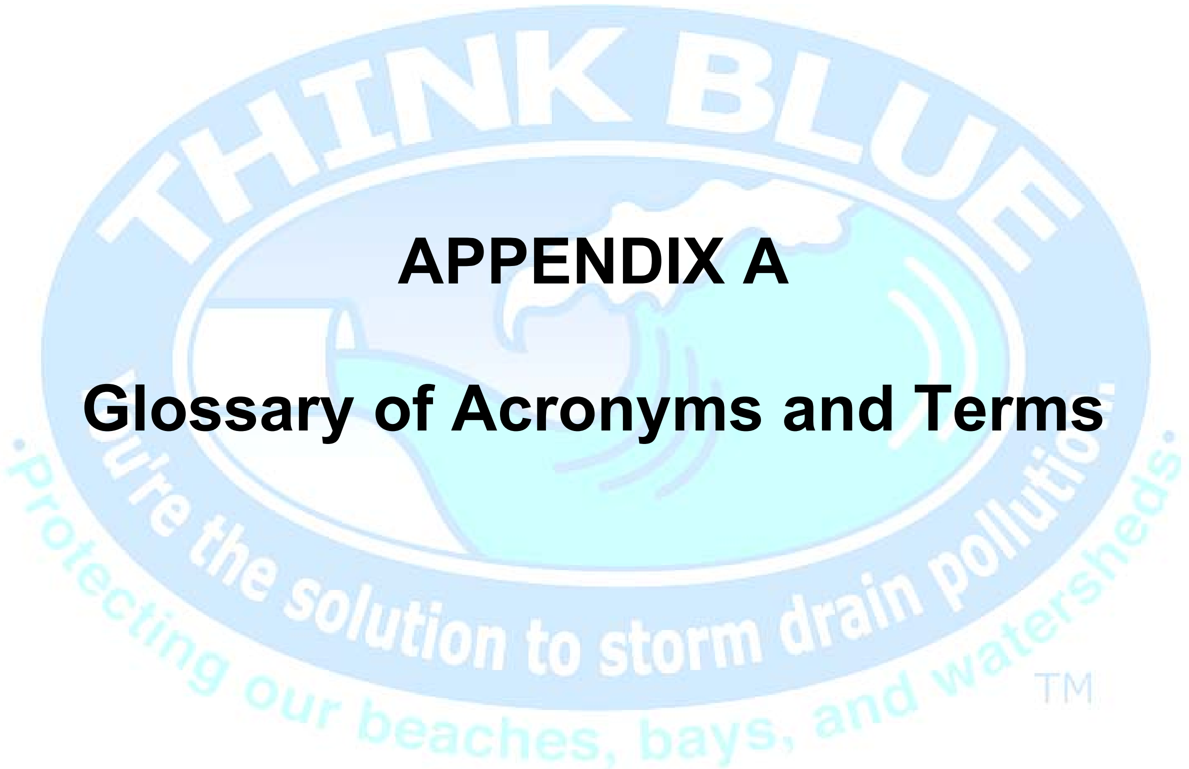
APPENDIX A

Glossary of Acronyms and Terms



Glossary of Acronyms and Terms

Assembly Bill 411 (AB411): enacted in October of 1997, the Bill requires weekly bacterial monitoring from April 1 through October 31 at all beaches adjacent to storm drains with summer flow with more than 50,000 annual visitors. Any beaches found to exceed the bacterial limits enforced by the Bill are posted with warning signs to notify the public of potential health risks.

AB411 sampling period: April 1 through October 31.

