Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

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PROTECTING LAKE MICHIGAN WATER QUALITY: ADDRESSING BEACH ISSUES IN 2003

VOLUME 1

June 2003

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PROTECTING LAKE MICHIGAN WATER QUALITY: ADDRESSING BEACH ISSUES IN 2003

VOLUME 1

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ACKNOWLEDGEMENTS

The dates of reversals as well as the volumes of water diverted to Lake Michigan in 2000 and 2001 were obtained from Vasant Trivedi, Senior Civil Engineer, Maintenance and Operations Department, Metropolitan Water Reclamation District of Greater Chicago (District). The dates of reversals as well as the volumes of water diverted to Lake Michigan in 2002 were obtained from Terry Woodson, Assistant Civil Engineer, also in the District's Maintenance and Operations Department.

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Department Lakes Management Unit, Lake County, Illinois: Illinois Beach State Park (IBSP) North, IBSP Sailing, IBSP South, Lake Bluff, Lake Forest, North Point Marina, Park Avenue, Rosewood, Waukegan North, Waukegan South, and Moraine Park.

Beach monitoring data collected in 2000 and 2001 for Glencoe Beach were obtained from Mike Kudla, Department of Public Works, Glencoe, Illinois. Beach monitoring data collected in 2000 and 2001 for five beaches (Kenilworth, Tower, Lloyd, Maple, and Elder) were obtained from Charles Imig, Winnetka Park District, Winnetka, Illinois. Beach monitoring data collected in 2000 and 2001 for the Wilmette North and South Beaches were obtained from Diane Dempsey, Winnetka Park District, Winnetka, Illinois.

This report was typed by Joan Scrima.

DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the District. The District was not involved in the sampling or analysis of any of the beach monitoring data presented and analyzed in this report.

SUMMARY AND CONCLUSIONS

One of the missions of the District is to protect the quality of water in Lake Michigan. Since the number of beach closings and advisories at Lake Michigan beaches increased every year from 1998 through 2002, the District undertook this study to find possible explanations for these increases that might be related to District operations. Bacterial beach monitoring data collected from 23 beaches in Chicago (2000 through 2002) and 26 beaches in the suburbs north of Chicago (2000 through 2001) were compiled. Basic statistics were computed from the data. The number of violations of the Illinois Bathing Beach Code, *Escherichia coli* (EC) >235 CFU/100 mL or fecal coliforms (FC) >500 CFU/100 mL, at all of the beaches studied was determined from the compiled data. The basic statistics and the violations of the Bathing Beach Code were used to assess, on a semi-quantitative or qualitative basis, water quality at the beaches in the study area.

As part of its normal operations the District maintained records of reversals to Lake Michigan and collected rainfall data for Chicago and the suburbs north of Chicago. The number of violations of the Bathing Beach Code coinciding with reversals was computed from the data. Statistical models were

developed to predict EC or FC concentrations at each beach studied. The following conclusions were drawn from this study.

1. Basic statistics, including geometric means (GMs) of EC and FC concentrations, calculated from beach monitoring data as well as the number of violations of the Bathing Beach Code, indicated that water quality at the Jackson/63rd Street Beach was the poorest of all the beaches studied while the water quality at the beaches in Evanston was the best.
2. Basic statistics and the results of statistical analyses (comparison of the equalities of the GMs of EC or FC concentrations by ANOVA and the Student-Newman-Keuls or SNK test) indicated the following:
   a. water quality at the Calumet, Rainbow, South Shore, 57th Street, 31st Street, 12th Street, Montrose, Hollywood/Osterman, Thorndale, and Jackson/63rd was poorer than that at the rest of the beaches in Chicago;
   b. there was no difference in water quality at six of the seven Evanston beaches. Water quality at Dog Beach in Evanston was

somewhat better than that at the other six beaches;

c. water quality at North Point Marina Beach was the poorest of all the beaches in Lake County; and

d. there was no difference in water quality at Illinois Beach State Park (IBSP) - North, IBSP - Sailing, Lake Bluff Park District, Lake Forest Park District, Moraine Park, Park Avenue, and Rosewood, and the water quality at these beaches was better than that at all of the other beaches in Lake County.

3. Results of statistical analyses (comparison of the equalities of the GMs of EC or FC concentrations by ANOVA and the SNK test performed with rainfall as a covariant, which standardizes the effect of rainfall) were the same as those obtained performing the statistical analyses without standardizing the effect of rainfall (see Conclusion 2 a through d above) and indicate that rainfall only mildly influences the EC or

FC concentration at a given beach in the study area (see Conclusion 5 below).

4. Comparison of the total number of violations of the Bathing Beach Code to the number of violations coinciding with river reversals demonstrated that river reversals to Lake Michigan are not responsible for the steady increase in the number of beach closings and advisories observed in the last several years. For example, there were no reversals to Lake Michigan in 2000, yet there were 347 violations of the Bathing Beach Code in the study area, based on the compiled data. Other potential sources of bacterial contamination must be considered in seeking a reason for the increased number of beach closings and advisories. These include:

    - Seagull and other bird droppings.
    - Pet droppings.
    - Droppings from vagrant humans.
    - Urban runoff (yards, roofs, roads, business and industrial sites).
    - Runoff from parks (grasslands and forests).

- Contaminated sediments.
- Fecal contamination from swimmers.
- *E.coli* in beach sand.
- Sanitary sewer overflows, combined sewer overflows, and/or nonpoint stormwater run-off from area discharges outside of Cook County, Illinois.

5. EC and FC densities at the Lake Michigan beaches were found to correlate weakly with a function of rainfall expressed by the equation:

   $\text{Ln EC (or ln FC)} = kI^{1/7}$

   where I = inches of rainfall and k = a constant peculiar to each beach.

   This simple regression model was found to be superior to auto regressive models (developed using the ln of EC or FC concentrations from the three previous days), as judged by Akaike's Information Criteria (AIC). That is, the simple regression models were better able to predict EC or FC concentrations (as ln values) than the auto regressive models. This simple regression model was also found to be superior to auto regressive models with rainfall as an explanatory variable as judged by AIC.

6. R^2 values for the simple regression models developed to predict EC and FC concentrations as a function of rainfall at the Lake Michigan beaches in Chicagoland range from 0.14 to 0.34 with an average value of 0.27. Although these values appear to be low and indicate only a weak correlation, they do indicate that the water quality at Lake Michigan beaches is affected by rainfall. Parenthetically, this finding suggests that it may be appropriate for local Park Districts to study the feasibility of implementing best management practices (BMP) (NRCS 1997; NRCS 1998) to minimize the impact of nonpoint source pollution at the beaches.

   Consideration of the many factors that affect the fate of fecal bacteria in Lake Michigan serves to put these R^2 values in the proper perspective. These factors include a) dispersion, which is influenced by wave height, air and water temperature, wind direction and strength, and b) the rapid disappearance of fecal organisms due to the self-purification of the Lake, which is in turn influenced by many factors, the most important of which are solar radiation, temperature, and the combined effects of solar radiation and temperature.

7. River reversal operations by the District to minimize basement sewer backup and surface flooding in the Chicagoland area are not the main cause of beach closings.

This study was conducted using monitoring data collected routinely. This study was not planned before the data were collected. Rather, it was conceived by District management in response to the concerns raised by citizens about water quality at the beaches in the Chicagoland area. The best data available were used in the study.

INTRODUCTION

Purpose of this Report

One of the missions of the Metropolitan Water Reclamation District of Greater Chicago is to protect the water quality of Lake Michigan (Lue-Hing, 1992). In response to public concerns about beach closings in the Chicagoland area, the District studied the effects of 1) combined sewer overflows (CSOs), or more specifically, reversals of the rivers to Lake Michigan caused by excessive rainfall events, and 2) rainfall, on Lake Michigan bacterial water quality as assessed by monitoring of *Escherichia coli* (EC) and fecal coliform (FC) densities at the Lake Michigan beaches in Chicago and the suburbs to the north of Chicago. The findings of the study are contained in this report.

Closings of Lake Michigan Beaches

The Lake Michigan Federation reported that the number of Lake Michigan beach closings and advisories due to high bacteria levels has increased steadily since 1998 as shown in Table 1 (Lake Michigan Federation, 2002).

The cause for this increase has not been determined, but the following possible reasons have been cited (Rohde, 2002;

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TABLE 1

LAKE MICHIGAN BEACH CLOSINGS AND ADVISORIES
1998-2002[1]

Year	Beach Closings and Advisories
1998	261
1999	347
2000	404
2001	601
2002	897

[1]Source: Lake Michigan Federation Press Release.

NRDC, 2002; Terry, 2002; Chicago Park District, 2002):

- Increased monitoring.
- Low level of Lake Michigan.
- Below average rainfall in 2000.
- Above average rainfall in 2001.
- Sewage discharges (point source pollution).
- Stormwater runoff (nonpoint source pollution).

This increase in the number of beach closings has sparked a public debate in the Chicagoland area which has focused on river reversals to the Lake and rainfall, and their effects on water quality at the Lake Michigan public beaches.

