Microbiological Monitoring and Assessment of Storm Drain Runoff Within the CBBEP Project Area

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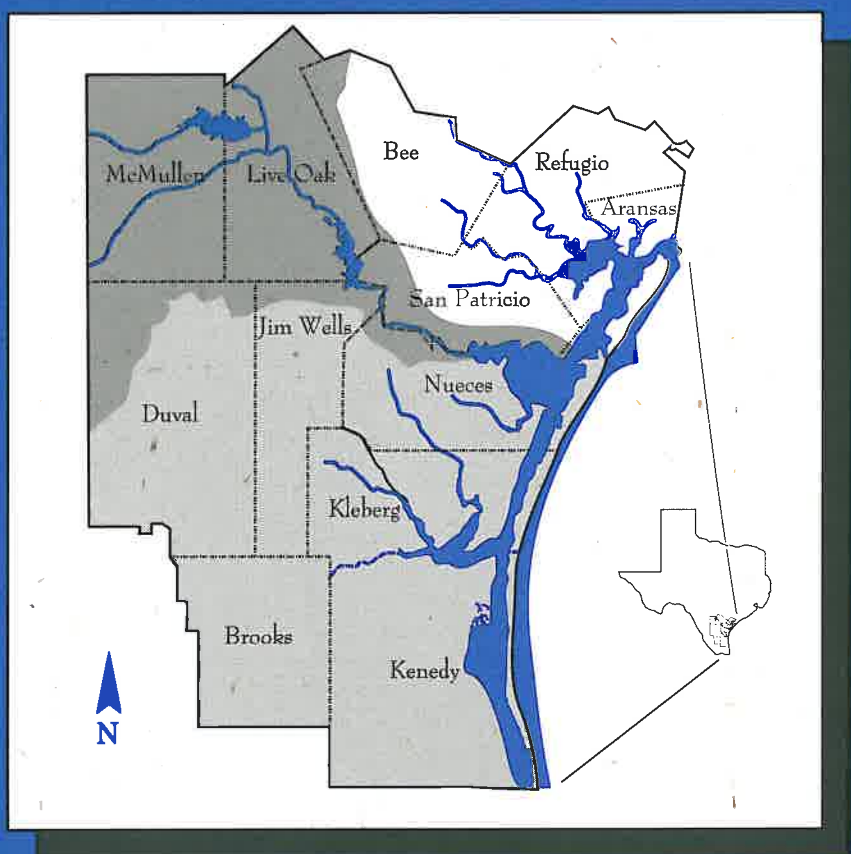

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Joanna Mott, Sara Heilman and Bryan Seidel

EXECUTIVE SUMMARY

Use of coastal waters for recreation increases each year, with concurrent growth in coastal populations. This has resulted in increased production of point and non-point source pollution and degradation in water quality. The safety of these waters for the public is therefore becoming a serious concern. The U.S. Environmental Protection Agency recently initiated a Beaches Environmental Assessment Closure and Health (BEACH) Program (USEPA, 1997a) to improve protection of public health from exposure to disease-causing microorganisms. The EPA document states:

> "Recently collected beach water quality information shows the major sources of pathogens in beach water are untreated or partially treated sewage and storm water runoff".

Among the focus areas of the BEACH program are strengthening beach standards and testing programs and predicting pollution by developing models to calculate potential adverse water quality conditions.

In 1995, an intensive study was conducted in Santa Monica (Haile, 1996). Over 15,000 people were interviewed after swimming near storm drains. An increased incidence of symptoms such as fever, eye discharge, vomiting, diarrhea or sore throats were found in people who had swum close to drains compared to those swimming 400+ yards away. The incidence decreased rapidly with distance from the drains. Indicator bacteria levels were found to be elevated adjacent to the flowing storm drains. Whereas several areas of the country municipalities monitor storm water discharged to coastal waters and close localized beach areas associated with specific storm or rain events, other cities lack such systematic monitoring.

The Coastal Bend Bays and Estuaries Program (CBBEP) project area includes three estuaries that are extensively used for recreational activities. Monitoring of water quality along the Corpus Christi Bay shoreline is conducted on a routine basis (monthly) in dry weather conditions to ensure that ambient levels of indicator bacteria do not exceed acceptable Texas standards for recreational waters (TNRCC, 1995). However, wet weather monitoring is not performed.

The Implementation Strategy for the Coastal Bend Bays Plan (CBBEP, 1998) includes an action plan for Public Health. The first objective in the Bays Plan is "to ensure that any threat of waterborne illness and disease is minimized". The action for that objective is to facilitate a regional approach to recreational water quality management. Development of a predictive model to assess contact recreation risk based on dry/wet weather monitoring is the second step of the Bays Plan action.

There were two parts to the present project. The first part relates specifically to the first action (PH-1) of the Public Health Action Plan in the Implementation Strategy for the Coastal Bend Bays Plan (CBBEP, 1998). This addresses the need for a proactive regional approach to assess and monitor recreational waters, and thus be able to address situations before they become a public concern. The first step listed in this action is to establish a workgroup of public health officials involved with contact recreation issues to address assessment and monitoring needs. In collaboration with CBBEP personnel, appropriate public health officials in the CBBEP area were identified and contacted to meet as a group.

The first workshop (July 21, 1999) was designed as an introductory session to form a working group and to review existing area monitoring programs in relation to national and state recommendations. This was followed by an additional workshop (September 13, 1999) to address issues, concerns and future directions in contact recreation assessment in the Coastal Bend area and to determine the feasibility of developing a coordinated monitoring program. The workshops were an informal discussion format with the main purpose being to facilitate a regional approach to recreational water quality management. Workshop summaries were submitted within 30 days of each meeting. Representatives from four counties participated at the workshops and showed interest in the concept of a regional approach to water quality monitoring. All participants were constrained by lack of funds, with the only consistent monitoring reported for the Corpus Christi Bay shoreline conducted by the City of Corpus Christi-Nueces County Health Department.

The second part of the project was also based on the Public Health Action Plan PH-1. Step two of the action is to identify popular recreation areas and establish a monitoring effort to examine storm drain runoff effects (i.e. wet weather sampling) on water quality. While it is known that most water bodies will exceed EPA criteria after storm drain runoff, the purpose of this study was to assess duration and extent of such impact. The approach was first to identify high-use recreation parks along Corpus Christi Bay. Storm drain outfalls were located and sites assessed for accessibility. The Corpus Christi-Nueces County Health Department and CBBEP personnel were consulted for recommendations. A program of monitoring was established at three of these locations, with three sites per location (at the outfall and at a specific distance each side of the outfall). An additional location, at a greater distance from a storm drain outfall was used as a reference site (Swantner Park). Monitoring was conducted for one and a half years with wet weather sampling after six rainfall events. For two periods of three months (fall and spring) samples were collected five times/month to allow comparison with the EPA standards based on the geometric mean of five samples in thirty days. Levels of fecal indicator organisms (fecal coliforms and enterococci) were enumerated using standard membrane filtration techniques. Total coliform populations were determined for the first year, to establish total:fecal coliform ratios which have been significantly correlated with illness (Haile, 1996). Standard water quality parameters (water temperature, salinity, specific conductance, dissolved oxygen, and pH) were measured at each site.

Trends and levels of each water quality parameter measured in the study were similar to those found in other studies of South Texas coastal waters and did not significantly affect indicator bacteria concentrations. The parameters appeared to be influenced by environmental factors such as seasonal changes (on water temperature) and rainfall (on dissolved oxygen and salinity). For water samples collected during dry weather, differences were found between fecal coliforms and enterococci in relation to the EPA standards. This has implications for evaluation of contact recreation water quality using the proposed standard of enterococci for marine waters instead of fecal coliforms. Enterococci levels exceeded maximum allowable densities more frequently in dry weather water samples and remained elevated after rainfall for a longer period than fecal coliforms, potentially increasing water-use restrictions or beach advisories based on this indicator. Parameters such as turbidity, wave height, wind and current speeds and directions, as well as fecal indicator levels in sediments, need to be evaluated to determine the cause(s) of elevated indicator levels found during dry weather sampling.

Results of wet weather sampling clarified the importance of rainfall on indicator bacteria levels (and probable fecal contamination) in Corpus Christi Bay via storm drain outflow. Levels of indicator bacteria peaked within two days of rainfall at levels sometimes exceeding 10,000 cfu/100 ml. Depending on the quantity of rainfall, levels of enterococci remained above single sample maximum densities for several days following rainfall, long after bay waters returned to calm conditions. Elevated levels of indicator bacteria were found for up to 6 days after 2.8-8.6 cm (≈1-3.5 inch) rainfall and 9-11 days (depending on location) after a 17 cm rainfall. Additional monitoring of wet weather events is needed to determine the relationships between quantity of rainfall and duration of elevated levels, for potential use in predictive modeling and swimming advisories. As rainfall-based alert curves are site-specific and can be based on rainfall characteristics or frequency of exceedance analysis (USEPA 1999a), data collection at each location is required to develop predictive models. The limitation on this work is the frequency, or paucity of rainfall events in the South Texas area.

The effects of storm water outflow extended further than the distances evaluated in this study, although other factors such as shoreline characteristics may influence distance impacted by stormwater outflow. Bacterial concentrations at sites distant from each outfall were not significantly different from those at the outfall in either dry or wet weather. On some occasions, during both dry and wet weather events, densities of bacterial indicators showed trends of higher numbers on one side of the outflow than the other side, possibly due to factors such as wind and wave direction, detrital matter accumulation, and sediment resuspension.

At Ropes Park the entire length of public access shoreline was affected by the outflow. Levels of indicator bacteria were not significantly different in water collected at a distance of 50m from the storm drain compared with concentrations at the storm drain. Cole Park shoreline was also affected at this distance each side of the outflow. The Swantner Park data suggests that at greater distances (the location was approx. 200 m from an outfall) the effect may be reduced. However, storm drain outfalls are generally closer than 200 m at public shoreline access areas along Corpus Christi Bay. Additional work is needed to further clarify the extent of influence of storm drain outflow along the shoreline and offshore and to identify other factors that may play a role in this, such as shoreline topography and wind direction/speed. Shoreline outfalls are not metered, so data was not available on quantities or duration of outflow at each location. It seems likely that differences in both these parameters between locations may at least partially account for differences in the extent and duration of elevated fecal indicator bacteria between locations. Previous rainfall and soil moisture will affect quantity of runoff from a particular rainfall event, in addition to the actual rainfall quantity. Water source differences between outflows may also affect levels of indicator bacteria in bay water samples. Another aspect not addressed in this study is the distance from the shoreline affected by storm drain outflow. Common recreational activities, such as windsurfing at Ropes Park, occur further offshore; additional work is needed to examine stormwater impact in these waters.

Our data show that rainfall would be a useful parameter in predictive modeling of water quality in Corpus Christi Bay. For rainfall events over one inch bacteria levels exceeded the EPA criteria for four to six days, and after extremely high rainfall quantities this period was approximately ten days. This information should be useful for public officials in determining appropriate advisories. Additional data should be collected on indicator levels following rainfall of different intensities to further elucidate the duration of elevated bacterial levels.

The proportion of samples in the "five in 30 day sampling periods" containing enterococci levels above the maximum allowable density is a cause for concern. It also illustrates the difference between using fecal coliforms and enterococci as the indicator for fecal contamination. For one of the months with elevated levels, trace rainfall occurred, without significant outflow into the bay, suggesting further work should include monitoring after small quantities of precipitation. While the standard levels were not exceeded by a large margin compared with wet weather samples, the EPA has linked elevated enterococci levels with increased risk for illness. Based on the results of our study, it is recommended that sampling of beach areas be increased to weekly intervals, at least during summer months when there is maximum use of these waters.

In comparing the shoreline locations studied, water quality at Ropes Park seemed to be the most compromised of the four locations, both in wet and dry weather, followed by Cole Park. This may be related to shoreline characteristics and/or the quantity and sources of stormwater runoff. This park is used by windsurfers in both dry weather and after rainfall, so increased frequency of water monitoring at this location is recommended.

While the total:fecal coliform ratio was affected by rainfall, use of this parameter is not recommended due to both methodology (need to analyze samples for both total coliforms and fecal coliforms) and lack of EPA recognition in standards.

The present research was restricted to four locations along Corpus Christi Bay and was intended as a pilot study to serve as a model for future studies of additional high use CBBEP area waters impacted by stormwater outflows or runoff from rainfall. The extent and duration of elevated indicator bacteria levels found in this study supports the importance of intensive monitoring and characterization of recreational waters. Bacteriological concentrations at urban beaches should be compared with both high usage and infrequently used rural beaches, in order to develop an effective, scientifically based program for beach management in the Coastal Bend region. The research has provided data to characterize effects of stormdrain outflow on Corpus Christi Bay waters that can be used in the development of a predictive model for advisories, based on rainfall. Other factors, such as turbidity, wave height, wind speed and direction still need to be evaluated and should be included in future studies.

Future investigations recommended to fill identified information gaps include: a study to assess Corpus Christi Bay sediment as a source of fecal bacteria; an evaluation of parameters such as turbidity, wave height, tides, antecedent rainfall and wind, as influences on bacteria levels in bay waters; and additional monitoring of wet weather events. Additional work is also needed to clarify the extent of the influence of storm drain outflows along the shoreline and to examine offshore distances impacted. Other factors that may play a role in this, such as shoreline topography and wind direction/speed, still need to be identified. Intensive dry and wet monitoring should be repeated at regular intervals to assess changes in water quality of Corpus Christi Bay shoreline waters, as they continue to be impacted by the increasing Coastal Bend population. Finally, using the present study as a model, other CBBEP recreational waters should be monitored using indicator bacteria to assess water quality and potential contact recreation risk under different environmental conditions.

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INTRODUCTION

Use of coastal waters for recreation increases each year, with concurrent growth in coastal populations. This has resulted in production of more point and non-point source pollution and degradation in water quality. In South Texas, growing populations and tourism both increasingly affect coastal waters, such as Corpus Christi Bay. This bay serves as a recreational area for millions of people (Goonan 1999).

Surface water pollution is usually a result of storm water runoff, sewage overflows, boating wastes, and malfunctioning septic systems (NRDC 1999; Vasconcelos and Anthony 1985). The U.S. Environmental Protection Agency (USEPA) identified the main sources of fecal contamination of beach waters in the statement:

> "Recently collected beach water quality information shows the major sources of pathogens in beach water are untreated or partially treated sewage and storm water runoff". (Beaches Environmental Assessment Closure and Health Program, USEPA 1997a)

Microbial pathogens from these sources can potentially be transmitted to humans during recreational use such as wading, swimming, snorkeling, and scuba diving (Fujioka 1997; Rose 2000). In addition to carrying microorganisms, runoff from stormwater outfalls increases freshwater inflow and nutrients from inland sources, allowing microorganisms already present within the bay to flourish.

Microbiological parameters are one direct way to evaluate water quality as influenced by man and other warm-blooded animals (Joyce 2000). Enteric bacteria have been evaluated as indicators of fecal pollution, and have been the focus of intense research in recent years with regard to their relationship with potential public health risks (Calderon et al. 1991; Ferguson et al. 1996; Schaub 2000; Vasconcelos and Anthony 1985). This subset of bacteria is generally not present or is rare in the water column (Deely et al. 1997). Enteric bacteria are relatively easy to assay, and they parallel the survival of at least some pathogenic organisms. Consequently, this group of microorganisms can serve as indicators of fecal contamination, and can be used to evaluate public health risks associated with recreational water use.

Typically, water quality assessment has relied on the use of total coliforms, fecal coliforms, and fecal streptococci as the enteric indicator organisms (Ferguson et al. 1996; Gannon and Busse, 1989; Joyce 2000). In 1986, the USEPA recommended use of enterococci as an additional indicator of fecal contamination in recreational water, mainly due to the correlation between swimming-associated illness and elevated levels of enterococci (APHA 1995; USEPA 1986). As of 1998, 17 states still relied on fecal coliforms as their primary indicator for marine water. Out of these 17 states, five have adopted the 1986 USEPA recommendation, while three states use both enterococci and fecal coliforms (PBS&J 1999).

Characterization of Indicator Organisms

Enterococci (ENT). These bacteria are generally gram-positive, spherical or ovoid cocci, mesophilic, and facultatively anaerobic (Holt et al. 1994). They occur ubiquitously in the gastrointestinal tracts of warm-blooded animals, comprising a large percentage of fecal biomass (Anderson et al. 1997; Holt et al. 1994). Since there are few strains of *Enterococcus* that naturally occur in the environment, these bacteria serve as good indicators of fecal pollution and, thus, the possible presence of enteric pathogens. (USEPA 1997b).

Enterococci have been shown to mimic the survival of pathogenic microorganisms, and when compared to the coliforms and *E. coli*, exhibit the highest correlation with gastrointestinal symptomology (Dufour, 1984; Messer and Dufour 1998; USEPA 1997b). Enterococci levels may reflect levels of pathogenic bacteria more closely than other indicators because of their higher survival rates than *E. coli* and coliforms (Joyce, 2000), and their greater resistance to chlorination in marine waters (Vasconcelos and Anthony 1985). In 1986, the USEPA approved enterococci as a bacterial indicator for fresh and marine waters.

Total coliforms (TC). By definition, the total coliform group includes four genera of the family Enterobacteriaceae: *Escherichia*, *Klebsiella*, *Citrobacter*, and *Enterobacter* (Jensen and Su 1992). Total coliforms are aerobic or facultatively anaerobic, gram-negative, nonsporulating, rod-shaped, and ferment lactose with gas and acid production within 48 hours at 35°C (APHA 1995). They can be found as normal flora within the gastrointestinal tracts of warm-blooded animals.

Total coliforms include microorganisms that are considered human pathogens. *Escherichia coli*, a member of the total coliform group, can cause many types of human illnesses (APHA 1995). In the past, total coliforms were used as one of the sole indicators of water quality, even though there was little evidence linking concentration of total coliforms to transmission of disease through contact recreation (Vasconcelos and Anthony 1985). However, the major objection to the continued use of total coliforms as an indicator is that some genera in the group are not fecal specific (Cabelli et al., 1983; Ferguson et al. 1996; USEPA 1986). Some coliforms occur naturally in soil, marine or freshwaters (Joyce 2000). For this reason, total coliforms are no longer recommended as an indicator of recreational water quality, but can be used to compare older data sets.

Total coliform: fecal coliform (TC: FC) ratios were calculated recently in a Santa Monica study assessing correlation of indicators with risk of illness. Decreases in the ratio were found to correspond with increased rates of gastrointestinal illness (Haile, 1996).

Fecal coliforms (FC). The fecal coliform group, a subgroup of total coliforms, are defined as heat tolerant coliforms that grow at an elevated temperature of 44.5°C (Dufour 1984). They are found within the gastrointestinal tract of warm-blooded animals, and can indicate contamination by human or animal sources. This group of bacteria are more directly related to fecal contamination than total coliforms and are, therefore, more useful in relating microbial concentrations to health risks (Vasconcelos and Anthony 1985).

In 1968, the National Technical Advisory Committee (NTAC) proposed fecal coliforms as the indicator of choice for marine waters (NTAC 1968). Bacterial water quality standards for Texas (TNRCC, 1995) currently follow these guidelines and are as follows:

> "(i) Fecal coliform content shall not exceed 200 colonies per 100 ml as a geometric mean based on a representative sampling of not less than five samples collected over not more than 30 days, and
> (ii) fecal coliform content shall not equal or exceed 400 colonies per 100 ml in more than 10% of all samples, but based on at least five samples, taken during any thirty day period. If ten or fewer samples are analyzed, no more than one sample shall exceed 400 colonies per 100 ml."

Researchers currently believe fecal coliforms to be a poor indicator of illness because they are not always fecal-specific (Cabelli 1983). The lack of correlation with disease and levels of pathogens makes fecal coliforms less desirable as an indicator of pathogenic organisms in marine waters (Dufour 1984; Joyce 2000; Vasconcelos and Anthony 1985).

Recently the Texas Natural Resource Conservation Commission (TNRCC) has proposed adoption of enterococci for Texas marine waters. For bathing (full body contact) recreational marine waters the 1986 USEPA publication includes a table showing maximum allowable densities for the geometric mean for enterococci as 35 colonies/ 100 ml, based on at least five samples in a 30-day period (USEPA 1986). Single sample maximum allowable density ranges from 104 cfu/ 100 ml for designated beach areas, to 501 cfu/100 ml for infrequently used full body contact recreation. Intermediate levels of 276 and 158cfu/100 ml are designated for moderate or light use, respectively.

The United States government has recognized the public health risk associated with polluted stormwater runoff into recreational areas and the safety of these waters for the public is becoming a serious concern. The Federal Water Pollution Control Act of 1972 was followed by the Clean Water Act of 1977 (USEPA 1977; USEPA 1997a) which helped reduce the quantity of untreated sewage entering U.S. coastal waters. More recently the U.S. Environmental Protection Agency initiated a Beaches Environmental Assessment Closure and Health (BEACH) Program (USEPA, 1997a) to improve protection of public health from exposure to disease-causing microorganisms. Among the focus areas of the BEACH program are strengthening beach standards and testing programs, and predicting pollution by developing models to calculate potential adverse water quality conditions.

There have been relatively few epidemiological studies to correlate human illness with microbiological water quality, measured using fecal indicator bacteria. Results of early U.S. Public Health Service studies (1940's and 1950's) on the relationship between indicator organisms and disease symptoms are reported in the EPA Ambient Water quality criteria for bacteria – 1986. At bathing beaches along Lake Michigan, no increased incidence of illness was found at coliform densities between 91 and 180 coliforms/100 ml of water, but an increased rate of illness became evident when swimmers were exposed to coliform densities greater than 2300 colony forming units per 100 ml (geometric mean). A similar study conducted on the Ohio River in Dayton, Kentucky showed that swimmers who were exposed to geometric mean concentrations greater than 2300/100 ml exhibited an excess of gastrointestinal illness (EPA 1986). More recent international epidemiological studies comparing indicator bacteria with disease incidence have provided additional information. No correlations between GI symptoms and *E. coli* or fecal coliforms were found by Kueh et al. 1995, whereas Kay et al. 1994 demonstrated a dose response with fecal streptococci but not fecal or total coliforms and Fleisher et al. (1996) reported pathogen-specific relationships with different indicators.

In the last few years, several areas within the U.S. have begun to monitor their coastal waters to determine fecal indicator levels and to try to correlate this data with public health, with limited success (NRDC 1999; PBS&J 1999). An intensive study in Santa Monica, conducted in 1995, included interviewing over 15,000 people after they swam near storm drains. An increased incidence of symptoms such as fever, eye discharge, vomiting, diarrhea or sore throats were found in people who had swum close to drains compared to those swimming 400+ yards away. Incidence decreased rapidly with distance from the drains. Indicator bacteria levels were elevated adjacent to the flowing storm drains. Quantity of stormwater runoff into the bay system was highly correlated with the degree of public health risk (Haile 1996).

One of the first large-scale monitoring programs has been conducted in New Jersey. In 1974, the New Jersey Department of Health began sampling over 300 coastal sites for fecal indicator bacteria, which could indicate the presence of pathogenic organisms. A site was closed when more than one sample per week showed a potential problem (EPA 1997a). Data was collected for more than ten years, and in 1986 the monitoring program was reconstructed, using fecal coliforms as the major bacterial indicator (Rosenblatt 2000). Today, New Jersey continues to monitor multiple stations along its coastline, with emphasis on sixteen stormwater outfalls.

In California, the city of San Francisco spent $1.45 billion creating a sewer system to control overflows, hence decreasing sewage runoff into San Francisco Bay via stormwater drains (USEPA 1997a). By decreasing the amount of sewage that entered the bay through the stormwater drain network, the city decreased the potential for transmission of pathogenic microorganisms to humans.

Across the country, numerous states have started to monitor their coastal waters for the presence of pathogenic microorganisms using microbial indicators. While in several areas of the country municipalities monitor storm water discharged to coastal waters and close localized areas of beaches in association with specific storm or rain events, other cities lack such systematic monitoring.

Another approach to evaluating water quality that has been gaining interest is the potential use of predictive models so that action such as beach advisories can be made without the time delays incurred with analysis. Kueh et al (1995) found turbidity to correlate with GI and GCGI symptoms and suggested using this parameter as a quick method to assess beach water quality. At the EPA Regional BEACH Program Conferences (1999) several presentations described models or factors that should be included in developing predictive models. Waters et al.(2000) reported on the development of a deterministic model of Lake Pontchartrain incorporating biotic and abiotic parameters, hydraulic and rainfall information and GIS mapping to evaluate the distribution and fate of pertinent microorganism indicators. Francy and Darner (1998) and Francy (2000) described factors that correlated with *E. coli* concentrations at Lake Erie beaches, including volumes of wastewater outflows and metered outfalls, wave heights, turbidity and antecedent rainfall. A recent review of potential modeling tools and approaches to support the BEACH Program published by USEPA (1999a) includes descriptions of predictive models currently used as beach management tools, such as rainfall-based alert curves and point source dominated predictive tools. More research is needed to collect data on a range of parameters and to determine their relationships to microbial indicator levels and fecal contamination of recreational waters, before more sophisticated models can be effectively developed and utilized.

The Coastal Bend Bays and Estuaries Program (CBBEP) project area includes three estuaries that are used extensively for recreational activities. The only consistent monitoring of water quality is along the Corpus Christi Bay shoreline, conducted by the Corpus Christi-Nueces County Health Department. Water is analyzed on a routine basis (monthly) at 16 stations in dry weather conditions to ensure that ambient levels of indicator bacteria do not exceed acceptable Texas standards for recreational waters (TNRCC, 1995). However, wet weather monitoring is not performed.

The Implementation Strategy for the Coastal Bend Bays Plan (CBBEP 1998) includes an Action Plan for Public Health (PH-1). The first objective in the Bays Plan is "to ensure that any threat of waterborne illness and disease is minimized". The action for that objective is to facilitate a regional approach to recreational water quality management. The development of a predictive model to assess contact recreation risk based on dry/wet weather monitoring is the second step of the Bays Plan action.

The two goals for this project addressed these two actions.

1. To examine recreational water quality assessment and monitoring needs in the Coastal Bend Bays and Estuaries Program study area using a regional approach by establishing a contact recreation workgroup of public health officials.

2. To initiate development of a predictive model as outlined in the public health action plan and allow development of guidelines for contact recreation in relation to runoff events by conducting dry/wet weather monitoring in the area.

It was not an objective of this study to compare the bacteriological concentrations observed for wet and dry weather conditions in Corpus Christi Bay with areas unaffected by urban development or recreational use.

This final report is divided into two sections to address the two goals of the project.

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SECTION I. REGIONAL APPROACH TO WATER QUALITY ASSESSMENT - WORKSHOPS

Methods and Measurements

The goal of this part of the project was to examine recreational water quality assessment and monitoring needs in the Coastal Bend Bays and Estuaries Program study area using a regional approach, by establishing a contact recreation workgroup of public health officials.

In collaboration with CBBEP, public health officials who have a role in assessing contact recreation water quality in the CBBEP study area were identified and invited to two workshops to review issues and concerns, and to assess the feasibility of a regional approach to contact recreational water quality.

The first Recreational Water Quality Workshop was held as a two-hour session on July 21, 1999. It was designed as an introductory session to form a working group and to review existing area monitoring programs in relation to national and state recommendations. The workshop was an informal discussion format with the main purpose being to facilitate a regional approach to recreational water quality management. The workshop was introduced by Marcia Lochman, representing CBBEP. The P.I. briefly described the purpose of the workshop, national initiatives and this project. The health officials described existing monitoring efforts in their counties and needed improvements.

The second Recreational Water Quality Workshop was held as a full day joint meeting with the On-Site Sewage Facilities (OSSF) Management Workshop, because a common group of officials were involved in the two topics. In this workshop the P.I. addressed national initiatives including the EPA BEACH Program, new fecal indicators and the emphasis on public education. The current research study was also outlined and initial results described. Dr. Paul Jensen (PBS&J) presented state initiatives and some of the topics being evaluated in a TNRCC bacterial indicators project on which he was working. The morning session was concluded with questions from the participants. In the afternoon, concurrent discussion sessions were held.

Reports on each workshop were submitted within 30 days and are included in Appendix A.

Results

At the first workshop four counties were represented by a total of six public health officials. After the introductions and outlines of current national initiatives, the public health officials described their current monitoring. The main fact that emerged was that except for the Corpus Christi-Nueces County Health Department monthly sampling, there is a lack of monitoring of CBBEP recreational waters. Aransas County sends occasional samples to the City of Corpus Christi-Nueces County Health Department. Kleberg and San Patricio Counties do not conduct monitoring. Discussion included concerns about septic systems, and public education. The main constraint for each county was described as lack of available funds.

The second workshop was more formal, due to the larger attendance. State and federal recreational water quality programs were outlined during the morning session. There was little participation in the afternoon discussion session, because, officials attended the concurrent OSSF session that included potential funding opportunities through the CBBEP for OSSF projects.

After review of the two workshops with CBBEP personnel, it was decided that further workshops were not warranted. Public health officials agreed with the concept of a regional approach, but due to lack of funding only Nueces County has a consistent monitoring program.

Conclusions and Recommendations

The current lack of public health monitoring of contact recreational waters in the CBBEP area, with the exception of Nueces County, is a significant concern. Lack of funding indicates that such monitoring is of low priority. The public health officials who participated in the workshops showed interest and willingness to develop a regional approach to monitoring. The workshops were effective in bringing public health officials together to discuss water quality issues and presentations at the two workshops provided a good overview of federal and state standards and new initiatives. The main outcome of the workshops was increased awareness of the need to evaluate quality of area recreational waters, but without additional funding this will not be addressed at the county level. As federal and state requirements become more stringent, (for example the recently passed Beaches Environmental Assessment and Coastal Health Act of 2000), funding will probably become more available and at that point the regional approach should be revisited as an important concept. These workshops laid some groundwork for such a coordinated approach in the future.

SECTION II. STUDY: MICROBIOLOGICAL MONITORING AND ASSESSMENT OF STORM DRAIN RUNOFF WITHIN THE CBBEP PROJECT AREA

Description of the Study Sites

Corpus Christi Bay is characterized as an enclosed, primary bay that is located along the mid-Texas coastline (Britton and Morton 1989) (Fig. 1). The bay encompasses an area of 205 square kilometers (Camp et al. 1991). Corpus Christi Bay receives the majority of its inflow from Nueces Bay, its secondary source, while a small tidal exchange occurs from passes through Aransas Pass from the Gulf of Mexico (Brown et al. 1976). Corpus Christi Bay also exchanges water with the Laguna Madre, a hypersaline lagoon to the southeast.

