October 1991

Combined Sewer Overflow Receiving Water Monitoring Boston Harbor and Tributary Rivers June 1989-October 1990

Massachusetts Water
Resources Authority

Environmental Quality Department

Technical Report No. 91-2

Executive Summary

Background

This report summarizes water quality measurements in areas of Boston Harbor and its tributary rivers (the Mystic, Charles, and Neponset) affected by combined sewer overflows (CSOs). This is the most intensive microbiological monitoring effort ever conducted in these waters; including 3,000 samples and 15,000 measurements of water quality parameters collected between June 1989 and October 1990.

Although the major purpose of this work was to satisfy the receiving water monitoring requirements of the Massachusetts Water Resources Authority's (MWRA) National Pollution Discharge Elimination System (NPDES) permit, the study is the beginning of a long-term monitoring program to measure changes over time as pollution abatement projects are implemented. There have already been significant improvements made in the wastewater infrastructure during the monitoring period; including increased pumping capacity to the Deer Island treatment plant, the opening of the Fox Point and Commercial Point CSO treatment facilities, the ongoing elimination of illegal sewer connections to storm drains, and improved maintenance and repair of tidegates and CSO regulators. Thus, although much of the data reflect "before" or baseline water quality, in some areas the data reflect changing environmental conditions. In addition to satisfying permit requirements, and measuring the effects of pollution abatement, some of the data and patterns discovered during this study should also be helpful in refining plans for CSO control projects.

The design of this monitoring plan incorporated several important elements:

1. The entire greater Boston CSO area, including tributary rivers, the Inner Harbor and the Outer Harbor was included. Therefore, the effects of CSOs belonging to different municipalities could be monitored in an integrated fashion.

2. The monitoring focused on measuring densities of the sewage indicator bacteria, fecal coliform and *Enterococcus*, and dissolved oxygen. The most egregious violations of water quality standards in this area have been fecal coliform violations; and the primary public concern about CSOs is the potential danger to public health from infectious disease because of exposure to sewage-contaminated waters during swimming; and the contamination of shellfish beds.

Most of Boston Harbor is classified as SB, which means that fishing and swimming are included in its designated uses. The fecal coliform criterion for Massachusetts SB waters is: the geometric mean count should be no more than 200 colonies/100 ml with no more than 10% of samples having greater than 400 colonies/100 ml. More stringent criteria apply to areas of the Harbor designated for shellfishing. The outer Harbor, including Dorchester Bay and Quincy Bay includes restricted shellfishing in its designated uses.[1] Part of Quincy Bay is designated SA--open for shellfishing.[2]

3. The study design incorporated frequent sampling at each station, enabling us to measure short-term variation during dry weather and wet weather.

4. The relatively large number of sampling stations allowed assessment of spatial variation within a body of water, including sites near to and distant from CSOs.

5. The data analysis incorporated both anthropogenic and natural environmental factors, allowing us to determine the relationships among variables that affect the numbers of sewage indicator bacteria in the water. Anthropogenic variables measured included flows and loads through wastewater treatment plants and combined sewer overflow treatment facilities. Natural variables included rainfall, tide, water temperature and salinity.

6. The monitoring complemented, rather than repeated, other studies by different agencies.

Results from Five Geographic Areas

CSOs affect a large area, discharging along the shoreline into streams, rivers, esturarine areas, shipping channels and bathing beaches throughout metropolitan Boston. Since it was not possible to sample all bodies of water simultaneously, we divided the CSO receiving waters into five

---

[1] For restricted shellfishing, the geometric mean of fecal coliform shall not exceed 88 per 100 ml measured by the "most probable number" (MPN) method, nor shall more than 10 per cent of the samples exceed an MPN of 260 per 100.

[2] For SA (shellfishing), waters shall not exceed a geometric mean of 14 organisms per 100 ml and not more than 10 percent of the samples exceed a MPN of 43 per 100 ml.

geographic areas: the Inner Harbor; Dorchester Bay and the Neponset River; the Alewife Brook/ Mystic River/ Chelsea River; the Charles River; and Quincy Bay. Summaries of the results from each area follow:

Inner Harbor

This area includes the Inner Harbor from the mouth of the Charles River seaward inside a line from the southern tip of Governor's Island to Fort Independence. The Inner Harbor is rimmed by 26 CSOs, with the largest flows from BOS-070, located at the head of Fort Point Channel; and from the Prison Point treatment facility, located at the mouth of the Charles River.

Sewage indicator bacteria levels in the Inner Harbor were correlated with rainfall. The results of our monitoring in the Inner Harbor showed that there was a statistically significant relationship between bacteria counts in water and rainfall, which would be expected if CSOs were a significant source of sewage indicator bacteria. The effect of rain was cumulative over time: fecal coliform and *Enterococcus* numbers in the Inner Harbor correlated best with rainfall added over the three to four preceeding days. However, there was a great deal of variability in counts, both in wet and dry weather. For example, in dry weather, (1990) counts near BOS-070 ranged from 20 to more than 10,000 colonies/100 ml, and counts in the main ship channel ranged from 0 to nearly 1,000 col/100 ml. During rainy weather, counts near BOS-070 ranged from approximately 1,000 to approximately 100,000 colonies/100 ml, and counts in the main ship channel ranged from less than 10 to approximately 5,000 colonies/100 ml.

On average, in 1989, fecal coliform counts exceeded the SB standard in the Inner Harbor when rain summed over four days exceeded 0.98 inches, with rain acounting for about 45% of the variation in counts. In 1990, on average, counts exceeded 200 colonies/100 ml when the sum of rain over three days was more than 1.3 inches, with rainfall accounting for about 24% of the variation in counts in the Inner Harbor as a whole. Other than rainfall, the most important predictor of bacteria counts in the Harbor was salinity, which correlates with distance from the Charles River, Mystic River and Fort Point Channel. Generally, the greater the distance was seaward from the confluence of the rivers, the lower the bacteria count.

Although it did not strictly meet class SB standards, water quality in much of the Inner Harbor approached standards. During dry weather, 11 out of 13 Inner Harbor stations met the criteria for class SB waters, with two stations showing more than 10% of samples exceeding 400 colonies/100 ml. The two stations with these exceedances were located in Fort Point Channel and in the main ship channel. During wet weather, none of the stations in the Inner Harbor met swimmability criteria because more than 10% of the samples at all stations exceeded 400 colonies/100 ml. However, even during wet weather, geometric mean counts seaward of Fort Point Channel were near or below 200 colonies/100 ml. (The geometric mean is a type of average ordinarily used for bacterial data. The calculation of the geometric mean reduces the effect that extremely high, but very infrequent, measurements have on the average.)

Routine maintenance of the CSO infrastructure can significantly decrease pollutant levels in the receiving water. The most dramatic improvement in water quality that we observed during this time period was in Fort Point Channel: after a dry-weather overflow was detected in the winter of 1989, repairs to a malfunctioning regulator were made and dry-weather counts at nearfield sites dropped 100-fold.

The patterns of relationships among rainfall, salinity, tidal currents and sewage indicator bacteria counts all are consistent with combined sewer overflows as a major source of sewage to the surface waters of the Inner Harbor. Bacteria counts in the bottom waters show different patterns with rainfall and tidal currents, however, and we speculate that sludge is a likely source to the bottom waters.

Neponset River and Dorchester Bay

This area includes northern Dorchester Bay (Old Harbor), southern Dorchester Bay and the lower Neponset River. Sampling stations included sites near the CSOs lining Carson Beach, near the two largest CSOs in Dorchester Bay (Commercial Point and Fox Point), stations offshore and in the lower Neponset River.

The water quality varies greatly at different locations in the Dorchester Bay area. Carson Beach and Northern Dorchester Bay were the least contaminated, and generally met water quality standards, despite the presence of seven CSO pipes along Carson Beach. In contrast, indicator bacteria counts in the Neponset River generally exceeded water quality standards, even during dry weather and upstream of all CSOs.

A comparison of average wet weather and dry weather data in northern Dorchester Bay showed unexpectedly little difference in bacteria counts. The geometric means for counts measured during both wet and dry seasons were well within state standards. Very few samples exceeded swimming standards, and those samples showing the highest counts were offshore, rather than nearshore, suggesting a non-CSO source. Our monitoring agrees well with flow measurements done by BWSC and beach water quality measurements done by MDC. One explanation for the surprisingly low counts in Northern Dorchester Bay after rain was that rainfall was coincident with high tide, which held the tide gates closed, and prevented the discharge of combined sewage. Increased pumping capacity at Deer Island enabled the combined sewage retained by the pressure of high tide to be successfully removed to the treatment plant.

There appear to be several significant sources of fecal indicator bacteria to southern Dorchester Bay. Two beaches (Tenean and Malibu) are located in this area. These beaches were frequently posted due to high fecal coliform counts in the water. Potential sources of pollution in this area include the Neponset River, the Commercial Point CSO, the Fox Point CSO, illegal connections, storm drains, and sludge from Nut Island. Thus, even if chlorination significantly reduces the sewage bacteria discharged from Fox Point and Commercial Point, these beaches will probably still be adversely affected by sewage from other sources.

Quincy Bay

Because Quincy Bay beaches are regularly monitored by the MDC and by the City of Quincy, we focused on sampling farther offshore, in order to assess the effects of effluent from the Nut Island Treatment Plant and the Moon Island CSO (BOS-125). In 1989, BOS-125 discharged a number of times, but in 1990 that CSO was deactivated.

As a general trend, offshore water quality in Quincy Bay was well within water quality standards, even within the effluent "boils". For example, in 1990, the geometric mean fecal coliform counts at the stations we sampled in Quincy Bay ranged from 1 colony/100 ml to 8 colonies/100 ml. Exceedences of bacterial water quality criteria were measured in Quincy Bay after rainstorms in both 1989 and 1990. In 1989, counts in Dorchester Bay near the Moon Island CSO were elevated above water quality standards until four days following a storm and discharge. However, counts in Quincy Bay remained within water quality standards. In 1990, samples collected only two days after a similar storm were within water quality standards. After rain, the highest offshore counts were closest to the Inner Harbor, not to Nut Island. Now that the Moon Island CSO has been deactivated, the Inner Harbor and Dorchester Bay are probably the greatest sources of untreated sewage to the offshore waters of Quincy Bay.

Quincy beaches showed high coliform counts at times when counts in samples from Nut Island effluent, outfalls and stations between the outfalls and the beaches were low. This finding is consistent with what would be expected if storm drains, which are located on the beaches, were the major source of sewage affecting Quincy Bay beaches rather than the treatment plant, Moon Island CSO or other offshore source.

Alewife Brook and the Mystic and Chelsea Rivers

This sampling area included a variety of aquatic environments. Alewife Brook is a small freshwater stream tributary to the Mystic River, and the receiving water for approximately ten CSOs and a number of stormdrains. The Mystic River, which is dammed at its mouth, is freshwater upstream of the dam, and marine downstream of the dam. The section of the Chelsea River affected by CSOs is considered part of the Inner Harbor and is marine. One CSO is located near the confluence of the Alewife and Mystic, three in the "basin" area of the Mystic, and others are located along the mouth of the river and at its confluence with the Chelsea River. Six CSOs discharge into the Chelsea River. The largest CSO is the outfall for the Somerville Marginal CSO treatment facility, MWR-205, and is located immediately downstream of the Amelia Earhart Dam.

The water quality in Alewife Brook was severely degraded. As well as having high densities of sewage indicator bacteria, there were very low levels of dissolved oxygen. Visible sewage-associated waste caused severe aesthetic degradation. Pollution from Alewife Brook adversely affected the water quality of the nearby portions of the Mystic River. High levels of sewage pollution in the Alewife was associated with even modest amounts of rainfall, but some of this sewage came from sources other than CSOs.

There was considerable variation in water quality along the length of the Mystic, with sewage entering the river from "nonpoint" sources as well as CSOs. The poorest water quality in the freshwater segment was near the confluence with the Alewife and at a station in the river remote from any CSO source. The "basin" area of the Mystic generally met water quality standards. The area near MWR-205 showed exceedences of bacterial water quality standards in wet and dry weather, as well as depressed dissolved oxygen levels. Rainfall produced exceedences of water quality standards even upstream of any CSOs. Water quality in the Chelsea River was similar to that in the Inner Harbor's main ship channel.

Charles River

Between the Charles River Dam and the Watertown Dam are 22 combined sewer outfalls that can discharge directly into the river. However, most of the combined sewage that enters the Charles River is discharged from the Cottage Farm screening and chlorination facility and from the Muddy River/Stony Brook, which carries combined sewage from CSOs located on the Fens.

Generally, the water quality in the Charles River was severely degraded by sewage. Fecal coliform levels greatly exceeded class B standards in 1989 and 1990. Water quality was poor, even during dry weather and light rains, and in the absence of combined sewer overflows.

Nonpoint sources of contamination and/or illegal connections to storm drains prevented the Charles River from meeting water quality standards in dry weather. Sampling stations located upstream of all CSOs had among the highest densities of sewage indicator bacteria measured.

Overflows from combined sewers significantly degrade water quality in the Charles. Despite the high level of non-CSO "background" contamination, we found that overflows from combined sewers, which occurred after heavy rains, produced dramatic elevations of sewage bacteria in nearfield zones. The "Basin" area of the Charles, where outflow is restricted by the Charles River Dam showed some of the highest fecal coliform counts recorded, even though effluent from Cottage Farm is disinfected. After one heavy rainfall, levels of dissolved oxygen in surface waters in the Basin became severely depressed for three days, possibly because of the large amount of oxygen-using materials (BOD) discharged by Cottage Farm. Sewage in the Basin after a heavy rain poses a threat to both human health and to the health of aquatic life.

Overview

There was a great deal of variation in water quality both among all the areas studied and within each area. Nevertheless, some general trends were observed:

- The best water quality was in the more offshore areas--in Northern Dorchester Bay and in Quincy Bay. Past monitoring in offshore areas (e.g. by the Aquarium) frequently found high offshore fecal coliform counts. We believe that the improvement in water quality is a reflection of improvements in treatment plant operation over the past few years, and the closure of the Moon Island CSO.

- The poorest water quality was found in the rivers and in localized areas within the Inner Harbor. Among these areas of poor water quality, we detected significant CSO impacts in the Inner Harbor, especially Fort Point Channel; in the Charles River Basin; in Alewife Brook; in the Neponset River estuary (southern Dorchester Bay); and at the mouth of the Mystic River. Other, "nonpoint" sources degrade water quality in the more upstream segment of the Charles River, the Mystic River, and the Neponset River.

- At Harbor beaches, water quality was good in northern Dorchester Bay because combined sewers located on these beaches rarely overflowed; while beaches in Quincy Bay were often polluted, evidently from contaminated storm drains. Beaches in southern Dorchester Bay were affected by CSOs, the Neponset River, and storm drains.

  Factors that have probably contributed to improvement in water quality at South Boston beaches include improved treatment and increased pumping capacity at the Deer Island plant. Improved treatment has decreased offshore sources of untreated sewage to the beach, and increased pumping capacity has increased the volume of sewage flowing to the treatment plant during storms, decreasing overflows of combined sewage from the seven CSOs located along the shore.

- Where rainfall and CSOs did have a significant impact on receiving waters, the effect on water quality depended on several environmental factors including the cumulative rainfall occurring over three to four days, as well as salinity, temperature and tidal current.

Acknowledgments

This report was written by Andrea Rex (MWRA). Graphic and statistical analyses were performed by Kenneth Keay (MWRA), John Freshman (Menzie-Cura Associates) and Andrea Rex. Victoria Gibson (Battelle Ocean Sciences) was the technical editor and formatted the manuscript. Maps were produced by Susan Curran (MWRA) and Luisa Valiela (MWRA) on the ArcInfo GIS System. Field sampling and laboratory analyses were performed by Kenneth Cunningham, Eileen Kelley, Colleen O'Rork, Ellen Case, Joan Abbott, Wilson Hu, Elizabeth Potter, William Lawrence, Maura Fitzsimmons, Lisa Wong, Jory Bell, David Timothy, Robert Rabideau, Kenneth Keay and Andrea Rex, all of MWRA.

We are grateful to the University of Massachusetts/Boston for providing laboratory space and permitting us to use their dock.

Table of Contents

1 Introduction

2 Materials and Methods

2.1 Field and Laboratory Methods

2.2 Data Analysis

3 The Inner Harbor

3.1 1989 Results

3.2 1990 Results

5. Quincy Bay

5.1 1989 Results

5.2 1990 Results

5.3 Discussion

6 Alewife Brook and the Mystic and Chelsea Rivers

6.1 1989 Results

6.2 1990 Results

List of Figures

List of Figures

List of Figures

List of Figures

List of Tables

List of Tables

List of Tables

1. Introduction

1.1 Background

Sewage pollution from combined sewer overflows (CSOs) has been identified as a major contributor to the degradation of water quality in Boston Harbor and its tributary rivers (MDC, 1980, 1981, 1982a, 1982b, 1982c; EPA, 1987; MWRA, 1990, 1991c). One of the most problematic aspects of remediating pollution from CSOs has been identifying the effects of these discharges and where and under what environmental conditions the impacts occur. These difficulties arise from logistical problems, like predicting a rainstorm with enough accuracy to deploy people to sample an overflow; as well as from sampling and statistical problems resulting from the great variability associated with environmental conditions. Two simple facts--that a single body of water often has many sources of contamination and that water moves--make it very difficult to determine the source(s) of pollutants in a water sample. In the Boston area, our incomplete understanding of how the ancient and labyrinthine sewer system functions adds an additional layer of complexity.

Although several scientific and engineering studies have measured or modeled the amounts of pollutants entering Boston-area waters from combined sewers and the effect on the receiving waters, most of these efforts have been relatively short term or limited in scope to one or a few CSOs. Longer term, ongoing water quality surveys have been conducted by the Massachusetts Department of Water Pollution Control (DWPC), the Massachusetts District Commission (MDC), the Massachusetts Division of Marine Fisheries (DMF) the New England Aquarium, and local municipalities. However, none of these water surveys were designed to assess the receiving water effects of combined sewer overflows.

The work reported here was performed to satisfy the CSO receiving water monitoring requirements in the Massachusetts Water Resources Authority's (MWRA) NPDES permit [Outfall Identification and Monitoring Requirements, Permit No. MA0102351(M-44), Part I, page 13, Section b.(2)]. The conditions of the permit require MWRA to (a) "assess compliance or non-compliance with water quality standards during wet weather and dry weather and minimum dilution conditions (for receiving waters); and (b) Provide an assessment of individual overflow impacts on the receiving waters." However, it was also our intention that the data gathered should be used as part of a long-term monitoring program to measure changes in water quality over time as pollution abatement programs are implemented. Much of the data collected here can be viewed as baseline information, although significant improvements in wastewater treatment were implemented during the two-year monitoring period. Finally, some of the data and patterns discovered should be useful in refining plans for CSO control facilities.

1.2 Elements of the Monitoring Plan

The MWRA receiving water monitoring plan incorporated six important elements:

1. The plan comprised the entire Greater Boston CSO area, including all tributary rivers, the Inner Harbor, and the Outer Harbor. This broad coverage allowed an integrated, coordinated approach to sampling water bodies that were affected by CSOs belonging to several municipalities.

2. Water column monitoring focused on measuring densities of the sewage indicator bacteria, fecal coliform and *Enterococcus*, and dissolved oxygen. We chose indicator bacteria because they are very sensitive indicators of the presence of raw sewage, and their densities in water are correlated with infectious disease hazards. The potential danger to public health from exposure to sewage-contaminated waters during recreational activities (swimming, boating) and from contamination of shellfish beds has been identified as the primary public concern about CSOs. In fact, past work has shown that the most egregious violations of water quality standards in the Boston area have been fecal coliform violations (MDC, 1982c; MWRA, 1990). Use of indicator bacteria densities as the primary measure of water quality in sewage-impacted waters has the additional advantage of being inexpensive and relatively rapid. The testing is done in-house by MWRA, which facilitates flexibility, optimal sample handling, and quality control.

   Our focus on monitoring indicator bacteria in the receiving water may prompt some concern that the potential problem of toxic pollution from combined sewers is being neglected. However, measurements of toxic pollutants in receiving waters and toxicity testing of combined sewage have shown that acute toxicity from sewage-derived priority pollutants in the water column is not a major problem in most Boston-area waters (MDC, 1980; MWRA, 1980, 1991a, b). Toxic materials may, however, accumulate in the sediments and produce environmental damage. How much various waste discharges contribute to toxic pollution, how patterns of water circulation affect movement of sediments, and how toxic chemicals in sediments affect aquatic life are complex problems, as shown in a DEP-sponsored study of the Fox Point CSO (MDEP, 1990). MWRA and EPA are now cosponsoring a group of studies aimed at further addressing these questions (personal communication, E.Adams, Massachusetts Institute of Technology) in Boston Harbor. MWRA is completing a study in which levels of organic compounds and metals in Dorchester Bay sediments were measured, together with potential sewage source tracers (MWRA, 1991d), to begin assessing the effects of CSOs on levels of toxic materials there.

3. The study design incorporated frequent sampling, from four to six days/week, enabling us to measure short-term variation during dry weather and wet weather.

4. The relatively large number of sampling stations allowed assessment of spatial variation within a body of water. The stations were located to permit assessment of nearfield and farfield effects of CSOs.

5. The data analysis incorporated both anthropogenic and natural environmental factors, allowing us to determine the relationships among variables that affect the densities of indicator bacteria in the receiving waters in different ways. Anthropogenic variables measured included flows and loads through wastewater treatment plants and facilities for treating the overflow from combined sewers. Natural variables included rainfall, tide, water temperature and salinity.

6. The monitoring was designed to complement, not repeat, other studies. Concurrent work included the EPA-MWRA sediment project, BWSC CSO monitoring, Cambridge CSO monitoring, MDC beach sampling, DWPC water quality surveys, and the MWRA CSO sediment effects study in Dorchester Bay.

1.3 Organization of the Report

This report is divided into seven sections, including this introduction (Section 1); a materials and methods section that describes the sampling design, technical methods, and data analysis (Section 2); and five sets of results and discussion, one for each geographic area monitored. These areas are the Inner Harbor (Section 3), Dorchester Bay and the Neponset River (Section 4), Quincy Bay (Section 5), the Alewife Brook/Mystic River/Chelsea River (Section 6), and the Charles River (Section 7).

2. Materials and Methods

2.1 Field and Laboratory Methods

2.1.a Sampling Area, Location of Combined Sewer Overflows and Sampling Stations

The study area of the 1989 and 1990 CSO Receiving Water Monitoring program included Boston Harbor and the segments of its tributaries that are affected by combined sewer overflows (CSOs). The bodies of water sampled were the Inner Harbor, Dorchester Bay, and Quincy Bay, as well as the Charles River, the Mystic River, the Chelsea river, the Neponset River, and Alewife Brook. Figure 2.01 shows the locations of CSOs. A total of 90 stations were sampled in 1989 (Figure 2.02) and a total of 71 stations in 1990 (Figure 2.03). For all the stations sampled, Table 2.01 lists the geographic landmarks used for triangulation, the latitude and longitude as determined by Loran-C, the approximate distance to the nearest CSO, and the years sampled.

2.1.b Sampling Schedule

We divided the study area into five geographic subareas in 1989 and six areas in 1990. These areas were the Charles River, the Alewife Brook/Mystic River/Chelsea River, the Inner Harbor, Northern Dorchester Bay, Southern Dorchester Bay/Neponset River, and Quincy Bay. Sampling focused on one area at a time and each area was monitored for approximately three consecutive weeks. In 1989, we sampled four days/week, Monday through Thursday; in 1990 we sampled six days/week, Monday through Saturday. We attempted to collect samples from all stations within the area each day. Table 2.02 summarizes the stations in each area and the sampling periods.

2.1.c Additional Samples

In addition to the intensive sampling described above, selected stations were monitored periodically throughout the summer of 1989 (Table 2.03).

2.1.d Sample Collection

Detailed field methods with quality assurance and quality control procedures are described in the MWRA Harbor Studies Field Standard Operating Procedure (1989a). Most samples were collected from a small motorboat, although some stations required sampling from a bridge, dock, or dam (Stations 18, 63, 39,

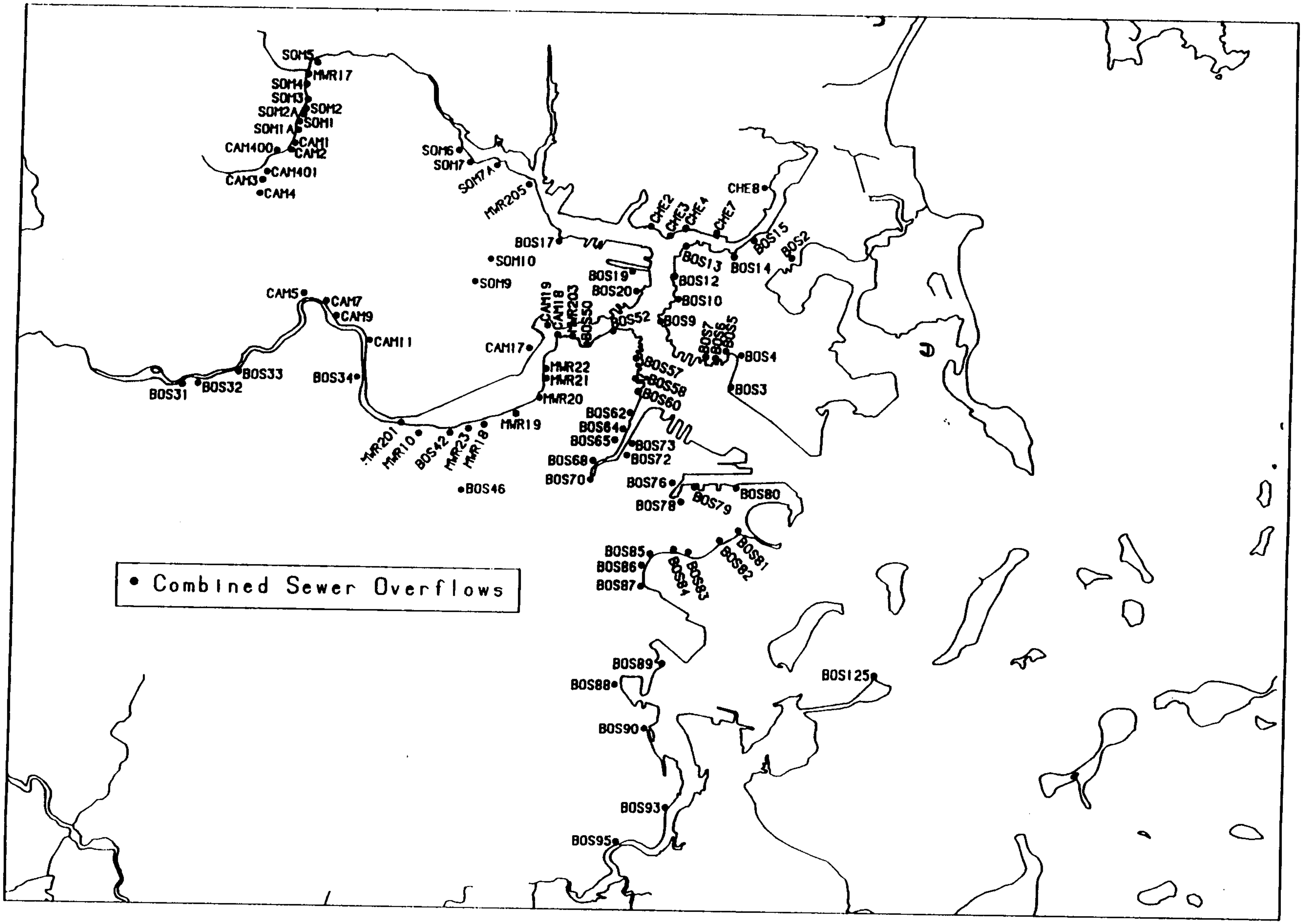


Figure 2.01. Combined Sewer Overflows in Boston Harbor and Its Tributary Rivers.

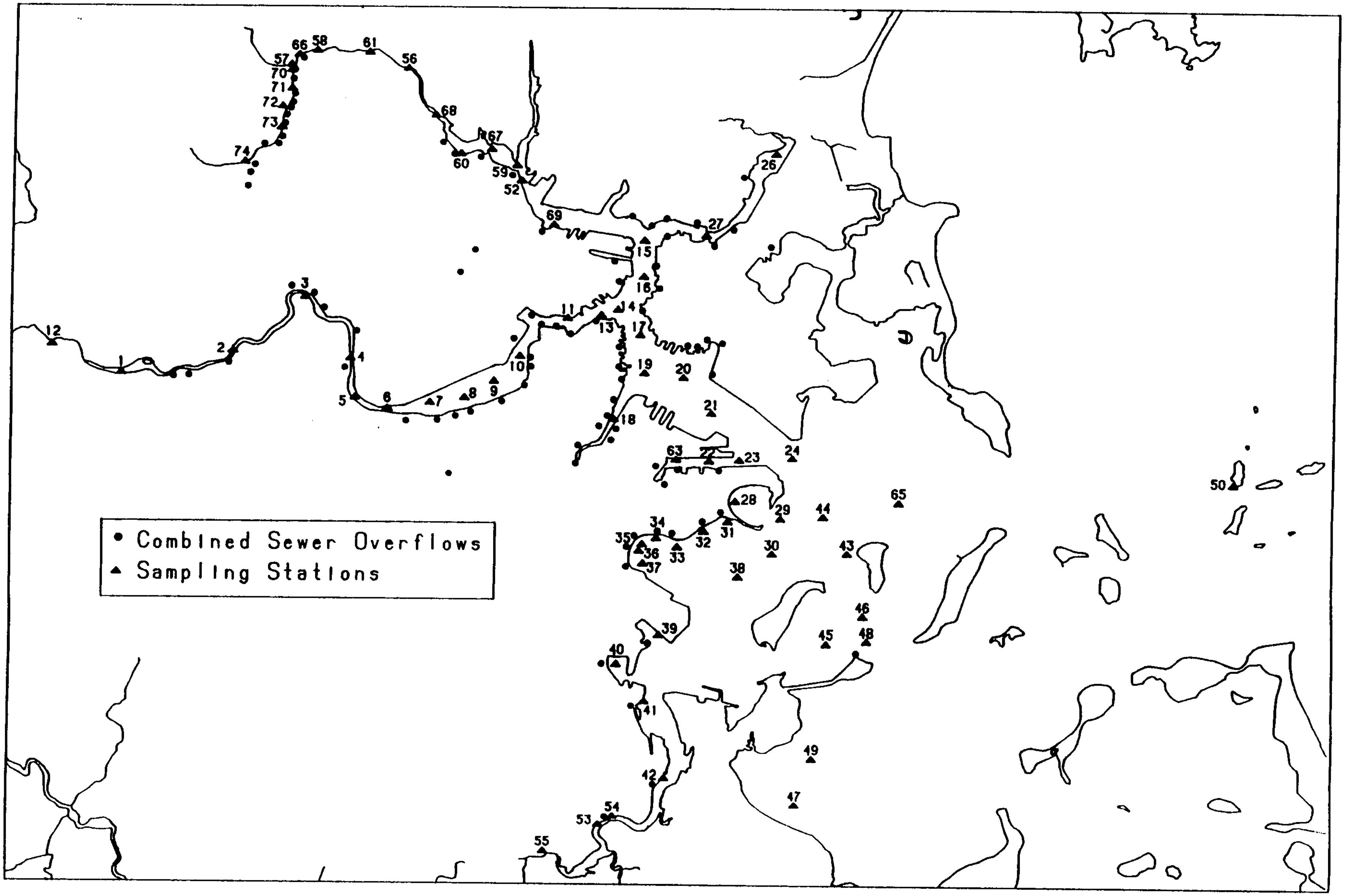


Figure 2.02. Water Quality Monitoring Stations, 1989.

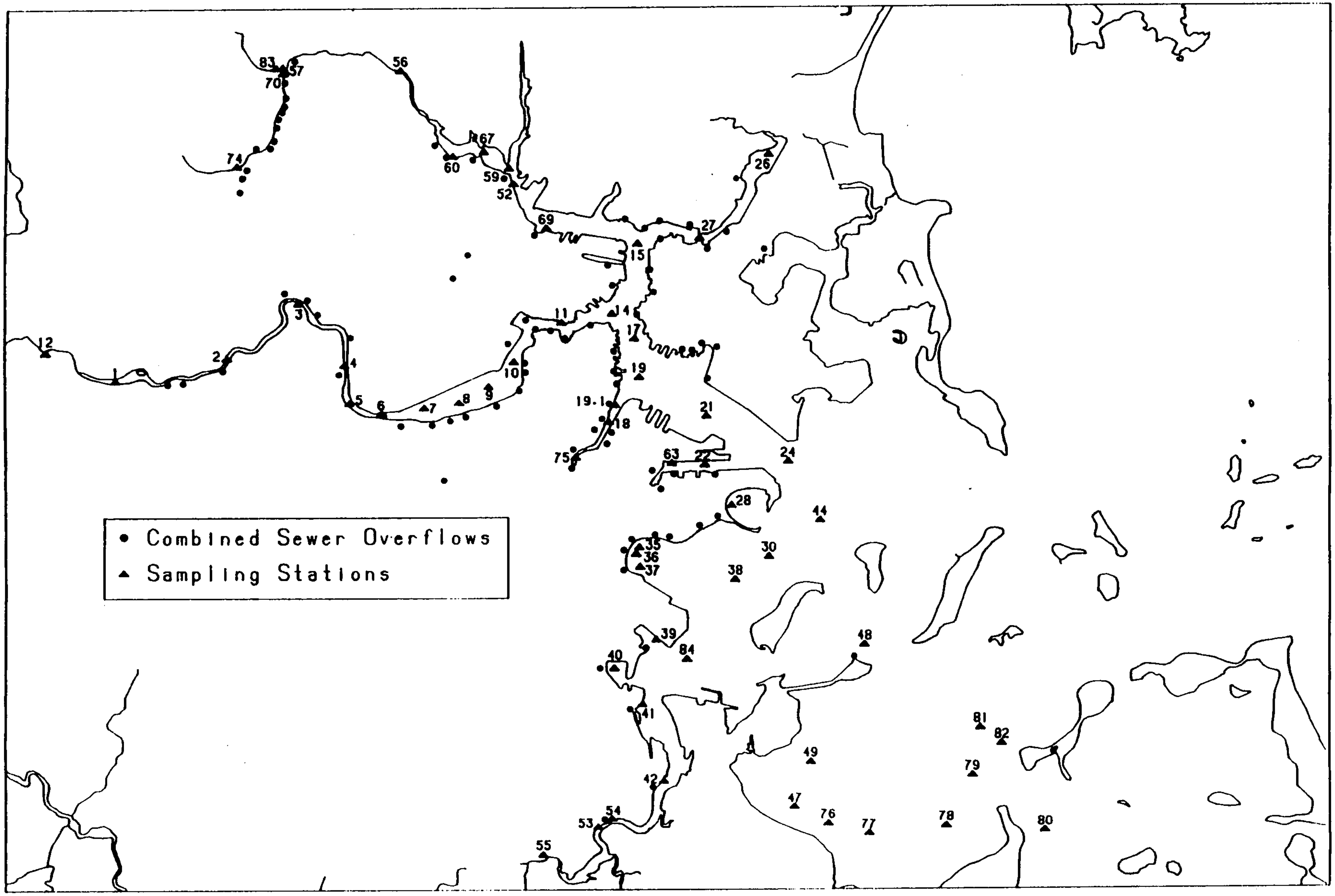


Figure 2.03. Water Quality Monitoring Stations, 1990.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
Alewife Brook Stations						
70	Midchannel, off SOM-004.	42° 24.86'	71° 07.99'	SOM-004	5 m	1989, 1990
71	Midchannel, off SOM-002A.	42° 24.65'	71° 07.98'	SOM-002A	5 m	1989
71.1*	Midchannel, off SOM-002.	...	...	SOM-002	5 m	1989
72	Midchannel, Alewife Brook Parkway/Broadway Bridge.	42° 24.45'	71° 08.12'	SOM-001	5 m	1989
73	Cambridge/Somerville line 100 m upstream of Woodstock St. Bridge. Midchannel.	42° 24.22'	71° 08.12'	CAM-002	30 m	1989
74	Offramp to Alewife T station. Midchannel from bridge.	42° 23.84'	71° 08.66'	CAM-401	~100 m	1989, 1990
Calf Island Station						
50	Calf Is., 20 m off dock.	42° 20.30'	70° 53.90'	BOS-125	>5 km	1989
Charles River Stations						
12	Immediately upstream of Watertown Dam; off footbridge.	42° 21.85'	71° 11.48'	BOS-031	>1 km	1989, 1990
1	Newton Yacht Club, at red buoy #12.	42° 21.54'	71° 10.45'	BOS-031	700 m	1989, 1990
1.5*	At BOS-031.	...	...	BOS-033	10 m	1989
2	10 m downstream of BOS-033 midchannel.	42° 21.78'	71° 08.80'	CAM-005	100 m	1989, 1990
3	Between CAM-005 and CAM-006, at hairpin bend in river. Tall apartment building dead ahead, directly opposite brown and blue building on Cambridge side. Midchannel.	42° 22.37'	71° 07.74'	BOS-034	100 m	1989, 1990
4	Midchannel midway between River St. and Western Ave bridges.	42° 21.70'	71° 07.06'	MWR-020	100 m	1989, 1990

*Stations sampled with reduced frequency.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
5	Downstream of stone building, 10 m from Cambridge shore at bend in river. Right edge of Howard Johnsons aligns with left edge of stone building.	42° 21.27'	71° 06.99'	MWR-201	100 m	1989, 1990
6	Immediately downstream of BU Bridge, midchannel. Downstream edge of boathouse is aligned. Steeple of BU building on Boston side is aligned with peak of roof. Upstream of MWR-010.	42° 21.15'	71° 06.51'	MWR-201	10 m	1989, 1990
6.1*	10 m off of MWR-010.	...	...	MWR-010	10 m	1989
7	10 m off MIT boathouse. Left side of boathouse is edge on. Left edge of Prudential aligns with right edge of brown skyscraper.	42° 21.33'	71° 05.88'	BOS-042	250 m	1989, 1990
7.1*	10 m off upstream of two BOS-042 signs approx. 200 m apart on river bank.	...	...	BOS-042	10 m	1989
7.5*	Between BOS-042 signs.	...	...	BOS-042	100 m	1989
8	Immediately downstream of Harvard Bridge. Opposite MIT dome: smokestack aligns with tree to left of dome. Left edge of Sheraton Hotel aligns with right edge of largest brick apartment building.	42° 21.27'	71° 05.37'			1989, 1990
8.1*	10 m off MWR-018.	...	...	MWR-018	10 m	1989
9	Midchannel, midway between Harvard and Longfellow Bridges. Church steeples on Boston side align. On Cambridge side, middle smokestack aligns with right edge of brick building.	42° 21.45'	71° 04.93'	MWR-019	200 m	1989, 1990

*Stations sampled with reduced frequency.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
9.1*	10 m offshore MWR-021.	...	...	MWR-021	10 m	1989
9.2*	10 m offshore MWR-020.	...	...	MWR-020	10 m	1989
9.3*	10 m offshore MWR-019.	...	...	MWR-019	10 m	1989
10	Downstream of Longfellow Bridge, opposite MWR-022. Midchannel. Large smokestacks on Cambridge side align, leftmost "salt and pepper" bridge posts align.	42° 21.72'	71° 04.55'	MWR-022	200 m	1989, 1990
11	Opposite BOS-049. Between drawbridge and Science Museum. Midchannel. Opposite "WAM-73" graffitti on Cambridge side. Lamppost on southern side lines up with vertical windows on brick building.	42° 22.14'	71° 03.84'	BOS-049	50 m	1989, 1990
Dorchester Bay Stations						
28	Pleasure Bay, sampled by wading from beach.	42° 20.12'	71° 01.33'	BOS-081	1.5 km†	1989, 1990
29	Off Castle Is., green buoy.	42° 19.93'	71° 00.65'	BOS-081	1 km†	1989
30	Dorchester Bay, off City Point.	42° 19.55'	71° 00.77'	BOS-081	1 km	1989, 1990
31	Carson Beach, 100 m off Kelly's Landing.	42° 19.90'	71° 01.43'	BOS-081	0-5 m†	1989
32	100 m offshore BOS-082 sign at N-street.	42° 19.80'	71° 01.79'	BOS-082	0-5 m†	1989
33	Carson Beach, at end of fence by L-Street Bath-house, 200 m from bathhouse.	42° 19.63'	71° 02.18'	BOS-083	0-5 m†	1989, 1990
34	Carson Beach, 100 m offshore sign for BOS-084.	42° 19.73'	71° 02.49'	BOS-084	0-5 m†	1989

*Stations sampled with reduced frequency.
†Estimates from charted locations; we have been unable to locate pipes.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
35	Carson Beach, off Columbus Park Headworks, directly offshore of sign for BOS-085.	42° 19.66'	71° 02.70'	BOS-085	0-5 m†	1989, 1990
35.5*	Carson Beach between stations 35 & 36, sampled when low water precluded differentiating between the sites.	...	...	BOS-085	0-5 m†	1989
36	Carson Beach, 100 m off righthand corner of Carson Beach bathhouse with sign for BOS-086.	42° 19.59'	71° 02.75'	BOS-086	0-5 m†	1989, 1990
37	Carson Beach, 50 m off blockhouse near dock with sign for BOS-087.	42° 19.45'	71° 02.69'	BOS-087	0-5 m†	1989, 1990
38	Dorchester Bay.	42° 19.30'	71° 01.28'	BOS-032	1.5 km	1989, 1990
39	Fox Point at BOS-089, off Savin Hill Yacht Club floating boat dock.	42° 18.68'	71° 02.45'	BOS-089	10 m	1989, 1990
39.1¶	Sampled off U/MASS Sailing Program dock.	...	...	BOS-089	100 m	1989, 1990
39.2§	Sampled 1/4 distance between UMB and SHYC docks.	...	...	BOS-089	75 m	1989
39.3§	1/2 distance between UMB and SHYC docks.	...	...	BOS-089	50 m	1989
39.4§	3/4 distance between UMB and SHYC docks.	...	...	BOS-089	25 m	1989
39.5§	Savin Hill Cove at end of line of pilings for SHYC fixed boat dock.	...	...	BOS-089	200 m	1989
39.6§	1/2 distance between pilings at fixed dock and corner of Columbia point.	...	...	BOS-089	200 m	1989

*Stations sampled with reduced frequency.
†Estimates from charted locations; we have been unable to locate pipes.
¶Often sampled in place of Station 39.
§Sampled in September and October 1989 only, along with Stations 39 and 39.1.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
39.7§	South side of Morrisey Blvd. Bridge at head of Savin Hill Cove.	...	...	BOS-089	400 m	1989
39.8§	North side of Morrisey Blvd. bridge at head of SHC.	...	...	BOS-089	400 m	1989
40	Malibu Bay, 50 m offshore BOS-088.	42° 18.37'	71° 03.08'	BOS-088	50 m	1989, 1990
40.1*	Malibu Bay, off Beach.	...	...	BOS-088	150 m	1989
41	Old Colony Yacht club, 50 m offshore sign for BOS-090.	42° 17.98'	71° 03.08'	BOS-090	50 m	1989
41.1*	Mouth of Neponset River at green buoy #11.	...	...	BOS-090	500 m	1989
43	Off Spectacle Is. Rock on drumlin aligns with edge of Deer Is. Red buoy aligns with smokestacks from S. Boston Edison.	42° 19.55'	70° 59.65'	BOS-125	~2 km	1989
44	Between Spectacle Is. and airport; 10 m from green buoy #5.	42° 19.95'	71° 00.01'	BOS-081	1 km	1989, 1990
Inner Harbor Stations						
65*	Between airport and Deer Is. Red channel marker.	42° 20.10'	70° 58.89'	BOS-125	2.5 km	1989
24	Mouth of Inner Harbor by airport; 10 m off red buoy #10.	42° 20.59'	71° 00.48'	BOS-081	1.2 km	1989, 1990
23	Mouth of Reserved Channel, at corner of dock, midchannel.	42° 20.57'	71° 01.27'	BOS-081	400 m	1989
22	Reserved Channel, midchannel by bay #BOS-3.	42° 20.56'	71° 01.72'	BOS-081	100 m	1989, 1990
63	Reserved Channel, off west (inland) side of Summer St. Bridge.	42° 20.58'	71° 02.21'	BOS-079	50 m	1989, 1990

*Stations sampled with reduced frequency.
§Sampled in September and October 1989 only, along with Stations 39 and 39.1.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
21	Airport tower is edge-on, top of old Hancock building aligns with right edge of new Hancock tower.	42o 21.10'	71° 01.69'	BOS-003	700 m	1989, 1990
20	World Trade Center is end-on. Tallest Edison smokestack aligns with "US Lines" sign on Pier 1.	42° 21.49'	71° 02.11'	BOS-003	500 m	1989
19	Mouth of Fort Point Channel. Directly off Harbor Tower closest to water. Airport tower is between Citgo sign and "B" on drydock.	42° 21.54'	71° 02.69'	BOS-062	500 m	1989, 1990
19.1	Center of northern (Harbor) side of Northern Ave Bridge.	42° 21.23'	71° 03.05'	BOS-062	200 m	1989, 1990
18	Fort Point Channel, off south side of Summer St. bridge.	42° 21.04'	71° 03.15'	BOS-064	100 m	1989, 1990
75	Fort Point Channel, off south side of Broadway.	42° 20.68'	71⁰ 02.63'	BOS-068 BOS-070	100 m 500 m	1990
17	"Hodge Boiler Works" is directly aligned with gray shed. Custom House Tower aligns with glassed peaked building.	42° 21.96'	71° 02.76'	BOS-057	300 m	1989, 1990
14	Mouth of Charles R. Left edge of Custom House Tower aligns with right edge of State Street Bank. Bunker Hill Monument aligns with corner of Pier 2.	42° 22.23	71° 03.09'	BOS-057 MWR-203	100 m	1989, 1990
13	Mouth of Charles R. Bunker Hill Monument is midway between elevator shafts on Barretts Bld. CSO sign BOS-052, light pole and steeple of Old North Church are aligned.	42° 22.17	71° 03.34'	BOS-052 MWR-203	100 m	1989

*Stations sampled with reduced frequency.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
26	Near neck of Chelsea river, upstream of CHE-8. Opposite smokestack near Chelsea side, 20 m from shore.	42° 23.93'	71° 00.76'	CHE-008	600 m	1989, 1990
27	Chelsea R. midchannel between grassy pier and low tin sheds.	42° 23.04'	71° 01.79'	BOS-014	200 m	1989, 1990
52	Mystic River, downstream of Amelia Earhart Dam, off MWR-205. Upstream of RR bridge. Directly aligned with control tower at locks.	42° 23.63'	71° 04.55'	MWR-205	10 m	1989, 1990
69	Mystic River, 50 m directly off BOS-017. Near Schraffts and pier.	42° 23.15'	71° 04.06'	BOS-017	50 m	1989, 1990
15	Confluence of Mystic R. and Chelsea R. Lower red stack behind Mystic Pier aligns with Hancock Tower. 6th vertical member on bridge after tall strut aligns with tallest Edison stack.	42° 22.98'	71° 02.71'	CHE-003	300 m	1989, 1990
16	Directly off pier with sunken fishing boat. Approach light aligns with corner of Bldg 49.	42° 22.59'	71° 02.71'	BOS-012	300 m	1989, 1990
Mystic River						
83	1/4 mile upriver from Alewife/Mystic confluence, Mystic River, midchannel at storm drain.	42° 24.92'	71° 08.10'	SOM-004	500 m	1990
57	Confluence of Alewife Brook and Mystic R., midchannel.	42° 24.92'	71° 07.99'	SOM-004	100 m	1989, 1990
66	Upstream side of Boston Ave. Bridge, midchannel.	42° 25.03'	71° 07.87'	SOM-005	20 m	1989

*Stations sampled with reduced frequency.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
58	Off sewer at Mystic Valley Pkwy/Auburn St. "Heartland." Midchannel.	42° 25.08'	71° 07.61'	SOM-005	300 m	1989
61	Medford Sq. Upstream of Mystic Valley Pkwy Bridge midchannel.	42° 25.06'	71° 06.83'	SOM-005	1.2 km	1989
56	100 m upstream of Rt. 93 bridge, midchannel.	42° 24.88'	71° 06.25'	SOM-005 SOM-007	2 km[u] 2 km[d]	1989, 1990
68	Mystic R. Basin, 10 m off pipe in peninsula with reeds. Near cement headwall with tracks. Directly opposite large apartment building.	42° 24.35'	71° 05.83'	SOM-005 SOM-007	2.5 km[u] 1 km[d]	1989
60	Mystic R. Basin, 100 m directly off MDC sailing dock and SOM-007.	42° 23.93'	71° 05.46'	SOM-007	30 m	1990
67	Immediately downstream of Route 28 bridge, midchannel.	42° 23.98'	71° 05.00'	SOM-007A	100 m	1989, 1990
59	Confluence of Mystic and Malden Rivers.	42° 23.80'	71° 04.62'	SOM-007A	700 m	1989, 1990
Neponset River Stations						
42	Downstream of BOS-093, midchannel, midway between bridges.	42° 17.13'	71° 02.36'	BOS-093	200 m	1989, 1990
53	Upstream of BOS-095 at hairpin bend in river.	42° 16.61'	71° 03.34'	BOS-095	100 m	1989, 1990
54	Downstream of BOS-095.	42° 16.70'	71° 03.13'	BOS-095	100 m	1989, 1990
55	Above dam in Milton/Lower Mills, at chocolate factory.	42° 16.30'	71° 04.16'	BOS-095	1.2 km	1989, 1990
84	At red buoy #12, off Columbia Pt.	42° 18.47'	71° 02.00'	BOS-089	700 m	1990

[u]CSO was upstream of sampling station.
[d]CSO was downstream of sampling station.

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
Quincy Bay Stations						
45	Off Thompson Is. Watch tower aligns with left edge of twin gray condos.	42° 18.58'	70° 59.96'	BOS-125	700 m	1989
46	Amid Long, Spectacle and Thompson Islands.	42° 18.87'	70° 59.42'	BOS-125	750 m	1989
47	Off Wollaston Beach, 200 m off "Clambox."	42° 16.83'	71° 00.42'	BOS-125	3 km	1989, 1990
48	Off Moon Is., 200 m from outfall pipes.	42° 18.61'	70° 59.36'	BOS-125	100 m	1989, 1990
49	Quincy Bay, 20 m off red buoy #2, near Squantum.	42° 17.33'	71° 00.17'	BOS-125	2 km	1989, 1990
76	Off Wollaston Beach, app. 1/4 mi SE of Sta. 47.	42° 16.63	70° 59.92'	BOS-125	3 km	1990
77	Off Merrymount Park.	42° 16.51'	70° 59.31'	BOS-125	3.5 km	1990
78	Off Hough's Neck near Seal Rock.	42° 16.59'	70° 58.16'	BOS-125	3.2 km	1990
79	At Nut Island POTW Outfall 103.	42° 17.15'	70° 57.39'	BOS-125	3.1 km	1990
80	Off Quincy Y.C. at red buoy #2.	42° 16.53'	70° 56.69'	BOS-125	4.5 km	1990
81	At Nut Island POTW West Outfall #102.	42° 17.66'	70° 57.27'	BOS-125	2.2 km	1990
82	At Nut Island POTW East Outfall #101.	42° 17.49'	70° 56.95'	BOS-125	3.1 km	1990
Constitution Beach Stations						
90	Con-1	42° 23.00'	71° 00.35'	BOS-002	1 km	1990
91	Con-2	42° 22.98'	71° 00.48'	BOS-002	800 m	1990
92	Con-3	42° 22.96'	71° 00.58'	BOS-002	700 m	1990

Table 2.01. Stations for the MWRA CSO Receiving Water Monitoring Program, continued

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
93	Con-4	42° 22.89'	71° 00.61'	BOS-002	600 m	1990
94	Con-5	42° 22.72'	71° 00.58'	BOS-002	600 m	1990
95	Con-6	42° 22.82'	71° 00.51'	BOS-002	750 m	1990
96	Con-7	42° 22.89'	71° 00.47'	BOS-002	800 m	1990
97	Con-8	42° 22.96'	71° 00.39'	BOS-002	900 m	1990
98	Con-9	42° 22.65'	71° 00.71'	BOS-002	400 m	1990
99	Con-10	42° 22.87'	71° 00.29'	BOS-002	1.1 km	1990

Table 2.02. MWRA Sampling Areas, Stations, and Time Periods Sampled

Area	Year	Sampling Period	Station Numbers
Inner Harbor			
	1989	July 24-August 17	13, 14, 17, 18, 19, 20, 21, 22, 23, 24, 63, 65
	1990	June 12-July 5 October 1-18	11, 14, 15, 17, 19, 19.1, 21, 22, 24, 44, 63, 75
Dorchester Bay/Neponset River			
	1989	June 28-July 20	28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 53, 54, 55
Northern Dorchester Bay			
	1990	June 12-July 5	19, 21, 24, 28, 30, 33, 35, 36, 37, 38, 44
Southern Dorchester Bay/Neponset River			
	1990	September 4-10	38, 39.1, 40, 41, 42, 44, 53, 54, 55, 84
Quincy Bay/Harbor Islands			
	1989	July 24-August 17	43, 44, 45, 46, 47, 48, 49, 50
	1990	August 2-14	44, 47, 48, 49, 76, 77, 78, 79, 81, 82
Mystic River/Alewife Brook/Chelsea River			
	1989	August 21- September 7	15, 16, 26, 27, 52, 56, 57, 58, 59, 60, 61, 66, 67, 68, 69, 70, 71, 72, 73, 74
	1990	August 15-31	15, 16, 26, 27, 52, 69, 56, 57, 59, 60, 70, 74, 83
Charles River			
	1989	June 1-26	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
	1990	July 9-13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14

Table 2.03. Stations Sampled Periodically in 1989

Area	Stations	Date(s) Sampled
Inner Harbor	15	June 29, July 24, July 25
	16	July 24, July 25
	17	June 29
	19	June 29, August 25
	24	June 29, August 25
Dorchester Bay	28	August 25
	33	August 25
	40	June 29, August 25
	41	June 29, August 25
Neponset River	54	August 25
Mystic River	57	June 29
	66	August 25
	67	June 29
Charles River	9	August 8, August 25
	12	August 25

55), and Pleasure Bay (Station 28) was sampled by wading to a depth of 1 m. Sample volume was 200 ml. Grab samples were collected 0.25 m below the water's surface at all stations. Where the depth of the water was greater than 4 m, a grab sample of bottom water was also collected 0.5 m above the bottom sediment. Surface samples were collected aseptically by hand directly into sterile sample jars. Bottom samples were collected in a Kemmerer sampler (Wildco) or an Alpha water bottle (Wildco) and transferred aseptically to sterile containers. Samplers were disinfected with 95% ethanol between samples. Immediately after collection, all water samples were placed in a cooler with ice-packs and stored until processing in the laboratory. Most samples were processed within 3 h of collection, and all but one were processed within 6 h of collection.

2.1.e Field Measurements

Temperature, conductivity, and salinity were measured in the field with a YSI model 33 portable S-C-T meter. Field measurements of dissolved oxygen were made with a YSI model 58 dissolved oxygen meter (calibrated in air). For each sample, the time of day collected was noted and the corresponding point in the tidal cycle derived from a tide chart. Other field observations included approximate windspeed; precipitation; presence of visible pollutants such as sewage and oil; and presence of a plume, odors, and floatables.

2.1.f Meteorological Data

Data on rainfall measured at Logan Airport were obtained from the National Weather Service.

2.1.g Microbiological Methods

Detailed laboratory methods with quality assurance and quality control procedures are described in the Harbor Studies Laboratory Standard Operating Procedure (1989b).

Fecal Coliform

Fecal coliform bacteria were enumerated by the membrane-filter procedure (APHA, 1989, Section 9222 D). Water samples were diluted in phosphate buffer (pH 7.2) as necessary, and filtered through 0.45-μm filters (Millipore). Filters were then placed on m-FC Agar (Difco) containing 0.01% rosolic acid. We incorporated a resuscitation step of a 2-h incubation at 35°C (APHA, 1985) before transferring cultures to incubate at 44.5°C in a circulating water bath. After incubation of 24 h ±2 h, plates were examined at low power under a binocular microscope (10-15X magnification) and blue colonies counted.

Cultures of *E. coli* (ATCC 25922) were used as positive controls.

Enterococcus

We enumerated *Enterococcus* by the membrane-filter technique (APHA, 1989, Section 9230 C), using m-*Enterococcus* agar (Difco). Water samples were diluted and filtered as described above, and cultures were incubated at 35°C for 48 h. All light red and dark red colonies were counted at 10-15X magnification.

Cultures of *Enterococcus fecaelis* (ATCC 29212) were the positive controls.

2.2. Data Analysis

Detailed descriptions of how the data were recorded, validated, and manipulated are in the appendix.

The data analysis had three basic goals. The first was to provide a descriptive picture of the concentrations of sewage indicator bacteria and dissolved oxygen in the water, and relate these data to geographic location and government water quality standards. This descriptive analysis can be used to compare findings with past and future work. The second goal was to determine the relationships among the pollution indicator variables (fecal coliform, *Enterococcus*, and dissolved oxygen) and environmental variables, including natural and anthropogenic parameters (e.g., rainfall, tide, salinity, temperature, treatment plant flow and loads). The third goal was to relate our observations of water quality to modeled and/or measured flows and loads through individual CSOs or groups of CSOs.

The data from each geographic area (Table 2.02) were analyzed separately and the results are reported in separate sections of this report.

2.2.a Descriptive Analysis

Because our data for indicator bacteria counts were lognormally distributed (typical for environmental microbiological measurements), a proper measure of central tendency in these populations was the geometric mean. Geometric means and their associated 95% confidence intervals were calculated for the measurements made at each separate station during a sampling period. Thus we could determine if the geometric means of fecal coliform and *Enterococcus* counts, measured at different times or locations, were significantly different. The geometric means and associated confidence intervals of fecal coliform and *Enterococcus* counts by year, depth, and station within geographic areas are provided in tables in each section of this report.

In this report, descriptive data for fecal coliform and *Enterococcus* counts and dissolved oxygen levels are displayed as percentile box plots. These plots are a way of presenting the frequency distributions of a group of measurements. In this report, a "box" comprises measurements from an individual sampling station and depth. Figure 2.04 illustrates how the frequency distribution is indicated in the box plots, and Figure 3.03 (Section 3) is an example of a box plot. Each horizontal line in a box indicates a value (read from the vertical axis) that includes the indicated percent of the data. For example, in Figure 3.03, the first box on the left represents all the fecal coliform counts from surface samples collected at Station 13 in 1989. Within this group of measurements, 90% (the top horizontal line) of the fecal coliform measurements were less than 5,000 col/100 ml; 75% were less than 500 col/100 ml; 50% were less than 150/100 ml; 25% were less than 80 col/100 ml; and 10% were less than 60 col/100 ml. Individual points beyond these ranges (outliers) are indicated as dots. One sample at Station 13 had a count of approximately 30,000 col/100 ml, and one sample had a count of approximately 50 col/100 ml.

The box plots enable one to see the range and central tendencies of the data immediately and to visually compare results among sampling stations. These plots are particularly appropriate for displaying fecal coliform data because the Massachusetts fecal coliform standards are written in terms of percentiles: class B and SB waters, suitable for swimming, should have a geometric mean fecal coliform count of 200 col/100 ml or less, with 90% of the samples having less than 400 col/100 ml. Thus, on the box plots, waters meeting fecal coliform standards have a geometric mean count of 200 col/100 ml or less, and the top horizontal line on the box (the 90th percentile) is below 400 col/100 ml.

The fecal coliform and *Enterococcus* count data are displayed on a logarithmic scale in all the box plots. The dissolved oxygen data are shown on a linear scale.

Descriptive statistics (means and geometric means, confidence intervals, frequency distributions, etc.) and figures were generated using the SPSSX statistical package (SPSS Inc., Chicago IL) on the MWRA VAX (Digital Equipment Corp., Maynard, MA), Lotus 1-2-3 (Lotus Corp., Cambridge, MA), Excel (MicroSoft Corp., Redmond, WA), Cricketgraph (Cricket Software, Malvern, PA) and MacDraw (Claris Corp., Mountainview, CA). We used the statistical package SOLO (BMDP Statistical Software, Los Angeles, CA) to produce percentile box plots.

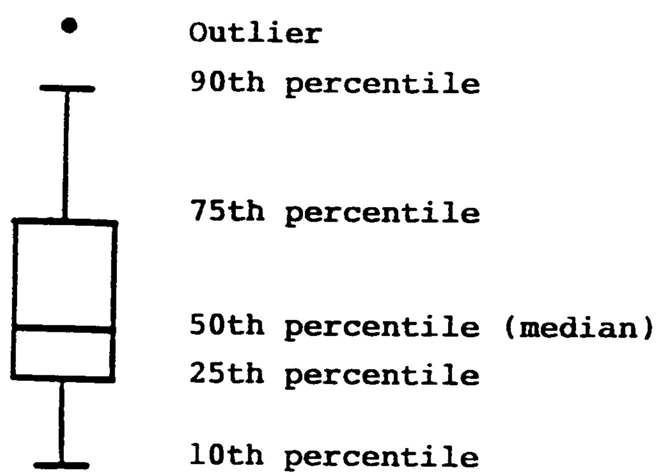


Figure 2.04. Percentile Distributions Indicated on Boxplots.

2.2.b Comparative Analyses

We used an exploratory analytical approach to determine relationships among environmental variables and pollution indicators. This inductive approach is often the most productive way to discover patterns and relationships in environmental data sets, which have a large number of uncontrolled variables. The ultimate goal of our analysis is to make progress toward determining causal relationships among different environmental factors and levels of pollution in the waters studied.

Data from each geographic area and year were analyzed separately, and the following analytic steps were followed for each area. Data from surface and bottom samples were analyzed separately. The first step of an analysis was to produce a large correlation matrix, intercorrelating all the variables listed in Tables 2.04, 2.05, and 2.06 (plus log-transformed fecal coliform and *Enterococcus* counts). All samples from all stations within an geographic area (e.g., the Inner Harbor, the Charles River) were included together in one correlation matrix. Then matrices were produced for the data collected at each individual station. All these matrices were examined for patterns of significant correlations.

Based on the results of the correlation analyses, we selected some significant explanatory variables (e.g., rainfall, treatment-plant flow, salinity) for linear regression analysis of counts of pollution indicator bacteria. Some of these analyses showed interesting and significant trends, and are presented in the Results sections of this report.

Finally, multiple regressions were performed, with log-transformed counts of fecal coliform and *Enterococcus* as the dependent variables, and the variables listed in Tables 2.04, 2.05, and 2.06 as potential explanatory variables. Multiple regression is the only statistical technique that can apportion the variance in a dependent variable among a group of explanatory variables. A stepwise multiple regression determines the order of importance among variables in explaining the variance in a dependent variable. Only those multiple regressions that yielded highly statistically significant results are presented in this report.

Correlation analyses, regression analyses, t-tests, and multiple regression analyses were carried out with SPSSX and SPSS Graphics.

2.2.c Comparison of Measured or Modeled CSO Flows and Loads to Receiving Water Data

Some of our samples were collected when measured or predicted overflows from nearby combined sewers occurred. Although we attempted to correlate the water quality measurements with measured and modeled overflows from the CSO treatment facilities and from individual CSOs, we did not obtain meaningful results from these analyses. This was because there were usually too few overflow events during a

Table 2.04. Parameters Measured during the MWRA CSO Receiving Water Monitoring Program

Variable	Description
STATION	Station numbers used in the field monitoring; for full description of station locations, see Table 2.0
SAMNUMBER	Sample number
SAMDATE	Date sample was taken
SAMTIME	Time of day sample was taken, in 24-hour military time
TIDE*	Coded variable giving the state of the tide when samples were taken; codes are as follows: 1: Slack high tide 2: High water, ebb tide 3: Low water, ebb tide 4: Low slack water 5: Low water, flood tide 6: High water, flood tide 9: Sample taken in a freshwater system (e.g., the Charles River) above the influence of the tides
DEPTH	Water depth in feet when sample taken
DEPTHSAM	Water depth in feet at which sample was taken
TEMP*	Water temperature in degrees Celsius
DO*	Dissolved oxygen in milligrams per liter
CONDUCT*	Conductivity in micromhos
SALINITY*	Salinity in parts per thousand
MF1	mFC fecal coliform counts for first of two laboratory duplicate filtrations, in colonies per 100 milliliters
MF2	mFC fecal coliform counts for duplicate filtrations
MFAV	Arithmetic average of the duplicate filtrations for fecal coliforms by mFC, in colonies per 100 milliliters
ME1	mENT *Enterococcus* counts for the first of two duplicate filtrations, in colonies per 100 milliliters
ME2	mENT *Enterococcus* counts for duplicate filtration
MEAV	Arithmetic average of the mENT *Enterococcus* filtrations, in colonies per 100 milliliters

*Variables used in multiple regression analysis.

Table 2.05. Rainfall and Sewerage Variables Used in the Analyses

Variable	Description and Source	Dates
LORN*	Daily rainfall recorded at Logan Airport, in inches. Measured by National Weather Service.	June 1, 1989 - October 31, 1990
CARN*	Daily rainfall recorded at 147 Hampshire Street, Cambridge. Measured by Cambridge DPW.	June 1 - September 31, 1989
DIFLOW*	Daily flow through Deer Island POTW, in MGD. All POTW variables are from treatment plant logs.	June 1, 1989 - October 31, 1990
DIEFF	Daily effluent fecal coliform concentrations per 100 milliliters from Deer Island POTW.	June 1, 1989 - October 31, 1990
NUTFLOW*	Daily flow through Nut Island POTW, MGD.	July 1 - August 31, 1989 and 1990
NUTEFF	Effluent fecal coliform concentrations from Nut Island POTW.	July 1 - August 31, 1989 and 1990
CAFLOW	MGD Discharge from Moon Island CSO (BOS-125) from Boston Water and Sewer Commision records.	June 1 - October 31, 1989
COFAFL	MGD Discharge from Cottage Farm CSO (MWR-201) screening and disinfection facility. From facility logs.	June 1 - October 31, 1989
COFAEFF	Effluent fecal coliform from Cottage Farm.	June 1 - October 31, 1989
PPFLOW	MGD Discharge from Prison Point CSO facility (MWR-203).	June 1 - October 31, 1989
PPEFF	Effluent fecal coliform from Prison Point.	June 1 - October 31, 1989
SOMAFL	MGD Discharge from Somerville Marginal CSO Facility (MWR-205).	June 1 - September 31, 1989
SOMAEFF	Effluent fecal coliform from Somerville Marginal CSO Facility.	June 1 - September 31, 1989

*Variables used in multiple regression analysis.

Table 2.06. Additional Rainfall and Sewage Variables Used in the Analyses

Description	Variable
Rainfall Variables†	
Additive rainfall variables	
Formula: RAINPx = RAIN1 + RAIN2 ...+ RAINx	
Calculated from rainfall measured at Logan Airport	LORNP2, LORNP3, LORNP4, LORNP5, LORNP6
Calculated from rainfall measured in Cambridge	CARNP2, CARNP3, CARN P4, CARNP5, CARNP6
Exponential decay variables	LORNE2 , LORNE3, LORNE4
Formula: RAINEx = RAIN1 + ($RAIN2*e^{-2}$) ... + ($RAINx*e^{-x}$)	
Delayed single day variables	LORNM1, LORNM2, LORNM3, LORNM4, LORNM5, LORNM6
Formula: RAINMx = RAINx	
Sewage Variables	
Deer Island fecal coliform loading	DILOAD
Nut Island fecal coliform load	NUTLOAD
Cottage Farm fecal coliform load	COFALO
Prison Point fecal coliform load	PPLOAD
Somerville Marginal fecal coliform load	SOMALO
Formula: LOAD (Fecal coliforms/Day) = Flow (MGD) * 10^6 * 3.785 L/G * 10(100 ml/l) * Effluent(Fecal coliforms/100 ml)	

†"RAIN" substitutes in the formulae for "LORN" or "CARN." RAIN1 = rain on that date, RAIN2 = Rain day before, ... RAIN6 = rain 5 days before.

sampling period to calculate a correlation (the minimum number of data points required is three), and because the large variability in these data meant that many overflows would have to be monitored in order to derive a statistically significant correlation. For these reasons, our analysis of the impact of individual CSOs and CSO treatment facilities on the receiving water is limited to descriptions of the changes in water quality observed after overflows or rainfalls.

3. The Inner Harbor

This section includes the Inner Harbor area from the mouth of the Charles River seaward inside a line from the southern tip of Governor's Island to Fort Independence. Results from Inner Harbor stations located in the lower Mystic River and the Chelsea River are in Section 6.

3.1 1989 Results

Raw data and additional tables and figures are given in Appendix A. Only figures and tables that illustrate meaningful trends are included in this section.

3.1.a Sampling Locations and Rainfall

Figure 3.01 shows the location of the stations sampled in the Inner Harbor between June 29 and August 17, 1989. Figure 3.02 shows the amount of rain that fell each day during the 1989 Inner Harbor sampling period.

3.1.b Indicator Bacteria Counts

Raw data for indicator bacteria counts are in Appendix A. Geometric mean counts are in Table 3.01.

Surface Samples

Fecal Coliform
Figure 3.03 shows percentile box plots for fecal coliform in all surface samples, both before and after rain. The station with the highest surface geometric mean fecal coliform count was Station 18, in Fort Point Channel; here the geometric mean fecal coliform count (1489 col/100 ml) was higher than the geometric mean stipulated by state water quality standards for class SC waters (1,000 col/100 ml). The lowest geometric mean count was at Reserved Channel Station 22 (33 col/100 ml).

Enterococcus
The geometric mean *Enterococcus* counts were below the EPA steady-state geometric mean swimmability standard of 35 col/100 ml at all stations except Station 18 (Table 3.01). Ninety-five percent of all samples

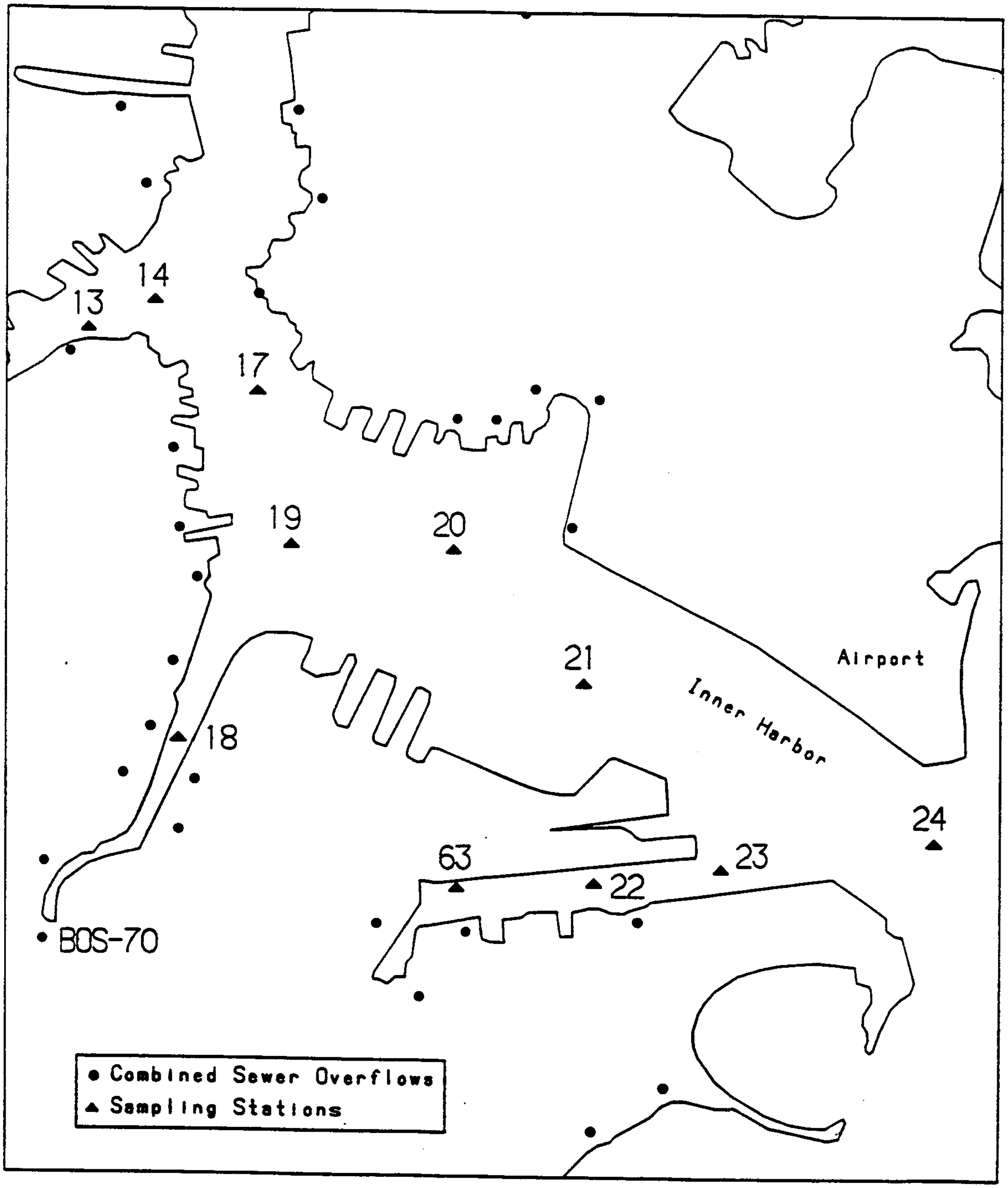
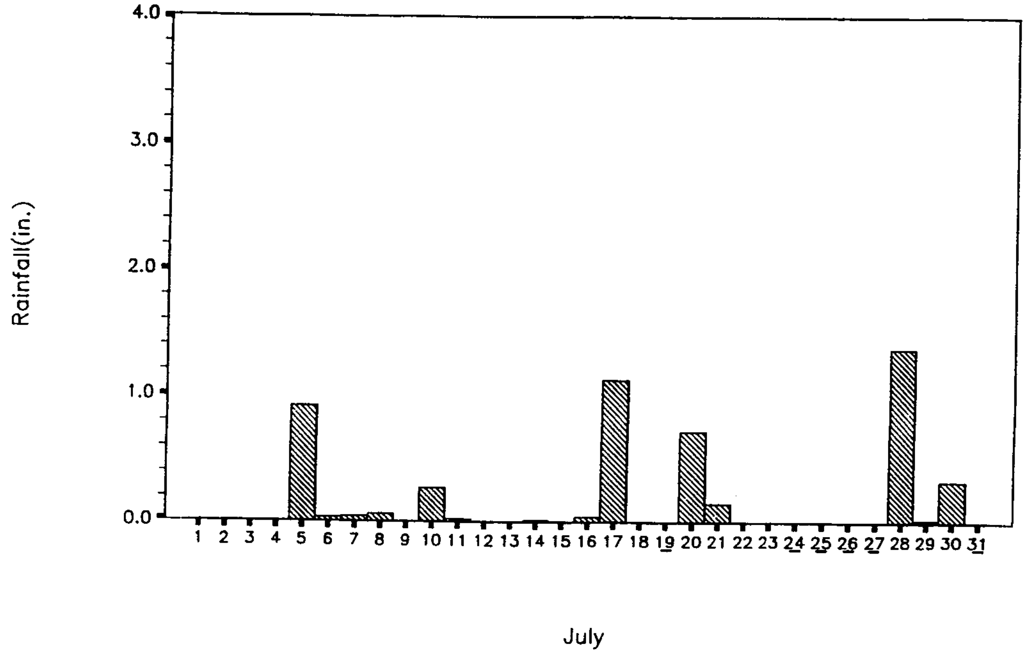


Figure 3.01. Stations Sampled during the 1989 Inner Harbor Monitoring.



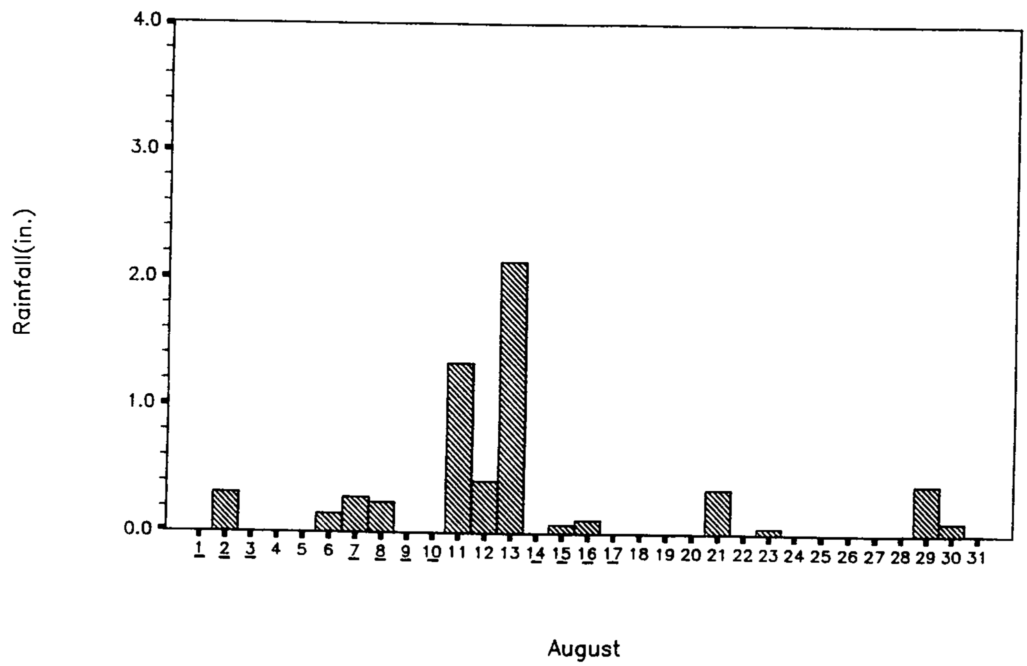


Figure 3.02. Daily Rainfall during the 1989 Monitoring Period in the Inner Harbor.

Samples were collected on dates underlined.

Stations 15, 17 and 19 were also sampled June 29 (not shown on figure.)

Table 3.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Inner Harbor Stations

Station			1989		1990					
			All		All		June-July		October	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)	n	mean (CI)	n	mean (CI)
Fecal Coliform										
11	Charles River	S	...	...	28	185(105-325)	20	93 (67-130)	8	1021 (391-2659)
		B	...	...	20	42 (33-53)	20	42 (34-52)	...	...
13	Charles River/Dam	S	15	299 (114-779)	...	...	...	...	...	...
		B	14	78 (29-206)	...	...	...	...	...	...
14	Charles River/Coast Guard	S	14	462 (165-1291)	25	93 (55-954)	18	81 (48-136)	7	134 (41-436)
		B	14	73 (31-170)	25	12 (6-23)	19	11 (5-22)	6	13 (2-74)
15	Mystic/Chelsea	S	...	...	...	...	18	47 (22-97)	...	...
		B	...	...	...	...	18	18 (9-34)	...	...
17	Mystic/Charles	S	16	354 (110-1137)	26	96 (56-163)	18	66 (45-97)	8	223 (62-793)
		B	13	60 (21-163)	19	10 (4-21)	19	10 (4-20)	...	...
18	Fort Pt Chan/Summer St	S	9	1492 (366-6072)	37	150 (75-301)	24	69 (38-124)	10	759 (157-3664)
		B	8	596 (147-2398)	28	34 (20-58)	23	26 (17-39)	3	180 (4-6086)
19	Fort Pt Chan/Mouth	S	17	309 (115-831)	26	117 (55-248)	17	67 (36-127)	9	327 (70-1525)
		B	13	73 (30-174)	27	18 (10-33)	18	16 (8-30)	9	25 (9-71)
19.1	Fort Pt Chan/Northern Av	S	...	...	...	...	3	118 (77-178)	...	...
		B	...	...	...	...	3	21 (8-55)	...	...
					...					

*S = surface; B = bottom.

Table 3.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Inner Harbor Stations, continued

Station			1989		1990					
			All		All		June-July		October	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)	n	mean (CI)	n	mean (CI)
20	Main Ship Chan/Trade Ctr	S	14	150 (41-537)	...	...	...	...	...	...
		B	13	131 (74-231)	...	...	...	...	...	...
21	Main Ship Chan/Airport	S	14	226 (48-1054)	26	9 (4-19)	18	41 (18-89)	8	116 (29-453)
		B	12	124 (44-348)	18	3 (1-7)	18	24 (12-44)	...	...
22	Reserved Channel	S	15	32 (7-136)	26	18 (7-42)	18	13 (5-30)	8	38 (8-166)
		B	12	115 (52-253)	16	34 (15-75)	16	34 (17-71)	...	...
23	Reserved Chan/Mouth	S	15	73 (18-294)	...	...	...	...	...	...
		B	12	154 (61-387)	...	...	...	...	...	...
24	Inner Harbor/Mouth	S	18	87 (23-325)	25	41(19-87)	17	26 (12-56)	8	107 (26-428)
		B	10	272 (108-684)	24	58 (31-109)	17	38 (19-74)	7	167 (76-365)
44	Spectacle Is/Airport	S	...	...	45	19 (11-35)	17	9 (3-21)	7	67 (13-321)
		B	...	...	28	22 (11-41)	17	31 (13-71)	1	38 (38-38)
63	Reserved Channel/Head	S	2	6 (1-17)	26	7 (4-14)	24	6 (3-12)	...	...
		B	3	16 (4-57)	25	11 (7-17)	23	9 (6-14)	...	...
75	Fort Pt Chan/Broadway St	S	...	...	30	457 (209-999)	25	288 (140-593)	3	3936 (213-72,536)
		B	...	...	17	102 (47-219)	16	74 (50-111)	...	...

*S = surface; B = bottom.

Table 3.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Inner Harbor Stations, continued

Station			1989		1990					
			All		All		June-July		October	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)	n	mean (CI)	n	mean (CI)
Enterococcus										
11	Charles River	S	...	...	28	14 (6-28)	20	6 (3-10)	8	96 (32-281)
		B	...	...	20	17 (10-29)	20	17 (11-28)	...	...
13	Charles River/Dam	S	15	17 (7-44)	...	...	...	...	...	...
		B	14	13 (5-30)	...	...	...	...	...	...
14	Charles River/Coast Guard	S	14	15 (6-37)	25	9 (4-19)	18	6 (3-13)	7	27 (6-106)
		B	14	7 (3-13)	25	6 (3-14)	19	3 (2-6)	6	44 (5-314)
15	Mystic/Chelsea	S	...	...	...	...	18	3 (1-9)	...	...
		B	...	...	...	...	18	4 (2-8)	...	...
17	Mystic/Charles	S	16	8 (3-21)	26	12 (6-24)	18	6 (3-13)	8	43 (14-132)
		B	13	5 (2-11)	19	4 (1-9)	19	4 (2-9)	...	...
18	Fort Pt Chan/Summer St	S	9	65 (16-259)	37	20 (9-45)	24	5 (3-10)	10	282 (75-1058)
		B	8	23 (5-96)	28	6 (3-12)	23	4 (2-6)	3	182 (15-2079)
19	Fort Pt Chan/Mouth	S	17	9 (4-18)	26	9 (3-24)	17	3 (1-7)	9	65 (16-257)
		B	13	6 (3-10)	27	9 (4-23)	18	3 (1-6)	9	83 (27-257)
19.1	Fort Pt Chan/Northern Av	S	...	...	...	...	3	5 (0-60)	...	...
		B	...	...	...	...	3	3 (0-17)	...	...

*S = surface; B = bottom.

Table 3.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Inner Harbor Stations, continued

Station			1989		1990					
			All		All		June-July		October	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)	n	mean (CI)	n	mean (CI)
20	Main Ship Chan/Trade Ctr	S	14	3 (1-10)	...	...	...	...	...	...
		B	13	7 (3-14)	...	...	...	...	...	...
21	Main Ship Chan/Airport	S	14	4 (1-13)	26	9 (4-19)	18	4 (2-9)	8	39 (12-120)
		B	12	11 (5-23)	18	3 (1-7)	18	3 (1-6)	...	...
22	Reserved Channel	S	15	2 (1-6)	26	6 (2-13)	18	3 (1-6)	8	23 (5-98)
		B	12	8 (4-14)	16	10 (4-24)	16	10 (4-23)	...	...
23	Reserved Chan/Mouth	S	15	3 (1-9)	...	...	...	...	...	...
		B	12	9 (4-19)	...	...	...	...	...	...
24	Inner Harbor/Mouth	S	18	2 (0-6)	25	5 (2-13)	17	2 (0-4)	8	42 (14-124)
		B	10	23 (10-49)	24	13 (5-30)	17	6 (2-14)	7	86 (55-133)
44	Spectacle Island/Mouth	S	...	...	45	7 (4-12)	17	3 (1-6)	7	43 (16-118)
		B	...	...	28	11 (6-21)	17	7 (3-15)	1	15
63	Reserved Chan/Head	S	2	5 (2-12)	26	1 (1-2)	24	1 (0-2)	...	...
		B	3	6 (4-8)	25	2 (1-4)	23	2 (1-4)	...	...
75	Fort Pt Chan/Broadway St	S	...	...	30	82 (32-208)	25	43 (19-94)	3	6639 (693-63,494)
		B	...	...	17	15 (6-33)	16	13 (6-27)	...	...

*S = surface; B = bottom.

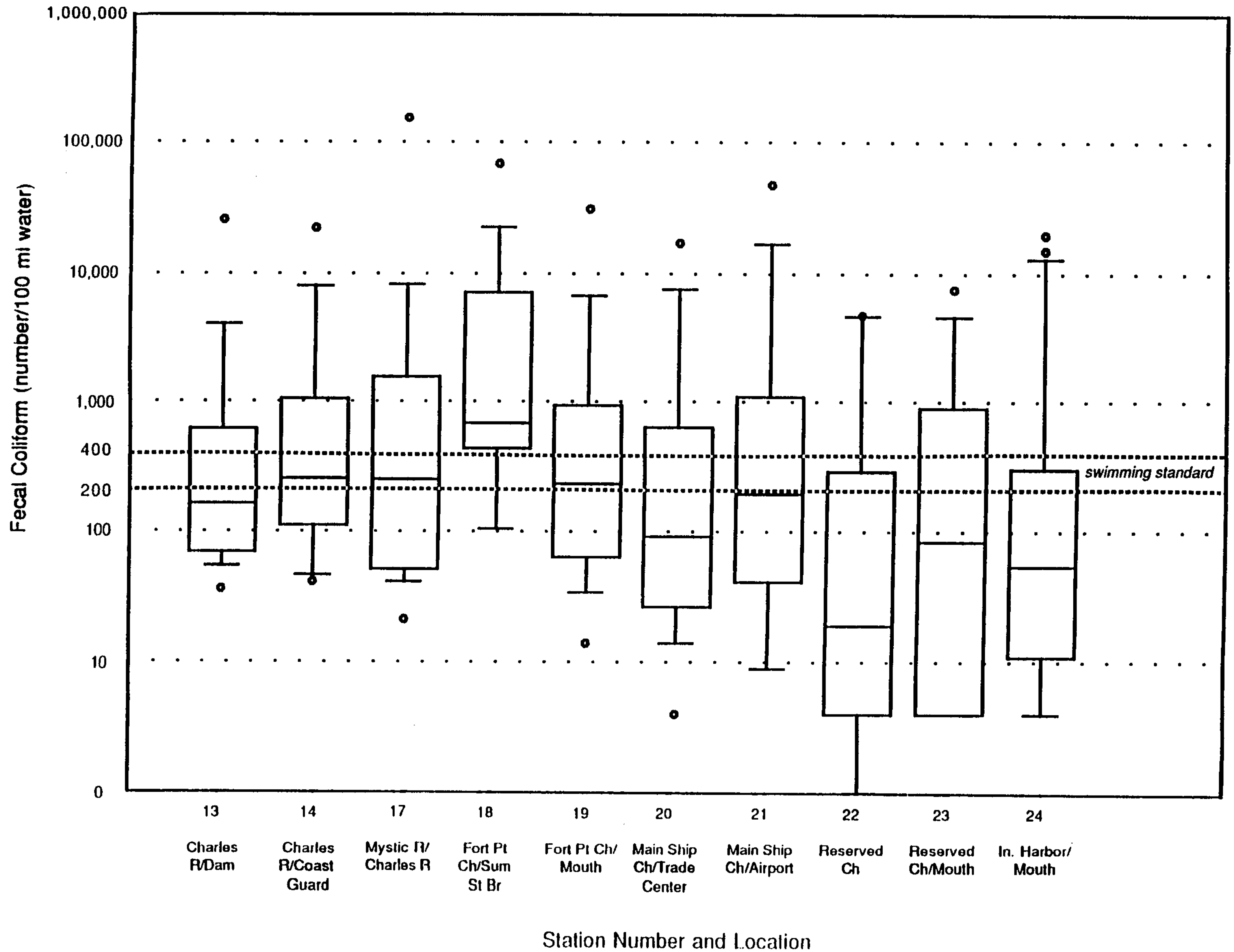


Figure 3.03. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in the Inner Harbor, 1989.

measured for *Enterococcus* fell below the EPA "single sample maximum allowable density for infrequent primary contact" of 500 col/100 ml (data not shown).

Surface *Enterococcus* counts in Fort Point Channel Station 18 were significantly higher than those at stations in the main shipping channel (Stations 20, 22, 23, 24).

Bottom Samples

Depths of bottom stations sampled in the Inner Harbor varied from 2 ft to 50 ft.

Fecal Coliform

Like the surface samples, bottom samples yielded the highest counts at Station 18 (Fort Point Channel, Figure 3.04). The geometric means of fecal coliform counts at all Inner Harbor bottom stations were below 1,000 col/100 ml, but more than 10% of samples showed counts greater than 2,000/100 ml at Stations 18, 23, and 24.

Enterococcus

The highest geometric mean *Enterococcus* counts (Table 3.01) were at Station 18 (Fort Point Channel) and Station 24 (main ship channel), but the 95% confidence intervals overlapped for all stations. All the bottom-water stations in the Inner Harbor met the geometric mean EPA swimmability standards (34 col/100 ml), but more than 10% of samples at Stations 13, 17, 18, 21, 22, and 24 had counts above this standard.

3.1.c Relationship between Indicator Bacteria and Rainfall

Surface Samples

The Inner Harbor was sampled during a time that received greater than average rainfall; 5.74 in. of rain fell between July 19, 1989, and August 17, 1989, a period of 34 days. Several rainfall variables showed high correlations (see Section 2 for analytic methods) with bacteria counts. Overall, fecal coliform counts in the Inner Harbor correlated most highly with the sum of the amount of rain occurring three days before sampling and the day of sampling ($r = 0.54$, $p < 0.001$). *Enterococcus* counts for the same samples correlated most highly with total rain occurring two days before sampling and the day of sampling ($r = 0.44$, $p < 0.001$).

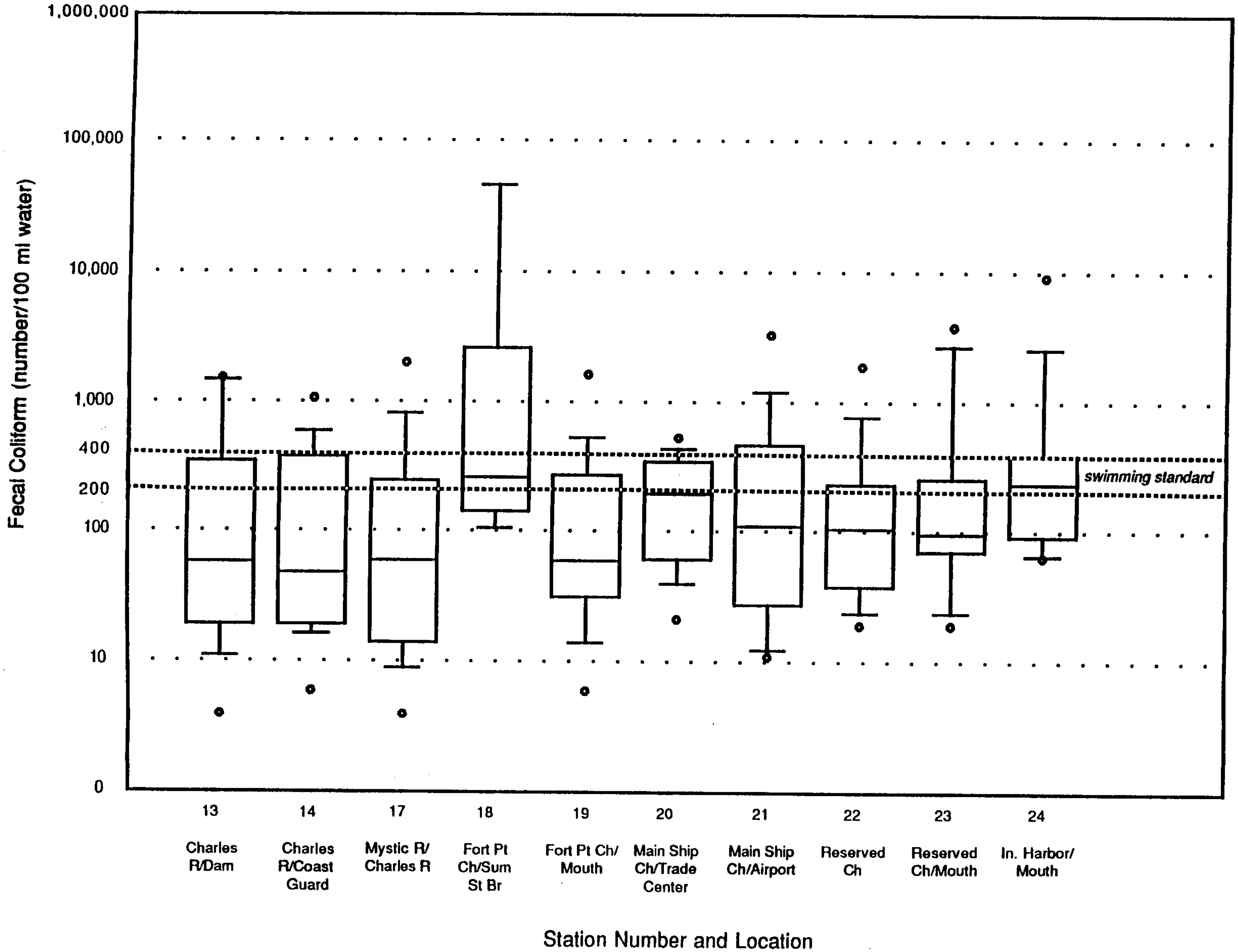


Figure 3.04. Percentile Box Plots of Fecal Coliform Counts from Bottom Samples in the Inner Harbor, 1989.

3. The Inner Harbor

Although there was an overall strong relationship with rainfall in the Inner Harbor, among individual stations within the Inner Harbor the correlations between indicator bacteria counts and rain variables showed considerable heterogeneity. Generally, the strongest correlations between rainfall and surface indicator bacteria counts were at the mouth of the Charles, in the main shipping channel, and in the Reserved Channel.

The relationship of rainfall with fecal coliform densities was weaker in Fort Point Channel than in the main channel. There was no significant correlation of rainfall with *Enterococcus* counts in Fort Point Channel.

The regression equation for the relationship of fecal coliform densities against 4-day summed rainfall for the Inner Harbor in 1989 was

Log(fecal coliform/100 ml + 1) = 1.624 + 0.684(4-day summed rain)
$R^2 = 0.45$, $p = 0.000$

Thus, during the 1989 sampling, fecal coliform densities at the surface in the Inner Harbor exceeded 200 col/100 ml [(2.3 - 1.624)/0.684 = 0.98] when the sum of rain falling over four days was 0.98 in. or more, with the variation in rain explaining about 45% of the variation in fecal coliform counts.

The regression equation for *Enterococcus* densities against 4-day summed rain was

Log(*Enterococcus* col/100 ml + 1) = 0.461 + 0.412(4-day summed rain)
$R^2 = 0.33$, $p < 0.001$

Thus, in the Inner Harbor, *Enterococcus* densities were 104 col/100 ml when 4-day summed rain was 3.78 in. or more [(2.02 - 0.461)/0.412 = 3.78], and *Enterococcus* densities exceeded 35 col/100 ml when 4-day summed rain was 2.67 in. or more [(1.56 - 0.461)/0.412 = 2.67]; with rain explaining about 33% of the variance in *Enterococcus* densities.

3.1.d Relationship between Indicator Bacteria and Flows and Loads through the Deer Island Treatment Plant

For the Inner Harbor stations as a group, flow through the Deer Island Treatment Plant was the single best correlate of indicator bacteria densities in the receiving water. There were strong positive correlations of both fecal coliform ($r = 0.60$, $p < 0.001$) and *Enterococcus* ($r = 0.50$, $p < 0.001$) with Deer Island flows. The overall correlations were somewhat weaker for bottom samples (fecal coliform: $r = 0.49$, $p < 0.001$; *Enterococcus*: $r = 0.41$, $p < 0.001$) than for surface waters.

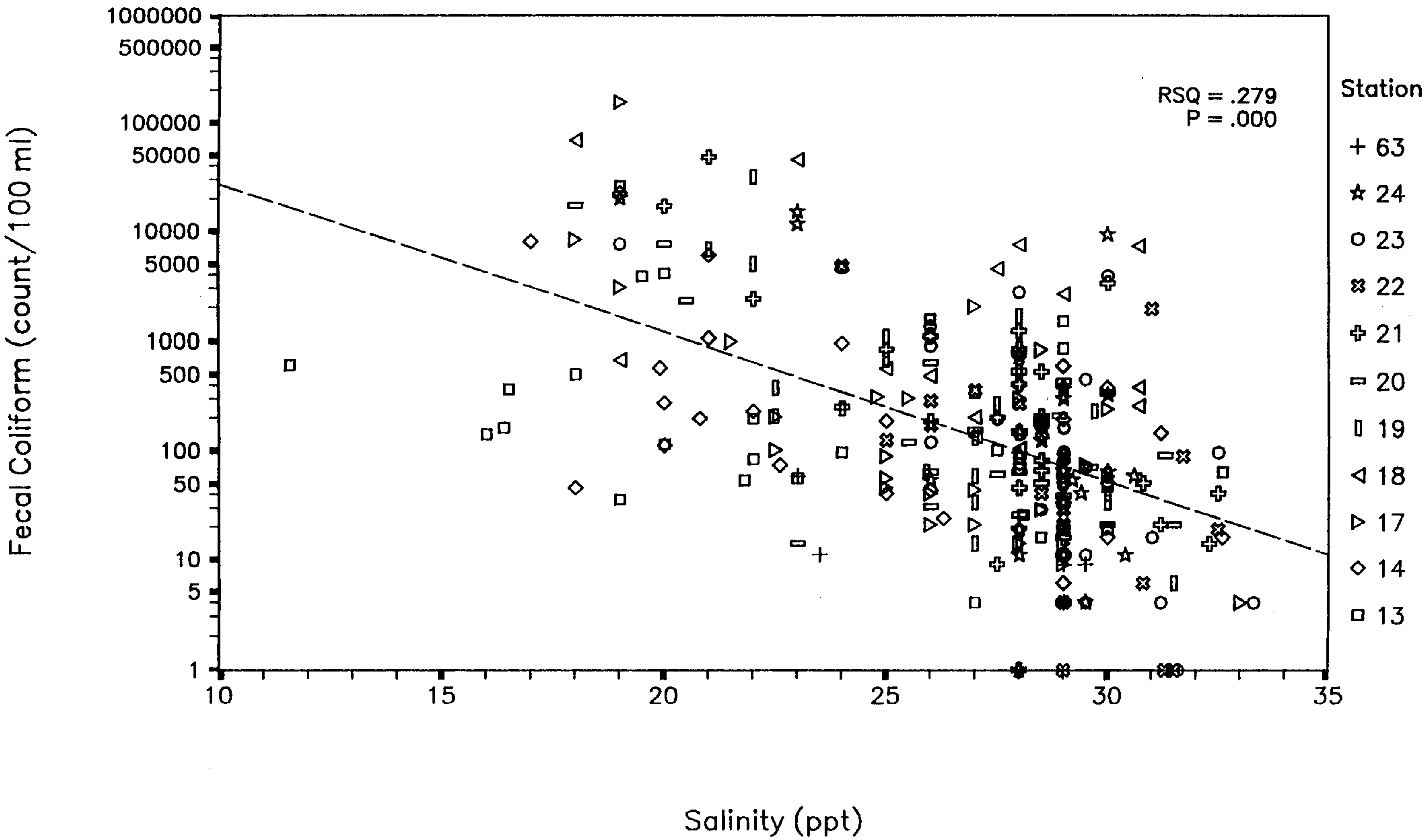


Figure 3.05. Relationship between Fecal Coliform Counts and Salinity for Surface Samples in the Inner Harbor, 1989.