River Reversals to Lake Michigan and Beach Closings

Unusually heavy rainfall in the Chicagoland area sometimes requires that gates at the Wilmette Pumping Station, the Chicago River Controlling Works (CRCW), or the O'Brien Lock and Dam be opened to prevent or to at least alleviate flooding in the Chicagoland area (Figure 1). When gates at one of these facilities is opened, river water (from the North Shore Channel, the Chicago River, or the Calumet River, respectively,) contaminated with CSOs and nonpoint stormwater runoff flows into Lake Michigan. These events are referred to as "reversals to the Lake."

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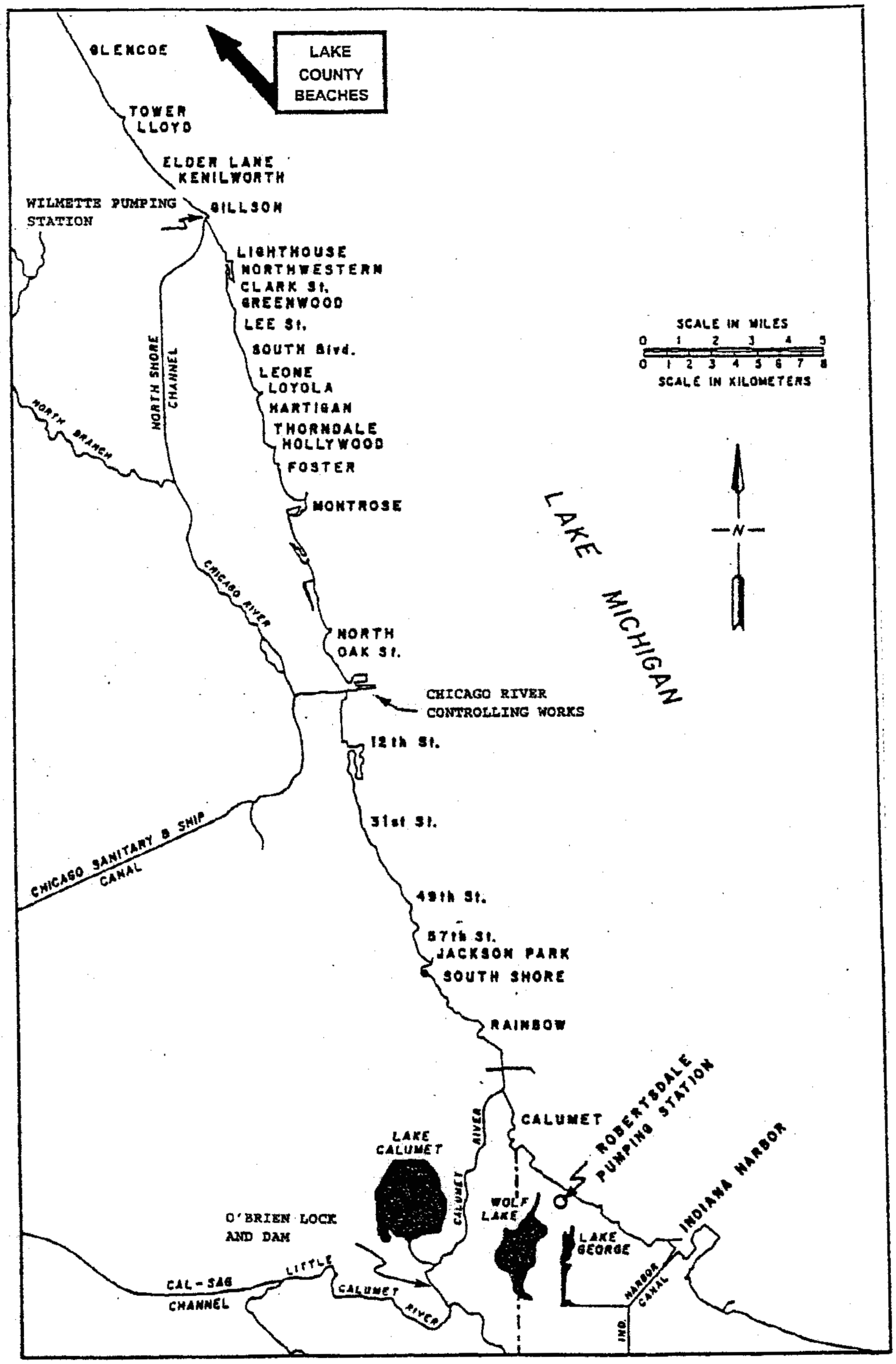
FIGURE 1

CHICAGO AREA BEACHES AND RIVER CONTROL LOCATIONS



As a precaution, the Chicago Park District and other beach authorities automatically ban swimming for two consecutive days whenever river water is discharged to Lake Michigan at one or more of the river control facilities (Chicago Park District, 2002). In accordance with United States Environmental Protection Agency (USEPA) guidelines (see Monitoring Bacterial Levels at Public Beaches in Illinois below), swimmers are not allowed in the water until bacterial monitoring tests show acceptable levels. Activities involving exposure to contaminants through swimming or other contact with the water can lead to infectious diseases such as hepatitis, gastrointestinal disorders, dysentery, and swimmer's ear (USEPA 2002b).

Rainfall and Beach Closings

Rainfall itself affects water quality at Lake Michigan beaches by causing nonpoint source stormwater runoff from grasslands and forests, residential back yards, roofs, roads, and business and industrial sites. This stormwater runoff picks up fecal matter from wildlife, pets, and other sources and washes it into the Lake. This is referred to as nonpoint source pollution. Pollution from nonpoint sources can degrade water quality at Lake Michigan beaches, as measured by monitoring bacterial levels, making it necessary to close the public beaches.

Land-based runoff is increasingly being recognized as a source of fecal bacteria and a public health concern at swimming beaches. This was pointed out by Noble et al., (2000, 2003) who found that Southern California Bight (SCB) shoreline has good water quality, except near areas that drain land-based runoff. They also found that 60 percent of the SCB shoreline failed water quality standards after a storm compared to only six percent during dry weather. Schiff et al., (in press) found that more than half of the beach water quality failures in Santa Monica Bay, California, are associated with rain events. The Natural Resources Defense Council (1999) also reported in a survey of coastal and Great Lakes communities that in 1998 more than 1,500 beach closings and advisories were associated with stormwater runoff (cited in the Federal Register/Vol. 64, December 8, 1999, 68727).

The Chicagoland area is densely populated. Therefore, it would be expected that nonpoint source pollution would have to be addressed, in addition to pollution from point sources. A 1999 study to determine the source of unexpectedly high river and stream bacterial contaminations near Nashville, Tennessee, showed that FC densities were directly related to the density of housing, population, development, percent impervious area, and apparent domestic animal density. Surface runoff samples from more densely populated sewered areas generally showed higher bacterial counts than runoff from less developed areas. The investigators concluded that surface runoff from high density urban areas may be a contributor to high fecal bacteria loadings (Young and Thackston, 1999). Similar results for a study conducted in North Carolina were reported by Mallin (1998). Mallin et al., (2000) also reported that FC concentrations in South Carolina coastal watersheds were directly correlated with the percent of impervious surface in the watershed. These findings should be kept in mind when considering ways to improve water quality at the Lake Michigan beaches in the study area.

Monitoring Bacterial Levels at Public Beaches in Illinois

In order to prevent swimming associated illnesses, the Illinois Department of Public Health (IDPH) requires that the water at licensed public beaches in Illinois be monitored to determine that the bacteria levels are within limits established in the Swimming Pool and Bathing Beach Code (77 Illinois Administrative Code 820)(Bathing Beach Code). The Bathing Beach Code presently allows for the monitoring of either EC or

FC levels. Both EC and FC are referred to as "indicator" organisms because their presence in water indicates that pathogens may be present in the water. The maximum EC level allowed is 235 colony forming units per 100 mL (cfu/100 mL), which is based upon USEPA guidance (USEPA, 1986). The maximum FC level allowed is 500 cfu/100 mL. When these levels are exceeded on two consecutive days at a beach a swimming ban is implemented. Swimming is not allowed at the beach until bacterial densities in the water fall to acceptable levels.

The USEPA has recommended that all States replace water quality criteria based upon FC with criteria based upon EC or enterococci (USEPA, 1986). Illinois has adopted the EC standard, but monitoring of FC is still allowed. The levels of indicator organisms are monitored because it is not possible to test for all of the pathogens that might be present. In brief, indicator organisms should have the following characteristics (USEPA June 2002a):

- Be easily detected using simple laboratory tests.
- Generally not be present in unpolluted waters.
- Appear in concentrations that can be correlated with the extent of contamination.

- Have a die-off rate that is not faster than the die-off rate of the pathogens of concern.

For a discussion of indicator organisms see Toranzos et al., (2002) and Havelaar (2001). As mandated by the Beaches Environmental Assessment and Coastal Health (BEACH) Act, passed on October 10, 2000, the USEPA is currently studying and within a few years will require the monitoring of certain pathogens at Lake Michigan beaches (USEPA, 2002a).