Corpus Christi Bay was formed during the Quaternary period in conjunction with the retreating of glacial sheets (Morton and Paine 1984). During the Holocene epoch, which ended about 18,000 years ago, the glaciers melted, releasing large amounts of water and hence raising sea level. This rise in sea level was at a rate of approximately 0.6 to 0.9 m per century, which later slowed to 0.03 to 0.127 m per century during the last 3,000 years (Flint 1971). Erosion of the Nueces River valley, due to the rise in sea level and an unstable shoreline, formed Corpus Christi Bay. In the last 3,000 years, sea levels have been stable within the bay (Brown et al. 1976).

Corpus Christi Bay can be characterized as non-vegetated and soft-bottomed due to the clay bluffs that were formed at the same time as the bay. These clay bluffs, accompanied by sandy slopes, marshes, and sand and shell beaches, make up the four most typical shorelines along Corpus Christi Bay. Before human influence, shoreline morphology and composition was controlled by regional processes and geology (Morton and Paine 1984). After the late 1800s, however, population growth resulted in structural alterations to the shoreline.

Before the 1930s, the area surrounding Corpus Christi Bay was mainly agricultural (Morton and Paine 1984). In 1931, breakwaters were constructed to protect downtown Corpus Christi and by 1938, the Corpus Christi ship channel had been completed, from Corpus Christi to Avery Point. During the next twenty years, the downtown Corpus Christi area was extended bayward with fill material, the seawall and the "T-heads" were constructed, and the Corpus Christi Naval Air Station occupied the northern end of the Encinal Peninsula (Morton and Paine 1984). By 1982, most of the riprap material had been distributed throughout the bay along the shorelines. Today, Corpus Christi Bay has several designated uses, including contact recreation, exceptional quality aquatic habitat, and shellfish waters (Camp et al. 1991; TNRCC 1996).

Sampling sites along Corpus Christi Bay shoreline were chosen after consideration of a number of factors, including recreational use. Both the Director of the City of Corpus Christi-Nueces County Health Department, Dr. Nina Sisley, and the Director of the Coastal Bend Bays and Estuaries program (at that time Richard Volk), were consulted and solicited for suggestions.

The final choice of sites was supported by both professionals. The locations selected are adjacent to major storm water outfalls at Cole Park, at Ropes Park, and at McGee Beach (Fig. 1, Table 1). McGee Beach is a public beach, Ropes Park is used primarily as a launch area for wind surfing, while Cole Park is a multi-purpose city park. A reference location (relatively unimpacted by a storm drain outfall) at Swantner Park was included for comparative purposes. Historical data (City of Corpus Christi-Nueces County Health Department) indicate that fecal coliforms are consistently found in low concentrations at this location. All locations are located along Corpus Christi Bay with public access from Shoreline Drive/Ocean Drive. Other considerations included the need for shoreline access at a range of distances from the outfall, the previous sites used by Carr et al. (1998) in their characterization study of sediments, and travelling time and distance. The latter consideration was included due to the frequency of sampling after rainfall events and the requirement for analysis commencement within six hours for microbial indicators.

Each of the sampling locations was divided into three sites, with the exception of Swantner Park (D), the reference location. Samples were collected immediately adjacent to the storm drains at each of the three locations, and at measured distances from the outfalls. Field markers were red spray paint circles at these distances, as approved by the City of Corpus Christi Department of Parks and Recreation. The markers ensured that sample collections were consistent throughout the study. Due to site-specific characteristics there was some variation between locations, in sampling distances from the storm drains, as described below.

On June 25, 1999, the McGee Beach location was changed to the Corpus Christi Marina. The outfall at McGee Beach was inoperative, and, after notification from the City of Corpus Christi, and with the approval of CBBEP personnel, was changed to the marina location.

Location A McGee. McGee Beach, located north of downtown Corpus Christi along Corpus Christi Bay, is subdivided into approximately 100 m breakwater units. The shores of this park are sandy with no rocks. Samples were collected approximately 24 m each side of the outfall, so that water was collected from between two different breakwaters to provide information regarding impact along the beach. The sampling sites were located 24 m on the north side of the stormwater outfall (A1) and 24 m on the south side of the outfall (A3), with one site (A2) at the outlet (Table 1).

Location A Marina. The Corpus Christi Marina seawall, located northwest of McGee Beach, contains a large stormwater outfall facing north, discharging perpendicular to the marina. The marina has a sandy floor, surrounded in part by the concrete seawall. The northern side of the marina is partially closed by riprap material to help protect vessels. Sampling sites were located 135 m on the north side of the stormwater drain (A1), the farthest feasible distance from the outfall, and an equal distance on the south side of the outfall (A3), with one site (A2) at the outlet (Table 1).

Location B. Cole Park, located east of McGee Beach, contains a large, dual set of stormwater drains at the west end of the park. The shores of Cole Park are sandy, and the park is mostly bounded by a concrete seawall. The sampling sites were located 50 m north of the stormdrain outfall (B1) and 50 m south of the stormdrain outfall (B3). B2 was at the stormwater outlet (Table 1).

Location C. Ropes Park, located east of Cole Park along Ocean Drive, has a rocky shoreline. The outfall is smaller than that at Cole Park, and is centrally located. Samples were collected 50 m to the north of the stormdrain outfall (C1) and 50 m to the south (C3), with one site (C2) at the outfall (Table 1), to generate information on impact along the whole shoreline of Ropes Park.

Location D. The reference site at Swantner Park, located east of Ropes Park on Ocean Drive is bounded by a concrete seawall for the entire distance of the park, and has a sandy sediment. Samples were collected at the marked location (D1), halfway (approximately 200 m) between two storm drains located at the extremes of the park (Table 1).

Table 1. Sampling sites along Ocean Drive/Shoreline Boulevard, Corpus Christi Bay, Corpus Christi, Texas.

Site ID	Site Name	Distance From Outfall (m)
A1	McGee Beach (north)	24
A2	McGee Beach (at outfall)	0
A3	McGee Beach (south)	24
A1	Marina (north)	135
A2	Marina (at outfall)	0
A3	Marina (south)	135
B1	Cole Park (north)	50
B2	Cole Park (at outfall)	0
B3	Cole Park (south)	50
C1	Ropes Park (north)	50
C2	Ropes Park (at outfall)	0
C3	Ropes Park (south)	50
D1	Swantner Park (no outfall)	

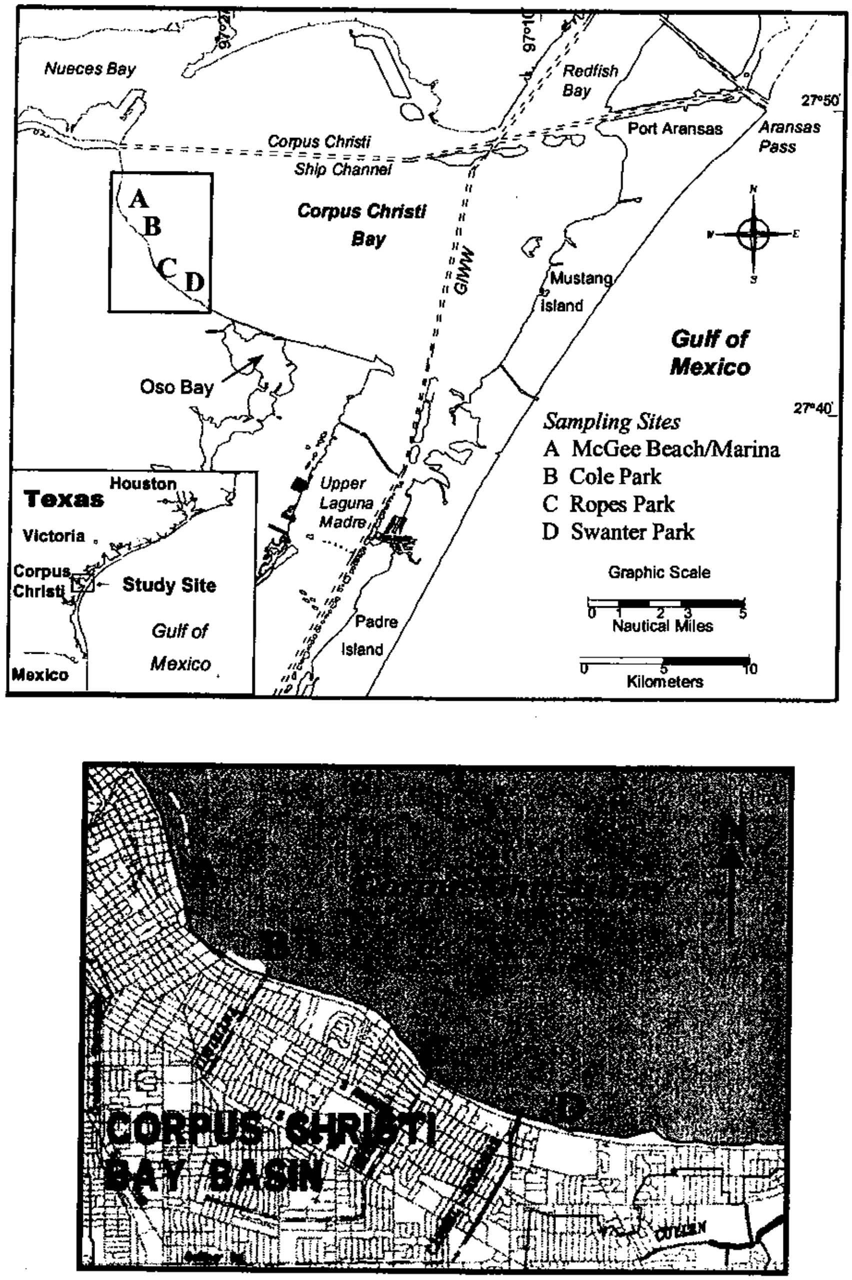

Figure. 1. Maps showing location and sampling sites, Corpus Christi Bay, Corpus Christi, Texas. General location map provided by Conrad Blucher Institute for Surveying and Science.

Methods and Measurements

Sample Collection

Water samples were collected twice a month from January 1999 until May 2000. For two three-month periods (September – November 1999 and February - April 2000) samples were collected five times per month, within 30 day intervals, (a total of thirty sampling events), to evaluate indicator bacteria levels in relation to standard guidelines set by the USEPA (USEPA 1986). In addition, water samples were collected and analyzed during and after six rainfall events. Sampling frequency differed for each wet weather event, based on 1) the quantity of rainfall received, 2) environmental conditions during sampling, and 3) fecal indicator levels. Sampling continued at regular intervals after rainfall until fecal indicator bacteria numbers returned to dry weather levels.

For each sampling event water was collected at all four locations (three sites at three of the locations, one site at the reference location, two replicate samples at each site) to give a total of 20 samples per event. Standard TNRCC approved field data sheets for all sampling sites were completed in the field, at the time of sample collection.

All water samples were collected at a depth of 0.3 to 0.5 m in 1000 ml sterile, plastic screw-cap, polypropylene bottles, leaving ample air space for shaking, according to Standard Methods for the Examination of Water and Wastewater, 19th ed., Section 9060A "Collection" (APHA 1995). Sample bottles were immediately placed in an ice chest and transported to the microbiology laboratory at Texas A&M University-Corpus Christi for analysis within six hours of collection

Field Parameters

A multi-parameter Hydrolab III instrument was used for each sampling event, to measure routine water quality parameters, including water temperature, salinity, specific conductance, dissolved oxygen, and pH, as defined by the TNRCC Surface Water Quality Monitoring Procedures Manual (SWQMPM) (1997). The Hydrolab was calibrated according to the manufacturer's specifications before and after each field collection trip. Post-calibration was conducted using TNRCC SWQMPM (1997). Rainfall data was provided by the National Weather Service.

Bacteriological Analyses

Collection and analysis methods adhered to the TNRCC Surface Water Quality Monitoring Procedures Manual (SWQMPM) 1997, or to alternate methods already reviewed and approved by the TNRCC through the Clean Rivers Program. Date, time and analyst signature were recorded for each sample collection, filtration and colony count to maintain chain of custody.

Water samples were analyzed for concentrations of total coliforms, fecal coliforms, and enterococci, following Section 9222B "Standard membrane filtration techniques" (Standard Methods for the Examination of Water and Wastewater, APHA 1995). For each duplicate sample, three volumes were filtered for each fecal indicator. Volumes filtered were adjusted based on environmental factors which increased/decreased the total number of bacteria collected within a sample (i.e. turbidity) to obtain 20-60 colonies per plate for fecal coliforms and enterococci, and 20-80 colonies for total coliforms (USEPA 1997b; APHA 1995).

Following filtration, each bacterial filter (0.45 µm) was transferred to a 50 mm X 9 mm Petri dish containing the selective medium for each fecal indicator group. The plates were then incubated for 24 hours at the appropriate temperature. Colonies were counted after 24 hours and colony forming units (cfu) were calculated using Standard Methods for the Examination of Water and Wastewater sections 9215 A8 and 9222 B6 (APHA 1995) and the "Microbiological Methods for Monitoring the Environment: Water and Wastes" (USEPA 1978). Final counts were averaged from the field duplicates and reported to two significant digits.

Fecal coliforms. Water samples were analyzed for fecal coliforms using Standard Methods for the Examination of Water and Wastewater Section 9222D. "Fecal coliform membrane filter procedure using mFC medium with 1% rosolic acid solution" (APHA 1995). After filtration, each filter was placed into a Petri dish containing mFC agar with rosolic acid. The plate was then incubated in a Whirlpak bag in a water bath set at 44.5°C for 24 hours. After 24 hours, all pale to blue colonies (larger than pinpoint size) were counted as fecal coliforms and reported as cfu per 100 ml (APHA 1995).

Enterococci. Numbers of enterococci were determined using EPA Method 1600—Membrane filter test method for enterococci in water EPA-821-R-97-004 (USEPA 1997b). Each filter was placed in a Petri dish containing mE agar. The plate was incubated at 41.0°C for 24 hours. All colonies retaining a blue pigment were counted as enterococci and recorded as cfu per 100 ml of water (USEPA 1997b).

Total coliforms. Total coliforms were enumerated using the procedure from Standard Methods for the Examination of Water and Wastewater Section 9222B "Standard total coliform membrane filter procedure" (APHA 1995). Each bacterial filter was placed in a Petri dish containing LES Endo agar with 95% ethanol. The plate was allowed to incubate at 35.0°C for 24 hours, at which time all colonies with a metallic sheen were counted as coliforms and recorded as cfu per 100 ml of water (APHA 1995). Total coliforms were not enumerated for the two three-month "five in 30 day" sampling periods, or for the year 2000 sampling events, as per our contract.

Quality Control and Instrumentation Requirements

Intralaboratory quality control procedures and instrument calibration and maintenance were based on relevant sections of the approved IQA/WP for the project and Standard Methods for the Examination of Water and Wastewater Section 9020B "Intralaboratory quality assurance" (APHA 1995). Each medium lot was tested for satisfactory performance using raw influent samples (positive control) from the Oso Wastewater Treatment Plant. A media log sheet showing date, medium, volume, signature and comments was kept for all media prepared. Measurement of method precision was followed as described in Section 9020B "Intralaboratory quality control guidelines 4. Analytical quality control procedures, b Measurement of analytical precision" (APHA 1995). Sterility checks were performed at the beginning of the filtration procedure for water samples from each site and for each indicator, halfway through the procedure (after ten plates), and at the end of the procedure to identify cross-contamination (Section 9222B 5C, APHA 1995). If contamination had occurred, all compromised data was eliminated from the data analysis.

Verifications of the three indicator groups were performed monthly using Standard Methods for the Examination of Water and Wastewater Section 9020 B "Intralaboratory quality control guidelines 4. Analytical quality control procedures, d. Quality control on membrane filtration procedure" (APHA 1995). Verification for enterococcus colonies was based on Method 1600 for enterococci. A Coli-firm™ confirmation kit was used for total coliforms.

Documentation

Bacteriological raw data log sheets were filled out by the analyst for each water sample as procedures were conducted. These were handwritten and included results of sterility checks, as per the IQA/WP for this project.

Statistical Analysis

Statistical analysis of the data was conducted using the statistics program, SPSS version 9.0 for Windows. Hydrological and biological data was analyzed using time sequences, and all comparisons were made by using a one-way nested ANOVA.

Results

Water Quality Parameters

For every sampling event, water quality parameters were measured at each site using a Hydrolab III instrument. Water temperature, salinity, dissolved oxygen, pH and specific conductance did not significantly differ between sites for any sampling date. Table 2 shows the mean, high and low for each parameter over the period of the study. The seasonal variations of water temperature, dissolved oxygen and salinity at each location (average of sites) are shown in Figures 2-4. As noted in the fifth quarterly report, the Hydrolab instrument did not record data at Cole Park, Ropes Park and the Marina for the December 31, 1999 sampling event.

Water temperature ranged from a low of 11.6°C, to a high of almost 31°C, the lows occurring during the winter months of 1999 and 2000 (January and February). Maximum temperatures were reached between June and September, 1999 (Figure 2).

Dissolved oxygen (Figure 3) ranged from 1.05 to 14.18 mg/L, with an average of 5.31 to 6.39 mg/L. During dry weather conditions, dissolved oxygen remained relatively constant. However, during periods of high winds and subsequently increased wave action, and during wet weather events, particularly March and May 1999, dissolved oxygen levels rose. pH remained relatively stable with a range from 7.11 to 8.40, averaging 7.94. Salinity (Figure 4) averaged 31.13‰ across all sites, but showed a gradual increase through the study period. The periodic drops in

Table 2. Mean and range of water quality parameters at all locations along Corpus Christi Bay between January 1999 and May 2000. Location A=Marina, B=Cole Park, C=Ropes Park, D=Swanter Park

	Water Temp (°C)			pH (SU)			Dissolved Oxygen (mg/L)			Salinity (‰)			Specific Conductance (µmhos/cm)		
		Range			Range			Range			Range			Range	
Site	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**	**Low**	**High**
A1	23.23	12.50	30.20	7.92	7.62	8.13	5.47	1.09	11.20	30.84	24.6	35.7	47,276	38,710	53,848
A2	23.23	12.60	30.10	7.94	7.69	8.13	5.65	1.76	11.50	30.73	24.1	33.9	47,132	37,890	51,506
A3	23.22	12.62	30.41	7.94	7.68	8.14	5.67	1.74	10.87	30.73	23.7	33.7	47,089	37,370	51,200
B1	23.58	12.13	30.93	7.93	7.64	8.13	5.31	1.82	10.28	31.02	23.2	34.7	47,579	38,830	52,200
B2	23.64	12.16	30.97	7.94	7.43	8.14	5.44	1.37	10.37	31.19	25.8	34.5	47,849	41,510	52,330
B3	23.53	12.15	30.99	7.93	7.57	8.17	5.67	1.05	11.97	31.24	26.8	34.6	47,821	41,400	52,210
C1	23.22	11.67	30.59	7.93	7.11	8.17	6.39	4.17	11.87	31.32	26.9	34.7	48,004	41,560	52,400
C2	23.24	11.68	30.45	7.94	7.56	8.17	6.17	2.36	10.46	31.36	26.7	34.8	48,025	41,620	52,500
C3	23.22	11.65	30.57	7.94	7.62	8.18	5.95	3.19	10.28	31.37	26.6	34.7	48,013	41,530	52,500
D1	23.11	11.67	30.65	7.95	7.51	8.40	6.35	2.29	14.18	31.48	24.2	34.6	48,209	41,620	52,590

salinity levels occurred after rainfall, especially in August and September of 1999, and were probably due to freshwater runoff into the bay. There were slight decreases in salinity for about 24 hours but rapid return to normal levels after cessation of flow from the stormwater outflows (Appendix B). None of the environmental factors measured significantly affected indicator bacterial concentrations.

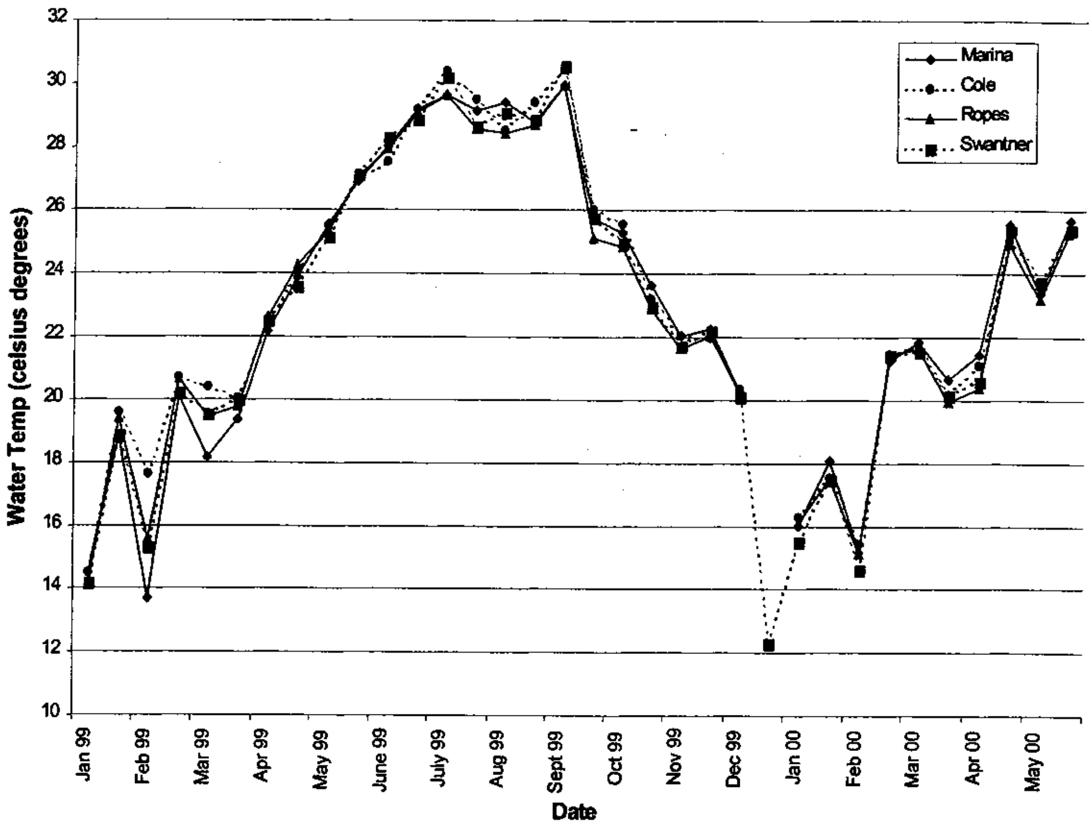

Figure 2. Mean water temperature at locations along Corpus Christi Bay between January 1999 and May 2000.

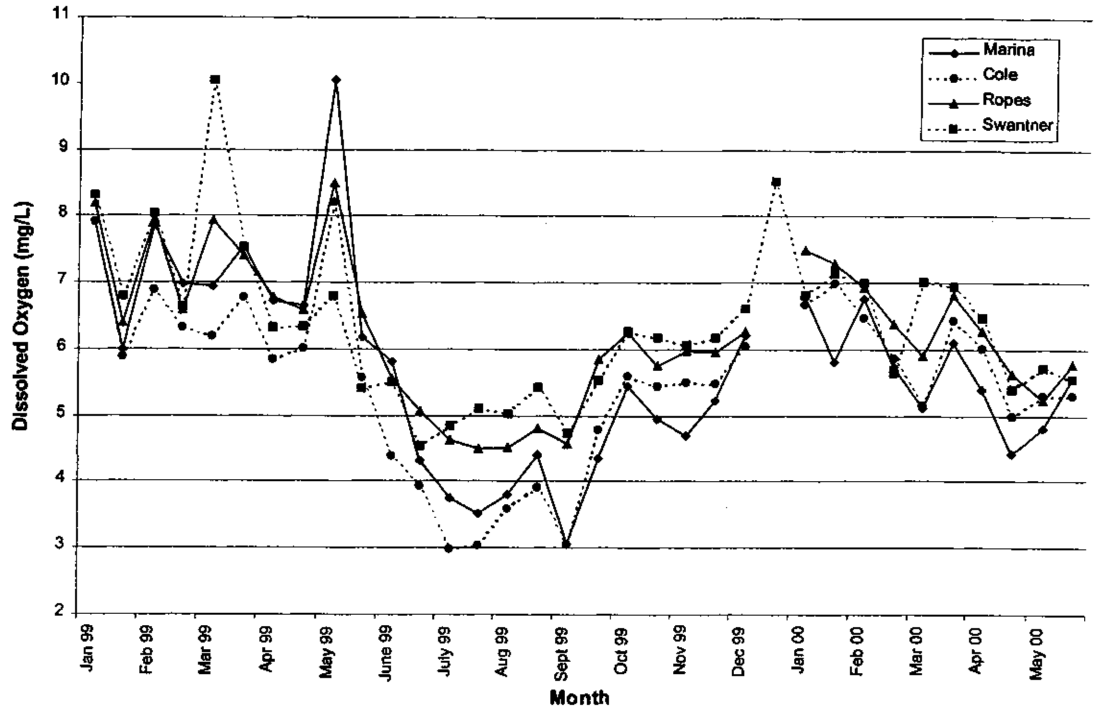

Figure 3. Mean dissolved oxygen levels at locations along Corpus Christi Bay between January 1999 and May 2000.

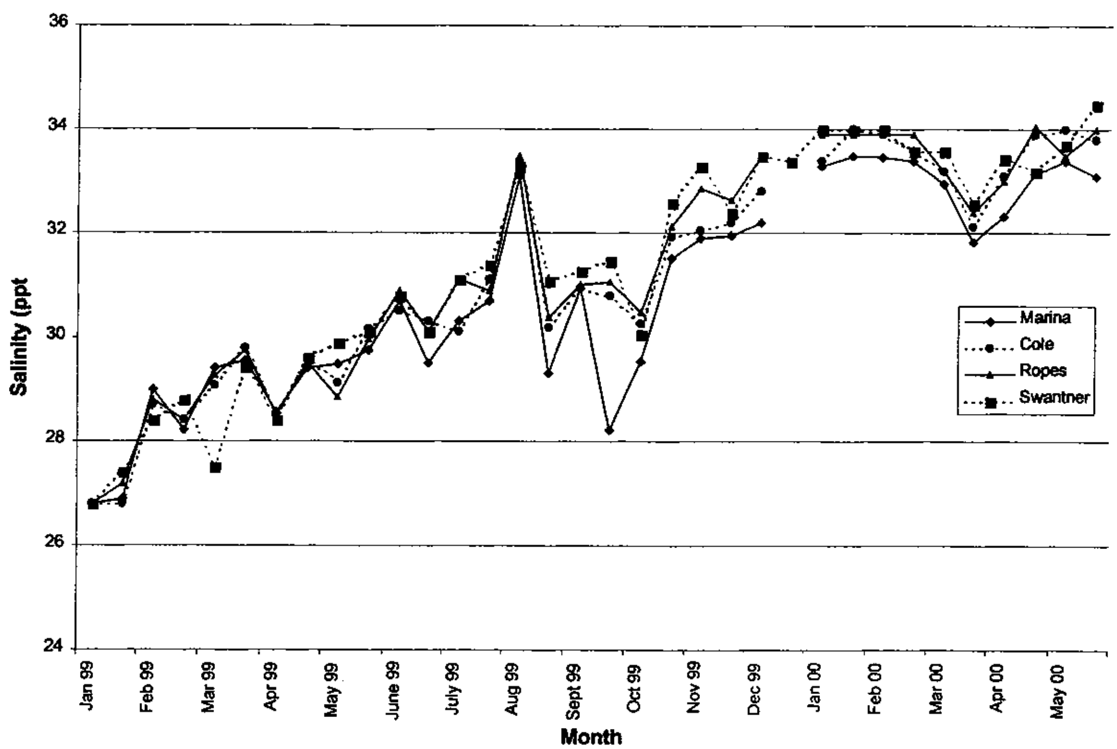

Figure 4. Mean salinity values at locations along Corpus Christi Bay between January 1999 and May 2000.

Microbial Fecal Indicators

Dry weather vs. wet weather water quality. Levels of three microbial indicators were assessed twice a month (dry weather) at three shoreline storm drain locations, with sites both at the outfall and at a distance each side of the drain, from January 1999 to May 2000. For three months (May 1999, August 1999 and March 2000), dry weather samples were only collected once, because rainfall events occurred during one of the planned dry weather collections for the month. Microbial indicator concentrations at a reference location (Swantner Park – D) were also determined. Wet weather samples were collected after six rainfall events. The data collected during the two three-month periods of "5 in 30 day" sampling was evaluated separately due to the difference in sampling intensity (see section on intensive sampling).

For each location, there was no significant difference between sites, i.e. distance from outfall was not significant ($p > 0.081$). Dry weather results shown in Table 3 are averages of the three sites at each location. Similarly wet weather microbial levels for each location, were not significantly different between sites, and are shown combined for comparison in Table 4. Complete data (indicator numbers for each site are the average of the duplicate samples) are included in Appendix B.

Table 3. Mean concentrations and ranges (cfu/100 ml) of microbial indicators in Corpus Christi Bay waters during dry weather conditions. Location A=Marina, B=Cole Park, C=Ropes Park, D= Swanter Park.

	Total Coliforms			Enterococci			Fecal Coliforms		
		Range			Range			Range	
Location	Mean	Low	High	Mean	Low	High	Mean	Low	High
A	339	5	5,000	80	1	2,200	110	1	2,200
B	10,114	54	80,000	103	1	2,900	177	1	2,200
C	4,747	5	80,000	134	4	2,100	135	4	1,600
D	2,177	5	38,000	87	1	2,000	59	1	520

Table 4. Mean concentrations and ranges (cfu/100 ml) of microbial indicators in Corpus Christi Bay waters during wet weather conditions. Location A=Marina, B=Cole Park, C=Ropes Park, D= Swanter Park.