AB411 standards: minimum protective bacteriological limits for waters adjacent to public beaches and public water-contact sports. An exceedance of these standards occurs when one or more of the indicator bacteria are found at levels greater than either the single sample standards or the 30-day geometric mean limits, as follows:

(1) Based on a single sample, the density of bacteria in water from each sampling station at a public beach or public water contact sports area shall not exceed:
  (A) 1,000 total coliform bacteria per 100 milliliters, if the ratio of fecal/total coliform bacteria exceeds 0.1; or
  (B) 10,000 total coliform bacteria per 100 milliliters; or
  (C) 400 fecal coliform bacteria per 100 milliliters; or
  (D) 104 enterococcus bacteria per 100 milliliters.
(2) Based on the mean of the logarithms of the results of at least five weekly samples during any 30-day sampling period, the density of bacteria in water from any sampling station at a public beach or public water contact sports area, shall not exceed:
  (A) 1,000 total coliform bacteria per 100 milliliters; or
  (B) 200 fecal coliform bacteria per 100 milliliters; or
  (C) 35 enterococcus bacteria per 100 milliliters.

beach advisory (general advisory for all coastal waters due to rainfall): an advisory issued after 0.2” or more rainfall to alert the public of ocean and bay water contamination by urban runoff. Because bacterial levels can increase significantly in ocean and bay waters, especially near all storm drain, river, and lagoon outlets, during and after rainstorms, the San Diego County Department of Environmental Health (DEH) advises beach users to avoid contact with ocean and bay waters for a period of 72 hours after rainfall ends. Additional temporary warning signs are not posted during General Advisories.

beach closure: the immediate closure of a beach to public use due to known sewage contamination. A water contact Closure is issued anytime a reported sewage spill impacts ocean or bay recreational waters. Sewage contaminated water may contain human pathogens that can cause illnesses. The DEH advises beach users to avoid contact with ocean and bay waters where closure signs are posted. Signs warning the public of this condition remain posted until the results of water testing indicate that bacteria levels are below the AB411 single sample standards.

beach posting: a warning to the general public that recreational water contact may cause illness at beaches where indicator bacteria concentrations are found to exceed AB411 standards. The DEH advises beach users to avoid contact with ocean and bay waters where advisory/ warning signs are posted. Signs posted around the perimeter of the beach (150 feet on each side of the sampling location) remain there until a re-sample produces results below the single sample standard and/or until subsequent sampling lowers the geometric mean below established limits.

conductivity (specific conductance): a measure of the ability of water to conduct electricity. Conductivity is dependent on the concentration of ions in water, and is thus a rapid method of estimating the total dissolved solids content, or salinity, of a water body.

closed circuit television (CCTV) a small push camera that is attached to a flexible cord capable of recording information within confined spaces, such as sewage pipelines.

de-watering system: a sump pump system commonly found at condominium units in the Sail Bay area of Mission Bay. Two distinct types of sump pumps have been found in this area. De-watering sump pumps are found at locations that have very large underground garage structures; they collect groundwater and tidally influenced water and send it out to the storm drain conveyance system. The second type of sump pump, rainwater sump pump, is found at locations that have a parking structure below the street surface. During high rainfall events these locations send water from the parking structure back onto the street surface via a sump pump.

diversion berm: a curb-like structure that directs storm drain flow into the sewer system, therefore preventing urban runoff from flowing into Mission Bay. The berm is usually 5 – 7 inches in height and is located on the downstream (bay side) end of the diversion rack.

diversion rack: a metal or plastic grate that reduces the amount of trash and organic debris entering the sanitary sewer system.

diversion system: refers to the Mission Bay Sewage Interceptor System (MBSIS).

diverted storm drain system: the portion of the storm water conveyance system that is upstream of the diversion structures associated with the MBSIS.

dry weather flow: water in or flowing from the storm water conveyance system that is not associated with precipitation events. Water flowing in or from the conveyance system during a storm or for 72 hours after the cessation of the event is not considered dry weather flow.

dry season: May 1 through September 30.

enterococcus: a subgroup within the fecal *Streptococcus* group. These bacteria are distinguished by their ability to survive in salt water, and in this respect they more closely mimic many pathogens than do other bacteriological indicators. EPA recommends enterococci as the best indicator of health risk in salt water used for recreation. If large numbers of enterococci are found in the water, there is a high probability that other pathogenic bacteria or organisms may be present.