It is necessary to understand the relationship of EC to FC to understand and properly analyze the data gathered for this report. The term "fecal coliforms" is not used to define any particular species of bacteria. It actually refers to a group of organisms that conform to certain criteria, and which are enumerated by particular laboratory tests. In other words, FC are defined operationally. (For a complete discussion see Brock, 1983.) *Escherichia coli* is a species of bacteria, and EC is the predominant fecal coliform. Reported values of the EC/FC ratio for various polluted water bodies range from 0.6 to 1 (Ferley et al., 1989) (Calderon et al., 1991) (Gore et al., in preparation) (Terrio, 1994). No attempt was made in this report to convert FC data to EC data to facilitate comparisons of the respective data sets. Such a conversion would be based upon the indefensible assumption that the EC to FC ratio is constant. In fact, as pointed out above, the ratio of EC to FC in polluted water is variable and would be influenced by a number of factors, including the type of water body and the source of pollution.

OBJECTIVES

The objectives of this study were: 1) to determine whether river reversals to Lake Michigan caused by CSO discharges from excessive rainfall events in the Chicago area are the reason for the increase in beach closings in the City of Chicago or in the suburban communities located north of Chicago; and 2) to determine whether EC and FC densities at Lake Michigan beaches in the City of Chicago or in the communities to the north of Chicago correlate with the amount of rainfall.

MATERIALS AND METHODS

Beach Monitoring Data

Beach monitoring data were provided by the Chicago Park District, the City of Evanston, the Village of Glencoe, the Lake County Health Department, the City of Wilmette, and the Village of Winnetka. These data are shown in Appendices AI through AVI, respectively. The Chicago Park District monitors beaches for EC concentrations. The other entities all monitor beaches for FC concentrations.

Rainfall Data

Rainfall data were collected by the District as part of normal operations and are shown in Table BI-1. The locations of the rain gauges are also shown in Table BI-1. The rainfall values used for the derivation of models to predict FC concentrations at the beaches are also shown in Appendices AI through AVI, where they are placed next to the corresponding beach monitoring data for convenient reference. The column reference numbers in Table BI-1 are also shown in Appendices AI through AVI to indicate where the rain gauge was located for the data used to derive each particular model. For example, the column reference number is 12 for the rain data used to derive predictive models from the monitoring data from

Calumet Beach, which from Table BI-1 indicates that the rain gauge was at the Calumet Water Reclamation Plant (WRP).

River Reversals to Lake Michigan and Related Storm Data

Reversal and related storm data were collected by the District as part of normal operations and are shown in Appendix CI.

Statistical Analysis

The ln EC and ln FC concentrations were tested for normality with the Kolmogorov-Smirnov (K-S) test (Gibbons and Chakraborti, 1992). The ln values of the monitoring data were considered to be from a normal population regardless of the value obtained with the K-S test if the number of data was greater than 30. Bartlett's test for homogeneity of variance (Walpole and Meyers, 1989; Dyer and Keating, 1980) was performed on natural log transformed EC and FC data for which there was no reason to question the assumption of normality. Standard parametric ANOVA was used to test the equalities of the geometric means of EC concentrations across all of the beaches in the Chicago Park District and equalities of the geometric means of FC concentrations across all beaches in the north suburban park districts (SAS Institute, 2000; Khattree and Dayanand, 1999). Multiple comparisons of the EC or FC geometric means, shown to be unequal by ANOVA for a given Park District, were performed by the Student-Newman-Keuls (SNK) test (SAS Institute, 1995; Khattree and Dayanand, 1999); this multiple comparison analysis was also performed using rainfall as a covariate (SAS Institute, 1995; Khattree and Dayanand, 1999). The PROC GLM and PROC REG sub-programs in SAS were used to derive models from beach monitoring data to predict EC or FC concentrations, as ln EC or ln FC, at each particular beach. The ln EC or ln FC concentrations for a particular beach were regressed against mathematically transformed rainfall amounts, "I" (Khattree and Dayanand, 1999). Standard search methods were used to determine which transformation of I gave the best fit for the simple regression model as determined by R^2 values and Mallow's CP statistics. Auto Regressive, or time series models, were developed to predict EC or FC concentrations, as ln EC or ln FC, for each beach from ln EC or ln FC concentrations measured on the three previous days (Box and Jenkins, 1970). Auto regressive models were also developed as above with rainfall as an explanatory variable (Box and Jenkins, 1970). Akaike's Information Criteria (AIC) were calculated to determine whether the simple regression model or an auto regressive model was better for each particular beach.

RESULTS AND DISCUSSION

Qualitative Assessment of Water Quality

Basic statistics calculated from the actual EC and FC monitoring data for each beach are shown in Table 2. These include the geometric means (GMs) and standard deviations of the EC or FC concentrations, the maximum likelihood estimates of the mean EC or FC concentrations, and the results of the Kolmogorov and Smirnov (KS) test for normality.

Geometric means at the Chicago Park District beaches ranged from 18 EC/100 mL at 49th Street to 134 EC/100 mL at Jackson/63rd Street. Geometric means at the Evanston, Lake County, Wilmette, and Winnetka beaches ranged from 1 FC/100 mL to 28 FC/100 mL, 26 FC/100 mL to 213 FC/100 mL, 32 FC/100 mL to 37 FC/100 mL, and 204 FC/100 mL to 272 FC/100 mL, respectively. The GM of the FC concentration at Glencoe Beach was 63 FC/100 mL.

Values calculated with the K-S test for normality were greater than 0.05 for 42 of the 49 data sets indicating that the ln EC or ln FC data in these data sets all came from a normal distribution. For the seven data sets giving results <0.05 for the K-S test the large sample theory is applicable because the sample size for each data set is >30, and the ln

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TABLE 2

BASIC STATISTICS

Park District	Beach	Parameter	Mean of Ln (EC or FC) Values	SD[1] of Ln (EC or FC) Values	GM[2] of EC or FC Values	M.L. Mean[3]	Sig. Prob. Normal Test[4]
			..... CFU/100 mL				
Chicago	Calumet	EC	4.19	1.44	66	186	0.727
Chicago	Rainbow	EC	4.34	1.45	76	219	0.907
Chicago	South Shore	EC	4.17	1.48	65	194	0.606
Chicago	Jackson/63rd	EC	4.89	1.52	134	425	0.719
Chicago	57th Street	EC	4.05	1.64	57	219	0.837
Chicago	31st Street	EC	4.06	1.72	58	253	0.937
Chicago	49th Street	EC	2.87	1.99	18	128	0.478
Chicago	12th Street	EC	3.92	1.68	50	205	0.868
Chicago	Ohio Street	EC	3.32	1.63	28	104	0.735
Chicago	Oak Street	EC	3.47	1.60	32	115	0.712
Chicago	North Ave	EC	3.57	1.62	35	131	0.797
Chicago	Montrose	EC	4.06	1.58	58	203	0.815
Chicago	Foster	EC	3.77	1.65	43	168	0.889
Chicago	Hollywood/ Osterman	EC	3.90	1.68	49	203	0.846
Chicago	Thorndale	EC	3.97	1.60	53	190	0.867
Chicago	Albion	EC	3.34	1.81	28	146	0.636
Chicago	Pratt	EC	3.44	1.79	31	153	0.881
Chicago	Leon/Loyola	EC	3.54	1.70	35	147	0.955
Chicago	Jarvis/Fargo	EC	3.36	1.84	29	156	0.502
Chicago	Howard	EC	3.31	1.88	27	160	0.456
Chicago	Rogers	EC	3.36	1.89	29	171	0.653
Chicago	North Shore	EC	3.35	1.75	29	132	0.601
Chicago	Juneway	EC	3.34	1.80	28	144	0.787
Evanston	Clark Street	FC	2.86	1.60	18	63	0.778
Evanston	Dog	FC	0.23	0.40	1	1	0.766
Evanston	Greenwood	FC	2.96	1.71	19	83	0.334
Evanston	Lee Street	FC	2.83	1.71	17	73	0.150
Evanston	Lighthouse	FC	2.91	1.61	18	67	0.418
Evanston	Northwestern	FC	3.33	1.49	28	85	0.718
Evanston	South Blvd	FC	2.82	1.78	17	82	0.169
Glencoe	Glencoe	FC	4.15	1.65	63	247	0.072
LC[5]	IBSP[6] - North	FC	3.80	1.36	44	113	0.000
LC	IBSP - South	FC	4.22	1.65	68	266	0.000
LC	IBSP - Sailing	FC	3.95	1.30	52	122	0.054

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TABLE 2 (Continued)

BASIC STATISTICS

Park District	Beach	Parameter	Mean of Ln (EC or FC) Values	SD[1] of Ln (EC or FC) Values	GM[2] of EC or FC Values	M.L. Mean[3]	Sig. Prob. Normal Test[4]
			..... CFU/100 mL				
LC	Lake Bluff	FC	3.31	1.22	27	58	0.000
LC	Lake Forest	FC	4.01	1.41	55	149	0.026
LC	Moraine Park	FC	3.28	1.41	26	72	0.662
LC	North Point	FC	5.36	1.54	213	697	0.002
LC	Park Avenue	FC	3.74	1.49	42	127	0.000
LC	Rosewood	FC	4.04	1.68	57	231	0.000
LC	Waukegan North	FC	4.66	1.37	106	269	0.748
LC	Waukegan South	FC	5.20	1.37	181	462	0.200
Wilmette	Wilmette North	FC	3.47	1.49	32	97	0.640
Wilmette	Wilmette South	FC	3.60	1.48	37	109	0.483
Winnetka	Elder	FC	5.37	1.76	215	1004	0.946
Winnetka	Ken	FC	5.56	1.49	260	790	0.952
Winnetka	Lloyd	FC	5.61	1.69	272	1129	0.726
Winnetka	Maple	FC	5.32	1.84	204	1116	0.446
Winnetka	Tower	FC	5.43	1.73	229	1015	0.389

[1]Standard Deviation.

