream locations.

The lower basin locations are stratified in summer, resulting in relatively low bottom water temperatures and extremely low bottom water dissolved oxygen in the Mid-Basin near the Longfellow Bridge. Seawater continues to enter through the Charles locks in summer, contributing to stratification of the basin, limiting exchange with contaminated 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 2009 except for TSS and phosphate, likely due to heavy rain in June and July 2009.

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.

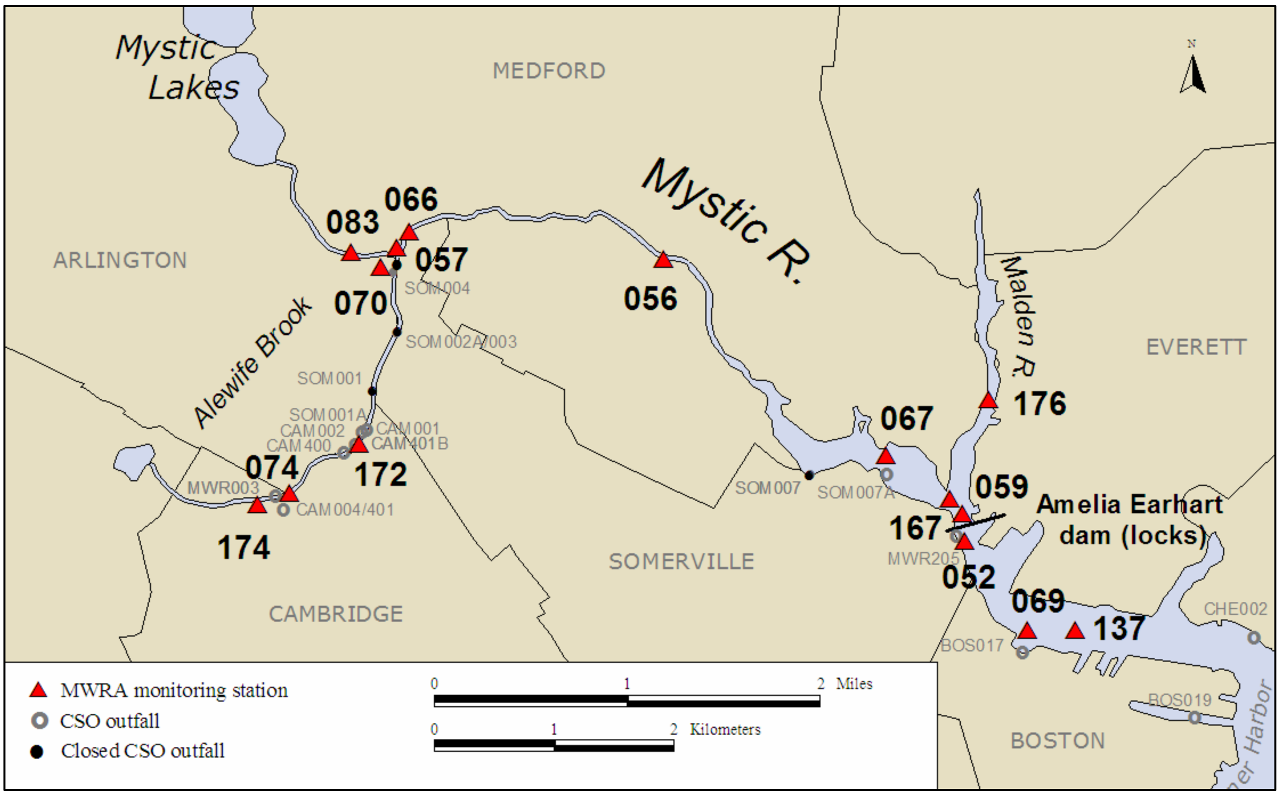

Figure 4-1. Map of Mystic River sampling locations.

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 screened and dechlorinated flow only during an activation occurring 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 2009, Somerville Marginal 205A/SOM007A had six discharge events, and Somerville Marginal 205 had 27 activations resulting in discharge below the dam. The Alewife Brook is the primary source of contaminated flow to the Upper Mystic River, in both dry and wet weather.

Table 4-3 shows the MWRA model simulation results for CSOs affecting the Mystic River and Alewife Brook in calendar year 2009. Metered CSO volumes and activation frequency are available for the Somerville Marginal CSO facility, while the remaining results are estimated using model results.

Table 4-4 summarizes the proportion of samples collected in dry, damp, and wet weather between 2004 and 2009.

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)
		069, Charlestown	Rear of Schrafft's Center at BOS-017 outfall
		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 2009	Yes Somerville Marginal (MWR205) Activated 27 times in 2009
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

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Table 4-3. Mystic River/Alewife Brook CSO activations, results of MWRA model simulations for 2009 system conditions and 2009 rainfall.[1]

CSO Outfall	Activation Frequency	Total Discharge Duration (hr)	Total Discharge Volume (Million Gallons)
Alewife Brook			
CAM001	0	0.00	0.00
CAM002	6	6.72	0.30
MWR003	0	0.00	0.00
CAM004	7	22.48	2.75
CAM400	6	7.51	0.13
CAM401A	0	0.00	0.00
CAM401B	18	70.19	7.08
SOM001A	6	11.83	2.06
TOTAL		118.73	12.31
Mystic River (upstream of dam)			
SOM007A/MWR205A [2]	4	2.18	0.92
TOTAL		2.18	0.92
Mystic River mouth (downstream of dam, marine outfalls)			
MWR205 (Somerville Marginal Facility) [3]	23	68.70	74.16
BOS017	0	0.00	0.00
TOTAL		68.70	74.16[4]

[1]Activation frequency and volume are from MWRA model results, except where noted.
[2]Activation frequency and volume are from MWRA depth sensor measurement and MWRA model results, respectively.
[3]Activation frequency and volume are from MWRA facility records (measurements).
[4]Treated discharge.

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

Sampling period	Dry[1]	Damp[1]	Wet[1]	Total
2004-2008	36% 1139 samples	29% 912 samples	35% 1104 samples	100% 3155 samples
2009	37% 246 samples	29% 198 samples	34% 230 samples	100% 674 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, 2005-2009

A detailed summary of water quality results collected from the last five years is shown in Table 4-5.

Table 4-5. Summary of water quality, Mystic River/Alewife Brook 2005 – 2009.