	Total Coliforms			Enterococci			Fecal Coliforms		
		Range			Range			Range	
Location	Mean	Low	High	Mean	Low	High	Mean	Low	High
A	1,268	10	14,000	926	5	12,000	895	5	10,000
B	18,204	5	80,000	1,352	5	7,100	1,267	5	8,300
C	16,754	5	80,000	2,189	30	11,000	1,340	10	6,000
D	5,045	5	53,000	1,515	5	11,600	797	5	10,000

Levels of enterococci and fecal coliforms in dry weather (twice a month samples) ranged from a low of 1 cfu/100 ml to 2,900 cfu/100 ml (Table 3). To evaluate the water quality, the single sample EPA standards were used as the sampling frequency did not meet the "five in thirty day" criterion. For fecal coliforms fewer samples (13%) exceeded the EPA standard (400 cfu/100 ml) and the overall means for each location were below this density. For enterococci even the mean of all the Ropes Park (C) samples (134 cfu/100 ml) was above the designated beach single sample standard of 104 cfu/100 ml, while at Cole Park (B) the mean was 103 cfu/100 ml. Of the total dry weather samples collected at all sites 40% exceeded the maximum allowable density for enterococci.

It should be noted that for enterococci the EPA (1986) single sample maximum allowable density depends on extent of water body use. The City of Corpus Christi-Nueces County Health Department bay water data sheets use the marine water bathing beach designation for all locations at which they sample (including the marina, McGee Beach, Cole Park, and Ropes Park) with the limit of 104 cfu/100ml. The EPA however, lists 158 cfu/100 ml as the single sample maximum allowable density for moderate full body contact recreation, 276 cfu/100 ml for lightly used full body contact recreation and 501cfu/100 ml for infrequently used full body contact recreation (EPA, 1986).

The number of dry weather samples which exceeded EPA standards varied with location. Figure 5 illustrates the differences for each location, with one site being represented at each location. For both fecal coliforms and enterococci the greatest proportion of samples exceeding standard levels were those collected from Ropes Park (29% samples exceeded fecal coliform standards, while 38% samples exceeded enterococci standards). At all locations except Cole Park, the maximum allowable density of enterococci was exceeded more frequently than fecal coliforms. At McGee Beach/Marina none of the samples exceeded fecal coliform standards in contrast to enterococci levels which were above maximum allowable densities in almost 30% samples. At the reference location, Swantner Park, only 10% samples exceeded fecal coliform levels.

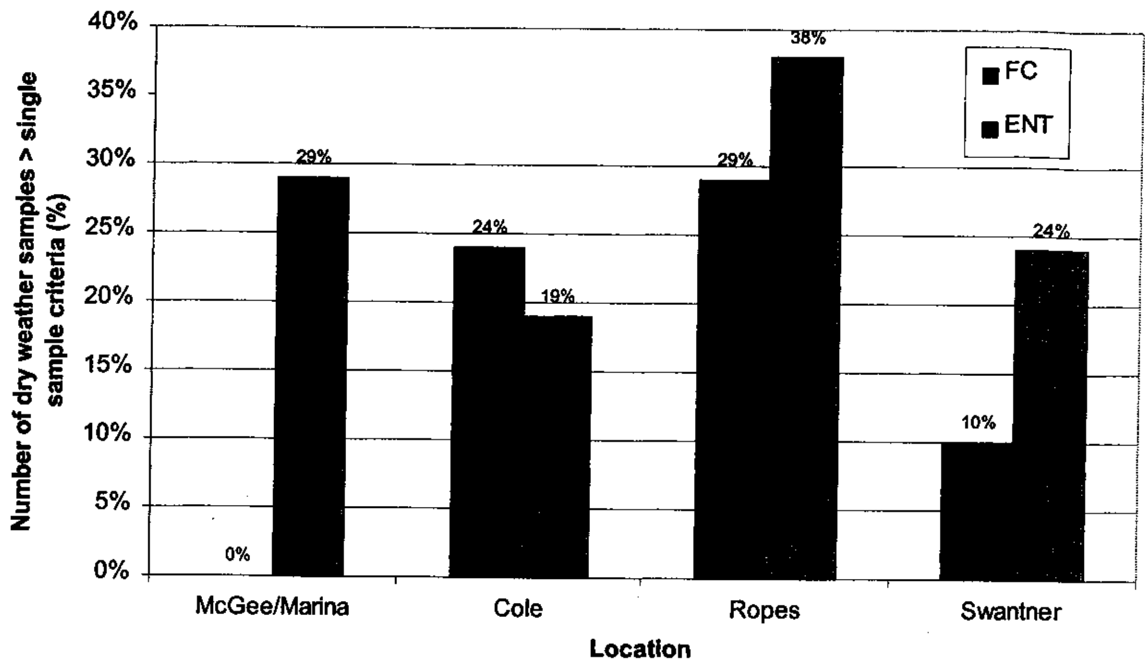

Figure 5. Percentage of single samples from one site at each location (n=21) which exceed EPA criteria for "designated beach area for marine water" (Fecal coliform=400 cfu/100 ml; Enterococcus=104 cfu/100 ml) during dry weather.

The seasonal distributions of enterococci and fecal coliforms are shown in Figures 8 and 9. Enterococci peaks occurred in February and March of 1999 and then December 1999 and January 2000. High fecal coliform levels generally corresponded with peaks in enterococci; however the maximum numbers of fecal coliforms occurred in June 1999, when enterococci were relatively low compared with other times during the year. High enterococci numbers correspond with periods of low water temperature (Figure 2) and strong winds. Wind speed was not measured; but field data sheets gave an indication of wind conditions as they included an observation of wind intensity (calm, slight, moderate or strong). Additionally, trace rainfall (less than one inch) preceded sampling for some of these occasions. It appears that factors such as wind speed, direction, turbidity, tides, wave action and water temperature affected levels of indicator bacteria in dry weather (when runoff was not occurring). This may be related to bacterial levels in sediment and resuspension in certain conditions. Additional research is needed to reach any conclusions on the relative importance of these factors.

Levels of enterococci in dry weather samples appeared lower during summer months when air temperatures were high. However during wet weather conditions, bacterial numbers increased regardless of temperature. This trend was not seen with fecal coliforms (Figures 6 and 7).

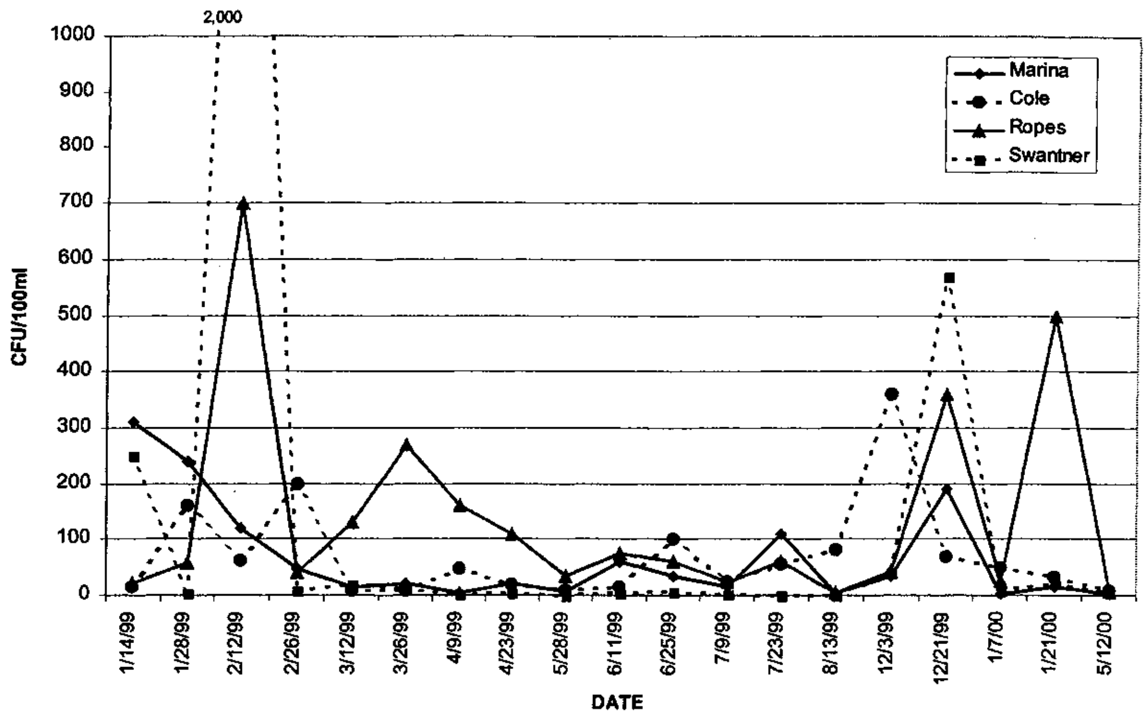

Figure 6. Seasonal distribution of enterococci counts during dry weather in Corpus Christi Bay waters.

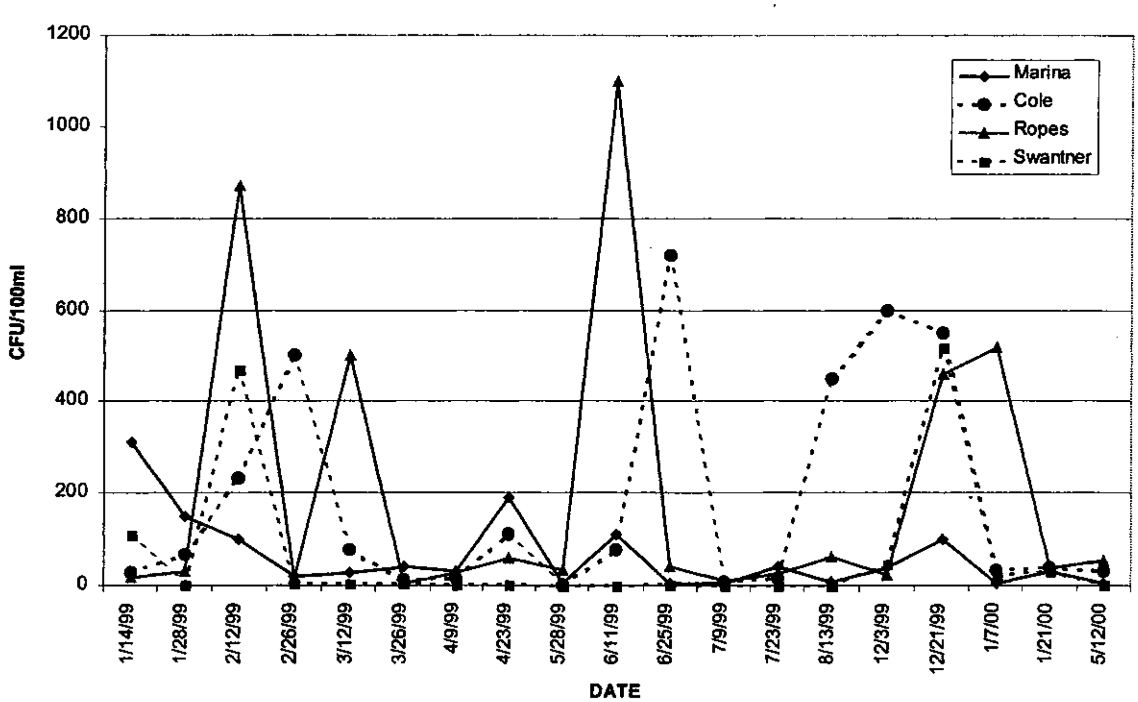

Figure 7. Seasonal distribution of fecal coliforms during dry weather in Corpus Christi Bay waters.

Wet weather levels of both enterococci and fecal coliforms reached highs of 10,000 to 12,0000/ 100 ml (Table 4). Means for each location, for both fecal coliforms and enterococci exceeded EPA criteria for single sample, designated beach area for marine waters. For enterococci the means were 9-20 times higher than the maximum allowable density, while for fecal coliforms the means were only 2-3 times the standard. The percentage of single samples which exceeded EPA standards was 37% for fecal coliform and 67% for enterococci. However, these percentages include all samples collected after a rainfall event. The sampling was designed to continue until numbers of indicator bacteria returned to pre-rainfall levels. These samples were usually the ones containing the lows shown in Table 4 and obviously reduce the percentage of samples exceeding standards. If only the levels of indicator bacteria in the first samples collected after rainfall are used, the percentage exceeding maximum allowable density are almost 100% for both fecal coliforms and enterococci.

Total coliform levels were similar in both wet and dry weather samples, with higher numbers being found at Cole Park (B) and Ropes Park (C), than the marina (A) or Swantner Park (D). These bacteria were enumerated mainly to examine changes in the TC:FC ratio (described in separate section, below).

Rainfall Events. Six rainfall events were monitored during the study. Sampling commenced shortly after runoff commenced, and continued on a regular basis (24/48 hr intervals) until microbial indicators returned to pre-rainfall levels. The quantity of rainfall for these individual events ranged from 2.8 to 17 cm (approx. 1.1 to 6.7 inches) (Table 5).

Table 5. Summary of rainfall events monitored during the study.

Rainfall Event	Rainfall Amount (cm)	Sampling Start Date	Sampling Finish Date	Days of Elevated Levels*
1	8.64	03/28/99	04/01/99	5+
2	2.79	05/12/99	05/17/99	5-6
3	17.02	08/24/99	09/03/99	9-11
4	7.62	09/30/99	10/03/99	4+
5	3.30	03/15/00	03/20/00	6+
6	3.81	05/03/00	05/06/00	4

*Based on fecal coliform and enterococci numbers in water samples collected after rainfall

Table 6. Statistical analysis by indicator, location, date, and rain event using one-way nested ANOVA (SPSS version 9.0 for Windows).

Variable(s)	Total Coliforms (p-value)	Fecal Coliforms (p-value)	Enterococci (p-value)
Location	0.000	0.000	0.000
Rain event	0.086	0.000	0.000
Location and rain event	0.417	0.118	0.081
Date and rain event	0.000	0.000	0.000
Location and date and rain event	0.000	0.000	0.000

There was a significant difference between numbers of both fecal coliform and enterococci in dry weather samples when compared to wet weather samples (Table 6). However, total coliform levels were not significantly affected by rainfall ($p>0.086$). Overall changes in each indicator level are shown in Table 7. The degree of change from dry to wet levels was greatest for enterococci and least for total coliforms.

Table 7. Differences in mean bacterial concentrations (cfu/100 ml) in Corpus Christi Bay waters during dry and wet weather events. Location A=Marina, B=Cole Park, C=Ropes Park, D= Swanter Park.

Location	Total Coliforms		Fecal Coliforms		Enterococci		Factor of Change
	Dry	Wet	Dry	Wet	Dry	Wet	
A	339	1,268	110	895	80	926	4.0 TC - 11.5 ENT
B	10,114	18,204	177	1,267	103	1,352	2.0 TC - 13.0 ENT
C	4,747	16,754	135	1,340	134	2,189	3.5 TC - 16.0 ENT
D	2,177	5,045	59	797	87	1515	2.0 TC - 17.5 ENT

For rainfall quantities of 2.8 to 8.6 cm (1.1-3.4 in) indicator levels generally returned to dry weather levels in 4 to 6 days. However, heavy rainfall of 17 cm (6.7 in) over a three day period-August 22 (11.5 cm, 4.5 in), August 23 (5 cm, 2.0 in), August 24 (0.5 cm, 0.2 in) resulted in a prolonged period (9-11 days) of elevated levels.

Changes in fecal coliform and enterococci levels with time after each rainfall event at each location are illustrated in Figures 8 to 19. Numbers of total coliforms are included in the data listed in Appendix B.

The first heavy rainfall event occurred on 27 March 1999 (8.6 cm, 3.4 in). Enterococci levels reached over 10,000 cfu/100 ml at two locations. Numbers of enterococci were highest at three of the four locations after two days, and remained above 1,000 cfu/ml for three days following rainfall at three of the four locations. Cole Park levels dropped after two days but were still well above maximum allowable densities. The last water samples collected were five days after rainfall and numbers of enterococci were still two-six times the 104 cfu/100 ml limit except at Swanter Park where levels were at acceptable levels.

Fecal coliforms. The second rainfall event was May 11, 1999 (2.8 cm, 1.1 in). This was a light rainfall with only a small quantity of runoff observed. Numbers of both enterococci and fecal coliforms were highest the day after rainfall. At Swantner Park and McGee Beach numbers were below the maximum allowable densities within three days, while Cole Park and Ropes Park indicator levels still exceeded standards at this time interval. By five days after sampling, both fecal indicators at all locations were at or below maximum allowable densities for single samples.

The third rainfall event monitored was the heaviest rainfall during the period of this study (17 cm, 6.7 in). The rain occurred over a two-day period (August 22-23) (16.5 cm, 6.5 in), with a trace amount on August 24 (0.5 cm, 0.2 in). The first sample collection was August 24, after the majority of the rain had fallen. The highest numbers of enterococci and fecal coliforms were found between two and three days after the initial rainfall. At Ropes Park, numbers of enterococci remained at approx. 1000 cfu/100 ml for five days after the first rainfall. After nine days, numbers were still above (Cole Park) or approximately at, the maximum allowable single sample level; and at 11 days were above pre-rainfall levels at two locations. Fecal coliform levels were considerably reduced after three days but at Cole Park and Ropes Park were still above the standard at four days.

Rainfall event 4 followed a month after the previous event, at the end of September 1999 with 7.6 cm (3 in). For this event highest numbers of fecal indicator bacteria were found at Ropes and Swantner Parks. Fecal coliforms returned to acceptable single sample levels within four days; however, enterococci numbers at Ropes Park still exceeded standards after four days.

The last two rainfall events included in this study occurred in March and May of 2000, with rainfall amounts of 3.3 cm (1.3 in) and 3.8 cm (1.5 in) respectively. Peaks of several thousand fecal coliforms and enterococci occurred the day after rainfall. In March fecal coliform numbers at the Marina and Swantner Park returned to acceptable levels within three days. Swantner Park waters still contained elevated numbers of enterococci. Water samples from sites at Cole Park and Ropes Park contained high numbers of both fecal coliforms (350-2200 cfu/100 ml) and enterococci (2000-6000 cfu/100 ml) at three days. The next day fecal coliform levels were acceptable but enterococci levels still exceeded the standard at Ropes Park after six days. In May 2000, after rainfall of 3.8 cm (1.5 in), with the exception of two sites at Ropes Park, enterococci numbers returned to acceptable levels within four days, fecal coliforms within three days.

While numbers between sites at each location were not significantly different, for certain events, numbers appeared to be higher to one side of the outfall than the other. Graphs of enterococci levels at all three sites for each location and rainfall event are included in Appendix C. The data are listed in Appendix B.

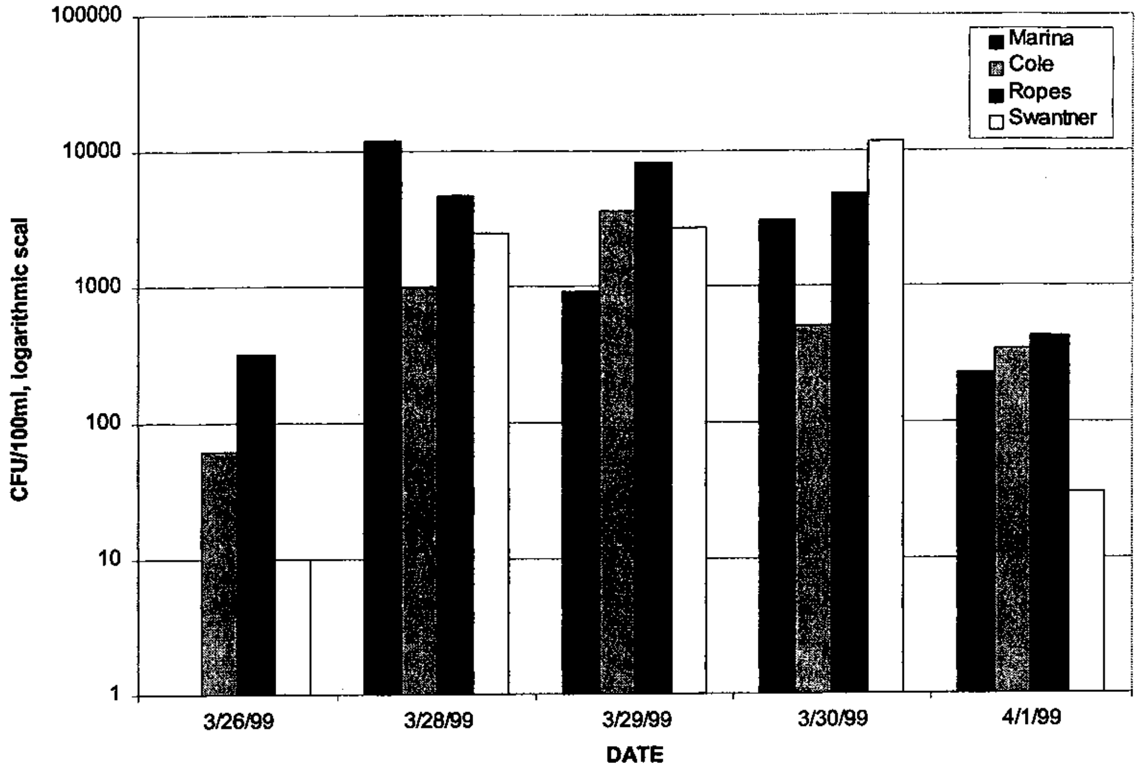

Figure 8. Enterococci counts before (3/26/99) and after March 27 1999 rainfall event 1 (8.64 cm, 3.4 inch) at stormdrain locations.

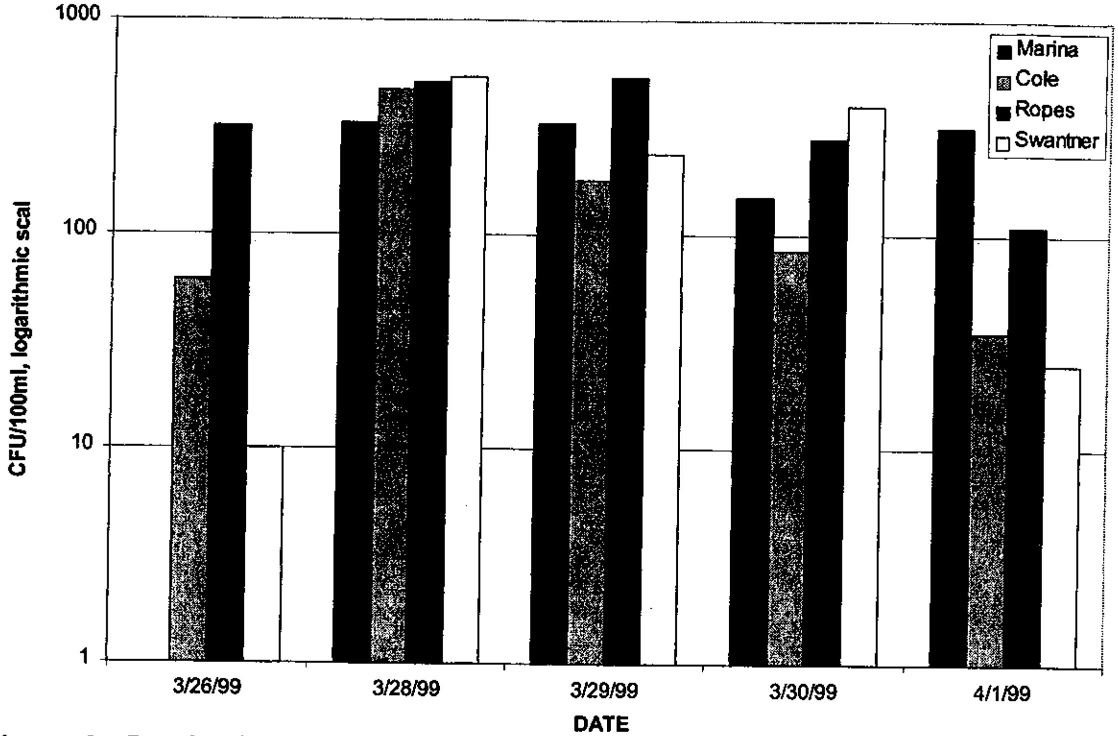

Figure 9. Fecal coliform counts before (3/26/99) and after March 27 1999 rainfall event 1 (8.64 cm, 3.4 inch) at stormdrain locations.

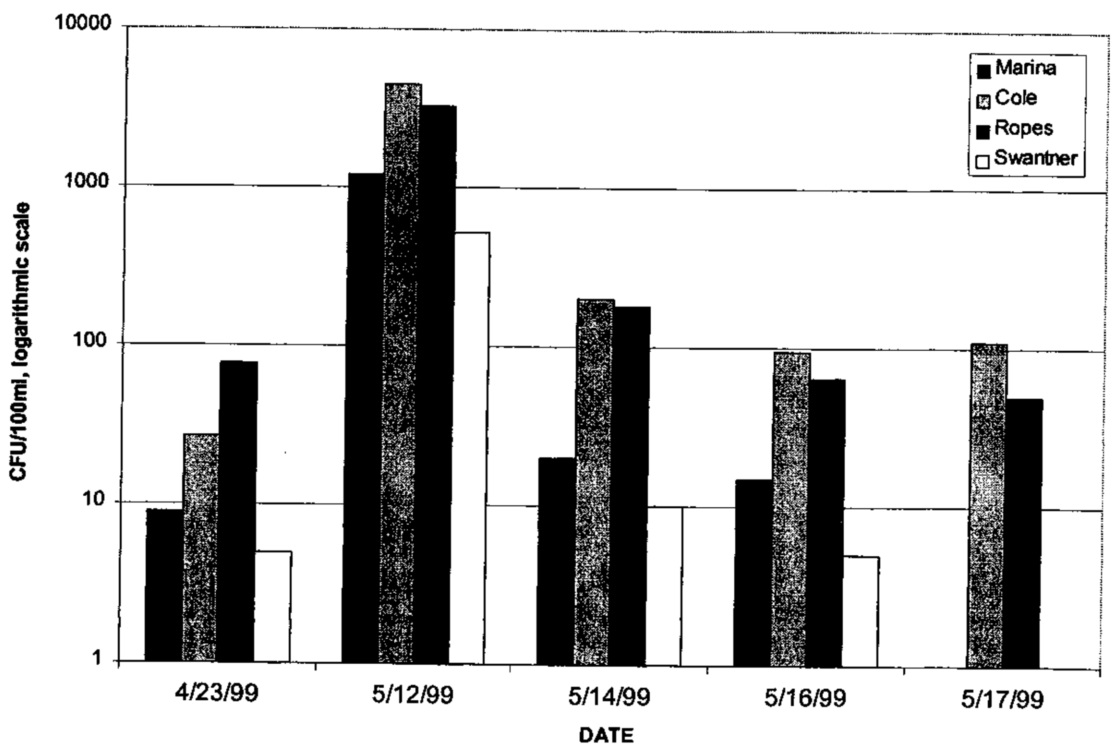

Figure 10. Enterococci counts before (4/23/99) and after May 11 1999 (2.79 cm, 1.1 inch) rainfall event 2 at stormdrain locations.

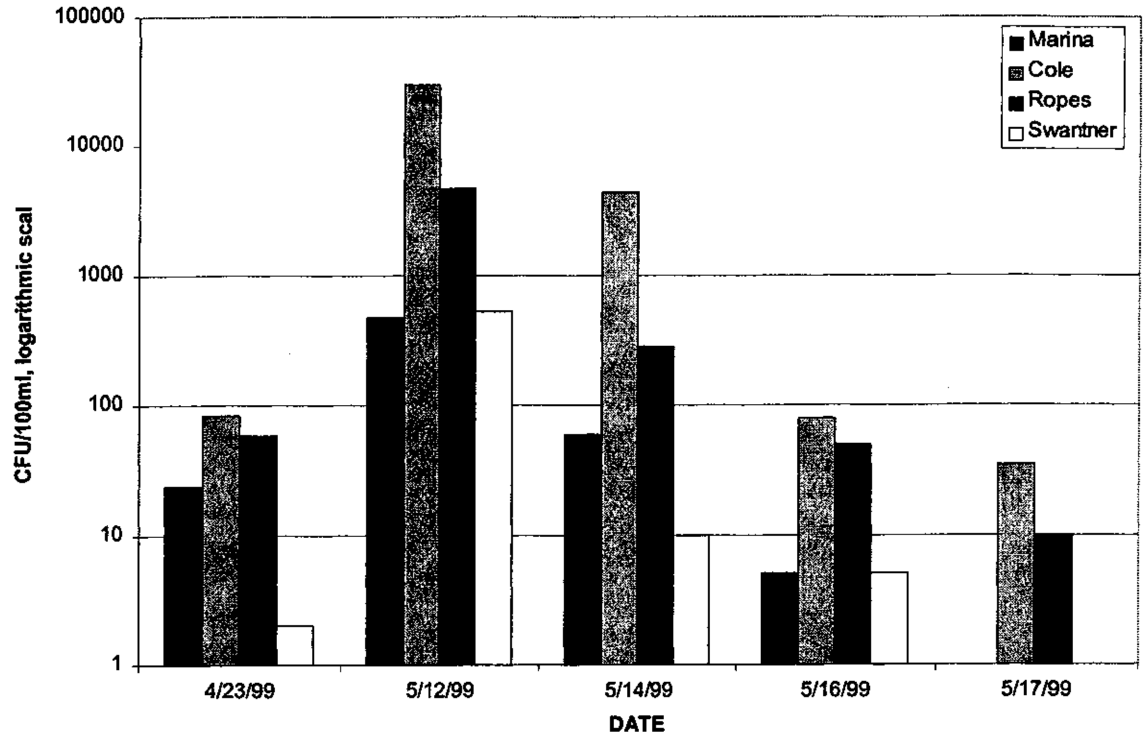

Figure 11. Fecal coliform counts before (4/23/99) and after May 11 1999 rainfall event 2 (2.79 cm, 1.1 inch) at stormdrain locations.