[2]Geometric Mean.

[3]Maximum Likelihood Estimate of Mean EC or FC Values = Exp(col 4+(col 5)**2/2).

[4]Significance Probability (P-value) is calculated by the Kolmogorov and Smirnov Method; a P-value of <0.05 indicates that the data are not from a normal distribution.

[5]Lake County.

[6]Illinois Beach State Park.

transformed FC concentrations in these data sets are all considered to be from a normal distribution. The seven results of <0.05 for the K-S test were all for Lake County beach monitoring data. No explanation for this observation is offered.

From the data in Table 3 it can be seen that there were 252, 274, and 239 violations of the Illinois Bathing Beach Code for the 23 beaches on Lake Michigan in Chicago in 2000, 2001, and 2002, respectively. (For the purposes of this report a measured value for EC >235 or FC >500 on any particular day is called a violation of the Bathing Beach Code. It is provided only to give a point of reference for discussion of the data.) These numbers are based on the monitoring data shown in Appendix AI. There were 95 and 140 violations of the Illinois Bathing Beach Code for the Lake Michigan beaches in the suburbs north of Chicago in 2000 and 2001, respectively, (Table 4). These numbers are based on the data in Appendices AII through AVI.

The EC concentration at the Jackson/63rd Street Beach was greater than 235 EC/100 mL on more days than at any of the other beaches studied. At the Jackson/63rd Street Beach the Bathing Beach Code was violated on 27 days in 2000, 31 days in 2001, and 15 days in 2002. In sharp contrast to these numbers, there was only one violation of the Bathing Beach Code

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TABLE 3

NUMBER OF DAYS THAT THE E.COLI CONCENTRATION WAS GREATER THAN 235 CFU/100 ML AT LAKE MICHIGAN BEACHES IN CHICAGO, 2000 THROUGH 2002

Park District	Beach	YEAR					
		2000		2001		2002	
Chicago	Calumet	14	(70)[1]	12	(72)	12	(72)
Chicago	Rainbow	15	(68)	18	(73)	14	(74)
Chicago	South Shore	11	(69)	11	(73)	12	(71)
Chicago	Jackson/63rd	27	(70)	31	(76)	15	(73)
Chicago	57th Street	15	(68)	12	(75)	10	(70)
Chicago	49th Street	ND		ND		7	(68)
Chicago	31st Street	21	(69)	18	(73)	8	(68)
Chicago	12th Street	15	(67)	15	(73)	11	(69)
Chicago	Ohio Street	3	(68)	6	(71)	11	(71)
Chicago	Oak Street	4	(68)	10	(73)	9	(71)
Chicago	North Ave	6	(68)	8	(73)	10	(71)
Chicago	Montrose	14	(67)	15	(75)	9	(71)
Chicago	Foster	11	(68)	12	(73)	9	(68)
Chicago	Hollywood/ Ostermann	17	(69)	12	(73)	8	(69)
Chicago	Thorndale	12	(69)	14	(73)	9	(69)
Chicago	Albion	7	(67)	12	(73)	11	(71)
Chicago	North Shore	7	(68)	11	(73)	11	(70)
Chicago	Pratt	9	(68)	13	(71)	9	(71)
Chicago	Leon/Loyola	9	(69)	9	(71)	9	(71)
Chicago	Jarvis/Fargo	8	(68)	10	(69)	10	(71)
Chicago	Howard	8	(67)	6	(73)	14	(71)
Chicago	Rogers	9	(66)	8	(71)	12	(72)
Chicago	Juneway	10	(67)	11	(72)	9	(69)
Totals		252		274		239	

[1]Number of days for which analysis for EC was performed.

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TABLE 4

NUMBER OF DAYS THAT THE FECAL COLIFORM CONCENTRATION WAS GREATER THAN 500 CFU/100 ML AT LAKE MICHIGAN BEACHES IN ILLINOIS NORTH OF CHICAGO, 2000 THROUGH 2001

Park District	Beach	Year 2000		Year 2001	
Evanston	Clark Street	0	(68)[1]	0	(55)
Evanston	Dog	0	(3)	ND	
Evanston	Greenwood	0	(65)	1	(63)
Evanston	Lee Street	0	(66)	0	(59)
Evanston	Lighthouse	0	(67)	0	(61)
Evanston	Northwestern	0	(60)	0	(32)
Evanston	South Blvd	0	(69)	0	(60)
Glenco	Glenco	12	(98)	18	(89)
Lake County	IBSP[2] - North	2	(43)	5	(95)
Lake County	IBSP - South	13	(70)	11	(96)
Lake County	IBSP - Sailing	4	(66)	ND	
Lake County	Lake Bluff	2	(58)	2	(95)
Lake County	Lake Forest	3	(61)	12	(95)
Lake County	Moraine Park	0	(2)	0	(4)
Lake County	North Point Marina	20	(67)	33	(94)
Lake County	Park Avenue	4	(59)	8	(95)
Lake County	Rosewood	4	(59)	16	(95)
Lake County	Waukegan North	11	(60)	10	(95)
Lake County	Waukegan South	9	(61)	20	(95)
Wilmette	Wilmette North	1	(93)	2	(88)
Wilmette	Wilmette South	2	(91)	2	(88)
Winnetka	Elder	2	(83)	ND	
Winnetka	Ken	3	(88)	ND	
Winnetka	Lloyd	0	(76)	ND	
Winnetka	Maple	2	(77)	ND	
Winnetka	Tower	1	(82)	ND	
Totals		95		140	

[1]Number of days for which analysis for FC was performed.
[2]Illinois Beach State Park.

at all six beaches in Evanston in 2000 and 2001, that is, the FC concentration was greater than 500 FC/100 mL at one beach (Greenwood) for one day during that two year period. These data suggest that the water quality at the Jackson/63rd Street Beach was the poorest of all the beaches studied, while the water quality at the beaches in Evanston was the best. At the suburban beaches north of Chicago the number of violations of the Bathing Beach Code was greatest at Lake County North Point Marina, 20 violations in 2000 and 33 violations in 2001.

Results of ANOVA indicated that the GMs of the EC concentrations at the beaches in Chicago are unequal, and that the GMs of the FC concentrations at the beaches in Evanston and in Lake County are also unequal. Results of ANOVA indicated that there was no difference in the GMs of the FC concentrations at the two beaches in Wilmette or the five beaches in Winnetka. These data are shown in Table 5. Differences in mean bacterial levels between individual beaches within the Chicago beach network and individual beaches within the Lake County beach network may be due to any of the following:

- The large expanse of Lake Michigan shoreline which they cover, when compared to the Wilmette

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TABLE 5

SIGNIFICANCE TEST ON THE EQUALITY OF GEOMETRIC MEANS OF E.COLI OR FECAL COLIFORM CONCENTRATIONS AT ALL BEACHES WITHIN EACH PARK DISTRICT

Park District	Number of Beaches to Compare	Bartlett Test or F Test on Equality of Variances[1]	Significance Probability (P-value) on Equality of Means[2]
Chicago	23	0.0712	0.0001 [a]
Evanston	7	0.6829	0.0238 [b]
Glencoe	1	*	*
Lake County	11	0.0693	0.0001 [c]
Wilmette	2	0.4805 [d]	0.3947
Winnetka	5	0.4428	0.8002

[1]Please see Column 5 of Table 2.
[2]A P-value of ≤ 0.05 indicates that means are unequal.
[a]Please see Table 6 for multiple comparison.
[b]Please see Table 7 for multiple comparison.
*Test is not applicable because there is only 1 beach.
[c]Please see Table 8 for multiple comparison.
[d]F test is applied.

or Winnetka beach network which did not show intracity differences;

- differences in the number of patrons at the different beaches;
- differences in housekeeping practices, including beach security, from beach to beach;
- the location and magnitude of point and nonpoint sources of pollution.

The variability in Evanston bacterial levels between beaches within Evanston may be a statistical anomaly as discussed later.

Results of the SNK test performed on data from the beaches in the Chicago Park District, shown in Table 6, are consistent with the conclusion that the water quality at the Jackson/63rd Street Beach was the poorest of all the beaches in Chicago. These data also suggest that the water quality at the Calumet, Rainbow, South Shore, 57th Street, 31st Street, 12th Street, Montrose, Hollywood/Osterman, Thorndale, and Jackson/63rd Street beaches was poorer than the water quality at the rest of the beaches in Chicago. This conclusion is reached by considering the results of the SNK test in conjunction with the basic statistics presented in Table 2.

