Report to EPA:
Results of intensive monitoring at Boston Harbor Beaches, 1996 – 2000

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RESULTS OF INTENSIVE MONITORING AT BOSTON HARBOR BEACHES, 1996 - 2000

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EXECUTIVE SUMMARY

This report summarizes the results of five years of water quality monitoring at four Boston Harbor beaches: Constitution Beach in East Boston, Carson Beach in South Boston, Tenean Beach in Dorchester and Wollaston Beach in Quincy. The study was jointly conducted by the Metropolitan District Commission (MDC) and the Massachusetts Water Resources Authority (MWRA). There were two goals of the study: (1) to characterize bacterial water quality at each beach, and (2) to learn how rainfall affected water quality in order to determine if swimming advisories could be posted based on rainfall. Water samples were collected daily during the swimming season (late June through early September of each year) and analyzed for counts of two sewage indicator bacteria: fecal coliform and *Enterococcus*. Rainfall measurements were made at rain gauges located near each beach. Bacterial results from the previous day were used to make decisions for whether a beach should be posted with a swimming advisory, and the program also provided daily water quality updates to the public on MDC's website.

Summary of beach water quality

All beaches met USEPA criterion of a geometric mean less than 35 colonies/100 mL, and met the Massachusetts state criterion for SB (fishable, swimmable) waters of a geometric mean less than 200 colonies/100 mL fecal coliform. However, two beaches failed to meet the second Massachusetts criterion: at Tenean and Wollaston beaches, more than 10% of samples exceeded the fecal coliform limit of 400 colonies per 100 mL. In addition, during wet weather, Tenean and Wollaston frequently exceeded limits set by MDC for posting swimming advisories.

The severity and frequency of bacterial pollution varied among beaches, and none of the beaches was suitable for swimming at all times. Carson was the cleanest beach, with 89% of samples meeting both MDC swimming guidelines; 81% of samples at Constitution Beach met swimming guidelines; Tenean Beach and Wollaston Beach samples met swimming guidelines 69% of the time. The percent of samples meeting each of the indicators is shown in Table ES-1.

Table ES-1. Percent of samples meeting MDC swimming criteria at Boston Harbor beaches 1996-2000

Beach	Fecal coliform[1] (%)	*Enterococcus*[2] (%)
Constitution	85	90
Carson	92	93
Tenean	72	87
Wollaston	71	85

[1]Fecal coliform < 200 col/100 mL
[2]*Enterococcus* <104 col/100 mL

Only two beaches showed notable changes in water quality across the five years of the monitoring program: Wollaston beach showed improving water quality from 1997 through 1999, but a decline in 2000. Tenean Beach demonstrated significantly poorer water quality in 1998 compared with other years.

No significant difference in water quality was found among the different sampling locations along each beach, with one exception: the Rice Road location on Wollaston Beach had significantly better water quality than the other three sampling locations along the beach; Rice Road samples met both MDC guidelines 81% of the time.

Relationship of bacteria with rainfall

Elevated bacteria counts at a beach are expected in wet weather, since rainfall results in stormwater runoff and discharge from combined sewer overflow pipes—sources that are known to be contaminated with human and/or animal waste. Water quality at all four beaches was significantly worse in wet weather. However, the relationship of rainfall and water quality somewhat weak, as there was a high degree of variation in water quality in all weather conditions, with elevated bacteria counts in dry weather, and low counts in wet weather. Table ES-2 summarizes the percent of samples at each beach that exceeded MDC's beach posting criteria for three different weather conditions: dry, damp, and wet.

Table ES-2. Percent of samples failing to meet water quality standards in dry, damp, and wet weather at Boston Harbor beaches for fecal coliform and *Enterococcus*

Beach	Percent of samples exceeding limit (number of samples)							
	Fecal Coliform				*Enterococcus*			
	Dry	Damp	Wet	Total	Dry	Damp	Wet	Total
Constitution	10% (470)	14% (422)	35% (134)	15% (1026)	3% (461)	8% (417)	32% (134)	9% (1012)
Carson	2% (463)	10% (418)	30% (134)	9% (1015)	3% (457)	5% (4140)	16% (134)	6% (1005)
Tenean	18% (389)	22% (377)	58% (124)	29% (890)	5% (389)	7% (373)	27% (122)	11% (884)
Wollaston	17% (630)	33% (577)	39% (187)	29% (1394)	6% (621)	13% (573)	26% (187)	14% (1381)

Dry = no rainfall within 48 hours prior to sample collection. Wet = rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories.

A counterintuitive result of the study was that the type and number of wet weather contamination sources at the beaches were not always related to beach water quality. Carson Beach, affected by more untreated CSOs than any other beach in the study, had the best water quality; Tenean Beach, impacted by stormwater, the Neponset River, and treated CSO flow, had poor water quality. The beach with the most storm drains, Wollaston, matched Tenean Beach for the worst water quality. Wollaston Beach, with the most storm drains of any beach in the study, matched Tenean Beach for the worst water quality. Constitution Beach, affected by stormwater and treated CSO flows, was relatively clean, and did not show a significant change after the nearby CSO facility was decommissioned. Dry weather contamination affected all beaches, but was worst at Tenean and Wollaston.

Nevertheless, water quality at all beaches was significantly worse in wet weather. An analysis of the relationship between antecedent 24-hour rainfall and patterns of bacteria levels did find, on average, a threshold of antecedent rainfall at which geometric mean bacteria counts at each beach exceeded the geometric

mean swimming standards. These rainfall thresholds were the same for both fecal coliform and for *Enterococcus*. (Because these are geometric mean values, the thresholds do not correspond precisely to the "single sample maximum" that MDC uses for posting based on individual bacterial counts.) Suggested guidelines appear in Table ES-3, if beach managers choose to use rainfall for precautionary beach postings.

Table ES-3. Recommended rainfall thresholds to trigger precautionary beach postings, using 24-hour antecedent rain

Beach	Antecedent 24-hour rain (inches)
Constitution	0.4 inches
Carson	0.6 inches
Tenean	0.2 inches
Wollaston	0.2 inches

1 Introduction

Many beaches in the Boston Harbor are located in or near urban and/or dense residential areas directly impacted by combined sewer overflows (CSOs) and contaminated storm drains. Ongoing efforts by nearby CSO communities and by the Massachusetts Water Resources Authority (MWRA) are planned to eliminate most untreated CSO discharges by 2008, and strategies to address stormwater contamination are being developed by harbor communities. In the meantime, however, stormwater and CSO overflows remain a significant source of contamination to Harbor beaches during and after rainfall events, and result in the posting of swimming advisories.

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Historically, managers of Boston Harbor beaches have used microbiological culture results from samples collected once or twice per week to determine whether or not a beach should be "posted"—an alert to swimmers of poor water quality—if bacterial results exceed certain guidelines. The limitation of this approach is that data are not available until the day following sample collection, and water quality may have changed significantly in the interim due to changing environmental conditions. As a result, water quality remains very difficult to predict in advance.

To improve understanding of the factors that influence beach water quality and to assist beach managers in deciding whether or not to post a beach, intensive daily monitoring was initiated in 1996 at several Harbor beaches owned by the Metropolitan District Commission (MDC). Sampling began in 1996 at Constitution, Carson, and Wollaston Beaches; Tenean Beach was added to the study in 1997.

This report provides a comprehensive overview of beach water quality from the 1996 – 2000 monitoring seasons, with particular attention given to rainfall effects. The report will describe bacterial water quality (fecal coliform and *Enterococcus*) at MDC harbor beaches, compare the data to swimming standards, and analyze the relationships between rainfall and bacterial water quality.

2 Materials and Methods

2.1 Field and Laboratory methods

2.1.1 Sampling Locations

Sampling was conducted at four Boston Harbor beaches, with a total of thirteen locations. Figure 2-1 shows the sampling sites: Constitution Beach in East Boston (three locations), Carson Beach in South Boston (three locations), Tenean Beach in Dorchester (three locations) and Wollaston Beach in Quincy (four locations).

Table 2-1. Sampling locations

MDC Beach and Location	MWRA Location Code
Constitution Beach North	MDC16
Constitution Bathhouse	MDC17
Constitution South	MDC18
Carson Beach at M Street	MDC21
Carson Beach at I Street	MDC22
Carson Beach at McCormack Bathhouse	MDC23
Tenean Beach North	MDC26
Tenean Beach Middle	MDC27
Tenean Beach South	MDC28
Wollaston Beach at Milton Street	MDC29
Wollaston Beach at Channing Street	MDC31
Wollaston Beach at Sachem Street	MDC30
Wollaston Beach at Rice Road	MDC32

2.1.2 Sample collection

200 mL seawater samples were collected at all 13 locations along the four beaches between mid-June and early September of each year, at least six days per week[1]. Tenean Beach was sampled only two days per week prior to 1997. At several locations, mud flats exposed at low tide made sampling difficult, so an attempt was made to collect samples within three hours of high tide, but some samples were occasionally collected at lower stages of the tide. *In situ* temperature and salinity measurements were made at each location prior to sample collection.

Water was collected in sterile sample bottles by wading out to a depth of 1 m, with the person collecting the sample standing down current of the sample collection point. Samples were collected 0.3 m below the surface and stored immediately on icepacks in a cooler. Samples were brought to the laboratory and processed within 6 hours of collection.

[1] MWRA analyzed samples five days per week at its Central Laboratory facility. MDC, through a consultant contract, analyzed samples one or two days per week. MDC would analyze samples on the second day only if fecal coliform counts from the first day exceeded the swimming standard.

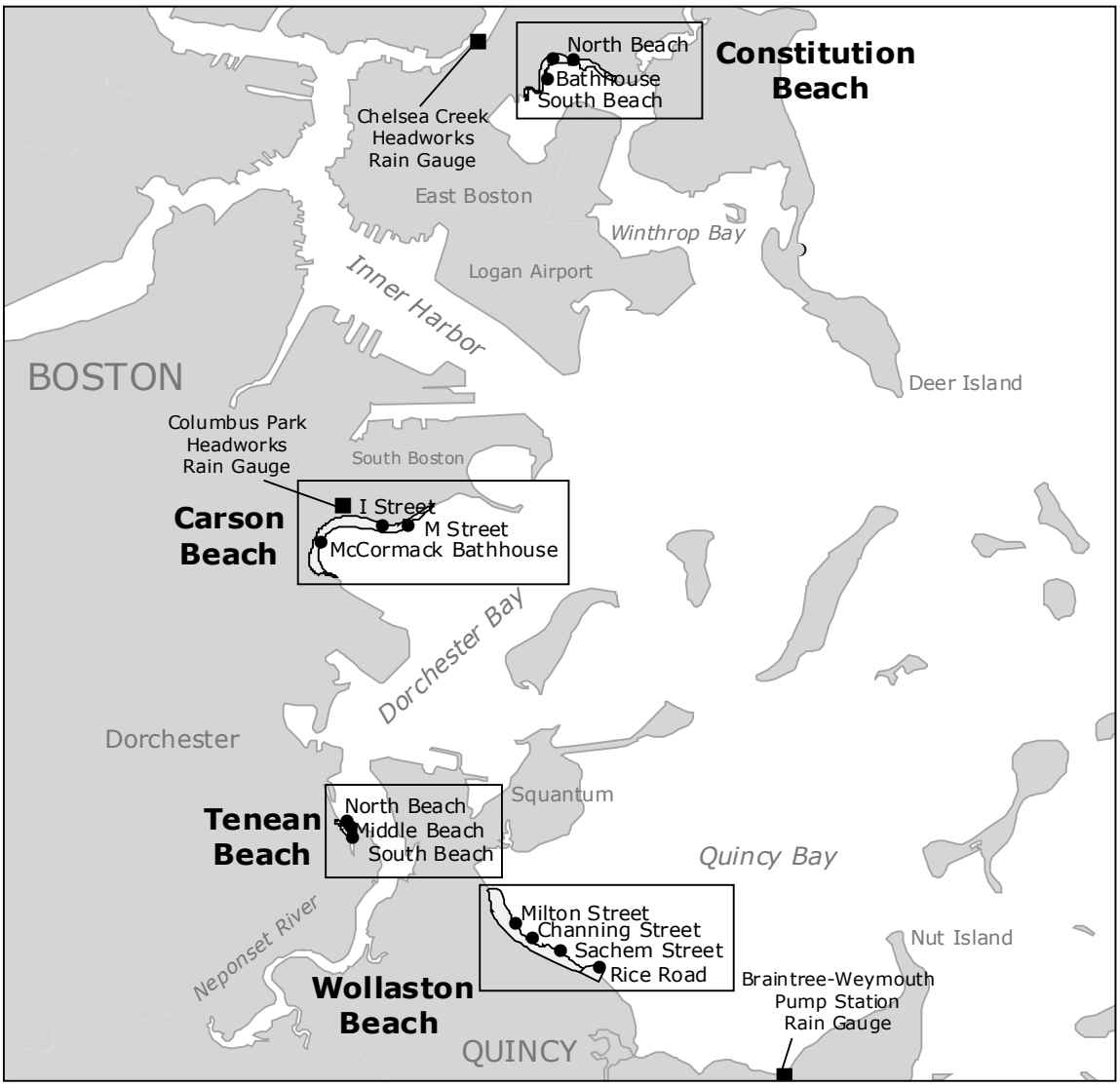

Figure 2-1. Beach monitoring locations

2.1.3 Parameters measured

Table 2-2 lists the variables measured as part of the monitoring program.

Table 2-2. Variables measured

Variable	Method
Water temperature	*in situ,* mercury thermometer
Salinity	Yellow Springs Instruments, model 58 (1996–1998, MWRA) YSI model 55 (1999–2000, MWRA) Horiba U-10 Water Checker (1996–2000, MDC)
Fecal coliform	Standard Methods 9222D, membrane filtration
Enterococcus	Standard Methods 9230C 2c, membrane filtration (for samples collected 1996 – 1998) USEPA Method 1600 (for samples collected 1999–2000)
Rainfall	MWRA rain gauges located at Columbus Park Headworks, Chelsea Creek Headworks, and Braintree-Weymouth Pump Station

Field measurements. Temperature and salinity were measured in the field, and the instruments used are shown in Table 2-2. For each bacteria sample, the time of collection was recorded, as were other field observations including presence of algae, sewage-related floatables, wildlife, and the number of swimmers.

Laboratory analyses. Samples were analyzed either at the MWRA Central Laboratory or at MDC's contract laboratory (G&L Laboratory, Inc.). For enumeration of bacteria, MWRA Central Laboratory Standard Operating Procedures were followed for MWRA analyzed samples, and G&L Standard Operating Procedures were followed for MDC analyzed samples. Both laboratories used the same methods[2]. To enumerate fecal coliform, an aliquot of sample is filtered through a sterile membrane filter, and the filter is placed on mFC agar and incubated at 44.5ºC for 24h. Following incubation, blue colonies are counted as fecal coliform. For enterococci, an aliquot of sample is filtered through a sterile membrane. The filter is placed on m*Enterococcus* agar and incubated at 35ºC for 48 h, or placed on mEI agar and incubated for 24 h, depending on the method used. Red colonies are counted as enterococci on m*Enterococcus* agar, blue colonies on mEI agar.

Rainfall Measurements. Rainfall measurements were taken at three MWRA rain gauge locations, shown in Table 2-3. Rainfall data were taken from MWRA rain gauges located nearest to each beach. The gauges record rainfall volume at 15-minute intervals. Data are downloaded from the gauges and stored in MWRA's EM&MS database.

[2] In 1999, both laboratories began using USEPA Method 1600 for *Enterococcus* enumeration, which allows results to be available within 24 hours of sample collection.

Table 2-3. MWRA rain gauge locations

MDC Beach	MWRA Rain Gauge
Constitution Beach, East Boston	Chelsea Creek Pumping Station, Chelsea
Carson Beach, South Boston	Columbus Park Headworks, South Boston
Tenean Beach, Dorchester	Columbus Park Headworks, South Boston
Wollaston Beach, Quincy	Braintree-Weymouth Pump Station, Braintree

Several rainfall variables were evaluated in this report, as shown in Table 2-4: 1-day, 2-day, and 3-day summed rain; and cumulative rainfall 48 hours, 24 hours, 12 hours, 6 hours and 3 hours prior to sample collection. The difference between the daily-summed and hourly-summed rainfall measures is the method used to calculate rainfall totals. Daily summed rainfall is the total rainfall from midnight to midnight of each day, whereas hourly summed rain is calculated back from the sample collection time. For example, if a sample were collected at 9:00 AM, a 1-day rain value would measure rainfall from 12:00 AM of the day the sample was collected until 12:00 AM of the following day. This period includes 15 hours when rain could fall *after* the sample was collected, weakening any potential relationship between rain and bacteria counts. The 24-hour antecedent rain value would be the total amount of rain falling between 9:00 AM of the previous day through to the sample collection time (9:00 AM).

Table 2-4. Rainfall variables used in this report

Variable	Description
1-day summed rain	Total rain falling from midnight of the sampling day to midnight of the following day*
2-day summed rain	Total rain falling from midnight of *day before* sampling day to midnight of *day following* sampling day
3-day summed rain	Total rain falling from midnight *two days before* sampling day to midnight of *day following* sampling day.
3-hour antecedent rain	Total rainfall during the 3 hours prior to sample collection
6-hour antecedent rain	Total rainfall during the 6 hours prior to sample collection
12-hour antecedent rain	Total rainfall during the 12 hours prior to sample collection
24-hour antecedent rain	Total rainfall during the 24 hours prior to sample collection
48-hour antecedent rain	Total rainfall during the 48 hours prior to sample collection

* Conventional one-day rainfall total used by the National Weather Service; this value includes approx. 15 hours *after* sample was collected during which time rain could fall, compromising any relationship between rain and sample results.

In an effort to simplify the relationship between rainfall and bacteria counts, rainfall was also grouped into three categories: dry, damp, and wet. Wet was defined as 48-hour antecedent rainfall greater than or equal to 0.2 inches. This value has been correlated with the activation of MWRA CSOs (see Appendix). Dry weather was defined as 48-hour antecedent rainfall equal to zero; i.e. no rain fell for at least 48 hours preceding sample collection. Damp weather fell between these two categories.

Sampling periods. Because the monitoring program included additional monitoring for some beaches and not others in the early years of the project, not all data collected during the monitoring program are included in this report. For consistency, data included in this report began with the first day of each summer that all beaches were sampled, and ended with the last day that all beaches were sampled. Dates are shown in Table 2-5.

Table 2-5. Sampling dates included in this report

Monitoring Year	Date range
1996	June 12 through September 1
1997	June 18 through August 31
1998	June 10 through September 6
1999	June 24 through September 5
2000	June 22 through September 3

Data Storage. Data are stored in the MWRA Laboratory Information Management System Database and the MWRA Environmental Quality Department Environmental Modeling and Mapping System (EM&MS) Oracle® Database.

2.2 Data analysis

One goal of this analysis was to describe bacterial water quality (fecal coliform and *Enterococcus*) at MDC harbor beaches, and to relate these data to USEPA recommended guidelines, to Massachusetts water quality standards, and to the guidelines used by the MDC to post swimming advisories. A second goal was to explore the relationships between sewage indicator bacteria and rainfall, which ultimately would improve beach managers' ability to anticipate water quality.

2.2.1 Descriptive Analysis

Environmental sewage indicator bacteria counts are typically log-normally distributed, and therefore a proper measure of central tendency for this data is the geometric mean. Geometric means were calculated for the measurements made at each station over the sampling period. Another descriptive tool for fecal coliform and *Enterococcus* counts is a percentile plot, as shown in Figure 2-2.

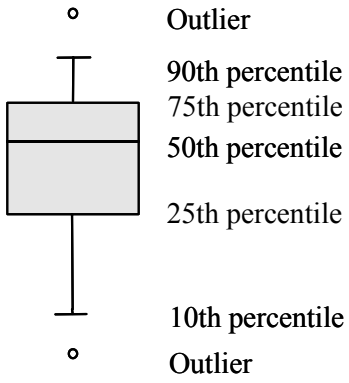

Figure 2-2. Percentile distributions indicated on percentile plots

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

The plots display the range and central tendencies of the data to be seen and allow for easy comparison of the results among stations and beaches. Since some of the State standards are written in terms of percentiles, these plots are particularly appropriate (see Section 2.3 for a description of these guidelines). All data are displayed on a logarithmic scale.

Fecal coliform and *Enterococcus* bacteria counts which fell at the detection limits (generally <5 and <10 colonies/100 mL, respectively) were assigned a value of 1 prior to analysis. (Raw data appear in the Appendix).

2.2.3 Statistical Analyses

The association between indicator counts and rainfall was evaluated using a variety of measures. Effects of rainfall condition (damp or wet weather) on beach contamination were examined by comparing counts failing to meet MDC guidelines among rainfall groups with a χ^2 test for a 2x2 contingency table. Log-transformed *Enterococcus* and fecal coliform were evaluated for spatial and temporal differences within each beach using an analysis of variance (ANOVA) with post hoc analysis performed by Fisher's protected least significant difference test for multiple comparisons. Linear regression models were constructed with log-transformed indicator counts as the dependent variable and each of the following as the independent variable: 1-day, 2-day, and 3-day summed rain; 48-hour, 24-hour, 12-hour, 6-hour and 3-hour antecedent rainfall.

Graphic and statistical analyses were performed using Excel (Microsoft Corp., Redmond, WA) and Statview (SAS, Inc., Cary, NC). Figures were generated using Statview and PowerPoint (Microsoft Corp., Redmond, WA).

2.3 Beach water quality criteria used in this report

Two bacterial pollution indicators are monitored at MDC beaches: fecal coliform and *Enterococcus* (Table 2-6). Massachusetts Department of Environmental Protection standards for Class SB waters (swimmable/fishable) are based on fecal coliform counts, while the USEPA recommends using *Enterococcus* in marine waters (USEPA 1986). The Massachusetts Department of Public Health has issued regulations for beach management based on USEPA criteria. Fecal coliform has been used for decades as an indicator of human waste and is a reasonably good indicator of the risk to human health from bacterial diseases like typhoid fever and shigellosis. *Enterococcus* is also found in human waste, although in lower numbers than fecal coliform. *Enterococcus* is much slower to die off in salt water than fecal coliform, and in some epidemiological studies has been found to be more closely correlated with the risk of acquiring gastroenteritis after swimming (Cabelli 1981). Because *Enterococcus* can survive for prolonged periods in salt water, it is thought to mimic the behavior of some viruses, which can persist in the marine environment.

Table 2-6. Bacterial water quality criteria for bathing beaches

Source of Guideline or Standard	Indicator organism	
	Fecal Coliform	***Enterococcus***
MDC: guideline for determining a swimming advisory (exceeding either standard will prompt an advisory, for all beaches except Wollaston, more than one site must exceed for the beach to be posted)	Single sample cannot exceed 200 colonies/100 mL	Single sample cannot exceed 104 colonies/100 mL
Massachusetts: surface water quality standard for Class SB waters (for marine waters designated for primary and secondary contact recreation)	Geometric mean cannot exceed 200 colonies/100 mL; no more than 10% of samples can exceed 400 colonies/100 mL[1]	Not used [1]
USEPA: guidelines for designated bathing beach, marine water (Ambient Water Quality Criteria for Bacteria (1986))	Not used	30-day geometric mean cannot exceed 35 colonies/100 mL; no single sample can exceed the upper 75% confidence limit for a Designated Beach Area[2]

[1]USEPA guidelines of *Enterococcus* single sample maximum of 104 and a 5-day geometric mean of 35 were adopted by the MDC and the Massachusetts Dept. of Public Health in 2001; fecal coliform was eliminated as a standard. However, fecal coliform is still used as an indicator of water quality for marine waters by the Massachusetts Dept. of Environmental Protection for water quality classification.
[2]USEPA recommends a single sample limit of 104 colonies per 100 mL if inadequate data are available to calculate the 75% confidence limit by the method specified in USEPA's *Ambient Water Quality Criteria for Bacteria* (1986).

3 Results

3.1 Overview of Four Harbor Beaches

3.1.1 Bacterial water quality

Between 1996 and 2000 more than 4,300 samples were analyzed for fecal coliform and *Enterococcus* at Constitution, Carson, Tenean and Wollaston beaches. The numbers of samples failing to meet either the state swimming standard or USEPA guidelines varied widely among beaches, among individual locations along each beach, and across years. Figure 3-1 shows the percent of samples that met swimming guidelines for each monitoring season since 1996.

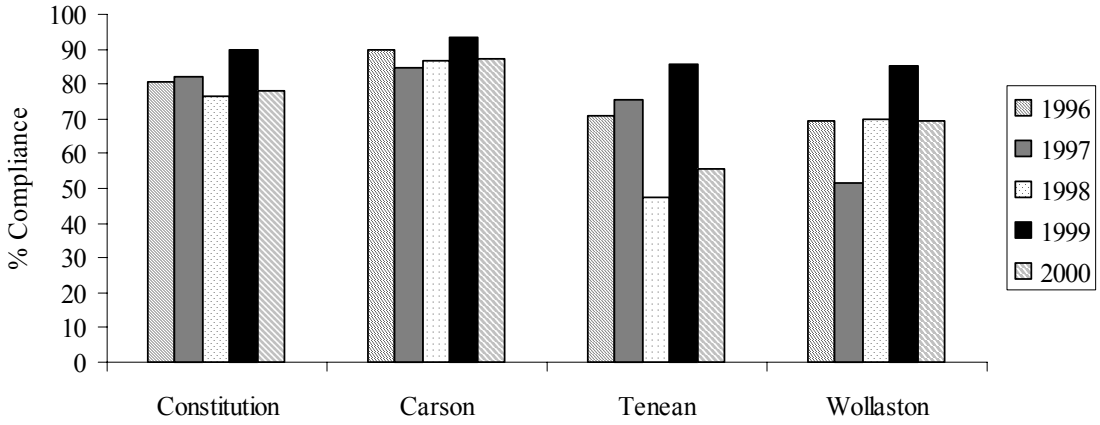

Figure 3-1. Compliance with MDC swimming advisory guidelines, temporal trends

Shown are annual percentages of all samples collected with counts that met both the MDC fecal coliform limit of 200 colonies/100 mL and the MDC *Enterococcus* limit of 104 colonies/100 mL.

None of the beaches met MDC guidelines 100 percent of the time. The percent of samples at each sampling location meeting the MDC guidelines are summarized in Table 3-1. Combining data for all years, Carson Beach had the best water quality, with 92% of samples meeting the standard, followed by Constitution Beach at 85%. Wollaston Beach had the poorest water quality, with 71% of all samples meeting the guideline. Tenean Beach was also poor, at 72%.

Generally beaches met the *Enterococcus* guideline more frequently than fecal coliform, and *Enterococcus* counts were often below detection. Figure 3-2 illustrates the difference between indicators for each beach. *Enterococcus* appears less conservative than fecal coliform. While the number of *Enterococcus* violations were generally similar to the number of fecal coliform violations at Carson Beach (93% of samples met the *Enterococcus* guideline, and 92% of samples meeting the fecal coliform standard for all years), there were fewer *Enterococcus* violations than fecal coliform violations at the remaining beaches with poorer water quality. Combining data from all years, each of these beaches failed to meet the fecal coliform standard about twice as often as they failed the *Enterococcus* guideline.

Table 3-1. Percent compliance with MDC swimming guidelines, 1996-2000

Beach	Fecal coliform[1] 1996-2000 %	*Enterococcus*[2] 1996-2000 %
Constitution		
All sites	85	90
North Beach	86	88
Bathhouse	84	90
South Beach	86	91
Carson		
All sites	92	93
M Street	94	95
I Street	90	92
McCormack Bathhouse	91	93
Tenean		
All sites	72	87
North Beach	75	89
Middle Beach	72	88
South Beach	70	85
Wollaston		
All sites	71	85
Milton Street	70	84
Channing Street	65	83
Sachem Street	66	83
Rice Road	85	91

[1]Fecal coliform > 200 col/100 ml, [2]*Enterococcus* >104 col/100 mL

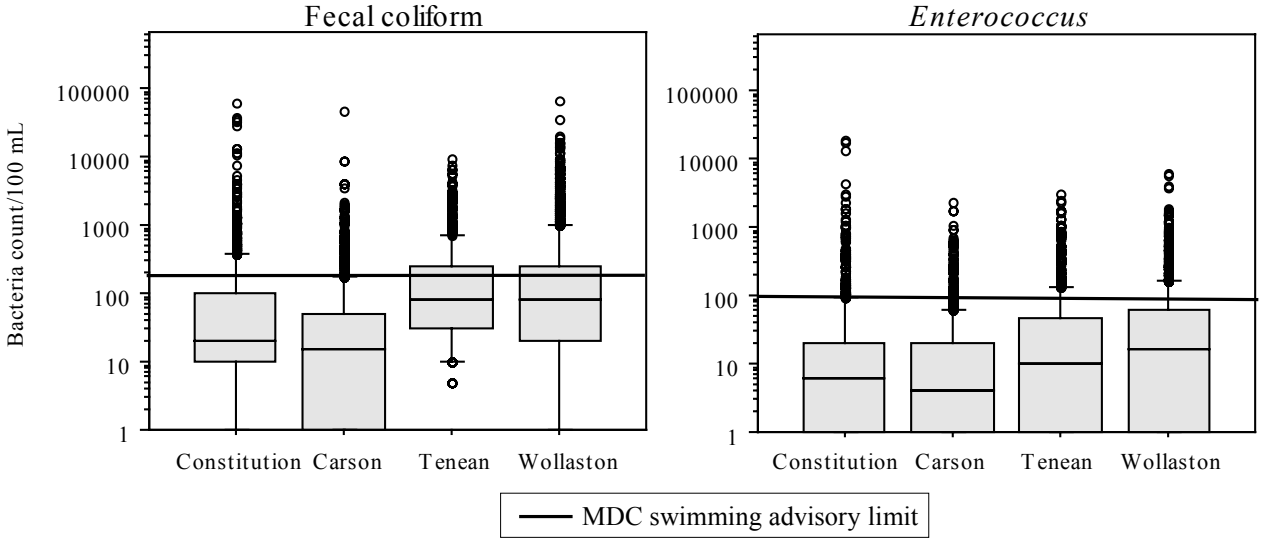

Figure 3-2. Percentile plots of fecal coliform and *Enterococcus* from samples collected 1996-2000, trends among beaches

No trend in bacterial water quality was apparent at any of the beaches over the five years, and year-to-year differences were generally not significant (see individual beach sections for discussion of inter-annual differences). Therefore, most data analyses in this report group all years together. Table 3-2 lists the geometric mean fecal coliform and *Enterococcus* counts at each sampling location and for samples collected in wet and dry weather for all years. All four beaches met both geometric mean limits in dry weather and when all weather conditions are grouped. In wet weather, however, Wollaston and Tenean Beaches fail to meet standards. Individual sites at Constitution Beach also fail to meet the geometric mean *Enterococcus* standard in wet weather.

Table 3-2. Geometric mean fecal coliform and *Enterococcus* counts, 1996-2000

Beach	Fecal Coliform			*Enterococcus*		
	All Weather	Dry weather	Wet Weather	All Weather	Dry Weather	Wet Weather
Constitution						
All sites	23	16	108	6	4	33
North Beach	22	14	110	6	4	42
Bathhouse	24	17	125	6	4	38
South Beach	23	17	91	6	3	22
Carson						
All sites	13	7	44	5	3	14
M Street	12	7	39	4	4	9
I Street	15	9	36	6	4	15
Bathhouse	11	6	62	4	3	21
Tenean						
All sites	73	41	403	11	7	61
North Beach	69	40	427	10	6	64
Middle Beach	72	41	370	10	6	50
South Beach	78	44	414	14	8	69
Wollaston						
All sites	67	43	183	13	8	53
Milton Street	71	47	169	13	7	54
Channing Street	110	69	337	19	12	86
Sachem Street	93	60	260	17	10	75
Rice Road	28	18	73	8	5	22

[1]Dry weather is defined as zero rainfall for at least 48 hours prior to sample collection.

