Statistical analysis of combined sewer overflow receiving water data, 1989-1996

Massachusetts Water Resources Authority

Environmental Quality Department

Report ENQUAD 98-09

Statistical Analysis of Combined Sewer Overflow
Receiving Water Data, 1989-1996

for

MWRA Harbor and Outfall Monitoring Project

submitted to

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Revised April 15, 1998

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1.0 INTRODUCTION

1.1 Background

Since 1989, the Massachusetts Water Resources Authority (MWRA) has performed water quality measurements in areas of Boston Harbor and the Mystic, Charles, and Neponset Rivers which are likely to be affected by combined sewer overflows (CSOs). Under this ongoing monitoring program, samples are collected and analyzed for densities of two sewage indicator bacteria, fecal coliform and *Enterococcus*, as well as for temperature, salinity, and dissolved oxygen. Sewage indicator bacteria in the CSO receiving water system (i.e., Boston Harbor and its tributary rivers) originate primarily from raw sewage that is released from CSO discharges during rainfall events, or from storm drains that have been contaminated with sewage.

This report investigates the issue of whether or not a statistically significant decrease in sewage indicator bacteria counts has occurred within the CSO receiving water system since the inception of the monitoring program. During this time period, a number of modifications and improvements to the MWRA sewer system have been implemented, intended to decrease the amount of raw sewage entering Boston Harbor. For example, two screening and chlorination plants have been constructed, an effort has been made to locate and remove illegal sewage connections to storm drains, and CSO tide gates are being inspected and maintained in good working order. Such improvements should lead to a systematic decrease in receiving water bacteria counts, i.e., some sort of statistically significant temporal trend should be discernable, which is correlated to known CSO system improvements.

1.2 Characteristics of the Data

This report utilizes CSO receiving water data that were collected between 1989 and 1996, and analyzed for counts of fecal coliform and *Enterococcus*. A total of 8646 fecal coliform and 8272 *Enterococcus* sample counts are available for this study, comprised of surface samples throughout the receiving water system and bottom samples for stations in the tributary rivers only. The tidal condition and sampling date for each sample were also used, and daily rainfall data at Logan Airport over this time period were obtained from the National Weather Service. A comprehensive description of the monitoring program is provided in the MWRA CSO Receiving Water Monitoring report (Rex, 1991).

A total of 130 sampling stations were utilized in this study. Station locations are shown in Figure 1-1. Due to the broad spatial coverage of the stations, samples could not be collected synoptically at all stations over a given time period. Also, the most intensive sampling occurred during warm weather periods; during colder weather, sampling was limited to those unfrozen waters easily accessible from shore. Few stations have data over the entire 1989-1996 period, and those that were sampled each year were not necessarily sampled in the same month each year. What results is a highly unevenly distributed data set, both spatially and temporally.

In addition to the irregular sampling intervals, the samples comprising the data set were collected under highly variable environmental conditions, which may influence sewage indicator bacteria counts. Examples of physical parameters which influence receiving water bacteria counts include rainfall, tidal state, geographic location, salinity, and temperature. In particular, bacteria counts are expected to be strongly related to rainfall, since raw sewage discharges occur primarily when stormwater runoff causes the capacity of the combined sewer/stormwater drainage and treatment system to be exceeded.

1.3 Previous Work

As part of their CSO Receiving Water Monitoring program, MWRA has produced reports summarizing the water quality within the receiving water system with respect to sewage indicator bacteria (Rex, 1991, 1993). These reports incorporate anthropogenic and environmental factors to help assess relationships between the variables that influence water quality, in particular the relationship between rainfall and bacteria counts. However, these reports focus on existing conditions in specific geographic areas within the receiving water system, and how they compare with water quality standards. Solow (1993) conducted a preliminary study on long term changes in the rainfall-bacteria count relationship at individual sampling stations. Gong *et al.* (1997) developed a more comprehensive framework to assess interannual variability in bacteria counts throughout the CSO receiving water system, and to correlate the changes to improvements in the CSO drainage and discharge system.

This report represents a continuation and extension of the work initiated in Gong *et al.* (1997), which utilized data collected between 1989 and 1995. The primary differences between the data sets used in Gong *et al.* (1997) and this study are the inclusion of 1996 data, and the use of recorded tidal elevations for all samples instead of predicted tidal elevations used in the previous study.

1.4 Study Objectives

Both the irregular nature of the sampling program and the various physical parameters involved in the complex CSO receiving water system present a challenge to analyzing the impact of improvements to the CSO drainage and treatment system on sewage indicator bacteria counts. Statistical techniques are developed in this study to account for the necessarily constrained and highly variable data, and to isolate the effect of systemwide improvements implemented during the period from 1989-1996. The objectives are to select, apply, and evaluate statistical methods suitable for answering the question: has CSO receiving water quality improved despite natural variations in rainfall and other environmental factors, and if so at what level of statistical significance?

1.5 Organization of this Report

Following this introduction (Section 1), Section 2 of this report describes the basic analytical approach that was followed to develop an appropriate statistical analysis, given the characteristics and constraints of the available data. The selected statistical methodology, a Factorial Analysis of Variance using Randomized Blocks, is described in Section 3. Section 4 contains a brief summary of the procedure used to carry out the analysis. The results of the statistical analysis applied to the overall receiving water system are presented and discussed in Section 5, for both fecal coliform and *Enterococcus*. Section 6 contains an evaluation of the applied statistical methodology, to assess the effectiveness in accounting for the various physical parameters and thus isolating the effects of systemwide improvements. Individual rainfall levels and geographic regions are analyzed using the same basic methodology in Section 7. Section 8 presents a brief comparison of this study to the work initiated in Gong et. al. (1997). Finally, conclusions are presented in Section 9.

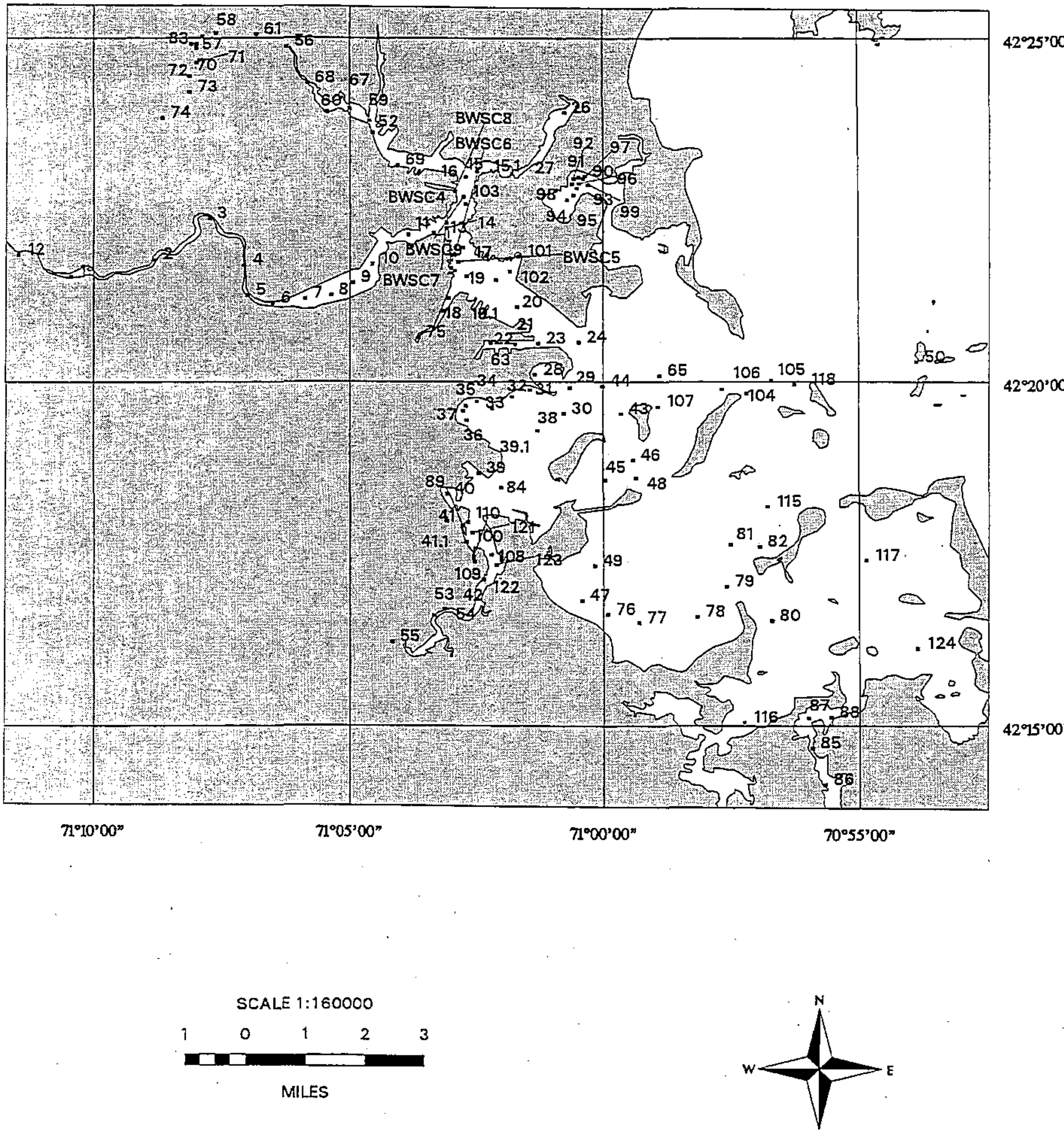

Figure 1-1
CSO Receiving Water Stations

2.0 ANALYTICAL APPROACH

Previous analyses of CSO receiving water quality have focused primarily on the relationship between sewage indicator bacteria counts and rainfall at individual stations, using basic statistical techniques such as linear regression (Rex, 1993). Linear regression is a fundamental technique, which can easily be extended to assess changes in water quality over time by comparing the regressed bacteria count-rainfall relationship obtained for different years. Unfortunately, the irregular nature of the available data set and the need to account for competing environmental factors make it difficult to reliably define a rainfall-bacteria relationship at an individual station, much less to detect statistically significant changes in the regression relationship from year to year. Although rainfall is likely to have the greatest influence on bacteria counts, other variables such as tides, geography and seasonality also exert considerable influence.

The analytical approach for the present study is described in this section, taking into consideration the objectives of the study and the characteristics of the available data set. The approach is comprised of three main parts: 1) Selection of an appropriate statistical hypothesis which maximizes the strength of the analysis while providing a meaningful result; 2) consideration of the entire CSO receiving water system within the scope of the analysis, and 3) identification of key variables which affect receiving water bacteria counts.

2.1 Selection of an Appropriate Statistical Hypothesis

The basic hypothesis investigated in this study is that sewage indicator bacteria counts in the CSO receiving water system have decreased during the period from 1989-1996, when the effects of all known environmental variables have been accounted for. Assuming that some unknown environmental factor is not responsible, this hypothesis then implies that improvements to the CSO drainage and treatment system during this time period are responsible for any observed decrease. The null hypothesis is that no temporal decrease in bacteria counts exists.

This hypothesis addresses the most fundamental question posed by the objectives of this analysis, since sewage indicator bacteria are indicative of CSO discharges. However, no attempt is made to address more complex questions, such as identifying functional relationships between bacteria counts and rainfall, or correlating bacteria counts with other parameters. Limiting the objectives of the study in this manner increases the potential for obtaining a statistically significant result. The selected hypothesis was carefully developed to maximize the strength of the statistical analysis while successfully addressing a worthwhile and fundamental question.

2.2 Consideration of the Entire CSO Receiving Water System

This analysis seeks to detect statistically significant decreases in bacteria counts at all CSO receiving water stations considered as a whole, instead of focusing on individual stations or local groups of stations. Previous analyses of CSO receiving water data have shown that more data need to be collected over a longer period of time to detect statistically significant changes at individual stations (Rex, 1991, 1993; Solow, 1993). In addition, focusing on individual stations makes the irregular sampling intervals more problematic, since long periods may exist that have little or no data.

By stepping back to a regional scale that looks at all stations considered together, the entire data set is utilized, and temporal coverage is improved to a level consistent with the overall monitoring program. As a result, the ability of an analysis to provide statistically significant results improves. Although detailed questions, such as whether bacteria counts immediately downstream of a newly expanded treatment plant have decreased, cannot be answered by such an approach, the fundamental question of whether bacteria counts within the entire CSO receiving water system have decreased can be answered with greater reliability.

2.3 Identification of Key Variables Affecting Sewage Indicator Bacteria Counts

In a system as complex as Boston Harbor and its tributary rivers, a multitude of variables can potentially impact sewage indicator bacteria counts. Examples range from sewer system improvements, to weather conditions (e.g., rainfall, temperature, and sunlight), to hydrodynamic flow and transport patterns. To include all possible factors would require incorporating sophisticated mathematical and physical modeling techniques.

On the other hand, neglecting the naturally occurring variations masks the ability to discern improvements resulting from the sewer system improvements. A straightforward comparison of bacteria counts before and after the implementation of system improvements is of little benefit. For example, rainfall and the subsequent volume of CSO discharge during the period after system improvements may be higher than during the period before system improvements. Under such conditions, receiving water bacteria counts may be higher for the period after system improvements if the increased volume of CSO discharge overwhelms the bacteria count decreases due to sewer system improvements.

Therefore, this statistical analysis focuses only on certain key variables. Key variables are defined as those which are expected to account for most of the variability in sewage indicator bacteria counts, and for which reliable sample data are available. Five key variables identified for this study are listed and briefly described below.

- Sampling Year. This is the fundamental variable of interest for this study, since the objective is to determine statistically significant interannual decreases in bacteria counts over the eight year period of study, from 1989 to 1996. Samples collected during the later years of this period may have lower bacteria counts than samples collected in early years, due to systematic improvements in the CSO drainage and discharge system, once competing environmental variables have been accounted for.

- Rainfall. Increased bacteria counts are expected to be strongly correlated to rainfall events, since CSO discharges principally occur when the addition of stormwater runoff exceeds existing pipe capacities. A lag time may exist between the incidence of a rain event over the sewer system and the responding bacteria count increase in the receiving water rivers, and in particular Boston Harbor. Counts are expected to be lowest during dry periods, and to increase in response to rainfall events of increasing intensity and/or duration. Daily rainfall data at Logan Airport were obtained from the National Weather Service.

- Geographic Location. Different regions within the CSO receiving water system may exhibit different bacteria count characteristics, due to a variety of physical reasons. Certain water bodies may receive a greater CSO discharge volume than others. The condition of the sewer system and the existence of treatment facilities varies throughout the system. Differences between river, estuarine, and oceanic mixing patterns are also likely to affect regional bacteria counts. Precise station location information is available for each sampling station.

- Tidal Condition. Sample bacteria counts are likely to vary with the tidal condition at the time of sampling. Flood tides introduce a substantial amount of oceanic mixing and dilution, increase the salinity of the receiving water, induce transport of bacteria, and may inhibit CSO discharges by keeping tide gates shut. In addition, only sampling stations located in or near Boston Harbor will be influenced by tides, while stations located in tributary rivers upstream of dams will not be subject to any tidal effects. Tidal condition information was recorded for every sample collected.

- Seasonality. Intra-annual seasonality effects can influence water bacteria counts in a number of ways. Temperature and salinity within the receiving waters can vary considerably throughout the course of the year. Factors such as spring snowmelt runoff may affect the amount of freshwater input and dilution. Precipitation patterns and intensities, and groundwater levels, vary throughout the year, which may affect the likelihood of CSO discharges. For this study, the month in which the sample was collected is used as the variable to account for overall seasonal variations in bacteria counts.

Of these five key variables affecting CSO receiving water bacteria counts, the sampling year and rainfall parameters are considered the primary variables of interest for this study. Rainfall is expected to be the single most influential variable in the CSO system, and sampling year is the variable which will be used to assess the impact of CSO system improvements. If the variability associated with these five key variables is accounted for in the statistical analysis, then the sampling year variable serves as an effective indicator of CSO receiving water quality improvement resulting from improvements to the CSO drainage and discharge system.

Following this approach, an appropriate statistical methodology is developed in Section 3 that tests the basic hypothesis concerning overall bacteria count decreases, considers the entire CSO receiving water system as a whole, and focuses on sampling year and rainfall while systematically accounting for variations in bacteria counts due to geographic location, tidal condition and seasonality.

3.0 STATISTICAL METHODOLOGY

3.1 Factorial Analysis of Variance using Randomized Blocks

In accordance with the analytical approach described in Section 2, a statistical methodology has been developed to address the basic hypothesis that sewage indicator bacteria counts in the CSO receiving water system have decreased during the period from 1989-1996, when the effects of all known environmental variables have been accounted for. The methodology is derived from classical analysis of variance (ANOVA) and experimental design techniques, and is applied to the entire CSO receiving water system as a whole. It consists of two components to account for all five key variables, a factorial ANOVA and a partitioning of the data set using randomized blocks.

The factorial ANOVA using randomized blocks technique is designed to investigate the subtle effects of a number of interacting variables (Scheffe, 1959; Kendall and Stuart, 1976). The methodology still falls within the realm of classical statistics, however, and has the benefit of being thoroughly tested in numerous applications. (Snedecor and Cochran, 1989).

<u>Factorial ANOVA</u>

A factorial ANOVA is based on the concept of experimental factors, variables which potentially have an effect on the measured dependent variable of the analysis. For this study, the five key variables listed in Section 2.3 are considered the relevant experimental factors. The dependent variables are calculated as

$$ln(FC+1)$$
$$ln(EN+1)$$

where FC and EN are the sample fecal coliform and *Enterococcus* counts, respectively, in units of counts per 100 ml. The analysis is similar to a standard ANOVA, except that more than one experimental factor can be incorporated into the analysis, whereas a standard ANOVA only allows for one factor. To facilitate the analysis, each experimental factor is partitioned into a small number of discrete categories, or levels (e.g., no rainfall, light rainfall, and heavy rainfall). The number and definition of these levels for an experimental factor can vary based on the nature of the data and the goals of the analysis. The factor levels assigned to each of the five variables in this study will be discussed in Sections 3.2 and 3.3.

Although all five factors are likely to impact bacteria counts, the performance of an ANOVA generally decreases as the number of factors and factor levels is increased. Maintaining a small number of well defined categories simplifies the tested hypothesis, and thus increases the power and robustness of the analysis. For this reason, there is merit to including only the most essential factors, and maintaining broad factor levels, in the ANOVA. In Section 2, the primary variables of interest were identified as sampling year and rainfall. Therefore only these two experimental factors are retained in the ANOVA. The total number of factor level combinations obtained from the sampling year and rainfall variables determines the number of treatments contained in the factorial ANOVA. The various treatments are then compared using classical ANOVA techniques, which test hypotheses involving statistically significant differences between treatment means.

Data Partitioning using Randomized Blocks

The effects of the experimental factors not contained in the ANOVA treatments can be accounted for by partitioning the data into groups called randomized blocks prior to performing the factorial ANOVA. Each block should contain data that are as similar as possible with respect to the environmental factors and levels not accounted for in the ANOVA treatments. In this study, three secondary experimental factors have been identified that are not distinguished by the ANOVA treatments: geographic location, tidal condition, and seasonality. Each randomized block should therefore contain all data from a single factor level combination of these three secondary variables. The total number of possible factor level combinations determines the number of randomized blocks. The number of randomized blocks represents the number of rounds of data, or replicates, utilized by the factorial ANOVA.

With the data partitioned in such a manner, most of the variability in the dependent variable (i.e., natural logarithm of bacteria counts) within a block is due to the treatments being analyzed in the ANOVA. Variability associated with the secondary environmental variables is thus reduced to differences between each block, which can be accounted for during the factorial ANOVA analysis.

Within a block, data falling under each ANOVA treatment category are averaged together, and the averaged values are treated as a single replicate by the factorial ANOVA. Thus the ANOVA analysis does not compare means calculated directly from all data points for a treatment, as is done in a standard ANOVA. Rather, the means are calculated from single values representing each randomized block, which themselves are averaged together from all appropriate data points within the block. In other words, each of the randomized blocks is given equal weight in the ANOVA, regardless of how many data points fall into that block.

For an ideal randomized blocks design the ANOVA treatments should be randomly distributed over all values within a block, so that there are no systematic biases with respect to the factors that have been omitted from the analysis. Usually, this is accomplished by experimental design. For this study, sample data have already been collected, and data are assigned to blocks after the fact. However, a considerable amount of freedom exists regarding the partitioning of the data, so that a random distribution can be approximated. The general idea is to distribute all available data among the various blocks and treatments as evenly as possible.

An important component of this analysis concerns the ability of the randomized blocking scheme to account for all variability in the bacteria count data due to factors other than rainfall and CSO system improvements, represented by the sampling year variable. By carefully grouping the available data using well defined blocking categories, the chances of detecting statistically significant interannual changes in bacteria counts can be maximized. Nevertheless, complications can arise during the blocking process, such as blocks with no data points for a particular treatment, or blocks with highly variable numbers of data points for different treatments. Estimation procedures have been developed to account for these issues, as described in Section 4.

3.2 Selection of Treatments

The sampling year and rainfall variables are considered the two experimental factors for this factorial ANOVA analysis. Sampling year was divided into two levels and rainfall was divided into three levels, resulting in a total of six treatments. The selected levels are summarized in Table 3-1, and they are briefly described below.

Sampling Year

Eight years of sampling data were utilized in this study, from June 1989 through September 1996. The sampling year variable was divided into two levels, 1989-1991 which represents conditions prior to most system improvements, and 1992-1996 which represents conditions after some system improvements were implemented. Examples of system improvements include general operational improvements such as:

- More reliable pumping at the Deer Island treatment plant
- Cessation of sludge discharge into the harbor
- Improved disinfection at both Deer and Nut Island treatment plants
- Reduction in treatment plant "bypasses"
- Community work to eliminate illegal sewer connections into storm drains

More specific CSO-related improvements include:

- Elimination of "dry weather overflows"
- Improved inspection and maintenance of tide gates
- Construction and operation of two CSO treatment facilities

Rainfall

It was mentioned previously that bacteria counts are strongly related to rainfall, but that antecedent conditions before the event affect the bacteria response in receiving waters. Therefore three days of rainfall were associated with each sample, consisting of the sampling date plus the two previous days. Furthermore, the actual rainfall parameter used for the study was the root-mean-square (RMS) of the three days of rainfall values, which is calculated as:

Install Equation Editor and double-click here to view equation.

where RMS = Root-mean-square of three days of rainfall [in]
R1 = Daily rainfall during sampling date [in]
R2 = Daily rainfall one day prior to sampling date [in]
R3 = Daily rainfall two days prior to sampling date [in]

This parameter places greater weight on high intensity events, which are more likely to result in CSO discharges. In other words, by using the RMS a given amount of rainfall distributed evenly over three days is given less weight than the same amount of rainfall concentrated in one of the three days.

This RMS rainfall variable was divided into three levels: dry conditions, light rain, and heavy rain. RMS values of 0 inches (i.e., no rain over the past three days) were considered dry. RMS values between 0 and 0.25 inches were placed in the light rain level. RMS values greater than 0.25 inches were considered as heavy rain. Note that the RMS rainfall parameter yields values that are always smaller than the straight sum of rainfall over the three day period. The selected RMS rainfall levels were chosen to realistically represent different rainfall conditions while distributing the available data as evenly as possible over all three levels.

3.3 Selection of Randomized Blocks

The geographic location, tidal condition and seasonality variables are used to divide the sample data into randomized blocks. A total of eight geographic locations were identified, and the tidal condition and seasonality factors were each split into three levels. The selected levels are summarized in Table 3-1, and they are briefly described below.

Geographic Location

Geographic locations were selected by grouping together sampling stations that resided in the same regional water body within the CSO receiving waters. The various rivers and estuaries within the receiving water system can have noticeably different physical characteristics and CSO discharge loads. A sufficient amount of data had to be available for each location, which restricted the delineation of the water bodies to fairly broad regions. The location of dams along tributary rivers also affected the selection of geographic locations, since there is no tidal influence upstream of dams.

The eight geographic locations are presented in Figure 3-1. Note that the Charles River was split into upper and lower portions, since the lower Charles River Basin is much wider than the narrow upper portion, and there are ample sample data for the entire river. Both Charles River regions, as well as the Mystic River and Neponset Headwaters regions consist of sampling stations which recorded no tidal influence.

Tidal Condition

For this analysis three tidal condition levels were distinguished, high tide, low tide and freshwater. Samples with observed tidal elevations above mean sea level were grouped together as the high tide level. Samples with observed tidal elevations below mean sea level were assigned to the low tide level. Samples collected in locations without any tidal influence were placed in the freshwater level.

Seasonality

The sample data were split into three temporal seasonality levels. The fall/winter season consists of samples collected from September through April, the spring season consists of May and June samples, and the summer season consists of July and August samples. These seasonality levels were developed to capture natural seasonal differences, and also to distribute the available data evenly among the three levels. Since most sampling occurred during warm weather months, the spring and summer seasonality levels are of shorter duration than the fall/winter level.

The two sampling year levels and three rainfall levels discussed in Section 3.2 yield a total of 2 x 3 = 6 ANOVA treatments. All possible combinations of the eight geographic location, three tidal condition and three seasonality variables yield the total number of randomized blocks, which are listed in Table 3-2. Note that a total of 36 blocks are obtained, which is considerably less than the total number of 8 x 3 x 3 = 72 block level combinations. This is because only one or two of the three tidal conditions can exist at any one geographic location. Regions which are tidally influenced fall under high tide or low tide, but do not have any stations with no tidal influence. Conversely, regions located upstream of dams fall only under the no tidal influence category.

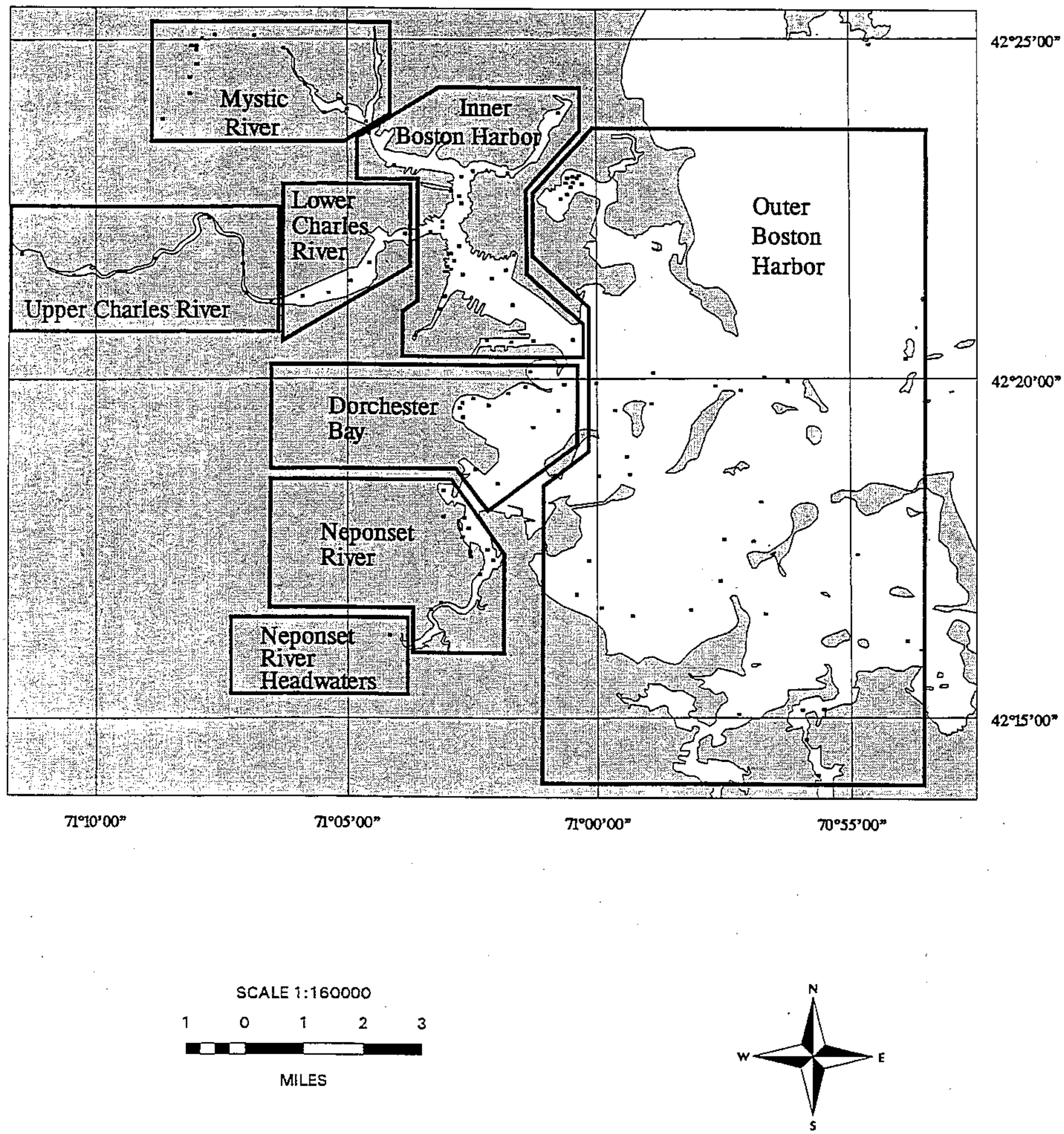

Figure 3-1
Geographic Locations for Randomized Blocks Partitioning

Table 3-1
Experimental Factor and Randomized Block Variable Levels for Factorial ANOVA

Variable	Number of Factor Levels	Factor Level Descriptions
Experimental Factors		
Sampling Year	2	1989-1991 (Before CSO system improvements)
		1992-1996 (After CSO system improvements)
Root-mean-square of 3 day rainfall (RMS)	3	RMS = 0 in
		RMS between 0 and 0.25 in
		RMS greater than 0.25 in
Randomized Blocks		
Geographic Location	8	Upper Charles River
		Lower Charles River
		Mystic River
		Neponset River Headwaters
		Neponset River
		Dorchester Bay
		Inner Boston Harbor
		Outer Boston Harbor
Tidal Condition	3	High Tide (above mean water level)
		Low Tide (above mean water level)
		Freshwater above TIdal Influence
Seasonality	3	Fall/Winter (September-April)
		Spring (May-June)
		Summer (July-August)

Table 3-2
Randomized Blocks for Factorial ANOVA

Block Number	Environmental Variables		
	Geographic Region	Tidal Condition	Season
1	Upper Charles River	Freshwater	Fall/Winter
2	Upper Charles River	Freshwater	Spring
3	Upper Charles River	Freshwater	Summer
4	Lower Charles River	Freshwater	Fall/Winter
5	Lower Charles River	Freshwater	Spring
6	Lower Charles River	Freshwater	Summer
7	Mystic River	Freshwater	Fall/Winter
8	Mystic River	Freshwater	Spring
9	Mystic River	Freshwater	Summer
10	Neponset River Headwaters	Freshwater	Fall/Winter
11	Neponset River Headwaters	Freshwater	Spring
12	Neponset River Headwaters	Freshwater	Summer
13	Neponset River	High Tide	Fall/Winter
14	Neponset River	High Tide	Spring
15	Neponset River	High Tide	Summer
16	Neponset River	Low Tide	Fall/Winter
17	Neponset River	Low Tide	Spring
18	Neponset River	Low Tide	Summer
19	Dorchester Bay	High Tide	Fall/Winter
20	Dorchester Bay	High Tide	Spring
21	Dorchester Bay	High Tide	Summer
22	Dorchester Bay	Low Tide	Fall/Winter
23	Dorchester Bay	Low Tide	Spring
24	Dorchester Bay	Low Tide	Summer
25	Inner Boston Harbor	High Tide	Fall/Winter
26	Inner Boston Harbor	High Tide	Spring
27	Inner Boston Harbor	High Tide	Summer
28	Inner Boston Harbor	Low Tide	Fall/Winter
29	Inner Boston Harbor	Low Tide	Spring
30	Inner Boston Harbor	Low Tide	Summer
31	Outer Boston Harbor	High Tide	Fall/Winter
32	Outer Boston Harbor	High Tide	Spring
33	Outer Boston Harbor	High Tide	Summer
34	Outer Boston Harbor	Low Tide	Fall/Winter
35	Outer Boston Harbor	Low Tide	Spring
36	Outer Boston Harbor	Low Tide	Summer

4.0 SUMMARY OF ANALYTICAL PROCEDURE

This section provides a brief summary of the procedure that was followed to perform the factorial ANOVA using randomized blocks. In addition to highlighting the various steps executed during the analysis, a number of issues raised during the course of the analysis are discussed.