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TABLE 6

GROUPING OF E.COLI GEOMETRIC MEANS
AT CHICAGO PARK DISTRICT BEACHES BY THE SNK METHOD

Beach Name	Number of Observations	Geometric Means (CFU/100 mL)	SNK Grouping[1,2]
Calumet	215	66.3	BC
Rainbow	216	76.5	B
South Shore	213	64.8	BC
Jackson/63rd	220	133.6	A
57th Street	214	57.2	BCD
31st Street	211	58.1	BCD
49th Street	69	17.7	H
12th Street	210	50.3	BCDEF
Ohio Street	211	27.7	GH
Oak Street	213	32.1	EFG
North Ave	213	35.4	DEFG
Montrose	215	58.1	BCD
Foster	210	43.2	CDEFG
Hollywood/Osterman	212	49.2	BCDEF
Thorndale	212	52.7	BCDE
Albion	212	28.3	GH
Pratt	211	31.1	FG
Leon/Loyola	212	34.5	DEFG
Jarvis/Fargo	212	28.8	GH
Howard	212	27.3	GH
Rogers	210	28.7	GH
North Shore	212	28.6	GH
Juneway	210	28.3	GH

[1]Results of the Student-Newman-Keuls (SNK) Test; Beaches with at least one letter in common have equal means.
[2]Results of the SNK test performed with rainfall as a covariate were the same as those shown here.

Results of the SNK test performed on data from the beaches in Evanston are shown in Table 7. These results would indicate that the water quality at Dog Beach is better than that at the six other beaches in Evanston. However, there were only three observations for Dog Beach, and it would not be appropriate to draw a conclusion based upon only three observations. The results shown in Table 7 indicate that there was no difference in the water quality at the remaining six beaches in Evanston.

Results of the SNK test performed on data from the beaches in Lake County, shown in Table 8, suggest that the water quality at the North Point Marina Beach was the poorest of all the beaches in Lake County. Results shown in Table 8 also show that there was no difference in water quality at IBSP - North, IBSP - Sailing, Lake Bluff Park District, Lake Forest Park District, Moraine Park, Park Avenue, and Rosewood, and the water quality at these beaches was better than that at the other beaches in Lake County.

River Reversals and Beach Closings

There were not enough river reversals in the 2000-2002 monitoring period to do any kind of meaningful statistical analysis regarding their impact on beach closings. However,

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TABLE 7

GROUPING OF FECAL COLIFORM GEOMETRIC MEANS AT EVANSTON BEACHES BY THE SNK METHOD

Beach Name	Number of Observations	Geometric Means (CFU/100 mL)	SNK Grouping[1,2]
Clark Street	123	17.5	A
Dog	3	1.3	B
Greenwood	129	19.3	A
Lee Street	126	17.0	A
Lighthouse	129	18.3	A
Northwestern	92	28.0	A
South Blvd.	129	16.7	A

[1]Results of the Student-Newman-Keuls (SNK) Test; Beaches with at least one letter in common have equal means.
[2]Results of the SNK test performed with rainfall as a covariate were the same as those shown here.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 8

GROUPING OF FECAL COLIFORM GEOMETRIC MEANS AT LAKE COUNTY PARK DISTRICT BEACHES BY THE SNK METHOD

Beach Name	Number of Observations	Geometric Means (CFU/100 mL)	SNK Grouping[1,2]
Illinois Beach State Park - North	187	44.5	DE
Illinois Beach State Park - South	249	68.2	CD
Illiois Beach State Park - Sailing	132	52.1	CDE
Lake Bluff Park	153	27.5	E
Lake Forest Park	156	55.3	CDE
Moraine Park	6	26.4	E
North Point Marina	258	213.0	A
Park Avenue	155	41.9	DE
Rosewood	154	56.7	CDE
Waukegan North	156	106.0	BC
Waukegan South	156	181.3	AB

[1]Results of the Student-Newman-Keuls (SNK) Test; Beaches with at least one letter in common have equal means.
[2]Results of the SNK test performed with rainfall as a covariate were the same as those shown here.

inspection of the data shows that reversals to the Lake at the Wilmette, Chicago River, and O'Brien facilities do not explain all of the beach closing in the Chicagoland area in those years. For example, there were no river reversals to the Lake in 2000, yet there were 347 violations of the Bathing Beach Code at the beaches in the study area as shown in Tables 2 and 3. Comparing the total number of violations of the Bathing Beach Code to the number of violations coinciding with river reversals to the Lake in 2001 and 2002 also supports the conclusion that beach closings have many causes other than river reversals. (See Figures 2 and 3.) This can be explained by the numerous other potential sources of bacterial contamination at Lake Michigan beaches, both man-made and natural, which contribute to the pollutant load. These include the following (Lue-Hing et al., 1981; Chicago Park District, 2002; Moffett, 2002; NRDC, 2002; Rohde, 2002; Skavroneck, 2000):

- Seagull and other bird droppings.
- Pet droppings.
- Droppings from vagrant humans.
- Urban runoff (yards, roofs, roads, business and industrial sites).

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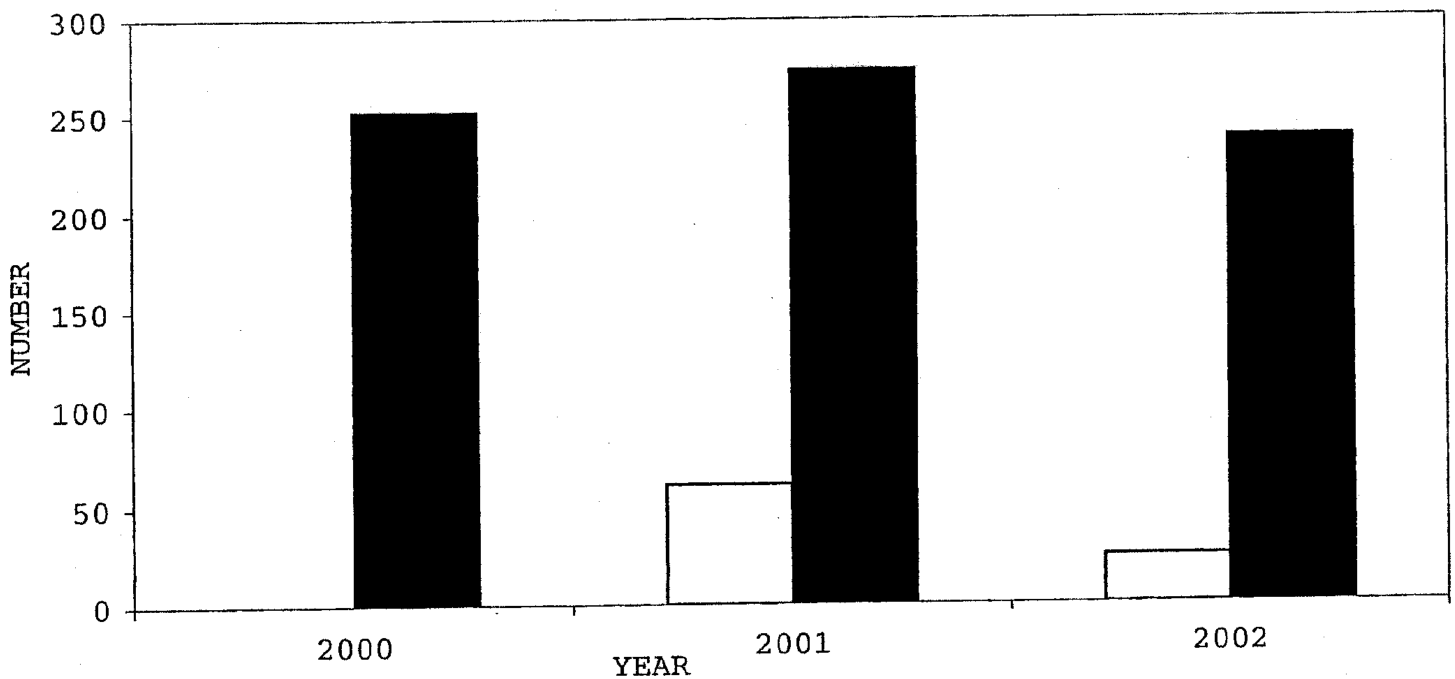
FIGURE 2

TOTAL NUMBER OF VIOLATIONS[1] OF THE BATHING BEACH CODE COMPARED TO THE NUMBER OF VIOLATIONS COINCIDING[2] WITH RIVER REVERSALS AT CHICAGO PARK DISTRICT BEACHES, 2000 - 2002



[1] Days on which the EC concentration was >235 CFU/100 mL.

[2] Same day as reversal or either of the following two days.