[2]Wet weather is defined as at least 0.2 inches of rain within 24 hours of sample collection.

3.1.2 Relationship with rainfall

Rainfall has long been considered to have an adverse effect on beach water quality, particularly in Boston Harbor. The four beaches included in this report are located near congested urban areas and are subject to stormwater and/or CSO discharges during rainstorms. Discharges from these sources can contain high levels of bacteria from sewage and street runoff. Tables 3-2 and 3-3 show this relationship between rainfall and bacteria at all beaches. Wet weather geometric means were consistently higher than the dry weather geometric means. Tenean Beach failed to meet the State standard for fecal coliform and the USEPA criteria for *Enterococcus* in wet weather. Three sites at Wollaston Beach and two sites at Constitution Beach failed to meet the USEPA geometric mean guideline for *Enterococcus* in wet weather.

Table 3-3. Percent of samples failing to meet water quality standards in dry, damp, and wet weather at Boston Harbor beaches for fecal coliform and *Enterococcus*

Beach	Percent of samples exceeding limit (number of samples)							
	Fecal Coliform				*Enterococcus*			
	Dry	Damp	Wet	Total	Dry	Damp	Wet	Total
Constitution	10% (470)	14% (422)	35% (134)	15% (1026)	3% (461)	8% (417)	32% (134)	9% (1012)
Carson	2% (463)	10% (418)	30% (134)	9% (1015)	3% (457)	5% (4140)	16% (134)	6% (1005)
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Wollaston	17% (630)	33% (577)	39% (187)	29% (1394)	6% (621)	13% (573)	26% (187)	14% (1381)

Analysis of different rainfall measures. Regression analyses of bacterial indicators against rainfall for all beaches combined show a significant but relatively weak relationship with rainfall, regardless of the rainfall measure used. For both indicators, variability was best explained by 24-hour and 12-hour antecedent rainfall. However, the R^2 values did not exceed 0.06 in any of the equations; thus, rainfall by any measure did not explain more than 6% of the variability in fecal coliform counts. *Enterococcus* had a similar relationship with rainfall than fecal coliform, with R^2 values as high as 0.08. (A sample regression plot appears in Appendix.) Given this weak relationship, other factors are likely contributing to high bacteria counts at the beaches, such as dry weather sources of contamination, time since last rainfall, salinity, air and/or water temperature, sunlight, tide, and wind.

Further analysis showed a somewhat stronger relationship between rainfall and bacteria counts at individual beaches, but results were not substantially different from earlier work (Rex et al 1997). Bacteria indicator counts were regressed against 48-, 24-, 12-, 6-, 3-hour rainfall, as well as one-day, two-day, and three-day summed rainfall. All regressions showed a statistically significant relationship, however the R^2 values were between 0.004 and 0.179 for all equations for fecal coliform and between 0.02 and 0.134 for all equations for *Enterococcus* ($p < 0.0001$ for most measures, results in Appendix). Of all rainfall measures, regressions using 48-hour rain, 24-hour rain and 12-hour rain generally showed the strongest relationship with both fecal coliform and *Enterococcus.*

24-hour rainfall and 48-day rainfall were used as the primary rainfall measures in this report because they had the strongest association with elevated indicator counts for most of the beaches. Results of this analysis appear in the Appendix, and rainfall measures that best explained variability in counts at each beach are provided later in this section.

Inter-annual rainfall variation. Variation in rainfall is an important consideration when evaluating beach water quality between years; persistent wet or dry conditions may affect the response of the beach to rainfall over the course of a monitoring season. Total summer rainfall for each year is shown in Table 3-4.

Table 3-4. Total rainfall for June through August of each year

Year (June – August)	Total 3-month rainfall (in.)
30-year average	9.17
1996	8.00
1997	5.05
1998	17.42
1999	4.83
2000	14.03

Data from National Weather Service, Logan Airport weather station. "30-year average" rainfall is average rainfall for June through August, 1961-1990.

3.2 Constitution Beach

3.2.1 Physical description and sampling locations

Developed by the State in the 1950s, Constitution Beach is located on a cove on the north side of Boston Harbor, in East Boston. The beach is approximately 0.5 miles long, with a soft slope and moderate tidal range, and is bordered by marshy areas, Logan International Airport, and several yacht clubs. It is located in an urban neighborhood, adjacent to parking lots and subway tracks. The beach has been designated by the State as Class SB (suitable for swimming/fishing) and has been monitored weekly for bacterial water quality during the swimming season by the MDC since 1973.

To provide a representative measure of water quality, MDC collects samples at three locations equidistant along the beach: the North site, the Bathhouse site in the middle of the beach, and the South site.

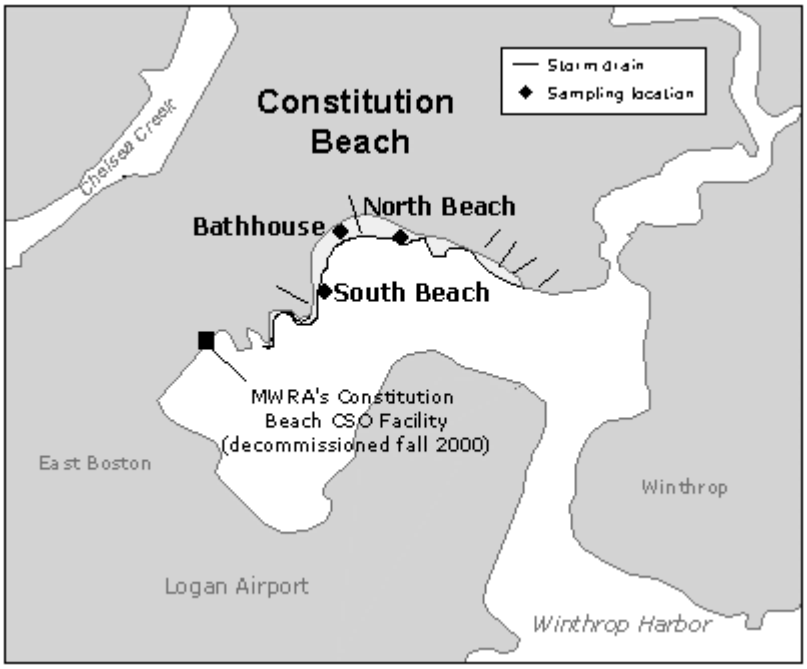

Figure 3-3. Constitution Beach map of sampling locations

3.2.2 Pollution sources

Six storm drains discharge near or onto the beach and the pipes are not visible above the water line. In the past, storm drains have been identified as being possibly contaminated with sewage (BWSC 1993), which may be a significant source of dry weather contamination to the beach. The Constitution Beach combined sewer overflow (CSO) facility, taken off-line in the fall of 2000, was located near the southern end of the beach, and discharged screened and chlorinated combined sewage and stormwater during heavy rain. On average, the facility activated approximately 6 times during the summer months, when large rainstorms (generally at least 0.4 inches of rain) overwhelmed the sewer system. The CSO discharged, on average, roughly 0.5 million gallons per activation. No changes in CSO infrastructure were made between 1996 and the summer of 2000, however Boston Water and Sewer Commission did attempt to identify and remove sewer infiltration to storm drains. Another more remote source of contamination to the beach is the Deer Island Wastewater Treatment Plant, whose outfalls on the outer edge of Winthrop Harbor discharged an average of 300 million gallons per

day of treated wastewater. Discharge through these outfalls ceased in September 2000 when flow was diverted to a new outfall 9.5 miles offshore.

3.2.3 Bacterial water quality

General. Constitution Beach is one of the less contaminated beaches in Boston Harbor, having the second lowest geometric mean count for indicator bacteria and the second lowest number of samples failing to meet MDC advisory limits after Carson Beach (see Section 3.3). A summary of the bacterial water quality and compliance with swimming standards appears in Table 3-5.

Table 3-5. Compliance with State and USEPA water quality criteria 1996-2000, Constitution Beach

Fecal coliform				
Location	% of samples meeting MDC limit (Limit: single sample ≤ 200 colonies/100 mL)	Compliance with Massachusetts swimming standards		
		Geometric mean (Limit: ≤ 200 colonies/100 mL)	Percent of samples greater than 400 colonies/100 mL (Limit: ≤ 10%)	Complies with standard?
All locations	85%	23	10%	Yes
North	86%	22	10%	Yes
Bathhouse	84%	24	9%	Yes
South	86%	23	9%	Yes
Enterococcus				
Location	% of samples meeting MDC limit (Limit: single sample ≤ 104 colonies/100 mL)	Compliance with USEPA swimming criteria		
		Geometric mean (Limit: ≤ 35 colonies/100mL)	Complies with geometric mean standard?	Calculated single sample maximum limit[1]
All locations	90%	6	Yes	125
North	88%	6	Yes	129
Bathhouse	90%	6	Yes	127
South	91%	6	Yes	120

[1]This value is the upper 75% confidence limit, which is the method USEPA recommends for calculating a single sample maximum. The single sample maximum used by MDC is recommended the default recommended by USEPA *Enterococcus* counts from all three locations measured during 1996-2000.

To calculate an *Enterococcus* limit that will trigger swimming advisories, USEPA recommends using the 75% confidence limit, which is calculated from *Enterococcus* counts measured at a beach during the previous thirty days (within the swimming season). For purposes of simplicity, the results in Table 3-5 show the 75% confidence limit for all *Enterococcus* counts measured between 1996 and 2000. For Constitution beach, the 75% confidence limit is 125 colonies/100 mL, meaning that an *Enterococcus* count higher than 125 colonies/100 mL would result in the posting of a swimming advisory. This value is higher than the 104 colonies/100 mL guideline that USEPA suggests should be used by beach managers if data are insufficient to calculate a 75% confidence limit. (104 colonies/100 mL is the value currently used by MDC as a limit to post swimming advisories.)

Inter-annual variation in indicator counts. There is no evidence of a trend of improving water quality at Constitution Beach over the five-year monitoring period. Annual summaries appear in Table 3-6. An analysis of covariance showed no significant difference in bacteria counts across years, after controlling for rainfall (not shown).

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Table 3-6. Annual geometric means and range of bacteria counts, Constitution Beach

Year	Total rainfall for monitoring season[1] (in.)	Fecal coliform		*Enterococcus*	
		Geometric mean	Range	Geometric mean	Range
1996	6.9	24	0 – 36,400	11	0 – 18,300
1997	4.1	16	0 – 2,350	5	0 – 640
1998	16.5	40	0 – 61,600	7	0 – 4,260
1999	5.4	16	0 – 11,000	3	0 – 1,260
2000	8.3	27	0 – 5,500	10	0 – 3,120

[1]Rainfall measured at MWRA's Chelsea Creek pump station. Date ranges specified in Section 2.2.
Bacteria results are in colonies/100 mL. Zero values represent results that were below detection.

Variation among sampling locations. There was no significant difference among any of the three sampling locations in either *Enterococcus* or fecal coliform counts. The indicator counts for each location at the beach for all samples collected 1996 – 2000 are shown in Figure 3-4.

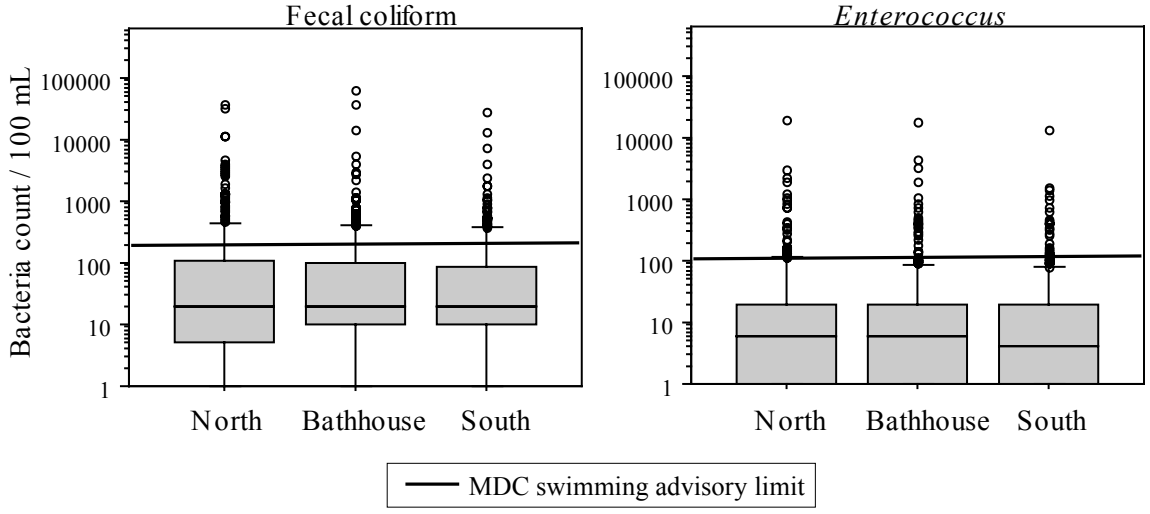

Figure 3-4. Percentile plots of fecal coliform and *Enterococcus* 1996-2000, Constitution Beach

3.2.4 Relationship of indicator counts and rainfall

Short term rainfall effects. Figure 3-5 shows the response of Constitution Beach to rainfall. Antecedent rainfall within 24 hours of collection was grouped into 0.2-inch increments and plotted against ln-transformed bacteria counts. Geometric mean counts failed to meet guidelines for several of the high volume rainfall categories. A one-way analysis of variance was conducted using ln-transformed indicator counts and these rainfall groupings. Results indicate that samples collected with no rainfall in the past 24 hours were significantly lower than samples collected with any amount of 24-hour rain ($F_{1, 1024} = 18.17$, $p < 0.0001$ for

fecal coliform, $F_{1, 1010} = 39.66$, $p < 0.0001$ for *Enterococcus*). There was no significant difference between counts in the rainfall categories exceeding 0.4 – 0.6 inches. This analysis suggests a threshold, particularly for *Enterococcus*—when antecedent rainfall is less than 0.4 inches, bacterial counts generally meet geometric mean limits. For rainfall equal to or greater than 0.4 inches, the confidence intervals all either overlap or are above the water quality standards for both fecal coliform and *Enterococcus*. (It should be noted, however, that sample sizes were not equal across these rainfall groups, as large rainfall events were relatively rare during the sampling period (n = 21 for the >0.8 category, n = 39 for the 0.6 – 0.8 category, and n = 24 for the 0.4 – 0.6 category, compared with n= 671 for the zero rainfall category)).

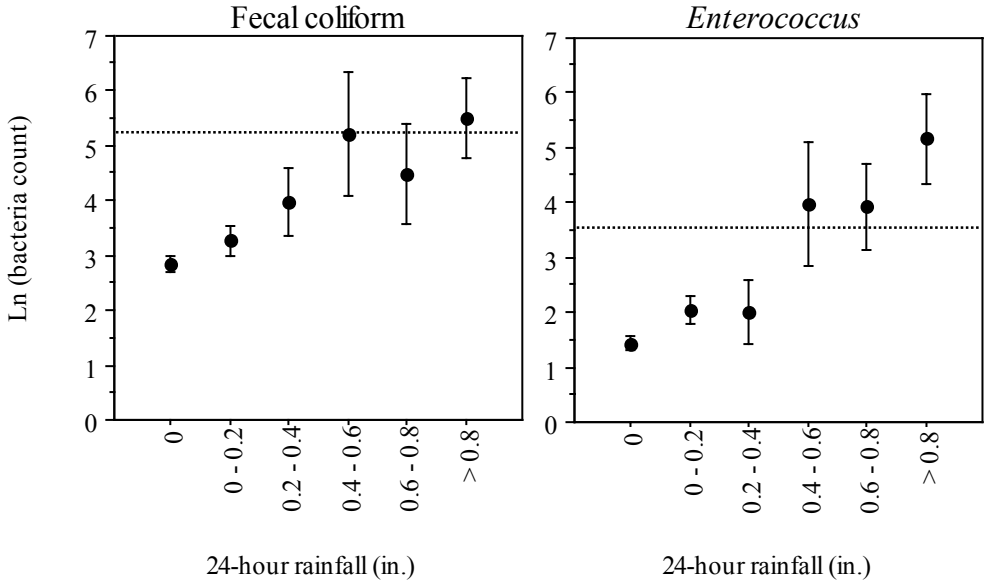

Figure 3-5. Indicator response to 24-hour antecedent rainfall, Constitution Beach.
Geometric mean and 95% confidence intervals are shown for each rainfall category. Dashed lines are geometric mean limits.

A Spearman rank order analysis found that the degree of association between 24-hour rain and bacteria counts was weakly positive and highly significant. Corrected for ties, the r_s was 0.23 ($p<0.0001$) for ln fecal coliform counts and 24-hour rainfall, and $r_s = 0.27$ ($p<0.0001$) for ln *Enterococcus* and 24-hour rainfall.

Linear regression analyses: relationship of fecal coliform and *Enterococcus* to rainfall. A linear regression analysis was performed of ln-transformed bacteria counts on continuous (as opposed to categorized) rainfall measures. The relationship of rainfall with both indicators was significant but weak. All rainfall measures were about twice as effective in predicting elevated *Enterococcus* counts as fecal coliform counts. Fecal coliform was most strongly associated with 3-day summed rain (sum of rain falling within 3 days of sample collection), a rainfall measure which had one of the weakest associations with fecal coliform for the other beaches ($R^2 = 0.063$, $p < 0.0001$). In general, however, R^2 values for fecal coliform and any rainfall measure were similar enough ($R^2 = 0.062$ for 24-hour antecedent rainfall, $p < 0.0001$) that 24-hour antecedent rain is a suitable rain measure for this beach, particularly since *Enterococcus* was most strongly associated with 24-hour rain, with an R^2 of 0.134 ($p<0.0001$).

Analysis by weather condition: dry, damp, wet. Bacteria results were grouped into three categories of rainfall conditions: Dry, Damp, and Wet. Dry weather is defined as no rainfall for at least 48 hours prior to sample collection. Wet weather is defined as rainfall of at least 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories. Table 3-7 shows the variability in counts

under different rainfall conditions. For each category, maximum counts for both indicators differed by an order of magnitude. While dry weather had the lowest geometric mean of the three categories (see Table 3-2), dry weather counts could be very high relative to those at the other three beaches. Dry weather fecal coliform counts reached a high of 4,700 colonies/100 mL in 1998. In wet weather, fecal coliform counts climbed to 61,600 colonies/100 mL for fecal coliform and 18,000 colonies/100 mL for *Enterococcus* in 1998, 1.5 days after a 1.75-inch rainstorm.

Table 3-7. Range of bacteria values for each rainfall condition 1996-2000, Constitution Beach
(results in colonies per 100 mL)

Location	Fecal coliform			*Enterococcus*		
	Dry	Damp	Wet	Dry	Damp	Wet
North	0 - 4,700	0 - 11,000	0 - 36,900	0 - 360	0 - 1,080	0 - 18,300
Bathhouse	0 - 2,700	0 - >4,000	0 - 61,600	0 - 390	0 - 820	0 - 18,000
South	0 - 7,400	0 - >4,000	0 - 28,000	0 - 350	0 - 1,110	0 - 13,200

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories.

To examine prolonged rainfall effects further, the Dry, Damp, and Wet rainfall categories were compared to bacterial data grouped by whether sample counts were above or within MDC guidelines. Chi-squared analyses (Table 3-8) indicate that high counts occur more frequently in wet weather for both indicators than would be due to chance ($\chi^2 = 15.2$, $p = 0.0001$ for fecal coliform, $\chi^2=24.8$, $p<0.0001$ for *Enterococcus*). There was no significant difference in elevated counts in damp weather as compared to dry weather, however. The table also shows that 11% of fecal coliform counts failed to meet guidelines in dry weather, and 25% failed in wet weather. For *Enterococcus*, 3% of samples failed to meet the guideline in dry weather and 19% failed in wet weather.

Table 3-8. Contingency table, Constitution Beach

Asterisks indicate significant differences from dry weather. Expected values (results that would be expected if bacteria counts had no relationship to rain) appear in small font.

Fecal Coliform

	Dry	Damp	Wet***	Totals
No. of samples ≤ 200	421 399	362 358	87 114	870
No. of samples > 200	49 71	60 64	47 20	156
Totals	470	422	134	1026
Percent of samples exceeding limit in each weather condition	10%	14%	35%	15%

Enterococcus

	Dry	Damp	Wet***	Totals
No. of samples ≤ 104	446 420	385 380	91 122	922
No. of samples > 104	15 41	32 37	43 12	90
Totals	461	417	134	1012
Percent of samples exceeding limit in each weather condition	3%	8%	32%	9%

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories. *** $p < 0.0001$, $\chi^2=42.416$ for fecal coliform, $\chi^2 = 67.699$ for *Enterococcus*. Damp weather was not significantly different from dry weather.

The proportion of fecal coliform counts failing to meet the MDC guideline in dry weather was not significantly different from damp weather, but the wet weather category had a relatively high proportion of

samples failing to meet the guideline. For *Enterococcus*, Constitution had the highest proportion of samples failing to meet the MDC guideline in wet weather of any beach in the study; however, the dry and damp weather categories were more consistent with the cleanest of Boston Harbor beaches, Carson Beach. These results suggest a discrepancy between the two bacterial indicators in their relationship to rainfall, despite similar correlation coefficients.

Odds ratios calculated from the contingency table indicate that the odds of either indicator exceeding MDC guidelines in wet weather were high, but much higher for *Enterococcus*. The odds of *Enterococcus* exceeding in wet weather were 14 times the odds of exceeding in dry weather (OR = 14.0, 95% CI = 7.4, 26.3). For fecal coliform, the odds of exceeding in wet versus dry weather were nearly 5 to 1 (OR = 4.6, 95% CI = 2.9, 7.4). The relationship between exceedances and damp weather was not significant.

3.3 Carson Beach

3.3.1 Physical description and sampling locations

Carson Beach was first developed as an extension of Olmstead's Emerald Necklace in the early 1900s. It is approximately one mile long, located in northern Dorchester Bay in South Boston. The beach is relatively flat, with a gentle slope and moderate tidal range. Behind the beach are a two-lane boulevard, grassy parkland and a dense residential area. It has been designated by the State as Class SB and has been monitored weekly during the swimming season for bacterial water quality since 1973 by the MDC.

MDC collects samples at three locations named for streets which run perpendicular to the beach: the M Street site on the northern end, the I Street site in the middle of the beach, and the McCormack Bathhouse site on the southern end.

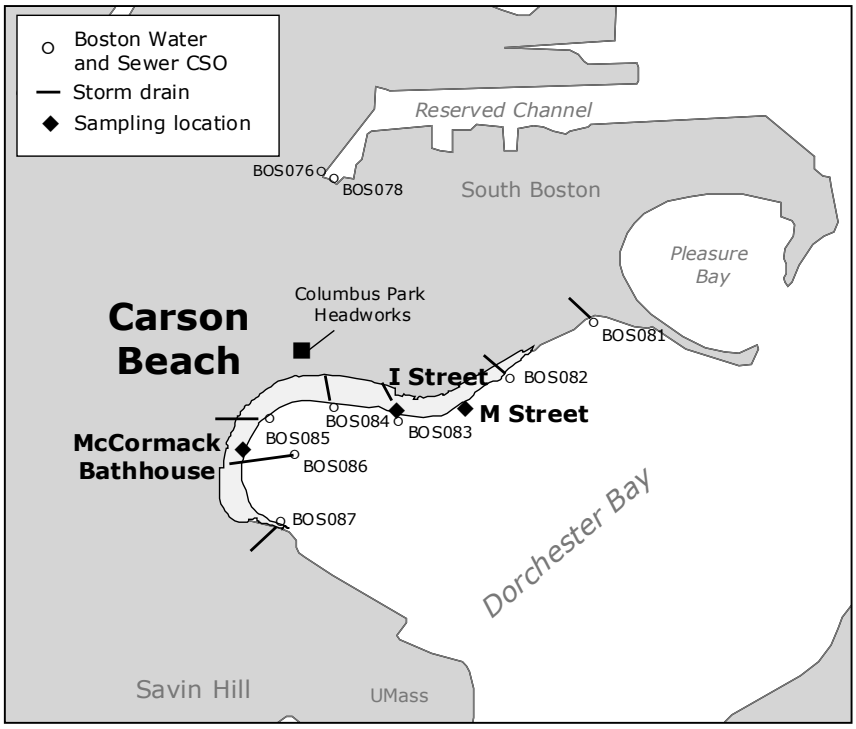

Figure 3-6. Carson Beach map of sampling locations

3.3.2 Pollution sources

Seven CSOs discharge near or onto the beach. During light to moderate rainstorms, all of the CSO outfalls also discharge uncombined storm water from storm drains connected downstream of the regulators. All outfalls are subtidal. The CSOs are not metered; models estimate that these CSOs discharge approximately 9 million gallons of combined sewage/stormwater into the receiving water each year (MWRA 1997). No changes in CSO or stormwater infrastructure were made between 1996 and 2000.

3.3.3 Bacterial water quality

General. Carson Beach had the best water quality of all the beaches studied, despite the fact that it is the only beach in the study affected both by untreated CSOs and stormwater. 92% of all samples meeting the MDC fecal coliform guideline and 93% of samples meeting the MDC *Enterococcus* guideline.

Table 3-9. Compliance with water quality criteria 1996-2000, Carson Beach

Fecal coliform				
Location	% of samples within MDC limit (Limit: single sample ≤ 200 colonies/100 mL)	Compliance with Massachusetts SB standard		
		Geometric mean (Limit: ≤ 200 colonies/100 mL)	Percent of samples greater than 400 colonies/100 mL (Limit: ≤ 10%)	Complies with SB?
All locations	92%	13	6%	Yes
M Street	94%	12	3%	Yes
I Street	90%	15	7%	Yes
McCormack Bathhouse	91%	11	7%	Yes
Enterococcus				
Location	% of samples within MDC limit (Limit: single sample ≤ 104 colonies/100 mL)	Compliance with USEPA criteria		
		Geometric mean (Limit: ≤ 35 colonies/100mL)	Complies with standard?	Calculated single sample maximum[1]
All locations	93%	5	Yes	116
M Street	95%	4	Yes	109
I Street	92%	6	Yes	120
McCormack Bathhouse	93%	4	Yes	119

[1]This value is the upper 75% confidence limit calculated from Carson *Enterococcus* counts from all three locations measured during 1996-2000. The limit is unique for each beach in this report.

Geometric means for both indicators are well within the State fecal coliform limits and the *Enterococcus* geometric mean recommended by USEPA. Carson Beach also meets the State criteria for designated swimming areas, with less than 10 percent of fecal coliform samples at all locations below the limit of 400 colonies per 100 mL.

Using the 75% confidence limit as the single sample maximum recommended by the USEPA, *Enterococcus* counts exceeding 116 colonies/100 mL would result in the posting of swimming advisory. This limit is slightly above the alternative guideline of 104 colonies/100 mL recommended by USEPA if data are insufficient to calculate the 75% confident limit.

Inter-annual variation. There is no evidence of a trend of improving water quality at Carson Beach over the five-year monitoring period. An analysis of covariance indicates that there was no significant difference in bacteria counts between years, after controlling for rainfall (data not shown). Annual summaries are shown in Table 3-10.

Table 3-10. Annual geometric means and range of bacteria counts, Carson Beach

Year	Total rainfall for monitoring season[1] (in.)	Fecal coliform		*Enterococcus*	
		Geometric mean	Range	Geometric mean	Range
1996	7.9	10	0 – >4,000	7	0 – 630
1997	4.2	13	0 – 9,000	8	0 – 1,750
1998	16.8	24	0 – 2,140	5	0 – 940
1999	5.1	9	0 – 47,200	3	0 – 1,730
2000	9.2	13	0 – 8,500	5	0 – 2,340

Bacteria results are in colonies/100 mL. Zero values represent results that were below detection.
[1]Rainfall measured at MWRA's Columbus Park Headworks facility. Date ranges specified in Section 2.2.

Variation among sampling locations. There was no significant difference in fecal coliform counts among any of the three sampling locations at Carson Beach. For *Enterococcus* however, a one-way ANOVA revealed that the I Street site had significantly higher *Enterococcus* counts than the other two sampling locations ($F_{1, 1013} = 3.598$, $p<0.03$). Figure 3-7 shows the indicator counts for each location.

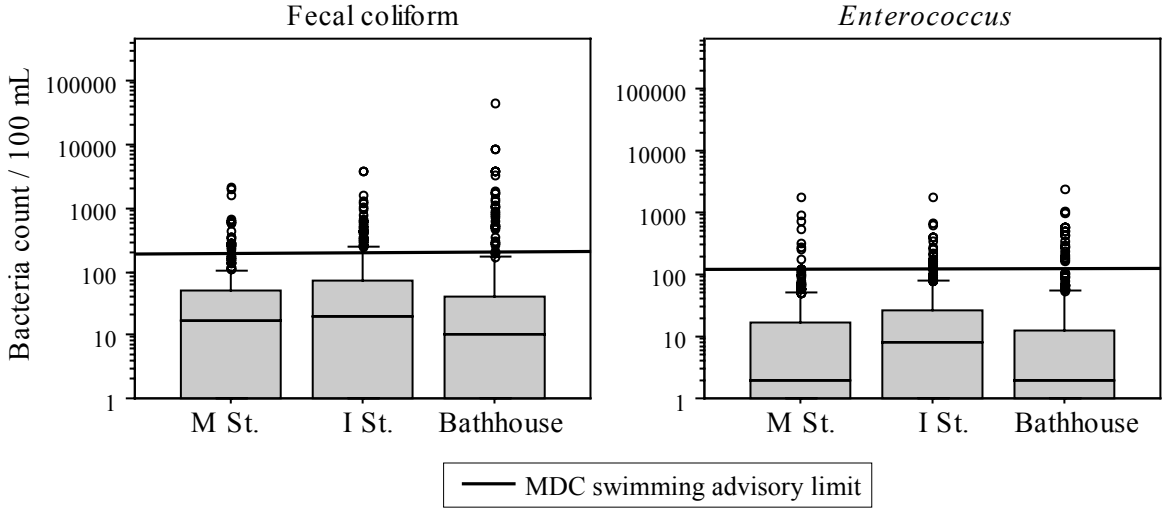

Figure 3-7. Percentile plots of fecal coliform and *Enterococcus* 1996-2000, Carson Beach

3.3.4 Relationship of Bacteria and Rainfall

Short term rainfall effects. Figure 3-8 shows the response of Carson Beach to rainfall: 24-hour antecedent rainfall in 0.2-inch increments is plotted against ln-transformed bacteria counts. Fecal coliform and *Enterococcus* did not exceed geometric mean limits for any amount of rainfall within 24 hours of sample collection. However, fecal coliform and *Enterococcus* counts were significantly different among some rainfall categories (one-way ANOVA, $F_{1, 1013} = 24.73$, $p < 0.0001$ for fecal coliform, $F_{1, 1003} = 39.66$, $p < 0.0001$ for *Enterococcus*), but these differences were not consistent for each indicator.

For fecal coliform, differences in counts associated with incremental increases in rainfall below the 0.4 – 0.6 inch category were highly significant, while differences among rainfall categories above 0.4 – 0.6 inches were not (although the 0.2 – 0.4 inch category had counts significantly lower than the >0.8 inch category, p <

0.0001). This may be explained in part by the fact that few samples were collected in the high rainfall categories (n = 29 for >0.8 inches, n = 31 for 0.6 – 0.8 inches, as compared to n = 666 where 24-hour rainfall was zero).