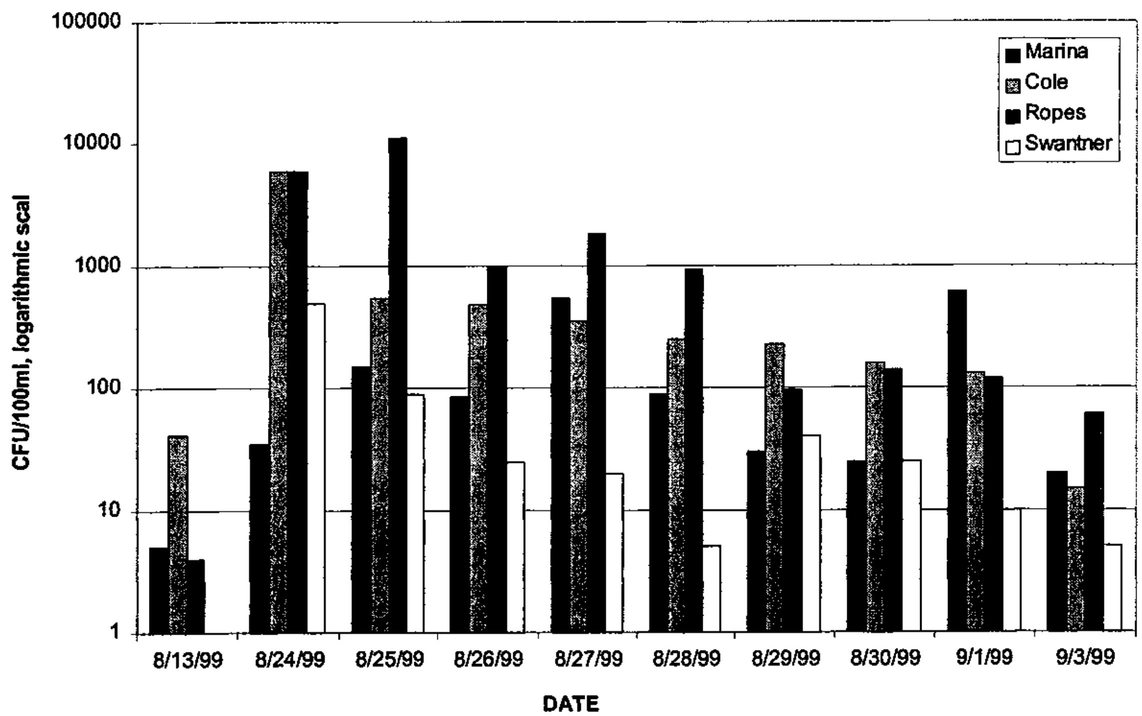

Figure 12. Enterococci counts before (8/13/99) and after August 22-23 1999 rainfall event 3 (17.02 cm, 6.7 inch) at stormdrain locations.

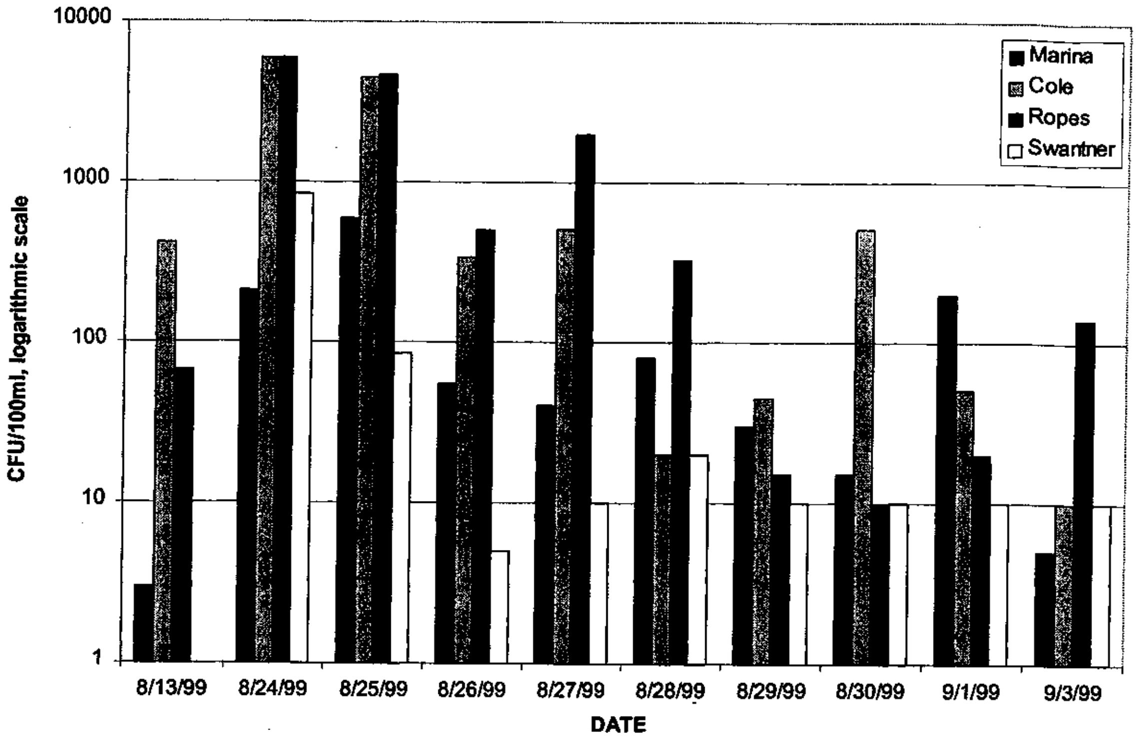

Figure 13. Fecal coliform counts before (8/13/99) and after August 22-23 1999 rainfall event 3 (17.02 cm, 6.7 inch) at stormdrain locations.

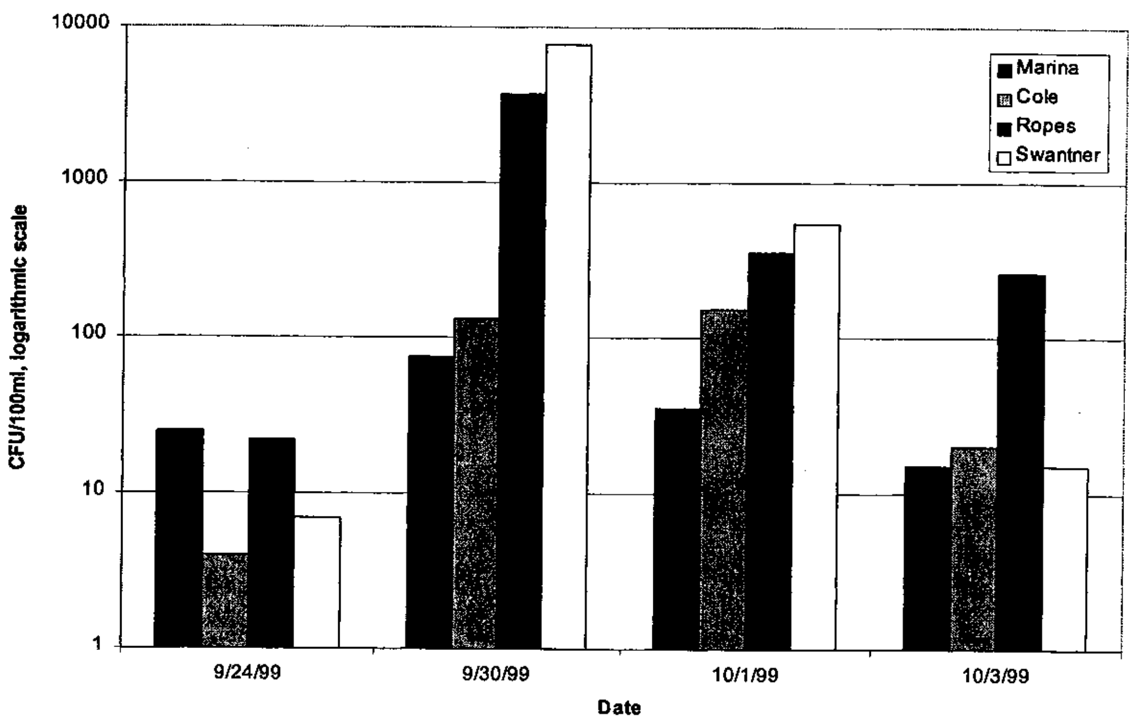

Figure 14. Enterococci counts before (9/24/99) and after September 29 1999 rainfall event 4 (7.62 cm, 3.0 inch) at stormdrain locations.

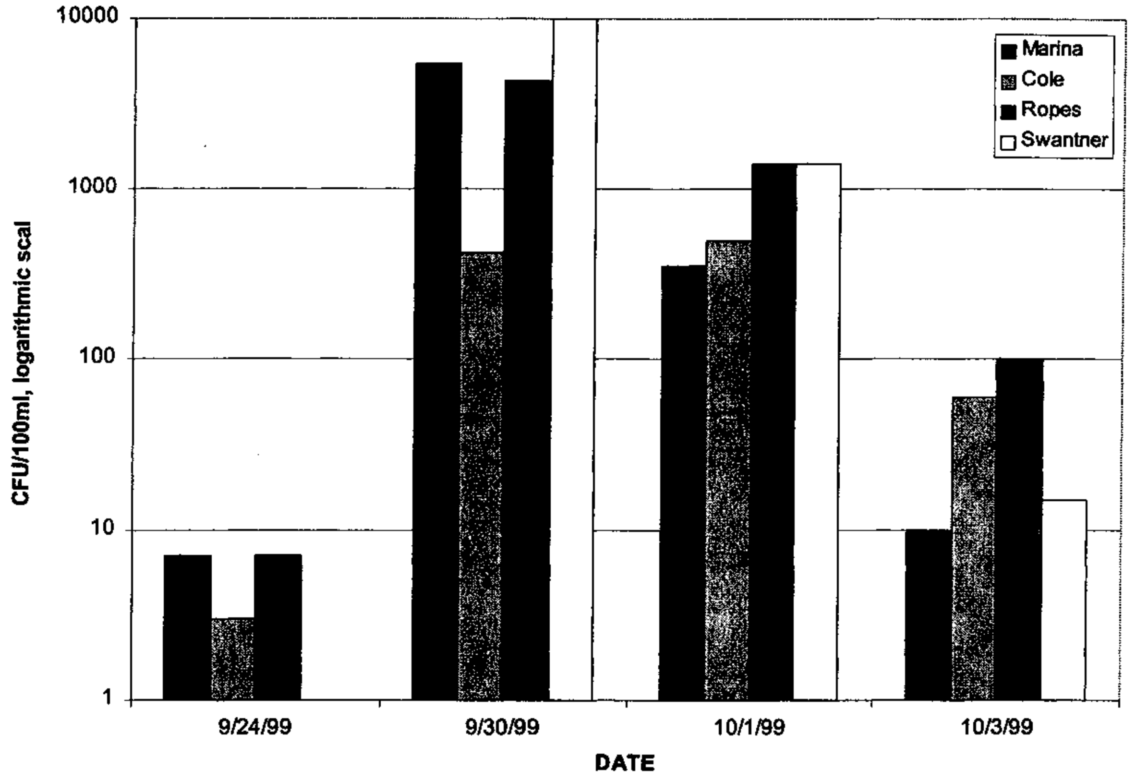

Figure 15. Fecal coliform counts before (9/24/99) and after September 29 1999 rainfall event 4 (7.62 cm, 3.0 inch) at stormdrain locations.

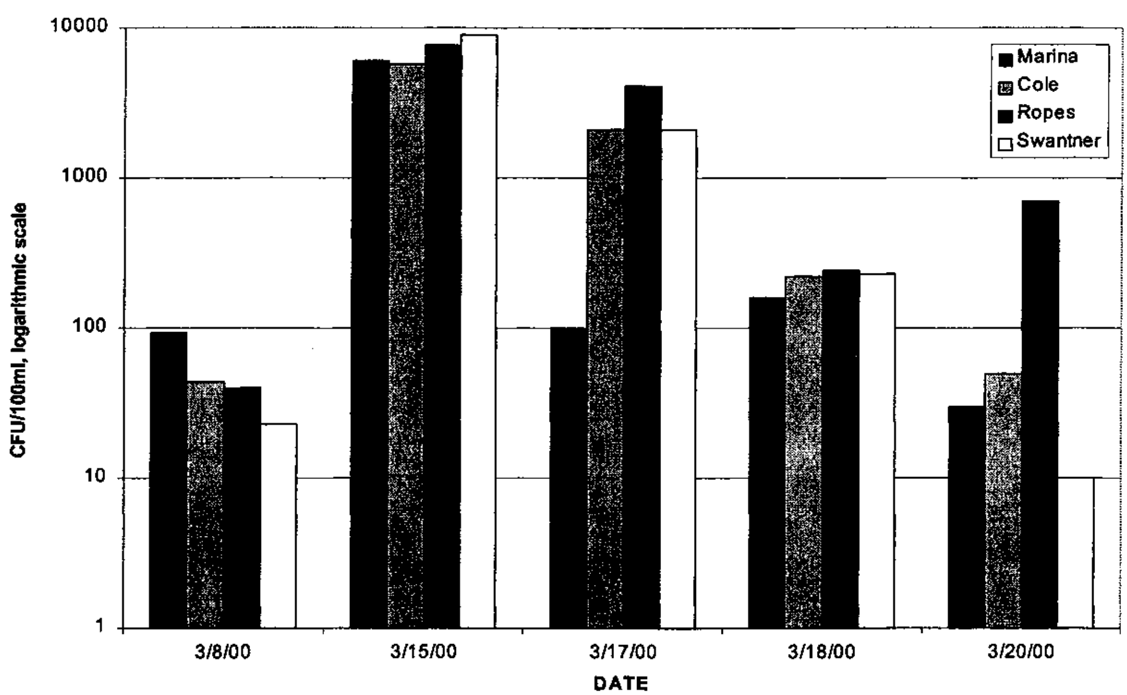

Figure 16. Enterococci counts before (3/8/00) and after March 14 2000 rainfall event 5 (3.30 cm, 1.3 inch) at stormdrain locations.

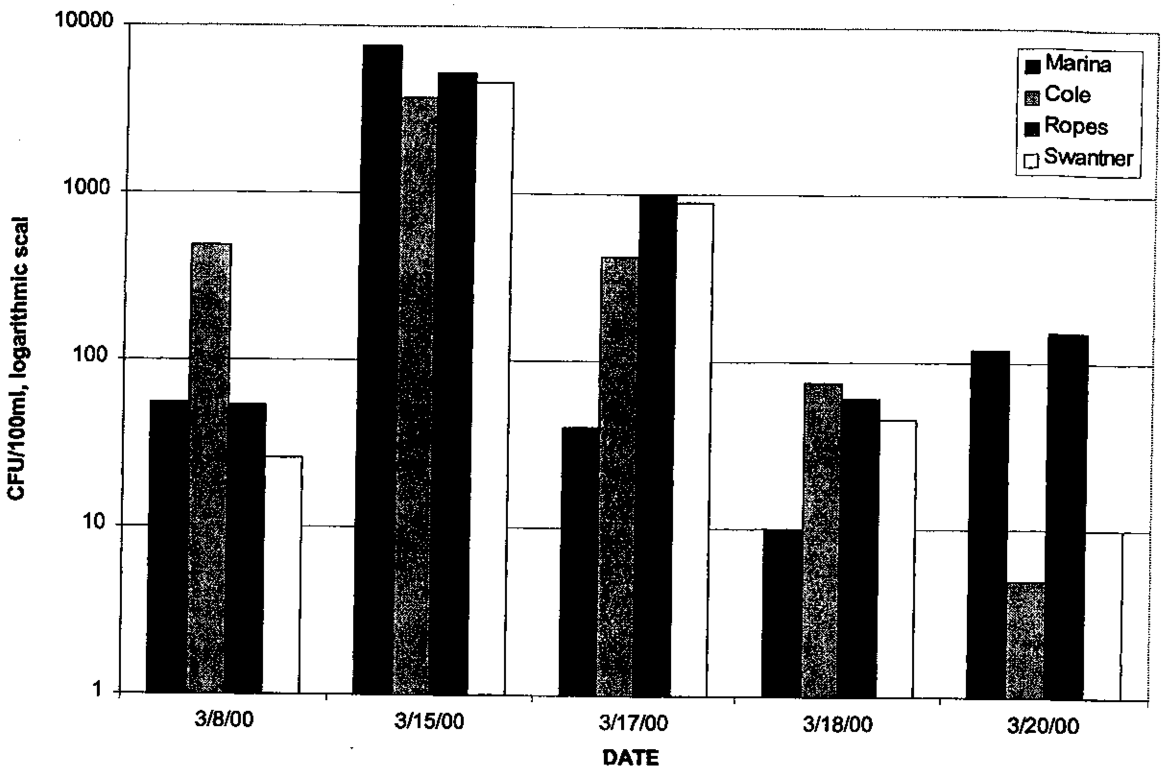

Figure 17. Fecal coliform counts before (3/8/00) and after March 14 2000 rainfall event 5 (3.30 cm, 1.3 inch) at stormdrain locations.

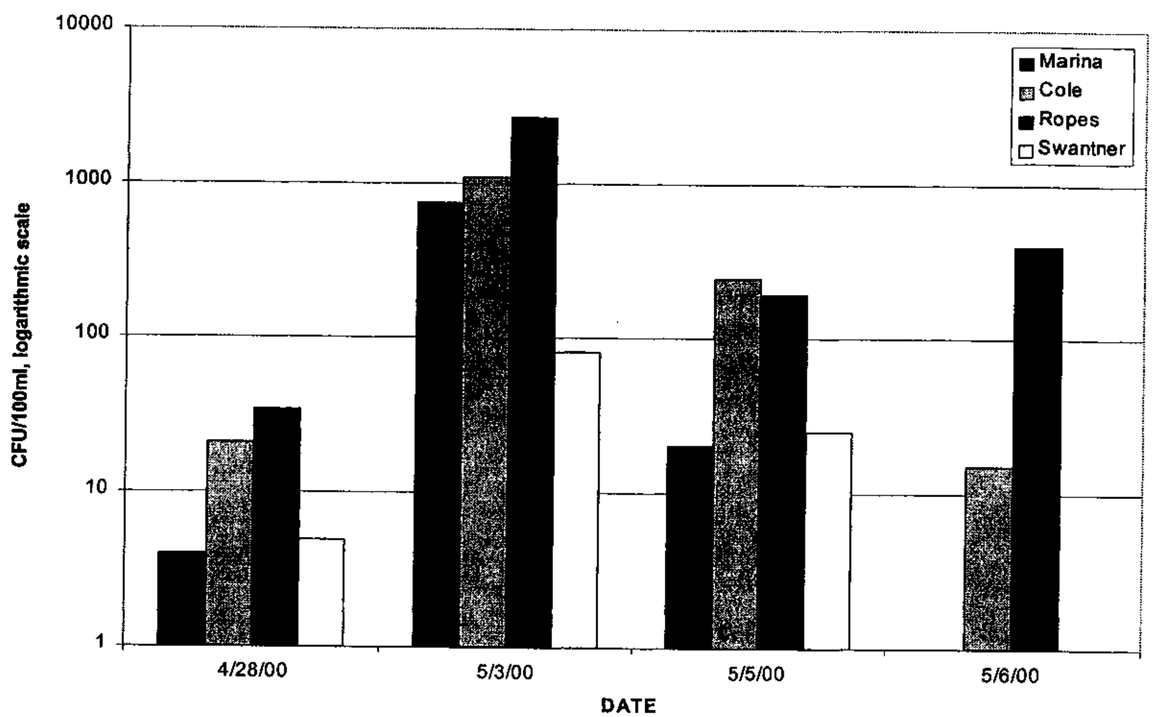

Figure 18. Enterococci counts before (4/28/00) and after May 2 2000 rainfall event 6 (3.81 cm, 1.5 inch) at stormdrain locations.

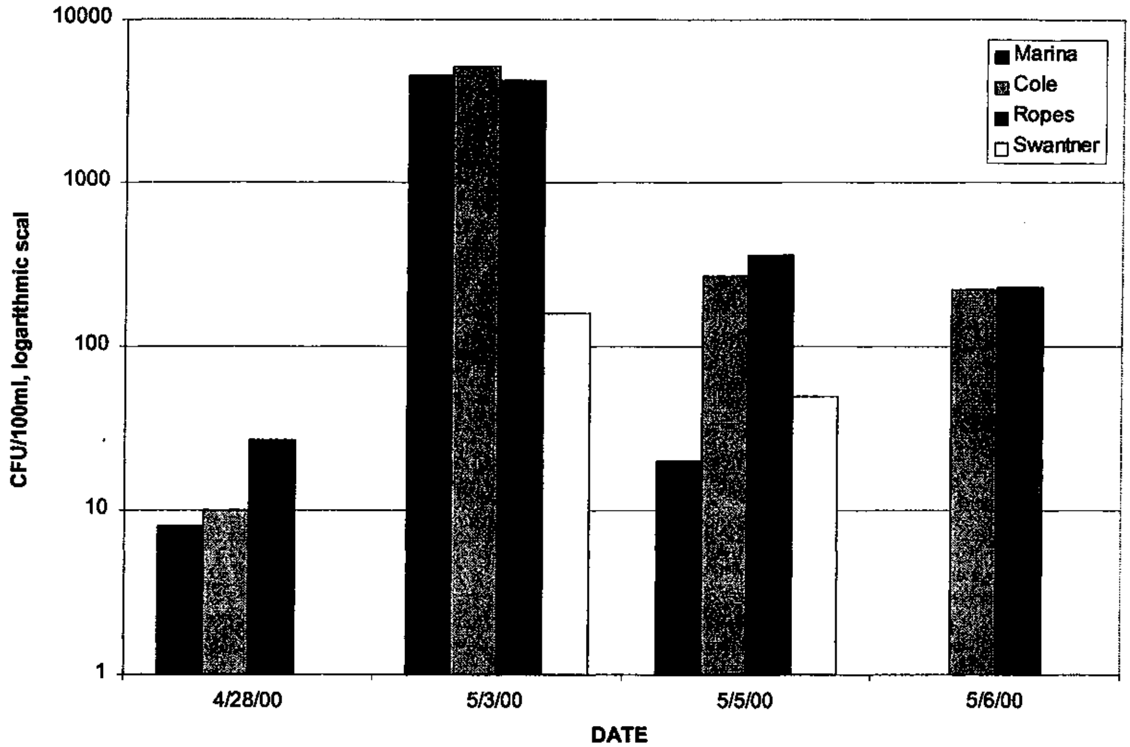

Figure 19. Fecal coliform counts before (4/28/00) and after May 2 2000 rainfall event 6 (3.81 cm, 1.5 inch) at stormdrain locations.

Total coliform:Fecal coliform Ratios. Ratios were calculated for each location, using the mean bacterial concentrations during wet and dry weather. While the overall levels of total coliforms were not affected by rain (Table 4), the ratio changed due to the elevated fecal coliform levels (Table 8). A ratio of 5.0 or less was used as a cutoff point for health risk because it is assumed that when one is exposed to sewage contaminations fecal coliform densities increase; thus decreasing the TC:FC ratio. (Haile, 1996). None of the ratios were reduced to this level except at the marina, where dry weather ratios were also low. Total coliform numbers were much lower at the marina than at other locations (Tables 3 and 4).

Table 8. Total coliform: fecal coliform ratios calculated from data collected by sampling Corpus Christi Bay waters during dry and wet weather conditions. Location A=Marina, B=Cole Park, C=Ropes Park, D= Swanter Park.

Location	Dry weather TC:FC	Wet weather TC:FC	Change in ratio
A	3.08	1.42	1.66
B	57.10	14.39	42.71
C	35.19	12.50	22.69
D	37.22	6.33	30.89

Intensive Sampling. ("5 samples collected in a 30 day period"). In addition to the twice a month collections, two three-month periods were sampled five times in 30 days to obtain data which could be compared to the EPA guidelines for this frequency of sampling (the geometric mean of the indicator bacteria in five samples should not exceed 200 cfu/100 ml for fecal coliforms, or 35 cfu/100 ml for enterococci). Samples were taken at regular intervals, regardless of rainfall, to obtain a representative set of samples for these periods.

Tables 9 and 10 show the results of this intensive sampling for enterococci and fecal coliforms. Fecal coliform levels only exceeded guidelines for one month - March 2000, (after a trace rainfall) at one site – the Marina (A), at a distance of 135 m south of the outfall. In contrast enterococci levels exceeded EPA criteria in half of the results. Water collected at Swanter Park (D) (the reference location) did not exceed the standard for any of the six months and at Cole Park (B) samples exceeded levels at the three sites only for March 2000. However, numbers were elevated at all three Ropes Park (C) sites for all but one of the sample months.

Table 9. Geometric mean values for "5 samples collected over a 30-day period" for fecal coliforms at the three sites at each location along Corpus Christi Bay. Numbers asterisked are those which exceed the EPA criteria of 200 cfu/100ml. Location A=Marina, B=Cole Park, C=Ropes Park, D= Swanter Park.

Date	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1
Sept 99	16	10	13	8	17	24	43	35	47	3
Oct 99	20	27	47	25	30	40	22	21	26	30
Nov 99	9	15	33	39	9	11	16	16	12	9
Feb 00	64	115	145	15	16	19	55	61	62	15
Mar 00	81	110	325*	127	92	82	132	129	128	24
Apr 00	52	51	144	102	158	119	109	82	112	10

Table 10. Geometric mean values for "5 samples collected over a 30-day period" for enterococci at the three sites at each location along Corpus Christi Bay. Numbers asterisked are those which exceed the EPA criteria of 35 cfu/100ml. Location A=Marina, B=Cole Park, C=Ropes Park, D= Swanter Park.

Date	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1
Sept 99	25	19	22	15	18	42*	82*	46*	58*	4
Oct 99	45*	44*	42*	24	29	27	48*	50*	36*	34
Nov 99	18	16	32	8	8	17	24	36*	21	26
Feb 00	21	40*	49*	21	35	32	39*	48*	44*	22
Mar 00	76*	80*	184*	110*	107*	191*	263*	308*	211*	35
Apr 00	30	21	15	46*	36*	22	136*	99*	101*	11

CONCLUSIONS AND RECOMMENDATIONS

Trends and levels of each water quality parameter measured in the study were similar to those found in other studies of South Texas coastal waters and did not significantly affect indicator bacteria concentrations. The parameters appeared to be influenced by seasonal changes and rainfall. Seasonal trends were seen in water temperature, while dissolved oxygen and salinity were affected by rainfall. Water temperature is known to affect survival of bacterial indicators. An inverse correlation between bacterial levels and water temperature was demonstrated in a study conducted for the Guadalupe Blanco River Authority and the TNRCC (PBS&J 1999). In a recent study in Oso Bay, Corpus Christi (Heilman et al. 2000), indicator bacteria numbers were also lower in warmer months and Salyer et al. (1975) reported higher coliform levels during winter months in an open bay study.

In the current study, differences were found between fecal and enterococci in relation to EPA standards for these indicators, in dry weather water samples. This has implications for evaluation of contact recreation water quality using the proposed standard of enterococci for marine waters instead of fecal coliforms. Enterococci levels exceeded standards more frequently in dry weather water samples and remained elevated after rainfall for a longer period than fecal coliforms. Other studies evaluating beach closures using enterococci versus fecal coliforms have also shown that the use of enterococci would result in more beach closures or water use restrictions (Heilman et al. 2000, McGee 2000; Nuzzi and Burhans 1997).

Additional factors should be evaluated to determine the cause(s) of elevated indicator levels found during dry weather sampling. Parameters such as wind and current speeds and directions play a role in resuspending bacteria in sediments, which are potential reservoirs for fecal indicator bacteria as shown by Francy and Darner (1998) in Lake Erie. Goyal et al. (1977) found higher numbers of fecal coliforms in sediments than in overlying water in Texas canals. Francy and Darner (1998) identified, in addition to rainfall, both turbidity and wave height as factors which affected *E. coli* numbers in Lake Erie beach waters, while water temperature, wind speed and direction were not significant parameters. A study to examine populations of indicator bacteria in Corpus Christi Bay sediments could elucidate whether this is an important source of these organisms. Turbidity, wave height, tides, and wind parameters should also be evaluated as influences on bacteria levels in bay waters.

This current study clarified the importance of rainfall on indicator bacteria levels (and probable fecal contamination) in Corpus Christi Bay, via storm drain outflow, and provides data on the duration of elevated numbers of both fecal coliforms and enterococci at four recreational park areas along Corpus Christi Bay. Numerous studies of surface waters have shown significant increases in levels of indicator bacteria after rainfall (Ferguson et al. 1996; Francy and Darner 1998; Gannon and Busse 1989; Young and Thackston 1999) and the need to close beaches at these times (for example Horvatin 2000). Levels of indicator bacteria in Corpus Christi Bay peaked within two days of rainfall at levels sometimes exceeding 10,000 cfu/100 ml, the exact timing probably depending on the lag time before outflow from the drains commenced. Other studies have shown the first flush of runoff to contain the highest numbers of indicator bacteria e.g. Davis et al. (1977).

Depending on the quantity of rainfall, levels of enterococci in this study remained above single sample maximum densities for several days following rainfall, after bay waters have returned to calm conditions. Elevated levels of both enterococcci and fecal coliforms were found for up to 6 days after 2.8-8.6 cm (≈1-3.5 inch) rainfall and 9-11 days (depending on location) after a 17 cm rainfall. A recent review by EPA (1999) cites several examples of local entities using predictive rainfall models for beach advisories or closures. For example, the city of Milwaukee, Wisconsin, guidelines for closure of one beach range from 48 hours for 0.3-0.69 inch to 96 hours for 1.5 inch or more. Nuzzi and Burhans (1997) suggested use of a rainfall-tidal model calibrated by routine monitoring for each beach as the best approach to protecting public health. As rainfall-based alert curves are site specific and can be based on rainfall characteristics or frequency of exceedance analysis (EPA 1999), data collection at each location is required. Additional monitoring of wet weather events is needed to collect data for Corpus Christi Bay on the relationship between quantity of rainfall and duration of elevated levels, for potential use in predictive modeling and swimming advisories for CBBEP area waters. The limitation on this work is the frequency, or paucity of rainfall events in the South Texas area. For the period of this study (1.5 years) there were only six rainfall events over the whole Coastal Bend area, exceeding one inch. Scattered heavy rainfall events occurred in parts of the Coastal Bend but these events usually do not generate runoff or drain into the bay, and so were not monitored.

Effects of storm water outflow extended further than the distances evaluated in this study, although other factors such as shoreline characteristics may influence distance impacted by stormwater outflow. Bacterial concentrations at sites distant from each outfall were not significantly different from those at the outfall, in either dry or wet weather. On some occasions, during both dry and wet weather events, densities of bacterial indicators showed trends of higher numbers one side of the outflow than the other. Environmental factors including wind and wave direction, detrital matter present, and sediment resuspension may have been responsible for these differences. The higher bacterial concentrations tended to occur in water at the most "sheltered" site, i.e. the site where debris was accumulating due to effects of wave action and direction. Deely et al. (1997) found variability in enterococci at marine beaches with elevated levels with high winds, incoming tide and nearby outfalls discharging, except for sites protected by landforms. The Santa Monica study (Haile, 1996) found a rapid decrease in incidence of disease and fecal bacteria with distance from storm drain, from 0 yards to 400 yards.