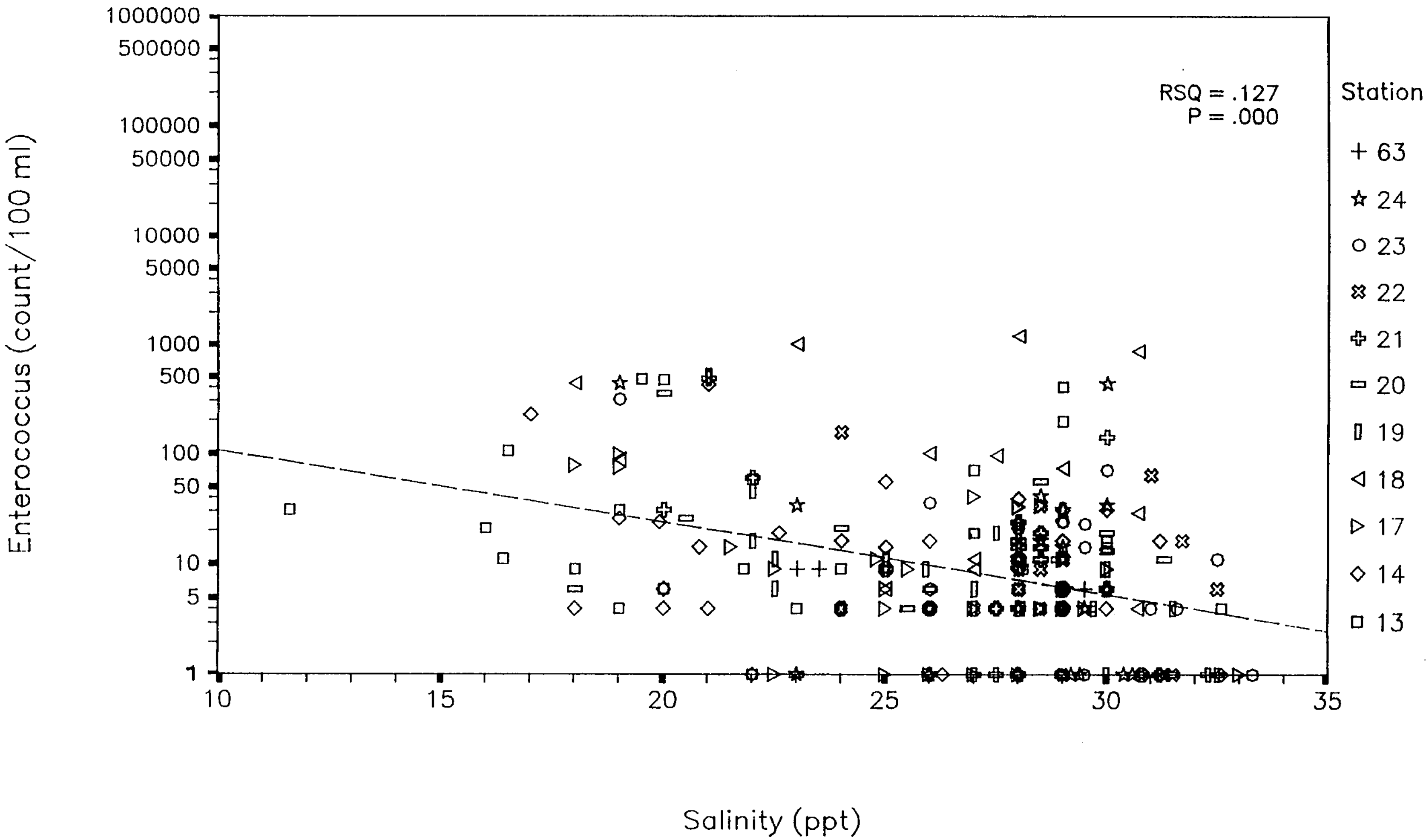


Figure 3.06. Relationship between *Enterococcus* and Salinity for Surface Samples in the Inner Harbor, 1989.

The relationships between indicator bacteria densities in the Inner Harbor and the Deer Island loadings of the indicators were weak and insignificant [Deer Is. load = (volume of flow through Deer Island) x (indicator bacteria counts in effluent)]. For fecal coliform, $r = -0.020$, $p = 0.39$; for *Enterococcus*, $r = 0.12$, $p = 0.04$.

There were strong intercorrelations of many of the rainfall variables with flow through Deer Island.

3.1.e Relationship between Indicator Bacteria and Salinity

In the Inner Harbor, samples were collected from waters with a broad range of salinities.

Surface Samples

Figure 3.05 shows a plot of log-transformed fecal coliform counts with salinity for all surface water samples taken in the Inner Harbor. Overall, there was a negative correlation of counts with increasing salinity ($r = -0.56$, $p < 0.001$.) This pattern of a strong negative relationship between surface counts and salinity was reflected at seven individual stations: those in the main ship channel and the Reserved Channel. Stations showing little relationship between fecal coliform densities and salinity were at the mouths of the rivers and in Fort Point Channel.

For *Enterococcus*, the relationship between surface counts and salinity at Inner Harbor stations was similar to the relationship between fecal coliform and salinity (Figure 3.06). At individual stations, significant negative correlations were again found in the main ship channel and the Reserved Channel, and not at the mouths of rivers or in Fort Point Channel. The negative relationships found between salinity and *Enterococcus* counts in the receiving water were weaker and less statistically significant than between fecal coliform and salinity.

Bottom Samples

Unlike the surface waters, bottom waters showed no significant correlations between indicator bacteria counts and salinity.

3.1.f Relationship between Indicator Bacteria and Tidal Current

Table 3.02 shows that fecal coliform counts and *Enterococcus* counts in Inner Harbor surface samples were significantly higher on the outgoing tide than on the incoming tide. However, the bottom samples showed no statistically significant differences between ebb and flood tides in densities of either fecal coliform or *Enterococcus*.

Surface salinity was higher on the flood tide, but bottom salinity was not found to vary significantly at ebb and flood tide.

3.1.g Dissolved Oxygen

Figures 3.07 and 3.08 are box plots of the percentile distributions of dissolved oxygen (DO) measurements at each surface and bottom station in Boston Inner Harbor.

Surface Measurements

The mean of all measurements at all surface stations was 6.6 mg/l. Measurements of surface DO in the Inner Harbor ranged from 3.9 mg/l to 10.5 mg/l. The highest mean DO, 7.5 mg/l, was at Station 24, the "outermost" Inner Harbor station. All of the 10 stations had a median DO above 5 mg/l, the standard for class SB waters.

Bottom Measurements

The mean level of DO in all bottom samples was 5.9 mg/l. DO levels in bottom samples ranged from 2.1 to 8.7 mg/l. Station 18 had the lowest mean DO in bottom waters, 4.1 mg/l; the highest mean DO, 7.5 mg/l, was at Station 24. Eight of 10 stations had median DO levels above 5 mg/l for bottom water measurements.

3.1.h Multiple Regression Analysis

Results of stepwise multiple regression analyses are shown in Table 3.03. Multiple regression is the only statistical technique that can apportion the variance in a dependent variable among a group of explanatory

Table 3.02. Tidal Variation in Densities of Indicator Bacteria and Salinity in the Inner Harbor in 1989

Tidal Current	Surface Samples				Bottom Samples			
	n	Mean	t	p	n	Mean	t	p
Fecal Coliform: Mean = Geometric mean (col/100 ml)								
Ebb	94	396			80	78		
Flood	120	148	3.11	0.002	106	78	0.86	0.393
***Enterococcus*: Mean = Geometric mean (col/100 ml)**								
Ebb	94	14			80	10		
Flood	120	6	3.54	0.000	106	8	1.42	0.158
Salinity: Mean = Arithmetic mean (ppm)								
Ebb	83	24.28			79	28.00		
Flood	118	26.01	-3.27	0.002	106	28.53	1.98	0.049

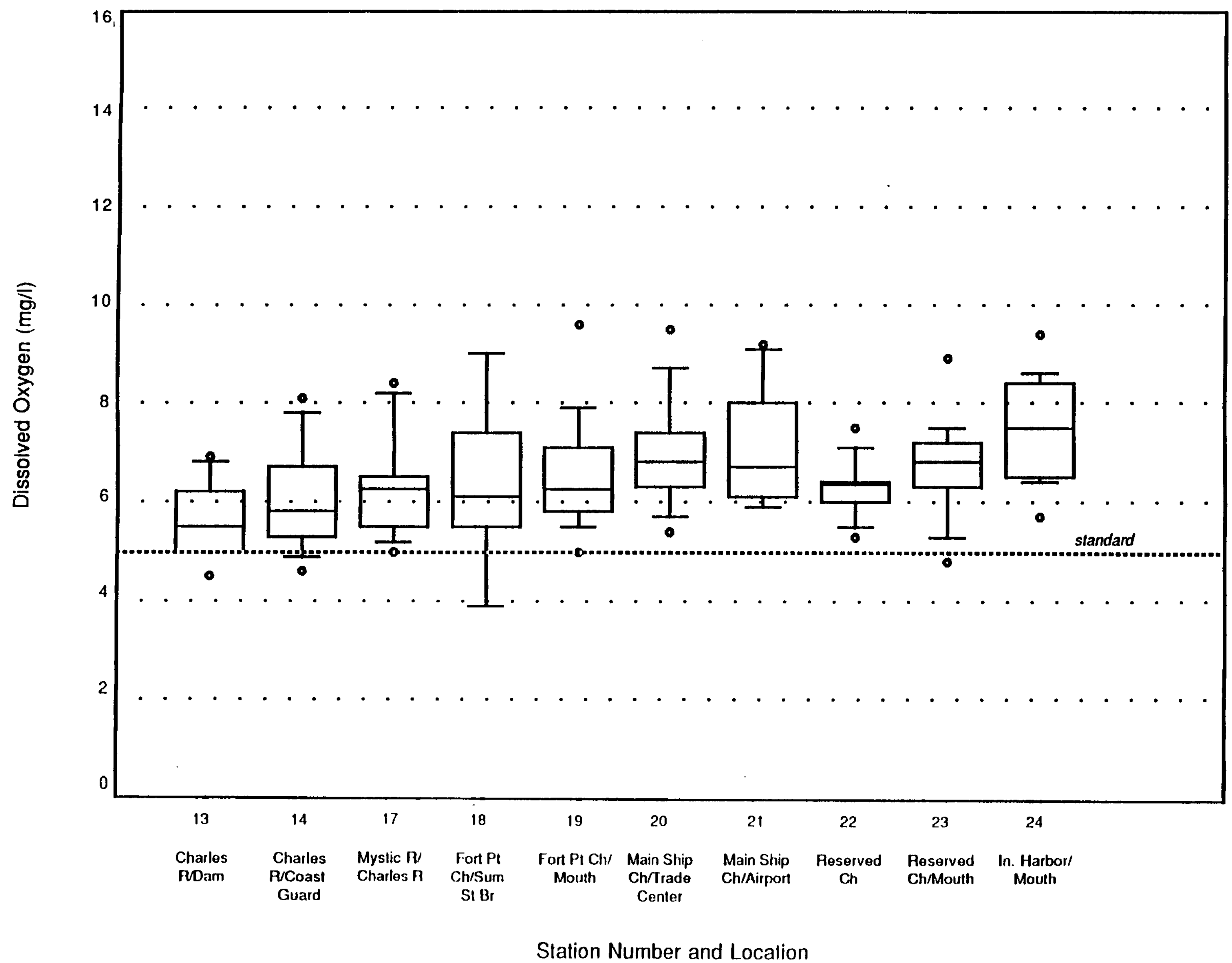


Figure 3.07. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in the Inner Harbor, 1989.

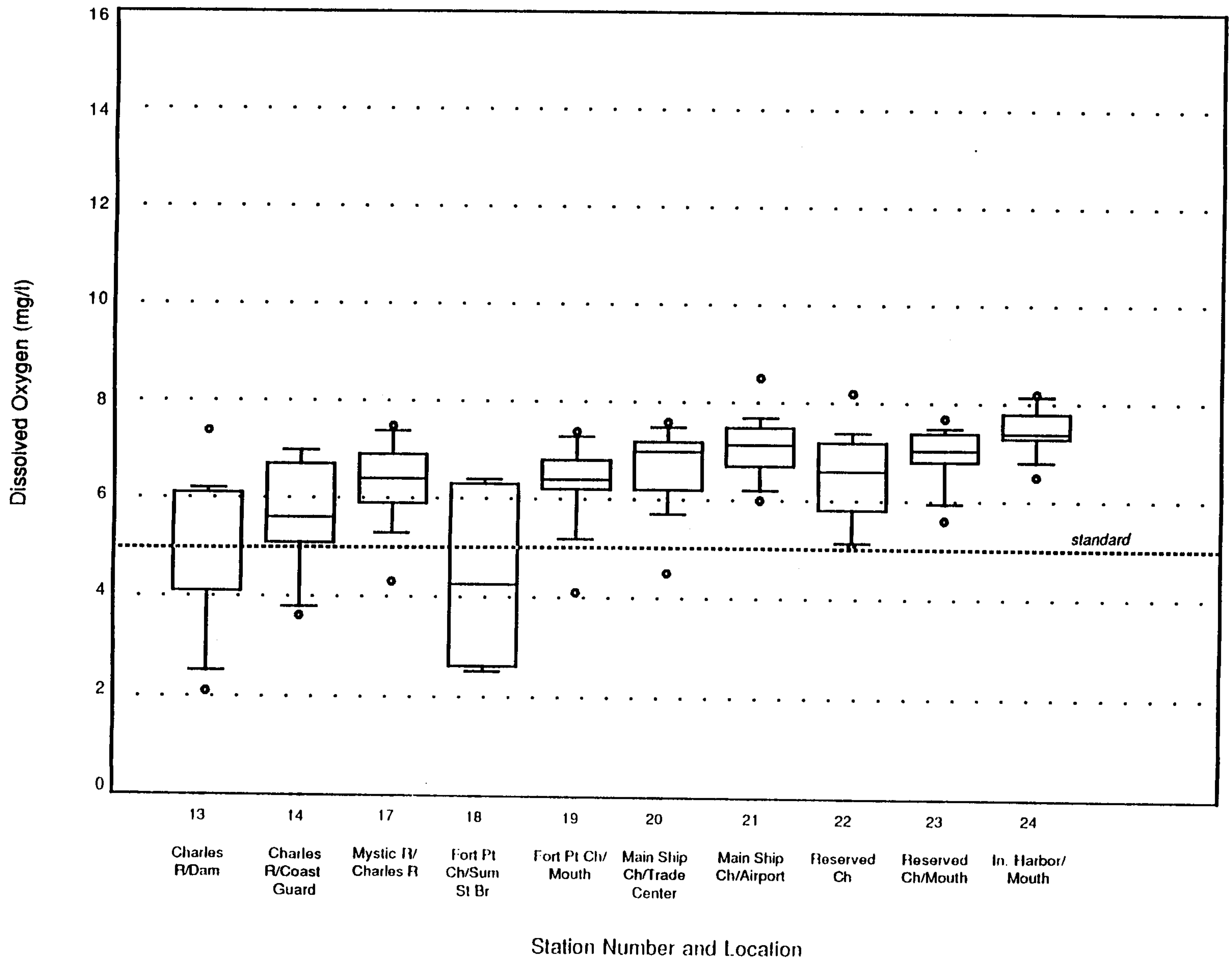


Figure 3.08. Percentile Box Plots of Dissolved Oxygen Measurements at Bottom Stations in the Inner Harbor, 1989.

Table 3.03. Multiple Regression Analysis for 1989 Inner Harbor Samples

List of Variables*

LOGFC	Log [(Fecal coliform counts/100 ml) + 1]
LOGENT	Log [(*Enterococcus* counts/100 ml) +1]
DIFLOW	Flow measured at the Deer Island WWTP on day of sampling in millions of gallons per day
SALINITY	Salinity of water sample in parts per thousand
LORNP(x)	Rain in inches summed over x days before sampling plus inches of rain the day of sampling
LORNM(x)	Amount of rain in inches that fell x days before sampling
TEMPERATURE	Temperature of water sampled in degrees Celsius
CURRENT	Direction of tidal current: entered into the regression as a dummy variable with the value 1 for ebb tide and 0 for flood tide

*A complete list of variables used in the regression analysis is in Section 2, Methods, Statistical Analysis.

Surface fecal coliform counts (log-transformed) as dependent variable

1. DIFLOW included as an independent variable in the variable list

LOGFC = 4.7215 + 0.006444(DIFLOW) - 0.085442(SALINITY) + 3.80365(LORNM4) - 0.099561(TEMPERATURE)

Multiple R = 0.71
$R^2 = 0.51$
$F_{(4,193)} = 49.71$ $p < 0.0001$

Table 3.03. Multiple Regression Analysis for 1989 Inner Harbor Samples, continued

---

2. *DIFLOW excluded as an independent variable*

LOGFC = 6.4631 + 0.3985(LORNP4) - 0.01030(SALINITY) - 0.0885(TEMPERATURE)

Multiple R = 0.67
$R^2 = 0.45$
$F_{(3,194)} = 52.76 \quad p < 0.0001$

Surface *Enterococcus* counts (log-transformed) as dependent variable

---

3. *DIFLOW included as independent variable*

LOGENT = 0.7136 + 0.0055(DIFLOW) - 0.04832(SALINITY)

Multiple R = 0.57
$R^2 = 0.32$
$F_{(2,196)} = 46.49 \quad p < 0.0001$

4. *DIFLOW excluded from the variable list*

LOGENT = 2.2393 + 0.4268(LORNP3) - 0.05852(SALINITY)

Multiple R = 0.56
$R^2 = 0.32$
$F_{(2,196)} = 45.17 \quad p < 0.0001$

Bottom fecal coliform counts (log-transformed) as dependent variable

---

5. *DIFLOW included in the variable list*

LOGFC = -0.1169 + 0.005476(DIFLOW) + 0.3296(CURRENT) + 0.2492(LORNM4)

Multiple R = 0.56
$R^2 = 0.31$
$F_{(3,181)} = 27.05 \quad p < 0.0001$

Table 3.03. Multiple Regression Analysis for 1989 Inner Harbor Samples, continued

---

6. *DIFLOW excluded from the variable list*

LOGFC = 1.04336 + 0.3839(LORNP4) + 0.3791(CURRENT)

Multiple R = 0.52
$R^2 = 0.28$
$F_{(2,282)} = 34.48$ $p < 0.0001$

Bottom *Enterococcus* counts (log-transformed) as dependent variable

---

7. *DIFLOW included in the variable list*

LOGENT = -0.07427 + 003852(DIFLOW)

Multiple R = 0.41
$R^2 = 0.17$
$F_{(1,183)} = 36.37$ $p < 0.0001$

8. *DIFLOW excluded from the variable list*

LOGENT = 0.7597 + 0.3208(LORNP3) + 0.1975(LORNM6)

Multiple R = 0.40
$R^2 = 0.16$
$F_{(2,182)} = 17.67$ $p < 0.0001$

---

variables. The variable that enters the equation first is the one that explains most of the variance, the next variable is the most important in explaining the remaining variance, and so forth.

Four stepwise multiple regressions were performed for each dependent variable (LOGFC and LOGENT): two for surface data and two for bottom data. For each pair of regressions, Deer Island flow (DIFLOW) was included as a predictive variable in one regression and excluded from the other. Details of the analytic method are given in Appendix B. Data from all Inner Harbor stations were used for these regression analyses.

In the stepwise multiple regressions of surface and bottom samples, for both fecal coliform and *Enterococcus*, DIFLOW entered into the equations first. For the surface samples, SALINITY was the next most important predictor of bacterial density, for both fecal coliform and *Enterococcus*. However, SALINITY did not enter into any of the equations for bottom bacterial counts. For fecal coliform in the surface waters, rainfall and water temperature were also significant predictors. Water temperature was not an important explanatory variable for *Enterococcus* in the surface. Tidal current (a positive sign indicating flood tide) was a significant predictor for fecal coliform in the bottom waters, but was not significant for *Enterococcus*.

When DIFLOW was not included in the variable lists, rainfall variables entered as the most important predictors in all of the equations.

3.2 1990 Results

Samples in the Inner Harbor were collected during two periods in 1990: June-July and October. Not all the stations sampled during the June time period were visited again in October.

3.2.a Sampling Locations and Rainfall

Figure 3.09 shows the stations sampled in the Inner Harbor during 1990. Figure 3.10 shows the rainfall during the 1990 monitoring. The June-July sampling occurred during very dry weather, whereas heavy rains fell during the October sampling period.

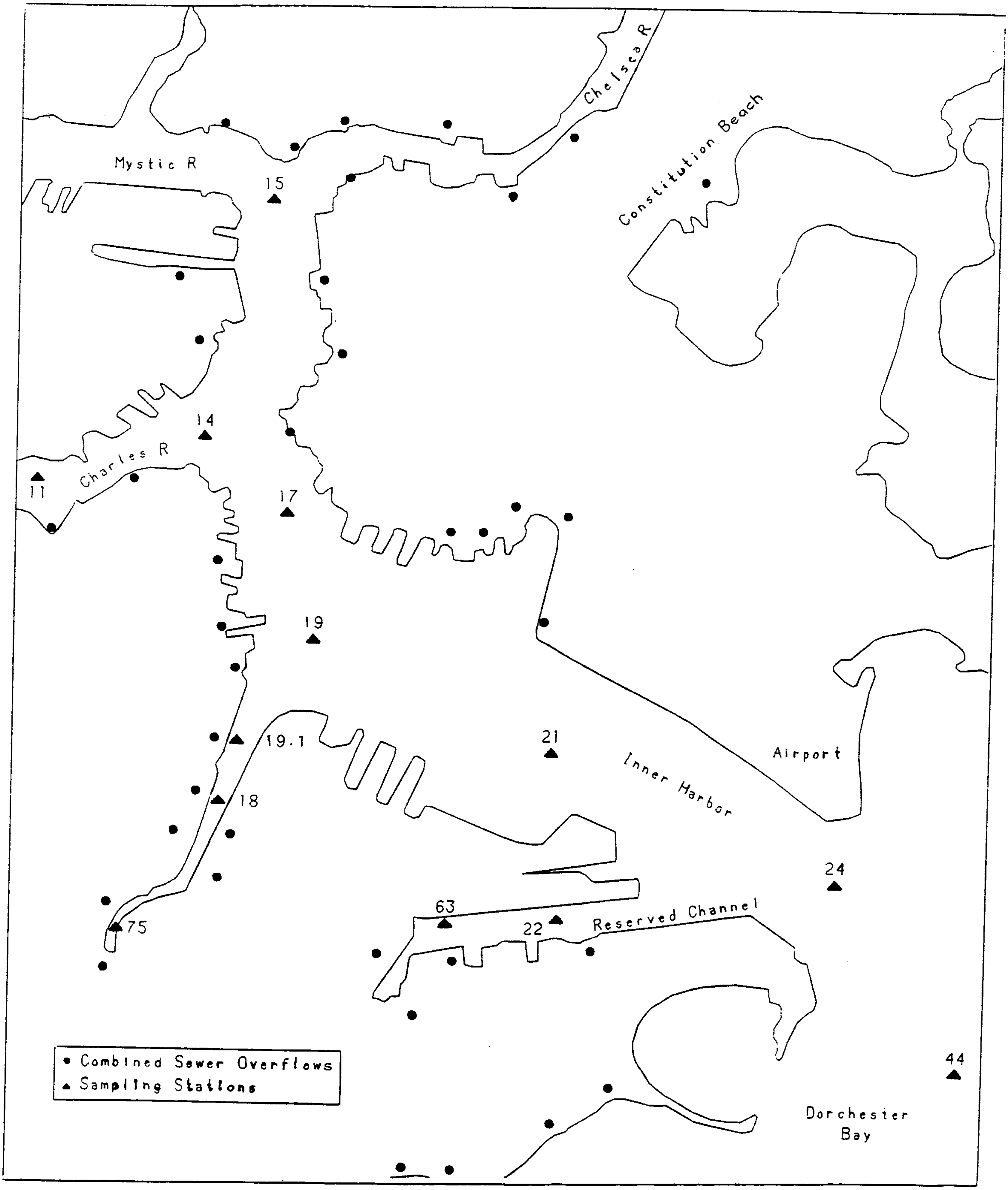


Figure 3.09. Stations Sampled during the 1990 Harbor Monitoring.

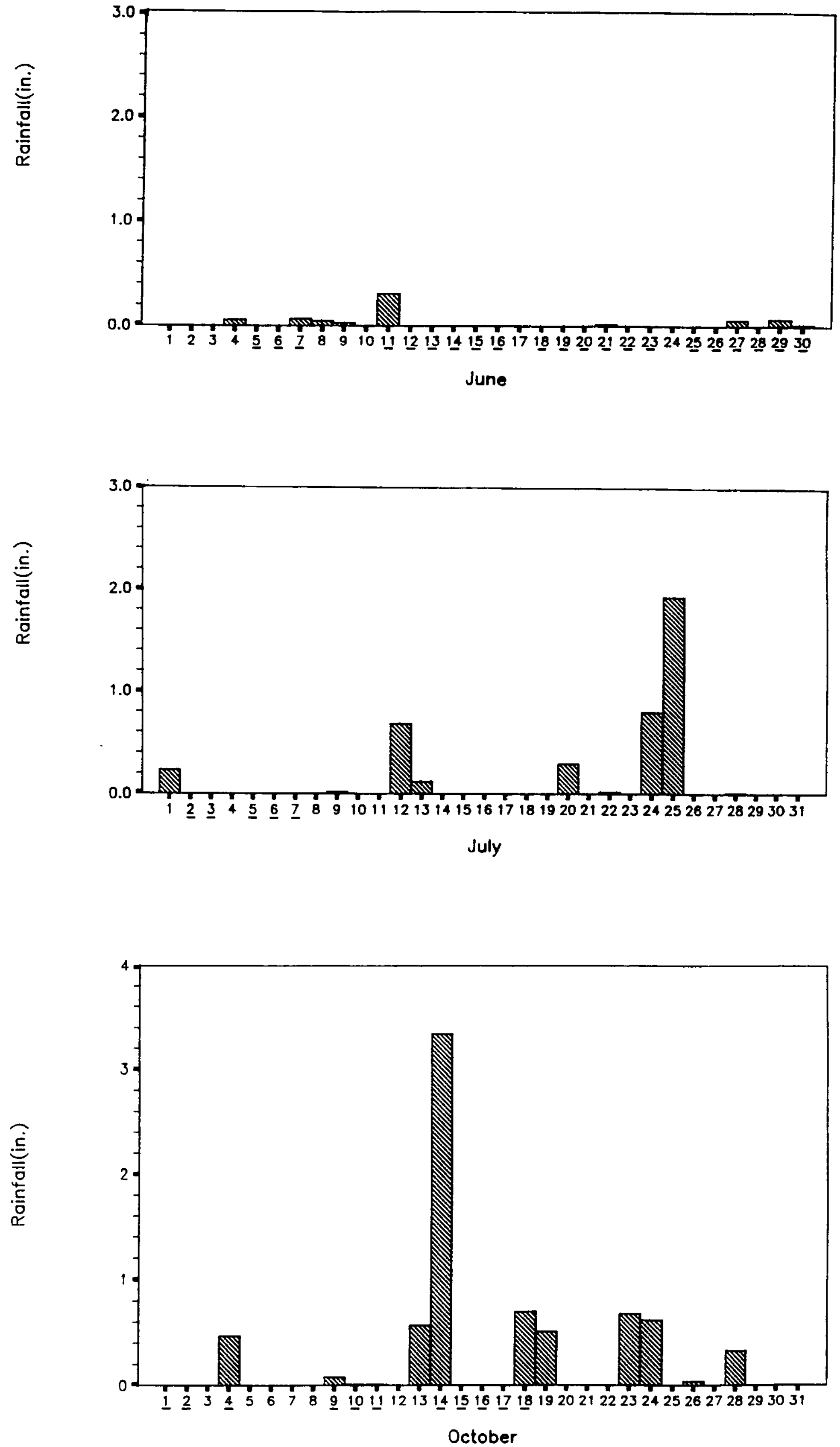


Figure 3.10. Daily Rainfall during the 1990 Inner Harbor Monitoring Period.

Samples were collected on dates underlined.

3.2.b Indicator Bacteria Counts

The distributions of fecal coliform and *Enterococcus* at stations in the Inner Harbor are shown in Figures 3.11-3.14. These percentile box plots show indicator bacteria densities in surface and bottom samples from two sampling periods: June-July and October.

The geometric means and corresponding 95% confidence intervals of fecal coliform and *Enterococcus* for the entire set of Inner Harbor samples are listed in Table 3.01.

Surface Samples

Fecal Coliform

The geometric means of counts in all surface samples, June-July and October combined (Table 3.01), were below 200 col/100 ml at all Inner Harbor stations, except Station 75, which is near BOS-070 in Fort Point Channel (geom. mean = 457 col/100 ml). The overall spatial pattern of fecal coliform densities was moderately high counts, on the order of 10^2 col/100 ml, at the mouth of the Charles River and in the main ship channel; higher counts, on the order of 10^2-10^3 col/100 ml, in Fort Point Channel; and lower counts, around 10^1-10^2 col/100 ml, at stations closest to the mouth of the Inner Harbor.

The June-July samples (Figure 3.11) were taken during a period of very little rain (see Figure 3.10); total rainfall between June 10 and July 5 (26 days) was 0.71 in. Seventy-five percent or more of the samples taken at all stations except Stations 75 and 18 in Fort Point Channel yielded less than 200 col/100 ml; and the geometric means and the upper 95% confidence limits were all below 200 col/100 ml except for surface counts at Station 75 (geometric mean = 288 col/100 ml).

October was a rainy period (Figure 3.10); the total rainfall from October 1 to October 18 (19 days) was 5.41 in. During the October sampling, the number of samples exceeding 200 col/100 ml increased, as did the number of stations where the geometric mean exceeded 200 col/100 ml (Figure 3.12). During this sampling period, geometric means exceeded 200 col/100 ml in surface samples at Stations 17, 18, 19, and 75. The 95% upper confidence limit was greater than 200/100 ml at all stations sampled except Station 22.

Enterococcus

Ninety percent or more of the samples taken during June-July and October were below the EPA-recommended "single sample maximum allowable density for infrequent primary contact," 500 col/100 ml, at all stations except the three stations in Fort Point Channel: Stations 75, 19, and 19.1. The geometric

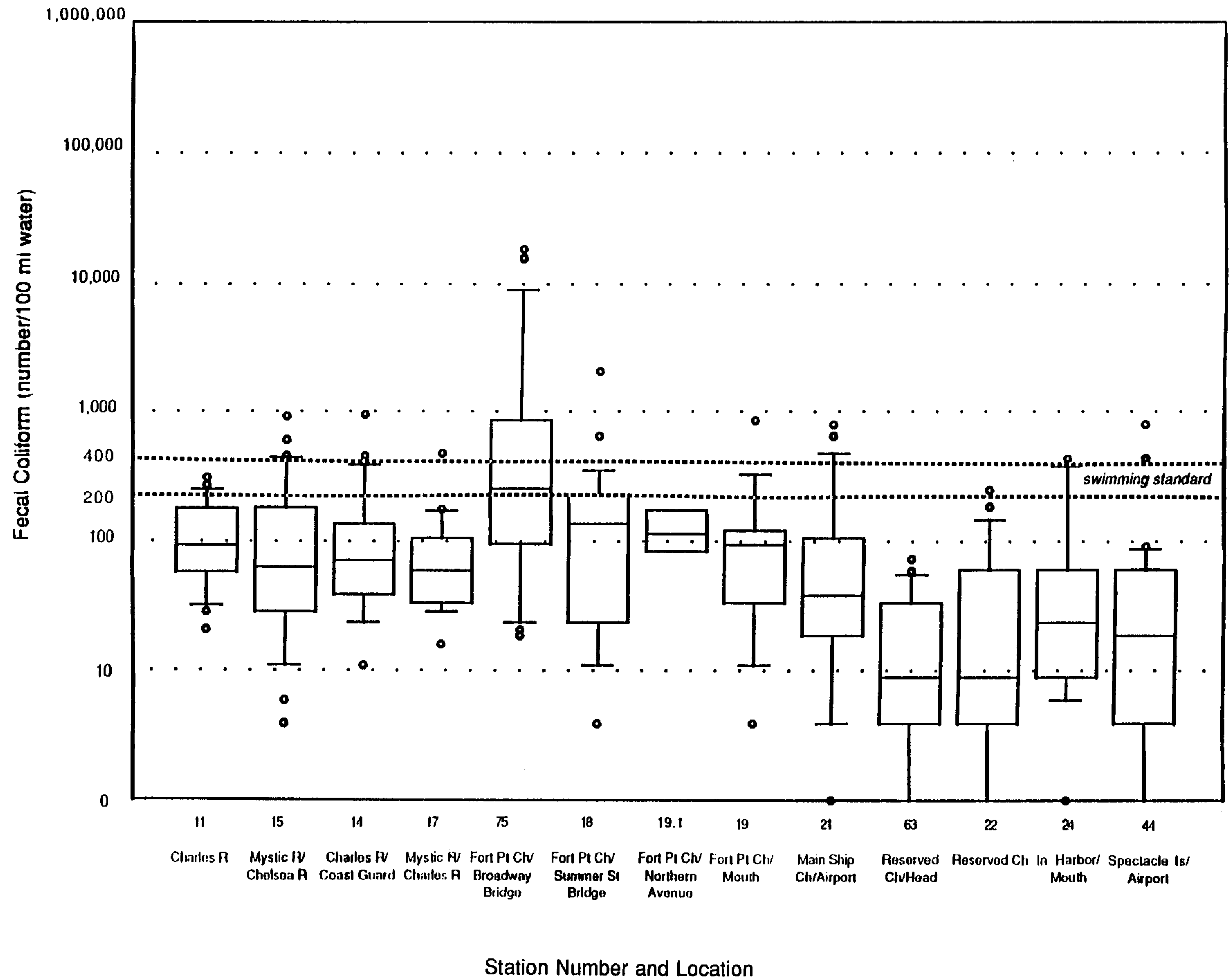


Figure 3.11. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in the Inner Harbor, June-July 1990.

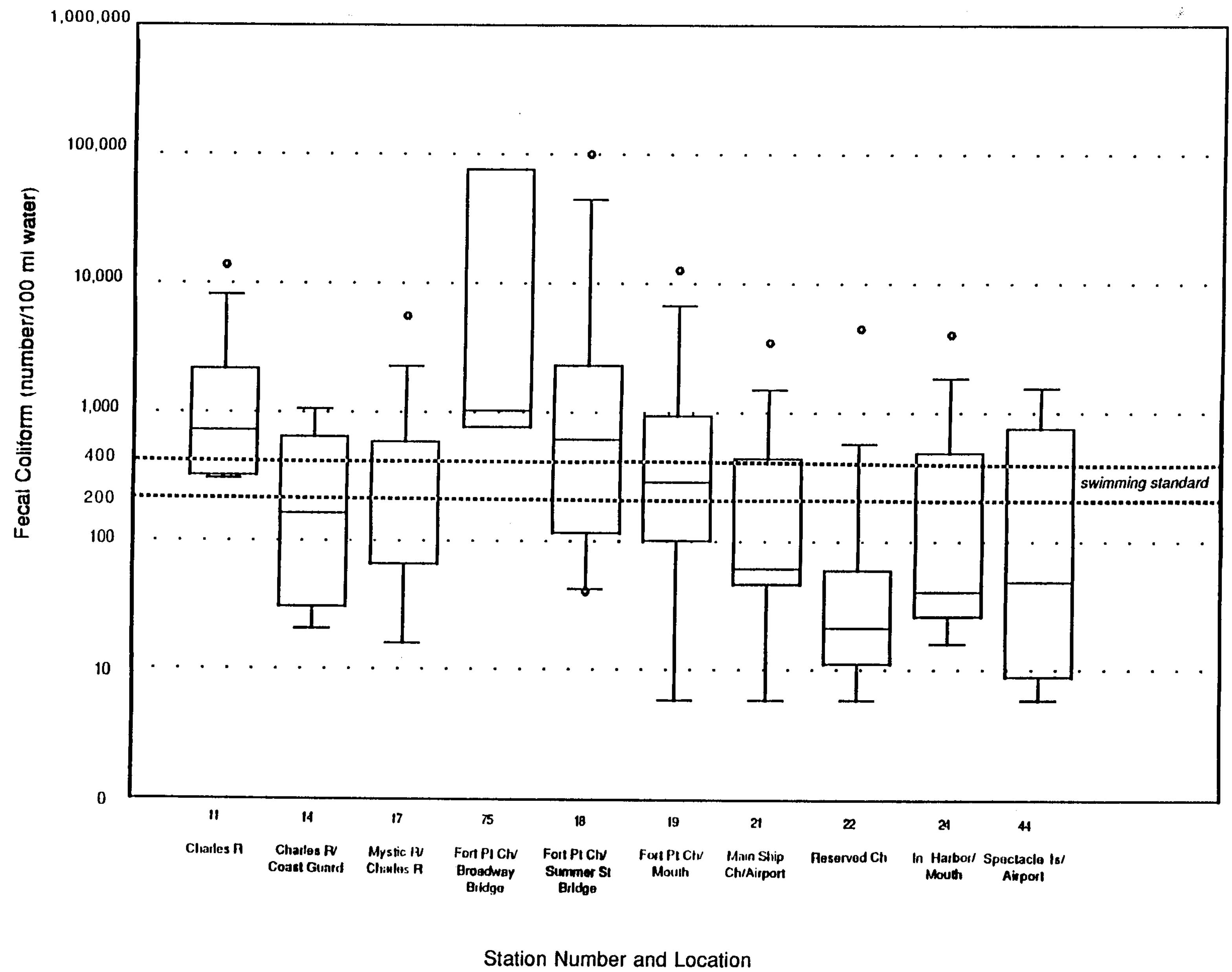


Figure 3.12. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in the Inner Harbor, October 1990.

means at all Inner Harbor stations, except Station 75, were well below 35 col/100 ml (Table 3.01), the EPA-recommended "steady state geometric mean" for a swimming area.

During the dry weather in June and July (Figure 3.13), 90% of samples at all stations except Stations 15 and 75 had *Enterococcus* counts less than 104 col/100 ml, the EPA-recommended "single sample maximum allowable density for a designated bathing beach," and the geometric means were well below 35 col/100 ml. The upper 95% confidence limits were all less than 35 col/100 ml except at Stations 19.1 and 75, and all upper 95% confidence limits were less than 104 col/100 ml (Table 3.01).

Figure 3.14 shows the percentile distributions of *Enterococcus* counts from samples taken during October, which was characterized by heavy rains (Figure 3.10). Although there was a wide range of counts at all stations, generally median counts were approximately 10-fold higher than during dry weather. Geometric mean counts from surface samples exceeded 35 col/100 ml at Stations 17, 18, 19, 21, 24, 44, and 75; and exceeded 104 col/100 ml at Stations 18 and 75 (closest to BOS-070).

Bottom Samples

Extensive bottom sampling was performed during the June-July sampling period, but not during the October sampling period.

Fecal Coliform

Table 3.01 gives the geometric means for bottom samples. Compared to surface samples, bottom samples had lower median counts and ranges of counts at all Inner Harbor stations except Stations 63, 22, 24, and 44, where bottom counts tended to be equal to or higher than surface samples. These stations are located in the Reserved Channel and close to the mouth of the Inner Harbor.

Enterococcus

The pattern for *Enterococcus* densities was similar to fecal coliform densities: bottom counts were lower than surface counts except in the Reserved Channel and near the mouth of the Inner Harbor (Table 3.01).

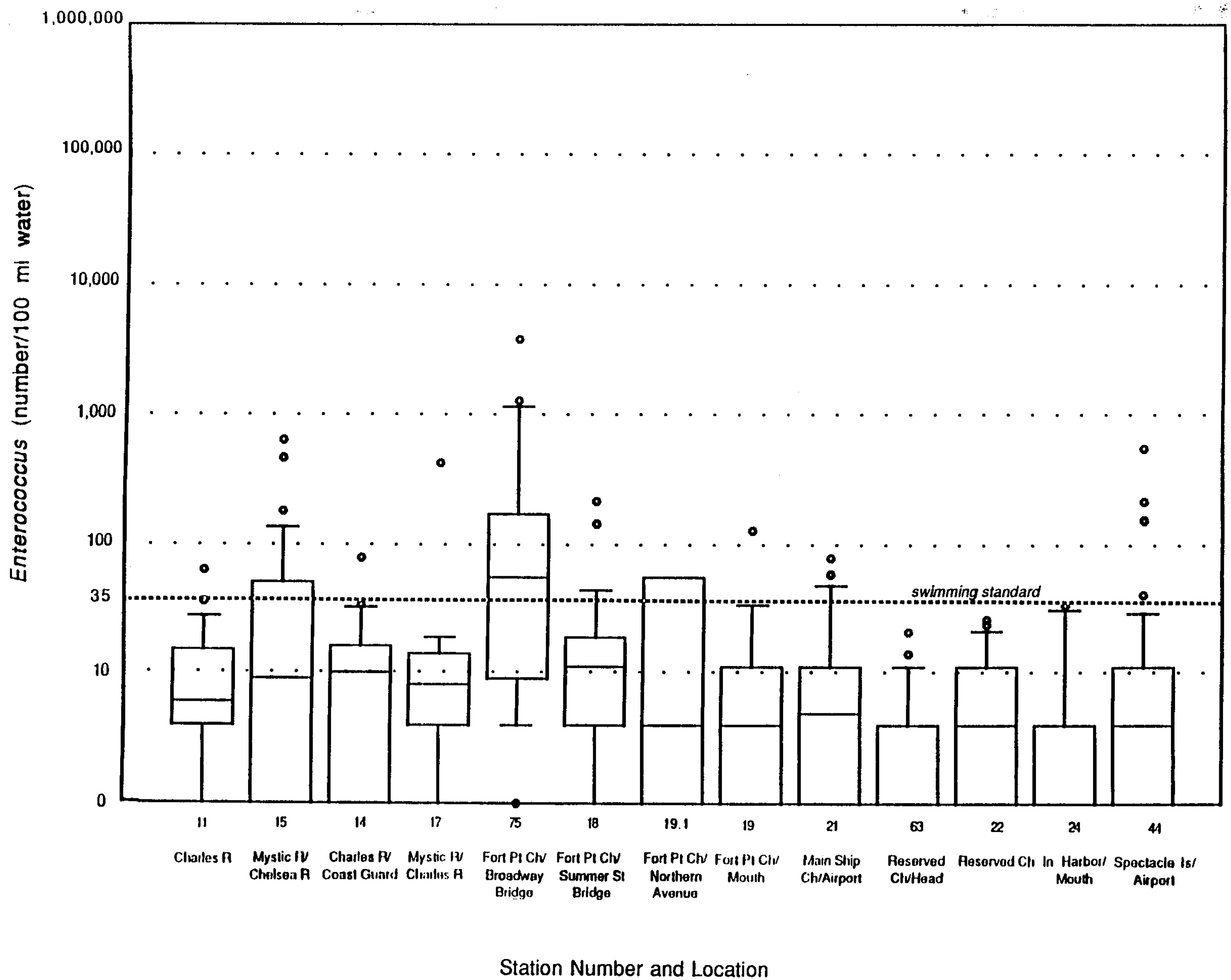


Figure 3.13. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in the Inner Harbor, June-July 1990.

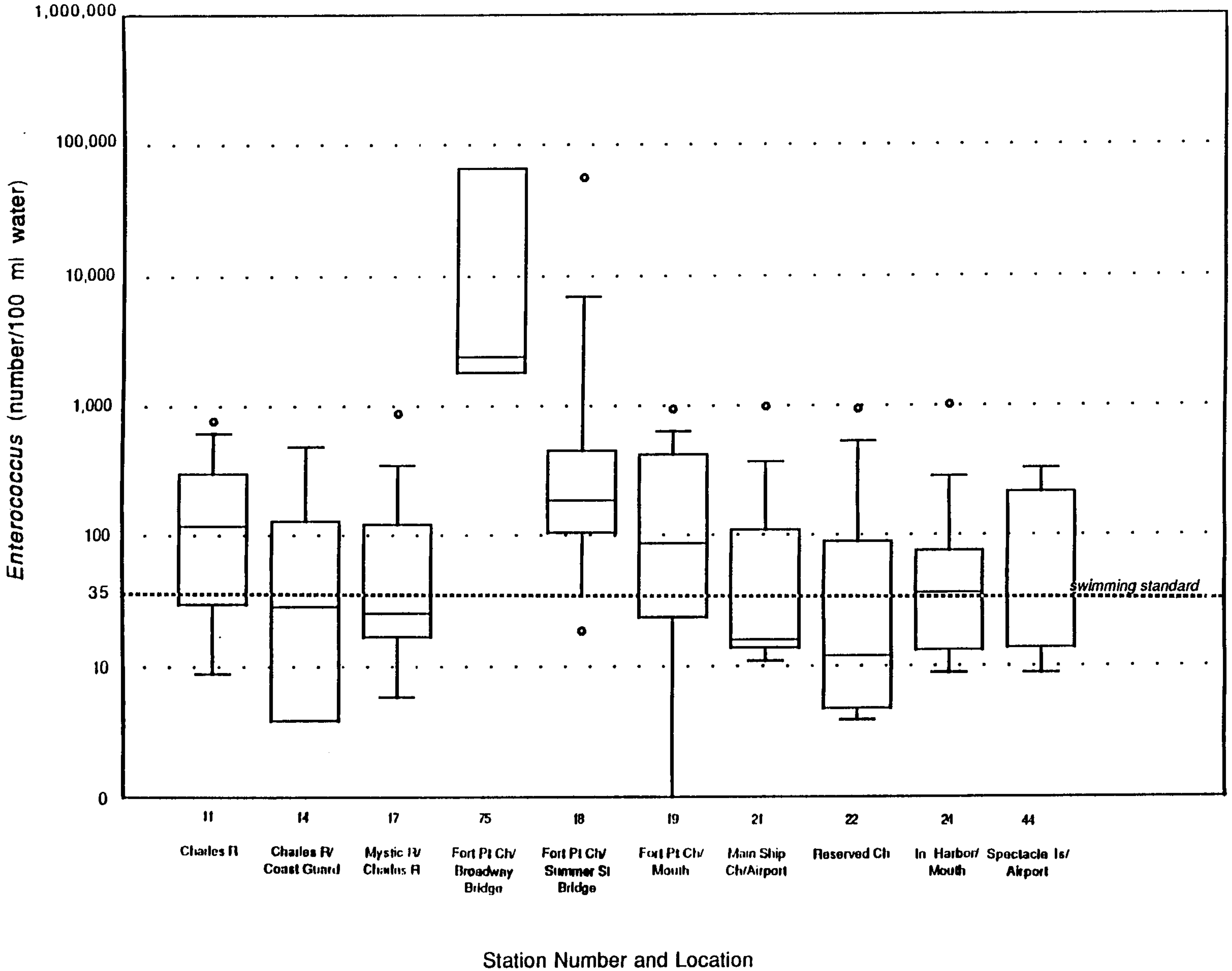


Figure 3.14. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in the Inner Harbor, October 1990.

3.2.c Relationship between Indicator Bacteria and Rainfall

Surface Samples

Fecal Coliform

The rainfall variable with the highest correlation with log-transformed fecal coliform densities for the Inner Harbor as a whole (12 stations) was 3-day summed rainfall (LORNP3; $r = 0.49$, $p < 0.001$). However, different individual stations in the Inner Harbor correlated with rainfall to different degrees. The stations with the strongest relationship with LORNP3 were in Fort Point Channel and the main ship channel. Weak or insignificant relationships were found in the Reserved Channel, at the mouth of the Mystic River, at the confluence of the Charles and Mystic Rivers, and outside the mouth of the Inner Harbor (Station 44).

Appendix Figure A.03 shows the regression of fecal coliform counts against 3-day summed rainfall for stations in the Inner Harbor. The regression includes data from Station 11 in the Charles River immediately upstream of the Charles River Dam. The equation for this regression is

Log(fecal coliform/100 ml) = 1.66 + 0.48 (3-day summed rain)

$R^2 = 0.24$, $p < 0.001$

Thus, surface fecal coliform density in the Inner Harbor exceeded 200 col/100 ml when the sum of rain over three days was more than 1.3 inches, with rainfall explaining approximately 24% of the variance for the Inner Harbor as a whole.

Enterococcus

Enterococcus in the Inner Harbor showed a pattern of relationships with rainfall similar to the relationship between fecal coliform and rainfall. Overall, the strongest rainfall correlate with log-transformed *Enterococcus* densities was 3-day summed rainfall ($r = 0.50$, $p < 0.001$). Again, strong correlations with rain (LORNP3) were found in Fort Point Channel and the main ship channel, with weak or insignificant relationships in the Reserved Channel, at the mouth of the Mystic River, at the confluence of the Charles, and outside the mouth of the Inner Harbor. This correlation was weaker for *Enterococcus* than for fecal coliform at Station 17, near the confluence of the Inner Harbor and the Charles River.

The regression of *Enterococcus* counts in the Inner Harbor, again including Station 11, against 3-day rainfall was calculated according to the equation

Log(*Enterococcus*/100 ml) = 0.852 + 0.498 (LORNP3)

$R^2 = 0.25$, $p < 0.001$

Thus, *Enterococcus* densities exceeded 35 col/100 ml on average in the Inner Harbor when rain summed over three days exceeded 1.39 in. Rainfall explained about 25% of the variance in *Enterococcus* counts.

Bottom Samples

For logistical reasons, we were able to collect far fewer samples at bottom stations during the October (rainy period) sampling than during the June-July period. Only one bottom station (Station 18) showed significant correlations of both indicators with 3-day summed rainfall. This may simply be because not enough wet-weather measurements were made to reveal a relationship between rain and fecal coliform counts at other stations.

3.2.d Relationship between Indicator Bacteria and Flows and Loads through the Deer Island Treatment Plant

Surface Samples

For all the Inner Harbor stations taken together, flow through the Deer Island Treatment Plant was significantly correlated with densities of both fecal coliform ($r = 0.43$, $p < 0.001$) and *Enterococcus* ($r = 0.45$, $p < 0.001$).

However, neither fecal coliform nor *Enterococcus* loadings at the Deer Island plant were significantly correlated with indicator bacteria densities in the Inner Harbor.

There was considerable variation among individual stations in the Inner Harbor in the strength and significance of the relationship between indicator bacteria counts and flow through Deer Island. For fecal coliform, there were significant correlations ($p < 0.001$) at Stations 11, 17, 18, 19, and 44. For *Enterococcus*, Stations 18, 24, and 44 had significant correlations of counts with flow through Deer Island.

Bottom Samples

For bottom samples, for the Inner Harbor as a whole, flow through Deer Island was significantly correlated with fecal coliform densities ($r = 0.24$, $p < 0.001$) and with *Enterococcus* densities ($r = 0.34$, $p < 0.001$). Among individual bottom stations, only one station showed a highly significant ($p < 0.001$) correlation of indicator bacteria densities with Deer Island flow: Station 18 in Fort Point Channel (for fecal colifom, $r = 0.77$, $p < 0.001$; for *Enterococcus*, $r = 0.70$, $p < 0.001$). This lack of significant relationships in bottom waters may be due to the fact that only a few samples were collected at bottom stations during rainy weather.

3.2.e Relationship between Indicator Bacteria and Salinity

Surface Samples

Fecal Coliform

A regression of fecal coliform counts against salinity was performed for all surface-water samples from the Inner Harbor. The overall relationship was weak but significant ($R^2 = 0.14$, $p < 0.001$, slope = -0.14). For the 1990 data, only three stations, all of them in Fort Point Channel, showed a significant ($p < 0.05$) negative relationship with salinity (Station 75, $R^2 = 0.30$, $p = 0.007$; Station 18, $R^2 = 0.30$, $p = 0.007$; and for Station 19, $R^2 = 0.33$, $p = 0.005$).

Enterococcus

The regression of *Enterococcus* against salinity was calculated for all 1990 Inner Harbor samples. The relationship of *Enterococcus* to salinity showed a pattern similar to fecal coliform: there was a weak but significant negative overall relationship ($R^2 = 0.05$, $p < 0.001$, slope = -0.064), and the only station with a significant ($p < 0.05$) relationship between counts and salinity was in Fort Point Channel (Station 18, $R^2 = 0.19$, $p = 0.017$).

Bottom Samples

For bottom samples collected from the Inner Harbor, the overall regression of fecal coliform against salinity was not significant. Only at Station 75 was there a significant negative relationship ($R^2 = 0.24$, $p < 0.05$). For *Enterococcus*, only Station 22 had a significant negative relationship ($R^2 = 0.27$, $p < 0.05$) with salinity.

3.2.f Relationship between Indicator Bacteria and Tidal Current

Table 3.04 shows how indicator bacteria counts in surface samples varied with tidal current in Boston's Inner Harbor. For fecal coliform, counts on the ebb tide were significantly higher than counts on the incoming tide. However, for *Enterococcus*, there was no significant difference in counts between ebb and flood tides. For bottom samples, neither fecal coliform nor *Enterococcus* showed significant differences with tidal cycles.

3.2.g Dissolved Oxygen

The percentile distributions of surface dissolved oxygen measurements at Inner Harbor stations are shown in Figure 3.15. At all stations but three [Stations 11 (Charles River), 75, and 18 (Fort Point Channel)], 75% or more of the measurements were greater than 5.0 mg/l, the current standard for class SB waters. For stations in the main ship channel and the Reserved Channel (Stations 17, 19, 21, 63, 22, 24, 44), 90% or more of the measurements were greater than 5.0 mg/l. Station 75, near BOS-090, had the lowest dissolved oxygen, with more than half the values less than 5 mg/l.

Measurements taken 0.5 m from the bottom generally showed lower dissolved oxygen levels (Figure 3.16) than measurements taken at the surface. The lowest values were at Station 11 in the Charles River (a stratified area), where all measurements were less than 6 mg/l, with a median of 3.5 mg/l.

3.2.h Multiple Regression Analysis

A multiple regression (Table 3.05) was performed for log-transformed counts of bacteria against the variable list in Table 3.03. (DIFLOW was included as an independent variable, DO was excluded.)

For surface samples, rainfall summed over three days was the most important explanatory variable for fecal coliform, and salinity was the next most important. Rainfall summed over two days followed by rainfall summed over four days were the two most important explanatory variables for *Enterococcus*.

These variables were able to account for approximately one-third of the variance in indicator bacteria counts over the whole Inner Harbor. Because the Inner Harbor is a heterogeneous environment, and we know that many factors affect the survival and distribution of allochthonous bacteria in the marine environment, the fact that rainfall and salinity explain so much variance underscores the importance of these parameters.

Table 3.04. Tidal Variation in Densities of Indicator Bacteria in the Inner Harbor in 1990

Tidal Current	Surface Samples				Bottom Samples			
	n	Mean*	*t*	*p*	n	Mean*	*t*	*p*
Fecal Coliform								
Ebb	156	84			142	34		
Flood	138	44	2.79	0.006	147	33	0.18	0.857
Enterococcus								
Ebb	156	12			142	8		
Flood	138	9	1.34	0.183	147	6	1.37	0.173

*Mean = Geometric mean (col/100 ml)

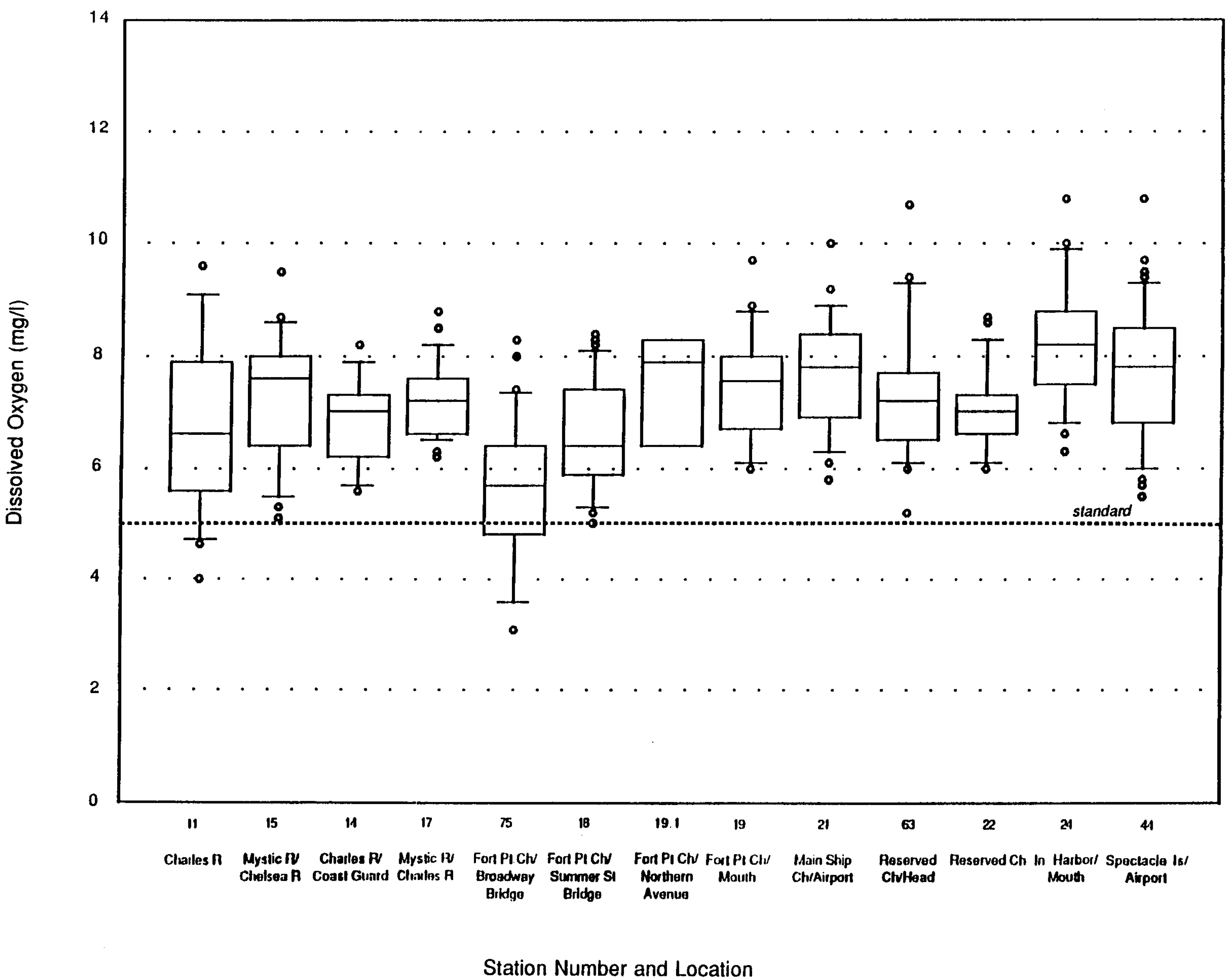


Figure 3.15. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in the Inner Harbor, June-July, and October 1990.

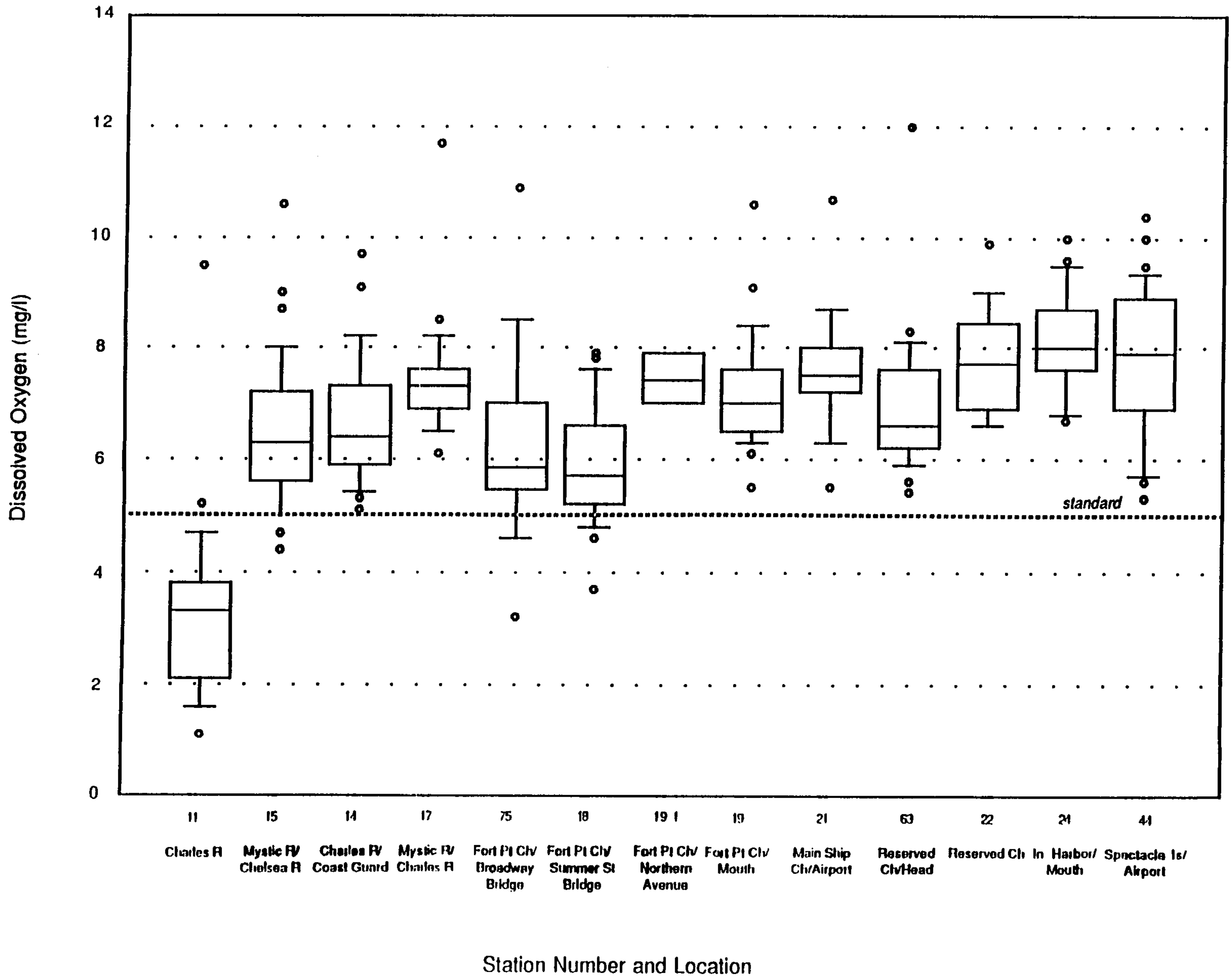


Figure 3.16. Percentile Box Plots of Dissolved Oxygen Measurements at Bottom Stations in the Inner Harbor, June-July, and October 1990.

Table 3.05. Multiple Regression Analysis for 1990 Inner Harbor Samples

Surface fecal coliform counts (log-transformed) as dependent variable

LOGFC = 2.297126 + 0.470403[LORNP3] - 0.026467[SALIN]

Multiple R = 0.57
$R^2 = 0.32$
$F_{(2,240)} = 56.59$ $p < 0.0001$

Other variables entered the equation with a significant F, but each explained 2% or less of the variance. These variables were, in order, LORNP2, - CURRENT, and LORNM4.

Surface *Enterococcus* counts (log-transformed) as dependent variable

LOGENT = 0.760439 + 0.43785[LORNP2] + 0.217585[LORNP4] +0.965801[LORNM6]

Multiple R = 0.58
$R^2 = 0.34$
$F_{(3,239)} = 41.54$ $p < 0.0001$

Bottom fecal coliform counts (log-transformed) as dependent variable

LOGFC = 1.39493 + 0.475220[LORNE4]

Multiple R = 0.27
$R^2 = 0.07$
$F_{(1,188)} = 14.36$ $p = 0.0002$

Bottom *Enterococcus* counts (log-transformed) as dependent variable

LOGENT = 0.83552 + 0.377389[LORNP3]

Multiple R = 0.36
$R^2 = 0.13$
$F_{(1,188)} = 27.43$ $p < 0.0001$

By contrast, in the bottom waters, only 7% (fecal coliform) to 13% (*Enterococcus*) of the variance was explained by rainfall variables, implying that other factors are more important in explaining indicator bacteria density in bottom waters.

3.3 Discussion

3.3.a Indicator Bacteria Counts Compared to Water Quality Standards and Relationship with Rainfall

Data collected in 1989 and during the October sampling in 1990 all reflect water quality in rainy conditions. In 1989, geometric mean fecal coliform counts in surface samples were less than 200 col/100 ml at Stations 20, 22, 23, 24, and 15. But all of the Inner Harbor stations except Station 26 had counts exceeding 400 col/100 ml in more than 10% of the samples, violating standards for SB waters. Similar results were obtained in 1990 wet weather. In contrast, during dry weather, most of the Inner Harbor stations (Stations 11, 14, 17, 18, 19, 63, 22, 24, and 44) met the swimmable criteria for fecal coliform, having geometric means less than 200 col/100 ml and less than 10% of samples exceeding 400 col/100 ml.

Enterococcus counts showed a pattern similar to fecal coliform. During the dry weather of June-July 1990, all stations except Station 75 (near BOS-070 in Fort Point Channel) had at least 90% of samples lower than 104 col/100 ml, with geometric means lower than 35 col/100 ml. During rainy weather, the proportion of samples exceeding 104 col/100 ml increased so that the "cleanest" station showed 25% of samples greater than 104 col/100 ml.

3.3.b Dry-Weather Sources of Sewage in Fort Point Channel

In 1989, we found relatively low correlations of bacterial densities with rain and with Deer Island flow at Fort Point Channel (Station 18). This result, coupled with high geometric mean counts, is consistent with a dry -weather source of sewage.

Further evidence for the presence of a dry-weather source of sewage in Fort Point Channel came from a study conducted by MWRA and the Massachusetts Institute of Technology (personal communication, E. Adams, Massachusetts Institute of Technology) in December 1989. During dry weather, dye was injected into BOS-070 at the head of Fort Point Channel. Dye concentrations, salinity, fecal coliform counts, and *Enterococcus* counts were measured over three tidal cycles at low tide at six stations located along the length of Fort Point Channel from the head of the channel to its mouth. Salinity concentrations showed a relatively time-invariant pattern, with lower salinities at the upstream end of the channel. Indicator bacteria counts showed a similar pattern, with densities of both fecal coliform and *Enterococcus* greater than 10^5 col/100 ml at the head of the channel, near BOS-070, and falling off to 10^2 col/100 ml at the mouth. By combining the measurements of salinity with the estimate of residence time based on dye measurements, the investigators inferred that there was a freshwater inflow on the order of 1 MGD during the survey. In fact, Boston Water and Sewer Commission confirmed that there was a malfunctioning regulator in BOS-070 at that time; the regulator was subsequently repaired. A wet-weather repetition of this dye study in the spring of 1990 showed wet-weather counts more than an order of magnitude **lower** than the previous dry-weather counts at stations near BOS-070.

In Fort Point Channel, the relationship of indicator bacteria counts with rain in 1990 was different from that found in 1989. In 1989 there was little correlation between rainfall and counts (consistent with a large dry-weather flow), but in 1990 the Fort Point Channel stations, like the rest of the Inner Harbor, showed a significant positive relationship between indicator bacteria and rainfall. This correlation is to be expected if sewage enters the receiving water from CSOs. In 1990, dry-weather measurements in Fort Point Channel (June-July data) showed geometric mean fecal coliform counts ranging from 288 col/100 ml at the head of the channel to 67 col/100 ml at the mouth. This is a dramatic decrease from the concentrations of 10^5 to 10^6 col/100 ml found during the December 1989 dry-weather sampling.

3.3.c Depth Distribution of Indicator Bacteria in the Inner Harbor

At most of the Inner Harbor stations sampled, surface fecal coliform counts ranged from 1.1 to almost 12 times as high as bottom fecal coliform counts. However, at several stations in the main ship channel, close to the mouth of the Inner Harbor, this pattern was reversed: geometric mean bottom counts were **higher** than surface counts. Because the 95% confidence intervals between surface and bottom counts overlap, these data are only suggestive of an interesting depth pattern. This pattern was observed in both 1989 and 1990. It is reasonable to presume that sewage indicator bacteria found in the bottom waters of this marine environment (depths from 30 to 50 ft) come from sources more distant in time and/or space than sewage (freshwater)-associated bacteria in the fresher water at the surface. Three possible sources of bacteria to the bottom water of the Inner Harbor are (1) the bottom sediment, (2) bacteria settling from the surface, and (3) sludge and effluent.

Analysis (*t*-tests) of the relationship of tidal currents to indicator bacteria counts showed that fecal coliform counts and *Enterococcus* counts in Inner Harbor surface samples were significantly higher on the outgoing tide than the incoming tide. This is consistent with a CSO source of sewage indicators, because CSOs are designed to discharge on the ebb tide. The *t*-tests of bottom samples showed no statistically significant differences between ebb and flood tides in densities of either fecal coliform or *Enterococcus*. However, in the multiple regression of bottom samples, CURRENT (flood tide) was a significant positive predictor for fecal coliform (but not *Enterococcus*). This is consistent with a non-CSO source of sewage indicator bacteria to the bottom waters.

3.3.d Relationship between Indicator Bacteria and Salinity

There was an overall strong negative correlation between surface fecal coliform counts and salinity in all areas; and between surface *Enterococcus* counts and salinity in the Inner Harbor. This pattern held for seven individual stations as well. There was no highly significant relationship between indicator bacteria counts and salinity in bottom-water samples. Salinity was also negatively and significantly correlated with rainfall in the Inner Harbor (for salinity with sum of rainfall over three days, $r = -0.40$, $p = 0.000$). A negative correlation between indicator bacteria and salinity would be expected if fresh water is associated with sewage. This relationship would also be expected if greater salinity imposed higher mortality on indicator bacteria--a phenomenon that has been reported for fecal coliform (Goyal, Gerba, and Melnick, 1977; Elliot and Colwell, 1985). However, in this study both fecal coliform and *Enterococcus*, which is known to be salt-tolerant, showed similar abundance patterns with salinity. Also, samples from bottom water did not show a clear relationship of counts with salinity. Therefore, simple mortality of fecal coliform due to high-salinity stress was probably not the main factor causing a negative correlation between abundance and salinity. The negative gradient of counts with increasing salinity in surface water samples is consistent with the assumption that the major sources of fresh water (CSOs, storm drains, and rivers) are also the main sources of sewage indicator bacteria to the surface waters of the Inner Harbor. The observed change in surface bacteria densities with salinity probably reflected dilution, settling, and mortality from exposure to environmental stressors (UV light, osmotic stress, predation, temperature) over time and distance from the source of pollution. The lack of relationship between salinity and indicator bacteria in the bottom waters of the Inner Harbor is consistent with the hypothesis of more distant sources of fecal coliform and *Enterococcus* in time and space--with potential sources including sludge, resuspension from the bottom sediments, and settling from the surface.

3.3.e Relationships among Environmental Variables and Bacterial Pollution Indicators in the Inner Harbor: General Trends

We expected that the variables rainfall and salinity would be important correlates of pollution indicator bacteria in the receiving waters. However, the results of the correlation analyses and the multiple regressions from the 1989 data showed the surprising result that, overall, flow through the Deer Island treatment plant on the day sampled was the single most important predictor of fecal coliform and *Enterococcus* densities in both surface and bottom samples. Because the bacterial loadings at Deer Island were not correlated with counts in the receiving waters, flow through Deer Island must have, in a simple way, reflected how the functioning of the combined sewer system affected the receiving waters. Of course, in this combined storm/sanitary sewer system, rainfall has a direct effect on flow through the treatment plant. Our analysis shows that during June through October, 1989, the strongest correlate of rain with Deer Island flow was the sum of rainfall over four days.

3. The Inner Harbor

Multiple regressions on the 1990 data gave results different from the 1989 data. Rainfall variables, rather than flow through Deer Island, were the most important predictors of indicator bacteria density (Table 3.05). There are no obvious reasons why rainfall was less important than Deer Island flow in 1989 and more important in 1990, and the difference may be a sampling artifact. Rainfall and Deer Island flow were highly intercorrelated in both years. Factors that might have influenced the multiple regression results are (1) in 1990 many more dry-weather samples were taken than in 1989, (2) pumping capacity at the Deer Island plant increased in 1990, and (3) the large dry-weather overflow in Fort Point Channel was dramatically decreased.

3.4 Conclusions

Boston's Inner Harbor is a complex physical marine environment. Within a relatively small area, which can be characterized as an arrangement of artificially dredged channels, this urban estuary receives fresh water from two rivers and is the only area of Boston Harbor where there is significant stratification, with a relatively fresh layer of water overlying a more saline bottom layer. The relationships among rainfall, CSOs, and water quality in the Inner Harbor vary greatly within this geographic area, and are affected by both anthropogenic factors (such as the structure and functioning of the sewer system) and natural factors (such as wind, tide, salinity, water temperature, and exposure to daylight).

The results of any attempt to measure water quality and relate it to environmental parameters inevitably rest on the study sampling design: where samples are taken, frequency of sampling, and number of samples. In this study, we measured water quality at stations both near CSOs and distant from CSOs and sampled during wet and dry weather, at surface and bottom, and during all phases of the tidal cycle. The high frequency of sampling has enabled us to create a data set that permits statistical analysis relating both natural and anthropogenic variables and allows us to draw some conclusions:

- **Variation with Environmental Parameters**

  Patterns of variation of fecal coliform and *Enterococcus* counts with rainfall, tide, salinity, and depth were all consistent with a CSO-associated source of sewage in the surface layer in the Inner Harbor. However, indicator bacteria densities in the bottom waters of the Inner Harbor did not appear to be strongly coupled with these environmental variables and probably have a source more remote in time and space. Sludge is one possible source.

3. The Inner Harbor

- **Indicator Density Variation within Stations**

Indicator bacteria counts exhibited high variability, sometimes over 3 orders of magnitude, within stations--both in dry and rainy weather. This implies that it will be necessary to continue to collect relatively large numbers of samples (e.g., at least 20) at each station to detect significant differences among stations and to detect change over time within stations.

- **Spatial Variation in Indicator Bacteria Densities**

Indicator counts varied considerably among stations in the Inner Harbor, as well as with depth sampled. Variation in indicator bacteria densities reflects the heterogeneous environment of the Inner Harbor. During 1989 and 1990, stations with the lowest measures of central tendency (geometric mean, median) for surface samples were at the mouth of the Inner Harbor, most distant from CSOs and rivers. Not surprisingly, Fort Point Channel stations had the highest sewage indicator bacteria counts. What was surprising was that, on average, indicator bacteria densities fell by approximately 90% from the head of the channel, near BOS-070, to the mouth of the channel. Therefore, previous estimates of fecal coliform loadings to the rest of the Inner Harbor from BOS-070 may have been overestimated by an order of magnitude.

- **Effect of Routine Maintenance**

The most dramatic improvement in water quality that we observed during this time period was in Fort Point Channel: after a dry-weather overflow was detected in the winter of 1989, repairs to a malfunctioning regulator were made and dry-weather counts at nearfield stations dropped several orders of magnitude.

- **Correlation with Rainfall**

Sewage indicator bacteria densities in the receiving water were correlated with cumulative rainfall over three to four antecedent days.

- **Relationship between Indicators**

Fecal coliform and *Enterococcus* patterns of distribution were similar, although *Enterococcus* was less strongly negatively correlated with salinity.

3. The Inner Harbor

- **Relationship to Water Quality Standards**

During dry weather (June-July 1990) 75% to 90% of the samples at each Inner Harbor station, except the two stations in Fort Point Channel closest to BOS-070, were within the Massachusetts standards for swimmable water (200 col/100 ml). The geometric mean counts were well below 200 col/100 ml at all stations except that closest to BOS-070.

During wet weather, (1989 data and October 1990 data) none of the stations in the Inner Harbor met the Massachusetts swimmability criteria: more than 10% of the samples at each station exceeded 400 col/100 ml. Yet at stations seaward of Fort Point Channel, the geometric mean counts were near or below 200 col/100 ml during periods of wet weather. Although the Inner Harbor has pockets of severe pollution and is rimmed with CSOs, most of the time water quality in much of the Inner Harbor approaches standards set for swimmable water.

4. Neponset River and Dorchester Bay

Monitoring in the Neponset River and Dorchester Bay was conducted in 1989 and 1990. In 1989, all stations were sampled during the same period, but in 1990 they were divided into two groups that were sampled at different times. Results in this section are presented separately for each sampling period. All 1989 results for the Neponset River and Dorchester Bay are presented in Section 4.1; 1990 results for Northern Dorchester Bay are in Section 4.2; and 1990 results for Southern Dorchester Bay and the Neponset River are in Section 4.3.

4.1 1989 Results: Neponset River and Dorchester Bay

4.1.a Sampling Locations and Rainfall

Figure 4.01 shows the location of the stations sampled in the Neponset River/Dorchester Bay area between June 28 and July 20, 1989. Twelve stations were located in the nearfield receiving water for individual combined sewer overflows (CSOs); BOS-081, BOS-082, BOS-083, BOS-084, BOS-085, BOS-086, BOS-087, BOS-088, BOS-089, BOS-090, BOS-093, and BOS-095. Five other stations were located in farfield areas.

Figure 4.02 shows the amount of rain that fell each day during the 1989 Neponset River/Dorchester Bay sampling period. During this time there were three storms that deposited more than 0.5 in. of rain in 24 hours, and several smaller rainfalls.

4.1.b Indicator Bacteria Counts

Figures 4.03 and 4.04 are percentile box plots of fecal coliform and *Enterococcus* counts from surface samples taken at each station in the Neponset River/Dorchester Bay area. The stations are arranged in the figures along a transect with the most upstream Neponset River station on the left and the South Boston beaches and offshore Dorchester Bay on the right.

Fecal Coliform

Geometric mean fecal coliform counts (Table 4.01) ranged from 5 col/100 ml at Station 35 to 2467 col/100 ml at Station 53. The most upstream station in the Neponset, Station 55, located above a dam and upstream of all CSO and tidal influence, had a comparably high geometric mean count: 2314 col/100

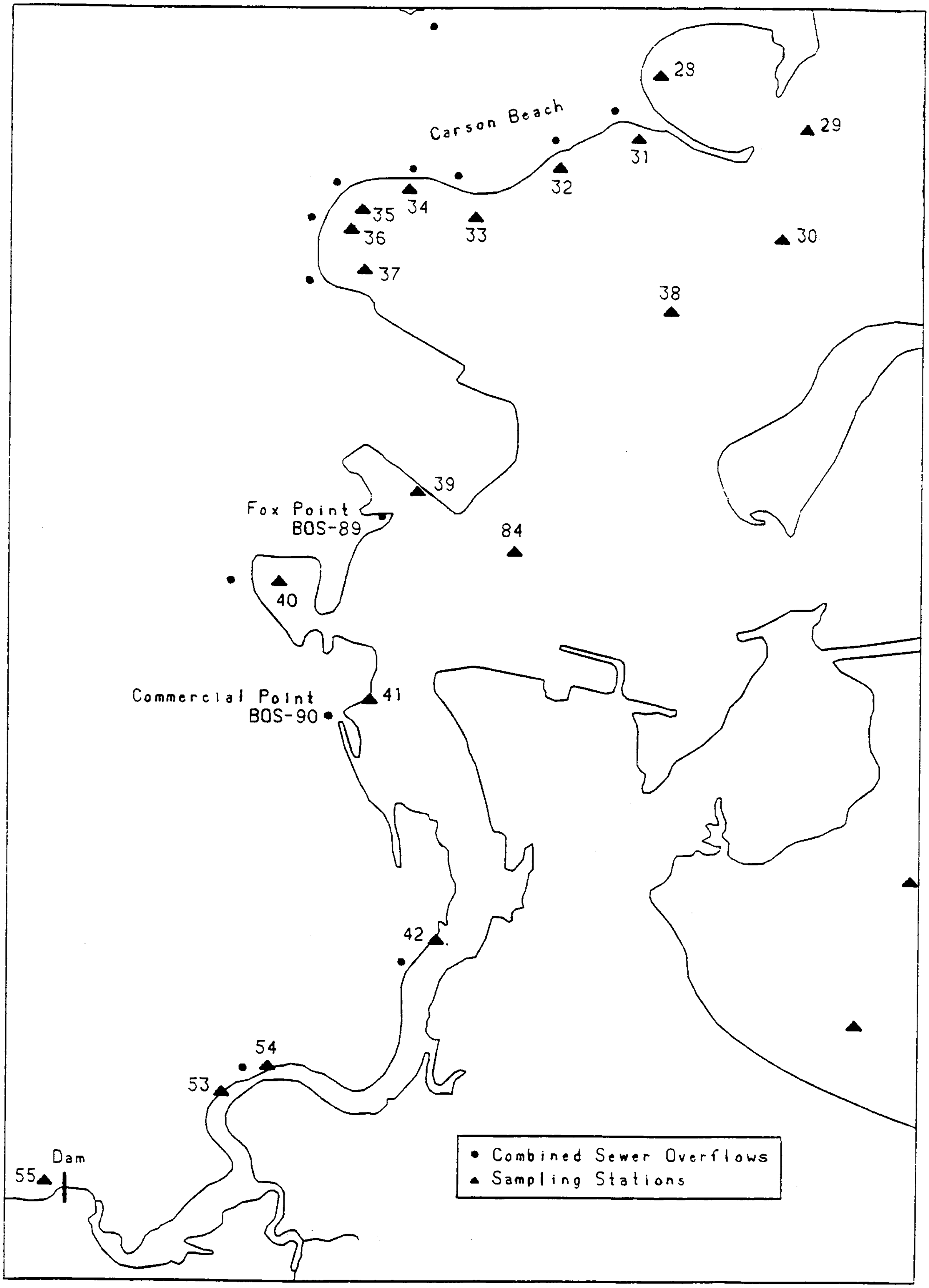
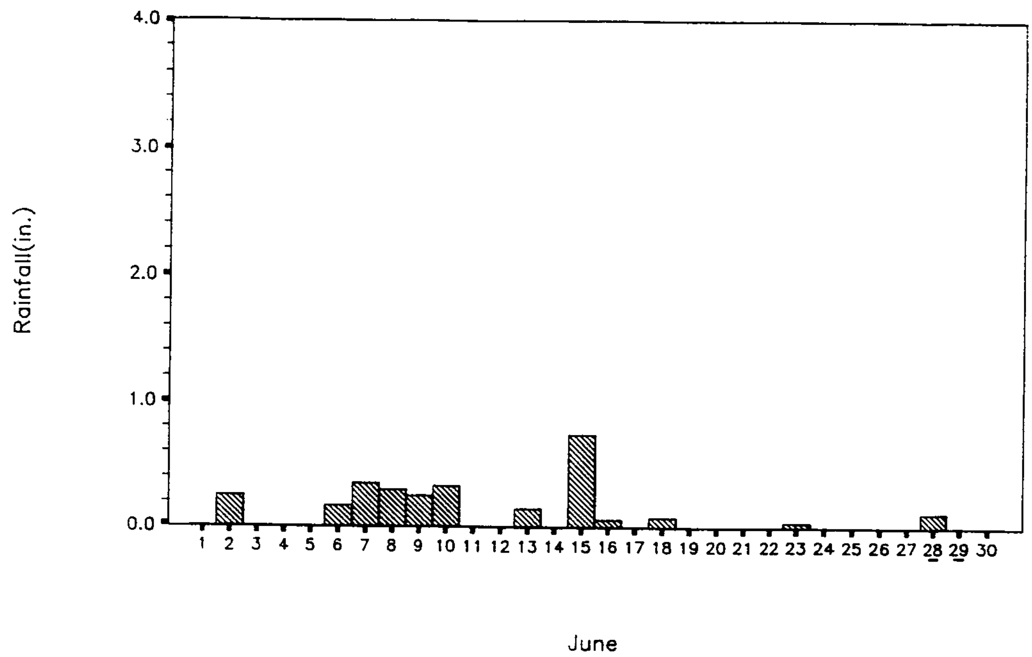


Figure 4.01. Stations Sampled during the 1989 Neponset River and Dorchester Bay Monitoring.



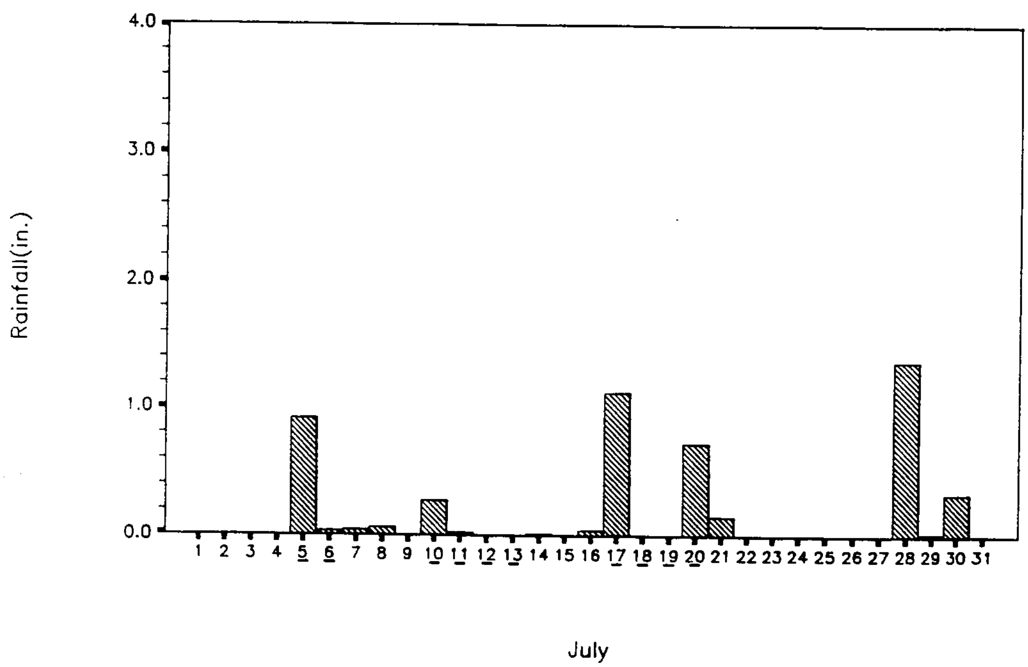


Figure 4.02. Daily Rainfall during the 1989 Neponset River and Dorchester Bay Monitoring Period.

Samples were collected on dates underlined.

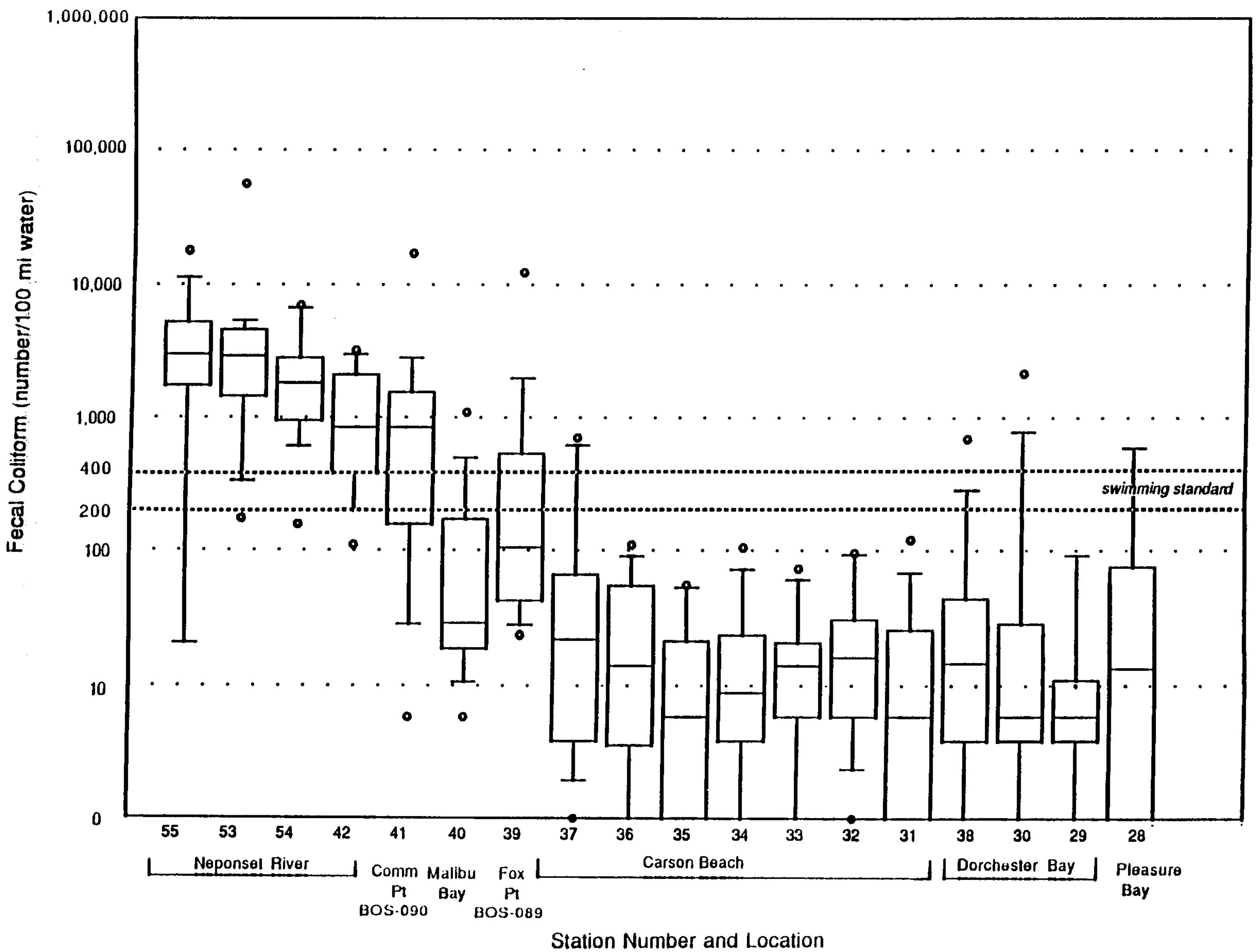


Figure 4.03. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in the Neponset River and Dorchester Bay, 1989.

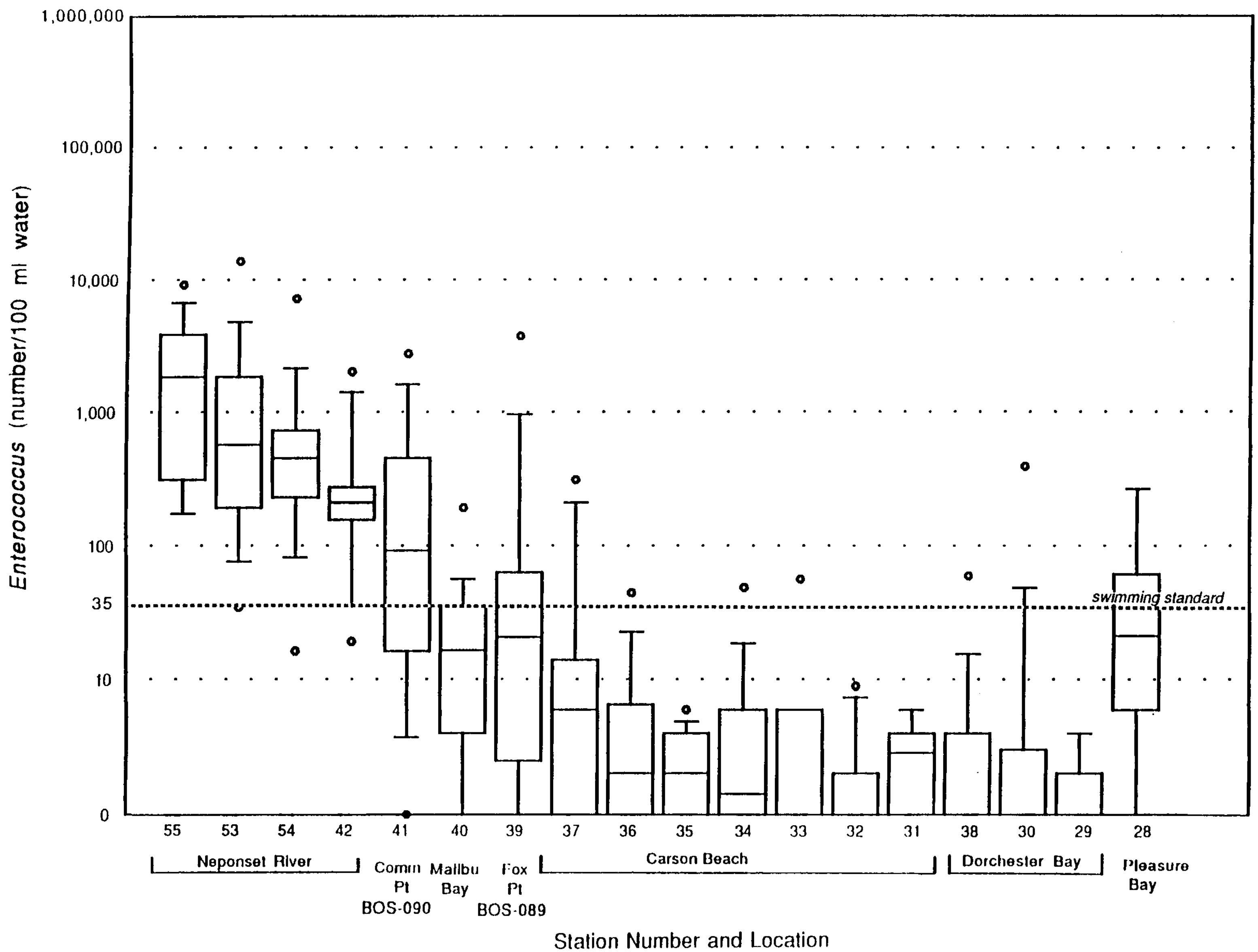


Figure 4.04. Percentile Box Plots of *Enterococcus* from Surface Samples in the Neponset River and Dorchester Bay, 1989.

Table 4.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Neponset River and Dorchester Bay Stations

Station			1989		1990	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal Coliform						
19	Inner Harbor/Fort Point Channel	S	..	...	17	68 (34-134)
		B	...	...	18	16 (8-31)
21	Inner Harbor	S	...	...	18	40 (17-94)
		B	...	...	18	24 (11-46)
24	Inner Harbor/Mouth	S	...	...	17	26 (11-59)
		B	...	...	17	38 (18-78)
38	Mid-Old Harbor (SDB)†	S	...	...	10	3 (1-7)
		B	...	...	10	7 (3-14)
28	Pleasure Bay	S	6	13 (1-103)	9	2 (0-6)
		B	...	...	...	...
29	Castle Island	S	8	7 (2-18)	...	...
		B	6	19 (5-71)	...	...
30	City Point	S	9	13 (2-71)	16	3 (1-6)
		B	9	32 (15-67)	16	7 (3-17)
31	Kelly's Landing (BOS-081)	S	10	6 (2-19)	...	...
		B	3	9 (1-44)	...	...
32	N-Street (BOS-082)	S	10	13 (5-32)	...	...
		B	...	...	...	...
33	L-Street (BOS-083)	S	13	9 (3-21)	...	...
		B	1	10	...	...
34	BOS-084	S	10	8 (2-21)	...	...
		B	1	15 (15-15)	...	...
35	BOS-085	S	8	5 (1-17)	23	9 (4-20)
		B	...	...	...	...
36	BOS-086	S	10	10 (3-35)	23	8 (3-18)
		B	...	...	...	...
37	Mother's Rest (BOS-087)	S	10	25 (6-97)	22	10 (4-27)
		B	...	...	...	...

S = surface; B = bottom.
†SDB = Southern Dorchester Bay period.

Table 4.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Neponset River and Dorchester Bay Stations, continued

Station			1989		1990	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
38	Mid-Old Harbor (NDB)¶	S	10	13 (3-51)	14	3 (2-6)
		B	3	18 (0-451)	16	9 (4-20)
39	Fox Point (BOS-089)	S	52	749 (403-1392)	9	82 (43-156)
		B	21	98	1	48 (48-48)
40	Malibu Bay (BOS-088)	S	13	59 (26-136)	8	35 (19-63)
		B	...	...	1	28
41	Commercial Point (BOS)-090)	S	14	503 (185-1364)	9	115 (46-284)
		B	...	...	...	...
42	Neponset River (BOS-093)	S	14	847 (508-1410)	10	160 (50-508)
		B	...	...	...	...
43	Spectacle Island	S	13	28 (8-87)	...	...
		B	...	...	...	...
44	Airport/Spectacle (NDB)¶	S	15	29 (7-116)	17	9 (3-21)
		B	2	270 (155-470)	17	31 (13-71)
44	Airport/Spectacle (SDB)†	S	...	...	10	10 (4-22)
		B	...	...	10	11 (4-26)
53	BOS-095 (upstream)	S	13	2467 (1204-5051)	9	491 (258-932)
		B	...	...	...	...
54	BOS-095 (downstream)	S	15	1916 (1111-3305)	10	274 (104-723)
		B	...	...	...	...
55	Lower Mills, above dam	S	9	2314 (663-8077)	10	812 (450-1465)
		B	...	...	...	...
84	Columbia Point	S	...	...	9	11 (3-40)
		B	...	...	9	10 (5-18)
Enterococcus						
19	Inner Harbor/Fort Point Ch.	S	...	...	17	3 (1-8)
		B	...	...	18	3 (1-7)

S = surface; B = bottom.
†SDB = Southern Dorchester Bay period.
¶NDB = Northern Dorchester Bay period.

Table 4.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Neponset River and Dorchester Bay Stations, continued

Station			1989		1990	
No. Location		Depth*	n	mean (CI)	n	mean (CI)
21	Inner Harbor	S	..	...	18	4 (2-10)
		B	...	...	18	3 (1-7)
24	Inner Harbor/Mouth	S	...	...	17	2 (0-4)
		B	...	...	17	6 (2-15)
28	Pleasure Bay	S	6	18 (3-85)	9	0 (0-1)
		B	...	...	...	...
29	Castle Island	S	8	0 (0-1)	...	...
		B	6	6 (0-28)	...	...
30	City Point	S	9	2 (0-9)	16	0 (0-1)
		B	9	3 (1-18)	16	3(1-6)
31	Kelly's Landing (BOS-081)	S	10	1 (1-3)	...	...
		B	3	1 (0-10)	...	...
32	N-Street (BOS-082)	S	10	1 (0-2)	...	...
		B	...	...	...	...
33	L-Street (BOS-083)	S	13	1 (0-4)	...	...
		B	1	0	...	...
34	BOS-084	S	10	2 (0-5)	...	...
		B	1	2	...	...
35	BOS-085	S	8	1 (0-3)	23	1 (0-3)
		B	...	...	...	...
36	BOS-086	S	10	2 (0-6)	23	2 (1-4)
		B	...	...	...	...
37	Mother's Rest (BOS-087)	S	10	6 (1-24)	22	2 (1-4)
		B	...	...	...	...
38	Mid-Old Harbor (NBD)¶	S	10	1 (0-4)	14	1 (0-2)
		B	3	5 (0-61)	16	2 (1-5)
38	Mid-Old Harbor (SDB)†	S	...	...	10	7 (2-16)
		B	...	...	10	22 (5-94)

S = surface; B = bottom.
†SDB = Southern Dorchester Bay period.
¶NDB = Northern Dorchester Bay period.