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 ± 4	100.0	7.3 - 25.9	436	20.3 ± 4.1	99.6	9.3 - 28.4	765	20.2 ± 4.2	100.0	8.8 - 27.8	698	20.2 ± 4.1	99.0	9 - 29.5	193	16.7 ± 2.8	100.0	9.3 - 23.1	300
	Winter		4.1 ± 2.1	100.0	0.8 - 8.1	28	3 ± 1.7	100.0	-0.6 - 7.6	75	3.8 ± 1.8	100.0	0.7 - 8.4	97	ND	ND	ND	0	2.8 ± 1.6	100.0	-0.7 - 6	54
Bottom water dissolved oxygen (mg/L)[1]	Summer	5.0	4.4 ± 1.9	35.3	1.1 - 10.8	434	6.9 ± 1.6	88.9	0.1 - 11.7	766	7.6 ± 2.5	85.2	0.1 - 14.7	697	5.4 ± 3.9	59.8	0 - 14.1	189	6.9 ± 1.6	92.3	3.5 - 12.4	298
	Winter	5.0	11.1 ± 1.4	100.0	8.2 - 13.9	28	11.8 ± 1.1	100.0	8 - 13.5	75	11.8 ± 1.3	100.0	5.9 - 14.4	97	ND	ND	ND	0	10.3 ± 0.8	100.0	8.6 - 11.9	54
pH[6] (S.U.)		6.5-8.3 (8.5 marine)	7.2 ± 0.3	99.1	6.4 - 8.3	644	7.5 ± 0.4	97.4	6 - 8.8	1132	7.5 ± 0.8	87.3	6.2 - 10	1102	7.3 ± 0.8	86.1	6 - 9.7	245	7.8 ± 0.3	98.8	6.7 - 9.4	482
Water clarity	Total Suspended Solids (mg/L)	NS	ND	-	ND	0	4.8 ± 4	-	0.2 - 44.3	287	7 ± 3.5	-	0.9 - 30.1	130	ND	-	ND	0	3 ± 1.4	-	0.2 - 9.9	233
	Secchi depth (m)	NS	0.5 ± 0.1	-	0.3 - 0.7	21	1.4 ± 0.7	-	0.1 - 4	219	0.8 ± 0.2	-	0.3 - 1.6	299	0.8 ± 0.2	-	0.4 - 1.8	110	2.4 ± 0.9	-	0.5 - 5.8	220
	Turbidity (NTU)	NS	14.4 ± 8.9	-	2.4 - 58.5	65	6.3 ± 4.6	-	0.8 - 42	636	10.8 ± 5.5	-	0.8 - 31.3	563	10.5 ± 6.3	-	0.4 - 49	188	4.6 ± 3.5	-	0 - 26.1	363

Table 4-5. Summary of water quality, Mystic River/Alewife Brook 2005 – 2009, 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]																	50 (37-67)	88.1	0 - 29100	201
	E. coli	126 / 235[3,4]	449 (406-496)	29.7	10 - 36000	599	88 (77-100)	73.4	0 - 27000	743	51 (44-60)	80.4	0 - 12400	567	63 (44-88)	74.6	0 - 10800	138	29 (21-38)	84.1	0 - 19900	276
	Enterococcus	33 / 61[3]	205 (177-238)	22.0	0 - 22000	595	33 (28-38)	63.1	0 - 18500	740	9 (7-11)	82.0	0 - 4800	572	20 (13-29)	72.7	0 - 9000	139	6 (5-7)	85.8	0 - 4500	479
Nutrients (μmol/L)	Phosphate	NS	ND	-	ND	0	0.49 ± 0.5	-	0.01 - 6.01	287	0.37 ± 0.28	-	0.01 - 1.53	129	ND	-	ND	0	0.8 ± 0.37	-	0 - 2.45	231
	Ammonium	NS	ND	-	ND	0	13.2 ± 12.1	-	0 - 48	287	10.9 ± 10.5	-	0.1 - 40.7	132	ND	-	ND	0	4.3 ± 4	-	0 - 28.4	233
	Nitrate+nitrite	NS	ND	-	ND	0	50.8 ± 27.3	-	0.3 - 167	287	38.1 ± 24.7	-	0 - 77.8	129	ND	-	ND	0	7.9 ± 8.1	-	0 - 47.4	231
Algae (μg/L)	Chlorophyll *a*	25[5]	ND	ND	ND	0	9 ± 6.4	97.9	0.2 - 36.7	287	23.4 ± 18.5	62.3	1.5 - 107	130	ND	ND	ND	0	3.5 ± 4.5	99.6	0.3 - 30.8	235

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 2009 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.

[6] Median and standard error of the median are shown for pH, not arithmetic mean and standard deviation.

4.4 Trends in water quality, 2009

This section reports spatial trends for water quality parameters measured in the Mystic River/Alewife Brook in 2009.

4.4.1 Physical measurements

Temperature. Summer mean temperatures for 2009 are shown for each sampling location in the uppermost 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. Dissolved oxygen is shown in the center graph of Figure 4-2. Mean surface and bottom dissolved oxygen concentrations are well above the State standard of 5.0 mg/L in much of the river, but downstream bottom-water portions of Alewife Brook, Malden River, and upstream of the Amelia Earhart dam fail to meet the standard. 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 and low dissolved oxygen values in the Malden River suggest the Malden River (station 176) 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 and several upper Mystic locations were too shallow to measure Secchi depth.) Clarity downstream of the Amelia Earhart dam improves markedly as the river flows are diluted by Boston Harbor water.