At Ropes Park the entire length of public access shoreline was affected by the outflow, and levels of indicator bacteria were not significantly different in water 50 m distance compared with that at the storm drain. Cole Park shoreline was also affected at this distance each side of the outflow. The Swantner Park data suggests that at greater distances (the location was approx. 200 m from an outfall) the effect may be reduced. However, storm drain outfalls are generally closer than 200 m at public shoreline access areas along Corpus Christi Bay. (Swantner Park was used as a reference location as it was the furthest distance that could be found from a stormdrain outflow, in a public access area).

Additional work is needed to further clarify the extent of influence of storm drain outflow along the shoreline and to identify other factors that may play a role in this, such as shoreline topography and wind direction/speed. Shoreline outfalls are not metered, so data was not available on quantities or duration of outflow at each location. It seems likely that differences in both these parameters between locations may at least partially account for differences in the extent and duration of elevated fecal indicator bacteria between locations. Previous rainfall and soil moisture will affect the quantity of runoff from a particular rainfall event, in addition to the actual rainfall quantity. Water source differences between outflows may also affect the levels of indicator bacteria in bay water samples.

Another aspect not addressed in this study is the distance from the shoreline affected by storm drain outflow. Common recreational activities, such as windsurfing at Ropes Park, occur further offshore; additional work is needed to examine stormwater impact in these waters.

Our data demonstrate that rainfall would be a useful parameter in predictive modeling of water quality in Corpus Christi Bay. For rainfall events over one inch bacteria levels exceeded the EPA criteria for four to six days, and after extremely high rainfall quantities this period was approximately ten days. This information should be useful for public officials in determining appropriate advisories. Additional data should be collected on indicator levels following rainfall of different intensities to further refine the duration of elevated levels after rainfall. Examples of rainfall-based beach advisories in the 1999 EPA report "Review of potential modeling tools and approaches to support the BEACH program", show ranges of 24-72 hour advisories for rainfall quantities of 0.2 inch to 1.5 inch for locations from Connecticut to California. For some, duration was 'until samples indicate low bacterial count'.

The proportion of samples in the "five in 30 day sampling periods" containing enterococci levels above the maximum allowable density is a cause for concern. It also illustrates the difference between using fecal coliforms and enterococci as the indicator for fecal contamination. For one of the months trace rainfall occurred, without significant outflow into the bay, suggesting further work should include monitoring after small quantities of precipitation. While the standard levels were not exceeded by a large margin compared with wet weather samples, the EPA has linked elevated enterococci levels with increased risk for illness. In light of the results of our study, it is recommended that sampling of beach areas be increased to weekly intervals, at least during summer months when there is maximum recreational use of these waters.

Water quality at Ropes Park seemed to be the most compromised of the four locations, both in wet and dry weather. This may be related to shoreline characteristics and/or the quantity and sources of stormwater runoff at this location. This park is used by windsurfers in both dry weather and after rainfall, so increased frequency of water monitoring at this location is recommended.

While the total:fecal coliform ratio changed after rainfall, the use of this parameter is not recommended due to both methodology (need to analyze samples for both total coliforms and fecal coliforms) and lack of EPA recognition in standards. Total coliform levels were the highest of the indicators throughout the study and were not significantly affected by rainfall. This may be partially explained by the fact that some members of this group of bacteria are normal inhabitants of marine waters (Joyce 2000) although most total coliforms are terrestrial (Vasconcelos and Anthony 1985). Plant material and soil carried into water at some locations after rainfall or increased winds, may contribute to higher total coliform concentrations in these waters. Water samples from locations with a gradual transition from beach to water allowing more soil and plant material (grass) to be washed into the water (Cole Park and Ropes Park) contained higher numbers than those where a concrete seawall was present (Marina and Swantner Park). Higher numbers at Swanter Park compared with the Marina could be due to the close proximity of grass area behind the seawall at the former location.

This research was restricted to four locations along Corpus Christi Bay and was intended as a pilot study to serve as a model for future studies of additional high use CBBEP area waters impacted by stormwater outflows or runoff from rainfall. The extent and duration of elevated indicator bacteria levels found in this study supports the importance of intensive monitoring and characterizing other CBBEP recreational waters to determine their microbiological water quality under different environmental conditions, for public health purposes. Bacteriological concentrations at urban beaches should be compared with both high usage and infrequently used rural beaches, in order to develop an effective, scientifically based program for beach management in the Coastal Bend region. Our study has provided data to characterize effects of storm drain outflow on Corpus Christi Bay waters that can be used in the development of a predictive model based on rainfall. Other factors, such as turbidity, wave height, wind speed and direction, still need to be evaluated and should be included in future studies.

Finally, it is recommended that intensive dry and wet monitoring be repeated at regular intervals to assess changes in water quality of Corpus Christi Bay shoreline waters, as they continue to be impacted by the increasing coastal bend population.

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APPENDICES

APPENDIX A

WORKSHOP REPORTS

MICROBIOLOGICAL MONITORING AND ASSESSMENT OF STORM DRAIN RUNOFF WITHIN THE CBBEP PROJECT AREA

PRINCIPAL INVESTIGATOR:

JOANNA B. MOTT, CENTER FOR COASTAL STUDIES
(361) 825-6024 FAX: 825-2742

CBBEP Project Coordinator: Marcia Lochmann

Date of submission: August 15, 1999

SUBMITTED TO:

Corpus Christi Bay National Estuary Program
Natural Resources Center Suite 3300
6300 Ocean Drive
Corpus Christi, TX 78412

Report on Recreational Water Quality Workshop

July 21, 1999, 10:00 a.m. – 12:00 p.m.
Natural Resources Center, Room 1009

Present were:
Marcia Lochmann, CBBEP
Joanna Mott, A&M-CC
Bryan Seidel, A&M-CC
Rachael Brooks, A&M-CC
Marilyn Torno, San Patricio County
Thomas Touchstone, Aransas County
Jim McFarland, Nueces County/Corpus Christi
Stephen Shepard, Nueces County/Corpus Christi
A.L. Noyola, Kleberg County/Kingsville
Simon Savedra, Kleberg County/Kingsville
Dave Sullivan, Naismith Engineering

Agenda:

I. Welcome and Introductions – Marcia Lochmann
II. Project Objectives and Status – Dr. Joanna Mott
III. EPA Action Plan for Beaches and Recreational Waters – Dr. Mott
IV. Existing Monitoring Efforts – Local Health Officials
V. Improvements Needed – Local Health Officials
VI. Contact Recreation Workgroup
  A. Other partners
VII. Next Meeting/Workshop
  A. Stakeholders to invite

The meeting was conducted by the CBBEP Project Coordinator, Marcia Lochmann, as an informal exchange of information and ideas regarding the status of microbiological monitoring in the CBBEP area.

I. Welcome and Introductions – Marcia Lochmann, CBBEP Planner

Marcia explained the Coastal Bend Bays and Estuaries Program and its goals. She then briefly reviewed the history of the Public Health action plan and the priority actions in the development of the Coastal Bend Bays Plan.

II. Recreational Water Quality Monitoring Project

Project Objectives and Status – Dr. Joanna Mott, Principal Investigator of the Microbiological monitoring and assessment of storm drain runoff within the CBBEP project area project and

Co-Leader of the CBBEP Public Health Task Force reviewed the history and development of the task force goals, objectives and actions. She also explained the storm drain runoff study and its initial findings. Lastly, she described the workshop component of the project.

III. EPA Action Plan for Beaches and Recreational Waters – Dr. Mott

Dr. Mott reviewed the EPA BEACH program which includes a new recommended indicator (enterococcus) and 24 hour method (Method 1600) for marine recreational water monitoring.

IV. Existing Monitoring Efforts – Local Health Officials

The representatives from each county described the current monitoring being conducted in their areas. The most comprehensive is that in the Corpus Christi area, where the health department conducts monthly monitoring at 16 stations, primarily along the Corpus Christi Bay shoreline within the city limits. Mr. McFarland commented that they are now sampling for fecal coliforms after some rain events. The indicator being analyzed is fecal coliform although some enterococcus analyses are being run. Mr. Touchstone stated that Aransas County sends occasional samples to Nueces County for fecal coliform analysis but that levels are generally very low due to tidal action. Kleberg County and San Patricio County do not conduct microbiological monitoring of their recreational waters.

V. Improvements Needed – Local Health Officials

The representatives from the counties discussed several issues including monitoring of septic systems, the need for education of the public and the lack of available funds to perform monitoring. It was generally felt that it was important to work proactively to inform policy makers of current monitoring recommendations and costs involved.

VI. Contact Recreation Workgroup

A. Other partners

The need to bring in other city officials from the CBBEP area was discussed.

VII. Next Meeting/Workshop

A. Stakeholders to invite

Marcia Lochmann suggested that as a number of the members of this workshop were also members of the On-Site Sewage Facilities workgroup, the two groups combine to hold a larger workshop September 13, 1999. Stakeholders to invite were discussed and a list was compiled including government officials. Marcia requested that if individuals identified additional stakeholders that they would send those to her for inclusion.

The workshop was adjourned at approx. 12.00 p.m.

MICROBIOLOGICAL MONITORING AND ASSESSMENT OF STORM DRAIN RUNOFF WITHIN THE CBBEP PROJECT AREA

PRINCIPAL INVESTIGATOR:

JOANNA B. MOTT, CENTER FOR COASTAL STUDIES
(361) 825-6024 FAX: 825-2742

CBBNEP Project Coordinator: Jeff Foster

Date of submission: October 4, 1999

SUBMITTED TO:

Corpus Christi Bay National Estuary Program
Natural Resources Center Suite 3300
6300 Ocean Drive
Corpus Christi, TX 78412

Report on Recreational Water Quality Workshop
(Joint Workshop with OSSF Management Workshop)

September 13, 1999, 9:00 a.m. – 3:00 p.m.
Blucher Institute 9:00 a.m. – 12:00 p.m.
Natural Resources Center, 1:00 – 3:00 p.m.

The workshop was a joint meeting for contact recreation water quality and OSSF Management. This report will cover only the contact recreation portion of the workshop.

Attendance:
Twenty-five participants attended the morning session, twenty returned for the afternoon discussions.
CBBEP has a full list of participants and contact information.

Reference Materials provided by CBBEP:
Copies of the EPA publications: Action Plan for Beaches, BEACH Program, Beach Brochure, Method 1600; CBBEP publications: Bays Plan, State of the Bay Report, Newsletters, Non-point Source Fact Sheets; NRDC Report.

Agenda:

I. **Introductions and Background – Marcia Lochmann, CBBEP**
II. OSSF Management
III. OSSF Regulations/Enforcement
IV. Health Implications associated with failing OSSFs
V. Questions/Suggestions for Panel
VI. **Recreational Water Quality Monitoring – Dr. Joanna Mott**
VII. **Recreational Water Quality Monitoring and Standards – Paul Jensen, PBS&J**
VIII. **Questions/Suggestions for Panel**
IX. **Discussion sessions**
A. Recreational Water Quality Monitoring/Public Notification Plan Task Force (Joanna Mott, TDH, City Officials, Health Officials)

I. Introductions and Background – Marcia Lochmann, CBBEP Planner

Marcia briefly reviewed the history of the Coastal Bend Bays and Estuaries Program and its goals. She then described the workshop issues – OSSF and Recreational water quality and introduced the panel of speakers.

VI. Recreational Water Quality Monitoring – Joanna Mott, TAMUCC

Dr. Joanna Mott presented an overview of national initiatives focussing on recreational water quality. She outlined the main objectives in the EPA BEACH program including a new recommended indicator (enterococcus) and 24 hour method (Method 1600) for marine recreational water monitoring, and the emphasis on public education and information. Key points in the EPA Beach Action Plan, The Clean Water Initiative and the Natural Resource Defense Council's 1999 report were described. Dr. Mott then reviewed the project for which she is Principal Investigator, under contract with the CBBEP, entitled "Microbiological monitoring and assessment of storm drain runoff within the CBBEP project area". Some preliminary findings were discussed, but it was emphasized that data analyses have not yet been performed.

VII. Recreational Water Quality Monitoring and Standards – Paul Jensen, PBS&J

Dr. Paul Jensen of PBS&J presented information on water quality initiatives at the state level, and in particular, the role of TNRCC. PBS&J is working under contract with the TNRCC on a bacterial indicator study to evaluate bacterial monitoring at the state level. Dr. Jensen outlined proposed changes in contact recreation water monitoring in which the level of recreational use will be used in determining the frequency of monitoring. Draft recommendations will be printed in the Texas Register in November.

VIII. Questions/Suggestions for Panel

Ray Allen of the CBBEP asked how economic impacts of beach closures would be addressed in the plans. Dr. Jensen replied that the responsibility of developing a monitoring plan would be at the local government level. Mr. Allen asked how the TNRCC would oversee the local program and Dr. Jensen replied that the monitoring would be approved through a quality assurance project plan process.

IX. Discussion sessions

A. Recreational Water Quality Monitoring/Public Notification Plan Task Force (Joanna Mott, TDH, City Officials, Health Officials)

Jim Soper of TDH met with Dr. Mott during the afternoon discussion session. The poor attendance was probably due to concurrent discussion sessions on OSSF issues, including potential funding for projects through CBBEP.

The workshop was adjourned at approx. 2.30 p.m.

X. Next Meeting/Workshop

After discussion between CBBEP personnel and the Principal Investigator it has been decided that little purpose will be served by holding further workshops on contact recreation water quality at this time. The purpose of the workshops was to examine the potential of developing a regional approach to monitoring and developing a consensus with public officials. This has been explored through two workshops and while public officials from several counties have participated and in principle agreed to the concept, current monitoring is limited primarily to the Nueces County-Corpus Christi Health Department due to funding constraints in the other counties.

APPENDIX B

DATA COLLECTED DURING THE PROJECT

(Bacterial indicator numbers shown are arithmetic means of the numbers in each of the duplicate water samples collected)

Appendix B: Bacterial counts, Corpus Christi Bay, Texas

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
01/14/99	A1	No	310	310	410	12.92	7.97	8.17	26.80	41920
01/14/99	A2	No	490	330	1000	13.06	8.00	8.16	26.80	41580
01/14/99	A3	No	430	390	550	13.27	8.03	8.06	26.80	41280
01/14/99	B1	No	27	16	220	14.53	8.10	7.87	26.80	41640
01/14/99	B2	No	16	20	100	14.52	8.10	7.90	26.80	41510
01/14/99	B3	No	19	25	210	14.48	8.10	8.00	26.80	41580
01/14/99	C1	No	18	21	250	14.12	8.11	8.16	26.90	41560
01/14/99	C2	No	10	24	100	14.14	8.12	8.23	26.80	41620
01/14/99	C3	No	20	28	110	14.07	8.12	8.18	26.80	41760
01/14/99	D1	No	110	250	290	14.20	8.19	8.31	26.80	41620
01/28/99	A1	No	150	240	3000	18.83	7.84	6.21	26.70	41655
01/28/99	A2	No	82	220	200	18.82	7.83	5.34	27.00	42021
01/28/99	A3	No	76	250	210	18.84	7.88	6.42	27.00	42029
01/28/99	B1	No	68	160	80000	19.62	7.87	5.39	26.50	41121
01/28/99	B2	No	210	33	42000	19.58	7.91	5.99	26.90	41919
01/28/99	B3	No	26	25	45	19.63	7.92	6.29	26.90	41583
01/28/99	C1	No	30	58	150	19.42	7.84	6.54	27.20	42245
01/28/99	C2	No	38	51	130	19.45	7.86	6.57	27.20	42276
01/28/99	C3	No	36	51	120	19.37	7.84	6.10	27.20	42242
01/28/99	D1	No	2	5	10	18.89	7.66	6.80	27.40	42534
02/12/99	A1	No	100	120	500	13.69	7.97	8.01	29.00	44750
02/12/99	A2	No	110	110	480	13.71	7.98	7.86	29.00	44810
02/12/99	A3	No	210	180	2100	14.04	7.98	7.94	29.00	44760
02/12/99	B1	No	230	62	2600	17.64	7.98	6.92	28.80	44440
02/12/99	B2	No	940	380	42000	17.66	7.99	6.90	28.70	44340
02/12/99	B3	No	600	530	80000	17.59	7.99	7.01	28.50	44150
02/12/99	C1	No	870	700	11000	15.60	7.97	7.90	28.80	44520
02/12/99	C2	No	870	500	4200	15.60	7.99	7.96	28.80	44390
02/12/99	C3	No	750	460	7600	15.51	7.99	7.91	28.80	44520
02/12/99	D1	No	470	2000	38000	15.33	7.93	8.04	28.40	43500
02/26/99	A1	No	21	48	220	20.13	7.93	6.82	27.70	43460
02/26/99	A2	No	18	30	40	20.14	8.08	7.02	28.40	43910
02/26/99	A3	No	62	24	95	20.23	8.05	6.99	28.20	43590
02/26/99	B1	No	500	200	56000	20.73	8.08	5.63	28.20	43700
02/26/99	B2	No	40	16	1400	20.74	8.14	6.32	28.50	44200
02/26/99	B3	No	26	42	45	20.49	8.04	6.46	28.40	44180
02/26/99	C1	No	16	40	130	20.68	8.11	6.70	28.40	44010
02/26/99	C2	No	13	40	120	20.68	8.12	6.58	28.40	44070
02/26/99	C3	No	27	32	210	20.73	8.13	6.22	28.50	43950
02/26/99	D1	No	5	8	5	20.21	7.98	6.64	28.80	44440
03/12/99	A1	No	27	16	250	22.50	7.96	6.69	28.50	43830
03/12/99	A2	No	24	10	35	22.50	7.95	6.58	28.50	43900
03/12/99	A3	No	35	50	60	22.48	7.95	6.66	28.40	43960
03/12/99	B1	No	77	8	510	22.48	7.96	5.26	27.70	43380
03/12/99	B2	No	53	11	260	22.48	8.01	5.77	28.20	43700
03/12/99	B3	No	45	7	420	22.48	8.03	6.36	28.30	43640

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
03/12/99	C1	No	500	130	54000	22.57	7.92	6.52	28.30	43900
03/12/99	C2	No	300	160	39000	22.57	7.96	6.64	28.30	43830
03/12/99	C3	No	460	91	29000	22.59	7.97	6.35	28.30	43710
03/12/99	D1	No	6	20	5	22.50	7.95	6.47	28.40	43830
03/13/99	A1	No	160	2200	300	18.99	7.90	6.33	29.10	44890
03/13/99	A2	No	350	160	410	19.60	7.91	6.70	29.10	44960
03/13/99	A3	No	110	90	250	19.37	7.92	6.73	29.00	44770
03/13/99	B1	No	50	2900	210	21.10	7.89	6.62	28.90	44920
03/13/99	B2	No	25	30	270	21.26	7.88	6.10	28.90	44870
03/13/99	B3	No	7	12	150	21.08	7.87	8.86	28.80	44480
03/13/99	C1	No	300	330	70	20.46	7.84	9.68	28.80	44940
03/13/99	C2	No	140	220	60	20.46	7.89	8.61	29.10	45130
03/13/99	C3	No	170	210	20	20.44	7.90	9.46	29.00	44810
03/13/99	D1	No	220	250	45	20.94	7.87	14.18	24.20	44310
03/14/99	A1	No	45	40	80	12.50	7.85	7.70	30.50	47030
03/14/99	A2	No	65	60	90	12.60	7.84	7.50	30.60	46770
03/14/99	A3	No	100	30	110	13.70	7.88	7.30	30.70	46880
03/14/99	B1	No	20	10	400	17.40	7.83	6.20	30.10	46220
03/14/99	B2	No	20	10	540	17.60	7.85	6.20	30.10	463470
03/14/99	B3	No	15	15	550	17.60	7.85	6.30	30.10	46280
03/14/99	C1	No	10	33	35	15.30	7.88	7.80	30.50	46670
03/14/99	C2	No	5	10	15	15.30	7.87	7.60	30.70	46550
03/14/99	C3	No	15	20	35	15.20	7.89	7.90	30.50	46690
03/14/99	D1	No	200	160	1700	15.23	7.91	9.50	29.90	46220
03/26/99	A1	No	42	22	430	19.19	7.80	7.77	29.30	45560
03/26/99	A2	No	12	1	35	19.15	7.78	7.55	28.60	44850
03/26/99	A3	No	14	3	40	19.35	7.92	7.91	29.70	45110
03/26/99	B1	No	12	9	140	20.15	7.95	7.34	29.60	45870
03/26/99	B2	No	51	61	430	19.89	8.00	7.46	29.50	45640
03/26/99	B3	No	70	81	280	19.84	8.02	7.66	29.80	45640
03/26/99	C1	No	4	270	5	20.00	8.10	8.30	29.90	45910
03/26/99	C2	No	8	320	10	19.95	8.10	8.45	29.80	45890
03/26/99	C3	No	11	52	5	20.04	8.10	7.92	29.90	45910
03/26/99	D1	No	4	10	10	20.37	8.40	8.33	29.90	45990
03/28/99	A1	Yes	130	1200		21.95	7.98	8.10	29.10	44935
03/28/99	A2	Yes	330	12000		21.95	7.98	8.35	29.10	44862
03/28/99	A3	Yes	210	2100		21.94	7.96	8.59	29.20	45036
03/28/99	B1	Yes	130	500		20.94	7.89	7.38	29.70	45698
03/28/99	B2	Yes	470	980		21.01	7.92	7.57	29.60	45572
03/28/99	B3	Yes	1600	4500		21.17	7.92	7.55	29.40	45375
03/28/99	C1	Yes	500	3500		21.38	7.88	7.36	29.40	45253
03/28/99	C2	Yes	510	4700		21.37	7.88	7.25	29.40	45277
03/28/99	C3	Yes	470	3900		21.44	7.89	7.18	29.30	45187
03/28/99	D1	Yes	540	2500		20.94	7.82	7.42	28.10	43548
03/29/99	A1	Yes	470	1200		19.45	7.84	6.98	29.70	45857
03/29/99	A2	Yes	330	930		19.45	7.85	6.99	29.90	45722
03/29/99	A3	Yes	240	930		19.45	7.86	7.05	30.00	46108
03/29/99	B1	Yes	70	2100		20.26	7.85	6.14	30.10	46245
03/29/99	B2	Yes	180	3600		20.35	7.87	6.13	30.00	46193

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
03/29/99	B3	Yes	880	5700		20.40	7.82	6.23	30.00	46033
03/29/99	C1	Yes	510	4800		19.79	7.83	6.80	29.70	45789
03/29/99	C2	Yes	540	8200		19.85	7.81	6.75	29.80	45800
03/29/99	C3	Yes	490	5000		19.82	7.84	7.00	29.70	45739
03/29/99	D1	Yes	240	2700		20.30	7.90	7.11	29.60	45530
03/30/99	A1	Yes	160	2200		16.95	7.70	7.16	29.90	46044
03/30/99	A2	Yes	150	3100		16.88	7.69	7.09	29.90	46069
03/30/99	A3	Yes	60	3800		17.53	7.75	6.89	30.10	46265
03/30/99	B1	Yes	35	470		18.89	7.78	5.94	30.00	46113
03/30/99	B2	Yes	85	510		18.87	7.79	5.98	30.00	46111
03/30/99	B3	Yes	270	900		18.89	7.79	5.97	29.90	46059
03/30/99	C1	Yes	280	5200		18.00	7.75	7.25	30.00	46168
03/30/99	C2	Yes	280	4800		17.96	7.77	7.17	30.00	46175
03/30/99	C3	Yes	260	3000		17.92	7.77	7.32	30.00	46185
03/30/99	D1	Yes	400	11600		18.33	7.71	7.28	30.10	46286
04/01/99	A1	Yes	280	240		20.84	7.90	7.01	28.80	44560
04/01/99	A2	Yes	320	230		20.83	7.90	6.97	28.80	43990
04/01/99	A3	Yes	50	45		20.80	7.89	7.72	28.90	44430
04/01/99	B1	Yes	95	320		20.72	7.81	6.67	28.60	44490
04/01/99	B2	Yes	35	340		20.72	7.85	6.61	28.70	44610
04/01/99	B3	Yes	140	710		20.87	7.82	6.64	28.70	44430
04/01/99	C1	Yes	80	590		21.07	7.84	7.58	28.60	44380
04/01/99	C2	Yes	110	430		21.05	7.84	7.40	28.60	44510
04/01/99	C3	Yes	90	380		21.01	7.82	7.17	28.60	44440
04/01/99	D1	Yes	25	30		20.89	7.87	6.85	28.40	43720
04/09/99	A1	No	31	5	220	23.36	7.89	6.48	28.00	43220
04/09/99	A2	No	26	6	110	23.54	7.89	6.32	28.30	43710
04/09/99	A3	No	27	6	30	23.84	7.92	6.46	28.30	43560
04/09/99	B1	No	15	47	50	24.30	7.86	4.78	28.30	43730
04/09/99	B2	No	1	40	30	24.56	7.91	5.05	28.20	43700
04/09/99	B3	No	7	91	20	24.14	7.87	5.14	28.40	43900
04/09/99	C1	No	28	160	140	24.18	7.91	6.16	28.40	43990
04/09/99	C2	No	31	37	140	24.03	7.89	6.21	28.40	43840
04/09/99	C3	No	58	29	230	24.26	7.92	5.73	28.30	44030
04/09/99	D1	No	2	3	10	24.21	7.87	5.82	28.40	44000
04/23/99	A1	No	190	22	360	23.86	7.96	6.63	29.60	45310
04/23/99	A2	No	24	9	80	23.88	7.98	6.93	26.20	45380
04/23/99	A3	No	17	8	45	23.90	7.98	6.66	29.40	45320
04/23/99	B1	No	110	20	260	24.01	7.91	5.80	29.60	45400
04/23/99	B2	No	83	27	160	24.01	7.92	6.02	25.80	45650
04/23/99	B3	No	46	20	170	23.97	7.93	6.51	29.70	45770
04/23/99	C1	No	60	110	270	24.26	7.88	6.59	29.50	45500
04/23/99	C2	No	58	78	230	24.24	7.89	6.64	29.50	45430
04/23/99	C3	No	54	91	270	24.28	7.89	6.46	29.40	45120
04/23/99	D1	No	2	5	5	23.63	7.86	6.34	29.60	45280
05/12/99	A1	Yes	200	50	260	26.62	7.94	11.20	29.60	45450
05/12/99	A2	Yes	470	1200	3000	26.90	7.94	11.50	29.70	45510
05/12/99	A3	Yes	310	510	2100	256.71	7.94	10.87	29.30	44890
05/12/99	B1	Yes	3400	2500	31000	25.94	7.93	10.28	27.80	43360

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
05/12/99	B2	Yes	30002	4500	37000	25.36	7.87	10.37	28.20	43100
05/12/99	B3	Yes	4000	7100	36000	25.90	7.90	11.97	26.90	41400
05/12/99	C1	Yes	3800	4900	71000	24.96	7.91	11.87	26.90	42060
05/12/99	C2	Yes	4700	3300	60000	25.29	7.93	10.46	26.70	41850
05/12/99	C3	Yes	4700	3800	50000	25.33	7.95	10.28	26.60	41530
05/12/99	D1	Yes	530	520	2500	25.00	7.91	7.08	29.60	45250
05/14/99	A1	Yes	40	10	220	26.13	7.87	8.93	29.50	45230
05/14/99	A2	Yes	60	20	300	26.19	7.88	8.14	29.40	45360
05/14/99	A3	Yes	45	15	250	26.13	7.89	8.90	29.40	45230
05/14/99	B1	Yes	6000	640	80000	26.53	7.87	6.06	29.50	45580
05/14/99	B2	Yes	4400	200	80000	26.87	7.93	7.20	30.00	46110
05/14/99	B3	Yes	1100	5800	45000	26.56	7.86	5.84	29.90	45780
05/14/99	C1	Yes	300	290	2600	26.38	7.91	8.74	30.20	46260
05/14/99	C2	Yes	280	180	2900	26.45	7.92	6.53	30.40	46280
05/14/99	C3	Yes	450	170	13000	26.54	7.95	6.48	30.30	46370
05/14/99	D1	Yes	10	10	35	26.87	7.89	6.53	30.50	46580
05/16/99	A1	Yes	15	30	270	26.62	8.00	6.80	30.30	46520
05/16/99	A2	Yes	5	15	170	26.66	8.01	5.32	30.40	46530
05/16/99	A3	Yes	25	25	150	26.58	8.02	6.68	30.20	46520
05/16/99	B1	Yes	90	120	310	26.56	8.02	6.61	30.20	46830
05/16/99	B2	Yes	80	95	320	26.43	8.00	6.72	30.30	46480
05/16/99	B3	Yes	65	100	150	26.45	8.01	6.89	29.90	46480
05/16/99	C1	Yes	75	60	290	26.90	8.05	6.93	30.10	46280
05/16/99	C2	Yes	50	65	500	26.70	8.08	6.08	30.00	46480
05/16/99	C3	Yes	75	110	330	26.73	8.09	6.07	29.70	46230
05/16/99	D1	Yes	5	5	10	26.75	8.03	5.07	30.50	46100
05/17/99	B1	Yes	30	95	240	26.85	8.01	6.27	30.50	46240
05/17/99	B2	Yes	35	110	120	26.83	8.01	5.83	30.60	46630
05/17/99	B3	Yes	65	45	85	26.90	8.03	6.18	30.10	46780
05/17/99	C1	Yes	35	50	110	27.08	7.98	9.83	30.00	46490
05/17/99	C2	Yes	10	50	160	27.09	8.04	9.85	30.30	46550
05/17/99	C3	Yes	40	85	220	27.09	8.05	7.85	29.30	46560
05/28/99	A1	No	6	7	70	27.19	7.94	5.68	29.20	44940
05/28/99	A2	No	15	14	170	26.62	7.90	5.84	29.20	44890
05/28/99	A3	No	1	1	10	27.61	7.96	5.46	29.20	44920
05/28/99	B1	No	1	9	5	27.57	7.87	3.55	29.50	45560
05/28/99	B2	No	1	25	5	27.80	7.92	3.85	29.80	45880
05/28/99	B3	No	2	47	15	26.70	7.89	4.98	29.90	45870
05/28/99	C1	No	33	34	210	27.27	7.91	5.20	30.10	46270
05/28/99	C2	No	27	30	230	27.36	7.91	4.68	30.10	46290
05/28/99	C3	No	23	22	200	27.36	7.89	4.34	30.10	46220
05/28/99	D1	No	1	1	10	27.57	8.00	4.76	30.20	46540
06/11/99	A1	No	110	60	2400	27.98	7.88	6.05	30.60	46990
06/11/99	A2	No	33	14	230	28.02	7.89	5.81	30.70	47010
06/11/99	A3	No	11	2	210	28.11	7.90	5.82	30.70	46760
06/11/99	B1	No	76	16	660	27.44	7.78	4.34	30.20	46390
06/11/99	B2	No	44	12	590	27.73	7.82	4.39	30.50	46550
06/11/99	B3	No	57	26	440	27.55	7.83	4.62	30.50	47200
06/11/99	C1	No	1100	74	10000	27.94	7.83	5.56	30.90	47180