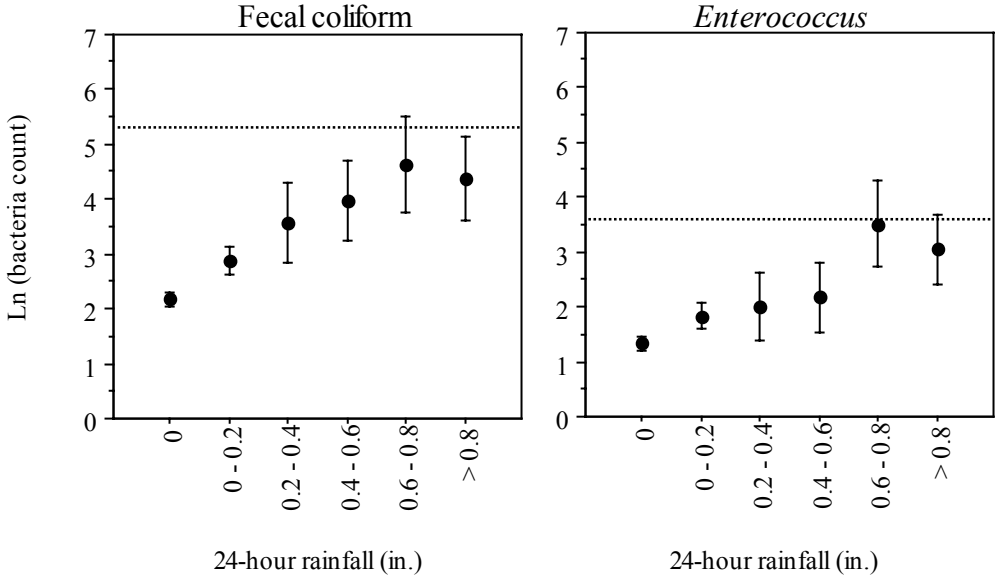

Figure 3-8. Response to 24-hour antecedent rainfall, Carson Beach.
Geometric mean and 95% confidence intervals shown for each rainfall category. Dashed lines are geometric mean limits.

For *Enterococcus*, differences among larger rainfall categories (> 0.4 inches) were significant, indicating that increasing rainfall does result in significantly higher counts. All categories were significantly different from the 0.6 – 0.8 category, and given that this category barely meets the geometric mean limit for *Enterococcus* it is suggestive of a rainfall cutoff to trigger beach postings. Interestingly, both indicators show a slight (though statistically insignificant) drop in counts in heavy rainfall (> 0.08 inches), suggesting that storm drains may be flushed of contaminants and/or CSO discharges are diluted during heavy rain.

A Spearman rank order analysis found that the degree of association between 24-hour antecedent rain and bacteria counts was weakly positive and highly significant. Corrected for ties, the r_s was 0.23 ($p<0.0001$) for ln fecal coliform counts and 24-hour rainfall, and $r_s = 0.30$ ($p<0.0001$) for ln *Enterococcus* and 24-hour rainfall.

Linear regression analyses: relationship of fecal coliform and *Enterococcus* to rainfall. Ln-transformed fecal coliform and *Enterococcus* were regressed against antecedent rainfall. Fecal coliform demonstrated a stronger relationship with rainfall than *Enterococcus*. However, R^2 values were low, indicating that rainfall is at best a weak predictor of indicator counts. The weakness of this relationship may be explained in part by the varying responses of the indicators to different amounts of rainfall in addition to other factors such as dry weather contamination. 48-hour antecedent rainfall had the best relationship with fecal coliform ($R^2 = 0.109$, $p<0.0001$ for fecal coliform, $R^2 = 0.065$, $p < 0.0001$ for *Enterococcus*). This relationship suggests that rainfall may have more prolonged effects at Carson Beach, and is consistent with earlier findings that Carson sometimes exhibits a delayed response to rainfall (Rex et al 1997). However it should be noted that indicator counts had similar R^2 values for 24-hour antecedent rainfall ($R^2 = 0.093$ for fecal coliform and $R^2=0.066$ for *Enterococcus,* $p < 0.0001$ for both).

Analysis by weather condition: dry, damp, wet. Data grouped into three rainfall categories—dry, damp, and wet—show that generally Carson had the lowest maximum counts for fecal coliform of any of the beaches (Table 3-11). Of the three locations at Carson, the Bathhouse location had the widest range and the highest maximum counts (the highest count measured in July 1999 at 47,200 colonies/100 mL one day after a 0.7-inch rainstorm). In general, however, counts at Carson Beach remained relatively low during wet weather, with counts rarely climbing above several hundred colonies/100 mL. For *Enterococcus*, the maximum counts occurred in damp or dry rather than wet weather. Carson had the lowest wet weather *Enterococcus* counts of any beach.

Table 3-11. Range of bacteria values for each rainfall condition, Carson Beach
(results in colonies per 100 mL)

Location	Fecal coliform			*Enterococcus*		
	Dry	Damp	Wet	Dry	Damp	Wet
M Street	0 - 650	0 - 2,140	0 - 2000	0 - 1,730	0 - 936	0 - 180
I Street	0 - 1,600	0 - 1,360	0 - >4,000	0 - 660	0 - 1,750	0 - 630
McCormack Bathhouse	0 - 760	0 - 9,000	0 - 47,200	0 - 500	0 - 1,060	0 - 2,340

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories.

Contingency table analyses indicate that elevated counts do occur more frequently in wet weather for both indicators (Table 3-12). There was no significant difference in bacterial counts in damp weather as compared to dry weather, however.

Of all beaches in the study, Carson had the lowest percentage of violations overall, and the lowest proportion of elevated *Enterococcus* counts in wet weather, at 16%. High dry weather counts were also infrequent relative to the other beaches studied, with only twenty-one dry weather samples having counts that exceeded either MDC limit during the five-year monitoring period. Unlike *Enterococcus*, fecal coliform demonstrated a dramatic increase in wet weather, with the percentage of samples violating the guideline increasing more than ten-fold relative to dry weather, from 2% to 30%.

Contingency table analyses revealed the largest odds ratio for fecal coliform of any beach for wet weather: the odds of fecal coliform exceeding in wet weather were more than twenty times the odds of exceeding in dry weather (OR = 21.4, 95% CI = 10.1, 45.7). The odds of *Enterococcus* exceeding in wet versus dry weather was nearly 6 to 1 (OR = 5.8, 95% CI = 2.9, 11.5).

Table 3-12. Contingency table, Carson Beach

Asterisks indicate significant differences from dry weather. Expected values (results that would be expected if bacteria counts had no relationship to rain) appear in small font.

Fecal Coliform

	Dry	Damp***	Wet***	Totals
No. of samples ≤ 200	454 422	378 381	94 122	926
No. of samples > 200	9 41	40 37	40 12	89
Totals	463	418	134	1015
Percent of samples exceeding limit	2%	10%	30%	9%

Enterococcus

	Dry	Damp	Wet***	Totals
No. of samples ≤ 104	442 431	393 390	112 126	947
No. of samples > 104	15 26	21 24	22 8	58
Totals	457	414	134	1005
Percent of samples exceeding limit	3%	5%	16%	6%

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories. Results of chi squared tests comparing dry to damp and dry to wet: damp weather was not significantly different from dry weather for *Enterococcus* ($p=0.188$); *** $p < 0.0001$, $\chi^2=19.9$, fecal coliform, damp; $\chi^2=63.129$, fecal coliform, wet; *** $p < 0.0001$, $\chi^2=25.000$, *Enterococcus*, wet.

3.4 Tenean Beach

3.4.1 Physical description and sampling locations

Developed by the city of Boston in the early 1900s, Tenean Beach is located in Dorchester, near the Neponset River mouth in southern Dorchester Bay. The beach is 1,100 feet long, relatively flat with a moderate tidal range and muddy flanks. It is in an urban location, bordered by a parking lot, grassy parkland, and by Interstate 93. The beach has been designated by the State as Class SB and has been monitored weekly for bacterial water quality during the swimming season by the MDC since 1974.
MDC collects samples at three locations on the beach.

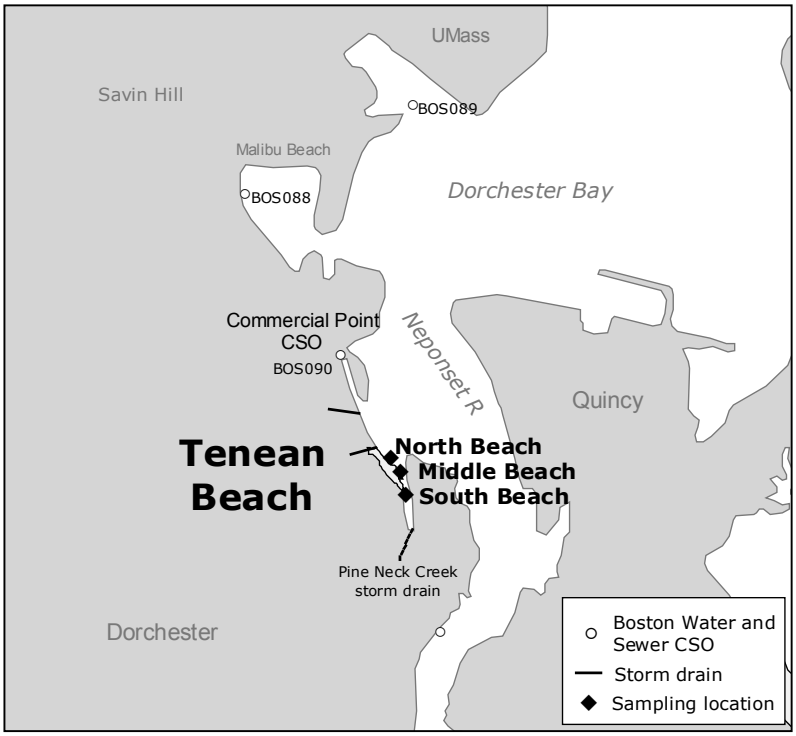

Figure 3-9. Tenean Beach map of sampling locations

3.4.2 Pollution sources

At least three storm drains and one CSO discharge near to the beach. Two of the storm drains are above the water line at low tide. The Commercial Point CSO, located approximately 0.3 miles from the beach, discharges chlorinated and screened combined sewage/stormwater during moderate to heavy rainstorms. The Pine Neck Creek culvert discharges on the southern end of the beach, draining stormwater from parts of Dorchester. An additional source of potential contamination is the Neponset River, which has been shown to adversely affect the bacteriological water quality of southern Dorchester Bay (Rex 1993, Leo et al 1994).

Two major changes between 1996 and 2000 may have affected Tenean Beach water quality. First, several CSOs in the Neponset River had been closed as of 1998, eliminating some contamination sources to the river during wet weather. Second, changes in sewer infrastructure made by BWSC resulted in increased flows to the Commercial Point CSO beginning in 1999, however no changes were made in stormwater infrastructure or to the Commercial Point CSO facility itself during the study period.

3.4.3 Bacterial water quality

General. Tenean Beach had the next-to-poorest water quality (after Wollaston Beach), with 72% of all samples meeting the MDC fecal coliform guideline and 87% meeting the MDC *Enterococcus* guideline. Geometric means for both indicators were below the State fecal coliform limit and the USEPA *Enterococcus* limit. However, the beach did not comply with the State criteria for designated swimming areas, with more than 10 percent of fecal coliform samples exceeding the limit of 400 colonies per 100 mL.

Using the USEPA criteria of the 75% confidence limit as the single sample maximum, *Enterococcus* counts exceeding 131 colonies/100 mL would result in the posting of a swimming advisory.

Table 3-13. Compliance with water quality criteria 1996-2000, Tenean Beach

Fecal coliform				
Location	% of samples within MDC limit (Limit: single sample ≤ 200 colonies/100 mL)	Compliance with Massachusetts SB standard		
		Geometric mean (Limit: ≤ 200 colonies/100 mL)	Percent of samples greater than 400 colonies/100 mL (Limit: ≤ 10%)	Complies with SB?
All locations	72%	73	16%	No
North	75%	69	15%	No
Middle	72%	72	17%	No
South	70%	78	16%	No
Enterococcus				
Location	% of samples within MDC limit (Limit: single sample ≤ 104 colonies/100 mL)	Compliance with USEPA swimming guidelines		
		Geometric mean (Limit: ≤ 35 colonies/100mL)	Complies with geometric mean criterion?	Calculated single sample maximum[1]
All locations	87%	11	Yes	131
North	89%	10	Yes	127
Middle	88%	10	Yes	129
South	85%	14	Yes	137

[1]This value is the upper 75% confidence limit calculated from Tenean *Enterococcus* counts from all three locations measured during 1996-2000. The limit is unique for each beach in this report.

Inter-annual variation. Bacterial indicator counts did not demonstrate a trend over the five years (see Table 3-14), however an analysis of covariance of fecal coliform counts revealed significant differences between some years, after controlling for 24-hour rainfall ($F_{4, 886} = 6.902$, $p < 0.0001$). For fecal coliform, 1998 was significantly higher than all other years ($p < 0.0001$), although 1996 was not significantly different from 2000. The intense rainfall of 1998 is a likely explanation for the increased counts during this year, even though 24-hour rainfall was controlled for in the model, since discharges from CSOs and storm drains increased dramatically and contamination was prolonged. *Enterococcus* showed no significant differences among years.

Table 3-14. Annual geometric means and range of bacteria counts, Tenean Beach

Year[1]	Total rainfall for monitoring season[2] (in.)	Fecal coliform		*Enterococcus*	
		Geometric mean	Range	Geometric mean	Range
1996	7.9	57	0 – 705	25	0 – 440
1997	4.2	58	0 – >4,000	11	0 – 930
1998	16.8	182	0 – >4,000	20	0 – 2,390
1999	5.1	42	0 – 6,400	5	0 – 2,400
2000	9.2	79	0 – 9,400	14	0 – 3,000

Bacteria results are in colonies/100 mL. Zero values represent results that were below detection.
[1]Daily monitoring did not begin at Tenean Beach until 1997. 1996 includes weekly monitoring only, and is included for comparison. [2]Rainfall measured at MWRA's Columbus Park headworks facility. Date ranges specified in Section 2.2.

Variation among sampling locations. For all samples collected at Tenean Beach between 1996 and 2000, there was no significant difference in fecal coliform or *Enterococcus* counts among any of the three sampling locations. Figure 3-10 shows the indicator counts for each station.

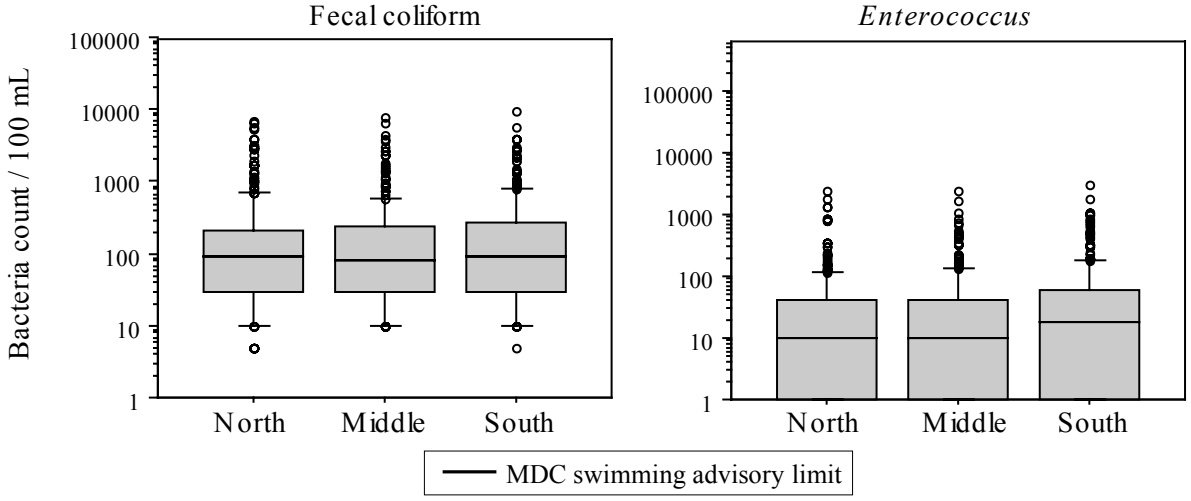

Figure 3-10. Percentile plots of fecal coliform and *Enterococcus* 1996-2000, Tenean Beach

3.4.4 Relationship of Bacteria and Rainfall

Short term rainfall effects. Tenean Beach is more sensitive to rainfall than the other beaches. Figure 3-11 shows that if 24-hour antecedent rain is 0.2 inches or greater, both fecal coliform and *Enterococcus* counts consistently exceed geometric mean guidelines. While some dry weather counts exceeded those of higher rainfall amounts (data not shown), there was a significant increase in counts as rainfall increased, except for the 0.2 – 0.4 and 0.4 – 0.6 categories (one-way ANOVA, $F_{1, 882} = 40.66$, $p < 0.0001$ for fecal coliform, $F_{1, 888} = 32.87$, $p < 0.0001$ for *Enterococcus*). For fecal coliform, geometric means failed to meet limits following a relatively small amount of rainfall as compared to the other three beaches. Tenean demonstrated a strong positive response for both fecal coliform and *Enterococcus* for large rainstorms, where rainfall exceeded 0.6 inches. (It should be noted that the sample size for the larger rainfall categories were relatively small; for the 0.6 – 0.8 category, n = 29 and the > 0.8 category, n = 21, compared to n = 575 for dry weather.)

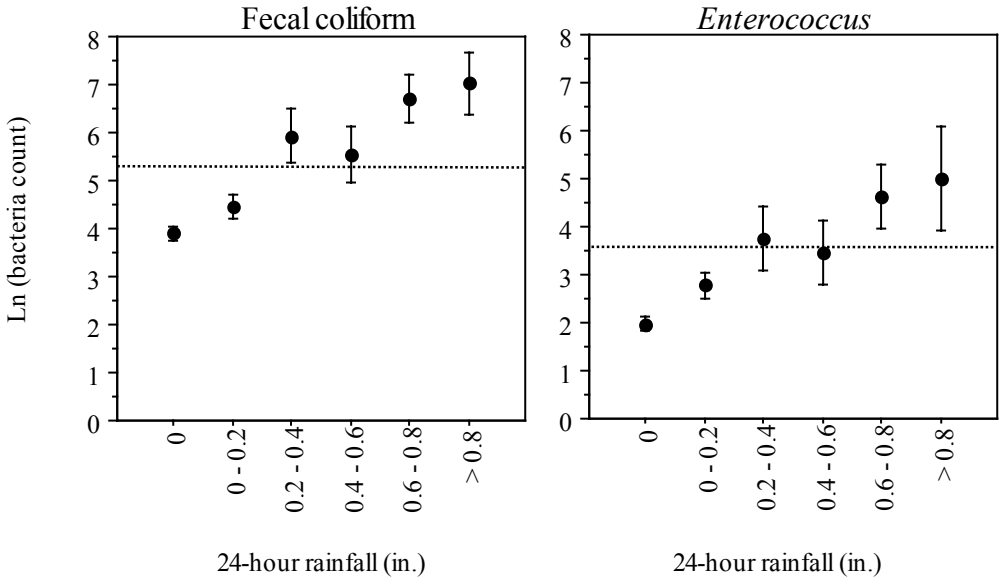

Figure 3-11. Response to 24-hour antecedent rainfall, Tenean Beach.
Geometric mean and 95% confidence intervals are shown for each rainfall category. Dashed lines are geometric mean limits.

24-hour antecedent rainfall and bacteria counts were also compared using the Spearman rank order correlation coefficient, and the degree of association was somewhat stronger than for Carson or Constitution Beaches. Corrected for ties, the r_s was 0.38 ($p<0.0001$) for ln fecal coliform counts and 24-hour rainfall, and $r_s = 0.36$ ($p<0.0001$) for ln *Enterococcus* and 24-hour rainfall.

Linear regression analyses: relationship of fecal coliform and *Enterococcus* to rainfall. When log-transformed fecal coliform and *Enterococcus* were regressed against antecedent 24-hour rainfall, both indicators demonstrated a significant relationship to rain. The analyses yielded the highest R^2 values of any of the four beaches, indicating that bacteria counts at Tenean are influenced by rainfall to a greater degree than any other beach in the study. Fecal coliform and *Enterococcus* demonstrated nearly the same relationship with 24-hour antecedent rain ($R^2 = 0.162$ for fecal coliform, $R^2 = 0.134$ for *Enterococcus*, $p < 0.0001$ for both). 48-hour antecedent rainfall also demonstrated highly significant relationships with bacteria counts, particularly fecal coliform ($R^2 = 0.179$ for two-day rain, $R^2 = 0.124$ for *Enterococcus*, $p < 0.0001$ for both), indicating that rainfall also has a delayed effect, like Carson Beach. This delay in high counts may be due in part to the Neponset River, as river water contaminated by upstream sources flows past the beach.

Analysis by weather condition: dry, damp, wet. Of all the beaches in the study, Tenean Beach had the lowest maximum counts overall after Carson Beach (Table 3-15). This is surprising considering the relatively high geometric means for both fecal coliform and *Enterococcus*. While counts at Tenean have not climbed as high as at other beaches, the beach maintains an elevated level of contamination in both dry and wet weather.

Table 3-15. Range of bacteria values for each rainfall condition, Tenean Beach

Location	Fecal coliform			*Enterococcus*		
	Dry	Damp	Wet	Dry	Damp	Wet
North	0 - 1,900	0 - >4,000	10 - 6,800	0 - 340	0 - 2,390	0 - 1,800
Middle	0 - 1,340	0 - 2,700	10 - 7,700	0 - 1,620	0 - 700	0 - 2,400
South	0 - 1,040	0 - >4,000	0 - 9,400	0 - 3,000	0 - 850	0 - 1,040

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories.

Contingency table analysis reveals that elevated counts do occur more frequently in wet weather than in dry weather for both indicators than would be due to chance. Damp weather was not significant.

Table 3-16. Contingency table, Tenean Beach

Asterisks indicate significant differences from dry weather. Expected values (results that would be expected if bacteria were not affected by rain) appear in small font.

Fecal Coliform

	Dry	Damp	Wet***	Totals
No. of samples ≤ 200	320 280	285 271	34 89	639
No. of samples > 200	69 110	92 106	90 35	251
Totals	389	377	124	890
Percent of samples exceeding limit	18%	22%	58%	29%

Enterococcus

	Dry	Damp	Wet***	Totals
No. of samples ≤ 104	368 341	336 327	71 107	775
No. of samples > 104	21 48	37 46	51 15	109
Totals	389	373	122	884
Percent of samples exceeding limit	5%	7%	27%	11%

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories. Results of chi squared tests comparing dry to damp and dry to wet: damp weather was not significant; *** $p < 0.0001$, χ^2=108.15, fecal coliform, wet; χ^2=76.338, *Enterococcus*, wet.

For fecal coliform, there was a relatively high percentage of exceedances, with more than half of all samples collected in wet weather failing to meet the MDC limit, the highest percentage of any of the four beaches. *Enterococcus* exceedances were much lower, at 27%. A total of seventy-nine dry weather samples had counts that exceeded at least one MDC limit during the five-year monitoring period (data not shown).

The odds of *Enterococcus* failing to meet limits in wet versus dry weather were nearly 13 to 1 (OR = 12.6, 95% CI = 7.1, 22.2), and the odds of fecal coliform failing to meet limits in wet weather were 12 times those of exceeding in dry weather (OR = 12.3, 95% CI = 7.7, 19.7).

3.5 Wollaston Beach

3.5.1 Physical description and sampling locations

Wollaston Beach is a 3.2-mile barrier beach located on Quincy Bay in Quincy, and was originally incorporated into the Quincy Shores Reservation in 1900. The beach is flanked by pockets of saltmarsh and has a substantial tidal range, exposing extensive tidal flats at low tide. The beach is bordered by parking lots and the four-lane Quincy Shore Drive, behind which lies a dense residential area. It has been designated by the State as Class SB and has been routinely monitored for bacterial water quality during the summer months by the MDC since 1973.

MDC collects samples at four locations roughly equidistant along the beach (Figure 3-12), located across from streets perpendicular to Quincy Shore Drive: Milton Street, Channing Street, Sachem Street and Rice Road.

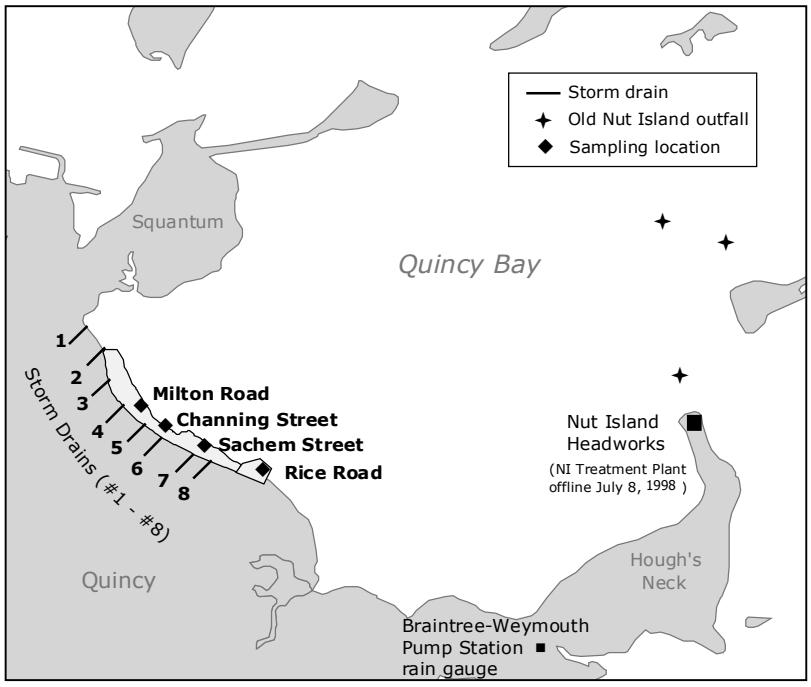

Figure 3-12. Wollaston Beach map of sampling locations

3.5.2 Pollution sources

Eight storm drains which drain stormwater from residential areas of east Quincy discharge directly onto Wollaston beach. Many of the drains are encased in cement and are visible at low tide. The sewer and drainage system in the area is very old: cracks and breaks in sewer pipes allow sanitary sewage to leak into the storm drains, resulting in contamination to the beach during dry and wet weather. The City of Quincy has spent nearly $24 million on surveys, repairs, and rehabilitation of the sewer and storm drain system in the area of Wollaston Beach since 1994. Sewers in the Strand area of the beach (near the Rice Road sampling location) were completely separated from the storm drain system by the City of Quincy in 1997. Extensive repairs were also made to drainage systems which affected other areas of the beach in 1998, including repair of cracked sewer lines and service connections, cleaning of outfalls and increased street and catch basin cleaning during the swimming season.

An additional source of potential contamination was MWRA's Nut Island Treatment Plant, which discharged an average of 140 million gallons per day of primary treated sanitary sewage into Quincy Bay (see map). Discharges to the bay ended in July of 1998 when the plant was converted to a headworks facility and flows were transferred to Deer Island Treatment Plant in Winthrop.

3.5.3 Bacterial water quality

General. Wollaston Beach had the poorest water quality of the four beaches in this study, with 71% of all samples meeting the MDC fecal coliform guideline and 85% meeting the MDC *Enterococcus* guideline. Geometric means for both indicators met the State fecal coliform limit and the *Enterococcus* guideline recommended by the USEPA. However, the beach did not comply with the SB criterion of less than 10 percent of fecal coliform samples exceeding the limit of 400 colonies/100 mL. Of the four locations, Sachem Street location had the poorest water quality, and Rice Road had the best water quality.

Table 3-17. Compliance with water quality criteria 1996-2000, Wollaston Beach

Fecal coliform				
Location	% of samples within MDC limit (Limit: single sample ≤ 200 colonies/100 mL)	Compliance with Massachusetts SB standard		
		Geometric mean (Limit: ≤ 200 colonies/100 mL)	Percent of samples greater than 400 colonies/100 mL (Limit: ≤ 10%)	Complies with SB?
All locations	71%	67	19%	No
Milton Street	70%	71	19%	No
Channing Street	65%	110	23%	No
Sachem Street	66%	93	23%	No
Rice Road	85%	28	9%	Yes
Enterococcus				
Location	% of samples within MDC limit (Limit: single sample ≤ 104 colonies/100 mL)	Compliance with USEPA swimming guidelines		
		Geometric mean (Limit: ≤ 35 colonies/100mL)	Complies with geometric mean criterion?	Calculated single sample maximum limit[1]
All locations	85%	13	Yes	135
Milton Street	84%	13	Yes	145
Channing Street	83%	19	Yes	134
Sachem Street	83%	17	Yes	133
Rice Road	91%	8	Yes	119

[1]This value is the upper 75% confidence limit calculated from Wollaston *Enterococcus* counts from all four locations measured during 1996-2000. The limit is unique for each beach in this report.

Using the USEPA criteria of the 75% confidence limit as the single sample maximum, *Enterococcus* counts exceeding 135 colonies/100 mL would result in the posting of swimming advisory. As with the other three beaches, this limit is higher than the alternative guideline of 104 colonies/100 mL recommended by USEPA if data are insufficient to calculate the 75% confidence limit.

Inter-annual variation. Wollaston Beach exhibited a significant trend of improving water quality (after controlling for rainfall) for several years during the monitoring period. For both fecal coliform and *Enterococcus*, counts dropped significantly from 1997 to 1999, with 1999 having significantly lower counts than all other years ($F_{4, 1389} = 4.810$, $p = 0.0007$ for fecal coliform; $F_{4, 1376} = 10.671$, $p < 0.0001$ for *Enterococcus*). Counts in 2000, however, were not significantly different from 1996. In contrast to Carson and Tenean Beaches, which had the highest counts in 1998, Wollaston had the highest counts in 1997. This suggests that repairs made to the sewer system infrastructure after the summer of 1997 and before the 1998 monitoring season may have somewhat mitigated the impact of the unusually wet weather during the summer of 1998. The data also suggest increased contamination from an unknown source in 2000.

Table 3-18. Annual geometric means and range of bacteria counts, Wollaston Beach

Year	Total rainfall for monitoring season[1] (in.)	Fecal coliform		*Enterococcus*	
		Geometric mean	Range	Geometric mean	Range
1996	7.4	64	0 – 8,700	16	0 – 6,300
1997	4.1	171	0 – 66,000	27	0 – 3,680
1998	12.9	73	0 – 7,100	12	0 – 1,870
1999	6.4	27	0 – 7,300	6	0 – 1,200
2000	13.6	71	0 – 19,000	17	0 – 3,930

Bacteria results are in colonies/100 mL. Zero values represent results that were below detection.
[1]Rainfall measured at MWRA's Braintree-Weymouth pump station. Date ranges specified in Section 2.2.

When individual stations were examined for interannual patterns and controlled for the effects of 24-hour rainfall, the Milton Street and Channing Street locations exhibited the strongest trend of improving water quality between 1997 and 1999 ($F_{4, 340} = 3.614$, $p = 0.007$ for *Enterococcus* and $F_{4, 340} = 3.788$, $p = 0.005$ for fecal coliform, Milton Street; $F_{4, 343} = 3.821$, $p = 0.0047$ for *Enterococcus*, Channing Street). Rice Road and Sachem Street had no significant changes in indicator counts across years.

Variation among sampling locations. Figure 3-13 shows the indicator counts at each location for 1996 through 2000. Bacteria counts were significantly different among locations (one-way ANOVA $F_{3, 1390} = 29.81$, $p < 0.0001$ for fecal coliform, $F_{3, 1072} = 11.113$, $p < 0.0001$ for *Enterococcus*). The Milton Street location had significantly lower fecal coliform and *Enterococcus* counts than the Channing Street location ($p = 0.018$ for fecal coliform, $p = 0.015$ for *Enterococcus*). For all years combined, the Rice Road location had significantly lower counts than the other three sites for both fecal coliform and *Enterococcus* ($p < 0.0001$). Rice Road was also the only location at the beach that fully complied with state water quality standards and USEPA guidelines.