- Partition data among all blocks and treatments. Partition all data into the 36 randomized blocks developed in Section 3.3. Within each block, partition the data into the six treatments developed in Section 3.2. Each block/treatment combination is called a cell. Table 4-1 presents the distribution of all 8646 fecal coliform data points into the resulting 36 x 6 = 216 cells. Table 4-2 presents the distribution of all 8272 *Enterococcus* data points into the same 216 cells.

- Remove blocks with minimal data. In Table 4-1, 14 out of the 216 fecal coliform cells do not have any data points. In Table 4-2, 18 out of the 216 *Enterococcus* cells do not have any data points. For both bacteria, some blocks contain relatively few data points, and contain multiple cells with zero data points. Based on this information, blocks with fewer than 100 data points and more than one zero cell are removed from the analysis. Blocks which are removed are indicated in Tables 4-1 and 4-2.

  This procedure reduces the number of zero data cells that subsequently need to be estimated, without sacrificing a large amount of data. Also, by removing entire blocks the quality of the blocking scheme is not compromised. For fecal coliform, 3 blocks containing 7 out of the 14 zero cells (50%) and 166 out of the 8646 data points (1.9%) are removed. For *Enterococcus*, 3 blocks containing 7 out of the 18 zero cells (39%) and 164 out of the 8272 data points (2.0%) are removed.

- Average data points within a cell. All data points within a cell are averaged together to obtain a single value for each cell.

- Estimate values for cells with no data points. For cells with no data points, a value is estimated from the cells that have data following an iterative procedure described in Steel and Torrie (1960). This procedure estimates zero cells using averages of values along the row (block) and column (treatment) of the zero cell, and also a grand average of all values. Estimated values are incorporated into each subsequent estimation until all zero cells are estimated. This procedure is then iteratively repeated until successive rounds yield the same value for all estimated cells. Resulting fecal coliform values for the 33 x 6 = 198 cells are compiled in Table 4-3 for fecal coliform and in Table 4-4 for *Enterococcus*. Estimated values are highlighted in the table.

- Perform the factorial ANOVA. Perform the factorial ANOVA on the average cell values, following Snedecor and Cochran (1989). The analysis is similar to a standard ANOVA (i.e., compilation of sum of squares, mean squares and degrees of freedom), except for a few variations to allow for comparisons and interactions between the various treatments, and the inclusion of the randomized blocks as a source of variation instead of simply a set of replicates. Like a standard ANOVA, the result of the factorial ANOVA is a calculated F value for each treatment comparison, which can be compared to the tabulated F distribution at various significance levels. Calculated F values which exceed the tabulated value indicate a statistically significant change in that treatment comparison.

- Correct for unequal cell variances. As seen in Tables 4-1 and 4-2, the available data are not evenly distributed among all cells. In addition to the zero cells that were either removed or estimated, some cells contain only a few data points, while others contain over 100 data points. This results in an inequality of variance among the cell values presented in Table 4-3 and 4-4, which are used to perform the factorial ANOVA.

  An approximate correction procedure described in Scheffe (1959) is utilized to account for this inequality in sample variance. It consists of calculating the ANOVA sum of squares term using the squares of all data points in each cell. Also, the ANOVA error mean-square term is adjusted by a factor comprised of the average over all cells of the reciprocal of the number of data points in each cell. These adjustments are applied to the factorial ANOVA analysis to yield the final calculated F factors used to assess statistically significant differences.

A strong randomized blocking scheme has been identified as a key component of a successful factorial ANOVA for detecting statistically significant interannual changes in sewage indicator bacteria counts. Therefore, in addition to the original blocking scheme developed in Section 3.3 (scheme A), two slight variations were also developed, in hopes of improving the analysis further. One variation (scheme B) treated the entire Charles River as one geographic location, without distinguishing an upper and lower portion. The other variation (scheme C) maintained two Charles River regions, but divided the summer season into individual July and August levels. The analytical procedure summarized above was repeated for each of these two alternative blocking schemes. The results for all three blocking schemes are presented for both fecal coliform and *Enterococcus* in Section 5.

Table 4-1
Distribution of Fecal Coliform Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total # samples in block	
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in			
			89-91	92-96	89-91	92-96	89-91	92-96		
Upper Charles	freshwater	fall/winter	89	0	19	1	72	0	181	
Upper Charles	freshwater	spring	23	45	31	55	14	20	188	
Upper Charles	freshwater	summer	39	61	36	93	69	100	398	
Lower Charles	freshwater	fall/winter	110	6	32	6	83	4	241	
Lower Charles	freshwater	spring	60	60	60	65	32	25	302	
Lower Charles	freshwater	summer	58	70	38	105	80	87	438	
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250	
Mystic R.	freshwater	spring	22	12	9	80	0	6	129	
Mystic R.	freshwater	summer	77	135	37	58	102	57	466	
Nepon. Head.	freshwater	fall/winter	11	2	15	0	8	2	38	
Nepon. Head.	freshwater	spring	0	8	2	3	0	6	19	X
Nepon. Head.	freshwater	summer	6	33	8	23	10	26	106	
Neponset R.	high	fall/winter	11	41	40	33	22	14	161	
Neponset R.	high	spring	0	34	7	39	3	25	108	
Neponset R.	high	summer	33	103	16	71	14	65	302	
Neponset R.	low	fall/winter	24	24	38	32	25	30	173	
Neponset R.	low	spring	1	35	8	15	4	41	104	
Neponset R.	low	summer	6	103	25	83	56	99	372	
Dorch. Bay	high	fall/winter	11	0	24	0	23	1	59	X
Dorch. Bay	high	spring	9	20	25	13	17	13	97	
Dorch. Bay	high	summer	45	83	26	80	43	65	342	
Dorch. Bay	low	fall/winter	20	4	38	0	35	2	99	
Dorch. Bay	low	spring	19	27	25	8	14	28	121	
Dorch. Bay	low	summer	9	113	36	77	89	82	406	
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251	
Inner Harbor	high	spring	30	56	48	70	17	22	243	
Inner Harbor	high	summer	115	115	55	103	142	72	602	
Inner Harbor	low	fall/winter	34	42	33	46	53	32	240	
Inner Harbor	low	spring	50	39	32	93	5	32	251	
Inner Harbor	low	summer	75	116	50	94	88	112	535	
Outer Harbor	high	fall/winter	49	10	9	10	22	5	105	
Outer Harbor	high	spring	2	25	15	11	2	7	62	
Outer Harbor	high	summer	43	142	23	121	57	133	519	
Outer Harbor	low	fall/winter	44	0	27	0	17	0	88	X
Outer Harbor	low	spring	4	19	23	21	0	17	84	
Outer Harbor	low	summer	59	160	37	106	77	127	566	

Total number of fecal coliform samples: 8646

X denotes block that is removed due to insufficient data (more than 1 zero cell and fewer than 100 data points)

Table 4-2
Distribution of *Enterococcus* Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total # samples in block	
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in			
			89-91	92-96	89-91	92-96	89-91	92-96		
Upper Charles	freshwater	fall/winter	89	**0**	19	**0**	72	**0**	180	
Upper Charles	freshwater	spring	**0**	47	**0**	56	**0**	20	123	
Upper Charles	freshwater	summer	39	60	36	93	68	100	396	
Lower Charles	freshwater	fall/winter	108	6	32	5	83	4	238	
Lower Charles	freshwater	spring	16	59	12	65	2	25	179	
Lower Charles	freshwater	summer	58	70	38	103	79	87	435	
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250	
Mystic R.	freshwater	spring	22	12	7	80	**0**	6	127	
Mystic R.	freshwater	summer	77	133	37	58	102	57	464	
Nepon. Head.	freshwater	fall/winter	10	1	14	**0**	8	2	35	
Nepon. Head.	freshwater	spring	**0**	8	2	3	**0**	6	19	X
Nepon. Head.	freshwater	summer	6	31	8	24	10	28	107	
Neponset R.	high	fall/winter	11	9	40	6	22	14	102	
Neponset R.	high	spring	**0**	16	7	16	3	24	66	
Neponset R.	high	summer	33	98	16	70	14	65	296	
Neponset R.	low	fall/winter	24	10	38	30	25	25	152	
Neponset R.	low	spring	1	29	8	10	4	32	84	
Neponset R.	low	summer	6	101	25	82	56	107	377	
Dorch. Bay	high	fall/winter	11	**0**	24	**0**	23	1	59	X
Dorch. Bay	high	spring	9	20	25	13	17	13	97	
Dorch. Bay	high	summer	45	82	26	80	43	65	341	
Dorch. Bay	low	fall/winter	20	2	38	**0**	35	2	97	
Dorch. Bay	low	spring	19	27	25	8	13	28	120	
Dorch. Bay	low	summer	9	108	36	78	89	88	408	
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251	
Inner Harbor	high	spring	30	53	48	70	17	24	242	
Inner Harbor	high	summer	115	112	55	103	142	72	599	
Inner Harbor	low	fall/winter	34	39	33	46	54	32	238	
Inner Harbor	low	spring	50	39	32	91	5	32	249	
Inner Harbor	low	summer	75	113	50	94	88	112	532	
Outer Harbor	high	fall/winter	49	10	9	9	22	5	104	
Outer Harbor	high	spring	2	20	15	11	2	7	57	
Outer Harbor	high	summer	43	140	23	121	57	134	518	
Outer Harbor	low	fall/winter	42	**0**	27	**0**	17	**0**	86	X
Outer Harbor	low	spring	4	19	23	21	**0**	17	84	
Outer Harbor	low	summer	59	156	37	104	77	127	560	

Total number of *Enterococcus* samples: 8272

X denotes block that is removed due to insufficient data (more than 1 zero cell and fewer than 100 data points)

Table 4-3
Cell Average Fecal Coliform Values: ln(FC+1)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in	
			89-91	92-96	89-91	92-96	89-91	92-96
Upper Charles	freshwater	fall/winter	6.48	**6.02**	7.06	5.71	7.29	**7.02**
Upper Charles	freshwater	spring	7.85	6.29	6.96	6.34	7.24	6.37
Upper Charles	freshwater	summer	6.60	6.14	6.10	6.92	7.41	6.94
Lower Charles	freshwater	fall/winter	5.81	7.06	6.14	6.04	6.69	6.40
Lower Charles	freshwater	spring	5.98	4.72	5.60	4.53	6.44	5.37
Lower Charles	freshwater	summer	5.43	4.28	5.13	4.86	6.52	5.68
Mystic R.	freshwater	fall/winter	5.48	5.83	6.25	6.45	8.12	6.62
Mystic R.	freshwater	spring	4.19	4.51	4.63	4.89	**5.94**	6.29
Mystic R.	freshwater	summer	4.69	4.88	4.86	3.98	6.21	6.60
Nepon. Head.	freshwater	fall/winter	6.72	6.16	6.56	**6.35**	7.54	7.77
Nepon. Head.	freshwater	summer	7.29	6.92	7.77	6.93	8.07	7.63
Neponset R.	high	fall/winter	4.42	2.97	5.38	4.32	5.96	5.91
Neponset R.	high	spring	**5.46**	4.77	6.80	3.90	8.15	5.45
Neponset R.	high	summer	4.35	5.01	4.92	4.81	5.92	6.86
Neponset R.	low	fall/winter	4.94	5.27	4.81	4.40	6.17	5.58
Neponset R.	low	spring	3.78	4.38	5.80	5.75	6.89	5.17
Neponset R.	low	summer	5.95	5.61	5.63	4.58	6.43	6.59
Dorch. Bay	high	spring	1.54	2.10	1.98	2.34	2.95	3.00
Dorch. Bay	high	summer	2.16	2.33	2.96	2.71	3.48	3.73
Dorch. Bay	low	fall/winter	4.55	4.28	3.64	**4.03**	6.34	4.34
Dorch. Bay	low	spring	1.87	2.43	2.61	1.80	4.25	2.70
Dorch. Bay	low	summer	4.38	2.36	2.67	2.15	3.57	3.64
Inner Harbor	high	fall/winter	4.82	3.67	4.29	3.88	6.26	4.58
Inner Harbor	high	spring	3.51	3.49	4.66	3.83	3.62	4.32
Inner Harbor	high	summer	4.07	4.15	4.68	4.57	5.99	5.75
Inner Harbor	low	fall/winter	5.03	5.15	4.85	4.77	6.35	4.82
Inner Harbor	low	spring	3.68	2.88	4.52	3.99	3.17	4.90
Inner Harbor	low	summer	4.20	4.12	5.48	4.33	5.44	5.48
Outer Harbor	high	fall/winter	2.72	1.33	4.72	2.32	3.62	2.07
Outer Harbor	high	spring	1.35	1.51	2.63	1.42	3.09	4.71
Outer Harbor	high	summer	1.60	1.93	4.53	1.75	2.92	2.44
Outer Harbor	low	spring	3.30	1.98	1.81	2.59	**3.43**	2.29
Outer Harbor	low	summer	1.86	2.01	2.01	1.89	2.65	2.68

Highlighted cells denote estimated values

Table 4-4
Cell Average *Enterococcus* Values: ln(EN+1)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in	
			89-91	92-96	89-91	92-96	89-91	92-96
Upper Charles	freshwater	fall/winter	5.63	**5.85**	6.14	**6.03**	7.16	**6.82**
Upper Charles	freshwater	spring	**4.52**	4.62	**4.75**	4.93	**5.88**	5.37
Upper Charles	freshwater	summer	4.58	4.41	4.07	5.33	6.53	5.92
Lower Charles	freshwater	fall/winter	4.62	6.94	4.84	5.87	6.11	6.67
Lower Charles	freshwater	spring	2.26	3.13	2.29	3.28	3.69	4.20
Lower Charles	freshwater	summer	3.02	2.76	3.10	3.25	4.60	3.98
Mystic R.	freshwater	fall/winter	3.86	3.50	5.82	4.14	8.00	4.36
Mystic R.	freshwater	spring	3.62	3.60	3.99	4.12	**5.22**	5.57
Mystic R.	freshwater	summer	3.81	3.84	3.69	3.50	4.73	5.47
Nepon. Head.	freshwater	fall/winter	5.94	6.91	6.06	**6.45**	7.81	6.99
Nepon. Head.	freshwater	summer	6.66	5.64	6.16	5.62	8.34	6.66
Neponset R.	high	fall/winter	4.23	3.58	4.56	5.92	5.16	5.54
Neponset R.	high	spring	**4.26**	3.39	4.62	3.66	7.44	5.17
Neponset R.	high	summer	3.19	3.80	2.97	3.71	4.83	5.43
Neponset R.	low	fall/winter	3.47	5.35	3.44	3.67	5.17	5.45
Neponset R.	low	spring	2.40	2.70	3.76	5.29	5.76	4.67
Neponset R.	low	summer	4.47	4.01	4.12	3.11	5.33	5.21
Dorch. Bay	high	spring	1.02	1.50	1.40	1.75	1.66	2.25
Dorch. Bay	high	summer	2.00	2.14	2.02	2.17	2.02	3.18
Dorch. Bay	low	fall/winter	2.64	2.42	2.52	**2.53**	4.43	2.09
Dorch. Bay	low	spring	1.26	1.52	1.58	1.14	3.04	2.03
Dorch. Bay	low	summer	2.04	2.20	1.62	2.03	2.40	3.04
Inner Harbor	high	fall/winter	3.49	2.36	4.05	2.84	5.24	2.62
Inner Harbor	high	spring	1.74	2.84	2.24	2.97	2.36	3.99
Inner Harbor	high	summer	2.48	2.52	2.98	3.03	3.54	4.01
Inner Harbor	low	fall/winter	3.84	3.31	4.69	2.96	5.98	3.62
Inner Harbor	low	spring	1.93	2.41	2.49	2.98	1.68	3.76
Inner Harbor	low	summer	3.12	2.49	2.72	3.16	3.44	3.90
Outer Harbor	high	fall/winter	3.19	1.33	4.01	1.22	4.41	1.09
Outer Harbor	high	spring	1.35	1.38	1.60	1.59	1.35	3.67
Outer Harbor	high	summer	1.57	1.71	1.71	1.61	2.07	2.04
Outer Harbor	low	spring	1.57	1.84	1.62	2.03	**3.00**	2.74
Outer Harbor	low	summer	1.61	1.81	1.61	1.89	1.92	2.21

Highlighted cells denote estimated values

5.0 RESULTS AND DISCUSSION

This section presents the results of the factorial analysis of variance (ANOVA) using randomized blocks methodology for assessing statistically significant interannual reductions in sewage indicator bacteria counts within the CSO receiving water system. The analysis is performed for both fecal coliform and *Enterococcus*, and for each indicator bacteria three slightly different randomized blocking schemes (schemes A, B and C; see Section 4) were considered, resulting in a total of six factorial ANOVA analyses. Summary tables are presented in this section, describing for each case the amount of decrease in bacteria counts between sampling year periods, and also the degree of statistical significance of the observed reduction. Complete ANOVA results tables for each case are provided in the appendix, which includes the number of data points and average cell values for each ANOVA analysis.

5.1 Amount of Bacteria Count Reduction

Average bacteria counts for each of the six treatments making up the ANOVA analysis (i.e., combinations of two sampling years and three rainfall levels) are compiled in Table 5-1, for both fecal coliform and *Enterococcus* and for all three blocking schemes. For example, the average values presented in Table 5-1 for fecal coliform, scheme A, are obtained from the cell values for the 31 blocks presented in Figure 4-3. The appendix lists cell values and averages for all six cases.

Note that Table 5-1 presents the actual bacteria counts in units of counts per 100 ml, not the natural logarithm-transformed values used to perform the factorial ANOVA analysis. Average log-transformed values were first calculated for each of the six treatments using cell values corresponding to each block retained in the analysis. These averages were then converted back to their untransformed values, in units of counts per 100 ml, and these untransformed averages are presented in Table 5-1.

In Table 5-1, average bacteria counts for the 1989-1991 and 1992-1996 sampling year levels are compared for each of the three rainfall levels, expressed as a percent reduction. Overall temporal reduction is also presented, calculated using the geometric mean over the three rainfall levels. Since Table 5-1 presents actual bacteria counts and not the log-transformed value, geometric mean should be used instead of the arithmetic mean to represent the average bacteria count over all rainfall conditions.

As indicated in Table 5-1, overall fecal coliform is reduced by 34%-36% between the periods 1989-1991 and 1992-1996, depending on the blocking scheme. The reduction is more pronounced during the low rain and high rain levels (34%-45%) than during dry conditions (20%-26%). This is consistent with the biggest improvements occurring during wet weather, when CSO discharges are most likely. Wet weather sewerage system improvements include more reliable pumping at the Deer Island plant, and construction and operation of two CSO treatment facilities. The somewhat smaller reduction in dry weather bacteria counts could be attributed to factors like the cessation of sludge discharges, elimination of dry weather overflows from combined sewer outfalls, and improved disinfection at the treatment plants. The reduction of illegal sewer connections to storm drains would improve water quality during both dry and wet weather.

Enterococcus exhibits a much smaller degree of temporal reduction than fecal coliform. For the three blocking schemes, overall *Enterococcus* is reduced by 8%-9% between 1989-1991 and 1992-1996. Dry and light rain conditions indicate either no change in bacteria count or a slight increase in bacteria count. Heavy rain conditions, however, indicate a consistent decrease of 25%-31%. As is the case for fecal coliform, noticeable temporal reduction in *Enterococcus* counts occurs during heavy rainfall conditions, when CSO discharges are more likely and bacteria counts are higher. However, *Enterococcus* does not exhibit temporal reduction during light rain and no rain conditions, whereas fecal coliform does. Note that for *Enterococcus* the greatest temporal reduction occurs during heavy rain, while for fecal coliform the greatest temporal reduction occurs during light rain.

This difference between fecal coliform and *Enterococcus* reductions may be attributable to a variety of reasons including differences in bacteria attenuation characteristics, sources and characteristics of bacteria release other than CSO discharges during rainfall events, or the relative quantity of each bacteria contained in CSO discharges under different conditions. For example, fecal coliform and *Enterococcus* in receiving waters under dry conditions may originate from different sources, such that dry weather system improvements only affect the source containing fecal coliform. Analogously, the sources affected by system improvements under heavy rain conditions may contain both fecal coliform and *Enterococcus*, resulting in the observed temporal reduction for both indicator bacteria.

Note in Table 5-1 that for all indicator bacteria, blocking schemes and rainfall conditions, higher values during 1989-1991 generally are followed by a greater percent reduction during 1992-1996. Cases with a twenty percent reduction or higher contain a 1989-1991 average bacteria count over 50 counts per 100 ml, regardless of the rainfall condition. Similarly when the 1989-1991 average bacteria count exceeds 100 counts per 100 ml, a temporal reduction of at least 33 percent is observed. The observed direct relationship between bacteria quantity and amount of temporal reduction may be indicative of a CSO discharge source that has not benefitted from the system improvements, or a background level of bacteria in receiving waters irrespective of the CSO drainage and discharge system.

Overall reductions between the 1989-1991 and 1992-1996 periods range from 34%-36% for fecal coliform, and from 8%-9% for *Enterococcus*. In order to discern whether or not the observed reductions are statistically significant and due to improvements to the CSO drainage and discharge system, the results of the factorial ANOVA using randomized blocks must be studied.

5.2 Degree of Statistical Significance

The factorial ANOVA using randomized blocks tests for statistically significant changes among its treatments by comparing a calculated F factor at its calculated degrees of freedom to tabulated F distribution values for varying significance levels. Factorial ANOVA results are summarized for fecal coliform and *Enterococcus* and all three blocking schemes in Table 5-2. The table lists the various sources of variation, or effects, that are accounted for by the factorial ANOVA analysis. Full ANOVA results tables are presented in the appendix. For each source of variation, the number of degrees of freedom (DoF) and the calculated F value are presented. Selected values from the tabulated F distribution are provided in Table 5-3 for comparison with the calculated values in Table 5-2. For a selected significance level and the corresponding effect and error DoF, a calculated F value greater than the tabulated value indicates a statistically significant change in the source of variation.

The sampling year treatment comparison is of primary interest in this factorial ANOVA study, since it is designed to represent changes in bacteria counts resulting from improvements to the CSO system. Changes in bacteria counts resulting from rainfall are presumably accounted for via the rainfall treatment in the factorial ANOVA, and changes due to the remaining key variables are presumably accounted for via the randomized blocks partitioning.

As indicated in Table 5-2, calculated fecal coliform F factors for the sampling year treatment comparison range from 19.53 to 26.04. These calculated values are conservatively compared to tabulated values in Table 5-3 at the DoF closest to but lower than the calculated DoF. The degrees of freedom associated with the sampling year treatment comparison (effect DoF; error DoF) range from 1;140 to 1;207. The calculated fecal coliform F factors far exceed the tabulated values in Table 5-3 for 1;120 DoF at the 0.5% significance level. Thus the reductions in fecal coliform count between 1989-1991 and 1992-1996, shown in Table 5-1, are determined by the factorial ANOVA to be statistically significant with 99.5% confidence.

The smaller temporal reduction in *Enterococcus,* as indicated in Table 5-1, is found by the factorial ANOVA analysis to be statistically insignificant. Sampling year treatment comparison F factors range from 0.54-1.13, with degrees of freedom between 1;140 and 1;203. As indicated in Table 5-3, these values are not statistically significant, even at 25% level of significance. Thus a statistically significant reduction in overall *Enterococcus* counts between 1989-1991 and 1992-1996 is not detected by the factorial ANOVA.

Note that for most comparisons, very little difference exists between the three blocking schemes; the observed degree of statistical significance for temporal reduction is consistent over the three schemes. Likewise the calculated F factors for the other treatment comparisons do not differ substantially among the three blocking schemes. Thus for the most part the selected blocking scheme has little bearing on the results of the analysis.

Blocking scheme A yields the greatest overall reduction for the fecal coliform sampling year treatment comparison, so it is considered as the optimal scheme out of the three that were analyzed. Using this scheme, fecal coliform counts between 1989-1991 and 1992-1996 are reduced by 36%, which is statistically significant at the 0.5% level of significance. This result for fecal coliform confirms the ability of the approach and methodology developed in Sections 2 and 3 to detect statistically significant decreases in sewage indicator bacteria within CSO receiving waters between the period from 1989 to 1996. The lack of a statistically significant temporal decrease for *Enterococcus* indicates that no temporal difference exists for this particular sewage indicator bacteria.

The results of the factorial ANOVA using randomized blocks analysis for the sampling year treatment indicate that fecal coliform, but not *Enterococcus*, exhibits a statistically significant decrease between the periods 1989-1991 and 1992-1996. In order to confirm that this temporal change results from improvements to the CSO drainage and discharge system, the effectiveness of the analysis at accounting for variations due to rainfall, geographic location, tidal condition and seasons must be evaluated. Similarly, evaluating the effectiveness of the analysis will confirm that the improvements to the CSO system have not resulted in significant decreases in *Enterococcus* counts.

5.3 Effectiveness of the Analysis

The different sources of variation considered by the factorial ANOVA are a block effect, an overall treatments effect, individual treatment effects, and error. A statistically significant F factor for a particular effect indicates that 1) the key variable represented by that effect is a significant source of variation in the bacteria count data, and 2) this variability is captured by the ANOVA analysis. If an F factor does not exceed its threshold value, then either that key variable does not exhibit statistically significant variations, or variations exist but the applied methodology fails to capture them.

As discussed in Sections 2 and 3, the sampling year variable represents changes due to CSO system improvements only if variations due to the four remaining key variables are captured by other components of the analysis. Therefore in order to confirm that CSO system improvements result in a decrease in fecal coliform but not *Enterococcus*, the statistical significance of the rainfall and blocks effects must be studied.

As indicated in Table 5-2, all calculated fecal coliform F factors for the various rainfall treatment effects exceed their critical values at their respective degrees of freedom. Similarly, all calculated *Enterococcus* F factors for the various rainfall treatment effects also exceed the their critical values at their respective degrees of freedom. Thus the consideration of rainfall as an explicit factor in the factorial ANOVA successfully accounts for the statistically significant variability in both fecal coliform and *Enterococcus* attributable to rainfall. This result is not surprising since rainfall is expected to be the single most influential factor on sewage indicator bacteria counts.

Table 5-2 also indicates that the calculated F factors for the blocks effect exceed their critical values at their respective degrees of freedom. Once again this result holds for both fecal coliform and *Enterococcus*. The randomized blocking technique developed in Section 3 was designed to capture variability in bacteria counts due to geographic location, tidal condition, and seasonality. Thus the blocking scheme applied to the data prior to the ANOVA analysis successfully accounts for the statistically significant variability in both fecal coliform and *Enterococcus* attributable to these variables.

Variations in both fecal coliform and *Enterococcus*, resulting from the naturally occurring environmental variables rainfall, geographic location, tidal condition and seasonality, have been shown to be statistically significant, and successfully captured by the utilization of randomized blocking and factorial ANOVA techniques. Thus any remaining variability due to sampling year can safely assumed to be attributable to improvements in the CSO drainage and discharge system. The sampling year treatment has been found to be statistically significant for fecal coliform but not for *Enterococcus*. Since competing environmental variability has been accounted for, it can be concluded that improvements to the CSO system have resulted in a decrease in fecal coliform counts within the receiving water system, but not in *Enterococcus* counts.