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06/11/99	C2	No	900	70	4900	27.96	7.83	5.78	30.90	47440
06/11/99	C3	No	730	80	6100	28.09	7.83	5.24	30.90	47280
06/11/99	D1	No	1	4	5	28.29	7.84	5.51	30.80	47200
06/25/99	A1	No	6	34	80	29.17	7.79	4.32	29.50	45320
06/25/99	A2	No	22	42	200	29.29	7.81	4.88	29.50	45360
06/25/99	A3	No	60	180	230	29.17	7.71	3.78	29.50	45520
06/25/99	B1	No	720	100	2600	29.13	7.78	3.94	29.90	45510
06/25/99	B2	No	220	38	1100	29.41	7.80	3.64	30.30	46320
06/25/99	B3	No	96	61	330	29.17	7.80	4.69	30.40	46580
06/25/99	C1	No	42	59	180	29.09	7.86	5.07	30.10	46370
06/25/99	C2	No	38	53	200	28.99	7.82	5.02	30.00	46130
06/25/99	C3	No	28	41	180	29.11	7.82	4.42	30.10	46370
06/25/99	D1	No	2	6	5	28.89	7.75	4.54	30.10	46100
07/09/99	A1	No	5	15	15	29.47	7.62	3.41	30.30	46660
07/09/99	A2	No	2	3	10	29.62	7.75	4.72	30.30	46770
07/09/99	A3	No	6	1	5	29.62	7.68	3.76	30.40	46770
07/09/99	B1	No	8	24	35	30.29	7.71	2.91	30.10	45990
07/09/99	B2	No	3	20	20	30.51	7.74	2.99	30.10	46330
07/09/99	B3	No	13	55	60	30.41	7.74	3.58	30.10	46300
07/09/99	C1	No	10	24	45	29.76	7.75	4.63	31.10	47660
07/09/99	C2	No	9	32	15	29.62	7.74	4.73	31.10	47220
07/09/99	C3	No	6	28	45	29.62	7.62	3.55	31.10	47230
07/09/99	D1	No	1	2	10	30.22	7.71	4.85	31.10	47680
07/23/99	A1	No	42	110	85	29.05	7.75	3.51	30.60	46900
07/23/99	A2	No	4	12	20	29.19	7.75	3.54	30.70	47010
07/23/99	A3	No	3	10	30	29.15	7.74	3.26	30.70	47130
07/23/99	B1	No	15	55	35	29.29	7.69	2.12	31.10	47830
07/23/99	B2	No	49	220	100	29.51	7.77	30.23	31.20	47700
07/23/99	B3	No	53	220	130	29.49	7.73	3.04	31.30	47700
07/23/99	C1	No	25	60	95	28.76	7.84	4.50	30.90	47270
07/23/99	C2	No	42	62	120	28.58	7.87	4.71	30.90	47610
07/23/99	C3	No	26	60	110	28.54	7.71	3.19	30.90	47160
07/23/99	D1	No	1	1	10	28.67	7.82	5.11	31.40	48280
08/13/99	A1	No	7	5	35	29.39	8.08	3.52	33.10	50390
08/13/99	A2	No	3	5	15	29.51	8.10	3.80	32.90	50430
08/13/99	A3	No	4	2	10	29.17	8.10	4.23	33.20	50510
08/13/99	B1	No	450	82	31000	28.52	8.01	3.32	33.10	50760
08/13/99	B2	No	420	41	26000	28.74	8.05	3.58	33.40	50960
08/13/99	B3	No	37	42	1700	28.27	8.10	5.10	33.60	51080
08/13/99	C1	No	61	5	340	28.31	7.95	5.00	33.50	51100
08/13/99	C2	No	66	4	210	28.42	7.95	4.52	33.50	50870
08/13/99	C3	No	93	7	210	28.66	7.99	4.28	33.40	50950
08/13/99	D1	No	1	1	10	29.10	8.06	5.03	33.30	50620
08/24/99	A1	Yes	230	40	320	28.78	8.09	5.89	26.50	41300
08/24/99	A2	Yes	210	35	250	28.83	8.11	6.29	26.60	41370
08/24/99	A3	Yes	310	90	390	30.41	8.10	6.64	25.70	40230
08/24/99	B1	Yes	6000	6000	80000	28.52	7.97	5.51	23.20	38830
08/24/99	B2	Yes	6000	6000	80000	29.19	7.94	4.89	30.10	46110
08/24/99	B3	Yes	6000	6000	80000	29.33	7.88	4.72	30.50	46970

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08/24/99	C1	Yes	6000	6000	80000	28.66	7.95	5.40	30.60	47360
08/24/99	C2	Yes	6000	6000	80000	28.80	7.97	5.38	31.00	47540
08/24/99	C3	Yes	6000	5400	80000	28.42	8.03	5.45	31.30	48270
08/24/99	D1	Yes	850	500	16000	28.05	8.07	6.05	31.30	47830
08/25/99	A1	Yes	1500	9300	14000	28.13	7.94	3.33	28.60	44320
08/25/99	A2	Yes	600	150	740	27.88	8.05	5.35	28.20	43670
08/25/99	A3	Yes	650	130	970	27.86	8.03	5.75	28.00	43470
08/25/99	B1	Yes	5800	540	62000	27.94	7.99	4.54	30.10	46790
08/25/99	B2	Yes	4500	550	78000	27.90	8.06	5.38	30.00	46710
08/25/99	B3	Yes	3600	3500	70000	27.88	8.06	5.52	30.00	46320
08/25/99	C1	Yes	2400	3500	23000	28.04	7.95	4.80	30.20	46480
08/25/99	C2	Yes	4700	11000	59000	28.05	7.76	2.94	30.00	46510
08/25/99	C3	Yes	2800	4600	30000	28.00	7.92	4.82	30.10	46550
08/25/99	D1	Yes	85	90	420	27.76	7.97	4.54	31.40	47930
08/26/99	A1	Yes	980	4500	4600	28.20	7.76	1.66	30.00	46220
08/26/99	A2	Yes	55	85	160	27.94	8.05	4.94	30.20	46490
08/26/99	A3	Yes	230	80	400	28.27	7.86	3.75	30.30	46440
08/26/99	B1	Yes	130	330	370	29.64	7.99	3.73	30.70	47180
08/26/99	B2	Yes	340	480	370	29.72	8.00	3.67	30.90	47350
08/26/99	B3	Yes	1400	2300	12000	29.41	7.67	2.67	30.80	47310
08/26/99	C1	Yes	420	2200	1200	28.74	8.05	4.84	30.40	46440
08/26/99	C2	Yes	500	1000	1100	28.83	8.09	5.50	30.30	46330
08/26/99	C3	Yes	350	1600	1200	28.76	8.06	5.17	30.40	46520
08/26/99	D1	Yes	5	25	45	28.44	8.09	5.55	31.40	47750
08/27/99	A1	Yes	60	520	200	28.76	7.87	3.39	30.10	46110
08/27/99	A2	Yes	40	550	210	28.76	7.84	3.10	30.30	46440
08/27/99	A3	Yes	10	95	55	28.70	7.86	2.87	30.20	46550
08/27/99	B1	Yes	480	410	1500	29.37	8.00	3.92	29.70	45770
08/27/99	B2	Yes	510	350	1500	29.56	7.94	3.13	30.00	46160
08/27/99	B3	Yes	2400	1600	6000	29.54	7.78	2.30	29.80	45760
08/27/99	C1	Yes	470	2400	20000	28.00	8.02	4.17	29.50	45450
08/27/99	C2	Yes	2000	1800	15000	28.00	7.99	2.36	29.40	45320
08/27/99	C3	Yes	2200	1600	18000	27.90	7.97	4.36	29.60	45560
08/27/99	D1	Yes	10	20	10	29.21	8.14	6.01	30.80	47350
08/28/99	A1	Yes	85	390	200	29.31	7.99	3.98	30.40	46660
08/28/99	A2	Yes	80	90	75	29.25	8.01	4.54	30.40	46640
08/28/99	A3	Yes	45	50	30	29.23	7.96	3.93	30.40	46630
08/28/99	B1	Yes	65	130	130	29.70	7.98	3.59	30.10	46450
08/28/99	B2	Yes	20	250	130	29.76	7.99	3.63	30.20	46280
08/28/99	B3	Yes	610	1000	1000	29.78	7.59	1.30	30.20	46410
08/28/99	C1	Yes	310	700	320	28.70	8.04	4.75	30.60	46870
08/28/99	C2	Yes	330	920	270	28.97	8.07	4.73	30.40	46750
08/28/99	C3	Yes	380	460	350	28.79	8.04	4.35	30.70	47020
08/28/99	D1	Yes	20	5	10	29.45	8.12	5.82	30.80	47480
08/29/99	A1	Yes	30	690	350	29.90	7.90	2.05	30.40	46710
08/29/99	A2	Yes	30	30	75	29.78	8.08	4.45	30.40	46670
08/29/99	A3	Yes	25	45	75	29.78	8.02	3.95	30.40	46670
08/29/99	B1	Yes	15	65	80	30.37	7.99	2.53	30.10	46330
08/29/99	B2	Yes	45	230	40	30.49	8.06	3.69	30.20	46440

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
08/29/99	B3	Yes	560	5700	820	30.52	7.97	2.85	30.20	46460
08/29/99	C1	Yes	45	110	130	29.90	8.12	4.56	30.80	46980
08/29/99	C2	Yes	15	95	200	30.20	8.14	4.89	30.70	47010
08/29/99	C3	Yes	10	140	150	30.02	8.08	4.04	30.70	47220
08/29/99	D1	Yes	10	40	10	30.33	8.11	4.67	30.80	47180
08/30/99	A1	Yes	40	420	110	30.20	7.89	2.09	30.70	47280
08/30/99	A2	Yes	15	25	10	30.10	8.01	3.83	31.10	47050
08/30/99	A3	Yes	10	60	10	29.98	7.92	2.43	30.90	47140
08/30/99	B1	Yes	510	75	1200	30.93	7.88	1.87	31.00	47400
08/30/99	B2	Yes	510	160	1700	30.97	7.96	3.19	30.80	47280
08/30/99	B3	Yes	610	360	1600	30.99	7.91	2.67	30.80	47640
08/30/99	C1	Yes	15	30	5	30.59	8.10	4.74	31.00	47750
08/30/99	C2	Yes	10	140	45	30.45	8.07	4.11	30.80	47820
08/30/99	C3	Yes	10	80	25	30.57	8.06	3.79	31.10	47930
08/30/99	D1	Yes	10	25	10	29.52	7.89	2.29	31.40	48050
09/01/99	A1	Yes	35	45	35	29.90	7.91	2.91	30.70	47100
09/01/99	A2	Yes	200	620	400	29.96	7.89	3.99	29.80	45870
09/01/99	A3	Yes	20	20	75	29.76	7.94	3.32	30.60	46920
09/01/99	B1	Yes	10	30	5	30.51	8.03	3.39	30.60	46910
09/01/99	B2	Yes	50	130	390	30.41	8.06	3.96	30.70	47000
09/01/99	B3	Yes	35	70	270	30.31	8.09	4.60	30.60	46970
09/01/99	C1	Yes	90	320	65	29.94	8.06	4.45	31.00	47170
09/01/99	C2	Yes	20	120	55	29.94	8.08	4.72	31.00	47310
09/01/99	C3	Yes	420	410	200	29.49	7.92	3.67	31.00	47410
09/01/99	D1	Yes	10	10	10	30.51	8.04	4.68	30.80	47290
09/03/99	A1	Yes	420	130	240	30.06	8.01	4.10	31.20	47750
09/03/99	A2	Yes	5	20	50	30.08	8.01	4.20	31.30	47820
09/03/99	A3	Yes	15	35	60	29.88	7.96	3.41	31.20	47750
09/03/99	B1	Yes	5	35	25	30.31	7.99	3.52	31.20	47720
09/03/99	B2	Yes	10	15	10	30.33	8.02	3.82	31.10	47770
09/03/99	B3	Yes	35	130	85	30.08	8.03	4.36	31.20	47760
09/03/99	C1	Yes	85	45	65	29.81	8.09	4.80	31.40	48000
09/03/99	C2	Yes	140	60	85	29.70	8.08	4.90	31.30	48150
09/03/99	C3	Yes	120	230	120	29.62	8.03	4.09	31.50	48330
09/03/99	D1	Yes	10	5	5	30.60	7.99	3.91	31.40	47950
09/10/99	A1	No	32	11	120	30.04	7.80	1.09	31.00	47400
09/10/99	A2	No	53	22	140	29.82	7.84	1.77	31.00	47330
09/10/99	A3	No	170	47	300	29.90	7.85	1.74	31.00	47450
09/10/99	B1	No	18	16	40	30.65	7.84	1.82	30.80	47610
09/10/99	B2	No	36	43	100	30.65	7.78	1.37	31.00	47470
09/10/99	B3	No	140	150	280	30.69	7.75	1.05	31.00	47560
09/10/99	C1	No	54	59	150	30.31	8.07	4.94	30.60	46700
09/10/99	C2	No	60	51	140	30.16	8.05	4.45	30.60	47110
09/10/99	C3	No	33	66	150	30.16	8.00	3.77	30.50	46770
09/10/99	D1	No	1	1	10	30.65	8.10	5.60	31.60	48140
09/17/99	A1	No	4	22	5	27.42	8.03	4.50	29.80	45950
09/17/99	A2	No	11	24	500	27.55	8.04	5.01	29.80	45840
09/17/99	A3	No	8	13	5	27.42	8.01	4.95	30.00	46170
09/17/99	B1	No	58	78	180	26.41	8.01	5.26	30.30	46600

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
09/17/99	B2	No	48	54	80	26.62	8.05	5.50	30.40	46900
09/17/99	B3	No	110	150	130	26.11	8.00	6.14	30.30	46920
09/17/99	C1	No	150	440	500	26.41	8.01	6.36	31.40	47880
09/17/99	C2	No	38	93	95	26.45	8.02	6.52	31.30	47840
09/17/99	C3	No	40	60	95	26.75	8.03	6.05	31.20	47840
09/17/99	D1	No	2	4	5	27.15	8.06	6.37	32.60	49630
09/20/99	A1	No	11	25	45	28.35	7.85	1.99	30.80	47080
09/20/99	A2	No	4	9	35	28.29	7.86	1.76	30.60	47040
09/20/99	A3	No	5	9	20	28.17	7.95	3.84	30.70	46960
09/20/99	B1	No	6	10	5	28.48	7.87	2.47	30.20	46390
09/20/99	B2	No	30	15	10	28.65	7.78	2.00	30.40	46770
09/20/99	B3	No	14	11	20	28.52	7.90	2.85	30.30	46680
09/20/99	C1	No	41	93	210	27.02	8.02	4.21	30.80	47070
09/20/99	C2	No	24	32	45	27.71	7.99	4.24	31.00	47500
09/20/99	C3	No	110	25	340	26.32	7.99	4.18	30.60	47160
09/20/99	D1	No	7	4	25	28.46	7.97	2.90	32.00	49090
09/24/99	A1	No	2	12	50					
09/24/99	A2	No	7	25	5					
09/24/99	A3	No	4	28	10					
09/24/99	B1	No	1	2	10					
09/24/99	B2	No	3	4	5					
09/24/99	B3	No	1	4	5					
09/24/99	C1	No	5	35	210					
09/24/99	C2	No	7	22	10					
09/24/99	C3	No	13	28	25					
09/24/99	D1	No	1	7	10					
09/30/99	A1	Yes	7400	95	9000	22.16	8.03	6.54	24.60	38710
09/30/99	A2	Yes	5400	75	13000	21.59	8.04	6.60	24.10	37890
09/30/99	A3	Yes	6900	25	2400	21.18	8.14	7.14	23.70	37370
09/30/99	B1	Yes	460	120	2100	23.11	7.97	6.42	31.80	48540
09/30/99	B2	Yes	420	130	1600	23.10	7.96	6.22	31.80	48600
09/30/99	B3	Yes	8300	830	42000	23.15	7.95	6.48	31.40	47900
09/30/99	C1	Yes	5200	3500	35000	21.92	7.92	7.00	31.10	47580
09/30/99	C2	Yes	4300	3700	52000	21.90	7.92	6.98	31.10	47640
09/30/99	C3	Yes	4500	3200	44000	21.78	7.91	6.85	30.90	47690
09/30/99	D1	Yes	10000	7800	53000	21.82	7.93	7.38	29.80	45060
10/01/99	A1	Yes	350	80	640	23.15	7.97	5.51	28.10	43620
10/01/99	A2	Yes	350	35	460	22.12	8.01	5.72	27.30	42470
10/01/99	A3	Yes	430	50	730	22.03	8.01	6.04	27.10	42140
10/01/99	B1	Yes	270	110	390	23.61	7.97	5.72	31.70	48370
10/01/99	B2	Yes	490	150	2800	23.61	7.99	6.34	31.40	48040
10/01/99	B3	Yes	2700	570	33000	23.56	8.00	6.33	31.60	48360
10/01/99	C1	Yes	2500	420	19000	22.45	7.92	6.90	31.80	48590
10/01/99	C2	Yes	1400	350	22000	22.43	7.92	6.69	31.70	48470
10/01/99	C3	Yes	2100	850	20000	22.37	7.90	6.48	31.70	48400
10/01/99	D1	Yes	1400	540	3600	22.41	7.94	6.75	31.00	47560
10/03/99	A1	Yes	20	5	20					
10/03/99	A2	Yes	10	15	15					
10/03/99	A3	Yes	5	10	10					

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
10/03/99	B1	Yes	5	5	30					
10/03/99	B2	Yes	60	20	50					
10/03/99	B3	Yes	210	30	2400					
10/03/99	C1	Yes	25	780	75					
10/03/99	C2	Yes	100	260	210					
10/03/99	C3	Yes	95	220	210					
10/03/99	D1	Yes	15	15	10	26.13	8.04	6.86	31.50	48120
10/04/99	A1	No	23	32	210	27.45	7.99	4.11	29.20	45102
10/04/99	A2	No	20	30	170	27.36	7.98	4.01	29.20	45000
10/04/99	A3	No	50	44	390	27.19	8.01	4.98	29.20	44985
10/04/99	B1	No	38	51	80	27.24	8.04	5.63	29.40	45330
10/04/99	B2	No	47	69	95	27.21	8.08	5.50	29.40	45360
10/04/99	B3	No	83	67	220	27.21	8.10	5.40	29.50	45420
10/04/99	C1	No	34	55	120	27.01	7.86	7.53	30.10	46260
10/04/99	C2	No	52	160	240	27.00	7.96	6.53	30.10	46274
10/04/99	C3	No	85	290	220	26.97	7.96	6.30	30.10	46183
10/04/99	D1	No	340	64	420	26.95	8.10	6.46	28.50	44098
10/08/99	A1	No	15	110	30	25.61	7.93	5.03	29.90	46010
10/08/99	A2	No	34	75	50	25.66	7.98	5.10	30.10	46340
10/08/99	A3	No	15	26	85	25.72	8.01	5.65	30.10	46350
10/08/99	B1	No	7	22	260	25.89	7.97	4.90	29.80	45810
10/08/99	B2	No	9	25	70	26.09	7.98	4.94	30.00	46110
10/08/99	B3	No	22	33	35	25.00	7.98	5.56	29.70	45710
10/08/99	C1	No	32	37	30	25.13	7.96	5.57	29.60	45600
10/08/99	C2	No	34	45	75	25.14	7.95	5.55	29.60	45540
10/08/99	C3	No	48	39	50	25.24	7.94	4.96	29.60	45630
10/08/99	D1	No	56	180	65	25.59	8.02	5.59	30.70	47150
10/15/99	A1	No	32	25	55	26.93	7.97	5.56	30.80	47250
10/15/99	A2	No	67	37	55	26.94	7.94	5.62	30.80	47230
10/15/99	A3	No	59	110	2000	26.70	7.87	4.53	30.70	47260
10/15/99	B1	No	510	35	26000	26.62	7.91	4.98	30.70	46910
10/15/99	B2	No	350	13	16000	27.00	7.93	5.08	31.00	47500
10/15/99	B3	No	410	14	2000	26.58	7.93	5.57	31.00	47610
10/15/99	C1	No	21	42	260	26.72	7.96	5.74	31.30	48020
10/15/99	C2	No	15	21	170	26.77	7.96	5.52	31.30	48100
10/15/99	C3	No	20	22	260	26.81	7.95	5.22	31.30	47950
10/15/99	D1	No	9	21	5	26.98	8.03	6.03	31.90	48780
10/22/99	A1	No	5	4	20	20.54	7.85	4.58	32.00	48750
10/22/99	A2	No	2	20	20	20.86	7.79	3.80	32.00	48900
10/22/99	A3	No	6	14	40	20.77	7.79	4.30	32.00	48770
10/22/99	B1	No	6	10	20	19.54	7.93	6.20	32.00	48930
10/22/99	B2	No	22	62	60	19.63	7.94	6.21	32.10	49020
10/22/99	B3	No	20	28	70	19.64	7.93	6.21	32.10	49020
10/22/99	C1	No	8	25	15	18.39	7.90	6.57	32.20	49190
10/22/99	C2	No	12	20	10	18.70	7.93	6.42	32.10	49030
10/22/99	C3	No	7	21	10	18.65	7.90	5.85	32.10	49130
10/22/99	D1	No	29	61	40	18.97	7.83	6.46	32.50	49570
10/29/99	A1	No	55	590	110	23.33	8.06	5.03	31.80	48481
10/29/99	A2	No	170	66	210	23.25	8.07	4.99	31.80	48632

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10/29/99	A3	No	830	62	250	23.25	8.02	5.27	31.60	48281
10/29/99	B1	No	12	15	20	23.39	8.04	5.03	32.20	48650
10/29/99	B2	No	8	16	20	23.49	8.06	5.05	32.70	49880
10/29/99	B3	No	7	20	5	23.26	8.10	5.42	32.80	49948
10/29/99	C1	No	26	43	40	23.26	8.08	5.75	32.90	50139
10/29/99	C2	No	13	55	75	23.32	8.10	5.35	33.00	50215
10/29/99	C3	No	20	49	800	23.40	8.12	5.23	33.00	50222
10/29/99	D1	No	5	6	35	23.04	8.14	6.04	33.40	50820
11/05/99	A1	No	6	9	45	20.67	8.00	5.68	32.50	49590
11/05/99	A2	No	6	4	100	20.69	8.00	5.64	32.50	49630
11/05/99	A3	No	24	7	280	20.79	7.96	5.53	32.40	49360
11/05/99	B1	No	1400	4	12000	20.70	7.95	6.10	31.60	48570
11/05/99	B2	No	5	3	30	20.67	7.98	6.13	32.70	49770
11/05/99	B3	No	12	6	40	20.75	7.96	5.99	32.60	49685
11/05/99	C1	No	22	14	80000	20.36	8.00	6.18	32.70	49790
11/05/99	C2	No	21	37	74000	20.38	7.96	5.82	32.60	49755
11/05/99	C3	No	9	9	55000	20.35	7.90	4.86	32.70	49811
11/05/99	D1	No	2	13	10	20.15	8.05	5.95	32.80	50007
11/10/99	A1	No	2	11	10	22.63	8.07	4.14	32.30	49328
11/10/99	A2	No	14	13	30	22.40	8.09	4.11	31.90	48725
11/10/99	A3	No	10	21	25	22.34	8.13	4.78	31.00	48643
11/10/99	B1	No	1	1	10	22.28	8.13	5.28	32.80	50081
11/10/99	B2	No	1	2	5	22.41	8.12	5.35	32.60	49820
11/10/99	B3	No	2	5	10	22.41	8.17	5.64	33.00	50214
11/10/99	C1	No	5	8	20	21.86	8.17	6.24	33.40	50760
11/10/99	C2	No	6	13	10	21.81	8.17	6.02	33.50	50875
11/10/99	C3	No	9	13	35	21.80	8.18	6.24	33.50	51010
11/10/99	D1	No	10	26	55	22.18	8.06	6.08	33.60	51200
11/12/99	A1	No	5	7	10	23.03	8.09	4.35	31.40	48064
11/12/99	A2	No	7	3	5	23.00	8.13	4.10	31.30	48000
11/12/99	A3	No	21	7	15	22.85	8.13	4.92	31.10	48104
11/12/99	B1	No	11	23	95	23.08	8.08	4.59	32.10	49100
11/12/99	B2	No	10	10	35	23.03	8.11	5.04	30.80	47120
11/12/99	B3	No	22	32	750	22.99	8.08	5.15	30.80	47018
11/12/99	C1	No	7	8	15	22.74	8.04	5.70	32.40	49361
11/12/99	C2	No	9	13	25	22.75	8.00	5.89	32.50	49489
11/12/99	C3	No	6	16	15	22.71	8.09	5.98	32.40	48560
11/12/99	D1	No	37	57	30	22.86	8.10	6.19	33.50	50914
11/19/99	A1	No	32	43	75	22.15	8.00	4.69	31.80	48613
11/19/99	A2	No	40	51	220	22.21	7.98	5.52	31.60	48168
11/19/99	A3	No	43	79	240	22.10	8.05	5.01	31.90	48670
11/19/99	B1	No	4	5	35000	22.05	8.01	5.23	32.10	48990
11/19/99	B2	No	1	4	47000	22.12	8.02	5.28	32.20	49391
11/19/99	B3	No	29	37	62000	21.61	7.99	5.63	32.20	49336
11/19/99	C1	No	21	65	130	21.85	7.98	5.93	32.60	49678
11/19/99	C2	No	22	180	200	21.81	7.97	5.71	32.10	490200
11/19/99	C3	No	15	46	260	21.93	7.97	5.43	32.60	49750
11/19/99	D1	No	11	40	30	22.01	8.01	6.20	32.20	49170
11/22/99	A1	No	28	67	2000	22.35	8.13	5.78	32.14	48850

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
11/22/99	A2	No	33	120	100	22.28	8.12	5.70	31.70	49330
11/22/99	A3	No	180	440	320	21.98	8.07	5.45	32.20	48940
11/22/99	B1	No	1500	78	41000	22.02	7.99	5.44	32.00	48730
11/22/99	B2	No	1400	150	67000	21.98	8.07	5.70	32.50	49500
11/22/99	B3	No	13	40	55	21.77	8.09	6.17	32.20	49750
11/22/99	C1	No	62	140	100	22.27	8.09	6.44	32.20	50050
11/22/99	C2	No	36	56	90	22.27	8.08	6.23	32.80	49930
11/22/99	C3	No	33	50	130	22.30	8.00	6.48	32.70	49670
11/22/99	D1	No	8	15	10	22.41	8.18	6.16	32.60	49870
12/03/99	A1	No	38	34	85	20.27	7.94	6.22	32.10	49035
12/03/99	A2	No	31	67	75	20.26	7.95	6.43	32.20	49191
12/03/99	A3	No	64	65	100	20.25	7.93	6.00	32.20	49065
12/03/99	B1	No	600	360	80000	20.37	7.94	5.77	32.50	49640
12/03/99	B2	No	600	190	68000	20.34	7.96	6.39	32.80	49885
12/03/99	B3	No	600	79	75000	20.25	7.94	6.06	32.80	50000
12/03/99	C1	No	22	42	35	20.21	8.00	6.57	33.50	50900
12/03/99	C2	No	23	48	25	20.24	8.01	6.28	33.50	50920
12/03/99	C3	No	20	48	15	20.24	7.99	5.96	33.50	50963
12/03/99	D1	No	47	40	60	20.11	8.01	6.61	33.50	50909
12/21/99	A1	No	100	190	540					
12/21/99	A2	No	210	200	620					
12/21/99	A3	No	410	470	2900					
12/21/99	B1	No	550	69	31000					
12/21/99	B2	No	580	47	16000					
12/21/99	B3	No	890	540	52000					
12/21/99	C1	No	460	360	23000					
12/21/99	C2	No	380	360	34000					
12/21/99	C3	No	430	400	35000					
12/21/99	D1	No	520	570	33000	12.34	7.74	8.53	33.40	50753
01/07/00	A1	No	5	2	770	15.91	8.10	7.08	33.30	50670
01/07/00	A2	No	20	4	250	16.01	8.06	6.80	33.30	50980
01/07/00	A3	No	99	12	5000	16.04	8.07	6.07	33.40	50790
01/07/00	B1	No	33	49	620	16.29	8.03	6.62	33.20	50110
01/07/00	B2	No	11	32	240	16.16	8.05	6.67	33.40	51140
01/07/00	B3	No	7	20	95	16.58	8.08	7.01	33.40	51130
01/07/00	C1	No	520	26	5100	16.04	8.11	7.41	33.90	51470
01/07/00	C2	No	360	21	1200	16.13	8.11	7.54	33.90	51540
01/07/00	C3	No	36	41	120	16.11	8.12	7.50	33.90	51590
01/07/00	D1	No	22	8	30	15.55	8.01	6.82	34.00	51590
01/21/00	A1	No	31	14	65	18.17	8.00	5.54	33.50	51000
01/21/00	A2	No	35	28	75	18.08	8.00	5.82	33.60	50790
01/21/00	A3	No	48	32	110	18.03	8.01	6.04	33.50	51000
01/21/00	B1	No	39	33	55	17.54	8.04	7.07	33.80	51650
01/21/00	B2	No	37	36	35	17.56	8.04	6.94	34.00	51330
01/21/00	B3	No	29	32	30	17.64	8.06	7.00	34.00	51250
01/21/00	C1	No	38	500	70	17.49	8.04	7.29	34.00	51440
01/21/00	C2	No	43	500	110	17.49	8.05	7.37	33.90	51380
01/21/00	C3	No	42	480	90	17.45	8.04	7.20	33.90	51320
01/21/00	D1	No	30	22	60	17.49	8.04	7.14	34.00	51590