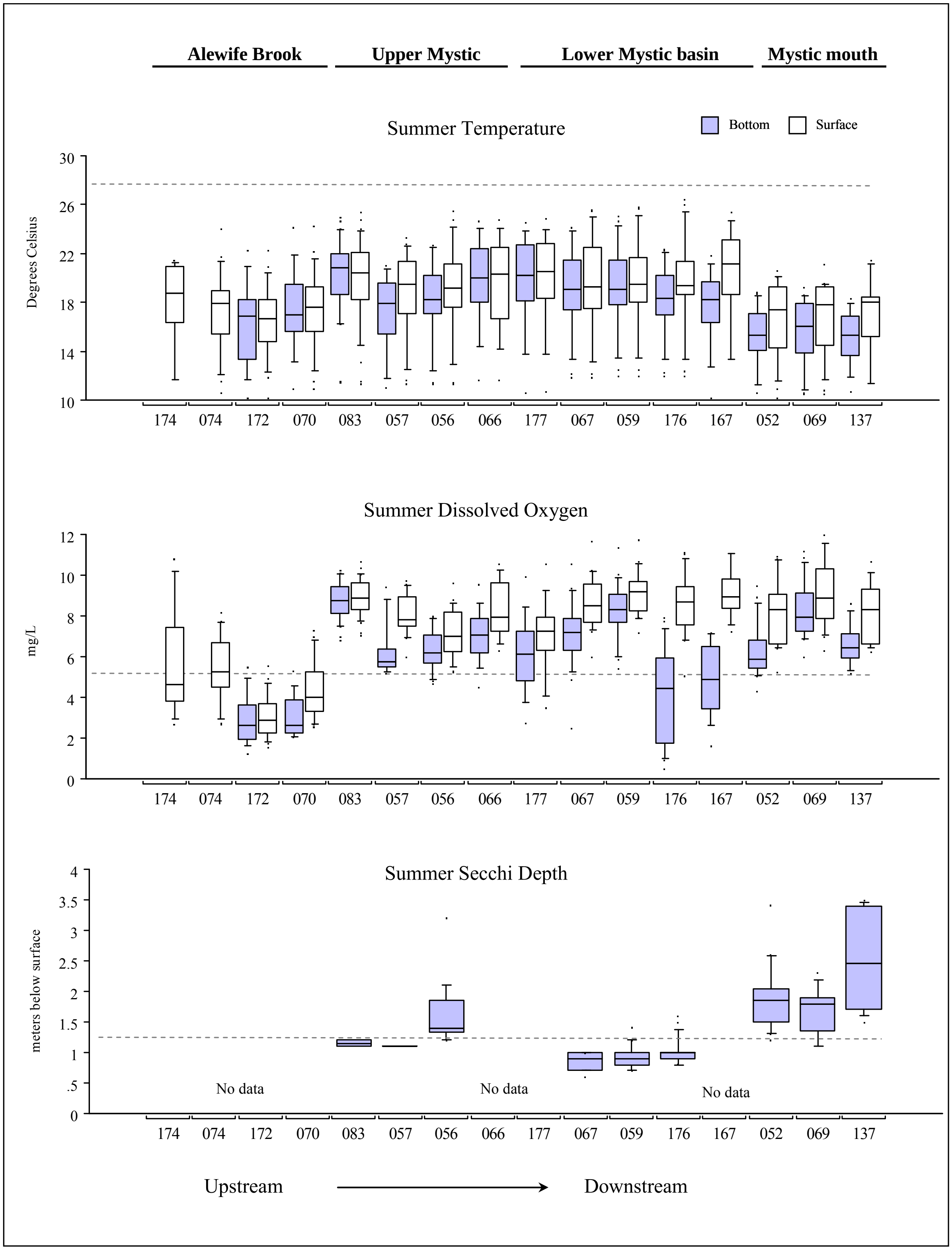

Figure 4-2. Summer temperature, dissolved oxygen, and Secchi depth, Mystic River, 2009.

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 Figures 4-3 through 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. 2009 results were very similar to the 2004-2008 average for all nutrient parameters, with the exception of Station 083 (upstream of Alewife Brook, downstream of Mystic Lakes), where phosphate and dissolved nitrogen values were slightly above average for autumn 2009.

Unlike the Charles River, there were no above-average increase TSS or phosphate concentrations in June or July 2009. 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 2009 at the river mouth may reflect increased wet weather runoff, originating from upstream sources.

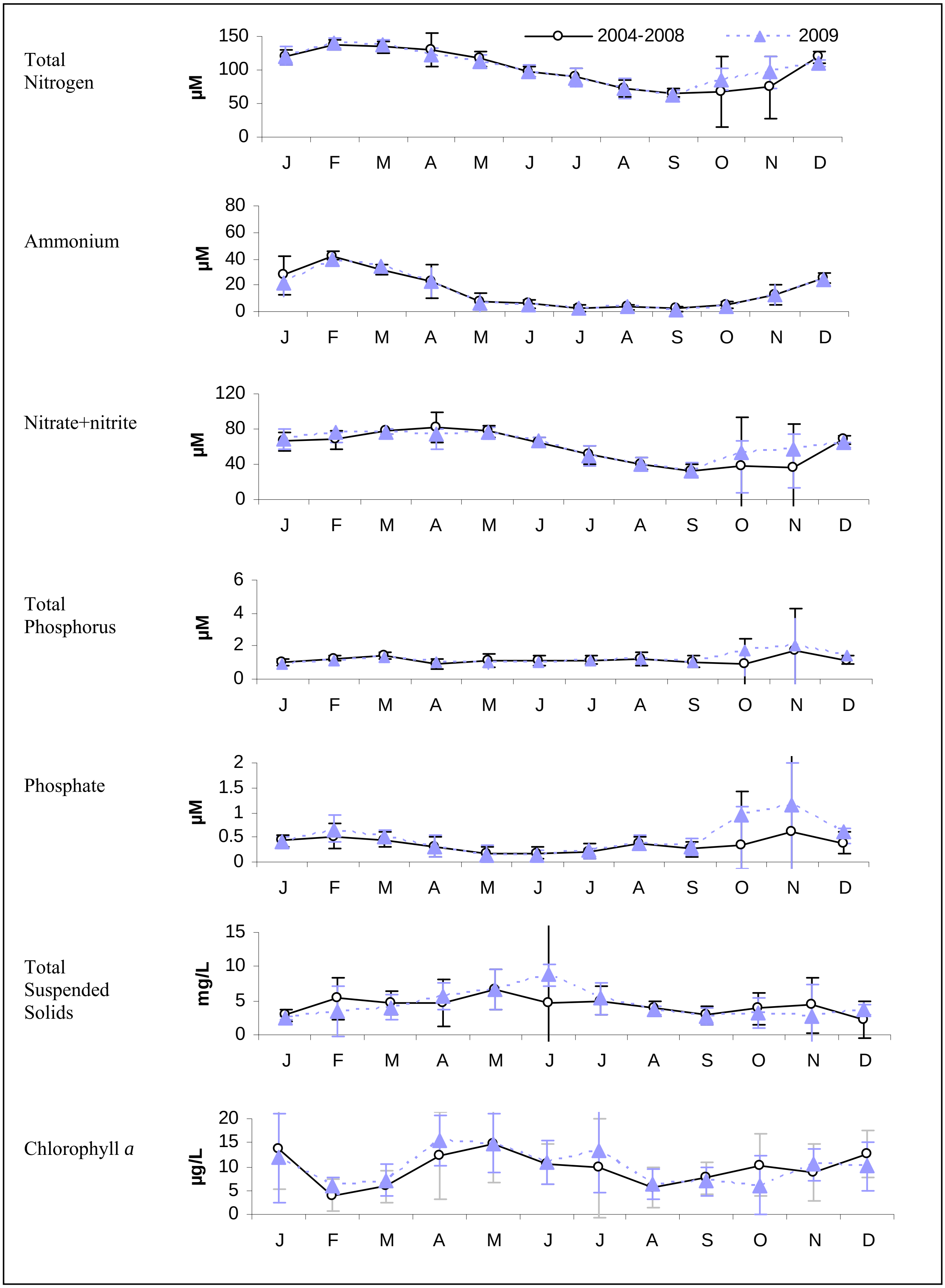

Figure 4-3. Monthly average nutrients, TSS and Chlorophyll 2005 – 2009, Station 083 (upstream of Alewife Brook)

Error bars are ± 1 SD. Note larger scale for Ammonium than for Figures 4-5 and 4-6.