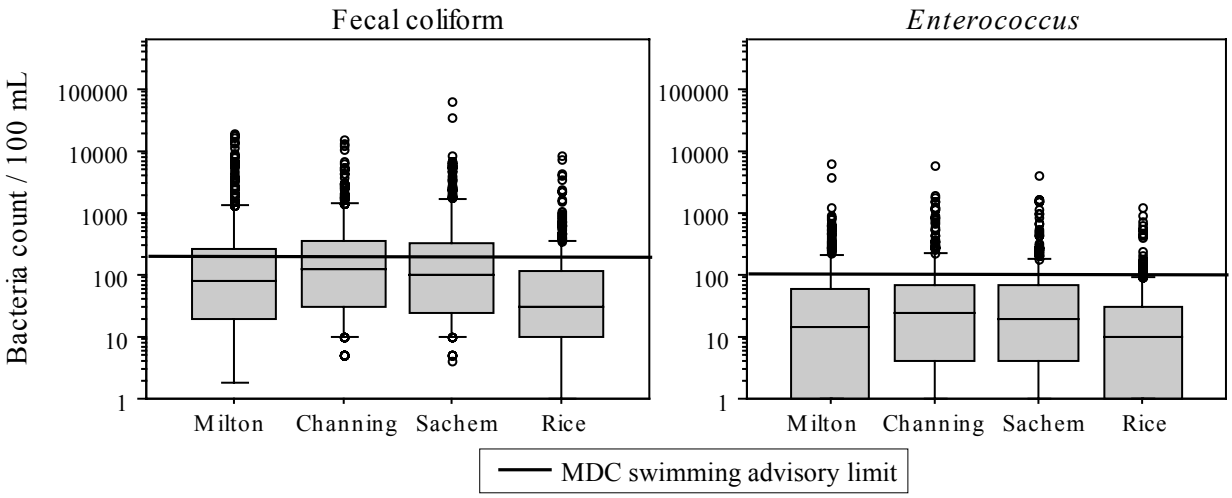

Figure 3-13. Percentile plots of fecal coliform and *Enterococcus* 1996-2000, Wollaston Beach

3.5.4 Relationship of Bacteria and Rainfall

Short term rainfall effects., Wollaston Beach demonstrated a similar, though less dramatic, response to 24-hour rainfall as Tenean Beach. When 24-hour rainfall exceeded 0.2 inches, the geometric mean bacteria counts and/or their 95% confidence intervals exceeded the geometric mean standards for both indicators (Figure 3-14). It should be noted that sample sizes decrease as rainfall increases for each of these categories, since heavy rainfall events are relatively rare (n = 44 for > 0.8 category, n = 12 for 0.6 – 0.8 category, versus n = 910 for the zero rain category). The unusually small sample size of the 0.6 – 0.8 category accounts for the large confidence intervals for this group. It suggests a possible problem with the Braintree-Weymouth rain gauge, since none of the other gauges reported such a small number of rainfall events between 0.6 and 0.8 inches for the five-year monitoring period.

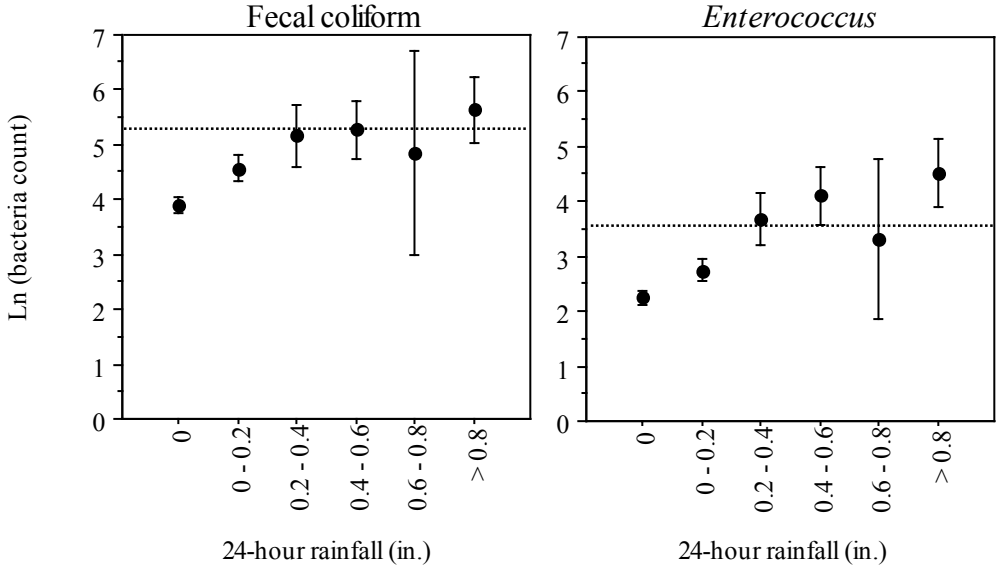

Figure 3-14. Response to 24-hour antecedent rainfall, Wollaston Beach.
Geometric mean and 95% confidence intervals are shown for each rainfall category. Dashed lines are geometric mean limits.

Spearman rank order analysis showed a significant but somewhat weak association between bacteria and rainfall, similar to Carson and Constitution Beaches. Corrected for ties, the r_s was 0.23 ($p<0.0001$) for ln fecal coliform counts and 24-hour rainfall, and $r_s = 0.26$ ($p<0.0001$) for ln *Enterococcus* and 24-hour rainfall.

Linear regression analyses: relationship of fecal coliform and *Enterococcus* to rainfall. The relationship of bacteria counts and rainfall at Wollaston was the weakest of any of the beaches studied, with all R^2 values below 0.05. The cumulative amount of rain falling 48 hours before sample collection demonstrated the best relationship with both indicators ($p < 0.0001$ for both indicators, $R^2 = 0.026$ for fecal coliform, 0.046 for *Enterococcus*). 24-hour antecedent rainfall was somewhat weaker ($p < 0.0001$ for both indicators, $R^2 = 0.018$ for fecal coliform, $R^2 = 0.044$ for *Enterococcus*). As at Constitution Beach, rainfall was more than twice as effective in predicting elevated *Enterococcus* counts as fecal coliform counts.

Analysis by weather condition: dry, damp, wet. Data grouped by the three categories of rainfall condition revealed wide variation in counts within each category, particularly for fecal coliform. Unlike the other beaches where maximum counts differed by at least an order of magnitude between categories, maximum counts at Wollaston were relatively similar, which indicate dry weather sources of contamination. At Channing Street, the highest count occurred in damp weather (in August of 1997). At the cleanest location, Rice Road, the highest counts in the dry and damp categories exceeded the wet category (in 1996 and 1997, respectively).

Table 3-19. Range of bacteria values for each rainfall condition, Wollaston Beach
(results in colonies per 100 mL)

Location	Fecal coliform			*Enterococcus*		
	Dry	Damp	Wet	Dry	Damp	Wet
Milton Street	0 - 19,000	0 - 20,200	0 - 20,000	0 - 830	0 - 3,680	0 - 6,300
Channing Street	0 - 12,800	0 - 15,800	0 - 7,300	0 - 560	0 - 1,550	0 - 5,700
Sachem Street	0 - 35,300	0 - 66,000	0 - 6,600	0 - 3,930	0 - 680	0 - 1,600
Rice Road	0 - 4,160	0 - 7,800	0 - 8,700	0 - 1,200	0 - 750	0 - 880

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories.

Contingency table analyses indicate that despite the similarity in maximum counts across rainfall categories and weak regression analyses, elevated counts do occur more frequently in both damp and wet weather for both indicators than would be due to chance.

Table 3-20. Contingency table, Wollaston Beach

Asterisks indicate significant differences from dry weather. Expected values (results that would be expected if bacteria counts were not affected by rain) appear in small font.

Fecal Coliform

	Dry	Damp***	Wet***	Totals
No. of samples ≤ 200	510 ₄₄₉	398 ₄₁₁	86 ₁₃₃	994
No. of samples > 200	120 ₁₈₁	179 ₁₆₆	101 ₅₄	400
Totals	630	577	187	1394
Percent of samples exceeding limit in each rainfall condition	17%	33%	39%	29%

Enterococcus

	Dry	Damp**	Wet***	Totals
No. of samples ≤ 104	573 ₅₃₄	502 ₄₉₃	112 ₁₆₁	1187
No. of samples > 104	48 ₈₇	71 ₈₀	75 ₂₆	194
Totals	621	573	187	1381
Percent of samples exceeding limit in each rainfall condition	6%	13%	26%	14%

Dry weather is defined as no rainfall within 48 hours prior to sample collection. Wet weather is defined as rain ≥ 0.2 inches within 24 hours prior to sample collection. Damp weather falls between the other two categories. Damp weather falls between the other two categories. Results of chi squared tests comparing dry to damp and dry to wet: *** $p < 0.0001$, χ^2=22.819 for fecal coliform, damp; χ^2=81.220 for fecal coliform, wet; χ^2 = 96.361 for *Enterococcus*, wet. ** p = 0.0077l, χ^2= 7.097 for *Enterococcus*, damp.

The odds of fecal coliform or *Enterococcus* failing to meet limits in wet weather were twelve times those of exceeding in dry weather (OR = 12.3, 95% CI = 7.7, 19.7 for fecal coliform, OR = 12.6, 95% CI = 7.1, 22.2 for *Enterococcus*). In damp weather, the odds of either fecal coliform and *Enterococcus* failing to meet limits were about twice those in dry weather (OR = 1.9, 95% CI = 1.5, 2.5 for fecal coliform, OR = 1.7, 95% CI = 1.1, 2.5 for *Enterococcus*).

4 Discussion

4.1 Water quality

Water quality at Boston Harbor beaches was highly variable, in both wet and dry weather. Despite this variability, all beaches met USEPA water quality guidelines (based on *Enterococcus*), but two beaches did not satisfy the Massachusetts SB standard (based on fecal coliform): Tenean and Wollaston both had more than 10 percent of samples exceeding 400 colonies/100 mL. Tenean beach also failed to meet state and USEPA geometric mean limits in wet weather.

The type and number of wet weather contamination sources were somewhat related to water quality, but not entirely. Wollaston was obviously affected by the eight storm drains located along the beach, but at Carson Beach the seven storm drains/CSOs demonstrated relatively little impact. Tenean had the greatest variety in contamination sources, with the Neponset River apparently having a significant impact. Constitution, with stormwater and CSO discharge as contamination sources, was one of the cleanest beaches.

There was no consistent trend of improving or worsening bacterial water quality over the five years of the monitoring program. At all beaches except Wollaston, the 1998 swimming season had the poorest water quality of the five years, which was the rainiest swimming season of any of the years studied. The lack of a multi-year trend is not surprising, as few significant changes were made in sewer or stormwater systems over this period that might affect water quality. However, the improvements made to sewers and storm drains at or near Wollaston Beach in 1997 did show a short-term improvement in water quality.

4.2 Factors contributing to water quality

Because the contamination sources at Boston beaches are primarily related to rainfall, rainfall was the principal factor examined in this study. The use of the 24-hour and 48-hour antecedent rainfall measures (among others) to correlate rain effects with bacteria counts were only partly successful. These measures were effective at explaining no more than 18% of the variability in bacteria counts, and with the exception of Tenean Beach, all were relatively similar (around 8%). Spearman rank correlation coefficients of bacteria and rain were also significant but weak, with an r_s of about 0.2 (that is, bacteria and rain were correlated about 20% of the time). Nevertheless, contingency table analyses revealed that, in wet weather, bacterial counts did have consistently higher odds of failing to meet limits than in dry weather.

Interestingly, the degree of beach contamination was inversely related to the odds of failing to meet guidelines in wet weather. Carson Beach, the cleanest beach, had the highest odds of failing to meet standards in wet weather, while Wollaston Beach, the dirtiest beach, had the lowest odds of failing standards in wet weather. These results indicate that the dirtier beaches may be more subject to dry weather contamination than cleaner beaches.

Other factors such as tide, sunlight intensity, wind strength and direction also affect water quality. While not discussed at length in this report, each of these factors was examined, and all were found to be weakly associated with indicator counts (results not shown). A logistic regression model including these factors was developed in an effort to predict water quality at each Boston Harbor beach. Factors included in the model were tide, sunlight intensity, wind direction, days since last rain, and rainfall condition (dry or wet). With all factors included, the model was effective at predicting water quality less than half the time. With dry weather contamination removed from the model, successful prediction was increased only to about 60% of the time. Even if this model were highly successful in predicting water quality, it would be unrealistic for a beach manager to obtain information on all factors listed above and employ the model to predict water quality on a

day-to-day basis. Given these challenges, along with the relatively weak predictive power of the model, prediction of water quality based purely on rainfall is a more straightforward approach.

***Enterococcus* vs. fecal coliform: different measures of water quality**

There has been considerable debate in the scientific literature over the selection of an appropriate indicator that can accurately determine if the water is "safe" for swimming. The two indicators used in the MDC monitoring program, *Enterococcus* and fecal coliform, are present in animal and human waste, but this study has demonstrated that each of these indicators were differentially affected by similar conditions. Fecal coliform or *Enterococcus*, used alone, would indicate different levels of sewage contamination.

An indirect measure of contamination is the rate of beach postings, calculated as the percent of samples failing to meet swimming standards (Table 4-1). The single sample limit for *Enterococcus* chosen by a beach manager can change this posting rate. Using methods specified in USEPA's *Ambient Water Quality for Bacteria--1986*, the beach manager can either use the recommended value of 104 colonies/100 mL as the single sample limit, or use sampling results to calculate a beach-specific limit (the 75% confidence limit, calculated using a geometric mean of 35 and the beach-specific standard deviation). The beach-specific limit is dependent upon the variability in *Enterococcus* counts: the larger the standard deviation, the higher the single sample limit. For Boston Harbor beaches, the dirtiest beaches had the largest standard deviation, and thus the highest single sample maximum. Table 4-1 shows the calculated single sample limit for each beach, and the percent of time that each beach would be posted using this limit, compared with the MDC posting guidelines used from 1996 – 2000.

Table 4-1. Comparison of exceedances by indicator

	Enterococcus				**Fecal coliform**
Beach	Single sample limit, calculated	Percent of samples failing to meet calculated limit	Percent of samples failing to meet 104 colonies/100 mL	Percent of samples failing to meet 35 colonies/100 mL	Percent of samples failing to meet 200 colonies/100 mL limit
Constitution	125	5%	6%	18%	9%
Carson	116	8%	9%	17%	15%
Tenean	131	10%	12%	30%	28%
Wollaston	135	11%	13%	33%	28%

Calculation of a beach-specific limit results in a *smaller* percentage of sample exceedances for the beaches with poorer water quality, and is thus less protective. Either *Enterococcus* limit is less sensitive than fecal coliform, particularly at the more contaminated beaches. For Tenean and Wollaston beaches, nearly 30% of fecal coliform samples fail to meet the limit; however only about 10% of the samples fail to meet either *Enterococcus* limit. Given that all beaches already satisfied USEPA's other *Enterococcus* criteria (geometric mean < 35 colonies/100 mL), use of the *Enterococcus* single sample limit to trigger swimming advisories would result in a reduction in the number of beach postings.

While not recommended by the USEPA, a single sample *Enterococcus* limit of 35 colonies/100 mL was included in Table 4-1 for comparison. An *Enterococcus* concentration of 35 colonies/100 mL has been linked to increased risk of bather illness, although this value is recommended as a geometric mean limit rather than as a single sample limit (USEPA 1986). Interestingly, the percentage of samples with counts above 35 colonies/100 mL *Enterococcus* are similar to the percentage of samples with counts of 200 colonies/100 mL fecal coliform.

Implications for use of *Enterococcus* as sole indicator of water quality

The USEPA has recommended that *Enterococcus* as the indicator of choice to measure water quality in marine swimming areas. In early 2001, the Massachusetts Department of Public Health and MDC adopted these guidelines, and fecal coliform was eliminated as an indicator. The former guidelines for fecal coliform were nevertheless included in this report for the sake of comparing indicators, and fecal coliform is still used by the Massachusetts Department of Environmental Protection in its water body classification. The inclusion of fecal coliform in this study demonstrates that use of *Enterococcus* alone may be inadequate in determining water quality at a beach:

- Results of the monitoring indicate that at less contaminated beaches, *Enterococcus* counts respond differently than fecal coliform to rainfall, particularly following small rainstorms, when fecal coliform is elevated but *Enterococcus* is not.
- At beaches with known sewage contamination, *Enterococcus* counts are lower than fecal coliform, indicating that *Enterococcus* is a less sensitive indicator of sewage in the water than fecal coliform.
- The lower sensitivity of *Enterococcus* means that counts often fall below detection (generally counts below 5 colonies per 100 mL are reported by the laboratory as non-detects). This presents problems with statistical analysis, as the data is skewed by the non-detects, the distribution of counts is not normal, and conventional statistical techniques (i.e. those that assume that the data is normally distributed) cannot be applied reliably. Thus using the upper 75% confidence interval as a limit to post swimming advisories is problematic since it assumes a normal distribution of indicator counts. Nonparametric analyses may be more appropriate.

4.3 Management of Boston Harbor beaches: recommendations

Ongoing bacteria water quality monitoring is an essential component of beach management since it allows managers to identify changes in water quality, either from the introduction of new contamination sources or the removal of existing sources. However, because of the 24-hour delay in obtaining bacteria results, the results are not very accurate for short-term, day-to-day evaluation of water quality for posting swimming advisories. Table 4-2 shows the percent of time that *Enterococcus* counts exceeded 104 col/100 ml, and that beaches had been correctly posted based on the previous day's water sample compared to using an antecedent rain criteria. The table shows the percent of time that bacteria counts were high (in retrospect), or that rainfall exceeded 0.2 inches, and that the beaches were posted. On average, beaches were actually posted on only about one quarter of the days when the water quality did not meet the swimming standard. Using the simple rainfall model would have doubled the number of times the beaches were correctly posted when the water did not meet swimming standards.

Table 4-2. Percent of time Boston Harbor beaches would have been correctly posted based on bacteria results compared to posting based on rainfall.

If posting based on previous day's *Enterococcus* > 104 col/100 ml	If posting based on antecedent rain > 0.2 inches
24.6%	41.3%

A statistical model which takes into account both sensitivity and specificity of predictor variables for beach water quality is being developed by the authors with the Harvard School of Public Health (Stanley et al. in preparation). However, a simple way to improve the sensitivity of beach posting for the day-to-day management of beaches to use rainfall measures, rather than the results of bacteria sampling from the previous day. Rainfall data are available in real-time, and once the relationship of bacteria levels to rainfall is

understood, antecedent rainfall is a more reliable and efficient way to determine whether or not a beach should be posted. Table 4.3 shows thresholds of antecedent 24-hour rainfall that could be used by beach managers to trigger precautionary beach postings.

Table 4-3. Recommended rainfall thresholds for precautionary beach postings

Beach	24-hour antecedent rainfall (inches)
Constitution	0.4
Carson	0.6
Tenean	0.2
Wollaston	0.2

Bacteria sampling remains a crucial part of beach monitoring: it enables beach managers to understand under what conditions beaches generally fail to meet swimming standards, it will detect problems (and improvements) due to changes in the sewerage and drainage system, and it can help identify non-rain-related sources of contamination. We recommend that re-opening of beaches after rainfall-related postings should be based on bacteria sampling results. However, for beach management on a daily basis, amount of antecedent rainfall is a more accurate indicator of beach water quality at these Boston Harbor beaches than the previous day's bacteria result.

ACKNOWLEDGEMENTS

An EMPACT grant from the USEPA provided staff support that allowed much of the data presented in this report to be collected and analyzed. We are grateful to Lisa Wong and Nicole O'Neill at the MWRA Central Laboratory for providing laboratory assistance. Andrea Rex, Lise Marx and Bill Hartford of MWRA and Matthew Liebman of USEPA provided advice and comments on this report. The opinions expressed in this report are those of the authors, and do not reflect official policy of MWRA, USEPA, MADEP, MDC, or MADPH.

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APPENDIX

Appendix Table 1. Summary of linear regression results of fecal coliform count and cumulative rainfall, grouped by beach

For all equations, $p < 0.0001$ unless otherwise indicated.

Cumulative rainfall measure	Constitution		Carson		Tenean		Wollaston	
	Equation	R^2	Equation	R^2	Equation	R^2	Equation	R^2
1-day rain†	y = 3.014 + 1.581x	0.043	y = 2.447 + 1.385x	0.037	y = 4.219 + 1.314x	0.028	y = 9.18 + 0.362x *	0.004
2-day rain†	y = 2.922 + 1.309x	0.058	y = 2.325 + 1.335x	0.073	y = 4.004 + 1.816x	0.12	y = 4.114 + 0.475x	0.014
3-day rain†	y = 2.854 + 1.158x	0.063	y = 2.218 + 1.327x	0.099	y = 3.959 + 1.399x	0.114	y = 4.093 + 0.391x	0.014
48-hour rain‡	y = 2.926 + 1.327x	0.051	y = 2.245 + 1.807x	0.109	y = 3.918 + 2.275x	0.179	y = 4.068 + 0.697x	0.026
24-hour rain‡	y = 2.958 + 2.134x	0.062	y = 2.346 + 2.369x	0.093	y = 4.045 + 3.044x	0.162	y = 4.13 + 0.815x	0.018
12-hour rain‡	y = 3.021 + 3.563x	0.057	y = 2.43 + 3.462x	0.071	y = 4.201 + 3.327x	0.059	y = 4.147 + 1.575x	0.019
6-hour rain‡	y = 3.053 + 5.255x	0.062	y = 2.489 + 4.844x	0.039	y = 4.237 + 6.31x	0.047	y = 4.165 + 2.617x	0.016
3-hour rain‡	y = 3.089 + 7.02x	0.043	y = 2.52 + 6.43x	0.022	y = 4.275 + 8.228x	0.029	y = 4.181 + 3.292x	0.013

* $p = 0.0177$

† total rainfall from midnight to midnight of each day, including entire day of sample collection

‡ total rainfall in x hours prior to sample collection

Appendix Table 2. Summary of linear regression results of *Enterococcus* count and cumulative rainfall, grouped by beach

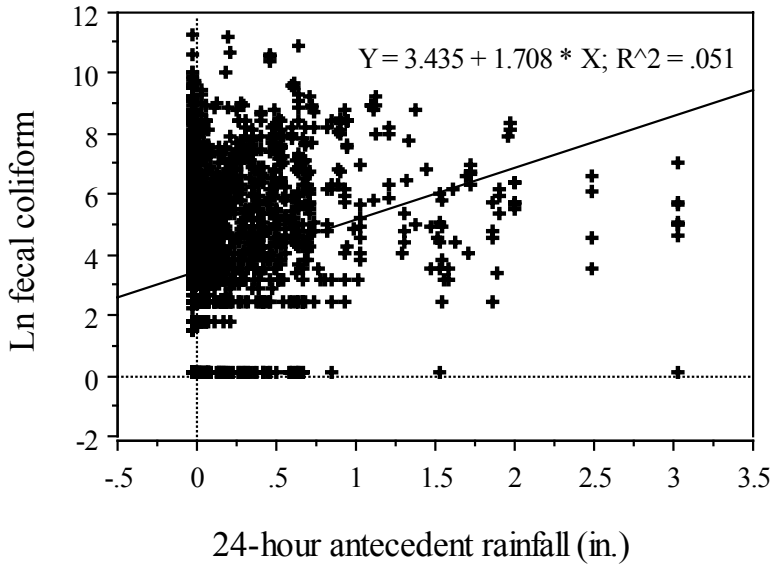
For all equations, $p < 0.0001$ unless otherwise indicated.

Cumulative rainfall measure	Constitution		Carson		Tenean		Wollaston	
	Equation	R^2	Equation	R^2	Equation	R^2	Equation	R^2
1-day rain†	y = 1.683 + 1.523x	0.05	y = 1.522+ 0.969x	0.024	y = 2.327 + 1.197x	0.021	y = 2.545 + 0.476x *	0.008
2-day rain†	y = 1.554 + 1.469x	0.093	y = 1.43 + 0.966x	0.05	y = 2.151 + 1.547x	0.08	y = 2.462 + 0.604x	0.027
3-day rain†	y = 1.485 + 1.272x	0.096	y = 1.358 + 0.937x	0.065	y = 2.086 + 1.286x	0.088	y = 2.433 + 0.503x	0.028
48-hour rain‡	y = 1.524 + 1.693x	0.104	y = 1.388 + 1.22x	0.065	y = 2.071 + 1.976x	0.124	y = 2.413 + 0.834x	0.046
24-hour rain‡	y = 1.557 + 2.795x	0.134	y = 1.442 + 1.736x	0.066	y = 2.157 + 2.89x	0.134	y = 2.467 + 1.169x	0.044
12-hour rain‡	y = 1.65 + 4.415x	0.111	y = 1.505 + 2.517x	0.049	y = 2.283 +3.69x	0.066	y = 2.513 + 1.806x	0.031
6-hour rain‡	y = 1.697 + 6.248x	0.111	y = 1.555 + 3.199x	0.022	y = 2.31 + 7.824x	0.067	y = 2.516 + 3.831x	0.043
3-hour rain‡	y = 1.741 + 8.123x	0.073	y = 1.577 + 4.138x *	0.012	y = 2.364 + 9.375x	0.034	y = 2.544 +4.463x	0.028

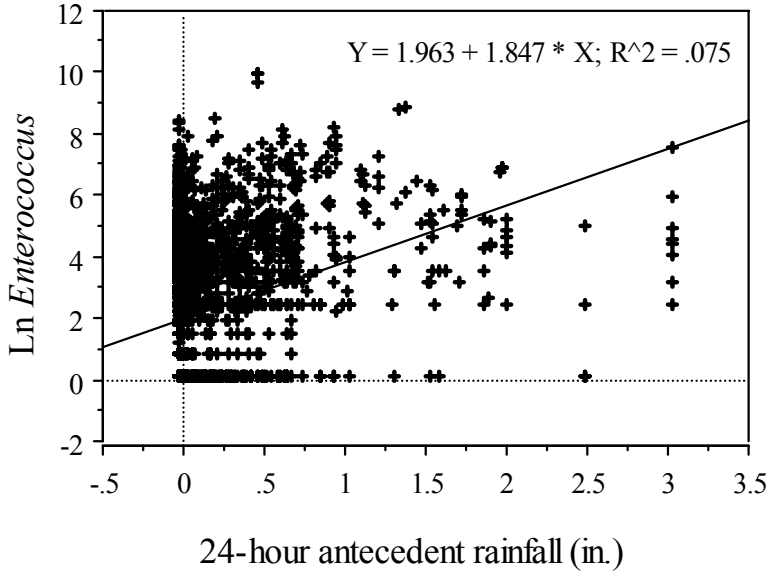
* $0.0004 < p < 0.0006$

† total rainfall from midnight to midnight of each day, including entire day of sample collection

‡ total rainfall in x hours prior to sample collection



Appendix Figure 1. Sample regression plot, fecal coliform from all beaches and 24-hour antecedent rainfall.



Appendix Figure 2. Sample regression plot, *Enterococcus* from all beaches and 24-hour antecedent rainfall.

Using Receiver Operating Characteristic (ROC) Curves to Determine a Rain Threshold for Identifying Wet and Dry Days

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ROC curves are used to determine which threshold value for several measures of rainfall best discriminates between wet and dry days. Since the definition of a wet day is inexact and no historical data are available, the analysis described here uses the activation of any of the six monitored CSOs as a surrogate for a wet day and uses CSO monitoring data from 1992 to 1999. Recognizing that CSO activations generally require more rain than a wet day, the threshold is chosen by selecting a lower than optimum value of rainfall that still has high discriminatory accuracy for identifying CSO activations. A threshold value of 0.15 inches of rain over two days is chosen.

When analyzing receiving water quality data, it is sometimes desirable to identify days when recent rainfall has likely affected water quality ("wet days"). In the past the MWRA has used several different rainfall thresholds and rainfall measures to decide which days are wet days. Rex has shown a relationship between the sum of three or four days of rain and bacteria levels in several regions of Boston Harbor and its tributary rivers.[3] Rex also used a threshold of 0.1 inches of rain over a two day period to classify days into wet and dry in an analysis of bacteria levels in the Neponset River and Dorchester Bay.[4] Gong et al. classified days with values of the root sum of squares of three days of rainfall greater than 0.25 inches as days of heavy rain for analyzing CSO receiving water data.[5] [6]

For this work, the amount of rainfall that best discriminates between days when any of the six monitored CSO facilities activate and days where no CSO facility activate is determined. (The six facilities are Somerville Marginal, Cottage Farm, Prison Point, Commercial Point, Constitution Beach and Fox Point.) Four measures of rainfall are analyzed; rain falling on the day of interest (one day sum), the sum of rain on the day of and the day before the day of interest (two day sum), the sum of

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[3] Rex AC. 1993. **Combined sewer overflow receiving water monitoring: Boston Harbor and its tributary rivers**. Boston: Massachusetts Water Resources Authority. Report ENQUAD 1993-04. 210 p.

[4] Rex AC. 1991. **Combined** sewer **overflow receiving water monitoring: June 1989-October 1990**. Boston: Massachusetts Water Resources Authority. Report ENQUAD 1991-02. 337 p. page 4-11

[5] Gong G, Lieberman J, McLaughlin D. 1996. **Statistical analysis of combined sewer overflow receiving water data, 1989-1995**. Boston: Massachusetts Water Resources Authority. Report ENQUAD 1996-09. 52 p.

[6] Gong G, Lieberman J, McLaughlin D. 1998. **Statistical analysis of combined sewer overflow receiving water data, 1989-1996**. Boston: Massachusetts Water Resources Authority. Report ENQUAD 1998-09. 120 p.

rain on the day of and the two days before the day of interest (three day sum), and the square root of the sum of squares of the daily rain on the day of and the two days prior to the day of interest (three day RSS).

CSO discharge data from 1992 to 1999 was obtained from two sources. CSO discharge information from January 1, 1992 to November 22, 1997 was obtained from a spreadsheet assembled by Jennifer Sullivan (Csoflows.wk4) and information from November 23, 1997 to January 1, 2000 was obtained from the CSO reporting application database on OPS. Daily NOAA rainfall data from Logan Airport was obtained from the EM&MS database.

This report uses ROC curves to determine a threshold value based on the specificity and sensitivity of that threshold in predicting CSO events. ROC curves are useful for identifying a value (or threshold) of a continuous exposure that best discriminates between two dichotomous outcomes. ROC curves are parametric curves: sensitivity is plotted against one minus specificity for many possible values of the threshold. The sensitivity is the fraction of the positive outcomes that have an exposure level above a given threshold. The specificity is the fraction of negative outcomes that have an exposure level below a given threshold. The best threshold has both high specificity and high sensitivity. On an ROC curve (because the ordinate is one minus specificity) the best threshold value occurs near the upper left corner of the plot.

The area under an ROC curve is always between 0.5 and 1.0 and represents the chance that, if one took at random a day with a positive outcome and one with a negative outcome, the positive outcome would have the greater exposure. If the area under the curve is 0.5 then there is no threshold for that exposure that does any better than chance at discriminating between the two outcomes. If the area is 1.0, then there is a threshold that predicts perfectly the outcome. A Wilcoxon Rank-Sum test is used to determine if the area under the ROC curve is different from 0.5. (The Wilcoxon test statistic is the area under an ROC curve minus one half, divided by the standard error.)

SPSS is used to generate the ROC curves for the CSO/Rain data and evaluate the areas and their significance. Over the eight-year period, there were 323 days where there was at least one CSO discharge and 2580 days where there were no discharges. Figure 1 shows the ROC curves for all four measures of rainfall. The area under each curve with associated p values and 95% confidence intervals are shown in table 1. There is very convincing evidence that all four measures of rain are better than chance at predicting a CSO event (all four p values <0.001). One day and two day rain appear to be better measures than the three day measures and either can be used with equal accuracy in predicting days with CSO discharges.