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (μmhos/cm)
02/04/00	A1	No	15	6		12.57	7.93	7.08	33.70	51130
02/04/00	A2	No	21	21		12.65	7.92	7.74	33.70	51440
02/04/00	A3	No	39	8		12.62	7.96	7.39	33.70	51050
02/04/00	B1	No	2	5		12.13	7.88	6.94	34.70	52010
02/04/00	B2	No	11	20		12.16	7.92	7.28	34.50	52330
02/04/00	B3	No	9	13		12.15	7.95	7.47	34.60	52210
02/04/00	C1	No	21	35		11.67	7.85	7.28	34.70	52330
02/04/00	C2	No	26	50		11.68	7.86	7.35	34.60	52400
02/04/00	C3	No	25	38		11.65	7.84	7.24	34.60	52330
02/04/00	D1	No	11	22		11.67	7.66	7.31	34.60	52590
02/08/00	A1	No	16	16		14.98	8.08	7.24	33.30	51000
02/08/00	A2	No	17	23		15.06	8.08	7.30	33.20	50540
02/08/00	A3	No	13	11		15.15	8.08	7.45	33.30	50590
02/08/00	B1	No	20	7		15.68	7.99	6.07	33.80	51500
02/08/00	B2	No	6	7		15.51	7.98	6.14	33.70	51580
02/08/00	B3	No	9	11		15.40	8.02	6.60	33.40	51270
02/08/00	C1	No	410	12		15.46	8.05	7.27	33.50	51260
02/08/00	C2	No	210	10		15.53	8.06	7.22	33.50	51190
02/08/00	C3	No	270	11		15.53	8.06	7.17	33.50	50740
02/08/00	D1	No	11	28		14.20	7.99	7.28	33.80	51350
02/11/00	A1	No	140	9		17.85	7.84	5.40	33.40	50440
02/11/00	A2	No	750	32		17.90	7.90	6.20	33.40	50390
02/11/00	A3	No	1000	40		17.90	7.82	5.58	33.40	50510
02/11/00	B1	No	2	4		18.60	7.92	6.23	33.40	51280
02/11/00	B2	No	1	7		18.65	7.95	5.68	33.40	50770
02/11/00	B3	No	1	3		18.63	7.97	6.00	33.60	51220
02/11/00	C1	No	8	21		18.19	7.75	6.71	33.60	51220
02/11/00	C2	No	8	23		18.14	7.76	6.30	33.40	51150
02/11/00	C3	No	8	14		18.20	7.88	6.01	33.60	51010
02/11/00	D1	No	5	8		18.10	7.57	6.40	33.60	51270
02/18/00	A1	No	94	56		21.64	7.92	5.64	33.30	50140
02/18/00	A2	No	96	71		21.59	7.90	5.54	33.00	50400
02/18/00	A3	No	210	240		21.52	7.91	5.45	33.30	50380
02/18/00	B1	No	270	780		22.05	7.86	4.87	33.30	50700
02/18/00	B2	No	400	1100		22.03	7.90	4.78	33.40	51090
02/18/00	B3	No	500	1300		21.67	7.94	5.99	33.40	51100
02/18/00	C1	No	96	98		21.77	7.88	6.35	33.40	50800
02/18/00	C2	No	300	110		21.80	7.86	6.10	33.40	50810
02/18/00	C3	No	160	110		21.84	7.87	5.86	33.40	50680
02/18/00	D1	No	38	41		22.03	7.88	5.68	33.50	51010
02/25/00	A1	No	330	76		20.89	7.94	6.00	33.40	50540
02/25/00	A2	No	770	90		20.87	7.91	5.96	33.50	50790
02/25/00	A3	No	600	330		20.86	7.93	5.69	33.50	50870
02/25/00	B1	No	41	42		20.99	7.92	5.84	33.10	50480
02/25/00	B2	No	44	47		20.94	7.94	6.05	33.90	51330
02/25/00	B3	No	55	62		20.91	7.93	6.11	33.70	50680
02/25/00	C1	No	77	110		21.09	7.90	6.67	34.40	52030
02/25/00	C2	No	63	200		21.11	7.92	6.70	34.30	51840
02/25/00	C3	No	110	250		21.12	7.92	6.46	34.40	51730

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
02/25/00	D1	No	31	27		20.87	7.92	6.45	33.80	51500
03/03/00	A1	No	22	11		22.24	7.95	5.32	33.50	50830
03/03/00	A2	No	45	32		22.16	7.94	4.57	33.60	50750
03/03/00	A3	No	46	29		22.14	7.92	4.56	33.50	50890
03/03/00	B1	No	8	12		22.25	7.97	4.23	33.90	51350
03/03/00	B2	No	20	13		22.21	7.98	4.26	33.90	51400
03/03/00	B3	No	29	55		21.89	7.96	5.12	34.10	51440
03/03/00	C1	No	54	33		22.20	7.98	5.52	33.70	51220
03/03/00	C2	No	22	48		22.18	7.95	5.54	33.80	51270
03/03/00	C3	No	28	37		22.21	7.91	4.65	33.70	51280
03/03/00	D1	No	1	4		21.90	7.96	8.24	33.40	50790
03/08/00	A1	No	39	78		22.57	7.80	5.69	33.90	51484
03/08/00	A2	No	55	93		22.56	7.80	5.69	33.90	51506
03/08/00	A3	No	360	370		22.44	7.75	6.02	33.50	50937
03/08/00	B1	No	840	29		22.92	7.80	5.49	33.90	51449
03/08/00	B2	No	490	44		22.90	7.79	6.04	33.90	51498
03/08/00	B3	No	35	24		22.89	7.79	6.31	33.90	51642
03/08/00	C1	No	45	90		23.06	7.80	6.56	33.80	61319
03/08/00	C2	No	53	40		23.06	7.81	6.30	33.80	51400
03/08/00	C3	No	34	23		23.08	7.81	6.08	33.80	51338
03/08/00	D1	No	26	23		23.04	7.87	5.80	34.40	52150
03/15/00	A1	Yes	5900	6000						
03/15/00	A2	Yes	7600	6000						
03/15/00	A3	Yes	10000	6000						
03/15/00	B1	Yes	3600	5900						
03/15/00	B2	Yes	3700	5700						
03/15/00	B3	Yes	4300	5300						
03/15/00	C1	Yes	5100	11000						
03/15/00	C2	Yes	5200	7600						
03/15/00	C3	Yes	4300	8900						
03/15/00	D1	Yes	4600	9000						
03/17/00	A1	Yes	55	160		20.97	7.81	5.37	31.50	48160
03/17/00	A2	Yes	40	100		20.87	7.74	5.61	31.40	48115
03/17/00	A3	Yes	45	85		20.42	7.69	6.45	31.50	48133
03/17/00	B1	Yes	350	2200		20.31	7.64	6.70	31.80	48507
03/17/00	B2	Yes	420	2100		20.26	7.80	6.45	31.80	48547
03/17/00	B3	Yes	2200	4500		20.16	7.81	6.99	31.80	48506
03/17/00	C1	Yes	780	5600		19.63	7.53	7.29	32.00	48945
03/17/00	C2	Yes	1000	4100		19.66	7.75	7.13	32.10	48945
03/17/00	C3	Yes	2000	5600		19.61	7.67	7.16	32.10	48832
03/17/00	D1	Yes	890	2100		19.78	7.51	7.38	33.00	49882
03/18/00	A1	Yes	20	40		19.2	7.90	5.94	31.60	48780
03/18/00	A2	Yes	10	160		19.17	7.95	5.57	31.80	48530
03/18/00	A3	Yes	400	70		18.83	7.92	5.94	31.90	48390
03/18/00	B1	Yes	10	130		18.89	7.97	5.33	32.20	49160
03/18/00	B2	Yes	75	220		18.97	7.91	5.70	32.00	49040
03/18/00	B3	Yes	100	320		18.92	7.91	5.90	32.20	49230
03/18/00	C1	Yes	50	270		17.91	7.96	6.32	32.10	49040
03/18/00	C2	Yes	60	240		17.83	7.89	6.73	32.20	49300

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
03/18/00	C3	Yes	65	230		17.8	7.88	6.75	32.20	49300
03/18/00	D1	Yes	45	230		18.36	7.98	6.87	32.40	49530
03/20/00	A1	Yes	35	55		18.74	8.00	7.44	32.30	49250
03/20/00	A2	Yes	120	30		18.64	7.97	7.39	32.30	49490
03/20/00	A3	Yes	110	80		18.56	7.97	7.51	32.20	49380
03/20/00	B1	Yes	45	80		18.41	8.01	7.07	32.20	49040
03/20/00	B2	Yes	5	50		18.40	7.98	6.89	32.20	49230
03/20/00	B3	Yes	40	160		17.89	7.97	7.32	32.20	49190
03/20/00	C1	Yes	130	500		18.34	7.97	7.37	32.60	49510
03/20/00	C2	Yes	150	700		18.44	7.93	6.73	32.50	49700
03/20/00	C3	Yes	200	1400		18.46	7.87	6.72	32.50	49510
03/20/00	D1	Yes	10	10		18.66	8.06	7.40	32.60	49570
03/31/00	A1	No	20	9		24.34	7.99	5.45	31.40	48050
03/31/00	A2	No	7	6		24.14	7.99	5.70	31.40	48390
03/31/00	A3	No	200	41		23.50	7.88	5.46	31.00	47930
03/31/00	B1	No	30	96		23.39	8.01	6.00	32.00	48410
03/31/00	B2	No	37	86		23.25	8.00	6.31	32.00	48970
03/31/00	B3	No	21	230		23.25	8.01	6.57	32.00	48830
03/31/00	C1	No	25	77		23.61	7.99	6.69	32.50	49410
03/31/00	C2	No	39	270		23.48	7.99	6.68	32.50	49200
03/31/00	C3	No	42	39		23.61	8.01	6.47	32.40	49340
03/31/00	D1	No	6	6		23.48	8.04	6.13	32.70	49960
04/04/00	A1	No	20	35		21.30	7.74	6.21	31.80	48603
04/04/00	A2	No	25	15		21.36	7.82	5.40	31.90	48726
04/04/00	A3	No	2200	20		20.34	7.84	5.12	31.90	48715
04/04/00	B1	No	25	35		20.49	7.76	6.69	32.30	49271
04/04/00	B2	No	100	35		20.30	7.76	6.66	32.30	49248
04/04/00	B3	No	40	10		20.23	7.84	6.92	32.40	49312
04/04/00	C1	No	120	55		18.59	7.67	7.49	32.10	48536
04/04/00	C2	No	210	45		18.48	7.75	7.28	32.20	49697
04/04/00	C3	No	350	65		18.38	7.79	7.48	32.60	49741
04/04/00	D1	No	490	90		18.87	7.68	7.29	32.70	48400
04/08/00	A1	No	42	9		21.69	7.94	5.02	32.50	49490
04/08/00	A2	No	47	8		21.66	7.94	5.22	32.60	50000
04/08/00	A3	No	85	15		21.67	7.96	5.41	32.70	49670
04/08/00	B1	No	600	74		21.58	7.92	5.06	32.40	49600
04/08/00	B2	No	1600	20		21.89	7.97	5.44	33.10	50410
04/08/00	B3	No	590	9		21.63	7.99	5.65	33.36	50580
04/08/00	C1	No	90	38		21.41	7.92	5.75	33.40	50880
04/08/00	C2	No	50	36		21.48	7.91	5.30	33.40	50760
04/08/00	C3	No	53	35		21.57	7.90	5.17	33.20	50440
04/08/00	D1	No	2	1		21.48	7.88	6.11	33.50	50820
04/14/00	A1	No	460	370		21.50	7.97	5.23	32.60	49630
04/14/00	A2	No	520	230		21.59	7.91	5.66	32.00	49050
04/14/00	A3	No	230	60		21.50	7.97	5.57	32.50	49440
04/14/00	B1	No	2200	450		21.13	7.99	5.73	33.50	51110
04/14/00	B2	No	610	820		21.43	8.01	5.91	33.90	51600
04/14/00	B3	No	510	410		21.52	8.01	5.98	33.90	51070
04/14/00	C1	No	1400	2000		21.18	8.01	6.05	33.40	51190

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
04/14/00	C2	No	1300	2000		21.19	8.00	6.15	33.40	51310
04/14/00	C3	No	1600	2100		21.29	7.98	5.61	33.40	51120
04/14/00	D1	No	10	15		21.53	8.02	6.01	34.10	51730
04/21/00	A1	No	170	10		25.45	7.83	4.22	33.80	51300
04/21/00	A2	No	70	35		25.64	7.86	4.64	33.70	51100
04/21/00	A3	No	30	5		25.35	7.85	4.62	33.70	51200
04/21/00	B1	No	15	15		24.34	7.87	5.80	34.40	52200
04/21/00	B2	No	100	5		24.59	7.90	5.34	34.30	52100
04/21/00	B3	No	140	5		24.85	7.91	5.57	34.40	52100
04/21/00	C1	No	40	300		24.47	7.93	5.98	34.50	52400
04/21/00	C2	No	10	85		24.52	7.92	5.74	34.80	52500
04/21/00	C3	No	30	80		24.51	7.92	5.87	34.70	52500
04/21/00	D1	No	10	20		24.50	7.95	6.22	34.40	52100
04/28/00	A1	No	6	21		25.66	7.85	4.23	32.60	49600
04/28/00	A2	No	8	4		25.71	7.86	4.77	32.60	49600
04/28/00	A3	No	48	8		25.56	7.82	4.12	32.30	49200
04/28/00	B1	No	22	12		25.56	7.88	4.41	33.00	50200
04/28/00	B2	No	10	21		25.80	7.91	4.40	33.40	50800
04/28/00	B3	No	14	27		25.16	7.91	4.98	33.40	50860
04/28/00	C1	No	25	37		25.37	7.88	5.42	33.40	50800
04/28/00	C2	No	27	34		25.32	7.88	5.41	33.40	50800
04/28/00	C3	No	20	27		25.37	7.87	5.04	33.40	50700
04/28/00	D1	No	1	5		25.39	7.86	5.39	33.20	50600
05/03/00	A1	Yes	5700	830		23.37	7.88	4.20	33.60	51012
05/03/00	A2	Yes	4500	750		23.40	7.93	4.81	33.40	50878
05/03/00	A3	Yes	1800	560		23.37	7.95	5.24	33.40	50933
05/03/00	B1	Yes	220	35		23.59	7.92	5.11	33.90	51432
05/03/00	B2	Yes	5100	1100		23.65	7.96	5.31	34.00	51426
05/03/00	B3	Yes	1600	460		23.56	7.97	5.36	34.00	51485
05/03/00	C1	Yes	4200	2300		23.28	7.93	5.43	33.50	50935
05/03/00	C2	Yes	4200	2700		23.21	7.92	5.24	33.40	50730
05/03/00	C3	Yes	4500	3000		23.18	7.92	5.01	33.60	50779
05/03/00	D1	Yes	160	80		23.79	7.99	5.72	33.70	51190
05/05/00	A1	Yes	25	15		25.75	7.83	5.56	33.10	50400
05/05/00	A2	Yes	20	20		25.69	7.81	5.52	33.10	50400
05/05/00	A3	Yes	45	30		25.56	7.81	5.86	33.10	50400
05/05/00	B1	Yes	120	480		25.27	7.82	5.31	33.20	50600
05/05/00	B2	Yes	270	240		25.33	7.81	5.14	33.80	51300
05/05/00	B3	Yes	160	140		25.24	7.81	5.49	33.80	51300
05/05/00	C1	Yes	380	420		25.40	7.86	5.80	34.00	51600
05/05/00	C2	Yes	360	190		25.41	7.88	5.77	34.00	51700
05/05/00	C3	Yes	230	120		25.43	7.84	5.65	34.10	51800
05/05/00	D1	Yes	50	25		25.46	7.76	5.56	34.50	52200
05/06/00	B1	Yes	160	40		25.37	7.75	4.16	34.20	51800
05/06/00	B2	Yes	220	15		25.32	7.43	4.32	34.20	51632
05/06/00	B3	Yes	210	20		25.41	7.57	4.34	34.30	51800
05/06/00	C1	Yes	220	140		25.63	7.11	5.70	31.40	52100
05/06/00	C2	Yes	230	400		25.65	7.56	5.50	34.40	52200
05/06/00	C3	Yes	200	95		25.67	7.65	5.45	34.40	52100

Date	Subsite	Rain Event	FC (cfu/100 ml)	ENT (cfu/100 ml)	TC (cfu/100 ml)	Water T (°C)	pH (s.u.)	DO (mg/L)	Salinity (ppt)	Condvty (µmhos/cm)
05/12/00	A1	No	5	2		26.76	8.07	5.59	35.70	53848
05/12/00	A2	No	7	3						
05/12/00	A3	No	28	6						
05/12/00	B1	No	32	8						
05/12/00	B2	No	30	6						
05/12/00	B3	No	33	25						
05/12/00	C1	No	53	6						
05/12/00	C2	No	42	24						
05/12/00	C3	No	44	44						
05/12/00	D1	No	2	5						

APPENDIX C

GRAPHS: ENTEROCOCCI CONCENTRATIONS (CFU/100 ML) AT EACH LOCATION AFTER RAINFALL COMPARED WITH CONCENTRATIONS AT SWANTNER PARK (REFERENCE SITE).

Individual sites are shown at the outfall (_2), compared with at distances from the outfall (_1 And _3) for each location.

Rainfall Event #1 – March 1999 - 8.64 cm (3.4 in)

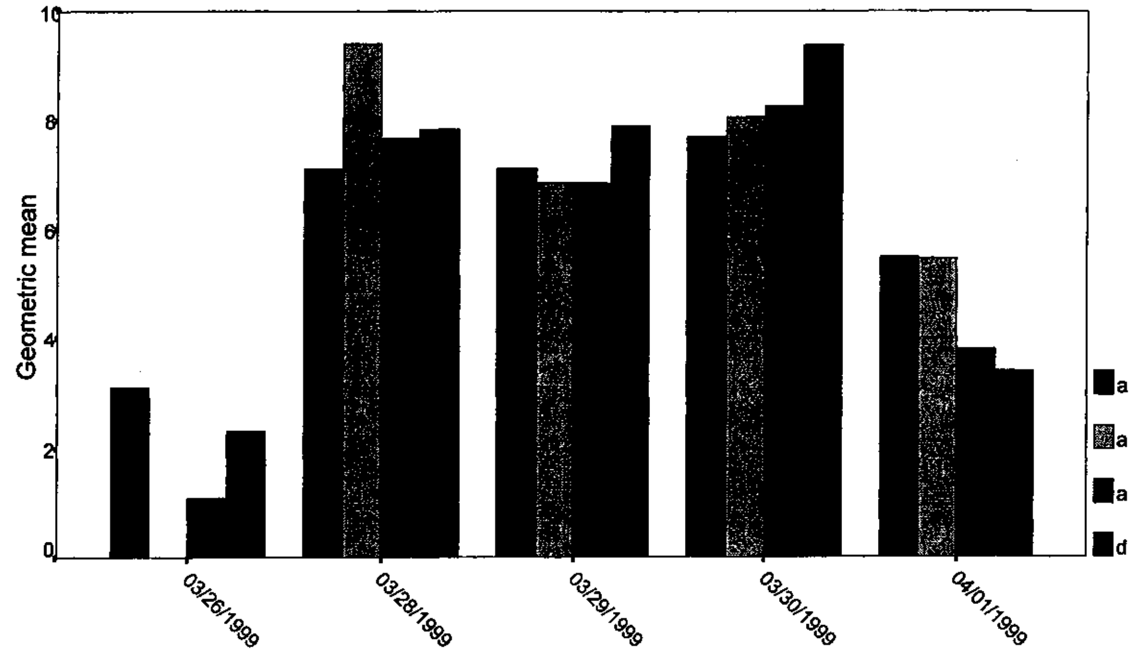

Figure A1. Geometric mean of enterococci during rainfall event #1 at McGee Beach

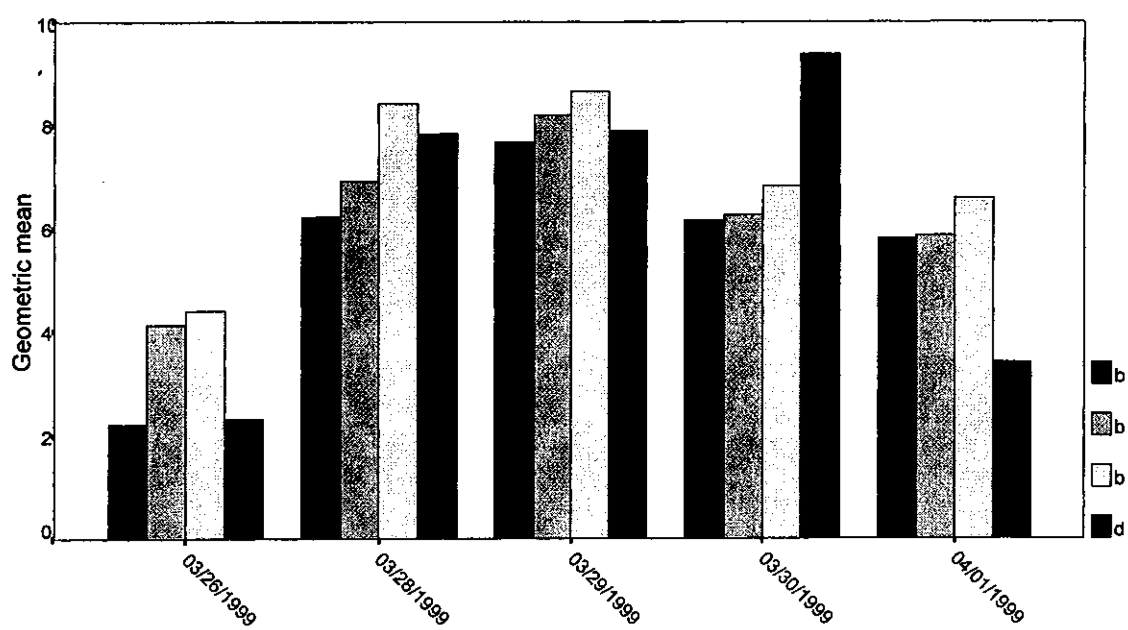

Figure A2. Geometric mean of enterococci during rainfall event #1 at Cole Park

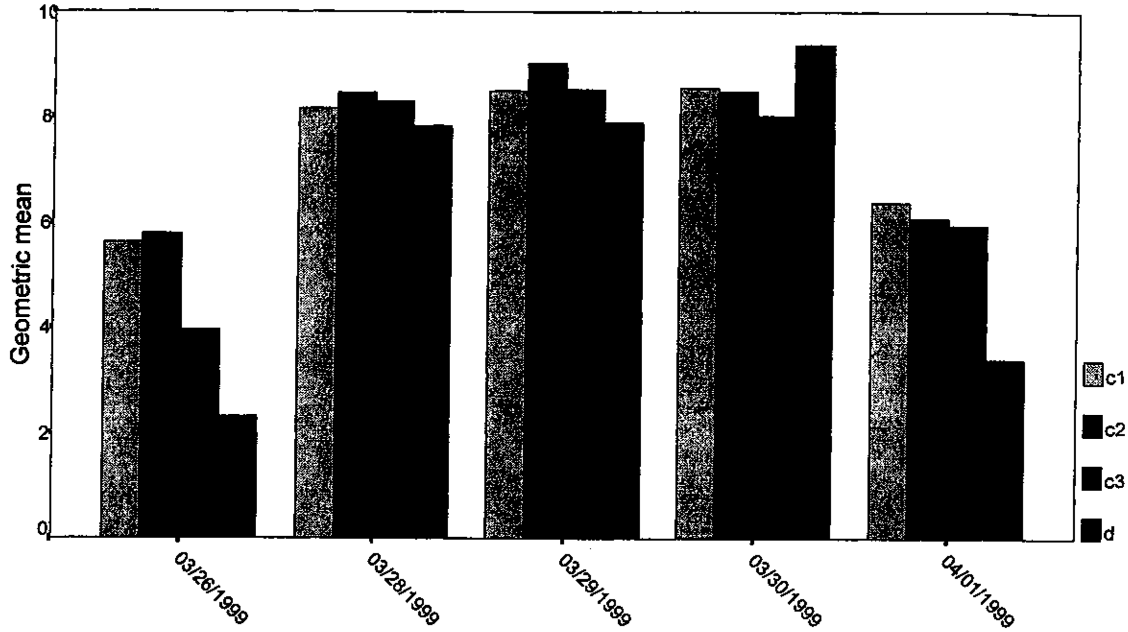

Figure A3. Geometric mean of enterococci during rainfall event #1 at Ropes Park

Rainfall Event #2 – May 1999 – 2.79 cm (1.1 in)

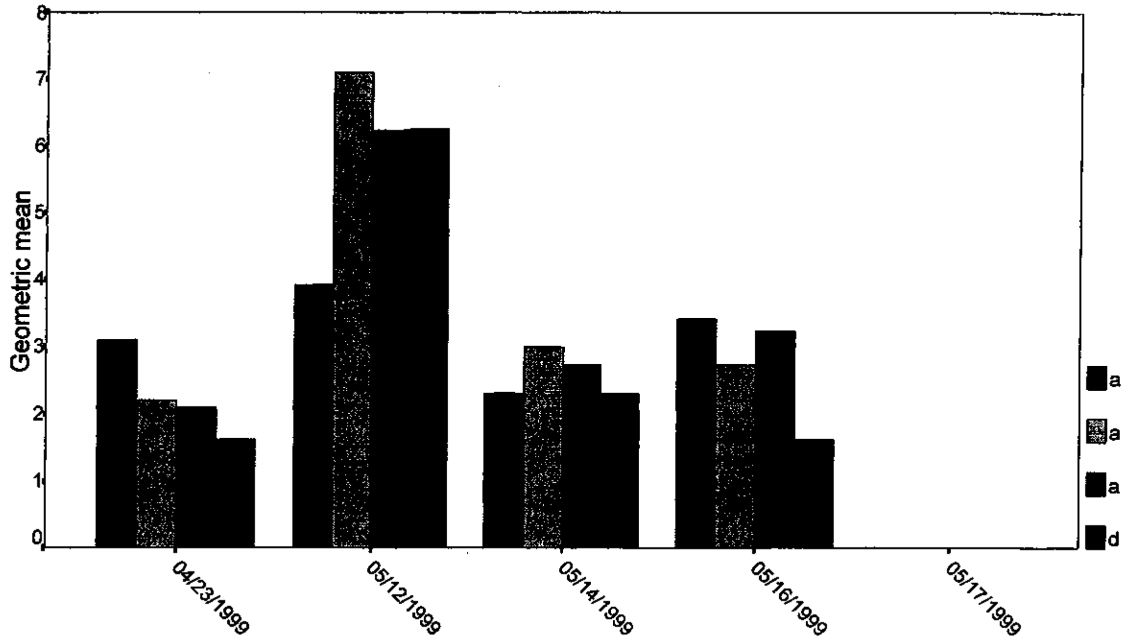

Figure A4. Geometric mean of enterococci during rainfall event #2 at McGee Beach

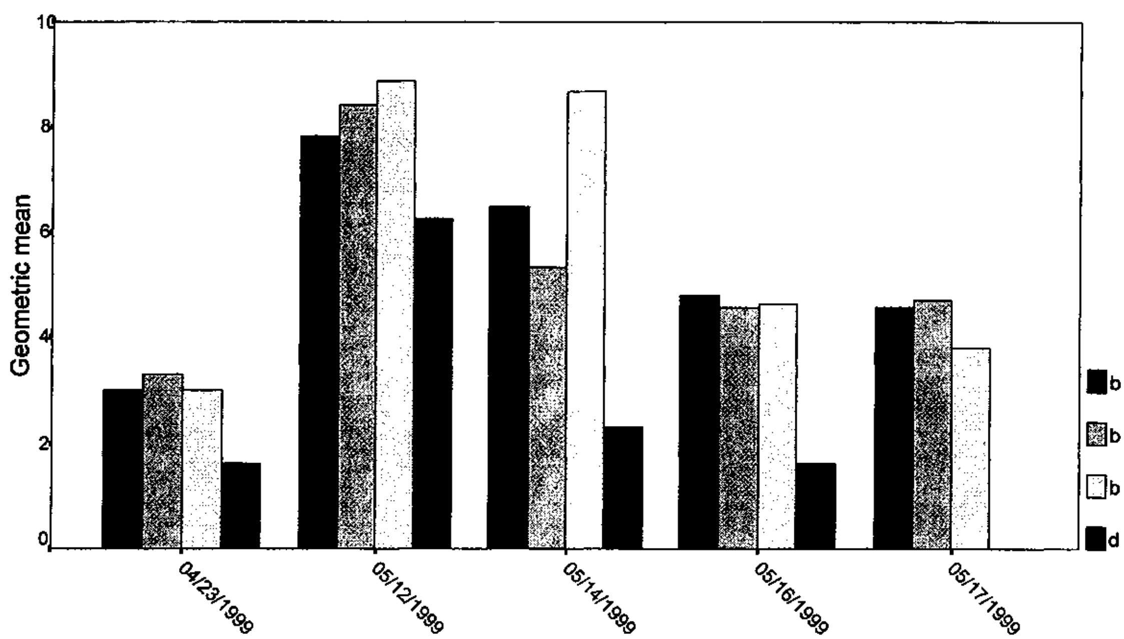

Figure A5. Geometric mean of enterococci during rainfall event #2 at Cole Park

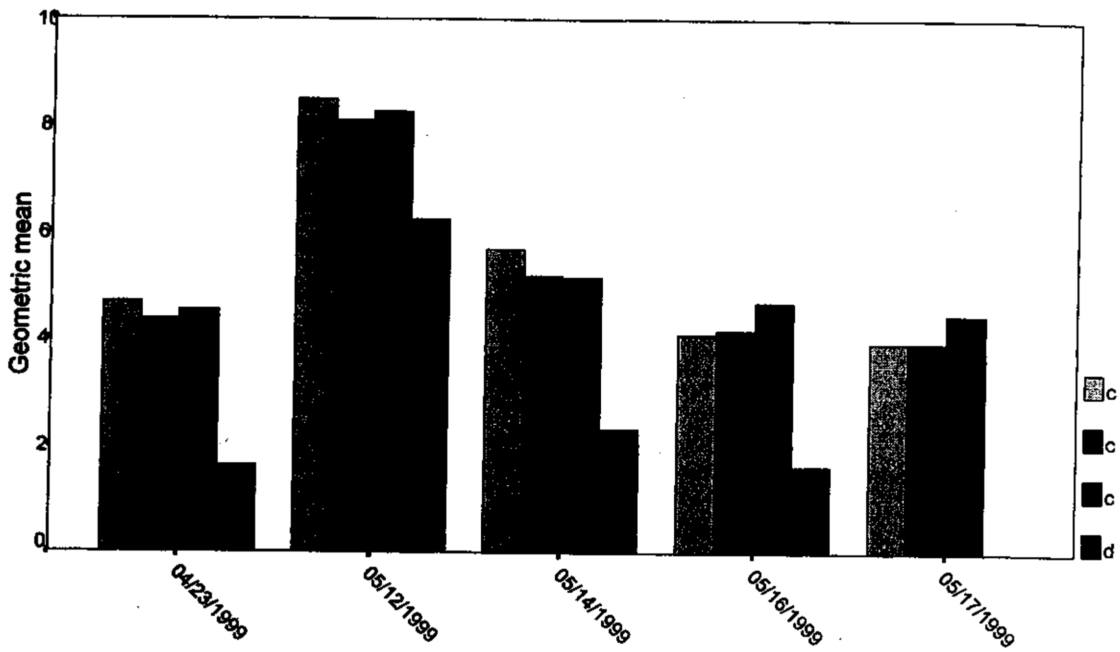

Figure A6. Geometric mean of enterococci during rainfall event #2 at Ropes Park

Rainfall Event #3 – August 1999 – 17.02 cm (6.7 in)