Table 5-1
Average Bacteria Count Values (counts per 100 ml)
with Temporal Percent Reductions

	Randomized Blocking Scheme	TREATMENTS						OVERALL	
		RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in			
		89-91	92-96	89-91	92-96	89-91	92-96	89-91	92-96
Fecal Coliform									
Mean	A	83	62	121	67	264	170	138	89
% Reduction		25%		45%		36%		36%	
Mean	B	66	53	104	57	229	150	116	77
% Reduction		20%		45%		34%		34%	
Mean	C	78	58	107	60	261	170	130	84
% Reduction		26%		44%		35%		35%	
Enterococcus									
Mean	A	23	25	30	31	94	68	40	37
% Reduction		-9%		-3%		28%		8%	
Mean	B	20	22	26	26	80	60	35	32
% Reduction		-10%		0%		25%		9%	
Mean	C	23	23	26	28	94	65	38	35
% Reduction		0%		-8%		31%		8%	

Table 5-2
Factorial ANOVA Results

FECAL COLIFORM

Source of Variation	Scheme A		Scheme B		Scheme C	
	DoF	F	DoF	F	DoF	F
Blocks	32	34.69	29	35.11	43	31.62
Overall Treatments	5	25.63	5	25.82	5	33.04
Sampling Year Treatments	**1**	**22.89**	**1**	**19.53**	**1**	**26.04**
Rainfall Treatments	2	51.76	2	53.51	2	68.82
Rain/no rain	1	45.44	1	49.09	1	52.87
high/low rain	1	58.07	1	57.93	1	84.77
Error	**153**		**140**		**207**	
Total	190		174		255	

ENTEROCOCCUS

Source of Variation	Scheme A		Scheme B		Scheme C	
	DoF	F	DoF	F	DoF	F
Blocks	32	27.39	29	30.02	43	24.15
Overall Treatments	5	22.25	5	22.96	5	27.88
Sampling Year Treatments	**1**	**0.62**	**1**	**0.54**	**1**	**1.13**
Rainfall Treatments	2	53.73	2	55.64	2	67.11
Rain/no rain	1	43.87	1	45.32	1	46.46
high/low rain	1	63.59	1	65.96	1	87.75
Error	**153**		**140**		**203**	
Total	190		174		251	

Table 5-3
Selected F-Distribution Values

Level of Significance	Degrees of Freedom					
	1;60	1;100	1;125	1;150	1;200	1;1000
25%	1.35	1.34	1.34	1.33	1.33	1.32
10%	2.79	2.76	2.75	2.74	2.73	2.71
5.0%	4.00	3.94	3.92	3.91	3.89	3.85
2.5%	5.29	5.18	5.15	5.13	5.10	5.04
1.0%	7.08	6.90	6.84	6.81	6.76	6.66
0.5%	8.49	8.24	8.17	8.12	8.06	7.91

6.0 EVALUATION OF APPLIED STATISTICAL METHODOLOGY

As demonstrated in Section 5, the factorial ANOVA using randomized blocks methodology is capable of detecting statistically significant temporal decreases in sewage indicator bacteria within the CSO receiving water system. These decreases between sampling year periods result from recent improvements to the CSO drainage and discharge system. This section evaluates the applied statistical methodology, to confirm the validity of the analysis and also to assess the effectiveness of the various components of the applied methodology. The evaluation is carried out by performing a series of quantitative tests and diagnostic variations on the analysis.

6.1 Verification of ANOVA Assumptions

An Analysis of Variance is a parametric statistical method; therefore underlying assumptions upon which the method is based must be met in order for the results to be considered reliable. The two assumptions for an ANOVA are that the treatment residuals are normally distributed and have equal variances. Treatment residuals are represented by the difference between the treatment mean and the individual treatment values.

Residual normality was verified by applying D'Agostino's test (Gibbons, 1994), which is a suitable alternative to the widely accepted Shapiro-Wilk test when the total number of data points exceeds 50. For the three blocking schemes considered in Sections 4 and 5, the total number of data points (i.e., the total number of cells) ranges from 180 to 264. D'Agostino's test was applied to all six factorial ANOVA analyses performed in Section 5, and all six tests passed the normality criteria.

Equality of residual variances was verified by applying Levene's test (US EPA, 1992), which was satisfied for five out of the six ANOVA analyses. Only *Enterococcus* under blocking scheme C was unable to satisfy the equal residual variances requirement, which implies that the lack of a statistically significant temporal decrease in *Enterococcus* counts under scheme C may not necessarily be an accurate result. However, all three blocking schemes were found to yield consistent results, and schemes A and B fail to detect statistically significant temporal *Enterococcus* decreases while satisfying the underlying ANOVA assumptions. Therefore it can be conservatively concluded that scheme C does indeed fail to detect statistically significant decreases in *Enterococcus*, even though one of the ANOVA assumptions is not satisfied.

6.2 Efficiency of the Selected Randomized Blocking Scheme

In Section 3, an optimal randomized blocking scheme was conscientiously developed using the geographic location, tidal condition, and seasonality variables. The effect of the blocking scheme was then explicitly accounted for in the factorial ANOVA by considering it as a source of variation, along with the ANOVA treatments and error. The effectiveness of the randomized blocking procedure in increasing the precision of the analysis can be assessed by calculating the "efficiency of blocking" (Snedecor and Cochran, 1989). This test was performed on one of the ANOVA analyses, fecal coliform under scheme B, to illustrate the contribution of the blocking scheme to the results of the analysis.

The standard error of analysis can readily be computed from the factorial ANOVA under the randomized blocks design, which in the case of scheme B consists of 30 blocked replicates. The efficiency of blocking calculation determines the number of replicates required to maintain the same standard error of analysis under a completely randomized design, in which blocking is not included as a source of variation. In other words, efficiency of blocking calculates the number of replicates needed to maintain the same level of precision without the benefit of blocking.

For fecal coliform, scheme B, the efficiency of blocking calculation resulted in 195 replicates required to maintain the same standard error without blocking as 30 replicates achieved with blocking. This represents in increase by a factor of 6.5, which indicates that the blocking procedure substantially improves the precision of the factorial ANOVA in detecting statistically significant decreases in fecal coliform counts over time.

6.3 Results for a Randomly Sampled Factorial ANOVA

The partitioning of the sewage indicator bacteria count data into treatments and randomized blocks has proven to be an integral part of the applied statistical methodology. Sample points in each cell of the ANOVA tables (see Tables 4-1 through 4-4) are as homogeneous as possible with respect to the key variables identified in Section 2.3. This careful partitioning allows for variability in bacteria counts due to environmental parameters to be captured, so that any statistically significant decrease due to CSO system improvements, represented by the two sampling year periods, can be detected. It follows that if the data were not so conscientiously partitioned prior to performing the factorial ANOVA, then the variability attributed to naturally occurring environmental factors would not be captured, rendering any observed decrease between the sampling year periods meaningless.

A second analysis on fecal coliform data was performed using an alternative partitioning strategy for the six treatments and 30 blocks comprising scheme B. Natural logarithms of the 8646 total fecal coliform samples in the data set were divided into two sets, the 1989-1991 period representing pre-CSO improvement conditions (3650 samples), and the 1992-1996 period representing post-CSO improvement conditions (4996 samples). Each set of data was then randomly assigned to the 90 cells (3 treatments and 30 blocks) for that sampling year period in the ANOVA table representing the rainfall treatment and the randomized blocks. Furthermore, for each cell 30 samples are randomly selected and averaged to obtain the value for the cell. As a result 2700 data points are randomly sampled from each of the 3650 pre-improvement and 4996 post-improvement data sets and utilized in this analysis.

The average log-transformed fecal coliform count for each cell is presented in Table 6-1, along with the average over all 30 replicates for each treatment. These treatment means were converted back to their untransformed values, and for each sampling year period the geometric mean of the three treatment means as calculated. Resulting average fecal coliform counts under this partitioning scheme are 133 per 100 ml for the 1989-1991 period, and 74 per 100 ml for the 1992-1996 period. This constitutes a 44% decrease between the two sampling year periods. Note that the zero cell and unequal cell variance corrections did not need to be applied, since each cell was comprised of an average of 30 randomly sampled values

This randomly sampled data partitioning strategy only accounts for one of the five key variables identified in Section 2.3, i.e. sampling year. The data are not partitioned into randomized blocks representing homogeneous combinations of the geographic location, tidal condition, and seasonality variables. Nor is the data in each block partitioned into three rainfall categories. Thus a statistically significant difference is not expected for the blocks effect and the rainfall treatment effect in the factorial ANOVA, indicating the inability of this partitioning scheme to account for variability in fecal coliform counts due to environmental factors.

The results of the factorial ANOVA using this randomly sampled partitioning scheme are presented in Table 6-2. The full ANOVA results table is presented in the appendix. As indicated in Table 6-2, the calculated F factor for the sampling year treatment is 82.42, which is statistically significant at the 99.5% level. However, the calculated F factor for the rainfall treatment and blocks effect are 0.12 and 1.33, respectively, which are not statistically significant. Thus this randomly sampled factorial ANOVA with block effects is unable to capture naturally occurring environmental variability in fecal coliform counts via the rainfall treatment and blocks effect components of the analysis. Therefore, the statistically significant decrease of 44% for the sampling year treatment may not be exclusively due to improvements to the CSO drainage and discharge system between the two periods. The observed decrease using this partitioning scheme may be partly attributable to environmental variability as well.

Since this random partitioning scheme was unable to explicitly account for environmental variability in fecal coliform counts, the observed temporal reduction cannot be conclusively attributed to CSO system improvements. This exercise demonstrates the ability of the applied statistical methodology to capture naturally occurring environmental variability in the fecal coliform data, but only if the data are partitioned appropriately and conscientiously as was done in Section 5. Only with the environmental variability explicitly captured, demonstrated via significant F factors for the blocks effect and rainfall treatment effect, can statistically significant decreases between the 1989-1991 and 1992-1996 sampling year periods be directly attributable to improvements in the CSO drainage and discharge system.

Table 6-1
Cell Average Fecal Coliform Values: ln(FC+1)
with Random Sampling of Replicates and Rainfall Treatment

RANDOM REPLICATES	TREATMENTS					
	Random Rain		Random Rain		Random Rain	
	89-91	92-96	89-91	92-96	89-91	92-96
1	4.57	4.66	4.81	4.26	5.43	4.23
2	5.47	4.28	4.91	3.28	5.03	4.17
3	5.05	3.84	5.00	4.36	4.31	4.05
4	4.29	4.02	4.96	4.06	4.32	4.01
5	4.93	4.64	5.66	4.23	5.09	5.12
6	4.70	3.88	4.92	3.61	5.79	4.43
7	4.47	4.05	4.96	3.87	4.77	4.93
8	4.60	4.49	4.96	4.58	4.78	4.19
9	5.30	4.56	4.59	4.70	5.64	4.18
10	5.46	4.75	4.80	4.21	5.27	4.03
11	5.43	4.26	5.20	4.37	5.00	4.46
12	5.22	3.37	4.25	3.39	4.30	4.32
13	5.00	3.86	4.27	4.67	4.65	4.73
14	5.03	3.42	4.61	4.54	4.36	4.60
15	4.64	3.56	4.82	5.31	4.62	4.32
16	4.55	4.47	5.26	4.37	4.97	3.97
17	4.52	3.64	4.85	4.84	4.70	3.75
18	4.62	4.50	5.16	5.40	4.69	4.55
19	4.93	4.18	4.51	4.12	5.11	4.27
20	4.62	4.20	4.71	3.85	5.16	4.39
21	4.83	4.23	5.48	4.68	4.42	4.30
22	5.14	5.04	4.50	4.98	5.92	4.02
23	5.40	4.57	5.43	4.85	5.19	3.96
24	5.05	5.41	4.45	3.78	5.69	4.44
25	4.77	4.70	4.80	4.15	4.52	3.82
26	4.84	4.95	4.39	4.25	4.82	5.10
27	5.42	4.73	4.07	4.00	4.37	4.74
28	3.85	4.24	4.50	3.92	4.89	4.15
29	5.03	3.83	5.50	4.48	4.92	4.76
30	5.12	4.02	5.54	5.02	4.99	3.74
Mean	**4.90**	**4.28**	**4.86**	**4.34**	**4.92**	**4.32**

Table 6-2
Factorial ANOVA Results with Random Sampling of Replicates and Rainfall Treatment

Fecal Coliform

Source of Variation	DoF	F
Blocks	29	1.33
Overall Treatments	5	16.61
Sampling Year Treatments	**1**	**82.42**
Rainfall Treatments	2	0.12
Rain/no rain	1	0.14
high/low rain	1	0.10
Error	**145**	
Total	179	

7.0 ANALYSIS OF INDIVIDUAL RAINFALL LEVELS AND GEOGRAPHIC REGIONS

The results of the factorial ANOVA on the sampling year treatment (Table 5-2) apply to the overall temporal reduction in bacteria counts (Table 5-1). This overall temporal reduction is expressed as an average over the three rainfall categories, which are themselves an average over all randomized blocks representing geographic region, tidal condition, and seasonality categories. No insight is attained as to the statistical significance of any observed reductions under specific conditions, e.g., during heavy rainfall or within the Lower Charles River region. The generality of the factorial ANOVA stems from the analytical approach of this study (Section 2), which seeks to detect decreases over time in sewage indicator bacteria counts within the CSO receiving water system data set taken as a whole, after taking into account the effect of key environmental variables.

The observed statistically significant reduction in fecal coliform resulting from CSO system improvements is not expected to apply uniformly over all environmental conditions. For example, system improvements are likely to have a greater impact during wet weather than dry weather, since CSO discharges are primarily wet weather events. As indicated earlier, more reliable pumping at the Deer Island plant and the construction of two CSO treatment facilities constitute wet weather improvements. Also, certain geographic regions within the CSO receiving water system may benefit from system improvements more than others. For example, the two screening and disinfection facilities are located at Fox Point and Commercial Point, which are in Dorchester Bay near the mouth of the Neponset River.

The factorial ANOVA using randomized blocks statistical methodology proved to be successful in isolating and detecting overall bacteria count reductions resulting from system improvements, in part because of the vast amount of data available for the study. Therefore, this methodology can potentially be applied to a subset of the entire data set corresponding to a particular environmental condition, in order to investigate temporal reductions under the specified condition. Such a procedure is applied in this section, to investigate the statistical significance of observed temporal reductions in bacteria counts during different rainfall conditions and for different geographic regions. If sufficient data is retained in these subsets to characterize the remaining environmental variables, the randomized blocking scheme will be able to account for environmental variability and thus yield meaningful results for any temporal reductions.

7.1 Analysis of Individual Rainfall Levels

As indicated in Table 5-1, the temporal percent reduction in both fecal coliform and *Enterococcus* counts varies considerably between the three rainfall categories. The percent reduction in fecal coliform under dry conditions of 20%-26% is noticeably less than the statistically significant overall percent reduction of 34%-36%. A lack of statistical significance during dry conditions would imply that only wet weather system improvements have been successful at reducing receiving water fecal coliform counts. Similarly, *Enterococcus* exhibits a reduction of 25%-31% during heavy rainfall, compared to the statistically insignificant overall reduction of only 8%-9%. This higher reduction observed during heavy rain may be statistically significant, which would imply that system improvements have actually resulted in *Enterococcus* count reductions, but only during major rainfall events.

In order to analyze temporal reductions under specific rainfall conditions, the factorial ANOVA was performed individually on three subsets of the data set, consisting of each of the three rainfall categories. The same blocking schemes was retained, so that the distribution of samples and non-zero cell averages presented in Tables 4-1 through 4-4 are unchanged. Since each analysis contains only one rainfall condition, what results is a single factor ANOVA using randomized blocks, with only two ANOVA treatments representing the two sampling year periods. Variability due to rainfall is no longer of concern since the data includes only one rainfall condition, and all remaining environmental variability is accounted for by the blocks.

This set of three analyses was performed for both fecal coliform and *Enterococcus*, and for each of the three blocking schemes, resulting in a total of 18 analyses. Blocks with zero cells were removed, eliminating the need for zero cell estimation. The unequal cell replicates correction procedure described in Section 4 was applied.

Results of the 18 ANOVA analyses are compiled in Table 7-1. For fecal coliform, light rain and heavy rain conditions yielded a statistically significant temporal reduction, while dry conditions did not. This result held true for all three blocking schemes. The blocks effect was statistically significant in all cases, indicating that the time treatment comparison accurately reflects changes resulting from CSO system improvements. The earlier result of a statistically significant overall reduction in receiving water fecal coliform counts can therefore be amended to conclude that significant reductions in fecal coliform only occur during wet weather. Thus not only do the majority of the CSO system improvements take effect during wet weather, but these wet weather improvements are the only ones which lead to statistically significant reductions in fecal coliform.

For *Enterococcus*, a statistically significant reduction was not detected for any of the three rainfall conditions. As for fecal coliform, this result holds for all three blocking schemes, and the blocks effect was significant in all cases. Even the relatively greater reduction in *Enterococcus* counts observed during heavy rain conditions is not statistically significant. Therefore it can be concluded that CSO system improvements have not led to statistically significant reductions in receiving water *Enterococcus* counts under any rainfall condition.

7.2 Analysis of Individual Geographic Regions

Since system improvements cannot be uniformly applied throughout the entire CSO system, different geographic regions within the receiving water system may potentially exhibit different amounts of temporal bacteria count reduction, and at different levels of statistical significance. A single factor ANOVA using randomized blocks was performed on eight subsets of the data, each representing one of the geographic region categories. The rainfall variable was treated as a blocking factor rather than an ANOVA treatment factor, resulting in a single factor ANOVA on the two sampling year treatments. Rainfall was considered as a blocking factor to partially compensate for the loss of blocks resulting from the analysis of individual geographic regions. The modification allows all environmental variability within the region to be accounted for using the randomized blocks, although the resulting ANOVA only assesses overall temporal reductions averaged over all environmental conditions.

For each of the eight regions, blocking schemes A and C with respect to the tidal condition and seasonality variables were analyzed, for both fecal coliform and *Enterococcus*. Therefore the distribution of samples and non-zero cell averages calculated previously are unchanged. The results for these 32 analyses are listed in Tables 7-2 and 7-3. Scheme A was selected since it yielded the greatest overall temporal reduction in fecal coliform, and scheme C was selected since it contained the greatest number of blocks. Since the number of blocks in the analysis is reduced, no blocks were removed due to the presence of cells with zero samples. Zero cell estimation was instead performed as described in Section 4, as was the unequal cell replicates correction.

For the sixteen scheme A analyses, none of the 8 geographic regions exhibited a statistically significant temporal decrease in either fecal coliform or *Enterococcus*. Furthermore, only three analyses, Inner Harbor fecal coliform and *Enterococcus*, and Lower Charles River *Enterococcus*, yielded a statistically significant blocks effect. A significant blocks effect is indicative of a successful accounting for environmental variability via the randomized blocking procedure, which is required in order for the time treatment to represent CSO system improvements. Therefore it can be concluded that system improvements have not led to statistically significant reductions in Inner Harbor fecal coliform, Inner Harbor *Enterococcus*, and Lower Charles River *Enterococcus* (Table 7-2). Nothing can be concluded for the remaining 13 analyses, where the apparent lack of significant temporal reductions may be due to environmental variability, since this source of variability is not captured by the blocking procedure.

For the sixteen scheme C analyses, the Inner Harbor, Lower Charles River and Dorchester Bay regions exhibited statistically significant blocks effects for fecal coliform. Of these three regions, Lower Charles River and Dorchester Bay exhibited statistically significant temporal reductions of 53% and 56%, respectively. This implies that CSO system improvements have succeeded in significantly reducing fecal coliform counts in these two regions, but have failed to significantly reduce fecal coliform counts in the

Inner Harbor (Table 7-3). The lack of significant temporal fecal coliform reductions in the remaining five regions is inconclusive since the blocks effect was not significant. *Enterococcus* analyses yielded significant blocks effects in the Inner Harbor, Lower Charles River and Neponset River, and no significant temporal reductions in any region. Therefore it can be concluded that CSO system improvements have not had a significant effect on *Enterococcus* counts in these three regions, while no conclusion regarding system improvements on Enterococcus can be drawn regarding the remaining five regions (Table 7-3).

A significant blocks effect allows a conclusion to be drawn as to whether CSO system improvements lead to reduced receiving water bacteria counts. Only three of the sixteen scheme A analyses yielded conclusive results, and only six of the sixteen scheme C analyses yielded conclusive results. The factorial ANOVA using randomized blocks methodology has been proven effective and conclusive when considering the entire data set (Section 5), and individual rainfall categories (Section 7.1). This methodology requires sufficient data to characterize the different sources of variability. The major difference when considering individual geographic regions is that considerably less data is available for each analysis. This implies that an insufficient amount of data is available for many of the regions, which inhibits the effectiveness of the analysis when applied to these geographic data subsets.

While both schemes yielded relatively few conclusive analyses, scheme C nevertheless yielded twice as many as scheme A. This is likely due to a greater number of blocks contained in the scheme C analyses. Scheme C consists of four seasonality factor levels compared to three for scheme A, which results in a 33% increase in the number of randomized blocks. A strong blocking scheme has already been identified as critical to the ability of the analysis to account for environmental variability. The increase in the number of blocks increases the strength of blocking scheme C, which enables the corresponding set of geographic region analyses to be more conclusive. Therefore scheme C is considered the optimal blocking scheme when considering temporal bacteria count reductions at individual geographic regions.

The two regions that have responded to system improvements with significant fecal coliform reductions are the Lower Charles River and Dorchester Bay. A majority of the CSO system improvements implemented since 1992 have focused on these two regions. The removal of illegal sewer connections to storm drains has concentrated on discharges to these two water bodies. Several major CSO discharges into these two regions (e.g. from Moon Island) have been deactivated. The two new CSO screening and disinfection facilities discharge into Dorchester Bay. Chlorination has increased at the Cottage Farm facility, which discharges into the Lower Charles River. Thus the portions of the CSO receiving water system which have received the most extensive CSO system improvements have responded with statistically significant temporal reductions in fecal coliform counts.

Section 5 demonstrated a statistically significant reduction in fecal coliform counts throughout the CSO receiving water system as a whole, resulting from recent improvements to the CSO drainage and discharge system. The results of the analyses presented in this section further enhances the overall conclusion, by demonstrating statistically significant fecal coliform reductions during wet weather when most system improvements take effect, and within geographic regions which have received most of the system improvements. In addition to confirming the anticipated characteristics of the receiving water response to system improvements, these results demonstrate the suitability and robustness of the factorial ANOVA using randomized blocks procedure. This data-based statistical approach has proven to be an effective means of accounting for environmental variability and isolating the effect of CSO system improvements over time.

Table 7-1
ANOVA Results for Individual Rainfall Conditions

ANOVA Analysis	Sampling Year Treatment		Significant CSO Improvements
	DoF	F	
Fecal Coliform			
RMS = 0 in; Scheme A	1;30	2.95	No
RMS = 0 in; Scheme B	1;28	1.58	No
RMS = 0 in; Scheme C	1;40	3.98	No
0 in < RMS < 0.25 in; Scheme A	1;31	16.19	Yes
0 in < RMS < 0.25 in; Scheme B	1;28	17.76	Yes
0 in < RMS < 0.25 in; Scheme C	1;43	12.21	Yes
RMS > 0.25 in; Scheme A	1;30	5.83	Yes
RMS > 0.25 in; Scheme B	1;28	4.84	Yes
RMS > 0.25 in; Scheme C	1;41	6.19	Yes
Enterococcus			
RMS = 0 in; Scheme A	1;29	0.38	No
RMS = 0 in; Scheme B	1;28	0.52	No
RMS = 0 in; Scheme C	1;39	0.02	No
0 in < RMS < 0.25 in; Scheme A	1;29	0.01	No
0 in < RMS < 0.25 in; Scheme B	1;28	0.0001	No
0 in < RMS < 0.25 in; Scheme C	1;41	0.18	No
RMS > 0.25 in; Scheme A	1;29	2.41	No
RMS > 0.25 in; Scheme B	1;28	2.10	No
RMS > 0.25 in; Scheme C	1;40	3.35	No

Table 7-2
ANOVA Results for Individual Geographic Regions, Scheme A

Geographic Region	Sampling Year Treatment		Blocks Effect		Significant CSO Improvements
	DoF	F	DoF	F	
Fecal Coliform					
Upper Charles River	1;6	2.44	8;6	0.32	Inconclusive
Lower Charles River	1;8	5.02	8;8	3.28	Inconclusive
Mystic River	1;7	0.04	8;7	3.18	Inconclusive
Neponset River Headwaters	1;5	1.27	8;5	0.63	Inconclusive
Neponset River	1;16	2.88	17;16	1.38	Inconclusive
Dorchester Bay	1;14	2.17	17;14	1.62	Inconclusive
Inner Boston Harbor	1;17	4.16	17;17	4.5	No
Outer Boston harbor	1;13	2.79	17;13	0.8	Inconclusive
Enterococcus					
Upper Charles River	1;2	0.02	8;2	0.39	Inconclusive
Lower Charles River	1;8	4.09	8;8	9.44	No
Mystic River	1;7	2.11	8;7	2.49	Inconclusive
Neponset River Headwaters	1;5	0.93	8;5	1.17	Inconclusive
Neponset River	1;16	0.04	17;16	1.45	Inconclusive
Dorchester Bay	1;14	0.08	17;14	0.73	Inconclusive
Inner Boston Harbor	1;17	0.68	17;17	4.44	No
Outer Boston harbor	1;13	0.90	17;13	0.75	Inconclusive

Table 7-3
ANOVA Results for Individual Geographic Regions, Scheme C

Geographic Region	Sampling Year Treatment		Blocks Effect		Significant CSO Improvements
	DoF	F	DoF	F	
Fecal Coliform					
Upper Charles River	1;7	1.43	11;7	0.64	Inconclusive
Lower Charles River	1;11	8.9	11;11	2.83	Yes
Mystic River	1;9	0.0002	11;9	2.41	Inconclusive
Neponset River Headwaters	1;8	3.03	11;8	1.03	Inconclusive
Neponset River	1;22	2.7	23;22	1.83	Inconclusive
Dorchester Bay	1;20	6.28	23;20	2.23	Yes
Inner Boston Harbor	1;23	3.64	23;23	3.17	No
Outer Boston harbor	1;19	0.68	23;19	0.93	Inconclusive
Enterococcus					
Upper Charles River	1;3	0.001	11;3	0.44	Inconclusive
Lower Charles River	1;11	0.71	11;11	6.21	No
Mystic River	1;9	0.07	11;9	1.93	Inconclusive
Neponset River Headwaters	1;8	3.48	11;8	1.52	Inconclusive
Neponset River	1;22	0.12	23;22	2.13	No
Dorchester Bay	1;20	0.21	23;20	1.71	Inconclusive
Inner Boston Harbor	1;23	0.004	23;23	3.82	No
Outer Boston harbor	1;19	0.90	23;19	0.89	Inconclusive

8.0 COMPARISON WITH PREVIOUS STUDY

The analytical approach and statistical methodology described in this report were originally developed and applied to CSO receiving water data from 1989-1995, as presented in the "Statistical Analysis of Combined Sewer Overflow Receiving Water Data, 1989-1995" (Gong *et. al.,* 1997). This report represents a continuation and extension of the previous study. This section presents a brief comparison of data sets, analytical techniques and results between this study and the previous one.

Bacteria count sample data and daily precipitation values used in this study were identical to those used in the previous study, with the addition of sample counts and precipitation data obtained during 1996. 1996 was considered as a post-CSO system improvement sampling year, so that for the current study the sampling year period representing post-CSO system improvements is expanded by one year, from 1992-1995 to 1992-1996. Tidal elevation data associated with each bacteria count sample in the 1989-1995 data set was obtained using published tide table predictions. For the current study, recorded tidal elevations associated with every sample over the entire 1989-1996 period was used instead. Use of recorded tidal elevations improves the precision of the analysis, since errors between predicted and actual tidal elevations may weaken the randomized blocking procedure, which partitions the data into homogeneous groups with respect to tidal elevation, geographic location, and seasonality.

The objectives and analytical approach to the issue being investigated are identical for the current and previous studies, although the statistical hypothesis being tested is more explicitly described in this study (Section 2.1). The same five key variables and their factor levels are used in both studies. The factorial ANOVA with randomized blocks technique developed in this study is unchanged from the previous one, and the same analytical procedure is applied. For both studies, the ANOVA was performed on the natural logarithm transformation of the bacteria count data, although for the current study the results are converted back to their untransformed values in Table 5-1.

The current study also extends the analysis beyond the previous study. The effectiveness of the analysis is discussed in Section 5.3. The statistical methodology is evaluated in Section 6 by verifying its underlying assumptions and comparing the results to a randomly sampled factorial ANOVA. The methodology is applied to individual rainfall levels and geopraphic regions in Section 7. These exercises serve to validate the results of the analysis.

The addition of 1996 data and the use of recorded tidal elevations in this study resulted in a slightly different partitioning of the data into the cells of the ANOVA table (Tables 4-1 to 4-4). These modifications to the data set did not substantially affect the basic characteristics of the observed temporal reductions caused by CSO system improvements. Fecal coliform reductions were apparent over all rainfall conditions, though somewhat less during dry weather than wet weather. *Enterococcus* reductions were only evident during high rain conditions. For both studies, the overall temporal reduction in fecal coliform counts was found to be strongly statistically significant.

However, the statistical significance of overall *Enterococcus* count reductions did vary between the two studies. The previous study was found to have borderline statistical significance, while the current study failed to detect any statistically significant temporal decreases in overall *Enterococcus* counts. The current study represents a more accurate analysis, since an additional year of post-CSO system improvement data is utilized and the use of recorded tidal elevations improves the homogeneity of the randomized blocks. Therefore it can be concluded that a statistically significant decrease in fecal coliform but not *Enterococcus* counts in the CSO receiving water system can be attributed to wet weather improvements to the CSO drainage and discharge system.

9.0 CONCLUSIONS

The objective of this study was to test the hypothesis that sewage indicator bacteria counts in the CSO receiving water system have experienced statistically significant decreases over the period from 1989 to 1996, in response to systemwide improvements to the CSO drainage and treatment network during this period. Such an investigation is complicated by the high natural variability in bacteria counts due to varying environmental conditions, and the uneven temporal and spatial distribution of the available data set. A factorial analysis of variance (ANOVA) technique was developed to perform the statistical analysis, adding a randomized blocks procedure to account for competing environmental variability. This methodology utilizes advanced statistical techniques yet still falls under the realm of classical statistics, and has been successfully implemented in a variety of applications.