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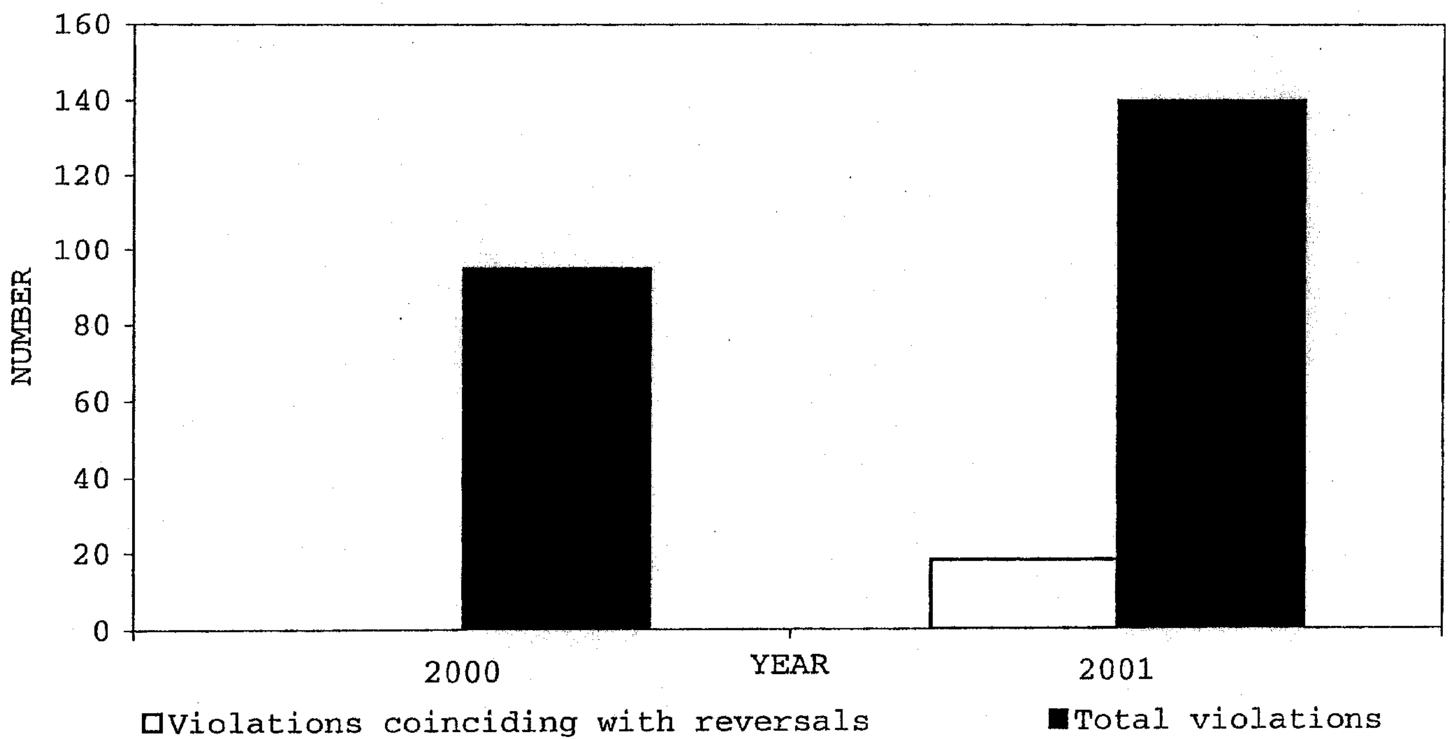
FIGURE 3

TOTAL NUMBER OF VIOLATIONS[1] OF THE BATHING BEACH CODE COMPARED TO THE NUMBER OF VIOLATIONS COINCIDING[2] WITH RIVER REVERSALS AT BEACHES NORTH[3] OF CHICAGO, 2000 - 2001



[1] Days on which the FC concentration was >500 CFU/100 mL.

[2] Same day as reversal or either of the following two days.

[3] Glencoe, Lake County, Wilmette, and Winnetka.

- Runoff from parks (grasslands and forests).
- Contaminated sediments.
- Fecal contamination from swimmers.
- *E.coli* in beach sand.
- Sanitary sewer overflows, combined sewer overflows, and/or nonpoint stormwater runoff from areas outside of Cook County, Illinois.

Models to Predict EC and FC Concentrations

Results of standard statistical analysis showed that $I^{1/7}$ (when I = inches of rainfall) gave the best fit for the simple regression models developed to predict EC or FC concentrations as a function of rainfall amount at a particular beach. The simple regression models are shown in Table 9.

Auto regressive models with rainfall as an explanatory variable predicted EC or FC concentrations better than those without rainfall. These models are also shown in Table 9. The auto regressive models developed without rainfall are not shown. Akaike's Information Criteria for both the auto regressive and simple regression models are shown in Table 10. In every case the AIC indicated that the simple regression

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TABLE 9

AUTO REGRESSIVE AND SIMPLE REGRESSION MODELS DERIVED FROM E.COLI (EC) OR FECAL COLIFORM (FC) DATA FROM ALL PARK DISTRICTS

Park District	Beach	Auto Reg Model[1] Ln(EC) or Ln(FC) =	Reg Model[2] Ln(EC) or Ln(FC) =
Chicago	Calumet	$0.50*V_{t-1}+0.32*V_{t-2}+0.16*V_{t-3}+0.35*I$	5.18*I
Chicago	Rainbow	$0.42*V_{t-1}+0.27*V_{t-2}+0.29*V_{t-3}+0.81*I$	5.81*I
Chicago	South Shore	$0.66*V_{t-1}+0.30*V_{t-2}+0.88*I$	5.17*I
Chicago	Jackson/63^{rd}	$0.61*V_{t-1}+0.36*V_{t-2}+0.58*I$	6.47*I
Chicago	57^{th} Street	$0.76*V_{t-1}+0.17*V_{t-2}+0.99*I$	5.57*I
Chicago	31^{st} Street	$0.55*V_{t-1}+0.39*V_{t-2}+1.12*I$	5.56*I
Chicago	49^{th} Street	$0.28*V_{t-1}+0.31*V_{t-2}+0.32*V_{t-3}$	NRD[3]
Chicago	12^{th} Street	$0.34*V_{t-1}+0.31*V_{t-2}+0.31*V_{t-3}+1.30*I$	5.36*I
Chicago	Ohio Street	$0.42*V_{t-1}+0.39*V_{t-2}+0.16*V_{t-3}+1.34*I$	4.65*I
Chicago	Oak Street	$0.35*V_{t-1}+0.30*V_{t-2}+0.31*V_{t-3}+1.33*I$	4.90*I
Chicago	North Ave	$0.39*V_{t-1}+0.34*V_{t-2}+0.24*V_{t-3}+1.39*I$	4.94*I
Chicago	Montrose	$0.57*V_{t-1}+0.38*V_{t-2}+0.58*I$	5.34*I
Chicago	Foster	$0.40*V_{t-1}+0.37*V_{t-2}+0.19*V_{t-3}+0.51*I$	5.22*I
Chicago	Hollywood/Osterman	$0.43*V_{t-1}+0.23*V_{t-2}+0.30*V_{t-3}+0.52*I$	5.65*I
Chicago	Thorndale	$0.36*V_{t-1}+0.34*V_{t-2}+0.26*V_{t-3}+0.57*I$	5.61*I
Chicago	Albion	$0.41*V_{t-1}+0.36*V_{t-2}+0.17*V_{t-3}+0.83*I$	4.82*I
Chicago	Pratt	$0.49*V_{t-1}+0.18*V_{t-2}+0.27*V_{t-3}+0.62*I$	4.94*I
Chicago	Leon/Loyola	$0.61*V_{t-1}+0.32*V_{t-2}+0.68*I$	5.06*I
Chicago	Jarvis/Fargo	$0.51*V_{t-1}+0.41*V_{t-2}+0.78*I$	4.79*I
Chicago	Howard	$0.54*V_{t-1}+0.35*V_{t-2}+0.79*I$	4.61*I
Chicago	Rogers	$0.50*V_{t-1}+0.40*V_{t-2}+0.88*I$	4.80*I
Chicago	North Shore	$0.47*V_{t-1}+0.46*V_{t-2}+0.67*I$	4.78*I
Chicago	Juneway	$0.42*V_{t-1}+0.30*V_{t-2}+0.20*V_{t-3}+0.93*I$	4.88*I
Evanston	Clark Street	$0.43*V_{t-1}+0.19*V_{t-2}+0.29*V_{t-3}+0.99*I$	4.42*I
Evanston	Dog	NRD	NRD
Evanston	Greenwood	$0.53*V_{t-1}+0.35*V_{t-2}+0.40*I$	4.31*I
Evanston	Lee Street	$0.51*V_{t-1}+0.38*V_{t-2}+1.63*I$	4.79*I
Evanston	Lighthouse	$0.29*V_{t-1}+0.32*V_{t-2}+0.31*V_{t-3}+0.09*I$	4.03*I
Evanston	Northwestern	$0.34*V_{t-1}+0.32*V_{t-2}+0.26*V_{t-3}+0.82*I$	4.43*I
Evanston	South Blvd	$0.36*V_{t-1}+0.22*V_{t-2}+0.34*V_{t-3}+0.61*I$	4.13*I

TABLE 9 (Continued)

AUTO REGRESSIVE AND SIMPLE REGRESSION MODELS DERIVED FROM E.COLI (EC) OR FECAL COLIFORM (FC) DATA FROM ALL PARK DISTRICTS