Table 4.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Neponset River and Dorchester Bay Stations, continued

Station			1989		1990	
No. Location		Depth*	n	mean (CI)	n	mean (CI)
39	Fox Point (BOS-089)	S	52	33 (19-56)	9	5 (2-13)
		B	1	8	1	5 (5-5)
40	Malibu Bay (BOS-088)	S	13	11 (4-27)	8	21 (7-62)
		B			1	3
41	Commercial Point (BOS-090)	S	14	104 (31-342)	9	18 (7-42)
		B	...	...	...	...
42	Neponset River (BOS-093)	S	14	202 (112-364)	10	55 (19-154)
		B	...	...	...	...
43	Spectacle Island	S	13	2 (1-5)	...	...
		B	...	....	...	...
44	Airport/Spectacle (NDB)¶	S	15	2 (0-7)	17	3 (1-6)
		B	2	3 (3-3)	17	7 (3-15)
44	Airport/Spectacle (SDB)†	S	...	...	10	7 (3-15)
		B	...	...	10	27 (13-55)
53	BOS-095 (upstream)	S	13	676 (288-1589)	9	123 (56-268)
		B	...	...	...	...
54	BOS-095 (downstream)	S	16	459 (233-901)	10	68 (23-193)
		B	...	...	...	...
55	Lower Mills, above dam	S	9	1510 (583-3910)	10	469 (269-817)
		B	...	...	...	...
84	Columbia Point	S	...	...	9	6 (2-14)
		B	...	...	9	7 (2-24)

*S = surface; B = bottom.
†SDB = Southern Dorchester Bay period.
¶NDB = Northern Dorchester Bay period.

ml. Generally, there was a decreasing trend in fecal coliform counts from the Neponset River toward South Boston and Dorchester Bay.

The fecal coliform water quality standards for class B and class SB waters (geometric mean 200 col/100 ml with no more than 10% of the samples exceeding 400 col/100 ml) are indicated on Figure 4.03. Stations in the Neponset and near the mouth of the river (Stations 41, 42, 53, 54, 55) showed extreme exceedences of water quality standards, with geometric mean counts 4- to 12-fold greater than the standard.

Other stations showed less severe exceedences of class SB standards. Station 40, in Malibu Bay, had a geometric mean count of 59 col/100 ml, but more than 10% of the samples exceeded 400 col/100 ml. Station 39, near the Fox Point CSO, had a geometric mean fecal coliform count of 749 col/100 ml, and more than 10% of the surface samples exceeded 3,000 col/100 ml. Station 37, near South Boston beaches, had a relatively low geometric mean (25 col/100 ml), but more than 10% of the samples exceeded 400 col/100 ml. Surface samples from Pleasure Bay (Station 28) and City Point (Station 30) in Dorchester Bay had very low geometric mean counts (13 col/100 ml). These stations each had a single sample with a high count: 217 col/100 ml on July 6 at Station 30, and 598 col/100 ml on July 10 at Station 28.

The rest of the stations along South Boston beach and in Dorchester Bay (Stations 36, 35, 34, 33, 32, 31, 38, 29) were "swimmable" during this sampling period; the geometric means ranged from 5 to 14 col/100 ml, and the 90th percentiles were all below 400 col/100 ml.

Enterococcus

Figure 4.03 shows that *Enterococcus* had a density pattern similar to fecal coliform, with high counts in the Neponset River and low counts near South Boston beaches and in Dorchester Bay. Surface samples from Stations 28, 29, 30, 31, 32, 33, 34, 35, 36, 38, 39, and 40 all had geometric mean counts within the EPA-recommended *Enterococcus* swimmability standard: a "steady state geometric mean" of 35 col/100 ml (Table 4.01). At all these stations except 28, 37, and 39, 90% of the samples had counts below 104 col/100 ml, the "maximum allowable density for a single sample at a beach" (Figure 4.03). In contrast, Stations 42, 53, 54, and 55 all had geometric mean counts ranging from 202 col/100 ml to 1510 col/100 ml--far exceeding the steady-state standard and also exceeding the maximum allowable density at a beach. Station 41 (close to BOS-090 and near Tenean Beach), had a geometric mean of 104, which also exceeded the steady-state EPA standard.

4.1.c Relationship between Indicator Bacteria and Rainfall

For the Neponset River/Dorchester Bay area (n = 264), there were some statistically significant, but weak, correlations between bacterial densities and rainfall. Figure 4.05 illustrates one of the strongest relationships of fecal coliform counts in this area with rainfall: the regression of fecal coliform counts against rainfall for the two days prior to sampling ($R^2 = 0.027$, $p = 0.004$). Given the huge variations in levels of indicator bacteria among the different stations in both dry and rainy weather, it was not surprising to find a weak relationship with rainfall.

Pearson correlation coefficients among all the rainfall variables (variables listed in Tables 2.05 and 2.06) and log-transformed fecal coliform counts and *Enterococcus* counts at individual stations showed no consistent pattern of strong, highly significant relationships between counts and rain.

Although correlation and regression analyses for the Neponset River/Dorchester Bay area showed a weak relationship between indicator bacteria and rainfall, some data collected in the Neponset River do illustrate a rain effect. Samples taken during dry weather can be compared to samples taken during wet weather if categories for dry and wet weather are defined. We arbitrarily defined dry weather as days when the sum of rain that fell during the day of sampling plus the previous day was less than or equal to 0.1 in.; we defined wet weather as all other days. All the data taken in the Neponset River are summarized in Table 4.02. Although the number of samples was too small to allow statistical comparisons, the higher counts found in the wet-weather category suggest that rainfall did increase the densities of sewage indicator bacteria in the Neponset River.

Samples in the Neponset River were collected during the heaviest rainfall of this sampling period (1.12 in. on July 17, 1989). The results are shown in Table 4.03. During the storm, water upstream of all tidal and CSO influence showed very high fecal coliform counts (17,750/100 ml). An apparent CSO influence was detected at Station 53 (55,000 fecal coliform/100 ml), which on an incoming tide is downcurrent of BOS-095 and BOS-093. By the next day, at Station 53, this increase over the upstream count had disappeared.

4.1.d Relationship between Indicator Bacteria and Salinity

For fecal coliform in the Neponset River/Dorchester Bay area, there was a strong and significant negative correlation with salinity ($r = -0.67$, $p < 0.001$). A similar pattern held for *Enterococcus* ($r = -0.72$, $p < 0.001$). However, within the Neponset River alone (Stations 55, 53, 54, 42) neither indicator bacteria was significantly correlated with salinity. When Dorchester Bay was analyzed alone, without samples from the Neponset, the negative correlation between indicator density and salinity still held.

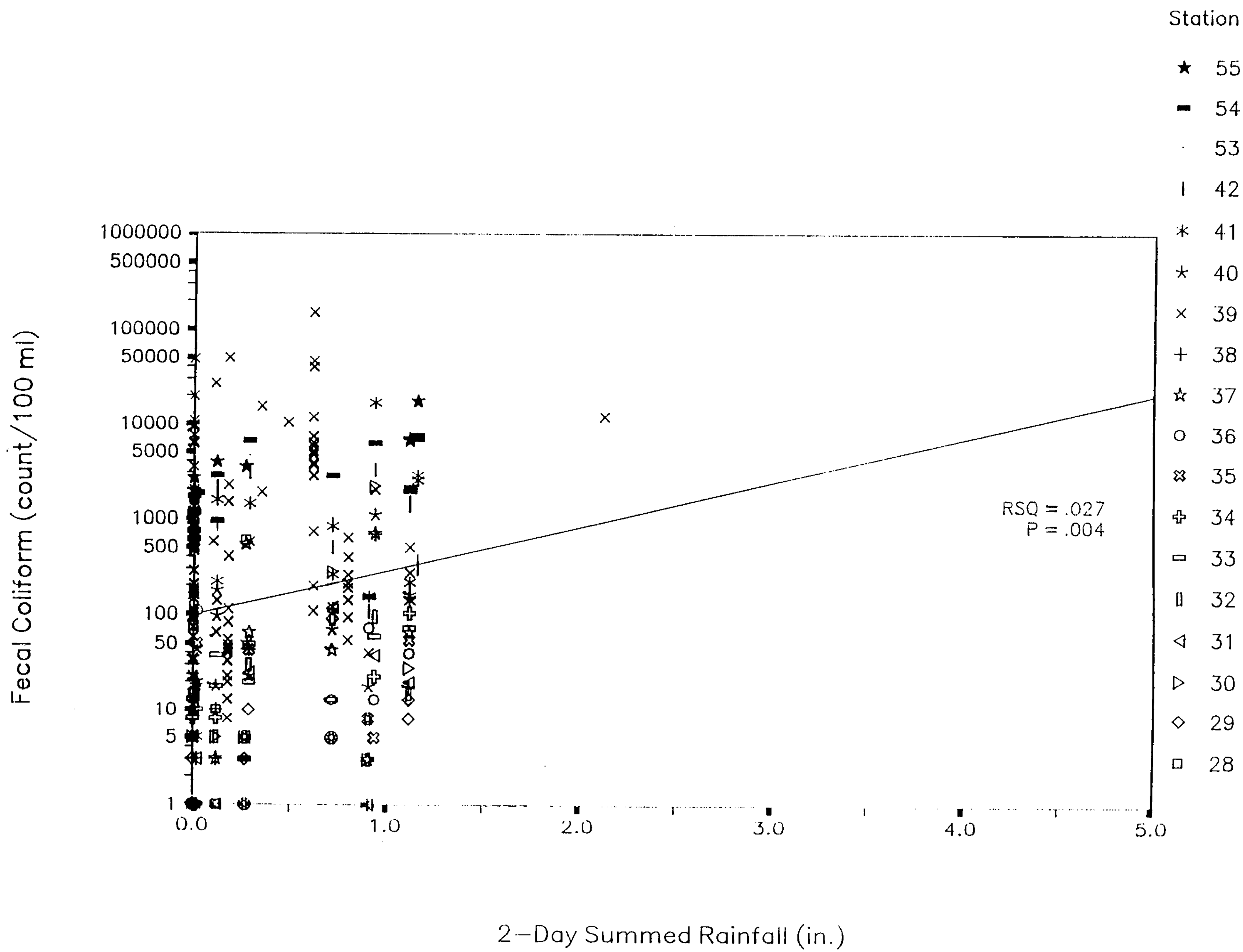


Figure 4.05. Relationship between Fecal Coliform Counts and 2-Day Summed Rainfall in the Neponset River and Dorchester Bay, 1989.

Table 4.02. Comparison of Fecal Coliform Counts (colonies/100 ml) in the Neponset River in Wet and Dry Weather*

Station		Dry Weather		Wet Weather	
No.	Location	n	Geomet. Mean (range)	n	Geomet. Mean (range)
55	Above dam, upstream of tidal effects	4	640 (20-2625)	5	6474 (3475-17750)
53	Below dam, upriver of BOS-095, tidally affected	5	1396 (640-2925)	10	2927 (170-55,000)
54	Below dam, downriver of BOS-095, upriver of BOS-093, tidally affected	5	1099 (608-1825)	11	1409 (3-7588)
42	Below dam, downriver of BOS-093, tidally affected	3	786 (385-1825)	11	866 (303-3250)
	All Stations	17	933 (20-2925)	37	1825 (3-55,000)

*Dry weather was defined as having 2-day summed rain less than or equal to 0.1 in. Wet weather was defined as having 2-day summed rain greater than 0.1 in.

Table 4.03. Fecal Coliform Counts in the Neponset River during (July 17) and after (July 18) 1.12 in. of rain, which fell on July 17, 1989*

Station		Fecal Coliform (colonies/100 ml water)	
No.	Location	July 17	July 18
55	Upstream of dam	17,750	7,000
53	Downcurrent of BOS-095 and BOS 093 (incoming tide)	55,000	2,300
54	Upcurrent of BOS-095, downcurrent of BOS-093	7,013	2,100
42	Upcurrent of BOS-093	368	1,400

*No rain fell on July 18. Stations were sampled during the incoming tide.

4.1.e Dissolved Oxygen

Figure 4.06 is a percentile box plot of dissolved oxygen (DO) measurements taken at the surface in the Neponset River/Dorchester Bay area. Only Station 53 at the mouth of the Neponset had samples (25%) below 5.0 mg DO/l, the standard for class SB waters. Median values at all other stations were well above 5.0 mg/l, and at most stations were between 7 and 9 mg/l.

4.2 1990 Results: Northern Dorchester Bay

In 1990, northern Dorchester Bay was sampled between June 12 and July 5. Southern Dorchester Bay and the Neponset River were sampled at a later time (see Section 4.3).

4.2.a Sampling Locations and Rainfall

Figure 4.07 shows the location of stations sampled in northern Dorchester Bay. Figure 4.08 shows that little rain fell during the sampling period. Rainfall between June 11 and July 5 totaled 0.71 in., with the two biggest rainfalls occurring on June 5 (0.31 in.) and July 1 (0.23 in.). Stations in the Inner Harbor were included with northern Dorchester Bay to assess the effect of the Inner Harbor on Dorchester Bay (or vice versa).

Surface samples were collected at Stations 19, 21, 24, 44, 30, 35, 36, 37, 38, and 28. Bottom samples were collected at Stations 19, 21, 24, 44, 30, and 38, where the water was more than 10 ft deep.

4.2.b Indicator Bacteria Counts

Surface Samples

Fecal Coliform

Figure 4.09 shows fecal coliform counts resulting from sampling in the Inner Harbor and northern Dorchester Bay in 1990. During this dry period, the only station in northern Dorchester Bay that exceeded swimming standards was Station 38, offshore. The geometric mean counts at all stations were well below the 200 col/100 ml standard: the highest geometric mean count during this sampling period was 68 col/100 ml, at Station 19 in the Inner Harbor (Table 4.01).

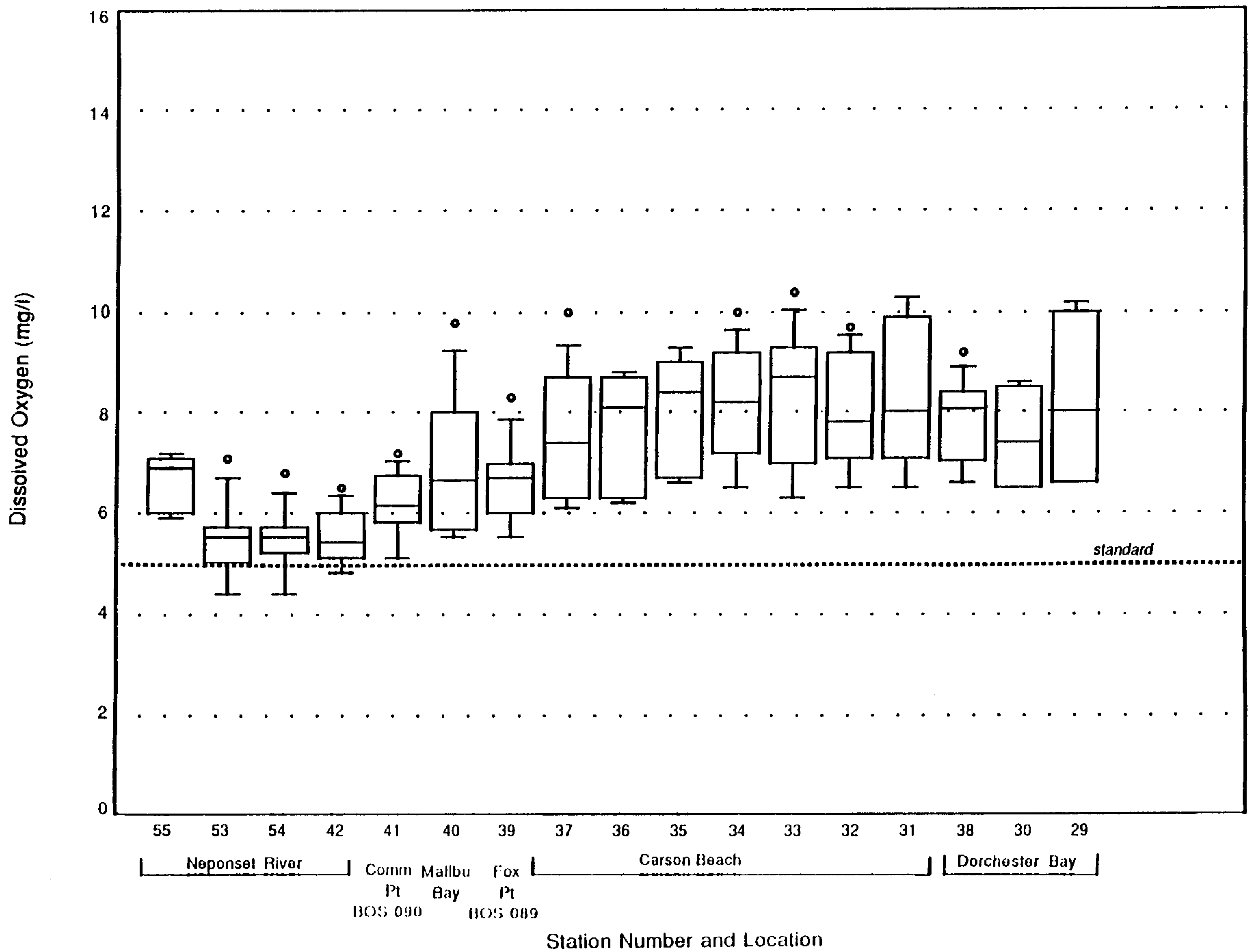


Figure 4.06. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in the Neponset River and Dorchester Bay, 1989.

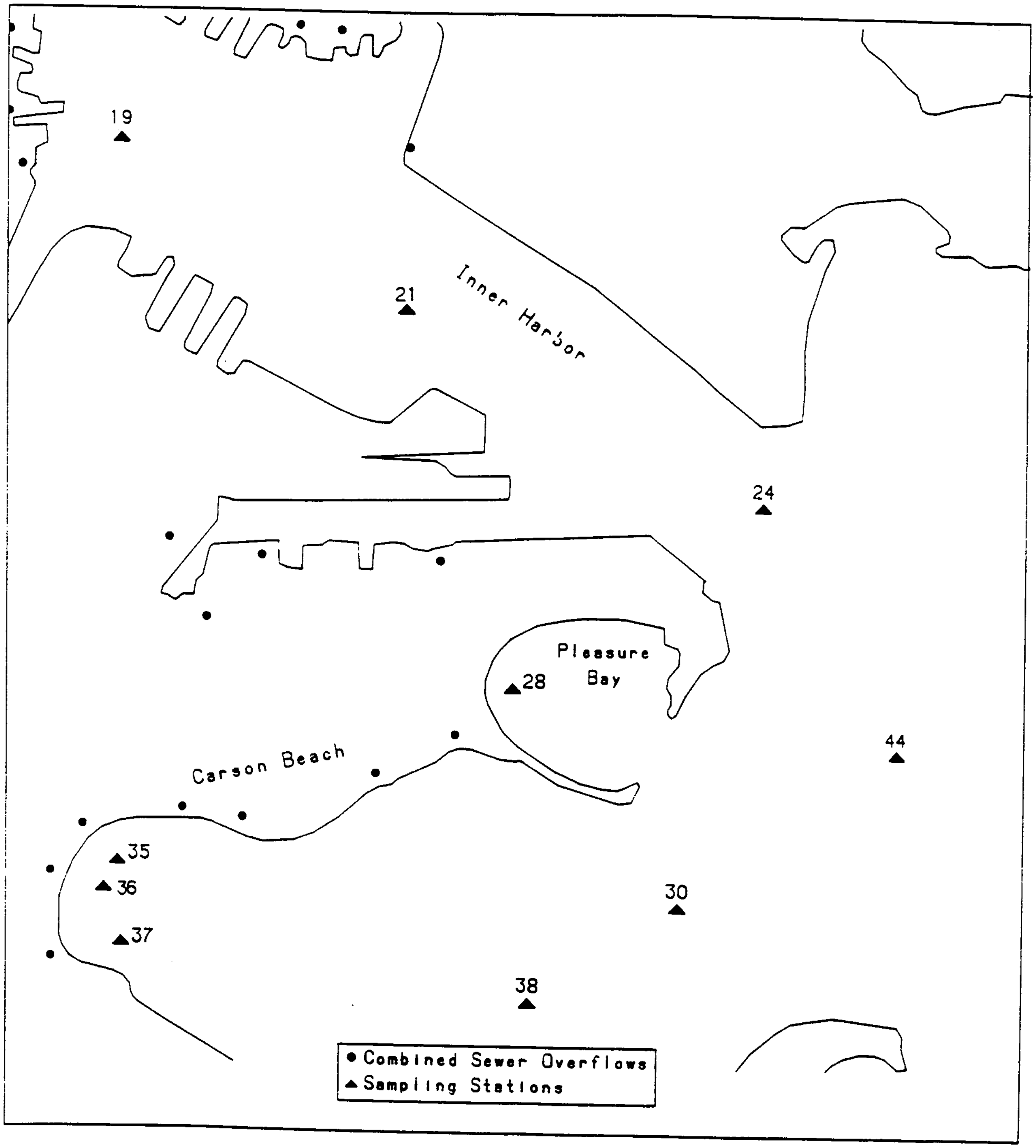
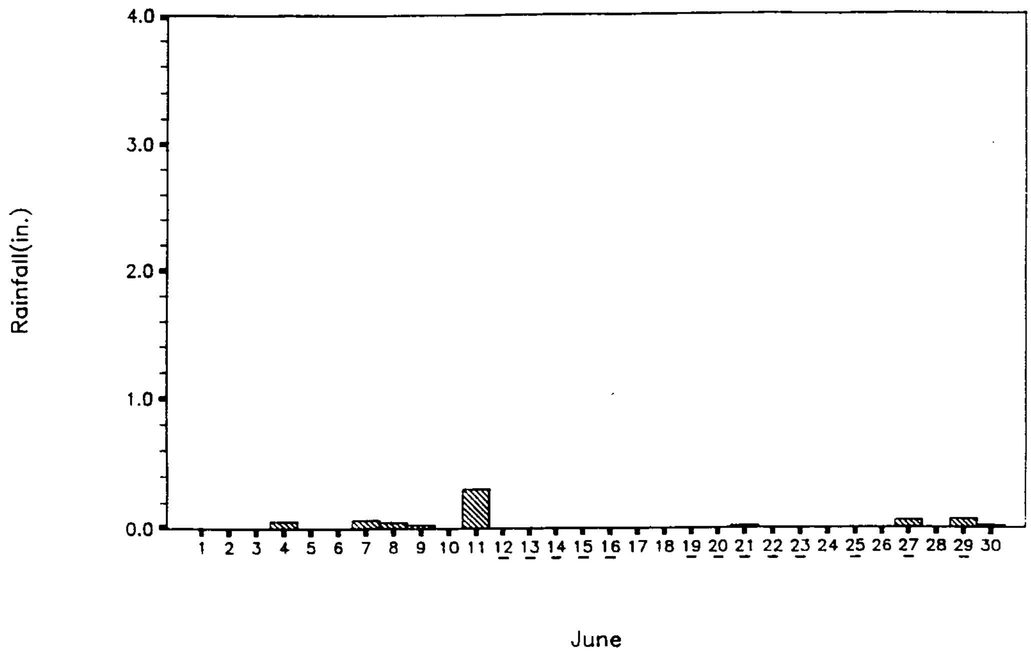


Figure 4.07. Stations Sampled during the 1990 Northern Dorchester Bay Monitoring.



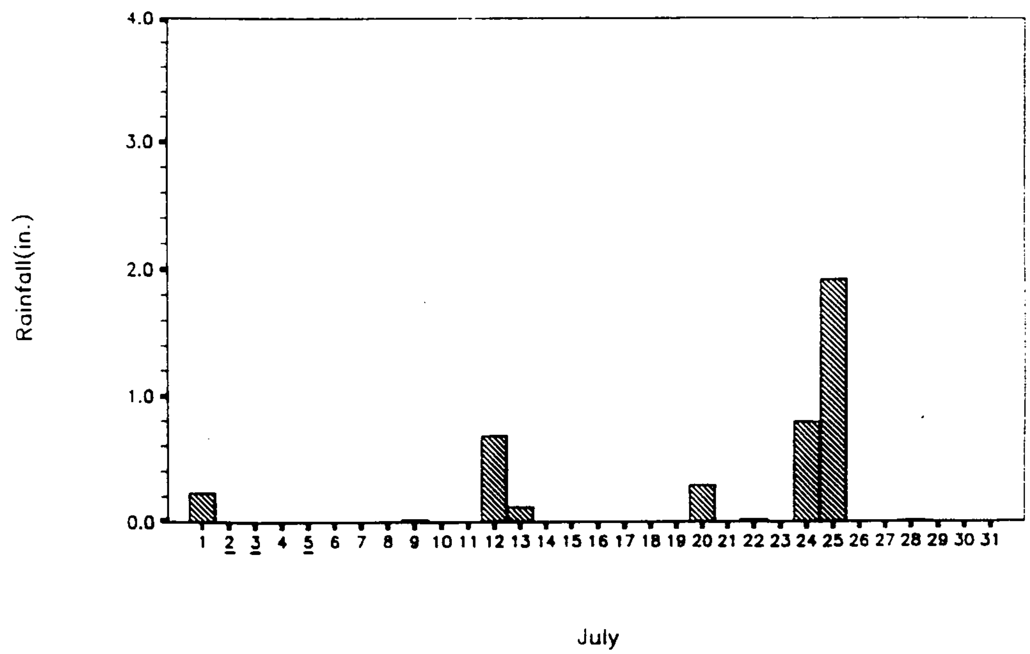


Figure 4.08. Daily Rainfall during the 1990 Northern Dorchester Bay Monitoring Period.

Samples were collected on dates underlined.

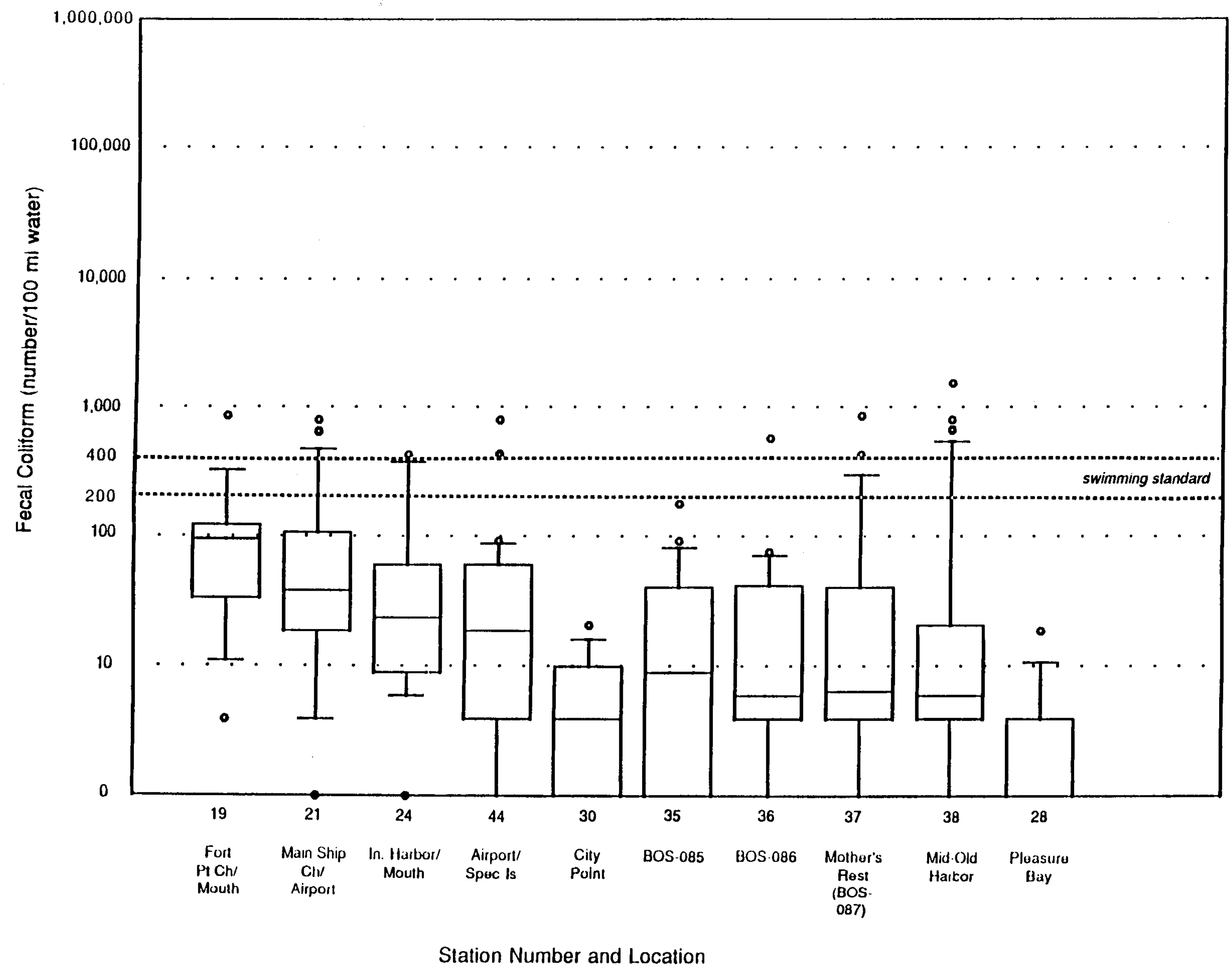


Figure 4.09. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in Northern Dorchester Bay, 1990.

4. Neponset River and Dorchester Bay

Enterococcus

Geometric mean *Enterococcus* levels in northern Dorchester Bay were well within EPA-recommended swimmability standards (Figure 4.10 and Table 4.01). At Station 35, one sample exceeded the recommended maximum single-sample density (104 col/100 ml), and approximately 10% of the samples at offshore Station 38 exceeded 104 col/100 ml. The geometric mean *Enterococcus* counts at all stations were well below the EPA standard (Table 4.01): the highest geometric mean was 11 col/100 ml, from bottom samples at Station 44.

Bottom Samples

Fecal Coliform

More than 90% of the samples at Stations 30 and 38 were well below 200 col/100 ml (Figure 4.11). Interestingly, one bottom sample at Station 38 in Dorchester Bay yielded a count greater than 10,000 col/100 ml, which was at least an order of magnitude higher than any surface count at this station. None of the bottom counts in the Inner Harbor approached this level. Generally, fecal coliform counts in bottom waters of the Inner Harbor and Dorchester Bay were similar, with geometric mean counts well below 200 col/100 ml (Table 4.01).

Enterococcus

Bottom *Enterococcus* patterns in the Inner Harbor and Northern Dorchester Bay were similar to bottom fecal coliform patterns (Figure 4.12): counts were similar in the Inner Harbor and Dorchester Bay. Geometric means were well within the EPA swimmability standard, and only a few counts were above 104 col/100 ml. Like the fecal coliform results, the single highest *Enterococcus* count was at Station 38, offshore in Dorchester Bay.

4.2.c Relationship between Indicator Bacteria and Rainfall

When all stations in northern Dorchester Bay were considered together, neither fecal coliform nor *Enterococcus* was significantly correlated with rainfall or with Deer Island flow. When stations were considered individually, only two showed significant correlations between surface counts and rain: at Station 28, fecal coliform with sum of rain over three days ($r = 0.76, p = .024$) and at Station 38, *Enterococcus* with sum of rain over three days ($r = 0.47$, $p = 0.044$). However, so many comparisons were made (14 rain variables x 10 stations x 2 dependent variables = 280 comparisons) that at least two comparisons could be significant due to chance alone. None of the bottom samples showed significant correlations with rainfall.

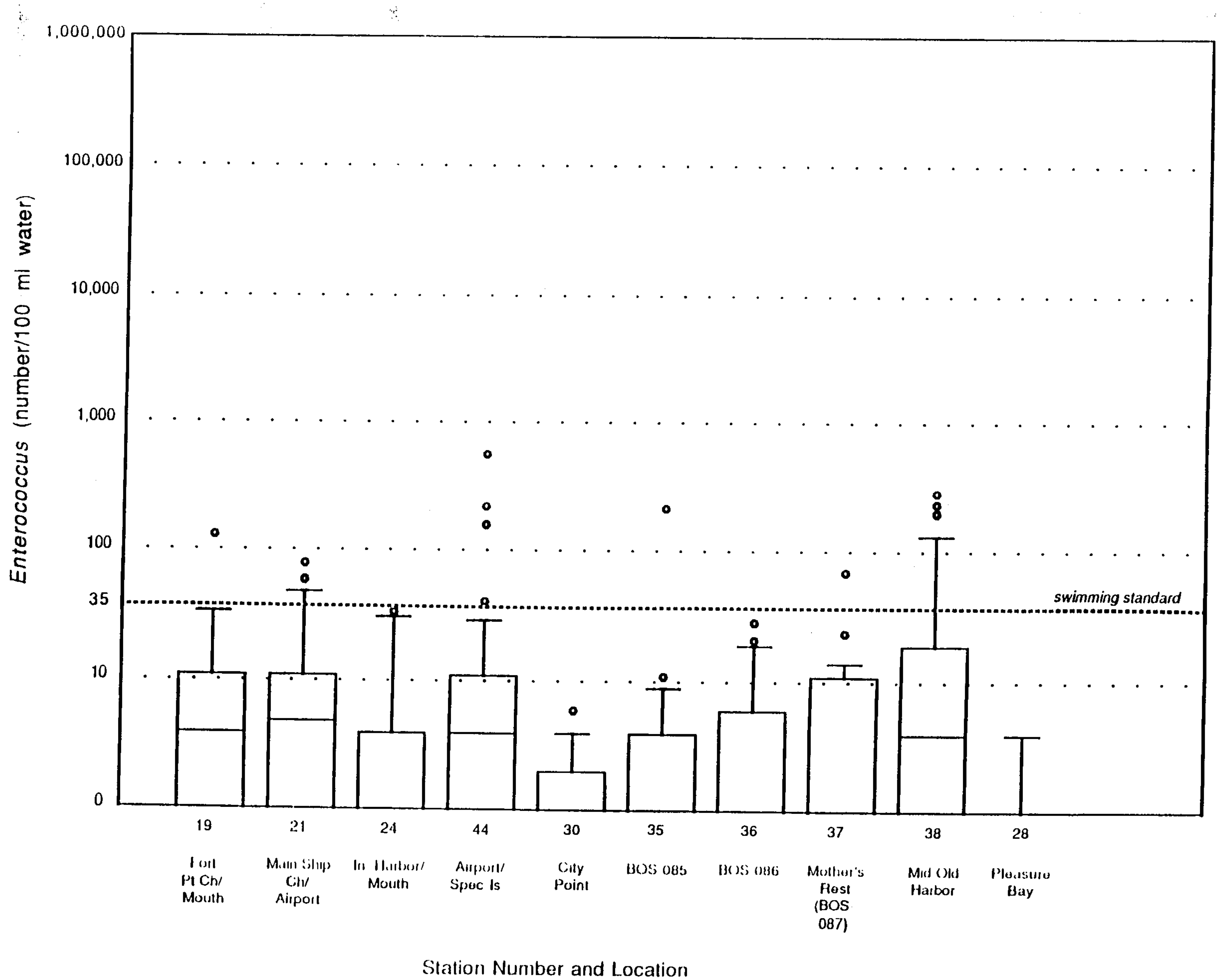


Figure 4.10. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in Northern Dorchester Bay, 1990.

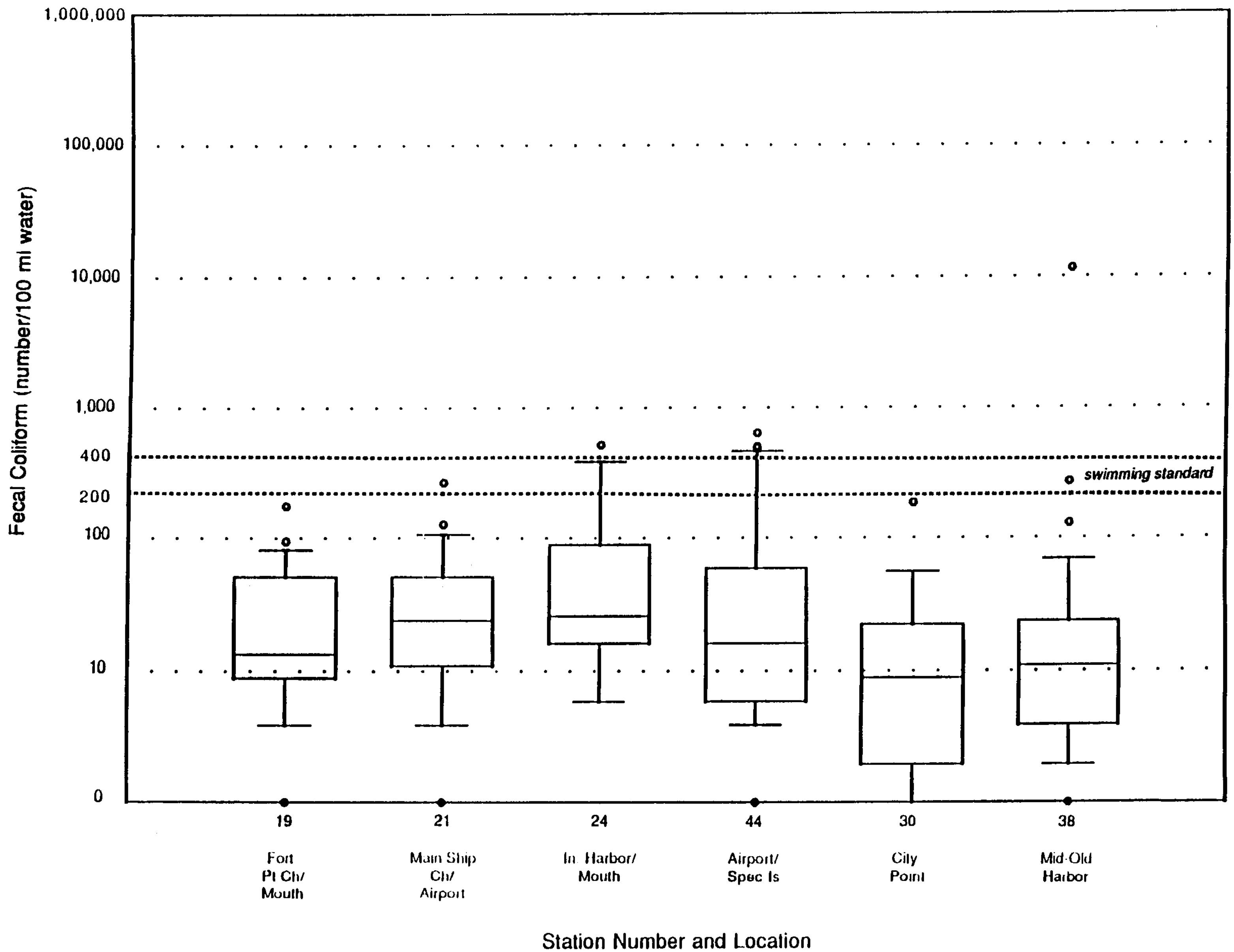


Figure 4.11. Percentile Box Plots of Fecal Coliform Counts from Bottom Samples in Northern Dorchester Bay, 1990.

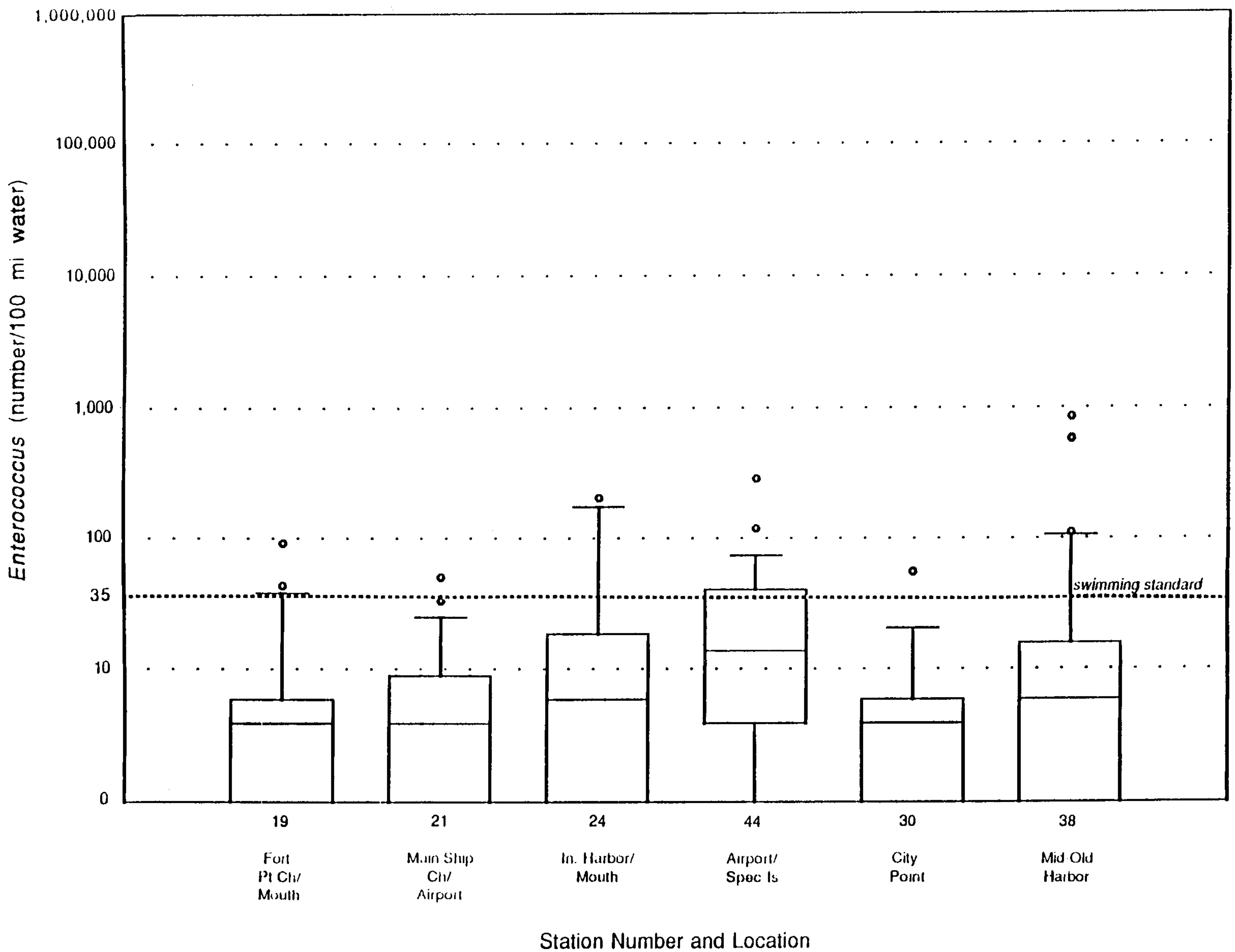


Figure 4.12. Percentile Box Plots of *Enterococcus* Counts from Bottom Samples in Northern Dorchester Bay, 1990.

4.2.d Relationship between Indicator Bacteria and Salinity

For the Inner Harbor/northern Dorchester Bay area as a whole, both fecal coliform ($r = -0.37, p < 0.001$) and *Enterococcus* ($r = -0.19$, $p = 0.021$) from surface samples were significantly and negatively correlated with salinity. At individual stations, there were no significant negative relationships with salinity--thus the pattern for the entire area is due to higher counts at stations with lower salinity (Inner Harbor), and lower counts at stations with higher salinity (Dorchester Bay).

There was no significant correlation between salinity and indicator bacteria for samples of bottom water.

4.2.e Dissolved Oxygen

Dissolved oxygen data for surface samples in the Inner Harbor and Dorchester Bay are shown in Figure 4.13. No samples had DO concentrations lower than the Massachusetts standard of 5 mg/l for SB waters, and the median DO measurements were between 7 mg/l and 10 mg/l at all stations. Bottom DO measurements were very similar to surface data.

4.3 1990 Results: Southern Dorchester Bay and Neponset River

4.3.a Sampling Locations and Rainfall

Figure 4.14 shows the location of stations sampled in the Neponset River and southern Dorchester Bay from September 4 to 19, 1990. Figure 4.15 shows the amount of rain that fell during the sampling period. The greatest rainfall, which fell on September 15, was 0.39 in., making this a relatively dry period.

4.3.b Indicator Bacteria Counts

Fecal Coliform

Figure 4.16 shows percentile box plots for fecal coliform in the Neponset River and southern Dorchester Bay. For 1990, as for 1989, fecal coliform counts tended to decrease from the Neponset River toward Dorchester Bay. The station in the Neponset upstream of all CSO influence (Station 55) had the highest geometric mean fecal coliform count (812 col/100 ml) in this area. After the Neponset River stations, the next highest counts were at the two stations near large CSOs: Commercial Point (Station 41) and Fox Point

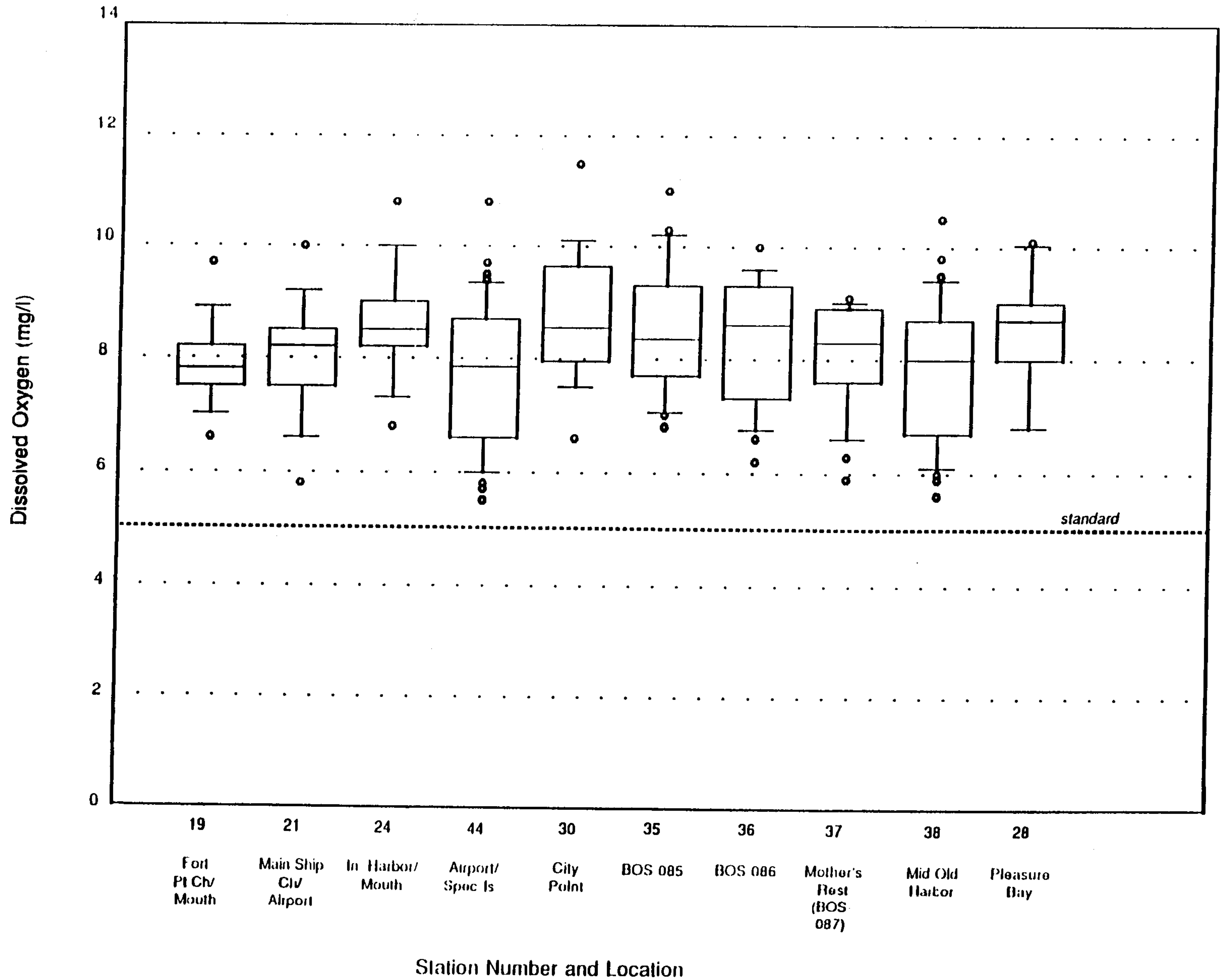


Figure 4.13. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in Northern Dorchester Bay, 1990.

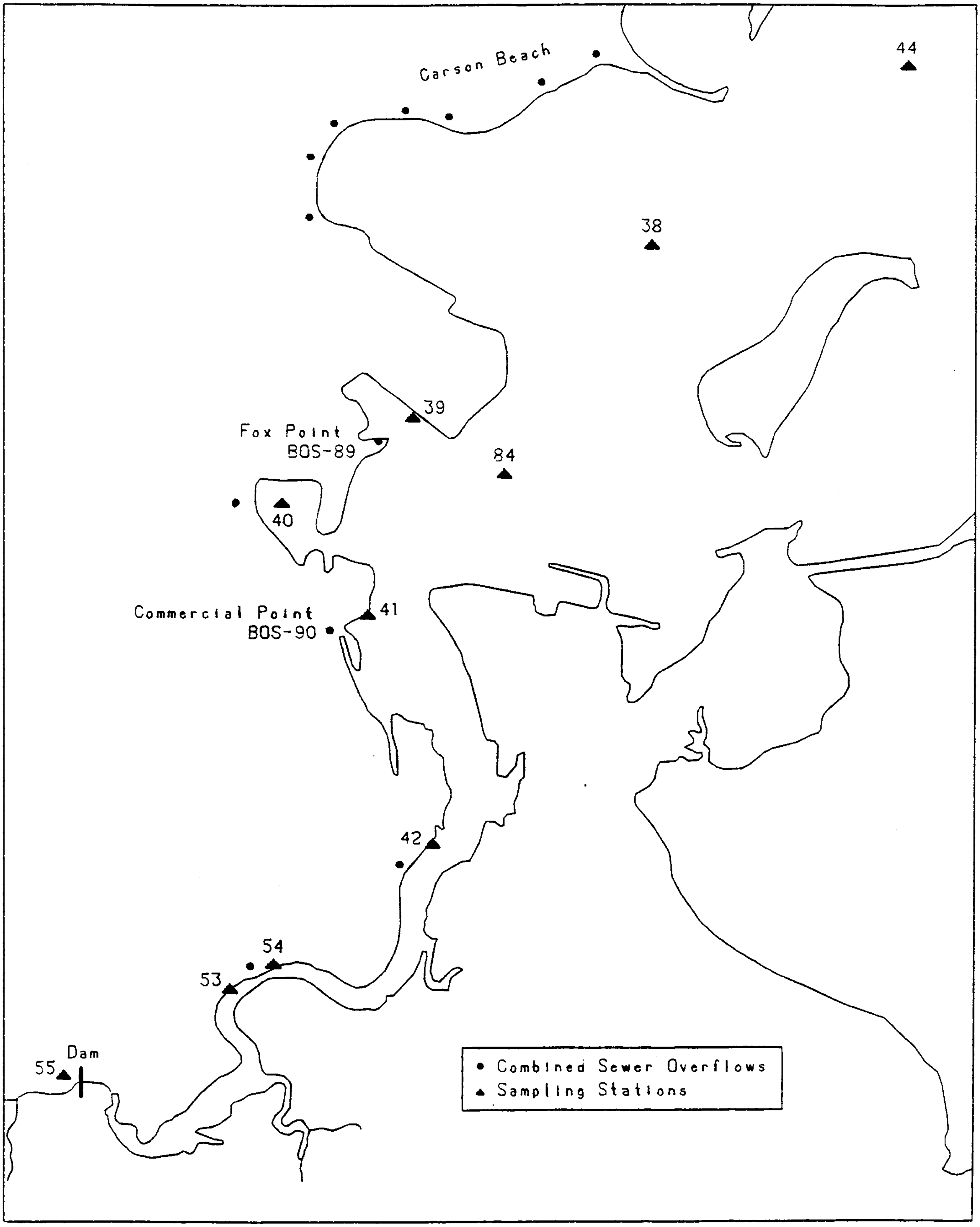


Figure 4.14. Stations Sampled during the 1990 Southern Dorchester Bay and Neponset River Monitoring.

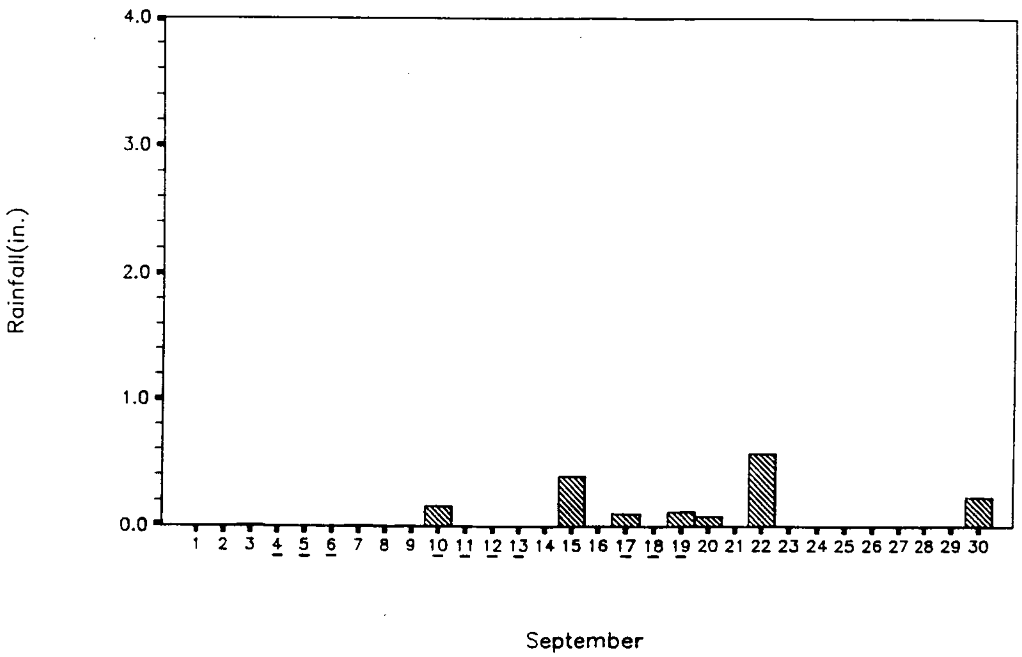


Figure 4.15. Daily Rainfall during the 1990 Southern Dorchester Bay and Neponset River Monitoring Period.

Samples were collected on dates underlined.

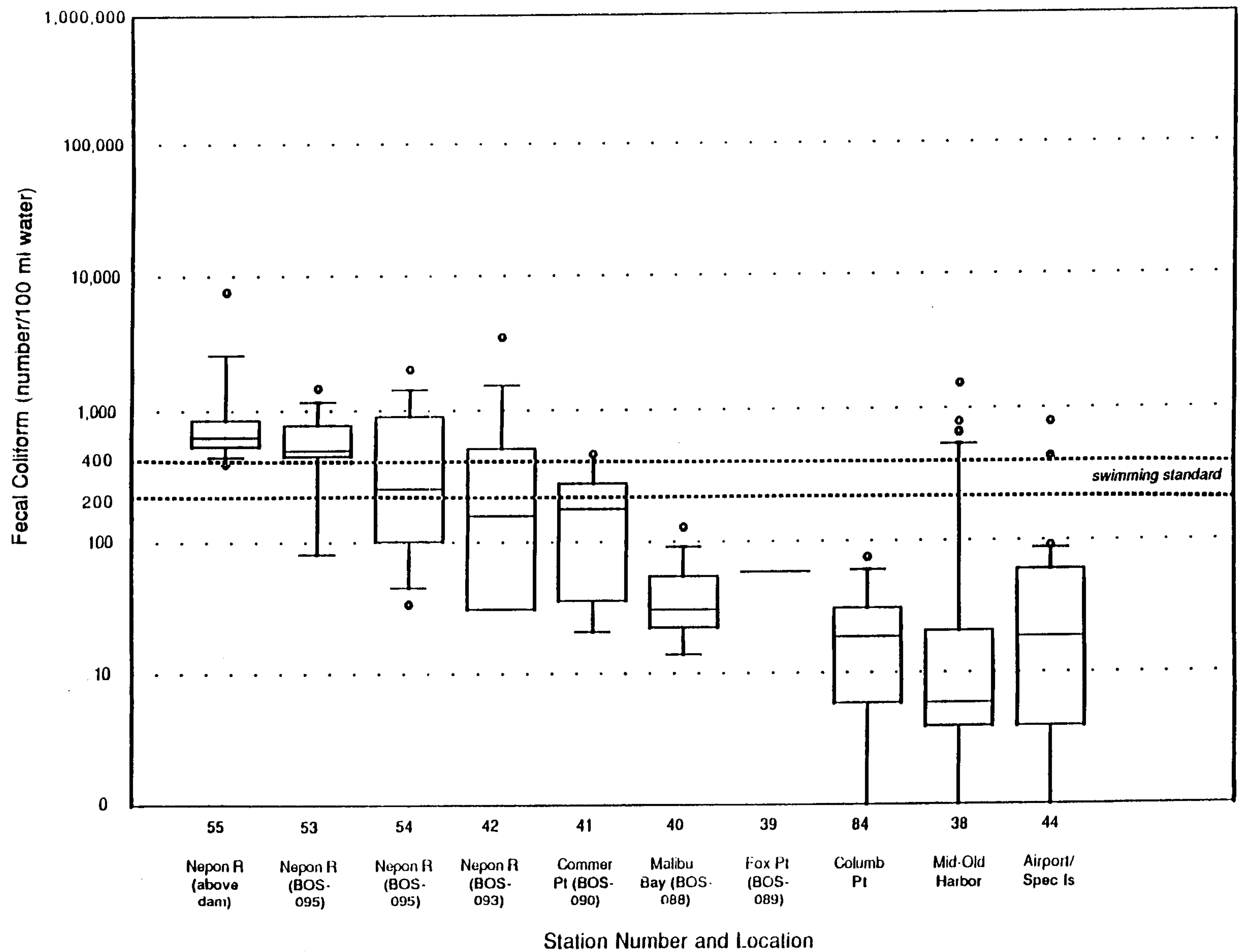


Figure 4.16. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in Southern Dorchester Bay and the Neponset River, 1990.

(Station 39). Both these sites had geometric mean fecal coliform counts less than 200 col/100 ml, and 90% of the samples had counts greater than 400 col/100 ml but less than 1,000 col/100 ml. In southern Dorchester Bay, the two sites with the lowest geometric mean counts were Station 40 (21 col/100 ml), in Malibu Bay, and Station 84 (6 col/100 ml), off Columbia Point (Table 4.01).

Enterococcus

The trend for *Enterococcus* counts was similar to that for fecal coliform. The highest counts were upstream in the Neponset River, with decreasing densities toward Dorchester Bay (Figure 4.17 and Table 4.01). Geometric mean counts were less than 35 col/100 ml at all stations except those in the Neponset River (Stations 42, 54, 53, 55). In southern Dorchester Bay (Stations 41, 40, 39, and 84), all samples except one (in Malibu Bay) yielded counts below the EPA maximum for a single sample at a beach.

4.3.c Relationship between Indicator Bacteria and Rainfall

During this sampling period, there were no correlations between either bacterial indicator and any rainfall variables at $p < 0.01$. This would be expected because the amount of rainfall varied very little during this relatively dry period.

4.3.d Relationship between Indicator Bacteria and Salinity

The most obvious pattern to emerge from this group of samples was the negative relationship between indicator bacteria counts and salinity. The regression of fecal coliform against salinity for surface samples at all stations (except Station 55, which is in fresh water) is shown in Figure 4.18. Salinity explained approximately 41% of the variance in fecal coliform density ($p < 0.001$). A similar, although somewhat weaker, relationship held for *Enterococcus* in surface samples (Figure 4.19), with salinity explaining about 37% of the variance ($p < 0.001$).

This negative relationship between counts and salinity did not hold for individual stations. The general trend for indicator bacteria to decrease with salinity corresponds to increasing *distance* (and increasing salinity) downstream along the Neponset River.

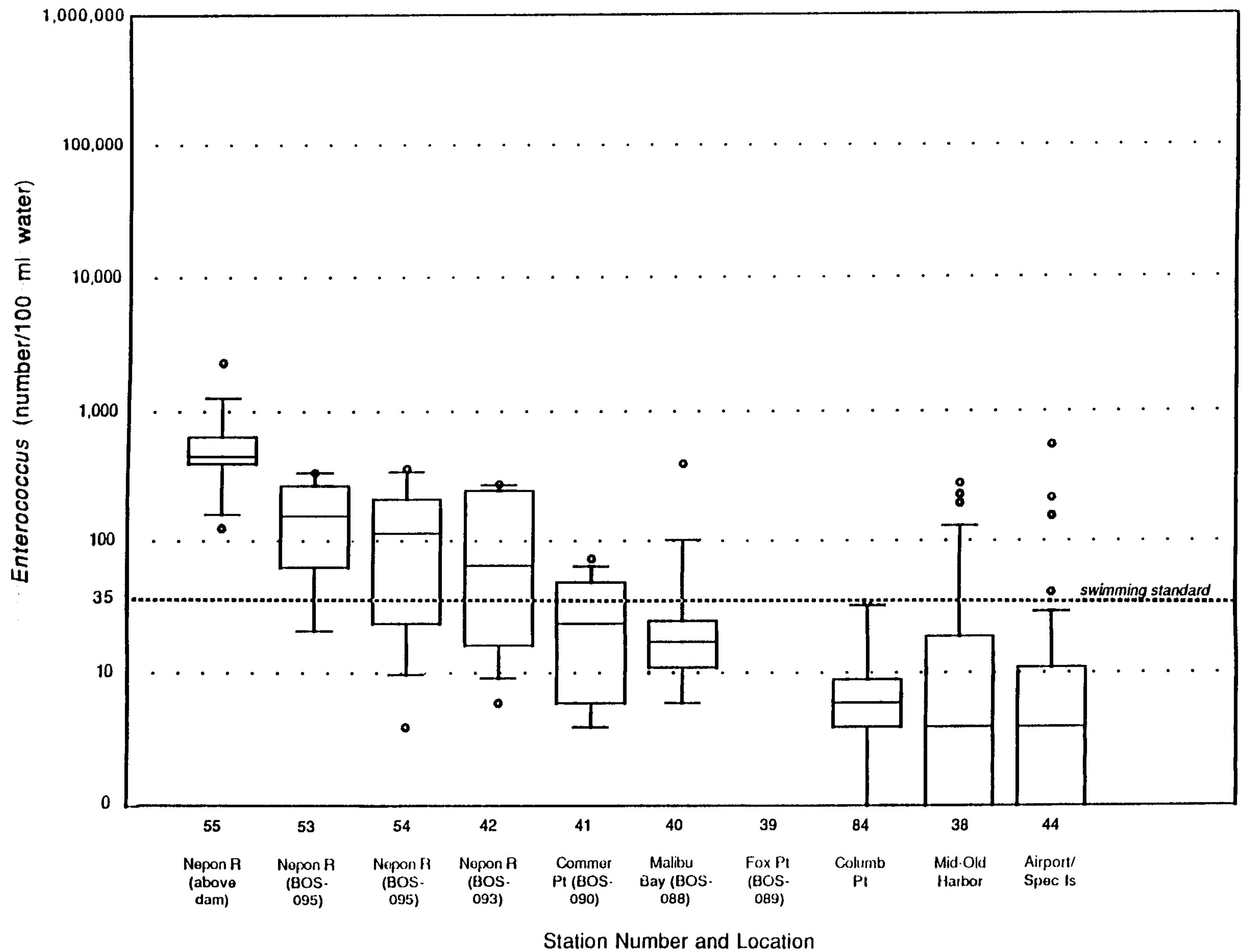


Figure 4.17. Percentile Box Plots of *Enterococcus* from Surface Samples in Southern Dorchester Bay and the Neponset River, 1990.

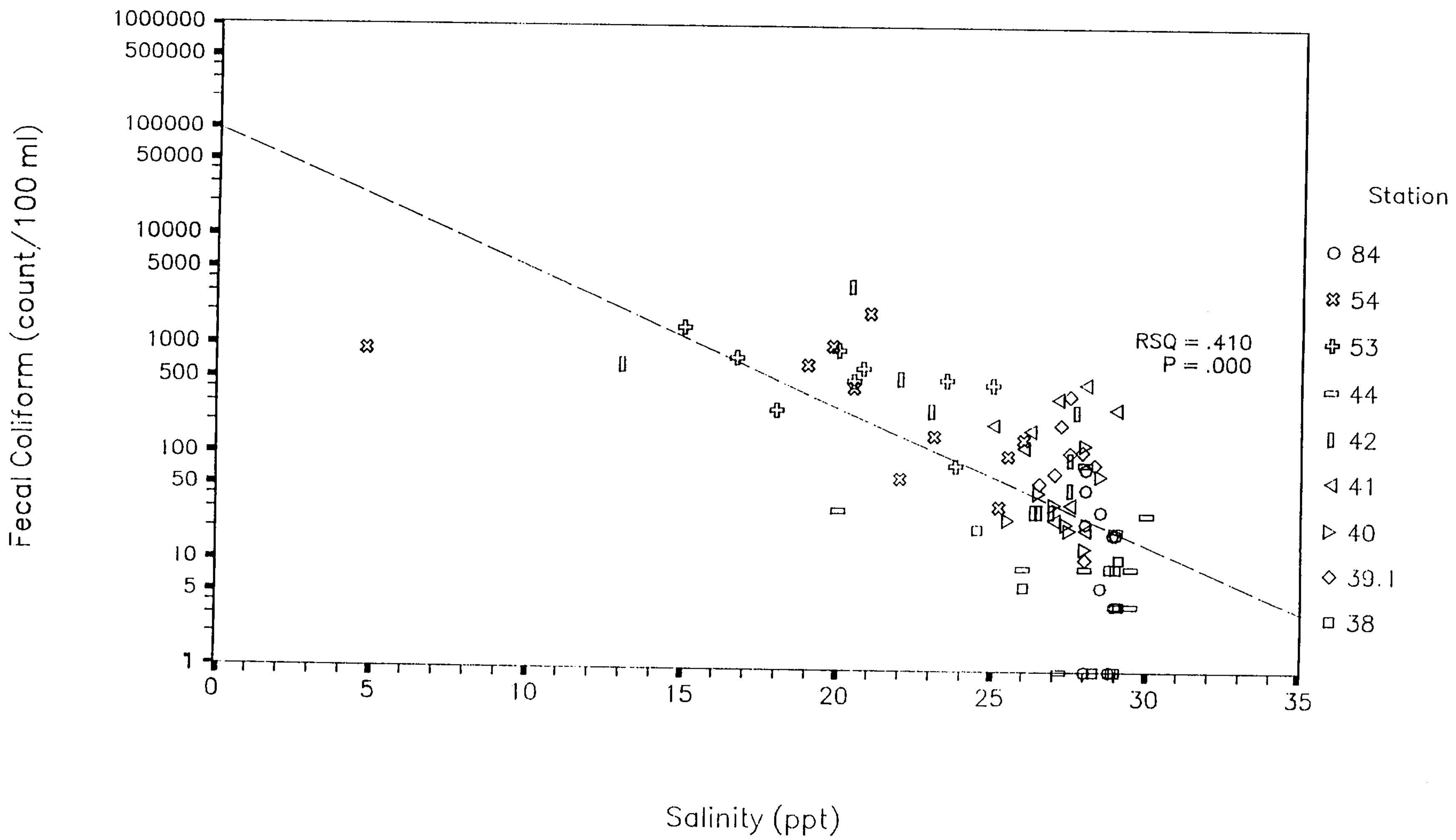


Figure 4.18. Relationship between Fecal Coliform Counts and Salinity for Surface Samples in Southern Dorchester Bay and the Neponset River, 1990.

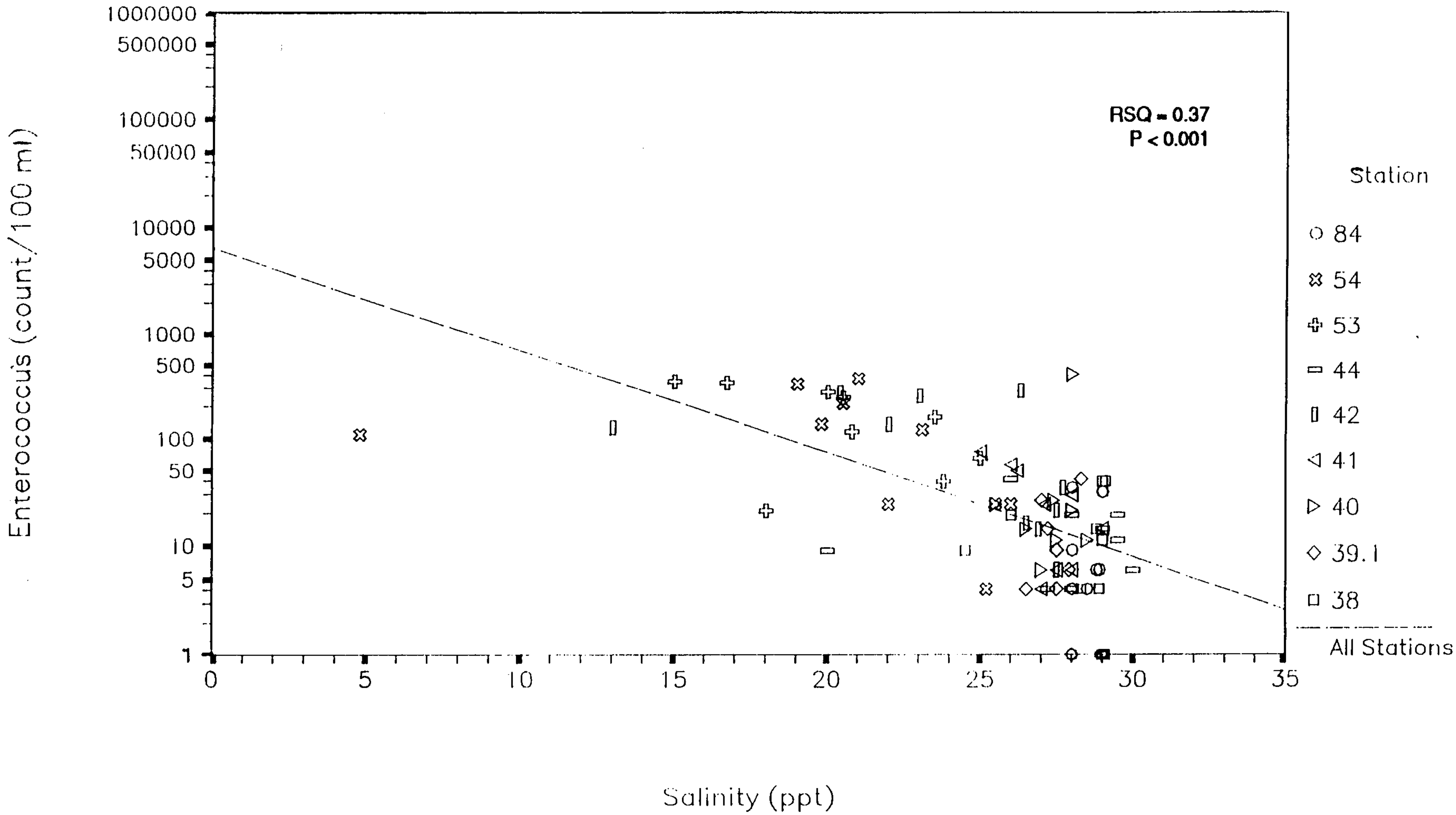


Figure 4.19. Relationship between *Enterococcus* Counts and Salinity for Surface Samples in Southern Dorchester Bay and the Neponset River, 1990.

4.3.e Dissolved Oxygen

The percentile distributions of DO measurements from surface samples are shown in Figure 4.20. Because the Neponset River is quite shallow, no data for bottom DO were collected in the river. All samples were above the Massachusetts standard of 5.0 mg/l. The highest median DO, 8.5 mg/l, was at Station 55, which is above all tidal influence. The stations with the lowest median DO measurements, 6.5 mg/l, were Stations 53 and 54, near BOS-095.

4.4 Discussion

4.4.a Geographic Variation in Water Quality in the Neponset River/Dorchester Bay Area

Great geographic variation in bacterial water quality was evident in the Neponset River/Dorchester Bay area of Boston Harbor. Although densities of indicator bacteria in the Neponset River consistently exceeded water quality standards, Carson Beach was one of the least contaminated areas studied. Even during dry weather, the Neponset River exceeded bacterial water quality standards, with stations upstream of the combined sewers showing the highest counts. In contrast, the Carson Beach area generally met water quality standards even during wet weather. Interestingly, in northern Dorchester Bay the stations furthest from the outfalls sometimes had the highest counts. The relatively good water quality near Carson Beach was surprising, given the presence of seven CSO pipes in this area and the original predictions (Boston Water and Sewer Commission, 1990), based on the MWRA Stormwater Management Model, for overflows from these pipes.

4.4.b Comparison of Indicator Counts during Different Rain Conditions

The differing weather conditions during the 1989 and 1990 monitoring in northern Dorchester Bay offer an opportunity to compare bacterial water quality during relatively dry (1990) and wet (1989) periods. Table 4.04 shows the geometric means with corresponding confidence intervals for the stations that were sampled both years. The geometric mean fecal coliform counts for both years were well within state standards, and the 95% confidence intervals about those means overlap. Thus there was no significant difference in overall water quality, as measured by fecal coliform counts, between relatively dry and rainy times.

Additional data were collected by MWRA during a cooperative storm-monitoring study with the Boston Water and Sewer Commission (BWSC) (Table 4.05). During dry weather, only one sample exceeded 200 col/100 ml--at Station 38 offshore. After rainfalls, only two samples exceeded 200 col/100 ml; both at offshore Station 38. Nearshore stations sampled on these days were well below 200 col/100 ml. These data are consistent with BWSC's observation that none of the combined sewers they monitored overflowed

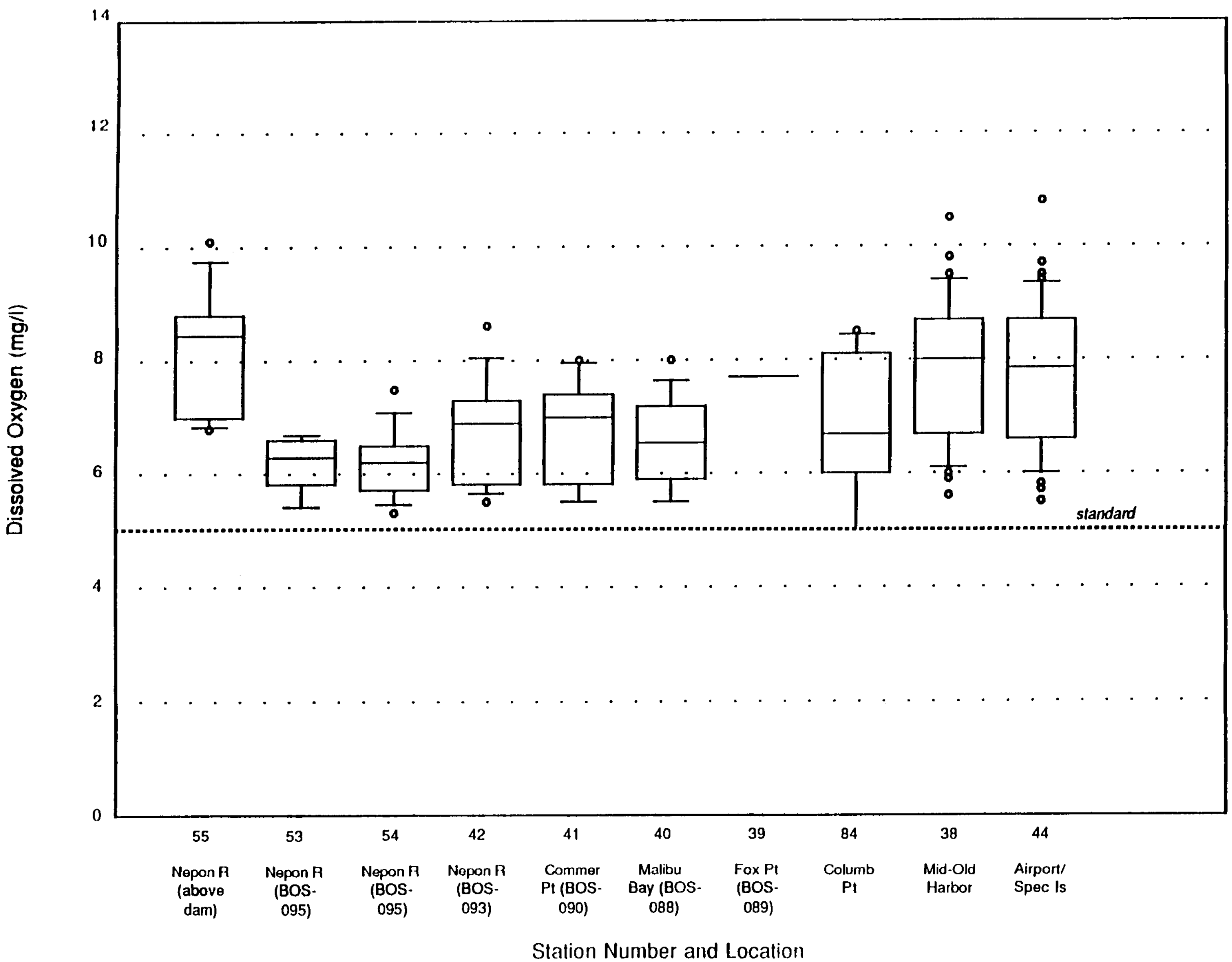


Figure 4.20. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in Southern Dorchester Bay and the Neponset River, 1990.

Table 4.04. Surface Geometric Mean Fecal Coliform Counts in Northern Dorchester Bay in 1989 and 1990*

Station No. & Location	Fecal Coliform (colonies/100 ml) 1989 (rainy)*	Fecal Coliform (colonies/100 ml) 1990 (dry)†
Offshore		
30	20 (8-52)	5 (2-8)
38	14 (4-48)	11 (5-23)
Near CSOs and Beaches		
35	5 (1-17)	9 (4-20)
36	10 (3-35)	8 (3-18)
37	25 (6-97)	10 (4-27)

*Weather during 1989 sampling was rainy; average rainfall/day was 0.18 in.

†Weather during 1990 sampling was dry; average rainfall/day was 0.02 in.

Table 4.05. Fecal Coliform (colonies/100 ml) in Dry and Wet Weather: Summary of Data Collected by the Boston Water and Sewer Commission (BWSC)

Dry Weather*					Wet Weather†						
	Station					Station				Rainfall	
Date	35	36	37	38	Date	35	36	37	38	in.	Date
7/3	3	0	15	13	7/02	0	0	3	10	0.23	7/1
7/5	0	0	0	0	7/13	5	15	20	50	0.68	7/12
										0.12	7/13
7/27	40	20	5	15	7/26¶	80	5	40	1535	1.92	7/25
8/30	...	...	...	75	8/12§	...	...	...	...	2.8	8/11
8/31	...	...	...	373	8/13#	68	70	73	800	2.8	8/11
9/4	...	...	...	0	9/10	...	...	...	20	0.16	9/10
9/5	...	...	...	0	9/11	...	...	...	8	0.16	9/10
9/6	...	...	...	0	9/17	...	...	...	3	0.10	9/11
9/12	...	...	...	3	9/18	...	...	...	8	0.1	9/17
					9/19	...	...	...	10	0.12	9/19
Geomet Mean	5	3	3	8	Geomet Mean	13	8	20	31		

*Dry weather is defined as no rain for 4 or more days.

†Wet weather is defined as rain on either the day of sampling or the day before sampling.

¶Storm monitored, no overflows recorded by BWSC.

§Storm monitored, overflow conditions observed at BOS-084, BOS-085, and BOS-086, but tide prevented discharge.

#BWSC classifies these as dry-weather samples, but because they were taken only 2 days after a major storm, we classify them as wet-weather samples.

during rainstorms. Data collected by the Metropolitan District Commission (MDC) during the 1990 swimming season are consistent with our observations: Carson Beach was never posted as having unacceptably high counts of bacteria (P.DiPetro, personal communication). Counts at the farfield stations were higher than at the nearfield stations, suggesting that the major sewage source to northern Dorchester Bay was offshore, rather than nearshore.

These 1990 observations contrast with MDC observations in 1989, when a storm of similar size (on August 13, 1989) caused exceedances at Carson Beach for the following two days. Figure 4.21 shows the amounts of rain falling each day during June, July, and August 1989, and fecal coliform and *Enterococcus* data from the MDC and MWRA during those months. Each point plotted on the figures represents the geometric mean of three to five samples taken at different sites on the beach that day. There were three rainstorms greater than 0.5 in. when fecal coliform sampling was done the next day. For fecal coliform, only one set of samples, collected on August 14 and 15 after a three-day period of very heavy rain, exceeded the 200 col/ml Massachusetts standard. *Enterococcus* data were obtained after two storms exceeding 0.8 in. of rain, but the geometric mean counts of these samples were well below the 104 col/100 ml EPA standard for "maximum allowable density for a single sample at a beach" (no *Enterococcus* counts were obtained following the heavy rain from August 11 to 13).

The difference in response to storms between 1989 and 1990 may be attributable to increased pumping capacity at the Deer Island wastewater treatment plant (R. Moore, Rizzo Associates, and M. Heineman, Camp Dresser and McKee; personal communication) combined with a coincidental high tide, which prevented the tide gates from opening. Wet-weather flows were stored in the interceptors rather than being discharged to the receiving waters.

Although South Boston beaches are rimmed with seven CSOs, the fact that these pipes rarely overflowed meant that northern Dorchester Bay had water among the cleanest in Boston Harbor in 1990.

4.4.c Southern Dorchester Bay and the Neponset River

The poorest water quality in this area was clearly in the Neponset River, during both wet weather and dry. Interestingly, the only station clearly not affected by CSOs, Station 55 (upstream of a dam), had the highest counts. Although the CSOs (BOS-093 and 095) in the Neponset River had a measurable effect in elevating fecal coliform bacteria in the nearfield during a severe storm, the effect disappeared after one day, and the counts in the river returned to a clear trend of decreasing in the downstream direction. In the intertidal area, flushing with relatively cleaner Outer Harbor water apparently acts to reduce the counts approximately an order of magnitude from the most upstream Neponset station to Station 84 in southern Dorchester Bay.

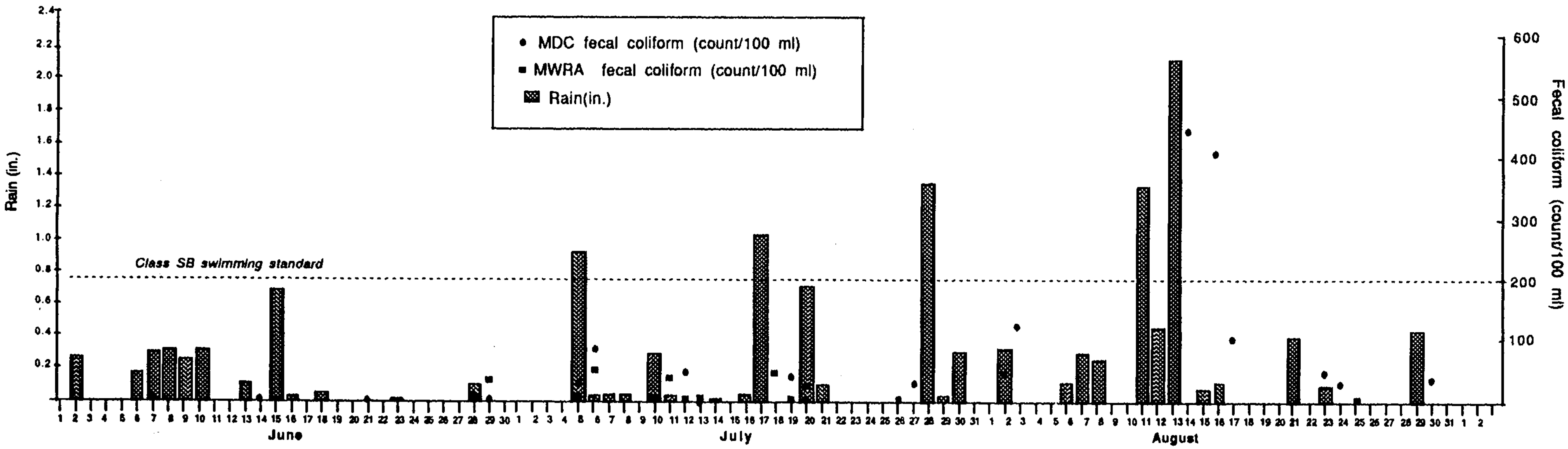


Figure 4.21 Relationship of Fecal Coliform Counts at Carson Beach, Boston Harbor, to Rainfall (June through August 1989).

MWRA points are geometric means of samples collected at seven sites, and MDC points are geometric means of samples collected at three sites.

4. Neponset River and Dorchester Bay

In addition to the river, two other sites that showed relatively elevated bacterial counts were Station 41, near BOS-090 (Commercial Point), and Station 39, near BOS-089 (Fox Point). These are two large CSOs. During this monitoring period, wet-weather flows from Fox Point were subjected to screening and disinfection at the Fox Point facility. Flows from Commercial Point were not treated.

The relatively high counts found near Fox Point and Commercial Point in dry weather (1990) indicate that there may be dry-weather sources of sewage in those areas, although it is difficult to separate the effect of the Neponset River from possible dry-weather flows from Commercial Point. Near Fox Point, which is further seaward into the Neponset estuary, it is more likely that elevated counts are attributable to dry-weather flows from the CSO or another nearby source.

During rainy weather (1989 sampling) fecal coliform counts in 50% to 70% of the samples at nearfield stations exceeded 200 col/100 ml. Approximately 25% of the samples at the farfield stations in Malibu Bay (Station 40) had counts greater than 200 col/100 ml, and the geometric mean was only 59 col/100 ml. Thus Malibu Bay appears to be somewhat sheltered from the effects of these two CSOs. Data collected by the MDC in 1989 agree well with these observations: about 29% of the samples collected at Malibu Beach exceeded 200 col/100 ml. In 1990, MWRA sampling took place during dry weather. All samples were less than 200 col/100 ml, with a geometric mean of 35 col/100 ml. The 1990 MDC data, which included the entire bathing season and several storms, showed that about 25% of the samples exceeded 200 col/100 ml--a situation very similar to 1989.

Tenean Beach is more likely than Malibu Beach to be affected by the Neponset River, Commercial Point, and any sewage entering from Pine Neck Creek. MDC data show that the water quality at this beach was poor, with 47% of samples exceeding 200 col/100 ml during 1989, and 33% exceeding the standard in 1990.

4.5 Conclusions

- Much of the sewage pollution in northern and southern Dorchester Bay came from outside the area, despite the presence of CSOs in the Bay. Two obvious sources are the Inner Harbor and the Neponset River, but other sources, including sludge, are possible.

- In northern Dorchester Bay, water quality consistently met swimmable criteria, even during periods of rainy weather, because the combined sewers rarely overflowed.

- In the Neponset River, upstream sources of bacterial pollution predominated over CSOs.

4. Neponset River and Dorchester Bay

- The possibility of dry-weather sources of pollution near Commercial Point and Fox Point should be investigated.

- Beaches near the Neponset River will continue to be adversely affected by upstream sources in the river and by other sources, including stormwater, even if the nearby CSOs are eliminated.

- Low dissolved oxygen was generally not a problem in Dorchester Bay (by our daytime measurements).

5. Quincy Bay

Stations in Quincy Bay were monitored in 1989 and 1990. In addition, some stations in Dorchester Bay were sampled to help identify effects from the Moon Island combined sewer overflow (CSO). Because Quincy Bay is shallow and the water is well mixed, samples were collected only at the surface.

5.1 1989 Results

5.1.a Sampling Locations and Rainfall

Figure 5.01 shows stations sampled in Quincy Bay during 1989. Most samples were collected between July 25 and August 17, with one sample collected at Station 48 on June 28. Because Quincy has separate storm and sanitary sewers, the only CSO directly affecting Quincy Bay is Moon Island (BOS-125). Thus, in 1989, we sited sampling stations near Moon Island and between Moon Island and Wollaston Beach. Figure 5.02 shows the amount of rain that fell each day during the 1989 sampling period.

5.1.b Indicator Bacteria Counts

Figure 5.03 shows percentile distributions of fecal coliform counts at stations forming a transect through Dorchester and Quincy Bays. All the geometric mean counts were well within the swimming standard for class SB waters (Table 5.01), and 90% of the samples had counts less than 400 col/100 ml except at Stations 45 and 48. Figure 5.04 illustrates *Enterococcus* counts at the same Dorchester/Quincy Bay stations. All counts of this indicator were well below the EPA-recommended steady-state standard for a swimming beach. Only one point exceeded the "EPA maximum allowable density at a beach," at Station 44 in Dorchester Bay.

5.1.c Relationship between Indicator Bacteria and Rainfall

Fecal Coliform

Elevated counts (>200 col/100 ml) were found on only two days, August 15 and August 16, after heavy rains that fell on August 11, 12, and 13 (Figure 5.03).

A regression of fecal coliform density against rainfall summed over four days (Figure 5.05) shows a significant linear relationship ($R^2 = 0.42$, $p < 0.001$).

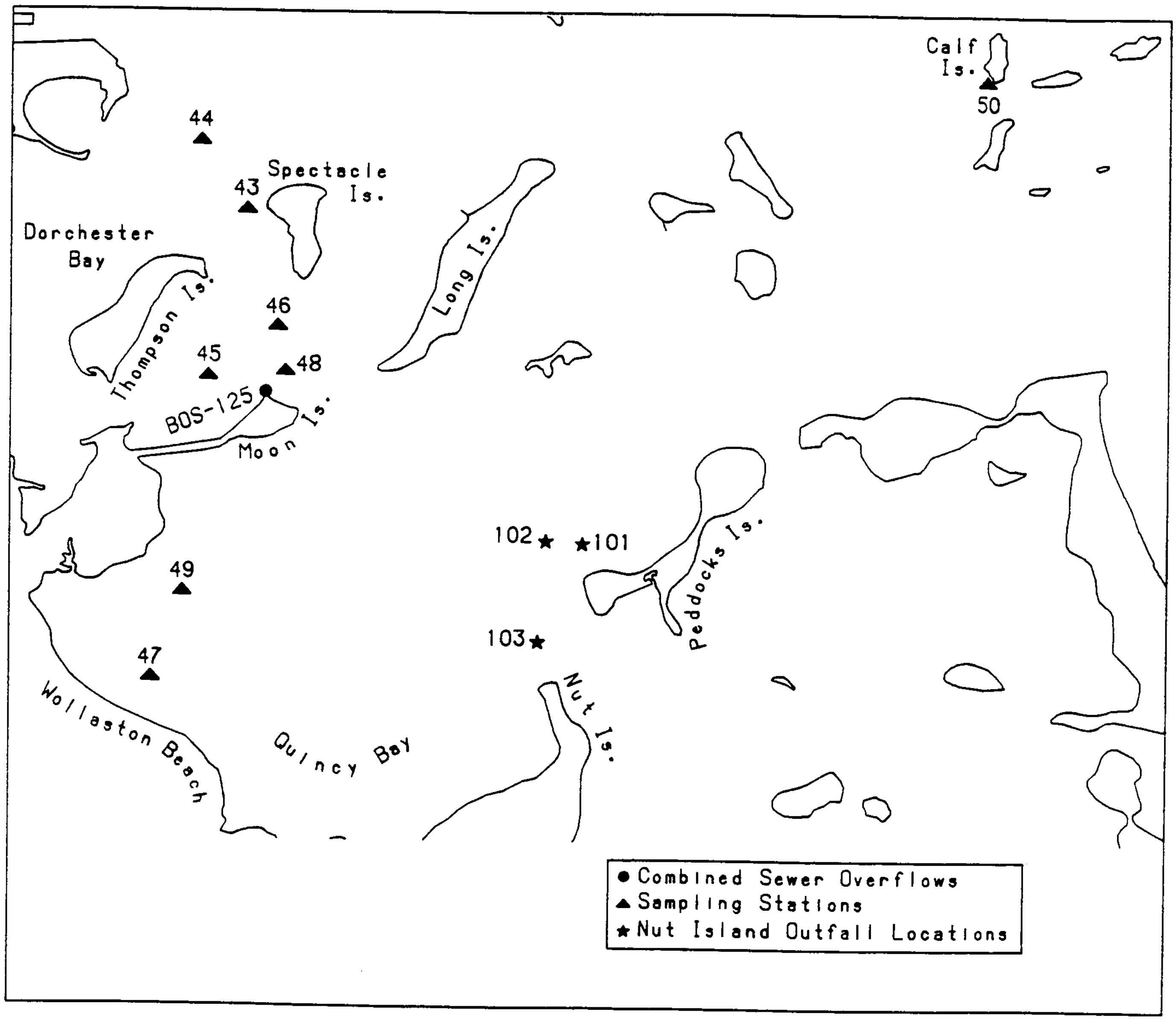
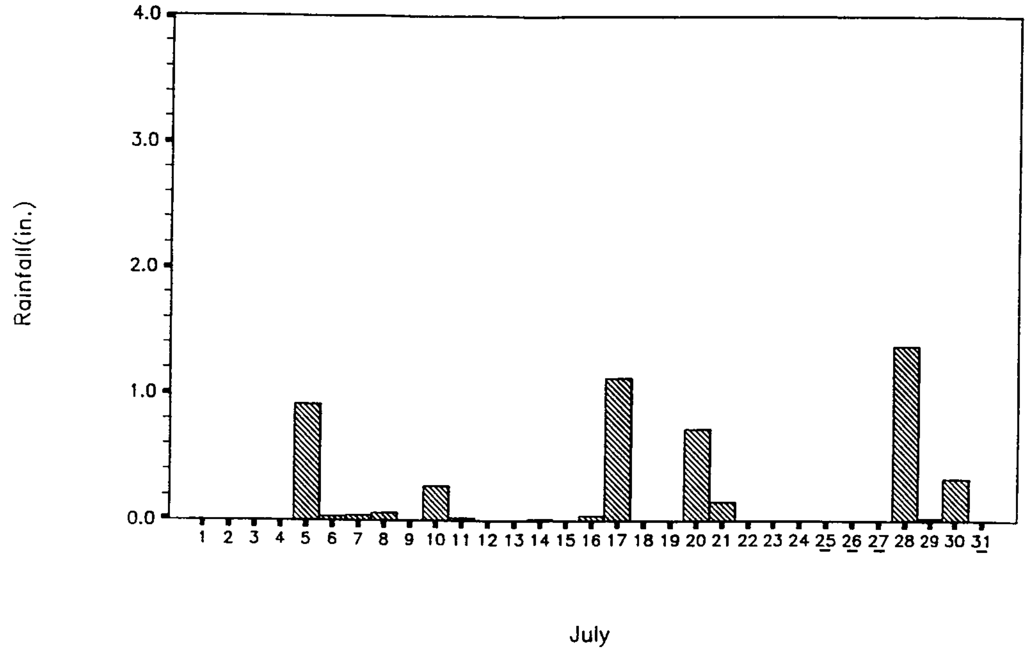


Figure 5.01. Stations Sampled during the 1989 Quincy Bay Monitoring.



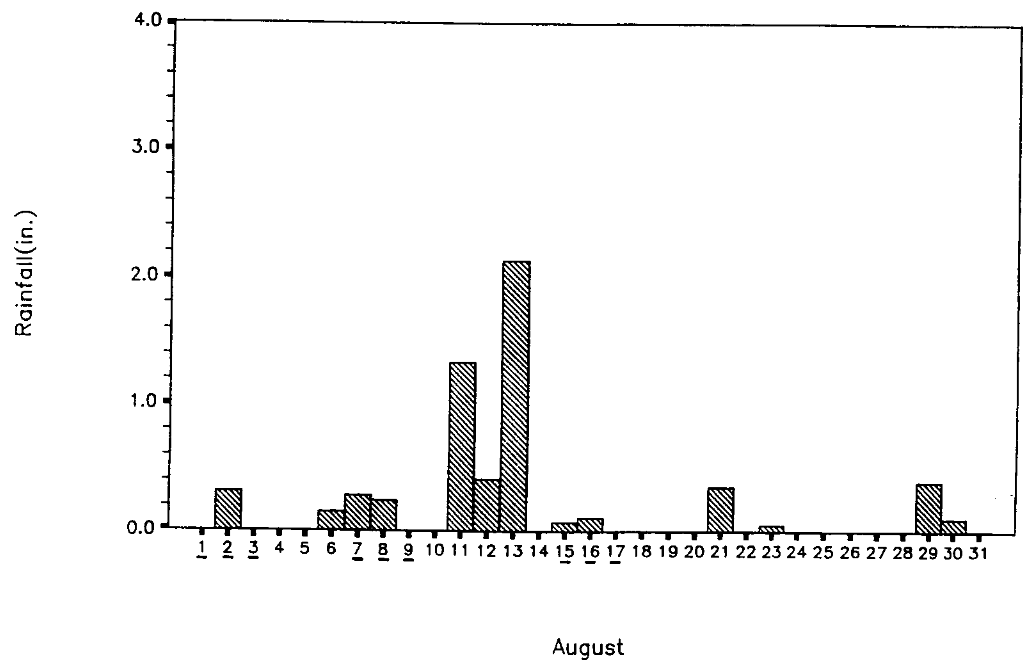


Figure 5.02. Daily Rainfall during the 1989 Quincy Bay Monitoring Period.

Samples were collected on dates underlined.