The analysis follows an approach which 1) defines an appropriate statistical hypothesis to maximize the strength of the analysis while providing a meaningful result, 2) fully utilizes all available data by considering the entire receiving water system as a whole, and 3) systematically accounts for naturally occurring bacteria count variability by addressing five key variables which affect bacteria counts: sampling year, rainfall, geographic location, tidal condition, and seasonality. By following this approach, a statistical methodology was developed which isolated the effect of CSO system improvements that have taken place, primarily during 1992.

Variability due to sampling year and rainfall are accounted for by considering each parameter as an explicit factor in the factorial ANOVA. Variability due to geographic region, tidal condition and seasonality is accounted for by partitioning the data into randomized blocks based on these parameters prior to performing the factorial ANOVA. With all sources of environmental variability accounted for, the sampling year parameter then represents changes in bacteria counts resulting from CSO system improvements. The sampling year period from 1989-1991 represents conditions prior to implementation of the CSO system improvements, and the period from 1992-1996 represents conditions after improvements have taken effect.

Based on the results of the implementation and evaluation of the applied statistical methodology, the following conclusions can be drawn regarding sewage indicator bacteria counts in the CSO receiving water system:

- Improvements to the CSO drainage and discharge system result in a statistically significant overall reduction in fecal coliform counts over the entire CSO receiving water system of roughly 36%.

- CSO system improvements do not result in a statistically significant reduction in *Enterococcus* counts within the CSO receiving water system.

- The factorial ANOVA with randomized blocks methodology successfully accounts for naturally occurring environmental variability in both fecal coliform and *Enterococcus* counts, as indicated by statistically significant F factors for the blocks effect and the rainfall treatment in the factorial ANOVA (Section 5). This ensures that the results for the sampling year treatment reflect improvements to the CSO drainage and discharge system.

- The results of the factorial ANOVA are valid since the underlying assumptions of residual normality and equality of residual variances are satisfied.

- The utilization of the randomized blocking technique substantially improves the precision of the analysis, as indicated by the "efficiency of blocking" calculation, which shows that 6.5 times as many replicates would be needed to maintain the same level of precision without blocking.

- Conscientious partitioning of the data into appropriate treatments and blocks is critical to the successful implementation of the applied methodology, as indicated by the inability of the randomly sampled factorial ANOVA to account for environmental variables and consequently isolate the effect of CSO system improvements.

- A statistically significant temporal reduction in fecal coliform counts only occurs during wet weather, which indicates that wet weather improvement to the CSO drainage and discharge system have been primarily effective at reducing receiving water fecal coliform counts. Significant reductions in *Enterococcus* counts did not occur under any rainfall condition.

- Statistically significant temporal fecal coliform reductions were detected in the Lower Charles River and Dorchester Bay. These geographic regions have received the majority of the CSO system improvements. Insufficient data were available to draw conclusions at a number of geographic regions.

10.0 REFERENCES

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APPENDIX A

RESULTS FOR FACTORIAL ANOVA USING RANDOMIZED BLOCKS

Fecal Coliform
Scheme A
Distribution of Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total # samples in block
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		
			89-91	92-95	89-91	92-95	89-91	92-95	
Upper Charles	freshwater	fall/winter	89	0	19	1	72	0	181
Upper Charles	freshwater	spring	23	45	31	55	14	20	188
Upper Charles	freshwater	summer	39	61	36	93	69	100	398
Lower Charles	freshwater	fall/winter	110	6	32	6	83	4	241
Lower Charles	freshwater	spring	60	60	60	65	32	25	302
Lower Charles	freshwater	summer	58	70	38	105	80	87	438
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250
Mystic R.	freshwater	spring	22	12	9	80	0	6	129
Mystic R.	freshwater	summer	77	135	37	58	102	57	466
Nepon. Head.	freshwater	fall/winter	11	2	15	0	8	2	38
Nepon. Head.	freshwater	spring	0	8	2	3	0	6	19
Nepon. Head.	freshwater	summer	6	33	8	23	10	26	106
Neponset R.	high	fall/winter	11	41	40	33	22	14	161
Neponset R.	high	spring	0	34	7	39	3	25	108
Neponset R.	high	summer	33	103	16	71	14	65	302
Neponset R.	low	fall/winter	24	24	38	32	25	30	173
Neponset R.	low	spring	1	35	8	15	4	41	104
Neponset R.	low	summer	6	103	25	83	56	99	372
Dorch. Bay	high	fall/winter	11	0	24	0	23	1	59
Dorch. Bay	high	spring	9	20	25	13	17	13	97
Dorch. Bay	high	summer	45	83	26	80	43	65	342
Dorch. Bay	low	fall/winter	20	4	38	0	35	2	99
Dorch. Bay	low	spring	19	27	25	8	14	28	121
Dorch. Bay	low	summer	9	113	36	77	89	82	406
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251
Inner Harbor	high	spring	30	56	48	70	17	22	243
Inner Harbor	high	summer	115	115	55	103	142	72	602
Inner Harbor	low	fall/winter	34	42	33	46	53	32	240
Inner Harbor	low	spring	50	39	32	93	5	32	251
Inner Harbor	low	summer	75	116	50	94	88	112	535
Outer Harbor	high	fall/winter	49	10	9	10	22	5	105
Outer Harbor	high	spring	2	25	15	11	2	7	62
Outer Harbor	high	summer	43	142	23	121	57	133	519
Outer Harbor	low	fall/winter	44	0	27	0	17	0	88
Outer Harbor	low	spring	4	19	23	21	0	17	84
Outer Harbor	low	summer	59	160	37	106	77	127	566

Total number of fecal coliform samples: 8646

Fecal Coliform
Scheme A
Cell Average Values (Blocks with Insufficient Data Removed)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in	
			89-91	92-95	89-91	92-95	89-91	92-95
Upper Charles	freshwater	fall/winter	6.48	**6.02**	7.06	5.71	7.29	**7.02**
Upper Charles	freshwater	spring	7.85	6.29	6.96	6.34	7.24	6.37
Upper Charles	freshwater	summer	6.60	6.14	6.10	6.92	7.41	6.94
Lower Charles	freshwater	fall/winter	5.81	7.06	6.14	6.04	6.69	6.40
Lower Charles	freshwater	spring	5.98	4.72	5.60	4.53	6.44	5.37
Lower Charles	freshwater	summer	5.43	4.28	5.13	4.86	6.52	5.68
Mystic R.	freshwater	fall/winter	5.48	5.83	6.25	6.45	8.12	6.62
Mystic R.	freshwater	spring	4.19	4.51	4.63	4.89	**5.94**	6.29
Mystic R.	freshwater	summer	4.69	4.88	4.86	3.98	6.21	6.60
Nepon. Head.	freshwater	fall/winter	6.72	6.16	6.56	**6.35**	7.54	7.77
Nepon. Head.	freshwater	summer	7.29	6.92	7.77	6.93	8.07	7.63
Neponset R.	high	fall/winter	4.42	2.97	5.38	4.32	5.96	5.91
Neponset R.	high	spring	**5.46**	4.77	6.80	3.90	8.15	5.45
Neponset R.	high	summer	4.35	5.01	4.92	4.81	5.92	6.86
Neponset R.	low	fall/winter	4.94	5.27	4.81	4.40	6.17	5.58
Neponset R.	low	spring	3.78	4.38	5.80	5.75	6.89	5.17
Neponset R.	low	summer	5.95	5.61	5.63	4.58	6.43	6.59
Dorch. Bay	high	spring	1.54	2.10	1.98	2.34	2.95	3.00
Dorch. Bay	high	summer	2.16	2.33	2.96	2.71	3.48	3.73
Dorch. Bay	low	fall/winter	4.55	4.28	3.64	**4.03**	6.34	4.34
Dorch. Bay	low	spring	1.87	2.43	2.61	1.80	4.25	2.70
Dorch. Bay	low	summer	4.38	2.36	2.67	2.15	3.57	3.64
Inner Harbor	high	fall/winter	4.82	3.67	4.29	3.88	6.26	4.58
Inner Harbor	high	spring	3.51	3.49	4.66	3.83	3.62	4.32
Inner Harbor	high	summer	4.07	4.15	4.68	4.57	5.99	5.75
Inner Harbor	low	fall/winter	5.03	5.15	4.85	4.77	6.35	4.82
Inner Harbor	low	spring	3.68	2.88	4.52	3.99	3.17	4.90
Inner Harbor	low	summer	4.20	4.12	5.48	4.33	5.44	5.48
Outer Harbor	high	fall/winter	2.72	1.33	4.72	2.32	3.62	2.07
Outer Harbor	high	spring	1.35	1.51	2.63	1.42	3.09	4.71
Outer Harbor	high	summer	1.60	1.93	4.53	1.75	2.92	2.44
Outer Harbor	low	spring	3.30	1.98	1.81	2.59	**3.43**	2.29
Outer Harbor	low	summer	1.86	2.01	2.01	1.89	2.65	2.68
		sum	146.06	136.54	158.44	139.13	184.12	169.70
		mean	4.43	4.14	4.80	4.22	5.58	5.14
		untransformed mean	**83**	**62**	**121**	**67**	**264**	**170**
		% reduction	**25.3%**		**44.6%**		**35.6%**	
		overall mean	**138**	**89**				
		overall % reduction	**35.5%**					

Highlighted cells denote estimated values

Fecal Coliform
Scheme A
Factorial ANOVA with Randomized Blocks

	ANOVA Multipliers										
	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		Factorial	Treatment	time	rain	interaction
	89-91	92-96	89-91	92-96	89-91	92-96	Effect Total	SS	SS	SS	SS
time	-1	1	-1	1	-1	1	-43.25	9.45	9.45		
rain/no rain	-2	-2	1	1	1	1	86.19	18.76		18.76	
interaction	2	-2	-1	1	-1	1	-14.69	0.54			0.54
high rain/low rain	0	0	-1	-1	1	1	56.25	23.97		23.97	
interaction	0	0	1	-1	-1	1	4.89	0.18			0.18
								52.90	9.45	42.73	0.73

Correction: C = 4405.74
Total SS = 1126.89
Blocks SS = 458.271
Error SS = 615.71

	Squares of ANOVA Multipliers						sum	divisor for SS
time	1	1	1	1	1	1	6	198
rain/no rain	4	4	1	1	1	1	12	396
interaction	4	4	1	1	1	1	12	396
high rain/low rain	0	0	1	1	1	1	4	132
interaction	0	0	1	1	1	1	4	132

#treat= 6
#blocks= 33
#cells= 198
#zeros= 7
avg of recip= 0.1026

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	32	458.27	14.32	34.69
Treatments	5	52.90	10.58	25.63
Time	1	9.45	9.45	**22.89**
Rainfall	2	42.73	21.36	51.76
Rain/no rain	*1*	*18.76*	*18.76*	*45.44*
high/low rain	*1*	*23.97*	*23.97*	*58.07*
Error	153	615.71	0.41	
Total	190	1126.89		

Fecal Coliform
Scheme B
Distribution of Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total # samples in block
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		
			89-91	92-95	89-91	92-95	89-91	92-95	
Charles R.	freshwater	fall/winter	199	6	51	7	155	4	422
Charles R.	freshwater	spring	83	105	91	119	46	45	489
Charles R.	freshwater	summer	97	132	74	198	149	187	837
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250
Mystic R.	freshwater	spring	22	12	9	80	0	6	129
Mystic R.	freshwater	summer	77	135	37	58	102	57	466
Nepon. Head.	freshwater	fall/winter	11	2	15	0	8	2	38
Nepon. Head.	freshwater	spring	0	8	2	3	0	6	19
Nepon. Head.	freshwater	summer	6	33	8	23	10	26	106
Neponset R.	high	fall/winter	11	41	40	33	22	14	161
Neponset R.	high	spring	0	34	7	39	3	25	108
Neponset R.	high	summer	33	103	16	71	14	65	302
Neponset R.	low	fall/winter	24	24	38	32	25	30	173
Neponset R.	low	spring	1	35	8	15	4	41	104
Neponset R.	low	summer	6	103	25	83	56	99	372
Dorch. Bay	high	fall/winter	11	0	24	0	23	1	59
Dorch. Bay	high	spring	9	20	25	13	17	13	97
Dorch. Bay	high	summer	45	83	26	80	43	65	342
Dorch. Bay	low	fall/winter	20	4	38	0	35	2	99
Dorch. Bay	low	spring	19	27	25	8	14	28	121
Dorch. Bay	low	summer	9	113	36	77	89	82	406
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251
Inner Harbor	high	spring	30	56	48	70	17	22	243
Inner Harbor	high	summer	115	115	55	103	142	72	602
Inner Harbor	low	fall/winter	34	42	33	46	53	32	240
Inner Harbor	low	spring	50	39	32	93	5	32	251
Inner Harbor	low	summer	75	116	50	94	88	112	535
Outer Harbor	high	fall/winter	49	10	9	10	22	5	105
Outer Harbor	high	spring	2	25	15	11	2	7	62
Outer Harbor	high	summer	43	142	23	121	57	133	519
Outer Harbor	low	fall/winter	44	0	27	0	17	0	88
Outer Harbor	low	spring	4	19	23	21	0	17	84
Outer Harbor	low	summer	59	160	37	106	77	127	566
								Total number of fecal coliform samples:	**8646**

Fecal Coliform
Scheme B
Cell Average Values (Blocks with Insufficient Data Removed)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in	
			89-91	92-95	89-91	92-95	89-91	92-95
Charles R.	freshwater	fall/winter	6.11	7.06	6.48	5.99	6.97	6.40
Charles R.	freshwater	spring	6.50	5.39	6.06	5.33	6.68	5.81
Charles R.	freshwater	summer	5.90	5.14	5.60	5.83	6.93	6.36
Mystic R.	freshwater	fall/winter	5.48	5.83	6.25	6.45	8.12	6.62
Mystic R.	freshwater	spring	4.19	4.51	4.63	4.89	**5.95**	6.29
Mystic R.	freshwater	summer	4.69	4.88	4.86	3.98	6.21	6.60
Nepon. Head.	freshwater	fall/winter	6.72	6.16	6.56	**6.35**	7.54	7.77
Nepon. Head.	freshwater	summer	7.29	6.92	7.77	6.93	8.07	7.63
Neponset R.	high	fall/winter	4.42	2.97	5.38	4.32	5.96	5.91
Neponset R.	high	spring	**5.39**	4.77	6.80	3.90	8.15	5.45
Neponset R.	high	summer	4.35	5.01	4.92	4.81	5.92	6.86
Neponset R.	low	fall/winter	4.94	5.27	4.81	4.40	6.17	5.58
Neponset R.	low	spring	3.78	4.38	5.80	5.75	6.89	5.17
Neponset R.	low	summer	5.95	5.61	5.63	4.58	6.43	6.59
Dorch. Bay	high	spring	1.54	2.10	1.98	2.34	2.95	3.00
Dorch. Bay	high	summer	2.16	2.33	2.96	2.71	3.48	3.73
Dorch. Bay	low	fall/winter	4.55	4.28	3.64	**4.03**	6.34	4.34
Dorch. Bay	low	spring	1.87	2.43	2.61	1.80	4.25	2.70
Dorch. Bay	low	summer	4.38	2.36	2.67	2.15	3.57	3.64
Inner Harbor	high	fall/winter	4.82	3.67	4.29	3.88	6.26	4.58
Inner Harbor	high	spring	3.51	3.49	4.66	3.83	3.62	4.32
Inner Harbor	high	summer	4.07	4.15	4.68	4.57	5.99	5.75
Inner Harbor	low	fall/winter	5.03	5.15	4.85	4.77	6.35	4.82
Inner Harbor	low	spring	3.68	2.88	4.52	3.99	3.17	4.90
Inner Harbor	low	summer	4.20	4.12	5.48	4.33	5.44	5.48
Outer Harbor	high	fall/winter	2.72	1.33	4.72	2.32	3.62	2.07
Outer Harbor	high	spring	1.35	1.51	2.63	1.42	3.09	4.71
Outer Harbor	high	summer	1.60	1.93	4.53	1.75	2.92	2.44
Outer Harbor	low	spring	3.30	1.98	1.81	2.59	**3.45**	2.29
Outer Harbor	low	summer	1.86	2.01	2.01	1.89	2.65	2.68
		sum	126.35	119.62	139.59	121.88	163.14	150.49
		mean	4.21	3.99	4.65	4.06	5.44	5.02
		untransformed mean	**66**	**53**	**104**	**57**	**229**	**150**
		% reduction	**19.7%**		**45.2%**		**34.5%**	
		overall mean	**116**	**77**				
		overall % reduction	**33.6%**					

Highlighted cells denote estimated values

Fecal Coliform
Scheme B
Factorial ANOVA with Randomized Blocks

	ANOVA Multipliers										
	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		Factorial	Treatment	time	rain	interaction
	89-91	92-96	89-91	92-96	89-91	92-96	Effect Total	SS	SS	SS	SS
time	-1	1	-1	1	-1	1	-37.09	7.64	7.64		
rain/no rain	-2	-2	1	1	1	1	83.16	19.21		19.21	
interaction	2	-2	-1	1	-1	1	-16.90	0.79			0.79
high rain/low rain	0	0	-1	-1	1	1	52.16	22.67		22.67	
interaction	0	0	1	-1	-1	1	5.06	0.21			0.21
								50.53	7.64	41.88	1.01

Correction: C =	3745.31
Total SS =	1037.72
Blocks SS =	398.424
Error SS =	588.77

	Squares of ANOVA Multipliers						sum	divisor for SS
time	1	1	1	1	1	1	6	180
rain/no rain	4	4	1	1	1	1	12	360
interaction	4	4	1	1	1	1	12	360
high rain/low rain	0	0	1	1	1	1	4	120
interaction	0	0	1	1	1	1	4	120

#treat= 6
#blocks= 30
#cells= 180
#zeros= 5
avg of recip= 0.0931

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	29	398.42	13.74	35.11
Treatments	5	50.53	10.11	25.82
Time	1	7.64	7.64	**19.53**
Rainfall	2	41.88	20.94	53.51
Rain/no rain	*1*	*19.21*	*19.21*	*49.09*
high/low rain	*1*	*22.67*	*22.67*	*57.93*
Error	140	588.77	0.39	
Total	174	1037.72		

Fecal Coliform
Scheme C
Distribution of Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total # samples in block
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		
			89-91	92-95	89-91	92-95	89-91	92-95	
Upper Charles	freshwater	fall/winter	89	0	19	1	72	0	181
Upper Charles	freshwater	spring	23	45	31	55	14	20	188
Upper Charles	freshwater	jul	39	54	35	86	69	83	366
Upper Charles	freshwater	aug	0	7	1	7	0	17	32
Lower Charles	freshwater	fall/winter	110	6	32	6	83	4	241
Lower Charles	freshwater	spring	60	60	60	65	32	25	302
Lower Charles	freshwater	jul	51	63	34	100	74	76	398
Lower Charles	freshwater	aug	7	7	4	5	6	11	40
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250
Mystic R.	freshwater	spring	22	12	9	80	0	6	129
Mystic R.	freshwater	jul	21	0	21	20	16	11	89
Mystic R.	freshwater	aug	56	135	16	38	86	46	377
Nepon. Head.	freshwater	fall/winter	11	2	15	0	8	2	38
Nepon. Head.	freshwater	spring	0	8	2	3	0	6	19
Nepon. Head.	freshwater	jul	2	15	4	20	8	15	64
Nepon. Head.	freshwater	aug	4	18	4	3	2	11	42
Neponset R.	high	fall/winter	11	41	40	33	22	14	161
Neponset R.	high	spring	0	34	7	39	3	25	108
Neponset R.	high	jul	12	46	11	57	11	43	180
Neponset R.	high	aug	21	57	5	14	3	22	122
Neponset R.	low	fall/winter	24	24	38	32	25	30	173
Neponset R.	low	spring	1	35	8	15	4	41	104
Neponset R.	low	jul	3	49	10	68	50	50	230
Neponset R.	low	aug	3	54	15	15	6	49	142
Dorch. Bay	high	fall/winter	11	0	24	0	23	1	59
Dorch. Bay	high	spring	9	20	25	13	17	13	97
Dorch. Bay	hugh	jul	19	37	18	61	39	43	217
Dorch. Bay	high	aug	26	46	8	19	4	22	125
Dorch. Bay	low	fall/winter	20	4	38	0	35	2	99
Dorch. Bay	low	spring	19	27	25	8	14	28	121
Dorch. Bay	low	jul	6	57	21	70	78	49	281
Dorch. Bay	low	aug	3	56	15	7	11	33	125
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251
Inner Harbor	high	spring	30	56	48	70	17	22	243
Inner Harbor	high	jul	54	48	14	79	25	41	261
Inner Harbor	high	aug	61	67	41	24	117	31	341
Inner Harbor	low	fall/winter	34	42	33	46	53	32	240
Inner Harbor	low	spring	50	39	32	93	5	32	251
Inner Harbor	low	jul	16	51	23	79	15	82	266
Inner Harbor	low	aug	59	65	27	15	73	30	269
Outer Harbor	high	fall/winter	49	10	9	10	22	5	105
Outer Harbor	high	spring	2	25	15	11	2	7	62
Outer Harbor	high	jul	6	42	2	38	2	29	119
Outer Harbor	high	aug	37	100	21	83	55	104	400
Outer Harbor	low	fall/winter	44	0	27	0	17	0	88
Outer Harbor	low	spring	4	19	23	21	0	17	84
Outer Harbor	low	jul	23	53	3	46	9	33	167
Outer Harbor	low	aug	36	107	34	60	68	94	399
Total number of fecal coliform samples:									8646

Fecal Coliform
Scheme C
Cell Average Values (Blocks with Insufficient Data Removed)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in	
			89-91	92-95	89-91	92-95	89-91	92-95
Upper Charles	freshwater	fall/winter	6.48	**6.03**	7.06	5.71	7.29	**7.06**
Upper Charles	freshwater	spring	7.85	6.29	6.96	6.34	7.24	6.37
Upper Charles	freshwater	jul	6.60	6.18	6.11	6.97	7.41	6.74
Lower Charles	freshwater	fall/winter	5.81	7.06	6.14	6.04	6.69	6.40
Lower Charles	freshwater	spring	5.98	4.72	5.60	4.53	6.44	5.37
Lower Charles	freshwater	jul	5.51	4.37	5.13	4.89	6.49	5.84
Lower Charles	freshwater	aug	4.88	3.49	5.16	4.26	6.85	4.58
Mystic R.	freshwater	fall/winter	5.48	5.83	6.25	6.45	8.12	6.62
Mystic R.	freshwater	spring	4.19	4.51	4.63	4.89	**5.96**	6.29
Mystic R.	freshwater	jul	4.18	**4.24**	4.53	3.49	4.94	7.50
Mystic R.	freshwater	aug	4.88	4.88	5.29	4.25	6.45	6.39
Nepon. Head.	freshwater	fall/winter	6.72	6.16	6.56	**6.33**	7.54	7.77
Nepon. Head.	freshwater	jul	7.37	6.83	7.05	6.88	7.69	7.90
Nepon. Head.	freshwater	aug	7.25	6.99	8.49	7.32	9.59	7.26
Neponset R.	high	fall/winter	4.42	2.97	5.38	4.32	5.96	5.91
Neponset R.	high	spring	**5.50**	4.77	6.80	3.90	8.15	5.45
Neponset R.	high	jul	4.51	4.33	5.06	4.60	5.59	6.72
Neponset R.	high	aug	4.26	5.55	4.62	5.67	7.12	7.13
Neponset R.	low	fall/winter	4.94	5.27	4.81	4.40	6.17	5.58
Neponset R.	low	spring	3.78	4.38	5.80	5.75	6.89	5.17
Neponset R.	low	jul	5.06	4.20	5.71	4.65	6.23	5.57
Neponset R.	low	aug	6.85	6.88	5.57	4.29	8.12	7.63
Dorch. Bay	high	spring	1.54	2.10	1.98	2.34	2.95	3.00
Dorch. Bay	hugh	jul	1.80	1.62	2.35	2.49	3.35	3.80
Dorch. Bay	high	aug	2.42	2.90	4.34	3.42	4.79	3.60
Dorch. Bay	low	fall/winter	4.55	4.28	3.64	**4.01**	6.34	4.34
Dorch. Bay	low	spring	1.87	2.43	2.61	1.80	4.25	2.70
Dorch. Bay	low	jul	2.84	2.00	2.15	2.14	3.10	3.32
Dorch. Bay	low	aug	7.46	2.72	3.39	2.23	6.91	4.12
Inner Harbor	high	fall/winter	4.82	3.67	4.29	3.88	6.26	4.58
Inner Harbor	high	spring	3.51	3.49	4.66	3.83	3.62	4.32
Inner Harbor	high	jul	3.85	3.82	3.90	4.81	5.60	5.80
Inner Harbor	high	aug	4.25	4.39	4.95	3.77	6.07	5.67
Inner Harbor	low	fall/winter	5.03	5.15	4.85	4.77	6.35	4.82
Inner Harbor	low	spring	3.68	2.88	4.52	3.99	3.17	4.90
Inner Harbor	low	jul	3.85	4.09	5.05	4.54	4.44	5.63
Inner Harbor	low	aug	4.30	4.14	5.84	3.22	5.64	5.07
Outer Harbor	high	fall/winter	2.72	1.33	4.72	2.32	3.62	2.07
Outer Harbor	high	spring	1.35	1.51	2.63	1.42	3.09	4.71
Outer Harbor	high	jul	1.53	2.73	0.92	2.06	1.35	2.01
Outer Harbor	high	aug	1.61	1.59	4.87	1.60	2.97	2.56
Outer Harbor	low	spring	3.30	1.98	1.81	2.59	**3.45**	2.29
Outer Harbor	low	jul	1.58	2.33	1.59	2.35	2.35	3.01
Outer Harbor	low	aug	2.03	1.85	2.05	1.54	2.69	2.56
		sum	192.39	178.93	205.82	181.05	245.29	226.13
		mean	4.37	4.07	4.68	4.11	5.57	5.14
		untransformed mean	**78**	**58**	**107**	**60**	**261**	**170**
		% reduction	**25.6%**		**43.9%**		**34.9%**	
		overall mean	**130**	**84**				
		overall % reduction	**35.4%**					

Highlighted cells denote estimated values

Fecal Coliform
Scheme C
Factorial ANOVA with Randomized Blocks

ANOVA Multipliers

	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		Factorial	Treatment	time	rain	interaction
	89-91	92-96	89-91	92-96	89-91	92-96	Effect Total	SS	SS	SS	SS
time	-1	1	-1	1	-1	1	-57.39	12.48	12.48		
rain/no rain	-2	-2	1	1	1	1	115.65	25.33		25.33	
interaction	2	-2	-1	1	-1	1	-17.01	0.55			0.55
high rain/low rain	0	0	-1	-1	1	1	84.55	40.62		40.62	
interaction	0	0	1	-1	-1	1	5.61	0.18			0.18
								79.15	12.48	65.95	0.73

Correction: C =	5727.05
Total SS =	1594.74
Blocks SS =	651.485
Error SS =	864.10

Squares of ANOVA Multipliers

							sum	divisor for SS
time	1	1	1	1	1	1	6	264
rain/no rain	4	4	1	1	1	1	12	528
interaction	4	4	1	1	1	1	12	528
high rain/low rain	0	0	1	1	1	1	4	176
interaction	0	0	1	1	1	1	4	176

#treat= 6
#blocks= 44
#cells= 264
#zeros= 8
avg of recip= 0.1148

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	43	651.49	15.15	31.62
Treatments	5	79.15	15.83	33.04
Time	1	12.48	12.48	**26.04**
Rainfall	2	65.95	32.97	68.82
Rain/no rain	*1*	*25.33*	*25.33*	*52.87*
high/low rain	*1*	*40.62*	*40.62*	*84.77*
Error	207	864.10	0.48	
Total	255	1594.74		

Enterococcus
Scheme A
Distribution of Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total # samples in block
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		
			89-91	92-95	89-91	92-95	89-91	92-95	
Upper Charles	freshwater	fall/winter	89	0	19	0	72	0	180
Upper Charles	freshwater	spring	0	47	0	56	0	20	123
Upper Charles	freshwater	summer	39	60	36	93	68	100	396
Lower Charles	freshwater	fall/winter	108	6	32	5	83	4	238
Lower Charles	freshwater	spring	16	59	12	65	2	25	179
Lower Charles	freshwater	summer	58	70	38	103	79	87	435
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250
Mystic R.	freshwater	spring	22	12	7	80	0	6	127
Mystic R.	freshwater	summer	77	133	37	58	102	57	464
Nepon. Head.	freshwater	fall/winter	10	1	14	0	8	2	35
Nepon. Head.	freshwater	spring	0	8	2	3	0	6	19
Nepon. Head.	freshwater	summer	6	31	8	24	10	28	107
Neponset R.	high	fall/winter	11	9	40	6	22	14	102
Neponset R.	high	spring	0	16	7	16	3	24	66
Neponset R.	high	summer	33	98	16	70	14	65	296
Neponset R.	low	fall/winter	24	10	38	30	25	25	152
Neponset R.	low	spring	1	29	8	10	4	32	84
Neponset R.	low	summer	6	101	25	82	56	107	377
Dorch. Bay	high	fall/winter	11	0	24	0	23	1	59
Dorch. Bay	high	spring	9	20	25	13	17	13	97
Dorch. Bay	high	summer	45	82	26	80	43	65	341
Dorch. Bay	low	fall/winter	20	2	38	0	35	2	97
Dorch. Bay	low	spring	19	27	25	8	13	28	120
Dorch. Bay	low	summer	9	108	36	78	89	88	408
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251
Inner Harbor	high	spring	30	53	48	70	17	24	242
Inner Harbor	high	summer	115	112	55	103	142	72	599
Inner Harbor	low	fall/winter	34	39	33	46	54	32	238
Inner Harbor	low	spring	50	39	32	91	5	32	249
Inner Harbor	low	summer	75	113	50	94	88	112	532
Outer Harbor	high	fall/winter	49	10	9	9	22	5	104
Outer Harbor	high	spring	2	20	15	11	2	7	57
Outer Harbor	high	summer	43	140	23	121	57	134	518
Outer Harbor	low	fall/winter	42	0	27	0	17	0	86
Outer Harbor	low	spring	4	19	23	21	0	17	84
Outer Harbor	low	summer	59	156	37	104	77	127	560