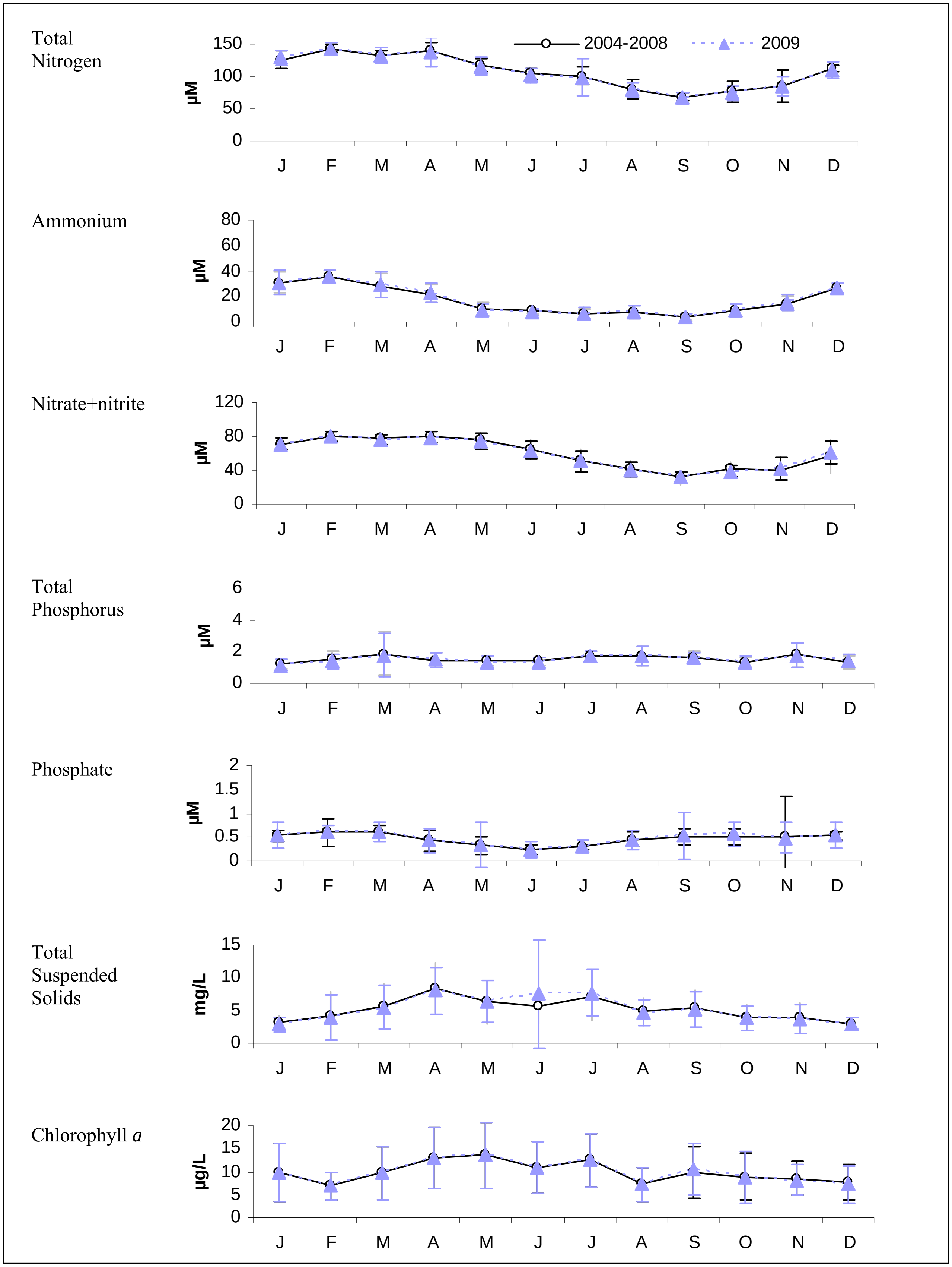

Figure 4-4. Monthly average nutrients, TSS and Chlorophyll 2005 – 2009, Station 066 (Boston Ave.)

Error bars are ± 1 SD. Note larger scale for Ammonium than for Figures 4-5 and 4-6.

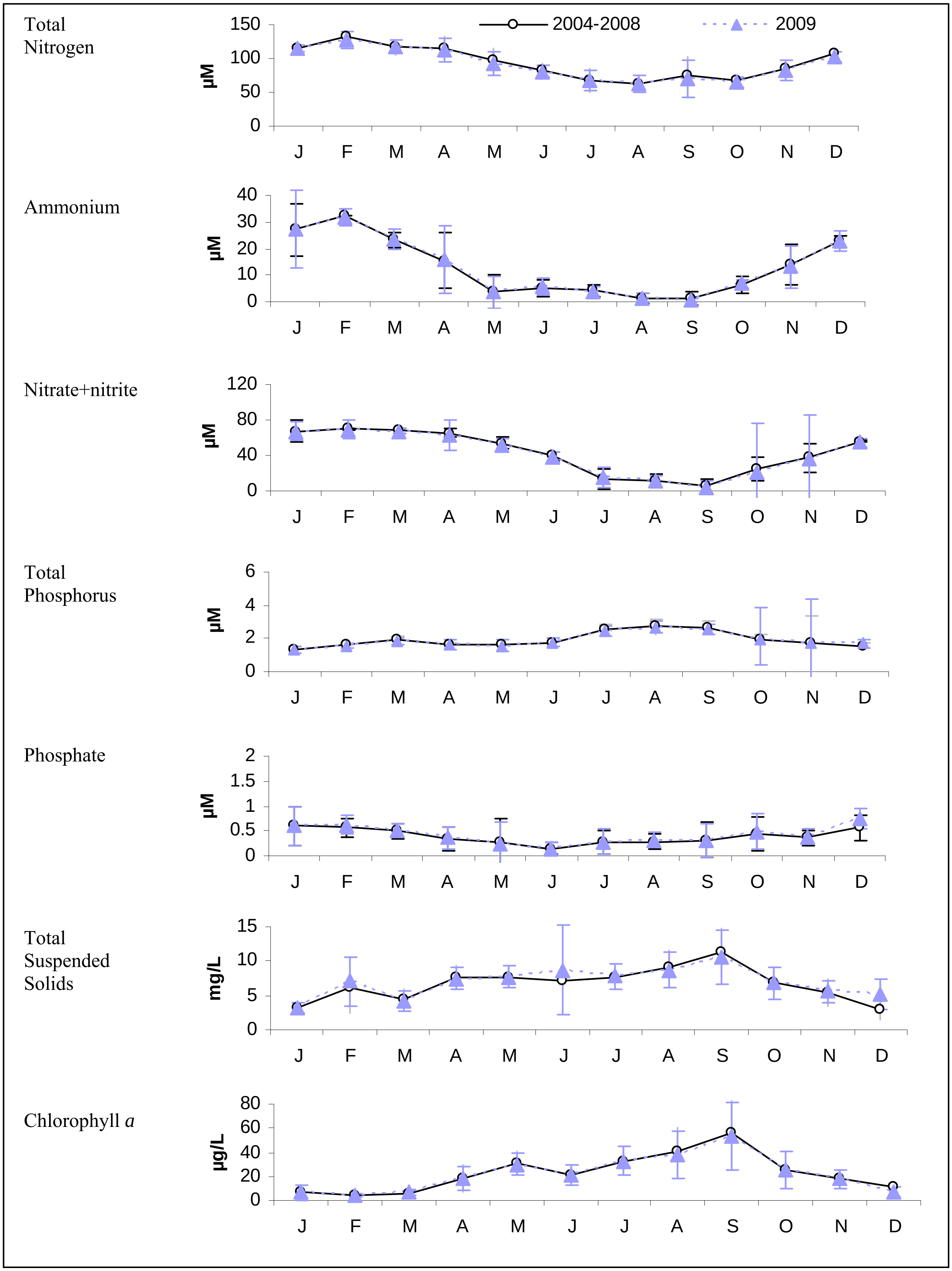

Figure 4-5. Monthly average nutrients, TSS and Chlorophyll 2005 – 2009, Station 167 (Amelia Earhart Dam (upstream/freshwater)).