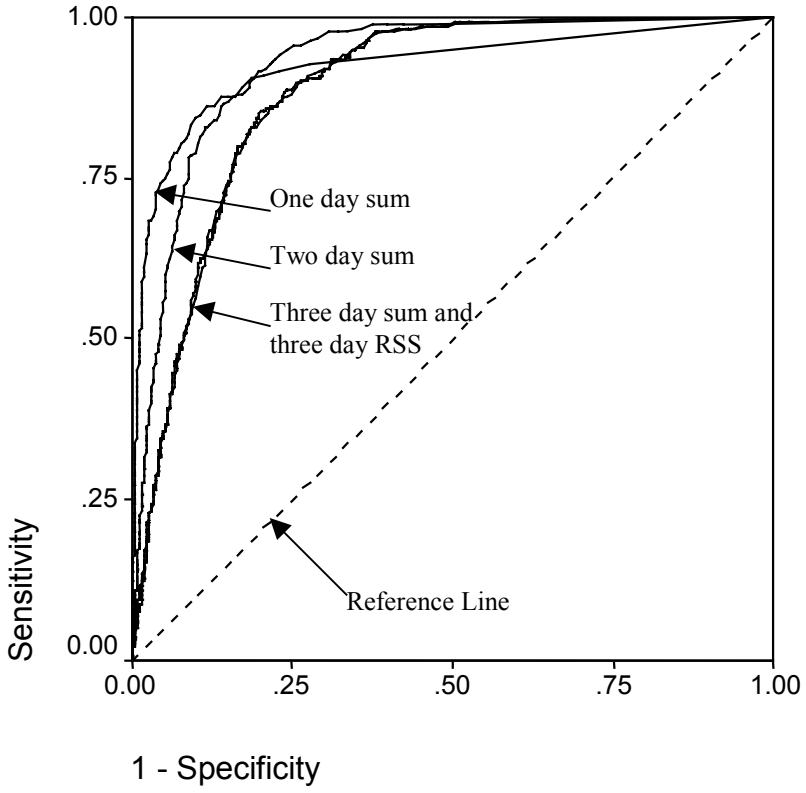

Figure 1: ROC curves for predicting any CSO activation using four measures of rain

Area Under the Curve

Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
ONE_DAY_RAIN	.925	.010	.000	.906	.944
TWO_DAY_RAIN	.928	.006	.000	.915	.940
THREE_DAY_RAIN	.888	.007	.000	.874	.902
THREE_DAY_RSS_RAIN	.888	.007	.000	.874	.902

The test result variable(s): ONE_DAY_RAIN, TWO_DAY_RAIN, THREE_DAY_RAIN, THREE_DAY_RSS_RAIN has at least one tie between the positive actual state group and the negativ actual state group. Statistics may be biased.

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Table 1: Area under four ROC curves with associated p values and 95% confidence interval.

Because the one and two day curves cross we can form a composite curve consisting of the outermost portions (up and to the left) of both curves and pick our threshold based on the sensitivity/specificity tradeoff along this composite curve. This curve is shown in figure 2. (Note that this curve is composed

of data from two different parameters, the area beneath the curve does not have the same meaning as an ROC curve. This curve just describes the locus of sensitivity/specificity pairs available to us.)

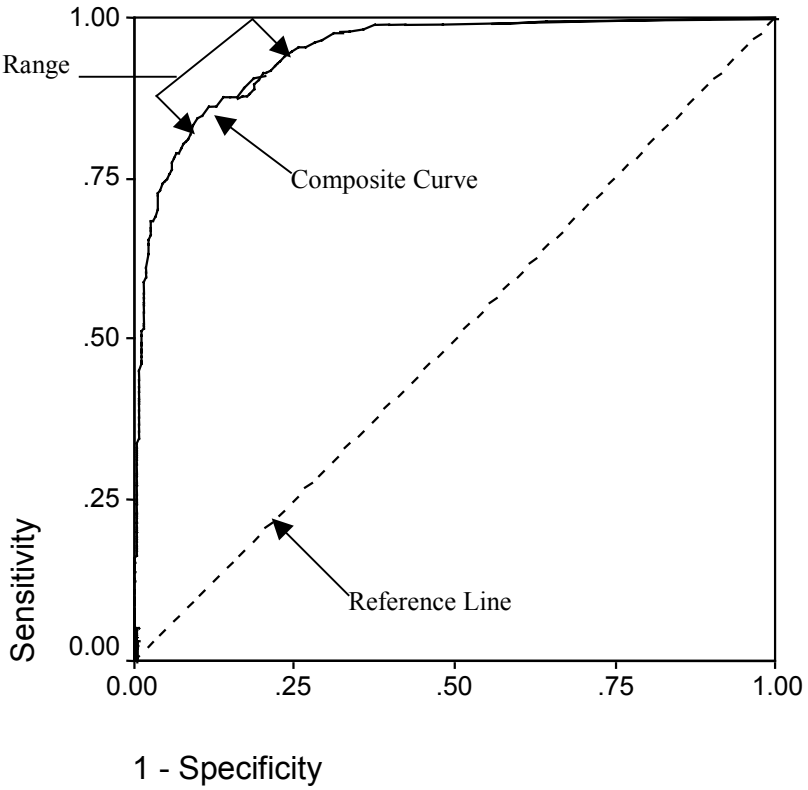

Figure 2: Composite curve showing locus of available sensitivity/specificity pairs

If specificity and sensitivity were equally desirable, then the threshold could be chosen by locating the point closest to the upper left corner of the plot. In this case, however, we are interested in capturing not only days with a CSO activation, but also days when a particular rain event had any impact on the receiving waters (a "wet" day). CSOs are likely to occur less frequently than wet days and occur on days with more rainfall. Thus predicting CSO events will lead to a greater threshold value than needed for predicting wet days. To account for this, we decide to look at lower threshold values that still do a good job at predicting CSO discharges.

As the rainfall threshold value decreases on the ROC curve, the sensitivity rises and the specificity falls. For the composite curve in figure 2, the region where sensitivity ranges between about 0.85 and 0.95 is fairly linear with a slope of about 1; we lose about one unit of specificity for every unit of sensitivity we gain. Outside of this range is a region of diminishing returns.

Table 3 shows the actual values for the composite ROC curve along with the corresponding threshold values in the linear region of interest. We see that the two day sum threshold ranges between 0.13 and 0.15 while the one day sum threshold ranges between 0.05 and 0.11. If we maximize our sensitivity in

this linear range, we end up with a threshold of two day rain of 0.13. Acknowledging the imprecision of this last step, a two day rainfall sum of 0.15 was chosen both to obtain a "round" number and to stay a little closer to the unbiased optimum point.

Threshold type	Threshold value (inches)	1-Specificity	Sensitivity
Two day Sum	0.13	0.24	0.95
	0.14	0.23	0.94
	0.15	0.22	0.93
	0.16	0.22	0.93
	0.17	0.22	0.93
	0.18	0.21	0.92
	0.19	0.20	0.92
	0.20	0.20	0.92
	0.21	0.19	0.90
One Day Sum	0.05	0.17	0.89
	0.06	0.16	0.88
	0.07	0.15	0.88
	0.08	0.14	0.88
	0.09	0.13	0.86
	0.10	0.12	0.86
	0.11	0.11	0.85

Table 3: Coordinates and threshold values for linear range of composite ROC curve

It is interesting to look at the positive and negative predictive ratio of the chosen threshold. The positive predictive ratio (PPR) is the number of true positive events divided by the total number of positive events predicted by the threshold. The negative predictive ratio (NPR) is the total number of true negative events divided by the total number of negative events predicted by the threshold. Because a CSO discharge only occurs on 11% of the days during the period studied, the ability to predict negative events will always be greater. In the extreme, just predicting every day to be a negative event creates a negative predictive ratio of 0.89.

Table 4 shows the predictive ratios for the sensitivity/specificity pairs given in table 3. We see that for all the values of the thresholds under consideration, the we are correct when predicting a CSO discharge only one third to one half of the time while our chances of being right given a negative prediction is near 98%. For the threshold chosen, PPR = 35% and NPR=99%. Since we are interested in wet days and not CSO events, the low PPR is not as great a concern. In order to obtain a higher PPR, we would need to miss some actual events (lowering our sensitivity) in order not to mistakenly classify a larger number of non-events as events.

Threshold type	Threshold value (inches)	1-Specificity	Sensitivity	Positive Predictive Ratio	Negative Predictive Ratio
Two day Sum	0.13	0.24	0.95	0.331	0.992
	0.14	0.23	0.94	0.338	0.990
	0.15	0.22	0.93	0.346	0.989
	0.16	0.22	0.93	0.346	0.989
	0.17	0.22	0.93	0.346	0.989
	0.18	0.21	0.92	0.354	0.987
	0.19	0.2	0.92	0.365	0.988
	0.2	0.2	0.92	0.365	0.988
	0.21	0.19	0.9	0.372	0.985
One Day Sum	0.05	0.17	0.89	0.396	0.984
	0.06	0.16	0.88	0.408	0.982
	0.07	0.15	0.88	0.423	0.983
	0.08	0.14	0.88	0.440	0.983
	0.09	0.13	0.86	0.453	0.980
	0.1	0.12	0.86	0.473	0.980
	0.11	0.11	0.85	0.492	0.979

Table 4: Positive and Negative Predictive Ratios for Thresholds Being Considered

Finally, it is important to consider that the ROC analysis is only useful if the system under consideration does not change over time. Because of the improvements in the CSO infrastructure, the chosen threshold will very likely overpredict the number of future CSO events. Again, since we are predicting wet days and not CSO events, this is less of an issue for this analysis. We assume here that in the past CSOs discharged often on wet days and in the future they will discharge only rarely on wet days so we use past data to identify wet days. Future work could be done to look for a threshold if only data from earlier years, say 1992 to 1996, are included

Appendix Table 3: Constitution Beach Raw Data

Date	24 hr rainfall (in.) Chelsea Creek Headworks	Fecal Coliform (colonies/100 mL) North MDC16	Fecal Coliform (colonies/100 mL) Bathhouse MDC17	Fecal Coliform (colonies/100 mL) South MDC18	*Enterococcus* (colonies/100 mL) North MDC16	*Enterococcus* (colonies/100 mL) Bathhouse MDC17	*Enterococcus* (colonies/100 mL) South MDC18
12-Jun-96	0.01	22	20	<5	8	6	2
19-Jun-96	0	20	475	516	<2	15	21
20-Jun-96	0.09	5	286	912	10	15	124
26-Jun-96	0	20	5	10	10	20	12
27-Jun-96	0	5	5	25	11	<2	4
1-Jul-96	0.05	5	5	5	11	14	7
2-Jul-96	0	5	5	5			
8-Jul-96	0	<10	<10	<10	<10	<10	10
9-Jul-96	0.04	20	30	70	<10	10	<10
10-Jul-96	0.24	10	15	5	47	14	8
11-Jul-96	0	5	5	5	7	10	59
12-Jul-96	0	<5	<5	10	<2	10	<10
13-Jul-96	1.6	140	280	350	150	400	470
14-Jul-96	1.57	120	40	10	140	90	30
15-Jul-96	0	20	<10	600	<10	10	80
16-Jul-96	0	50	30	10	<10	10	<10
17-Jul-96	0	26	25	10	8	10	4
18-Jul-96	0	45	40	32	17	4	<2
19-Jul-96	0	50	40	7400	40	20	260
20-Jul-96	0.04	40	80	<10	<10	<10	<10
21-Jul-96	0	<10	<10	<10	10	<10	<10
22-Jul-96	0	10	<10	<10	<10	<10	<10
23-Jul-96	0	110	2700	300	<10	390	20
24-Jul-96	0.66	60	88	102	130	30	156
25-Jul-96	0	90	75	30	210	381	610
26-Jul-96	0.08	30	30	30	1080	820	1110
27-Jul-96	0.01	20	5	5	5	10	10
28-Jul-96	0	10	5	5	5	5	<2
29-Jul-96	0	40	10	10	20	<10	10
30-Jul-96	0	20	20	40	10	20	10
2-Aug-96	0.01	210	20	20	50	<10	20
3-Aug-96	0	80	<10	50	<10	<10	30
4-Aug-96	0	200	10	20	10	<10	10
5-Aug-96	0	10	20	390	<10	<10	350
6-Aug-96	0	<10	10	<10	<10	<10	10
7-Aug-96	0	40	30	<10	10	10	10
8-Aug-96	0	35	30	35			
10-Aug-96	0.17	50	90	170	<10	20	20
11-Aug-96	0	<10	10	10	<10	<10	<10
12-Aug-96	0	20	20	<10	10	<10	<10
13-Aug-96	0.16	1600	280	10	40	10	<10
14-Aug-96	0.08	20	12	30	129	290	65
15-Aug-96	0	30	25	138	52	44	110
16-Aug-96	0	<10	1100	20	<10	180	<10
17-Aug-96	0	30	20	20	10	<10	20
18-Aug-96	0	20	50	<10	<10	<10	<10
19-Aug-96	0	20	30	<10	10	10	<10
20-Aug-96	0	20	10	10	10	<10	<10
21-Aug-96	0	20	25	12	20	<2	20
23-Aug-96	0	30	<10	<10	30	<10	<10
24-Aug-96	0.48	32000	36400	28000	18300	18000	13200

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 3: Constitution Beach Raw Data

Date	24 hr rainfall (in.) Chelsea Creek Headworks	Fecal Coliform (colonies/100 mL) North MDC16	Fecal Coliform (colonies/100 mL) Bathhouse MDC17	Fecal Coliform (colonies/100 mL) South MDC18	*Enterococcus* (colonies/100 mL) North MDC16	*Enterococcus* (colonies/100 mL) Bathhouse MDC17	*Enterococcus* (colonies/100 mL) South MDC18
25-Aug-96	0	120	20	20	10	<10	<10
26-Aug-96	0	20	40	<10	10	30	<10
27-Aug-96	0	140	20	80	130	20	80
28-Aug-96	0.1	25	30	28	225	78	402
29-Aug-96	0.17	195	20	30	<2	70	<2
30-Aug-96	0	20	40	44	95	85	28
31-Aug-96	0	10	10	10			
1-Sep-96	0	180	30	30			
18-Jun-97	0.02	342	248	165	26	16	8
19-Jun-97	0.36	40	58	65	8	4	2
25-Jun-97	0	5	5	40	<2	<2	8
26-Jun-97	0	30	10	25	8	2	10
30-Jun-97	0	465	390	225	4	2	4
1-Jul-97	0	<10	<10	<10	<10	<10	<10
2-Jul-97	0.01	760	390	<5	100	30	<2
3-Jul-97	0.06	40	35	70	6	6	10
4-Jul-97	0.06	20	<10	<10	10	10	10
5-Jul-97	0	<10	<10	<10	<10	<10	50
6-Jul-97	0	10	<10	<10	<10	<10	<10
7-Jul-97	0	<10	<10	290	<10	<10	10
8-Jul-97	0	390	20	<10	80	10	<10
9-Jul-97	0	5	<5	<5	<2	14	<2
10-Jul-97	0.07	1330	15	185	26	94	16
11-Jul-97	0	<10	<10	10	<10	10	<10
12-Jul-97	0	<10	<10	<10	<10	<10	<10
13-Jul-97	0	<10	20	<10	<10	20	40
14-Jul-97	0	<10	<10	<10	<10	<10	<10
15-Jul-97	0	<10	<10	10	10	30	<10
16-Jul-97	0.06	90	480	80	92	640	110
17-Jul-97	0	1060	1430	2350	30	26	38
18-Jul-97	0.01	40	20	20	<2	<2	<2
19-Jul-97	0	5	20	40	2	20	2
20-Jul-97	0	20	60	40	<10	<10	10
21-Jul-97	0	<10	<10	<10	<10	<10	<10
22-Jul-97	0.07	10	<10	<10	<10	<10	10
23-Jul-97	0	585	640	540	18	6	90
24-Jul-97	0	5	20	30	4	8	2
25-Jul-97	0.044	10	5	10	16	6	2
26-Jul-97	0.01	<10	<10	<10	10	<10	<10
27-Jul-97	0	70	10	<10	100	40	<10
28-Jul-97	0	20	<10	<10	20	110	10
29-Jul-97	0	10	90	120	40	<10	20
30-Jul-97	0	430	390	555	12	14	8
31-Jul-97	0	265	235	110	14	10	10
1-Aug-97	0	5	25	15	2	<2	4
2-Aug-97	0	<10	<10	10	<10	<10	<10
3-Aug-97	0	<10	<10	<10	<10	<10	<10
4-Aug-97	0.71	10	60	40	40	20	40
5-Aug-97	0.1	<10	<10	10	10	<10	<10
6-Aug-97	0	80	150	125	2	4	4
7-Aug-97	0	5	20	25	4	<2	<2

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 3: Constitution Beach Raw Data

Date	24 hr rainfall (in.) Chelsea Creek Headworks	Fecal Coliform (colonies/100 mL) North MDC16	Fecal Coliform (colonies/100 mL) Bathhouse MDC17	Fecal Coliform (colonies/100 mL) South MDC18	*Enterococcus* (colonies/100 mL) North MDC16	*Enterococcus* (colonies/100 mL) Bathhouse MDC17	*Enterococcus* (colonies/100 mL) South MDC18
8-Aug-97	0	<10	30	<10	<10	10	<10
9-Aug-97	0.21	<10	10	30	<10	<10	<10
10-Aug-97	0.21	120	160	370	10	20	20
11-Aug-97	0	20	50	60	<10	10	20
12-Aug-97	0.01	20	20	10	<10	<10	<10
13-Aug-97	0	220	430	95	14	22	60
14-Aug-97	0.64	140	115	160	84	22	58
15-Aug-97	0	<10	130	10	<10	20	10
16-Aug-97	0	30	40	10	<10	10	10
17-Aug-97	0	30	10	<10	20	<10	30
18-Aug-97	0.57	10	20	20	20	<10	10
19-Aug-97	0	10	20	10	10	<10	<10
20-Aug-97	0	85	285	750	6	18	32
21-Aug-97	0.39	50	360	770	50	336	390
22-Aug-97	0.7	70	10	10	110	40	70
23-Aug-97	0.02	10	20	90	<10	270	<10
24-Aug-97	0	<10	90	<10	<10	20	10
25-Aug-97	0	<10	20	10	<10	<10	<10
26-Aug-97	0	20	140	20	10	10	<10
28-Aug-97	0	175	125	115	26	24	30
29-Aug-97	0.01	10	30	350	<10	<10	40
30-Aug-97	0.02	<10	10	<10	<10	<10	<10
31-Aug-97	0	<10	20	70	<10	20	<10
10-Jun-98	0	5	<5	20	2	2	2
17-Jun-98	0.1	1360	450	550	144	96	136
18-Jun-98	0.16	1000	370	1360	155	230	400
24-Jun-98	0.02		105	60		32	8
25-Jun-98	0.01	3080	2920	75	360	460	50
26-Jun-98	0.55	65	35	40	42	16	4
30-Jun-98	0	80	80	30	2	<2	20
30-Jun-98	0.23	36900	61600	40	2290	4280	<10
1-Jul-98	2.03	270	245	215	156	110	92
3-Jul-98	0	<10	20	40	<10	<10	10
4-Jul-98	0	1290	<10	<10	100	<10	<10
5-Jul-98	0.03	40	20	110	30	10	20
6-Jul-98	0	20	10	<10	20	10	10
7-Jul-98	0	<10	20	20	<10	<10	<10
8-Jul-98	0	50	1040	1140	<2	2	50
9-Jul-98	0.01	5	<5	10	4	4	2
10-Jul-98	0	20	<10	5	<10	10	10
11-Jul-98	0	210	100	70	30	20	60
12-Jul-98	0	100	20	<10	20	40	20
13-Jul-98	0	3500	300	20	320	20	20
14-Jul-98	0	<10	20	20	<10	10	<10
15-Jul-98	0	25	10	15	20	<2	<2
16-Jul-98	0	90	30	40	6	2	4
17-Jul-98	0	<10	<10	<10	<10	<10	10
18-Jul-98	0.01	<10	10	10	<10	10	<10
19-Jul-98	0	10	<10	10	<10	<10	10
20-Jul-98	0	<10	40	50	<10	<10	<10
21-Jul-98	0.32	40	20	55	10	10	<10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 3: Constitution Beach Raw Data

Date	24 hr rainfall (in.) Chelsea Creek Headworks	Fecal Coliform (colonies/100 mL) North MDC16	Fecal Coliform (colonies/100 mL) Bathhouse MDC17	Fecal Coliform (colonies/100 mL) South MDC18	*Enterococcus* (colonies/100 mL) North MDC16	*Enterococcus* (colonies/100 mL) Bathhouse MDC17	*Enterococcus* (colonies/100 mL) South MDC18
22-Jul-98	0	280	420	200	30	64	14
23-Jul-98	0	20	15	35	2	2	2
24-Jul-98	0.59	50	90	70	10	50	30
25-Jul-98	0	<10	<10	20	<10	<10	<10
26-Jul-98	0	<10	10	10	<10	<10	<10
27-Jul-98	0	4700	30	<10	360	<10	10
28-Jul-98	0	<10	20	60	10	<10	<10
29-Jul-98	0	<5	<5	5	<2	<2	2
30-Jul-98	0.24	960	800	1080	36	24	2
31-Jul-98	0.63	11500	13700	13100	2910	1870	980
1-Aug-98	0.2	10	30	30	<10	<10	<10
2-Aug-98	0	20	10	<10	<10	<10	<10
3-Aug-98	0	10	10	30	<10	<10	10
4-Aug-98	0	10	20	10	10	<10	10
5-Aug-98	0	235	315	405	2	46	26
6-Aug-98	0	170	245	150	24	18	10
7-Aug-98	0.01	10	60	70	10	<10	<10
8-Aug-98	0	10	70	10	10	30	<10
9-Aug-98	0	10	40	90	<10	10	<10
10-Aug-98	0	10	<10	<10	10	10	<10
11-Aug-98	0	970	120	380	170	60	10
12-Aug-98	0.06	145	130	60	4	4	22
13-Aug-98	0.05	10	30	25	<2	6	6
14-Aug-98	0	30	10	<10	<10	<10	<10
15-Aug-98	0	50	<10	40	<10	<10	10
16-Aug-98	0.02	30	<10	<10	10	<10	10
17-Aug-98	0	40	80	660	<10	10	100
18-Aug-98	1.49	130	30	120	390	140	60
19-Aug-98	0.59	175	440	285	114	64	78
20-Aug-98	0	120	70	120	4	8	2
21-Aug-98	0	10	30	50	20	<10	<10
22-Aug-98	0	30	20	20	<10	<10	<10
23-Aug-98	0	40	10	80	<10	<10	10
24-Aug-98	0.3	20	40	30	<10	20	<10
25-Aug-98	0.3	110	100	140	<10	20	<10
26-Aug-98	0.18	175	110	55	4	6	12
27-Aug-98	0.2	<5	5	<5	<2	20	2
28-Aug-98	0	120	1100	300	<10	130	40
29-Aug-98	0.11	<100	100	90	<10	10	10
30-Aug-98	0.12	120	180	60	10	20	<10
31-Aug-98	0.01	190	390	320	20	80	70
1-Sep-98	0	30	20	540	<10	<10	40
2-Sep-98	0	120	310	435	32	22	18
3-Sep-98	0.04	210	745	420	2	<2	<2
4-Sep-98	0	170	540	30	30	40	10
5-Sep-98	0	10	20	200	<10	10	130
6-Sep-98	0	<10	120	60	<10	10	<10
24-Jun-99	0	100	280	165	26	34	16
25-Jun-99	0	5	25	10	<2	2	4
1-Jul-99	0.92	2800	800	460	1260	750	274
2-Jul-99	0.36	600	95	85	24	10	6

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 3: Constitution Beach Raw Data

Date	24 hr rainfall (in.) Chelsea Creek Headworks	Fecal Coliform (colonies/100 mL) North MDC16	Fecal Coliform (colonies/100 mL) Bathhouse MDC17	Fecal Coliform (colonies/100 mL) South MDC18	*Enterococcus* (colonies/100 mL) North MDC16	*Enterococcus* (colonies/100 mL) Bathhouse MDC17	*Enterococcus* (colonies/100 mL) South MDC18
3-Jul-99	0	10	<10	<10	<10	<10	<10
4-Jul-99	0	30	20	20	<10	<10	10
5-Jul-99	0	30	20	20	<10	<10	<10
6-Jul-99	0	<10	<10	<10	<10	<10	<10
7-Jul-99	0.21	190	10	20	<10	<10	<10
8-Jul-99	0	155	330	275	10	2	8
9-Jul-99	0	10	5	25	<2	4	4
10-Jul-99	0.02	10	<10	10	<10	10	<10
11-Jul-99	0	<10	10	10	<10	<10	<10
12-Jul-99	0	<10	40	30	<10	<10	<10
13-Jul-99	0.09	<10	170	20	10	260	<10
14-Jul-99	0	<10	<10	20	<10	<10	<10
15-Jul-99	0	40	130	295	2	<2	2
16-Jul-99	0	<5	<5	5	2	2	<2
17-Jul-99	0	<10	<10	10	<10	<10	<10
18-Jul-99	0	<10	<10	<10	<10	<10	<10
19-Jul-99	0	<10	<10	10	<10	<10	<10
20-Jul-99	0.53	1300	500	<10	160	<10	<10
21-Jul-99	0	30	<10	<10	<10	<10	<10
22-Jul-99	0	60	10	40	6	6	2
23-Jul-99	0	80	25	20	14	<2	2
24-Jul-99	0.65	10	<10	<10	<10	<10	<10
25-Jul-99	0.14	110	20	60	50	<10	<10
26-Jul-99	0.77	10	140	100	10	20	<10
27-Jul-99	0	10	<10	10	20	10	<10
28-Jul-99	0	10	<10	10	<10	10	<10
29-Jul-99	0	540	40	175	22	14	70
30-Jul-99	0	15	20	5	14	8	<2
31-Jul-99	0	30	10	20	10	<10	<10
1-Aug-99	0	20	<10	10	<10	<10	<10
2-Aug-99	0	830	760	<10	20	20	<10
3-Aug-99	0	10	10	10	<10	<10	<10
4-Aug-99	0	20	20	20	<10	<10	<10
5-Aug-99	0	<5	125	55	2	2	6
6-Aug-99	0.35	<5	10	<5	<2	8	<2
7-Aug-99	0.16	20	30	20	<10	<10	<10
8-Aug-99	0	180	40	60	10	<10	<10
9-Aug-99	0	<10	50	200	<10	<10	10
10-Aug-99	0	<10	30	10	<10	<10	10
11-Aug-99	0	50	40	30	<10	<10	<10
12-Aug-99	0	710	630	540	116	118	104
13-Aug-99	0	50	160	105	8	12	16
14-Aug-99	0.08	10	<10	10	<10	<10	20
15-Aug-99	0.61	<10	10	<10	10	<10	<10
16-Aug-99	0.05	11000	60	60	130	<10	10
17-Aug-99	0	700	20	<10	40	<10	<10
18-Aug-99	0	<10	10	<10	<10	<10	<10
19-Aug-99	0	10	15	<5	<2	4	<2
20-Aug-99	0	155	175	130	2	12	8
21-Aug-99	0.04	20	30	30	<10	<10	10
22-Aug-99	0.17	20	<10	<10	<10	<10	<10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 3: Constitution Beach Raw Data

Date	24 hr rainfall (in.) Chelsea Creek Headworks	Fecal Coliform (colonies/100 mL) North MDC16	Fecal Coliform (colonies/100 mL) Bathhouse MDC17	Fecal Coliform (colonies/100 mL) South MDC18	*Enterococcus* (colonies/100 mL) North MDC16	*Enterococcus* (colonies/100 mL) Bathhouse MDC17	*Enterococcus* (colonies/100 mL) South MDC18
23-Aug-99	0.01	<10	<10	20	<10	<10	<10
24-Aug-99	0	10	<10	20	<10	<10	<10
25-Aug-99	0	30	<10	70	<10	<10	<10
26-Aug-99	0	100	175	75	8	14	14
27-Aug-99	0.01	40	320	210	2	26	28
28-Aug-99	0.22	<10	30	30	<10	10	<10
29-Aug-99	0	<10	20	120	<10	<10	<10
30-Aug-99	0	<10	10	30	10	<10	<10
31-Aug-99	0	170	10	10	20	<10	10
1-Sep-99	0	<10	20	10	<10	<10	10
2-Sep-99	0	30	40	15	<2	<2	<2
3-Sep-99	0	5	5	<5	<2	<2	2
4-Sep-99	0	140	100	160	10	<10	<10
5-Sep-99	0	<10	<10	20	<10	<10	<10
22-Jun-00	0.01	20	35	20	6	14	2
23-Jun-00	0.1	5	<5	<5	<2	<2	<2
24-Jun-00	0	10	<10	10	<10	<10	<10
25-Jun-00	0	<10	<10	10	<10	<10	10
26-Jun-00	0	<10	<10	<10	<10	<10	<10
27-Jun-00	0.2	10	10	<10	<10	<10	<10
28-Jun-00	0.21	30	50	50	<10	<10	<10
29-Jun-00	0.12	50	30	25	10	6	10
30-Jun-00	0	150	30	180	20	8	32
1-Jul-00	0	70	<10	10	20	40	30
2-Jul-00	0	20	30	<10	10	20	<10
3-Jul-00	0	20	30	30	10	80	10
4-Jul-00	0	<10	10	10	30	<10	<10
5-Jul-00	0	20	<10	<10	<10	<10	<10
6-Jul-00	0	<5	20	5	2	2	2
7-Jul-00	0	15	20	15	<2	6	6
8-Jul-00	0.1	40	<10	20	10	10	<10
9-Jul-00	0	30	30	20	<10	<10	<10
10-Jul-00	0.54	20	80	20	20	30	60
11-Jul-00	0	10	10	40	<10	10	10
12-Jul-00	0	<10	100	<10	<10	20	<10
13-Jul-00	0	30	110	65	6	2	4
14-Jul-00	0.01	10	45	20	<2	4	4
15-Jul-00	0	20	20	50	<10	<10	190
16-Jul-00	1.34	70	100	190	<10	30	30
17-Jul-00	0	<10	20	100	<10	<10	<10
18-Jul-00	0	10	30	20	<10	10	<10
19-Jul-00	0.17	<10	20	30	<10	20	<10
20-Jul-00	0	35	<5	<5	32	<2	2
21-Jul-00	0	50	5	65	<2	2	4
22-Jul-00	0.26	1340	640	300	450	100	70
23-Jul-00	0	<10	10	20	<10	20	<10
24-Jul-00	0	20	640	20	<10	30	<10
25-Jul-00	0	<10	50	20	<10	10	<10
26-Jul-00	0.02	30	20	<10	<10	20	10
27-Jul-00	0.7	80	600	70	35	30	25
28-Jul-00	0.95	3800	5500	1800	1840	3120	1580

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 3: Constitution Beach Raw Data