Total number of *Enterococcus* samples: 8272

Enterococcus
Scheme A
Cell Average Values (Blocks with Insufficient Data Removed)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in 89-91	RMS = 0 in 92-95	0 in < RMS < .25 in 89-91	0 in < RMS < .25 in 92-95	RMS > .25 in 89-91	RMS > .25 in 92-95
Upper Charles	freshwater	fall/winter	5.63	**5.85**	6.14	**6.03**	7.16	**6.82**
Upper Charles	freshwater	spring	**4.52**	4.62	**4.75**	4.93	**5.88**	5.37
Upper Charles	freshwater	summer	4.58	4.41	4.07	5.33	6.53	5.92
Lower Charles	freshwater	fall/winter	4.62	6.94	4.84	5.87	6.11	6.67
Lower Charles	freshwater	spring	2.26	3.13	2.29	3.28	3.69	4.20
Lower Charles	freshwater	summer	3.02	2.76	3.10	3.25	4.60	3.98
Mystic R.	freshwater	fall/winter	3.86	3.50	5.82	4.14	8.00	4.36
Mystic R.	freshwater	spring	3.62	3.60	3.99	4.12	**5.22**	5.57
Mystic R.	freshwater	summer	3.81	3.84	3.69	3.50	4.73	5.47
Nepon. Head.	freshwater	fall/winter	5.94	6.91	6.06	**6.45**	7.81	6.99
Nepon. Head.	freshwater	summer	6.66	5.64	6.16	5.62	8.34	6.66
Neponset R.	high	fall/winter	4.23	3.58	4.56	5.92	5.16	5.54
Neponset R.	high	spring	**4.26**	3.39	4.62	3.66	7.44	5.17
Neponset R.	high	summer	3.19	3.80	2.97	3.71	4.83	5.43
Neponset R.	low	fall/winter	3.47	5.35	3.44	3.67	5.17	5.45
Neponset R.	low	spring	2.40	2.70	3.76	5.29	5.76	4.67
Neponset R.	low	summer	4.47	4.01	4.12	3.11	5.33	5.21
Dorch. Bay	high	spring	1.02	1.50	1.40	1.75	1.66	2.25
Dorch. Bay	high	summer	2.00	2.14	2.02	2.17	2.02	3.18
Dorch. Bay	low	fall/winter	2.64	2.42	2.52	**2.53**	4.43	2.09
Dorch. Bay	low	spring	1.26	1.52	1.58	1.14	3.04	2.03
Dorch. Bay	low	summer	2.04	2.20	1.62	2.03	2.40	3.04
Inner Harbor	high	fall/winter	3.49	2.36	4.05	2.84	5.24	2.62
Inner Harbor	high	spring	1.74	2.84	2.24	2.97	2.36	3.99
Inner Harbor	high	summer	2.48	2.52	2.98	3.03	3.54	4.01
Inner Harbor	low	fall/winter	3.84	3.31	4.69	2.96	5.98	3.62
Inner Harbor	low	spring	1.93	2.41	2.49	2.98	1.68	3.76
Inner Harbor	low	summer	3.12	2.49	2.72	3.16	3.44	3.90
Outer Harbor	high	fall/winter	3.19	1.33	4.01	1.22	4.41	1.09
Outer Harbor	high	spring	1.35	1.38	1.60	1.59	1.35	3.67
Outer Harbor	high	summer	1.57	1.71	1.71	1.61	2.07	2.04
Outer Harbor	low	spring	1.57	1.84	1.62	2.03	**3.00**	2.74
Outer Harbor	low	summer	1.61	1.81	1.61	1.89	1.92	2.21
		sum	105.39	107.81	113.24	113.78	150.30	139.72
		mean	3.19	3.27	3.43	3.45	4.55	4.23
		untransformed mean	**23**	**25**	**30**	**31**	**94**	**68**
		% reduction	**-8.7%**		**-3.3%**		**27.7%**	
		overall mean	**40**	**37**				
		overall % reduction	**7.5%**					

Highlighted cells denote estimated values

Enterococcus
Scheme A
Factorial ANOVA with Randomized Blocks

	ANOVA Multipliers										
	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		Factorial	Treatment	time	rain	interaction
	89-91	92-96	89-91	92-96	89-91	92-96	Effect Total	SS	SS	SS	SS
time	-1	1	-1	1	-1	1	-7.62	0.29	0.29		
rain/no rain	-2	-2	1	1	1	1	90.64	20.75		20.75	
interaction	2	-2	-1	1	-1	1	-14.88	0.56			0.56
high rain/low rain	0	0	-1	-1	1	1	63.00	30.07		30.07	
interaction	0	0	1	-1	-1	1	-11.12	0.94			0.94
								52.60	0.29	50.81	1.50

Correction: C =	2693.18
Total SS =	1039.90
Blocks SS =	414.408
Error SS =	572.89

	Squares of ANOVA Multipliers						sum	divisor for SS
time	1	1	1	1	1	1	6	198
rain/no rain	4	4	1	1	1	1	12	396
interaction	4	4	1	1	1	1	12	396
high rain/low rain	0	0	1	1	1	1	4	132
interaction	0	0	1	1	1	1	4	132

#treat= 6
#blocks= 33
#cells= 198
#zeros= 7
avg of recip= 0.1263

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	32	414.41	12.95	27.39
Treatments	5	52.60	10.52	22.25
Time	1	0.29	0.29	**0.62**
Rainfall	2	50.81	25.41	53.73
Rain/no rain	*1*	*20.75*	*20.75*	*43.87*
high/low rain	*1*	*30.07*	*30.07*	*63.59*
Error	153	572.89	0.47	
Total	190	1039.90		

Enterococcus
Scheme B
Distribution of Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total # samples in block
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		
			89-91	92-95	89-91	92-95	89-91	92-95	
Charles R.	freshwater	fall/winter	197	6	51	5	155	4	418
Charles R.	freshwater	spring	16	106	12	121	2	45	302
Charles R.	freshwater	summer	97	130	74	196	147	187	831
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250
Mystic R.	freshwater	spring	22	12	7	80	**0**	6	127
Mystic R.	freshwater	summer	77	133	37	58	102	57	464
Nepon. Head.	freshwater	fall/winter	10	1	14	**0**	8	2	35
Nepon. Head.	freshwater	spring	**0**	8	2	3	**0**	6	19
Nepon. Head.	freshwater	summer	6	31	8	24	10	28	107
Neponset R.	high	fall/winter	11	9	40	6	22	14	102
Neponset R.	high	spring	**0**	16	7	16	3	24	66
Neponset R.	high	summer	33	98	16	70	14	65	296
Neponset R.	low	fall/winter	24	10	38	30	25	25	152
Neponset R.	low	spring	1	29	8	10	4	32	84
Neponset R.	low	summer	6	101	25	82	56	107	377
Dorch. Bay	high	fall/winter	11	**0**	24	**0**	23	1	59
Dorch. Bay	high	spring	9	20	25	13	17	13	97
Dorch. Bay	high	summer	45	82	26	80	43	65	341
Dorch. Bay	low	fall/winter	20	2	38	**0**	35	2	97
Dorch. Bay	low	spring	19	27	25	8	13	28	120
Dorch. Bay	low	summer	9	108	36	78	89	88	408
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251
Inner Harbor	high	spring	30	53	48	70	17	24	242
Inner Harbor	high	summer	115	112	55	103	142	72	599
Inner Harbor	low	fall/winter	34	39	33	46	54	32	238
Inner Harbor	low	spring	50	39	32	91	5	32	249
Inner Harbor	low	summer	75	113	50	94	88	112	532
Outer Harbor	high	fall/winter	49	10	9	9	22	5	104
Outer Harbor	high	spring	2	20	15	11	2	7	57
Outer Harbor	high	summer	43	140	23	121	57	134	518
Outer Harbor	low	fall/winter	42	**0**	27	**0**	17	**0**	86
Outer Harbor	low	spring	4	19	23	21	**0**	17	84
Outer Harbor	low	summer	59	156	37	104	77	127	560
						Total number of *Enterococcus* samples:			8272

Enterococcus
Scheme B
Cell Average Values (Blocks with Insufficient Data Removed)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in	
			89-91	92-95	89-91	92-95	89-91	92-95
Charles R.	freshwater	fall/winter	5.08	6.94	5.32	5.87	6.60	6.67
Charles R.	freshwater	spring	2.26	3.79	2.29	4.04	3.69	4.72
Charles R.	freshwater	summer	3.64	3.52	3.57	4.24	5.49	5.02
Mystic R.	freshwater	fall/winter	3.86	3.50	5.82	4.14	8.00	4.36
Mystic R.	freshwater	spring	3.62	3.60	3.99	4.12	**5.20**	5.57
Mystic R.	freshwater	summer	3.81	3.84	3.69	3.50	4.73	5.47
Nepon. Head.	freshwater	fall/winter	5.94	6.91	6.06	**6.45**	7.81	6.99
Nepon. Head.	freshwater	summer	6.66	5.64	6.16	5.62	8.34	6.66
Neponset R.	high	fall/winter	4.23	3.58	4.56	5.92	5.16	5.54
Neponset R.	high	spring	**4.26**	3.39	4.62	3.66	7.44	5.17
Neponset R.	high	summer	3.19	3.80	2.97	3.71	4.83	5.43
Neponset R.	low	fall/winter	3.47	5.35	3.44	3.67	5.17	5.45
Neponset R.	low	spring	2.40	2.70	3.76	5.29	5.76	4.67
Neponset R.	low	summer	4.47	4.01	4.12	3.11	5.33	5.21
Dorch. Bay	high	spring	1.02	1.50	1.40	1.75	1.66	2.25
Dorch. Bay	high	summer	2.00	2.14	2.02	2.17	2.02	3.18
Dorch. Bay	low	fall/winter	2.64	2.42	2.52	**2.52**	4.43	2.09
Dorch. Bay	low	spring	1.26	1.52	1.58	1.14	3.04	2.03
Dorch. Bay	low	summer	2.04	2.20	1.62	2.03	2.40	3.04
Inner Harbor	high	fall/winter	3.49	2.36	4.05	2.84	5.24	2.62
Inner Harbor	high	spring	1.74	2.84	2.24	2.97	2.36	3.99
Inner Harbor	high	summer	2.48	2.52	2.98	3.03	3.54	4.01
Inner Harbor	low	fall/winter	3.84	3.31	4.69	2.96	5.98	3.62
Inner Harbor	low	spring	1.93	2.41	2.49	2.98	1.68	3.76
Inner Harbor	low	summer	3.12	2.49	2.72	3.16	3.44	3.90
Outer Harbor	high	fall/winter	3.19	1.33	4.01	1.22	4.41	1.09
Outer Harbor	high	spring	1.35	1.38	1.60	1.59	1.35	3.67
Outer Harbor	high	summer	1.57	1.71	1.71	1.61	2.07	2.04
Outer Harbor	low	spring	1.57	1.84	1.62	2.03	**2.98**	2.74
Outer Harbor	low	summer	1.61	1.81	1.61	1.89	1.92	2.21
		sum	91.74	94.35	99.23	99.23	132.07	123.17
		mean	3.06	3.15	3.31	3.31	4.40	4.11
		untransformed mean	**20**	**22**	**26**	**26**	**80**	**60**
		% reduction	**-10.0%**		**0.0%**		**25.0%**	
		overall mean	**35**	**32**				
		overall % reduction	**8.6%**					

Highlighted cells denote estimated values

Enterococcus
Scheme B
Factorial ANOVA with Randomized Blocks

ANOVA Multipliers	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		Factorial	Treatment	time	rain	interaction
	89-91	92-96	89-91	92-96	89-91	92-96	Effect Total	SS	SS	SS	SS
time	-1	1	-1	1	-1	1	-6.29	0.22	0.22		
rain/no rain	-2	-2	1	1	1	1	81.52	18.46		18.46	
interaction	2	-2	-1	1	-1	1	-14.12	0.55			0.55
high rain/low rain	0	0	-1	-1	1	1	56.78	26.87		26.87	
interaction	0	0	1	-1	-1	1	-8.90	0.66			0.66
								46.76	0.22	45.33	1.21

Correction: C =	2274.06
Total SS =	952.09
Blocks SS =	354.579
Error SS =	550.75

Squares of ANOVA Multipliers							sum	divisor for SS
time	1	1	1	1	1	1	6	180
rain/no rain	4	4	1	1	1	1	12	360
interaction	4	4	1	1	1	1	12	360
high rain/low rain	0	0	1	1	1	1	4	120
interaction	0	0	1	1	1	1	4	120

#treat= 6
#blocks= 30
#cells= 180
#zeros= 5
avg of recip= 0.1035

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	29	354.58	12.23	30.02
Treatments	5	46.76	9.35	22.96
Time	1	0.22	0.22	**0.54**
Rainfall	2	45.33	22.66	55.64
Rain/no rain	*1*	*18.46*	*18.46*	*45.32*
high/low rain	*1*	*26.87*	*26.87*	*65.96*
Error	140	550.75	0.41	
Total	174	952.09		

Enterococcus
Scheme C
Distribution of Samples over Treatments and Blocks

RANDOMIZED BLOCKS			TREATMENTS						Total #
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		samples
			89-91	92-95	89-91	92-95	89-91	92-95	in block
Upper Charles	freshwater	fall/winter	89	0	19	0	72	0	180
Upper Charles	freshwater	spring	0	47	0	56	0	20	123
Upper Charles	freshwater	jul	39	54	35	86	68	83	365
Upper Charles	freshwater	aug	0	6	1	7	0	17	31
Lower Charles	freshwater	fall/winter	108	6	32	5	83	4	238
Lower Charles	freshwater	spring	16	59	12	65	2	25	179
Lower Charles	freshwater	jul	51	64	34	98	73	76	396
Lower Charles	freshwater	aug	7	6	4	5	6	11	39
Mystic R.	freshwater	fall/winter	46	68	19	59	8	50	250
Mystic R.	freshwater	spring	22	12	7	80	0	6	127
Mystic R.	freshwater	jul	21	0	21	20	16	11	89
Mystic R.	freshwater	aug	56	133	16	38	86	46	375
Nepon. Head.	freshwater	fall/winter	10	1	14	0	8	2	35
Nepon. Head.	freshwater	spring	0	8	2	3	0	6	19
Nepon. Head.	freshwater	jul	2	15	4	21	8	16	66
Nepon. Head.	freshwater	aug	4	16	4	3	2	12	41
Neponset R.	high	fall/winter	11	9	40	6	22	14	102
Neponset R.	high	spring	0	16	7	16	3	24	66
Neponset R.	high	jul	12	45	11	56	11	43	178
Neponset R.	high	aug	21	53	5	14	3	22	118
Neponset R.	low	fall/winter	24	10	38	30	25	25	152
Neponset R.	low	spring	1	29	8	10	4	32	84
Neponset R.	low	jul	3	49	10	67	50	50	229
Neponset R.	low	aug	3	52	15	15	6	57	148
Dorch. Bay	high	fall/winter	11	0	24	0	23	1	59
Dorch. Bay	high	spring	9	20	25	13	17	13	97
Dorch. Bay	hugh	jul	19	37	18	61	39	43	217
Dorch. Bay	high	aug	26	45	8	19	4	22	124
Dorch. Bay	low	fall/winter	20	2	38	0	35	2	97
Dorch. Bay	low	spring	19	27	25	8	13	28	120
Dorch. Bay	low	jul	6	57	21	71	78	48	281
Dorch. Bay	low	aug	3	51	15	7	11	40	127
Inner Harbor	high	fall/winter	52	43	46	31	49	30	251
Inner Harbor	high	spring	30	53	48	70	17	24	242
Inner Harbor	high	jul	54	48	14	79	25	41	261
Inner Harbor	high	aug	61	64	41	24	117	31	338
Inner Harbor	low	fall/winter	34	39	33	46	54	32	238
Inner Harbor	low	spring	50	39	32	91	5	32	249
Inner Harbor	low	jul	16	51	23	79	15	82	266
Inner Harbor	low	aug	59	62	27	15	73	30	266
Outer Harbor	high	fall/winter	49	10	9	9	22	5	104
Outer Harbor	high	spring	2	20	15	11	2	7	57
Outer Harbor	high	jul	6	42	2	38	2	29	119
Outer Harbor	high	aug	37	98	21	83	55	105	399
Outer Harbor	low	fall/winter	42	0	27	0	17	0	86
Outer Harbor	low	spring	4	19	23	21	0	17	84
Outer Harbor	low	jul	23	52	3	46	9	32	165
Outer Harbor	low	aug	36	104	34	58	68	95	395

Total number of *Enterococcus* samples: 8272

Enterococcus

Scheme C

Cell Average Values (Blocks with Insufficient Data Removed)

RANDOMIZED BLOCKS			TREATMENTS					
Geographic Region	Tidal Condition	Season	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in	
			89-91	92-95	89-91	92-95	89-91	92-95
Upper Charles	freshwater	fall/winter	5.63	5.81	6.14	5.97	7.16	6.76
Upper Charles	freshwater	spring	4.62	4.62	4.73	4.93	5.95	5.37
Upper Charles	freshwater	jul	4.58	4.38	4.03	5.33	6.53	5.62
Lower Charles	freshwater	fall/winter	4.62	6.94	4.84	5.87	6.11	6.67
Lower Charles	freshwater	spring	2.26	3.13	2.29	3.28	3.69	4.2
Lower Charles	freshwater	jul	2.97	2.79	3.15	3.27	4.56	4.1
Lower Charles	freshwater	aug	3.33	2.4	2.73	2.94	5.14	3.15
Mystic R.	freshwater	fall/winter	3.86	3.5	5.82	4.14	8	4.36
Mystic R.	freshwater	spring	3.62	3.6	3.99	4.12	5.27	5.57
Mystic R.	freshwater	jul	3.72	3.8	3.8	3.5	4.28	6.33
Mystic R.	freshwater	aug	3.84	3.84	3.53	3.49	4.81	5.27
Nepon. Head.	freshwater	fall/winter	5.94	6.91	6.06	6.41	7.81	6.99
Nepon. Head.	freshwater	jul	6.98	5.33	5.85	5.5	7.87	6.83
Nepon. Head.	freshwater	aug	6.5	5.94	6.48	6.49	10.23	6.42
Neponset R.	high	fall/winter	4.23	3.58	4.56	5.92	5.16	5.54
Neponset R.	high	spring	4.36	3.39	4.62	3.66	7.44	5.17
Neponset R.	high	jul	3.31	3.28	2.81	3.61	4.25	5.36
Neponset R.	high	aug	3.12	4.24	3.31	4.1	6.97	5.56
Neponset R.	low	fall/winter	3.47	5.35	3.44	3.67	5.17	5.45
Neponset R.	low	spring	2.4	2.7	3.76	5.29	5.76	4.67
Neponset R.	low	jul	2.97	3.06	3.5	3.15	4.96	4.33
Neponset R.	low	ayg	5.97	4.89	4.54	2.94	8.37	5.98
Dorch. Bay	high	spring	1.02	1.5	1.4	1.75	1.66	2.25
Dorch. Bay	hugh	jul	1.81	1.41	1.66	1.98	1.98	3.14
Dorch. Bay	high	aug	2.13	2.74	2.85	2.77	2.43	3.26
Dorch. Bay	low	fall/winter	2.64	2.42	2.52	2.49	4.43	2.09
Dorch. Bay	low	spring	1.26	1.52	1.58	1.14	3.04	2.03
Dorch. Bay	low	jul	0.92	1.79	1.34	1.98	1.97	2.67
Dorch. Bay	low	aug	4.29	2.66	2.01	2.58	5.46	3.49
Inner Harbor	high	fall/winter	3.49	2.36	4.05	2.84	5.24	2.62
Inner Harbor	high	spring	1.74	2.84	2.24	2.97	2.36	3.99
Inner Harbor	high	jul	1.73	2.3	1.76	3.14	2.86	3.99
Inner Harbor	high	aug	3.14	2.68	3.39	2.68	3.68	4.03
Inner Harbor	low	fall/winter	3.84	3.31	4.69	2.96	5.98	3.62
Inner Harbor	low	spring	1.93	2.41	2.49	2.98	1.68	3.76
Inner Harbor	low	jul	1.97	2.59	2.96	3.3	2.91	3.99
Inner Harbor	low	aug	3.43	2.41	2.51	2.41	3.55	3.66
Outer Harbor	high	fall/winter	3.19	1.33	4.01	1.22	4.41	1.09
Outer Harbor	high	spring	1.35	1.38	1.6	1.59	1.35	3.67
Outer Harbor	high	jul	1.69	1.91	1.15	1.71	0.92	1.92
Outer Harbor	high	aug	1.56	1.62	1.76	1.56	2.11	2.07
Outer Harbor	low	spring	1.57	1.84	1.62	2.03	3.05	2.74
Outer Harbor	low	jul	1.09	1.73	1.5	1.93	1.63	2.67
Outer Harbor	low	aug	1.94	1.84	1.62	1.86	1.96	2.06
		sum	140.03	140.07	144.69	147.45	200.15	184.51
		mean	3.18	3.18	3.29	3.35	4.55	4.19
		untransformed mean	**23**	**23**	**26**	**28**	**94**	**65**
		% reduction	**0.0%**		**-7.7%**		**30.9%**	
		overall mean	**38**	**35**				
		overall % reduction	**7.9%**					

Highlighted cells denote estimated values

Enterococcus
Scheme C
Factorial ANOVA with Randomized Blocks

	ANOVA Multipliers										
	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		Factorial	Treatment	time	rain	interaction
	89-91	92-96	89-91	92-96	89-91	92-96	Effect Total	SS	SS	SS	SS
time	-1	1	-1	1	-1	1	-12.84	0.62	0.62		
rain/no rain	-2	-2	1	1	1	1	116.60	25.75		25.75	
interaction	2	-2	-1	1	-1	1	-12.96	0.32			0.32
high rain/low rain	0	0	-1	-1	1	1	92.52	48.64		48.64	
interaction	0	0	1	-1	-1	1	-18.40	1.92			1.92
								77.25	0.62	74.39	2.24

Correction: C =	3468.4
Total SS =	1500.99
Blocks SS =	575.472
Error SS =	848.27

	Squares of ANOVA Multipliers						sum	divisor for SS
time	1	1	1	1	1	1	6	264
rain/no rain	4	4	1	1	1	1	12	528
interaction	4	4	1	1	1	1	12	528
high rain/low rain	0	0	1	1	1	1	4	176
interaction	0	0	1	1	1	1	4	176

#treat= 6
#blocks= 44
#cells= 264
#zeros= 12
avg of recip= 0.1326

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	43	575.47	13.38	24.15
Treatments	5	77.25	15.45	27.88
Time	1	0.62	0.62	**1.13**
Rainfall	2	74.39	37.19	67.11
Rain/no rain	*1*	*25.75*	*25.75*	*46.46*
high/low rain	*1*	*48.64*	*48.64*	*87.75*
Error	203	848.27	0.55	
Total	251	1500.99		

APPENDIX B

RESULTS FOR A RANDOMLY SAMPLED FACTORIAL ANOVA

Fecal Coliform
Random Sampling
Distribution of Samples over Treatments and Blocks

RANDOM REPLICATES	TREATMENTS						Total # samples in block
	Random Rain		Random Rain		Random Rain		
	89-91	92-96	89-91	92-96	89-91	92-96	
1	30	30	30	30	30	30	180
2	30	30	30	30	30	30	180
3	30	30	30	30	30	30	180
4	30	30	30	30	30	30	180
5	30	30	30	30	30	30	180
6	30	30	30	30	30	30	180
7	30	30	30	30	30	30	180
8	30	30	30	30	30	30	180
9	30	30	30	30	30	30	180
10	30	30	30	30	30	30	180
11	30	30	30	30	30	30	180
12	30	30	30	30	30	30	180
13	30	30	30	30	30	30	180
14	30	30	30	30	30	30	180
15	30	30	30	30	30	30	180
16	30	30	30	30	30	30	180
17	30	30	30	30	30	30	180
18	30	30	30	30	30	30	180
19	30	30	30	30	30	30	180
20	30	30	30	30	30	30	180
21	30	30	30	30	30	30	180
22	30	30	30	30	30	30	180
23	30	30	30	30	30	30	180
24	30	30	30	30	30	30	180
25	30	30	30	30	30	30	180
26	30	30	30	30	30	30	180
27	30	30	30	30	30	30	180
28	30	30	30	30	30	30	180
29	30	30	30	30	30	30	180
30	30	30	30	30	30	30	180
					Total number of fecal coliform samples:		5400

Fecal Coliform
Random Sampling
Cell Average Values

RANDOM REPLICATES	TREATMENTS					
	Random Rain		Random Rain		Random Rain	
	89-91	92-96	89-91	92-96	89-91	92-96
1	4.57	4.66	4.81	4.26	5.43	4.23
2	5.47	4.28	4.91	3.28	5.03	4.17
3	5.05	3.84	5.00	4.36	4.31	4.05
4	4.29	4.02	4.96	4.06	4.32	4.01
5	4.93	4.64	5.66	4.23	5.09	5.12
6	4.70	3.88	4.92	3.61	5.79	4.43
7	4.47	4.05	4.96	3.87	4.77	4.93
8	4.60	4.49	4.96	4.58	4.78	4.19
9	5.30	4.56	4.59	4.70	5.64	4.18
10	5.46	4.75	4.80	4.21	5.27	4.03
11	5.43	4.26	5.20	4.37	5.00	4.46
12	5.22	3.37	4.25	3.39	4.30	4.32
13	5.00	3.86	4.27	4.67	4.65	4.73
14	5.03	3.42	4.61	4.54	4.36	4.60
15	4.64	3.56	4.82	5.31	4.62	4.32
16	4.55	4.47	5.26	4.37	4.97	3.97
17	4.52	3.64	4.85	4.84	4.70	3.75
18	4.62	4.50	5.16	5.40	4.69	4.55
19	4.93	4.18	4.51	4.12	5.11	4.27
20	4.62	4.20	4.71	3.85	5.16	4.39
21	4.83	4.23	5.48	4.68	4.42	4.30
22	5.14	5.04	4.50	4.98	5.92	4.02
23	5.40	4.57	5.43	4.85	5.19	3.96
24	5.05	5.41	4.45	3.78	5.69	4.44
25	4.77	4.70	4.80	4.15	4.52	3.82
26	4.84	4.95	4.39	4.25	4.82	5.10
27	5.42	4.73	4.07	4.00	4.37	4.74
28	3.85	4.24	4.50	3.92	4.89	4.15
29	5.03	3.83	5.50	4.48	4.92	4.76
30	5.12	4.02	5.54	5.02	4.99	3.74
sum	146.85	128.35	145.87	130.13	147.72	129.73
mean	4.90	4.28	4.86	4.34	4.92	4.32
untransformed mean	**133**	**71**	**128**	**76**	**137**	**75**
% reduction	**46.4%**		**41.1%**		**45.4%**	
overall mean	**133**	**74**				
overall % reduction	**44.4%**					

Fecal Coliform
Random Sampling
Factorial ANOVA with Randomized Blocks

ANOVA Multipliers	RMS = 0 in		0 in < RMS < .25 in		RMS > .25 in		Factorial	Treatment	time	rain	interaction
	89-91	92-96	89-91	92-96	89-91	92-96	Effect Total	SS	SS	SS	SS
time	-1	1	-1	1	-1	1	-52.23	15.16	15.16		
rain/no rain	-2	-2	1	1	1	1	3.05	0.026		0.026	
interaction	2	-2	-1	1	-1	1	3.27	0.030			0.030
high rain/low rain	0	0	-1	-1	1	1	1.45	0.018		0.018	
interaction	0	0	1	-1	-1	1	-2.25	0.042			0.042
								15.27	15.16	0.043	0.072

Correction: C =	3814.78
Total SS =	49.05
Blocks SS =	7.11214
Error SS =	26.66

Squares of ANOVA Multipliers							sum	divisor for SS
time	1	1	1	1	1	1	6	180
rain/no rain	4	4	1	1	1	1	12	360
interaction	4	4	1	1	1	1	12	360
high rain/low rain	0	0	1	1	1	1	4	120
interaction	0	0	1	1	1	1	4	120

#treat= 6
#blocks= 30
#cells= 180
#zeros= 0

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	29	7.11	0.25	1.33
Treatments	5	15.27	3.05	16.61
Time	1	15.16	15.16	**82.42**
Rainfall	2	0.04	0.02	0.12
Rain/no rain	*1*	*0.03*	*0.03*	*0.14*
high/low rain	*1*	*0.02*	*0.02*	*0.10*
Error	145	26.66	0.18	
Total	179	49.05		

APPENDIX C

RESULTS FOR ANALYSIS OF INDIVIDUAL RAINFALL LEVELS

C-1

Fecal Coliform
Scheme A
RMS = 0 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	may-jun	7.85	6.29
upper cha	fresh	jul-aug	6.60	6.14
lower cha	fresh	sep-apr	5.81	7.06
lower cha	fresh	may-jun	5.98	4.72
lower cha	fresh	jul-aug	5.43	4.28
mystic	fresh	sep-apr	5.48	5.83
mystic	fresh	may-jun	4.19	4.51
mystic	fresh	jul-aug	4.69	4.88
nepon head	fresh	sep-apr	6.72	6.16
nepon head	fresh	jul-aug	7.29	6.92
neponset	high	sep-apr	4.42	2.97
neponset	high	jul-aug	4.35	5.01
neponset	low	sep-apr	4.94	5.27
neponset	low	may-jun	3.78	4.38
neponset	low	jul-aug	5.95	5.61
dorchester	high	may-jun	1.54	2.10
dorchester	high	jul-aug	2.16	2.33
dorchester	low	sep-apr	4.55	4.28
dorchester	low	may-jun	1.87	2.43
dorchester	low	jul-aug	4.38	2.36
inner harb	high	sep-apr	4.82	3.67
inner harb	high	may-jun	3.51	3.49
inner harb	high	jul-aug	4.07	4.15
inner harb	low	sep-apr	5.03	5.15
inner harb	low	may-jun	3.68	2.88
inner harb	low	jul-aug	4.20	4.12
outer harb	high	sep-apr	2.72	1.33
outer harb	high	may-jun	1.35	1.51
outer harb	high	jul-aug	1.60	1.93
outer harb	low	may-jun	3.30	1.98
outer harb	low	jul-aug	1.86	2.01
		sum	134.08	125.74
		mean	4.33	4.06
		untransformed mean	**75**	**57**
		% reduction	**23.9%**	