Error bars are ± 1 SD. Note larger scale for Chlorophyll than for Figures 4-3, 4-4, and 4-6.

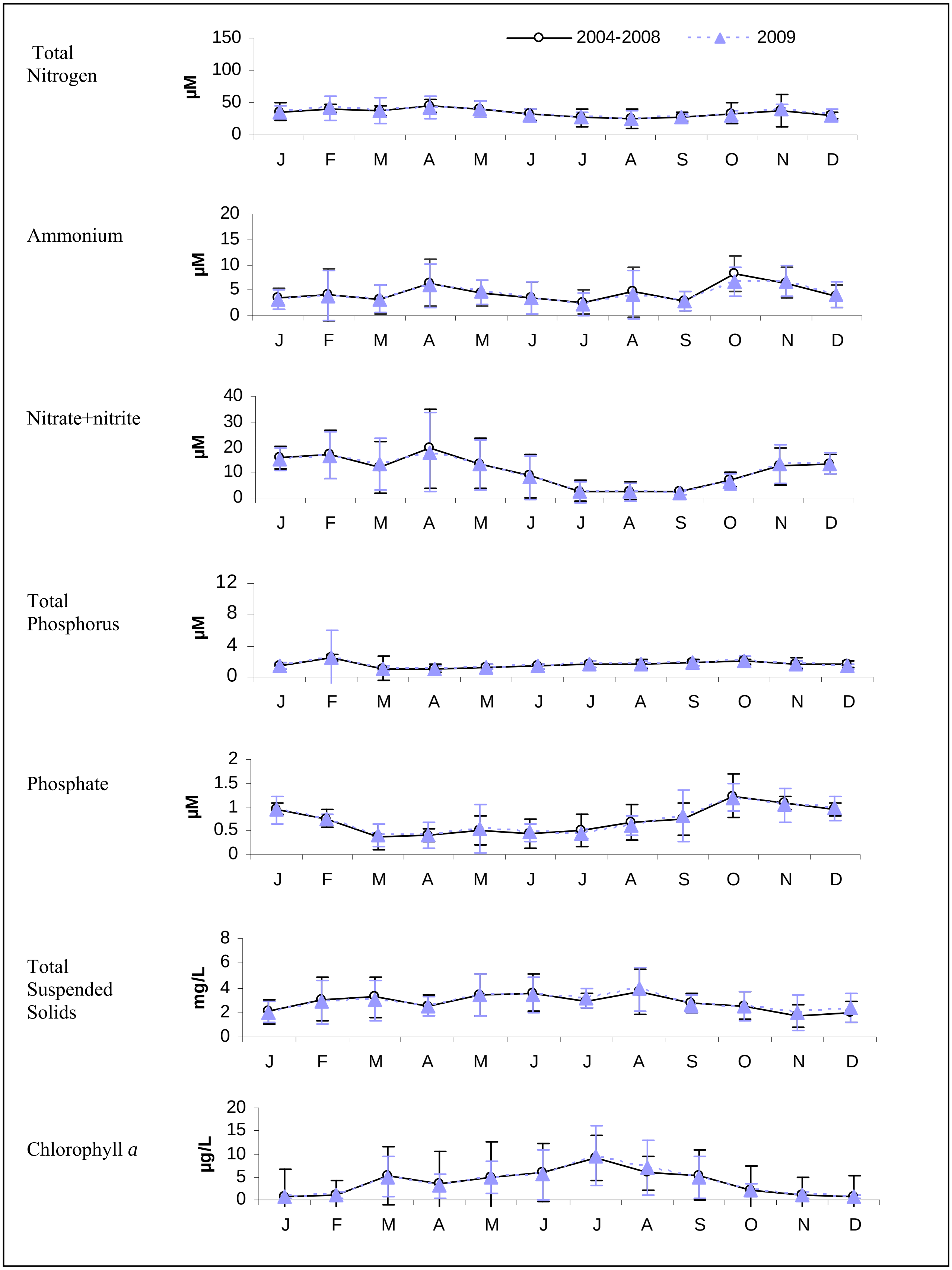

Figure 4-6. Monthly average nutrients, TSS and Chlorophyll 2005 – 2009, Station 137 Mystic River mouth (marine).

Error bars are ± 1 SD. Note smaller scales for Ammonium, Nitrate+nitrite and TSS than for Figures 4-3, 4-4 and 4-5.

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 2009. 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 2005 – 2009 appear in Table 4-6.

Enterococcus. The uppermost graph in Figure 4-7 shows percentile plots of *Enterococcus* counts for each location, arranged from upstream to downstream for 2009. 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 2005-2009 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, geometric means in the last three years for the Alewife have decreased significantly (see Figure 4-11), and most Mystic River locations met *Enterococcus* swimming standards.

The change in *Enterococcus* concentrations since 1989 in Alewife Brook and the Mystic River appear in Figure 4-8 through Figure 4-10. 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 2009. *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 has demonstrated a marked improvement in recent years. This is particularly noteworthy considering a relatively wet year in 2008 and 2009, where other downstream locations had similar geometric mean concentrations compared to previous years. Figure 4-11 shows the significant change in Alewife Brook water quality beginning in 2007.

Fecal coliform. Fecal coliform monitoring replaced *E. coli* in marine waters in 2009, due to methodological reasons. Fecal coliform is shown for marine locations, which meet the former state geometric mean standard of 200 colonies/100 mL. Fecal coliform appears in the bottom graph in Figure 4-7.