Date	24 hr rainfall (in.) Chelsea Creek Headworks	Fecal Coliform (colonies/100 mL) North MDC16	Fecal Coliform (colonies/100 mL) Bathhouse MDC17	Fecal Coliform (colonies/100 mL) South MDC18	*Enterococcus* (colonies/100 mL) North MDC16	*Enterococcus* (colonies/100 mL) Bathhouse MDC17	*Enterococcus* (colonies/100 mL) South MDC18
29-Jul-00	0	200	500	680	10	<10	90
30-Jul-00	0	240	70	170	40	20	40
31-Jul-00	0.7	1100	2200	1080	980	1020	1370
1-Aug-00	0.03	120	50	150	70	50	90
2-Aug-00	0.01	140	80	130	840	340	330
3-Aug-00	0	395	255	170	70	26	68
4-Aug-00	0.09	60	55	85	32	18	28
5-Aug-00	0	510	60	20	170	<10	50
6-Aug-00	0	150	<10	<10	30	40	40
7-Aug-00	0.01	<10	<10	<10	80	20	10
8-Aug-00	0.03	<10	<10	<10	10	10	<10
9-Aug-00	0	<10	<10	20	10	<10	40
10-Aug-00	0.07	15	290	20	14	72	6
11-Aug-00	0	100	80	50	74	6	6
12-Aug-00	0	<10	10	30	<10	10	70
13-Aug-00	0	<10	10	40	<10	70	20
14-Aug-00	0.62	<10	<10	80	10	40	<10
15-Aug-00	0.02	310	120	80	40	<10	10
16-Aug-00	0.71	3100	240	810	720	440	430
17-Aug-00	0.71	1860	1040	1800	710	490	750
18-Aug-00	0	180	240	20	126	140	160
19-Aug-00	0.19	<10	10	40	<10	20	100
20-Aug-00	0	10	60	20	<10	10	10
21-Aug-00	0	60	20	10	<10	<10	<10
22-Aug-00	0.01	270	10	10	40	10	50
23-Aug-00	0	<10	10	<10	10	<10	<10
24-Aug-00	0.31	95	25	25	60	14	50
25-Aug-00	0	1240	65	25	270	70	22
26-Aug-00	0	40	150	40	<10	<10	<10
27-Aug-00	0	50	20	260	<10	<10	20
28-Aug-00	0	<10	30	490	20	<10	50
29-Aug-00	0	10	130	560	<10	100	<10
30-Aug-00	0	260	110	<10	110	100	<10
31-Aug-00	0	65	95	265	44	8	116
1-Sep-00	0	10	20	20	4	20	26
2-Sep-00	0.03	70	30	20	10	<10	<10
3-Sep-00	0.51	2600	740	790	160	110	140

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 4: Carson Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) M St. MDC21	Fecal Coliform (colonies/100 mL) I St MDC22	Fecal Coliform (colonies/100 mL) Bathhouse MDC23	*Enterococcus* (colonies/100 mL) M St. MDC21	*Enterococcus* (colonies/100 mL) I St MDC22	*Enterococcus* (colonies/100 mL) Bathhouse MDC23
12-Jun-96	0	15	28	<5	4	12	4
19-Jun-96	0	<5	25	20	2	12	40
20-Jun-96	0.14	15	5	10	<2	10	10
26-Jun-96	0	22	5	15	2	18	10
27-Jun-96	0	5	<5	<5	14	<2	2
1-Jul-96	0.13	70	152	20	34	38	108
2-Jul-96	0	15	811	5			
8-Jul-96	0	10	<10	<10	<10	<10	<10
9-Jul-96	0.04	<10	50	80	<10	20	10
10-Jul-96	0.05	<5	5	<5	127	82	55
11-Jul-96	0	<5	5	<5	25	10	275
12-Jul-96	0	<5	<5	<5	30	<10	<10
13-Jul-96	1.5	70	410	800	180	220	570
14-Jul-96	1.5	80	30	<10	20	<10	20
15-Jul-96	0	30	430	10	10	10	<10
16-Jul-96	0	<10	10	10	<10	<10	<10
17-Jul-96	0	25		15	17		22
18-Jul-96	0	20	22	<5	4	15	<2
19-Jul-96	0	100	180	20	10	160	<10
20-Jul-96	0.08	10	<10	10	<10	10	<10
21-Jul-96	0	10	10	<10	10	<10	<10
22-Jul-96	0	<10	<10	<10	10	<1	<10
23-Jul-96	0	10	<10	10	<10	<10	<10
24-Jul-96	0.72	232	60	55	69	62	24
25-Jul-96	0	58	178	60	44	181	16
26-Jul-96	0.09	10	10	<10	10	20	10
27-Jul-96	0	15	10	5	<2	10	<2
28-Jul-96	0	<5	<5	10	5	5	15
29-Jul-96	0	60	<10	10	10	<10	70
30-Jul-96	0	30	40	<10	50	10	<10
2-Aug-96	0.02	<10	<10	260	<10	<10	60
3-Aug-96	0	10	<10	<10	<10	10	<10
4-Aug-96	0	<10	10	10	<10	<10	<10
5-Aug-96	0	<10	10	<10	<10	<10	<10
6-Aug-96	0	10	<10	<10	30	<10	<10
7-Aug-96	0	<10	10	<10	<10	10	10
8-Aug-96	0.29	18	>4000	>4000	6	630	300
10-Aug-96	0.67	35	360	70	10	20	50
11-Aug-96	0	<10	<10	20	20	<10	10
12-Aug-96	0	<10	10	10	20	10	10
13-Aug-96	0.18	10	20	290	60	10	50
14-Aug-96	0.16	40	48	20	63	64	7
15-Aug-96	0	20	20	40	59	64	54
16-Aug-96	0	<10	10	<10	<10	<10	10
17-Aug-96	0	20	100	<10	<10	<10	<10
18-Aug-96	0	10	70	<10	<10	<10	<10
19-Aug-96	0	10	<10	10	<10	<10	10
20-Aug-96	0	100	<10	10	<10	10	<10
21-Aug-96	0	5	<5	25	<2	5	10
23-Aug-96	0	<10	45	10	<10	15	<10
24-Aug-96	0.36	40	<10	30	<10	10	<10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 4: Carson Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) M St. MDC21	Fecal Coliform (colonies/100 mL) I St MDC22	Fecal Coliform (colonies/100 mL) Bathhouse MDC23	*Enterococcus* (colonies/100 mL) M St. MDC21	*Enterococcus* (colonies/100 mL) I St MDC22	*Enterococcus* (colonies/100 mL) Bathhouse MDC23
25-Aug-96	0.08	20	180	30	<10	50	<10
26-Aug-96	0	20	20	<10	<10	40	10
27-Aug-96	0	30	180	90	10	410	280
28-Aug-96	0	20	85	15	25	52	62
29-Aug-96	0.11	20	112	68	<2	22	18
30-Aug-96	0	90	10	40	<10	10	<10
31-Aug-96	0	50	10	40			
1-Sep-96	0	10	<10	10			
18-Jun-97	0.03	338	260	5	26	98	<2
19-Jun-97	0.28	453	1000	1320	72	60	90
20-Jun-97	0	85	35	55	4	16	22
25-Jun-97	0	45	20	<5	<2	8	<2
26-Jun-97	0	25	540	<5	<2	28	<2
1-Jul-97	0	55	205	<5	210	4	80
2-Jul-97	0.01	10	10	<5	6	4	<2
4-Jul-97	0.01	<10	20	10	<10	50	<10
5-Jul-97	0	10	<10	<10	20	<10	110
6-Jul-97	0	10	<10	<10	20	40	<10
7-Jul-97	0	<10	<10	<10	10	<10	<10
8-Jul-97	0.03	<10	10	<10	<10	10	<10
9-Jul-97	0	5	40	25	30	42	26
10-Jul-97	0.02	15	5	<5	2	<2	4
11-Jul-97	0	20	<10	10	<10	<10	10
12-Jul-97	0	<10	<10	<10	<10	<10	<10
13-Jul-97	0	<10	<10	<10	<10	<10	<10
14-Jul-97	0	<10	<10	10	<10	70	20
15-Jul-97	0	<10	<10	80	10	<10	20
16-Jul-97	0.08	105	<5	80	34	76	12
17-Jul-97	0	600	700	1100	22	66	44
18-Jul-97	0.01	20	5	30	5	5	10
19-Jul-97	0	5	5	40	4	80	2
20-Jul-97	0	<10	10	<10	10	10	<10
21-Jul-97	0	<10	1600	<10	<10	10	<10
22-Jul-97	0.06	10	<10	<10	<10	<10	<10
23-Jul-97	0	700	240	280	18	36	22
24-Jul-97	0	20	20	30	10	38	4
25-Jul-97	0.08	10	25	20	36	46	30
26-Jul-97	0.03	<10	<10	<10	<10	10	<10
27-Jul-97	0	<10	<10	20	10	40	40
28-Jul-97	0	10	<10	<10	30	80	<10
29-Jul-97	0	10	10	10	50	80	40
30-Jul-97	0	30	5	320	2	6	6
31-Jul-97	0	10	25	20	4	10	4
1-Aug-97	0	<10	80	<10	<10	10	<10
2-Aug-97	0	<10	<10	20	<10	10	<10
3-Aug-97	0	<10	<10	<10	<10	10	30
4-Aug-97	0.44	60	40	830	<10	10	10
5-Aug-97	0.15	290	280	170	<10	<10	40
6-Aug-97	0	105	130	40	4	2	<2
7-Aug-97	0	65	95	<5	14	<2	2
8-Aug-97	0	<10	<10	<10	<10	<10	<10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 4: Carson Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) M St. MDC21	Fecal Coliform (colonies/100 mL) I St MDC22	Fecal Coliform (colonies/100 mL) Bathhouse MDC23	*Enterococcus* (colonies/100 mL) M St. MDC21	*Enterococcus* (colonies/100 mL) I St MDC22	*Enterococcus* (colonies/100 mL) Bathhouse MDC23
9-Aug-97	0.19	10	<10	50	<10	<10	10
10-Aug-97	0.1	160	90	120	40	70	40
11-Aug-97	0	50	<10	<10	<10	<10	<10
12-Aug-97	0.01	<10	20	30	10	40	180
13-Aug-97	0	15	45	120	4	8	4
14-Aug-97	0.65	25	330	65	50	56	20
15-Aug-97	0	40	80	9000	60	30	290
16-Aug-97	0.01	40	20	<10	60	30	10
17-Aug-97	0	40	50	20	20	<10	<10
18-Aug-97	0.53	70	110	30	<10	10	10
19-Aug-97	0	30	10	20	10	20	10
21-Aug-97	0.5	185	365	1920	72	288	580
22-Aug-97	0.72	40	70	370	20	410	520
23-Aug-97	0	30	270	70	8	48	66
24-Aug-97	0	<10	20	10	10	<10	10
25-Aug-97	0	<10	<10	<10	10	<10	<10
26-Aug-97	0	<10	300	20	10	340	<10
27-Aug-97	0	5	80	10	5	15	2
28-Aug-97	0	10	15	10	6	2	6
29-Aug-97	0.01	30	50	80	20	10	<10
30-Aug-97	0.02	<10	10	<10	<10	10	<10
31-Aug-97	0	30	<10	10	<10	<10	10
10-Jun-98	0	5	10	5	1	4	2
17-Jun-98	0.02	2140	1360	1420	102	122	450
18-Jun-98	0.38	2000	430	1760	115	135	350
25-Jun-98	0	195		115	40		14
30-Jun-98	0.05	120	400	20	8	52	2
30-Jun-98	0.13	10	<10	20	10	10	<10
1-Jul-98	2.03	265	500	510	10	52	68
3-Jul-98	0	70	120	110	<10	<10	<10
4-Jul-98	0	70	30	80	<10	<10	<10
5-Jul-98	0.02	60	10	70	<10	<10	30
6-Jul-98	0.01	120	90	30	100	20	<10
7-Jul-98	0	50	20	10	<10	10	<10
8-Jul-98	0	150	30	10	10	4	<2
9-Jul-98	0.01	<5	<5	10	8	4	8
10-Jul-98	0	<10	10	10	70	20	<10
11-Jul-98	0	10	1040	60	10	80	20
12-Jul-98	0	30	<10	10	10	<10	30
13-Jul-98	0	70	10	10	20	<10	<10
14-Jul-98	0	<10	<10	10	10	<10	<10
15-Jul-98	0	15	35	5	4	2	<2
16-Jul-98	0	<5	40	<5	<2	2	<2
17-Jul-98	0	<10	90	<10	<10	<10	<10
18-Jul-98	0.01	<10	10	<10	<10	<10	<10
19-Jul-98	0	10	20	20	<10	10	<10
20-Jul-98	0	<10	30	<10	10	10	<10
21-Jul-98	0.03	10	300	10	<10	100	<10
22-Jul-98	0	20	25	70	6	<2	6
23-Jul-98	0	55	<5	35	4	<2	2
24-Jul-98	0.52	30	130	80	<10	<10	10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 4: Carson Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) M St. MDC21	I St MDC22	Bathhouse MDC23	*Enterococcus* (colonies/100 mL) M St. MDC21	I St MDC22	Bathhouse MDC23
25-Jul-98	0	30	20	<10	<10	<10	<10
26-Jul-98	0	20	60	<10	<10	<10	<10
27-Jul-98	0	10	<10	10	<10	<10	<10
28-Jul-98	0	20	<10	10	10	<10	<10
29-Jul-98	0	15	145	20	<2	50	10
30-Jul-98	0.31	10	140	640	2	10	6
31-Jul-98	0.39	50	30	510	<10	<10	40
1-Aug-98	0.19	30	10	20	20	<10	<10
2-Aug-98	0	<10	10	<10	<10	<10	<10
3-Aug-98	0	10	<10	<10	<10	<10	<10
4-Aug-98	0	<10	130	40	<10	660	10
5-Aug-98	0	<5	30	25	<2	<2	<2
6-Aug-98	0	20	15	25	10	2	6
7-Aug-98	0.04	<10	30	220	10	30	170
8-Aug-98	0	260	30	30	936	40	10
9-Aug-98	0	<10	10	40	<10	10	<10
10-Aug-98	0	<10	20	<10	<10	20	<10
11-Aug-98	0	40	30	<10	120	120	<10
12-Aug-98	0.17	660	460	30	16	4	<2
13-Aug-98	0.08	115	50	25	72	18	10
14-Aug-98	0	20	20	20	<10	<10	10
15-Aug-98	0.01	50	20	10	<10	<10	<10
16-Aug-98	0.05	20	100	<10	60	<10	10
17-Aug-98	0	20	20	50	10	<10	30
18-Aug-98	1.75	50	620	470	20	130	210
19-Aug-98	0.56	580	75		22	20	
20-Aug-98	0	20	35	5	14	26	10
21-Aug-98	0	<10	10	10	<10	10	<10
22-Aug-98	0	170	40	60	320	<10	<10
23-Aug-98	0	140	70	90	<10	20	40
24-Aug-98	0.26	20	30	50	10	60	<10
25-Aug-98	0	60	<10	50	<10	10	20
26-Aug-98	0.2	35	25	30	6	6	2
27-Aug-98	0.17	30	70	115	<2	<2	18
28-Aug-98	0	60	50	140	10	<10	<10
29-Aug-98	0.22	<10	<100	10	<10	<10	<10
30-Aug-98	0.15	80	90	20	<10	10	<10
31-Aug-98	0.14	70	30	20	50	10	5
1-Sep-98	0.04	60	<10	<10	<10	<10	<10
2-Sep-98	0	55	120	100	<2	<2	<2
3-Sep-98	0.19	55	630	560	4	52	46
4-Sep-98	0	20	450	<10	<10	160	30
5-Sep-98	0	10	50	20	<10	10	80
6-Sep-98	0	50	30	40	10	30	10
24-Jun-99	0	<5	<5	10	2	<2	<2
25-Jun-99	0	15	60	<5	4	<2	<2
1-Jul-99	0.97	1600	60	>4000	46	8	42
2-Jul-99	0.67	355	>4000	60	120	144	4
3-Jul-99	0	30	70	10	<10	10	<10
4-Jul-99	0	<10	80	<10	<10	10	<10
5-Jul-99	0.01	10	20	<10	<10	<10	<10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 4: Carson Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) M St. MDC21	Fecal Coliform (colonies/100 mL) I St MDC22	Fecal Coliform (colonies/100 mL) Bathhouse MDC23	*Enterococcus* (colonies/100 mL) M St. MDC21	*Enterococcus* (colonies/100 mL) I St MDC22	*Enterococcus* (colonies/100 mL) Bathhouse MDC23
6-Jul-99	0	20	10	<10	<10	<10	<10
7-Jul-99	0.44	<10	<10	30	20	<10	10
8-Jul-99	0	35	500	50	<2	4	12
9-Jul-99	0	100	5	135	32	4	2
10-Jul-99	0.03	290	10	10	50	<10	<10
11-Jul-99	0	<10	10	10	<10	<10	<10
12-Jul-99	0	10	<10	<10	270	70	10
13-Jul-99	0.09	<10	10	70	<10	<10	<10
14-Jul-99	0	<10	<10	10	<10	<10	<10
15-Jul-99	0	55	45	15	2	<2	<2
16-Jul-99	0	20	<5	<5	<2	2	<2
17-Jul-99	0	<10	10	10	<10	<10	<10
18-Jul-99	0	<10	10	<10	<10	10	<10
19-Jul-99	0	20	<10	<10	20	<10	<10
20-Jul-99	0.66	<10	<10	<10	<10	<10	<10
21-Jul-99	0.29	<10	<10	10	30	<10	<10
22-Jul-99	0	10	25	80	6	6	2
23-Jul-99	0.43	25	10	45	4	2	10
24-Jul-99	0	10	190	10	<10	60	<10
25-Jul-99	0.67	70	10	47200	<10	70	950
26-Jul-99	0.54	40	130	1130	<10	20	60
27-Jul-99	0	<10	10	<10	10	60	<10
28-Jul-99	0	30	10	10	20	10	<10
29-Jul-99	0	80	20	5	2	2	<2
30-Jul-99	0	10	130	25	4	84	8
31-Jul-99	0	80	10	<10	30	80	<10
1-Aug-99	0	10	10	10	<10	180	20
2-Aug-99	0	<10	10	<10	<10	<10	<10
3-Aug-99	0	<10	<10	<10	<10	<10	<10
4-Aug-99	0	10	10	10	<10	<10	<10
5-Aug-99	0	10	10	<5	<2	2	<2
6-Aug-99	0.02	<5	<5	5	<2	<2	4
7-Aug-99	0.1	10	<10	<10	<10	<10	<10
8-Aug-99	0.01	30	110	<10	10	20	<10
9-Aug-99	0	<10	10	<10	<10	<10	<10
10-Aug-99	0	<10	20	<10	<10	10	<10
11-Aug-99	0	<10	10	<10	<10	10	<10
12-Aug-99	0	<5	20	15	<2	<2	<2
13-Aug-99	0	10	<5	<5	<2	4	2
14-Aug-99	0.01	20	90	10	<10	10	<10
15-Aug-99	0.33	20	50	10	<10	20	100
16-Aug-99	0.03	100	<10	10	<10	<10	<10
17-Aug-99	0	40	<10	<10	<10	<10	<10
18-Aug-99	0	<10	<10	<10	<10	<10	<10
19-Aug-99	0	70	<5	20	38	4	<2
20-Aug-99	0	5	10	<5	6	8	<2
21-Aug-99	0.04	20	<10	10	<10	10	<10
22-Aug-99	0.32	20	<10	<10	<10	<10	<10
23-Aug-99	0	10	<10	10	10	<10	<10
24-Aug-99	0	50	10	170	<10	20	190
25-Aug-99	0	80	<10	30	10	<10	10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 4: Carson Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) M St. MDC21	Fecal Coliform (colonies/100 mL) I St MDC22	Fecal Coliform (colonies/100 mL) Bathhouse MDC23	*Enterococcus* (colonies/100 mL) M St. MDC21	*Enterococcus* (colonies/100 mL) I St MDC22	*Enterococcus* (colonies/100 mL) Bathhouse MDC23
26-Aug-99	0	50	80	65	2	<2	<2
27-Aug-99	0.01	135	250	205	2	62	4
28-Aug-99	0.06	20	30	100	<10	10	10
29-Aug-99	0	<10	60	<10	<10	<10	<10
30-Aug-99	0	20	10	<10	10	<10	<10
31-Aug-99	0	650	<10	<10	1730	<10	<10
1-Sep-99	0	30	<10	<10	20	<10	<10
2-Sep-99	0	<5	25	5	6	2	2
3-Sep-99	0	105	30	5	16	6	2
4-Sep-99	0	<10	30	10	<10	10	<10
5-Sep-99	0	<10	10	<10	<10	<10	<10
1-Jun-00	0	125	510	25	40	74	2
8-Jun-00	0.1	345	245	265	38	98	62
15-Jun-00	0	35	90	65	16	16	12
22-Jun-00	0.01	16	120	5	2	28	2
23-Jun-00	0.03	<5	10	20	<2	2	18
24-Jun-00	0	<10	<10	<10	<10	<10	<10
25-Jun-00	0	<10	<10	20	<10	<10	<10
26-Jun-00	0	<10	20	<10	<10	<10	<10
27-Jun-00	0.02	<10	20	<10	<10	<10	<10
28-Jun-00	0.88	<10	10	20	10	<10	10
29-Jun-00	0.1	240	450	1780	12	68	236
30-Jun-00	0.01	85	70	75	12	42	40
1-Jul-00	0	<10	10	40	<10	60	20
2-Jul-00	0	10	40	<10	<10	20	<10
3-Jul-00	0	20	<10	<10	10	<10	<10
4-Jul-00	0	<10	40	30	<10	<10	<10
5-Jul-00	0	<10	<10	<10	<10	<10	10
6-Jul-00	0	10	<5	85	<2	<2	2
7-Jul-00	0	5	10	10	<2	4	12
8-Jul-00	0.16	<10	60	60	<10	<10	10
9-Jul-00	0	<10	<10	20	10	<10	<10
10-Jul-00	0.45	<10	10	<10	<10	130	<10
11-Jul-00	0	30	20	30	<10	<10	<10
12-Jul-00	0	<10	440	10	<10	<10	<10
13-Jul-00	0	40	75	15	<2	<2	2
14-Jul-00	0	40	<5	95	2	<2	34
15-Jul-00	0	<10	<10	<10	<10	<10	10
16-Jul-00	1.05	160	50	900	90	10	30
17-Jul-00	0	<10	10	1100	<10	30	<10
18-Jul-00	0	<10	90	30	<10	30	10
19-Jul-00	0.96	20	50	10	<10	20	<10
20-Jul-00	0	10	20	20	2	20	2
21-Jul-00	0	10	5	15	<2	2	4
22-Jul-00	0.17	20	40	<10	<10	<10	<10
23-Jul-00	0	<10	10	<10	<10	<10	<10
24-Jul-00	0	<10	<10	10	<10	<10	<10
25-Jul-00	0	20	<10	50	20	<10	<10
26-Jul-00	0.03	20	30	20	10	<10	20
27-Jul-00	0.8	20	20	30	10	25	15
28-Jul-00	1.04	110	20	40	10	15	45

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 4: Carson Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) M St. MDC21	Fecal Coliform (colonies/100 mL) I St MDC22	Fecal Coliform (colonies/100 mL) Bathhouse MDC23	*Enterococcus* (colonies/100 mL) M St. MDC21	*Enterococcus* (colonies/100 mL) I St MDC22	*Enterococcus* (colonies/100 mL) Bathhouse MDC23
29-Jul-00	0	80	100	<10	70	80	90
30-Jul-00	0	<10	20	<10	20	30	10
31-Jul-00	0.74	350	180	8500	250	110	600
1-Aug-00	0.06	70	40	3500	60	50	430
2-Aug-00	0.01	10	1220	20	30	400	40
3-Aug-00	0	10	605	10	2	250	2
4-Aug-00	0.09	5	5	<5	2	6	<2
5-Aug-00	0	60	<10	20	<10	10	30
6-Aug-00	0	10	<10	<10	<10	<10	<10
7-Aug-00	0.01	<10	<10	<10	110	210	<10
8-Aug-00	0	<10	<10	<10	<10	<10	<10
9-Aug-00	0	10	<10	<10	550	<10	10
10-Aug-00	0.08	15	<5	15	2	2	2
11-Aug-00	0	20	15	5	6	<2	2
12-Aug-00	0	30	20	10	80	<10	10
13-Aug-00	0	20	70	80	<10	<10	10
14-Aug-00	0.62	10	330	200	30	10	<10
15-Aug-00	0.02	290	20	70	50	10	<10
16-Aug-00	0.42	270	480	570	40	<10	70
17-Aug-00	0.42	55	15	20	8	4	12
18-Aug-00	0	15	<5	20	<2	<2	4
19-Aug-00	0.26	20	20	20	10	<10	10
20-Aug-00	0	10	<10	<10	<10	<10	20
21-Aug-00	0	10	<10	30	<10	<10	20
22-Aug-00	0	10	<10	<10	10	10	<10
23-Aug-00	0	20	<10	10	<10	<10	<10
24-Aug-00	0.38	95	35	15	18	10	18
25-Aug-00	0	5	55	35	2	14	10
26-Aug-00	0	50	<10	10	30	<10	10
27-Aug-00	0	10	40	20	<10	30	40
28-Aug-00	0	20	50	760	20	20	500
29-Aug-00	0	<10	70	20	<10	40	<10
30-Aug-00	0	<5	80	<10	710	50	<10
31-Aug-00	0	135	10	10	16	8	12
1-Sep-00	0	55	10	15	26	2	14
2-Sep-00	0.02	170	70	10	40	90	<10
3-Sep-00	0.65	100	230	>800	20	90	2340
7-Sep-00	0	20	175	<5	10	10	2

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 5: Tenean Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) North MDC26	Fecal Coliform (colonies/100 mL) Bathhouse MDC27	Fecal Coliform (colonies/100 mL) South MDC28	*Enterococcus* (colonies/100 mL) North MDC26	*Enterococcus* (colonies/100 mL) Bathhouse MDC27	*Enterococcus* (colonies/100 mL) South MDC28
12-Jun-96	0	58	20	45	<2	<2	10
19-Jun-96	0	18	40	40	24	25	14
20-Jun-96	0.14	50	54	30	7	10	18
26-Jun-96	0	52	35	65	35	61	26
27-Jun-96	0	20	12	45	4	16	6
2-Jul-96	0	35	50	42			
10-Jul-96	0.05	22	15	10	60	115	120
11-Jul-96	0	25	68	55	18	16	440
15-Jul-96	0	98	66	82	118	61	137
17-Jul-96	0	30			42		
18-Jul-96	0	440	262	502	15	11	8
19-Jul-96	0	75	38	30	4	4	9
24-Jul-96	0.72	705	482	672	223	130	220
26-Jul-96	0.083	30	42	28	63	19	18
8-Aug-96	0.29	10	40	<5			49
14-Aug-96	0.11	192	208	265	11	61	80
15-Aug-96	0	150	112	58	75	13	94
21-Aug-96	0	35	18	5	15	162	15
28-Aug-96	0.01	458	592	540	90	228	95
29-Aug-96	0.09	35	65	78	<2	22	<2
18-Jun-97	0.03	92	48	290	26	20	20
19-Jun-97	0.28	1340	380	1920	30	38	82
20-Jun-97	0	75	110	90	8	20	18
25-Jun-97	0	120	145	515	10	8	24
26-Jun-97	0	115	930	120	8	30	30
1-Jul-97	0	680	230	190	42	930	180
2-Jul-97	0.01	40	20	185	2	2	2
4-Jul-97	0.01	50	120	80	<10	10	20
5-Jul-97	0	40	40	20	100	<10	50
6-Jul-97	0	<10	10	10	<10	<10	<10
7-Jul-97	0	100	190	180	<10	10	<10
8-Jul-97	0.03	90	80	150	<10	40	80
9-Jul-97	0	65	290	1025	4	4	40
10-Jul-97	0.02	245	410	395	52	100	190
11-Jul-97	0	50	70	30	20	54	86
12-Jul-97	0	10	10	20	10	<10	<10
13-Jul-97	0	10	40	<10	10	<10	10
14-Jul-97	0	<10	<10	<10	<10	<10	<10
15-Jul-97	0	150	50	50	40	40	40
16-Jul-97	0.08	575	280	200	50	88	22
17-Jul-97	0	>4000	1150		68	48	
18-Jul-97	0.01	10	20	40	10	5	10
19-Jul-97	0	60	40	30	4	6	14
20-Jul-97	0	80	130	1040	<10	10	10
21-Jul-97	0	300	240	250	<10	20	<10
22-Jul-97	0.06	310	210	320	20	20	40
23-Jul-97	0	410	980	920	14	78	68
24-Jul-97	0	360	640	400	24	18	32
25-Jul-97	0.09	230	5	175	74	20	88
26-Jul-97	0.04	90	70	150	<10	10	30
27-Jul-97	0	20	<10	30	130	60	100

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 5: Tenean Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) North MDC26	Fecal Coliform (colonies/100 mL) Bathhouse MDC27	Fecal Coliform (colonies/100 mL) South MDC28	*Enterococcus* (colonies/100 mL) North MDC26	*Enterococcus* (colonies/100 mL) Bathhouse MDC27	*Enterococcus* (colonies/100 mL) South MDC28
28-Jul-97	0	<10	<10	20	60	170	10
29-Jul-97	0	40	<10	60	100	<10	<10
30-Jul-97	0	285	265	230	22	12	20
31-Jul-97	0	60	95	105	16	22	4
1-Aug-97	0	20	<10	<10	10	<10	<10
2-Aug-97	0	<10	<10	<10	<10	<10	<10
3-Aug-97	0	20	<10	90	10	<10	20
4-Aug-97	0.44	90	100	40	10	<10	<10
5-Aug-97	0.15	620	410	400	40	90	30
6-Aug-97	0	190	290	170	2	4	<2
7-Aug-97	0	165	55	190	38	42	34
8-Aug-97	0	20	10	10	<10	<10	40
9-Aug-97	0.19	90	130	100	<10	<10	30
10-Aug-97	0.1	10	120	50	10	10	<10
11-Aug-97	0	10	<10	<10	<10	<10	<10
12-Aug-97	0.01	30	10	40	80	30	100
13-Aug-97	0	35	45	15	4	6	<2
14-Aug-97	0.65	65	1100	270	64	74	76
15-Aug-97	0	40	55	50	8	30	4
16-Aug-97	0.01	30	<10	30	<10	10	<10
17-Aug-97	0	<10	10	<10	<10	20	30
18-Aug-97	0.53	200	60	220	90	60	60
19-Aug-97	0	120	70	90	20	20	<10
21-Aug-97	0.5	575	2280	3060	90	480	300
22-Aug-97	0.73	100	100	270	30	40	190
23-Aug-97	0	30	130	20	40	34	26
24-Aug-97	0	20	10	10	<10	<10	<10
25-Aug-97	0	40	40	80	10	<10	10
26-Aug-97	0	10	20	30	<10	<10	10
27-Aug-97	0	125	110	85	8	16	16
28-Aug-97	0	85	100	60	20	14	6
29-Aug-97	0	70	90	60	40	<10	10
30-Aug-97	0.02	<10	20	10	<10	10	10
31-Aug-97	0	60	20	20	20	<10	10
10-Jun-98	0	25	100		6		
17-Jun-98	0.02	2840	1860	>4000	1300	700	640
18-Jun-98	0.38	2960	1380	2260	800	435	1040
26-Jun-98	0.09	260	215	185	42	28	24
30-Jun-98	0.1	445	535	2900	10	40	850
1-Jul-98	2	2880	3680	2420	860	840	740
3-Jul-98	0	800	1600	1400	220	200	330
4-Jul-98	0	960	1340	990	240	150	290
5-Jul-98	0.02	2400	2700	2200	340	410	410
6-Jul-98	0.01	1450	860	830	210	330	180
7-Jul-98	0	630	580	690	30	30	20
8-Jul-98	0	170	50	785	60	30	10
9-Jul-98	0.01	5	30	100	6	8	20
10-Jul-98	0	140	80	120	40	10	10
11-Jul-98	0	1900			340		
12-Jul-98	0	230	240	250	70	70	60
13-Jul-98	0	160	40	60	70	20	10