#treat	2
#blocks	31
#cells	62
#zeros	0
avg of recip	0.076

Correction: C =	1088.87
Total SS =	315.05
Blocks SS =	163.86
Treatment SS =	1.12
Error SS =	150.07

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	30	163.86	5.46	14.35
Time Treatments	1	1.12	1.12	**2.95**
Error	**30**	150.07	0.38	
Total	61	315.05		

F-Dist. at	1,30 DoF	30,30 DoF
25%	1.38	1.28
10%	2.88	1.61
5%	**4.17**	**1.84**

Fecal Coliform
Scheme A
0 in < RMS < .25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	sep-apr	7.06	5.71
upper cha	fresh	may-jun	6.96	6.34
upper cha	fresh	jul-aug	6.10	6.92
lower cha	fresh	sep-apr	6.14	6.04
lower cha	fresh	may-jun	5.60	4.53
lower cha	fresh	jul-aug	5.13	4.86
mystic	fresh	sep-apr	6.25	6.45
mystic	fresh	may-jun	4.63	4.89
mystic	fresh	jul-aug	4.86	3.98
nepon head	fresh	may-jun	7.37	6.25
nepon head	fresh	jul-aug	7.77	6.93
neponset	high	sep-apr	5.38	4.32
neponset	high	may-jun	6.80	3.90
neponset	high	jul-aug	4.92	4.81
neponset	low	sep-apr	4.81	4.40
neponset	low	may-jun	5.80	5.75
neponset	low	jul-aug	5.63	4.58
dorchester	high	may-jun	1.98	2.34
dorchester	high	jul-aug	2.96	2.71
dorchester	low	may-jun	2.61	1.80
dorchester	low	jul-aug	2.67	2.15
inner harb	high	sep-apr	4.29	3.88
inner harb	high	may-jun	4.66	3.83
inner harb	high	jul-aug	4.68	4.57
inner harb	low	sep-apr	4.85	4.77
inner harb	low	may-jun	4.52	3.99
inner harb	low	jul-aug	5.48	4.33
outer harb	high	sep-apr	4.72	2.32
outer harb	high	may-jun	2.63	1.42
outer harb	high	jul-aug	4.53	1.75
outer harb	low	may-jun	1.81	2.59
outer harb	low	jul-aug	2.01	1.89
		sum	155.62	135.00
		mean	4.86	4.22
		untransformed mean	**128**	**67**
		% reduction	**47.9%**	

#treat	2
#blocks	32
#cells	64
#zeros	0
avg of recip	0.069

Correction: C =	1319.65
Total SS =	339.95
Blocks SS =	148.82
Treatment SS =	6.64
Error SS =	184.49

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	31	148.82	4.80	11.70
Time Treatments	1	6.64	6.64	**16.19**
Error	**31**	184.49	0.41	
Total	63	339.95		

F-Dist. at	1,31 DoF	31,31 DoF
25%	1.37	1.28
10%	2.87	1.61
5%	**4.16**	**1.83**

Fecal Coliform
Scheme A
RMS > 0.25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	may-jun	7.24	6.37
upper cha	fresh	jul-aug	7.41	6.94
lower cha	fresh	sep-apr	6.69	6.40
lower cha	fresh	may-jun	6.44	5.37
lower cha	fresh	jul-aug	6.52	5.68
mystic	fresh	sep-apr	8.12	6.62
mystic	fresh	jul-aug	6.21	6.60
nepon head	fresh	sep-apr	7.54	7.77
nepon head	fresh	jul-aug	8.07	7.63
neponset	high	sep-apr	5.96	5.91
neponset	high	may-jun	8.15	5.45
neponset	high	jul-aug	5.92	6.86
neponset	low	sep-apr	6.17	5.58
neponset	low	may-jun	6.89	5.17
neponset	low	jul-aug	6.43	6.59
dorchester	high	sep-apr	4.84	1.79
dorchester	high	may-jun	2.95	3.00
dorchester	high	jul-aug	3.48	3.73
dorchester	low	sep-apr	6.34	4.34
dorchester	low	may-jun	4.25	2.70
dorchester	low	jul-aug	3.57	3.64
inner harb	high	sep-apr	6.26	4.58
inner harb	high	may-jun	3.62	4.32
inner harb	high	jul-aug	5.99	5.75
inner harb	low	sep-apr	6.35	4.82
inner harb	low	may-jun	3.17	4.90
inner harb	low	jul-aug	5.44	5.48
outer harb	high	sep-apr	3.62	2.07
outer harb	high	may-jun	3.09	4.71
outer harb	high	jul-aug	2.92	2.44
outer harb	low	jul-aug	2.65	2.68
		sum	172.29	155.88
		mean	5.56	5.03
		untransformed mean	**258**	**152**
		% reduction	**41.3%**	

#treat	2
#blocks	31
#cells	62
#zeros	0
avg of recip	0.092

Correction: C =	1737.11
Total SS =	400.15
Blocks SS =	152.20
Treatment SS =	4.34
Error SS =	243.61

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	30	152.20	5.07	6.82
Time Treatments	**1**	4.34	4.34	**5.83**
Error	**30**	243.61	0.74	
Total	61	400.15		

F-Dist. at	1,30 DoF	30,30 DoF
25%	1.38	1.28
10%	2.88	1.61
5%	**4.17**	**1.84**

C-3

Fecal Coliform
Scheme B
RMS = 0 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
charles	fresh	sep-apr	6.11	7.06
charles	fresh	may-jun	6.50	5.39
charles	fresh	jul-aug	5.90	5.14
mystic	fresh	sep-apr	5.48	5.83
mystic	fresh	may-jun	4.19	4.51
mystic	fresh	jul-aug	4.69	4.88
nepon head	fresh	sep-apr	6.72	6.16
nepon head	fresh	jul-aug	7.29	6.92
neponset	high	sep-apr	4.42	2.97
neponset	high	jul-aug	4.35	5.01
neponset	low	sep-apr	4.94	5.27
neponset	low	may-jun	3.78	4.38
neponset	low	jul-aug	5.95	5.61
dorchester	high	may-jun	1.54	2.10
dorchester	high	jul-aug	2.16	2.33
dorchester	low	sep-apr	4.55	4.28
dorchester	low	may-jun	1.87	2.43
dorchester	low	jul-aug	4.38	2.36
inner harb	high	sep-apr	4.82	3.67
inner harb	high	may-jun	3.51	3.49
inner harb	high	jul-aug	4.07	4.15
inner harb	low	sep-apr	5.03	5.15
inner harb	low	may-jun	3.68	2.88
inner harb	low	jul-aug	4.20	4.12
outer harb	high	sep-apr	2.72	1.33
outer harb	high	may-jun	1.35	1.51
outer harb	high	jul-aug	1.60	1.93
outer harb	low	may-jun	3.30	1.98
outer harb	low	jul-aug	1.86	2.01
		sum	120.93	114.84
		mean	4.17	3.96
		untransformed mean	**64**	**51**
		% reduction	**19.2%**	

#treat	2
#blocks	29
#cells	58
#zeros	0
avg of recip	0.079

Correction: C =	958.42
Total SS =	288.68
Blocks SS =	144.43
Treatment SS =	0.64
Error SS =	143.60

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	28	144.43	5.16	12.73
Time Treatments	1	0.64	0.64	**1.58**
Error	**28**	143.60	0.41	
Total	57	288.68		

F-Dist. at	1,28 DoF	28,28 DoF
25%	1.38	1.29
10%	2.89	1.64
5%	**4.20**	**1.89**

Fecal Coliform
Scheme B
0 in < RMS < .25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
charles	fresh	sep-apr	6.48	5.99
charles	fresh	may-jun	6.06	5.33
charles	fresh	jul-aug	5.60	5.83
mystic	fresh	sep-apr	6.25	6.45
mystic	fresh	may-jun	4.63	4.89
mystic	fresh	jul-aug	4.86	3.98
nepon head	fresh	may-jun	7.37	6.25
nepon head	fresh	jul-aug	7.77	6.93
neponset	high	sep-apr	5.38	4.32
neponset	high	may-jun	6.80	3.90
neponset	high	jul-aug	4.92	4.81
neponset	low	sep-apr	4.81	4.40
neponset	low	may-jun	5.80	5.75
neponset	low	jul-aug	5.63	4.58
dorchester	high	may-jun	1.98	2.34
dorchester	high	jul-aug	2.96	2.71
dorchester	low	may-jun	2.61	1.80
dorchester	low	jul-aug	2.67	2.15
inner harb	high	sep-apr	4.29	3.88
inner harb	high	may-jun	4.66	3.83
inner harb	high	jul-aug	4.68	4.57
inner harb	low	sep-apr	4.85	4.77
inner harb	low	may-jun	4.52	3.99
inner harb	low	jul-aug	5.48	4.33
outer harb	high	sep-apr	4.72	2.32
outer harb	high	may-jun	2.63	1.42
outer harb	high	jul-aug	4.53	1.75
outer harb	low	may-jun	1.81	2.59
outer harb	low	jul-aug	2.01	1.89
		sum	136.77	117.75
		mean	4.72	4.06
		untransformed mean	**111**	**57**
		% reduction	**48.5%**	

#treat	2
#blocks	29
#cells	58
#zeros	0
avg of recip	0.055

Correction: C =	1116.97
Total SS =	313.67
Blocks SS =	129.45
Treatment SS =	6.24
Error SS =	177.99

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	28	129.45	4.62	13.16
Time Treatments	1	6.24	6.24	**17.76**
Error	**28**	177.99	0.35	
Total	57	313.67		

F-Dist. at	1,28 DoF	28,28 DoF
25%	1.38	1.29
10%	2.89	1.64
5%	**4.20**	**1.89**

Fecal Coliform
Scheme B
RMS > 0.25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
charles	fresh	sep-apr	6.97	6.40
charles	fresh	may-jun	6.68	5.81
charles	fresh	jul-aug	6.93	6.36
mystic	fresh	sep-apr	8.12	6.62
mystic	fresh	jul-aug	6.21	6.60
nepon head	fresh	sep-apr	7.54	7.77
nepon head	fresh	jul-aug	8.07	7.63
neponset	high	sep-apr	5.96	5.91
neponset	high	may-jun	8.15	5.45
neponset	high	jul-aug	5.92	6.86
neponset	low	sep-apr	6.17	5.58
neponset	low	may-jun	6.89	5.17
neponset	low	jul-aug	6.43	6.59
dorchester	high	sep-apr	4.84	1.79
dorchester	high	may-jun	2.95	3.00
dorchester	high	jul-aug	3.48	3.73
dorchester	low	sep-apr	6.34	4.34
dorchester	low	may-jun	4.25	2.70
dorchester	low	jul-aug	3.57	3.64
inner harb	high	sep-apr	6.26	4.58
inner harb	high	may-jun	3.62	4.32
inner harb	high	jul-aug	5.99	5.75
inner harb	low	sep-apr	6.35	4.82
inner harb	low	may-jun	3.17	4.90
inner harb	low	jul-aug	5.44	5.48
outer harb	high	sep-apr	3.62	2.07
outer harb	high	may-jun	3.09	4.71
outer harb	high	jul-aug	2.92	2.44
outer harb	low	jul-aug	2.65	2.68
		sum	158.58	143.69
		mean	5.47	4.95
		untransformed mean	**236**	**141**
		% reduction	**40.3%**	

#treat	2
#blocks	29
#cells	58
#zeros	0
avg of recip	0.095

Correction: C =	1575.33
Total SS =	381.75
Blocks SS =	144.32
Treatment SS =	3.82
Error SS =	233.61

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	28	144.32	5.15	6.52
Time Treatments	1	3.82	3.82	**4.84**
Error	**28**	233.61	0.79	
Total	57	381.75		

F-Dist. at	1,28 DoF	28,28 DoF
25%	1.38	1.29
10%	2.89	1.64
5%	**4.20**	**1.89**

C-6

Fecal Coliform
Scheme C
RMS = 0 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	may-jun	7.85	6.29
upper cha	fresh	jul	6.60	6.18
lower cha	fresh	sep-apr	5.81	7.06
lower cha	fresh	may-jun	5.98	4.72
lower cha	fresh	jul	5.51	4.37
lower cha	fresh	aug	4.88	3.49
mystic	fresh	sep-apr	5.48	5.83
mystic	fresh	may-jun	4.19	4.51
mystic	fresh	aug	4.88	4.88
nepon head	fresh	sep-apr	6.72	6.16
nepon head	fresh	jul	7.37	6.83
nepon head	fresh	aug	7.25	6.99
neponset	high	sep-apr	4.42	2.97
neponset	high	jul	4.51	4.33
neponset	high	aug	4.26	5.55
neponset	low	sep-apr	4.94	5.27
neponset	low	may-jun	3.78	4.38
neponset	low	jul	5.06	4.20
neponset	low	aug	6.85	6.88
dorchester	high	may-jun	1.54	2.10
dorchester	hugh	jul	1.80	1.62
dorchester	high	aug	2.42	2.90
dorchester	low	sep-apr	4.55	4.28
dorchester	low	may-jun	1.87	2.43
dorchester	low	jul	2.84	2.00
dorchester	low	aug	7.46	2.72
inner harb	high	sep-apr	4.82	3.67
inner harb	high	may-jun	3.51	3.49
inner harb	high	jul	3.85	3.82
inner harb	high	aug	4.25	4.39
inner harb	low	sep-apr	5.03	5.15
inner harb	low	may-jun	3.68	2.88
inner harb	low	jul	3.85	4.09
inner harb	low	aug	4.30	4.14
outer harb	high	sep-apr	2.72	1.33
outer harb	high	may-jun	1.35	1.51
outer harb	high	jul	1.53	2.73
outer harb	high	aug	1.61	1.59
outer harb	low	may-jun	3.30	1.98
outer harb	low	jul	1.58	2.33
outer harb	low	aug	2.03	1.85
		sum	176.20	163.91
		mean	4.30	4.00
		untransformed mean	**73**	**53**
		% reduction	**26.3%**	

#treat	2
#blocks	41
#cells	82
#zeros	0
avg of recip	0.089

Correction: C =	1410.63
Total SS =	438.41
Blocks SS =	228.13
Treatment SS =	1.84
Error SS =	208.44

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	40	228.13	5.70	12.31
Time Treatments	1	1.84	1.84	3.98
Error	40	208.44	0.46	
Total	81	438.41		

F-Dist. at	1,40 DoF	40,40 DoF
25%	1.36	1.24
10%	2.84	1.51
5%	4.08	1.69

C-7

REPORTAPC97.XLSIFCC Rain1

4501-007-29P

Fecal Coliform
Scheme C
0 in < RMS < .25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	sep-apr	7.06	5.71
upper cha	fresh	may-jun	6.96	6.34
upper cha	fresh	jul	6.11	6.97
upper cha	fresh	aug	5.74	6.28
lower cha	fresh	sep-apr	6.14	6.04
lower cha	fresh	may-jun	5.60	4.53
lower cha	fresh	jul	5.13	4.89
lower cha	fresh	aug	5.16	4.26
mystic	fresh	sep-apr	6.25	6.45
mystic	fresh	may-jun	4.63	4.89
mystic	fresh	jul	4.53	3.49
mystic	fresh	aug	5.28	4.25
nepon head	fresh	may-jun	7.37	6.25
nepon head	fresh	jul	7.05	6.88
nepon head	fresh	aug	8.49	7.32
neponset	high	sep-apr	5.38	4.32
neponset	high	may-jun	6.80	3.90
neponset	high	jul	5.06	4.60
neponset	high	aug	4.62	5.67
neponset	low	sep-apr	4.81	4.40
neponset	low	may-jun	5.80	5.75
neponset	low	jul	5.71	4.65
neponset	low	aug	5.57	4.29
dorchester	high	may-jun	1.98	2.34
dorchester	hugh	jul	2.35	2.49
dorchester	high	aug	4.34	3.42
dorchester	low	may-jun	2.61	1.80
dorchester	low	jul	2.15	2.14
dorchester	low	aug	3.39	2.23
inner harb	high	sep-apr	4.29	3.88
inner harb	high	may-jun	4.66	3.83
inner harb	high	jul	3.90	4.81
inner harb	high	aug	4.95	3.77
inner harb	low	sep-apr	4.85	4.77
inner harb	low	may-jun	4.52	3.99
inner harb	low	jul	5.05	4.54
inner harb	low	aug	5.84	3.22
outer harb	high	sep-apr	4.72	2.32
outer harb	high	may-jun	2.63	1.42
outer harb	high	jul	0.92	2.06
outer harb	high	aug	4.87	1.60
outer harb	low	may-jun	1.81	2.59
outer harb	low	jul	1.59	2.35
outer harb	low	aug	2.05	1.54
		sum	208.75	183.23
		mean	4.74	4.16
		untransformed mean	**114**	**63**
		% reduction	**44.4%**	

#treat	2
#blocks	44
#cells	88
#zeros	0
avg of recip	0.102

Correction: C =	1745.94
Total SS =	482.49
Blocks SS =	218.57
Treatment SS =	7.40
Error SS =	256.52

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	43	218.57	5.08	8.38
Time Treatments	1	7.40	7.40	12.21
Error	43	256.52	0.61	
Total	87	482.49		

F-Dist. at	1,43 DoF	43,43 DoF
25%	1.36	1.24
10%	2.83	1.51
5%	4.07	1.69

Fecal Coliform
Scheme C
RMS > 0.25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	may-jun	7.24	6.37
upper cha	fresh	jul	7.41	6.74
lower cha	fresh	sep-apr	6.69	6.40
lower cha	fresh	may-jun	6.44	5.37
lower cha	fresh	jul	6.49	5.84
lower cha	fresh	aug	6.85	4.58
mystic	fresh	sep-apr	8.12	6.62
mystic	fresh	jul	4.94	7.50
mystic	fresh	aug	6.45	6.39
nepon head	fresh	sep-apr	7.54	7.77
nepon head	fresh	jul	7.69	7.90
nepon head	fresh	aug	9.59	7.26
neponset	high	sep-apr	5.96	5.91
neponset	high	may-jun	8.15	5.45
neponset	high	jul	5.59	6.72
neponset	high	aug	7.12	7.13
neponset	low	sep-apr	6.17	5.58
neponset	low	may-jun	6.89	5.17
neponset	low	jul	6.23	5.57
neponset	low	aug	8.12	7.63
dorchester	high	sep-apr	4.84	1.79
dorchester	high	may-jun	2.95	3.00
dorchester	hugh	jul	3.35	3.80
dorchester	high	aug	4.79	3.60
dorchester	low	sep-apr	6.34	4.34
dorchester	low	may-jun	4.25	2.70
dorchester	low	jul	3.10	3.32
dorchester	low	aug	6.91	4.12
inner harb	high	sep-apr	6.26	4.58
inner harb	high	may-jun	3.62	4.32
inner harb	high	jul	5.60	5.80
inner harb	high	aug	6.07	5.67
inner harb	low	sep-apr	6.35	4.82
inner harb	low	may-jun	3.17	4.90
inner harb	low	jul	4.44	5.63
inner harb	low	aug	5.64	5.07
outer harb	high	sep-apr	3.62	2.07
outer harb	high	may-jun	3.09	4.71
outer harb	high	jul	1.35	2.01
outer harb	high	aug	2.97	2.56
outer harb	low	jul	2.35	3.01
outer harb	low	aug	2.69	2.56
		sum	233.43	212.27
		mean	5.56	5.05
		untransformed mean	**258**	**156**
		% reduction	39.7%	

#treat	2
#blocks	42
#cells	84
#zeros	0
avg of recip	0.103

Correction: C =	2364.90
Total SS =	582.32
Blocks SS =	235.09
Treatment SS =	5.33
Error SS =	341.90

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	41	235.09	5.73	6.67
Time Treatments	1	5.33	5.33	**6.19**
Error	**41**	341.90	0.86	
Total	83	582.32		

F-Dist. at	1,40 DoF	40,40 DoF
25%	1.36	1.24
10%	2.83	1.51
5%	4.08	1.69

Enterococcus
Scheme A
RMS = 0 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	jul-aug	4.58	4.41
lower cha	fresh	sep-apr	4.62	6.94
lower cha	fresh	may-jun	2.26	3.13
lower cha	fresh	jul-aug	3.02	2.76
mystic	fresh	sep-apr	3.86	3.50
mystic	fresh	may-jun	3.62	3.60
mystic	fresh	jul-aug	3.81	3.84
nepon head	fresh	sep-apr	5.94	6.91
nepon head	fresh	jul-aug	6.66	5.64
neponset	high	sep-apr	4.23	3.58
neponset	high	jul-aug	3.19	3.80
neponset	low	sep-apr	3.47	5.35
neponset	low	may-jun	2.40	2.70
neponset	low	jul-aug	4.47	4.01
dorchester	high	may-jun	1.02	1.50
dorchester	high	jul-aug	2.00	2.14
dorchester	low	sep-apr	2.64	2.42
dorchester	low	may-jun	1.26	1.52
dorchester	low	jul-aug	2.04	2.20
inner harb	high	sep-apr	3.49	2.36
inner harb	high	may-jun	1.74	2.84
inner harb	high	jul-aug	2.48	2.52
inner harb	low	sep-apr	3.84	3.31
inner harb	low	may-jun	1.93	2.41
inner harb	low	jul-aug	3.12	2.49
outer harb	high	sep-apr	3.19	1.33
outer harb	high	may-jun	1.35	1.38
outer harb	high	jul-aug	1.57	1.71
outer harb	low	may-jun	1.57	1.84
outer harb	low	jul-aug	1.61	1.81
		sum	90.95	93.93
		mean	3.03	3.13
		untransformed mean	**20**	**22**
		% reduction	**-11.0%**	

#treat	2
#blocks	30
#cells	60
#zeros	0
avg of recip	0.094

Correction: C =	569.71
Total SS =	231.72
Blocks SS =	111.11
Treatment SS =	0.15
Error SS =	120.46

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	29	111.11	3.83	9.84
Time Treatments	1	0.15	0.15	**0.38**
Error	**29**	120.46	0.39	
Total	59	231.72		

F-Dist. at	1,29 DoF	29,29 DoF
25%	1.38	1.29
10%	2.89	1.62
5%	**4.18**	**1.86**

Enterococcus
Scheme A
0 in < RMS < .25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	jul-aug	4.07	5.33
lower cha	fresh	sep-apr	4.84	5.87
lower cha	fresh	may-jun	2.29	3.28
lower cha	fresh	jul-aug	3.10	3.25
mystic	fresh	sep-apr	5.82	4.14
mystic	fresh	may-jun	3.99	4.12
mystic	fresh	jul-aug	3.69	3.50
nepon head	fresh	may-jun	5.17	5.56
nepon head	fresh	jul-aug	6.16	5.62
neponset	high	sep-apr	4.56	5.92
neponset	high	may-jun	4.62	3.66
neponset	high	jul-aug	2.97	3.71
neponset	low	sep-apr	3.44	3.67
neponset	low	may-jun	3.76	5.29
neponset	low	jul-aug	4.12	3.11
dorchester	high	may-jun	1.40	1.75
dorchester	high	jul-aug	2.02	2.17
dorchester	low	may-jun	1.58	1.14
dorchester	low	jul-aug	1.62	2.03
inner harb	high	sep-apr	4.05	2.84
inner harb	high	may-jun	2.24	2.97
inner harb	high	jul-aug	2.98	3.03
inner harb	low	sep-apr	4.69	2.96
inner harb	low	may-jun	2.49	2.98
inner harb	low	jul-aug	2.72	3.16
outer harb	high	sep-apr	4.01	1.22
outer harb	high	may-jun	1.60	1.59
outer harb	high	jul-aug	1.71	1.61
outer harb	low	may-jun	1.62	2.03
outer harb	low	jul-aug	1.61	1.89
		sum	98.94	99.38
		mean	3.30	3.31
		untransformed mean	**26**	**26**
		% reduction	**-1.5%**	

#treat	2
#blocks	30
#cells	60
#zeros	0
avg of recip	0.061

Correction: C =	655.53
Total SS =	251.81
Blocks SS =	98.87
Treatment SS =	0.00
Error SS =	152.93

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	29	98.87	3.41	10.60
Time Treatments	1	0.00	0.00	**0.01**
Error	**29**	152.93	0.32	
Total	59	251.81		
Total	59	231.72482		

F-Dist. at	1,29 DoF	29,29 DoF
25%	1.38	1.29
10%	2.89	1.62
5%	**4.18**	**1.86**

Enterococcus
Scheme A
RMS > 0.25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	jul-aug	6.53	5.92
lower cha	fresh	sep-apr	6.11	6.67
lower cha	fresh	may-jun	3.69	4.20
lower cha	fresh	jul-aug	4.60	3.98
mystic	fresh	sep-apr	8.00	4.36
mystic	fresh	jul-aug	4.73	5.47
nepon head	fresh	sep-apr	7.81	6.99
nepon head	fresh	jul-aug	8.34	6.66
neponset	high	sep-apr	5.16	5.54
neponset	high	may-jun	7.44	5.17
neponset	high	jul-aug	4.83	5.43
neponset	low	sep-apr	5.17	5.45
neponset	low	may-jun	5.76	4.67
neponset	low	jul-aug	5.33	5.21
dorchester	high	sep-apr	3.39	1.79
dorchester	high	may-jun	1.66	2.25
dorchester	high	jul-aug	2.02	3.18
dorchester	low	sep-apr	4.43	2.09
dorchester	low	may-jun	3.04	2.03
dorchester	low	jul-aug	2.40	3.04
inner harb	high	sep-apr	5.24	2.62
inner harb	high	may-jun	2.36	3.99
inner harb	high	jul-aug	3.54	4.01
inner harb	low	sep-apr	5.98	3.62
inner harb	low	may-jun	1.68	3.76
inner harb	low	jul-aug	3.44	3.90
outer harb	high	sep-apr	4.41	1.09
outer harb	high	may-jun	1.35	3.67
outer harb	high	jul-aug	2.07	2.04
outer harb	low	jul-aug	1.92	2.21
		sum	132.44	121.04
		mean	4.41	4.03
		untransformed mean	**82**	**56**
		% reduction	**32.0%**	

#treat	2
#blocks	30
#cells	60
#zeros	0
avg of recip	0.101

Correction: C =	1070.86
Total SS =	419.39
Blocks SS =	158.19
Treatment SS =	2.17
Error SS =	259.03

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	29	158.19	5.45	6.06
Time Treatments	1	2.17	2.17	**2.41**
Error	**29**	259.03	0.90	
Total	59	419.39		

F-Dist. at	1,29 DoF	29,29 DoF
25%	1.38	1.29
10%	2.89	1.62
5%	**4.18**	**1.86**

Enterococcus
Scheme B
RMS = 0 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
charles	fresh	sep-apr	5.08	6.94
charles	fresh	may-jun	2.26	3.79
charles	fresh	jul-aug	3.64	3.52
mystic	fresh	sep-apr	3.86	3.50
mystic	fresh	may-jun	3.62	3.60
mystic	fresh	jul-aug	3.81	3.84
nepon head	fresh	sep-apr	5.94	6.91
nepon head	fresh	jul-aug	6.66	5.64
neponset	high	sep-apr	4.23	3.58
neponset	high	jul-aug	3.19	3.80
neponset	low	sep-apr	3.47	5.35
neponset	low	may-jun	2.40	2.70
neponset	low	jul-aug	4.47	4.01
dorchester	high	may-jun	1.02	1.50
dorchester	high	jul-aug	2.00	2.14
dorchester	low	sep-apr	2.64	2.42
dorchester	low	may-jun	1.26	1.52
dorchester	low	jul-aug	2.04	2.20
inner harb	high	sep-apr	3.49	2.36
inner harb	high	may-jun	1.74	2.84
inner harb	high	jul-aug	2.48	2.52
inner harb	low	sep-apr	3.84	3.31
inner harb	low	may-jun	1.93	2.41
inner harb	low	jul-aug	3.12	2.49
outer harb	high	sep-apr	3.19	1.33
outer harb	high	may-jun	1.35	1.38
outer harb	high	jul-aug	1.57	1.71
outer harb	low	may-jun	1.57	1.84
outer harb	low	jul-aug	1.61	1.81
		sum	87.45	90.95
		mean	3.02	3.14
		untransformed mean	**19**	**22**
		% reduction	**-13.4%**	

#treat	2
#blocks	29
#cells	58
#zeros	0
avg of recip	0.096

Correction: C =	548.73
Total SS =	227.24
Blocks SS =	109.80
Treatment SS =	0.21
Error SS =	117.23

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	28	109.80	3.92	9.77
Time Treatments	1	0.21	0.21	**0.52**
Error	**28**	117.23	0.40	
Total	57	227.24		