fecal coliform: a specific subgroup of total coliform bacteria. These organisms are separated from the total coliform group by their ability to grow at elevated temperatures, and are associated only with the fecal material of warm-blooded animals. Fecal coliform bacteria may indicate the presence of sewage contamination in a waterway and the possible presence of other pathogenic organisms that can exist in fecal material.

illegal discharge (ID): a point source discharge of pollutants to the storm water conveyance system which is not comprised entirely of storm water and not authorized by a NPDES permit. Wash water, sediment, spilled chemicals, and other pollutants allowed to enter the storm water conveyance system, either intentionally or unintentionally, can contribute to the degradation of the local water quality. Illegal discharges include sewage spills. Releases from the sanitary sewer or private laterals can allow pathogens, ammonia, detergents, and other contaminants to enter the storm water conveyance system.

illicit connections (IC): conveyances that that have been illegally connected to the storm water conveyance system. These connections provide pathways for pollutants to enter the storm water conveyance system. Improperly installed or defective rain diversion systems or devices that release pollutants into the storm water conveyance system are also considered illicit connections.

indicator bacteria: bacteria that are common I warm blooded vertebrate feces and are used in analyses to indicate potential sewage contamination. They include total coliform, fecal coliform, and enterococcus. The presence of these bacteria in high concentrations suggests an increased chance that other pathogenic organisms typically associated with fecal contamination are also present. The bacterial indicators are not specific to humans, and may be from other sources including wildlife, pets, soils, and rotting vegetation like kelp.

irrigation runoff: runoff from the irrigation system in Mission Bay Park or from individual residences that results from an excessive volume or duration of watering. This runoff can enter the storm water conveyance system either upstream or downstream of the Mission Bay Sewage Interceptor System, depending on the site and the location of storm drain inlets.

Mission Bay Sewage Interceptor System (MBSIS): a system that was engineered and built by the City of San Diego to protect the water quality of Mission Bay by diverting pollutants that flow through the storm drains to the sewer system before they enter the Bay. Dry weather flows from the upstream Mission Bay watersheds are intercepted and diverted to the sanitary sewer system via a series of diversion structures and pump stations. The MBSIS is an important feature in preventing dry weather runoff, and associated bacterial loads, from reaching the Bay.

Multiple Separate Storm Sewer System (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, natural drainage features or channels, modified natural channels, man-made channels, or storm drains) that is owned or operated by any public body having jurisdiction over disposal of sewage, industrial wastes, storm water, or other wastes. It is designated or used for collection or conveying storm water and is not combined with the sewer system.

non-point source discharge: discharge from a diffuse pollution source (i.e., without a single point of origin or not introduced into a receiving water from a specific outlet).

non-storm water discharge: any discharge to a storm drain system or receiving water that is not composed entirely of storm water.

outlet: the point source where a municipal storm sewer discharges to receiving waters.

pH: the negative log of the hydrogen ion concentration, which indicates the acidity or alkalinity of a water sample. The pH is a potentially critical environmental factor that can influence the chemistry and biology of an aquatic system. It can affect the solubility of chemical substances, chemical equilibria, availability of nutrients, relative toxicity of environmental contaminants, and the leechability of trace elements (i.e., cadmium, lead, copper, and zinc) from sediments and suspended material. The normal pH of surface marine waters is 8.1.

point source: any discernible, confined and discrete conveyance, including any pipe, ditch, channel, tunnel, conduit, vessel, etc., from which pollutants are or may be discharged.

receiving waters: all surface water bodies into which wastewater or treated effluent is discharged.

salinity: a measure of the concentration of dissolved salts

sanitary sewer: underground pipes that carry only domestic or industrial wastewater, not storm water.

sediment: organic or inorganic material that is carried by or suspended in water and that settles out to form deposits in the storm drain system or receiving waters.

storm drain inlet: a drainage structure that collects surface runoff and funnels it into the storm water conveyance system.