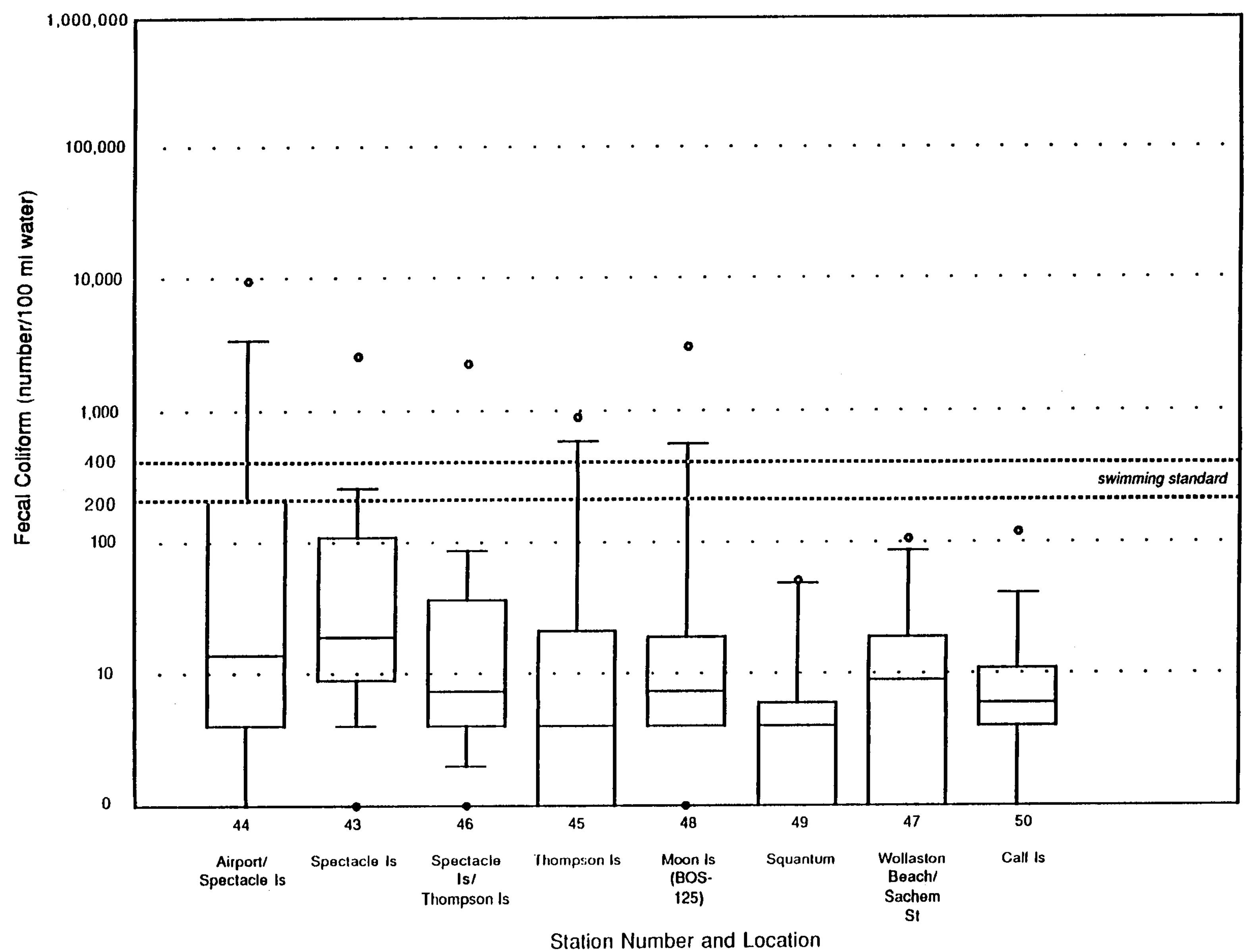


Figure 5.03. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in Quincy Bay, 1989.

Table 5.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Outer Harbor and Quincy Bay Stations

Station			1989		1990	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal Coliform						
44	Airport/Spectacle Island	S	...	...	11	53 (16-174)
45	Thompson Island	S	13	8 (2-32)	...	...
46	Spectacle Island/Thompson Island	S	12	12 (12 (3-42)	...	...
47	Wollaston Beach/Sachem Street	S	13	6 (1-17)	11	2 (0-8)
48	Moon Island (BOS-125)	S	14	14 (4-45)	11	8 (2-27)
		B	1	13		
49	Squantum	S	13	3 (1-8)	11	4 (1-15)
50	Calf Island	S	10	5 (2-14)	...	...
76	Offshore, Wollaston Beach		...	...	11	5 (2-12)
77	Wollaston Beach/Merrymount	...	...	...	11	3 (1-7)
78	Hough's Neck	S	...	...	10	1 (0-3)
79	Outfall 103	S	...	...	11	6 (2-18)
80	Quincy Yacht Club	S	...	...	11	7 (2-24)
81	Outfall 102	S	...	...	10	7 (2-21)
82	Outfall 101	S	...	...	10	5 (1-15)
Enterococcus						
44	Airport/Spectacle Island		...	...	11	6 (1-28)
45	Thompson Island	S	13	1 (0-3)	...	...
46	Spectacle Island/Thompson Island	S	12	1 (0-2)	...	...
47	Wollaston Beach/Sachem Street	S	13	1 (0-4)	11	2 (1-4)
48	Moon Island (BOS-125)	S	14	2 (1-4)	11	2 (0-11)
		B	1	0	...	...

S = surface; B = bottom.

Table 5.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Outer Harbor and Quincy Bay Stations, continued

Station			1989		1990	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
49	Squantum	S	13	1 (0-2)	11	2 (0-11)
50	Calf Island	S	10	1 (0-1)	...	...
76	Offshore, Wollaston Beach	S	...	...	11	2 (0-8)
77	Wollaston Beach/Merrymount	S	...	...	11	3 (0-13)
78	Hough's Neck	S	...	...	10	1 (0-2)
79	Outfall 103	S	...	...	11	9 (2-32)
80	Quincy Yacht Club	S	...	...	11	5 (1-13)
81	Outfall 102	S	...	...	10	3 (1-10)
82	Outfall 101	S	...	...	10	4 (0-14)

*S = surface; B = bottom.

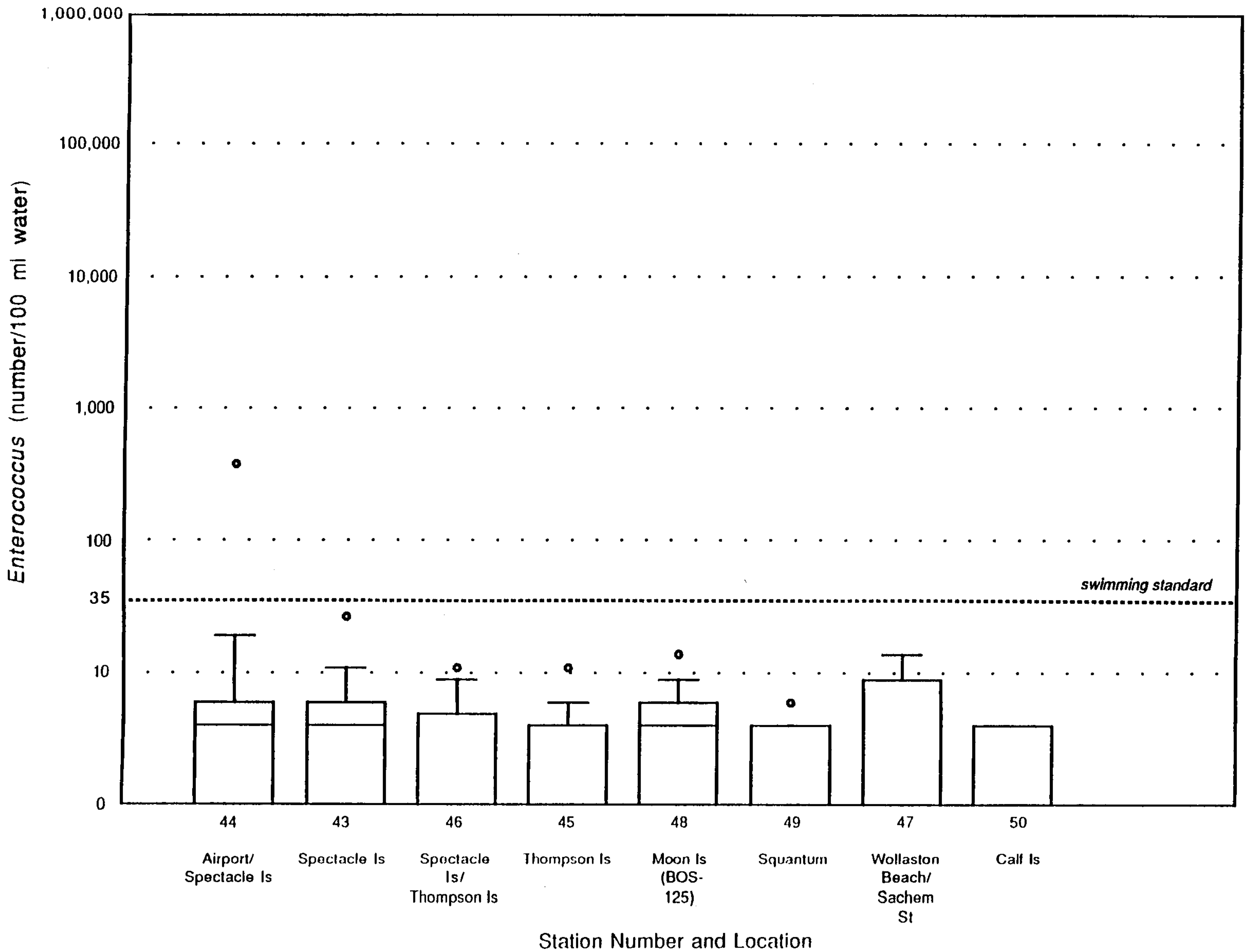


Figure 5.04. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in Quincy Bay, 1989.

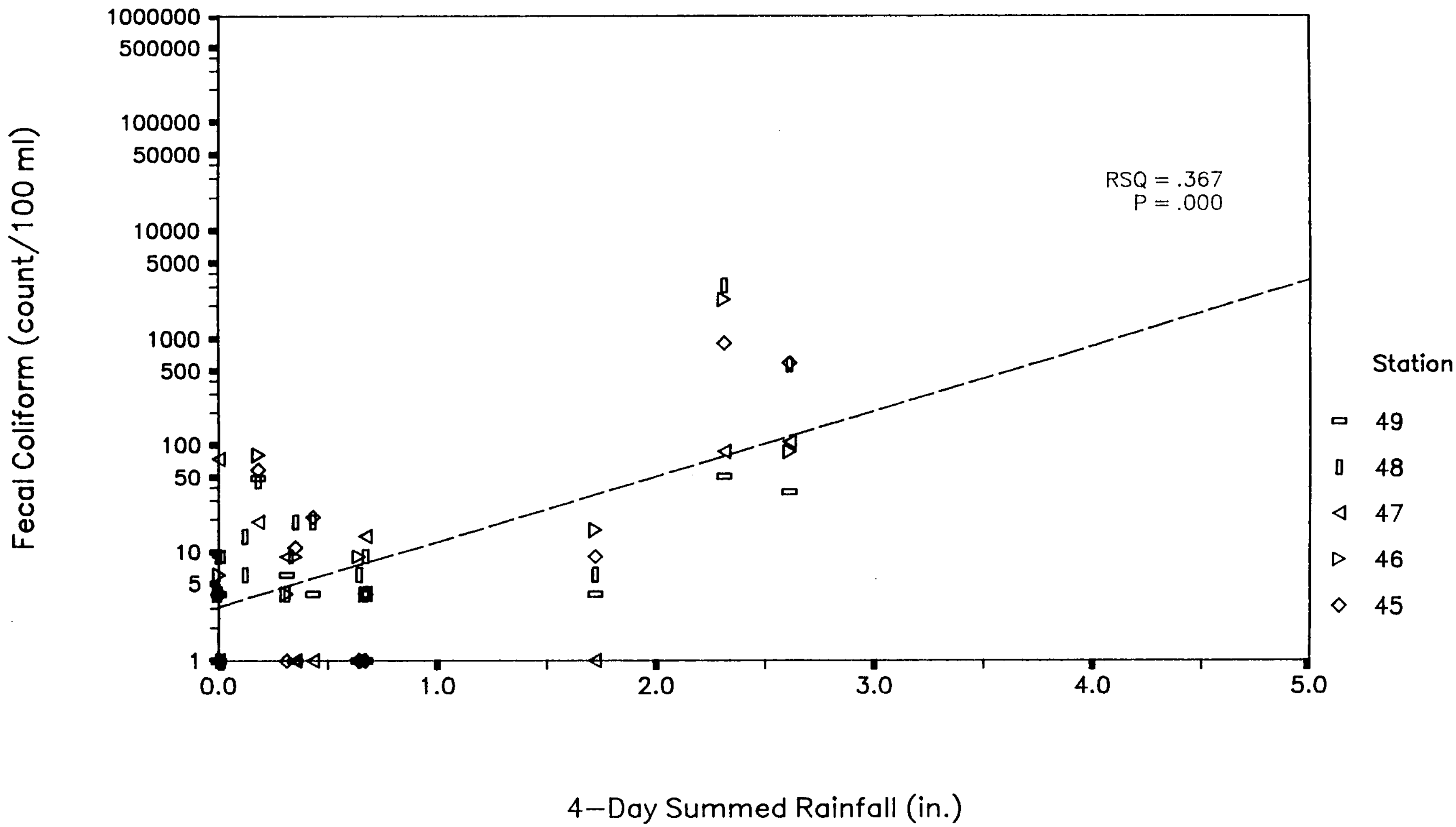


Figure 5.05. Relationship between Fecal Coliform Counts and 4-Day Summed Rainfall in Quincy Bay, 1989.

Enterococcus

The regression of *Enterococcus* against 4-day summed rain (Figure 5.06) shows a significant but weaker relationship ($R^2 = 0.20, p < 0.001$) than fecal coliform against rain.

5.1.d Relationship between Indicator Bacteria and Flow from BOS-125

Table 5.02 lists the recorded overflows from the Moon Island CSO (BOS-125) and the bacteria counts measured in the receiving water. By chance, most rainfalls occurred on weekends, so receiving water was not sampled until one day or more after overflows. For two of the four overflows, any effect had disappeared after three to four days. After the heavy rains and concomitant overflow of August 13, fecal coliform counts in all areas sampled were 10- to 300-fold higher than typical dry-weather levels. Fecal coliform counts three days after August 13 were higher than counts after two days. Fecal coliform were most elevated at the stations nearest the CSO (Station 48) and nearest the Inner Harbor (Station 44); whereas fecal coliform counts in Quincy Bay proper (Stations 49 and 47) tended to be relatively low and still within water quality standards. Interestingly, there was a very poor correspondence between *Enterococcus* levels and fecal coliform counts in the days following these heavy rains, with *Enterococcus* remaining very close (within an order of magnitude) to its typical dry-weather levels.

5.1.e Relationship between Indicator Bacteria and Salinity

Figure 5.07 shows how fecal coliform counts at stations in the Outer Harbor and Quincy Bay varied with salinity. Over all stations, when a regression of log-transformed fecal coliform counts against salinity was performed, there was a highly significant relationship ($R^2 = 0.27, p = 0.0001$). However, within individual stations, only two had a significant relationship between counts and salinity: Stations 44 ($r = -0.89$, $p < 0.01$) and 43 ($r = -0.82, p < 0.01$). These were the two stations closest to the Inner Harbor. The significant correlation between counts and salinity for the entire group of stations appears to reflect distance from the Inner Harbor. *Enterococcus* counts were only weakly correlated with salinity ($r = 0.25, p < 0.05$).

5.1.f. Dissolved Oxygen

The percentile distributions of dissolved oxygen (DO) measurements along a Dorchester Bay/Quincy Bay transect and including Station 50 at Calf Island in the Outer Harbor are shown in Figure 5.08. All these

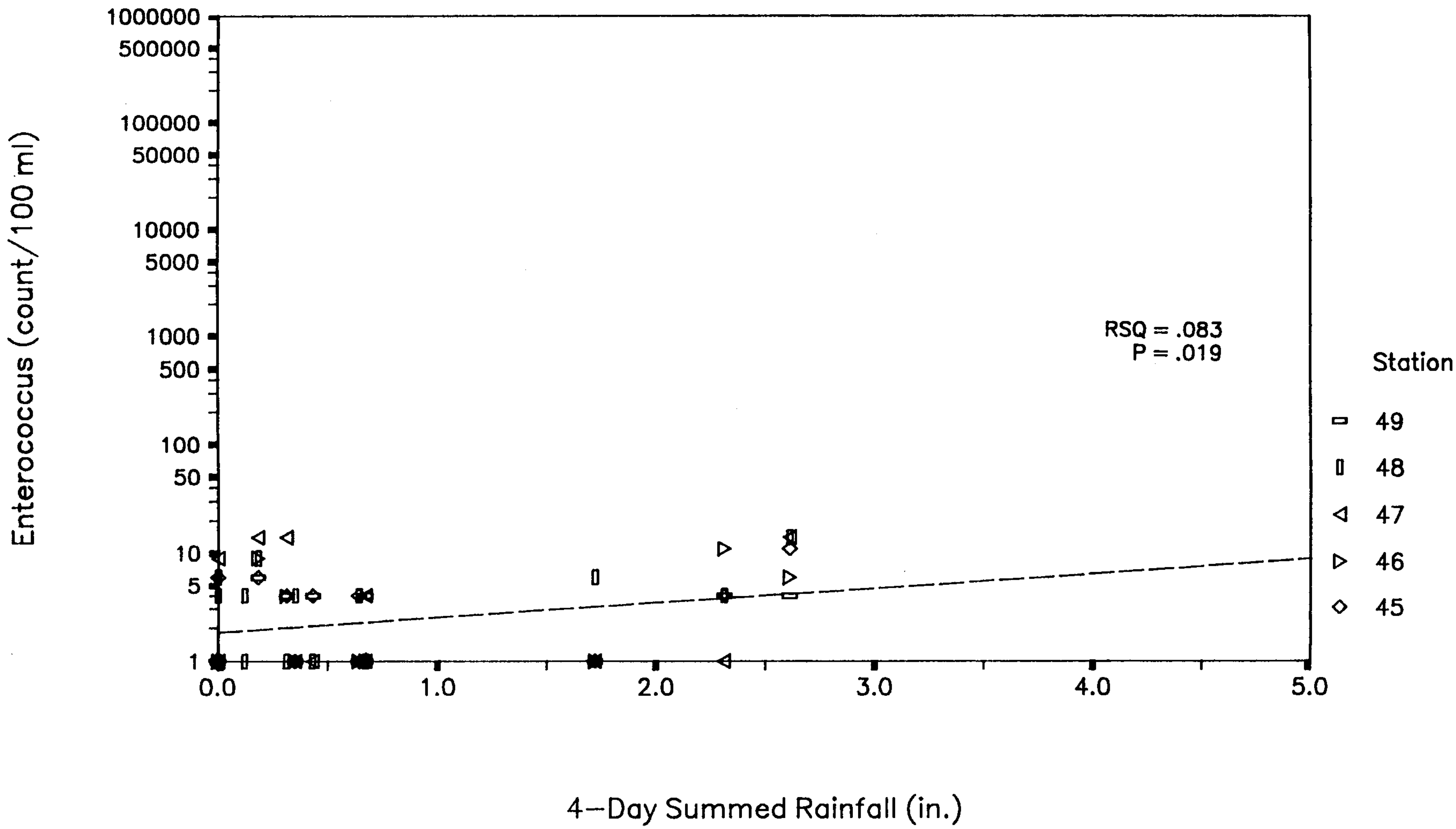


Figure 5.06. Relationship between *Enterococcus* Counts and 4-Day Summed Rainfall in Quincy Bay, 1989.

Table 5.02. Comparison of Metered Overflows at BOS-125 and Counts of Indicator Bacteria in Receiving Water in Quincy Bay

		Fecal Coliform Colonies/100 ml Water							*Enterococcus* Colonies/100 ml Water						
		Station													
Date*	Flow (MGD)	44	43	45	46	47	48	49	44	43	45	46	47	48	49
7/21	9.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7/25	0.0	0	0	0	3	8	0	0	0	0	0	0	8	3	0
7/26	0.0	0	18	3	5	73	8	0	0	0	0	0	0	0	0
7/27	0.0	3	13	3	3	0	3	3	0	0	5	0	0	5	0
7/28	2.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7/31	0.0	23	3	8	15	0	5	3	3	3	0	0	0	5	0
8/01	0.0	10	8	10	8	0	18	0	0	3	0	0	0	3	0
8/02	0.0	3	0	0	8	0	5	0	0	0	3	0	0	3	0
8/03	0.0	13	3	0	3	8	3	5	3	0	3	3	13	0	3
8/07	0.0	98	108	20	...	0	18	3	5	10	3	...	0	0	3
8/08	0.0	208	140	3	0	13	8	0	18	3	0	0	3	0	3
8/09	0.0	8	13	0	3	3	3	0	0	3	0	0	0	0	0

*All dates between July 21 and August 17, 1989, on which either overflows or sampling took place are included.

Table 5.02. Comparison of Metered Overflows at BOS-125 and Counts of Indicator Bacteria in Receiving Water in Quincy Bay, continued

		Fecal Coliform Colonies/100 ml Water							*Enterococcus* Colonies/100 ml Water						
		Station													
Date*	Flow (MGD)	44	43	45	46	47	48	49	44	43	45	46	47	48	49
8/11	3.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8/13	11.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8/14	0.0	9475	...	...	...	...	...	...	373	...	...	...	...	...	...
8/15	0.0	203	255	588	85	105	558	35	8	25	10	5	13	13	3
8/16	0.0	3400	2575	900	2250	85	3025	50	3	8	3	10	0	3	3
8/17	0.0	43	60	58	80	18	45	48	3	5	5	8	13	8	5

*All dates between July 21 and August 17, 1989, on which either overflows or sampling took place are included.

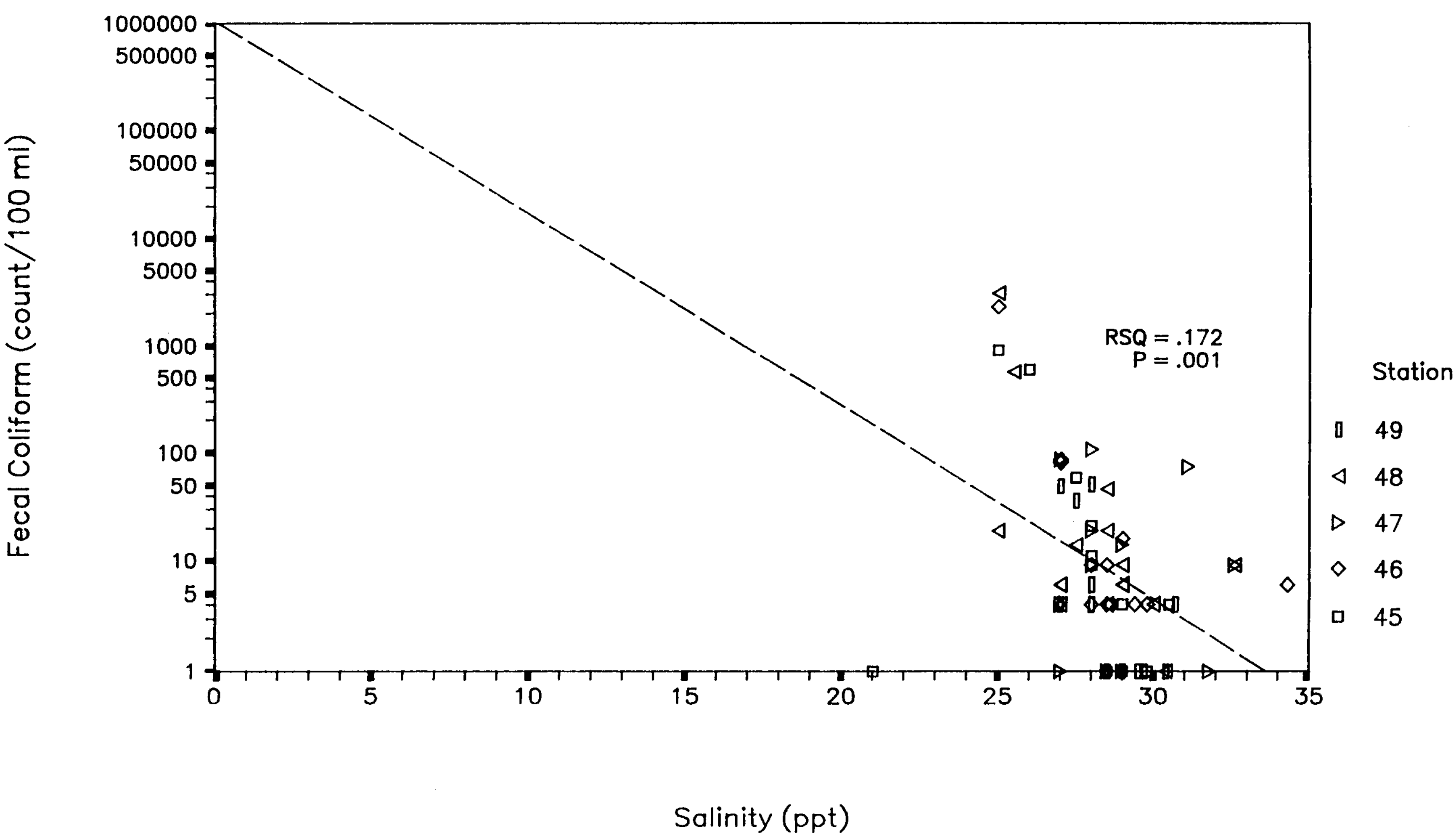


Figure 5.07. Relationship between Fecal Coliform Counts and Salinity for Surface Samples in Quincy Bay, 1989.

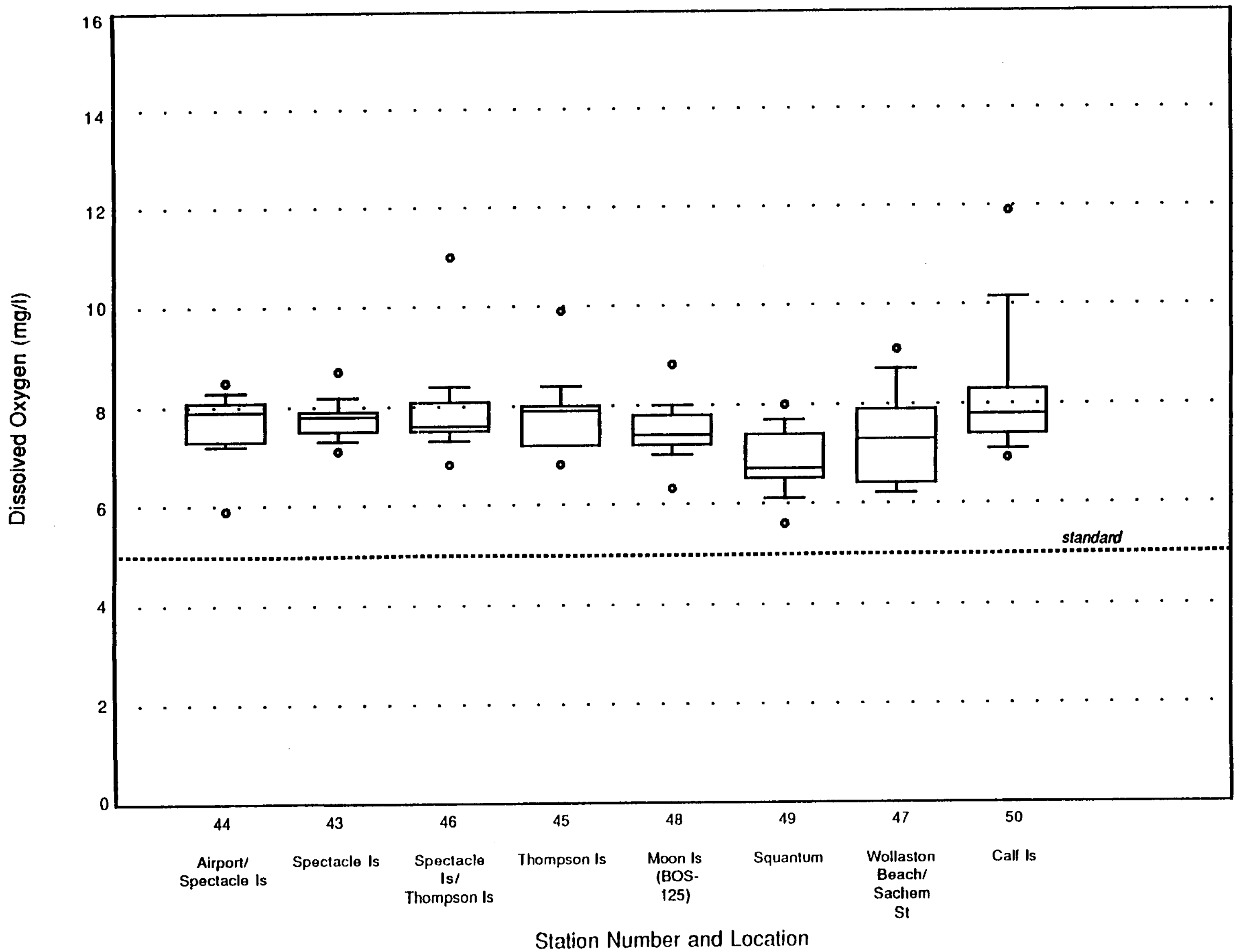


Figure 5.08. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in Quincy Bay, 1989.

measurements, made during the day, were above 5 mg DO/l. The median levels of were between 6 and 8 mg/l at all these stations.

5.1.g. Multiple Regression Analysis

Multiple regressions were performed with log-transformed fecal coliform and *Enterococcus* counts as the dependent variables (Table 5.03). Only data from Stations 45, 46, 47, 48, and 49 were included. Independent variables are listed in Table 3.03, with the addition of variables NUTFLOW (daily flow through the Nut Island wastewater treatment plant) and NUTCOL (daily fecal coliform loading at the Nut Island wastewater treatment plant).

The explanatory variable that entered into both multiple regression equations first was NUTFLOW, which absorbed 63% of the variance in fecal coliform counts and 36% of the variance in *Enterococcus* counts. The rainfall variable LORNM4 entered as a secondary variable in explaining fecal coliform counts. NUTCOL, fecal coliform loadings from the Nut Island wastewater treatment plant , was not significantly correlated with indicator bacteria at the stations sampled in Quincy Bay and near Moon Island.

5.2 1990 Results

5.2.a Sampling Locations and Rainfall

In 1990, Quincy Bay was sampled between August 2 and 14. We increased the number of sampling stations in Quincy Bay in 1990 (Figure 5.09) to help assess the effects of the effluent from the Nut Island treatment plant on beaches in Quincy Bay. Because the Moon Island CSO was deactivated during this sampling period, there were no direct combined sewer overflows into Quincy Bay during the 1990 monitoring. There were three rainfalls during this time (Figure 5.10): 0.19 in. on August 6, 0.65 in. on August 8, and 0.28 in. on August 11.

5.2.b Indicator Bacteria Counts

Fecal Coliform

Figure 5.11 shows the percentile distributions of fecal coliform counts at Quincy Bay stations during the 1990 sampling period. Geometric mean counts are in Table 5.01. As a general trend, geometric mean fecal coliform counts in Quincy Bay were extremely low--less than 10 col/100 ml at all stations except Station 44 in Dorchester Bay. Counts exceeding 200 col/100 ml were found in only two samples: Station 44 had

Table 5.03. Multiple Regression Analysis for 1989 Quincy Bay Surface Samples

Fecal coliform counts (log-transformed) as dependent variable

LOGFC = -1.069 + 0.0145[NUTFLOW] + 0.286[LORNM4]

Multiple R = 0.82
$R^2 = 0.67$
$F_{(2,61)} = 62.02$ $p < 0.0001$

Surface *Enterococcus* counts (log-transformed) as dependent variable

LOGENT = 0.760439 + 0.43785[LORNP2] + 0.217585[LORNP4] +0.965801[LORNM6]

Multiple R = 0.58
$R^2 = 0.34$
$F_{(3,239)} = 41.54$ $p < 0.0001$

Bottom fecal coliform counts (log-transformed) as dependent variable

LOGFC = 1.39493 + 0.475220[LORNE4]

Multiple R = 0.27
$R^2 = 0.07$
$F_{(1,188)} = 14.36$ $p = 0.0002$

Bottom *Enterococcus* counts (log-transformed) as dependent variable

LOGENT = 0.83552 + 0.377389[LORNP3]

Multiple R = 0.36
$R^2 = 0.13$
$F_{(1,188)} = 27.43$ $p < 0.0001$

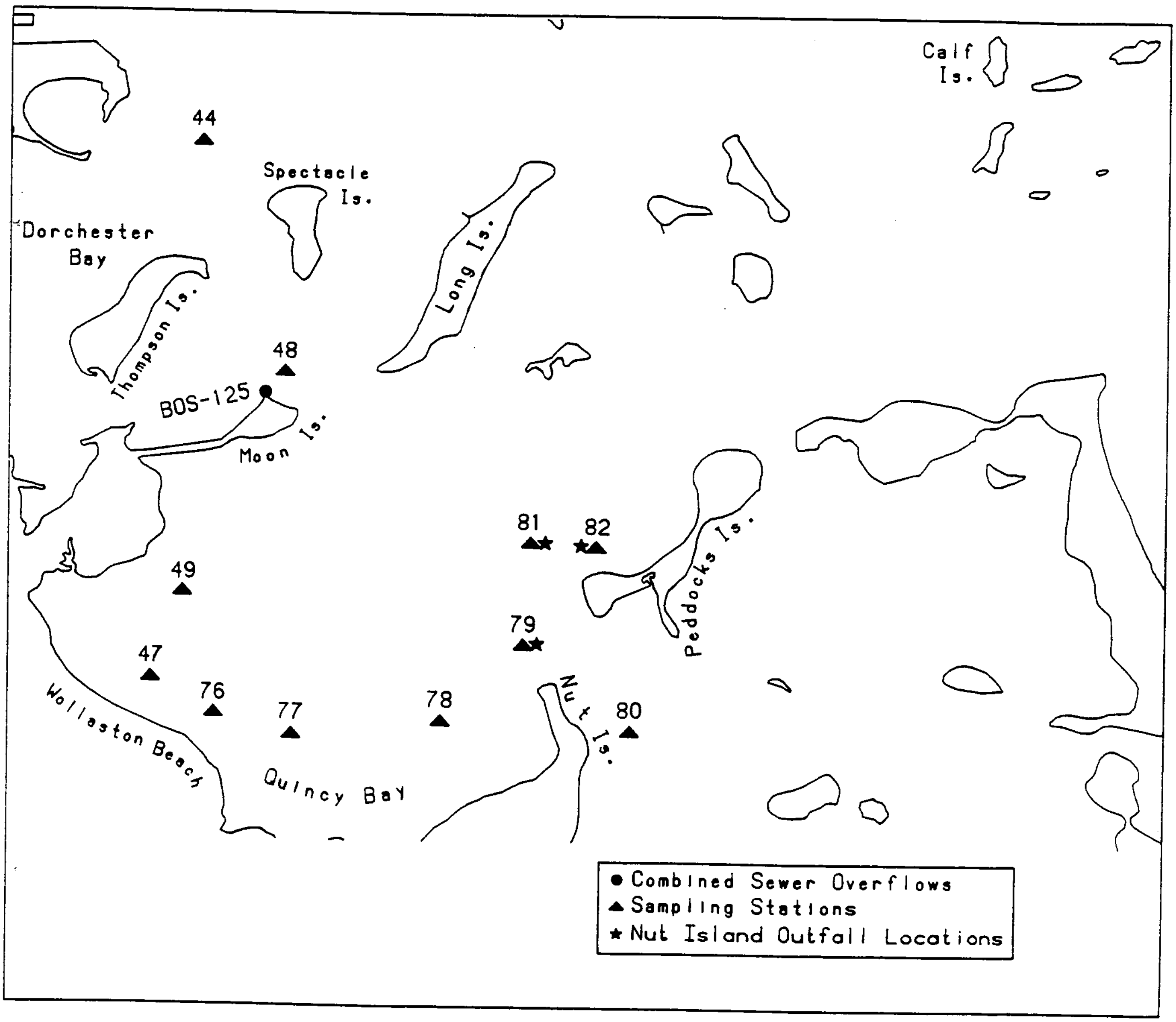


Figure 5.09. Stations Sampled during the 1990 Quincy Bay Monitoring.

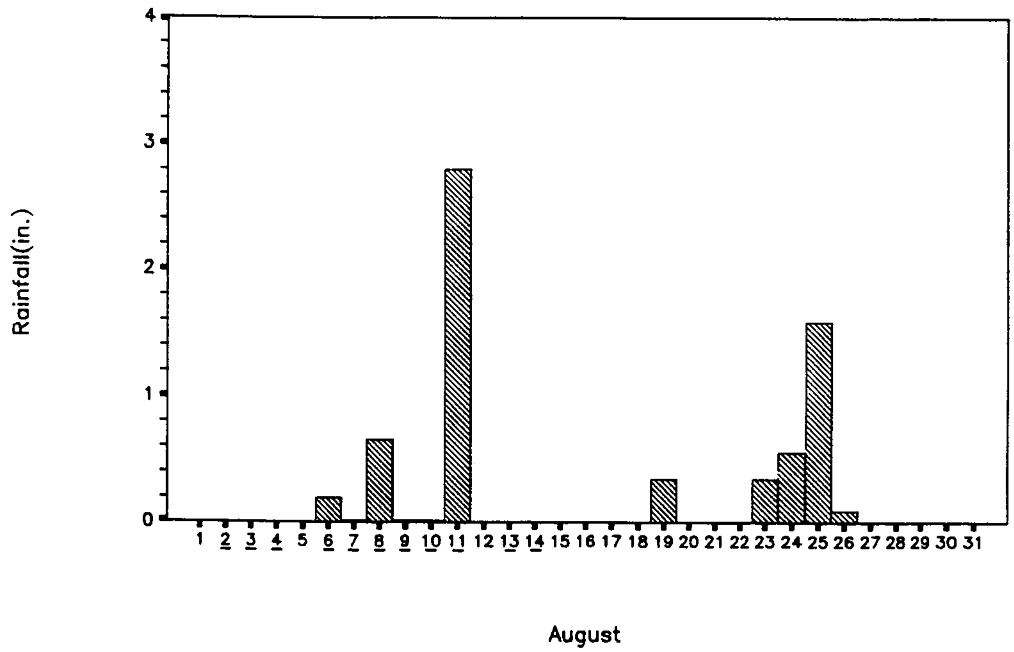


Figure 5.10. Daily Rainfall during the 1990 Quincy Bay Monitoring Period.

Samples were collected on dates underlined.

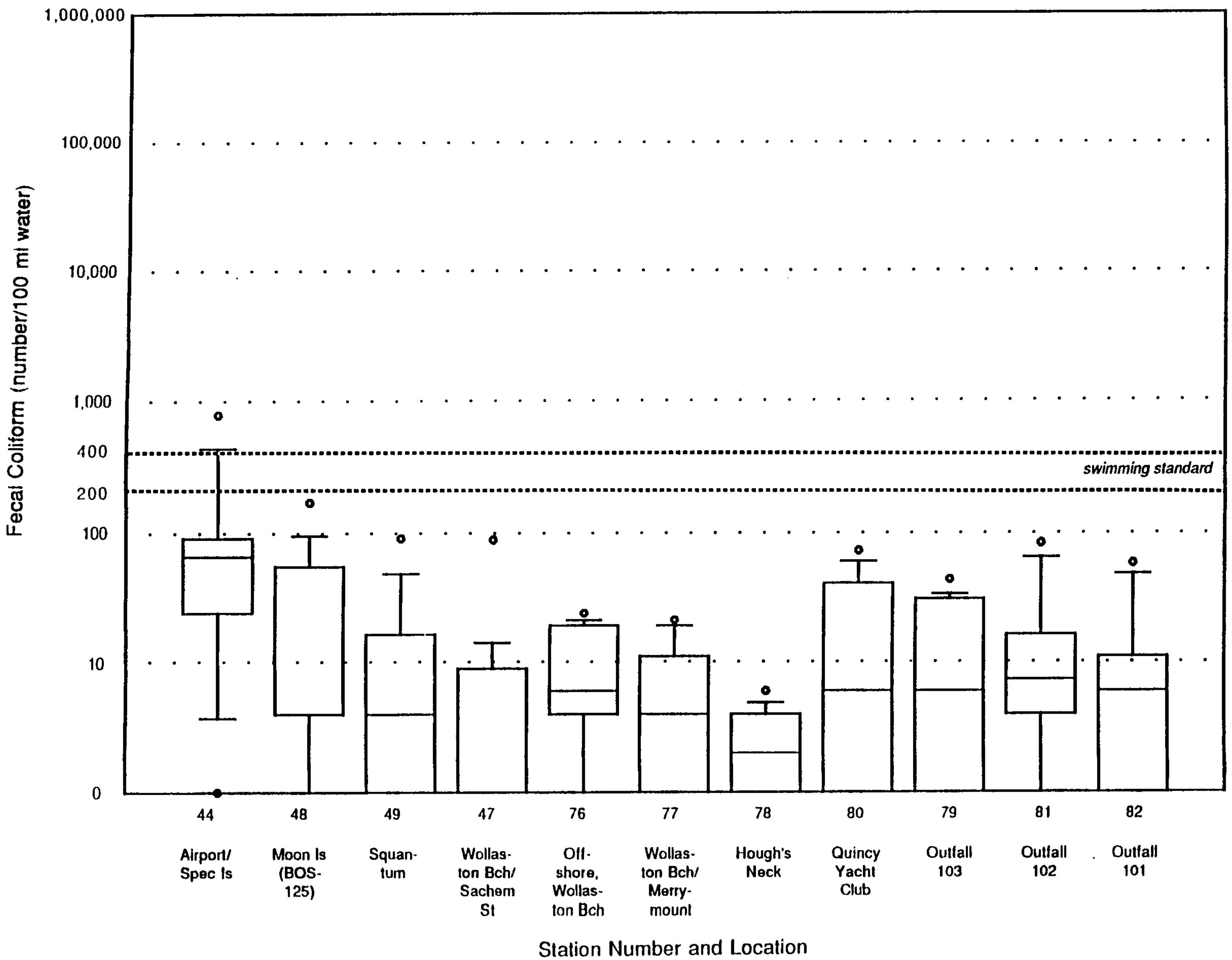


Figure 5.11. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in Quincy Bay, 1990.

800 col/100 ml on August 13 and 438 col/100 ml on August 14. Even in samples taken directly in the three effluent boils at the point of discharge from the Nut Island wastewater treatment plant (Stations 79, 81, and 82), all counts were less than 100 col/100 ml.

Enterococcus

Like fecal coliform, *Enterococcus* had geometric mean counts less than 35 col/100 ml at all stations (Figure 5.12). All samples yielded counts less than 104 *Enterococcus*/100 ml except at Station 76 (August 10, 120 col/100 ml), Station 44 (August 11, 558 col/100 and August 13, 215 col/100 ml), Station 48 (August 11, 325 col/100 ml), Station 49 (August 11, 555 col/100 ml), and Station 79 in the Nut Island boil (August 14, 805 col/100 ml).

5.2.c Relationship between Indicator Bacteria and Rainfall

The rainfall variable with the strongest correlation to indicator bacteria densities was rain summed over five days (LORNP5). The regression of fecal coliform against rainfall is shown in Figure 5.13 ($R^2 = 0.18$); and of *Enterococcus* against rainfall in Figure 5.14 ($R^2 = 0.28$). Although indicator bacteria densities increased as the sum of rain falling over five days increased, there was a considerable amount of scatter in the data.

5.2.d Dissolved Oxygen

The percentile distributions of DO measurements are displayed in Figure 5.15. (Measurements were not taken in the boils because chlorine interferes with the functioning of the dissolved oxygen probe.) Median DO levels were between 6 and 8 mg/l. One measurement, at Station 77, was less than 5 mg/l.

5.2.e Multiple Regression Analysis

Results of multiple regressions for 1990 are summarized in Table 5.04. The variables used in the regression are listed in Table 3.03, with the addition of NUTFLOW (daily flow measured at the Nut Island wastewater treatment plant) and NUTCOL (daily fecal coliform loading at the Nut Island wastewater treatment plant). The predictor variable that entered first for fecal coliform counts was NUTFLOW, followed by CURRENT. NUTFLOW absorbed approximately 24% of the variance in fecal coliform counts in Quincy Bay, and CURRENT explained approximately 3% of the variance. For *Enterococcus*, DIFLOW was the only significant explanatory variable, explaining 47% of the variance in counts.

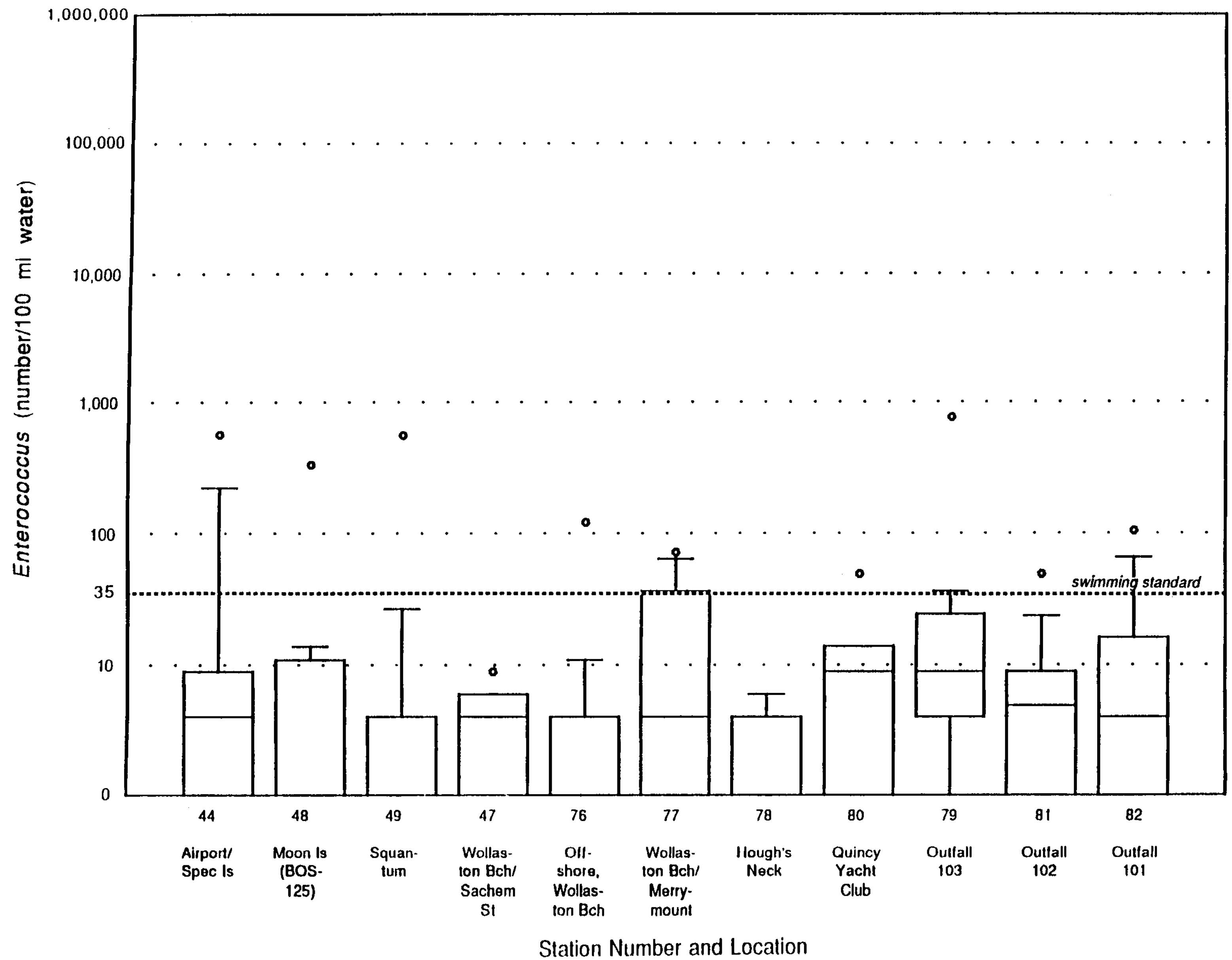


Figure 5.12. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in Quincy Bay, 1990.

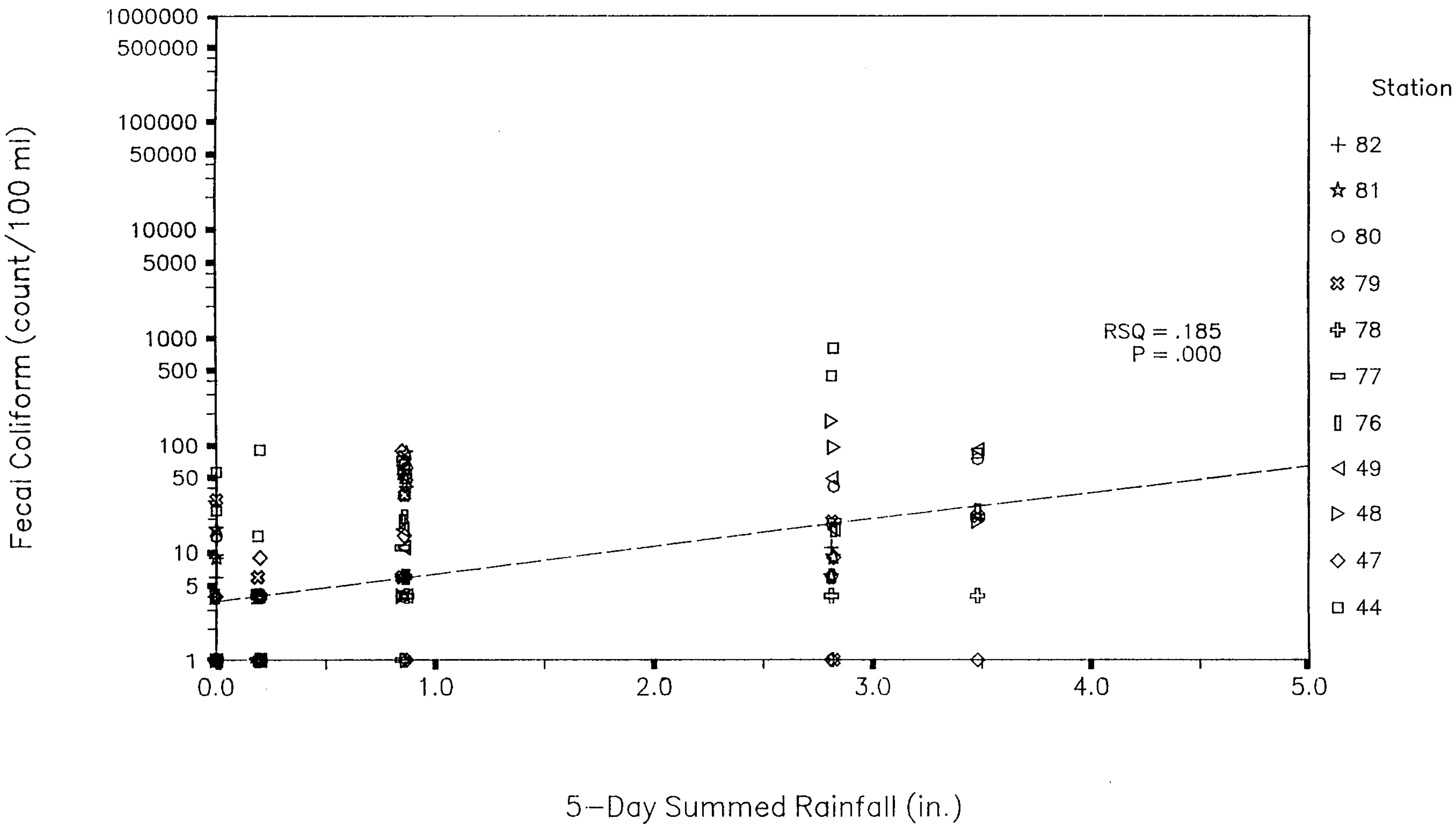


Figure 5.13. Relationship between Fecal Coliform Counts and 5-Day Summed Rainfall for Surface Samples in Quincy Bay, 1990.

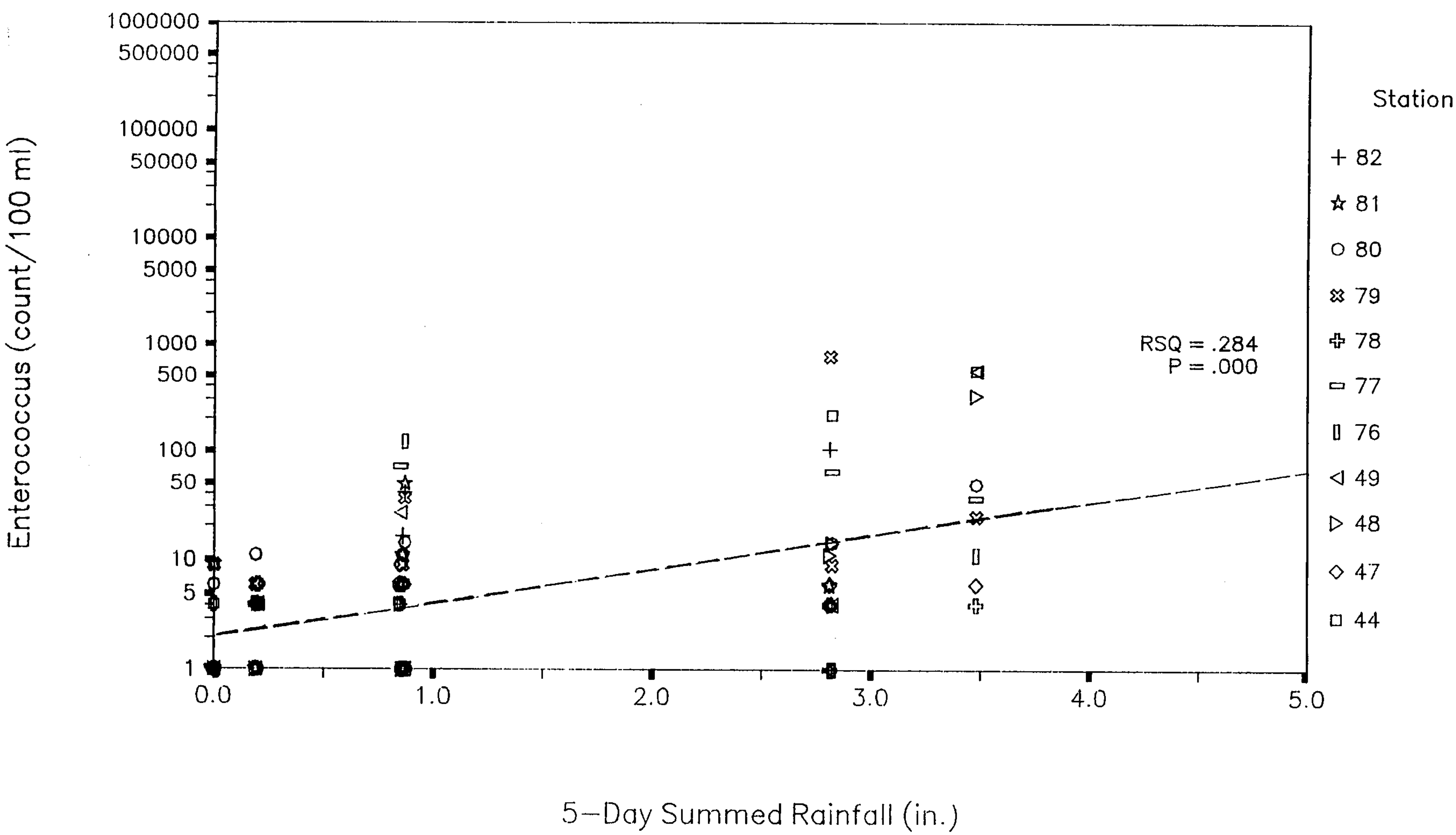


Figure 5.14. Relationship between *Enterococcus* Counts and 5-Day Summed Rainfall for Surface Samples in Quincy Bay, 1990.

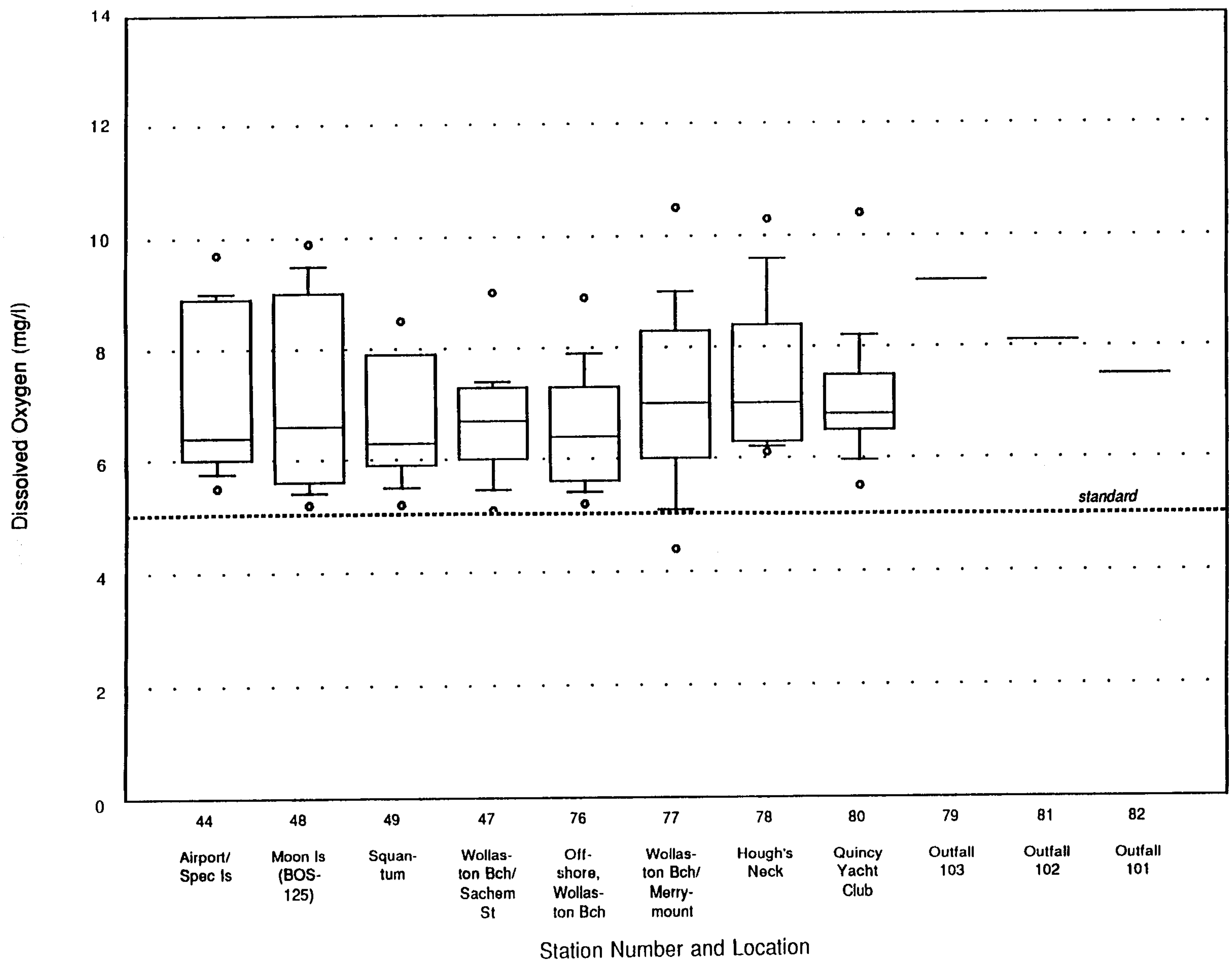


Figure 5.15. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in Quincy Bay, 1990.

Table 5.04. Multiple Regression Analysis for 1990 Quincy Bay Surface Samples

Fecal coliform counts (log-transformed) as dependent variable

LOGFC = -1.2550 + 0.01344[NUTFLOW] + 0.2856[CURRENT]

Multiple R = 0.53
$R^2 = 0.28$
$F_{(2,85)} = 16.43$ $p < 0.001$

Enterococcus counts (log-transformed) as dependent variable

LOGENT = -1.6203 + 0.0079[DIFLOW]

Multiple R = 0.69
$R^2 = 0.47$
$F_{(1,86)} = 77.84$ $p < 0.001$

5.3 Discussion

5.3.a Water Quality in Quincy Bay

As a general trend, offshore water quality in Quincy Bay, as measured by densities of sewage indicator bacteria and concentrations of DO, was well within standards for class SB waters. Even in the three effluent boils from the treatment plant, counts of fecal coliform bacteria were well below 200 col/100 ml, indicating effective disinfection of the effluent. Exceedences of bacterial water quality criteria were measured in Quincy Bay after rainstorms in both 1989 and 1990.

5.3.b Effect of the Moon Island CSO

Somewhat similar rainstorms occurred during sampling in both 1989 and 1990 (Table 5.05). In 1989, BOS-125 at Moon Island overflowed, but in 1990 that CSO was deactivated. This gives an opportunity to compare the water quality patterns of receiving water with and without the effect of overflows from BOS-125. Water not affected by BOS-125 was still, of course, affected by other rain-related sources.

In 1989, the rainstorm of August 13 was followed by sampling in Quincy Bay on August 15, 16, and 17 (Table 5.02). Whereas stations in Quincy Bay proper (Stations 47 and 49) showed counts within water quality standards, counts in Dorchester Bay near the Moon Island CSO (Stations 45, 46, and 48) were elevated above water quality standards for three days following the storm. In 1990, there was a rainstorm on August 11. Stations in Quincy Bay were sampled on August 11, 13, and 14. Stations in Quincy Bay proper (49, 47, 76, 77, 78, 80) and near Moon Island (Station 48) had fecal coliform counts within water quality standards on all days (Table 5.06). *Enterococcus* levels, however, had a somewhat different pattern, with elevated counts (above 104 col/100 ml) on August 11 at stations 48 and 49, decreasing to background levels by August 13. Thus, in 1989, counts near the CSO were elevated until the fourth day following a major storm at stations nearer Dorchester Bay. In 1990, fecal coliform counts at those stations were within water quality standards two days after a major storm. Although it is difficult to separate the effects of BOS-125 from the input from the Inner Harbor or Dorchester Bay, the lower post-storm fecal coliform counts in 1990 may be due in part to the lack of flow from BOS-125.

5.3.c Comparison of MWRA Offshore Data (1990) with Beach Monitoring Data

Table 5.06 shows results of MWRA fecal coliform monitoring in the Nut Island effluent at the treatment plant and in the receiving water at the three outfalls, together with beach monitoring carried out during the

Table 5.05. Comparison of Some Rainfall Patterns in 1989 and 1990 during Quincy Bay Sampling

1989		1990	
Date	Rainfall (in.)	Date	Rainfall (in.)
8/10	0.00	8/5	0.00
8/11	1.33	8/6	0.19
8/12	0.41	8/7	0.01
8/13	2.13	8/8	0.65
8/14	0.00	8/9	0.01
8/15	0.07	8/10	0.01
8/16	0.00	8/11	2.80
		8/12	0.00

Table 5.06. Fecal Coliform Counts (colonies/100 ml) from MWRA, Quincy, and MDC Sampling during First Two Weeks in August 1990

			MWRA Sampling										Quincy Sampling				MDC Sampling			
			Boil Stations			Offshore Stations							Nut Island Beaches				Wollaston Beaches			
Date	Rain*	Effluent†	81	82	79	80	78	77	76	47	49	48	PI	PH	EW	RH	MI	SA	CH	RI
7/31	0.00	...	...	...	...	...	...	...	...	...	...	...	...	110	40	10	...	...	...	...
8/1	0.00	25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3440	165	200	648
8/2	0.00	11	0	5	0	0	0	0	0	3	0	3	...	...	...	...	18	80	25	5
8/3	0.00	14	15	0	30	13	0	0	3	0	0	3	...	...	...	...	...	...	...	...
8/4	0.00	12	8	8	0	0	0	0	3	0	0	0	...	...	...	...	...	...	...	...
8/5	0.00	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8/6	0.19	9	0	3	5	0	3	0	0	0	0	3	...	...	...	...	...	...	...	...
8/7	0.01	12	3	0	3	3	0	0	3	8	0	3	0	30	20	20	...	...	...	...
8/8	0.65	61	5	5	5	18	0	10	18	88	15	3	...	...	...	...	728	10	588	18
8/9	0.01	26	50	68	33	33	5	5	20	13	10	55	...	...	...	...	72	25	120	46
8/10	0.01	17	83	40	43	60	3	3	5	0	3	0	...	...	...	...	...	...	...	...
8/11	2.80	12	...	20	20	73	3	23	23	0	90	18	...	...	...	...	...	...	...	...
8/12	0.00	12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8/13	0.00	18	8	0	0	40	...	18	15	8	15	95	...	...	...	...	...	...	...	...
8/14	0.00	81	5	18	18	5	3	3	5	0	48	168	20	50	0	50	...	...	...	...
8/15	0.00	36	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

PI = Post Island; PH = Parkhurst; EW = Edgewater; RH = Rhoda; MI = Milton; SA = Sachem; CH = Channing; RI = Rice.

*Rainfall in in.

†Counts of fecal coliform (no./100 ml) in Nut Island effluent.

same time period by the City of Quincy and the Metropolitan District Commission (MDC). These data include samples from the effluent boils, from stations between the boils and the beaches, and at the beaches--providing a measure of the effect of offshore sources of indicator bacteria compared to nearshore sources.

The weekly beach sampling carried out by Quincy and the MDC showed two occasions during this time when beaches were posted as being unsafe for swimming because of fecal coliform contamination: Wollaston beaches showed counts exceeding 200 col/100 ml on August 1 and August 8. Although MWRA was not sampling the receiving water in Quincy Bay on dates immediately preceding August 1, counts in the Nut Island effluent were 110 col/100 ml on August 1, far below counts at the Milton Street and Rice Road beaches and less than at the Sachem Street and Channing Street beaches. On August 8, when 0.65 in. of rain fell, there were high indicator bacteria counts at the Milton Street and Channing Street beaches, but all counts in wastewater effluent, in the zone of initial dilution, and at stations between the outfalls and the beaches were well below the nearshore counts. This is consistent with a nearshore source of fecal coliform, rather than an offshore source.

Preliminary data (March 1991, data not shown) from a cooperative Quincy/MWRA sampling study of storm drains tributary to the storm drain that discharges on the Milton Street beach showed elevated fecal coliform counts within a number of those drains. The storm drain is the most likely source of contamination to the Milton Street beach. Storm drains located on other beaches should also be tested to determine their contribution to nearshore beach contamination.

5.3.d Relationship between Indicator Bacteria and Flows through the Deer Island and Nut Island Treatment Plants

For 1989 data, NUTFLOW was the first explanatory variable that entered into the multiple regression equations for both fecal coliform and *Enterococcus*. This is difficult to explain, because Deer Island flow was also included in the variable lists in the multiple regression analyses, and the Moon Island CSO is part of the "north system"--the sewers that connect to the Deer Island wastewater treatment plant. However, Deer Island and Nut Island flows were highly intercorrelated (for July 1 - August 31, 1989 r of DIFLOW with NUTFLOW = 0.83, $p < 0.001$; and for the days samples were taken $r = 0.90$, $p < 0.001$); and the stronger correlation of Nut Island flow with indicator counts near Moon Island and Quincy Bay may have been due to chance.

Results of the 1990 multiple regression analyses were similar to those for 1989. NUTFLOW was the first variable entering the equation for explaining fecal coliform counts, followed by CURRENT. For *Enterococcus*, DIFLOW was the only significant explanatory variable. Again, for 1990, DIFLOW and NUTFLOW were correlated, although not as highly as in 1989 (for July 1-August 31, 1990, $r = 0.80$, $p < 0.001$; and for days samples were taken $r = 0.75$, $p < 0.05$).

5. Quincy Bay

Because there were no significant relationships between indicator bacteria loadings at the treatment plant and counts in the receiving waters, flow through the treatment plants should be regarded as reflecting the functioning of the sewer system, not as indicating direct input from the plants.

Although Quincy has separate systems for stormwater and sewage, it has been well documented in the past that there is substantial infiltration into sanitary sewers (Moore Associates, Inc., 1977, 1980, 1981). This explains the high correlation between flows at Deer Island and Nut Island.

Even though the Moon Island CSO, which was the most obvious source of indicator bacteria to Quincy Bay, was deactivated in 1990, the variable(s) that best explained variance in indicator counts in Quincy Bay were still treatment plant flows. Potential sources of indicator bacteria to Quincy Bay that may be correlated with treatment plant flows include storm drains, the Inner Harbor, and Outer Harbor CSOs.

5.4 Conclusions

- As a general trend, offshore water quality in Quincy Bay was well within state water quality standards for fecal coliform and dissolved oxygen, and within EPA standards for *Enterococcus*.

- Quincy beaches showed high coliform counts at times when counts in samples from Nut Island effluent, outfalls, and stations between the outfalls and the beaches were low. This finding is consistent with the presence of nearshore sources of sewage indicator bacteria to the beaches.

- After a rainstorm, the highest offshore counts were closest to the Inner Harbor, not to Nut Island. Now that the Moon Island CSO has been deactivated, the Inner Harbor and Dorchester Bay are probably the greatest sources of untreated sewage to the offshore waters of Quincy Bay.

6. Alewife Brook and the Mystic and Chelsea Rivers

Stations in Alewife Brook, the Mystic River, and the Chelsea River were monitored during the same time periods. The Mystic River has both tidal and freshwater segments, separated by the Amelia Earhart Dam and locks. The dam is located immediately upstream of the outfall for the Somerville Marginal CSO (combined sewer overflow) treatment facility (MWR-205), and sampling Station 52. Waters downstream of the dam are marine and tidal, and upstream of the dam are fresh. The portion of the Chelsea River affected by CSOs and monitored for this study is marine.

6.1 1989 Results

6.1.a Sampling Locations and Rainfall

Figure 6.01 shows the location of the stations sampled in Alewife Brook, the Mystic River, and the Chelsea River between August 21 and September 8, 1989. Figure 6.02 shows the amount of rain that fell each day during the sampling period, which was relatively dry. Only four days of precipitation were recorded, and the largest daily rainfall was 0.39 in.

6.1.b Indicator Bacteria Counts

Fecal Coliform

Percentile distributions for fecal coliform counts at individual stations in Alewife Brook and the Mystic and Chelsea Rivers are shown in Figure 6.03. The stations are arranged with the most upstream stations, in Alewife Brook and the Mystic River, on the left and the Chelsea River stations on the right. Stations 74, 73, 72, 71, 70, 57, 66, 58, 61, 56, 68, 60, 67, and 58 are all freshwater; and Stations 52, 69, 26, 27, 15, and 16 are marine. There was a general trend of decreasing counts from the confluence with Alewife Brook toward the Earhart Dam. The four stations closest to the dam (Stations 68, 60, 67, and 59) all had geometric mean counts <200 col/100 ml (Table 6.01). Below the dam, however, fecal coliform counts were very high at Station 52 (geometric mean count at the surface was 1577 col/100 ml). Although counts were lower at Station 69, they were still in violation of standards for class SB waters (geometric mean count at the surface was 603 col/100 ml).

The highest geometric mean fecal coliform counts in surface samples were at Station 52, near MWR-205, the outfall in the lower Mystic River for the Somerville Marginal CSO treatment facility; and at Station 58, an upstream site in the Mystic near a pipe (not a CSO) that often had a visible discharge. The stations with the lowest geometric mean counts, Stations 60 and 67, were located in the Mystic River Basin.

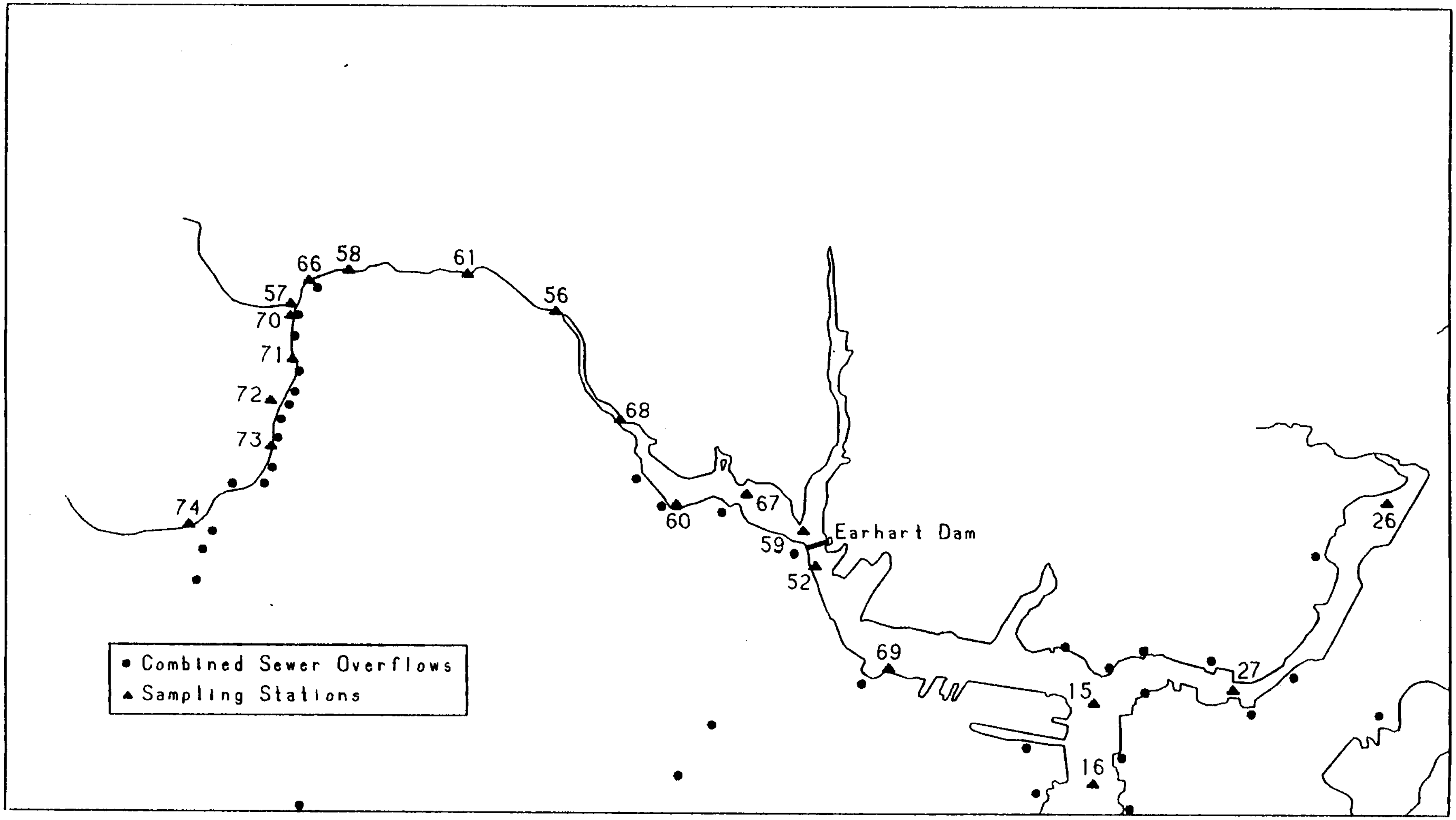
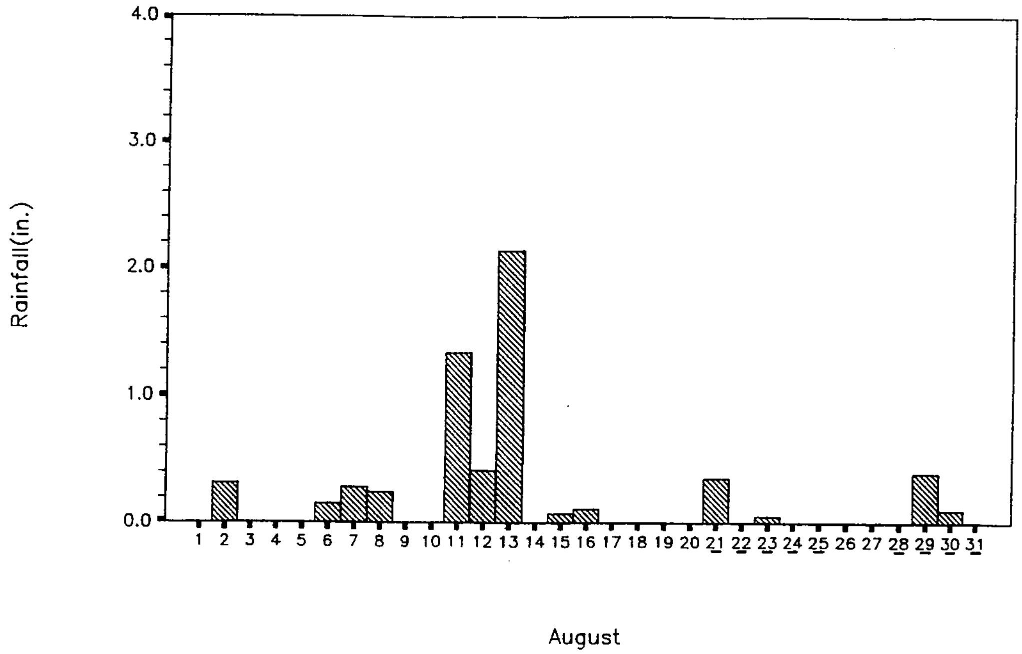


Figure 6.01. Stations Sampled during the 1989 Monitoring in Alewife Brook and the Mystic and Chelsea Rivers.



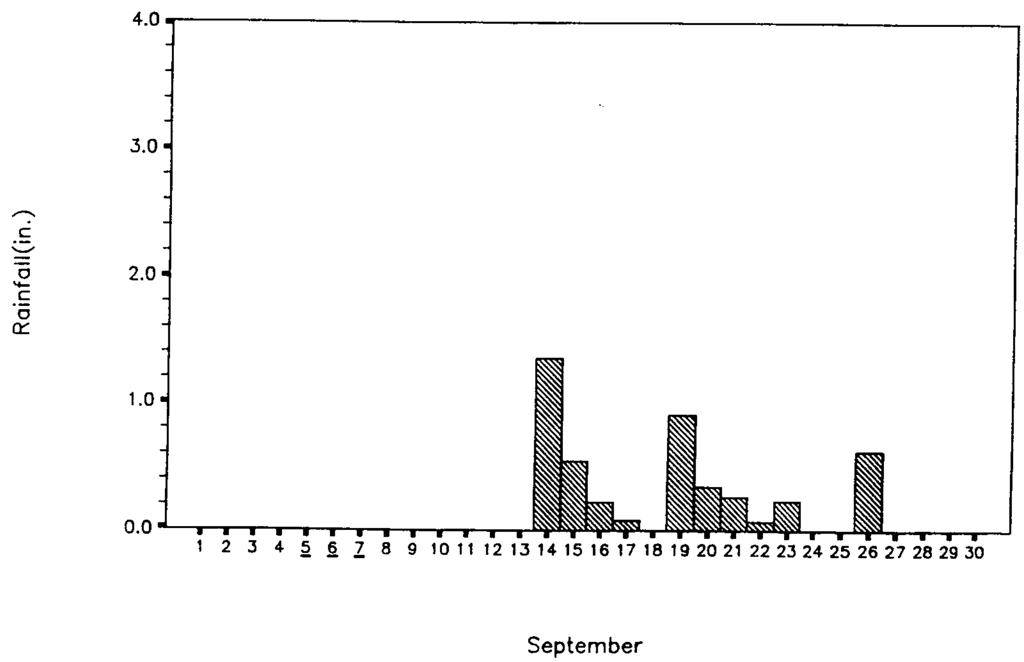


Figure 6.02. Daily Rainfall during the 1989 Monitoring Period for Alewife Brook and the Mystic and Chelsea Rivers.

Samples were collected on dates underlined.

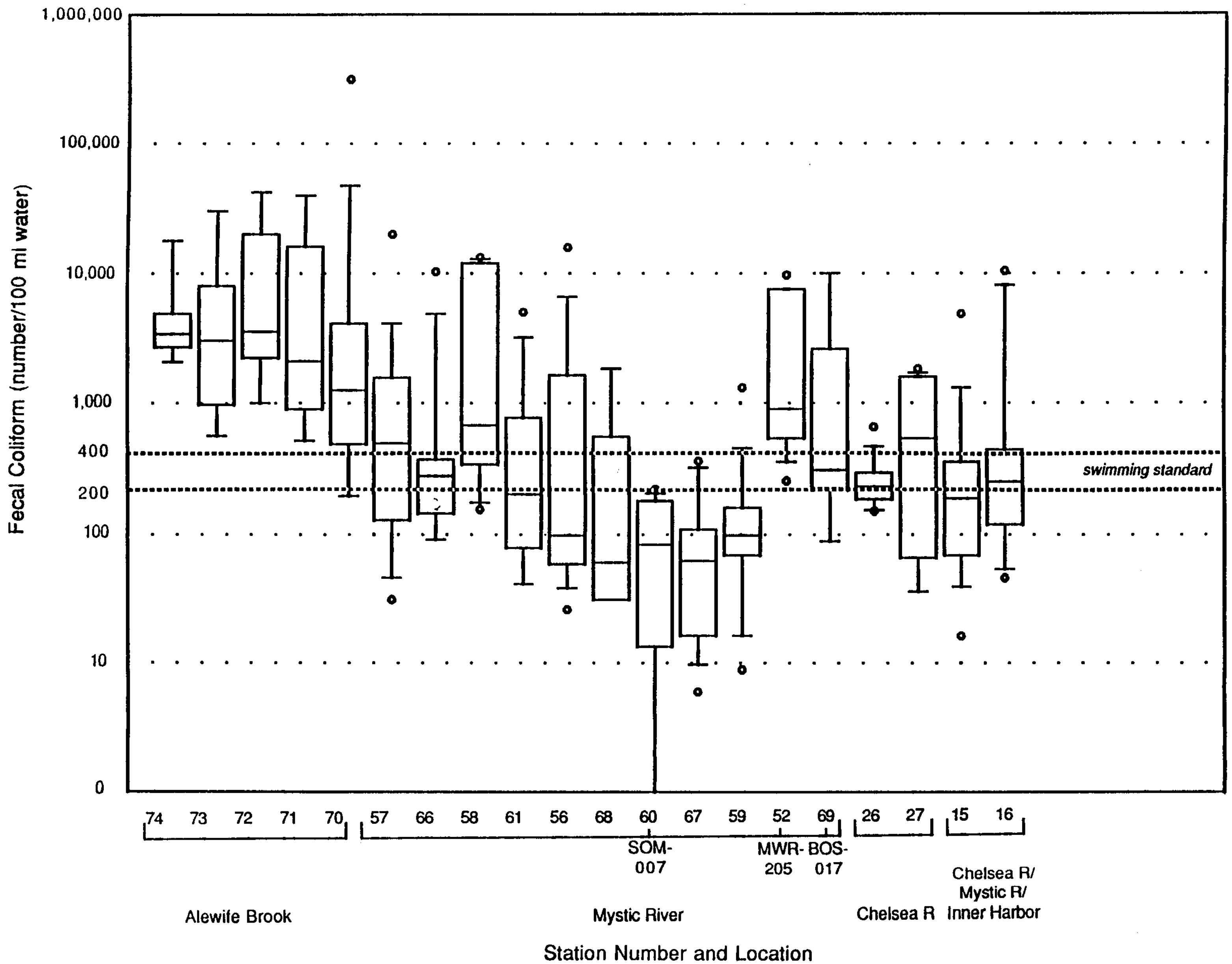


Figure 6.03. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in Alewife Brook and the Mystic and Chelsea Rivers, 1989.

Table 6.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Stations in Alewife Brook and the Mystic and Chelsea Rivers

Station			1989		1990	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal Coliform						
15	Mystic River/Chelsea River	S	16	191 (96-382)	11	124 (63-242)
		B	13	37 (23-58)	13	16 (7-39)
16	Mystic River/Chelsea River/Charles River	S	13	336 (135-835)	13	130 (75-223)
		B	13	34 (18-65)	13	9 (5-16)
26	Chelsea River , Head	S	10	242 (184-319)	13	23 (8-60)
		B	10	37 (19-74)	...	...
27	Chelsea River	S	9	315 (108-913)	13	108 (57-200)
		B	10	54 (29-100)	13	17 (12-26)
52	MWR-205/Mystic River	S	11	1577 (732-3393)	12	359 (163-786)
		B	10	133 (40-438)	10	606 (194-1887)
56	Route 93/Mystic River	S	10	269 (72-993)	13	530 (297-945)
		B	...	...	...	...
57	Alewife Brook/Mystic River	S	12	503 (176-1430)	13	131 (60-283)
		B	...	...	...	...
58	Mystic V. Parkway	S	10	1154 (390-3410)	...	...
		B	...	...	...	...
59	Mystic River/Malden River	S	11	102 (47-220)	11	105 (53-208)
		B	...	...	...	...
60	MDC Dock (SOM-007)/Mystic River	S	8	40 (10-153)	13	138 (72-264)
		B	...	...	...	...
61	Medford Square/Mystic River	S	8	272 (84-883)	...	...
		B	...	...	...	...
66	Boston Ave Bridge/Mystic River	S	9	400 (145-1096)	...	...
		B	...	...	...	...
67	Route 28 Bridge/Mystic River	S	10	54 (24-121)	13	98 (58-167)
		B	...	...	...	...
68	Mystic River Basin	S	7	118 (35-390)	...	...
		B	...	...	...	...
69	Mystic River (BOS-017)	S	6	603 (146-2484)	13	737 (402-1351)
		B	6	115 (25-515)	12	62 (29-130)
70	Alewife Brook (SOM-004)	S	8	2110 (427-10,419)	3	1408 (259-7637)
		B	...	...	...	...

*S = surface; B = bottom.

Table 6.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Stations in Alewife Brook and the Mystic and Chelsea Rivers, continued

Station			1989		1990	
No.	Location	Depth	n	mean (CI)	n	mean (CI)
71	Alewife Brook (SOM-002A)	S	7	3463 (1099-10,910)	...	...
		B	...	...	...	...
72	Broadway Bridge/Alewife Brook	S	6	5437 (1735-16,472)	...	...
		B	...	...	...	...
73	Woodstock Street/Alewife Brook	S	7	2892 (1045-8004)	...	...
		B	...	...	...	...
74	Alewife Brook/T-Station	S	6	7735 (4187-2266)	5	444 (60-3220)
		B	...	...	..	...
83	Mystic River, Upstream of Alewife Brook	S	...	...	13	77 (36-161)
		B	...	...	...	...
Enterococcus						
15	Mystic River/Chelsea River	S	16	4 (1-11)	11	47 (19-115)
		B	13	3 (1-5)	13	11 (4-27)
16	Mystic River/Charles River/Chelsea River	S	13	11 (5-23)	13	49 (19-123)
		B	13	4 (2-7)	13	8 (4-19)
26	Charles River, Head	S	10	24 (10-55)	13	11 (3-30)
		B	10	11 (5-23)	...	...
27	Chelsea River	S	9	36 (15-80)	13	30 (11-80)
		B	10	9 (6-15)	13	10 (4-22)
52	MWR-205/Mystic River	S	11	18 (10-30)	13	27 (10-74)
		B	10	10 (3-25)	10	43 (24-79)
56	Route 93/Mystic River	S	10	30 (9-96)	13	159 (79-320)
		B	...	...	...	...
57	Alewife Brook/Mystic River	S	11	63 (37-107)	13	106 (57-195)
		B	...	...	...	...
58	Mystic V. Parkway	S	10	100 (36-275)	...	...
		B	...	...	..	...
59	Mystic River/Malden River	S	11	8 (3-20)	11	15 (6-36)
		B	...	...	...	...
60	MDC Dock (SOM-007)/Mystic River	S	8	2 (0-8)	13	36 (17-77)
		B	...	...	...	...

*S = surface; B = bottom.

Table 6.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Stations in Alewife Brook and the Mystic and Chelsea Rivers, continued

Station			1989		1990	
No.	Location	Depth	n	mean (CI)	n	mean (CI)
61	Medford Square/Mystic River	S	8	61 (20-183)	...	...
		B	...	...	...	...
66	Boston Ave Bridge/Mystic River	S	9	67 (29-153)	...	...
		B	...	...	...	...
67	Route 28 Bridge/Mystic River	S	9	5 (2-12)	13	28 (14-55)
		B	...	...	...	...
68	Mystic River Basin	S	7	28 (8-94)	...	...
		B	...	...	...	...
69	Mystic River (BOS-017)	S	6	13 (6-25)	12	38 (12-120)
		B	6	6 (4-10)	12	22 (9-51)
70	Alewife Brook (SOM-004)	S	8	360 (116-1115)	3	233 (115-475)
		B	...	...	...	...
71	Alewife Brook (SOM-002A)	S	7	552 (269-1131)	...	...
		B	...	...	...	...
72	Broadway Bridge/Alewife Brook	S	6	2190 (631-7593)	...	...
		B	...	...	...	...
73	Woodstock Street/Alewife Brook	S	7	1136 (503-2565)	...	...
		B	...	..	...	...
74	Alewife Brook/T-Station	S	6	516 (188-1408)	5	107 (10-1071)
		B	...	...	...	...
83	Mystic River, Upsteam of Alewife Brook	S	...	...	13	61 (35-108)
		B	...	...	..	...

*S = surface; B = bottom.

6. Alewife Brook and the Mystic and Chelsea Rivers

In Alewife Brook, geometric mean counts at all stations were 10 to 20 times higher than the standard for class B waters, and the geometric mean of all stations in Alewife Brook was 3147 col/100 ml. There was no clear geographic trend of increasing or decreasing fecal coliform densities along the length of the brook. Fecal coliform counts were significantly higher in Alewife Brook than in the Mystic River (except at Stations 70, 57, 58, and 60, where the 95% confidence intervals overlap).

In the Chelsea River, both stations (26 and 27) had surface geometric mean counts exceeding SB standards. At the confluence of the Mystic and Chelsea Rivers, Station 15 had a geometric mean count essentially at the class SB standard, and Station 16 exceeded the standard.

Bottom samples were collected at the deeper stations in the lower Mystic/Chelsea area. Except at Station 69, all the bottom stations had geometric mean fecal coliform counts significantly lower ($p < 0.05$) than surface counts.

Enterococcus

Figure 6.04 shows percentile distributions of *Enterococcus* densities in Alewife Brook and the Mystic and Chelsea Rivers. The overall pattern of counts among stations along the length of the river differed from that of fecal coliform. Like fecal coliform, *Enterococcus* showed a general trend of decreasing counts from Alewife Brook to the Earhart Dam; unlike fecal coliform, *Enterococcus* at the two stations downstream of the dam (Stations 52 and 69) had geometric mean counts well below the EPA steady-state swimmability standard of 35 col/100 ml.

Bottom geometric mean *Enterococcus* counts were not significantly different from surface counts.

6.1.c Relationship between Indicator Bacteria and Rainfall

For the small amounts of rain that fell during this period, the relationship between fecal coliform density in the Mystic River and the best rainfall correlate, 4-day summed rain, was weak ($R^2 = 0.14$). In Alewife Brook, the relationship between 4-day summed rainfall and fecal coliform counts was stronger ($R^2 = 0.33$). The relationship between *Enterococcus* and rainfall was weak in both the Mystic River ($R^2 = 0.13$) and Alewife Brook ($R^2 = 0.17$).

Although the regression analyses showed a substantial amount of scatter, an effect of even a relatively small rainfall is shown if fecal coliform counts at individual stations are plotted by day. Counts in Alewife Brook (Figure 6.05) and at the upstream stations in the Mystic River (Figure 6.06) were elevated after a mild wet-

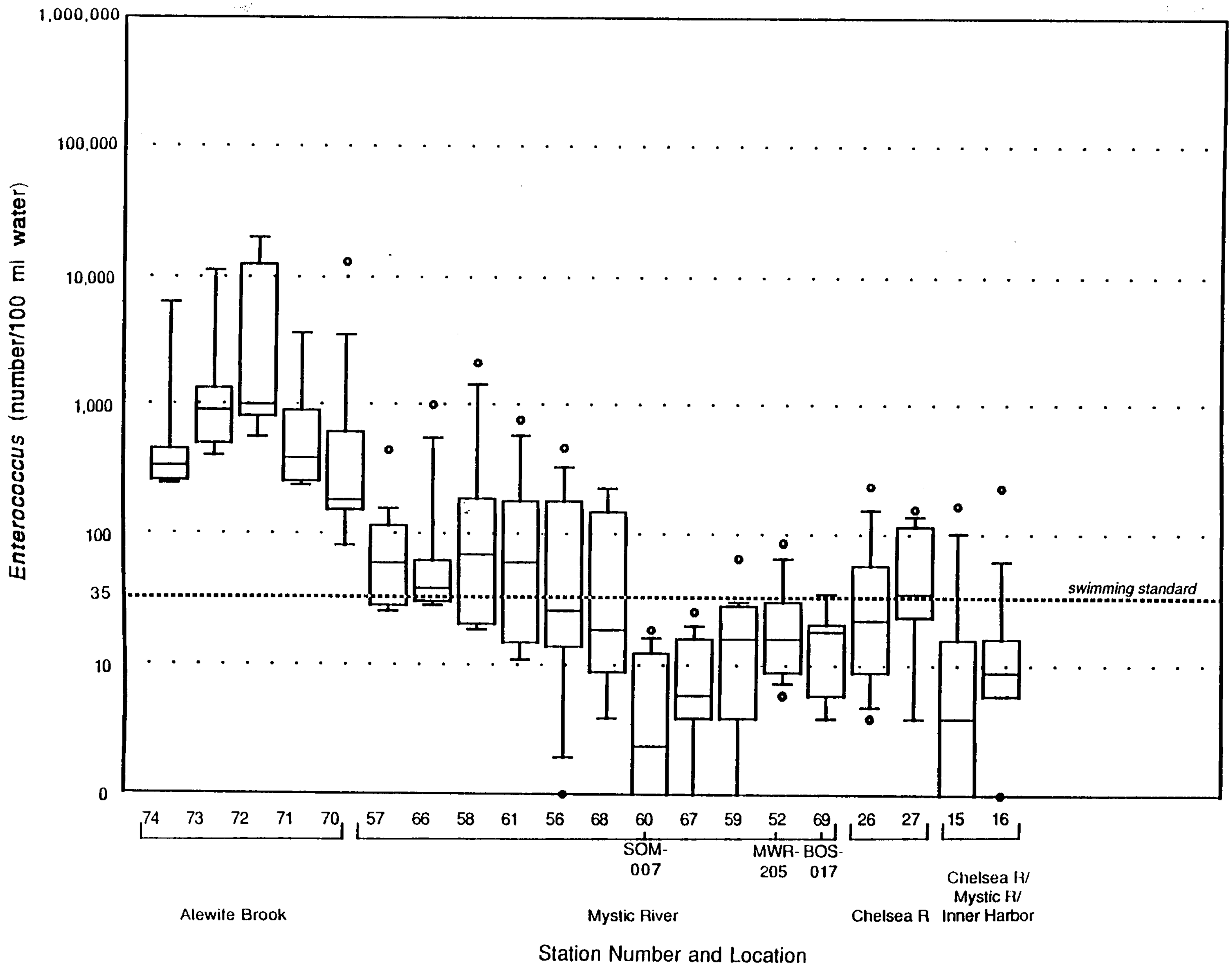


Figure 6.04. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in Alewife Brook and the Mystic and Chelsea Rivers, 1989.

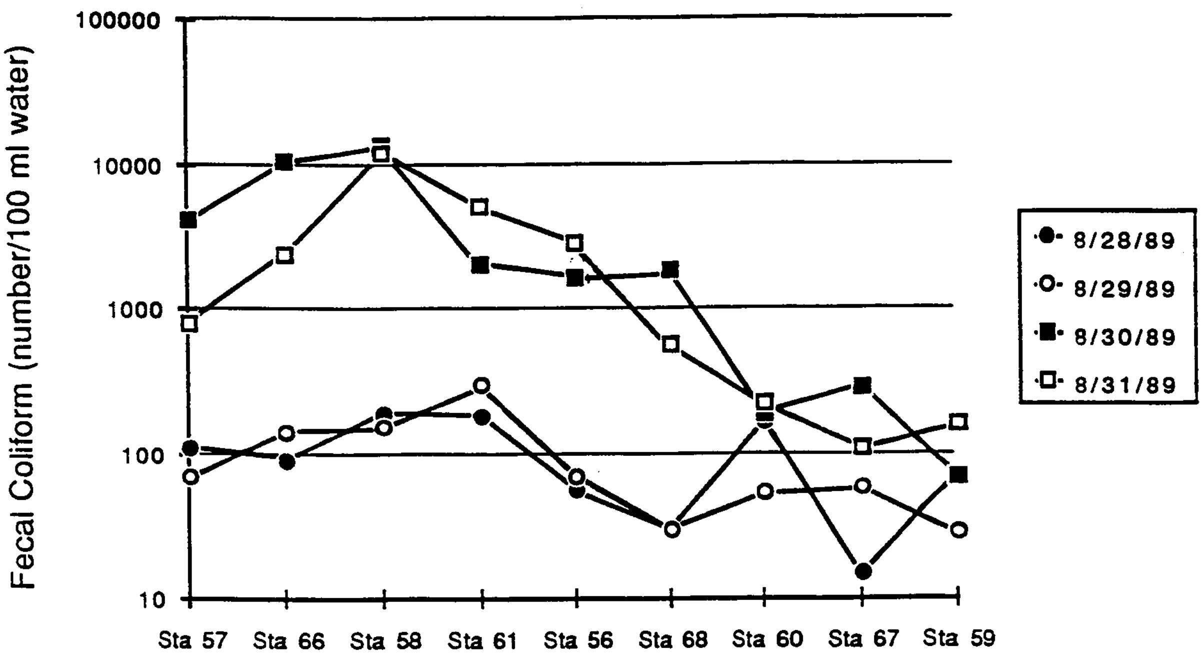


Figure 6.05. The Effect of Rain on Fecal Coliform Counts in Alewife Brook, 1989.

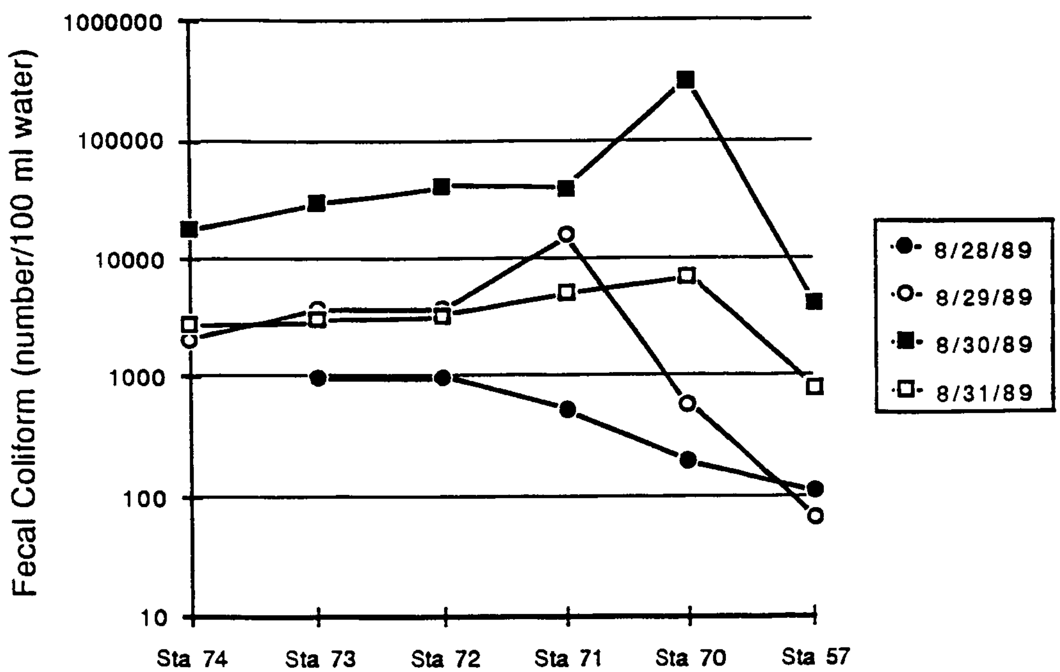


Figure 6.06. The Effect of Rain on Fecal Coliform Counts in the Mystic River, 1989.

Rainfall during this sampling period: August 28 = 0.00 in., August 29 = 0.39 in., August 30 = 0.10 in., August 31 = 0.00 in.

weather event: 0.39 in. of rain on August 29, followed by 0.10 in. on August 30. Geometric mean fecal coliform counts in Alewife Brook were significantly higher ($p < 0.05$) on August 30 and 31 than on August 28, before the rain. In the Mystic River, the spatial pattern of fecal coliform densities among stations differed before and after the rain. Before the rain, counts were approximately the same at all stations along the length of the Mystic River. After the rain, the highest counts were at the three stations nearest the confluence with Alewife Brook, with a general decreasing trend downstream. Geometric mean fecal coliform counts in the Mystic River were significantly ($p < 0.05$) higher on August 30 and 31 than on August 28 and 29.

In response to the small rainstorm described above, the pattern of *Enterococcus* counts in the Mystic River and Alewife Brook was similar to the pattern of fecal coliform counts. The elevation of counts after the rain was most evident at stations near Alewife Brook.