F-Dist. at	1,28 DoF	28,28 DoF
25%	1.38	1.29
10%	2.89	1.64
5%	**4.20**	**1.89**

Enterococcus
Scheme B
0 in < RMS < .25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
charles	fresh	sep-apr	5.32	5.87
charles	fresh	may-jun	2.29	4.04
charles	fresh	jul-aug	3.57	4.24
mystic	fresh	sep-apr	5.82	4.14
mystic	fresh	may-jun	3.99	4.12
mystic	fresh	jul-aug	3.69	3.50
nepon head	fresh	may-jun	5.17	5.56
nepon head	fresh	jul-aug	6.16	5.62
neponset	high	sep-apr	4.56	5.92
neponset	high	may-jun	4.62	3.66
neponset	high	jul-aug	2.97	3.71
neponset	low	sep-apr	3.44	3.67
neponset	low	may-jun	3.76	5.29
neponset	low	jul-aug	4.12	3.11
dorchester	high	may-jun	1.40	1.75
dorchester	high	jul-aug	2.02	2.17
dorchester	low	may-jun	1.58	1.14
dorchester	low	jul-aug	1.62	2.03
inner harb	high	sep-apr	4.05	2.84
inner harb	high	may-jun	2.24	2.97
inner harb	high	jul-aug	2.98	3.03
inner harb	low	sep-apr	4.69	2.96
inner harb	low	may-jun	2.49	2.98
inner harb	low	jul-aug	2.72	3.16
outer harb	high	sep-apr	4.01	1.22
outer harb	high	may-jun	1.60	1.59
outer harb	high	jul-aug	1.71	1.61
outer harb	low	may-jun	1.62	2.03
outer harb	low	jul-aug	1.61	1.89
		sum	95.83	95.80
		mean	3.30	3.30
		untransformed mean	**26**	**26**
		% reduction	**0.1%**	

#treat	2
#blocks	29
#cells	58
#zeros	0
avg of recip	0.062

Correction: C =	633.13
Total SS =	247.41
Blocks SS =	97.28
Treatment SS =	0.00
Error SS =	150.13

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	28	97.28	3.47	10.48
Time Treatments	1	0.00	0.00	0.00
Error	**28**	150.13	0.33	
Total	57	247.41		

F-Dist. at	1,28 DoF	28,28 DoF
25%	1.38	1.29
10%	2.89	1.64
5%	**4.20**	**1.89**

Enterococcus
Scheme B
RMS > 0.25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
charles	fresh	sep-apr	6.60	6.67
charles	fresh	may-jun	3.69	4.72
charles	fresh	jul-aug	5.49	5.02
mystic	fresh	sep-apr	8.00	4.36
mystic	fresh	jul-aug	4.73	5.47
nepon head	fresh	sep-apr	7.81	6.99
nepon head	fresh	jul-aug	8.34	6.66
neponset	high	sep-apr	5.16	5.54
neponset	high	may-jun	7.44	5.17
neponset	high	jul-aug	4.83	5.43
neponset	low	sep-apr	5.17	5.45
neponset	low	may-jun	5.76	4.67
neponset	low	jul-aug	5.33	5.21
dorchester	high	sep-apr	3.39	1.79
dorchester	high	may-jun	1.66	2.25
dorchester	high	jul-aug	2.02	3.18
dorchester	low	sep-apr	4.43	2.09
dorchester	low	may-jun	3.04	2.03
dorchester	low	jul-aug	2.40	3.04
inner harb	high	sep-apr	5.24	2.62
inner harb	high	may-jun	2.36	3.99
inner harb	high	jul-aug	3.54	4.01
inner harb	low	sep-apr	5.98	3.62
inner harb	low	may-jun	1.68	3.76
inner harb	low	jul-aug	3.44	3.90
outer harb	high	sep-apr	4.41	1.09
outer harb	high	may-jun	1.35	3.67
outer harb	high	jul-aug	2.07	2.04
outer harb	low	jul-aug	1.92	2.21
		sum	127.29	116.68
		mean	4.39	4.02
		untransformed mean	**80**	**55**
		% reduction	**31.0%**	

#treat	2
#blocks	29
#cells	58
#zeros	0
avg of recip	0.103

Correction: C =	1026.22
Total SS =	408.00
Blocks SS =	154.36
Treatment SS =	1.94
Error SS =	251.70

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	28	154.36	5.51	5.94
Time Treatments	1	1.94	1.94	**2.10**
Error	**28**	251.70	0.93	
Total	57	408.00		

F-Dist. at	1,28 DoF	28,28 DoF
25%	1.38	1.29
10%	2.89	1.64
5%	**4.20**	**1.89**

Enterococcus
Scheme C
RMS = 0 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	jul	4.58	4.38
lower cha	fresh	sep-apr	4.62	6.94
lower cha	fresh	may-jun	2.26	3.13
lower cha	fresh	jul	2.97	2.79
lower cha	fresh	aug	3.33	2.40
mystic	fresh	sep-apr	3.86	3.50
mystic	fresh	may-jun	3.62	3.60
mystic	fresh	aug	3.84	3.84
nepon head	fresh	sep-apr	5.94	6.91
nepon head	fresh	jul	6.98	5.33
nepon head	fresh	aug	6.50	5.94
neponset	high	sep-apr	4.23	3.56
neponset	high	jul	3.31	3.28
neponset	high	aug	3.12	4.24
neponset	low	sep-apr	3.47	5.35
neponset	low	may-jun	2.40	2.70
neponset	low	jul	2.97	3.06
neponset	low	aug	5.97	4.89
dorchester	high	may-jun	1.02	1.50
dorchester	hugh	jul	1.81	1.41
dorchester	high	aug	2.13	2.74
dorchester	low	sep-apr	2.64	2.42
dorchester	low	may-jun	1.26	1.52
dorchester	low	jul	0.92	1.79
dorchester	low	aug	4.29	2.66
inner harb	high	sep-apr	3.49	2.36
inner harb	high	may-jun	1.74	2.84
inner harb	high	jul	1.73	2.30
inner harb	high	aug	3.14	2.66
inner harb	low	sep-apr	3.84	3.31
inner harb	low	may-jun	1.93	2.41
inner harb	low	jul	1.97	2.59
inner harb	low	aug	3.43	2.41
outer harb	high	sep-apr	3.19	1.33
outer harb	high	may-jun	1.35	1.38
outer harb	high	jul	1.69	1.91
outer harb	high	aug	1.56	1.62
outer harb	low	may-jun	1.57	1.84
outer harb	low	jul	1.09	1.73
outer harb	low	aug	1.94	1.84
		sum	121.67	122.45
		mean	3.04	3.06
		untransformed mean	**20**	**20**
		% reduction	**-2.1%**	

#treat	2
#blocks	40
#cells	80
#zeros	0
avg of recip	0.103

Correction: C =	744.96
Total SS =	310.39
Blocks SS =	158.29
Treatment SS =	0.01
Error SS =	152.09

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	39	158.29	4.06	10.12
Time Treatments	1	0.01	0.01	**0.02**
Error	39	152.09	0.40	
Total	79	310.39		

F-Dist. at	1,39 DoF	39,39 DoF
25%	1.36	1.24
10%	2.84	1.51
5%	**4.09**	**1.69**

Enterococcus
Scheme C
0 in < RMS < .25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	jul	4.03	5.33
upper cha	fresh	aug	5.46	5.36
lower cha	fresh	sep-apr	4.84	5.87
lower cha	fresh	may-jun	2.29	3.28
lower cha	fresh	jul	3.15	3.27
lower cha	fresh	aug	2.73	2.94
mystic	fresh	sep-apr	5.82	4.14
mystic	fresh	may-jun	3.99	4.12
mystic	fresh	jul	3.80	3.50
mystic	fresh	aug	3.53	3.49
nepon head	fresh	may-jun	5.17	5.56
nepon head	fresh	jul	5.85	5.50
nepon head	fresh	aug	6.48	6.49
neponset	high	sep-apr	4.56	5.92
neponset	high	may-jun	4.62	3.66
neponset	high	jul	2.81	3.61
neponset	high	aug	3.31	4.10
neponset	low	sep-apr	3.44	3.67
neponset	low	may-jun	3.76	5.29
neponset	low	jul	3.50	3.15
neponset	low	aug	4.54	2.94
dorchester	high	may-jun	1.40	1.75
dorchester	hugh	jul	1.66	1.98
dorchester	high	aug	2.85	2.77
dorchester	low	may-jun	1.58	1.14
dorchester	low	jul	1.34	1.98
dorchester	low	aug	2.01	2.58
inner harb	high	sep-apr	4.05	2.84
inner harb	high	may-jun	2.24	2.97
inner harb	high	jul	1.76	3.14
inner harb	high	aug	3.39	2.68
inner harb	low	sep-apr	4.69	2.96
inner harb	low	may-jun	2.49	2.98
inner harb	low	jul	2.96	3.30
inner harb	low	aug	2.51	2.41
outer harb	high	sep-apr	4.01	1.22
outer harb	high	may-jun	1.60	1.59
outer harb	high	jul	1.15	1.71
outer harb	high	aug	1.76	1.56
outer harb	low	may-jun	1.62	2.03
outer harb	low	jul	1.50	1.93
outer harb	low	aug	1.62	1.86
		sum	135.88	138.54
		mean	3.24	3.30
		untransformed mean	24	26
		% reduction	-6.8%	

#treat	2
#blocks	42
#cells	84
#zeros	0
avg of recip	0.096

Correction: C =	896.47
Total SS =	342.74
Blocks SS =	146.53
Treatment SS =	0.08
Error SS =	196.12

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	41	146.53	3.57	7.66
Time Treatments	1	0.08	0.08	0.18
Error	41	196.12	0.47	
Total	83	342.74		

F-Dist. at	1,41 DoF	41,41 DoF
25%	1.36	1.24
10%	2.83	1.51
5%	4.08	1.69

Enterococcus
Scheme C
RMS > 0.25 in

Cell Average Values (Zero Blocks Removed)

RANDOMIZED BLOCKS			TREATMENTS	
Geographic Region	Tidal Condition	Season	89-91	92-96
upper cha	fresh	jul	6.53	5.62
lower cha	fresh	sep-apr	6.11	6.67
lower cha	fresh	may-jun	3.69	4.20
lower cha	fresh	jul	4.56	4.10
lower cha	fresh	aug	5.14	3.15
mystic	fresh	sep-apr	8.00	4.36
mystic	fresh	jul	4.28	6.33
mystic	fresh	aug	4.81	5.27
nepon head	fresh	sep-apr	7.81	6.99
nepon head	fresh	jul	7.87	6.83
nepon head	fresh	aug	10.23	6.42
neponset	high	sep-apr	5.16	5.54
neponset	high	may-jun	7.44	5.17
neponset	high	jul	4.25	5.36
neponset	high	aug	6.97	5.56
neponset	low	sep-apr	5.17	5.45
neponset	low	may-jun	5.76	4.67
neponset	low	jul	4.96	4.33
neponset	low	aug	8.37	5.98
dorchester	high	sep-apr	3.39	1.79
dorchester	high	may-jun	1.66	2.25
dorchester	hugh	jul	1.98	3.14
dorchester	high	aug	2.43	3.26
dorchester	low	sep-apr	4.43	2.09
dorchester	low	may-jun	3.04	2.03
dorchester	low	jul	1.97	2.67
dorchester	low	aug	5.46	3.49
inner harb	high	sep-apr	5.24	2.62
inner harb	high	may-jun	2.36	3.99
inner harb	high	jul	2.86	3.99
inner harb	high	aug	3.68	4.03
inner harb	low	sep-apr	5.98	3.62
inner harb	low	may-jun	1.68	3.76
inner harb	low	jul	2.91	3.99
inner harb	low	aug	3.55	3.66
outer harb	high	sep-apr	4.41	1.09
outer harb	high	may-jun	1.35	3.67
outer harb	high	jul	0.92	1.92
outer harb	high	aug	2.11	2.07
outer harb	low	jul	1.63	2.67
outer harb	low	aug	1.96	2.06
		sum	182.11	165.89
		mean	4.44	4.05
		untransformed mean	**84**	**56**
		% reduction	**33.1%**	

#treat	2
#blocks	41
#cells	82
#zeros	0
avg of recip	0.110

Correction: C =	1476.93
Total SS =	599.89
Blocks SS =	247.86
Treatment SS =	3.21
Error SS =	348.82

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	40	247.86	6.20	6.47
Time Treatments	1	3.21	3.21	3.35
Error	40	348.82	0.96	
Total	81	599.89		

F-Dist. at	1,40 DoF	40,40 DoF
25%	1.36	1.24
10%	2.84	1.51
5%	4.08	1.69

APPENDIX D

RESULTS FOR ANALYSIS OF INDIVIDUAL GEOGRAPHIC REGIONS

Fecal Coliform
Scheme A
Upper Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	6.48	**5.84**
0	fresh	may-jun	7.85	6.29
0	fresh	jul-aug	6.60	6.14
0 : 0.25	fresh	sep-apr	7.06	5.71
0 : 0.25	fresh	may-jun	6.96	6.34
0 : 0.25	fresh	jul-aug	6.10	6.92
> 0.25	fresh	sep-apr	7.29	**6.65**
> 0.25	fresh	may-jun	7.24	6.37
> 0.25	fresh	jul-aug	7.41	6.94
		sum	62.99	57.20
		mean	7.00	6.36
		untransformed mean	**1094**	**575**
		% reduction	**47.5%**	

#treat	2
#blocks	9
#cells	18
#zeros	2
avg of recip	0.190

Correction: C =	802.54
Total SS =	27.95
Blocks SS =	1.96
Treatment SS =	1.86
Error SS =	24.12

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	1.96	0.25	0.32
Time Treatments	1	1.86	1.86	**2.44**
Error	6	24.12	0.76	
Total	15	27.95		

F-Dist. at	1,6 DoF	8,6 DoF
25%	1.62	1.78
10%	3.78	2.98
5%	**5.99**	**4.15**

Fecal Coliform
Scheme A
Lower Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.81	7.06
0	fresh	may-jun	5.98	4.72
0	fresh	jul-aug	5.43	4.28
0 : 0.25	fresh	sep-apr	6.14	6.04
0 : 0.25	fresh	may-jun	5.60	4.53
0 : 0.25	fresh	jul-aug	5.13	4.86
> 0.25	fresh	sep-apr	6.69	6.40
> 0.25	fresh	may-jun	6.44	5.37
> 0.25	fresh	jul-aug	6.52	5.68
		sum	53.74	48.94
		mean	5.97	5.44
		untransformed mean	**391**	**229**
		% reduction	**41.4%**	

#treat	2
#blocks	9
#cells	18
#zeros	0
avg of recip	0.048

Correction: C =	585.81
Total SS =	50.40
Blocks SS =	6.68
Treatment SS =	1.28
Error SS =	42.45

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	6.68	0.83	3.28
Time Treatments	1	1.28	1.28	**5.02**
Error	8	42.45	0.25	
Total	17	50.40		

F-Dist. at	1,8 DoF	8,8 DoF
25%	1.54	1.64
10%	3.46	2.59
5%	**5.32**	**3.44**

Fecal Coliform Scheme A Mystic River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.48	5.83
0	fresh	may-jun	4.19	4.51
0	fresh	jul-aug	4.69	4.88
0 : 0.25	fresh	sep-apr	6.25	6.45
0 : 0.25	fresh	may-jun	4.63	4.89
0 : 0.25	fresh	jul-aug	4.86	3.98
> 0.25	fresh	sep-apr	8.12	6.62
> 0.25	fresh	may-jun	**6.37**	6.29
> 0.25	fresh	jul-aug	6.21	6.60
		sum	50.80	50.05
		mean	5.64	5.56
		untransformed mean	**282**	**259**
		% reduction	**8.0%**	

#treat	2
#blocks	9
#cells	18
#zeros	1
avg of recip	0.098

Correction: C =	565.04
Total SS =	70.18
Blocks SS =	18.41
Treatment SS =	0.03
Error SS =	51.75

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	18.41	2.30	3.18
Time Treatments	1	0.03	0.03	**0.04**
Error	**7**	51.75	0.72	
Total	16	70.18		

F-Dist. at	1,7 DoF	8,7 DoF
25%	1.57	1.7
10%	3.59	2.75
5%	**5.59**	**3.73**

Fecal Coliform Scheme A Neponset River Headwaters

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	6.72	6.16
0	fresh	may-jun	**7.22**	6.70
0	fresh	jul-aug	7.29	6.92
0 : 0.25	fresh	sep-apr	6.56	**6.04**
0 : 0.25	fresh	may-jun	7.37	6.25
0 : 0.25	fresh	jul-aug	7.77	6.93
> 0.25	fresh	sep-apr	7.54	7.77
> 0.25	fresh	may-jun	**7.88**	7.36
> 0.25	fresh	jul-aug	8.07	7.63
		sum	66.42	61.76
		mean	7.38	6.86
		untransformed mean	**1603**	**954**
		% reduction	**40.4%**	

#treat	2
#blocks	9
#cells	18
#zeros	3
avg of recip	0.328

Correction: C =	912.78
Total SS =	20.42
Blocks SS =	4.76
Treatment SS =	1.21
Error SS =	14.46

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	4.76	0.59	0.63
Time Treatments	1	1.21	1.21	**1.27**
Error	**5**	14.46	0.95	
Total	14	20.42		

F-Dist. at	1,5 DoF	8,5 DoF
25%	1.69	1.89
10%	4.06	3.34
5%	**6.61**	**4.88**

Fecal Coliform
Scheme A
Neponset River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	4.42	2.97
0	high	may-jun	**5.34**	4.77
0	high	jul-aug	4.35	5.01
0	low	sep-apr	4.94	5.27
0	low	may-jun	3.78	4.38
0	low	jul-aug	5.95	5.61
0 : 0.25	high	sep-apr	5.38	4.32
0 : 0.25	high	may-jun	6.80	3.90
0 : 0.25	high	jul-aug	4.92	4.81
0 : 0.25	low	sep-apr	4.81	4.40
0 : 0.25	low	may-jun	5.80	5.75
0 : 0.25	low	jul-aug	5.63	4.58
> 0.25	high	sep-apr	5.96	5.91
> 0.25	high	may-jun	8.15	5.45
> 0.25	high	jul-aug	5.92	6.86
> 0.25	low	sep-apr	6.17	5.58
> 0.25	low	may-jun	6.89	5.17
> 0.25	low	jul-aug	6.43	6.59
		sum	101.64	91.33
		mean	5.65	5.07
		untransformed mean	**282**	**159**
		% reduction	**43.8%**	

#treat	2
#blocks	18
#cells	36
#zeros	1
avg of recip	0.112

Correction: C =	1034.37
Total SS =	173.57
Blocks SS =	24.04
Treatment SS =	2.95
Error SS =	146.57

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	24.04	1.41	1.38
Time Treatments	**1**	2.95	2.95	**2.88**
Error	**16**	146.57	1.02	
Total	34	173.57		

F-Dist. at	1,16 DoF	17,16 DoF
25%	1.42	1.41
10%	3.05	1.92
5%	**4.49**	**2.32**

Fecal Coliform
Scheme A
Dorchester Bay

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	5.66	**5.10**
0	high	may-jun	1.54	2.10
0	high	jul-aug	2.16	2.33
0	low	sep-apr	4.55	4.28
0	low	may-jun	1.87	2.43
0	low	jul-aug	4.38	2.36
0 : 0.25	high	sep-apr	3.34	**2.78**
0 : 0.25	high	may-jun	1.98	2.34
0 : 0.25	high	jul-aug	2.96	2.71
0 : 0.25	low	sep-apr	3.64	**3.08**
0 : 0.25	low	may-jun	2.61	1.80
0 : 0.25	low	jul-aug	2.67	2.15
> 0.25	high	sep-apr	4.84	1.79
> 0.25	high	may-jun	2.95	3.00
> 0.25	high	jul-aug	3.48	3.73
> 0.25	low	sep-apr	6.34	4.34
> 0.25	low	may-jun	4.25	2.70
> 0.25	low	jul-aug	3.57	3.64
		sum	62.79	52.66
		mean	3.49	2.93
		untransformed mean	**32**	**18**
		% reduction	**44.4%**	

#treat	2
#blocks	18
#cells	36
#zeros	3
avg of recip	0.170

Correction: C =	370.24
Total SS =	147.40
Blocks SS =	36.19
Treatment SS =	2.85
Error SS =	108.35

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	36.19	2.13	1.62
Time Treatments	1	2.85	2.85	**2.17**
Error	**14**	108.35	1.31	
Total	32	147.40		

F-Dist. at	1,14 DoF	17,14 DoF
25%	1.44	1.44
10%	3.1	1.99
5%	**4.60**	**2.43**

Fecal Coliform
Scheme A
Outer Boston Harbor

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	2.72	1.33
0	high	may-jun	1.35	1.51
0	high	jul-aug	1.60	1.93
0	low	sep-apr	2.41	**1.83**
0	low	may-jun	3.30	1.98
0	low	jul-aug	1.86	2.01
0 : 0.25	high	sep-apr	4.72	2.32
0 : 0.25	high	may-jun	2.63	1.42
0 : 0.25	high	jul-aug	4.53	1.75
0 : 0.25	low	sep-apr	2.23	**1.65**
0 : 0.25	low	may-jun	1.81	2.59
0 : 0.25	low	jul-aug	2.01	1.89
> 0.25	high	sep-apr	3.62	2.07
> 0.25	high	may-jun	3.09	4.71
> 0.25	high	jul-aug	2.92	2.44
> 0.25	low	sep-apr	3.56	**2.98**
> 0.25	low	may-jun	**2.87**	2.29
> 0.25	low	jul-aug	2.65	2.68
		sum	49.88	39.38
		mean	2.77	2.19
		untransformed mean	**15**	**8**
		% reduction	**47.1%**	

#treat	2
#blocks	18
#cells	36
#zeros	4
avg of recip	0.185

Correction: C =	221.32
Total SS =	95.04
Blocks SS =	15.01
Treatment SS =	3.06
Error SS =	76.97

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	15.01	0.88	0.80
Time Treatments	1	3.06	3.06	**2.79**
Error	**13**	76.97	1.10	
Total	31	95.04		

F-Dist. at	1,13 DoF	17,13 DoF
25%	1.45	1.46
10%	3.14	2.03
5%	**4.67**	**2.50**

Fecal Coliform
Scheme A
Inner Boston Harbor

D-6

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	4.82	3.67
0	high	may-jun	3.51	3.49
0	high	jul-aug	4.07	4.15
0	low	sep-apr	5.03	5.15
0	low	may-jun	3.68	2.88
0	low	jul-aug	4.20	4.12
0 : 0.25	high	sep-apr	4.29	3.88
0 : 0.25	high	may-jun	4.66	3.83
0 : 0.25	high	jul-aug	4.68	4.57
0 : 0.25	low	sep-apr	4.85	4.77
0 : 0.25	low	may-jun	4.52	3.99
0 : 0.25	low	jul-aug	5.48	4.33
> 0.25	high	sep-apr	6.26	4.58
> 0.25	high	may-jun	3.62	4.32
> 0.25	high	jul-aug	5.99	5.75
> 0.25	low	sep-apr	6.35	4.82
> 0.25	low	may-jun	3.17	4.90
> 0.25	low	jul-aug	5.44	5.48
		sum	84.61	78.66
		mean	4.70	4.37
		untransformed mean	**109**	**78**
		% reduction	**28.4%**	

#treat	2
#blocks	18
#cells	36
#zeros	0
avg of recip	0.027

Correction: C =	740.51
Total SS =	170.44
Blocks SS =	18.05
Treatment SS =	0.98
Error SS =	151.41

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	18.05	1.06	4.50
Time Treatments	1	0.98	0.98	**4.16**
Error	**17**	151.41	0.24	
Total	35	170.44		

F-Dist. at	1,17 DoF	17,17 DoF
25%	1.42	1.4
10%	3.03	1.89
5%	**4.45**	**2.28**

Fecal Coliform
Scheme C
Upper Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	6.48	**5.97**
0	fresh	may-jun	7.85	6.29
0	fresh	jul	6.60	6.18
0	fresh	aug	**6.33**	5.82
0 : 0.25	fresh	sep-apr	7.06	5.71
0 : 0.25	fresh	may-jun	6.96	6.34
0 : 0.25	fresh	jul	6.11	6.97
0 : 0.25	fresh	aug	5.74	6.28
> 0.25	fresh	sep-apr	7.29	**6.78**
> 0.25	fresh	may-jun	7.24	6.37
> 0.25	fresh	jul	7.41	6.74
> 0.25	fresh	aug	**8.43**	7.92
		sum	83.50	77.37
		mean	6.96	6.45
		untransformed mean	**1051**	**630**
		% reduction	**40.0%**	

#treat	2
#blocks	12
#cells	24
#zeros	4
avg of recip	0.282

Correction: C =	1078.30
Total SS =	36.61
Blocks SS =	7.78
Treatment SS =	1.57
Error SS =	27.26

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	7.78	0.71	0.64
Time Treatments	1	1.57	1.57	1.43
Error	**7**	27.26	1.10	
Total	19	36.61		

F-Dist. at	1,7 DoF	11,7 DoF
25%	1.57	1.69
10%	3.59	2.69
5%	5.59	3.60

Fecal Coliform
Scheme C
Lower Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.81	7.06
0	fresh	may-jun	5.98	4.72
0	fresh	jul	5.51	4.37
0	fresh	aug	4.88	3.49
0 : 0.25	fresh	sep-apr	6.14	6.04
0 : 0.25	fresh	may-jun	5.60	4.53
0 : 0.25	fresh	jul	5.13	4.89
0 : 0.25	fresh	aug	5.16	4.26
> 0.25	fresh	sep-apr	6.69	6.40
> 0.25	fresh	may-jun	6.44	5.37
> 0.25	fresh	jul	6.49	5.84
> 0.25	fresh	aug	6.85	4.58
		sum	70.69	61.55
		mean	5.89	5.13
		untransformed mean	**361**	**168**
		% reduction	**53.4%**	

#treat	2
#blocks	12
#cells	24
#zeros	0
avg of recip	0.078

Correction: C =	728.57
Total SS =	70.90
Blocks SS =	12.17
Treatment SS =	3.48
Error SS =	55.25

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	12.17	1.11	2.83
Time Treatments	1	3.48	3.48	8.90
Error	**11**	55.25	0.39	
Total	23	70.90		

F-Dist. at	1,11 DoF	11,11 DoF
25%	1.47	1.52
10%	3.23	2.23
5%	4.84	2.82

Fecal Coliform
Scheme C
Mystic River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.48	5.83
0	fresh	may-jun	4.19	4.51
0	fresh	jul	4.18	**4.19**
0	fresh	aug	4.88	4.88
0 : 0.25	fresh	sep-apr	6.25	6.45
0 : 0.25	fresh	may-jun	4.63	4.89
0 : 0.25	fresh	jul	4.53	3.49
0 : 0.25	fresh	aug	5.29	4.25
> 0.25	fresh	sep-apr	8.12	6.62
> 0.25	fresh	may-jun	**6.28**	6.29
> 0.25	fresh	jul	4.94	7.50
> 0.25	fresh	aug	6.45	6.39
		sum	65.22	65.29
		mean	5.44	5.44
		untransformed mean	**228**	**230**
		% reduction	**-0.6%**	

#treat	2
#blocks	12
#cells	24
#zeros	2
avg of recip	0.130

Correction: C =	709.70
Total SS =	93.29
Blocks SS =	25.83
Treatment SS =	0.00
Error SS =	67.46

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	25.83	2.35	2.41
Time Treatments	1	0.00	0.00	0.00
Error	9	67.46	0.97	
Total	21	93.29		

F-Dist. at	1,9 DoF	11,9 DoF
25%	1.51	1.59
10%	3.36	2.4
5%	5.12	3.10

Fecal Coliform
Scheme C
Neponset River
Headwaters

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	6.72	6.16
0	fresh	may-jun	**7.33**	6.70
0	fresh	jul	7.37	6.83
0	fresh	aug	7.25	6.99
0 : 0.25	fresh	sep-apr	6.56	**5.93**
0 : 0.25	fresh	may-jun	7.37	6.25
0 : 0.25	fresh	jul	7.05	6.88
0 : 0.25	fresh	aug	8.49	7.32
> 0.25	fresh	sep-apr	7.54	7.77
> 0.25	fresh	may-jun	**7.99**	7.36
> 0.25	fresh	jul	7.69	7.90
> 0.25	fresh	aug	9.59	7.26
		sum	90.95	83.35
		mean	7.58	6.95
		untransformed mean	**1956**	**1038**
		% reduction	**46.9%**	

#treat	2
#blocks	12
#cells	24
#zeros	3
avg of recip	0.331

Correction: C =	1265.85
Total SS =	30.54
Blocks SS =	8.97
Treatment SS =	2.41
Error SS =	19.17

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	8.97	0.82	1.03
Time Treatments	1	2.41	2.41	3.03
Error	8	19.17	0.79	
Total	20	30.54		

F-Dist. at	1,8 DoF	11,8 DoF
25%	1.54	1.63
10%	3.46	2.52
5%	5.32	3.31

Fecal Coliform
Scheme C
Neponset River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	4.42	2.97
0	high	may-jun	**5.27**	4.77
0	high	jul	4.51	4.33
0	high	aug	4.26	5.55
0	low	sep-apr	4.94	5.27
0	low	may-jun	3.78	4.38
0	low	jul	5.06	4.20
0	low	aug	6.85	6.88
0 : 0.25	high	sep-apr	5.38	4.32
0 : 0.25	high	may-jun	6.80	3.90
0 : 0.25	high	jul	5.06	4.60
0 : 0.25	high	aug	4.62	5.67
0 : 0.25	low	sep-apr	4.81	4.40
0 : 0.25	low	may-jun	5.80	5.75
0 : 0.25	low	jul	5.71	4.65
0 : 0.25	low	aug	5.57	4.29
> 0.25	high	sep-apr	5.96	5.91
> 0.25	high	may-jun	8.15	5.45
> 0.25	high	jul	5.59	6.72
> 0.25	high	aug	7.12	7.13
> 0.25	low	sep-apr	6.17	5.58
> 0.25	low	may-jun	6.89	5.17
> 0.25	low	jul	6.23	5.57
> 0.25	low	aug	8.12	7.63
		sum	137.07	125.09
		mean	5.71	5.21
		untransformed mean	**301**	**182**
		% reduction	**39.4%**	

#treat	2
#blocks	24
#cells	48
#zeros	1
avg of recip	0.121

Correction: C =	1431.83
Total SS =	251.52
Blocks SS =	46.52
Treatment SS =	2.99
Error SS =	202.01