storm water: urban runoff consisting only of those discharges that originate from precipitation events. Storm water is the portion of precipitation that flows across a surface to the storm drain system or receiving waters. In general, runoff increases as the perviousness of a surface decreases. During precipitation events in urban areas, rain water picks up and transports pollutants through storm water conveyance systems, and ultimately to a receiving water body.

storm water conveyance system: streets, gutters, inlets, conduits, natural or artificial drains, channels and watercourses, or other facilities that are owned, operated, maintained, and used for the purpose of collecting, storing, transporting, or disposing of storm water.

surface runoff: water that flows off a surface when precipitation or irrigation exceeds the rate at which it can infiltrate the surface or be stored in small surface depressions.

storm drain runoff (or urban runoff): water flowing in or from the storm water conveyance system that originates from many diffuse sources within the upstream watershed. These sources include activities such as car-washing and lawn watering, however, flow from storm events is also considered urban runoff. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and coastal waters.

temperature: a physical parameter of water quality that is necessary in order to assess the significance of other parameters and to calculate the values of parameters that vary with temperature. It has an important influence on water density, DO saturation, the solubility and toxicity of constituents in water, pH, specific conductance, rate of chemical reactions, biological activity, and the type of biota found in an area.

total coliform: a natural part of the microbiology of the intestinal tract of cold- and warm-blooded animals, including humans. Because they are relatively easy to culture in the laboratory, the total coliform group has been selected as the primary bacteria used to indicate the presence of disease causing organisms. If large numbers of coliforms are found in the water, there is an increased probability that other pathogenic bacteria or organisms may be present.

total dissolved solids (TDS): inorganic salts and small amounts of organic matter that are dissolved in water. Potential sources include natural inputs, sewage, urban runoff, and industrial wastewater.

total organic carbon (TOC): TOC is associated with decaying organic matter and serves as a food source for bacteria. It affects various interactions and biogeochemical processes, including nutrient cycling, biological availability, and chemical transport. In water, organic matter is comprised of thousands of components such as macroscopic particles, colloids, dissolved macromolecules, and specific compounds.

total suspended solids (TSS): TSS consists of any particles or substances that are neither dissolved nor settled in a water sample. They can originate from silt, decaying organic matter, industrial wastes, or sewage. In high concentrations, the particles result in turbid water.

turbidity: a measure of water cloudiness, or the concentration of suspended solids in the water column. High levels of turbidity can block light from reaching submerged vegetation, trap infra-red waves which subsequently increase water temperature, and can result in an overload of particulates to filter-feeding organisms.

un-diverted storm drain system: any portion of the storm water conveyance system that is downstream of the MBSIS or any storm drain that is not associated with the MBSIS.

wet weather flow: water within or flowing from the storm water conveyance system that originated from a precipitation event.

wet season: October 1 through April 30.

wrack: organic material (algae, eel grass, kelp, etc.) and other debris (e.g., trash) that accumulates on the beach face.

wrack line: wrack that forms a line on the each parallel to the water. The wrack line is usually deposited by the water at high tide. If deposited during a spring tide, the wrack line can persist on the beach for several weeks.

APPENDIX B

Sources of Human Sewage from Park Infrastructure

Interim Report for

Mission Bay Clean Beaches Initiative Source Identification Surveys

Task 1: Sources of Human Sewage from Park Infrastructure

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INTRODUCTION

Historical Background

Mission Bay is an enclosed, recreational water body in San Diego, California that is used by twelve million people each year. Numerous recreational activities take place in Mission Bay, including swimming, diving, boating, fishing, kayaking, and water skiing. Water quality in the Bay has been monitored since the mid-1960s and exceedances of bacterial standards have been recorded from surface waters of the Bay since the early 1970s. Poor tidal flushing, contamination from storm drains, and periodic overflows from the City of San Diego sewage system were thought to the primary causes of most of the bacterial problems in the Bay.