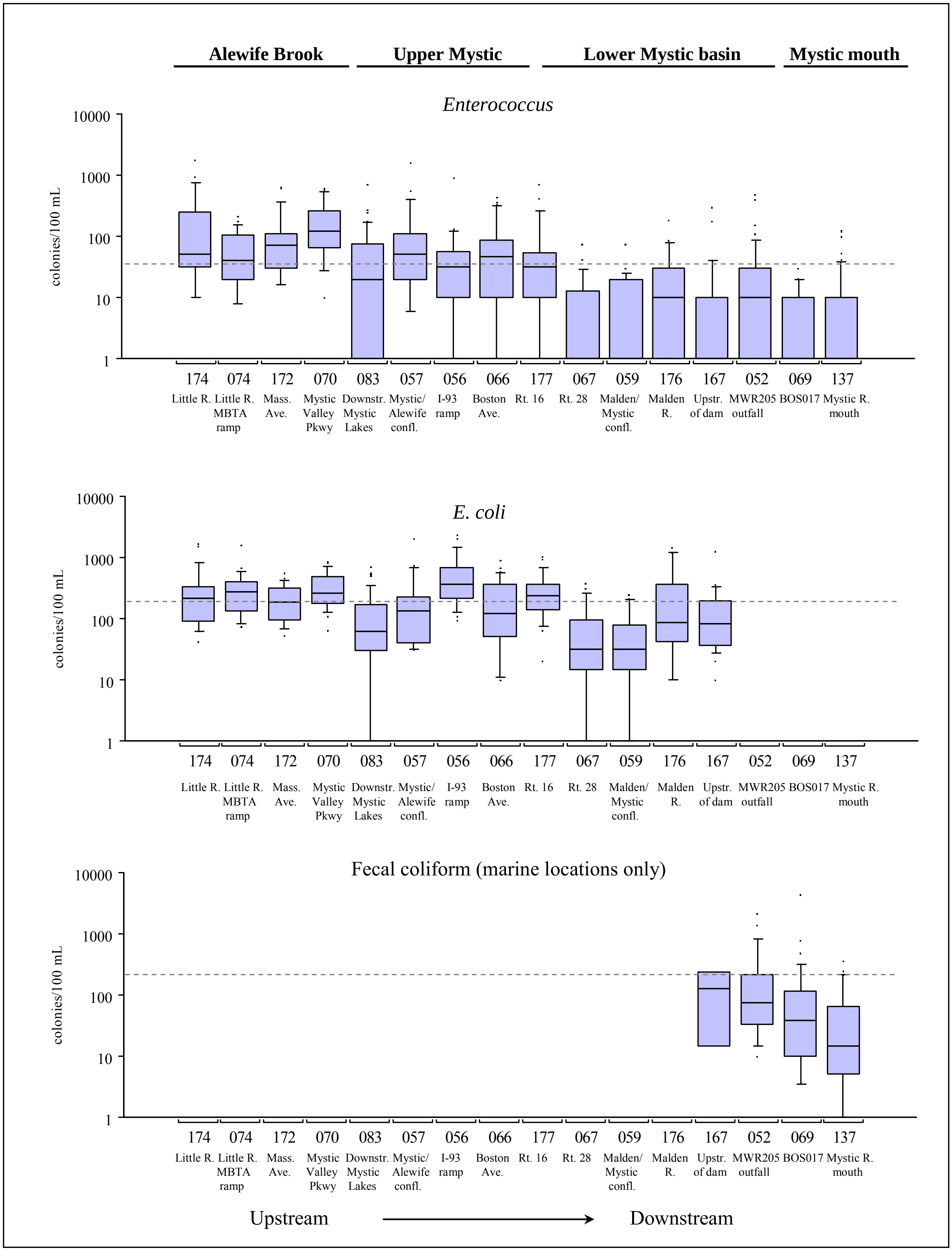

Figure 4-7. Indicator bacteria concentrations, Mystic River/Alewife Brook, 2009.

Dotted lines show MADEP *Enterococcus* and *E. coli* standard and former fecal coliform standard.
E. coli testing was discontinued in 2009 in marine waters for methodological reasons.

Table 4-6. Geometric mean indicator bacteria, Mystic River/Alewife Brook, 2005 – 2009.

Station	Location	Surface or Bottom	Number of samples[1]	*Enterococcus* (95% CI) colonies/100 mL		*E. coli*[2] (95% CI) colonies/100 mL	
				2004 - 2008	2009	2004 – 2008	2009
174	Cambridge, Little River, upstream of Rt. 2 and off ramp to Alewife T station	S	115/23	209 (153-286)	63 (31-127)	482 (390-596)	204 (137-304)
074	Cambridge, Little River, at off ramp to Alewife T station	S	136/2223	220 (156-310)	35 (19-63)	541 (433-676)	234 (169-322)
172	Arlington, Alewife Brook, upstream of Massachusetts Ave bridge, midchannel	S	120/23	273 (208-358)	54 (28-103)	524 (416-661)	169 (126-226)
070	Arlington, Alewife Brook, off Mystic Valley Parkway bridge	S	136/23	338 (245-465)	106 (59-189)	499 (401-620)	279 (211-367)
083	Medford, upstream of confluence of Mystic River and Alewife Brook	S	177/45	27 (20-36)	14 (7-26)	65 (53-80)	49 (29-83)
057	Medford, confluence of Mystic River and Alewife Brook	S	110/22	43 (31-60)	44 (20-96)	90 (68-119)	124 (76-202)
056	Medford, Mystic River, upstream of I-93 bridge	S	104/20	47 (32-68)	22 (10-47)	259 (200-336)	384 (262-562)
066	Medford, Mystic River, Boston Ave bridge	S	132/26	60 (43-85)	25 (11-55)	127 (97-166)	89 (46-174)
177	Medford, Downstream of Rt. 16 bridge, mid-channel	S	116/25	28 (19-40)	21 (9-44)	138 (104-182)	222 (158-312)
067	Medford, Mystic River, Rt. 28 bridge	S	105/21	7 (5-11)	3 (1-7)	32 (22-46)	28 (12-62)
059	Everett, confluence of Mystic and Malden Rivers	S	105/20	5 (3-8)	3 (1-7)	29 (20-42)	23 (10-53)
176	Malden River, upstream of Rt. 16 bridge	S	107/20	18 (11-28)	9 (4-19)	65 (44-95)	88 (36-211)
167	Medford, Mystic River, upstream side of Amelia Earhart Dam	S	116/25	8 (5-12)	3 (1-8)	39 (27-55)	86 (55-133)
052[2]	Somerville, Mystic River, near Somerville Marginal CSO facility (MWR205)	S	123/25 *23/25*	25 (16-39)	11 (5-27)	*436 (171-1109)*	*61 (3-863)*
		B	93/20 *19/19*	9 (6-13)	5 (2-10)	*58 (31-105)*	*135 (54-339)*
069[2]	Charlestown, near Schrafft's Center at BOS-017 outfall	S	20/20 *0/20*	28 (9-88)	2 (1-4)	No data	*52 (34-81)*
137[2]	Mystic River, upstream of Tobin Bridge	S	117/24 *19/24*	7 (5-10)	5 (2-11)	*115 (57-232)*	*16 (7-35)*
		B	115/23 *19/23*	2 (1-3)	2 (1-4)	*7 (4-13)*	*60 (36-97)*

[1]N values for *Enterococcus* and *E. coli* for the 2004-2008 and 2009 periods, respectively.

[2]Results in italics are fecal coliform, not *E. coli*. *E. coli* testing was discontinued in 2007 in marine waters for methodological reasons.