In the marine stations, rainfall summed over two days was a significant but weak correlate of fecal coliform counts ($r = 0.49$, $p < 0.001$) and *Enterococcus* counts ($r = 0.21$, $p = 0.04$) for all stations considered together. At individual stations, the relationship with rainfall varied. Downstream in the Mystic River, samples from Station 52, near MWR-205, were weakly correlated with rain: here a rainfall variable incorporating exponential decay was the best correlate with bacterial indicators ($r = 0.55$, $p = 0.04$). Counts at this station were high during dry as well as rainy periods. Station 15, at the confluence of the Mystic and Chelsea Rivers, also showed a relatively weak correlation between fecal coliform counts and rain (the best correlation was with rain summed over two days, $r = 0.55$, $p = 0.01$), but Station 16 showed no significant relationship between bacteria densities and any rainfall variables examined.

At Stations 26 and 27 in the Chelsea River, neither fecal coliform nor *Enterococcus* showed significant correlations with rainfall.

6.1.d Relationship between Indicator Bacteria and Salinity

Surface samples from the marine stations (15, 16, 26, 27, 52, 69) were considered both as a group and individually to evaluate the relationship between salinity and indicator bacteria densities in this area. There were no significant correlations or regressions between either fecal coliform counts and salinity or *Enterococcus* counts and salinity for these five marine stations as a group or individually ($p > 0.05$ for all comparisons).

6.1.e Relationship between Indicator Bacteria and Tidal Current

In surface samples from marine stations, *t*-tests showed no statistical differences in bacteria densities for ebb compared to flood tide in surface samples. In bottom samples, fecal coliform were significantly higher on the flood tide ($t = 2.87$, $p = 0.006$), but *Enterococcus* showed no difference.

6.1.f Dissolved Oxygen

Figure 6.07 shows percentile box plots for surface dissolved oxygen (DO) measurements. In the freshwater portion of the Mystic River, surface DO measurements were well above 5.0 mg/l. However, at the two lower Mystic saltwater stations below the Earhart Dam, DO measurements were considerably lower (the mean was 4.2 mg/l for Station 52 and 5.9 mg/l for Station 69). Bottom DO measurements at Station 52 had a mean of 3.1 mg/l.

In Alewife Brook, median levels of DO ranged from 4.0 mg/l at Station 73 to 6.25 mg/l at Station 70. All measurements were made during daylight, the time in the diurnal cycle when DO levels are expected to be highest.

In the Chelsea River, approximately 95% of the measurements at Stations 26 and 27 showed surface DO levels above 5 mg/l, whereas only half of bottom measurements were above 5 mg/l.

6.2 1990 Results

6.2.a Sampling Locations and Rainfall

Figure 6.08 shows the stations in Alewife Brook, the Mystic River, and the Chelsea River that were sampled during 1990. Because so little variation was found along the length of Alewife Brook in 1989, we deleted three stations from this area in 1990, leaving one station at the head of the brook and another just upstream of the confluence with the Mystic River. Stations 66, 58, 61, and 68 were not sampled in 1990 because they were not near CSOs. To assess the effects of possible upstream sources, one station, 83, was added in the Mystic River, upstream of the confluence with Alewife Brook. Rainfall during the sampling period, August 15 to 31, is shown in Figure 6.09. There were five days of precipitation, with four days of rain falling on the consecutive days August 23, 24, 25, and 26, and the heaviest rainfall, 1.58 in., falling on August 25.

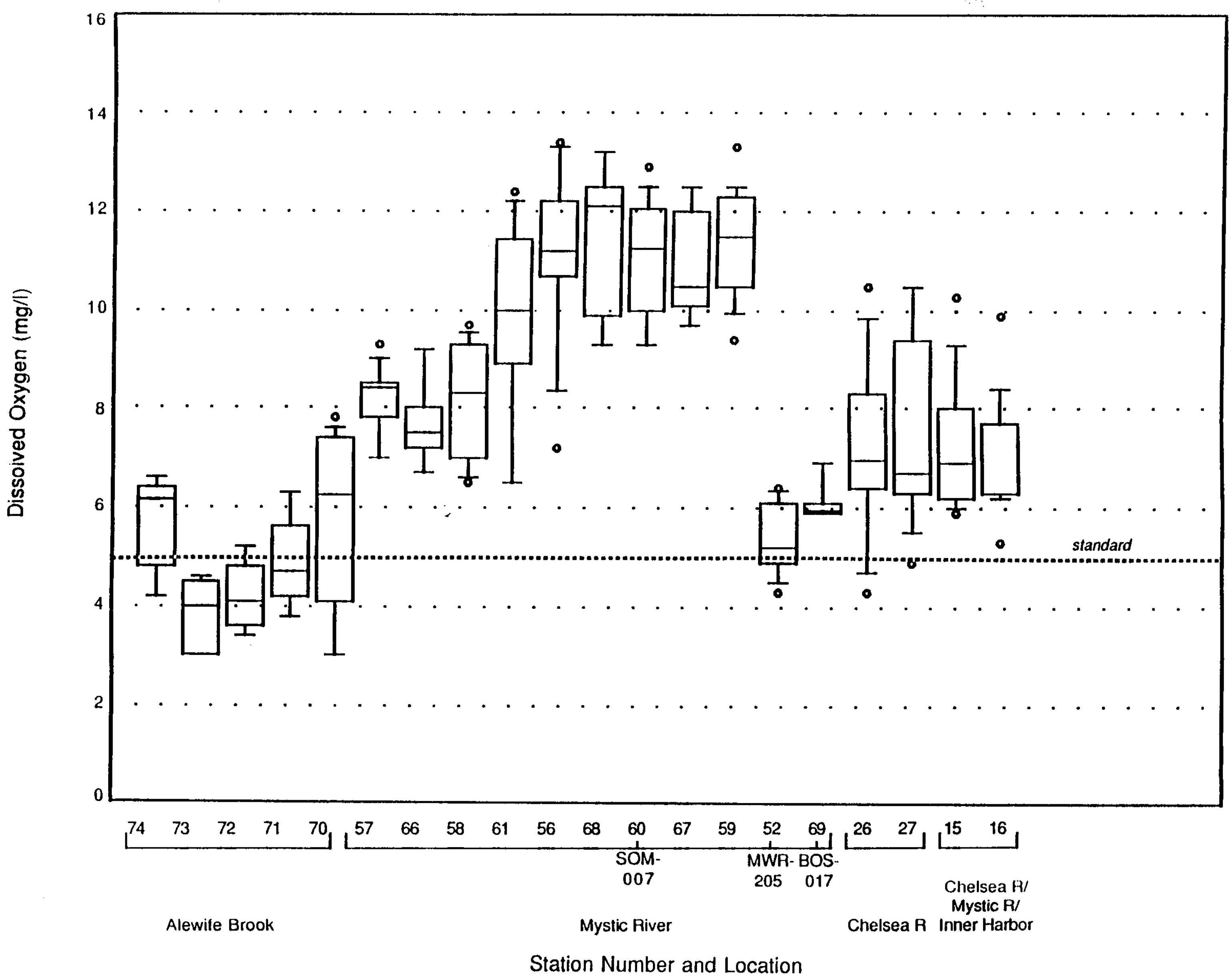


Figure 6.07. Percentile Box Plots of Surface Dissolved Oxygen Measurements in Alewife Brook and the Mystic and Chelsea Rivers, 1989.

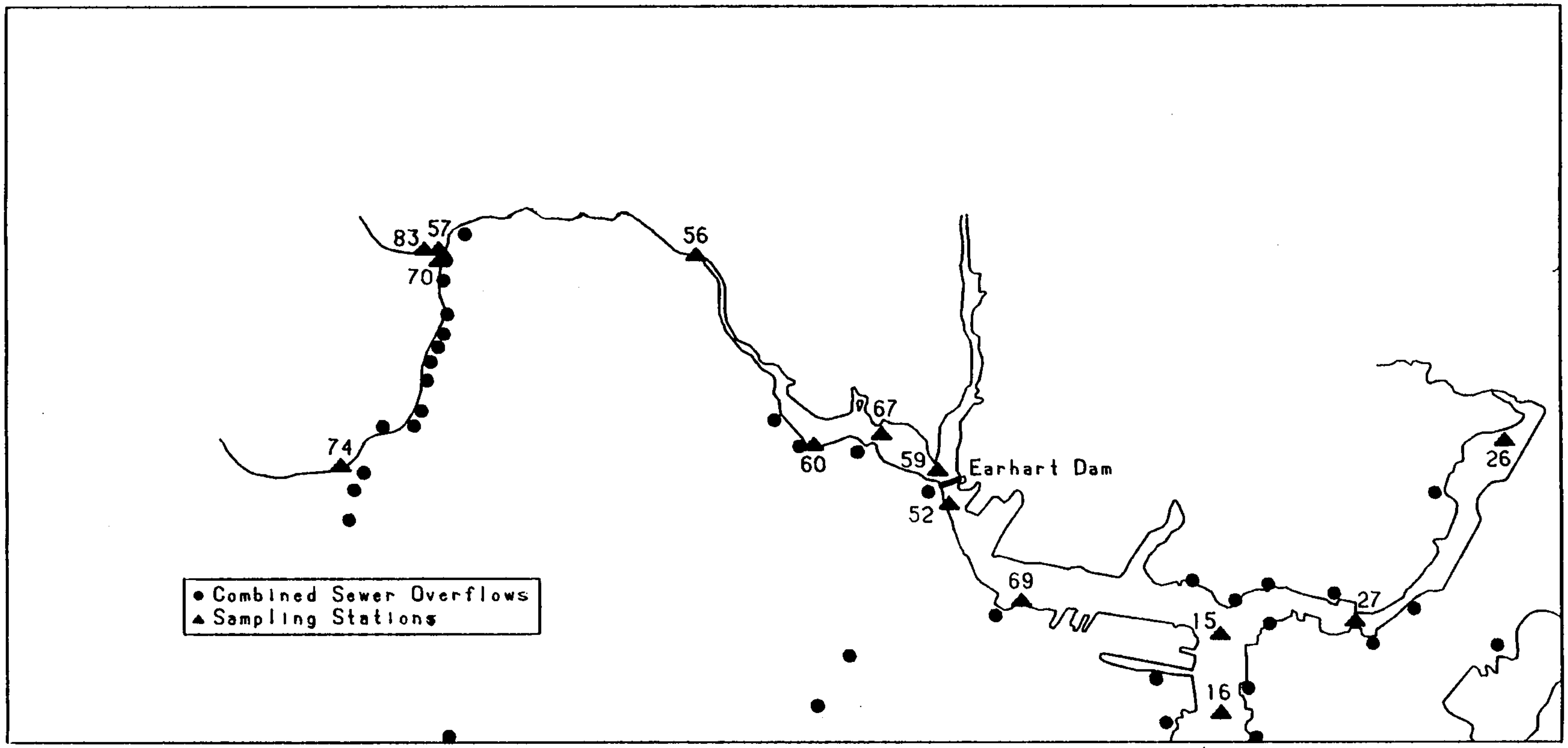


Figure 6.08. Stations Sampled during the 1990 Monitoring in Alewife Brook and the Mystic and Chelsea Rivers.

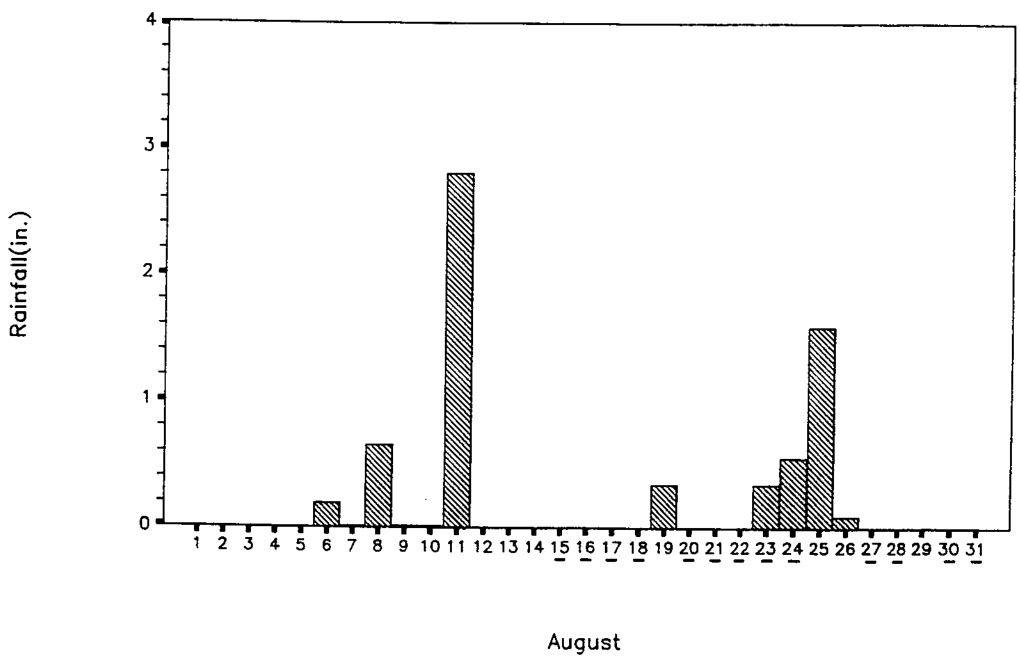


Figure 6.09. Daily Rainfall during the 1990 Monitoring Period for Alewife Brook and the Mystic and Chelsea Rivers.

Samples were collected on dates underlined.

6.2.b Indicator Bacteria Counts

Fecal Coliform

Percentile box plots for fecal coliform counts in Alewife Brook, the Mystic River, and the Chelsea River are shown in Figure 6.10. Geometric means and corresponding confidence intervals are given in Table 6.01. In the freshwater portion of this area, the highest geometric mean counts, greater than 200 col/100 ml, were at the two Alewife Brook stations, and, in the Mystic River, at Station 56, which is not near any obvious source of sewage. The station with the lowest geometric mean count was Station 83, in the Mystic River upstream of the Alewife Brook confluence.

Among surface samples collected in the marine portion of the area, the highest fecal coliform counts were found at the two Mystic River stations below the Earhart Dam (Station 52, near MWR-205, and Station 69, near BOS-017). The other four marine stations (26, 27, 15, 16), located in the Chelsea River and at the confluence of the Mystic and Chelsea, all had geometric mean counts below 200 col/100 ml.

Samples were collected from bottom waters at the six marine stations. Near MWR-205 (Station 52), the geometric mean fecal coliform count from bottom samples was higher than the surface average. At the other five marine stations, bottom counts were significantly lower ($p < 0.05$) than surface counts.

Enterococcus

Enterococcus counts (Figure 6.11) followed a pattern similar to fecal coliform, except for Station 52, near MWR-205. Here, unlike fecal coliform counts which were very high, *Enterococcus* counts were relatively low, with a surface geometric mean of 27 col/100 ml and a bottom geometric mean of 43 col/100 ml (Table 6.01).

At Stations 15 and 16, in the Inner Harbor section, where fecal coliform geometric mean counts were below 200 col/100 ml, *Enterococcus* geometric means exceeded EPA swimmability standards.

6.2.c Relationship between Indicator Bacteria and Rainfall

In the freshwater portions of the Alewife/Mystic area, correlation and regression analyses showed that indicator bacteria counts were only weakly related to any rainfall variables, both when the stations were considered as a group and when they were considered individually. There were no more significant correlations with rain than would be expected by chance alone.

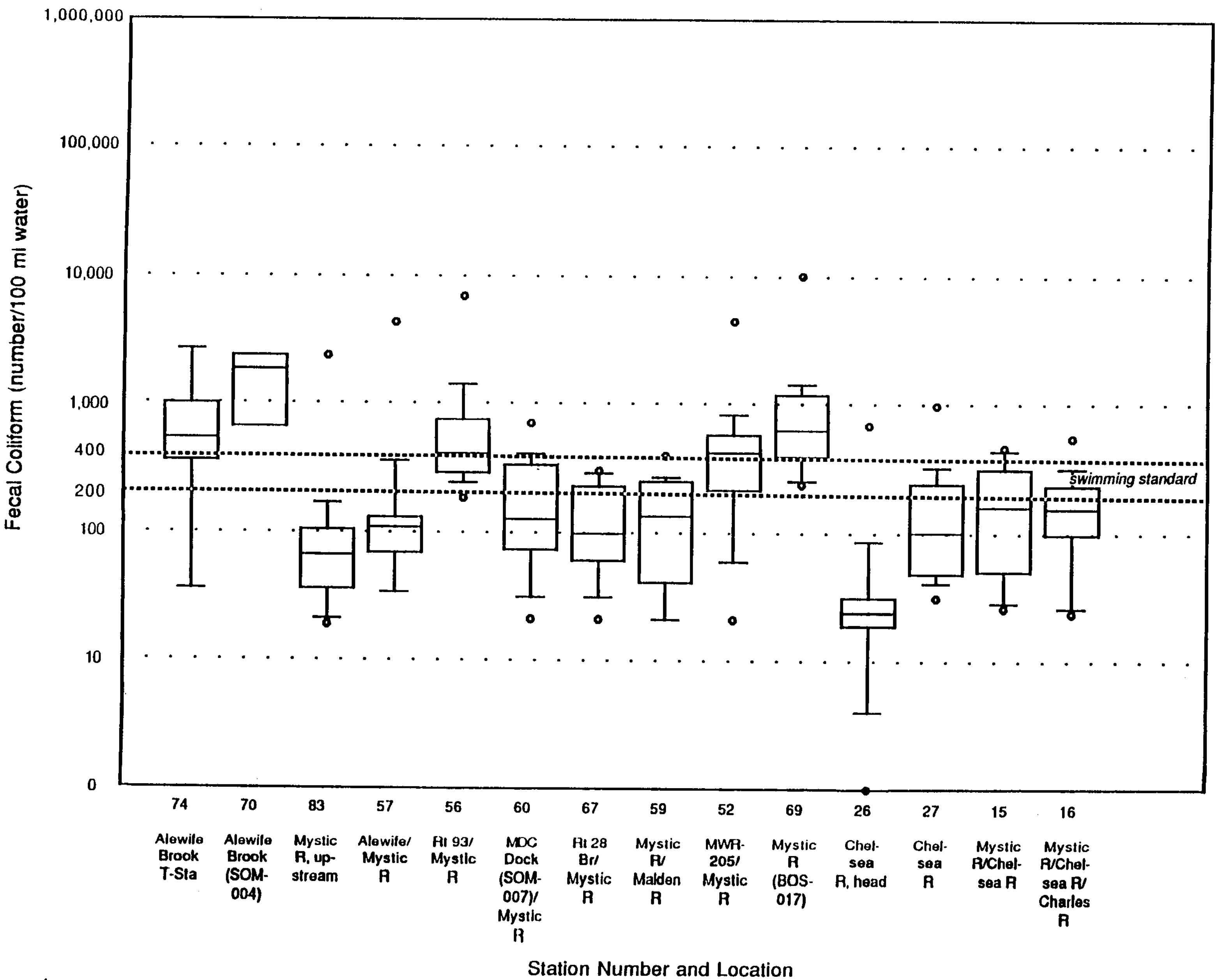


Figure 6.10. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in Alewife Brook and the Mystic and Chelsea Rivers, 1990.

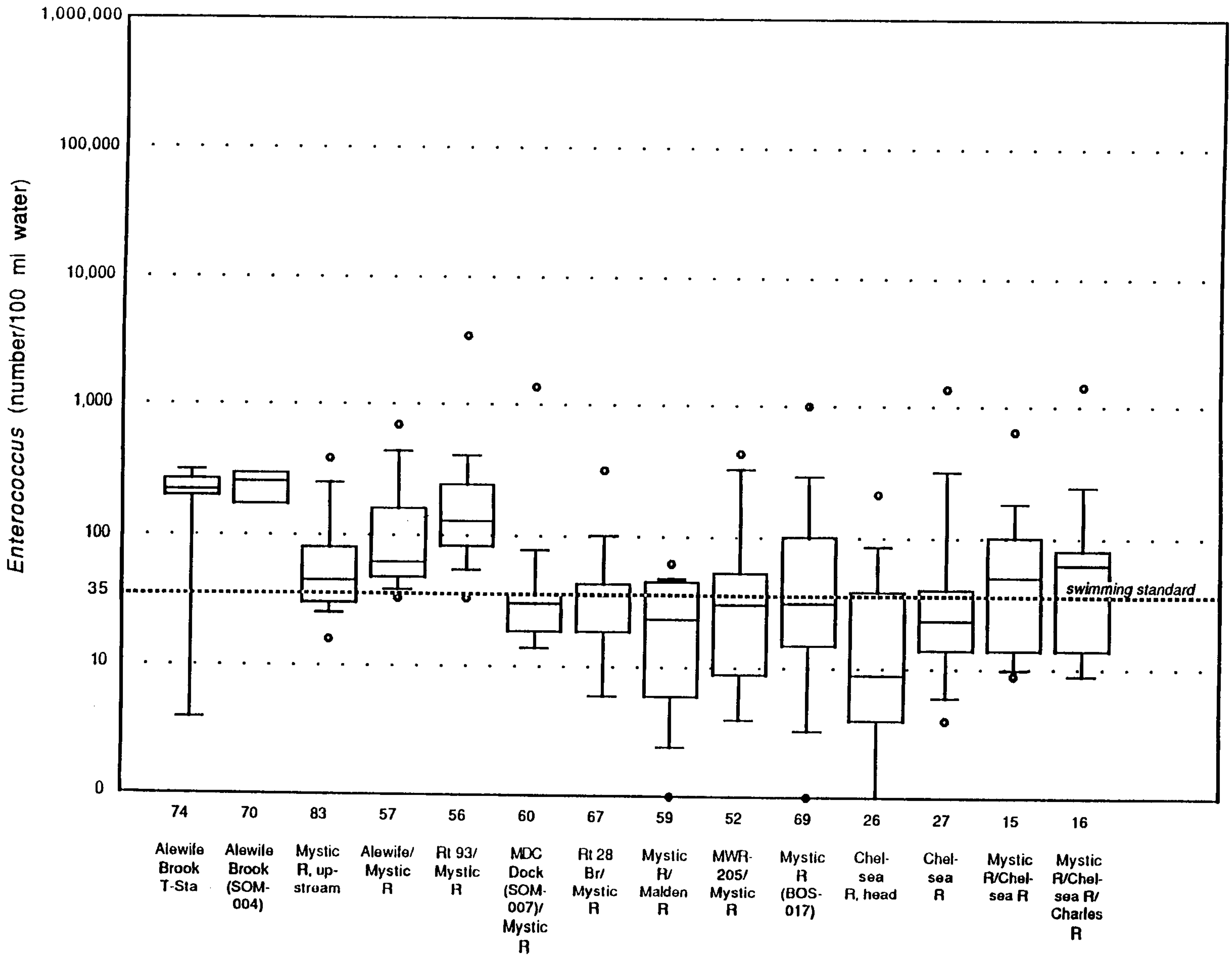


Figure 6.11. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in Alewife Brook and the Mystic and Chelsea Rivers, 1990.

At the marine stations (15, 16, 26, 27, 52, 69), for all stations (surface samples) considered together, there were no significant correlations between fecal coliform counts and rainfall variables. However, for *Enterococcus*, seven rainfall variables were significantly correlated with bacteria densities. The strongest correlate was LORNE4 [four days of rain summed, with an exponential decay factor ($r = 0.54, p < 0.001$)]. For stations considered individually, fecal coliform counts showed significant correlations with rainfall variables at only two stations. LORNE3 (rain summed over three days with decay factor) was significantly related to fecal coliform at Station 15 ($r = 0.54, p = 0.04$) and Station 16 ($r = 0.57, p = 0.02$). *Enterococcus* counts showed a more consistent pattern of significant correlations with rain among stations, with significant relationships with a suite of rainfall variables at Station 15 (for LORNE3, $r = 0.79$, $p = 0.002$), Station 16 (for LORNE3, $r = 0.79, p = 0.001$), Station 26 (for LORNE3, $r = 0.48$, $p = 0.048$), Station 52 (for LORNP3, $r = 0.73, p = 0.002$), and Station 69 (for LORNE4, $r = 0.64$, $p = 0.012$). There were no significant relationships with rainfall for either indicator at Station 27.

The lack of a consistent relationship between rainfall and fecal coliform counts in the Mystic River is illustrated in Table 6.02. Four days of "dry" (no rain had occurred for four or more days) and four days of "wet" (rain occurred either on the day of sampling or the day before sampling) fecal coliform measurements in the Alewife Brook and the Mystic River are given. Three (Stations 67, 59, and 62) out of eight stations had geometric mean wet-weather counts less than geometric mean dry-weather counts.

The 0.34 in. of rain that fell on August 19 was followed on August 20 by a dramatic increase in counts to levels above 2,000 col/100 ml at Stations 83, 57, and 56, but the rain seemed to have no effect at the stations in the Mystic River Basin (67 and 59) or at Stations 52 and 69 in the lower Mystic below the dam. On August 23, 0.34 in. of rain again fell, but there were no increases in fecal coliform counts at the upstream stations (83 and 57), in the Basin, or at Station 52. However, we measured very high fecal coliform (10,100 col/100 ml) at Station 69. Although counts at some stations were elevated after some rains, there was a substantial variation within stations in response to rain.

6.2.d Relationship between Indicator Bacteria and Salinity

Stations 15, 16, 26, 27, 52, and 69, the marine stations in the Mystic/Chelsea area, were analyzed for the relationship between indicator bacteria counts and salinity. When all stations were considered together, there were significant correlations between fecal coliform counts and salinity ($r = -0.36, p = 0.001$) and between *Enterococcus* and salinity ($r = -0.49, p < 0.001$). When stations were considered individually, significant correlations between bacteria counts and salinity were not found at most stations. Two stations, in the nearfield zone of CSOs, did show significant correlations: Station 52, near MWR-205 (r of fecal coliform with salinity = -0.19, p = NS; r of *Enterococcus* with salinity = -0.86, $p < 0.001$) and Station 69,

Table 6.02. Fecal Coliform Counts (colonies/100 ml) in Alewife Brook and the Mystic River during Wet and Dry Weather in August 1990

	Dry Weather*					Wet Weather†				
Station	8/15/90	8/16/90	8/17/90	8/18/90	Geomet Mean	8/20/90	8/23/90	8/24/90	8/27/90	Geomet Mean
74	...	...	...	...	...	350	...	993	...	...
70	...	...	...	...	...	1,825	...	...	...	...
83	165	128	18	65	70	2,350	78	35	48	132
57	105	120	53	353	124	4,375	130	108	33	212
56	743	345	270	283	374	6,925	1,400	760	338	1,256
60	325	125	58	30	92	400	700	75	340	291
67	295	140	20	135	103	45	60	30	280	69
59	390	85	20	180	104	133	40	20	200	68
52	235	425	593	543	423	400	168	...	445	310
69	353	1,400	1,100	680	780	380	10,100	248	540	847

*Dry weather is defined as no rain for 4 or more days.

†Wet weather is defined as rain on either the day of sampling or the day before sampling.

near BOS-017 (r of fecal coliform with salinity = -0.71, $p = 0.003$; r of *Enterococcus* with salinity = -0.64, $p = 0.012$).

6.2.e Relationship between Indicator Bacteria and Tidal Current

When the marine stations were tested for tidal effect on indicator bacteria density, flood-tide counts were greater than ebb for surface *Enterococcus* measurements ($t = 4.25$, $p = 0.001$), but there was no difference in fecal coliform counts with tidal cycle. Bottom samples showed no difference in counts by tidal cycle for either *Enterococcus* or fecal coliform.

6.2.f Dissolved Oxygen

All DO measurements were taken during the day. Figure 6.12 shows the percentile distributions of surface DO measurements. Except at Station 52, below the Earhart Dam, 90% or more measurements at all stations were above 5 mg/l. Bottom measurements were made at the five marine stations (Figure 6.13). As would be expected, DO levels at the bottom were significantly lower than at the surface, ($t = 4.7$, $p < 0.001$), with 40% to 50% of the measurements less than 5 mg/l. Some very low measurements, <3 mg/l, were recorded at Station 52 at the bottom.

6.3 Discussion

6.3.a Trends by Geographic Area

Alewife Brook

Alewife Brook is one of the most polluted streams in the greater Boston area. It has been impacted by industrial pollution, contaminated stormwater, and CSOs. Low levels of DO and high densities of fecal coliform, as observed in this study, have been noted previously by the Massachusetts Division of Water Pollution Control (MDEP, 1988) and during the 1988 sampling for the MWRA CSO Facilities Plan (MWRA, 1990). During sampling in both 1989 and 1990, we saw visible evidence of raw sewage pollution in the brook, including toilet paper and other "floatables" in the vegetation along its banks. Fecal coliform counts far exceeded state standards for class B waters, and DO measurements typically were below the 5 mg/l standards, even during daylight hours.

In 1988, DWPC noted a dramatic difference in fecal coliform levels between samples collected in July during dry weather and samples taken in September after 0.28 in. of rain. Similarly, in the present study,

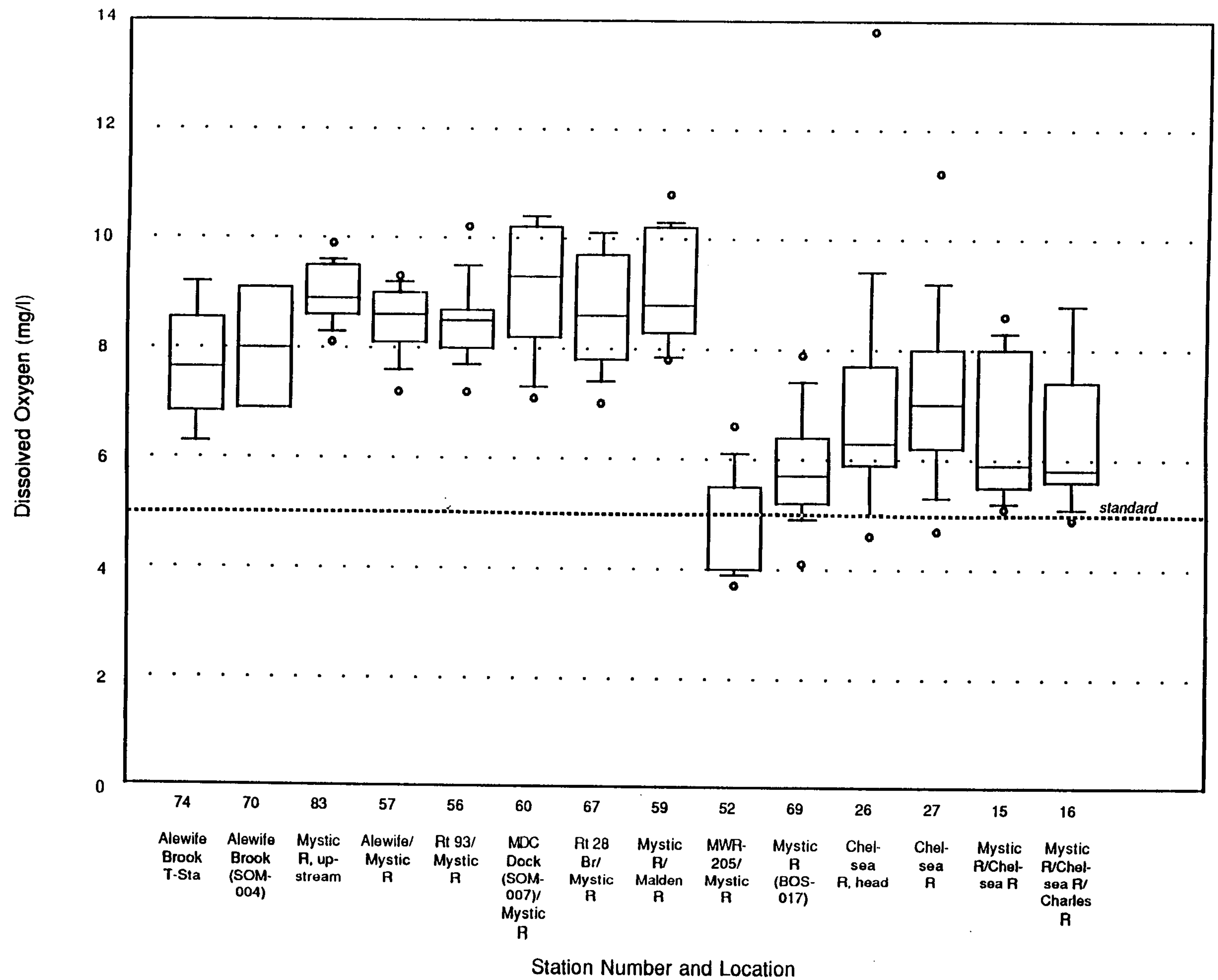


Figure 6.12. Percentile Box Plots of Surface Dissolved Oxygen Measurements in Alewife Brook and the Mystic and Chelsea Rivers, 1990.

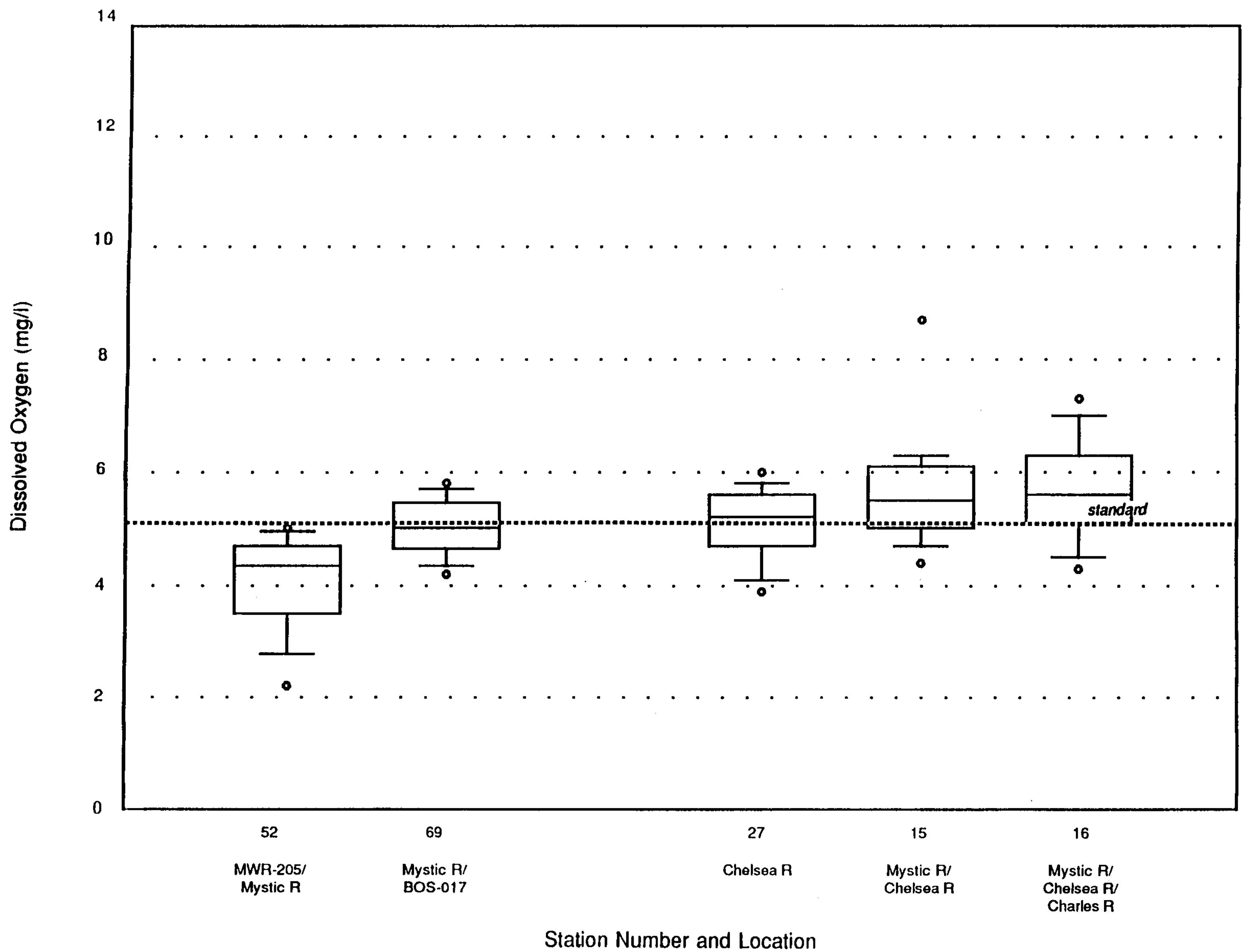


Figure 6.13. Percentile Box Plots of Bottom Dissolved Oxygen Measurements at the Five Marine Stations in the Mystic and Chelsea Rivers, 1990.

we observed that fecal coliform density increased by approximately an order of magnitude in Alewife Brook waters after only 0.39 in. of rain in August 1989. Interestingly, the City of Cambridge reported no measured overflows from its Alewife CSOs (CAM-001, CAM-002, CAM-003, CAM-004, CAM-400, CAM-410) after that rainfall, which suggests that sewage was contributed by another source (e.g., contaminated stormwater).

Because previous work had well established that Alewife Brook is grossly impacted by sewage pollution, and because there was little variation along the length of the brook, in 1990 we decreased the number of stations sampled and the number of samples taken in the brook. The 1990 results were similar to those observed in 1989: in one case, high fecal coliform counts occurred after only 0.34 in. of rain.

Although the differences in geometric means at the two Alewife Brook stations sampled in both years (Stations 70 and 74) were not statistically significant due to the small number of samples collected, the 1990 geometric means were lower.

Mystic River

In addition to the combined sewers in Alewife Brook, which feeds into the Mystic River, there are three CSOs in the Mystic upstream of the Earhart Dam: SOM-005, just downstream of the Alewife/Mystic confluence, between Stations 57 and 66; SOM-007, in the Mystic River basin near the MDC sailing dock, near Station 60; and SOM-007A near Station 67 (between Stations 60 and 59).

In 1989, the overall pattern of sewage indicator bacteria in the Mystic River was one of decreasing densities from the confluence with the Alewife to the Earhart Dam. Thus, Alewife Brook appears to be a significant source of sewage to the Mystic River. The lowest counts were found at Station 83 in the Mystic, upstream of the confluence with the Alewife; but this station showed elevated counts during wet weather, implying that there are significant non-CSO sources of pollution far upstream in the river.

Station 58 was an exception to the trend of declining counts along the Mystic River. This station was near an outfall that was not a CSO but still apparently discharged sewage. Station 56 also had very high counts in both 1989 and 1990. High counts here are difficult to explain, because there are no obvious point sources of sewage nearby.

In both years, the best water quality was in the "Basin" area of the Mystic, just upstream of the dam.

Lower Mystic and Chelsea Rivers

The general pattern of declining counts downstream along the Mystic River was reversed below the dam, where samples were taken in the nearfield area of the CSOs MWR-205 (Station 52) and BOS-017 (Station 69).

At Station 52, near the only CSO in this area from which flow measurements are available (MWR-205), correlation analyses showed a general positive and significant relationship between fecal coliform counts in the water and preceding rainfall. The somewhat stronger relationship found in 1990 may be due to the fact that more rain fell during that year's sampling period.

A more detailed look at the variability in the way the quality of the receiving water corresponded to flow from MWR-205 is provided in Table 6.03. This table lists rainfall, measured flow from MWR-205, and fecal coliform and *Enterococcus* densities measured in the receiving water during sampling periods in 1989 and 1990. Although three of the highest fecal coliform counts in the receiving water (August 21 and 30, 1989, and August 24, 1990) followed rain events that resulted in overflows, other high counts followed dry periods when no overflows were reported (e.g., August 28, 1989, and August 21 and 22, 1990). There was also great variability in the relationship between the amount of rain that fell and the volume of overflow recorded.

It has been suggested that *Enterococcus* is a better indicator of marine water quality than fecal coliform because *Enterococcus* is more resistant to die-off in salt water and is therefore a more conservative indicator. However, at the marine stations sampled in this area, *Enterococcus* had a better correlation with rainfall than did fecal coliform because at some stations fecal coliform showed *elevated* counts in *dry* weather, whereas *Enterococcus* did not (e.g., at Station 52; see Table 6.03). It is not clear why this happened. It may be that the two indicators came from different sources at that station.

The tidal effects in this Inner Harbor area are also difficult to interpret: in 1989 fecal coliform counts in bottom samples were higher on the flood tide, but no tidal effect was evident in surface samples. In 1990, the only significant relationship with tide was that *Enterococcus* counts were greater on the flood tide than on the ebb. These data give no clear evidence that CSOs discharging on the outgoing tide were responsible for increased counts.

The relationship between indicator bacteria and salinity was not consistent between sampling years. In 1989, there were no significant salinity relationships, which may be due simply to lack of rain. In 1990, there were significant negative correlations at stations near MWR-205 and BOS-017. Interestingly, *Enterococcus* was significantly negatively correlated with salinity near MWR-205, but fecal coliform was not. This suggests that fecal coliform in the area may have come from a source that was not associated with

Table 6.03. Relationship among Rainfall, Flow from MWR-205, and Receiving Water Indicator Bacteria Counts at Station 52 in 1989 and 1990

Date	Rainfall (in.)	Flow (MGD)	Sample Depth*	Colonies/100 ml	
				Fecal Coliform	*Enterococcus*
8/21/89	0.35	7.07	S	7,550	85
			B	...	...
8/22/89	0.00	0.00	S	778	8
			B	538	15
8/23/89	0.05	0.00	S	540	30
			B	575	65
8/24/89	0.00	0.00	S	255	8
			B	58	13
8/25 - 8/27/89	0.00	0.00	...	...	...
8/28/89	0.00	0.00	S	7,600	15
			B	65	10
8/29/89	0.39	0.00	S	3,650	25
			B	320	13
8/30/89	0.10	2.00	S	9,700	58
			B	4,275	10
8/31/89	0.00	0.00	S	500	15
			B	100	15
9/1 - 9/4/89	0.00	0.00	...	...	...
9/5/89	0.00	0.00	S	2,650	5
			B	18	0
9/6/89	0.00	0.00	S	570	8
			B	35	3
9/7/89	0.00	0.00	S	905	65
			B	20	5
8/11/90	2.80	8.059	...	...	...
8/12 - 8/14/90	0.00	0.00	...	...	...
8/15/90	0.00	0.00	S	235	33
			B	540	128

*S = surface; B = bottom.

Table 6.03. Relationship among Rainfall, Flow from MWR-205, and Receiving Water Indicator Bacteria Counts at Station 52 in 1989 and 1990, continued

Date	Rainfall (in.)	Flow (MGD)	Sample Depth*	Colonies/100 ml	
				Fecal Coliform	*Enterococcus*
8/16/90	0.00	0.00	S	425	8
			B	448	50
8/17/90	0.00	0.00	S	593	3
			B	360	65
8/18/90	0.00	0.00	S	543	40
			B	195	45
8/19/90	0.34	0.524	...	...	...
8/20/90	0.00	0.00	S	400	8
			B	440	45
8/21/90	0.00	0.00	S	825	53
			B	1,550	88
8/22/90	0.00	0.00	S	4,450	18
			B	1,625	23
8/23/90	0.34	0.524	S	160	325
			B	900	100
8/24/90	0.55	0.305	S	...	163
			B	13,625	10
8/25/90	1.58	2.750	...	...	...
8/26/90	0.09	0.785	...	...	...
8/27/90	0.00	0.00	S	445	428
			B	338	128
8/28/90	0.00	0.00	S	188	30
			B	...	...
8/29/90	0.00	0.00	...	...	...
8/30/90	0.00	0.00	S	20	3
			B	28	13
8/31/90	0.00	0.00	S	325	5
			B	...	...

*S = surface; B = bottom.

freshwater input. Near BOS-017, both indicators were significantly and negatively correlated with salinity, which is consistent with a CSO source.

6.3.b Comparison of Descriptive Results for Indicator Bacteria in 1989 and 1990

Geometric means and confidence intervals for indicator bacteria (Table 6.01) generally were not statistically different when data for 1989 and 1990 were compared. A comparison of the distributions of results shown in the percentile box plots for fecal coliform (Figures 6.03 and 6.10) and for *Enterococcus* (Figures 6.04 and 6.11) reveals that, in general, fecal coliform counts tended to be lower in 1990 than 1989, whereas *Enterococcus* counts tended to be higher in 1990 than 1989.

6.4 Conclusions

- Water quality did not meet standards for Alewife Brook, the Mystic River, or the Chelsea River.

- Alewife Brook displayed severe water quality degradation, indicated by high densities of sewage indicator bacteria and low levels of DO, as well as aesthetic degradation due to the presence of sewage-derived paper and other visible waste. Pollution from Alewife Brook adversely affected the water quality of the upper portions of the Mystic River studied here. High levels of sewage pollution in the Alewife were associated with even modest amounts of rainfall, but some of this pollution was derived from sources other than CSOs.

- During wet weather, the segment of the Mystic River upstream of all CSOs exhibited high counts of fecal indicator bacteria. Stations remote from any known point source of sewage also showed high counts. Both observations imply that there were nonpoint sources to the Mystic.

- Although there was a positive and statistically significant correlation between rainfall and indicator bacteria densities in the receiving water near the Somerville Marginal outfall, the data were very variable. The results imply that there has been a nearby dry-weather source of fecal coliform, but not *Enterococcus*.

- Comparison of data from 1989 and 1990 did not show clear evidence of either improving or worsening water quality in these areas.

7. The Charles River

There are a number of combined sewer overflows (CSOs) along the length of the Charles River downstream of the Watertown Dam. However, most of the combined sewage that is discharged into the river receives treatment (screening and disinfection) at the Cottage Farm CSO treatment facility. Combined sewage is also screened and chlorinated at the Prison Point CSO treatment facility before discharge at the mouth of the Charles downstream of the Charles River Dam.

Sampling in the Charles River during 1989 focused on stations downstream of the Watertown Dam and upstream of the Charles River Dam. In 1990, we added a station upstream of the Watertown Dam to improve our understanding of upstream effects and a station downstream of the Charles River Dam to assess any effect of the Prison Point CSO facility.

Only surface samples were collected at most stations in the Charles River, with bottom samples collected at sites where the water was more than 20 ft deep.

7.1 1989 Results

In 1989, samples from the Charles River were not analyzed for *Enterococcus*. All results in Section 7.1 are for fecal coliform only.

7.1.a. Sampling Locations and Rainfall

Figure 7.01 shows the location of stations sampled in the Charles River during 1989. Most samples were taken between June 5 and June 22, but Stations 9 and 12 were also sampled in July and August. Daily rainfall during the sampling period is shown in Figure 7.02. Between June 5 and June 22 there were 10 days of relatively light (less than 0.3 in.) precipitation and one rainstorm greater than 0.5 in. (June 15).

7.1.b Indicator Bacteria Counts

Surface Samples

Figure 7.03 is a percentile box plot of fecal coliform counts in surface samples from the Charles River. The boxes are arranged with the most upstream station (Station 1) on the left and the most downstream station (Station 11) on the right. Station 1 is upstream of all CSOs. The median counts, as well as the geometric mean counts (shown in Table 7.01), at all stations were all above 200 col/100 ml, exceeding standards for

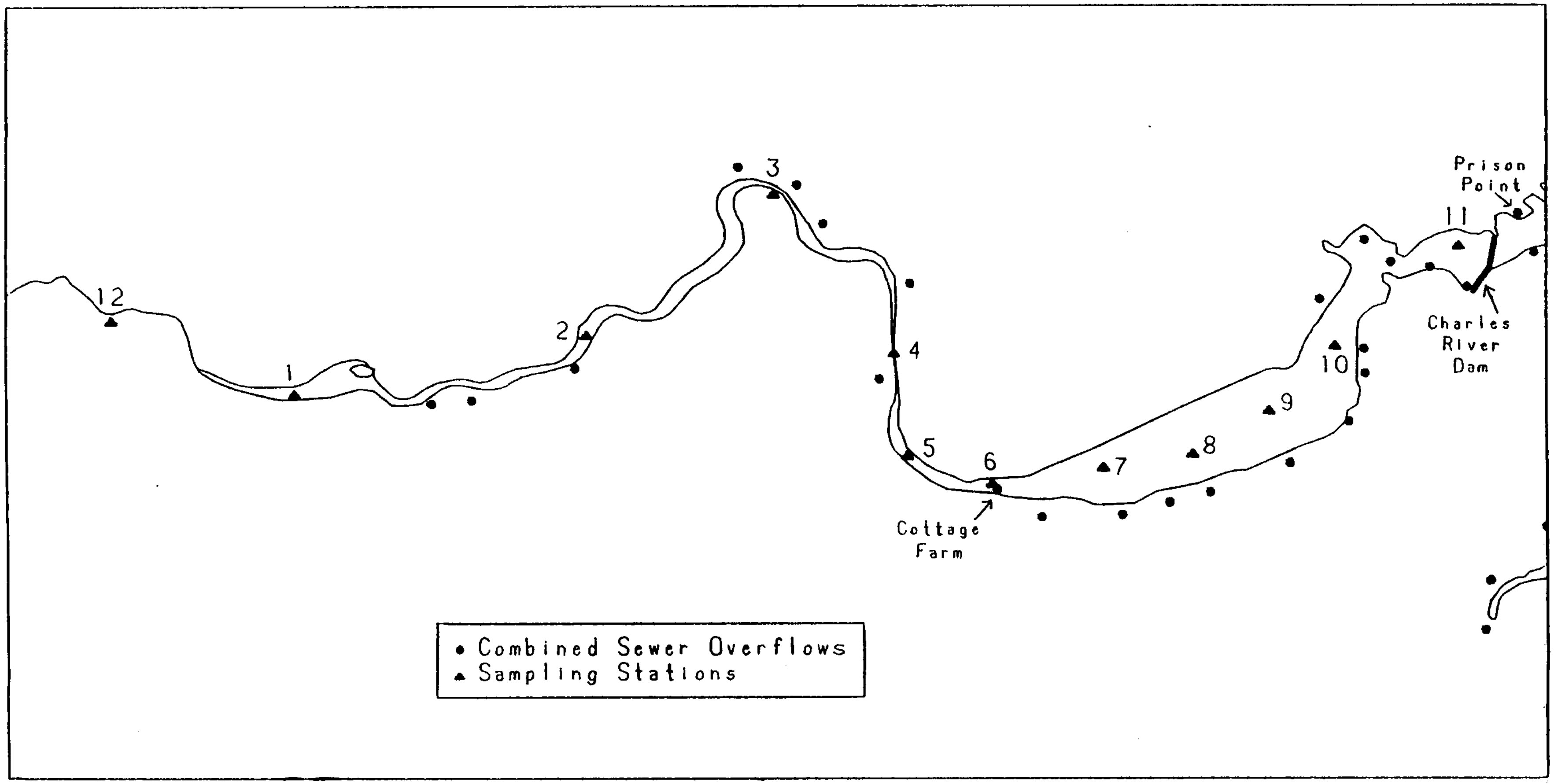


Figure 7.01. Stations Sampled during the 1989 Charles River Monitoring.

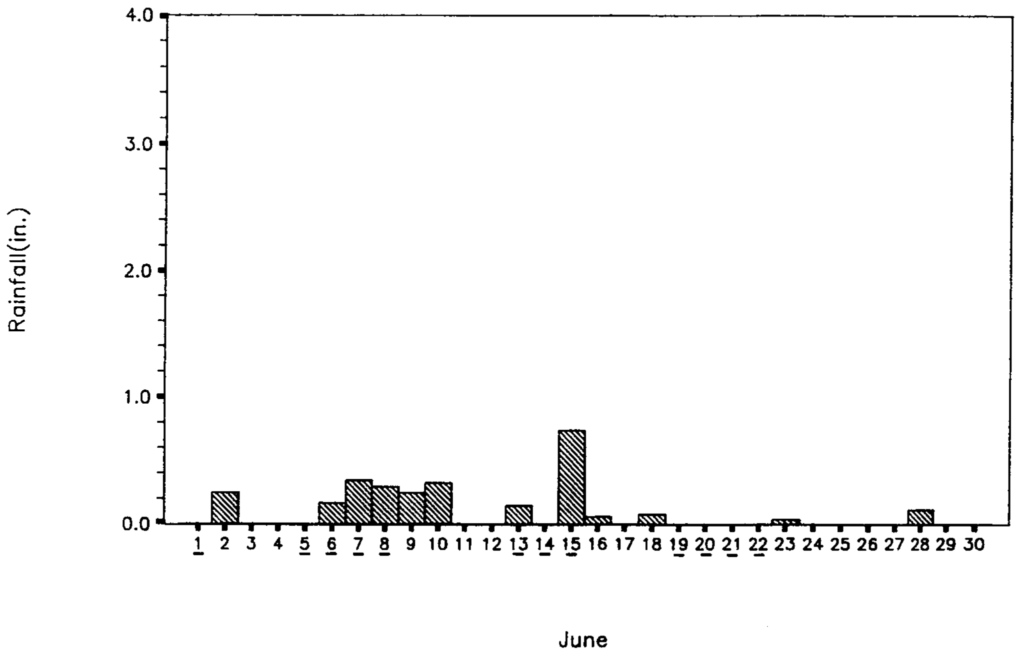


Figure 7.02. Daily Rainfall during the 1989 Charles River Monitoring Period.

Samples were collected on dates underlined.

Station 9 was also sampled on July 19, August 8, and August 25, and Station 12 was sampled August 8 and August 25 (not shown on figure.)

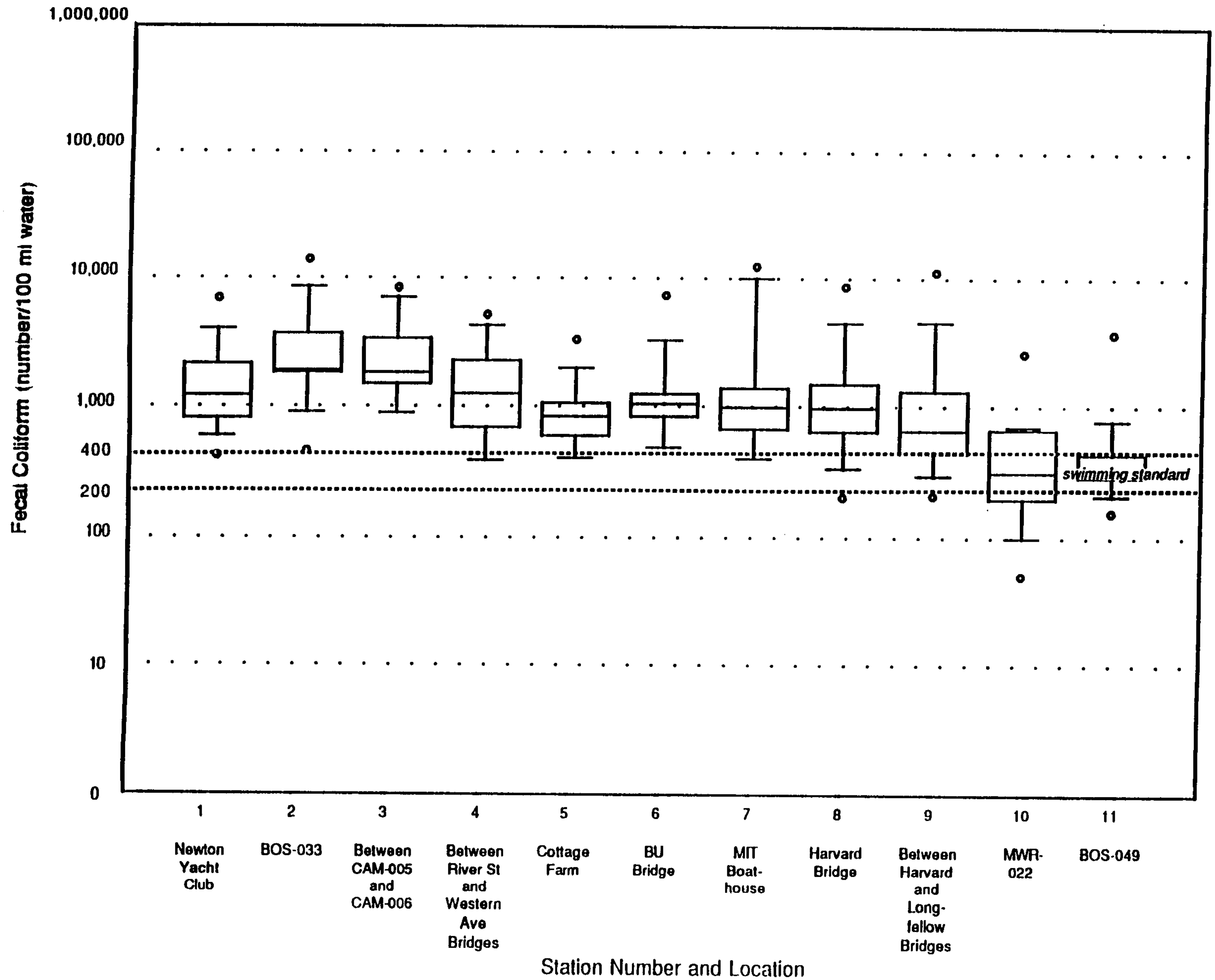


Figure 7.03. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in the Charles River, 1989.

Table 7.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Charles River Stations

Station			1989		1990	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal Coliform						
1	Newton Yacht Club	S	16	1546 (1042-2294)	19	1634 (825-3265)
		B	3	1282 (554-2963)	...	...
1.5	BOS-031	S	3	1524 (955-2434)	...	...
		B	...	...	...	...
2	BOS-033	S	10	2359 (1367-4072)	19	874 (483-1580)
		B	1	15699		
3	Between CAM-005 and CAM-006	S	8	2242 (1325-3795)	19	410 (186-905)
		B	...	...	...	...
4	Between River St and Western Ave Bridges	S	8	1301 (716-2360)	19	970 (586 (1602)
		B	...	...	...	...
5	Cottage Farm	S	9	1026 (639-1647)	19	554 (318-965)
		B	1	530	...	...
6	BU Bridge	S	9	1457 (789-2691)	19	654 (332-1287)
		B	7	2534 (974-6588)	11	1258 (380-4129)
7	MIT Boathouse	S	10	1646 (762-3556)	20	860 (364-2031)
		B	10	2500 (1094-5715)	10	981 (318-3019)
8	Harvard Bridge	S	11	1272 (670-2412)	18	999 (409-2426)
		B	11	1866 (693-5024)	10	1544 (606-3934)
9	Between Harvard and Longfellow Bridges	S	13	902 (488-1669)	19	299 (115-773)
		B	10	678 (222-2067)	11	580 (151-2212)
10	MWR-022	S	12	341 (200-581)	19	183 (73-489)
		B	13	131 (50-340)	11	78 (20-302)
11	BOS-049	S	12	383 (239-616)	39	113 (70-183)
		B	12	235 (130-426)	31	85 (46-157)
12	Watertown Dam	S	2	579 (170-1965)	17	3572 (1713-7429)
		B	...	...	...	...
14	Charles River/Coast Guard	S	...	...	37	107 (64-180)
		B	...	...	38	30 (15-61)

*S = surface; B = bottom.

Table 7.01. Geometric Means (number of colonies per 100 ml) with 95% Confidence Intervals (CI) for Charles River Stations, continued

Station			1989		1990	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Enterococcus						
1	Newton Yacht Club	S	...	...	19	427 (173-1046)
		B	...	...	...	...
2	BOS-033	S	...	...	19	241 (95-607)
		B	...	...	...	...
3	Between CAM-005 and CAM-006	S	...	...	19	96 (31-295)
		B	...	...	...	...
4	Between River St and	S	...	...	19	137 (55-343)
	Western Ave Bridges	B	...	...	...	...
5	Cottage Farm	S	...	...	19	85 (32-227)
		B	...	...	...	...
6	BU Bridge	S	...	...	19	134 (54-331)
		B	...	...	11	341 (103-1118)
7	MIT Boathouse	S	...	...	20	143 (57-352)
		B	...	...	10	177 (48-642)
8	Harvard Bridge	S	...	...	18	94 (32-270)
		B	...	...	10	274 (102-732)
9	Between Harvard and	S	...	...	19	19 (6-60)
	Longfellow Bridges	B	...	...	11	27 (9-76)
10	MWR-022	S	...	...	19	10 (3-26)
		B	...	...	11	8 (2-21)
11	BOS-049	S	...	...	39	11 (6-18)
		B	...	...	31	19 (12-47)
12	Watertown Dam	S	...	...	17	1270 (574-2817)
		B	...	...	...	...
14	Charles River/Coast Guard	S	...	...	37	8 (4-15)
		B	...	...	38	4 (2-8)

*S = surface; B = bottom.

class B waters. There was a general, average decreasing trend in fecal coliform densities from upstream to downstream. Median counts at Stations 1, 2, 3, and 4 were all above 1,000 col/100 ml; median counts at Stations 5, 6, 7, 8, and 9 were all between 400 col/100 ml and 1,000 col/100 ml; and median counts at Stations 10 and 11 were between 200 and 400 col/100 ml.

Bottom Samples

In bottom samples taken at stations where the water was deeper than 10 ft, there again was a decreasing trend of fecal coliform densities from upstream to downstream. Stations 6, 7, and 8 all had median counts above 1,000 col/100 ml; Station 9 had a median between 400 and 1,000 col/100 ml; and Stations 10 and 11 had median counts between 200 and 400 col/100 ml (data not shown). Although the difference was not statistically significant, average counts from bottom samples were higher than surface counts at Stations 6, 7, and 8; and average bottom-water counts at Stations 9, 10 and 11 were lower than surface counts.

Table 7.01 gives the geometric means with 95% confidence intervals for fecal coliform counts at all stations in the Charles River. At Stations 10 and 11, nearest the mouth of the Charles, fecal coliform densities were significantly lower than at Stations 1 through 8.

7.1.c Relationship between Indicator Bacteria and Rainfall

Figure 7.04 shows the regression of surface fecal coliform densities against rainfall summed over four days. For the amount of rain (0.74 in./day was the maximum) that fell during this sampling period, there was no significant relationship between rain and fecal coliform densities. This lack of association with rain held for the individual stations in the Charles as well as for all the stations taken together. Bottom samples yielded the same pattern of negative or weak correlations with rainfall as the surface samples.

There was, however, a significant association of rainfall with Deer Island flow during the time samples were collected from the Charles (e.g., DIFLOW with LORNP2, $r = 0.88$, $p < 0.001$).

7.1.d Relationship between Indicator Bacteria and Flows from Combined Sewers and Combined Sewer Treatment Facilities

Figure 7.05 shows all flows reported from the Cottage Farm facility (MWR-203) during June, and all the fecal coliform measurements obtained from surface samples at two adjacent stations: Station 5, upstream of the outfalls, and Station 6, in the nearfield zone of the outfalls. The figure illustrates the lack of association between flows or loads from the facility and fecal coliform counts at Station 6.

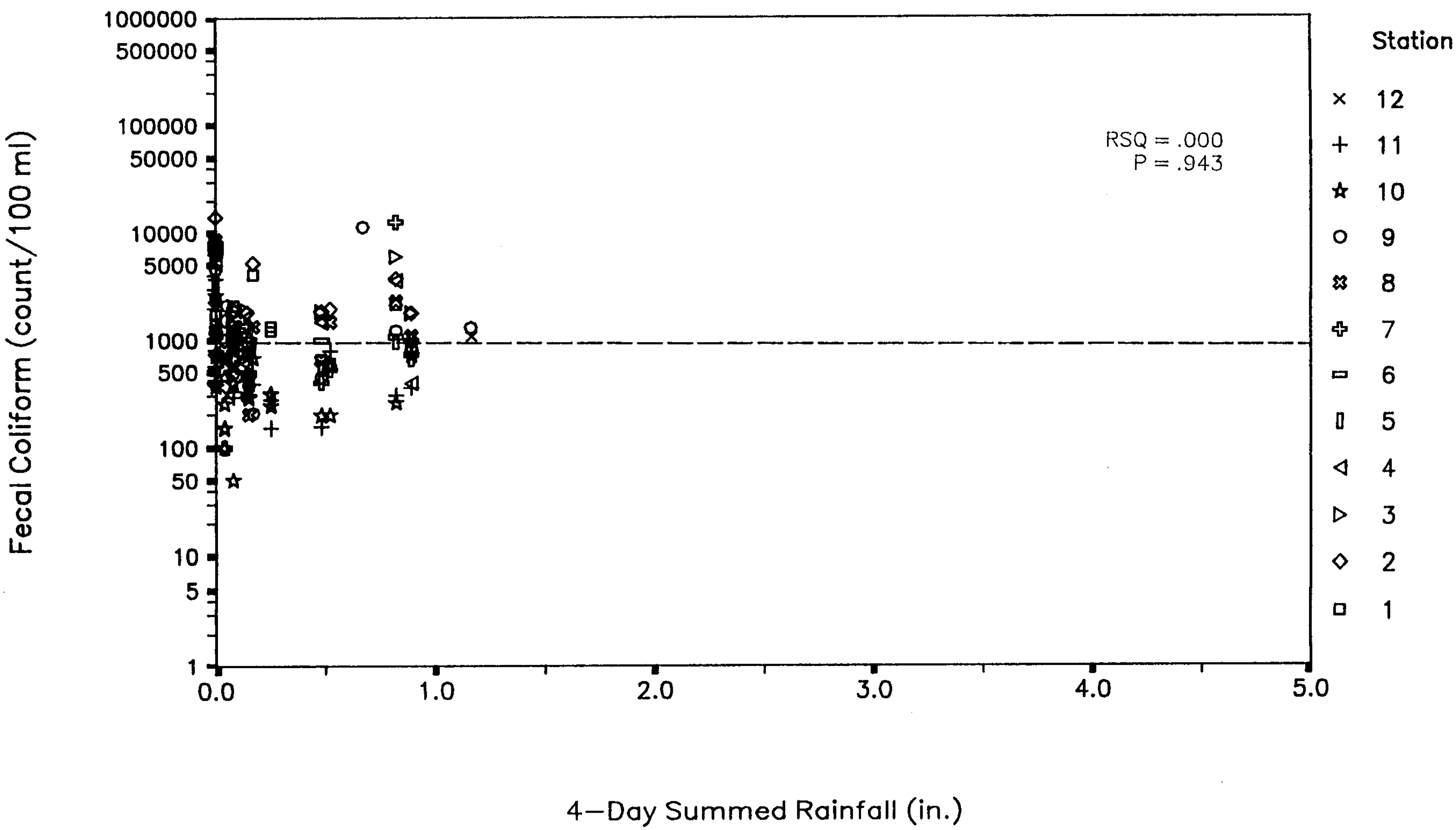


Figure 7.04. Relationship between Fecal Coliform Counts and 4-Day Summed Rainfall in the Charles River, 1989.

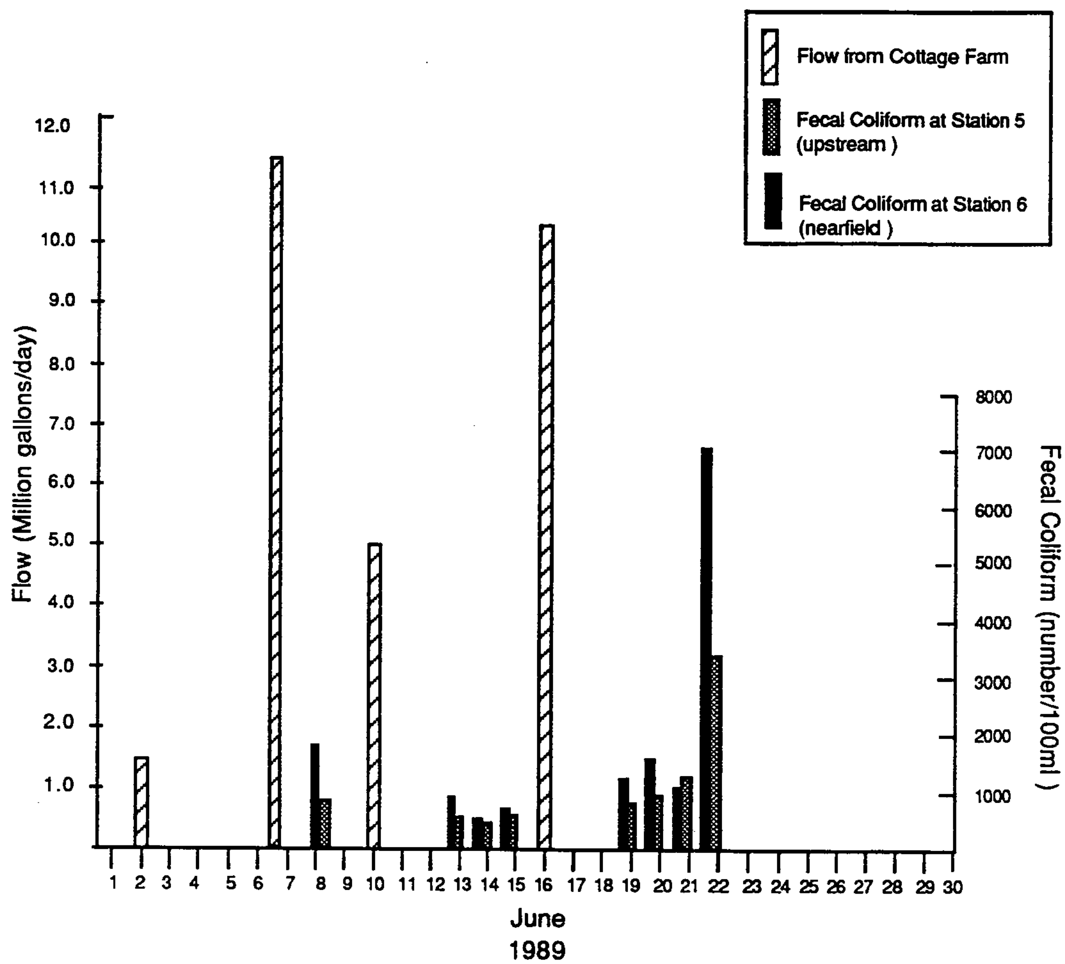


Figure 7.05. Relationship between Fecal Coliform Counts from Surface Samples at Downstream and Upstream Stations in the Charles River anf Flow from the Cottage Farm CSO, June 1989.

During this sampling period, the Cottage Farm treatment facility discharged four times. Only one of these discharges (June 7) was followed by sampling near the discharge pipes (Station 6) on the next day. The fecal coliform count in this sample was not higher than counts in samples taken four to seven days after a similar discharge on June 16.

According to flow records reported by the City of Cambridge, there was only one discharge event from a Cambridge CSO into the Charles River during this sampling period: 2,569 gallons from CAM-009 on June 7. The results of sampling on June 8 showed that Station 3, upstream of CAM-009, yielded higher counts (5,950 fecal coliform/100 ml) than Station 4 (3,550 fecal coliform/100 ml), downstream of CAM-009. Thus, any effect of the discharge from CAM-009 was effectively masked by the high level of upstream contamination.

7.1.e Dissolved Oxygen

Because of equipment failure, we were unable to obtain reliable dissolved oxygen measurements in the Charles River during June 1989.

7.2 1990 Results

7.2.a Sampling Locations and Rainfall

Figure 7.06 shows the location of the stations sampled in the Charles River from July 9 to 31, 1990. Two new stations were added: Station 12, upstream of the Watertown Dam, and Station 14, downstream of the Charles River Dam (estuarine conditions). Figure 7.07 shows the amount of rain that fell each day during the Charles River sampling period. Compared to 1989, there was considerably more rain: moderate rain fell on two successive days (July 12 and 13), light rain fell on one day (July 20), and relatively heavy rain fell on two successive days (July 24 and 25).

7.2.b Indicator Bacteria Counts

Surface Samples

Figure 7.08 shows percentile distributions of fecal coliform counts from surface samples in the Charles River, and Table 7.01 gives the geometric means and corresponding 95% confidence intervals for each station. The geometric means of all stations upstream of Station 10 were greater than 200 col/100 ml

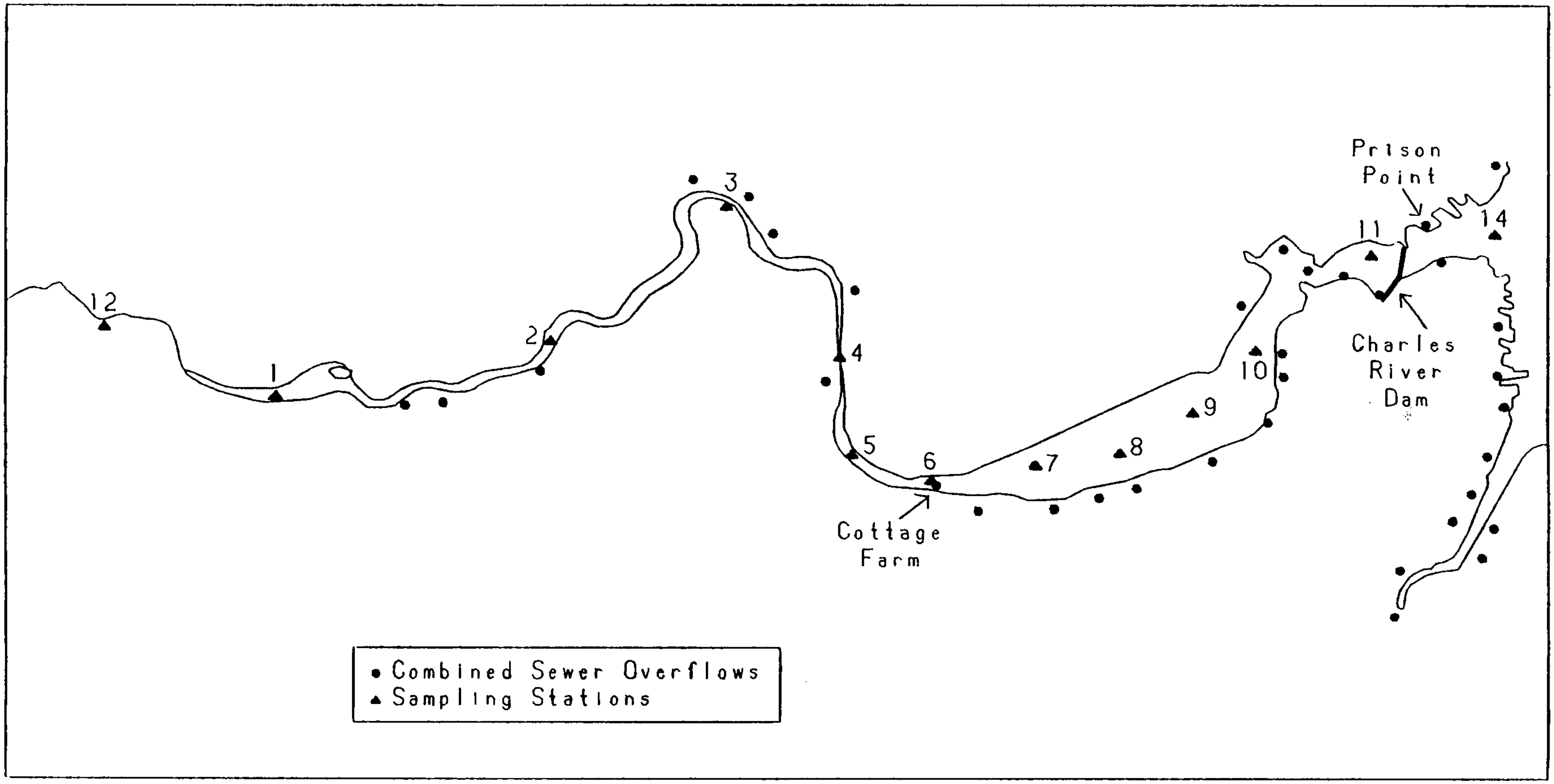


Figure 7.06. Stations Sampled during the 1990 Charles River Monitoring.

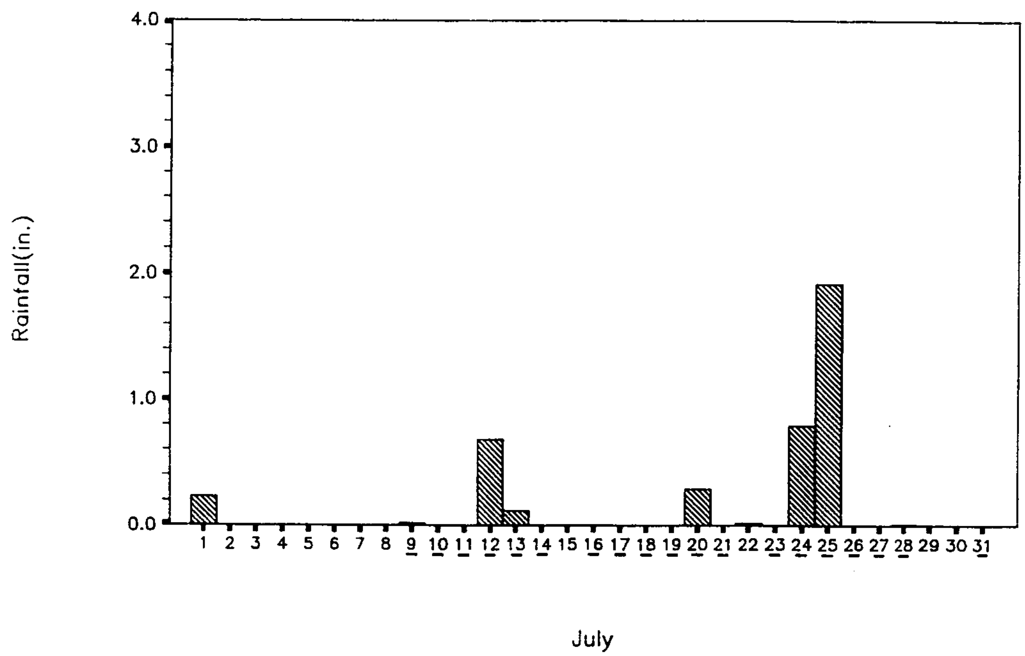


Figure 7.07. Daily Rainfall during the 1990 Charles River Monitoring Period.

Samples were collected on dates underlined.

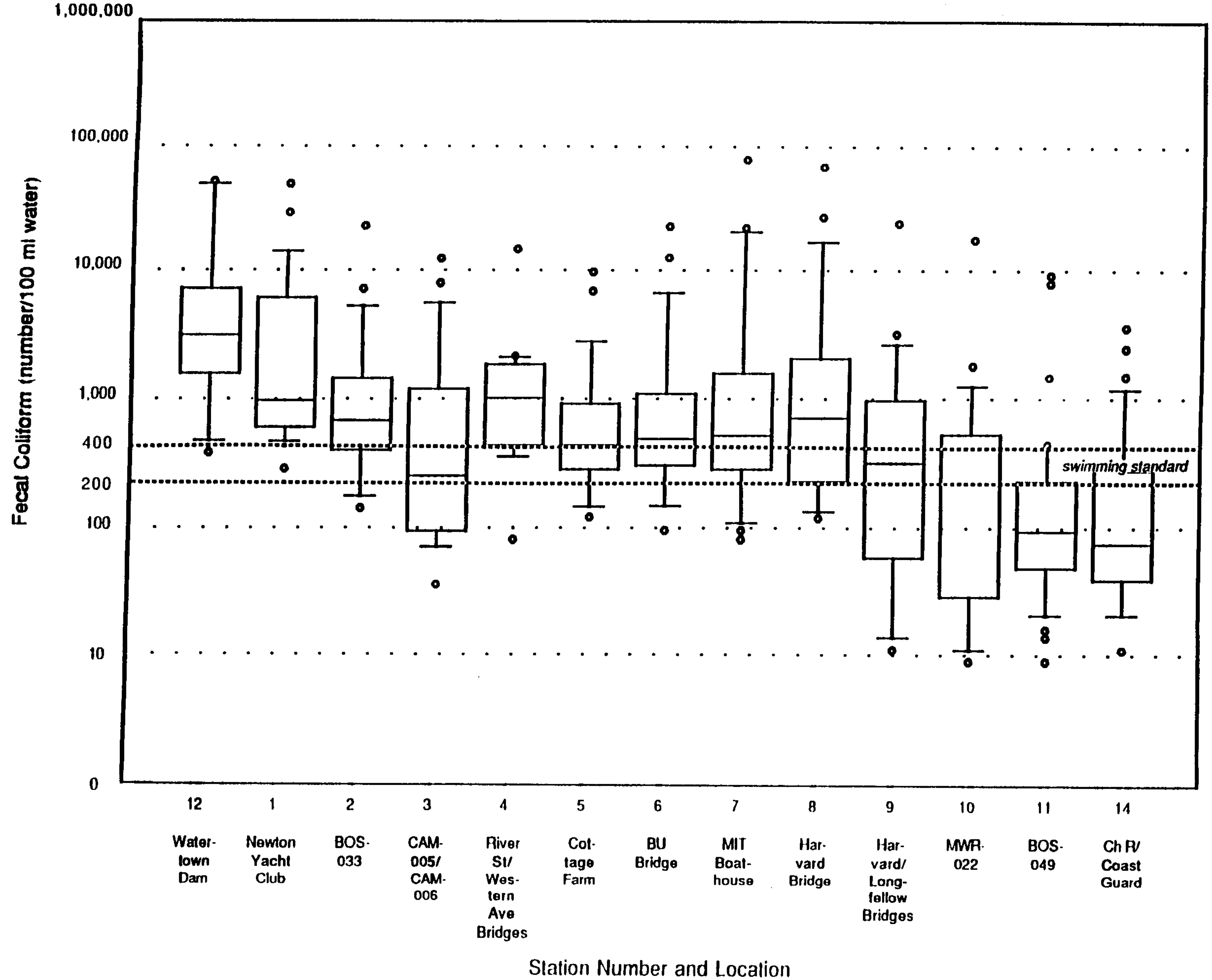


Figure 7.08. Percentile Box Plots of Fecal Coliform Counts from Surface Samples in the Charles, River, 1990.

(ranging from 299 col/100 ml at Station 9 to 3572 col/100 ml at Station 12), exceeding class B standards. At Stations 10 and downstream, where the geometric means were less than 200 col/100 ml, more than 10% of the samples had densities higher than 400 col/100 ml, which still exceeded class B and SB standards. Station 12, the most upstream station, had the highest average fecal coliform density--the geometric mean of 3572 col/100 ml was significantly higher than surface counts at Stations 2, 3, 4, 5, 6, 9, 10, 11, and 14. Stations 1, 2, 3, 4, 5, 6, 7, and 8 had geometric means ranging from 410 to 1634 col/100 ml, and were not significantly different. The most downstream Stations (9, 10, 11 and 14) all had significantly lower geometric mean fecal coliform counts (ranging from 107 to 299 col/100 ml) than the most upstream stations (1 and 2). The two saltwater stations, 11 and 14, had the lowest counts of all, significantly lower than all stations upstream of Station 9. Thus, there was a general decreasing trend in average surface fecal coliform counts in the downstream direction.

Enterococcus (Figure 7.09, Table 7.01) showed a geographic pattern similar to fecal coliform, with Station 12 showing significantly higher geometric mean counts than Stations 3 and downstream. Upstream of Station 9, geometric mean *Enterococcus* counts were on the order of 10^2-10^3/100 ml. The most downstream stations (10, 11, and 14) had significantly lower *Enterococcus* densities, on the order of 10/100 ml, than the other stations.

Bottom Samples

At Stations 6 and downstream, the water was more than 10 feet deep, and bottom samples were collected. As for surface counts, counts of both fecal coliform and *Enterococcus* at the more upstream stations (6, 7, and 8) were significantly higher than counts at the downstream stations (10, 11, and 14) (Figures 7.10 and 7.11, Table 7.01). Although the differences were not statistically significant, Stations 6, 7, 8, and 9 had higher average counts from bottom-water samples than from surface samples for both fecal coliform and *Enterococcus*. Stations 10, 11, and 14 had lower fecal coliform counts from bottom samples than from surface samples; Stations 10 and 14 had lower *Enterococcus* counts on the bottom than at the surface.

7.2.c Relationship between Indicator Bacteria and Rainfall

Most of the rainfall variables tested in correlation and regression analyses were significantly related to both fecal coliform counts and *Enterococcus* counts in the water. A pattern of significant associations with rainfall was found when all stations were considered together and when stations were considered individually. Rainfall summed over three days produced the most significant relationships. Figure 7.12 shows the regression of fecal coliform counts from all Charles River surface stations against rainfall summed over three days ($R^2 = 0.34$, $p < 0.001$). The regression predicts that even with no rain, the fecal coliform count would be 276 col/100 ml--above class B standards. Figure 7.13 shows the regression of

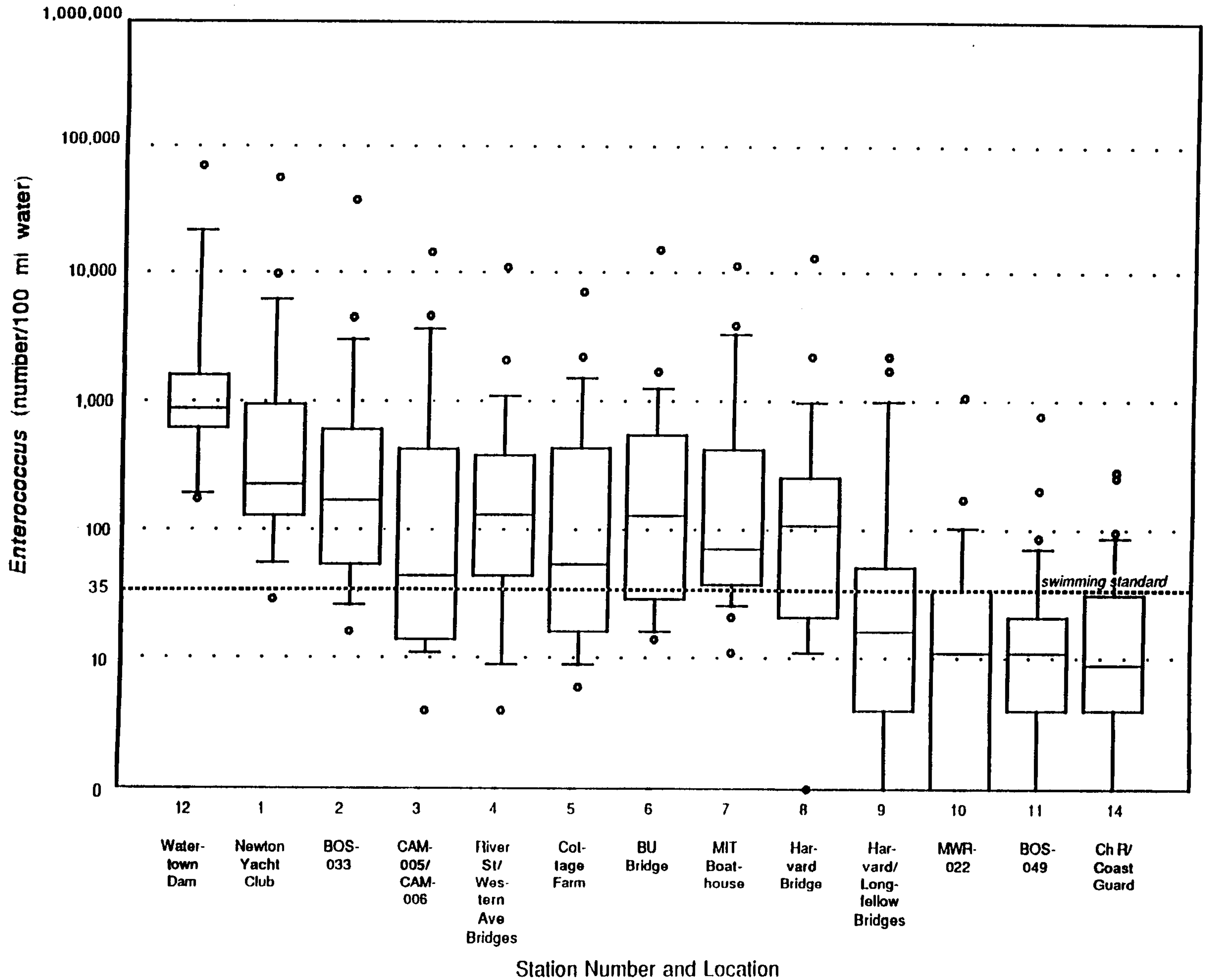


Figure 7.09. Percentile Box Plots of *Enterococcus* Counts from Surface Samples in the Charles River, 1990.

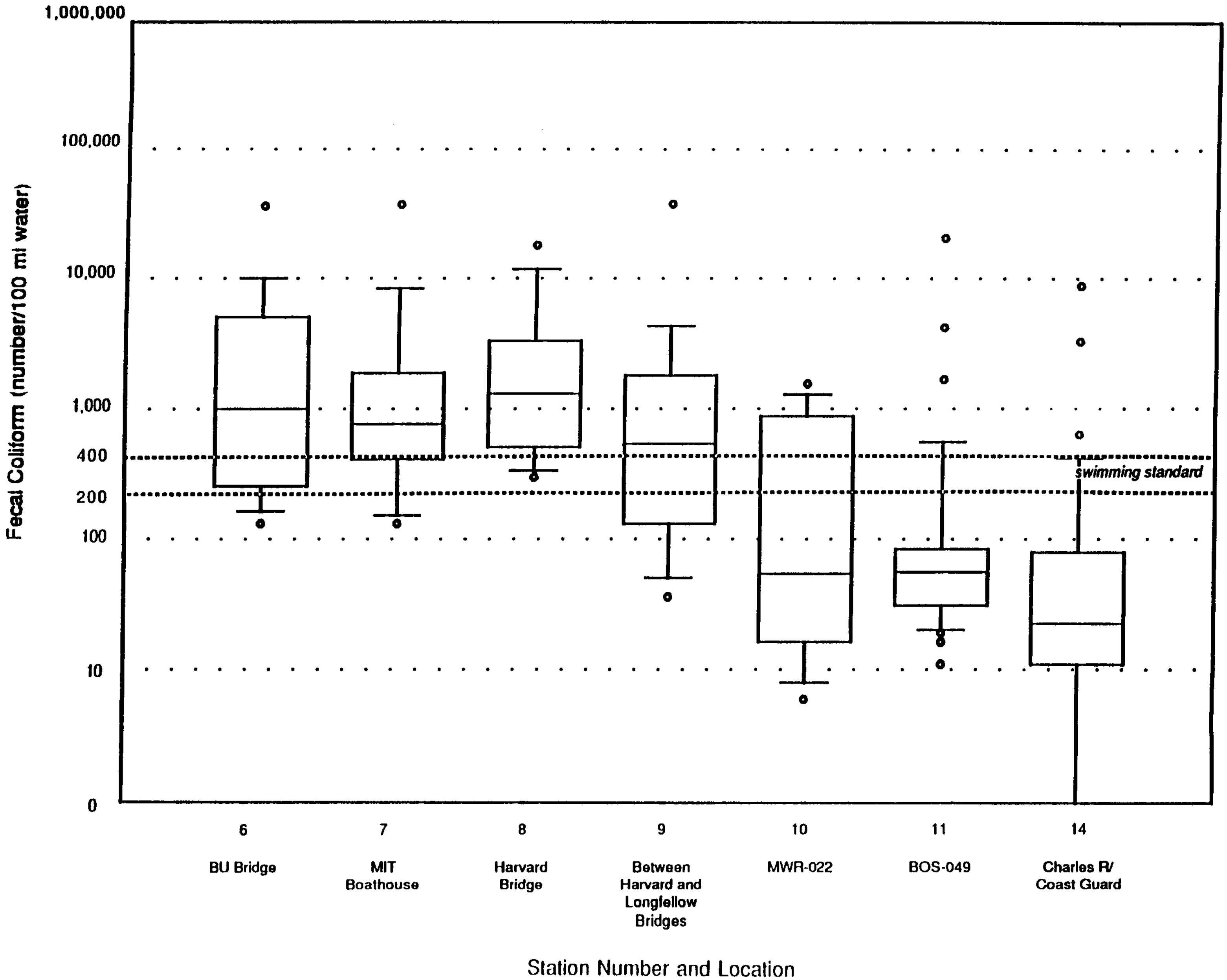


Figure 7.10. Percentile Box Plots of Fecal Coliform Counts from Bottom Samples in the Charles River, 1990.

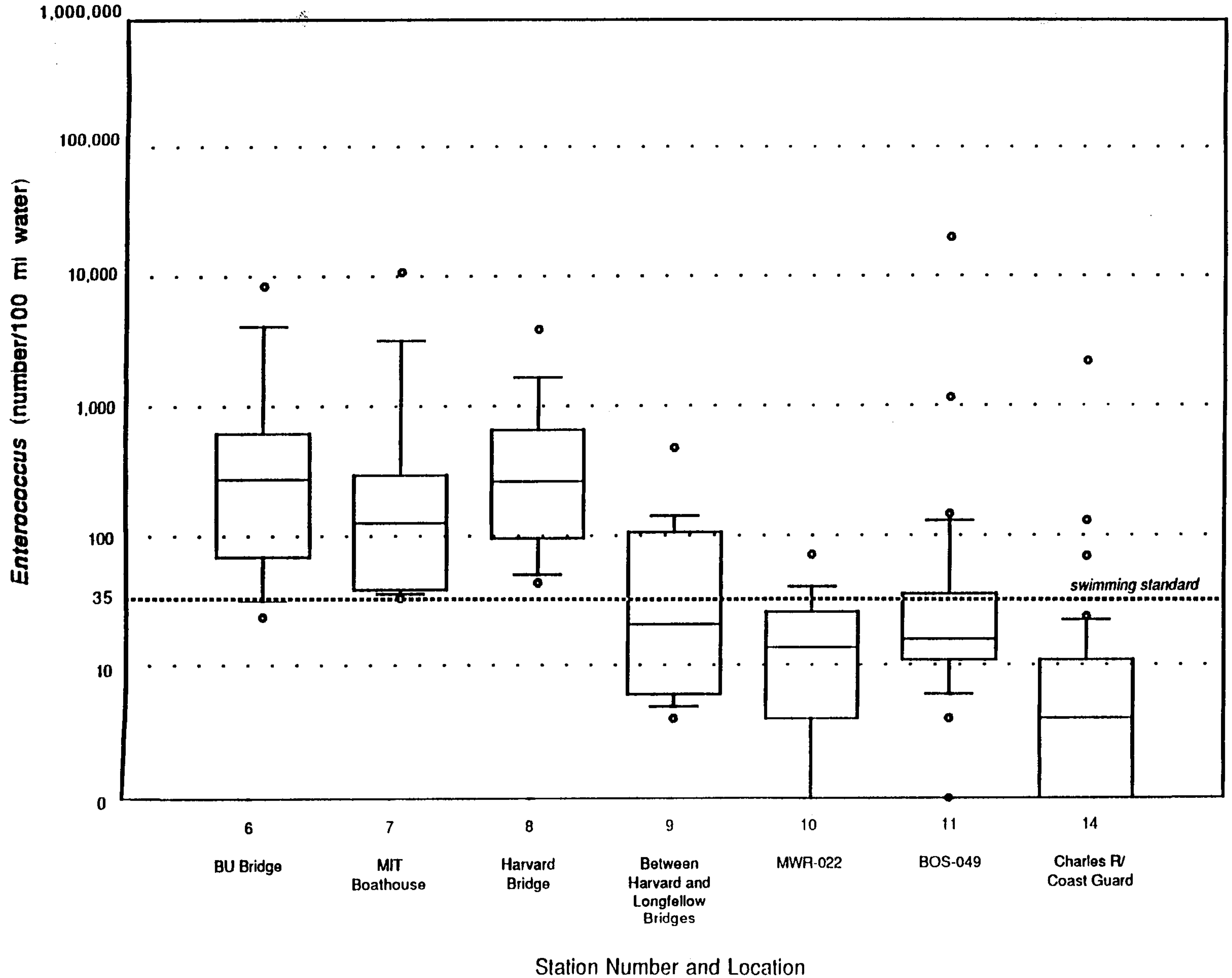


Figure 7.11. Percentile Box Plots of *Enterococcus* Counts from Bottom Samples in the Charles River, 1989.

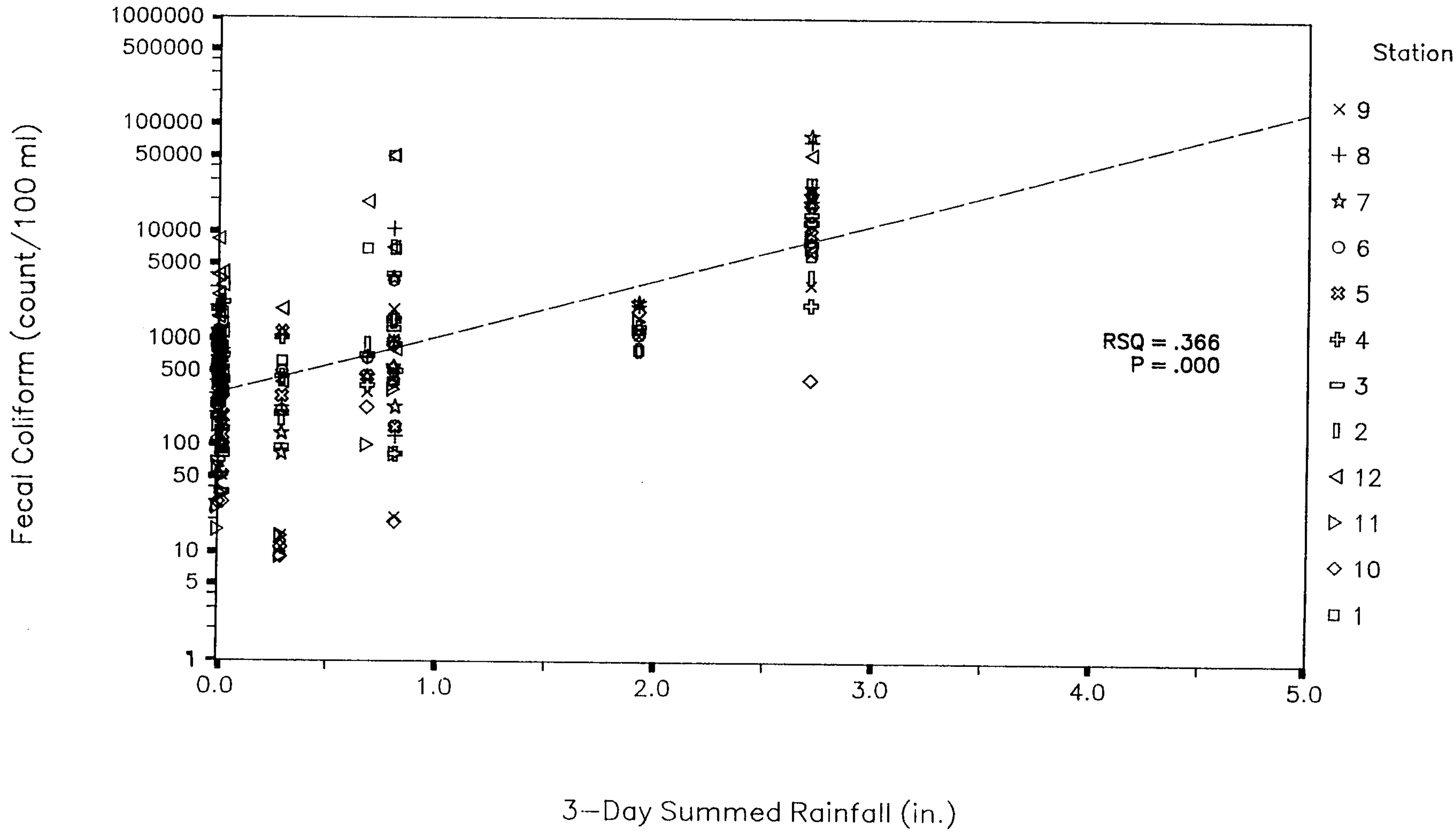


Figure 7.12. Relationship between Fecal Coliform Counts and 3-Day Summed Rainfall in the Charles River, 1990.