In 1987, the City of San Diego built the East Mission Bay Sewer Interceptor System (MBSIS) to divert dry weather flow from storm drains that emptied into Mission Bay. EBISS also reduced the incidence of sewage spills that periodically impacted the Bay. In 1993, the City completed the Mission Bay Peripheral Sewage Interceptor System (MBPSIS). Together, these two systems intercept and divert dry weather flows from 66 of the 89 storm drains that enter into the Bay. The 23 drains that are not included in the MBSIS or MBPSIS were considered in the Sewage Interceptor System Master Plan to have no sewage spill potential (City of San Diego, 1987).

Although the interceptor system dramatically reduced the major sources of bacterial contamination to Mission Bay, exceedances of bacterial standards remain a persistent problem at several beach areas throughout the Bay. Water quality monitoring data from weekly sampling at 20 shoreline stations provided by the County of San Diego Department of Environmental Health showed that areas of Mission Bay were posted or closed a total of 1,453 days in the Year 2000 based on AB411 (the Beach Safety Bill) criteria. Greater than fifty percent of the total days that Mission Bay was posted in 2000 was due to bacterial exceedances at four shoreline areas: Bahia Point and Bonita Cove in the southwestern portion of the Bay, and De Anza Cove and the Visitor's Center in the northeastern portion of the Bay (Figure 1). The beaches adjacent to the mouths of Rose Creek on the north side of the Bay and Tecolote Creek on the east side of the Bay contributed to 20% of the postings. Swimming areas around Leisure Lagoon, the Wildlife Refuge, and north Pacific Passage (all on the northeastern portion of the Bay) contributed to an additional 22% of the postings.

Figure 1. Map of Mission Bay.

The City of San Diego contracted with MEC Analytical Systems, Inc. (MEC) to investigate the potential sources of bacterial contamination to Mission Bay. As part of the contract with the City, MEC produced a Quality Assurance Project Plan (QAPP), which identified three main tasks designed to investigate those sources:

1) Investigate and identify sources of human sewage from Park restroom infrastructure;
2) Investigate sources of human sewage from the discharge of boat holding tanks; and
3) Conduct visual observations of other potential sources of bacterial contamination.

This Interim Report summarizes the information collected in Task 1 - Investigate and identify sources of human sewage from Park restroom infrastructure.

Although the most likely source of anthropogenic bacterial contamination to the Bay was eliminated with the completion of the MBSIS and MBPSIS interceptor system, the integrity of the smaller, numerous lateral lines that deliver sewage from the Park restrooms to the main lines had not been examined previously. In addition, the restrooms on the northeast and southeast areas of Mission Bay have sumps and lift pumps, which had not been inspected for possible leaks prior to this investigation. The infrastructure that services the sanitary systems within the Mission Bay Park presents a potentially large source of bacterial contamination to the Bay. The focus of this task of the study was to investigate and report on the integrity of those lateral lines. A photograph of a typical restroom facility in Mission Bay Park is presented in Figure 2.

Figure 2. Mission Bay Park restroom facility.

Study Objectives

The primary goal of this study was to examine the integrity of the sewage system infrastructure within Mission Bay Park to determine the extent to which the system may contribute bacteria to the waters of Mission Bay. The study had the following objectives:

1) Investigate the integrity of the sewage system infrastructure within Mission Bay Park using Closed Circuit Television (CCTV).
2) Assess bacterial contamination (total coliforms, fecal coliforms, and Enterococci) in the Bay immediately adjacent to the Park restrooms to determine the extent to which these areas may be contributing bacterial contamination to the Bay and establish baseline conditions prior to any work on the infrastructure that may take place.
3) `Where the CCTV investigation indicates problems, conduct a dye study to observe and track leakage into Mission Bay.
4) Make recommendations to the City on areas where infrastructure problems are apparent and in need of repair.
5) Re-assess the beach water quality using the bacterial indicator tests following any corrective/repair actions that have been made to verify elimination or reduction of water quality exceedances as a result of the repair.