Park District	Beach	Auto Reg Model[1] Ln(EC) or Ln(FC) =	Reg Model[2] Ln(EC) or Ln(FC) =
Glencoe	Glencoe	$0.40*V_{t-1}+0.30*V_{t-2}+0.25*V_{t-3}+0.75*I$	5.49*I
Lake Cty[4]	IBSP[5] - North	$0.92*V_{t-1}+0.50*I$	4.85*I
Lake Cty	IBSP - South	$0.73*V_{t-1}+0.21*V_{t-2}+0.85*I$	5.47*I
Lake Cty	IBSP - Sailing	$0.97*V_{t-1}+1.30*I$	4.67*I
Lake Cty	Lake Bluff	$0.59*V_{t-1}+0.35*V_{t-2}+0.17*I$	4.02*I
Lake Cty	Lake Forest	$0.31*V_{t-1}+0.25*V_{t-2}+0.41*V_{t-3}+0.69*I$	5.20*I
Lake Cty	Moraine Park	$0.82*V_{t-1}+9.12*I$	4.97*I
Lake Cty	North Point Marina	$0.66*V_{t-1}+0.31*V_{t-2}+0.63*I$	6.78*I
Lake Cty	Park Avenue	$0.51*V_{t-1}+0.23*V_{t-2}+0.22*V_{t-3}+0.54*I$	4.47*I
Lake Cty	Rosewood	$0.66*V_{t-1}+0.28*V_{t-2}+1.18*I$	4.77*I
Lake Cty	Waukegan North	$0.48*V_{t-1}+0.23*V_{t-2}+0.26*V_{t-3}+0.19*I$	5.78*I
Lake Cty	Waukegan South	$0.37*V_{t-1}+0.26*V_{t-2}+0.35*V_{t-3}+0.15*I$	6.38*I
Wilmette	Wilmette North	$0.36*V_{t-1}+0.40*V_{t-2}+0.19*V_{t-3}+0.35*I$	4.32*I
Wilmette	Wilmette South	$0.53*V_{t-1}+0.41*V_{t-2}+0.31*I$	4.63*I
Winnetka	Elder	$0.95*V_{t-1}+0.25*I$	7.21*I
Winnetka	Ken	$0.96*V_{t-1}+0.74*I$	6.80*I
Winnetka	Lloyd	$0.96*V_{t-1}+0.77*I$	7.59*I
Winnetka	Maple	$0.96*V_{t-1}+0.13*I$	6.83*I
Winnetka	Tower	$0.95*V_{t-1}+0.47*I$	7.00*I

[1]V_t = Ln(EC or FC) at Time t;
V_{t-1} = Ln(EC or FC) at t minus one day;
V_{t-2} = Ln(EC or FC) at t minus two days;
V_{t-3} = Ln(EC or FC) at t minus three days;
$I = (\text{Inches of rain})^{1/7}$.

[2]Simple Regression Model where $I = (\text{Inches of rain})^{1/7}$.

[3]No Rain Data.

[4]Lake County.

[5]Illinois Beach State Park.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 10

FIT CRITERIA FOR THE AUTO REGRESSIVE AND SIMPLE REGRESSION MODELS[1]

Park District	Beach	AIC[2] Auto Reg Model	AIC Regression Model	R2 Regression Model
Chicago	Calumet	497.40	382.30	0.29
Chicago	Rainbow	482.20	385.90	0.31
Chicago	South Shore	489.50	380.30	0.27
Chicago	Jackson/63rd	564.60	431.80	0.33
Chicago	57th Street	557.00	379.40	0.32
Chicago	31st Street	561.80	391.60	0.29
Chicago	49th Street	525.70	NRD[3]	NRD
Chicago	12th Street	525.70	364.80	0.31
Chicago	Ohio Street	478.00	299.20	0.33
Chicago	Oak Street	509.00	316.40	0.34
Chicago	North Ave	497.80	333.60	0.30
Chicago	Montrose	574.10	384.10	0.28
Chicago	Foster	499.40	329.90	0.27
Chicago	Hollywood/Osterman	509.90	344.70	0.28
Chicago	Thorndale	493.20	339.40	0.28
Chicago	Albion	508.80	294.70	0.29
Chicago	Pratt	507.80	304.10	0.28
Chicago	Leon/Loyola	496.70	315.10	0.28
Chicago	Jarvis/Fargo	508.70	300.80	0.27
Chicago	Howard	529.10	296.40	0.27
Chicago	Rogers	515.40	287.40	0.28
Chicago	North Shore	508.90	298.00	0.28
Chicago	Juneway	523.70	292.30	0.30
Evanston	Clark Street	449.10	248.60	0.22
Evanston	Dog	NRD	NRD	NRD
Evanston	Greenwood	483.60	271.60	0.21
Evanston	Lee Street	477.10	253.30	0.26
Evanston	Lighthouse	489.30	265.80	0.19
Evanston	Northwestern	353.80	215.40	0.14
Evanston	South Blvd.	476.30	263.90	0.20

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 10 (Continued)

FIT CRITERIA FOR THE AUTO REGRESSIVE AND SIMPLE REGRESSION MODELS[1]

Park District	Beach	AIC[2] Auto Reg Model	AIC Regression Model	R2 Regression Model
Glencoe	Glencoe	690.20	467.90	0.25
Lake County	IBSP[4] - North	688.50	452.50	0.24
Lake County	IBSP - South	931.20	651.40	0.28
Lake County	IBSP - Sailing	385.50	329.20	0.19
Lake County	Lake Bluff Park Dist.	547.20	340.60	0.25
Lake County	Lake Forest Park Dist.	589.00	395.60	0.28
Lake County	Moraine Park	30.00	16.10	0.16
Lake County	North Point Marina	943.90	788.20	0.29
Lake County	Park Avenue	582.00	382.70	0.25
Lake County	Rosewood	611.40	410.90	0.23
Lake County	Waukegan North	583.50	437.50	0.28
Lake County	Waukegan South	563.40	467.10	0.29
Wilmette	Wilmette North	616.10	416.40	0.22
Wilmette	Wilmette South	633.60	423.00	0.23
Winnetka	Elder	331.50	255.50	0.31
Winnetka	Ken	350.50	283.70	0.23
Winnetka	Lloyd	304.50	242.20	0.28
Winnetka	Maple	309.60	239.30	0.28
Winnetka	Tower	346.60	256.90	0.28

[1]See Table 9.

[2]Akaike's Information Criterion.

[3]No Rain Data.

[4]Illinois Beach State Park.

model is better than the auto regressive model with rainfall as an explanatory variable.

The R^2 values calculated for the simple regression models range from 0.14 to 0.34 with an average value of 0.27. These values are shown in Table 10. These values indicate that the ln EC and ln FC concentrations at the beaches studied do correlate with a function of rainfall, specifically, $I^{1/7}$, but the range of these R^2 values indicates that the correlation is weak.

Given the many factors affecting bacterial levels at any given beach, discussed below, the calculated R^2 values in this rather low range is perhaps not that surprising. Furthermore, the number of EC or FC washed into the Lake from nonpoint sources almost certainly varies from one rainfall event to the next. The "first flush" after a long dry spell may wash many more bacteria into the Lake than a rainfall event closely following the previous rainfall event.

Factors Affecting Bacterial Levels at a Given Beach

Following the introduction of fecal pollution in Lake Michigan from one or more of the sources cited above, nature will take its course and "clean up" the Lake. Consider the case of extremely heavy rainfall in the Chicagoland area resulting in reversals to the Lake. The FC concentrations at various locations in Lake Michigan are monitored by the District after a reversal occurs. The FC levels drop to very low to undetectable levels within a few hours of the reversal, and beach closings have rarely lasted for more than 48 hours following a reversal event. See MSD, 1986, for example. This observation is consistent with observations for other bodies of water including Onondaga Lake, the Potomac River, and Grand Traverse Bay, Lake Michigan cited by Auer and Niehaus (1993).

Lake Michigan is a large body of water and contaminants, including the bacterial indicator organisms as well as any pathogens, will be dispersed. Dispersion will be influenced by factors such as wave height, air and water temperature, and wind direction and strength. See Francey and Darner (1998). The trajectory of material floating on a large body of water such as Lake Michigan is determined primarily by wind direction and strength (See Lue-Hing et al., 1981). The transfer of energy from wind to the water is affected by the temperature difference between air and water. The rate of dispersion and the direction the contaminants travel will be dependent upon all of these factors.

The bacterial indicator organisms and any pathogens will also die-off with time. The rapid disappearance of these organisms due to the self-purification of the water body is influenced by the following factors:

- Sedimentation.
- Adsorption onto surfaces.
- Predation.
- Dilution.
- Temperature.
- Algal toxins.
- Bacteriophages.
- Lack of nutrients.
- pH.
- Solar radiation.

Among these, solar radiation, temperature, and the combined effects of solar radiation and temperature are considered the most important (Mitchell and Chamberlin, 1978).

Simple Regression Models in Perspective

At this point it is appropriate to emphasize that the data used for this study are routine monitoring data. The study was conceived after the data were collected to address public concerns. The rainfall data used are the best available data, but the rainfall data were not collected at the given beaches for a designed study. Intuition indicates that the R^2 values for the simple regression models derived by the method described above and shown in Table 10 might be higher if rainfall data at the beach were available. While this is speculative, it is appropriate to mention here because in the design of an experimental study, data should be collected where the variable would likely impact the result. Nevertheless, the modeling results indicate that the correlation of EC and FC levels with rainfall is weak.

Salient Findings of this Study

The data and analyses in this report showed that CSO discharges, or more specifically, river reversals to the Lake, are not the cause for the increase in beach closings and advisories in the Chicagoland area between 1998 and 2002. As of 2001, the Tunnel and Reservoir Plan (TARP) has cumulatively captured 565 billion gallons of CSO that would otherwise have flowed to area receiving waters. Prior to the implementation of TARP, reversals to Lake Michigan were not an uncommon occurrence. During periods of excessive rainfall it was often necessary to reverse the rivers to prevent or to at least alleviate flooding. The implementation of TARP has already dramatically reduced the number of times the rivers are reversed to the Lake (Lue-Hing, 1992).