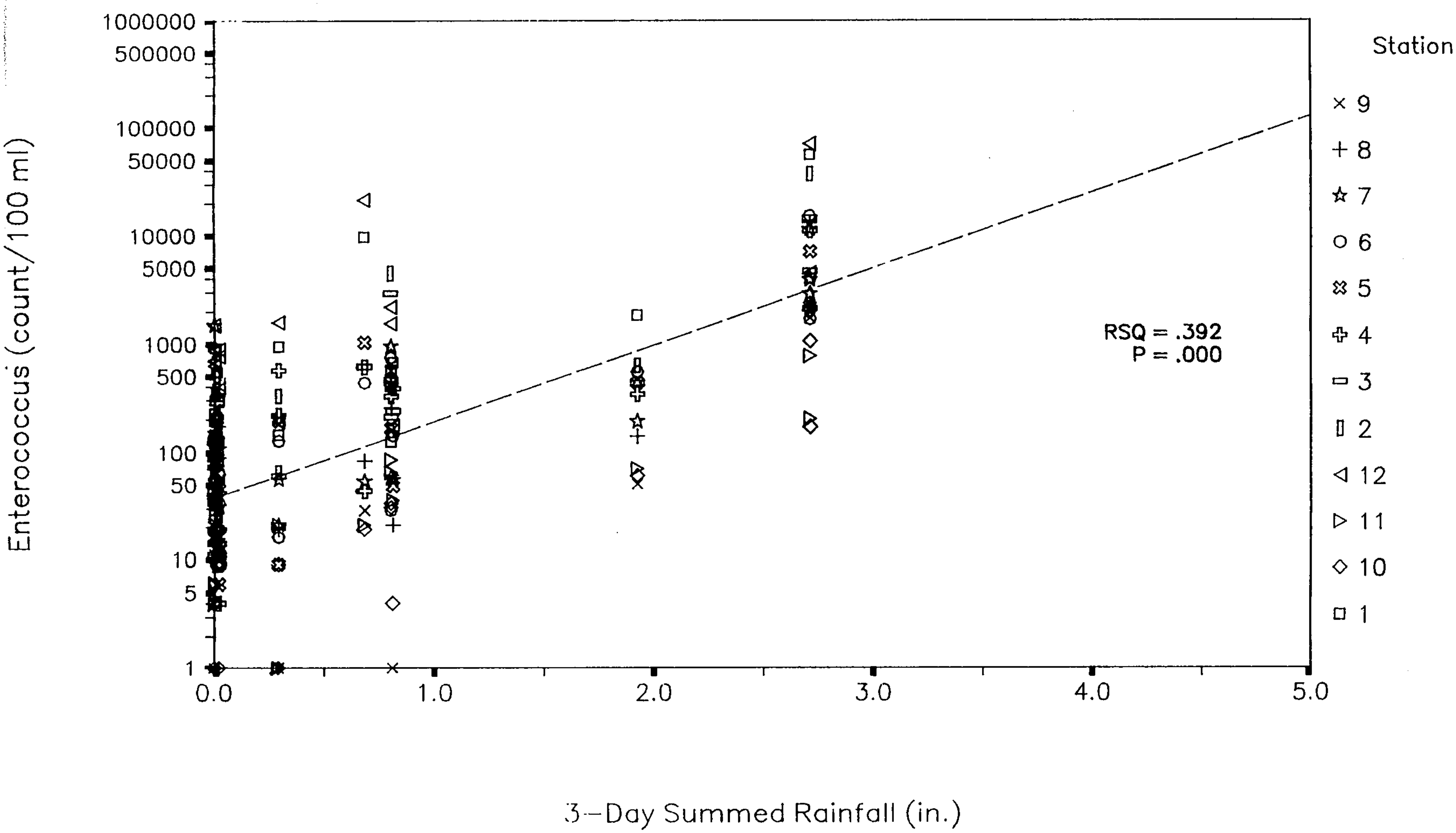


Figure 7.13. Relationship between *Enterococcus* Counts and 3-Day Summed Rainfall in the Charles River, 1990.

Enterococcus against rain summed over three days ($R^2 = 0.34$, $p < 0.001$). For both indicators, rain on the day of sampling added to the previous two days explained approximately one-third of the variation in counts.

The heavy rains that fell on July 24 and 25 (See Figure 7.02) had a clear effect on both fecal coliform and *Enterococcus* levels in the Charles. Figure 7.14 illustrates how fecal coliform counts along the Charles changed after the rain. Comparing the counts measured on July 24 to those on July 25 and 26 shows that fecal coliform densities were elevated at least 10-fold, and at some stations (6, 7, and 8) more than 100-fold, after the rain. *Enterococcus* levels were also dramatically elevated after this rainstorm, at some stations 1,000-fold over dry-weather densities (data not shown). Three days after the rainstorm, indicator bacteria counts were close to background levels. Figure 7.14 also illustrates substantial local differences in post-rain fecal coliform counts (compare counts of approximately 300 col/100 ml at Station 10 to counts of approximately 80,000 at Station 7). These sharp differences in bacteria counts are probably associated with nearby sources of contamination. Over time, after the rain, these dramatic differences among stations disappeared.

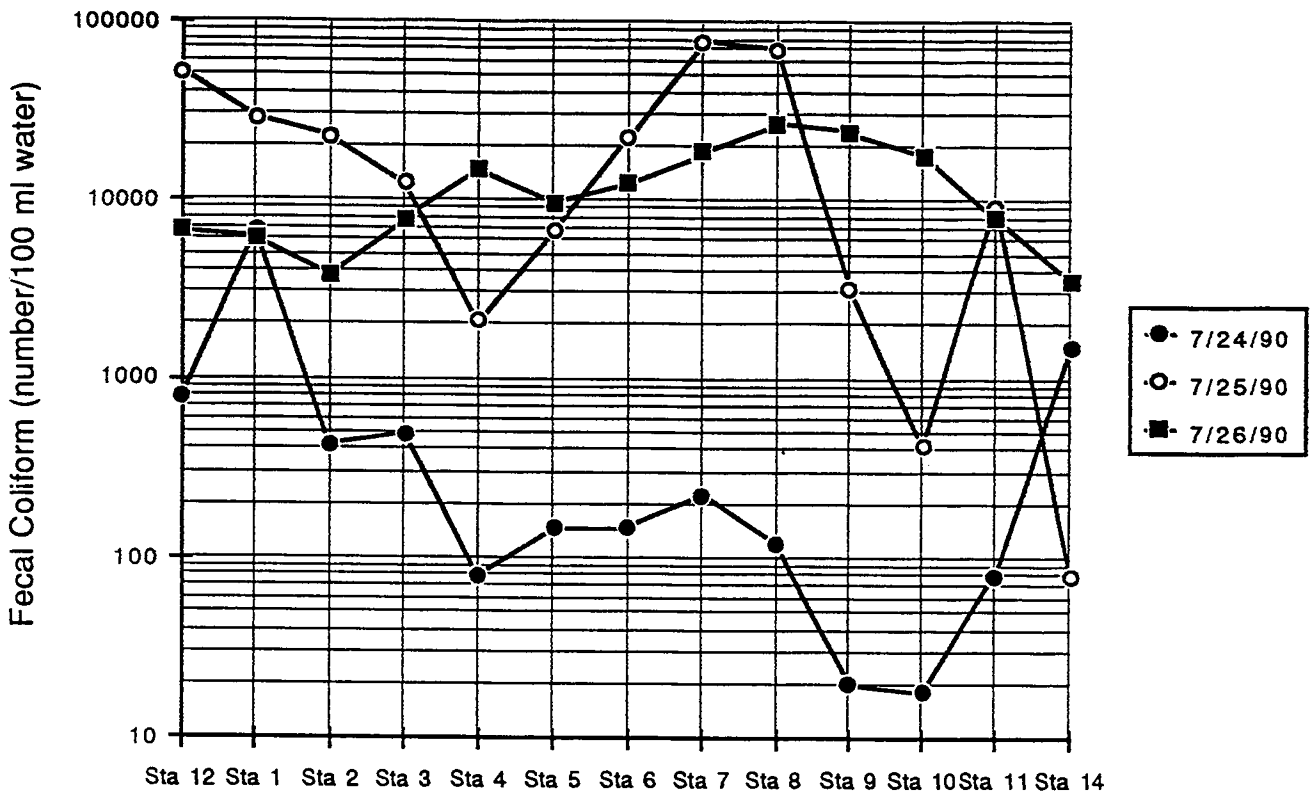
7.2.d Relationship between Indicator Bacteria and Flows from Combined Sewers and Combined Sewer Treatment Facilities

The moderate to heavy rainstorms that occurred during the 1990 Charles River monitoring period typically were associated with dramatic elevations in fecal coliform and *Enterococcus* numbers (e.g., see Figure 7.14). Comparing samples collected upstream and downstream of CSOs should help determine whether individual CSOs or groups of CSOs might be affecting the numbers of sewage indicator bacteria in the water.

CSO Treatment Facilities

Samples were collected in the Charles River before and after several recorded overflow events. Tables 7.02 and 7.03 show rainfall, amount of overflow, and fecal coliform counts in the receiving waters near the Cottage Farm and Prison Point CSO treatment facilities.

Three overflows were recorded at the Cottage Farm facility (Table 7.02). On all the days when moderate to heavy rains fell, with consequent overflows, fecal coliform counts from samples collected at Station 6 (located in the nearfield zone of the outfall) were 3 to 4 times higher than at Station 5, upstream of the facility. Although these data are consistent with an effect from the Cottage Farm discharge, the fecal coliform counts measured in the chlorinated effluent at the plant were only 10 col/100 ml. If these numbers are correct, the effluent could not account for fecal coliform densities in the thousands and tens of thousands



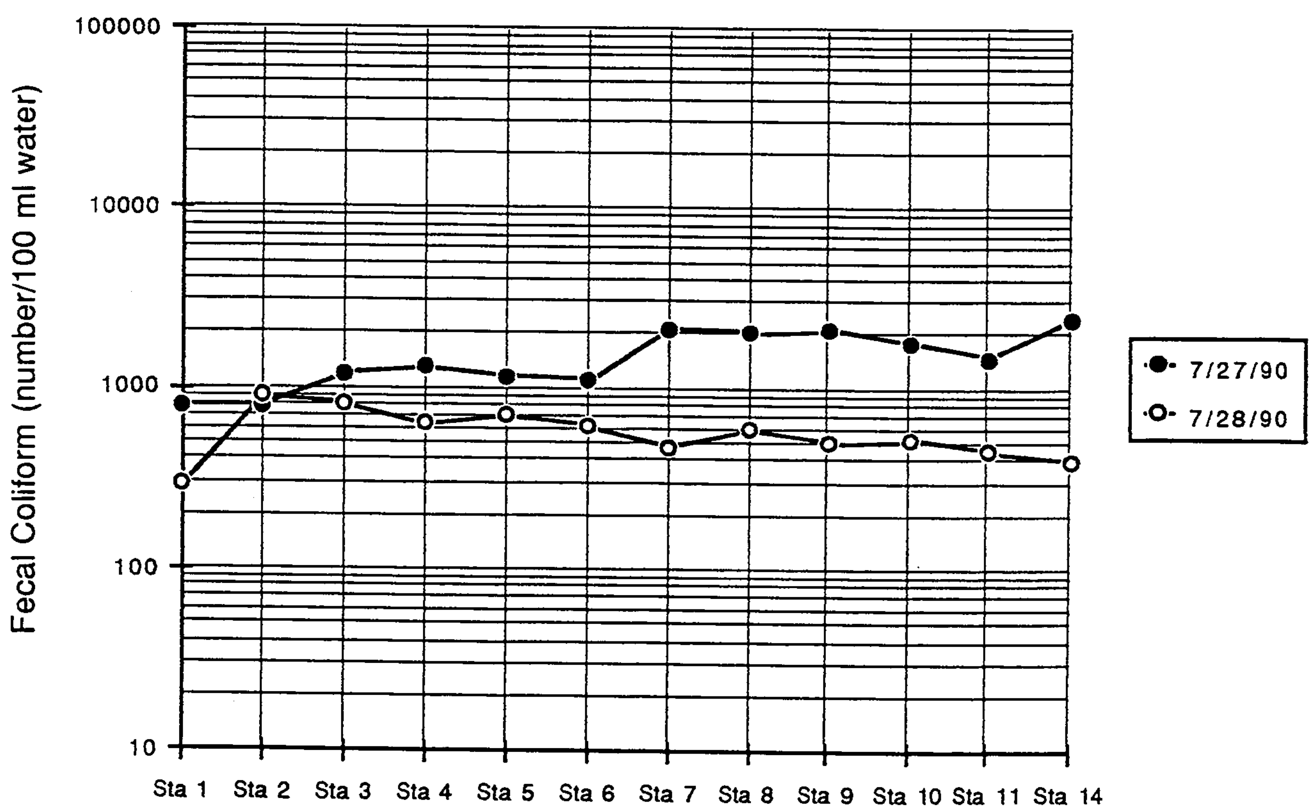


Figure 7.14. Effect of heavy rain on Fecal Coliform Counts in the Charles River: 0.79 in. of rain fell on July 24,1990, and 1.92 in. fell on July 25, 1990.

Table 7.02. Relationship between Flow from the Cottage Farm CSO Treatment Facility and Fecal Coliform Counts (colonies per 100 ml) at Upstream, Nearfield, and Downstream Stations, July 1990

			Fecal Coliform			
Date	Rainfall (in.)	Cottage Farm Flow (gal)	Station 5 (Upstream)	Station 6 (Nearfield)	Station 7 (Dnstream: near MIT Boathouse)	Station 8 (Dnstream: near Stony Brook)
7/11	0	0	298	340	700	795
7/12	0.68	1,600,000	443	663	433	675
7/13	0.12	0	925	3475	3650	10,600
7/14	0	0	448	390	540	930
7/23	0	0	120	95	95	133
7/24	0.79	7,300,000	145	148	225	118
7/25	1.92	88,600,000	6800	22,600	78,500	69,300
7/26	0	0	9700	12,550	18,850	26,850

Table 7.03. Relationship between Flow from the Prison Point CSO Treatment Facility and Fecal Coliform Counts (colonies per 100 ml) at Upstream and Nearfield Stations, July 1990

			Fecal Coliform			
Date	Rainfall (in.)	Prison Point Flow (gal)	Station 11* (Upstream)		Station 14* (Nearfield)	
7/11	0	0	S	50	S	38
			B	...	B	93
7/12	0.68	3,600,000	S	98	S	63
			B	...	B	20
7/13	0.12	0	S	330	S	1175
			B	...	B	635
7/23	0	0	S	103	S	158
			B	35	B	20
7/24	0.79	0	S	80	S	1500
			B	90	B	...
7/25	1.92	38,100,000	S	9100	S	80
			B	1680	B	8800
7/26	0	0	S	7950	S	3600
			B	20,550	B	50

*S = surface; B = bottom.

per 100 ml found in the river. Interestingly, the two stations (7 and 8) located further downstream yielded even higher counts after rain.

Table 7.03 gives the results of sampling near the Prison Point treatment facility before and after two rain events and overflows. These data did not show a consistent pattern. After the July 12 overflow, fecal coliform counts in the nearfield, Station 14, were 3.5-fold higher than counts upstream at Station 11. However, after the 38 million gallon overflow on July 25, upstream counts were higher than nearfield counts. As at Cottage Farm, fecal coliform measurements in Prison Point effluent were low: 10 and 50 col/100 ml.

Recorded Combined Sewer Overflows into the Charles River

The City of Cambridge measured overflows on July 25 at four CSOs on the Charles. These data, together with receiving water data before and after the overflows and upstream and downstream of the outfalls, are shown in Tables 7.04 and 7.05. Station 3 was located upstream of CAM-007, 009, and 011. Station 4 was downstream of all these outfalls. On the day the overflows were recorded, July 25, the upstream station showed counts almost 6 times higher (12,500 col/100 ml) than the downstream station (2,100 col/100 ml). Since all the stations upstream of this group of combined sewers (Stations 12, 1, 2, and 3) showed counts in the tens of thousands on July 25, there clearly was an important upstream source of sewage. The next day, the downstream count (14,850 col/100 ml) was almost twice as high as the upstream count (7,900 col/100 ml), which may indicate an effect of the overflows.

Although CAM-017, in the lower part of the Charles River Basin, overflowed, an effect on the receiving water was not detected in our sampling study. Table 7.05 gives the upstream and nearfield fecal coliform counts before and after a measured overflow of 26,701 gallons. The upstream counts were consistently higher than the nearfield densities.

7.2.e Dissolved Oxygen

The percentile distributions of dissolved oxygen (DO) measurements at the surface of Charles River stations are shown in Figure 7.15. Generally, 75% to 90% of the measurements were above 5 mg/l, with the medians at each station falling between 6 mg/l and 8 mg/l. Surface DO measurements had a very broad range: from 2.1 mg/l at Station 11 to 12.6 mg/l at Station 9. Many of the lowest surface DO levels were measured after the rainstorm of July 24 to 25, and were found at relatively downstream stations; including Stations 6, 7, 8, 9, and 10 in the "Basin" section of the river, and at estuarine Stations 11 and 14.

Table 7.04. Relationship between Flow from Three Cambridge CSOs (CAM-007, CAM-009, and CAM-011) and Fecal Coliform Counts (colonies per 100 ml) at Upstream and Downstream Stations, July 1990

Date	Rainfall (in.)	Flow (gal)			Fecal Coliform	
		CAM-007	CAM-009	CAM-011	Station 3 (Upstream)	Station 4 (Dnstream)
7/23	0	0	0	0	138	430
7/24	0.7	0	0	0	495	80
7/25	1.92	463,678	10,764	63,645	12,500	2,100
7/26	0	0	0	0	7,900	14,850
7/27	0	0	0	0	1,200	1,300

Table 7.05. Relationship between Flow from Cambridge CSO CAM-017 and Fecal Coliform Counts (colonies per 100 ml) at Upstream and Nearfield Stations, July 1990

				Fecal Coliform	
Date	Rainfall (in.)	CAM-007 Flow (gal)	Depth Sampled*	Station 9 (Upstream)	Station 10 (Nearfield)
7/23	0	0	S	90	200
			B	203	15
7/24	0.79	0	S	20	18
			B	35	15
7/25	1.92	26,701	S	3,200	420
			B	1,820	230
7/26	0	0	S	24,000	17,800
			B	37,500	1,285
7/27	0	0	S	2,150	1,800
			B	4,350	1,550

*S = surface; B = bottom.

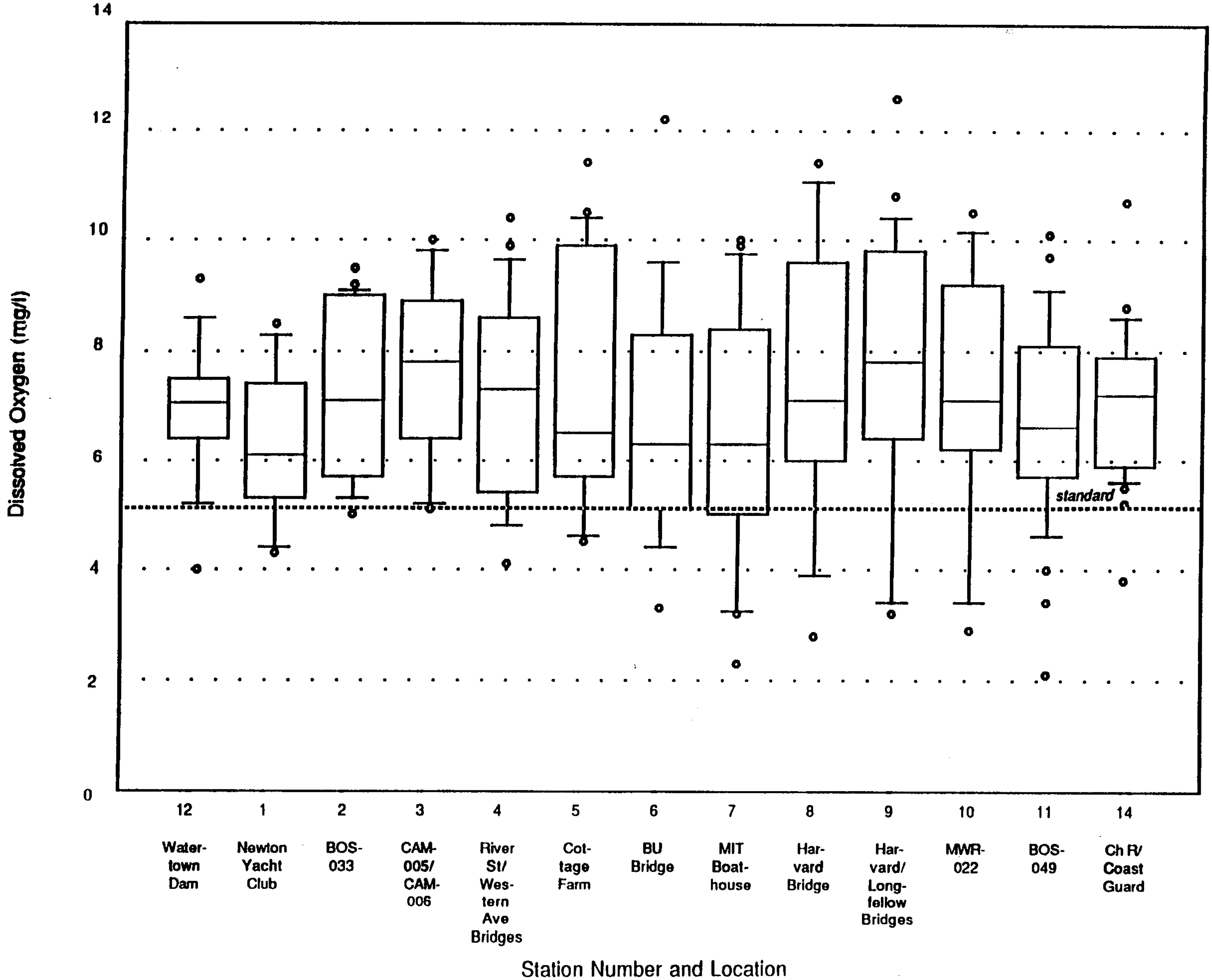


Figure 7.15. Percentile Box Plots of Dissolved Oxygen Measurements at Surface Stations in the Charles, River, 1990.

Bottom-water measurements of DO, taken at Stations 6, 7, 8, 9, 10, and 14, are shown in Figure 7.16. These measurements tended to be lower than surface DO levels, although all the stations except 9 and 10 had a broad range of values. The most striking observation is that bottom waters at Stations 9 and 10, in the Basin, were virtually anoxic. At all stations except 14, the bottom waters of the Charles clearly did not meet the Massachusetts standard of 5 mg/l.

7.2.f Multiple Regression Analysis

Results of multiple regression analyses for Charles River samples are in Table 7.06. The significant explanatory variables for surface fecal coliform and *Enterococcus* counts were the same for both indicators, and entered into the equations in the same order. Rainfall summed over three days (LORNP3) entered first, followed by conductivity (with a negative sign), temperature, and flow through the Deer Island treatment plant. Together, these four variables explained 53% of the variance in both fecal coliform and *Enterococcus* densities at a high level of significance.

Results of multiple regressions from bottom data were somewhat different. Rain summed over three days was again the most important explanatory variable for fecal coliform densities, followed by temperature. For *Enterococcus*, the same two variables entered the equation, but in the reverse order. These two variables explained 60% of the variance in bottom fecal coliform counts and 65% of the variance in bottom *Enterococcus* counts.

7.3 Discussion

The variety of weather conditions that occurred during the 1989 and 1990 monitoring periods provided an opportunity to compare the water quality measurements in the Charles River among dry, rainy, and "drizzly" conditions. The most striking observations were, first, that water quality in the Charles did not come close to meeting fecal coliform standards for class B water in any weather condition; and, second, that on average, the worst water quality was found at the two most upstream stations, near the Newton Yacht Club and above the Watertown Dam. These two stations are well upstream of all combined sewers.

In 1989, sampling was done during a period characterized by gentle rain, generally 1/3 in./day or less, falling for several consecutive days, interspersed with dry days. Data collected during this period showed no association between fecal coliform levels in the water and amount of rain that fell. Although combined sewer overflows occurred, both at the Cottage Farm facility and from CAM-009, our sampling was unable to detect an effect of these overflows on the receiving water. We suggest that the sources of fecal coliform found in the Charles during this time were predominately storm drains, illegal connections, and upstream sources.

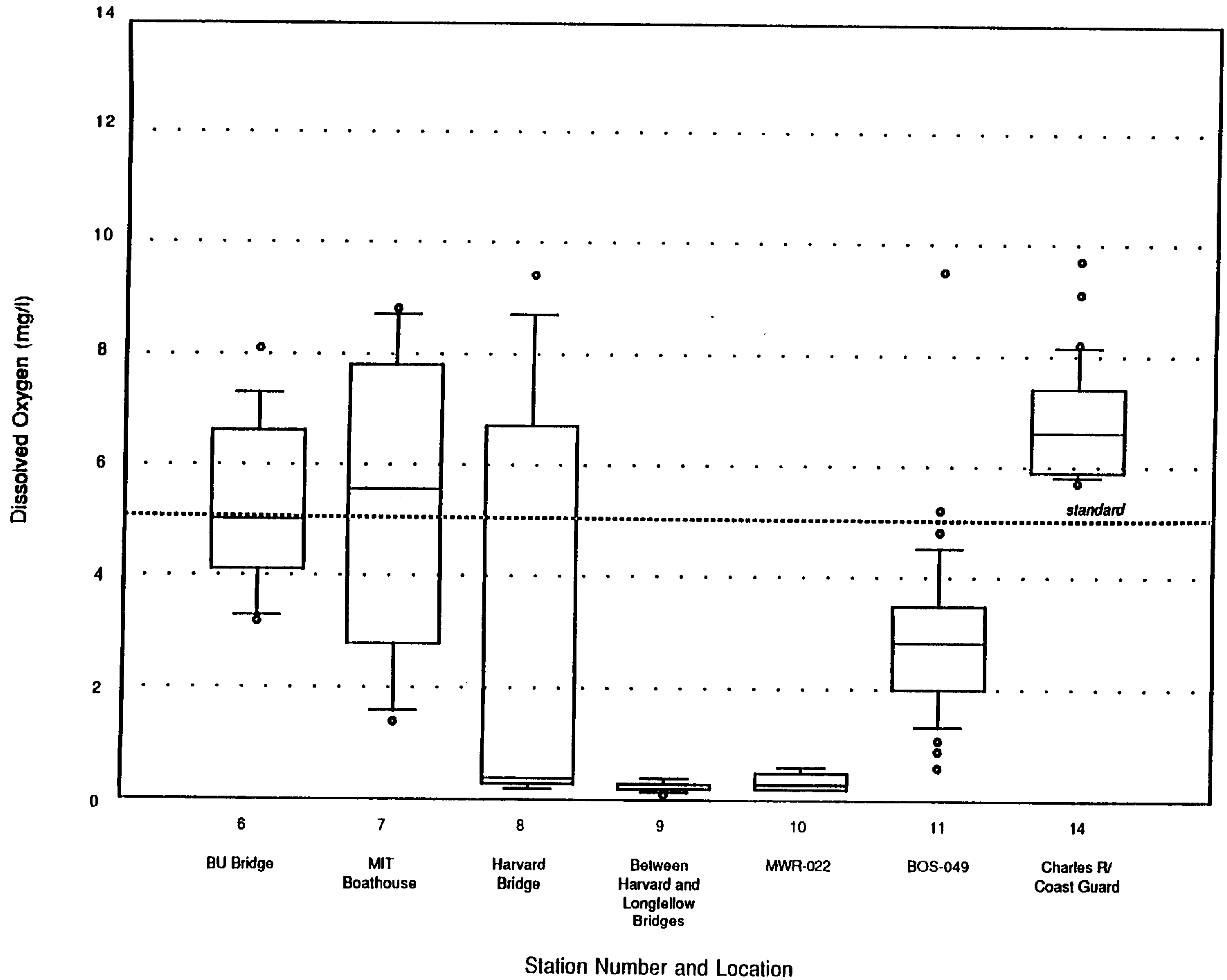


Figure 7.16. Percentile Box Plots of Dissolved Oxygen Measurements at Bottom Stations in the Charles River, 1990.

Table 7.06. Multiple Regression Analysis for 1990 Charles River Samples

---

Surface fecal coliform counts (log-transformed) as dependent variable

---

LOGFC = 6.535 + 0.181[LORNP3] - 0.0000507[CONDUCTIVITY] - 0.00438[TEMPERATURE] + 0.00438[DIFLOW]

Multiple R = 0.72
$R^2 = 0.53$
$F_{(4,224)} = 63.59 \quad p < 0.0001$

Surface *Enterococcus* counts (log-transformed) as dependent variable

---

LOGENT = 6.0631 + 0.196[LORNP3] - 0.0000617[CONDUCTIVITY] - 0.233[TEMPERATURE] + 0.00664[DIFLOW]

Multiple R = 0.73
$R^2 = 0.53$
$F_{(4,229)} = 64.35 \quad p < 0.0001$

Bottom fecal coliform counts (log-transformed) as dependent variable

---

LOGFC = 0.236 + 0.587[LORNP3] + [TEMPERATURE]

Multiple R = 0.78
$R^2 = 0.60$
$F_{(2,78)} = 59.72 \quad p < 0.0001$

Bottom *Enterococcus* counts (log-transformed) as dependent variable

---

LOGENT = -1.348 + 0.135[TEMPERATURE] + 0.540[LORNP3]

Multiple R = 0.80
$R^2 = 0.65$
$F_{(2,78)} = 71.58 \quad p < 0.0001$

---

7. **The Charles River**

In 1990, a number of dry days were interspersed with periods of moderate to heavy rain. In contrast to 1989, this weather pattern resulted in a strong and significant relationship between rainfall and levels of indicator bacteria in the water. Moreover, the receiving-water data showed apparent effects of some combined sewer overflows and discharges from the Cottage Farm facility after heavy rains. Although overflows from the Cambridge combined sewers and the Cottage Farm facility appeared to increase the levels of sewage indicator bacteria in nearfield zones, the worst water quality after the storm was downstream in the "Basin" area of the Charles, possibly reflecting the impact of the Muddy River/Stony Brook. The apparent effect of the Cottage Farm discharge conflicts with the reported fecal coliform count in the effluent: an effluent count of only 10 colonies/100 ml could not have caused receiving-water densities in the tens of thousands per 100 ml. One possibility is that the actual discharge might have had a shorter chlorine contact time than the effluent sample, and consequently a higher fecal coliform count. Another possibility is that there was another nearby source of sewage.

The heavy rains of July 24 and 25 were also associated with an adverse impact on DO levels in the lower Basin area of the Charles (Stations 7, 8, 9, 10, and 11): daytime surface concentrations of DO in this area were well below 5 mg/l for three days. These depressed oxygen levels may have been caused by the BOD associated with the Cottage Farm discharge (95.9 million gal., BOD = 254 mg/l), other CSOs, the Muddy River/Stony Brook, and/or the cumulative effect of nonpoint sources.

The chronic anoxic condition of the bottom waters in the Charles River Basin has been previously observed. This condition results from the intrusion of saltwater into the river, which settles in a stagnant layer in the deepest areas of the Basin.

7.4 Conclusions

- The Charles River suffered from severely degraded water quality (measured by densities of fecal indicator bacteria), even during dry weather and light rains, and in the absence of combined sewer overflows. Standards for class B waters were greatly exceeded during 1989 and 1990. Nonpoint sources of contamination and/or illegal connections to storm drains prevent the Charles River from meeting water quality standards in dry weather.

- The stations located upstream of all CSOs, in Newton and Watertown, had among the highest densities of sewage indicator bacteria measured, even when the CSOs had recorded discharges.

- Overflows from combined sewers, resulting from heavy rains, were associated with dramatic elevations of indicator bacteria in nearfield zones.

7. The Charles River

- The greatest effect of rainfall-associated sewage input was in the "Basin" area of the Charles. This area, where outflow is limited by the Charles River Dam, ultimately receives sewage from upstream sources, including Cottage Farm, as well as from the Stony Brook and the Muddy River. Samples taken from the Basin had the highest fecal coliform counts recorded. After a heavy rain, levels of DO in the Basin were very low and remained depressed for three days. Sewage in the Basin after a heavy rain poses a threat to both human health and to the health of aquatic life.

8. References

APHA. 1985. *Laboratory Procedures for the Examination of Seawater and Shellfish.* Greenberg, A.E., and D.A Hunt (eds). 5th Edition. American Public Health Association, Washington, DC.

APHA. 1989. *Standard Methods for the Examination of Water and Wastewater.* Clesceri, L.S., A.E. Greenberg, and R. Rhodes Trussell (eds). 17th Edition. American Public Health Association, Washington, DC.

Boston Water and Sewer Commission. 1990. Quarterly CSO Monitoring Report for the Period: 4/1/90 - 6/30/90. Boston Water and Sewer Commission, Boston, MA.

Elliot, E.L., and R.R. Colwell. 1985. Indicator organisms for estuarine and marine waters. *FEMS Microbiol. Rev.* 32:61-79.

EPA. 1985. A Methodological Approach to an Economic Analysis of the Beneficial Outcomes of Water Quality Improvements from Sewage Treatment Plant Upgrading and Combined Sewer Overflow Controls. Report No. EPA-230-11-89-017. Prepared by MetaSystems, Inc., for the U.S. Environmental Protection Agency, Office of Policy Analysis, Washington, DC.

EPA. 1987. Report on the Results of Toxicity Tests Conducted on Effluents from Deer Island and Nut Island Sewage Treatment Plants and Associated Receiving Waters. April 1-8, 1987. ERLN Contribution No. 859. G. Morrison, Environmental Protection Agency, Narragansett, RI.

Goyal, S.M., C.P. Gerba, and J.L. Melnick. 1977. Occurrence and distribution of bacterial indicators and pathogens in canal communities along the Texas coast. *Appl. Environ. Microbiol.* 34: 139-149.

MDC. 1980. Combined Sewer Overflow Facilities Plan for the Neponset River Estuary. Report prepared by Havens and Emerson, Inc., for the Metropolitan District Commission, Boston, MA.

MDC. 1981. Report on Combined Sewer Overflows in the Dorchester Bay Area. Volume II. Environmental Assessment for the Metropolitan District Commission. Report prepared by Camp Dresser and McKee for the Metropolitan District Commission, Boston, MA.

MDC. 1982a. Combined Sewer Overflow Project Inner Harbor Area Facilities Plan. Volume III, Book 3. Report prepared by O'Brien and Gere Engineers, Inc., for the Metropolitan District Commission, Boston, MA.

8. References

MDC. 1982b. Combined Sewer Overflow Project : Summary Report on Facilities Planning. Metropolitan District Commission, Boston, MA.

MDC. 1982c. Final Report to the Metropolitan District Commission on Combined Sewer Overflows; Charles River Basin Facilities Planning Area, Boston, MA. Report prepared by Metcalf and Eddy, Inc., for the Metropolitan District Commission, Boston, MA.

MDEP. 1988. Little River/Alewife Brook Survey. Sampling Data and Analysis. L.K. O'Shea and L.E. Kennedy, Massachusetts Department of Environmental Protection, Division of Water Pollution Control, Boston, MA.

MDEP. 1990. A Synthesis of Phase-I Biological and Chemical Studies to Identify the Impact of the Fox Point CSO Before Modification. Draft final report prepared by E. Gallagher, G. Wallace, and R. Eganhouse for the Massachusetts Department of Environmental Protection, Boston, MA.

Moore Associates, Inc. 1977. Drainage Contamination Study for North Quincy, Massachusetts. Boston, MA.

Moore Associates, Inc. 1980. Wollaston Beach Exploration/Remedial Program Regarding Storm Water Contamination. Boston, MA.

Moore Associates, Inc. 1981. Facility Plan for Water Pollution Control, Volume I, Quincy, Massachusetts. Boston, MA.

MWRA. 1989a. Harbor Studies Field Standard Operating Procedure. Massachusetts Water Resources Authority, Boston, MA.

MWRA. 1989b. Harbor Studies Laboratory Standard Operating Procedure. Massachusetts Water Resources Authority, Boston, MA.

MWRA. 1990. Final Combined Sewer Overflow Facilities Plan and Final Environmental Impact Report. Report prepared by CH2MHill Team for the Massachusetts Water Resources Authority, Boston, MA.

MWRA. 1991a. Effluent Toxicity Tests Conducted for Massachusetts Water Resources Authority. March 1991. Final report prepared by Aquatech, Inc., for the Massachusetts Water Resources Authority, Boston, MA.

8. References

MWRA. 1991b. Effluent Toxicity Tests Conducted on Deer Island and Nut Island POTW Effluent and Combined Sewer Overflow Discharges with Additional Testing of Nut Island Effluent. May 1991. Final report prepared by Aquatech, Inc., for the Massachusetts Water Resources Authority, Boston, MA.

MWRA. 1991c. Boston Harbor Estimates of Loadings. Report prepared by Menzie-Cura and Associates for the Massachusetts Water Resources Authority, Boston, MA.

MWRA. 1991d. CSO Effects on Contamination of Boston Harbor Sediments. Draft report prepared by Battelle Ocean Sciences for the Massachusetts Water Resources Authority, Boston, MA.

New England Aquarium. 1990. New England Aquarium's Ten-Year Boston Harbor Monitoring Program. First Report (March 1987-July 1989). P.W. Robinson, T. Coffey, and P. Sullivan. Boston, MA.

Appendix A

Additional Tables and Figures

Table A.01 Rainfall measured by National Weather Service at Logan Airport during 1989 monitoring: June 1- October 31, 1989.

Date	Rain	Date	Rain	Date	Rain
01-Jun	0.00	23-Jul	0.00	13-Sep	0.00
02-Jun	0.25	24-Jul	0.00	14-Sep	1.35
03-Jun	0.00	25-Jul	0.00	15-Sep	0.54
04-Jun	0.00	26-Jul	0.00	16-Sep	0.22
05-Jun	0.00	27-Jul	0.00	17-Sep	0.08
06-Jun	0.17	28-Jul	1.37	18-Sep	0.00
07-Jun	0.35	29-Jul	0.02	19-Sep	0.90
08-Jun	0.30	30-Jul	0.33	20-Sep	0.34
09-Jun	0.25	31-Jul	0.00	21-Sep	0.26
10-Jun	0.33	01-Aug	0.00	22-Sep	0.07
11-Jun	0.00	02-Aug	0.31	23-Sep	0.23
12-Jun	0.00	03-Aug	0.00	24-Sep	0.00
13-Jun	0.15	04-Aug	0.00	25-Sep	0.00
14-Jun	0.00	05-Aug	0.00	26-Sep	0.62
15-Jun	0.74	06-Aug	0.15	27-Sep	0.00
16-Jun	0.06	07-Aug	0.28	28-Sep	0.00
17-Jun	0.00	08-Aug	0.24	29-Sep	0.00
18-Jun	0.08	09-Aug	0.00	30-Sep	0.00
19-Jun	0.00	10-Aug	0.00	01-Oct	0.00
20-Jun	0.00	11-Aug	1.33	02-Oct	0.62
21-Jun	0.00	12-Aug	0.41	03-Oct	0.00
22-Jun	0.00	13-Aug	2.13	04-Oct	0.00
23-Jun	0.04	14-Aug	0.00	05-Oct	0.00
24-Jun	0.00	15-Aug	0.07	06-Oct	0.03
25-Jun	0.00	16-Aug	0.11	07-Oct	0.00
26-Jun	0.00	17-Aug	0.00	08-Oct	0.00
27-Jun	0.00	18-Aug	0.00	09-Oct	0.00
28-Jun	0.12	19-Aug	0.00	10-Oct	0.00
29-Jun	0.00	20-Aug	0.00	11-Oct	0.18
30-Jun	0.00	21-Aug	0.35	12-Oct	0.00
01-Jul	0.00	22-Aug	0.00	13-Oct	0.00
02-Jul	0.00	23-Aug	0.05	14-Oct	0.57
03-Jul	0.00	24-Aug	0.00	15-Oct	0.48
04-Jul	0.00	25-Aug	0.00	16-Oct	0.00
05-Jul	0.91	26-Aug	0.00	17-Oct	1.18
06-Jul	0.03	27-Aug	0.00	18-Oct	0.07
07-Jul	0.04	28-Aug	0.00	19-Oct	0.72
08-Jul	0.06	29-Aug	0.39	20-Oct	0.94
09-Jul	0.00	30-Aug	0.10	21-Oct	0.02
10-Jul	0.27	31-Aug	0.00	22-Oct	0.00
11-Jul	0.02	01-Sep	0.00	23-Oct	0.00
12-Jul	0.00	02-Sep	0.00	24-Oct	0.00
13-Jul	0.00	03-Sep	0.00	25-Oct	0.00
14-Jul	0.01	04-Sep	0.00	26-Oct	0.00
15-Jul	0.00	05-Sep	0.00	27-Oct	0.00
16-Jul	0.04	06-Sep	0.00	28-Oct	0.00
17-Jul	1.12	07-Sep	0.00	29-Oct	0.00
18-Jul	0.00	08-Sep	0.00	30-Oct	0.00
19-Jul	0.00	09-Sep	0.00	31-Oct	0.80
20-Jul	0.72	10-Sep	0.00		
21-Jul	0.15	11-Sep	0.00		
22-Jul	0.00	12-Sep	0.00		

Table A.02 Rainfall measured by National Weather Service at Logan Airport during 1990 monitoring: June 1- October 31, 1990.

Date	Rain	Date	Rain	Date	Rain	Date	Rain
01-Jun-90	0.00	12-Jul-90	0.68	22-Aug-90	0.00	2-Oct-90	0.00
02-Jun-90	0.00	13-Jul-90	0.12	23-Aug-90	0.34	3-Oct-90	0.00
03-Jun-90	0.00	14-Jul-90	0.00	24-Aug-90	0.55	4-Oct-90	0.47
04-Jun-90	0.06	15-Jul-90	0.00	25-Aug-90	1.58	5-Oct-90	0.00
05-Jun-90	0.00	16-Jul-90	0.00	26-Aug-90	0.09	6-Oct-90	0.00
06-Jun-90	0.00	17-Jul-90	0.00	27-Aug-90	0.00	7-Oct-90	0.00
07-Jun-90	0.07	18-Jul-90	0.00	28-Aug-90	0.00	8-Oct-90	0.00
08-Jun-90	0.05	19-Jul-90	0.00	29-Aug-90	0.00	9-Oct-90	0.08
09-Jun-90	0.03	20-Jul-90	0.29	30-Aug-90	0.00	10-Oct-90	0.01
10-Jun-90	0.00	21-Jul-90	0.00	31-Aug-90	0.00	11-Oct-90	0.01
11-Jun-90	0.31	22-Jul-90	0.02	01-Sep-90	0.00	12-Oct-90	0.00
12-Jun-90	0.00	23-Jul-90	0.00	02-Sep-90	0.00	13-Oct-90	0.57
13-Jun-90	0.00	24-Jul-90	0.79	03-Sep-90	0.01	14-Oct-90	3.34
14-Jun-90	0.00	25-Jul-90	1.92	04-Sep-90	0.00	15-Oct-90	0.00
15-Jun-90	0.00	26-Jul-90	0.00	05-Sep-90	0.00	16-Oct-90	0.00
16-Jun-90	0.00	27-Jul-90	0.00	06-Sep-90	0.00	17-Oct-90	0.00
17-Jun-90	0.00	28-Jul-90	0.01	07-Sep-90	0.01	18-Oct-90	0.70
18-Jun-90	0.00	29-Jul-90	0.00	08-Sep-90	0.00	19-Oct-90	0.51
19-Jun-90	0.00	30-Jul-90	0.00	09-Sep-90	0.00	20-Oct-90	0.00
20-Jun-90	0.00	31-Jul-90	0.00	10-Sep-90	0.16	21-Oct-90	0.00
21-Jun-90	0.02	01-Aug-90	0.00	11-Sep-90	0.00	22-Oct-90	0.00
22-Jun-90	0.00	02-Aug-90	0.00	12-Sep-90	0.00	23-Oct-90	0.68
23-Jun-90	0.00	03-Aug-90	0.00	13-Sep-90	0.00	24-Oct-90	0.62
24-Jun-90	0.00	04-Aug-90	0.00	14-Sep-90	0.00	25-Oct-90	0.00
25-Jun-90	0.00	05-Aug-90	0.00	15-Sep-90	0.39	26-Oct-90	0.04
26-Jun-90	0.00	06-Aug-90	0.19	16-Sep-90	0.00	27-Oct-90	0.00
27-Jun-90	0.06	07-Aug-90	0.01	17-Sep-90	0.10	28-Oct-90	0.33
28-Jun-90	0.00	08-Aug-90	0.65	18-Sep-90	0.00	29-Oct-90	0.00
29-Jun-90	0.07	09-Aug-90	0.01	19-Sep-90	0.12	30-Oct-90	0.00
30-Jun-90	0.02	10-Aug-90	0.01	20-Sep-90	0.08	31-Oct-90	0.00
01-Jul-90	0.23	11-Aug-90	2.80	21-Sep-90	0.00		
02-Jul-90	0.00	12-Aug-90	0.00	22-Sep-90	0.57		
03-Jul-90	0.00	13-Aug-90	0.00	23-Sep-90	0.00		
04-Jul-90	0.00	14-Aug-90	0.00	24-Sep-90	0.00		
05-Jul-90	0.00	15-Aug-90	0.00	25-Sep-90	0.00		
06-Jul-90	0.00	16-Aug-90	0.00	26-Sep-90	0.00		
07-Jul-90	0.00	17-Aug-90	0.00	27-Sep-90	0.00		
08-Jul-90	0.00	18-Aug-90	0.00	28-Sep-90	0.00		
09-Jul-90	0.02	19-Aug-90	0.34	29-Sep-90	0.00		
10-Jul-90	0.00	20-Aug-90	0.00	30-Sep-90	0.23		
11-Jul-90	0.00	21-Aug-90	0.00	1-Oct-90	0.00		

Table A.03 Key to Abbreviations in Raw Data Tables.

Site	Station number
Samnum	Sample number. "a" or "b" appended to the sample number indicates that a replicate field sample was taken.
Tide	State of the tide when sample taken. The code used is as follows: 1 High Slack Tide 2 High Ebb Tide 3 Low Ebb Tide 4 Low Slack Tide 5 Low Flood Tide 6 High Flood Tide 9 Freshwater above tidal influence
DS	Depth Sampled (Feet)
Temp	Temperature (Degrees Celsius)
Cond	Conductivity (micromhos)
Salin	Salinity (Parts per thousand)
DO	Dissolved Oxygen (mg/l)
F. Colif	Fecal Coliforms/100 mls (average of duplicate laboratory filtrations)
Entero	Enterococcus/100 mls (average of duplicate laboratory filtrations)

Table A.04 Raw Data from MWRA 1989 CSO Receiving Water Monitoring.

Region: Alewife Brook

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
21-Aug	70	0831	9	0	23.0	650	0.0	7.3	1650	388
28-Aug	70	0918	9	0	20.0	.	.	7.4	195	80
	71	0919	9	0	21.0	.	.	6.3	520	320
	71.1	0922	9	0	21.5	.	.	6.2	535	340
	72	0921	9	0	20.0	.	.	4.8	1005	1200
	73	0920	9	0	19.5	.	.	4.6	983	760
29-Aug	70	0942	9	0	19.0	.	.	5.2	600	158
	71	0943	9	0	19.0	.	.	5.6	15875	383
	72	0944	9	0	20.0	.	.	5.2	3750	560
	73	0945	9	0	19.0	.	.	4.0	3725	498
	74	0946	9	0	20.0	.	.	6.1	2075	253
30-Aug	70	0974	9	0	21.0	.	.	3.8	313000	13050
	71	0975	9	0	21.0	.	.	4.2	39500	3625
	72	0976	9	0	20.5	.	.	3.6	41850	12375
	73	0977	9	0	21.0	.	.	3.6	30000	11150
	74	0978	9	0	23.0	.	.	6.6	17575	6375
31-Aug	70	1000	9	0	21.0	.	.	3.0	7150	958
	71	1001	9	0	22.0	.	.	4.8	5075	893
	72	1002	9	0	21.0	.	.	3.4	3325	803
	73	1003	9	0	19.0	.	.	3.0	3025	895
	74	1004	9	0	20.0	.	.	6.2	2775	448
05-Sep	70	1025	9	0	18.0	.	.	7.4	400	168
	71	1026	9	0	18.0	.	.	4.7	2100	675
	72	1027	9	0	18.0	.	.	3.6	2225	825
	73	1028	9	0	16.5	.	.	3.0	8075	1225
	74	1029	9	0	17.0	.	.	4.8	4100	290
06-Sep	70	1053	9	0	17.0	.	.	4.4	2350	188
	71	1054	9	0	16.0	.	.	3.8	1900	233
	73	1055	9	0	17.0	.	.	4.5	565	398
	74	1056	9	0	16.5	.	.	6.4	4850	375
07-Sep	70	1079	9	0	19.0	.	0.0	7.8	960	143
	71	1080	9	0	18.5	.	0.0	4.6	903	250
	72	1082	9	0	19.0	.	0.0	4.6	20000	20000
	73	1081	9	0	19.0	.	0.0	4.0	1115	1325
	74	1083	9	0	19.0	.	0.0	4.2	2675	238

Table A.04 continued 1989 Raw Data

Region: Calf Island

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
25-Jul	50	0482	5	0	18.0	40000	29.3	7.3	10	3
26-Jul	50	0490	3	0	16.5	43300	34.2	6.9	3	0
27-Jul	50	0516	3	0	15.8	44700	35.9	7.7	5	3
31-Jul	50	0528	2	0	16.0	38000	29.5	7.5	5	0
01-Aug	50	0554	6	0	15.8	29000	29.0	7.9	8	0
02-Aug	50	0581	6	0	16.0	38000	29.0	7.9	3	0
03-Aug	50	0611	6	0	16.0	38000	29.0	8.4	13	0
09-Aug	50	0695	5	0	15.0	37000	29.0	8.3	0	3
16-Aug	50	0788	2	0	18.0	37000	27.0	7.4	118	0
17-Aug	50	0803	6	0	15.1	37000	29.0	11.9	0	0

Table A.04 continued 1989 Raw Data

Region: Charles River

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
01-Jun	1	021a	9	0	20.0	232	0.0	.	1420	.
	1	021b	9	0	20.0	232	0.0	.	1770	.
	1	022a	9	3	20.0	232	0.0	.	905	.
	1	022b	9	3	20.0	232	0.0	.	775	.
	1	0023	9	0	20.0	236	0.0	.	2475	.
	1	0024	9	3	20.0	236	0.0	.	3000	.
05-Jun	1	029a	9	0	25.0	232	0.0	.	1220	.
	1	029b	9	0	25.0	232	0.0	.	1355	.
	10	027a	9	17	20.0	14000	9.5	.	135	.
	10	027b	9	17	20.0	14000	9.5	.	85	.
	10	028a	9	0	24.0	800	0.0	.	310	.
	10	028b	9	0	24.0	800	0.0	.	240	.
	11	025a	9	24	16.0	27000	20.0	.	110	.
	11	025b	9	24	16.0	27000	20.0	.	105	.
	11	026a	9	0	23.0	900	0.0	.	275	.
	11	026b	9	0	23.0	900	0.0	.	150	.
06-Jun	1	0039	9	0	22.0	230	0.0	.	4050	.
	2	0038	9	0	22.0	250	0.0	.	5150	.
	8	0036	9	34	8.0	21000	20.5	.	45	.
	8	0037	9	0	21.0	600	0.0	.	1355	.
	9	0034	9	24	10.0	24000	21.0	.	935	.
	9	0035	9	0	21.0	700	0.0	.	205	.
	10	0032	9	28	8.0	26000	24.0	.	135	.
	10	0033	9	0	22.0	700	0.0	.	670	.
	11	0030	9	22	16.0	27500	22.0	.	270	.
	11	0031	9	0	22.0	900	0.5	.	390	.
07-Jun	1	0051	9	0	21.0	230	0.1	.	605	.
	2	0050	9	0	21.0	230	0.2	.	1950	.
	7	0048	9	11	20.5	900	1.0	.	1250	.
	7	0049	9	0	22.0	350	0.5	.	525	.
	8	0046	9	11	20.0	1000	1.0	.	1620	.
	8	0047	9	0	21.0	700	0.5	.	1485	.
	9	0044	9	22	12.0	21000	17.0	.	175	.
	9	0045	9	0	21.0	700	0.5	.	575	.
	10	0042	9	32	8.5	26000	24.0	.	125	.
	10	0043	9	0	21.0	800	0.5	.	195	.
	11	0040	9	24	15.5	25000	19.0	.	385	.
	11	0041	9	0	21.5	2000	1.5	.	790	.
08-Jun	1	0067	9	0	21.0	200	0.0	.	2150	.
	2	0066	9	0	20.0	200	0.0	.	3700	.
	3	0065	9	0	20.0	185	0.0	.	5950	.
	4	0064	9	0	20.0	220	0.0	.	3550	.
	5	0063	9	0	20.0	240	0.0	.	960	.
	6	0062	9	0	20.0	230	0.5	.	1070	.

Table A.04 continued 1989 Raw Data

Region: Charles River (cont.).

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
08-Jun	7	0060	9	15	22.0	3000	2.0	.	11600	.
	7	0061	9	0	19.0	280	0.0	.	12500	.
	8	0058	9	13	20.0	700	1.0	.	3035	.
	8	0059	9	0	20.0	700	1.0	.	2295	.
	9	0056	9	23	17.0	16000	11.5	.	1795	.
	9	0057	9	0	20.0	600	1.0	.	1225	.
	10	0054	9	30	10.0	28000	24.5	.	30	.
	10	0055	9	0	20.0	950	1.0	.	255	.
	11	0052	9	24	16.0	26000	20.0	.	395	.
	11	0053	9	0	19.0	1100	1.0	.	300	.
13-Jun	1	0088	9	0	17.0	750	0.5	.	660	.
	2	0087	9	0	19.0	750	0.5	.	1860	.
	3	0086	9	0	20.0	750	0.5	.	1855	.
	4	0085	9	0	20.0	1100	1.0	.	1485	.
	5	0083	9	9	19.0	600	0.5	.	530	.
	5	0084	9	0	19.0	600	0.5	.	550	.
	6	0081	9	10	19.0	800	0.5	.	690	.
	6	0082	9	0	19.0	600	0.5	.	990	.
	7	0079	9	11	.	.	.	.	280	.
	7	0080	9	0	.	.	.	.	400	.
	8	0077	9	13	.	.	.	.	605	.
	8	0078	9	0	.	.	.	.	645	.
	9	0075	9	23	.	.	.	.	70	.
	9	0076	9	0	.	.	.	.	445	.
	10	0073	9	32	.	.	.	.	0	.
	10	0074	9	0	.	.	.	.	195	.
	11	0071	9	23	.	.	.	.	50	.
	11	0072	9	0	.	.	.	.	155	.
14-Jun	1	0105	9	0	.	.	.	.	425	.
	2	0104	9	0	.	.	.	.	460	.
	3	0103	9	0	.	.	.	.	900	.
	4	0102	9	0	.	.	.	.	805	.
	5	0101	9	0	.	.	.	.	405	.
	6	0099	9	0	.	.	.	.	490	.
	6	0100	9	11	.	.	.	.	1425	.
	7	0097	9	0	.	.	.	.	1020	.
	7	0098	9	18	.	.	.	.	5150	.
	8	0095	9	0	.	.	.	.	200	.
	8	0096	9	15	.	.	.	.	1440	.
	9	0093	9	0	.	.	.	.	375	.
	9	0094	9	23	.	.	.	.	30	.
	10	0091	9	0	.	.	.	.	285	.
	10	0092	9	29	.	.	.	.	80	.
	11	0089	9	0	.	.	.	.	310	.
	11	0090	9	25	.	.	.	.	85	.

Table A.04 continued 1989 Raw Data

Region: Charles River (cont.).

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
15-Jun	1	0121	9	0	18.0	250	0.0	.	860	.
	2	0120	9	0	19.3	250	0.0	.	1800	.
	3	0119	9	0	18.5	258	0.8	.	1805	.
	4	0118	9	0	22.0	261	0.0	.	390	.
	5	0117	9	0	20.0	268	0.5	.	665	.
	6	0116	9	0	19.0	320	0.5	.	730	.
	7	0114	9	17	18.0	950	0.8	.	1030	.
	7	0115	9	0	19.0	950	0.8	.	985	.
	8	0112	9	19	18.5	2200	0.5	.	920	.
	8	0113	9	0	15.0	90	0.0	.	1095	.
	9	0110	9	21	16.0	18000	13.5	.	1065	.
	9	0111	9	0	19.0	600	0.5	.	810	.
	10	0108	9	32	7.0	26000	26.0	.	265	.
	10	0109	9	0	19.0	600	0.5	.	710	.
	11	0106	9	25	17.0	26000	19.0	.	210	.
	11	0107	9	0	19.0	750	0.5	.	355	.
19-Jun	1	0138	9	0	22.0	200	0.0	.	1105	.
	2	0137	9	0	23.0	200	0.0	.	1825	.
	3	0136	9	0	23.0	200	0.0	.	1915	.
	4	0135	9	0	24.0	200	0.0	.	610	.
	5	0134	9	0	24.0	200	0.0	.	755	.
	6	0132	9	0	21.0	200	0.0	.	1025	.
	6	0133	9	10	20.0	250	0.0	.	1250	.
	7	0130	9	0	21.0	200	0.0	.	1380	.
	7	0131	9	11	20.0	250	0.0	.	1195	.
	8	0128	9	0	21.0	250	0.0	.	765	.
	8	0129	9	15	16.0	17000	13.0	.	2660	.
	9	0126	9	0	20.0	350	0.0	.	295	.
	9	0127	9	22	12.0	23000	19.0	.	1030	.
	10	0124	9	0	21.0	350	0.0	.	485	.
	10	0125	9	31	11.0	25000	23.0	.	235	.
	11	0122	9	0	21.0	500	0.0	.	435	.
	11	0123	9	22	21.0	10000	6.0	.	465	.
20-Jun	1	0155	9	0	23.0	180	0.0	.	820	.
	2	0154	9	0	22.0	190	0.0	.	1915	.
	3	0153	9	0	22.0	190	0.0	.	1245	.
	4	0152	9	0	23.5	190	0.0	.	1190	.
	5	0151	9	0	23.0	190	0.0	.	940	.
	6	0149	9	0	22.5	190	0.0	.	1445	.
	6	0150	9	9	20.0	240	0.0	.	1065	.
	7	0147	9	0	22.0	210	0.0	.	680	.
	7	0148	9	16	19.0	500	0.5	.	1530	.
	8	0145	9	0	23.0	210	0.0	.	560	.
	8	0146	9	14	20.0	600	0.0	.	5450	.
	9	0143	9	0	22.0	210	0.0	.	490	.
	9	0144	9	23	14.0	23000	18.0	.	1235	.
	10	0141	9	0	22.0	320	0.2	.	390	.
	10	0142	9	31	9.0	25000	22.5	.	685	.

Table A.04 continued 1989 Raw Data

Region: Charles River (cont.).

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
20-Jun	11	0139	9	0	21.0	700	0.5	.	290	.
	11	0140	9	23	18.0	24000	17.0	.	250	.
21-Jun	1	0172	9	0	24.0	190	0.0	.	2115	.
	2	0171	9	0	23.0	170	0.0	.	1905	.
	3	0170	9	0	24.0	195	0.0	.	1780	.
	4	0169	9	0	25.0	210	0.0	.	1320	.
	5	0168	9	0	25.0	200	0.0	.	1200	.
	6	0166	9	0	23.0	200	0.0	.	1080	.
	6	0167	9	10	20.0	480	0.0	.	2080	.
	7	0164	9	0	19.0	315	0.0	.	955	.
	7	0165	9	11	23.0	220	0.0	.	1270	.
	7.5	0174	9	0	22.0	440	0.0	.	980	.
	7.5	0175	9	15	17.0	900	1.0	.	219500	.
	8	0162	9	0	25.0	200	0.0	.	875	.
	8	0163	9	10	21.0	420	0.0	.	1040	.
	9	0160	9	0	24.0	220	0.0	.	655	.
	9	0161	9	22	15.0	23000	17.0	.	1380	.
	10	0158	9	0	26.0	270	0.0	.	50	.
	10	0159	9	16	10.0	26000	22.5	.	400	.
	10	0173	9	8	26.0	270	0.0	.	345	.
	11	0156	9	0	22.0	390	0.0	.	330	.
	11	0157	9	24	18.0	39000	21.5	.	195	.
22-Jun	1	194a	9	0	25.0	190	0.0	.	6900	.
	1	194b	9	0	25.0	190	0.0	.	6150	.
	1.5	0193	9	0	25.0	200	0.0	.	2285	.
	2	0191	9	0	25.0	195	0.0	.	14000	.
	2	0192	9	12	24.0	225	0.0	.	15700	.
	3	0190	9	0	26.0	210	0.0	.	8400	.
	4	0189	9	0	24.0	210	0.0	.	5150	.
	5	188b	9	0	24.0	100	0.0	.	3100	.
	5	188a	9	0	24.0	100	0.0	.	3350	.
	6	186a	9	0	25.0	210	0.0	.	7400	.
	6	186b	9	0	25.0	210	0.0	.	6600	.
	6	187a	9	10	19.0	320	0.0	.	13800	.
	6	187b	9	10	19.0	320	0.0	.	17800	.
	7	184a	9	0	26.0	170	0.0	.	8000	.
	7	184b	9	0	26.0	170	0.0	.	7700	.
	7	185a	9	16	19.0	1300	1.0	.	13300	.
	7	185b	9	16	19.0	1300	1.0	.	14300	.
	8	182a	9	0	26.0	210	0.0	.	8600	.
	8	182b	9	0	26.0	210	0.0	.	6650	.
	8	183a	9	20	18.0	18500	13.0	.	17000	.
	8	183b	9	20	18.0	18500	13.0	.	20600	.
	9	0180	9	0	26.0	240	0.0	.	4550	.
	9	0181	9	25	13.0	22000	17.0	.	16950	.
	10	0178	9	0	25.0	280	0.0	.	2600	.
	10	0179	9	32	10.0	28000	23.0	.	1175	.

Table A.04 continued 1989 Raw Data

Region: Charles River (cont.).

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
22-Jun	11	0176	9	0	24.0	400	0.0	.	3700	.
	11	0177	9	25	19.5	30000	21.0	.	2955	.
26-Jun	1.5	206a	9	0	27.0	210	0.0	.	1000	.
	1.5	206b	9	0	27.0	210	0.0	.	1550	.
	6.1	205a	9	3	27.0	220	0.0	.	150	.
	6.1	205b	9	3	27.0	220	0.0	.	350	.
	7.1	202a	9	3	27.0	230	0.0	.	200	.
	7.1	202b	9	3	27.0	230	0.0	.	250	.
	7.5	203a	9	0	26.0	220	0.0	.	100	.
	7.5	203b	9	0	26.0	220	0.0	.	100	.
	7.5	204a	9	7	21.0	280	0.0	.	700	.
	7.5	204b	9	7	21.0	280	0.0	.	1050	.
	8.1	200a	9	10	23.0	550	0.0	.	300	.
	8.1	200b	9	10	23.0	550	0.0	.	350	.
	8.1	201a	9	0	26.0	230	0.0	.	800	.
	8.1	201b	9	0	26.0	230	0.0	.	700	.
	9.1	195a	9	0	25.0	265	0.0	.	250	.
	9.1	195b	9	0	25.0	265	0.0	.	150	.
	9.1	196a	9	10	19.0	1200	0.5	.	200	.
	9.1	196b	9	10	19.0	1200	0.5	.	250	.
	9.2	197a	9	0	25.0	390	0.0	.	150	.
	9.2	197b	9	0	25.0	390	0.0	.	100	.
	9.2	198a	9	22	13.0	22000	18.0	.	750	.
	9.2	198b	9	22	13.0	22000	18.0	.	500	.
	9.3	199a	9	0	26.0	240	0.0	.	450	.
	9.3	199b	9	0	26.0	240	0.0	.	650	.
27-Jun	8.1	213a	9	0	28.0	240	0.0	.	1145	.
	8.1	213b	9	0	28.0	240	0.0	.	1260	.
	9.1	207a	9	0	25.0	250	0.0	.	540	.
	9.1	207b	9	0	25.0	250	0.0	.	365	.
	9.1	208a	9	10	16.0	260	0.0	.	640	.
	9.1	208b	9	10	16.0	260	0.0	.	470	.
	9.2	209a	9	0	26.0	250	0.0	.	400	.
	9.2	209b	9	0	26.0	250	0.0	.	535	.
	9.2	210a	9	23	17.0	24000	17.0	.	430	.
	9.2	210b	9	23	17.0	24000	17.0	.	600	.
	9.3	211a	9	0	27.0	250	0.0	.	705	.
	9.3	211b	9	0	27.0	250	0.0	.	765	.
	9.3	212a	9	13	24.0	650	0.0	.	490	.
	9.3	212b	9	13	24.0	650	0.0	.	525	.
19-Jul	9	0406	9	0	.	.	.	.	1300	.
	12	0418	9	0	.	.	.	.	1080	.
08-Aug	9	0686	9	0	.	.	.	.	11250	388
25-Aug	9	0896	9	0	.	.	.	.	2125	215
	12	0884	9	0	.	.	.	.	310	235

Table A.04 continued 1989 Raw Data

Region: Dorchester Bay

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
28-Jun	31	0214	2	0	20.0	.	28.0	.	0	5
	31	215a	2	12	21.0	38000	27.0	.	45	10
	31	215b	2	12	21.0	38000	27.0	.	3	0
	32	0216	2	0	20.0	38500	27.5	.	5	8
	33	0217	2	0	20.0	39000	27.5	.	38	5
	34	0218	2	0	21.0	39000	27.0	.	8	5
	35	0219	2	0	20.0	.	28.0	.	0	3
	36	0220	2	0	20.0	39000	28.5	.	0	3
	37	0221	2	0	20.0	39000	28.0	.	3	8
	38	0224	2	0	19.0	38000	28.0	.	10	0
	40	0229	2	0	20.0	33500	23.5	.	18	3
	41	0228	2	0	21.5	33000	22.5	.	1550	90
29-Jun	28	0243	2	0	.	.	.	.	10	18
	30	0237	2	0	19.0	36000	27.0	.	5	0
	33	0250	2	0	.	.	.	.	18	0
	38	0235	2	0	18.0	36000	27.0	.	3	3
	38	0236	2	11	18.0	35000	27.0	.	25	3
	39	0238	2	0	19.0	37000	27.0	.	65	0
	39	0239	2	10	18.0	37000	28.0	.	98	8
	39	0253	2	0	.	.	.	.	138	0
	40	0234	2	0	19.0	37000	26.0	.	178	23
	40.1	0252	2	0	.	.	.	.	95	3
	41	0233	2	0	19.0	37000	26.0	.	220	15
	41.1	0251	2	0	.	.	.	.	375	25
	41.1	0412	2	0	.	.	.	.	47	3
05-Jul	30	0255	5	11	18.3	.	.	8.1	3	0
	30	0256	5	0	18.4	.	.	8.2	3	2
	31	0257	5	9	18.2	.	.	8.9	5	0
	31	0258	5	0	19.3	.	.	8.5	0	0
	32	0259	5	0	19.7	.	.	9.2	8	0
	33	0260	5	10	19.1	.	.	7.9	10	0
	33	0261	5	0	19.4	.	.	9.2	0	3
	34	0262	5	11	19.3	.	.	8.9	15	2
	34	0263	5	0	19.4	.	.	9.2	3	0
	35	0264	5	0	20.0	.	.	8.7	8	0
	36	0265	5	0	20.3	.	.	8.1	73	10
	37	0266	5	0	20.4	.	.	10.0	3	3
	38	0267	5	11	18.5	.	.	8.6	0	0
	38	0268	5	0	18.5	.	.	8.1	0	0
	39	0274	6	0	20.0	.	.	6.7	40	0
	40	0273	6	0	20.8	.	.	6.5	18	13
	41	0272	6	0	20.0	.	.	6.6	155	35
06-Jul	30	0275	6	0	19.0	38500	24.0	7.4	2175	390
	30	0276	6	9	19.0	38500	27.5	7.8	248	35
	31	0277	6	0	19.5	39000	28.0	7.9	38	5
	32	0278	6	0	19.0	39000	28.5	7.8	95	5
	33	0279	6	0	20.0	39500	28.0	8.7	60	55

Table A.04 continued 1989 Raw Data

Region: Dorchester Bay (cont.).

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
06-Jul	34	0280	6	0	20.0	39000	28.0	8.2	23	47
	35	0281	6	0	20.0	39000	28.0	8.4	5	5
	36	0282	6	0	20.0	39500	28.0	8.3	13	43
	37	0283	6	0	20.0	39500	28.0	7.4	705	305
	38	0284	6	0	19.5	36000	26.0	8.0	695	58
	38	0285	6	8	19.0	33500	25.0	8.2	263	56
	39	0291	6	0	20.5	33000	23.0	6.8	2000	3700
	40	0290	6	0	20.5	33000	23.0	6.8	1100	190
	41	0289	6	0	21.0	33000	22.5	6.2	17000	1600
10-Jul	28	0304	5	0	.	.	.	.	598	262
	29	0292	3	12	19.0	.	.	9.3	0	0
	29	0293	3	0	19.8	.	.	9.4	3	0
	30	0294	3	10	19.0	.	.	8.4	18	0
	30	0295	3	0	19.0	.	.	8.6	5	0
	31	0296	3	0	19.7	.	.	10.3	5	1
	32	0297	3	0	20.0	.	.	9.4	5	0
	33	0298	3	0	20.0	.	.	10.4	5	0
	34	0299	3	0	20.0	.	.	10.0	0	1
	35.5	0300	3	0	20.0	.	.	10.0	0	7
	37	0301	3	0	20.0	.	.	8.7	540	138
	39	0305	5	0	.	.	.	.	48	21
11-Jul	29	0311	3	10	18.9	.	.	7.9	30	5
	29	0312	3	0	18.9	.	.	8.0	10	1
	30	0313	3	9	19.1	.	.	7.8	45	0
	30	0314	3	9	19.1	.	.	7.8	35	2
	31	0315	3	0	19.0	.	.	8.0	25	1
	32	0316	3	0	18.8	.	.	7.2	30	1
	33	0317	4	0	20.0	.	.	7.8	20	1
	34	0318	4	0	20.2	.	.	7.7	50	6
	35.5	0319	4	0	20.0	.	.	7.3	43	1
	37	0320	4	0	20.3	.	.	7.1	65	9
	38	0321	4	0	19.7	.	.	8.2	43	1
	39	0322	5	0	20.4	.	.	7.4	573	56
	40	0310	3	0	20.1	.	.	7.3	23	6
	41	0309	3	0	20.7	.	.	6.1	1425	450
12-Jul	28	0343	5	0	.	.	.	.	0	5
	29	0330	2	0	20.0	39000	28.0	10.0	0	0
	29	0331	3	12	19.0	38000	31.0	8.6	50	0
	30	0332	3	0	21.0	41000	28.0	8.5	0	0
	30	0333	3	10	20.0	38000	27.0	9.7	18	5
	31	0335	3	0	21.0	40000	27.5	10.3	3	3
	32	0336	3	0	21.0	40000	27.5	9.7	15	0
	33	0337	3	0	21.5	48000	28.0	9.7	0	0
	34	0338	3	0	21.0	40000	27.5	9.3	10	0
	35	0339	3	0	20.5	40000	28.0	9.3	50	0
	36	0340	3	0	20.0	40000	28.0	8.7	108	0
	37	0341	4	0	21.0	40000	28.0	8.1	0	0

Table A.04 continued 1989 Raw Data

Region: Dorchester Bay (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
12-Jul	38	0334	3	0	21.0	40000	27.5	9.2	3	0
	39	0342	5	0	24.0	37000	24.0	8.3	43	5
	40	0329	2	0	21.5	39000	26.5	8.7	18	0
	41	0328	2	0	22.0	32000	21.0	6.9	5	0
13-Jul	28	0363	5	0	21.0	40000	26.0	.	15	22
	29	0351	3	0	21.0	39000	28.0	10.2	5	0
	29	0352	3	13	19.0	39000	28.0	8.5	13	15
	30	0353	3	0	21.0	39000	27.0	.	0	0
	30	0354	3	12	18.0	38000	27.0	.	55	10
	31	0355	3	0	21.0	40000	27.0	9.9	0	3
	32	0356	3	0	21.0	40000	27.0	9.0	15	0
	33	0357	3	0	22.0	40000	28.0	9.3	8	0
	34	0358	3	0	22.0	40000	27.0	9.0	0	0
	35	0359	3	0	21.0	41000	28.0	9.0	0	3
	36	0360	3	0	21.0	40000	28.0	8.8	13	0
	37	0361	3	0	21.0	40000	27.0	8.7	10	0
	38	0362	3	0	22.0	38000	26.0	8.6	30	0
	39	0345	2	0	21.0	36000	24.5	7.0	33	10
	40	0346	2	0	21.0	39000	27.0	9.8	5	3
	41	0347	2	0	22.0	34000	23.0	7.2	.	.
17-Jul	41	368a	6	0	.	.	.	.	2825	2738
	41	368b	6	0	.	.	.	.	2498	2650
18-Jul	29	0377	6	17	19.0	39000	28.0	6.4	60	5
	29	378a	6	0	19.5	39500	28.0	6.6	8	0
	29	378b	6	0	19.5	39500	28.0	6.6	13	0
	30	0379	1	17	20.0	38000	27.0	6.3	38	3
	30	0380	1	0	20.0	39000	27.0	6.5	28	5
	31	0381	1	0	21.5	39000	26.0	6.5	20	0
	32	0382	1	0	22.0	39000	26.0	6.5	15	0
	33	0383	1	0	21.5	38500	26.0	6.6	73	0
	34	0384	2	0	21.5	39000	26.5	6.5	103	3
	35	0385	2	0	21.0	39000	26.5	6.6	55	3
	36	0386	2	0	21.0	39000	26.5	6.2	40	0
	37	0387	2	0	20.5	39000	27.0	6.1	65	13
	38	0388	2	0	20.5	39500	27.0	6.6	18	0
	39	376b	6	0	20.0	.	.	5.5	273	15
	39	376a	6	0	20.0	.	.	5.5	508	68
	40	375a	6	0	20.0	.	.	5.5	160	28
	40	375b	6	0	20.0	.	.	5.5	148	15
	41	374a	6	0	20.0	.	.	5.9	138	38
	41	374b	6	0	20.0	.	.	5.9	218	20
19-Jul	28	0416	6	0	.	.	.	.	75	60
	29	0396	6	0	18.0	39000	29.0	6.6	3	0
	30	0397	6	0	19.0	40000	29.0	6.5	5	0
	31	0398	6	0	20.0	40000	28.0	6.6	5	0
	32	0399	6	0	21.0	37000	25.0	6.8	0	0

Table A.04 continued 1989 Raw Data

Region: Dorchester Bay, (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
19-Jul	33	0400	1	0	21.5	40000	27.0	6.3	13	0
	33	0411	2	0	.	.	.	.	0	5
	34	0401	1	0	21.5	40000	27.0	6.6	8	0
	35	0402	1	0	21.5	40000	27.0	6.7	0	0
	36	0403	1	0	22.0	41000	28.0	6.3	0	3
	37	0404	2	0	22.0	41000	28.0	6.3	10	0
	38	0405	2	0	20.5	40000	28.0	6.8	0	0
	39	0395	6	0	21.5	34500	23.0	6.0	90	18
	39	0414	2	0	.	.	.	.	23	0
	40	0394	6	0	21.0	36500	25.0	5.6	35	18
	40	0413	2	0	.	.	.	.	23	0
	41	0393	6	0	20.0	36000	25.0	5.7	153	13
20-Jul	29	0428	6	0	19.0	36000	26.0	7.1	90	3
	29	0429	6	17	20.0	34000	24.0	7.1	53	133
	30	0437	1	0	19.0	.	.	7.1	280	0
	30	0438	1	18	17.0	.	.	7.0	38	10
	31	0430	6	0	19.5	.	.	7.1	118	3
	32	0431	6	0	19.6	.	.	7.1	90	0
	33	0432	6	0	20.0	.	.	7.0	13	5
	34	0433	6	0	19.8	.	.	7.2	5	0
	35	0434	6	0	20.0	.	.	7.1	5	0
	36	0435	6	0	20.3	.	.	6.6	13	0
	37	0436	6	0	20.4	.	.	6.1	43	0
	38	0439	1	0	19.0	.	.	7.3	115	3
	39	0427	5	0	20.3	35000	24.0	5.6	118	48
	40	0426	5	0	20.5	36000	24.0	5.7	70	40
	41	425a	5	0	20.0	35000	25.0	5.1	843	283
	41	425b	5	0	20.0	35000	25.0	5.1	263	178
24-Jul	44	0459	5	0	20.1	43900	31.5	5.9	3	0
25-Jul	43	0465	4	0	20.0	42100	31.0	7.8	0	0
	44	0466	4	0	21.0	41700	30.0	7.9	0	0
26-Jul	43	0484	3	0	20.0	41500	30.0	7.9	18	0
	44	0491	4	0	18.0	46900	31.3	7.3	0	0
27-Jul	43	0510	3	0	20.0	44700	29.9	8.2	13	0
	44	0509	3	0	20.3	45400	31.0	8.3	3	0
31-Jul	43	0522	6	0	18.0	38000	28.5	7.5	3	3
	44	0521	6	0	15.5	37500	29.5	8.1	23	3
01-Aug	43	0548	6	0	17.6	39000	27.0	7.1	8	3
	44	0547	6	0	17.0	36000	29.0	7.9	10	0
02-Aug	43	0575	6	0	18.0	38500	29.0	7.6	25	0
	44	0574	6	0	18.0	39000	28.5	8.5	3	0

Table A.04 continued **1989 Raw Data**

Region: Dorchester Bay (cont.).

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
03-Aug	43	0605	6	0	19.0	39000	28.0	7.9	3	0
	44	0604	5	0	19.0	39000	28.0	8.0	13	3
07-Aug	43	0635	5	0	22.0	39000	26.0	7.4	108	10
	44	0634	5	0	20.0	40000	28.5	7.2	98	5
08-Aug	43	0662	3	0	17.7	38000	28.0	7.8	140	3
	44	0661	3	0	17.1	38000	29.0	7.2	208	18
09-Aug	43	0689	3	0	17.0	38000	29.0	7.8	13	3
	44	0688	3	0	16.5	38000	29.0	8.0	8	0
14-Aug	39	0737	3	0	23.0	23000	16.0	6.1	12200	963
	44	0718	2	0	19.0	33000	24.0	7.3	9475	373
15-Aug	43	0742	1	0	18.0	36000	26.5	8.7	255	25
	44	0740	1	0	17.0	36000	27.0	8.1	203	8
	44	0741	1	22	15.0	32000	25.0	7.7	203	3
16-Aug	39.1	0795	3	0	.	.	.	.	50000	103
	43	0789	2	0	20.0	34000	22.0	7.3	2575	8
	44	0784	2	20	15.0	36000	28.0	7.8	358	3
	44	0785	2	0	20.0	35000	25.0	7.3	3400	3
17-Aug	39.1	0824	2	0	24.0	23000	15.0	8.3	26800	118
	43	0797	6	0	17.0	36000	26.5	7.6	60	5
	44	0796	6	0	15.3	36000	28.0	7.8	43	3
18-Aug	39.1	0827	3	0	.	.	.	.	1300	95
19-Aug	39.1	0828	6	0	20.0	29000	19.5	5.9	6350	160
20-Aug	39.1	0829	3	0	21.0	30000	21.0	6.4	10800	60
21-Aug	39.1	0838	6	0	.	.	.	.	15475	28
22-Aug	39.1	0853	6	0	.	.	.	.	1875	8
25-Aug	28	0887	3	0	.	.	.	.	0	0
	33	0895	4	0	.	.	.	.	8	0
	39.1	0890	5	0	.	.	.	.	485	50
	39.1	0898	5	0	.	.	.	.	19750	988
	40	0894	4	0	.	.	.	.	498	55
	41	0891	3	0	.	.	.	.	1175	130
28-Aug	39.1	0923	5	0	.	.	.	.	48250	233
30-Aug	39.1	0970	2	0	21.0	36500	25.0	7.0	10500	13

Table A.04 continued 1989 Raw Data

Region: Dorchester Bay (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
31-Aug	39.1	0997	2	0	.	.	.	.	578	10
06-Sep	39.1	1051	5	0	17.9	34000	26.0	6.9	100	3
07-Sep	39.1	1078	5	0	.	.	.	.	35	98
26-Sep	39.1	1110	3	0	.	.	.	.	151500	3825
27-Sep	39.1	1111	3	0	.	.	.	.	108	5
28-Sep	39	1129	2	0	.	.	.	.	285	25
	39.1	1130	2	0	.	.	.	.	7500	103
02-Oct	39	1135	6	0	.	.	.	.	2800	100
	39.1	1131	6	0	.	.	.	.	7400	360
	39.2	1132	6	0	.	.	.	.	46250	1100
	39.3	1133	6	0	.	.	.	.	40000	1005
	39.4	1134	6	0	.	.	.	.	11925	213
	39.5	1136	1	0	.	.	.	.	4725	163
	39.6	1137	1	0	.	.	.	.	5825	150
03-Oct	39	1148	6	0	16.0	34000	26.0	7.8	3825	195
	39.1	1152	6	0	.	.	.	.	3650	113
	39.2	1151	6	0	16.0	33000	25.0	7.3	6325	238
	39.3	1150	6	0	15.5	33000	25.0	7.3	5100	200
	39.4	1149	6	0	15.5	33000	26.0	7.0	3775	153
	39.5	1146	6	0	15.0	34000	27.0	8.4	200	50
	39.6	1147	6	0	15.0	33500	26.5	8.3	743	53
04-Oct	39	1153	6	0	14.0	33000	26.5	8.1	870	50
	39.1	1157	1	0	14.0	33500	26.0	5.5	1175	58
	39.2	1156	1	0	.	.	.	.	975	65
	39.3	1155	1	0	.	.	.	.	845	58
	39.4	1154	6	0	.	.	.	.	848	55
	39.7	1158	2	0	.	.	.	.	783	38
	39.8	1159	2	0	.	.	.	.	558	25
05-Oct	39	1162	6	0	13.0	32000	26.5	7.9	1325	15
	39.1	1168	6	0	13.0	32000	26.0	7.4	1075	13
	39.2	1165	6	0	13.0	32000	26.5	8.0	595	3
	39.3	1164	6	0	13.0	35000	24.5	8.3	795	5
	39.4	1163	6	0	13.0	32000	26.5	8.0	790	5
	39.5	1160	6	0	13.0	34000	27.0	5.2	208	8
	39.6	1161	6	0	13.0	32500	27.0	10.1	165	3
	39.7	1167	6	0	13.0	32000	27.0	5.4	1950	10
	39.8	1166	6	0	13.0	32000	26.0	5.3	1700	23

Table A.04 continued **1989 Raw Data**

Region: Dorchester Bay (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
10-Oct	39	1173	5	0	12.5	30500	25.0	7.8	3450	10
	39.1	1169	4	0	13.0	31500	26.5	6.2	1850	3
	39.2	1170	4	0	12.5	30000	25.0	7.6	9250	10
	39.3	1171	5	0	12.5	30000	25.0	8.2	9650	10
	39.4	1172	5	0	12.5	30000	25.0	8.2	6125	8
	39.5	1174	5	0	12.5	29000	24.0	8.3	58	3
	39.6	1175	5	0	13.0	30500	25.0	7.8	203	8
11-Oct										
	39	1178	2	0	12.0	32000	27.0	7.7	40	0
	39.1	1184	2	0	12.0	31500	26.5	7.3	408	45
	39.2	1183	2	0	.	.	.	.	43	5
	39.3	1182	2	0	.	.	.	.	13	0
	39.4	1181	2	0	.	.	.	.	20	3
	39.5	1179	2	0	.	.	.	.	45	0
	39.6	1180	2	0	.	.	.	.	8	0
	39.7	1177	2	0	.	.	.	.	1475	1825
	39.8	1176	2	0	.	.	.	.	2225	218
12-Oct	39	1187	2	0	12.5	32000	27.0	8.1	23	5
	39.1	1193	2	0	13.0	30500	25.0	6.4	113	48
	39.2	1192	2	0	13.0	31000	25.0	7.7	83	0
	39.3	1191	2	0	13.0	31000	26.0	7.7	55	0
	39.4	1190	2	0	12.5	32000	27.0	7.8	13	0
	39.5	1188	2	0	12.5	32000	26.5	8.6	40	3
	39.6	1189	2	0	12.0	32000	27.0	8.6	33	3
	39.7	1186	2	0	12.5	30500	25.5	7.3	48	5
	39.8	1185	2	0	12.0	29500	25.0	7.1	400	8
23-Oct	39	1196	3	0	12.5	18000	14.5	6.8	728	68
	39.1	1202	3	0	11.5	17000	14.5	7.2	643	103
	39.2	1201	3	0	11.5	17500	14.5	7.0	520	160
	39.3	1200	3	0	11.5	18000	15.0	7.0	498	93
	39.4	1199	3	0	11.5	18000	15.0	7.0	565	105
	39.5	1197	3	0	12.5	20000	16.0	6.8	458	103
	39.6	1198	3	0	11.5	20000	16.5	7.0	515	93
	39.7	1195	3	0	12.5	16000	13.0	6.8	703	108
	39.8	1194	3	0	12.5	20000	16.5	6.6	618	90
26-Oct	39	1205	3	0	13.5	19500	15.5	7.0	158	43
	39.1	1211	3	0	14.5	19000	14.5	7.0	168	85
	39.2	1210	3	0	13.5	19000	14.5	7.2	73	75
	39.3	1209	3	0	13.5	19000	15.0	7.2	143	55
	39.4	1208	3	0	13.5	19000	15.0	7.3	185	48
	39.5	1206	3	0	12.5	20500	17.0	7.0	93	43
	39.6	1207	3	0	12.5	20500	17.0	7.2	178	103
	39.7	1203	3	0	15.0	18500	14.0	7.0	673	18
	39.8	1204	3	0	17.0	22000	17.0	6.5	108	78

Table A.04 continued 1989 Raw Data

Region: Dorchester Bay (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
31-Oct	39	1214	1	0	14.0	25000	20.0	6.2	210	5
	39.1	1220	2	0	13.0	30000	24.0	5.0	55	18
	39.2	1219	2	0	13.0	29000	23.0	5.7	190	20
	39.3	1218	2	0	13.5	28000	22.0	5.7	140	13
	39.4	1217	2	0	13.0	29000	24.0	5.7	395	18
	39.5	1215	2	0	14.0	29500	24.0	6.4	93	3
	39.6	1216	2	0	14.0	29500	24.0	6.0	638	10
	39.7	1213	1	0	13.0	28000	22.0	6.5	213	10
	39.8	1212	1	0	13.0	27000	22.0	5.8	260	20

Table A.04 continued 1989 Raw Data

Region: Inner Harbor

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
29-Jun	15	0248	2	0	.	.	.	.	1300	163
	17	0247	2	0	.	.	.	.	2500	195
	19	0246	2	0	.	.	.	.	933	45
	24	0245	2	0	.	.	.	.	625	25
19-Jul	13	0408	2	0	.	.	.	.	68	3
	15	0407	2	0	.	.	.	.	75	0
	19	0409	2	0	.	.	.	.	60	5
	24	0410	2	0	.	.	.	.	10	0
24-Jul	13	0440	4	31	17.0	44700	32.6	3.7	63	3
	13	0441	4	0	22.5	19450	11.6	4.5	608	30
	14	0442	4	33	17.0	41800	32.6	3.6	15	0
	14	0443	5	0	22.0	30200	19.9	4.6	568	23
	15	0444	5	38	17.0	40000	30.5	4.0	30	0
	15	0445	5	0	21.5	39750	27.3	6.2	210	3
	16	0446	5	41	17.0	40200	30.0	4.6	15	0
	16	0447	5	0	22.5	43200	29.1	5.3	345	8
	17	0448	5	41	16.9	42300	33.0	4.3	3	0
	17	0449	5	0	22.0	35000	24.8	5.0	310	10
	19	0450	5	25	17.4	42000	31.5	4.1	5	3
	19	0451	5	0	21.6	42200	29.7	5.0	228	3
	20	0452	5	35	17.0	41000	31.5	4.5	20	0
	20	0453	5	0	21.5	42500	29.6	5.4	70	3
	21	0454	5	43	15.7	40000	32.3	6.0	13	0
	21	0455	5	0	21.4	43800	30.8	5.9	50	0
	22	0456	5	0	23.2	40000	31.3	5.3	0	0
	23	0457	5	0	23.0	49800	33.3	4.8	3	0
	24	0458	5	0	20.6	42500	30.4	5.7	10	0
25-Jul	13	0470	5	0	22.0	26600	16.4	5.0	160	10
	13	0471	5	29	17.5	40200	28.1	4.1	25	8
	14	0472	5	0	21.9	31200	20.8	5.1	195	13
	14	0473	5	32	17.1	35500	26.3	5.1	23	0
	15	0474	5	0	22.8	44100	29.7	6.1	15	0
	15	0475	5	37	17.1	35900	27.7	5.1	15	5
	16	0476	5	0	22.4	42000	29.7	7.0	53	13
	16	0477	5	41	17.1	38400	29.7	5.1	5	13
	17	0478	5	0	22.0	34500	22.5	5.3	100	8
	18	0483	6	0	.	.	.	.	103	10
	19	0479	5	0	22.0	38700	25.9	5.6	63	8
	20	0480	5	0	23.0	42300	28.9	6.5	208	10
	21	0481	5	0	22.0	36300	32.5	6.0	40	0
	22	0468	4	0	23.5	47000	31.5	5.5	0	0
	23	0469	4	0	23.0	46700	31.6	5.3	0	3
	24	0467	4	0	20.0	41700	29.2	6.8	53	0
26-Jul	13	0506	5	0	22.8	33900	21.8	5.0	53	8
	13	0507	5	31	17.5	40500	30.0	2.5	46	13

Table A.04 continued 1989 Raw Data

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
26-Jul	14	0504	5	0	22.5	33400	22.6	5.5	73	18
	14	0505	5	31	17.5	40900	31.2	5.1	143	15
	17	0502	5	0	22.0	40100	27.0	5.5	43	3
	17	0503	5	37	16.5	40100	30.0	5.9	58	8
	19	0500	5	0	22.0	43900	30.0	5.9	33	8
	19	0501	5	25	17.0	39900	30.0	5.2	40	5
	20	0498	5	0	21.8	43300	30.0	5.8	20	5
	20	0499	5	31	16.7	40300	31.3	5.9	90	10
	21	0497	5	0	21.5	43900	31.2	6.1	20	0
	22	0493	4	37	15.8	39900	31.7	6.6	88	15
	22	0494	4	0	23.0	48200	32.5	5.6	18	5
	23	0495	4	36	15.7	40800	32.5	5.6	95	10
	23	0496	4	0	21.3	45800	31.2	5.6	3	0
	24	0492	4	0	21.5	43500	30.6	6.4	58	0
27-Jul	18	508a	6	0	23.2	46700	30.7	6.1	7175	863
	18	520a	5	9	20.5	43700	30.7	4.0	255	3
	18	520b	5	9	20.5	43700	30.7	4.0	380	28
	22	0518	5	0	23.2	35900	30.8	6.3	5	0
	23	0519	5	0	22.3	46100	31.0	6.5	15	3
	24	0517	5	0	20.8	42100	29.4	8.6	40	0
31-Jul	13	0543	2	0	21.0	24000	16.0	5.5	140	20
	13	0544	2	35	15.0	30000	24.0	4.8	95	8
	14	0545	2	0	20.0	32000	22.0	6.7	228	0
	14	0546	2	35	15.0	34000	26.0	5.3	43	3
	17	0541	2	0	19.0	36000	26.0	6.5	40	0
	17	0542	2	49	15.0	36000	28.0	5.3	13	0
	19	0539	2	0	20.0	35000	25.0	6.5	670	10
	19	0540	2	44	16.0	37000	29.0	6.3	30	3
	20	0537	2	0	20.0	37000	26.0	7.4	633	5
	20	0538	2	39	16.0	37000	29.0	6.5	38	5
	21	0535	2	0	20.0	36000	25.0	8.0	828	8
	21	0536	2	42	15.5	36000	28.5	6.6	65	13
	22	0531	2	0	20.0	39000	27.0	6.4	355	3
	22	0532	2	40	15.5	35000	29.0	5.2	28	5
	23	0533	2	0	20.0	37000	26.0	7.5	893	5
	23	0534	2	43	15.0	37000	29.5	6.8	70	13
	24	0529	2	0	18.0	38000	28.0	7.8	148	3
	24	0530	2	42	15.0	37000	30.0	7.3	63	5
01-Aug	13	0570	2	40	15.4	37000	30.0	4.8	18	15
	13	0571	2	0	21.3	30000	20.0	6.8	113	5
	14	0568	2	41	15.3	37000	30.0	5.5	15	5
	14	0569	2	0	19.6	35000	25.0	7.0	40	13
	17	0566	2	45	15.8	37000	26.0	6.5	20	0
	17	0567	2	0	20.4	37500	27.0	8.1	20	0
	18	0572	2	0	.	.	.	.	433	8
	18	0573	2	10	.	.	.	.	138	3

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
01-Aug	19	0564	2	45	15.7	36500	29.0	6.4	50	3
	19	0565	2	0	20.5	35000	24.0	7.2	243	3
	20	0562	2	39	16.2	38000	29.0	6.8	428	3
	20	0563	2	0	19.9	37000	26.0	8.2	30	3
	21	0560	1	50	15.8	37500	29.0	6.8	10	3
	21	0561	1	0	19.5	38500	27.5	8.7	200	0
	22	0556	1	45	15.5	37500	29.0	6.6	18	3
	22	0557	1	0	21.1	36500	29.0	6.4	20	0
	23	0558	1	44	15.7	37500	29.0	7.0	18	0
	23	0559	1	0	19.2	39300	29.0	7.1	83	0
	24	0555	1	0	17.5	30000	29.5	8.2	3	3
02-Aug	13	0598	2	40	16.0	37000	29.0	4.8	50	5
	13	0599	2	0	21.0	32000	22.0	6.2	195	58
	14	0596	2	41	16.0	37000	29.0	5.3	33	5
	14	0597	2	0	21.0	35000	24.0	8.1	940	15
	17	0594	2	50	16.0	37000	29.0	6.0	8	5
	17	0595	2	0	20.0	37000	25.5	8.2	300	8
	18	0600	3	10	19.1	30000	28.0	6.4	103	3
	18	0601	3	0	20.4	30500	27.5	7.4	4450	95
	19	0592	2	32	17.0	34500	27.0	6.0	13	5
	19	0593	2	0	20.0	38500	27.0	9.6	130	0
	20	0590	1	45	17.0	38000	28.5	7.1	203	13
	20	0591	1	0	20.0	39000	28.0	9.5	25	0
	21	0588	1	48	17.0	38000	28.5	7.1	203	18
	21	0589	1	0	20.0	39000	28.0	9.1	0	0
	22	0584	6	44	17.0	38000	28.5	6.5	188	33
	22	0585	6	0	22.0	42000	29.0	6.2	10	3
	23	0586	6	45	17.0	38000	28.5	7.2	138	18
	23	0587	6	0	21.0	42000	29.5	6.3	3	0
	24	0582	6	42	17.5	38000	29.0	7.4	385	30
	24	0583	6	0	19.0	39000	28.0	8.6	0	3
	63	0602	3	0	22.8	34000	29.0	6.9	3	3
	63	0603	3	29	21.0	33000	29.0	3.8	8	5
03-Aug	13	0628	2	0	28.0	33000	23.0	6.2	55	3
	13	0629	2	39	17.0	31000	28.5	2.1	15	3
	14	0626	2	0	22.0	36000	25.0	7.8	185	55
	14	0627	2	43	17.0	37000	28.0	3.8	18	8
	17	0624	2	0	21.0	37000	25.0	8.4	88	0
	17	0625	2	49	17.0	38000	28.5	6.6	28	3
	18	0630	3	10	21.0	39000	27.0	6.3	200	8
	18	0631	3	0	18.0	39000	27.0	9.0	133	10
	19	0622	2	0	20.0	36000	25.0	7.9	1073	8
	19	0623	2	32	17.0	36000	27.0	6.5	58	3
	20	0620	2	0	20.0	38500	27.0	8.7	153	0
	20	0621	2	41	17.0	38000	27.5	6.2	60	0
	21	0618	2	0	21.0	38000	26.0	9.2	185	0
	21	0619	2	48	17.0	38000	28.5	7.1	80	10
	22	0614	1	0	22.0	42000	29.0	6.4	3	0

Table A.04 continued 1989 Raw Data

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
03-Aug	22	0615	1	44	17.0	38000	28.5	5.1	40	3
	23	0616	1	0	21.0	40000	28.0	8.9	75	0
	23	0617	1	46	17.5	38000	28.0	6.8	85	10
	24	0612	1	0	20.0	39000	28.0	9.4	10	0
	24	0613	1	45	17.0	38000	28.5	6.5	160	40
	63	0632	3	39	20.5	33000	23.0	3.4	58	8
	63	0633	3	0	24.0	37000	23.5	6.1	10	8
07-Aug	13	0657	6	35	16.0	35000	27.0	5.2	3	18
	13	0658	6	0	22.0	32000	19.0	5.0	35	3
	14	0655	6	38	16.0	37000	29.0	7.0	5	3
	14	0656	6	0	24.0	28000	18.0	4.9	45	3
	17	0653	5	42	15.0	37000	29.0	7.2	13	3
	17	0654	5	0	21.0	37000	25.0	6.3	45	5
	18	0659	6	10	18.0	39000	29.0	2.5	2600	73
	18	0660	6	0	24.0	39000	25.0	6.0	558	5
	19	0651	5	29	16.0	37000	28.0	6.8	13	3
	19	0652	5	0	20.0	39000	27.0	6.1	33	3
	20	0649	5	38	15.0	32000	26.0	7.2	63	3
	20	0650	5	0	20.0	32000	23.0	7.0	13	0
	21	0647	5	44	15.0	36000	28.0	7.7	45	10
	21	0648	5	0	21.0	40000	28.0	6.8	45	3
	22	0643	5	42	14.0	35000	29.0	6.8	55	3
	22	0644	5	0	22.0	42000	29.0	6.0	18	10
	23	0645	5	39	15.0	36000	29.0	7.3	95	0
	23	0646	5	0	20.0	41000	29.0	6.4	160	23
	24	0641	5	38	15.0	36000	28.0	7.4	90	8
	24	0642	5	0	21.0	40000	28.0	8.4	18	0
08-Aug	13	0682	5	33	13.4	32000	27.5	5.4	100	3
	13	0683	5	0	20.0	26000	18.0	5.0	500	8
	14	0680	5	37	13.4	36000	30.0	7.0	50	3
	14	0681	5	0	19.9	31000	21.0	5.3	1050	3
	17	0678	5	39	13.3	36000	29.5	7.4	73	3
	17	0679	5	0	20.1	31000	21.5	5.5	975	13
	19	0676	5	27	13.4	31000	30.0	7.4	60	0
	19	0677	5	0	19.6	32500	22.5	5.8	205	10
	20	0674	5	34	13.4	36000	30.0	7.1	340	18
	20	0675	5	0	16.9	36000	28.0	6.6	63	0
	21	0672	5	42	13.1	36000	30.0	7.2	3275	140
	21	0673	5	0	18.1	37500	28.0	6.1	838	13
	22	0670	5	39	12.7	36000	31.0	7.1	1900	63
	22	0671	5	0	19.9	41000	29.0	6.2	85	5

Table A.04 continued 1989 Raw Data

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
08-Aug	23	0684	5	42	12.3	35000	30.0	7.7	3825	70
	23	0685	5	0	20.0	39000	27.5	6.8	193	3
	24	0668	5	36	12.5	35500	30.0	7.8	9150	428
	24	0669	5	0	17.3	38000	29.0	6.9	298	13
09-Aug	13	0712	5	33	14.5	36000	29.0	5.5	10	3
	13	0713	5	0	18.0	29000	22.0	5.5	83	0
	14	0710	5	37	13.0	36000	30.0	6.7	373	30
	14	0711	5	0	19.0	29500	20.0	5.5	110	3
	17	0708	5	39	13.0	36000	30.0	6.9	238	8
	17	0709	5	0	18.0	34500	25.0	6.2	55	3
	19	0706	5	27	14.0	36000	27.5	7.0	265	18
	19	0707	5	0	18.0	38000	28.0	7.1	13	3
	20	0704	5	36	14.0	36000	30.0	7.0	338	12
	20	0705	5	0	17.0	38000	29.0	7.3	3	0
	21	0702	5	43	15.0	36000	28.5	7.3	525	18
	21	0703	5	0	20.0	38500	27.5	7.3	8	3
	22	0698	5	37	16.0	36000	28.0	7.3	268	5
	22	0699	5	0	20.0	40000	29.0	6.5	0	0
	23	0700	5	39	14.0	36000	29.5	7.5	445	22
	23	0701	5	0	19.0	40500	29.5	6.6	10	0
	24	0696	5	37	14.0	36000	29.0	7.4	363	10
	24	0697	5	0	18.0	38000	28.0	7.5	10	0
10-Aug	18	0715	2	0	19.0	38000	28.0	5.5	7400	1200
	63	0716	2	4	18.5	40000	29.5	5.5	8	5
	63	0717	2	0	20.3	42000	30.0	6.4	.	.
14-Aug	13	0733	2	36	16.0	36000	27.0	6.2	340	70
	13	0734	2	0	20.0	29000	20.0	5.3	4050	468
	14	0735	3	36	16.0	36000	28.0	6.5	398	38
	14	0736	3	0	21.0	29000	21.0	5.7	5950	423
	17	0731	2	46	15.0	36000	28.0	6.4	300	32
	17	0732	2	0	22.0	29000	18.0	6.4	8300	78
	18	0738	3	2	20.0	33000	23.0	2.6	45250	1003
	18	0739	3	0	22.2	27000	18.0	3.9	68500	435
	19	0729	2	29	16.0	36000	28.0	6.7	525	23
	19	0730	2	0	20.0	29000	21.0	6.7	6750	508
	20	0727	2	39	15.0	32000	24.0	5.7	250	20
	20	0728	2	0	20.0	30000	20.0	6.6	7525	350
	21	0725	2	39	16.0	36000	28.0	6.4	405	13
	21	0726	2	0	20.0	31000	21.0	5.9	47800	480
	22	0723	2	39	15.0	32000	25.0	5.3	123	8
	22	0724	2	0	23.0	37000	24.0	6.4	4650	155
	23	0721	2	44	15.0	36000	28.0	6.3	140	5
	23	0722	2	0	21.0	31000	19.0	6.8	7550	308
	24	0719	2	42	13.0	28000	30.0	7.1	323	33
	24	0720	2	0	19.0	28000	19.0	6.5	19850	433

Table A.04 continued 1989 Raw Data

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
15-Aug	13	0747	2	36	15.3	28500	29.0	6.1	1475	400
	13	0748	2	0	19.0	28000	19.5	5.8	3825	475
	14	0749	2	38	16.0	37000	29.0	5.7	591	15
	14	0750	2	0	20.0	26000	17.0	6.2	7975	225
	17	0751	2	46	15.5	36000	28.5	5.7	825	33
	17	0752	2	0	20.0	27000	19.0	6.2	3025	75
	19	0753	2	29	16.0	37000	29.0	6.2	335	30
	19	0754	2	0	20.0	32000	22.0	5.9	4975	45
	20	0755	2	44	16.0	36500	28.5	7.2	188	55
	20	0756	2	0	20.0	30000	20.5	6.3	2275	25
	21	0757	3	39	16.0	36000	28.0	7.2	145	23
	21	0758	3	0	20.0	31000	22.0	6.6	2350	60
	22	0759	3	38	16.0	36500	28.5	6.3	173	8
	22	0760	3	0	22.0	38500	26.0	7.1	285	3
	23	0761	3	39	16.0	36000	28.0	6.9	68	20
	23	0762	3	0	21.0	37000	26.0	7.2	1325	35
	24	0745	2	42	15.0	36000	28.5	8.1	123	15
	24	0746	2	0	20.0	33000	23.0	7.1	11450	33
16-Aug	13	0766	6	41	16.0	33000	26.0	7.4	1525	3
	13	0767	6	0	20.0	28000	19.0	5.5	25650	30
	14	0768	6	41	16.0	35000	26.0	6.6	1075	15
	14	0769	6	0	21.0	28000	19.0	5.9	22300	25
	17	0770	6	47	17.0	37000	27.0	6.3	2000	40
	17	0771	6	0	21.0	28000	19.0	5.2	153600	98
	19	0772	1	30	17.0	37000	28.0	6.3	1625	18
	19	0773	1	0	20.0	33000	22.0	5.5	31400	15
	20	0774	1	40	16.0	36000	28.0	7.6	525	15
	20	0775	1	0	22.0	28000	18.0	5.7	17175	5
	21	0776	1	38	16.0	36000	28.0	8.5	1200	15
	21	0777	1	0	21.0	30000	20.0	6.5	16850	30
	22	0778	2	41	16.0	36000	28.0	8.2	775	10
	22	0779	2	0	21.0	35000	24.0	.	4750	3
	23	0780	2	44	16.0	36000	28.0	7.1	2700	22
	23	0781	2	0	21.0	35000	24.0	6.9	4575	3
	24	0782	2	41	16.0	37000	28.0	7.7	725	10
	24	0783	2	0	21.0	34000	23.0	6.4	14975	0
	65	0786	2	49	12.0	35000	30.0	7.8	318	5
	65	0787	2	0	18.0	37000	27.0	7.4	588	3
17-Aug	65	0804	6	0	15.4	36000	28.0	8.5	10	15
	65	0805	6	47	11.9	35000	30.0	8.9	5	3
	13	0822	2	38	14.8	36000	29.0	6.1	850	195
	13	0823	2	0	20.2	24500	16.5	6.9	365	105
	14	0820	2	41	15.2	36000	29.0	6.7	193	30
	14	0821	2	0	20.0	30000	20.0	6.0	273	5
	17	0818	2	48	14.6	36000	29.0	7.5	65	10
	17	0819	2	0	19.4	31000	22.5	6.5	203	0
	18	0825	2	10	19.1	39000	26.0	4.5	480	100
	18	0826	2	0	22.0	31000	19.0	6.1	673	88

Table A.04 continued 1989 Raw Data

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
17-Aug	19	0816	2	32	15.0	36000	29.0	7.3	88	5
	19	0817	2	0	19.8	32500	22.5	6.4	375	5
	20	0814	1	39	14.8	36000	28.5	7.5	50	10
	20	0815	1	0	19.8	36000	25.5	7.1	118	3
	21	0812	1	40	14.4	36000	29.0	7.7	15	5
	21	0813	1	0	19.6	36000	26.0	7.4	1090	3
	22	0808	1	43	14.5	36000	29.0	7.4	33	3
	22	0809	1	0	19.2	36000	26.0	7.5	170	3
	23	0810	1	44	14.1	36000	28.5	7.5	28	3
	23	0811	1	0	19.6	36000	26.0	7.2	118	3
	24	0806	6	42	13.9	35000	29.0	8.2	65	30
	24	0807	6	0	19.1	36000	26.0	8.4	53	0
21-Aug	15	0834	6	44	15.4	37500	28.5	7.6	18	8
	15	0835	6	0	20.7	31000	21.5	9.3	153	13
	16	0836	6	48	15.4	36000	28.0	7.4	33	5
	16	0837	6	0	20.4	29500	20.0	8.4	300	5
	52	0830	5	0	.	.	.	.	7550	85
22-Aug	15	0849	6	45	15.3	36500	29.0	8.5	33	0
	15	0850	6	0	21.0	39000	27.0	10.3	208	3
	16	0851	6	49	15.0	36500	29.0	8.7	30	8
	16	0852	6	0	22.1	32000	21.5	9.9	213	5
	26	0841	5	26	15.7	36000	28.0	5.5	190	15
	26	0842	5	0	20.9	36000	27.5	10.5	670	13
	27	0839	5	36	15.0	36000	29.0	7.1	20	5
	27	0840	5	0	18.3	36000	26.0	10.5	930	8
	52	0847	6	0	20.9	36000	25.0	6.4	778	8
	52	0848	6	24	19.5	38500	27.5	6.5	538	15
23-Aug	15	0864	5	38	16.0	37000	29.0	7.3	70	8
	15	0865	5	0	20.0	37000	26.0	8.9	235	5
	16	0866	5	43	16.0	36000	28.0	7.2	80	10
	16	0867	5	0	20.0	33000	23.0	7.9	250	8
	26	0854	4	25	17.0	36000	28.0	6.3	10	13
	26	0855	4	0	20.0	27000	26.0	9.2	255	100
	27	0856	4	35	16.0	37000	28.0	7.9	33	3
	27	0857	4	0	20.0	37000	26.0	10.5	53	23
	52	0862	5	17	19.0	39000	29.0	4.3	575	65
	52	0863	5	0	20.0	35000	25.0	4.9	540	30
24-Aug	15	0880	5	39	15.0	36000	28.5	6.4	85	3
	15	0881	5	0	19.8	38000	27.0	8.0	63	0
	16	0882	5	37	15.7	36000	29.0	6.2	195	15
	16	0883	5	0	20.4	34500	24.0	6.3	45	8
	26	0868	3	14	15.7	34000	26.5	6.7	83	3
	26	0869	3	0	19.9	37000	26.0	7.5	153	8
	27	0870	3	35	14.9	36000	29.0	7.7	15	5
	27	0871	3	0	19.0	37000	26.5	9.4	35	3

Table A.04 continued 1989 Raw Data

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
24-Aug	52	0878	5	15	17.1	37000	28.0	6.7	58	13
	52	0879	5	0	20.1	37000	26.0	6.3	255	8
25-Aug	15	0897	3	0	.	.	.	.	60	3
	17	0889	3	0	.	.	.	.	405	18
	19	0893	3	0	.	.	.	.	88	5
	24	0892	3	0	.	.	.	.	145	3
28-Aug	15	0914	3	49	16.0	36000	28.0	6.4	18	3
	15	0915	3	0	19.0	34000	25.0	7.9	38	0
	16	0916	3	49	16.0	36000	28.0	6.4	13	0
	16	0917	3	0	19.0	35000	25.0	7.7	83	0
	26	0899	2	29	16.0	28000	22.0	6.3	8	5
	26	0900	2	0	17.0	36000	28.0	8.3	188	35
	27	0901	2	49	16.0	37000	29.0	6.2	48	8
	27	0902	2	0	18.0	31000	22.0	7.1	105	53
	52	0912	2	17	18.0	34000	23.0	0.1	65	10
	52	0913	2	0	19.0	34000	25.0	6.1	7600	15
29-Aug	15	0940	1	49	16.0	37000	28.5	5.8	8	0
	15	0947	1	0	19.0	35000	25.0	6.4	403	0
	16	0948	2	49	16.0	37000	28.5	5.9	18	3
	16	0949	2	0	18.0	36000	26.0	6.2	443	5
	26	0924	6	0	17.4	36500	27.0	6.4	183	43
	26	0925	6	34	15.0	.	26.0	3.5	38	3
	27	0926	6	29	15.7	36500	29.0	5.5	125	15
	27	0927	6	0	17.8	36000	27.0	6.3	1575	153
	52	0936	1	24	19.0	39000	28.0	3.0	320	13
	52	0937	1	0	20.0	35000	24.0	5.3	3650	25
	69	0938	1	24	20.0	40000	28.0	5.5	145	8
	69	0939	1	0	21.0	38000	26.5	6.0	2600	35
30-Aug	15	0966	1	46	18.0	37000	27.0	6.7	95	0
	15	0967	1	0	21.0	37000	26.0	6.9	4900	100
	16	0968	1	48	16.0	37000	29.0	7.0	100	0
	16	0969	1	0	21.0	33000	23.0	6.4	10500	63
	26	0950	6	27	16.0	37000	28.0	6.7	20	5
	26	0951	6	0	18.0	36500	26.5	7.4	293	58
	27	0952	6	43	17.0	37000	28.0	6.1	250	15
	27	0953	6	0	18.0	37000	27.5	6.1	1575	118
	52	0962	6	0	21.0	37000	27.0	5.4	9700	20
	52	0963	6	25	19.0	35000	26.0	0.9	4275	58
	69	0964	1	19	19.0	38000	27.5	5.9	3925	10
	69	0965	1	0	21.0	39000	27.0	5.9	9950	15
31-Aug	15	0993	6	45	15.9	37000	28.0	5.9	143	3
	15	0994	6	0	19.3	38000	27.0	5.9	168	0
	16	0995	6	49	15.7	37000	28.0	6.3	208	8
	16	0996	6	0	19.6	37500	26.5	6.2	118	8

Table A.04 continued 1989 Raw Data

Region: Inner Harbor (cont.)