MATERIALS AND METHODS

Site Locations

There are 23 permanent restroom facilities located in the Park (Figure 3). Of these, a total of 16 were investigated as part of this study (Table 1). Eleven of these are in close proximity to one of the 12 designated sampling sites. Three of the additional five are located on the west side of the Bay (Ventura Point, El Carmel Point, and Santa Clara Point), one is located on the northeastern side of Crown Point, and one is located on Vacation Isle at Paradise Point. All of the restrooms associated with a site were investigated, except for the facilities at Campland and the Visitor's Center building (the restroom to the south of the Visitor's Center was investigated). Two of the 12 sites have no restrooms associated with them (Site 4 - Riviera Shores and Site 12 - Hidden Anchorage).

Base map source: SANDAG

Figure 3. Map of Mission Bay showing infrastructure investigation sites.

Table 1. Sampling sites and descriptions for Mission Bay infrastructure investigation.

MEC Site #	Facility Name	Facility Number	Site Description
1	Bonita Cove North	521	Northern end of Bonita Cove
1	Bonita Cove East	1056	Eastern shore or Bonita Cove
2	Bahia Point	834	Northeast shoreline of Bahia Point
3	Fanual Park	9950	At end of Fanuel Street behind playground
5	Crown Point North	522	Northeastern end of Crown Point near wildlife refuge
7	De Anza Cove	10087	North shore of Cove near pumpstation on west side of Cove
8	Visitor's Center	1091	South of Visitor's Center Building
9	Leisure Lagoon North	1092	On northeast end of Lagoon across from island
9	Leisure Lagoon South	1093	At southern end of Lagoon
10	North Pacific Passage	1094	South of Hilton Hotel ~ 300 m
11	Tecolote Creek	1406	West of the playground
nd	Ventura Point	10096	Eastern end of Ventura Cove
nd	Paradise Point	1087	On north end of Vacation Isle at Paradise Point
nd	El Carmel Point	579	On Peninsula at end of El Carmel Street
nd	Santa Clara Point	9939	On Peninsula at end of Santa Clara Street
nd	Crown Point South	576	Southeastern end of Crown Point

Closed Circuit Television

The lateral lines of each of the restroom facilities were investigated using close circuit television (CCTV) to look for cracks, tree roots, sedimentation, and other evidence of integrity problems. The system consists of a push camera connected via a 250-foot long cable to a video monitor and VCR. The camera was inserted down the sump or line to be investigated and pushed the length of the pipe (up to 250 feet). A typical investigation started inside the restroom facility, but lines were also accessed from clean outs located outside the facility along the pipe's length (Figure 4). The camera image was viewed on the monitor and recorded by the VCR. The locations of any pipe transitions or potential problem areas were identified on the tape as was the audio recording of the technician's observations.

Following the camera investigation, the tape was reviewed for pipe integrity. The tape was digitized on a compact disc for future reference and a report was generated for each facility outlining any areas of concern. All of the CCTV work was completed by experienced technicians and engineers at Affordable Pipeline Services, a sub-contractor on the project. A photograph of a typical CCTV investigation is shown in Figure 4.

Because there were no obvious breaks or holes in any of the lines investigated, the additional components of the study outlined in the scope of work (establishing a bacterial baseline, conducting dye studies, and re-assessing bacteria levels after repair procedures have taken place) were not necessary.

Figure 4. Photograph of typical CCTV investigation in Mission Bay Park.

RESULTS

An overview of the results of the CCTV investigation is presented in Table 2. An individual assessment of each of the facilities investigated is presented below. Each of the video tapes from individual investigations were analyzed by engineers at Affordable Pipeline Services. Detailed results of these analyses including photographs, diagrams of the investigation, and the locations of areas of interest are presented by site in Appendices A through P.

Data for restroom facilities 1092 and 1093 in Leisure Lagoon and facility number 1094 at North Pacific Passage have been investigated, but have not yet been analyzed. This information will be included in a future monthly status report and the final project report.

Table 2. Results of CCTV investigations at Mission Bay Park Restroom laterals.