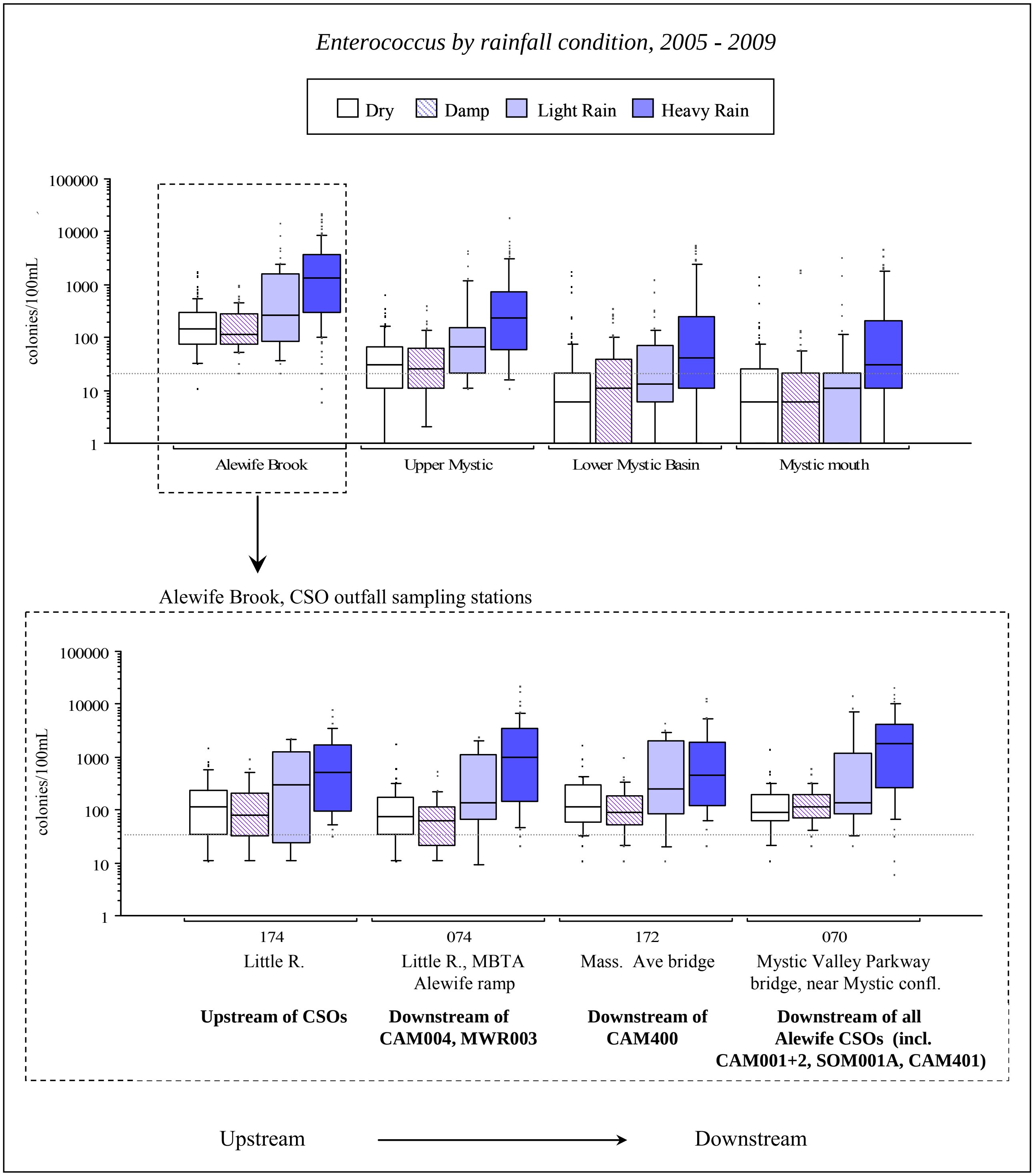

Figure 4-8. *Enterococcus* by rainfall condition, Mystic River/Alewife Brook, 2005 - 2009.
Dotted line shows State standard. Rainfall is NOAA rainfall from Logan airport. "Dry": no rainfall for previous 3 days; "Heavy": more than 0.5 inches in previous 3 days; "Damp" and/or rain distant in time: any 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.

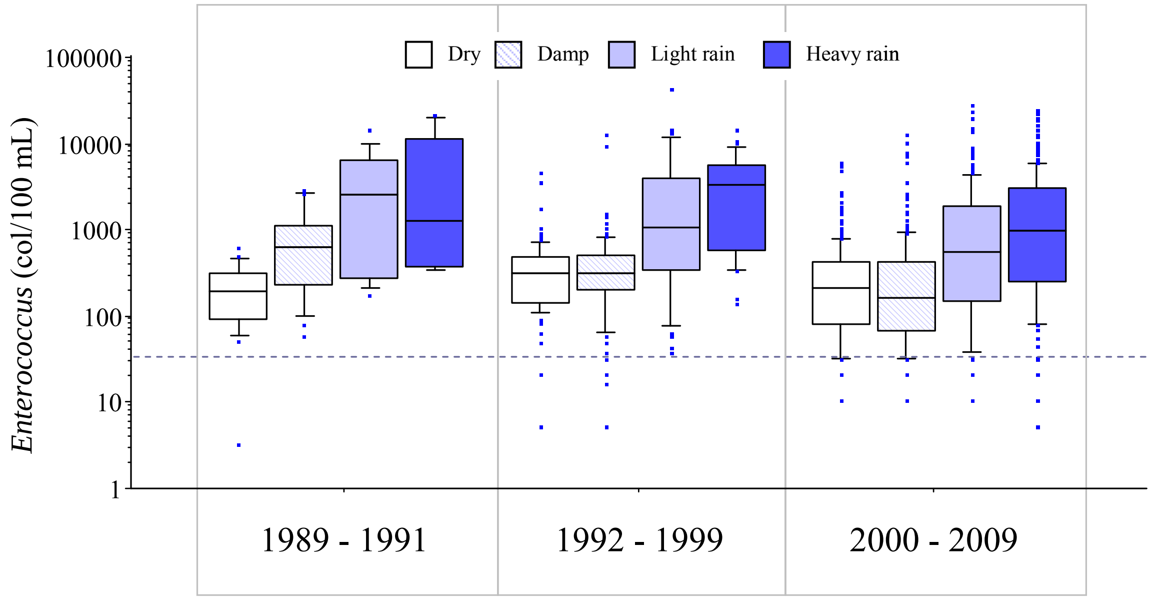

Figure 4-9. *Enterococcus* over time, Alewife Brook by phase of Long Term CSO Plan and rainfall condition.

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.