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
31-Aug	26	0971	5	0	19.5	37000	27.0	6.5	203	5
	26	0972	5	29	15.6	35000	26.5	5.4	143	8
	27	0979	5	41	15.6	37000	27.5	5.5	190	35
	27	0980	5	0	19.4	36500	26.0	6.4	65	33
	52	0989	6	25	19.0	34000	23.0	1.5	233	13
	52	0990	6	0	19.4	37000	25.0	5.0	500	15
	69	0991	6	18	17.8	32000	24.0	5.1	108	15
	69	0992	6	0	19.9	38000	26.5	5.9	223	20
05-Sep	15	1021	6	42	14.8	35000	28.5	5.9	23	5
	15	1022	6	0	20.0	34000	24.0	7.0	105	5
	16	1023	6	42	14.8	36000	28.5	6.1	5	0
	16	1030	6	0	19.0	35000	25.5	6.3	188	15
	26	1005	5	26	15.2	31000	25.0	3.3	28	30
	26	1006	5	0	17.4	36500	27.0	4.3	263	232
	27	1007	5	37	14.7	35500	27.5	4.0	38	13
	27	1008	5	0	15.9	35000	27.0	4.9	543	113
	52	1017	5	19	17.7	37000	27.0	1.9	18	0
	52	1018	5	0	19.6	31500	22.5	4.3	2650	5
	69	1019	5	14	15.7	34500	27.0	4.7	50	3
	69	1020	5	0	19.6	36000	27.0	6.9	88	3
06-Sep	15	1033	3	38	14.7	34000	28.0	4.9	85	8
	15	1034	3	0	19.6	37500	26.0	6.0	815	40
	16	1031	3	42	14.9	36000	28.5	5.2	40	8
	16	1032	3	0	17.7	35500	26.0	6.3	713	20
	26	1035	4	26	15.7	36000	28.0	4.4	80	138
	26	1036	4	0	17.0	36000	27.0	5.1	328	3
	27	1037	5	37	15.1	36000	28.5	5.4	95	3
	27	1038	5	0	17.2	35000	27.0	6.9	1825	35
	52	1041	5	19	19.5	32000	27.0	2.0	40	0
	52	1042	5	0	19.1	30000	21.5	5.1	570	8
	69	1039	5	18	15.0	31000	24.5	2.5	35	3
	69	1040	5	0	19.4	35000	24.5	6.1	255	5
07-Sep	15	1060	3	40	15.0	36000	28.0	5.1	30	13
	15	1061	3	0	19.0	37000	27.0	6.9	313	17
	16	1058	3	37	15.0	33000	26.0	5.9	55	8
	16	1059	3	0	19.0	37000	27.0	6.3	8150	225
	26	1062	3	26	16.0	36000	28.0	4.4	15	13
	26	1063	3	0	19.0	37000	27.0	6.5	150	13
	27	1064	3	38	16.0	37000	28.0	4.9	18	18
	27	1065	3	0	19.0	36000	26.0	6.5	.	.
	52	1068	3	19	18.0	37000	27.0	4.4	5	10
	52	1069	3	0	20.0	36000	25.0	4.7	905	65
	69	1066	3	29	16.0	32000	24.0	4.9	20	5
	69	1067	3	0	20.0	37000	26.0	5.9	368	20

Table A.04 continued 1989 Raw Data

Region: Mystic River

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
29-Jun	57	0241	9	0	.	.	.	.	3000	.
	67	0240	9	0	.	.	.	.	65	.
19-Jul	66	0417	9	0	.	.	.	.	333	38
	67	0419	9	0	.	.	.	.	50	15
21-Aug	57	0832	9	0	24.1	500	0.0	8.5	600	73
	59	0833	9	0	24.7	655	0.0	11.3	98	5
22-Aug	56	0845	9	0	25.0	500	0.0	10.9	15650	175
	57	0843	9	0	25.5	550	0.0	9.3	20000	63
	58	0844	9	0	25.0	550	0.0	9.7	12200	185
	59	0846	9	0	25.2	600	0.0	13.3	105	15
23-Aug	56	0860	9	0	26.0	600	0.0	10.7	483	28
	57	0858	9	0	27.0	470	0.0	8.4	480	25
	58	0859	9	0	26.0	500	0.0	9.4	1200	20
	59	0861	9	0	27.0	650	0.0	11.9	455	20
24-Aug	56	0876	9	0	25.1	500	0.0	12.2	135	13
	57	0873	9	0	25.1	400	0.0	8.0	520	113
	58	0874	9	0	24.4	450	0.0	8.9	383	80
	59	0877	9	0	24.9	650	0.0	12.0	75	0
	60	0872	9	0	24.4	600	0.0	9.3	15	0
	61	0875	9	0	25.1	450	0.0	12.4	218	53
25-Aug	66	0886	9	0	.	.	.	.	115	30
	67	0888	9	0	.	.	.	.	15	3
28-Aug	56	0907	9	0	23.0	400	0.0	13.4	55	23
	57	0903	9	0	23.0	400	0.0	8.7	110	55
	58	0905	9	0	21.0	390	0.0	9.0	193	48
	59	0911	9	0	23.0	600	0.0	12.3	73	15
	60	0909	9	0	24.0	700	0.0	11.0	168	0
	61	0906	9	0	22.0	380	0.0	12.0	183	70
	66	0904	9	0	22.0	400	0.0	9.2	90	28
	67	0910	9	0	23.0	550	0.0	11.7	15	5
	68	0908	9	0	23.0	500	0.0	10.3	30	8
29-Aug	56	0931	9	0	21.0	400	0.0	11.1	70	18
	57	0941	9	0	.	.	.	.	68	28
	58	0929	9	0	21.0	410	0.0	6.7	153	18
	59	0935	9	0	21.0	900	0.0	11.5	28	30
	60	0933	9	0	21.0	700	0.0	10.7	53	5
	61	0930	9	0	21.0	390	0.0	10.3	300	70
	66	0928	9	0	21.0	410	0.0	7.4	143	38
	67	0934	9	0	22.0	750	0.0	10.5	58	8
	68	0932	9	0	21.0	550	0.0	9.9	30	8

Table A.04 continued 1989 Raw Data

Region: Mystic River

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
30-Aug	56	0957	9	0	22.0	400	0.0	9.5	1625	465
	57	0973	9	0	23.0	.	.	7.2	4125	443
	58	0955	9	0	22.0	400	0.0	7.0	13275	2125
	59	0961	9	0	23.0	800	0.0	12.5	68	5
	60	0959	9	0	23.0	600	0.0	12.9	190	13
	61	0956	9	0	23.0	400	0.0	8.5	2025	760
	66	0954	9	0	23.0	410	0.0	7.2	10275	993
	67	0960	9	0	23.0	700	0.0	12.5	290	15
	68	0958	9	0	23.0	470	0.0	13.2	1838	145
31-Aug	56	0984	9	0	21.6	395	0.0	7.2	2808	228
	57	0999	9	0	23.0	.	.	7.0	808	155
	58	0982	9	0	21.8	380	0.0	6.5	11900	968
	59	0988	9	0	21.6	900	0.0	10.5	158	28
	60	0986	9	0	21.3	650	0.0	9.3	220	10
	61	0983	9	0	21.6	385	0.0	6.5	5000	433
	66	0981	9	0	23.2	390	0.0	6.7	2335	305
	67	0987	9	0	21.6	800	0.0	9.7	108	25
	68	0985	9	0	21.6	490	0.0	9.3	558	223
05-Sep	56	1012	9	0	20.6	400	0.0	11.7	70	50
	57	1024	9	0	20.0	.	.	7.8	255	60
	58	1010	9	0	19.7	390	0.0	9.3	638	60
	59	1016	9	0	20.6	1000	0.5	11.5	1305	65
	60	1014	9	0	20.8	650	0.0	12.0	128	18
	61	1011	9	0	20.1	380	0.0	9.3	40	10
	66	1009	9	0	19.6	420	0.0	8.0	278	38
	67	1015	9	0	20.7	700	0.0	12.0	360	5
	68	1013	9	0	21.1	505	0.0	12.5	60	95
06-Sep	56	1046	9	0	19.9	400	0.0	11.3	58	0
	57	1052	9	0	19.5	.	.	.	30	25
	58	1044	9	0	19.4	400	0.0	7.5	733	153
	59	1050	9	0	20.6	700	0.0	10.5	130	3
	60	1048	9	0	21.2	620	0.0	11.5	10	0
	61	1045	9	0	19.8	390	0.0	9.7	140	15
	66	1043	9	0	19.8	600	0.0	7.5	210	30
	67	1049	9	0	20.8	700	0.0	10.5	70	0
	68	1047	9	0	21.2	450	0.0	12.1	155	18
07-Sep	56	1073	9	0	21.0	420	0.0	13.2	25	3
	57	1057	9	0	20.0	.	.	8.4	145	28
	58	1071	9	0	20.0	410	0.0	7.7	338	18
	59	1077	9	0	22.0	800	0.0	9.4	8	0
	60	1075	9	0	22.0	650	0.0	12.1	0	0
	61	1072	9	0	21.0	400	0.0	10.9	43	13
	66	1070	9	0	21.0	410	0.0	7.9	370	63
	67	1076	9	0	21.0	800	0.0	10.1	5	0
	68	1074	9	0	22.0	500	0.0	12.2	35	3

Table A.04 continued 1989 Raw Data

Region: Neponset River

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
28-Jun	42	0227	2	0	22.5	28500	19.0	.	850	153
	53	0226	2	0	23.0	19000	14.0	.	1825	190
	54	0225	2	0	23.5	22000	14.0	.	950	255
29-Jun	42	0232	2	0	21.0	27000	19.0	.	2125	160
	53	0230	2	0	22.0	17000	10.0	.	3175	450
	54	0231	2	0	20.0	19500	12.0	.	2825	280
	55	0244	9	0	.	.	.	.	3900	248
05-Jul	42	0271	6	0	20.6	.	.	6.0	108	18
	53	0269	6	0	20.5	.	.	5.0	170	33
	54	0270	6	0	21.0	.	.	5.2	153	15
06-Jul	42	0288	6	0	21.0	29000	20.0	4.8	3250	2000
	53	0286	6	0	22.0	26000	17.0	4.4	5425	4775
	54	0287	6	0	21.5	25000	17.0	4.4	6350	7175
10-Jul	53.5	0303	5	0	.	.	.	.	3	103
	55	0302	9	0	.	.	.	.	3475	3070
11-Jul	42	0308	3	0	21.3	.	.	5.4	3025	1400
	53	0306	3	0	21.8	.	.	5.7	4625	1780
	54	0307	3	0	21.5	.	.	5.7	6700	2120
12-Jul	42	0327	2	0	22.0	21000	13.5	6.5	1825	270
	53	0325	2	0	22.0	11000	6.5	7.1	2925	565
	54	0326	2	0	21.5	14000	9.0	6.8	1825	550
	55	0324	9	0	.	.	.	.	20	.
13-Jul	42	0348	2	0	22.5	22000	14.0	6.2	688	208
	53	0350	2	0	24.0	13000	12.0	6.3	1450	168
	54	0349	2	0	22.0	17000	13.0	6.0	1155	225
	55	0344	9	0	21.0	200	0.0	6.0	1580	1260
17-Jul	42	367a	6	0	20.5	40000	28.0	5.4	368	199
	42	367b	6	0	20.5	40000	28.0	5.4	303	172
	53	0365	6	0	20.0	39000	25.0	4.8	55000	13800
	54	366a	6	0	19.5	39000	25.0	4.9	7013	1150
	54	366b	6	0	19.5	39000	25.0	4.9	7588	1125
	55	0364	9	0	21.1	.	5.0	5.9	17750	9200
18-Jul	42	373a	6	0	22.0	30500	19.5	5.0	1400	225
	42	373b	6	0	22.0	30500	19.5	5.0	1475	145
	53	371a	6	0	21.0	22000	11.5	5.5	2300	600
	53	371b	6	0	21.0	22000	11.5	5.5	2900	648
	54	372a	6	0	21.0	24000	16.0	5.5	2100	725
	54	372b	6	0	21.0	24000	16.0	5.5	1950	453
	55	370a	9	0	.	.	.	.	7000	4750
	55	370b	9	0	.	.	.	.	6750	5450

Table A.04 continued 1989 Raw Data

Region: Neponset River, cont.

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
19-Jul	42	0392	6	0	20.5	31000	21.0	5.1	385	63
	53	0390	6	0	20.5	25000	16.5	5.6	640	195
	54	0391	6	0	21.0	24500	16.0	5.6	743	200
	54	0420	6	0	.	.	.	.	608	80
	55	0389	9	0	20.0	600	0.0	7.2	1925	385
20-Jul	42	424a	5	0	21.0	30000	20.5	5.2	503	238
	42	424b	5	0	21.0	30000	20.5	5.2	900	152
	53	422a	5	0	21.0	22000	15.0	5.2	4125	1825
	53	422b	5	0	21.0	22000	15.0	5.2	1225	1375
	54	423a	5	0	21.0	24000	15.5	5.3	2825	640
	54	423b	5	0	21.0	24000	15.5	5.3	.	900
	55	0421	9	0	22.0	220	0.0	6.9	.	2700
10-Aug	55	0714	9	0	22.9	800	0.0	7.1	2625	170
25-Aug	54	0885	3	0	.	.	.	.	1675	450

Table A.04 continued **1989 Raw Data**

Region: Quincy Bay

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
28-Jun	48	0222	2	0	20.0	38000	27.0	.	5	3
	48	0223	2	11	21.0	37000	27.5	.	13	0
25-Jul	45	0463	3	0	20.0	41700	29.8	7.2	0	0
	46	0464	3	0	20.0	42100	29.8	7.3	3	0
	47	0460	3	0	20.5	45700	32.6	6.8	8	8
	48	0462	3	0	20.0	42000	30.4	7.1	0	3
	49	0461	3	0	21.0	43500	30.4	6.1	0	0
26-Jul	45	0486	3	0	20.0	41800	28.6	8.1	3	0
	46	0485	3	0	20.0	47000	34.3	7.6	5	0
	47	0489	3	0	20.7	44000	31.1	7.2	73	0
	48	0487	3	0	20.3	44700	32.6	7.5	8	0
	49	0488	3	0	21.3	43600	29.7	5.6	0	0
27-Jul	45	0512	3	0	20.5	42900	30.5	8.4	3	5
	46	0511	3	0	20.9	44400	29.4	8.4	3	0
	47	0515	3	0	20.7	44800	31.8	7.6	0	0
	48	0513	3	0	20.1	42700	30.0	8.0	3	5
	49	0514	3	0	21.1	44300	30.7	6.7	3	0
31-Jul	45	0524	6	0	18.5	39000	28.0	7.2	8	0
	46	0523	6	0	17.5	38000	29.0	7.6	15	0
	47	0527	1	0	21.0	40500	28.5	6.2	0	0
	48	0525	6	0	18.0	39000	29.0	6.3	5	5
	49	0526	1	0	19.0	39500	28.0	7.4	3	0
01-Aug	45	0550	6	0	17.8	30000	28.0	7.2	10	0
	46	0549	6	0	17.8	30000	28.0	7.5	8	0
	47	0553	6	0	20.0	32000	29.0	8.7	0	0
	48	0551	6	0	17.5	30000	28.5	7.4	18	3
	49	0552	6	0	18.8	31000	29.5	6.5	0	0
02-Aug	45	0577	6	0	20.0	40000	28.5	6.8	0	3
	46	0576	6	0	18.5	39000	28.5	8.0	8	0
	47	0580	6	0	21.0	41000	28.5	6.4	0	0
	48	0578	6	0	18.5	39000	29.0	7.2	5	3
	49	0579	6	0	21.0	40500	28.5	6.7	0	0
03-Aug	45	0607	6	0	19.0	31000	21.0	8.0	0	3
	46	0606	6	0	19.0	39000	28.5	7.3	3	3
	47	0610	6	0	19.0	40000	28.0	7.3	8	13
	48	0608	6	0	19.0	36000	27.0	7.5	3	0
	49	0609	6	0	21.0	40000	28.0	7.6	5	3
07-Aug	45	0637	5	0	20.0	40000	28.0	7.2	20	3
	46	0636	5	0	20.0	40000	28.0	6.8	.	.
	47	0640	5	0	20.0	39000	27.0	6.2	0	0
	48	0638	5	0	20.0	35000	25.0	7.2	18	0
	49	0639	5	0	18.0	36000	27.0	6.7	3	3

Table A.04 continued 1989 Raw Data

Region: Quincy Bay, cont.

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif	Entero
08-Aug	45	0664	3	0	18.3	39000	29.0	7.8	3	0
	46	0663	3	0	18.1	38500	28.5	8.2	0	0
	47	0667	4	0	18.7	40000	29.0	7.4	13	3
	48	0665	4	0	18.3	39000	29.0	7.8	8	0
	49	0666	4	0	18.2	39000	29.0	6.7	0	3
09-Aug	45	0691	3	0	19.0	39000	29.0	8.0	0	0
	46	0690	3	0	19.0	39000	28.0	8.1	3	0
	47	0694	4	0	22.0	40000	27.0	7.9	3	0
	48	0692	4	0	18.5	39000	28.5	7.2	3	0
	49	0693	4	0	19.0	40000	28.5	7.4	0	0
15-Aug	45	0765	3	0	19.0	36000	26.0	9.9	588	10
	46	0763	3	0	19.0	37000	27.0	11.0	85	5
	47	0744	2	0	20.0	39000	28.0	8.0	105	13
	48	0764	3	0	10.0	36000	25.5	8.8	558	13
	49	0743	2	0	18.0	37000	27.5	8.0	35	3
16-Aug	45	0790	2	0	20.0	36000	25.0	7.9	900	3
	46	0791	2	0	20.0	36000	25.0	7.5	2250	10
	47	0794	2	0	20.0	39000	27.0	6.2	85	0
	48	0792	2	0	20.0	36000	25.0	7.0	3025	3
	49	0793	2	0	21.0	40000	28.0	6.3	50	3
17-Aug	45	0800	6	0	17.2	36000	27.5	8.0	58	5
	46	0798	6	0	17.0	36000	27.0	8.1	80	8
	47	0801	6	0	19.7	39000	28.0	9.1	18	13
	48	0799	6	0	16.0	36000	28.5	7.8	45	8
	49	0802	6	0	17.1	36000	27.0	7.7	48	5

Table A.05 Raw Data from MWRA 1990 CSO Receiving Water Monitoring.

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
05-May	14	1606	2	0	12.10	17000	15.0	7.2	135	13
	14	1605	2	35	10.10	31500	27.5	9.1	0	3
	16	1604	2	0	12.30	28000	24.0	8.0	233	35
	16	1603	2	40	10.50	31500	27.0	9.1	0	3
18-May	35	1562	6	0	11.80	29000	26.0	7.9	65	210
	36	1563	6	0	12.30	29000	26.5	7.3	20	0
	37	1564	6	0	12.00	29000	25.0	7.5	105	105
	38	1561	6	0	11.80	22000	18.0	8.0	545	230
	38	1560	6	10	10.50	30500	27.0	8.2	20	0
30-May	35	1569	5	0	13.40	31000	25.4	10.0	40	8
	36	1570	5	0	13.60	31100	25.5	9.6	75	3
	37	1571	5	0	14.10	31500	25.5	8.3	298	68
	38	1568	4	0	12.80	29600	25.0	.	670	195
	38	1567	4	16	12.80	29400	24.0	8.4	128	88
01-Jun	39	1573	3	0	15.60	26200	19.8	7.7	58	0
	39	1574	3	6	15.00	30000	23.7	7.6	48	5
04-Jun	35	1625	2	0	17.00	35000	26.0	9.2	175	10
	36	1626	2	0	16.80	35000	26.0	9.0	580	20
	37	1627	2	0	16.20	34000	27.0	7.9	863	13
	38	1624	2	0	14.30	32000	26.0	9.5	5	18
	38	1623	2	12	13.10	32000	29.0	9.6	3	3
	42	1621	2	0	18.00	18500	13.0	8.6	668	125
	54	1588	2	0	20.90	7000	4.8	6.5	903	108
	55	1589	2	0	21.50	198	0.0	7.0	650	123
05-Jun	18	1592	2	0	15.50	33000	26.0	6.9	70	0
	18	1593	2	20	12.50	34000	30.0	.	45	3
	19.1	1596	2	0	15.00	34800	28.0	6.4	83	0
	19.1	1597	2	12	12.20	34200	30.0	7.0	10	0
	63	1594	2	0	20.00	40000	30.0	7.0	55	5
	63	1595	2	10	16.00	37000	30.0	7.0	15	8
	75	1590	2	0	18.00	34100	25.0	5.0	95	10
	75	1591	2	10	16.50	34500	26.0	.	48	18
06-Jun	18	1662	1	0	15.00	35000	27.0	6.3	353	30
	18	1663	1	27	11.00	34000	30.0	6.9	125	18
	19.1	1660	6	0	14.00	32000	26.0	7.9	173	3
	19.1	1661	6	17	11.50	34000	30.0	7.9	53	8
	63	1658	6	0	18.00	39500	30.5	7.6	8	3
	63	1659	6	11	16.00	39000	29.5	7.7	45	3
	75	1664	1	0	15.00	34000	27.3	6.4	213	55
	75	1665	1	12	12.50	35000	30.0	6.0	183	33

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
07-Jun	18	1668	6	0	15.00	33400	27.0	8.1	165	15
	18	1669	6	30	12.00	34000	29.5	7.6	28	13
	19.1	1670	6	0	15.00	31800	25.1	8.3	113	55
	19.1	1671	6	25	11.00	33800	30.2	7.4	18	8
	63	1666	6	0	18.00	39500	30.0	7.2	13	10
	63	1667	6	12	15.80	37500	29.8	7.5	8	13
	75	1672	1	0	15.00	34700	28.3	7.4	80	68
	75	1673	1	12	14.30	34000	28.0	8.0	45	43
11-Jun	35	1678	5	0	14.50	32500	26.0	8.3	40	5
	36	1679	5	0	14.80	32500	27.0	7.4	41	8
	37	1680	5	0	15.00	32000	26.0	8.2	6	1
	38	1682	5	0	13.50	32000	28.2	9.0	27	2
	38	1681	5	9	13.40	32000	26.5	9.6	19	4
12-Jun	14	1686	5	0	14.00	21500	20.0	6.7	335	78
	14	1685	5	34	10.60	31500	27.0	8.1	5	3
	15	1684	5	0	12.90	3200	27.0	8.4	33	3
	15	1683	5	39	10.80	31500	28.0	9.0	5	0
	17	1688	5	0	14.60	28000	22.0	7.5	105	428
	17	1687	5	44	10.60	31500	27.5	8.5	3	0
	18	1709	1	0	15.20	30000	23.0	8.0	3	3
	18	1708	1	25	11.70	32000	27.0	7.9	28	3
	19	1690	5	0	14.10	27500	22.0	7.5	140	33
	19	1689	5	25	11.40	32000	27.5	9.1	10	0
	21	1692	5	0	13.50	32000	25.0	8.4	8	5
	21	1691	5	36	10.80	32000	27.0	8.7	3	8
	22	1694	5	0	13.90	32500	26.0	8.2	45	8
	22	1693	5	36	11.50	32000	27.0	9.0	73	15
	24	1696	5	0	12.50	32500	27.0	8.8	23	0
	24	1695	5	36	11.50	32000	27.0	9.6	88	18
	30	1700	5	0	13.00	32500	28.0	8.6	15	0
	30	1699	5	12	12.50	32000	27.5	9.0	30	5
	35	1703	6	0	14.10	33000	26.5	7.7	8	0
	36	1704	6	0	14.60	33000	27.0	7.8	3	0
	37	1705	6	0	15.10	33700	26.8	8.4	0	0
	38	1702	5	0	13.20	32000	26.5	8.5	18	0
	38	1701	5	12	13.20	32000	26.5	8.8	33	0
	44	1698	5	0	12.90	32000	28.5	8.6	43	5
	44	1697	5	16	11.40	32500	28.5	8.9	645	40
	63	1711	2	0	17.30	35500	26.5	7.7	3	3
	63	1710	2	11	17.10	36000	27.0	7.5	3	3
	75	1707	6	0	16.00	31000	23.1	7.3	403	8
	75	1706	6	12	14.40	32000	25.5	6.3	163	33
13-Jun	11	1738	6	0	20.00	370	0.0	4.0	133	10
	11	1737	6	23	14.90	23200	18.0	5.2	65	145

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	14	1715	5	0	15.80	18500	12.5	7.7	65	13
	14	1714	5	32	10.90	32000	27.5	9.7	5	0
	15	1713	5	0	14.70	30000	23.5	8.7	10	0
	15	1712	5	36	11.30	32000	28.0	10.6	28	5
	17	1717	5	0	14.60	29500	25.5	7.4	60	3
	17	1716	5	44	10.90	32000	26.5	11.7	8	5
	18	1740	6	0	16.00	32200	24.6	6.1	13	19
	18	1739	6	26	11.70	32300	28.0	6.6	25	3
	19	1719	5	0	15.30	29000	22.0	7.6	33	0
	19	1718	5	26	11.40	32000	27.5	10.6	8	3
	21	1721	5	0	14.80	31500	25.0	8.2	20	5
	21	1720	5	36	11.80	32000	27.5	10.7	13	0
	22	1723	5	0	16.60	36000	27.0	7.0	3	25
	22	1722	5	37	12.40	32500	27.0	9.9	15	48
	24	1725	5	0	14.50	32500	25.5	8.3	18	3
	24	1724	5	36	11.80	32000	26.5	10.0	13	5
	30	1729	5	0	14.70	32000	26.5	7.8	8	0
	30	1728	5	11	12.80	32000	26.5	9.0	8	0
	35	1732	5	0	16.80	34500	26.0	7.1	8	0
	36	1733	5	0	16.70	35000	26.5	6.9	0	3
	37	1734	6	0	16.70	36000	28.0	6.9	35	0
	38	1731	5	0	14.30	32500	26.0	7.8	5	25
	38	1730	5	9	13.40	32500	26.0	9.2	68	0
	44	1727	5	0	13.10	32500	27.0	7.8	10	0
	44	1726	5	16	12.10	32000	27.5	9.2	5	5
	63	1742	6	0	17.00	36500	27.5	6.2	15	0
	63	1741	6	13	14.60	35000	28.0	12.0	10	3
	75	1736	6	0	16.10	33300	25.8	6.5	20	0
	75	1735	6	8	15.00	33300	26.0	10.9	53	0
14-Jun	11	1769	6	0	20.60	394	0.0	6.3	98	10
	11	1768	6	21	15.30	24000	18.0	3.5	68	48
	14	1746	5	0	16.80	20000	14.0	7.5	10	0
	14	1745	5	39	11.60	32500	28.5	7.6	15	20
	15	1744	5	0	16.60	33800	26.0	7.9	3	0
	15	1743	5	43	11.40	32500	28.0	7.6	53	3
	17	1748	5	0	16.80	26500	20.0	7.8	58	13
	17	1747	5	41	11.40	32500	29.0	7.4	3	0
	18	1771	1	0	16.40	33000	25.0	7.9	15	15
	18	1770	6	29	11.90	32500	27.5	6.3	15	8
	19	1750	5	0	15.50	32500	25.5	8.8	10	0
	19	1749	5	31	12.40	33000	28.0	8.4	63	90
	21	1752	5	0	15.70	32500	25.0	8.9	3	0
	21	1751	5	43	11.90	32500	28.0	8.0	0	3
	22	1754	5	0	16.80	34000	26.0	8.3	3	0
	22	1753	5	39	11.80	32500	28.6	8.1	0	0
	24	1756	5	0	14.80	34000	26.0	9.9	0	0

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	24	1755	5	44	12.10	33000	28.0	8.3	5	0
	30	1760	5	0	14.30	34000	27.0	9.9	0	0
	30	1759	5	11	13.80	34000	27.0	10.2	0	0
	35	1763	5	0	17.60	35500	26.0	7.9	3	0
	36	1764	5	0	18.00	36000	26.0	8.2	3	0
	37	1765	5	0	19.00	37000	27.0	8.9	3	0
	38	1762	5	0	14.70	33000	26.0	9.4	3	0
	38	1761	5	8	13.80	33500	27.5	10.1	5	0
	44	1758	5	0	14.50	33500	27.0	9.5	5	0
	44	1757	5	19	12.90	33000	28.0	8.7	3	8
	63	1773	1	0	18.70	37000	27.0	7.8	0	3
	63	1772	1	15	18.00	37000	27.0	8.1	0	8
	75	1767	6	0	18.50	33000	23.0	8.0	18	8
	75	1766	6	14	15.80	33000	26.0	8.5	48	0
15-Jun	11	1796	5	0	20.60	369	0.0	6.6	93	13
	11	1795	5	21	15.60	25000	18.0	2.8	53	30
	14	1777	3	0	15.80	28000	21.0	7.7	75	33
	14	1776	3	37	12.60	33000	27.5	8.2	10	3
	15	1775	3	0	15.80	34000	26.5	8.0	33	85
	15	1774	3	42	12.10	32500	27.5	8.0	5	28
	17	1779	3	0	16.50	28000	21.5	7.6	100	3
	17	1778	3	45	11.90	33000	28.0	7.6	8	3
	18	1798	6	0	17.30	34000	25.0	8.4	10	0
	18	1797	6	18	12.80	33000	28.0	6.3	43	3
	19	1781	3	0	15.50	33000	25.5	8.0	110	8
	19	1780	3	26	13.20	38000	27.5	8.2	8	5
	21	1783	3	0	16.00	33200	25.5	7.8	50	38
	21	1782	3	38	12.30	33000	28.0	7.6	8	5
	22	1785	4	0	19.70	39000	27.5	7.0	8	0
	22	1784	4	38	12.50	33300	27.5	7.7	13	180
	24	1787	4	0	15.00	33500	26.0	8.7	8	0
	24	1786	4	36	13.00	33500	28.0	8.4	58	20
	30	1791	5	0	16.30	34000	26.0	8.5	3	3
	30	1790	5	8	14.50	34000	27.0	9.3	0	3
	38	1793	5	0	15.80	33700	26.0	8.5	3	3
	38	1792	5	7	15.20	34000	26.5	8.9	0	5
	44	1789	4	0	15.60	34000	26.0	8.5	0	5
	44	1788	4	15	14.00	34000	27.5	8.6	23	8
	63	1800	6	0	20.50	39000	29.0	8.0	3	0
	63	1799	6	15	19.10	38000	28.0	8.1	8	0
	75	1794	5	0	17.60	33000	24.0	5.4	118	3
16-Jun	11	1827	5	0	21.10	412	1.0	4.6	78	3
	11	1826	5	26	15.80	24200	17.0	2.7	50	28
	14	1825	5	0	16.60	26500	21.0	5.7	38	0
	14	1824	5	38	12.70	32800	27.0	5.9	5	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	15	1823	5	0	18.20	34000	24.7	6.5	35	0
	15	1822	5	43	12.70	33000	27.2	5.6	0	3
	17	1821	5	0	17.20	32200	24.0	6.7	150	10
	17	1820	5	42	12.60	29800	24.2	6.1	5	3
	18	1817	5	0	18.00	31500	23.0	5.5	68	8
	18	1816	5	25	13.10	33000	26.5	5.4	50	10
	19	1819	5	0	17.40	32900	24.2	7.0	30	0
	19	1818	5	26	13.50	33100	27.0	7.3	3	0
	21	1813	3	0	17.00	32200	27.0	5.8	345	78
	21	1812	3	38	13.50	33500	26.2	5.5	15	3
	22	1809	3	0	18.90	35500	26.0	6.7	0	10
	22	1808	3	37	14.00	34000	27.8	6.9	28	5
	24	1807	3	0	16.40	33000	25.0	7.5	98	0
	24	1806	3	38	13.10	33800	27.5	7.6	30	0
	30	1829	5	0	16.80	34300	26.3	8.1	8	0
	30	1828	5	11	15.50	34100	26.0	7.9	3	3
	35	1801	3	0	19.00	36500	26.5	9.3	0	0
	36	1802	3	0	18.70	37000	27.0	9.6	3	0
	37	1803	3	0	18.60	36500	26.8	8.9	0	0
	38	1831	5	0	16.50	34500	26.0	7.4	10	0
	38	1830	5	11	15.80	34000	26.0	7.9	10	0
	44	1805	3	0	16.40	33500	26.0	8.0	35	0
	44	1804	3	16	15.00	34500	27.2	8.4	10	0
	63	1811	3	0	19.40	38000	27.5	5.2	0	0
	63	1810	3	8	17.50	31700	26.5	5.6	3	3
	75	1815	4	0	18.00	29200	21.0	3.1	855	95
	75	1814	4	3	17.90	29200	21.0	3.2	563	38
18-Jun	11	1835	3	0	23.30	35200	0.0	9.1	55	10
	11	1834	3	26	16.80	26500	19.5	4.2	30	0
	18	1837	3	0	17.80	35000	26.5	7.4	10	10
	18	1836	3	33	13.40	33200	28.0	4.8	35	13
	63	1839	3	0	19.70	38500	28.0	6.5	8	0
	63	1838	3	13	19.30	38000	28.0	6.6	8	0
	75	1833	3	0	17.80	32500	19.5	5.0	575	125
	75	1832	3	9	17.30	35000	26.5	6.8	68	20
19-Jun	11	1866	3	0	24.30	391	0.0	9.1	20	0
	11	1865	3	20	20.00	15000	9.0	3.1	28	13
	14	1843	2	0	18.40	29000	19.0	8.2	70	8
	14	1842	2	38	13.80	34000	28.0	5.7	3	3
	15	1841	2	0	19.40	34000	25.0	9.5	23	0
	15	1840	2	43	13.80	34000	28.0	6.3	5	3
	17	1845	2	0	19.00	32000	24.0	8.5	58	10
	17	1844	2	46	14.40	35000	28.0	6.9	23	178
	18	1867	3	29	.	35500	28.5	5.6	28	3
	18	1868	3	.	19.00	28700	26.5	6.6	60	5

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	19	1847	2	0	18.30	33000	25.0	8.2	328	10
	19	1846	2	32	14.80	35000	28.0	7.5	15	0
	21	1849	2	0	17.80	34000	25.0	8.5	70	3
	21	1848	2	39	14.20	34000	28.0	7.2	88	33
	22	1851	2	0	20.60	36000	28.0	6.2	5	0
	22	1850	2	38	14.60	35000	28.0	6.9	85	28
	24	1853	2	0	18.30	35000	24.0	8.5	155	3
	24	1852	2	39	13.10	34000	28.0	8.2	388	175
	30	1857	3	0	17.30	36000	28.0	7.5	0	0
	30	1856	3	12	15.90	35000	28.0	7.3	0	3
	35	1860	3	0	18.00	37000	28.0	7.7	3	3
	36	1861	3	0	17.70	36000	28.0	6.6	3	3
	37	1862	3	0	17.70	36000	28.0	5.9	3	0
	38	1859	3	0	16.30	35000	28.0	6.9	5	3
	38	1858	3	10	14.70	35000	28.0	7.5	33	5
	44	1855	3	0	15.80	35000	28.0	7.5	60	20
	44	1854	3	17	12.80	34000	28.0	7.9	93	28
	63	1870	3	0	21.00	42000	29.0	10.7	5	0
	63	1869	3	9	20.00	40000	29.0	7.0	13	0
	75	1864	3	0	18.00	32500	24.0	7.2	493	63
20-Jun	11	1899	9	0	23.90	3000	0.0	8.6	35	0
	11	1898	9	20	16.60	28200	20.5	9.5	43	25
	14	1877	.	0	18.20	31000	23.0	5.7	86	18
	14	1876	.	44	14.20	34000	28.0	6.3	73	10
	15	1875	.	0	19.00	34500	29.0	7.9	63	3
	15	1874	.	45	14.00	34000	28.0	7.8	85	28
	17	1879	.	0	18.50	34000	25.0	7.4	28	18
	17	1878	.	55	14.00	34000	28.0	7.9	95	55
	18	1881	.	0	18.30	33000	24.0	7.2	230	15
	18	1897	3	0	18.60	31900	26.5	6.3	143	18
	18	1896	3	19	15.50	37300	22.0	5.5	30	0
	19	1880	.	46	14.50	33000	21.5	7.0	173	33
	21	1883	.	0	18.10	33000	24.0	6.9	78	5
	21	1882	.	48	14.00	33500	28.0	7.8	265	50
	22	1885	.	0	19.30	36000	26.0	6.6	33	10
	22	1884	.	44	13.70	33500	28.0	7.0	173	35
	24	1887	.	0	17.80	34000	25.5	6.8	60	3
	24	1886	.	38	12.60	33000	28.0	7.6	375	20
	30	1891	.	0	17.00	35000	27.0	6.6	20	3
	30	1890	.	17	15.00	34500	28.0	6.7	55	20
	35	1871	.	0	17.20	36000	26.0	8.7	90	3
	36	1872	.	0	17.20	35500	27.5	8.9	68	5
	37	1873	.	0	17.30	35000	27.0	8.3	28	10
	38	1893	.	0	16.50	35000	28.0	6.7	5	8
	38	1892	.	13	15.00	34000	27.5	6.5	7	5
	44	1889	.	0	17.00	35000	27.0	6.8	60	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	44	1888	.	24	13.40	33500	27.5	6.9	503	55
	63	1895	2	0	20.90	36600	28.0	7.3	25	13
	63	1894	2	9	19.00	39200	29.0	6.1	18	5
	75	1900	3	0	20.60	34500	25.2	4.1	530	210
21-Jun	11	1927	3	0	23.10	417	0.0	5.7	28	3
	11	1926	3	14	18.60	16500	11.0	3.5	40	10
	14	1907	2	0	17.70	27000	20.1	5.9	453	15
	14	1906	2	47	13.90	33500	28.0	6.2	60	23
	15	1905	2	0	17.90	32000	23.5	6.5	600	13
	15	1904	2	52	13.90	33500	27.5	6.0	58	5
	17	1909	2	0	17.80	30000	23.5	6.6	475	18
	17	1908	2	59	14.20	34000	27.3	6.5	80	35
	18	1929	3	0	18.50	37000	29.5	8.3	143	13
	18	1928	3	19	14.90	36600	29.0	6.6	5	5
	19	1911	2	0	17.70	3200	24.0	7.6	293	13
	19	1910	2	49	13.70	33500	28.0	6.5	93	43
	21	1913	2	0	17.50	34500	26.2	7.5	800	10
	21	1912	2	54	13.80	33500	27.5	6.6	125	18
	22	1915	2	0	19.70	38500	28.5	6.1	185	8
	22	1914	2	46	14.10	33500	27.5	6.7	110	23
	24	1917	2	0	16.40	34500	26.0	8.2	5	0
	24	1916	2	46	13.60	33500	27.0	8.0	528	205
	28	1932	2	0	16.90	38200	29.0	6.8	3	3
	30	1921	2	0	15.50	34500	27.0	7.5	10	5
	30	1920	2	18	14.70	33700	27.0	7.5	185	55
	35	1901	6	0	17.10	37500	27.0	6.8	38	0
	36	1902	1	0	17.20	35500	27.0	7.4	68	28
	37	1903	1	0	17.30	35500	27.3	7.3	433	8
	38	1923	2	0	16.20	35000	26.7	7.3	5	0
	38	1922	2	14	14.10	34000	27.0	7.2	268	83
	44	1919	2	0	14.20	34000	27.2	7.9	425	155
	44	1918	2	23	13.50	33500	27.5	7.7	470	118
	63	1931	3	0	19.70	40100	28.8	9.3	3	3
	63	1930	3	8	18.20	39800	29.0	7.8	43	10
	75	1925	3	0	18.20	33000	24.2	4.6	435	160
	75	1924	3	7	17.50	36600	27.3	5.4	123	58
22-Jun	11	1934	6	0	23.20	900	2.0	5.6	90	0
	11	1933	6	24	16.60	29900	22.9	3.3	43	15
	14	1936	1	0	18.10	31000	22.0	7.9	63	0
	14	1935	1	45	14.00	34500	28.9	6.4	53	3
	15	1938	1	0	19.40	36500	26.9	8.0	298	5
	15	1937	1	46	14.10	34500	28.3	6.8	35	10
	17	1940	2	0	18.70	32200	23.7	7.2	33	0
	17	1939	2	46	14.00	34100	28.1	6.9	30	15
	18	1944	2	0	19.30	35000	26.5	6.6	50	0

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	18	1943	2	28	15.10	34900	28.0	5.8	25	0
	19	1942	2	0	17.90	34200	25.9	8.9	33	0
	19	1941	2	42	14.00	34500	28.2	7.4	50	8
	21	1948	2	0	18.30	34800	26.4	10.0	23	3
	21	1947	2	43	13.90	34400	28.2	7.4	53	13
	22	1952	2	0	19.60	39000	29.0	7.2	105	18
	22	1951	2	39	13.90	34500	28.6	7.6	63	20
	24	1954	2	0	18.50	36000	27.3	10.8	8	0
	24	1953	2	46	14.00	34700	29.0	8.7	25	0
	28	1964	3	0	17.40	36600	28.5	9.0	3	3
	30	1958	2	0	17.60	36800	28.3	10.1	0	0
	30	1957	2	14	14.10	34700	28.3	8.9	10	5
	35	1961	3	0	16.60	36000	28.2	10.2	30	0
	36	1962	3	0	16.40	36000	28.1	9.6	5	3
	37	1963	3	0	16.60	35800	28.0	9.1	3	3
	38	1960	2	0	15.70	35000	28.6	8.8	5	0
	38	1959	2	10	14.50	35000	28.5	8.9	18	10
	44	1956	2	0	15.10	35300	29.0	9.0	3	3
	44	1955	2	18	13.50	34500	29.1	9.5	20	0
	63	1950	2	0	20.40	38200	28.8	7.3	0	0
	63	1949	2	14	18.10	37000	28.0	6.4	10	0
	75	1946	2	0	19.20	33800	24.9	5.8	233	28
	75	1945	2	12	16.50	35500	27.9	5.7	50	15
23-Jun	14	1985	1	0	18.20	32000	26.0	7.3	190	10
	14	1984	1	46	14.60	34500	28.0	5.9	60	18
	15	1987	1	0	18.40	36000	27.0	7.2	133	0
	15	1986	1	47	14.70	35000	28.5	6.3	23	13
	17	1983	6	0	18.20	33000	25.0	7.5	175	3
	17	1982	6	48	14.20	34500	28.0	6.8	8	5
	18	1991	2	0	18.10	38000	28.0	7.1	323	15
	19	1981	6	0	17.80	35000	26.0	8.0	108	8
	19	1980	6	45	15.10	35000	28.5	7.1	33	5
	21	1979	6	0	16.20	36000	28.5	8.2	0	0
	21	1978	6	42	14.60	35000	28.5	7.4	10	0
	22	1976	6	0	14.30	34500	28.5	7.3	18	8
	22	1977	6	0	19.40	38500	29.0	6.7	245	3
	24	1975	6	0	14.90	35000	28.5	8.2	5	8
	24	1974	6	43	14.00	34500	29.0	8.8	8	5
	30	1971	6	0	14.60	34500	28.5	8.5	5	3
	30	1970	6	14	14.50	34500	26.5	8.3	8	5
	35	1967	6	0	16.40	37000	28.5	8.2	0	0
	36	1968	6	0	16.50	34000	26.5	8.6	13	0
	37	1969	6	0	16.90	34200	26.0	7.3	40	13
	38	1966	6	0	15.20	36000	28.5	7.6	0	3
	38	1965	6	12	15.00	35000	28.5	9.0	5	5
	44	1973	6	0	13.70	35000	29.0	8.7	0	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	44	1972	6	19	13.60	34500	29.0	8.6	8	0
	63	1990	2	0	21.00	42000	27.5	9.4	38	0
	63	1989	2	24	18.00	40000	20.0	6.1	8	0
	75	1992	2	0	18.20	38000	28.0	5.7	255	23
25-Jun	11	2019	9	0	24.50	900	0.5	5.5	48	3
	11	2018	9	25	17.50	28000	21.0	1.6	30	10
	14	1995	5	33	14.60	35000	28.0	6.5	0	3
	15	1994	5	0	18.70	34000	25.5	7.9	40	8
	15	1993	5	34	14.70	35000	28.5	6.6	3	8
	17	1998	5	0	18.30	34500	25.0	6.9	53	3
	17	1997	5	42	14.50	35000	28.5	7.3	0	0
	18	2023	2	0	20.30	39300	28.0	7.8	3	0
	18	2022	2	15	18.50	38000	28.0	6.8	0	0
	19	2000	6	0	17.80	35500	27.5	7.5	33	0
	19	1999	6	38	14.40	35000	28.5	7.1	0	0
	21	2002	6	0	17.40	36000	28.0	8.1	35	0
	21	2001	6	36	14.30	35000	28.5	8.0	30	0
	22	2004	6	0	20.00	39500	29.0	7.2	0	0
	22	2003	6	37	14.00	35000	29.0	7.7	20	0
	24	2006	6	0	16.10	36000	28.5	9.0	8	0
	24	2005	6	36	14.40	35000	28.0	8.0	15	3
	30	2010	6	0	15.20	35000	29.0	8.6	3	0
	30	2009	6	13	14.70	35000	28.5	8.5	23	5
	35	2013	6	0	17.50	37000	28.0	9.0	0	0
	36	2014	6	0	17.50	37000	28.0	9.0	0	0
	37	2015	6	0	17.60	37000	28.0	8.9	0	0
	38	2012	6	0	15.80	35500	28.5	8.6	3	0
	38	2011	6	10	15.40	35500	28.5	8.5	3	0
	44	2008	6	0	15.20	35000	29.0	8.4	3	0
	44	2007	6	16	13.70	35000	28.5	8.4	13	23
	63	2021	2	0	17.90	36300	27.0	6.5	73	0
	63	2020	2	25	15.30	35000	28.0	6.4	13	3
	74	1996	5	0	19.30	29000	21.0	6.3	35	3
	75	2017	2	0	18.50	36000	27.0	6.1	95	30
	75	2016	2	14	17.20	36000	27.0	5.5	38	3
26-Jun	11	2037	2	0	25.40	1500	0.5	6.6	73	3
	11	2036	2	13	17.60	25500	17.0	2.1	30	15
	14	2027	6	0	18.80	27000	20.0	5.8	30	0
	14	2026	6	35	14.20	34000	27.7	7.4	0	3
	15	2025	6	0	19.30	36000	27.0	7.5	28	0
	15	2024	6	38	14.40	34200	28.0	6.8	83	0
	17	2029	6	0	18.80	34100	21.0	6.5	70	5
	17	2028	6	44	14.00	34000	28.0	7.5	0	0
	18	2039	2	0	19.10	37000	27.0	6.3	68	0
	18	2038	2	16	15.60	36500	28.0	6.1	28	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	19	2031	6	0	17.90	36000	27.9	7.6	3	0
	19	2030	6	39	13.40	34100	28.0	7.4	3	0
	21	2033	6	0	.	.	.	.	13	0
	21	2032	6	41	.	.	.	.	48	0
	63	2041	2	0	21.30	40500	28.0	7.3	3	0
	63	2040	2	7	19.10	39000	28.0	6.5	18	8
	75	2035	2	0	20.10	.	25.0	6.4	98	8
	75	2034	1	14	16.80	36000	27.0	5.6	55	8
27-Jun	11	2047	5	0	24.00	1100	0.7	6.9	270	18
	11	2046	5	22	17.00	30000	22.0	4.2	20	3
	14	2045	5	0	18.10	36000	27.0	6.9	70	0
	14	2044	5	32	14.10	35000	29.0	7.0	28	0
	15	2043	5	0	18.40	37000	27.0	8.6	10	0
	15	2042	5	34	14.20	35000	28.0	7.1	30	0
	17	2049	5	0	18.70	37000	28.0	7.7	30	0
	17	2048	5	41	14.00	35000	29.5	7.3	10	0
	19	2051	5	0	17.30	37000	27.5	7.8	20	0
	19	2050	5	34	13.80	35000	28.5	7.7	3	0
	21	2053	5	0	17.60	37000	28.0	7.9	18	3
	21	2052	5	35	13.80	35000	28.0	8.2	18	0
	22	2055	5	0	19.60	39000	28.0	7.7	3	3
	22	2054	5	34	13.80	35000	28.5	8.8	328	43
	24	2056	5	0	17.00	37000	28.0	8.9	430	30
	24	2057	5	34	13.30	34500	29.0	8.8	20	5
	28	2067	6	0	18.20	38000	26.0	10.1	0	0
	30	2061	5	0	15.70	36000	28.0	9.5	3	0
	30	2060	5	10	15.40	35500	28.0	9.5	20	3
	33	2063	5	0	17.00	36000	27.0	9.5	3	0
	33	2062	5	8	16.00	36000	28.0	9.9	3	3
	35	2064	5	0	18.00	37000	28.0	9.7	5	0
	36	2065	5	0	18.00	37000	28.0	8.7	3	0
	37	2066	5	0	18.00	37000	28.0	9.1	3	0
	44	2059	5	0	16.00	36000	28.0	9.4	18	10
	44	2058	5	15	14.00	35000	28.0	9.1	210	28
	75	2069	6	0	18.50	29200	29.5	7.1	23	8
	75	2068	6	8	18.20	37100	27.0	7.2	23	3
28-Jun	11	2076	5	0	25.20	1200	0.7	7.9	308	3
	11	2075	5	16	17.10	31300	23.0	1.1	15	8
	18	2073	5	0	17.90	39500	28.0	5.2	653	43
	18	2072	5	21	15.20	39800	32.0	5.2	60	10
	28	2070	4	0	17.30	38800	30.5	8.0	3	0
	63	2074	5	0	20.00	42000	35.0	6.4	58	0
	75	2071	5	0	17.80	37200	27.8	4.3	5150	1140
29-Jun	11	2082	9	0	24.50	1500	0.8	8.1	153	15

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	11	2081	9	21	17.40	30000	22.0	2.9	40	10
	14	2080	3	0	17.50	38000	29.5	6.5	23	3
	14	2079	3	31	13.80	36500	30.0	7.0	78	0
	15	2078	3	0	18.10	39000	30.0	7.6	183	3
	15	2077	3	37	13.60	36500	30.0	7.2	123	8
	17	2084	5	0	17.60	39000	30.0	6.6	63	13
	17	2083	5	40	13.20	36000	30.5	7.1	180	10
	18	2105	6	0	18.20	38900	29.8	5.6	215	3
	18	2104	6	26	14.80	37100	30.0	5.5	60	3
	19	2086	5	0	17.50	38500	30.0	7.4	93	5
	19	2085	5	31	13.60	37000	30.5	6.9	70	0
	21	2088	5	0	17.60	39000	29.0	7.0	40	5
	21	2087	5	38	13.20	37000	28.0	7.7	48	3
	22	2090	5	0	20.00	42000	31.5	7.1	8	3
	22	2089	5	31	13.40	36500	31.0	7.9	25	3
	24	2092	5	0	16.50	37000	29.5	8.2	15	0
	24	2091	5	32	13.40	35500	30.0	7.8	45	5
	28	2102	4	0	17.70	39900	30.7	8.5	18	0
	30	2096	5	0	16.60	38500	30.0	9.2	0	0
	30	2095	5	8	16.00	38500	30.0	9.1	5	0
	35	2099	5	0	16.80	39000	31.0	8.5	0	0
	36	2100	5	0	17.30	39500	31.0	9.6	3	0
	37	2101	5	0	17.20	39500	30.5	8.8	0	0
	38	2098	5	5	16.60	38000	30.0	7.3	3	3
	38	2097	5	6	16.00	38000	30.0	8.2	3	0
	44	2094	5	0	16.40	38500	30.5	9.0	15	3
	44	2093	5	13	13.80	37000	30.5	8.9	58	3
	63	2107	6	0	20.30	41900	30.0	6.9	8	3
	63	2106	6	11	19.50	41100	30.6	6.8	8	3
	75	2103	6	0	18.70	38800	29.0	5.9	173	3
30-Jun	11	2127	2	0	23.50	.	.	.	228	35
	11	2126	2	23	17.40	.	.	.	55	28
	14	2111	6	0	17.50	34500	26.0	6.5	950	30
	14	2110	6	29	13.70	31000	28.5	6.3	23	5
	15	2109	6	0	17.80	38000	28.5	6.4	925	470
	15	2108	6	29	13.40	36500	30.5	6.6	85	38
	17	2113	6	0	17.20	.	.	6.6	168	10
	17	2112	6	34	13.80	35000	29.0	7.0	70	0
	18	2129	2	0	18.10	.	.	.	285	23
	18	2128	2	25	15.70	.	.	.	15	5
	19	2115	6	0	17.40	.	.	6.6	858	128
	19	2114	6	24	14.10	.	.	6.8	28	3
	21	2117	6	0	17.30	.	.	6.6	653	58
	21	2116	6	34	13.60	.	.	7.4	50	0
	22	2119	6	0	20.30	.	.	6.6	8	0
	22	2118	6	34	14.50	.	.	6.6	45	25

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	24	2121	6	0	16.70	.	.	7.3	378	33
	24	2120	6	34	13.30	.	.	8.0	88	13
	28	2124	2	0	17.80	.	.	7.6	0	0
	44	2123	6	0	15.70	.	.	7.9	0	0
	44	2122	6	14	14.60	.	.	7.4	28	5
	63	2131	2	0	21.20	.	.	.	0	3
	63	2130	2	14	19.50	.	.	.	5	0
	75	2125	2	0	18.00	.	.	.	15750	1275
02-Jul	11	2140	2	0	22.60	.	.	6.1	210	63
	11	2139	2	22	17.30	.	.	1.9	65	23
	14	2138	2	0	16.90	.	.	7.2	23	13
	14	2137	2	36	13.90	.	.	6.1	15	3
	15	2136	2	0	17.40	.	.	7.5	158	23
	15	2135	2	43	13.90	.	.	6.3	13	10
	17	2142	2	0	16.80	.	.	7.7	38	0
	17	2141	2	40	14.00	.	.	7.7	15	3
	18	2160	5	0	18.40	.	.	7.9	128	10
	18	2159	5	19	15.30	.	.	4.6	23	15
	19	2144	2	0	17.20	.	.	8.2	75	10
	19	2143	2	38	14.10	.	.	8.0	10	3
	21	2146	2	0	17.30	.	.	8.6	105	20
	21	2145	2	42	13.90	.	.	7.5	10	8
	22	2148	2	0	17.70	.	.	8.6	60	23
	22	2147	2	36	14.10	.	.	7.7	5	3
	24	2150	2	0	16.80	.	.	9.9	43	5
	24	2149	2	38	14.00	.	.		5	0
	30	2154	3	0	16.30	.	.	9.8	3	0
	30	2153	3	10	16.00	.	.	10.3	0	5
	35	2132	2	0	18.00	.	.	10.3	0	0
	36	2133	2	0	18.00	.	.	9.3	0	18
	37	2134	2	0	18.00	.	.	8.2	3	10
	38	2156	3	0	16.70	.	.	8.7	0	0
	38	2155	3	8	16.50	.	16.5	10.0	10	10
	44	2152	3	0	16.80	.	.	9.3	18	8
	44	2151	3	16	15.70	.	.	10.0	5	0
	63	2162	5	0	23.40	.	.	6.8	3	3
	63	2161	5	8	20.60	.	.	6.6	15	15
	75	2157	3	0	19.00	.	.	3.1	18350	3825
03-Jul	11	2171	2	0	22.70	.	.	7.3	230	5
	11	2170	2	21	17.80	.	.	2.0	83	25
	14	2169	2	0	17.70	.	.	8.2	125	8
	14	2168	2	37	14.50	.	.	6.5	18	3
	15	2167	2	0	17.80	.	.	8.2	5	3
	15	2166	2	41	14.60	.	.	7.2	5	0
	17	2173	2	0	17.80	.	.	8.8	15	5

Table A.05 continued 1990 Raw Data

Date	Site	Sammum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	17	2172	2	46	14.40	.	.	7.2	5	5
	17	2172	2	46	14.40	.	.	7.2	5	5
	18	2190	3	0	20.00	.	.	8.2	68	0
	18	2189	3	19	15.70	.	.	5.2	15	3
	19	2175	2	0	17.20	.	.	9.7	120	3
	19	2174	2	38	14.30	.	.	6.9	8	0
	21	2177	2	0	17.30	.	.	9.2	30	0
	21	2176	2	38	14.80	.	.	6.3	18	0
	22	2179	3	0	20.30	.	.	8.7	0	0
	22	2178	3	35	14.90	.	.	8.8	15	0
	24	2181	3	0	17.60	.	.	10.0	28	3
	24	2180	3	38	15.10	.	.	9.5	18	3
	30	2185	3	0	18.10	.	.	11.5	0	0
	30	2184	3	11	15.70	.	.	10.8	8	0
	35	2163	2	0	18.00	.	.	11.0	3	0
	36	2164	2	0	18.10	.	.	10.0	0	3
	37	2165	2	0	18.30	.	.	8.6	15	3
	38	2187	3	0	17.80	.	.	9.8	0	0
	38	2186	3	9	16.40	.	.	11.2	13	3
	44	2183	3	0	17.00	.	.	10.8	0	0
	44	2182	3	16	15.40	.	.	10.4	15	3
	63	2192	4	0	21.20	.	.	7.7	13	0
	63	2191	4	6	21.00	.	.	8.3	0	0
	75	2188	3	0	19.00	.	.	4.8	3380	315
05-Jul	11	2220	3	0	25.00	.	.	6.9	83	5
	11	2219	3	17	18.20	.	.	3.5	75	50
	14	2196	2	0	19.10	.	.	7.1	53	8
	14	2195	.	39	15.40	.	.	6.6	10	0
	15	2194	2	0	20.30	.	.	7.8	10	0
	15	2193	2	43	15.50	.	.	6.4	5	0
	17	2198	2	0	18.50	.	.	8.2	30	13
	17	2197	2	47	15.80	.	.	7.3	0	5
	18	2224	5	0	23.00	.	.	7.3	23	3
	18	2223	5	5	21.40	.	.	7.8	58	0
	19	2200	2	0	18.90	.	.	8.3	115	0
	19	2199	2	43	15.90	.	.	6.6	28	5
	21	2202	2	0	18.70	.	.	8.4	110	3
	21	2201	2	41	15.60	.	.	6.3	50	5
	22	2204	2	0	21.20	.	.	7.0	115	0
	22	2203	2	42	16.60	.	.	6.6	153	5
	24	2206	2	0	18.60	.	.	8.3	45	0
	24	2205	2	37	16.40	.	.	7.9	25	0
	28	2216	3	0	20.50	.	.	8.7	3	0
	30	2210	2	0	18.60	.	.	8.3	10	0
	30	2209	2	15	18.00	.	.	8.0	10	0
	35	2213	2	0	20.10	.	.	8.2	0	0

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	36	2214	2	0	19.40	.	.	8.6	0	0
	37	2215	2	0	19.60	.	.	9.0	0	0
	38	2212	2	0	18.20	.	.	8.2	8	0
	38	2211	2	11	18.10	.	.	8.3	0	0
	44	2208	2	0	17.90	.	.	8.0	3	0
	44	2207	2	19	16.20	.	.	7.9	3	3
	63	2222	5	0	20.00	.	.	8.6	5	0
	63	2221	5	17	16.70	.	.	6.3	20	0
	75	2218	3	0	19.10	.	.	4.8	303	43
	75	2217	3	3	19.00	.	.	6.7	188	40
06-Jul	11	2233	9	0	24.50	.	.	5.7	98	5
	11	2232	9	14	18.10	.	.	3.8	75	48
	18	2229	6	0	20.00	.	.	6.4	170	3
	18	2228	6	25	16.10	.	.	3.7	45	13
	28	2225	6	0	19.50	.	.	10.0	0	0
	63	2231	1	0	22.20	.	.	6.1	0	0
	63	2230	6	9	20.50	.	.	5.4	10	3
	75	2227	6	0	20.30	.	.	5.9	88	80
	75	2226	6	8	19.40	.	.	5.3	38	125
07-Jul	11	2242	9	0	24.50	1500	1.0	4.7	60	20
	11	2241	9	17	20.10	28500	19.5	3.3	18	13
	18	2238	3	0	19.10	37000	27.5	6.5	203	5
	18	2237	3	20	17.30	36500	28.0	5.0	18	0
	28	2234	3	0	19.10	36000	27.0	9.0	5	0
	63	2240	3	0	21.30	40000	29.0	6.0	33	0
	63	2239	3	8	20.80	40000	28.5	5.9	23	0
	75	2236	3	0	19.90	37000	27.0	5.5	58	5
	75	2235	3	5	19.60	37000	28.5	5.5	63	3
09-Jul	1	2255	9	0	24.00	20	0.0	6.0	833	123
	2	2254	9	0	24.10	300	0.0	6.2	328	25
	3	2253	9	0	24.00	300	0.0	7.8	35	3
	4	2252	9	0	24.20	300	0.0	6.6	685	3
	5	2251	9	0	24.00	400	0.0	6.5	153	8
	6	2250	9	0	23.70	600	0.0	4.8	313	63
	7	2249	9	0	23.50	900	0.0	4.6	393	108
	8	2248	9	0	24.00	1200	0.0	6.0	163	43
	9	2247	9	0	24.00	1200	0.0	6.4	50	15
	10	2246	9	0	24.10	1300	0.0	6.2	28	10
	11	2245	9	0	24.10	1400	0.0	5.1	35	10
	12	2256	9	0	24.20	280	0.0	6.6	1160	770
	14	2244	6	0	19.70	35000	26.0	7.7	833	70
	14	2243	5	38	17.00	.	26.0	5.7	.	.
10-Jul	1	2269	9	0	25.30	400	0.0	5.8	1400	55

Table A.05 continued 1990 Raw Data

Date	Site	Sammum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	2	2268	9	0	24.70	400	0.0	5.7	380	15
	3	2267	9	0	24.40	300	0.0	6.9	78	13
	4	2266	9	0	24.80	400	0.1	7.4	2150	8
	5	2265	9	0	24.90	700	0.2	6.2	358	10
	6	2264	9	0	24.60	900	0.4	5.5	305	18
	7	2263	9	0	24.50	1200	0.7	5.6	365	30
	8	2262	9	0	24.80	1000	0.5	5.9	2075	350
	9	2261	9	0	24.30	1100	0.8	6.2	188	13
	10	2260	9	0	25.00	1200	0.8	6.6	53	0
	11	2259	9	0	24.90	1500	0.9	6.3	33	18
	12	2270	9	0	25.60	300	0.0	8.6	3125	423
	14	2258	6	0	20.90	35000	24.2	6.8	53	5
	14	2257	6	38	15.90	36000	28.0	7.4	150	5
11-Jul	1	2283	9	0	24.00	470	0.0	5.5	1725	128
	2	2282	9	0	24.20	400	0.1	5.8	628	50
	3	2281	9	0	24.20	310	0.1	7.4	85	18
	4	2280	9	0	23.90	450	0.2	6.7	388	18
	5	2279	9	0	24.10	800	0.2	7.3	298	45
	6	2278	9	0	24.00	900	0.5	6.0	340	33
	7	2277	9	0	24.50	1200	0.9	5.8	700	85
	8	2276	9	0	23.80	1200	0.8	6.3	795	173
	9	2275	9	0	24.60	1200	0.8	7.7	578	15
	10	2274	9	0	24.70	1300	0.8	7.6	288	10
	11	2273	9	0	24.80	1600	0.9	5.9	50	10
	12	2284	9	0	23.40	290	0.0	6.7	4100	900
	14	2272	5	0	19.30	37000	28.0	7.3	38	3
	14	2271	5	34	15.50	30000	28.9	7.2	93	8
12-Jul	1	2302	9	0	21.50	620	0.2	6.2	6900	9700
	2	2301	9	0	22.70	650	0.2	5.6	888	610
	3	2300	9	0	22.70	650	0.3	5.2	703	615
	4	2299	9	0	23.00	.	.	5.9	360	43
	5	2298	9	0	23.10	.	.	5.7	443	1038
	6	2297	9	0	23.50	.	.	4.8	663	435
	7	2296	9	0	23.40	.	.	5.2	433	53
	8	2295	9	0	23.50	.	.	6.1	675	83
	9	2294	9	0	23.20	.	.	6.5	310	28
	10	2293	9	0	23.90	.	.	6.2	223	18
	11	2292	9	0	23.90	.	.	5.8	98	20
	12	2303	9	0	21.30	580	0.1	6.1	18900	21450
	14	2291	6	0	18.80	.	.	5.5	63	8
	14	2290	6	38	15.40	.	.	6.3	20	5
	18	2287	5	0	18.80	40000	29.0	5.0	2050	215
	18	2286	5	14	17.10	40000	30.5	5.2	33	18
	63	2289	5	0	20.80	.	.	6.6	35	8
	63	2288	5	6	21.40	.	.	6.1	43	10

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	75	2285	5	0	19.40	35000	26.0	3.6	3675	860
13-Jul	1	2316	9	0	21.50	300	0.0	6.1	50000	575
	2	2315	9	0	21.20	300	0.0	5.3	7125	4450
	3	2314	9	0	22.10	350	0.0	5.2	3950	2925
	4	2313	9	0	22.40	320	0.0	5.0	1450	468
	5	2312	9	0	22.30	450	0.0	5.1	925	445
	6	2311	9	0	22.50	500	0.0	5.1	3475	748
	7	2310	9	0	23.00	720	0.1	5.1	3650	950
	8	2309	9	0	23.10	1120	0.2	6.6	10600	433
	9	2308	9	0	22.10	1100	0.2	6.5	1850	565
	10	2307	9	0	22.10	1250	0.2	6.9	875	33
	11	2306	9	0	21.90	1480	0.5	6.7	330	65
	12	2317	9	0	22.10	250	0.0	6.7	50000	1550
	14	2305	5	0	17.20	34000	24.0	5.8	1175	253
	14	2304	5	34	13.50	39000	29.0	6.5	635	68
	18	2321	6	0	18.50	30800	27.8	5.2	280	143
	18	2320	6	28	15.50	39200	31.0	6.0	85	3
	35	2327	6	0	.	.	.	.	5	3
	36	2324	6	0	.	.	.	.	15	0
	37	2325	6	0	.	.	.	.	20	0
	38	2326	6	0	.	.	.	.	50	3
	63	2323	6	0	21.00	44000	31.4	6.5	53	20
	63	2322	6	11	19.90	43200	31.5	6.3	108	18
	75	2319	6	0	20.40	38000	27.0	4.8	9000	170
	75	2318	6	10	17.80	40000	30.0	4.6	14000	100
14-Jul	1	2340	9	0	22.20	400	0.0	6.8	925	125
	2	2339	9	0	22.70	350	0.0	5.7	1450	160
	3	2338	9	0	22.30	300	0.0	5.2	1230	210
	4	2337	9	0	23.20	400	0.0	5.3	1530	325
	5	2336	9	0	23.10	350	0.0	5.2	448	165
	6	2335	9	0	25.00	400	0.0	6.5	390	28
	7	2334	9	0	26.60	750	0.2	7.7	540	58
	8	2333	9	0	25.00	750	0.2	7.8	930	253
	9	2332	9	0	25.80	1000	0.2	7.8	970	55
	10	2331	9	0	23.70	1300	0.5	7.3	533	30
	11	2330	9	0	23.20	1500	1.5	6.5	368	85
	12	2341	9	0	25.00	275	0.0	.	7100	2200
	14	2329	4	0	19.60	33000	25.5	5.9	280	75
	14	2328	4	28	14.80	40000	35.0	5.8	75	15
16-Jul	1	2354	9	0	25.00	40	0.0	6.6	975	198
	2	2353	9	0	25.20	41	0.0	9.0	685	115
	3	2352	9	0	24.70	41	0.0	8.0	180	18
	4	2351	9	0	25.00	40	0.0	7.6	858	130
	5	2350	9	0	24.00	40	0.0	6.6	350	15

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	6	2349	9	0	24.50	55	0.0	8.0	470	920
	7	2348	9	0	24.00	800	0.1	6.8	958	1500
	8	2347	9	0	24.00	800	0.2	8.8	473	83
	9	2346	9	0	24.50	900	0.2	8.6	323	15
	10	2345	9	0	25.00	800	0.4	9.6	180	3
	11	2344	9	0	25.30	1200	0.8	9.1	150	3
	12	2355	9	0	25.80	330	0.0	8.2	2525	700
	14	2343	6	0	20.50	37000	26.5	8.8	20	0
	14	2342	6	34	15.00	36000	25.4	5.8	15	0
17-Jul	1	2374	9	0	25.40	280	0.0	6.5	1060	145
	2	2373	9	0	25.80	300	0.0	9.0	938	345
	3	2372	9	0	25.50	400	0.0	9.8	253	10
	4	2371	9	0	24.90	310	0.0	8.6	1850	130
	5	2370	9	0	25.20	380	0.0	9.9	800	53
	6	2369	9	0	25.20	500	0.0	8.3	1175	140
	6	2368	9	10	23.60	890	0.2	4.2	5075	273
	7	2367	9	0	24.80	980	0.2	8.2	1150	113
	7	2366	9	10	24.90	900	0.3	6.9	1600	293
	8	2365	9	0	24.90	990	0.3	9.6	1900	158
	8	2364	9	13	24.10	950	0.3	6.7	3325	728
	9	2363	9	0	25.10	1050	0.3	9.8	253	33
	9	2362	9	20	20.40	21200	13.9	0.2	253	3
	10	2361	9	0	25.90	1150	0.8	10.5	110	0
	10	2360	9	27	15.80	31000	24.0	0.2	53	15
	11	2359	9	0	25.80	1400	0.6	9.7	60	3
	11	2358	9	21	19.00	30000	19.0	1.8	70	8
	12	2375	9	0	26.00	290	0.0	7.5	3875	878
	14	2357	3	0	20.10	38900	27.0	7.7	75	3
	14	2356	3	35	15.00	38000	31.0	8.0	0	3
18-Jul	1	2394	9	0	26.30	300	0.0	6.0	615	28
	2	2393	9	0	26.60	300	0.0	9.2	528	33
	3	2392	9	0	25.90	300	0.0	8.8	238	43
	4	2391	9	0	26.40	350	0.0	10.4	908	43
	5	2390	9	0	26.70	400	0.0	11.4	493	20
	6	2389	9	0	25.20	550	0.0	9.6	568	35
	6	2388	9	10	24.30	990	0.0	5.0	928	250
	7	2387	9	0	25.60	990	0.0	10.0	640	35
	7	2386	9	11	24.90	990	0.0	8.6	752	38
	8	2385	9	0	25.90	990	0.0	11.4	515	13
	8	2384	9	14	23.10	290	1.5	0.4	960	120
	9	2383	9	0	26.10	990	0.0	12.6	528	0
	9	2382	9	22	18.30	2100	15.0	0.3	545	5
	10	2381	9	0	26.20	110	0.5	9.8	223	0
	10	2380	9	26	13.00	2400	21.0	0.3	55	0
	11	2379	9	0	26.50	1400	0.5	10.1	25	5

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	11	2378	9	21	18.60	33000	23.0	3.2	75	15
	12	2395	9	0	27.10	250	0.0	7.4	1575	633
	14	2377	2	0	20.50	40500	29.0	8.3	23	3
	14	2376	2	38	14.60	37500	31.0	7.3	3	0
19-Jul	1	2414	9	0	26.90	300	0.0	5.3	475	225
	2	2413	9	0	26.70	310	0.0	7.8	140	53
	3	2412	9	0	26.80	250	0.0	9.8	70	13
	4	2411	9	0	27.00	350	0.0	9.9	1875	88
	5	2410	9	0	26.70	400	0.0	10.5	250	15
	6	2409	9	0	26.30	500	0.0	9.6	183	55
	6	2408	9	10	24.20	950	0.1	4.5	2050	575
	7	2407	9	0	25.40	900	0.1	9.6	213	35
	7	2406	9	15	25.00	910	0.2	7.6	1900	993
	8	2405	9	0	25.90	900	0.1	10.7	175	10
	8	2404	9	13	24.50	900	0.2	3.6	300	58
	9	2403	9	0	26.60	1000	0.2	10.8	58	3
	9	2402	9	22	19.30	2200	15.0	0.4	130	38
	10	2401	9	0	26.80	1200	1.0	10.5	28	0
	10	2400	9	30	10.70	27000	22.5	0.5	5	3
	11	2399	9	0	27.20	1300	0.5	8.3	15	5
	11	2398	9	22	18.20	32000	23.0	2.3	560	10
	12	2415	9	0	27.10	250	0.0	6.9	1950	708
	14	2397	2	0	19.50	39500	29.0	8.0	10	3
	14	2396	2	40	14.50	37500	30.5	7.0	408	0
20-Jul	1	2434	9	0	27.10	310	0.0	5.3	618	145
	2	2433	9	0	27.60	320	0.0	9.0	175	328
	3	2432	9	0	27.30	345	0.0	10.0	93	20
	4	2431	9	0	27.20	450	0.0	8.0	1025	218
	5	2430	9	0	27.40	450	0.0	10.3	285	8
	6	2429	9	0	26.90	550	0.0	9.6	210	15
	6	2428	9	9	25.50	950	0.2	8.1	130	23
	7	2427	9	0	26.20	850	0.0	9.6	125	55
	7	2426	9	10	25.70	900	0.0	8.8	173	33
	8	2425	9	0	26.80	900	0.0	10.7	230	18
	8	2424	9	14	26.30	900	0.1	8.0	1050	660
	9	2423	9	0	27.30	1100	0.1	9.9	13	0
	9	2422	9	22	21.00	19000	11.0	0.3	70	5
	10	2421	9	0	27.40	1100	0.2	9.2	10	8
	10	2420	9	29	11.30	28000	24.0	0.6	35	3
	11	2419	9	0	27.30	1300	0.5	9.0	13	0
	11	2418	9	21	18.20	32000	23.0	2.2	10	23
	12	2435	9	0	27.80	300	0.0	7.2	1875	1600
	14	2417	1	0	19.30	38500	27.0	8.6	10	0
	14	2416	1	41	15.00	37000	26.0	8.1	150	130

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
21-Jul	1	2451	9	0	27.00	293	0.0	4.8	508	950
	2	2450	9	0	27.50	335	0.0	7.1	408	65
	3	2449	9	0	27.50	372	0.0	8.1	195	60
	4	2448	9	0	27.40	400	0.0	9.4	440	570
	5	2452	9	0	27.80	280	0.0	6.2	1145	195
	6	2447	9	0	26.90	700	0.0	7.6	495	128
	6	2446	9	9	25.30	900	0.0	4.1	998	618
	7	2445	9	0	26.70	1000	0.0	8.6	80	20
	7	2444	9	14	25.00	1150	0.0	1.8	673	195
	9	2443	9	0	28.30	1100	0.0	10.0	10	0
	9	2442	9	20	20.20	22200	15.5	0.1	625	58
	10	2441	9	0	26.90	1100	0.0	9.0	8	0
	10	2440	9	27	11.00	25500	23.0	0.2	10	0
	11	2439	9	0	27.10	1460	0.0	8.5	8	20
	11	2438	9	21	18.30	31500	22.5	0.9	318	35
	12	2453	9	0	27.30	280	0.0	6.2	388	193
	14	2437	6	0	18.90	38000	27.5	8.4	23	8
	14	2436	6	38	13.70	37000	30.0	8.2	10	11
23-Jul	1	2472	9	0	26.40	280	0.0	4.3	1375	290
	2	2471	9	0	27.00	300	0.0	5.4	660	168
	3	2470	9	0	27.70	380	0.0	8.9	138	10
	4	2469	9	0	27.00	400	0.0	4.8	430	18
	5	2468	9	0	27.60	490	0.0	6.5	120	5
	6	2467	9	0	27.60	500	0.1	5.7	95	13
	6	2466	9	10	27.30	850	0.2	6.6	253	68
	7	2465	9	0	27.10	800	0.2	7.1	95	10
	7	2464	9	17	26.20	1000	0.6	3.8	130	38
	8	2463	9	0	27.00	1100	0.8	9.0	133	0
	8	2462	9	17	21.70	13000	8.0	0.3	378	43
	9	2461	9	0	26.90	1010	0.8	8.7	90	10
	9	2460	9	21	18.70	23000	16.0	0.2	203	20
	10	2459	9	0	26.90	1100	0.8	8.1	200	8
	10	2458	9	31	10.00	26200	23.0	0.5	15	3
	11	2457	9	0	26.60	1250	0.8	8.0	103	8
	11	2456	9	24	17.90	32800	24.0	2.8	35	8
	12	2473	9	0	26.90	305	0.0	5.2	485	383
	14	2455	6	0	19.10	38000	28.5	8.6	158	5
	14	2454	6	37	14.00	37000	30.0	7.0	20	0
24-Jul	1	2492	9	0	25.80	270	0.0	4.4	6750	675
	2	2491	9	0	26.30	310	0.0	5.0	430	415
	3	2490	9	0	26.80	300	0.0	6.5	495	238
	4	2489	9	0	27.60	350	0.0	5.4	80	385
	5	2488	9	0	26.60	400	0.0	4.5	145	48
	6	2487	9	0	26.60	650	0.0	4.4	148	143
	6	2486	9	8	26.20	1250	0.0	3.4	270	265

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	7	2485	9	0	26.50	900	0.0	5.5	225	55
	7	2484	9	10	26.10	2000	0.0	4.2	413	60
	8	2483	9	0	25.00	1000	0.1	7.6	118	20
	8	2482	9	16	21.50	13500	11.0	0.2	513	270
	9	2481	9	0	26.90	1100	0.5	8.2	20	0
	9	2480	9	19	18.50	20000	15.0	0.3	35	13
	10	2479	9	0	27.30	1200	0.1	7.1	18	3
	10	2478	9	27	12.50	27500	22.0	0.3	15	13
	11	2477	9	0	27.20	1500	0.9	7.3	80	35
	11	2476	9	21	17.50	33000	23.0	3.4	90	3
	12	2493	9	0	25.90	290	0.0	4.0	800	173
	14	2475	3	0	19.30	38000	27.0	6.5	1500	95
	14	2474	3	36	14.10	41000	32.0	6.9	3310	0
25-Jul	1	2512	9	0	22.90	170	0.0	7.4	29000	56000
	2	2511	9	0	22.40	145	0.0	6.7	22500	37200
	3	2510	9	0	23.90	220	0.0	5.1	12500	14400
	4	2509	9	0	25.30	295	0.0	4.1	2100	2090
	5	2508	9	0	25.70	312	0.0	4.6	6800	2200
	6	2507	9	0	25.60	400	0.0	3.3	22600	15100
	6	2506	9	13	25.50	450	0.0	3.2	35800	8400
	7	2505	9	0	25.80	600	0.0	3.2	78500	11300
	7	2504	9	14	24.60	650	0.0	1.4	36500	10700
	8	2503	9	0	25.40	600	0.0	4.1	69300	13000
	8	2502	9	24	21.40	14000	8.5	0.3	7600	640
	9	2501	9	0	25.80	900	0.0	6.6	3200	1730
	9	2500	9	28	19.30	23500	16.0	0.4	1820	140
	10	2499	9	0	25.90	1000	0.1	7.1	420	170
	10	2498	9	28	14.30	30000	23.5	0.6	230	40
	11	2497	9	0	26.30	1400	0.5	6.6	9100	770
	11	2496	9	28	18.90	31000	22.0	0.6	1680	130
	12	2513	9	0	22.70	355	0.0	7.5	52000	70000
	14	2495	6	0	21.50	24000	14.0	5.8	80	0
	14	2494	6	53	15.10	38500	30.0	7.0	8800	2220
26-Jul	1	2549	9	0	24.10	360	0.0	8.1	6050	3950
	2	2548	9	0	23.90	360	0.0	7.5	3850	2050
	3	2547	9	0	23.50	350	0.0	6.4	7900	4600
	4	2546	9	0	23.20	200	0.0	6.0	14850	10950
	5	2545	9	0	22.90	280	0.0	6.0	9700	7000
	6	2544	9	0	24.00	310	0.0	5.3	12550	1700
	6	2543	9	11	22.70	300	0.0	5.4	9950	4150
	7	2541	9	0	24.00	400	0.0	3.3	18850	3850
	7	2542	9	0	24.50	550	0.0	2.3	22100	2850
	8	2540	9	0	25.00	700	0.0	2.8	26850	2200
	8	2539	9	23	21.90	650	9.0	0.4	18050	3900
	9	2538	9	0	24.80	800	0.0	3.2	24000	2200

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	9	2537	9	28	20.40	25000	17.0	0.3	37500	105
	10	2536	9	0	25.20	950	0.0	3.4	17800	1060
	10	2535	9	31	10.50	29000	26.0	0.4	1285	25
	11	2534	9	0	25.80	1250	0.0	5.2	7950	200
	11	2533	9	26	19.30	25000	20.0	4.8	20550	20000
	12	2550	9	0	23.90	360	0.0	7.5	6700	4400
	14	2532	5	0	18.00	.	.	5.6	3600	85
	14	2531	5	44	14.20	.	.	6.6	50	20
	35	2551	6	0	19.50	41000	29.0	7.0	80	0
	36	2552	6	0	22.10	41000	29.0	7.1	5	0
	37	2553	6	0	20.00	40000	28.5	7.6	40	0
	38	2530	5	0	16.50	37800	29.0	6.0	1535	130
	38	2529	5	5	16.20	39000	30.0	6.6	11550	105
27-Jul	1	2572	9	0	23.80	300	0.0	8.3	800	1850
	2	2571	9	0	23.20	280	0.0	7.1	800	635
	3	2570	9	0	23.30	270	0.0	7.1	1200	430
	4	2569	9	0	24.50	290	0.0	7.8	1300	340
	5	2568	9	0	24.00	290	0.0	6.2	1150	435
	6	2567	9	0	23.90	280	0.0	6.3	1100	550
	6	2566	9	11	23.80	280	0.0	6.4	1950	445
	7	2565	9	0	25.20	65	0.0	4.9	2150	190
	7	2564	9	19	23.50	290	0.0	2.8	1950	200
	8	2563	9	0	25.00	70	0.0	3.9	2050	140
	8	2562	9	23	21.30	14000	9.0	0.2	1750	250
	9	2561	9	0	24.60	450	0.0	3.4	2150	50
	9	2560	9	32	18.60	24000	17.0	0.2	4350	480
	10	2559	9	0	24.90	600	0.0	2.9	1800	60
	10	2558	9	38	11.50	28000	25.0	0.2	1550	70
	11	2557	9	0	24.80	900	0.0	2.1	1475	70
	11	2556	9	28	19.50	24000	18.0	2.2	4200	1160
	14	2555	5	0	20.40	21000	14.5	3.8	2450	280
	14	2554	5	52	14.30	38000	27.0	5.9	420	0
	14	2554	5	52	14.30	38000	27.0	5.9	420	0
	35	2575	5	0	19.40	39000	28.5	8.4	40	0
	36	2576	5	0	19.40	39000	28.0	7.2	20	0
	37	2577	5	0	19.20	39000	28.0	7.8	5	0
	38	2574	6	0	17.30	39000	29.5	7.4	15	0
	38	2573	6	18	15.30	38000	24.0	8.4	15	0
28-Jul	1	2590	9	0	23.90	290	0.0	8.5	290	550
	2	2589	9	0	23.50	300	0.0	7.2	895	500
	3	2588	9	0	24.00	300	0.0	8.8	810	315
	4	2587	9	0	23.50	200	0.0	7.3	630	285
	5	2586	9	0	23.60	300	0.0	7.2	705	205
	6	2585	9	0	24.00	300	0.0	8.0	620	205
	7	2584	9	0	25.10	400	0.0	7.2	475	105

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	8	2583	9	0	24.80	530	0.0	6.2	590	135
	9	2582	9	0	24.70	600	0.0	4.5	505	35
	10	2581	9	0	24.80	600	0.0	4.6	530	55
	11	2580	9	0	24.50	800	0.0	3.4	450	70
	14	2579	5	0	18.40	29500	24.0	5.2	395	65
	14	2578	5	28	14.50	39000	32.0	5.9	15	5
31-Jul	1	2611	9	0	24.80	300	0.0	8.3	535	128
	2	2610	9	0	25.90	300	0.0	9.5	1780	75
	3	2609	9	0	24.70	250	0.0	9.3	590	33
	4	2608	9	0	25.10	200	0.0	8.6	1125	73
	5	2607	9	0	25.30	200	0.0	10.0	415	80
	6	2606	9	0	25.50	300	0.0	12.2	635	23
	6	2605	9	14	24.20	280	0.0	7.3	200	43
	7	2604	9	0	25.00	300	0.0	9.9	515	38
	7	2603	9	15	24.30	300	0.0	7.8	800	80
	8	2602	9	0	25.10	400	0.0	11.4	775	35
	8	2601	9	20	24.30	450	0.0	9.4	1635	95
	9	2600	9	0	24.90	490	0.0	9.1	595	10
	9	2599	9	28	19.20	24800	23.0	0.2	1440	10
	10	2598	9	0	24.70	500	0.0	6.5	620	18
	10	2597	9	41	12.70	28500	25.0	0.3	885	15
	11	2596	9	0	25.10	620	0.0	7.0	380	5
	11	2595	9	32	19.00	32000	23.0	1.7	550	8
	12	2612	9	0	25.00	200	0.0	9.3	8500	1505
	14	2594	3	0	21.00	35000	25.0	10.7	255	3
	14	2593	3	54	15.30	39000	32.0	5.7	30	3
02-Aug	44	2623	3	0	20.60	29800	28.0	9.0	23	3
	47	2615	2	0	21.00	41000	29.0	9.0	3	0
	48	2613	2	0	20.70	36500	27.3	9.5	3	0
	49	2614	2	0	20.40	40500	29.0	7.9	0	0
	76	2616	2	0	21.00	41000	29.0	8.9	0	0
	77	2617	2	0	20.30	40000	28.0	10.5	0	0
	78	2618	2	0	20.20	40000	28.5	10.3	0	0
	79	2619	2	0	20.00	40200	29.2	9.2	0	0
	80	2620	2	0	20.10	40000	29.9	10.4	0	0
	81	2621	3	0	19.60	40000	28.0	8.1	0	0
	82	2622	3	0	19.80	40000	29.0	7.5	5	0
03-Aug	44	2634	2	0	20.10	40100	28.0	8.9	55	8
	47	2626	2	0	21.70	42000	30.0	6.8	0	0
	48	2624	2	0	20.70	39900	28.3	9.0	3	0
	49	2625	2	0	20.70	41500	30.0	7.6	0	0
	76	2627	2	0	21.20	42200	29.2	7.9	3	0
	77	2628	2	0	21.00	.	.	9.0	0	0
	78	2629	2	0	20.80	41500	29.0	9.6	0	0