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 5: Tenean Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) North MDC26	Fecal Coliform (colonies/100 mL) Bathhouse MDC27	Fecal Coliform (colonies/100 mL) South MDC28	*Enterococcus* (colonies/100 mL) North MDC26	*Enterococcus* (colonies/100 mL) Bathhouse MDC27	*Enterococcus* (colonies/100 mL) South MDC28
14-Jul-98	0	70	50	40	30	40	50
15-Jul-98	0	5	105	220	<2	4	4
16-Jul-98	0	50	35	20	16	2	2
17-Jul-98	0	20	20	30	10	60	10
18-Jul-98	0.01	70	160	70	10	50	90
19-Jul-98	0	120	90	110	20	<10	<10
20-Jul-98	0	10	20	10	<10	<10	<10
21-Jul-98	0.03	190	220	510	<10	20	80
22-Jul-98	0	660	410	780	4	4	12
23-Jul-98	0	490	445	600	6	2	16
24-Jul-98	0.52	1700	2300	2200	100	160	130
25-Jul-98	0	190	450	610	<10	10	<10
26-Jul-98	0	140	200	180	20	<10	10
27-Jul-98	0	<10	20	30	10	90	90
28-Jul-98	0	10	<10	<10	<10	<10	<10
29-Jul-98	0	<5	<5	<5	<2	6	2
30-Jul-98	0.31	1020	400	345	28	34	46
31-Jul-98	0.36	1700	1090	1030	140	130	130
1-Aug-98	0.2	340	480	630	50	<10	60
2-Aug-98	0	40	60	80	130	<10	130
3-Aug-98	0	60	30	50	<10	<10	<10
4-Aug-98	0	170	450	30	10	20	10
5-Aug-98	0	20	80	65	4	2	<2
6-Aug-98	0	30	40	35	4	6	8
7-Aug-98	0.04	60	30	70	20	40	<10
8-Aug-98	0	40	60	<10	20	<10	<10
9-Aug-98	0	210	220	210	<10	10	10
10-Aug-98	0	150	120	110	10	30	10
11-Aug-98	0	20	130	140	<10	60	80
12-Aug-98	0.17	145	1380		28	26	
13-Aug-98	0.08	125	410	760	88	96	128
14-Aug-98	0	140	110	320	<10	30	70
15-Aug-98	0.01	110	270	110	10	10	<10
16-Aug-98	0.05	1040	50	60	2390	<10	30
17-Aug-98	0	140	70	100	10	10	<10
18-Aug-98	1.75	700	900	750	180	360	330
19-Aug-98	0.56	1170	520	915	188	150	138
20-Aug-98	0	105	240	200	2	6	2
21-Aug-98	0	310	370	280	60	30	20
22-Aug-98	0	220	240	370	20	30	30
23-Aug-98	0	100	180	160	10	<10	10
24-Aug-98	0.26	1300	450	270	60	80	30
25-Aug-98	0	230	290	250	30	30	<10
26-Aug-98	0.18	870	90	470	120	2	<2
27-Aug-98	0	320	390	280	70	40	20
27-Aug-98	0.13	320	315	150	24	34	16
28-Aug-98	0	120	<100	130	65	40	40
29-Aug-98	0.21	1700	1500	550	310	490	240
30-Aug-98	0.15	540	410	530	40	20	110
31-Aug-98	0.1	190	140	140	50	50	50
1-Sep-98	0.12	240	160	380	<10	10	120

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 5: Tenean Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) North MDC26	Fecal Coliform (colonies/100 mL) Bathhouse MDC27	Fecal Coliform (colonies/100 mL) South MDC28	*Enterococcus* (colonies/100 mL) North MDC26	*Enterococcus* (colonies/100 mL) Bathhouse MDC27	*Enterococcus* (colonies/100 mL) South MDC28
2-Sep-98	0	210	305	65	16	12	<2
3-Sep-98	0.19	605	385	225	6	4	12
4-Sep-98	0	80	200	150	30	30	<10
5-Sep-98	0	380	270	230	30	40	20
6-Sep-98	0	350	410	310	10	60	40
15-Jun-99	0	80			5		
24-Jun-99	0	105	90	40	4	2	<2
25-Jun-99	0	40	20	60	6	10	2
1-Jul-99	0.97	>4000	>4000	>4000	1800	2400	1000
2-Jul-99	0.67	6400	760	1340	70	26	60
3-Jul-99	0	160	100	110	20	<10	<10
4-Jul-99	0	90	20	40	<10	<10	70
5-Jul-99	0.02	30	270	60	<10	<10	<10
6-Jul-99	0	170	410	310	<10	<10	<10
7-Jul-99	0.44	190	90	100	40	<10	<10
8-Jul-99	0	165	70	2640	<2	<2	48
9-Jul-99	0	375	155	35	26	14	18
10-Jul-99	0.03	40	20	40	<10	<10	20
11-Jul-99	0	40	60	40	<10	10	10
12-Jul-99	0	10	50	10	10	<10	<10
13-Jul-99	0.09	190	60	60	20	10	30
14-Jul-99	0	10	40	50	<10	10	<10
15-Jul-99	0	145	80		4	4	
16-Jul-99	0	<5	10	65	2	<2	10
17-Jul-99	0	10	30	20	10	<10	10
18-Jul-99	0	70	70	20	20	<10	<10
19-Jul-99	0	50	80	60	<10	<10	<10
20-Jul-99	0.66	220	260	330	10	<10	<10
21-Jul-99	0.29	90	70	80	<10	<10	<10
22-Jul-99	0	40	120	30	2	<2	<2
23-Jul-99	0.43	95	45	120	18	32	22
24-Jul-99	0	20	20	180	<10	<10	30
25-Jul-99	0.67	1110	850	1120	170	160	100
26-Jul-99	0.54	1700	4400	1500	40	70	80
27-Jul-99	0	20	20	170	<10	<10	<10
28-Jul-99	0	10	20	10	<10	<10	<10
29-Jul-99	0	25	40	120	<2	<2	<2
30-Jul-99	0	40	115		22	26	
31-Jul-99	0	30	70	40	20	<10	<10
1-Aug-99	0	30	20	20	<10	<10	10
2-Aug-99	0	80	40	150	<10	40	50
3-Aug-99	0	80	10	20	10	10	30
5-Aug-99	0	<5	<5	<5	<2	<2	<2
6-Aug-99	0.02	5	<5	<5	<2	<2	<2
7-Aug-99	0.1	<10	10	<10	<10	<10	<10
8-Aug-99	0.01	10	<10	10	<10	<10	<10
9-Aug-99	0	10	10	<10	<10	<10	10
10-Aug-99	0	<10	<10	<10	10	<10	<10
11-Aug-99	0	30	20	10	<10	<10	<10
12-Aug-99	0	25	40	35	<2	<2	4
13-Aug-99	0	55	50		10	2	

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 5: Tenean Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) North MDC26	Fecal Coliform (colonies/100 mL) Bathhouse MDC27	Fecal Coliform (colonies/100 mL) South MDC28	*Enterococcus* (colonies/100 mL) North MDC26	*Enterococcus* (colonies/100 mL) Bathhouse MDC27	*Enterococcus* (colonies/100 mL) South MDC28
14-Aug-99	0.01	30	60	60	10	10	20
15-Aug-99	0.33	3200	2400	4000	350	450	330
16-Aug-99	0.03	180	160	310	50	20	20
17-Aug-99	0	<10	50	40	10	<10	40
18-Aug-99	0	10	10	10	<10	<10	<10
19-Aug-99	0	15	55	115	<2	28	<2
20-Aug-99	0	5	15	30	<2	4	6
21-Aug-99	0.04	90	60	90	30	10	<10
22-Aug-99	0.32	150	20	120	120	40	30
23-Aug-99	0	710	10	10	<10	<10	<10
24-Aug-99	0	10	<10	<10	<10	<10	<10
25-Aug-99	0	200	20	10	30	<10	30
26-Aug-99	0	55	70	<5	12	36	2
27-Aug-99	0.01	175	80	175	38	42	20
28-Aug-99	0.06	10	80	<10	<10	<10	<10
29-Aug-99	0	60	470	400	30	220	10
30-Aug-99	0	30	<10	30	10	<10	<10
31-Aug-99	0	40	10	20	60	<10	10
1-Sep-99	0	60	40	40	10	10	10
2-Sep-99	0	20	15	15	2	4	2
3-Sep-99	0	5	15	165	2	8	112
4-Sep-99	0	20	<10	10	<10	10	<10
5-Sep-99	0	50	40	30	<10	<10	20
22-Jun-00	0.01	90	25	55	10	12	40
23-Jun-00	0.03	25	80	85	4	34	82
24-Jun-00	0	40	110	50	10	20	10
25-Jun-00	0	<10	40	20	<10	<10	10
26-Jun-00	0	10	10	<10	<10	<10	<10
27-Jun-00	0.02	10	<10	<10	30	<10	<10
28-Jun-00	0.88	410	480	4000	<10	10	990
29-Jun-00	0.1	260	1700	1340	110	130	112
30-Jun-00	0	100	295	210	62	18	44
1-Jul-00	0	285	300	240	8	20	34
2-Jul-00	0	300	180	500	60	20	10
3-Jul-00	0	50	80	30	10	50	<10
4-Jul-00	0	80	80	90	10	<10	<10
5-Jul-00	0	110	50	70	10	<10	10
6-Jul-00	0	65	10	55	<2	8	28
7-Jul-00	0	130	90	75	8	10	66
8-Jul-00	0.16	<10	10	40	<10	10	<10
9-Jul-00	0	<10	<10	20	<10	<10	<10
10-Jul-00	0.45	10	10	30	10	<10	<10
11-Jul-00	0	30	10	90	30	<10	10
12-Jul-00	0	<10	40	60	<10	<10	<10
13-Jul-00	0	140	95	165	6	2	6
14-Jul-00	0	150	105	130	8	4	8
15-Jul-00	0	20	30	<10	<10	<10	<10
16-Jul-00	1.05	80	120	240	<10	10	10
17-Jul-00	0	150	90	170	<10	<10	<10
18-Jul-00	0	<10	20	20	<10	<10	20
19-Jul-00	0.96	260	420	320	50	70	90

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 5: Tenean Beach Raw Data

Date	24 hr rainfall (in.) Columbus Park Headworks	Fecal Coliform (colonies/100 mL) North MDC26	Fecal Coliform (colonies/100 mL) Bathhouse MDC27	Fecal Coliform (colonies/100 mL) South MDC28	*Enterococcus* (colonies/100 mL) North MDC26	*Enterococcus* (colonies/100 mL) Bathhouse MDC27	*Enterococcus* (colonies/100 mL) South MDC28
20-Jul-00	0	360	200	335	156	34	50
21-Jul-00	0	80	45	60	12	6	16
22-Jul-00	0.17	90	30	610	40	30	100
23-Jul-00	0	60	40	100	<10	<10	10
24-Jul-00	0	10	20	<10	10	<10	<10
25-Jul-00	0	30	40	30	<10	<10	<10
26-Jul-00	0	80	10	70	<10	10	30
27-Jul-00	0.76	5400	3100	1900	1280	185	540
28-Jul-00	1.13	6800	6500	5800	820	545	700
29-Jul-00	0	50	40	60	<10	<10	30
30-Jul-00	0	170	70	110	30	10	10
31-Jul-00	0.74	250	410	750	60	100	63
1-Aug-00	0.05	130	180	80	60	80	520
2-Aug-00	0.01	300	190	200	120	60	70
3-Aug-00	0	130	105	75	14	18	38
4-Aug-00	0.09	65	45	30	14	16	18
5-Aug-00	0	210	70	80	40	60	30
6-Aug-00	0	20	<10	80	50	1620	1750
7-Aug-00	0.01	<10	40	10	<10	420	190
8-Aug-00	0	50	30	10	<10	<10	<10
9-Aug-00	0	<10	20	<10	<10	740	770
10-Aug-00	0.08	170	105	45	54	36	50
11-Aug-00	0	80	120	200	2	8	8
12-Aug-00	0	110	740	250	<10	330	520
13-Aug-00	0	20	70	340	<10	120	3000
14-Aug-00	0.62	3100	2600	2200	300	190	480
15-Aug-00	0.02	360	390	160	50	10	20
16-Aug-00	0.42	90	80	270	20	130	80
17-Aug-00	0.42	550	265	325	60	62	190
18-Aug-00	0	40	195	50	158	68	44
19-Aug-00	0.26	190	220	30	<10	<10	<10
20-Aug-00	0	30	50	50	<10	<10	10
21-Aug-00	0	20	40	90	<10	10	20
22-Aug-00	0	30	20	40	10	10	30
23-Aug-00	0	<10	50	10	<10	10	<10
24-Aug-00	0.38	120	120	220	34	12	58
25-Aug-00	0	90	185	170	20	68	24
26-Aug-00	0	40	60	30	<10	10	<10
27-Aug-00	0	110	160	60	30	80	<10
28-Aug-00	0	100	460	370	10	10	160
29-Aug-00	0	170	120	280	10	10	70
30-Aug-00	0	30	80	130	<10	<10	140
31-Aug-00	0	140	285	265	44	46	58
1-Sep-00	0	355	415	395	152	144	146
2-Sep-00	0.01	130	60	80	30	30	60
3-Sep-00	0.66	5900	7700	9400	790	1050	1060

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
12-Jun-96	0	48	15	<5	5	4	2	<2	<2
19-Jun-96	0		625	675	<5		17	15	3
20-Jun-96	0.01	320				12			
20-Jun-96	0.07		1860	190	15		101	21	60
26-Jun-96	0.1	<5	12	226	289	2	12	65	33
27-Jun-96	0		115	10	15		11	<2	8
1-Jul-96	0.07	15	135	2760	45	26	85	84	39
2-Jul-96	0	<5	428	440	30				
5-Jul-96	0.01	12	62	150	188	10	10	26	20
8-Jul-96	0	10	<10	20	<10	<10	<10	<10	10
9-Jul-96	0.04	10	130	90	10	<10	<10	10	10
10-Jul-96	0.05	32	12	30	662	19	18	12	90
11-Jul-96	0	<5	50	10	10	52	50	75	75
12-Jul-96	0	<5	<5	<5	650	<10	<10	<10	30
13-Jul-96	1.4	5600	1990	560	50	6300	5700	270	10
14-Jul-96	1.65	20	30	20	70	10	<10	30	30
15-Jul-96	0	40	10	160	<10	100	20	40	<10
16-Jul-96	0	20	170	140	40	10	10	<10	10
17-Jul-96	0	25	22	255	<5	50	26	180	112
18-Jul-96	0	25	185	60	52	6	9	17	4
19-Jul-96	0.04	30	890	58	75	50	55	70	3
20-Jul-96	0.09	<10	20	200	170	<10	10	270	10
21-Jul-96	0	<10	20	30	110	<10	<10	<10	20
22-Jul-96	0	<10	10	2200	50	<10	<10	80	<10
23-Jul-96	0	<10	140	320	10	10	60	80	10
24-Jul-96	0.56	595	1680	1820	1700	320	870	950	480
25-Jul-96	0	118	115	120	<5	537	1550	16	66
26-Jul-96	0.03	40	120	60	40	10	20	110	30
27-Jul-96	0	5	50	620	630	5	35	15	10
28-Jul-96	0	50	95	120	145	50	25	10	15
29-Jul-96	0	120	130	70	<10	100	80	30	80
30-Jul-96	0	410	570	370	30	100	10	30	70
2-Aug-96	0	10	160	8700	30	<10	270	510	10
3-Aug-96	0	80	40	250	<10	<10	<10	10	<10
4-Aug-96	0	<10	40	20	10	<10	10	<10	<10
5-Aug-96	0	<10	150	4300	60	<10	10	50	10
6-Aug-96	0	<10	110	80	20	<10	30	10	70
7-Aug-96	0	10	140	110	30	140	50	20	<10
8-Aug-96	0	10	112	148	15	6	68		70
10-Aug-96	0.58	150	110	430	160	150	90	170	10
11-Aug-96	0.11	20	240	120	490	20	30	40	10
12-Aug-96	0	260	10	1900	10	900	<10	80	20
13-Aug-96	0.22	80	180	6200	20	90	120	180	30
14-Aug-96	0.21	12	20	168	794	9	32	39	40
15-Aug-96	0	565	2080	3820	75	74	81	140	28
16-Aug-96	0	70	90	<10	10	<10	<10	<10	<10
17-Aug-96	0	50	170	1810	40	<10	40	20	<10
18-Aug-96	0	590	170	150	10	<10	40	<10	<10
19-Aug-96	0	20	510	190	100	<10	30	10	<10
20-Aug-96	0	250	330	40	10	<10	50	10	<10
21-Aug-96	0	1100	735	2020	20	45	28	242	62

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
23-Aug-96	0	<10	<10	20	50	<10	10	<10	10
24-Aug-96	0.36	20	70	120	280	<10	50	70	40
25-Aug-96	0.19	80	30	170	30	<10	30	50	10
26-Aug-96	0	30	260	360	40	<10	40	70	<10
27-Aug-96	0	130	150	3700	10	70	20	90	70
28-Aug-96	0.04	218	1180	2720	3690	222	1120	168	615
29-Aug-96	0.13	35	40	270	210	<2	88	22	15
30-Aug-96	0	140	185	2400	4500	95	80	85	80
31-Aug-96	0	20	210	580	<10				
1-Sep-96	0	<10	110	640	80				
9-Jun-97	0	<10	100	<10	<10	<10	40	<10	<10
10-Jun-97	0	<10	<10	<10	<10	<10	<10	<10	<10
11-Jun-97	0	10	10	340	200	10	<2	<2	650
12-Jun-97	0	20	20	380	290	<10	110	<10	10
13-Jun-97	0	60	<10	80	50	20	10	30	30
16-Jun-97	0	200	210	20	<10	<10	10	10	20
17-Jun-97	0	790	590	3600	<10	50	10	80	40
18-Jun-97	0.05	9520	400	5000	25	8	6	30	20
19-Jun-97	0.23	605	382	562	20	670	550	70	30
20-Jun-97	0	970	800	75	80	90	8	30	70
23-Jun-97	0.23	10	670	930	2380	<10	430	60	130
24-Jun-97	0	180	140	80	680	<10	20	10	10
25-Jun-97	0	55	60	5760	700	20	14	16	14
26-Jun-97	0	40	30	3400	350	12	54	62	2
27-Jun-97	0	260	80	670	35	50	70	50	6
28-Jun-97	0	35	5	90	25	4	4	34	10
30-Jun-97	0	50	10	30	120	10	<10	<10	10
1-Jul-97	0	175	315	840	4160	30	44	660	550
2-Jul-97	0.01	20	150	3320	5	<2	4	240	2
2-Jul-97	0.05	7000	2870	680	40	70	50	60	<10
3-Jul-97	0	4200	1800	410	30	130	70	20	10
4-Jul-97	0.07	3400	180	270	20	20	10	20	10
5-Jul-97	0	20	20	190	590	<10	<10	70	<10
6-Jul-97	0	20	50	140	10	10	20	20	<10
7-Jul-97	0	10	40	20	30	<10	70	<10	<10
8-Jul-97	0.33	50	200	220	<10	<10	80	40	10
9-Jul-97	0	615	80	220	10	20	30	8	8
10-Jul-97	0.01	525	800	2400	210	400	58	80	50
11-Jul-97	0	80	45	70	5	10	50	98	32
12-Jul-97	0	320	30	40	10	<10	40	50	80
13-Jul-97	0	<10	110	120	40	<10	<10	20	10
14-Jul-97	0	990	60	<10	<10	<10	<10	<10	<10
15-Jul-97	0	420	5100	70	20	60	20	30	<10
16-Jul-97	0.02	7100	2150	50	430	66	20	128	84
17-Jul-97	0.01	1600	1700	280	110	72	<2	50	36
18-Jul-97	0.01	280	50	660	90	15	<2	290	30
19-Jul-97	0	25	220	20	75	10	62	50	36
20-Jul-97	0	<10	50	<10	40	<10	20	250	10
21-Jul-97	0	850	20	10	20	270	<10	20	30
22-Jul-97	0.13	100	700	30	40	50	200	10	<10
23-Jul-97	0	220	180	150	50	60	70	680	30

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
23-Jul-97	0.01	540	400	1000	480	66	80	56	116
24-Jul-97	0	16800	40	6400	280	30	24	80	18
25-Jul-97	0.21	>20000	830	300	35	>2000	200	100	86
26-Jul-97	0.062	20	10	40	20	30	<10	10	10
27-Jul-97	0	20	<10	330	10	40	90	80	<10
29-Jul-97	0	70	60	300	70	<10	<10	20	10
30-Jul-97	0	5	50	35300	30	6	8	540	6
31-Jul-97	0	5	290	615	30	4	350	8	<2
1-Aug-97	0	<10	10	150	20	<10	<10	80	20
2-Aug-97	0	4900	<10	110	140	50	10	<10	40
3-Aug-97	0	10	180	80	60	<10	<10	20	10
4-Aug-97	0	970	430	210	70	70	270	60	70
5-Aug-97	0.18	300	100	100	60	30	20	160	10
6-Aug-97	0.01	1810	300	320	40	8	40	4	20
7-Aug-97	0	50	210	35	260	16	40	12	410
8-Aug-97	0	170	2700	<10	70	10	70	<10	110
9-Aug-97	0.47	240	40	10	<10	10	20	100	20
10-Aug-97	0.09	80	30	170	20	60	<10	20	10
11-Aug-97	0	280	2800	220	10	100	280	<10	<10
12-Aug-97	0.01	580	350	1580	20	<10	60	10	<10
13-Aug-97	0	9100	550	66000	60	3680	4	330	30
14-Aug-97	0.48	1400	290	400	90	32	80	72	80
15-Aug-97	0	230	340	270	30	160	200	60	<10
16-Aug-97	0	110	90	20	10	<10	20	20	10
17-Aug-97	0	10	10	80	<10	50	10	50	<10
18-Aug-97	0.57	300	2400	1200	1020	210	1220	1530	550
19-Aug-97	0	290	590	260	120	30	140	50	20
20-Aug-97	0	490	580	355	30	500	370	94	92
21-Aug-97	0.28	1400	800	5700	560	360	280	280	100
21-Aug-97	0.29	800	160	240	150	660	174	224	156
22-Aug-97	0.41	160	850	220	120	80	50	200	200
23-Aug-97	0.02	20	190	250	170	8	90	40	40
24-Aug-97	0	20	70	140	<10	20	10	30	20
25-Aug-97	0	11500	840	50	20	830	450	<10	<10
26-Aug-97	0	2100	1040	2600	40	130	290	260	10
27-Aug-97	0.01	90	5	65	220	25	5	20	2
28-Aug-97	0	320	515	2500	95	64	910	8	750
29-Aug-97	0.2	30	425	800	25	30	44	30	50
30-Aug-97	0.35	85	1340	205	180	30	80	25	20
31-Aug-97	0	40	30	60	130	<10	<10	<10	<10
10-Jun-98	0	5	215	10	110	1	8	4	2
17-Jun-98	0.03	1360	1920	720	150	160	96	62	100
18-Jun-98	0.38	1560	1360	155	335	170	200	55	20
24-Jun-98	0				35				12
25-Jun-98	0	115	125	1400	125	8	14	94	8
30-Jun-98	0.09	65	15	180	20	4	2	36	50
1-Jul-98	1.93	325	180	420	25	148	68	70	12
3-Jul-98	0	20	30	50	30	<10	30	<10	10
4-Jul-98	0	<10	170	40	10	20	<10	20	<10
5-Jul-98	0.056	<10	1500	70	<10	10	50	70	<10
6-Jul-98	0.11	180	30	230	70	50	90	160	150

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
7-Jul-98	0	120	140	150	<10	10	30	70	<10
8-Jul-98	0	90	130	20	5	30	82	4	<2
9-Jul-98	0	35	20	10	5	24	12	8	30
10-Jul-98	0	40	100	<10	20	10	10	10	<10
11-Jul-98	0	10	160	50	50	20	120	30	10
12-Jul-98	0	80	230	80	140	10	70	<10	30
13-Jul-98	0	690	1460	50	20	30	110	60	<10
14-Jul-98	0	240	30	20	<10	<10	10	<10	<10
15-Jul-98	0	55	60	70	30	2	<2	8	2
16-Jul-98	0	320	170	145	25	<2	2	2	2
17-Jul-98	0	20	10	30	<10	<10	30	<10	<10
18-Jul-98	0	60	40	<10	10	<10	350	<10	140
19-Jul-98	0.01	10	340	30	<10	10	30	10	<10
20-Jul-98	0	20	<10	20	<10	10	10	<10	<10
21-Jul-98	0.03	220	1800	100	280	40	30	<10	20
22-Jul-98	0	20	375	100	40	<2	36	4	28
23-Jul-98	0	180	210	70	15	4	4	10	2
24-Jul-98	0.7	470	1000	1100	130	130	50	50	10
25-Jul-98	0	30	1500	90	<10	<10	280	<10	<10
26-Jul-98	0	80	180	10	40	<10	90	<10	<10
27-Jul-98	0	170	60	20	100	20	30	20	10
28-Jul-98	0	140	20	10	20	30	20	<10	10
29-Jul-98	0	100	125	<5	<5	4	<2	6	<2
30-Jul-98	0.32	1640	<5	1160	1580	46	4	62	48
31-Jul-98	0.26	70	1200	580	<10	30	540	220	<10
1-Aug-98	0.15	60	60	7100	60	30	40	10	20
2-Aug-98	0	10	190	40	120	10	40	<10	<10
3-Aug-98	0	100	190	820	900	<10	30	90	30
4-Aug-98	0	330	640	350	190	70	130	160	40
5-Aug-98	0	45	115	10	25	20	16	4	8
6-Aug-98	0	95	55	20	30	12	16	8	10
7-Aug-98	0.02	50	10	290	<10	<10	<10	90	10
8-Aug-98	0	260	1500	20	10	10	200	10	20
9-Aug-98	0	30	40	40	10	30	<10	30	<10
10-Aug-98	0	40	<10	30	10	<10	30	20	<10
11-Aug-98	0	10	160	40	10	<10	20	<10	10
12-Aug-98	0.55	>4000	3020			46	820		
13-Aug-98	0.09	155	80	145	150	32	46	50	26
14-Aug-98	0	320	82	90	<10	20	20	50	10
15-Aug-98	0.15	40	30	670	<10	10	<10	270	<10
16-Aug-98	0.14	180	70	10	10	70	10	<10	<10
17-Aug-98	0	540	210	245	180	120	54	<10	10
18-Aug-98	1.89	100	260	80	10	30	160	60	10
19-Aug-98	0.44	50	135	510	635	28	128	130	92
20-Aug-98	0	35	130	55	105	14	10	12	8
21-Aug-98	0	150	470	330	20	10	50	80	<10
22-Aug-98	0	100	10	10	<10	10	<10	10	<10
23-Aug-98	0	150	660	5700	90	<10	80	20	<10
24-Aug-98	0.39	30	90	240	<10	20	10	140	<10
25-Aug-98	0	50	150	90	<10	<10	10	<10	<10
26-Aug-98	0.19	1140	210	25	<5	172	<2	<2	6

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Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
27-Aug-98	0.09	355	430	675	370	92	54	42	8
28-Aug-98	0	70	60	60	40	20	150	40	20
29-Aug-98	0.51	3500	5600	2400	340	480	1870	1140	80
30-Aug-98	0.14	110	100	5900	90	20	<10	450	20
31-Aug-98	0.01	270	160	2300	140	60	70	210	20
1-Sep-98	0.01	20	160	60	190	<10	50	10	<10
2-Sep-98	0	355	250	490	20	42	10	34	10
3-Sep-98	0.04	225	340	190	160	8	2	<2	<2
4-Sep-98	0	350	40	650	90	50	10	420	30
5-Sep-98	0	130	420	60	380	<10	30	60	30
6-Sep-98	0	20	30	490	20	20	30	50	20
3-Jun-99	0	<5	15	15	5	<2	<2	<2	<2
10-Jun-99	0	35	35	15	15	<2	<2	<2	<2
17-Jun-99	0.01	95	165	5	30	18	94	4	10
24-Jun-99	0	165	5	80	<5	22	<2	4	<2
25-Jun-99	0	230	5	25	15	30	2	6	<2
29-Jun-99	0	100	5	10	5	2	<2	8	4
1-Jul-99	1.24	2480	3200	300	480	640	1200	140	450
2-Jul-99	0.48	300	40	45	15	88	10	14	2
3-Jul-99	0	10	30	2900	10	<10	10	50	<10
4-Jul-99	0.01	160	<10	80	10	50	<10	50	10
5-Jul-99	0.02	<10	580	<10	10	<10	50	<10	<10
6-Jul-99	0	<10	610	50	140	<10	270	10	40
7-Jul-99	0.4	60	70	10	<10	<10	<10	<10	<10
8-Jul-99	0	<5	50	65	350	<2	<2	4	<2
9-Jul-99	0	5	25	335	10	6	12	22	6
10-Jul-99	0.02	80	160	40	<10	<10	20	<10	<10
11-Jul-99	0	30	880	<10	10	<10	330	<10	<10
12-Jul-99	0	70	60	20	<10	<10	<10	<10	<10
13-Jul-99	0.09	180	460	360	10	40	40	110	<10
14-Jul-99	0	10	730	<10	<10	<10	<10	10	<10
15-Jul-99	0	10	25	620	5	2	4	28	<2
16-Jul-99	0	5	<5	<5	15	4	4	4	<2
17-Jul-99	0	<10	20	<10	10	<10	20	<10	<10
18-Jul-99	0.01	<10	960	<10	20	<10	<10	<10	<10
19-Jul-99	0	10	60	<10	<10	<10	<10	10	10
20-Jul-99	0.41	150	200	10	280	60	30	10	10
21-Jul-99	0	10	60	<10	<10	20	<10	<10	10
22-Jul-99	0	110	<5	25	<5	20	4	6	<2
23-Jul-99	0.48	60	110	20	10	32	62	14	2
24-Jul-99	0.04	20	60	<10	40	<10	20	<10	170
25-Jul-99	0.31	1120	7300	1980	470	460	1160	970	150
26-Jul-99	0.43	690	3900	4900	50	210	580	840	10
27-Jul-99	0	100	240	280	40	<10	10	<10	20
28-Jul-99	0	210	590	200	80	30	70	<10	<10
29-Jul-99	0	8	305	20	150	2	24	2	2
30-Jul-99	0	50	325	5	5	24	34	4	2
31-Jul-99	0	120	20	80	10	<10	<10	<10	<10
1-Aug-99	0	30	10	30	<10	<10	10	<10	<10
2-Aug-99	0	70	480	10	180	30	120	30	60
3-Aug-99	0	<10	30	<10	40	10	10	<10	30