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	46.52	2.02	1.83
Time Treatments	1	2.99	2.99	**2.70**
Error	**22**	202.01	1.11	
Total	46	251.52		

F-Dist. at	1,22 DoF	23,22 DoF
25%	1.4	1.33
10%	2.95	1.74
5%	**4.30**	**2.04**

Fecal Coliform
Scheme C
Dorchester Bay

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	5.66	**4.87**
0	high	may-jun	1.54	2.10
0	high	jul	1.80	1.62
0	high	aug	2.42	2.90
0	low	sep-apr	4.55	4.28
0	low	may-jun	1.87	2.43
0	low	jul	2.84	2.00
0	low	aug	7.46	2.72
0 : 0.25	high	sep-apr	3.34	**2.55**
0 : 0.25	high	may-jun	1.98	2.34
0 : 0.25	high	jul	2.35	2.49
0 : 0.25	high	aug	4.34	3.42
0 : 0.25	low	sep-apr	3.64	**2.85**
0 : 0.25	low	may-jun	2.61	1.80
0 : 0.25	low	jul	2.15	2.14
0 : 0.25	low	aug	3.39	2.23
> 0.25	high	sep-apr	4.84	1.79
> 0.25	high	may-jun	2.95	3.00
> 0.25	high	jul	3.35	3.80
> 0.25	high	aug	4.79	3.60
> 0.25	low	sep-apr	6.34	4.34
> 0.25	low	may-jun	4.25	2.70
> 0.25	low	jul	3.10	3.32
> 0.25	low	aug	6.91	4.12
		sum	88.47	69.41
		mean	3.69	2.89
		untransformed mean	**39**	**17**
		% reduction	**56.2%**	

#treat	2
#blocks	24
#cells	48
#zeros	3
avg of recip	0.156

Correction: C =	519.29
Total SS =	223.75
Blocks SS =	61.86
Treatment SS =	7.57
Error SS =	154.32

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	61.86	2.69	2.23
Time Treatments	1	7.57	7.57	**6.28**
Error	**20**	154.32	1.21	
Total	44	223.75		

F-Dist. at	1,20 DoF	23,20 DoF
25%	1.4	1.35
10%	2.97	1.78
5%	**4.35**	**2.09**

Fecal Coliform
Scheme C
Inner Boston Harbor

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	4.82	3.67
0	high	may-jun	3.51	3.49
0	high	jul	3.85	3.82
0	high	aug	4.25	4.39
0	low	sep-apr	5.03	5.15
0	low	may-jun	3.68	2.88
0	low	jul	3.85	4.09
0	low	aug	4.30	4.14
0 : 0.25	high	sep-apr	4.29	3.88
0 : 0.25	high	may-jun	4.66	3.83
0 : 0.25	high	jul	3.90	4.81
0 : 0.25	high	aug	4.95	3.77
0 : 0.25	low	sep-apr	4.85	4.77
0 : 0.25	low	may-jun	4.52	3.99
0 : 0.25	low	jul	5.05	4.54
0 : 0.25	low	aug	5.84	3.22
> 0.25	high	sep-apr	6.26	4.58
> 0.25	high	may-jun	3.62	4.32
> 0.25	high	jul	5.60	5.80
> 0.25	high	aug	6.07	5.67
> 0.25	low	sep-apr	6.35	4.82
> 0.25	low	may-jun	3.17	4.90
> 0.25	low	jul	4.44	5.63
> 0.25	low	aug	5.64	5.07
		sum	112.51	105.22
		mean	4.69	4.38
		untransformed mean	**108**	**79**
		% reduction	**26.4%**	

#treat	2
#blocks	24
#cells	48
#zeros	0
avg of recip	0.032

Correction: C =	987.63
Total SS =	240.67
Blocks SS =	22.15
Treatment SS =	1.10
Error SS =	217.41

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	22.15	0.96	3.17
Time Treatments	**1**	1.10	1.10	**3.64**
Error	**23**	217.41	0.30	
Total	47	240.67		

F-Dist. at	1,23 DoF	23,23 DoF
25%	1.39	1.33
10%	2.94	1.73
5%	**4.28**	**2.01**

Fecal Coliform
Scheme C
Outer Boston Harbor

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Fecal Coliform; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	2.72	1.33
0	high	may-jun	1.35	**1.51**
0	high	jul	1.53	2.73
0	high	aug	1.61	1.59
0	low	sep-apr	2.41	**2.18**
0	low	may-jun	3.30	1.98
0	low	jul	1.58	2.33
0	low	aug	2.03	1.85
0 : 0.25	high	sep-apr	4.72	2.32
0 : 0.25	high	may-jun	2.63	1.42
0 : 0.25	high	jul	0.92	2.06
0 : 0.25	high	aug	4.87	1.60
0 : 0.25	low	sep-apr	2.23	**2.00**
0 : 0.25	low	may-jun	1.81	2.59
0 : 0.25	low	jul	1.59	2.35
0 : 0.25	low	aug	2.05	1.54
> 0.25	high	sep-apr	3.62	2.07
> 0.25	high	may-jun	3.09	4.71
> 0.25	high	jul	1.35	2.01
> 0.25	high	aug	2.97	2.56
> 0.25	low	sep-apr	3.56	**3.33**
> 0.25	low	may-jun	**2.52**	2.29
> 0.25	low	jul	2.35	3.01
> 0.25	low	aug	2.69	2.56
		sum	59.50	53.92
		mean	2.48	2.25
		untransformed mean	**11**	**8**
		% reduction	**22.6%**	

#treat	2
#blocks	24
#cells	48
#zeros	4
avg of recip	0.178

Correction: C =	268.00
Total SS =	122.90
Blocks SS =	20.31
Treatment SS =	0.65
Error SS =	101.95

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	20.31	0.88	0.93
Time Treatments	**1**	0.65	0.65	**0.68**
Error	**19**	101.95	0.95	
Total	43	122.90		

F-Dist. at	1,19 DoF	23,19 DoF
25%	1.41	1.37
10%	2.99	1.8
5%	**4.38**	**2.12**

Enterococcus
Scheme A
Upper Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.63	**5.79**
0	fresh	may-jun	**4.46**	4.62
0	fresh	jul-aug	4.58	4.41
0 : 0.25	fresh	sep-apr	6.14	**6.30**
0 : 0.25	fresh	may-jun	**4.77**	4.93
0 : 0.25	fresh	jul-aug	4.07	5.33
> 0.25	fresh	sep-apr	7.16	**7.32**
> 0.25	fresh	may-jun	**5.21**	5.37
> 0.25	fresh	jul-aug	6.53	5.92
		sum	48.55	49.99
		mean	5.39	5.55
		untransformed mean	**219**	**257**
		% reduction	**-17.4%**	

#treat	2
#blocks	9
#cells	18
#zeros	6
avg of recip	0.348

Correction: C =	539.45
Total SS =	40.97
Blocks SS =	14.30
Treatment SS =	0.12
Error SS =	26.56

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	14.30	1.79	0.39
Time Treatments	1	0.12	0.12	**0.02**
Error	**2**	26.56	4.63	
Total	11	40.97		

F-Dist. at	1,2 DoF	8,2 DoF
25%	2.57	3.35
10%	8.53	9.37
5%	**18.51**	**19.37**

D-13

Enterococcus
Scheme A
Lower Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	4.62	6.94
0	fresh	may-jun	2.26	3.13
0	fresh	jul-aug	3.02	2.76
0 : 0.25	fresh	sep-apr	4.84	5.87
0 : 0.25	fresh	may-jun	2.29	3.28
0 : 0.25	fresh	jul-aug	3.10	3.25
> 0.25	fresh	sep-apr	6.11	6.67
> 0.25	fresh	may-jun	3.69	4.20
> 0.25	fresh	jul-aug	4.60	3.98
		sum	34.54	40.08
		mean	3.84	4.45
		untransformed mean	**45**	**85**
		% reduction	**-86.9%**	

#treat	2
#blocks	9
#cells	18
#zeros	0
avg of recip	0.082

Correction: C =	309.28
Total SS =	73.65
Blocks SS =	31.42
Treatment SS =	1.70
Error SS =	40.52

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	31.42	3.93	9.44
Time Treatments	1	1.70	1.70	**4.09**
Error	**8**	40.52	0.42	
Total	17	73.65		

F-Dist. at	1,8 DoF	8,8 DoF
25%	1.54	1.64
10%	3.46	2.59
5%	**5.32**	**3.44**

Enterococcus
Scheme A
Mystic River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	3.86	3.50
0	fresh	may-jun	3.62	3.60
0	fresh	jul-aug	3.81	3.84
0 : 0.25	fresh	sep-apr	5.82	4.14
0 : 0.25	fresh	may-jun	3.99	4.12
0 : 0.25	fresh	jul-aug	3.69	3.50
> 0.25	fresh	sep-apr	8.00	4.36
> 0.25	fresh	may-jun	**6.19**	5.57
> 0.25	fresh	jul-aug	4.73	5.47
		sum	43.71	38.10
		mean	4.86	4.23
		untransformed mean	**128**	**68**
		% reduction	**46.7%**	

#treat	2
#blocks	9
#cells	18
#zeros	1
avg of recip	0.100

Correction: C =	371.83
Total SS =	76.38
Blocks SS =	16.47
Treatment SS =	1.75
Error SS =	58.16

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	16.47	2.06	2.49
Time Treatments	1	1.75	1.75	**2.11**
Error	**7**	58.16	0.83	
Total	16	76.38		

F-Dist. at	1,7 DoF	8,7 DoF
25%	1.57	1.7
10%	3.59	2.75
5%	**5.59**	**3.73**

Enterococcus
Scheme A
Neponset River Headwaters

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.94	6.91
0	fresh	may-jun	**5.73**	5.28
0	fresh	jul-aug	6.66	5.64
0 : 0.25	fresh	sep-apr	6.06	**5.61**
0 : 0.25	fresh	may-jun	5.17	5.56
0 : 0.25	fresh	jul-aug	6.16	5.62
> 0.25	fresh	sep-apr	7.81	6.99
> 0.25	fresh	may-jun	**6.59**	6.14
> 0.25	fresh	jul-aug	8.34	6.66
		sum	58.46	54.41
		mean	6.50	6.05
		untransformed mean	**661**	**421**
		% reduction	**36.3%**	

#treat	2
#blocks	9
#cells	18
#zeros	3
avg of recip	0.357

Correction: C =	707.76
Total SS =	23.79
Blocks SS =	9.15
Treatment SS =	0.91
Error SS =	13.73

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	8	9.15	1.14	1.17
Time Treatments	1	0.91	0.91	**0.93**
Error	**5**	13.73	0.98	
Total	14	23.79		

F-Dist. at	1,5 DoF	8,5 DoF
25%	1.69	1.89
10%	4.06	3.34
5%	**6.61**	**4.82**

Enterococcus
Scheme A
Neponset River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	4.23	3.58
0	high	may-jun	**3.31**	3.39
0	high	jul-aug	3.19	3.80
0	low	sep-apr	3.47	5.35
0	low	may-jun	2.40	2.70
0	low	jul-aug	4.47	4.01
0 : 0.25	high	sep-apr	4.56	5.92
0 : 0.25	high	may-jun	4.62	3.66
0 : 0.25	high	jul-aug	2.97	3.71
0 : 0.25	low	sep-apr	3.44	3.67
0 : 0.25	low	may-jun	3.76	5.29
0 : 0.25	low	jul-aug	4.12	3.11
> 0.25	high	sep-apr	5.16	5.54
> 0.25	high	may-jun	7.44	5.17
> 0.25	high	jul-aug	4.83	5.43
> 0.25	low	sep-apr	5.17	5.45
> 0.25	low	may-jun	5.76	4.67
> 0.25	low	jul-aug	5.33	5.21
		sum	78.23	79.66
		mean	4.35	4.43
		untransformed mean	**76**	**83**
		% reduction	**-8.4%**	

#treat	2
#blocks	18
#cells	36
#zeros	1
avg of recip	0.123

Correction: C =	692.48
Total SS =	202.46
Blocks SS =	32.33
Treatment SS =	0.06
Error SS =	170.07

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	32.33	1.90	1.45
Time Treatments	1	0.06	0.06	**0.04**
Error	**16**	170.07	1.31	
Total	34	202.46		

F-Dist. at	1,16 DoF	17,16 DoF
25%	1.42	1.41
10%	3.05	1.92
5%	**4.49**	**2.32**

Enterococcus
Scheme A
Dorchester Bay

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	2.27	**2.19**
0	high	may-jun	1.02	1.50
0	high	jul-aug	2.00	2.14
0	low	sep-apr	2.64	2.42
0	low	may-jun	1.26	1.52
0	low	jul-aug	2.04	2.20
0 : 0.25	high	sep-apr	2.20	**2.12**
0 : 0.25	high	may-jun	1.40	1.75
0 : 0.25	high	jul-aug	2.02	2.17
0 : 0.25	low	sep-apr	2.52	**2.44**
0 : 0.25	low	may-jun	1.58	1.14
0 : 0.25	low	jul-aug	1.62	2.03
> 0.25	high	sep-apr	3.39	1.79
> 0.25	high	may-jun	1.66	2.25
> 0.25	high	jul-aug	2.02	3.18
> 0.25	low	sep-apr	4.43	2.09
> 0.25	low	may-jun	3.04	2.03
> 0.25	low	jul-aug	2.40	3.04
		sum	39.51	38.00
		mean	2.20	2.11
		untransformed mean	**8**	**7**
		% reduction	**9.1%**	

#treat	2
#blocks	18
#cells	36
#zeros	3
avg of recip	0.177

Correction: C =	166.88
Total SS =	71.60
Blocks SS =	9.68
Treatment SS =	0.06
Error SS =	61.86

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	9.68	0.57	0.73
Time Treatments	1	0.06	0.06	**0.08**
Error	**14**	61.86	0.78	
Total	32	71.60		

F-Dist. at	1,14 DoF	17,14 DoF
25%	1.44	1.44
10%	3.1	1.99
5%	4.60	2.43

Enterococcus
Scheme A
Inner Boston Harbor

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	3.49	2.36
0	high	may-jun	1.74	2.84
0	high	jul-aug	2.48	2.52
0	low	sep-apr	3.84	3.31
0	low	may-jun	1.93	2.41
0	low	jul-aug	3.12	2.49
0 : 0.25	high	sep-apr	4.05	2.84
0 : 0.25	high	may-jun	2.24	2.97
0 : 0.25	high	jul-aug	2.98	3.03
0 : 0.25	low	sep-apr	4.69	2.96
0 : 0.25	low	may-jun	2.49	2.98
0 : 0.25	low	jul-aug	2.72	3.16
> 0.25	high	sep-apr	5.24	2.62
> 0.25	high	may-jun	2.36	3.99
> 0.25	high	jul-aug	3.54	4.01
> 0.25	low	sep-apr	5.98	3.62
> 0.25	low	may-jun	1.68	3.76
> 0.25	low	jul-aug	3.44	3.90
		sum	58.00	55.76
		mean	3.22	3.10
		untransformed mean	**24**	**21**
		% reduction	**12.2%**	

#treat	2
#blocks	18
#cells	36
#zeros	0
avg of recip	0.026

Correction: C =	359.50
Total SS =	147.28
Blocks SS =	15.50
Treatment SS =	0.14
Error SS =	131.64

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	15.50	0.91	4.44
Time Treatments	1	0.14	0.14	0.68
Error	17	131.64	0.21	
Total	35	147.28		

F-Dist. at	1,17 DoF	17,17 DoF
25%	1.42	1.4
10%	3.03	1.89
5%	**4.45**	**2.28**

Enterococcus
Scheme A
Outer Boston Harbor

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	3.19	1.33
0	high	may-jun	1.35	1.38
0	high	jul-aug	1.57	1.71
0	low	sep-apr	2.24	**1.94**
0	low	may-jun	1.57	1.84
0	low	jul-aug	1.61	1.81
0 : 0.25	high	sep-apr	4.01	1.22
0 : 0.25	high	may-jun	1.60	1.59
0 : 0.25	high	jul-aug	1.71	1.61
0 : 0.25	low	sep-apr	2.22	**1.92**
0 : 0.25	low	may-jun	1.62	2.03
0 : 0.25	low	jul-aug	1.61	1.89
> 0.25	high	sep-apr	4.41	1.09
> 0.25	high	may-jun	1.35	3.67
> 0.25	high	jul-aug	2.07	2.04
> 0.25	low	sep-apr	3.84	**3.54**
> 0.25	low	may-jun	**3.04**	2.74
> 0.25	low	jul-aug	1.92	2.21
		sum	40.93	35.56
		mean	2.27	1.98
		untransformed mean	**9**	**6**
		% reduction	**28.8%**	

#treat	2
#blocks	18
#cells	36
#zeros	4
avg of recip	0.186

Correction: C =	162.52
Total SS =	74.74
Blocks SS =	11.47
Treatment SS =	0.80
Error SS =	62.47

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	17	11.47	0.67	0.75
Time Treatments	**1**	0.80	0.80	**0.90**
Error	**13**	62.47	0.89	
Total	31	74.74		

F-Dist. at	1,13 DoF	17,13 DoF
25%	1.45	1.46
10%	3.14	2.03
5%	**4.67**	**2.50**

Enterococcus
Scheme C
Upper Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.63	**5.65**
0	fresh	may-jun	**4.60**	4.62
0	fresh	jul	4.58	4.38
0	fresh	aug	**4.68**	4.70
0 : 0.25	fresh	sep-apr	6.14	**6.16**
0 : 0.25	fresh	may-jun	**4.91**	4.93
0 : 0.25	fresh	jul	4.03	5.33
0 : 0.25	fresh	aug	5.46	5.36
> 0.25	fresh	sep-apr	7.16	**7.18**
> 0.25	fresh	may-jun	**5.35**	5.37
> 0.25	fresh	jul	6.53	5.62
> 0.25	fresh	aug	**7.36**	7.38
		sum	66.43	66.68
		mean	5.54	5.56
		untransformed mean	**253**	**258**
		% reduction	**-2.1%**	

#treat	2
#blocks	12
#cells	24
#zeros	8
avg of recip	0.402

Correction: C =	738.26
Total SS =	53.63
Blocks SS =	21.12
Treatment SS =	0.00
Error SS =	32.51

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	21.12	1.92	0.44
Time Treatments	1	0.00	0.00	0.00
Error	**3**	32.51	4.36	
Total	15	53.63		

F-Dist. at	1,3 DoF	11,3 DoF
25%	2.02	2.44
10%	5.54	5.23
5%	10.13	8.76

D-19

Enterococcus
Scheme C
Lower Charles River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	4.62	6.94
0	fresh	may-jun	2.26	3.13
0	fresh	jul	2.97	2.79
0	fresh	aug	3.33	2.40
0 : 0.25	fresh	sep-apr	4.84	5.87
0 : 0.25	fresh	may-jun	2.29	3.28
0 : 0.25	fresh	jul	3.15	3.27
0 : 0.25	fresh	aug	2.73	2.94
> 0.25	fresh	sep-apr	6.11	6.67
> 0.25	fresh	may-jun	3.69	4.20
> 0.25	fresh	jul	4.56	4.10
> 0.25	fresh	aug	5.14	3.15
		sum	45.69	48.73
		mean	3.81	4.06
		untransformed mean	**44**	**57**
		% reduction	**-29.5%**	

#treat	2
#blocks	12
#cells	24
#zeros	0
avg of recip	0.104

Correction: C =	371.47
Total SS =	94.50
Blocks SS =	37.01
Treatment SS =	0.38
Error SS =	57.11

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	37.01	3.36	6.21
Time Treatments	1	0.38	0.38	0.71
Error	**11**	57.11	0.54	
Total	23	94.50		

F-Dist. at	1,11 DoF	11,11 DoF
25%	1.47	1.52
10%	3.23	2.23
5%	4.84	2.82

Enterococcus
Scheme C
Mystic River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	3.86	3.50
0	fresh	may-jun	3.62	3.60
0	fresh	jul	3.72	**3.38**
0	fresh	aug	3.84	3.84
0 : 0.25	fresh	sep-apr	5.82	4.14
0 : 0.25	fresh	may-jun	3.99	4.12
0 : 0.25	fresh	jul	3.80	3.50
0 : 0.25	fresh	aug	3.53	3.49
> 0.25	fresh	sep-apr	8.00	4.36
> 0.25	fresh	may-jun	**5.91**	5.57
> 0.25	fresh	jul	4.28	6.33
> 0.25	fresh	aug	4.81	5.27
		sum	55.18	51.10
		mean	4.60	4.26
		untransformed mean	**98**	**70**
		% reduction	**29.1%**	

#treat	2
#blocks	12
#cells	24
#zeros	2
avg of recip	0.131

Correction: C =	470.64
Total SS =	96.09
Blocks SS =	20.34
Treatment SS =	0.69
Error SS =	75.05

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	20.34	1.85	1.69
Time Treatments	1	0.69	0.69	**0.63**
Error	9	75.05	1.09	
Total	21	96.09		

F-Dist. at	1,9 DoF	11,9 DoF
25%	1.51	1.59
10%	3.36	2.40
5%	5.12	3.10

D-20

Enterococcus
Scheme C
Neponset River
Headwaters

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	fresh	sep-apr	5.94	6.91
0	fresh	may-jun	**6.04**	5.28
0	fresh	jul	6.98	5.33
0	fresh	aug	6.50	5.94
0 : 0.25	fresh	sep-apr	6.06	**5.30**
0 : 0.25	fresh	may-jun	5.17	5.56
0 : 0.25	fresh	jul	5.85	5.50
0 : 0.25	fresh	aug	6.48	6.49
> 0.25	fresh	sep-apr	7.81	6.99
> 0.25	fresh	may-jun	**6.90**	6.14
> 0.25	fresh	jul	7.87	6.83
> 0.25	fresh	aug	10.23	6.42
		sum	81.83	72.69
		mean	6.82	6.06
		untransformed mean	**914**	**426**
		% reduction	**53.4%**	

#treat	2
#blocks	12
#cells	24
#zeros	3
avg of recip	0.352

Correction: C =	994.85
Total SS =	42.97
Blocks SS =	16.74
Treatment SS =	3.48
Error SS =	22.75

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	11	16.74	1.52	1.52
Time Treatments	1	3.48	3.48	3.48
Error	8	22.75	1.00	
Total	20	42.97		

F-Dist. at	1,8 DoF	11,8 DoF
25%	1.54	1.63
10%	3.46	2.52
5%	5.32	3.31

Enterococcus
Scheme C
Neponset River

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	4.23	3.58
0	high	may-jun	**3.50**	3.39
0	high	jul	3.31	3.28
0	high	aug	3.12	4.24
0	low	sep-apr	3.47	5.35
0	low	may-jun	2.40	2.70
0	low	jul	2.97	3.06
0	low	aug	5.97	4.89
0 : 0.25	high	sep-apr	4.56	5.92
0 : 0.25	high	may-jun	4.62	3.66
0 : 0.25	high	jul	2.81	3.61
0 : 0.25	high	aug	3.31	4.10
0 : 0.25	low	sep-apr	3.44	3.67
0 : 0.25	low	may-jun	3.76	5.29
0 : 0.25	low	jul	3.50	3.15
0 : 0.25	low	aug	4.54	2.94
> 0.25	high	sep-apr	5.16	5.54
> 0.25	high	may-jun	7.44	5.17
> 0.25	high	jul	4.25	5.36
> 0.25	high	aug	6.97	5.56
> 0.25	low	sep-apr	5.17	5.45
> 0.25	low	may-jun	5.76	4.67
> 0.25	low	jul	4.96	4.33
> 0.25	low	aug	8.37	5.98
		sum	107.59	104.89
		mean	4.48	4.37
		untransformed mean	**87**	**78**
		% reduction	**10.8%**	

#treat	2
#blocks	24
#cells	48
#zeros	1
avg of recip	0.129

Correction: C =	940.58
Total SS =	284.14
Blocks SS =	63.40
Treatment SS =	0.15
Error SS =	220.59

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	63.40	2.76	2.13
Time Treatments	1	0.15	0.15	**0.12**
Error	**22**	220.59	1.29	
Total	46	284.14		

F-Dist. at	1,22 DoF	23,22 DoF
25%	1.4	1.33
10%	2.95	1.74
5%	**4.30**	**2.04**

Enterococcus
Scheme C
Dorchester Bay

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	2.27	**2.16**
0	high	may-jun	1.02	1.50
0	high	jul	1.81	1.41
0	high	aug	2.13	2.74
0	low	sep-apr	2.64	2.42
0	low	may-jun	1.26	1.52
0	low	jul	0.92	1.79
0	low	aug	4.29	2.66
0 : 0.25	high	sep-apr	2.20	**2.09**
0 : 0.25	high	may-jun	1.40	1.75
0 : 0.25	high	jul	1.66	1.98
0 : 0.25	high	aug	2.85	2.77
0 : 0.25	low	sep-apr	2.52	**2.41**
0 : 0.25	low	may-jun	1.58	1.14
0 : 0.25	low	jul	1.34	1.98
0 : 0.25	low	aug	2.01	2.58
> 0.25	high	sep-apr	3.39	1.79
> 0.25	high	may-jun	1.66	2.25
> 0.25	high	jul	1.98	3.14
> 0.25	high	aug	2.43	3.26
> 0.25	low	sep-apr	4.43	2.09
> 0.25	low	may-jun	3.04	2.03
> 0.25	low	jul	1.97	2.67
> 0.25	low	aug	5.46	3.49
		sum	56.26	53.62
		mean	2.34	2.23
		untransformed mean	**9**	**8**
		% reduction	**11.5%**	

#treat	2
#blocks	24
#cells	48
#zeros	3
avg of recip	0.162

Correction: C =	251.53
Total SS =	110.93
Blocks SS =	26.74
Treatment SS =	0.15
Error SS =	84.04

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	26.74	1.16	1.71
Time Treatments	1	0.15	0.15	**0.21**
Error	**20**	84.04	0.68	
Total	44	110.93		

F-Dist. at	1,20 DoF	23,20 DoF
25%	1.4	1.35
10%	2.97	1.78
5%	**4.35**	**2.09**

Enterococcus
Scheme C
Inner Boston Harbor

D–23

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	3.49	2.36
0	high	may-jun	1.74	2.84
0	high	jul	1.73	2.30
0	high	aug	3.14	2.68
0	low	sep-apr	3.84	3.31
0	low	may-jun	1.93	2.41
0	low	jul	1.97	2.59
0	low	aug	3.43	2.41
0 : 0.25	high	sep-apr	4.05	2.84
0 : 0.25	high	may-jun	2.24	2.97
0 : 0.25	high	jul	1.76	3.14
0 : 0.25	high	aug	3.39	2.68
0 : 0.25	low	sep-apr	4.69	2.96
0 : 0.25	low	may-jun	2.49	2.98
0 : 0.25	low	jul	2.96	3.30
0 : 0.25	low	aug	2.51	2.41
> 0.25	high	sep-apr	5.24	2.62
> 0.25	high	may-jun	2.36	3.99
> 0.25	high	jul	2.86	3.99
> 0.25	high	aug	3.68	4.03
> 0.25	low	sep-apr	5.98	3.62
> 0.25	low	may-jun	1.68	3.76
> 0.25	low	jul	2.91	3.99
> 0.25	low	aug	3.55	3.66
		sum	73.62	73.83
		mean	3.07	3.08
		untransformed mean	**20**	**21**
		% reduction	**-0.9%**	

#treat	2
#blocks	24
#cells	48
#zeros	0
avg of recip	0.032

Correction: C =	452.95
Total SS =	189.47
Blocks SS =	20.69
Treatment SS =	0.00
Error SS =	168.79

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	20.69	0.90	3.82
Time Treatments	1	0.00	0.00	**0.00**
Error	**23**	168.79	0.24	
Total	47	189.47		

F-Dist. at	1,23 DoF	23,23 DoF
25%	1.39	1.33
10%	2.94	1.73
5%	**4.28**	**2.01**

Enterococcus
Scheme C
Outer Boston Harbor

Cell Average Values (Highlighted Cells Denote Estimated Value))

Cell Averages: Enterococcus; ln(FC+1)				
RANDOMIZED BLOCKS			TREATMENTS	
RMS Rainfall	Tidal Condition	Season	89-91	92-95
0	high	sep-apr	3.19	1.33
0	high	may-jun	1.35	1.38
0	high	jul	1.69	1.91
0	high	aug	1.56	1.62
0	low	sep-apr	2.24	**2.19**
0	low	may-jun	1.57	1.84
0	low	jul	1.09	1.73
0	low	aug	1.94	1.84
0 : 0.25	high	sep-apr	4.01	1.22
0 : 0.25	high	may-jun	1.60	1.59
0 : 0.25	high	jul	1.15	1.71
0 : 0.25	high	aug	1.76	1.56
0 : 0.25	low	sep-apr	2.22	**2.17**
0 : 0.25	low	may-jun	1.62	2.03
0 : 0.25	low	jul	1.50	1.93
0 : 0.25	low	aug	1.62	1.86
> 0.25	high	sep-apr	4.41	1.09
> 0.25	high	may-jun	1.35	3.67
> 0.25	high	jul	0.92	1.92
> 0.25	high	aug	2.11	2.07
> 0.25	low	sep-apr	3.84	**3.79**
> 0.25	low	may-jun	**2.79**	2.74
> 0.25	low	jul	1.63	2.67
> 0.25	low	aug	1.96	2.06
		sum	49.12	47.92
		mean	2.05	2.00
		untransformed mean	**7**	**6**
		% reduction	**5.6%**	

#treat	2
#blocks	24
#cells	48
#zeros	4
avg of recip	0.178

Correction: C =	196.18
Total SS =	92.01
Blocks SS =	14.86
Treatment SS =	0.03
Error SS =	77.12

ANOVA Results

Source of Variation	DoF	SS	MS	F
Blocks	23	14.86	0.65	0.89
Time Treatments	1	0.03	0.03	**0.04**
Error	**19**	77.12	0.72	
Total	43	92.01		

F-Dist. at	1,19 DoF	23,19 DoF
25%	1.41	1.37
10%	2.99	1.8
5%	**4.38**	**2.12**

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