Table A.05 continued   1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	79	2630	2	0	.	.	.	.	30	8
	80	2631	2	0	20.20	.	.	8.2	13	5
	81	2632	2	0	.	.	.	.	15	8
	82	2633	2	0	.	.	.	.	0	0
04-Aug	44	2635	6	0	21.00	42000	27.5	9.7	0	0
	47	2638	2	0	22.40	43000	29.5	6.3	0	0
	48	2636	6	0	21.70	42500	30.0	9.9	0	0
	49	2637	1	0	21.20	42000	29.5	8.5	0	0
	76	2639	2	0	22.60	43500	29.5	7.3	3	3
	77	2640	2	0	22.10	43500	29.5	8.3	0	0
	78	2641	2	0	22.30	44000	30.0	8.4	0	0
	79	2642	2	0	.	.	.	.	0	0
	80	2643	2	0	20.80	42000	28.5	7.1	0	0
	81	2644	2	0	.	.	.	.	8	0
	82	2645	2	0	.	.	.	.	8	0
06-Aug	44	2646	6	0	20.80	42000	30.5	8.0	13	0
	47	2649	6	0	21.80	43000	31.5	7.0	0	3
	48	2647	6	0	20.80	42000	30.5	7.3	3	0
	49	2648	6	0	21.50	43000	30.0	7.2	0	0
	76	2650	6	0	21.60	43500	31.5	6.8	0	0
	77	2651	6	0	21.40	43000	30.5	7.9	0	3
	78	2652	6	0	21.20	43000	30.0	7.5	3	3
	79	2653	6	0	.	.	.	.	5	5
	80	2654	6	0	20.50	42500	30.0	7.5	0	10
	81	2655	6	0	.	.	.	.	0	0
	82	2656	6	0	.	.	.	.	3	3
07-Aug	44	2657	6	0	21.00	43000	27.0	7.5	90	5
	47	2660	6	0	21.70	44800	31.0	5.1	8	3
	48	2658	6	0	20.70	43500	30.5	6.7	3	3
	49	2659	6	0	21.80	44500	31.5	6.3	0	3
	76	2661	6	0	21.50	43900	30.8	5.6	3	3
	77	2662	6	0	21.20	44000	34.8	7.0	3	3
	78	2663	6	0	21.20	43900	34.5	7.2	0	5
	79	2664	6	0	.	.	.	.	3	3
	80	2665	6	0	19.70	39500	28.0	7.1	3	0
	81	2666	6	0	.	.	.	.	3	3
	82	2667	6	0	.	.	.	.	0	3
08-Aug	44	2668	6	0	20.40	41800	30.0	6.3	70	3
	47	2671	6	0	22.30	43000	30.0	6.0	88	8
	48	2669	6	0	20.40	42000	30.5	5.6	3	3
	49	2670	6	0	22.30	42200	29.5	5.2	15	25
	76	2672	6	0	21.60	42000	29.1	6.3	18	3
	77	2673	6	0	21.10	40900	29.0	5.8	10	70

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	78	2674	6	0	21.10	42000	30.0	6.1	0	5
	79	2675	6	0	.	.	.	.	5	5
	80	2676	6	0	18.30	40500	31.0	6.5	3	8
	81	2677	6	0	.	.	.	.	5	5
	82	2678	6	0	.	.	.	.	5	3
09-Aug	44	2679	5	0	20.00	41200	29.2	6.0	65	0
	47	2682	6	0	22.00	44100	30.0	6.7	13	0
	48	2680	5	0	20.80	32800	25.0	6.1	55	0
	49	2681	5	0	21.00	42500	30.0	5.8	10	0
	76	2683	6	0	21.60	43900	29.8	5.7	20	0
	77	2684	6	0	21.20	43800	29.3	7.2	5	0
	78	2685	6	0	20.70	41200	29.0	6.3	5	0
	79	2686	6	0	.	.	.	.	33	8
	80	2687	6	0	18.60	40000	27.7	6.4	33	10
	81	2688	6	0	.	.	.	.	50	10
	82	2689	6	0	.	.	.	.	58	15
10-Aug	44	2690	5	0	19.80	41000	29.0	6.1	48	5
	47	2693	5	0	22.60	43200	29.0	7.4	0	5
	48	2691	5	0	20.30	42000	30.3	5.7	0	0
	49	2692	5	0	21.30	43000	29.0	6.2	3	0
	76	2694	5	0	22.00	43000	30.0	5.2	5	120
	77	2695	5	0	21.00	42800	29.5	6.0	3	0
	78	2696	5	0	21.30	43000	30.0	6.7	3	0
	79	2697	5	0	.	.	.	.	43	35
	80	2698	5	0	19.00	39800	29.0	6.5	60	13
	81	2699	5	0	.	.	.	.	83	48
	82	2700	5	0	.	.	.	.	40	40
11-Aug	44	2701	5	0	20.80	40500	29.0	6.4	83	558
	47	2704	5	0	21.00	41000	28.0	5.8	0	5
	48	2702	5	0	20.90	42000	30.0	5.6	18	325
	49	2703	5	0	21.90	41500	28.5	5.9	90	555
	76	2705	5	0	20.70	41000	28.0	5.6	23	10
	77	2706	5	0	20.70	41000	28.0	4.4	20	35
	78	2707	5	0	20.60	41000	28.5	6.3	3	3
	79	2708	5	0	.	.	.	.	20	23
	80	2709	5	0	18.30	39500	38.9	6.6	73	48
13-Aug	35	2723	5	0	22.50	40000	27.2	7.1	68	3
	36	2724	5	0	22.30	40200	22.5	6.2	70	15
	37	2725	5	0	21.30	41300	28.2	6.3	73	23
	38	2711	3	0	21.20	37000	24.9	6.6	800	280
	38	2710	3	6	19.00	39300	28.1	5.4	.	.
	44	2712	3	0	21.50	36000	23.0	5.5	800	215
	47	2715	5	0	21.60	41800	28.8	7.3	8	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	48	2713	4	0	20.00	39000	26.8	5.2	95	13
	49	2714	4	0	21.10	32700	28.8	7.9	15	3
	76	2716	5	0	21.40	41500	23.7	6.6	15	0
	77	2717	5	0	21.00	41000	28.3	6.3	18	63
	78	2718	5	0	21.60	41100	28.3	7.0	.	.
	79	2719	5	0	.	.	.	.	0	8
	80	2720	5	0	19.70	40200	28.8	5.5	40	13
	81	2721	5	0	.	.	.	.	8	3
	82	2722	5	0	.	.	.	.	0	0
14-Aug	44	2726	3	0	20.10	.	30.0	6.0	438	3
	47	2729	3	0	20.20	41000	29.0	6.1	0	5
	48	2727	3	0	19.90	.	30.0	6.6	168	10
	49	2728	3	0	20.30	41500	30.5	6.3	48	0
	76	2730	3	0	19.90	41000	29.0	6.4	5	3
	77	2731	3	0	19.70	40900	29.0	6.9	3	3
	78	2732	3	0	19.60	40800	29.0	6.9	3	0
	79	2733	3	0	.	.	.	.	18	763
	80	2734	3	0	18.90	39000	20.0	6.8	5	3
	81	2735	3	0	.	.	.	.	5	5
	82	2736	3	0	.	.	.	.	10	103
15-Aug	15	2751	5	0	22.10	37000	26.1	8.3	70	10
	15	2750	5	38	16.10	38100	27.0	6.3	28	10
	16	2753	5	0	22.20	34700	23.8	8.8	83	8
	16	2752	5	48	16.00	32300	27.0	6.3	10	15
	26	2737	3	0	23.10	31500	21.8	13.8	30	13
	27	2738	3	0	22.00	32800	22.3	11.2	48	60
	27	2739	3	45	16.70	38900	27.0	5.8	33	25
	52	2746	5	0	22.00	29900	19.9	4.8	235	33
	52	2747	5	11	21.20	34700	23.1	4.2	540	128
	56	2742	9	0	23.80	400	0.0	7.8	743	408
	57	2741	9	0	23.80	385	0.0	7.8	105	128
	59	2745	9	0	25.00	480	0.0	8.8	390	25
	60	2743	9	0	24.60	42500	0.0	8.2	325	15
	67	2744	9	0	24.50	440	0.0	7.0	295	38
	69	2749	5	0	22.40	32900	23.2	5.5	353	85
	69	2748	5	17	19.70	40100	28.8	4.9	40	15
	83	2740	9	0	24.40	380	0.0	8.3	165	80
16-Aug	15	2757	2	0	21.10	32000	21.0	8.6	123	100
	15	2756	2	41	16.30	38500	27.0	6.1	15	55
	16	2755	2	0	20.90	31000	20.0	7.4	193	80
	16	2754	2	46	16.40	38500	29.5	7.0	23	10
	26	2758	2	0	21.80	34000	25.0	7.7	3	8
	27	2760	2	0	20.90	32500	24.5	9.2	273	28
	27	2759	2	40	16.40	39000	30.0	5.8	25	13

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	52	2764	2	0	20.80	39500	28.5	3.7	425	8
	52	2763	2	11	19.70	40500	29.0	3.5	448	50
	56	2768	9	0	23.80	2400	0.0	8.7	345	245
	57	2769	9	0	24.40	4000	0.0	8.9	120	138
	59	2765	9	0	24.50	5000	0.5	7.9	85	8
	60	2767	9	0	24.70	4900	0.0	8.5	125	20
	67	2766	9	0	24.30	5000	0.2	7.8	140	45
	69	2762	2	0	21.20	37000	26.5	7.4	1400	25
	69	2761	2	16	17.70	39000	30.5	5.5	83	528
	83	2770	9	0	24.40	4900	0.0	8.6	128	165
17-Aug	15	2773	2	44	16.70	38500	30.0	5.7	5	10
	15	2774	2	44	22.10	32000	21.5	8.7	795	53
	16	2772	2	0	22.60	31500	20.0	8.8	228	13
	16	2771	2	46	16.50	38500	30.0	5.7	10	5
	26	2775	2	0	22.40	37500	29.0	9.4	18	0
	27	2777	2	0	21.50	37000	23.0	8.3	133	20
	27	2776	2	41	16.70	39000	30.0	5.3	10	0
	52	2781	2	0	22.30	36500	24.5	6.1	593	3
	52	2780	2	11	20.50	40000	28.5	4.6	360	65
	56	2785	9	0	24.80	400	0.0	8.4	270	128
	57	2787	9	0	24.50	400	0.0	8.1	53	158
	59	2782	9	0	25.70	500	0.0	10.8	20	5
	60	2784	9	0	25.90	445	0.0	10.2	58	13
	67	2783	9	0	25.30	450	0.0	9.6	20	5
	69	2779	2	0	22.30	34000	23.0	7.9	1100	13
	69	2778	2	19	17.80	39500	29.0	5.3	33	5
	83	2786	9	0	25.50	360	0.0	8.8	18	30
18-Aug	15	2791	1	0	22.80	29000	19.0	8.0	178	73
	15	2790	1	44	16.80	38800	26.0	5.9	10	8
	16	2789	1	0	22.10	33000	22.0	8.3	195	73
	16	2788	1	45	17.10	39000	29.5	6.3	15	0
	26	2792	2	0	23.00	37000	24.0	8.6	23	58
	27	2794	2	0	22.50	29800	19.0	8.0	315	315
	27	2793	2	41	16.90	38500	30.0	5.5	18	15
	52	2798	2	0	22.60	37000	23.5	6.6	543	40
	52	2797	2	14	20.70	40000	28.0	4.9	195	45
	56	2802	9	0	25.30	400	0.0	9.5	283	168
	57	2804	9	0	25.80	440	0.0	8.7	353	395
	59	2799	9	0	25.60	500	0.0	10.2	180	48
	60	2801	9	0	24.90	500	0.0	7.8	30	30
	67	2800	9	0	25.70	500	0.0	9.7	135	38
	69	2796	2	0	23.60	38000	26.0	6.6	680	38
	69	2795	2	12	20.50	39300	28.0	5.7	123	28
	83	2803	9	0	25.90	365	0.0	9.6	65	78

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
20-Aug	16	2819	2	0	19.70	37500	27.0	6.1	100	8
	16	2818	2	44	17.10	38000	29.0	6.2	10	18
	26	2807	1	0	19.50	38000	27.5	4.6	83	8
	27	2806	6	0	19.30	37000	27.0	5.7	63	23
	27	2805	6	45	17.10	38900	29.0	5.6	13	25
	52	2811	2	0	20.00	34500	24.5	5.5	400	8
	52	2810	2	11	19.70	38500	28.0	3.5	440	45
	56	2815	9	0	22.50	345	0.0	7.2	6925	193
	57	2816	9	0	21.10	340	0.0	7.2	4375	700
	59	2812	9	0	23.00	800	0.0	8.4	133	13
	60	2814	9	0	22.90	430	0.0	7.1	400	35
	67	2813	9	0	22.60	600	0.0	8.1	45	20
	69	2809	1	0	20.30	36000	25.5	6.2	380	20
	69	2808	1	8	20.30	37900	27.0	5.8	335	15
	70	2820	9	0	21.40	500	0.0	9.1	1825	253
	74	2821	9	0	23.60	580	0.0	9.2	350	220
	83	2817	9	0	22.80	330	0.0	8.1	2350	385
21-Aug	15	2825	6	0	18.80	37400	27.7	5.5	25	83
	15	2824	6	50	17.40	38800	28.8	5.4	18	5
	16	2823	6	0	19.00	34500	27.3	5.6	118	63
	16	2822	6	50	17.10	38800	26.9	5.6	13	10
	26	2826	6	0	18.30	38500	28.5	5.0	8	85
	27	2828	6	0	19.10	38100	26.3	5.3	48	20
	27	2827	6	50	17.30	38800	28.5	5.0	8	30
	52	2832	6	0	20.60	27000	19.8	5.0	825	53
	52	2831	6	15	20.00	37800	27.5	4.5	1550	88
	56	2836	9	0	21.20	356	0.0	7.7	460	83
	57	2837	9	0	20.80	370	0.0	7.6	68	63
	59	2833	9	0	21.60	750	0.2	7.8	105	23
	60	2835	9	0	21.80	435	0.0	7.3	308	68
	67	2834	9	0	21.70	470	0.0	7.4	98	315
	69	2830	6	0	21.10	26200	18.3	6.4	1175	118
	69	2829	6	35	18.60	39100	29.0	4.8	30	20
	83	2838	9	0	22.80	340	0.0	8.4	50	25
22-Aug	15	2842	6	0	19.90	34500	25.0	6.4	158	15
	15	2841	6	42	17.30	38000	29.0	6.3	13	0
	16	2840	6	0	20.00	30000	20.5	5.8	155	80
	16	2839	6	45	17.30	38500	29.0	7.3	8	15
	26	2843	6	0	18.60	38500	28.0	5.9	28	0
	27	2845	6	0	19.50	38000	29.0	6.4	133	13
	27	2844	6	42	17.40	39000	29.0	6.0	15	5
	52	2849	6	0	20.20	30000	24.0	5.1	4450	18
	52	2848	6	10	19.50	38500	29.0	5.0	1625	23
	56	2853	9	0	21.70	380	0.0	9.1	678	65
	57	2855	9	0	22.00	390	0.0	9.2	338	60

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	59	2850	9	0	21.90	750	0.5	8.3	243	0
	60	2852	9	0	22.30	450	0.0	10.4	103	13
	67	2851	9	0	22.20	500	0.1	10.1	283	18
	69	2847	6	0	21.80	40000	30.5	6.0	233	15
	69	2846	6	23	18.00	39000	29.5	5.4	50	30
	70	2856	9	0	.	.	.	.	650	170
	74	2857	9	0	.	.	.	.	525	198
	83	2854	9	0	23.10	350	0.0	9.9	103	38
23-Aug	15	2861	6	0	19.90	31000	22.0	5.9	308	180
	15	2860	6	51	17.20	38500	28.5	5.5	8	5
	16	2859	6	0	20.00	26000	20.0	5.4	228	243
	16	2858	6	57	17.20	38500	28.0	5.6	15	5
	26	2862	6	0	18.70	38000	27.0	6.3	675	213
	27	2864	6	0	19.80	35000	25.0	6.2	975	1375
	27	2863	6	51	17.40	38500	28.5	5.2	20	15
	52	2868	6	0	20.60	25000	15.0	5.0	168	325
	52	2867	6	15	20.30	38500	27.0	4.7	900	100
	56	2872	9	0	20.90	380	0.0	8.0	1400	3450
	57	2873	9	0	22.10	450	0.0	9.0	130	435
	59	2869	9	0	21.20	600	0.0	8.7	40	63
	60	2871	9	0	21.60	410	0.0	9.3	700	1375
	67	2870	9	0	21.40	520	0.0	7.5	60	43
	69	2866	6	0	21.10	29000	17.5	5.7	10100	1000
	69	2865	6	29	17.90	38500	29.0	5.1	113	73
	83	2874	9	0	22.30	350	0.0	9.5	78	250
24-Aug	15	2878	5	0	19.50	35000	27.0	5.7	433	650
	15	2877	5	50	17.40	39000	29.0	5.0	5	15
	16	2876	5	0	20.00	36000	27.0	4.9	540	1425
	16	2875	5	50	17.40	39000	28.0	5.1	8	10
	26	2879	5	0	19.30	38000	28.0	5.8	23	38
	27	2881	5	0	19.30	38000	27.0	4.7	40	25
	27	2880	5	50	17.50	39000	29.0	4.7	25	20
	52	2885	5	0	20.50	22000	15.0	5.6	.	163
	52	2884	5	13	20.20	39500	28.5	3.3	13625	10
	56	2889	9	0	21.80	375	0.0	8.2	760	243
	57	2890	9	0	22.20	375	0.0	8.5	108	38
	59	2886	9	0	21.70	700	0.0	9.2	20	5
	60	2888	9	0	21.70	450	0.0	8.9	75	35
	67	2887	9	0	21.70	600	0.0	9.1	30	5
	69	2883	5	0	21.50	40000	28.0	5.2	248	.
	69	2882	5	29	18.10	39000	29.0	4.7	45	3
	74	2892	9	0	20.80	.	.	7.4	993	313
	83	2891	9	0	22.40	350	0.0	8.8	35	15
27-Aug	15	2896	5	0	21.80	34100	23.8	5.3	180	50

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	15	2895	5	36	17.70	38800	29.0	4.4	28	15
	16	2894	5	0	21.90	32000	23.0	5.1	313	185
	16	2893	5	40	17.80	38600	29.0	4.3	28	5
	26	2897	5	0	22.60	35100	23.5	6.4	18	5
	27	2899	5	0	21.90	34200	22.5	7.1	235	40
	27	2898	5	37	17.80	38700	29.0	5.2	38	60
	52	2902	5	0	20.90	23800	16.0	5.2	445	428
	56	2906	9	0	23.30	358	0.0	8.5	338	128
	57	2907	9	0	23.50	349	0.0	9.0	33	33
	59	2903	9	0	23.80	360	0.0	9.7	200	45
	60	2905	9	0	23.70	375	0.0	10.2	340	78
	67	2904	9	0	23.60	378	0.0	9.9	280	100
	69	2901	5	0	22.70	32000	21.8	4.9	540	85
	69	2900	5	23	17.90	38500	28.8	4.5	35	25
	83	2908	9	0	23.80	333	0.0	9.6	48	65
28-Aug	15	2912	3	0	20.50	37000	25.0	5.5	50	33
	15	2911	3	40	17.90	38500	29.0	4.7	50	208
	16	2910	3	0	22.40	36500	24.5	5.8	25	13
	16	2909	3	41	17.90	38500	29.0	4.5	10	218
	26	2913	3	0	21.30	37500	25.5	6.3	85	3
	27	2915	3	0	21.50	37500	25.0	6.8	40	8
	27	2914	3	37	17.90	38500	29.0	4.1	28	10
	52	2918	3	0	22.40	40500	28.0	3.9	188	30
	56	2922	9	0	23.50	360	0.0	8.5	398	95
	57	2923	9	0	23.90	350	0.0	8.6	110	43
	59	2919	9	0	24.10	385	0.0	10.3	260	40
	60	2921	9	0	24.40	390	0.0	9.3	263	30
	67	2920	9	0	23.70	390	0.0	8.5	223	35
	69	2917	3	0	23.00	37000	25.0	5.1	1435	290
	69	2916	3	28	18.00	39000	29.0	4.2	5	8
	70	2925	9	0	23.60	.	.	6.9	2350	295
	74	2926	9	0	25.20	.	.	7.9	2625	265
	83	2924	9	0	24.00	350	0.0	9.2	103	43
30-Aug	15	2930	3	0	20.50	39200	28.4	5.1	30	8
	15	2929	3	48	18.60	39200	29.0	5.3	5	5
	16	2928	3	0	20.70	39000	27.0	5.6	23	18
	16	2927	3	48	18.60	39000	29.0	5.3	3	3
	26	2931	3	0	21.60	38800	27.0	6.3	0	3
	27	2933	3	0	20.80	38200	26.5	7.7	30	3
	27	2932	3	48	18.30	38800	28.0	3.9	3	3
	38	2938	9	0	24.60	425	0.0	10.5	75	38
	52	2937	3	0	21.70	39000	28.9	4.0	20	3
	52	2936	3	8	20.40	39500	28.0	2.2	28	13
	56	2941	9	0	25.00	370	0.0	10.2	180	55
	57	2942	9	0	25.00	343	0.0	9.3	33	48

Table A.05 continued   1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	60	2940	9	0	24.80	400	0.0	10.4	73	23
	67	2939	9	0	24.70	430	0.0	10.1	63	18
	69	2935	3	0	21.50	39000	27.0	5.2	400	0
	69	2934	3	23	20.00	39200	28.9	4.6	448	23
	83	2943	9	0	25.50	339	0.0	9.4	35	30
31-Aug	15	2947	2	0	21.40	38000	25.5	6.2	455	13
	15	2946	2	41	18.30	32000	26.0	5.0	3	3
	16	2945	2	0	21.60	37500	25.0	6.2	98	20
	16	2944	2	44	18.20	39200	29.2	4.9	0	3
	26	2948	2	0	20.30	38400	27.0	6.7	23	13
	27	2950	2	0	20.80	34500	23.5	7.0	100	5
	27	2949	2	41	18.70	39200	29.0	4.6	30	0
	38	2953	9	0	24.00	460	0.0	8.9	373	0
	52	2952	2	0	22.80	39000	25.0	3.9	325	5
	56	2956	9	0	23.90	360	0.0	8.5	235	33
	57	2957	9	0	23.70	345	0.0	8.4	80	63
	60	2955	9	0	24.20	395	0.0	9.5	20	18
	67	2954	9	0	23.50	450	0.0	8.6	78	8
	69	2951	2	0	22.50	38900	25.8	4.1	625	10
	83	2958	9	0	23.90	330	0.0	8.9	20	45
04-Sep	38	2962	6	0	19.50	39500	29.0	8.7	0	10
	38	2961	6	13	19.30	39800	29.0	7.8	23	78
	39.1	2970	2	0	20.70	40000	28.0	8.5	10	0
	40	2965	2	0	20.20	37500	25.5	8.0	25	23
	41	2966	2	0	20.20	37000	27.0	8.0	25	3
	42	2967	2	0	20.50	38000	26.3	7.5	30	278
	44	2960	6	0	18.70	39800	26.0	7.8	8	40
	44	2959	6	19	18.60	39000	28.0	7.5	5	50
	53	2969	2	0	20.80	28000	18.0	6.3	265	20
	54	2968	2	0	20.50	34000	23.1	6.1	153	118
	55	2971	9	0	22.70	370	0.0	10.1	635	678
	84	2964	6	0	20.00	39500	28.5	8.5	5	3
	84	2963	1	24	19.60	39300	28.9	8.6	3	8
05-Sep	38	2975	6	0	19.40	40000	28.9	8.6	0	3
	38	2974	6	14	19.10	40000	29.3	7.8	28	15
	39.1	2983	2	0	20.20	38000	27.5	7.8	108	8
	40	2978	6	0	20.00	38000	27.0	7.3	35	5
	41	2979	6	0	20.00	39250	28.0	7.9	20	5
	42	2980	6	0	20.20	37500	27.5	7.3	48	5
	44	2973	6	0	19.00	40000	29.5	7.6	8	18
	44	2972	6	20	18.90	40000	29.0	7.3	68	73
	53	2982	6	0	20.30	33500	23.5	6.6	505	155
	54	2981	6	0	20.30	36000	25.5	7.5	100	23
	55	2984	9	0	21.20	320	0.0	8.5	400	203

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	84	2977	6	0	19.80	40000	28.8	8.4	0	5
	84	2976	6	25	19.30	40000	29.0	8.0	5	10
06-Sep	38	2990	6	0	20.10	39800	28.3	8.6	0	3
	38	2989	6	15	19.40	39500	20.5	7.7	0	5
	40	2991	6	0	21.00	37500	26.5	7.1	45	13
	41	2992	6	0	21.10	39000	27.5	7.4	35	5
	42	2993	6	0	20.40	37900	26.5	7.0	30	15
	44	2986	6	0	19.20	39800	28.0	7.9	8	3
	44	2985	6	23	18.80	39500	28.0	6.9	15	18
	53	2995	6	0	21.60	31800	20.0	6.7	928	270
	54	2994	6	0	20.50	37100	22.0	6.3	60	23
	55	2996	9	0	21.90	450	0.0	9.4	875	598
	84	2988	6	0	19.80	39300	28.0	8.1	0	3
	84	2987	6	28	19.40	39300	28.0	7.4	5	5
10-Sep	38	3000	5	0	18.80	34000	24.5	6.2	20	8
	38	2999	5	7	18.50	28500	29.0	6.1	5	583
	39.1	3008	6	0	19.30	37000	27.0	6.2	68	25
	40	3003	5	0	19.00	37000	27.5	6.6	20	10
	41	3004	5	0	19.00	35000	26.2	5.5	175	48
	42	3005	5	0	19.20	32500	23.0	5.8	265	248
	44	2998	5	0	19.00	39000	20.0	6.6	30	8
	44	2997	5	16	18.10	39500	29.4	6.1	38	13
	53	3007	5	0	19.50	29250	20.5	5.6	490	238
	54	3006	5	0	19.20	29500	20.5	5.7	425	210
	55	3009	9	0	19.50	390	0.0	6.8	793	503
	84	3002	5	0	18.80	38500	28.0	6.0	23	8
	84	3001	5	19	18.70	39200	28.0	6.3	8	100
11-Sep	38	3013	5	0	18.70	39250	28.8	5.9	8	13
	38	3012	5	6	18.70	39500	28.6	6.2	10	110
	39.1	3021	5	0	19.60	39500	28.3	5.6	83	40
	40	3016	5	0	19.20	38750	28.0	5.5	13	398
	41	3017	5	0	19.30	36000	26.0	5.7	120	55
	42	3018	5	0	19.80	31250	22.0	5.8	518	133
	44	3011	5	0	19.70	39500	28.0	5.8	83	18
	44	3010	4	14	18.60	39500	29.0	6.0	10	290
	53	3020	5	0	20.00	31000	20.8	5.4	638	113
	54	3019	5	0	20.40	28750	19.8	5.6	1013	133
	55	3022	9	0	21.00	389	0.0	6.9	505	398
	84	3015	5	0	19.20	39000	28.5	5.7	30	3
	84	3014	5	16	18.60	39500	29.0	6.0	10	23
12-Sep	38	3026	3	0	19.40	39800	29.1	5.6	3	38
	38	3025	3	6	18.60	39900	29.0	5.4	3	855
	39.1	3034	5	0	20.30	39000	27.2	5.5	198	13

A-64

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	40	3029	3	0	19.70	38300	27.4	5.5	23	25
	41	3030	3	0	20.00	35900	25.0	5.8	198	73
	42	3031	3	0	20.10	29800	20.4	5.5	3550	268
	44	3024	3	0	19.30	40000	29.5	5.7	3	10
	44	3023	3	12	18.50	39600	29.0	5.3	3	45
	53	3033	5	0	20.30	26000	16.7	5.8	785	335
	54	3032	5	0	20.20	26700	19.0	5.3	678	323
	84	3028	3	0	19.60	39000	28.0	5.0	48	33
	84	3027	3	13	19.40	39500	27.3	5.3	28	18
13-Sep	44	3036	3	0	18.90	39900	29.0	6.4	20	13
	44	3035	3	14	18.20	39500	29.0	5.7	53	10
	55	3037	9	0	20.70	421	0.0	8.4	543	645
17-Sep	38	3041	2	0	17.70	37800	29.0	6.3	3	0
	38	3040	2	14	17.20	38100	29.7	6.1	18	3
	39.1	3049	2	0	17.90	38200	27.9	6.4	110	5
	40	3044	2	0	18.30	37200	28.0	6.3	128	20
	41	3045	2	0	18.30	36400	28.0	6.2	470	28
	42	3046	2	0	18.20	37000	27.7	6.3	263	33
	44	3039	1	0	16.00	35000	27.2	6.8	0	3
	44	3038	1	23	15.80	38200	29.0	6.6	0	5
	53	3048	2	0	19.00	21700	15.0	6.7	1475	343
	54	3047	2	0	18.70	30700	21.0	6.1	2025	365
	55	3050	9	0	18.10	290	0.0	7.5	7675	2350
	84	3043	2	0	18.00	37200	28.0	6.4	75	0
	84	3042	2	24	17.80	28900	25.0	6.4	28	5
18-Sep	38	3054	6	0	16.50	38500	29.0	6.6	8	38
	38	3053	6	14	16.40	37500	29.0	6.8	5	5
	39.1	3062	2	0	16.40	30000	27.5	6.5	368	3
	40	3057	6	0	16.70	36200	28.5	6.5	65	10
	41	3058	6	0	16.70	37000	29.0	7.0	278	13
	42	3059	6	0	16.60	35200	27.5	6.8	93	20
	44	3052	6	0	15.60	38000	30.0	7.3	28	5
	44	3051	6	20	15.40	37900	29.0	9.0	5	13
	53	3061	2	0	16.70	32700	25.0	6.3	458	63
	54	3060	1	0	16.90	33600	26.0	6.3	143	23
	55	3063	9	0	16.70	305	0.0	8.7	855	398
	84	3056	6	0	16.60	37900	29.0	6.7	18	30
	84	3055	6	25	16.50	38000	29.5	6.6	23	0
19-Sep	38	3067	6	0	16.00	37400	29.1	7.2	10	0
	38	3066	6	13	15.90	37200	29.0	7.3	13	0
	39.1	3075	6	0	15.90	34500	26.5	7.4	55	3
	40	3070	6	13	15.60	35200	27.2	6.7	28	3
	41	3071	6	0	16.00	36200	27.1	7.2	348	23

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	42	3072	6	0	15.90	35000	26.9	7.0	30	13
	44	3065	6	0	15.90	37500	29.0	7.2	3	0
	44	3064	6	18	15.60	37200	29.2	7.0	15	23
	53	3074	6	0	15.90	30100	23.8	6.5	80	38
	54	3073	6	0	16.00	33200	25.2	6.7	33	3
	55	3076	9	0	15.00	285	0.0	8.8	605	418
	84	3069	6	0	15.90	37200	28.9	7.4	18	5
	84	3068	6	25	15.70	37200	28.9	7.0	5	0
24-Sep	85	3078	5	0	16.00	36900	28.5	6.5	5	208
	85	3077	5	16	16.00	36800	28.5	6.4	18	18
	86	3079	6	0	16.00	36000	28.0	6.8	8	13
	87	3081	6	0	16.00	37000	28.5	6.7	13	13
	87	3080	6	20	15.00	37000	28.5	6.7	13	3
	88	3082	6	0	16.00	37000	29.0	6.7	10	5
25-Sep	85	3084	5	0	16.00	35900	28.2	6.9	5	3
	85	3083	5	16	15.90	34900	28.2	6.8	15	5
	86	3085	5	0	17.10	35900	26.4	8.1	0	5
	87	3087	5	0	16.20	36100	28.0	7.4	8	3
	87	3086	5	19	15.90	36300	28.2	7.3	23	13
	88	3088	5	0	16.10	36200	28.2	7.1	10	10
26-Sep	85	3090	5	0	16.00	33000	27.5	7.1	13	10
	85	3089	5	16	15.80	36000	28.0	6.8	8	8
	86	3091	5	0	16.00	34000	26.0	7.8	8	48
	87	3093	5	0	15.90	34000	26.2	7.2	0	13
	87	3092	5	21	15.60	34800	26.8	7.3	10	35
	88	3094	5	0	15.90	34000	26.3	7.3	0	5
01-Oct	11	3108	2	0	19.60	1390	1.4	9.6	343	15
	14	3107	2	0	17.70	37200	28.5	7.1	33	8
	14	3106	2	38	14.70	37800	29.8	5.6	0	0
	17	3105	2	0	17.40	38000	28.8	7.0	178	13
	18	3102	2	0	17.10	36000	27.0	6.6	43	63
	19	3104	2	0	17.70	38000	28.7	7.2	213	23
	19	3103	2	27	14.90	37500	30.0	6.3	53	445
	21	3101	2	0	16.70	37700	28.0	7.8	50	15
	22	3100	2	0	16.90	36800	27.0	8.0	28	3
	24	3099	2	0	16.80	37500	28.0	7.7	28	8
	24	3098	2	40	14.20	37200	30.0	7.5	908	225
	36	3096	2	0	16.50	38000	29.2	9.6	8	3
	38	3095	2	0	16.30	37000	25.0	9.3	0	3
	44	3097	2	0	16.30	37100	28.3	8.1	73	30
02-Oct	11	3119	2	0	18.80	1600	1.0	8.6	308	8
	14	3118	2	0	16.50	38000	29.0	7.0	30	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	17	3116	2	0	16.60	37500	28.5	7.2	35	5
	18	3113	2	0	16.70	38750	30.0	6.5	40	18
	19	3115	2	0	16.30	38000	28.5	7.5	30	18
	19	3114	2	30	15.00	38000	30.5	6.7	35	30
	21	3112	2	0	16.20	38000	29.2	7.8	43	13
	22	3111	2	0	18.50	40000	30.0	6.9	13	8
	24	3110	2	0	15.60	38500	30.0	8.1	15	15
	24	3109	2	42	14.40	38000	31.0	8.2	88	48
	44	3117	2	36	14.80	37500	30.0	5.6	38	15
04-Oct	14	3131	2	0	16.60	38000	29.4	7.1	20	3
	14	3130	2	48	14.50	37000	28.8	7.3	23	815
	17	3129	2	0	16.00	38000	29.5	7.5	15	20
	19	3128	2	0	15.60	38000	29.8	7.6	5	0
	19	3127	2	27	14.20	37200	29.8	7.6	8	23
	21	3126	1	0	15.50	.	.	8.0	5	10
	22	3125	6	0	18.30	40000	29.5	7.1	5	5
	24	3124	6	0	14.10	37000	30.0	8.0	275	55
	24	3123	6	47	13.80	36800	29.8	7.7	523	143
	36	3121	6	0	14.80	37000	30.2	9.4	23	0
	38	3120	6	0	14.90	37000	27.9	8.8	10	5
	44	3122	6	0	13.20	36500	29.8	7.8	1550	215
09-Oct	14	3144	6	0	16.00	35500	27.0	6.4	163	490
	14	3143	6	45	13.80	34900	28.5	5.9	0	488
	17	3142	6	0	16.30	35000	26.5	6.5	120	880
	18	3139	6	0	16.50	37000	29.0	5.9	183	168
	19	3141	6	0	15.90	35500	27.0	6.7	100	428
	19	3140	6	41	13.80	37000	30.0	6.1	0	1848
	21	3138	5	0	15.50	37000	29.0	6.9	48	138
	22	3137	5	0	16.80	38800	29.1	7.0	73	303
	24	3136	5	0	14.60	36200	29.1	7.1	23	80
	24	3135	5	39	13.50	37000	30.1	6.8	173	65
	36	3133	5	0	15.60	38500	30.5	6.9	28	15
	38	3132	5	0	15.00	36800	29.0	7.9	10	5
	44	3134	5	0	14.60	37500	30.0	7.4	8	35
10-Oct	11	3148	9	0	18.50	169	1.0	7.2	313	103
	18	3147	5	0	15.90	37000	29.0	6.3	115	198
	18	3146	5	39	15.10	38000	31.0	5.4	43	73
	75	3145	5	0	19.70	36200	28.0	8.3	768	2425
	89	3149	6	0	15.60	36000	28.0	4.3	580	135
11-Oct	11	3153	9	0	18.30	161	1.0	7.5	763	55
	18	3152	4	0	16.60	36500	28.3	5.8	948	878
	18	3151	4	34	14.50	37700	30.3	5.9	20	38
	75	3150	4	0	17.00	34500	25.8	4.1	1035	1825

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	89	3154	.	0	16.10	27800	20.8	2.6	4950	830
14-Oct	18	3171	5	0	19.40	19000	13.1	6.0	101400	56100
	18	3170	5	23	14.60	37200	30.1	4.8	6375	2125
	19	3174	5	0	15.80	22000	15.8	6.3	12700	425
	19	3173	5	23	14.10	37000	29.9	6.3	205	80
	36	3168	3	0	16.40	36000	27.5	6.7	8750	7625
	38	3169	4	0	17.80	37200	29.0	8.8	1275	1500
	75	3172	5	0	18.90	21500	14.8	6.0	76600	66100
15-Oct	11	3186	9	0	19.60	640	0.5	5.4	13700	495
	17	3185	2	0	18.10	30200	21.4	6.3	5600	140
	18	3182	2	0	18.60	30100	21.7	5.3	19300	453
	19	3184	2	0	16.60	33300	24.8	6.0	3550	948
	19	3183	2	43	14.10	37500	30.0	5.5	53	345
	21	3181	2	0	17.10	32000	24.0	6.1	3500	988
	22	3180	2	0	18.40	32000	25.2	6.4	4480	943
	24	3179	2	0	17.10	31900	25.0	6.3	4030	1028
	24	3178	2	42	14.00	37200	30.0	6.7	60	108
	36	3176	2	0	16.10	37000	28.7	7.1	320	175
	38	3175	2	0	16.10	35200	27.9	7.3	925	425
	44	3177	2	0	15.70	35500	28.0	7.2	758	330
16-Oct	11	3200	9	0	18.80	500	0.9	5.1	4780	768
	14	3199	2	0	16.30	30000	21.8	6.0	1063	128
	14	3198	2	39	14.30	37100	29.1	5.3	108	45
	17	3197	2	0	15.60	30800	23.3	6.6	928	103
	18	3194	2	0	16.00	32500	26.5	5.6	2300	103
	19	3196	2	0	15.50	33900	26.1	6.1	955	85
	19	3195	2	42	14.20	37000	29.4	6.4	80	60
	21	3193	2	0	15.40	33900	26.8	6.6	658	85
	22	3192	2	0	18.60	40100	30.0	6.1	48	25
	24	3191	2	0	15.00	34000	27.9	6.6	868	70
	24	3190	2	43	13.70	38000	30.1	7.2	135	70
	36	3188	2	0	14.40	36800	30.1	7.1	70	20
	38	3187	2	0	14.50	35800	28.8	7.2	233	48
	44	3189	2	0	13.90	36800	30.2	7.2	48	33
17-Oct	11	3214	9	0	18.30	500	0.5	5.8	1008	185
	14	3213	2	0	16.10	31900	24.8	5.6	650	28
	14	3212	2	40	14.30	37000	30.0	5.1	70	20
	17	3211	2	0	15.70	31000	23.9	6.2	378	20
	18	3208	2	0	15.20	31900	24.0	6.0	743	183
	19	3210	2	0	15.50	35100	27.5	6.1	290	40
	19	3209	2	42	14.10	36800	28.8	6.4	33	10
	21	3207	2	0	15.50	32900	26.8	6.3	303	15
	22	3206	1	0	17.20	39000	32.5	6.0	8	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	24	3205	1	0	14.10	35800	29.5	7.0	48	10
	24	3204	1	43	13.90	36500	30.0	6.8	60	45
	36	3202	6	0	13.90	36000	29.0	8.1	20	5
	38	3201	6	0	14.10	35600	29.0	7.4	35	8
	44	3203	6	0	13.60	36700	30.0	7.2	28	13
18-Oct	11	3228	9	0	18.10	410	0.2	6.7	703	130
	14	3227	2	0	16.70	29500	22.2	6.2	323	48
	14	3226	2	41	14.40	37000	29.0	5.4	38	20
	17	3225	2	0	16.40	28700	22.0	6.7	253	30
	18	3222	2	0	16.40	36100	28.9	5.9	523	190
	19	3224	2	0	16.20	31000	24.0	6.4	870	88
	19	3223	2	44	14.20	36500	29.0	6.7	10	18
	21	3221	1	0	16.10	35500	28.2	6.5	73	13
	22	3220	6	0	18.20	40000	32.2	6.1	15	15
	24	3219	6	0	14.20	36100	29.0	7.6	33	23
	24	3218	6	44	13.80	36500	29.0	7.3	.	.
	36	3216	6	0	14.70	36000	28.5	8.3	62	15
	38	3215	6	0	14.60	35000	27.9	7.9	45	13
	44	3217	6	0	13.50	36500	29.0	7.5	5	8

Other Monitoring Data

Boston Water and Sewer

05-May	BWSC7	1608	2	0	12.10	21000	17.0	7.3	75	18
	BWSC7	1607	2	24	10.20	31200	8.1	8.1	5	3
	BWSC8	1602	2	0	12.50	23200	21.0	8.4	1500	320
	BWSC8	1601	2	40	9.90	31200	28.5	9.4	0	3

Constitution

05-Jun	CON-1	1628	2	0	15.60	34000	27.5	8.9	58	3
	CON-2	1629	2	0	15.70	34000	28.0	9.4	30	0
	CON-3	1630	2	0	15.50	34000	26.5	9.1	35	3
	CON-4	1631	2	0	16.10	35000	27.0	8.3	5	5
	CON-5	1632	2	0	16.20	35000	27.0	8.6	0	3
	CON-6	1633	2	0	16.20	34500	27.0	9.5	0	0
	CON-7	1634	2	0	16.10	34500	27.0	9.2	15	3
	CON-8	1635	2	0	16.00	34500	27.0	9.4	8	3
	CON-9	1636	2	0	16.60	35000	27.0	8.1	28	0
	CON10	1637	2	0	16.40	34500	26.5	9.4	5	0
06-Jun	CON-1	1638	6	0	15.50	34000	26.5	9.5	13	8
	CON-2	1639	1	0	15.40	34000	27.0	9.4	8	8
	CON-3	1640	1	0	15.40	34000	27.0	9.5	28	0
	CON-4	1641	1	0	15.30	34000	27.0	9.1	8	0
	CON-5	1642	1	0	15.40	34000	27.0	8.7	0	0
	CON-6	1643	1	0	15.50	34000	27.0	7.9	0	3

Table A.05 continued 1990 Raw Data

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. Colif.	Entero
	CON-7	1644	1	0	15.40	34000	27.0	8.8	0	0
	CON-8	1645	1	0	15.30	34000	27.0	8.3	0	3
	CON-9	1646	2	0	15.50	34000	27.0	8.4	8	3
	CON10	1647	2	0	15.40	34000	27.0	8.4	3	3
07-Jun	CON-1	1648	6	0	14.70	34000	27.0	9.5	5	5
	CON-2	1649	6	0	14.60	33500	26.0	9.5	5	5
	CON-3	1650	6	0	14.50	33000	27.0	9.6	13	3
	CON-4	1651	6	0	14.50	34000	27.0	9.7	3	3
	CON-5	1652	6	0	14.40	33500	27.0	9.5	8	5
	CON-6	1653	6	0	14.40	33500	27.0	9.3	18	10
	CON-7	1654	6	0	14.50	33500	27.0	9.3	8	8
	CON-8	1655	6	0	14.50	33500	27.0	9.2	5	0
	CON-9	1656	6	0	14.50	33500	27.0	9.0	8	5
	CON10	1657	6	0	14.40	33500	27.0	9.1	5	8

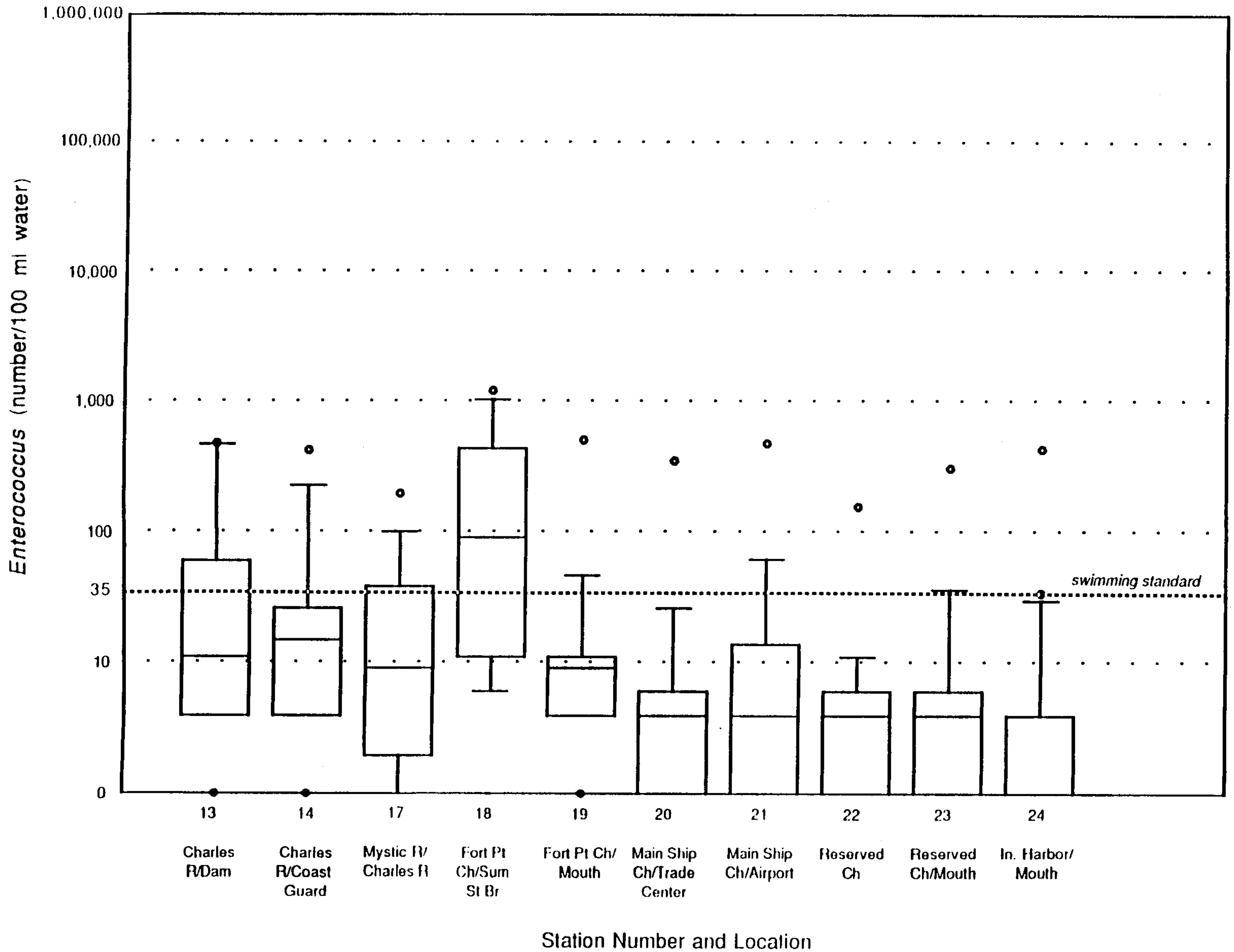


Figure A.01. Percentile Box Plots of *Enteroccocus* Counts from Surface Samples in the Inner Harbor, 1989.

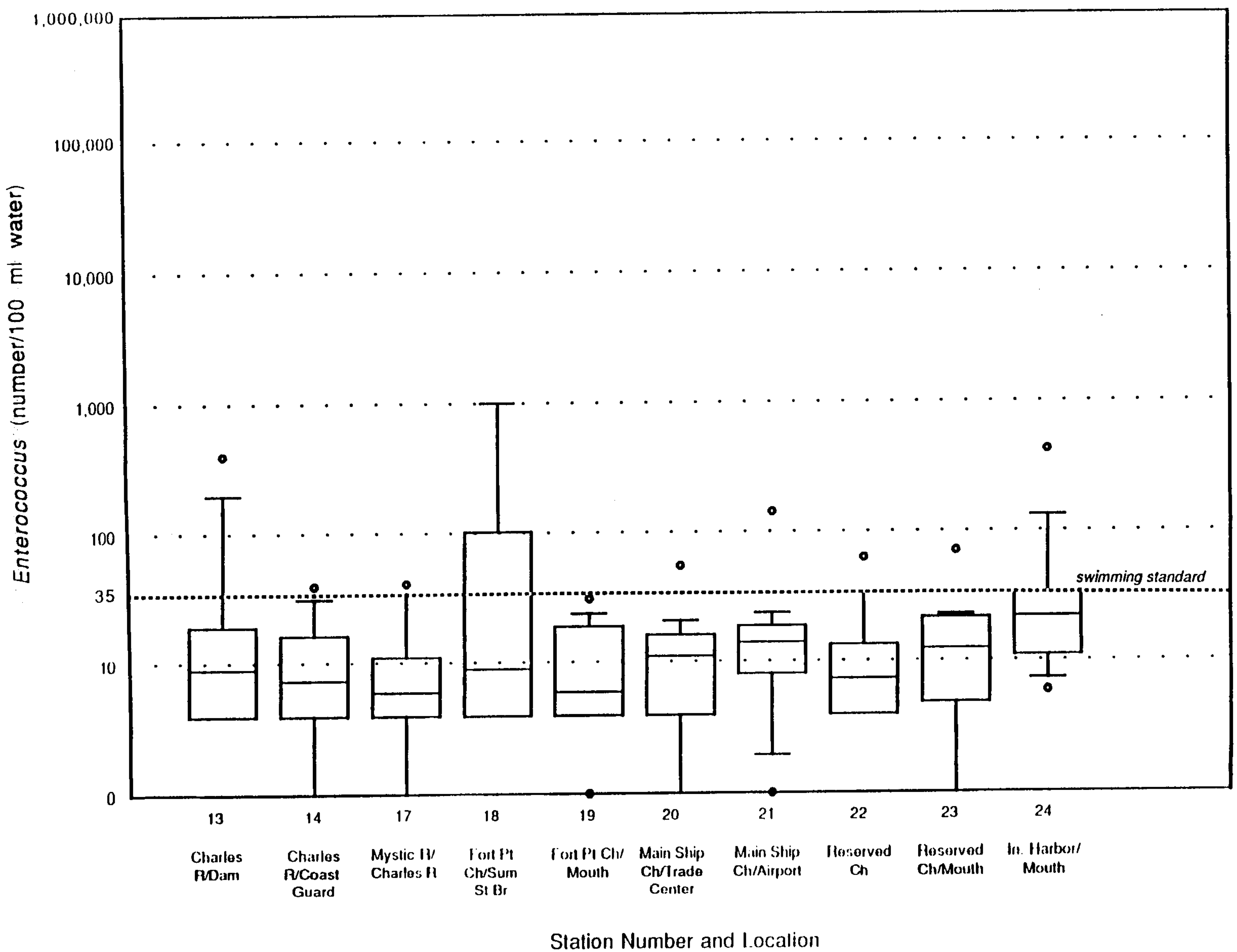


Figure A.02. Percentile Box Plots of *Enteroccocus* Counts from Bottom Samples in the Inner Harbor, 1989.

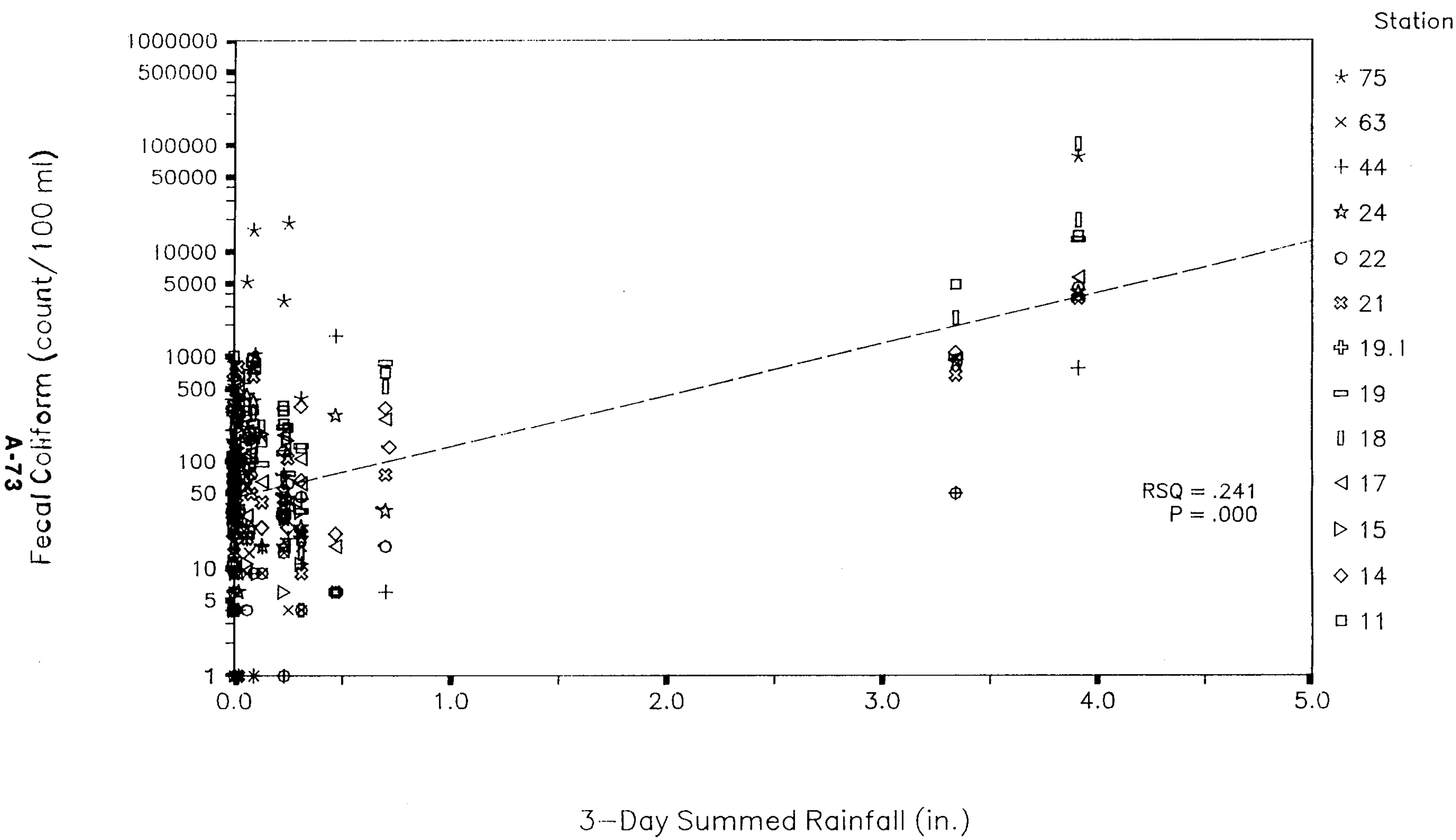


Figure A.03. Relationship between Fecal Coliform Counts from Surface Samples in the Inner Harbor and Three-Day Summed Rainfall, 1990.

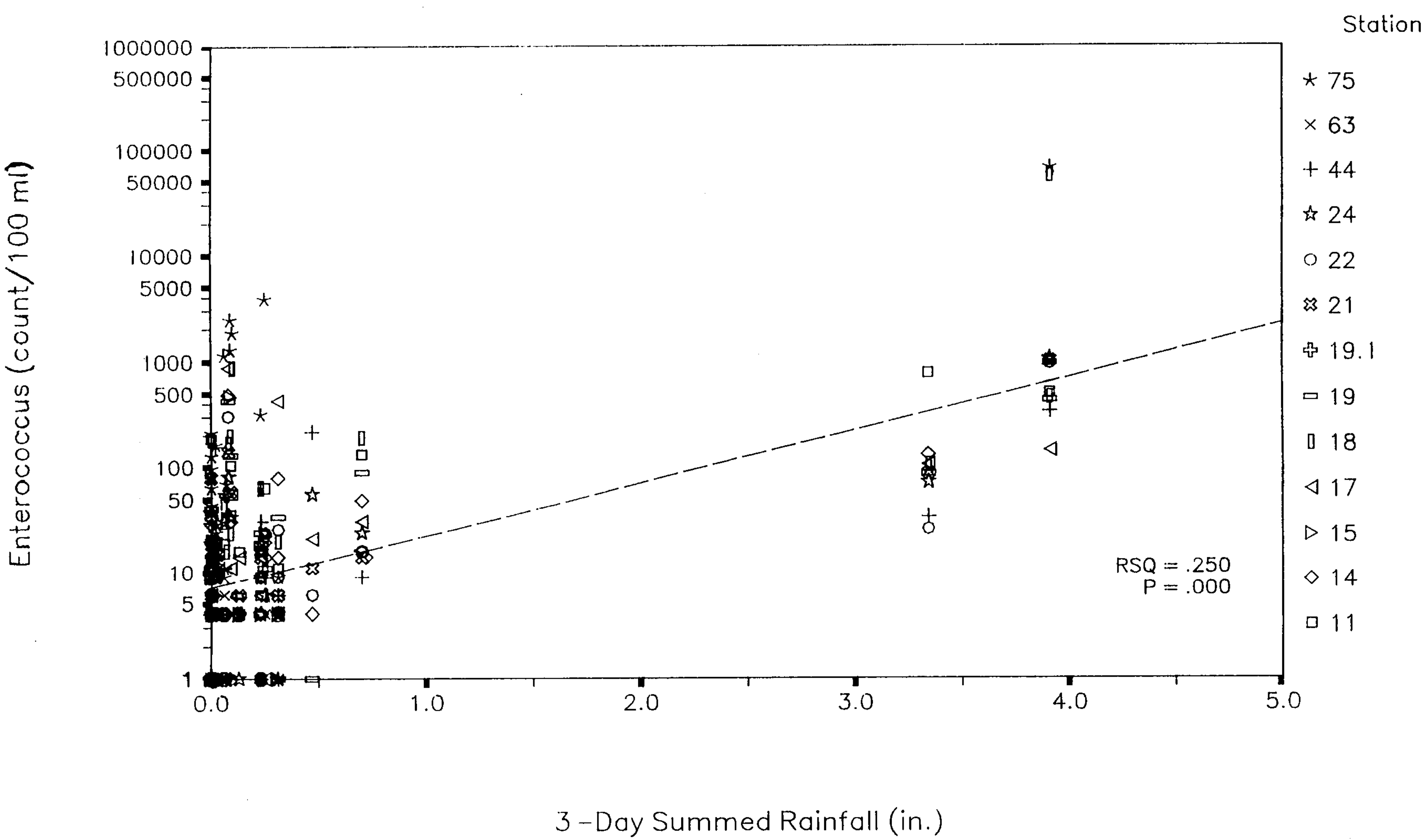


Figure A.04. Relationship between *Enterococcus* Counts from Surface Samples in the Inner Harbor and Three-Day Summed Rainfall, 1990.

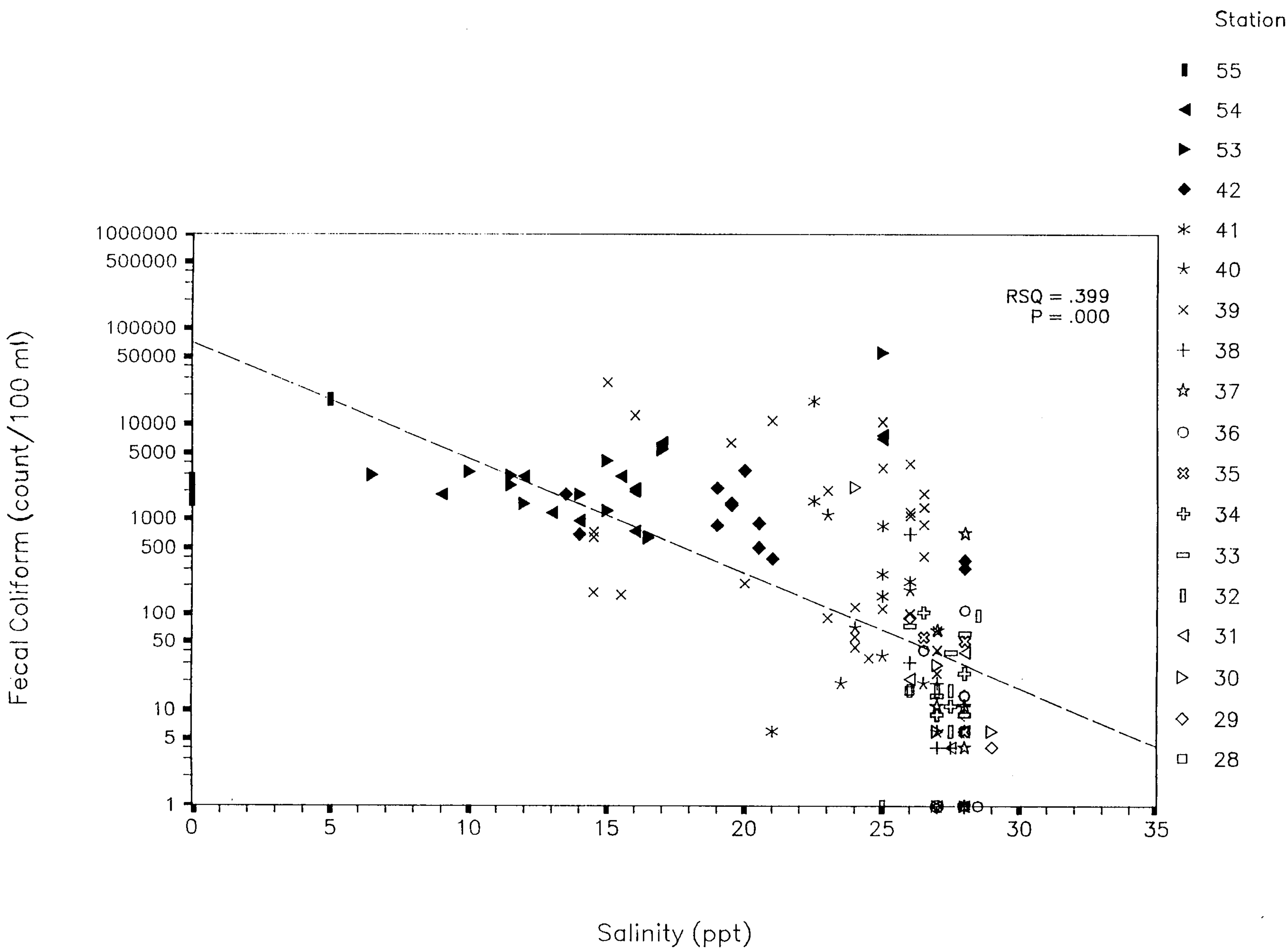


Figure A.05. Relationship between Fecal Coliform and Salinity in Dorchester Bay/Neponset River, 1989.

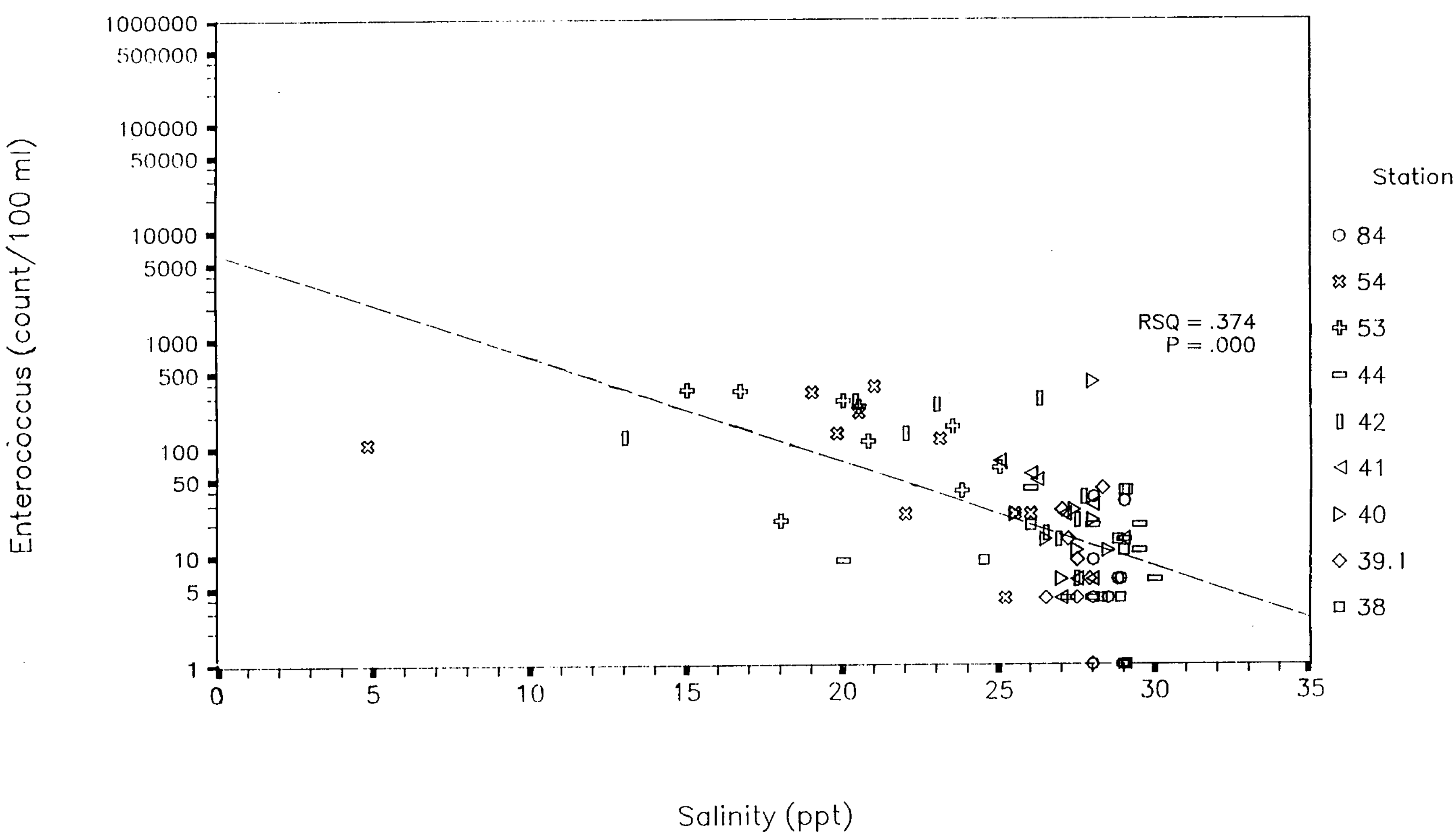


Figure A.06. Relationship between *Enterococcus* Counts and Salinity in the Neponset River, 1990. (Station 55 excluded.)

Appendix B

Data Handling and Statistical Analysis Procedures

Appendix B

Data Analytical Techniques

1. Data Sources

A. Monitoring Program

1. Field. Field observations and measurements (Table B.01) were immediately entered into waterproof field notebooks. Unique sample numbers, which were assigned to each sample prior to sampling, were preprinted onto the sample labels, the field notebooks, and the Lab Data Sheets. Field data were transcribed daily from the field notebooks onto the data sheets in the laboratory. Daily checks were made to ensure transcription accuracy. Full field notebooks were stored in the laboratory.

2. Laboratory. Bacterial counts were entered onto lab data sheets in the laboratory. On a monthly basis the data sheets were xeroxed, and the copies stored in our Charlestown Navy Yard offices. The originals were filed at the laboratory.

B. Rainfall and System Loads

1. Rainfall. We obtained National Weather Service daily rainfall records for the period June 1, 1989 to October 31, 1991. Daily rainfall records were also provided by the Cambridge department of Public Works for June 1 1989 to September 30 1989 for 147 Hampshire Street, Cambridge.

2. MWRA Treatment Plant Flows. We obtained daily flow and effluent fecal coliform measurements for June 1 1989 - October 31 1990 from treatment plant logs for the Deer and Nut Island POTWs. The Nut Island data used span only the periods July 1 to August 31, in 1989 and 1990, during which receiving water sampling in Quincy Bay was occurring (Table B.02).

3. CSO Activations. Flow records and effluent fecal coliforms for the period June 1 to October 31, 1989 were obtained from 3 MWRA CSO screening and disinfection facilities; Cottage Farm (MWRA-204) and Prison Point (MWRA-203) in Cambridge, and Somerville Marginal (MWRA-205) in Somerville. Flow records were also obtained for the same period for the Moon Island CSO (BOS-125), owned by the Boston Water and Sewer Commission (Table B.02). 1990 data were not obtained for these discharges.

4. Model Predictions. Sewer System model predictions for City of Boston CSOs discharging into salt water during our 1989 and 1990 field monitoring were obtained from the Boston Water and Sewer Commission (Table B.03).

2. Data Entry and Validation

A. Monitoring Program Data.

1. Entry We developed a screen entry template for dBASE III+ (Ashton-Tate, Torrance CA) that mimics the lab data sheets. Data entry was performed at the laboratory. Key-punched data were checked against the lab data sheets by lab personnel after each session. Files were backed up daily to both fixed and floppy disks. These files were transferred on a monthly basis to the fixed disk of a separate PC at the Charlestown Navy Yard.

2. Validation

a. 1989 A hard copy listing of the dBASE data file was made at the end of the 1989 field season. Every field for each sample was checked against entries in the original lab data sheets by a team of 2 people. Errors in the printouts identified by these checks were corrected in the data files. Following error correction, a second listing of the data was printed out. The second listing was checked against the first to ensure that all errors were corrected, with random spot-checking of approximately 10% of the fields that were correct in the original to ensure that errors were not inadvertently added in the correction process.

b. 1990 In order to shorten the large amount of time that went into data checking of the 1989 data, we greatly modified our data validation procedures for the 1990 field monitoring data. The 1990 data were entered twice into identical dBASE tables. The first keypunching was performed by lab personnel, the second by a professional data entry consultant. Following the 1990 field season, we input ASCII versions of these files to a program which electronically compared every field of each record in one file to the corresponding field in the second file. The program flagged inconsistencies between the 2 files, which indicated data entry error in one file or the other. The inconsistent fields were checked against the data sheets to identify and correct errors.

Once the errors identified by the file-checking program were corrected, we consulted industrial quality control tables (ASQC 1981) to determine the proper numbers of samples for further checking. A pseudo-random number generator was used to generate sample numbers for this check, and the Acceptable Quality Limit (AQL) was set at 1 percent. All fields in the randomly selected records were then checked against the corresponding data sheets. This means that a data file meeting the acceptance criteria in the ASQC tables, as the 1990 field monitoring data did, contains a maximum of 1 percent of **records** (samples) with one or more erroneous **fields** (variables).

B. Rainfall and Sewage Flows. Daily rainfall, treatment plant and CSO flows were entered onto LOTUS 123 (LOTUS Development Corp., Cambridge, MA) spreadsheets. Rainfall and flow data were validated following similar procedures to those followed for the 1989 field monitoring data. Supplemental variables calculated within LOTUS 123 were checked manually to ensure that the formulae used were correctly implemented.

C. Model Predictions. CSO Model predictions were received from BWSC in electronic format (LOTUS 123 spreadsheet). The data were manipulated within 123 into an appropriate form for analysis. Printouts of the predictions were received from BWSC along with the data files, and the results of the file manipulations were checked against those printouts to ensure that errors were not introduced.

D. File Storage

1. Monitoring Data. Backup copies of the raw data files were maintained in 2 separate locations. These files were erased as data were validated and appended to the databases. we maintained separate data files for the 1989 and the 1990 monitoring data. The validated database files were maintained on a separate subdirectory on fixed disk, and on a floppy disk backup. No alterations except for addition of new validated data were permitted to these copies of the files. All analyses and transformations were performed upon copies of the files.

2. Other files. Validated copies of all other datafiles were maintained on separate subdirectories on a fixed disk, backed up to floppy disk. As with the monitoring data, all analyses and transformations were performed on copies of the files.

D. File Transformations and Applications used

Data analysis and graphics presentation required the passage of the data through several different applications on different platforms. Following such transformations data were printed out and all the fields in roughly 5% of the records were checked against the originals to ensure that errors were not added in the file manipulations.

Several different software packages were used for data analysis and the preparation of summary tables and figures. In cases where similar analyses were run using different packages, the results were checked against each other for consistency.

1. MS-DOS Applications. Word Perfect (Word Perfect Corp, Orem, UT) was used in the preparation of tables of the raw data. Some preliminary analyses were run on the PCs using LOTUS 123. Some analyses and figures for the 1990 field monitoring data were prepared using SOLO (BMDP Statistical Software, Los Angeles, CA) and EXCEL (MicroSoft Corp., Redmond WA).

2. VAX. We prepared most of the data summaries and analyses on the MWRA VAX using SPSSX (SPSS Inc, Chicago, IL). The monitoring databases and the rainfall and flow data were combined within SPSSX, related by date. This resulted in one large SPSSX system file for each of the 1989 and 1990 field seasons. SPSSX was run in batch mode, and SPSS Graphics was used to prepare report quality figures.

3. MacIntosh. Selected portions of the database were imported from 123 worksheet format into Macintosh EXCEL worksheet format for graphics preparation and limited data analyses on Apple Macintosh microcomputers. EXCEL, as well as CRICKETGRAPH (Cricket software, Malvern PA) and MACDRAW (Claris Corp. Mountain View, CA), were used to prepare summary figures and tables. Correlations and regressions run in CRICKETGRAPH were checked against the results of similar analyses run in SPSSX.

3. Analyses Run

A: Supplemental Variables.

In addition to the data listed in Tables B.01 through B.03, many supplemental variables were derived from the raw data for use in the analyses.

1. Monitoring Program data. The following variables calculated from the field monitoring data were used extensively in the data analyses:

REGION Sample data were aggregated into the regions shown in Table B.04, using SPSSX SELECT IF statements. In 1990 we sampled several stations (e.g. station 44) while monitoring more than one region, so data from those stations were assigned to different regions by date ranges.

LGFC,LGME The fecal coliform and *Enterococcus* data gathered in both the 1989 and 1990 field monitoring were log-normally distributed. Since the parametric statistics used in the analyses assume normally distributed data (Sokal and Rohlf, 1981), $\log_{10}(x+1)$ transformations were computed for both the fecal coliform (LGFC) and the *Enterococcus* (LGME) data within SPSSX. Frequency distributions of log-transformed counts did not violate the assumptions of normality.

CURRENT The tidal information coded in the TIDE variable was further grouped into a current variable whose value equalled "1" for the ebb tide, and "2" for flood tides. The rare occasion where tide was coded as high slack (TIDE = 1) or low slack (TIDE = 4) were arbitrarily coded as flood and ebb, respectively.

2. Rainfall and System loads.

a. Rainfall. Several supplemental variables were computed from Logan Airport and Cambridge DPW rainfall data in order to further test for effects of rainfall. These variables and the formulae used to derive them are detailed in Table B.05. In brief, the supplemental variables tested for delayed and/or additive effects of rainfall over several days, and for exponential decay effects within an additive model.

b. Treatment Plant and CSO Facilities.
For data from both the treatment plants and for the 1989 data from the Prison Point, Cottage Farm, and Somerville Marginal CSO facilities the effluent fecal coliform loading was calculated from the flow and effluent coliform concentrations (Table B.05).

c. Model Predictions. We received CSO model predictions for 42 individual CSOs for the periods covering the 1989 and the 1990 field seasons from the Boston Water and Sewer Commission. The 1989 model predictions were generated by the original, uncalibrated version of the BWSC sewer system model. The 1990 model predictions were generated by an updated version of the model, which estimates the effects of tides on CSO discharges and is calibrated to the CSO flows measured by BWSC during their 1990 CSO system monitoring.

We limited our analyses using CSO model predictions to only three areas, and summed the predicted flows within each area. Predictions for all CSOs in Fort Point Channel (BOS-062 through BOS-075) were summed for each date. Summations of predicted flows for 2, 3, and 4 days were also calculated. Similar single and multiple-day predictions were also constructed for predicted overflows into Dorchester Bay (BOS-081 through BOS-090). Two to four day summations were calculated for 1989 predicted discharges from the Calf Pasture/Moon Island

CSO (BOS-125). As BWSC shut down the Calf Pasture pumping station in Spring 1990, there were no predicted (or actual) overflows at BOS-125 during our summer 1990 monitoring in Quincy Bay.

B. Analyses. Analyses are described in approximately the order in which we carried them out. Several analyses which are not specifically referenced in the body of the report, but which form the basis for later analyses are included here. The names of the specific SPSSX procedures used are provided.

We only ran limited on the 1989 and 1990 field data combined. Most analyses were run separately on the 1989 and 1990 data.

In many cases analyses were run on only the data gathered in a particular region, and/or on a station by station basis. Table X.6 provides a sample SPSSX command file utilizing the procedure **PEARSON CORR**, and illustrates the procedures used to select subsamples of the data. After setting the output line width and opening the SPSSX system file which contains the monitoring data, The command file first selects only those records for which the variable REGION equals "INNERH", the Inner Harbor (line 3). The working file is further restricted by choosing only those records for which DPTHSAM equals zero (line 4). The file is then sorted into ascending order by station number (line 5). This results in the selection of a working file which contains data on only Inner Harbor surface samples, as reflected in the title lines 6 & 7. After an initial analysis of all selected records (line 8), the file is split by station number (line 9), and the analyses repeated for each station (line 11). The results of this job, presented in Figure x.1, gives Pearson product-moment correlation coefficients between Salinity and log-transformed fecal coliform counts for Inner Harbor surface samples, for the whole inner Harbor and for each individual station.

In addition to analyses that were run on the data set as a whole, some were run in the same way for each region of the Harbor. Those analyses are detailed in this section, to avoid needless repetition.

1. Frequency Distributions and Boxplots Frequency distributions for the fecal coliform and *Enterococcus* data were created for the entire data set for the 1989 and the 1990 data, as well as for the Inner Harbor data (lumped and split by station), using the FREQUENCY module in SPSSX. These distributions were visually inspected to confirm expectations that the raw bacterial data were log-normally distributed. After log(x+1) transformation the frequency distributions were repeated,and did not show substantial departures from normality.

Using SOLO, we constructed percentile boxplots for the data for each bacterial indicator at each station sampled. These plots were split by depth sampled (surface vs. bottom) where appropriate, and were grouped by region. Separate boxplots were constructed for each year's data, and for both years combined for stations sampled in both 989 and 1990.

2. Summary Tabulation Tables of geometric means for both fecal coliform and *Enterococcus* data were calculated in the following manner for each year separately, and for the two years combined for the stations monitored both years:

The SPSSX BREAKDOWN module was used to generate means and standard deviations for log(x+1) transformed bacterial data, broken down by region, station within region, and depth sampled (surface/bottom) within station. This output was downloaded to PC and imported into LOTUS 123. Within 123 standard errors were calculated from the standard deviations and sample sizes, calculated by SPSS. The 95% confidence intervals were calculated from the standard error, using a confidence level of .05 from a normal distribution (1.96 * SE) rather than the more appropriate "t" statistic ($t_{.05,n}$ * SE) because 123 does not have a table lookup feature for finding the appropriate t statistic given the degrees of freedom. Thus, the 95% CIs in tables XX.X may slightly underestimate the true confidence intervals, especially for categories with fewer than 5 records.

After the 95% Confidence Intervals were calculated, the log mean and the CIs were back-transformed to give the geometric means and confidence intervals for each category
(e.g. Geom. mean = $10^{\log \text{mean}}-1$).

3. Regression and correlation Regression and correlation analyses were run for each year on the entire data set using the SPSSX procedures PLOT, which constructs simple scattergrams of pairs of variables with linear regression statistics, PEARSON CORR, which calculates Pearson product-moment correlation coefficients, and NONPAR CORR, which as used calculates Spearman rank-order correlation coefficients.

a. Replicates In order to determine the extent of variation in replicate field samples and duplicate laboratory filtrations, regressions and scatterplots were constructed for both raw and log-transformed bacterial counts. Each year's complete monitoring data set was used in the regressions of lab duplicates, which were run on every sample. A subset of the monitoring data for which the variable **REP** equalled "Y" was used in the regressions of field replicate samples.

b. Indicators Linear regressions and scattergrams were run for both the 1989 and 1990 monitoring on the entire data set on the raw and log-transformed fecal coliforms against the raw and log-transformed Enterococcus counts, to investigate the relationship between the two indicators.

c. Rainfall Logan Airport and rainfall measured by Cambridge DPW for June 1 - September 30, 1989 were regressed against each other, to see how well the rain at each location predicted the rain at the other. The correlation was so high (> 0.9) that only the Logan rain variables were used in further analyses.

d. Rainfall and Sewage Pearson correlation coefficients were run for all pairs of sewage (except for Nut Island flows and loads) and Logan rainfall variables for the entire period June 1 - October 31 1989. This was done in order to determine the relationship between those variables for the entire 152 day period, for comparison to the correlation coefficients for the 70 days during that period during which sampling occurred. These analyses were not repeated in 1990.

e. Indicators vs other Variables Both Pearson(both years) and Spearman (1989 only) correlation analyses were run for each year's data on all possible pairs of variables from the following data list:

Fecal Coliform	Log(x+1) Fecal Coliform
Enterococcus	Log(x+1) Enterococcus
Dissolved Oxygen	Salinity
Water Temperature	all Logan rain variables
All sewage flow and load variables	

The dataset was then split into surface and bottom samples, and the correlation analyses were repeated on both subsets.

For stations sampled both years, the surface data were pooled by regions and Pearson correlation analyses run between bacterial indicator data and the rainfall and flow variables. The analyses were run by region and split by station.

Since the rainfall and sewage variables contained single measurements for each date sampled, and were spread over the many samples taken each day, correlations with these variables for the entire dataset were deemed significant only if the probability of Type I error were less than 0.01. Scattergrams were constructed of significant correlations with indicators and dissolved oxygen, in order to see the shape of the relationships.

f. Regional Analyses The dataset was split into regions. Regions which were sampled simultaneously were grouped as shown (Table B.04). Within each region Pearson correlation analyses were run on the variable list given above. Analyses run on the Quincy region included the addition of Nut Island flow and effluent fecal coliform loading.

After the correlation analyses were run on the data for an entire region, the data were sorted and split by station. For each station Pearson correlation coefficients were calculated for raw and transformed fecal coliforms and *Enterococcus*, along with salinity, dissolved oxygen, and temperature against the variable list shown in section 5.0 above. Scattergrams were constructed of all significant correlations with log-transformed indicators in order to check that the correlations were not being driven by single outliers. The correlation analyses were run separately on surface and bottom samples.

g. Correlations by Station. Each year's data were split into regions. Within each region the data were further split by region and by depth sampled (Surface/Bottom). Pearson correlation analyses were then run on the bacterial indicator results from each station/depth against the results from every other station/depth sampled by date, in order to test how well the bacterial indicator levels at one station predicted the bacterial levels at another station.

h. Correlations with predicted CSO flows.

Pearson correlation analyses were run between the 1989 Inner Harbor surface indicator levels (both combined and split by station) and the Fort Point Channel summed model predictions. Pearson correlation analyses were run between the 1990 summed model predictions for Fort Point Channel and the surface and bottom indicator levels for just the 3 stations (75, 18, and 19) within or near to the Channel.

Indicator levels at Carson Beach stations, for both years, both pooled and split by station were analyzed using PEARSON CORR against summed CSO predictions for Dorchester Bay.

Correlation analyses were run for the 1989 data only for single and multiple-day Moon Island CSO predictions against indicator levels in Quincy Bay.

4. T-TESTS. T-Tests were run on portions of the 1989 and 1990 datasets to test for significant differences in parameter means. The SPSSX procedure TTEST was used for all such analyses.

a. Inner Harbor. 2 variables were used to split the Inner Harbor into groups for t-tests. The first set of t-tests were run between surface and bottom samples. A temporary variable was created whose value equalled "1" for all surface samples, "2" for all bottom samples. These t-tests were run for both bacterial indicators (log-transformed), dissolved oxygen, salinity, and temperature.

The tidal data were grouped into the summary variable CURRENT (Table B.05), which split the data into 2 groups, flood (incoming) and ebb (outgoing) tides. T-Tests were run separately on Inner Harbor surface and bottom indicator counts, dissolved oxygen, salinity, and temperature in order to test for differences due to an effect of the tide.

b. Charles River. Three sets of t-tests were run on the data from Charles River surface samples for both the 1989 and 1990 datasets. The data were split by station into 2 groups, one containing the stations in the wide Charles River basin (6-11), and the other containing the upper 6 stations from upstream of the Boston University Bridge to the Watertown Dam (Stations 1-5, 12). T-tests between the upstream and downstream groups these groups were run on the conductivity, temperature, and fecal coliform data from 1989, and for those variables plus the Enterococcus data from 1990.

The data for the 6 stations in the Charles River basin (6-11) in which both surface and bottom samples had been gathered were further split into groups by surface/bottom. T-tests were run on the fecal coliform, salinity, and temperature data.

5. Stepwise Multiple Regressions. We ran stepwise multiple regressions on log-transformed fecal coliform and Enterococcus counts for various portions of the data sets from each year. These regressions were Type II, in that we were not attempting to build predictive equations for use in further work, but rather were attempting to explain the variance in the bacterial indicator data based upon the other variables (Sokal and Rohlf, 1981). The regressions were run with the SPSSX procedure REGRESSION, using the STEPWISE subcommand. The analyses used the SPSSX default operating parameters (p to enter of 0.05, p to remove 0.10 (SPSS, 1986)).

Detailed analysis of residuals was carried out on the results of all regressions in which more than one significant predictor entered the equation. Scattergrams were constructed of the standardized residuals from each step versus the variable that entered the equation at the next step. The shape of the scattergram was scrutinized to ensure that the significant partial correlation coefficients were not being driven by single outliers (Draper and Smith, 1981).

In some of the multiple regressions two or more rainfall variables entered the equations as significant predictors of bacterial indicator levels. When 2 rain variables containing different information entered, (e.g. three-day summed rain and single-day rain 5 days before sampling) the results were accepted as potentially valid. If, as occasionally happened, the second rain predictor entered with a negative correlation with residual indicator counts the regression was terminated prior to the entry of the second predictor.

As mentioned in the correlation section the rainfall and sewage variables contained single values for each date, while the field monitoring data (e.g. salinity, DO, indicators) were measured at 10-20 stations per date. Because of this significance levels for these variables in the equations of greater than 0.005 were disregarded. In practice, the significance levels seen when sewage or rainfall variables entered the equations as primary predictors were nearly always less than 0.001.

Since we expected the various regions in the harbor to behave differently based on the results of the correlation analyses, the regressions were only run on the data from each region, not on the entire data set. Regressions were not run at the individual station level because at most stations the number of predictor variables exceeded the available degrees of freedom. In regions with both surface and bottom data for most stations, regressions were run separately on surface and bottom data.

Deer and Nut Island effluent coliforms and coliform loadings showed nonsignificant correlations with indicator counts measured, while Deer or Nut Island flows show very high correlations with indicators measured in the field. The treatment plant flows were included in regressions as a measure of system loading rather than as a direct influence on indicator levels themselves.

a. Inner Harbor. We ran two sets of multiple regressions on both the surface and the bottom indicator counts from the Inner Harbor 1989 monitoring. The variable list for the first is given in Table B.07. In the second set of regressions Deer Island flow, which was included only as an analog of system loading, was left out of the list of independent variables.

For the 1990 data the same variable lists were used, but the Inner Harbor was analyzed as 2 separate regions, the "Mystic Branch", which included all Mystic and Chelsea River estuarine stations inland of the Mystic/Charles confluence, the "Charles Branch" , from the confluence to station 44, including stations 11 & 14 in the Charles River (Table B.04).

b. Dorchester Bay/Neponset River. Since bottom samples were only consistently taken at three stations in this area (30, 43, & 44) in 1989, stepwise multiple regressions for that year were only run on the surface data. As with the Inner Harbor regressions, Dorchester Bay/Neponset River regressions were run both with and without Deer Island Flow in the variable list. After the analyses of both regions together, the regressions were repeated on Dorchester Bay and the Neponset River separately.

In 1990 we sampled the Dorchester Bay and Neponset River separately, although there was some station overlap between the 2 regions. We also took surface and bottom samples at a larger number of stations in 1990 than in 1989. Because of this, 1990 data from the 2 regions were not pooled for the multiple regressions, and multiple regressions were run on both surface and on bottom data.

c. Charles River. Since Enterococcus samples were not gathered in the Charles River in 1989, log-transformed fecal coliforms were the only dependent variables in the Charles River multiple regressions for that year. The regressions were run separately on surface and bottom samples. Since salinities in the surface samples were essentially zero, conductivity was used in its place as an independent variable in regressions on surface samples. Salinity was used as a potential predictor variable in regressions on the bottom samples.

We ran similar multiple regressions on the data from the 1990 sampling in the Charles River, with the addition of log-transformed Enterococcus counts as a dependent variable.

d. Mystic River/Alewife Brook. The regressions were run on log-transformed fecal coliforms and Enterococcus data from each year with the same variable list as that used on the Charles River surface samples, i.e. conductivity in place of salinity in the variable list. The limited data from the Alewife brook was not analyzed separately from that in the Mystic.

e. Quincy Bay. We ran multiple regressions on Quincy Bay data in three regressions per indicator for each year's data. The first set included Deer Island flow in the independent variable list. The second included Nut Island flow in the independent variable list. The third regression per indicator excluded treatment plant flow from the independent variable list.

4. References

American Society for Quality Control, 1981. American National Standard Sampling Procedures and Tables for Sampling by Attributes. ANSI/ASQC Z1.4 - 1981. In 1990 Annual Book of ASTM Standards, American Society of Testing and Materials. Vol. 14.02, pp. 1102-1110.

Draper, N. R. and H. Smith, 1981. Applied Regression Analysis, Second Edition. John Wiley & Sons, New York. pp. 141-191.

Sokal, R.R. and F. J. Rohlf, 1981. Biometry Second Edition. W. H. Freeman & Co. New York.

SPSS, 1986. SPSSX User's Guide, Second Edition. McGraw-Hill Book Co. New York.

Table B.01 **Parameters gathered during MWRA 1989 CSO Receiving Water Monitoring.**

Variable	Description
STATION:	Station numbers used in the field monitoring. For full description of station locations, see Table 2.01.
SAMNUMBER:	Sample number.
SAMDATE:	Date sample was taken.
SAMTIME:	Time of day sample was taken, in 24 hour military time.
TIDE:	Coded variable giving the state of the tide at the time samples were taken. The codes are as follows: 1: Slack high tide 2: High water, ebb tide 3: Low water, ebb tide 4: Low slack water 5: Low water, flood tide 6: High water, flood tide. 9: Sample taken in a freshwater system (e.g. the Charles River) above the influence of the tides.
DEPTH	Water depth in feet when sample taken.
DEPTHSAM	Water depth in feet at which sample was taken.
TEMP	Water temperature in degrees Celsius.
DO	Dissolved Oxygen in mg/l.
CONDUCT	Conductivity in micromhos.
SALINITY	Salinity in parts per thousand.
MF1	mFC fecal coliform counts for first of 2 laboratory duplicate filtrations, in colonies per 100 mls.
MF2	mFC fecal coliform counts for duplicate filtrations.

Table B.01, Parameters(cont.)

Variable	Description
MFAV	Arithmetic average of the duplicate filtrations for fecal coliform by mFC, in colonies/100 mls.
ME1	mENT Enterococcus counts for the first of 2 duplicate filtrations, in colonies/100 mls.
ME2	mENT Enterococcus counts for duplicate filtration.
MEAV	Arithmetic average of the mENT Enterococcus filtrations, in colonies per 100 mls.

Table B.02 Rainfall and Sewage Variables used in the Analyses.

Variable	Description and source	Dates Used
LORN	Daily Rainfall measured at Logan Airport, Inches. Measured by National Weather Service.	1 June 1989 - 31 Oct. 1990
CARN	Daily Rainfall at 147 Hampshire Street, Cambridge. Measured by Cambridge DPW	1 June - September 31 1989.
DIFLOW	Daily flow through Deer Island POTW, in MGD. All POTW variables are from treatment plant logs.	1 June 1989 - 31 Oct. 1990
DIEFF	Daily effluent fecal coliforms per 100 mls from Deer Island POTW.	1 June 1989 - 31 Oct. 1990
NUTFLOW	Daily flow through Nut Island POTW, MGD	1 July -31 Aug. '89 & '90
NUTEFF	Effluent Fecal Coliform concentrations from Nut Island POTW	1 July -31 Aug. '89 & '90
CAFLOW	MGD Discharge from Moon Island CSO (BOS-125) from Boston Water and Sewer Commision records.	1 June -31 Oct. 1989
COFAFL(MGD)	Discharge from Cottage Farm CSO (MWR-201) screening and disinfection facility. From facility logs.	1 June -31 Oct. 1989
COFAEFF	Effluent fecal coliforms from Cottage Farm	1 June -31 Oct. 1989
PPFLOW	MGD Discharge from Prison Point CSO facility (MWR-203).	1 June -31 Oct. 1989
PPEFF	Effluent fecal coliform from Prison Point.	1 June -31 Oct. 1989

Variable	Description and source	Dates Used
SOMAFL	MGD Discharge from Somerville Marginal CSO Facility (MWR-205).	1 June - 31 Sep. 1989
SOMAEFF	Effluent fecal coliform from Somerville Marginal CSO Facility.	1 June - 31 Sep. 1989

Table B.03 **Boston Water and Sewer Commision CSOs with predicted flows used in Data Analyses**

Region	CSO NPDES permit numbers
Inner Harbor, Fort Point Channel	BOS-062; BOS-064; BOS-065; BOS-068; BOS-070; BOS-070; BOS-073.
Dorchester Bay	BOS-081 - BOS-090.
Quincy Bay	BOS-125.

Table B.04 Regions used in the Analysis of Monitoring Program Data.

1989 Region[1]	Stations
Alewife Brook	70 - 74
Mystic River	56 - 61, 66 - 68
Charles River	1-12
Dorchester Bay	28-41, 43[2], 44[2,3]
Neponset River	42, 53 - 55
Inner Harbor	13-24, 26, 27, 52, 65, 69
Quincy Bay	44[2,3], 45-49
Calf Island	50[2]

1 Regions not separated by a blank line were analyzed together.
2 Analyses in this region were carried out both with and without this station's data.
3 Station 44 data were included in analyses for both Dorchester Bay and Quincy Bay.

Table B.04 continued Regions used in the Analysis

1990 Region[1]	Stations, Date Ranges
Alewife Brook	70, 74
Mystic River	56, 57, 59, 60, 67, 83, 15 - 31 August 1990
Charles River	1-12, 14[1] 9 - 31 July 1990
Dorchester Bay	19, 21, 24, 44, 28, 30, 35 - 38 12 June - 5 July 1990 35 - 38 All Dates
Inner Harbor "Charles Branch"	11[1], 14, 15, 17 - 19, 19.1, 21, 22, 24, 63, 75 12 June - 5 July 1990
Inner Harbor "Mystic Branch"	15, 16, 26, 27, 52, 69 15 - 31 August 1990
Neponset River	38 - 42, 44, 53 - 55, 84 4 - June, 4 - 19 September 1990
Quincy Bay	44, 47 - 49, 76 - 82 2 - 14 August 1990

1 These stations were left out of multiple regression analyses.

Table B.05 Supplemental Rainfall and Sewage Variables used in the Analyses

Rainfall Variables[1]

Additive Rainfall Variables LORNP2 - LORNP6 (Logan)
CARNP2 - CARNP6 (Cambridge)

Formula: RAINPx = RAIN1 + RAIN2 ...+ RAINx

Exponential Decay Variables LORNE2 - LORNE4

Formula: RAINEx = RAIN1 + ($RAIN2*e^{-2}$) ... + ($RAINx*e^{-x}$)

Delayed Single Day Variables LORNM1 - LORNM6

Formula: RAINMx = RAINx

Sewage Variables	**Description**
DILOAD	Deer Island Fecal Coliform Loading
NUTLOAD	Nut Island Load
COFALO	Cottage Farm Load
PPLOAD	Prison Point Load
SOMALO	Somerville Marginal Load

Formula: LOAD (Fecal coliforms/Day) = Flow (MGD) * 10^6 * 3.785 L/G * 10(100ml/L) * Effluent(Fecal coliforms/100ml)

1 "RAIN" subtsitutes in the formulae for "LORN" or "CARN".
RAIN1 = rain on that date, RAIN2 = Rain day before, ... RAIN6 = rain 5 days before.

Table B.06 Sample SPSSX Command File

Line #	Command
1	SET WIDTH 80
2	GET FILE = 'CSODATA3.SYS'
3	SELECT IF(REGION EQ 'INNERH')
4	SELECT IF(DPTHSAM EQ 0)
5	SORT CASES BY STATION
6	TITLE 'Correlations, Salinity vs Fecal Coliforms and Enterococcus'
7	SUBTITLE 'Whole Inner Harbor'
8	PEARSON CORR SALIN WITH LGFC LGME
9	SPLIT FILE BY STATION
10	SIBTITLE 'Inner Harbor Split by STATION'
11	PEARSON CORR SALIN WITH LGFC LGME

Table B.07 **Variables included in the Multiple Regressions**

Variable	
	Dependent
	Log-transformed fecal coliforms
	Log-Transformed Enterococcus
	Predictor
	Deer Island Flow, MGD
	Nut Island Flow, MGD[1]
	Salinity
	Conductivity[2]
	Water Temperature
	Logan Airport rainfall
	2-6 day additive rainfall
	2-4 day additive rain, exponential model
	2-6 day single-day rainfall

1 Nut Island flow was only used as a predictor in regressions on Quincy Bay data.
2 Conductivity was used instead of salinity multiple regressions on data from freshwater rivers.

Figure B.01 SPSSX Output from Sample Command File shown in Table B.06

```
3-Jul-90  SPSS-X RELEASE 3.1 FOR VAX/VMS      Page  1

   1 0 SET WIDTH 80
   2 GET FILE = 'CSODATA3.SYS'
File DUB3:[HARBOR_STUDIES1.SPSS]CSODATA3.SYS;
     Created:   9-APR-90 16:45:36 - 71 variables

   3 SELECT IF(REGION EQ 'INNERH')
   4 SELECT IF(DPTHSAM EQ 0)
   5 SORT CASES BY STATION
SIZE OF FILE TO BE SORTED:    216 CASES OF   568 BYTES EACH.
SORT COMPLETED SUCCESSFULLY. FILE SIZE:     240 BLOCKS.
Preceding task required 2.44 seconds CPU time; 4.48 seconds elapsed.

   6 TITLE 'Correlations, Salinity vs Fecal Coliforms and Enterococcus'
   7 SUBTITLE 'Whole Inner Harbor'
   8 PEARSON CORR SALIN WITH LGFC LGME
PEARSON CORR problem requires 144 bytes of workspace.

3-Jul-90 Correlations, Salinity vs Fecal Coliforms and Enterococcus    Page  2
 11:54:40  Whole Inner Harbor

PEARSON CORRELATION COEFFICIENTS
       LGFC     LGME
SALIN      -.5580     -.4439
         ( 199)    ( 199)
         P= .000   P= .000

(COEFFICIENT / (CASES) / 1-TAILED SIG)

" . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
3-Jul-90 Correlations, Salinity vs Fecal Coliforms and Enterococcus    Page  3
 11:54:40  Whole Inner Harbor

0Preceding task required .38 seconds CPU time; .75 seconds elapsed.

   9 SPLIT FILE BY STATION
  10 SUBTITLE 'Inner Harbor Split by STATION'
  11 PEARSON CORR SALIN WITH LGFC LGME
PEARSON CORR problem requires 144 bytes of workspace.
3-Jul-90 Correlations, Salinity vs Fecal Coliforms and Enterococcus    Page  4
```

11:54:40 Inner Harbor Split by STATION

PEARSON CORRELATION COEFFICIENTS

STATION: 13

	LGFC	LGME
SALIN	-.2093	-.2256
	(14)	(14)
	P= .236	P= .219

STATION: 14

	LGFC	LGME
SALIN	-.4072	-.0680
	(14)	(14)
	P= .074	P= .409

2 Pages of output truncated

The Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Charlestown, MA 02129
(617) 242-6000