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
4-Aug-99	0	10	10	10	<10	<10	<10	<10	<10
5-Aug-99	0	<5	10	<5	45	<2	<2	<2	<2
6-Aug-99	0.7	20	30	<5	<5	6	4	<2	2
7-Aug-99	0.09	180	30	10	50	10	<10	<10	<10
8-Aug-99	0	80	10	90	<10	10	10	40	<10
9-Aug-99	0	180	20	40	140	40	10	<10	10
10-Aug-99	0	90	30	<10	<10	50	<10	10	<10
11-Aug-99	0	80	80	130	130	80	10	10	10
12-Aug-99	0	60	60	20	25	4	<2	2	4
13-Aug-99	0	50	15	25	20	18	<2	<2	<2
14-Aug-99	0.11	50	<10	120	<10	<10	<10	10	<10
15-Aug-99	0.93	2900	4400	720	2500	280	740	250	120
16-Aug-99	0.05	80	60	10	30	10	<10	30	<10
17-Aug-99	0	<10	<10	<10	<10	10	20	20	<10
18-Aug-99	0	20	110	80	20	<10	<10	<10	<10
19-Aug-99	0	25	120	125	165	2	30	24	16
20-Aug-99	0	10	5	100	<5	<2	2	6	<2
21-Aug-99	0.05	10	30	50	80	100	<10	20	40
22-Aug-99	0.17	80	320	150	50	110	190	40	10
23-Aug-99	0.1	10	<10	<10	10	<10	<10	<10	<10
24-Aug-99	0	100	20	60	70	<10	10	<10	10
25-Aug-99	0	10	30	120	<10	20	10	<10	80
26-Aug-99	0	25	140	45	<5	<2	16	4	<2
27-Aug-99	0	150	120	25	5	12	28	18	6
28-Aug-99	0.25	40	80	10	<10	10	<10	<10	<10
29-Aug-99	0	110	400	80	120	30	60	80	20
30-Aug-99	0.01	50	190	10	740	70	50	<10	180
31-Aug-99	0	60	130		20	<10	10	70	<10
1-Sep-99	0	20	<10	20	20	10	<10	<10	<10
2-Sep-99	0	10	<5	45	<5	<2	<2	8	<2
3-Sep-99	0	5	5	25	10	<2	4	2	10
4-Sep-99	0	190	190	10	<10	70	30	<10	<10
5-Sep-99	0	30	70	30	160	<10	<10	<10	10
1-Jun-00	0	1425	5	15	<5	78	2	2	<2
8-Jun-00	0.09	120	155	145	160	54	128	46	16
15-Jun-00	0	260	15	5	5	50	2	2	2
22-Jun-00	0	20	<5	5	<5	2	<2	2	<2
23-Jun-00	0.01	135	65	25	55	14	28	20	16
24-Jun-00	0	200	80	40	10	10	<10	10	<10
25-Jun-00	0	10	120	<10	<10	<10	40	<10	<10
26-Jun-00	0	50	20	40	<10	30	10	40	<10
27-Jun-00	0	<10	30	20	<10	80	<10	10	<10
28-Jun-00	3.05	90	130	240	140	80	20	50	120
29-Jun-00	0.11	1220	1380	190	170	1220	252	66	42
30-Jun-00	0.02	230	105	110	90	48	50	90	8
1-Jul-00	0	230	50	30	20	70	<10	100	30
2-Jul-00	0	60	20	30	30	10	30	60	10
3-Jul-00	0	20	640	20	<10	<10	20	10	20
4-Jul-00	0	<10	480	30	<10	10	<10	<10	10
5-Jul-00	0	40	140	120	20	<10	<10	10	<10
6-Jul-00	0	<5	30	160	240	2	10	30	90

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
7-Jul-00	0	70	185	145	385	14	34	46	148
8-Jul-00	0	<10	360	30	80	<10	350	<10	20
9-Jul-00	0	20	70	60	20	10	10	<10	<10
10-Jul-00	0.49	50	<10	10	<100	<10	<10	10	<10
11-Jul-00	0	300	120	120	250	<10	30	<10	20
12-Jul-00	0	90	10	<10	10	20	<10	10	<10
13-Jul-00	0	740	<5	110	410	2	2	2	2
14-Jul-00	0	65	60	45	55	20	4	<2	4
15-Jul-00	0	780	4400	60	20	<10	50	<10	10
16-Jul-00	2.51	370	640	80	30	<10	130	<10	10
17-Jul-00	0.01	2600	11400	7200	170	100	80	10	<10
18-Jul-00	0	230	110	220	<10	<10	<10	120	<10
19-Jul-00	3.06	<10	130	1000	260	320	10	1600	70
20-Jul-00	0	880	220	60	780	470	74	14	124
21-Jul-00	0	450	195	500	65	50	20	56	16
22-Jul-00	0.23	90	250	60	10	20	40	20	<10
23-Jul-00	0	<10	40	110	<10	<10	<10	<10	<10
24-Jul-00	0	10	400	960	50	10	50	<10	<10
25-Jul-00	0	180	80	10	20	30	40	<10	<10
26-Jul-00	0	230	110	20	20	90	220	<10	10
27-Jul-00	0.74	6100	6600	210	60	760	1760	90	10
28-Jul-00	1.15	280	2600	6600	8700	265	205	480	240
29-Jul-00	0	30	60	40	<10	240	100	30	<10
30-Jul-00	0	50	480	140	10	<10	40	40	10
31-Jul-00	0.85	420	3100	100	130	630	780	30	120
1-Aug-00	0.04	1600	1200	10	190	300	170	60	110
2-Aug-00	0.02	14800	120	190	20	580	70	50	40
3-Aug-00	0.01	160	130	20	35	10	16	8	36
4-Aug-00	0.06	10	10	20	35	4	2	6	6
5-Aug-00	0	250	350	50	120	440	100	20	60
6-Aug-00	0	30	150	30	<10	10	90	3930	130
7-Aug-00	0	<10	70	30	<10	40	120	140	1200
8-Aug-00	0.01	60	200	10	10	20	30	30	<10
9-Aug-00	0	8100	<10	40	<10	650	80	10	
10-Aug-00	0	2020	545	165	60	132	160	40	<2
11-Aug-00	0	2580	80	30	<5	28	12	4	2
12-Aug-00	0	100	130	90	30	50	90	60	120
13-Aug-00	0	490	5300	500	50	30	40	30	50
14-Aug-00	0	170	<10	160	200	130	<10	200	<10
15-Aug-00	0	19000	2100	310	740	360	560	70	90
16-Aug-00	0.06	6600	140	130	70	550	50	160	<10
17-Aug-00	0.09	5	295	50	25	8	12	2	10
18-Aug-00	0	20	45	4	4	12	64	10	5
19-Aug-00	0.19	170	200	110	360	<10	10	20	50
20-Aug-00	0	300	160	580	30	150	10	40	50
21-Aug-00	0	10	50	50	<10	<10	10	<10	<10
22-Aug-00	0	50	130	60	930	20	50	10	<10
23-Aug-00	0	570	200	710	10	60	30	40	10
24-Aug-00	0.53	445	205	485	165	168	18	96	28
25-Aug-00	0.01	65	10	15	455	28	12	4	26
26-Aug-00	0	<10	120	60	30	<10	<10	90	40

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
27-Aug-00	0	100	20	190	40	20	20	100	60
28-Aug-00	0	160	250	720	160	20	150	1680	70
29-Aug-00	0	100	230	270	240	30	20	220	30
30-Aug-00	0	220	90	270	20	30	30	90	<10
31-Aug-00	0	80	200	170	20	46	24	22	14
1-Sep-00	0	<5	5	20	15	2	2	12	8
2-Sep-00	0.02	20	<10	20	240	<10	30	10	20
3-Sep-00	0.43	800	1500	5100	2300	280	670	1520	880
7-Sep-00	0	25	35	45	10	2	6	8	<2

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
12-Jun-96	0	48	15	<5	5	4	2	<2	<2
19-Jun-96	0		625	675	<5		17	15	3
20-Jun-96	0.01	320				12			
20-Jun-96	0.07		1860	190	15		101	21	60
26-Jun-96	0.1	<5	12	226	289	2	12	65	33
27-Jun-96	0		115	10	15		11	<2	8
1-Jul-96	0.07	15	135	2760	45	26	85	84	39
2-Jul-96	0	<5	428	440	30				
5-Jul-96	0.01	12	62	150	188	10	10	26	20
8-Jul-96	0	10	<10	20	<10	<10	<10	<10	10
9-Jul-96	0.04	10	130	90	10	<10	<10	10	10
10-Jul-96	0.05	32	12	30	662	19	18	12	90
11-Jul-96	0	<5	50	10	10	52	50	75	75
12-Jul-96	0	<5	<5	<5	650	<10	<10	<10	30
13-Jul-96	1.4	5600	1990	560	50	6300	5700	270	10
14-Jul-96	1.65	20	30	20	70	10	<10	30	30
15-Jul-96	0	40	10	160	<10	100	20	40	<10
16-Jul-96	0	20	170	140	40	10	10	<10	10
17-Jul-96	0	25	22	255	<5	50	26	180	112
18-Jul-96	0	25	185	60	52	6	9	17	4
19-Jul-96	0.04	30	890	58	75	50	55	70	3
20-Jul-96	0.09	<10	20	200	170	<10	10	270	10
21-Jul-96	0	<10	20	30	110	<10	<10	<10	20
22-Jul-96	0	<10	10	2200	50	<10	<10	80	<10
23-Jul-96	0	<10	140	320	10	10	60	80	10
24-Jul-96	0.56	595	1680	1820	1700	320	870	950	480
25-Jul-96	0	118	115	120	<5	537	1550	16	66
26-Jul-96	0.03	40	120	60	40	10	20	110	30
27-Jul-96	0	5	50	620	630	5	35	15	10
28-Jul-96	0	50	95	120	145	50	25	10	15
29-Jul-96	0	120	130	70	<10	100	80	30	80
30-Jul-96	0	410	570	370	30	100	10	30	70
2-Aug-96	0	10	160	8700	30	<10	270	510	10
3-Aug-96	0	80	40	250	<10	<10	<10	10	<10
4-Aug-96	0	<10	40	20	10	<10	10	<10	<10
5-Aug-96	0	<10	150	4300	60	<10	10	50	10
6-Aug-96	0	<10	110	80	20	<10	30	10	70
7-Aug-96	0	10	140	110	30	140	50	20	<10
8-Aug-96	0	10	112	148	15	6	68		70
10-Aug-96	0.58	150	110	430	160	150	90	170	10
11-Aug-96	0.11	20	240	120	490	20	30	40	10
12-Aug-96	0	260	10	1900	10	900	<10	80	20
13-Aug-96	0.22	80	180	6200	20	90	120	180	30
14-Aug-96	0.21	12	20	168	794	9	32	39	40
15-Aug-96	0	565	2080	3820	75	74	81	140	28
16-Aug-96	0	70	90	<10	10	<10	<10	<10	<10
17-Aug-96	0	50	170	1810	40	<10	40	20	<10
18-Aug-96	0	590	170	150	10	<10	40	<10	<10
19-Aug-96	0	20	510	190	100	<10	30	10	<10
20-Aug-96	0	250	330	40	10	<10	50	10	<10
21-Aug-96	0	1100	735	2020	20	45	28	242	62

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
23-Aug-96	0	<10	<10	20	50	<10	10	<10	10
24-Aug-96	0.36	20	70	120	280	<10	50	70	40
25-Aug-96	0.19	80	30	170	30	<10	30	50	10
26-Aug-96	0	30	260	360	40	<10	40	70	<10
27-Aug-96	0	130	150	3700	10	70	20	90	70
28-Aug-96	0.04	218	1180	2720	3690	222	1120	168	615
29-Aug-96	0.13	35	40	270	210	<2	88	22	15
30-Aug-96	0	140	185	2400	4500	95	80	85	80
31-Aug-96	0	20	210	580	<10				
1-Sep-96	0	<10	110	640	80				
9-Jun-97	0	<10	100	<10	<10	<10	40	<10	<10
10-Jun-97	0	<10	<10	<10	<10	<10	<10	<10	<10
11-Jun-97	0	10	10	340	200	10	<2	<2	650
12-Jun-97	0	20	20	380	290	<10	110	<10	10
13-Jun-97	0	60	<10	80	50	20	10	30	30
16-Jun-97	0	200	210	20	<10	<10	10	10	20
17-Jun-97	0	790	590	3600	<10	50	10	80	40
18-Jun-97	0.05	9520	400	5000	25	8	6	30	20
19-Jun-97	0.23	605	382	562	20	670	550	70	30
20-Jun-97	0	970	800	75	80	90	8	30	70
23-Jun-97	0.23	10	670	930	2380	<10	430	60	130
24-Jun-97	0	180	140	80	680	<10	20	10	10
25-Jun-97	0	55	60	5760	700	20	14	16	14
26-Jun-97	0	40	30	3400	350	12	54	62	2
27-Jun-97	0	260	80	670	35	50	70	50	6
28-Jun-97	0	35	5	90	25	4	4	34	10
30-Jun-97	0	50	10	30	120	10	<10	<10	10
1-Jul-97	0	175	315	840	4160	30	44	660	550
2-Jul-97	0.01	20	150	3320	5	<2	4	240	2
2-Jul-97	0.05	7000	2870	680	40	70	50	60	<10
3-Jul-97	0	4200	1800	410	30	130	70	20	10
4-Jul-97	0.07	3400	180	270	20	20	10	20	10
5-Jul-97	0	20	20	190	590	<10	<10	70	<10
6-Jul-97	0	20	50	140	10	10	20	20	<10
7-Jul-97	0	10	40	20	30	<10	70	<10	<10
8-Jul-97	0.33	50	200	220	<10	<10	80	40	10
9-Jul-97	0	615	80	220	10	20	30	8	8
10-Jul-97	0.01	525	800	2400	210	400	58	80	50
11-Jul-97	0	80	45	70	5	10	50	98	32
12-Jul-97	0	320	30	40	10	<10	40	50	80
13-Jul-97	0	<10	110	120	40	<10	<10	20	10
14-Jul-97	0	990	60	<10	<10	<10	<10	<10	<10
15-Jul-97	0	420	5100	70	20	60	20	30	<10
16-Jul-97	0.02	7100	2150	50	430	66	20	128	84
17-Jul-97	0.01	1600	1700	280	110	72	<2	50	36
18-Jul-97	0.01	280	50	660	90	15	<2	290	30
19-Jul-97	0	25	220	20	75	10	62	50	36
20-Jul-97	0	<10	50	<10	40	<10	20	250	10
21-Jul-97	0	850	20	10	20	270	<10	20	30
22-Jul-97	0.13	100	700	30	40	50	200	10	<10
23-Jul-97	0	220	180	150	50	60	70	680	30

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
23-Jul-97	0.01	540	400	1000	480	66	80	56	116
24-Jul-97	0	16800	40	6400	280	30	24	80	18
25-Jul-97	0.21	>20000	830	300	35	>2000	200	100	86
26-Jul-97	0.062	20	10	40	20	30	<10	10	10
27-Jul-97	0	20	<10	330	10	40	90	80	<10
29-Jul-97	0	70	60	300	70	<10	<10	20	10
30-Jul-97	0	5	50	35300	30	6	8	540	6
31-Jul-97	0	5	290	615	30	4	350	8	<2
1-Aug-97	0	<10	10	150	20	<10	<10	80	20
2-Aug-97	0	4900	<10	110	140	50	10	<10	40
3-Aug-97	0	10	180	80	60	<10	<10	20	10
4-Aug-97	0	970	430	210	70	70	270	60	70
5-Aug-97	0.18	300	100	100	60	30	20	160	10
6-Aug-97	0.01	1810	300	320	40	8	40	4	20
7-Aug-97	0	50	210	35	260	16	40	12	410
8-Aug-97	0	170	2700	<10	70	10	70	<10	110
9-Aug-97	0.47	240	40	10	<10	10	20	100	20
10-Aug-97	0.09	80	30	170	20	60	<10	20	10
11-Aug-97	0	280	2800	220	10	100	280	<10	<10
12-Aug-97	0.01	580	350	1580	20	<10	60	10	<10
13-Aug-97	0	9100	550	66000	60	3680	4	330	30
14-Aug-97	0.48	1400	290	400	90	32	80	72	80
15-Aug-97	0	230	340	270	30	160	200	60	<10
16-Aug-97	0	110	90	20	10	<10	20	20	10
17-Aug-97	0	10	10	80	<10	50	10	50	<10
18-Aug-97	0.57	300	2400	1200	1020	210	1220	1530	550
19-Aug-97	0	290	590	260	120	30	140	50	20
20-Aug-97	0	490	580	355	30	500	370	94	92
21-Aug-97	0.28	1400	800	5700	560	360	280	280	100
21-Aug-97	0.29	800	160	240	150	660	174	224	156
22-Aug-97	0.41	160	850	220	120	80	50	200	200
23-Aug-97	0.02	20	190	250	170	8	90	40	40
24-Aug-97	0	20	70	140	<10	20	10	30	20
25-Aug-97	0	11500	840	50	20	830	450	<10	<10
26-Aug-97	0	2100	1040	2600	40	130	290	260	10
27-Aug-97	0.01	90	5	65	220	25	5	20	2
28-Aug-97	0	320	515	2500	95	64	910	8	750
29-Aug-97	0.2	30	425	800	25	30	44	30	50
30-Aug-97	0.35	85	1340	205	180	30	80	25	20
31-Aug-97	0	40	30	60	130	<10	<10	<10	<10
10-Jun-98	0	5	215	10	110	1	8	4	2
17-Jun-98	0.03	1360	1920	720	150	160	96	62	100
18-Jun-98	0.38	1560	1360	155	335	170	200	55	20
24-Jun-98	0				35				12
25-Jun-98	0	115	125	1400	125	8	14	94	8
30-Jun-98	0.09	65	15	180	20	4	2	36	50
1-Jul-98	1.93	325	180	420	25	148	68	70	12
3-Jul-98	0	20	30	50	30	<10	30	<10	10
4-Jul-98	0	<10	170	40	10	20	<10	20	<10
5-Jul-98	0.056	<10	1500	70	<10	10	50	70	<10
6-Jul-98	0.11	180	30	230	70	50	90	160	150

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
7-Jul-98	0	120	140	150	<10	10	30	70	<10
8-Jul-98	0	90	130	20	5	30	82	4	<2
9-Jul-98	0	35	20	10	5	24	12	8	30
10-Jul-98	0	40	100	<10	20	10	10	10	<10
11-Jul-98	0	10	160	50	50	20	120	30	10
12-Jul-98	0	80	230	80	140	10	70	<10	30
13-Jul-98	0	690	1460	50	20	30	110	60	<10
14-Jul-98	0	240	30	20	<10	<10	10	<10	<10
15-Jul-98	0	55	60	70	30	2	<2	8	2
16-Jul-98	0	320	170	145	25	<2	2	2	2
17-Jul-98	0	20	10	30	<10	<10	30	<10	<10
18-Jul-98	0	60	40	<10	10	<10	350	<10	140
19-Jul-98	0.01	10	340	30	<10	10	30	10	<10
20-Jul-98	0	20	<10	20	<10	10	10	<10	<10
21-Jul-98	0.03	220	1800	100	280	40	30	<10	20
22-Jul-98	0	20	375	100	40	<2	36	4	28
23-Jul-98	0	180	210	70	15	4	4	10	2
24-Jul-98	0.7	470	1000	1100	130	130	50	50	10
25-Jul-98	0	30	1500	90	<10	<10	280	<10	<10
26-Jul-98	0	80	180	10	40	<10	90	<10	<10
27-Jul-98	0	170	60	20	100	20	30	20	10
28-Jul-98	0	140	20	10	20	30	20	<10	10
29-Jul-98	0	100	125	<5	<5	4	<2	6	<2
30-Jul-98	0.32	1640	<5	1160	1580	46	4	62	48
31-Jul-98	0.26	70	1200	580	<10	30	540	220	<10
1-Aug-98	0.15	60	60	7100	60	30	40	10	20
2-Aug-98	0	10	190	40	120	10	40	<10	<10
3-Aug-98	0	100	190	820	900	<10	30	90	30
4-Aug-98	0	330	640	350	190	70	130	160	40
5-Aug-98	0	45	115	10	25	20	16	4	8
6-Aug-98	0	95	55	20	30	12	16	8	10
7-Aug-98	0.02	50	10	290	<10	<10	<10	90	10
8-Aug-98	0	260	1500	20	10	10	200	10	20
9-Aug-98	0	30	40	40	10	30	<10	30	<10
10-Aug-98	0	40	<10	30	10	<10	30	20	<10
11-Aug-98	0	10	160	40	10	<10	20	<10	10
12-Aug-98	0.55	>4000	3020			46	820		
13-Aug-98	0.09	155	80	145	150	32	46	50	26
14-Aug-98	0	320	82	90	<10	20	20	50	10
15-Aug-98	0.15	40	30	670	<10	10	<10	270	<10
16-Aug-98	0.14	180	70	10	10	70	10	<10	<10
17-Aug-98	0	540	210	245	180	120	54	<10	10
18-Aug-98	1.89	100	260	80	10	30	160	60	10
19-Aug-98	0.44	50	135	510	635	28	128	130	92
20-Aug-98	0	35	130	55	105	14	10	12	8
21-Aug-98	0	150	470	330	20	10	50	80	<10
22-Aug-98	0	100	10	10	<10	10	<10	10	<10
23-Aug-98	0	150	660	5700	90	<10	80	20	<10
24-Aug-98	0.39	30	90	240	<10	20	10	140	<10
25-Aug-98	0	50	150	90	<10	<10	10	<10	<10
26-Aug-98	0.19	1140	210	25	<5	172	<2	<2	6

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
27-Aug-98	0.09	355	430	675	370	92	54	42	8
28-Aug-98	0	70	60	60	40	20	150	40	20
29-Aug-98	0.51	3500	5600	2400	340	480	1870	1140	80
30-Aug-98	0.14	110	100	5900	90	20	<10	450	20
31-Aug-98	0.01	270	160	2300	140	60	70	210	20
1-Sep-98	0.01	20	160	60	190	<10	50	10	<10
2-Sep-98	0	355	250	490	20	42	10	34	10
3-Sep-98	0.04	225	340	190	160	8	2	<2	<2
4-Sep-98	0	350	40	650	90	50	10	420	30
5-Sep-98	0	130	420	60	380	<10	30	60	30
6-Sep-98	0	20	30	490	20	20	30	50	20
3-Jun-99	0	<5	15	15	5	<2	<2	<2	<2
10-Jun-99	0	35	35	15	15	<2	<2	<2	<2
17-Jun-99	0.01	95	165	5	30	18	94	4	10
24-Jun-99	0	165	5	80	<5	22	<2	4	<2
25-Jun-99	0	230	5	25	15	30	2	6	<2
29-Jun-99	0	100	5	10	5	2	<2	8	4
1-Jul-99	1.24	2480	3200	300	480	640	1200	140	450
2-Jul-99	0.48	300	40	45	15	88	10	14	2
3-Jul-99	0	10	30	2900	10	<10	10	50	<10
4-Jul-99	0.01	160	<10	80	10	50	<10	50	10
5-Jul-99	0.02	<10	580	<10	10	<10	50	<10	<10
6-Jul-99	0	<10	610	50	140	<10	270	10	40
7-Jul-99	0.4	60	70	10	<10	<10	<10	<10	<10
8-Jul-99	0	<5	50	65	350	<2	<2	4	<2
9-Jul-99	0	5	25	335	10	6	12	22	6
10-Jul-99	0.02	80	160	40	<10	<10	20	<10	<10
11-Jul-99	0	30	880	<10	10	<10	330	<10	<10
12-Jul-99	0	70	60	20	<10	<10	<10	<10	<10
13-Jul-99	0.09	180	460	360	10	40	40	110	<10
14-Jul-99	0	10	730	<10	<10	<10	<10	10	<10
15-Jul-99	0	10	25	620	5	2	4	28	<2
16-Jul-99	0	5	<5	<5	15	4	4	4	<2
17-Jul-99	0	<10	20	<10	10	<10	20	<10	<10
18-Jul-99	0.01	<10	960	<10	20	<10	<10	<10	<10
19-Jul-99	0	10	60	<10	<10	<10	<10	10	10
20-Jul-99	0.41	150	200	10	280	60	30	10	10
21-Jul-99	0	10	60	<10	<10	20	<10	<10	10
22-Jul-99	0	110	<5	25	<5	20	4	6	<2
23-Jul-99	0.48	60	110	20	10	32	62	14	2
24-Jul-99	0.04	20	60	<10	40	<10	20	<10	170
25-Jul-99	0.31	1120	7300	1980	470	460	1160	970	150
26-Jul-99	0.43	690	3900	4900	50	210	580	840	10
27-Jul-99	0	100	240	280	40	<10	10	<10	20
28-Jul-99	0	210	590	200	80	30	70	<10	<10
29-Jul-99	0	8	305	20	150	2	24	2	2
30-Jul-99	0	50	325	5	5	24	34	4	2
31-Jul-99	0	120	20	80	10	<10	<10	<10	<10
1-Aug-99	0	30	10	30	<10	<10	10	<10	<10
2-Aug-99	0	70	480	10	180	30	120	30	60
3-Aug-99	0	<10	30	<10	40	10	10	<10	30

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
4-Aug-99	0	10	10	10	<10	<10	<10	<10	<10
5-Aug-99	0	<5	10	<5	45	<2	<2	<2	<2
6-Aug-99	0.7	20	30	<5	<5	6	4	<2	2
7-Aug-99	0.09	180	30	10	50	10	<10	<10	<10
8-Aug-99	0	80	10	90	<10	10	10	40	<10
9-Aug-99	0	180	20	40	140	40	10	<10	10
10-Aug-99	0	90	30	<10	<10	50	<10	10	<10
11-Aug-99	0	80	80	130	130	80	10	10	10
12-Aug-99	0	60	60	20	25	4	<2	2	4
13-Aug-99	0	50	15	25	20	18	<2	<2	<2
14-Aug-99	0.11	50	<10	120	<10	<10	<10	10	<10
15-Aug-99	0.93	2900	4400	720	2500	280	740	250	120
16-Aug-99	0.05	80	60	10	30	10	<10	30	<10
17-Aug-99	0	<10	<10	<10	<10	10	20	20	<10
18-Aug-99	0	20	110	80	20	<10	<10	<10	<10
19-Aug-99	0	25	120	125	165	2	30	24	16
20-Aug-99	0	10	5	100	<5	<2	2	6	<2
21-Aug-99	0.05	10	30	50	80	100	<10	20	40
22-Aug-99	0.17	80	320	150	50	110	190	40	10
23-Aug-99	0.1	10	<10	<10	10	<10	<10	<10	<10
24-Aug-99	0	100	20	60	70	<10	10	<10	10
25-Aug-99	0	10	30	120	<10	20	10	<10	80
26-Aug-99	0	25	140	45	<5	<2	16	4	<2
27-Aug-99	0	150	120	25	5	12	28	18	6
28-Aug-99	0.25	40	80	10	<10	10	<10	<10	<10
29-Aug-99	0	110	400	80	120	30	60	80	20
30-Aug-99	0.01	50	190	10	740	70	50	<10	180
31-Aug-99	0	60	130		20	<10	10	70	<10
1-Sep-99	0	20	<10	20	20	10	<10	<10	<10
2-Sep-99	0	10	<5	45	<5	<2	<2	8	<2
3-Sep-99	0	5	5	25	10	<2	4	2	10
4-Sep-99	0	190	190	10	<10	70	30	<10	<10
5-Sep-99	0	30	70	30	160	<10	<10	<10	10
1-Jun-00	0	1425	5	15	<5	78	2	2	<2
8-Jun-00	0.09	120	155	145	160	54	128	46	16
15-Jun-00	0	260	15	5	5	50	2	2	2
22-Jun-00	0	20	<5	5	<5	2	<2	2	<2
23-Jun-00	0.01	135	65	25	55	14	28	20	16
24-Jun-00	0	200	80	40	10	10	<10	10	<10
25-Jun-00	0	10	120	<10	<10	<10	40	<10	<10
26-Jun-00	0	50	20	40	<10	30	10	40	<10
27-Jun-00	0	<10	30	20	<10	80	<10	10	<10
28-Jun-00	3.05	90	130	240	140	80	20	50	120
29-Jun-00	0.11	1220	1380	190	170	1220	252	66	42
30-Jun-00	0.02	230	105	110	90	48	50	90	8
1-Jul-00	0	230	50	30	20	70	<10	100	30
2-Jul-00	0	60	20	30	30	10	30	60	10
3-Jul-00	0	20	640	20	<10	<10	20	10	20
4-Jul-00	0	<10	480	30	<10	10	<10	<10	10
5-Jul-00	0	40	140	120	20	<10	<10	10	<10
6-Jul-00	0	<5	30	160	240	2	10	30	90

Note: if more than one sample per day was collected, maximum count for that day is shown

Appendix Table 6: Wollaston Beach Raw Data

Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
7-Jul-00	0	70	185	145	385	14	34	46	148
8-Jul-00	0	<10	360	30	80	<10	350	<10	20
9-Jul-00	0	20	70	60	20	10	10	<10	<10
10-Jul-00	0.49	50	<10	10	<100	<10	<10	10	<10
11-Jul-00	0	300	120	120	250	<10	30	<10	20
12-Jul-00	0	90	10	<10	10	20	<10	10	<10
13-Jul-00	0	740	<5	110	410	2	2	2	2
14-Jul-00	0	65	60	45	55	20	4	<2	4
15-Jul-00	0	780	4400	60	20	<10	50	<10	10
16-Jul-00	2.51	370	640	80	30	<10	130	<10	10
17-Jul-00	0.01	2600	11400	7200	170	100	80	10	<10
18-Jul-00	0	230	110	220	<10	<10	<10	120	<10
19-Jul-00	3.06	<10	130	1000	260	320	10	1600	70
20-Jul-00	0	880	220	60	780	470	74	14	124
21-Jul-00	0	450	195	500	65	50	20	56	16
22-Jul-00	0.23	90	250	60	10	20	40	20	<10
23-Jul-00	0	<10	40	110	<10	<10	<10	<10	<10
24-Jul-00	0	10	400	960	50	10	50	<10	<10
25-Jul-00	0	180	80	10	20	30	40	<10	<10
26-Jul-00	0	230	110	20	20	90	220	<10	10
27-Jul-00	0.74	6100	6600	210	60	760	1760	90	10
28-Jul-00	1.15	280	2600	6600	8700	265	205	480	240
29-Jul-00	0	30	60	40	<10	240	100	30	<10
30-Jul-00	0	50	480	140	10	<10	40	40	10
31-Jul-00	0.85	420	3100	100	130	630	780	30	120
1-Aug-00	0.04	1600	1200	10	190	300	170	60	110
2-Aug-00	0.02	14800	120	190	20	580	70	50	40
3-Aug-00	0.01	160	130	20	35	10	16	8	36
4-Aug-00	0.06	10	10	20	35	4	2	6	6
5-Aug-00	0	250	350	50	120	440	100	20	60
6-Aug-00	0	30	150	30	<10	10	90	3930	130
7-Aug-00	0	<10	70	30	<10	40	120	140	1200
8-Aug-00	0.01	60	200	10	10	20	30	30	<10
9-Aug-00	0	8100	<10	40	<10	650	80	10	
10-Aug-00	0	2020	545	165	60	132	160	40	<2
11-Aug-00	0	2580	80	30	<5	28	12	4	2
12-Aug-00	0	100	130	90	30	50	90	60	120
13-Aug-00	0	490	5300	500	50	30	40	30	50
14-Aug-00	0	170	<10	160	200	130	<10	200	<10
15-Aug-00	0	19000	2100	310	740	360	560	70	90
16-Aug-00	0.06	6600	140	130	70	550	50	160	<10
17-Aug-00	0.09	5	295	50	25	8	12	2	10
18-Aug-00	0	20	45	4	4	12	64	10	5
19-Aug-00	0.19	170	200	110	360	<10	10	20	50
20-Aug-00	0	300	160	580	30	150	10	40	50
21-Aug-00	0	10	50	50	<10	<10	10	<10	<10
22-Aug-00	0	50	130	60	930	20	50	10	<10
23-Aug-00	0	570	200	710	10	60	30	40	10
24-Aug-00	0.53	445	205	485	165	168	18	96	28
25-Aug-00	0.01	65	10	15	455	28	12	4	26
26-Aug-00	0	<10	120	60	30	<10	<10	90	40

Note: if more than one sample per day was collected, maximum count for that day is shown

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Date	24 hr rainfall (in.) Braintree Weymouth Pump Station	Fecal Coliform (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd. MDC32	*Enterococcus* (colonies/100 mL) Milton St. MDC29	Channing St. MDC31	Sachem St. MDC30	Rice Rd MDC32
27-Aug-00	0	100	20	190	40	20	20	100	60
28-Aug-00	0	160	250	720	160	20	150	1680	70
29-Aug-00	0	100	230	270	240	30	20	220	30
30-Aug-00	0	220	90	270	20	30	30	90	<10
31-Aug-00	0	80	200	170	20	46	24	22	14
1-Sep-00	0	<5	5	20	15	2	2	12	8
2-Sep-00	0.02	20	<10	20	240	<10	30	10	20
3-Sep-00	0.43	800	1500	5100	2300	280	670	1520	880
7-Sep-00	0	25	35	45	10	2	6	8	<2

Note: if more than one sample per day was collected, maximum count for that day is shown