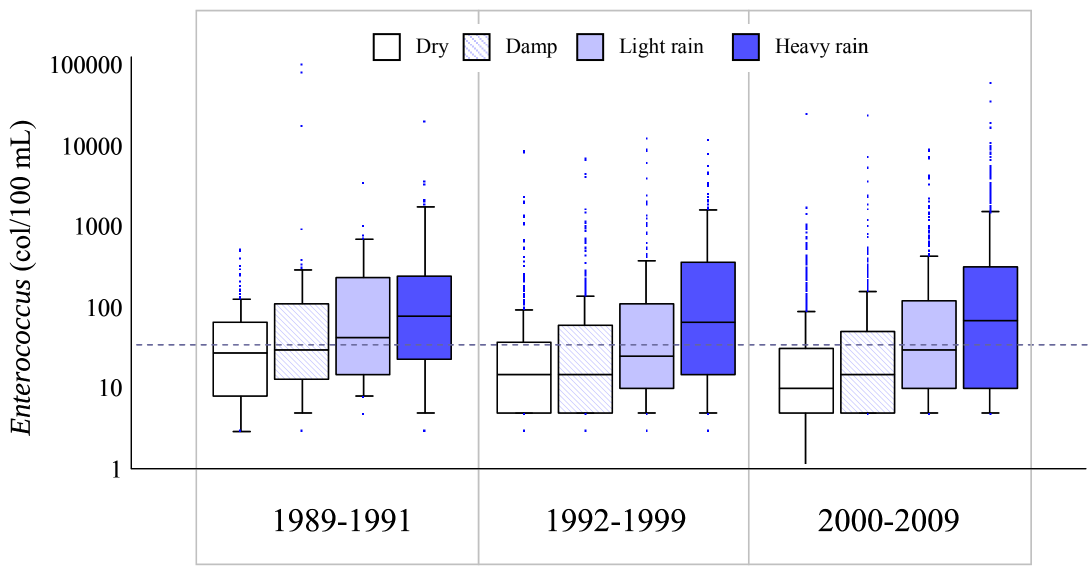

Figure 4-10. *Enterococcus* over time, Mystic River by phase of Long Term CSO Plan and rainfall condition.

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.

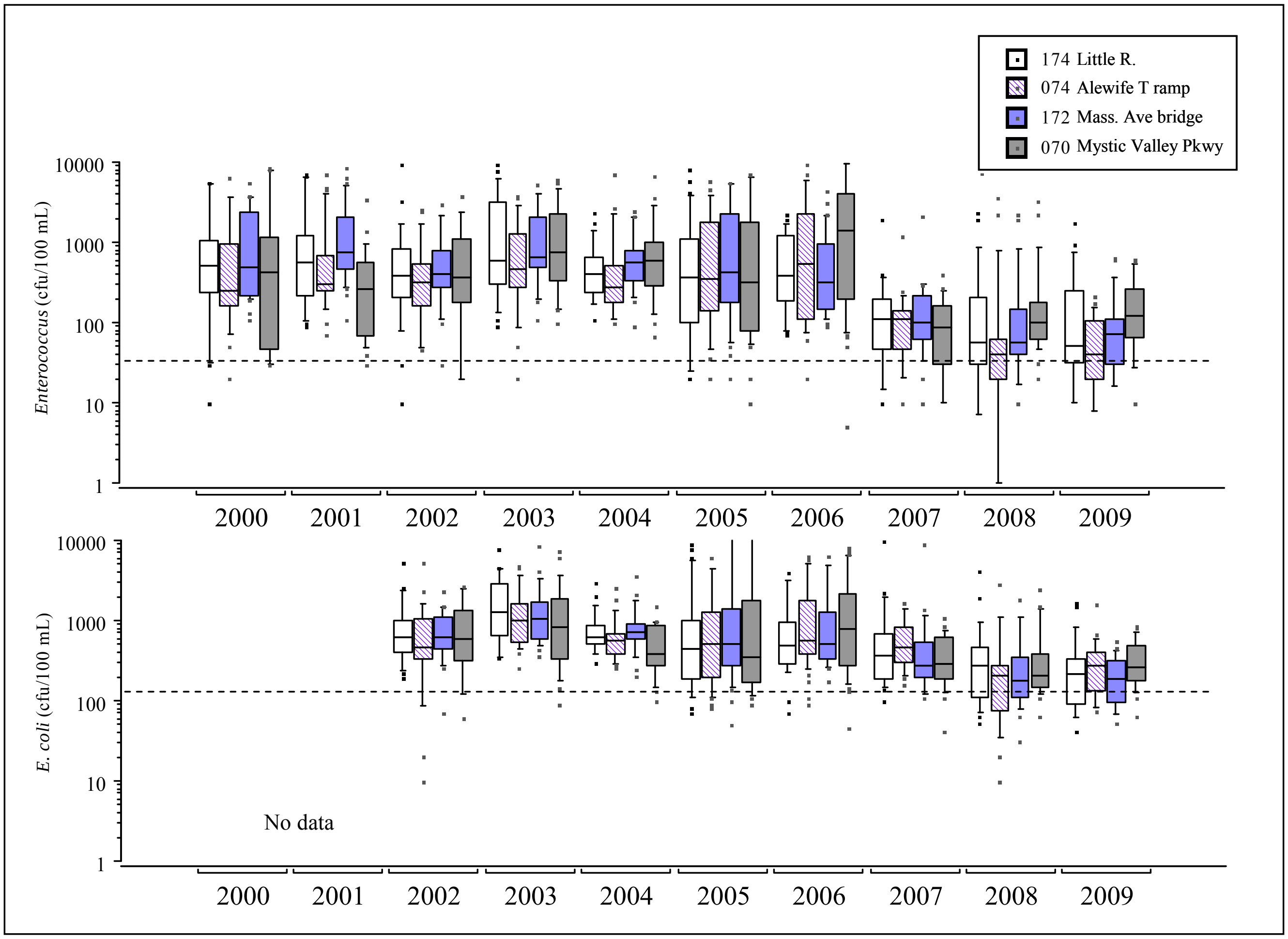

Figure 4-11. *Enterococcus* and *E. coli* over time, Alewife Brook, 2000–2009.
Dotted line shows State standards. Data includes results for all Alewife Brook locations.

4.5 Summary of Mystic River/Alewife Brook water quality

Water quality in the Mystic River meets water quality standards for much of the Lower Mystic Basin and Mystic River mouth, but fails to meet limits in the Upper Mystic, Alewife Brook and Malden River. Despite an improvement in recent years (2007 – 2009), bacterial counts in the Alewife consistently fail to meet standards, and water clarity and dissolved oxygen also remain poor in this area. Conditions improve dramatically further downstream, particularly at the river mouth.

2007 through 2009 results indicate significant improvement in bacterial water quality in the Alewife compared to the previous 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 2009, all locations met the *Enterococcus* geometric mean limit of 35 colonies/100 mL downstream of Medford Square. While *E. coli* monitoring was discontinued in the marine area of the river mouth, fecal coliform concentrations at the Somerville Marginal outfall location (MWR205) were relatively good, with geometric mean concentrations for both fecal coliform and *Enterococcus* meeting geometric mean limits (or former limits for fecal coliform).

Like the Charles River, nutrients and chlorophyll show strong seasonal fluctuations. 2009 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 elevated concentrations during the cold weather months when biological activity is reduced.

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