MEC Site #	Facility Name	Facility Number	Date of Investigation	General Condition
1	Bonita Cove North	521	9/19/02	Good –no major cracks or break in line
1	Bonita Cove East	1056	9/19/02	Good –no major cracks or break in line
2	Bahia Point	834	9/19/02	Good –no major cracks or break in line
3	Fanual Park	9950	9/26/02	Good –no major cracks or break in line
5	Crown Point North	522	9/26/02	Good –no major cracks or break in line
7	De Anza Cove	10087	9/26/02	Good –no major cracks or break in line
8	Visitor's Center	1091	10/17/02	Fair – line has some corrosion
9	Leisure Lagoon North	1092	10/24/02	Good – no major cracks or break in line
9	Leisure Lagoon South	1093	10/24/02	Good – no major cracks or break in line
10	North Pacific Passage	1094	10/31/02	Good – no major cracks or break in line
11	Tecolote Creek	1406	10/03/02	Good – no major cracks or break in line
nd	Ventura Point	10096	10/03/02	Fair – one large root mass
nd	Paradise Point	1087	10/3/02	Good – no major cracks or break in line
nd	El Carmel Point	579	10/10/02	Good – no major cracks or break in line
nd	Santa Clara Point	9939	10/10/02	Fair – one length of pipe was corroded
nd	Crown Point South	576	10/10/02	Good – no major cracks or break in line

Facility 521 – Bonita Cove North

This facility is located at the northern end of Site 2 - Bonita Cove (Figure 3). It was investigated on September 19, 2002. The four inch PVC line from the restroom was accessed through clean out in the center of the building on the south side. The line travels west from the clean out for approximately 30 feet where it transitions into a six inch PVC line that heads southwest. The engineer was able to push the camera a total distance of 160 feet. At this point there was a clean out that had been buried and was not visible from the surface. The pipe was 72 inches below the surface at this point. Aside from light corrosion at approximately 21 feet from the restroom and some minor root intrusions, there were no structural problems observed in the pipe.

Facility 1056 – Bonita Cove East

This facility is located on the eastern shore of Bonita Cove between restroom 521 and the jetty (Figure 3). It was investigated on September 19, 2002. Two runs were conducted here. The first run started from the clean out in the middle of the bathroom on the west side. The four inch ABS line ran east from the restroom for approximately 35 feet where the line changed to 4 inch clay pipe and a clean out. Two more clean outs were encountered at 116 feet and 125 feet. The second run started from the clean out at 125 feet. The line continued east for another 138 feet where it dumped into a manhole. In the manhole there was a second line coming from the south that appeared to have been abandoned. The integrity of all the lines investigated was good and there were no structural problems or evidence or corrosion in the pipe.

Facility 834 – Bahia Point

This facility is located at the end of Bahia Point (Figure 3). It was investigated on September 19, 2002. Two runs were conducted here. The first was from the clean out located on the south side of the restroom. The four inch ABS pipe heads south from the restroom approximately 19 feet to a clean out in the grass. At 12 feet the pipe transitions to cast iron, then back to ABS at the clean out. From there, the pipe runs an additional 10 feet southeast to a manhole. The second run started at the manhole and ran for another 97 feet to the southeast. Here the line follows Gleason Street and can be seen from an old cut in the asphalt. Aside from some very mild corrosion in the cast iron portion of the pipe, there were no structural problems observed in either run.

Facility 9950 – Fanuel Park

This facility is located at Site 3 where Fanuel Street terminates at Mission Bay (Figure 3). It was investigated on September 26, 2002. Two runs were conducted here. The first was accessed through a four inch ABS clean out in the concrete directly south of the building. Here the line turns 90 degrees and runs west for approximately 23 feet to a clean out in the grass southwest of the building. Here the line turns 90 degrees again and heads north, parallel with Fanuel Street. At a distance of 85 feet from the initial access point there is a service connection that comes from the northern set of restrooms, directly across from restroom #9. The pipe continues north an additional 24 feet from this point and empties into a clean out just northwest of the building. The second run started from this clean out. Here the line turns approximately 45 degrees, runs for approximately 105 feet, and empties into the main line at the manhole in the middle of Fanuel Street. The integrity of all the lines investigated was good and there were no structural problems or evidence or corrosion in the pipe.