The data and analyses presented in this report showed that water quality, as assessed by monitoring EC and FC densities at the Lake Michigan beaches in the Chicagoland area, is weakly correlated with rainfall. Specifically, EC and FC densities at the Lake Michigan beaches correlated weakly with a function of rainfall, $I^{1/7}$, where I equals inches of rainfall. This may be linked to the impact of nonpoint source runoff of stormwater into the Lake. Parenthetically, this finding suggests that it may be appropriate for local park districts to study the feasibility of implementing best management practices (BMP) (NRCS 1997; NRCS 1998; Tunkiewicz and D, 2003) to minimize the impact of nonpoint source pollution at the beaches in the Chicagoland area.

REFERENCES

Auer, M. T. and S. L. Niehaus, 1993, Modeling Fecal Coliform Bacteria-Field and Laboratory Determination of Loss Kinetics, Water Research 27: 693-701.

Box, G. E. P. and G. M. Jenkins, 1970, *Times Series Analysis, Forecasting and Control*, Holden-Day Inc., San Francisco, California.

Brock, T. D., 1983, Microbiological Examination of Water, In *Membrane Filtration: A User's Guide and Reference Manual*, T. D. Brock, Science Tech, Inc., Madison, Wisconsin.

Calderon, R. L., E. W. Mood, and A. Dufour, 1991, Health Effects of Swimmers and Nonpoint Sources of Contaminated Water, *International Journal of Environmental Health Research* 1: 21-31.

Chicago Park District, 2002, 2002 *Final Beach Report, Chicago Park District*, Chicago, Illinois.

Dyer, D. D. and J. P. Keating, 1980, On the Determination of Critical Values for Bartlett's Test, *Journal of the American Statistical Association* Volume 75, Number 370, Applications Section.

Ferley, J. P., D. Zmirou, F. Balduci, B. Baleux, P. Feras, G. Larbaigt, E. Jaco, B. Moissonnier, A. Blineau, and J. Boudot, 1989, Epidemiological Significance of Microbiological Pollution Criteria for River Recreational Waters, *International Journal of Epidemiology* 18: 198-205.

Francy, D. S. and R. A. Darner, 1998, Factors Affecting *Escherichia coli* Concentrations at Lake Erie Public Bathing Beaches: U.S. Geological Survey Water-Resources Investigations Report 98-4241.

Gibbons, J. D., and S. Chakraborti, 1992, *Nonparametric Statistical Inference*, 3rd Edition, Marcel Dekker Inc., New York, New York.

Gore, R., J. T. Zmuda, Z. Abedin, B. Sawyer, and R. Lanyon, (In preparation), *Escherichia coli* to Fecal Coliform Ratios in Effluents and Receiving Waters in the Metropolitan Water Reclamation District of Greater Chicago, Metropolitan Water Reclamation District of Greater Chicago, Chicago, Illinois.

Havelaar, A., U. J. Blumenthal, M. Strauss, D. Kay, and J. Bartram, 2001, Guidelines: the Current Position, In *Water Quality: Guidelines, Standards and Health*, L. Fewtrell and J. Bartram, Editors, IWA Publishing, London, UK.

Khattree, R. and N. N. Dayanand, 1999, *Applied Multivariate Statistics, With SAS Software*, 2nd Edition, SAS Institute Inc., Cary, North Carolina.

Lake Michigan Federation, 2002, 2002 Beach Closings Press Release, Chicago, Illinois.

Lue-Hing, C., 1992, *Protecting Lake Michigan Water Quality: Overview of the Policies and Programs of the Metropolitan Water Reclamation District of Greater Chicago*, Report No. 92-19, Metropolitan Water Reclamation District of Greater Chicago, Chicago, Illinois, July 1992.

Mallin, M. A., 1998, Land-Use Practices and Fecal Coliform Pollution of Coastal Water, Proceedings, 14th Annual North Carolina On-Site Wastewater Treatment Conference, North Carolina Department of Environment, Health, and Natural Resources, North Carolina State University, Raleigh, North Carolina, October 27-29, 1998.

Mallin, M., K. Williams, E. Esham, and R. Lowe, 2000, Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds, *Ecol. Appl*. 10: 1047-1056.

Mitchell, R. and C. Chamberlin, 1978, Survival of Indicator Organisms In *Indicators of Viruses in Water and Food*, G. Berg ed., Ann Arbor Science, Ann Arbor, Michigan.

Moffett, N., 2002, Drawing a Curtain on Beach Closings, Chicago Sun-Times, December 16, 2002, Chicago, Illinois.

MSD, 1986, Lake Michigan Water Quality Clean Water Quality, Fourth Quarter 1986, Research and Development Department, Metropolitan Sanitary District of Greater Chicago, February 1987.

MWRDGC, 1988, *Facilities Planning Study Update Supplement and Summary December 1988*, Metropolitan Water Reclamation District of Greater Chicago, Chicago, Illinois.

Natural Resources Defense Council, 1999, A Guide to Water Quality at Vacation Beaches, National Resources Defense Council, New York, New York.

Noble, R. T., J. Dorsey, M. Leecaster, D. Reid, K. C. Schiff, and S. B. Weisberg, 2000, A Regional Survey of the Microbiological Water Quality Along Southern California Bight shoreline, *Environ. Monit. Assess.* 64: 435-447.

Noble, R. T., S. B. Weisberg, M. K. Leecaster, C. D. McGhee, J. H. Dorsey, P. Vainik, and V. Orozco-Borbon, 2003, Storm Effects on Regional Beach Water Quality Along the Southern California Shoreline, *Journal of Water and Health* 1: 23-31.

NRCS, 1997, *National Handbook of Conservation Practices*, Contour Buffer Strips, Code 332, National Resource Conservation Service, July 1997.

NRCS, 1998, *National Handbook of Conservation Practices*, Filter Strips, Code 393, National Resource Conservation Service, September 1998.

NRDC, 2002, Illinois, in *Testing the Waters*, National Resources Defense Council, July 2002, New York, New York.

Rohde, M., 2002, Experts Can't Pin Down Surge in Beach Closing, JSOnline, Milwaukee Journal Sentinal, Updated October 28, 2002, Milwaukee, Wisconsin.

SAS Institute Inc., 1995, *SAS Procedures Guide*, SAS Institute Inc., Cary, North Carolina.

SAS Institute Inc., 2000, *Forecasting Techniques Using SAS/ETS Software*, Course Notes, SAS Institute Inc., Cary, North Carolina.

Schiff, K. C., J. Morton, and S. B. Weisberg, In press, Retrospective Evaluation of Shoreline Water Quality Along Santa Monica Bay Beaches, *Mar. Environ. Res.*

Skavronek, S., 2000, No Swimming Allowed! Bacterial Hazards at Lake Michigan Beaches, Citizens for a Better Environment, Milwaukee, Wisconsin.

Terrio, P. J., 1994, Relation of Changes in Wastewater Treatment Practices to Changes in Stream Water Quality During 1978-1988 in the Chicago, Area, Illinois, and Implications for Regional and National Water Quality Assessments, *Water Resources Investigation Report 93-4188*, U. S. Geological Survey.

Terry, D., 2002, Milwaukee Blamed for Beach Closings, Chicago Tribune, May 29, 2002, Chicago, Illinois.

Toranzos, G. A., G. A. McFeters, and J. J. Borrego, 2002, Detection of Microorganisms in Environmental Freshwaters and Drinking Waters, In *Manual of Environmental Microbiology*, C. J. Hurst, Editor in Chief, ASM Press, Washington, D.C.

Tunkieicz, J. and D., 2003, DNR Plan Would Spur Closer Scrutiny of Beaches, JS Online, Milwaukee Journal Sentinal, Updated January 25, 2003, Milwaukee, Wisconsin.

United States Environmental Protection Agency, 1986, *Ambient Water Quality Criteria for Bacteria - 1986*, EPA-440/5-84-002, U. S. Environmental Protection Agency, Office of Water, Washington, D.C.

United States Environmental Protection Agency, 2001, Report to Congress: *Implementation and Enforcement of the Combined Sewer Overflow Control Policy*, EPA 833-R-01-003, U. S. Environmental Protection Agency, Office of Water, Washington, D.C.

United States Environmental Protection Agency, 2002a, *National Beach Guidance and Required Performance Criteria for Grants*, EPA-823-B-02-004, U. S. Environmental Protection Agency, Office of Water, Washington, D.C.

United States Environmental Protection Agency, 2002b, Summary of the August 14-15, 2002, Experts Workshop on Public Health Impacts of Sewer Overflows, EPA 833-R-02-002, U. S. Environmental Protection Agency, Office of Wastewater Management, Washington, D.C.

Walpole, R. E. and R. H. Meyers, 1989, *Probability and Statistics for Engineers and Scientists*, 4th Edition, Macmillan Publishing Company, New York, New York.

Young, K. D. and E. L. Thackston, 1999, Housing Density and Bacterial Loading in Urban Streams, *Journal of Environmental Engineering Division of the ASCE* 125: 1177-1180.