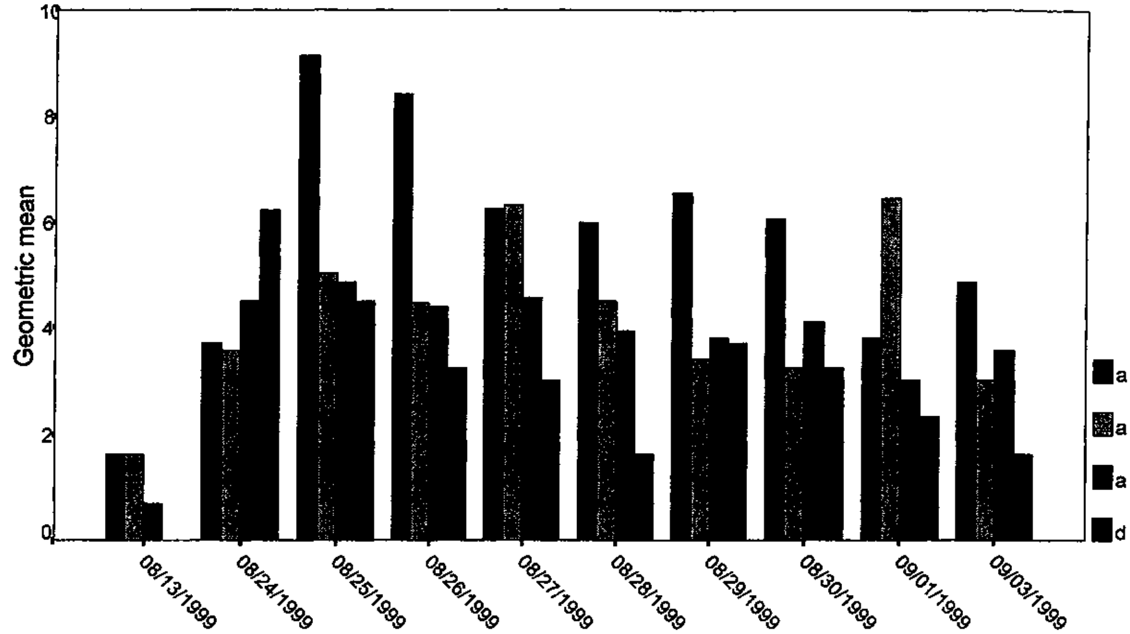

Figure A7. Geometric mean of enterococci during rainfall event #3 at the Marina

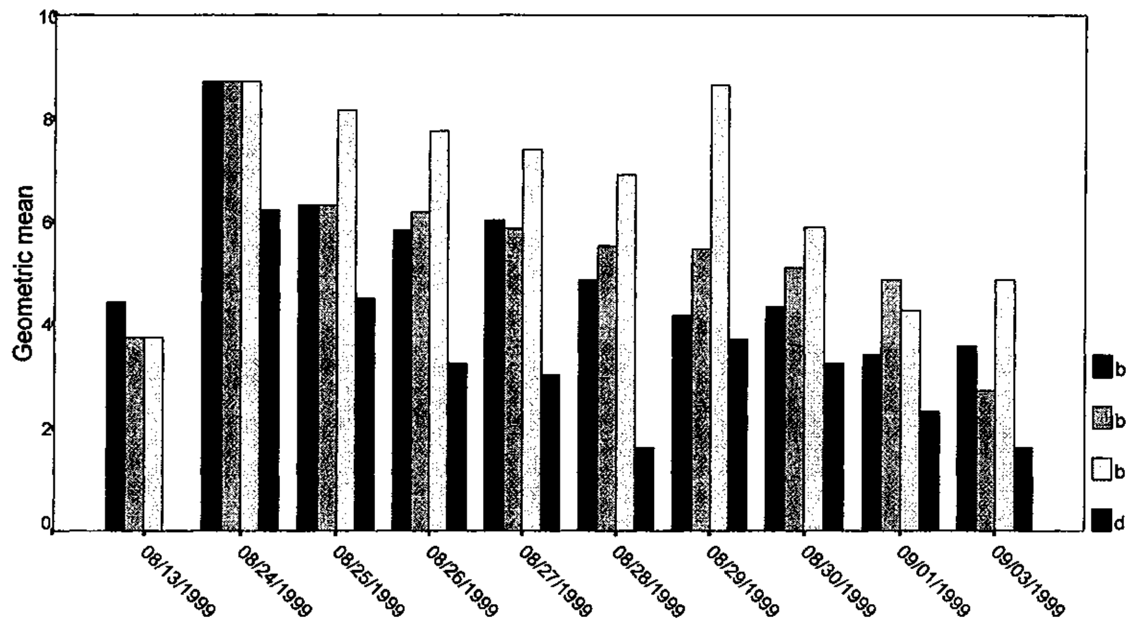

Figure A8. Geometric mean of enterococci during rainfall event #3 at Cole Park

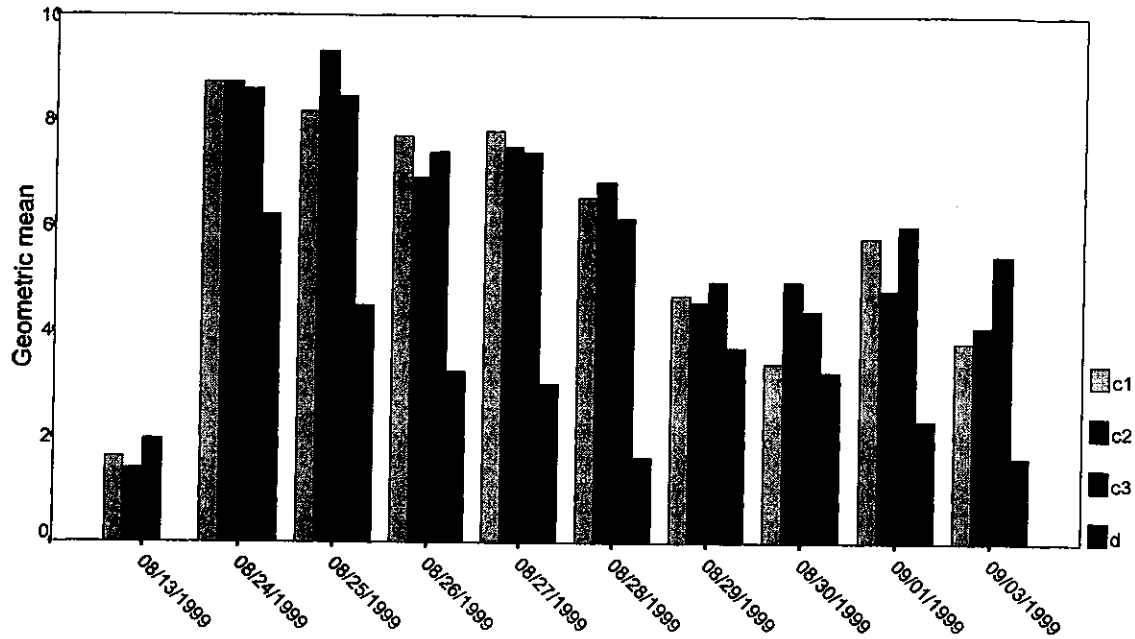

Figure A9. Geometric mean of enterococci during rainfall event #3 at Ropes Park

Rainfall Event #4 – September 1999 – 7.62 cm (3 in)

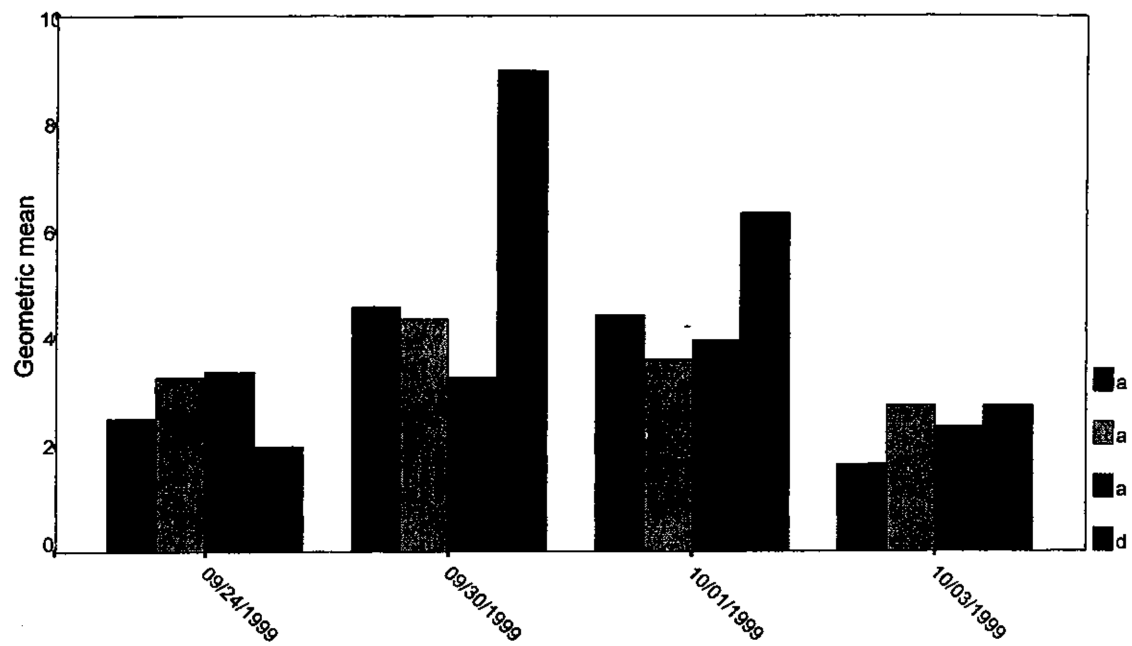

Figure A10. Geometric mean of enterococci during rainfall event #4 at McGee Beach/Marina

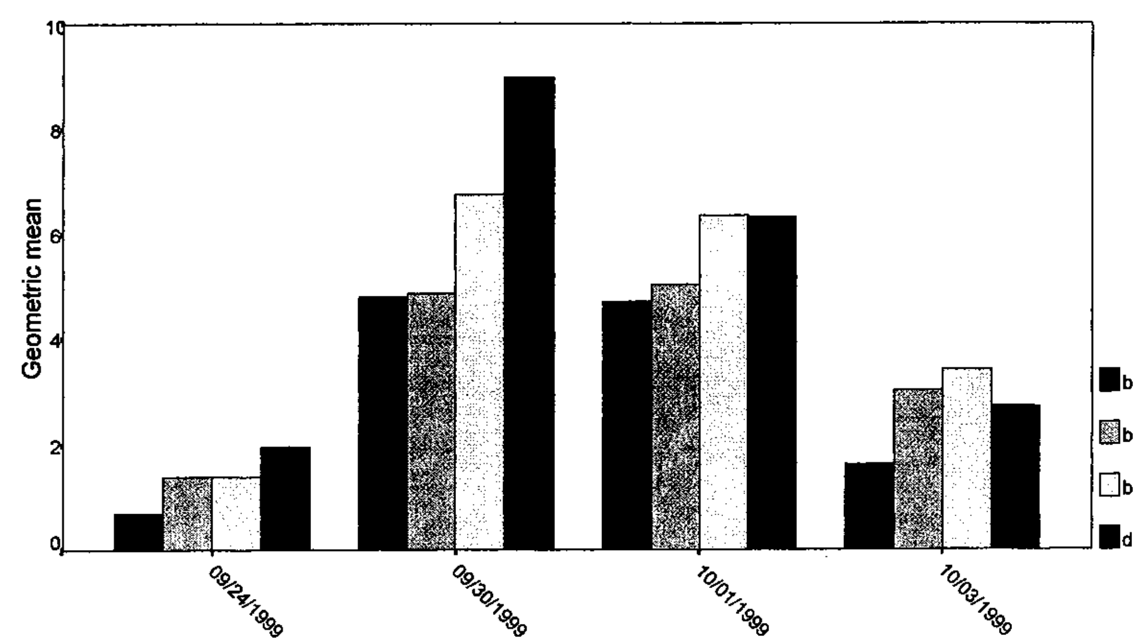

Figure A11. Geometric mean of enterococci during rainfall event #4 at Cole Park

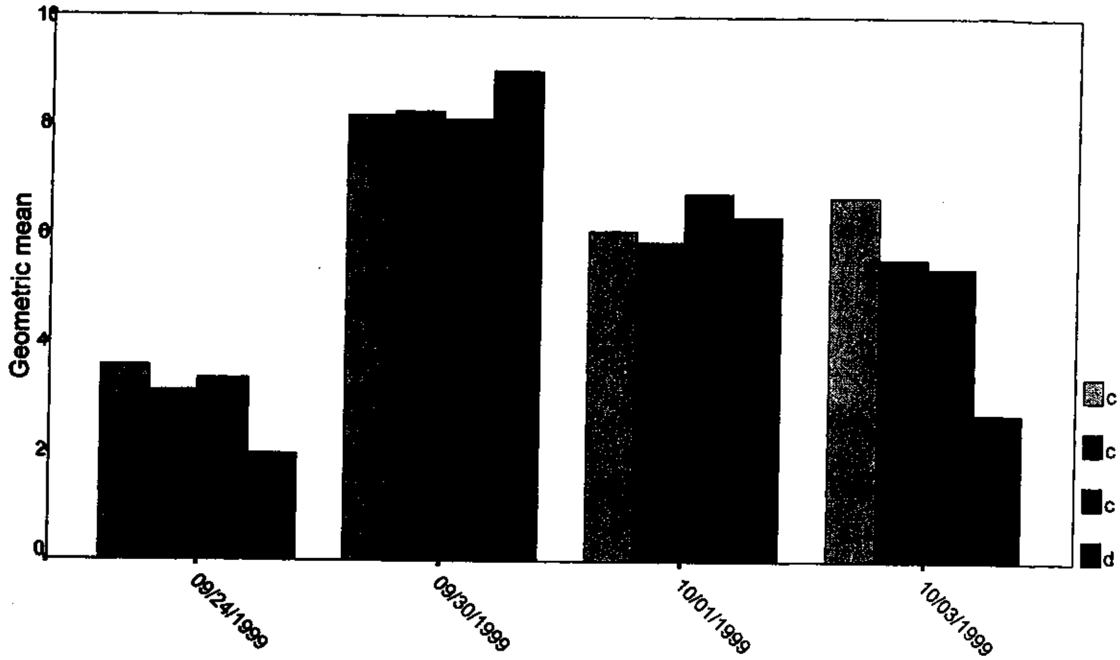

Figure A12. Geometric mean of enterococci during rainfall event #4 at Ropes Park

Rainfall Event #5 – March 2000 – 3.30 cm (1.3 in)

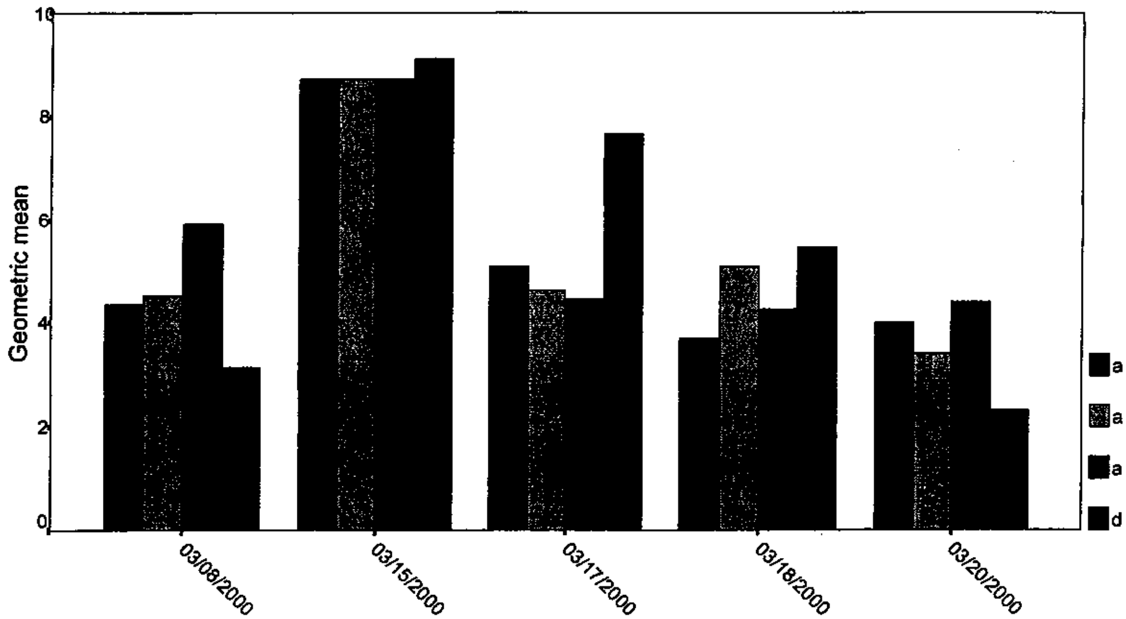

Figure A13. Geometric mean of enterococci during rainfall event #5 at the Marina

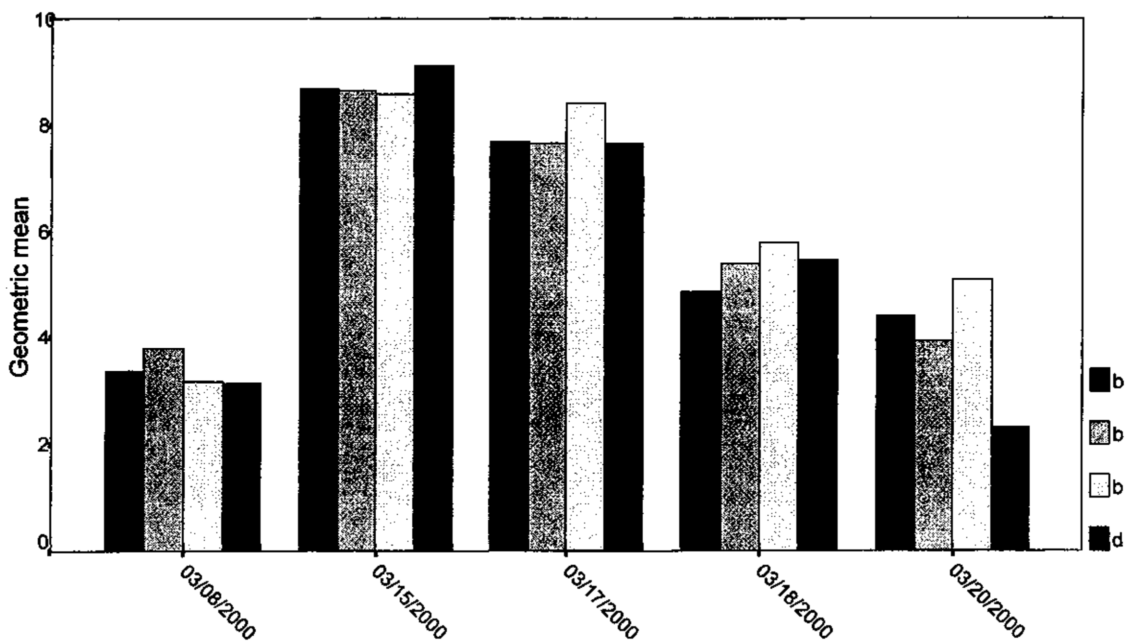

Figure A14. Geometric mean of enterococci during rainfall event #5 at Cole Park

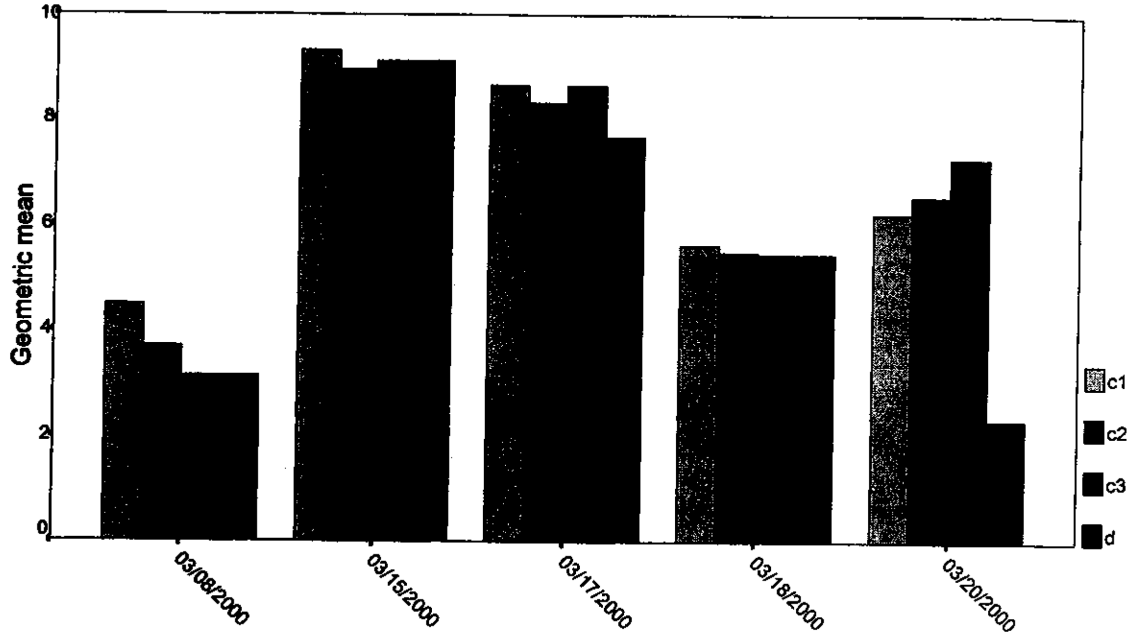

Figure A15. Geometric mean of enterococci during rainfall event #5 at Ropes Park

Rainfall Event #6 – May 2000 – 3.81 cm (1.5 in)

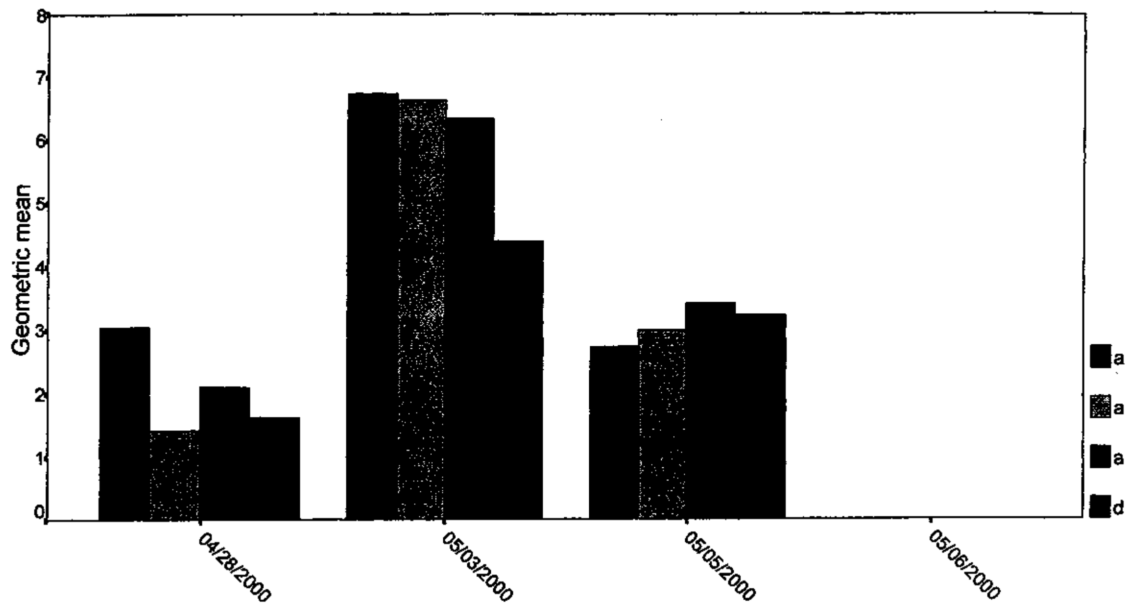

Figure A16. Geometric mean of enterococci during rainfall event #6 at the Marina

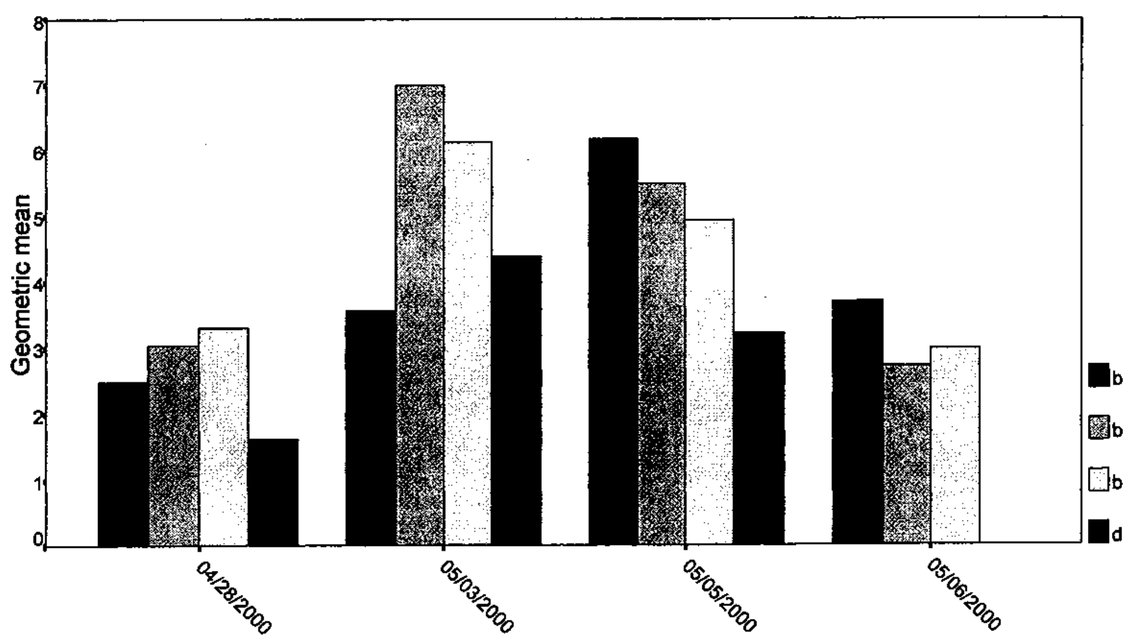

Figure A17. Geometric mean of enterococci during rainfall event #6 at Cole Park

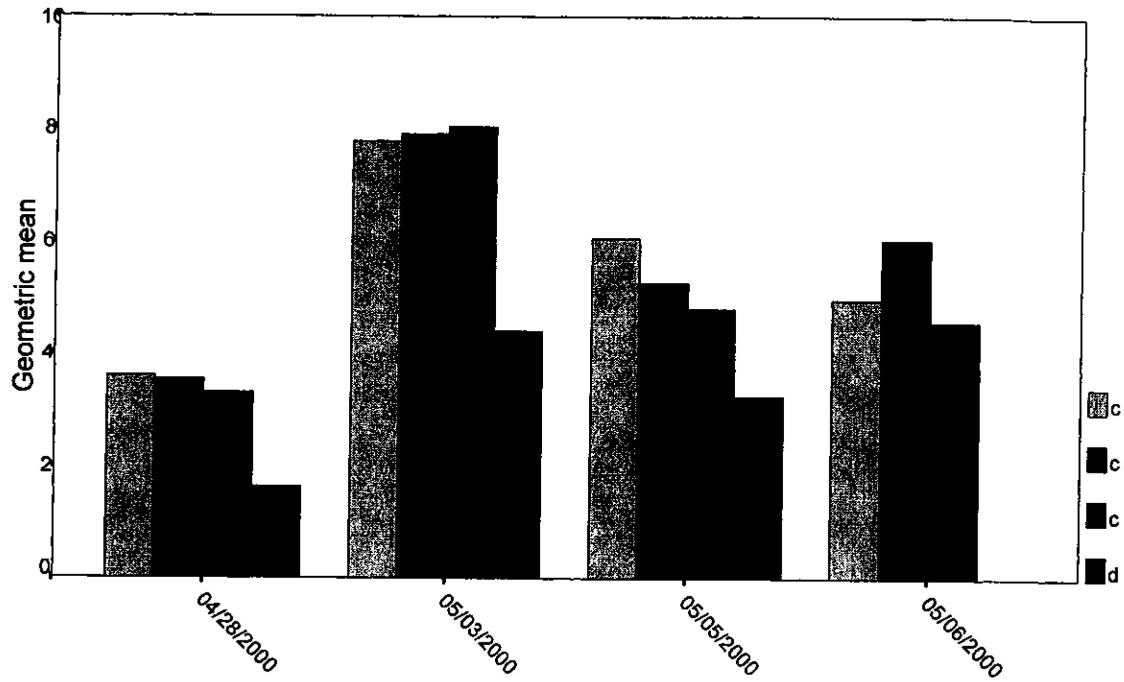

Figure A18. Geometric mean of enterococci during rainfall event #6 at Ropes Park