Facility 522 – Crown Point North

This facility is located at Site 5, on the eastern shore of Crown Point just south of the Wildlife Refuge (Figure 3). It was investigated on September 26, 2002. This line was accessed through a two inch clean out on the east (Bay side) of the restroom. Here the pipe is made of four inch cast iron and runs directly west from the access point under the restroom. At 29 feet from the access point there is a buried clean out that is not visible from the surface. The line continues west to a distance of 59 feet from the starting point and empties into a manhole. Here the pipe transitions to six inch clay pipe and runs an additional 17 feet where the camera lost push. Aside from light corrosion in cast iron, there were no structural problems observed in the run.

Facility 10087 – De Anza Cove

This facility is located at Site 7, on the northern shore of De Anza Cove (Figure 3). It was investigated on September 26, 2002. Four runs were conducted here. The first two were from inside the restroom where they joined at a clean out approximately two feet just north of center of the restroom. The third run was initiated from this clean out. From here, the four inch ABS line runs east, parallel with the sidewalk to a service connection approximately 25 feet from the first clean out. Here the line turns 90 degrees to the north for a distance of approximately four feet where it terminates in a six inch pipe via a saddle valve. This pipe runs perpendicular to the four foot pipe and flows due west. Thus the flow from the restroom heads east for 25 feet then joins another line that heads due west. Technicians from the City suggested that this “hairpin” configuration was likely the result of the existing restroom joining the line of an old restroom facility that was located just to the east. The third run continued another 20 feet from the junction where it entered a manhole in the grass, west of the restroom. A fourth run was initiated here. The six inch clay pipe ran west towards the pump station on the western end of De Anza Cove. The run was stopped at a distance of 158 feet due to inability to push the camera. The integrity of all the lines investigated at this site was good and there was no evidence of structural problems or corrosion.

Facility 1406 – Tecolote Creek

This facility is located at Site 11, just north of the mouth of Tecolote Creek (Figure 3). It was investigated on October 3, 2002. Two runs were conducted here. The first line was accessed from the west side of the restroom. Here, the four inch cast iron line runs due east under the playground, transitions to PVC at approximately 12 feet and continues an additional 78 feet to a clean out in the playground. At 27 feet from the restroom, the engineer observed what appeared to be a break in the pipe. However, upon further investigation of the video tape, it was evident that a hole had been patched and there was no sign of potential leakage. The second run continued from the clean out east to a manhole east of the playground. Aside from light corrosion in cast iron, there were no structural problems observed in the run.

Facility 576 – Crown Point South

This facility is located on the eastern shore of Crown Point, south of Site 5 and restroom 522 (Figure 3). It was investigated on October 3, 2002. Two runs were conducted here. The first was initiated from inside the restroom on the east (Bay side) of the building. Here, the four inch cast iron pipe runs west, under the restroom. At approximately 38 feet, the pipe transitions to clay pipe and at 45 feet, the pipe turns to the northeast to a manhole north of the building. The second run was initiated from the manhole. Here the line turns north and runs parallel to the shore. The run ended approximately 105 feet from the manhole due to an ability to push the camera. There were several small root intrusions in the clay pipe and some minor corrosion of the cast iron, but there were no structural problems observed in either run.

Facility 1087 – Paradise Point

This facility is located on the northern end of Vacation Isle at Paradise Point (Figure 3). It was investigated on October 3, 2002. The pipe was accessed from inside the restroom on the west side of the building. The four inch cast iron pipe ran east, under the restroom. Between 41 and 57 feet, the pipe transitioned from cast iron to ABS, to PVC, and to clay. The run ended 191 feet from the restroom due to an ability to push the camera. It was evident that it terminated in a manhole approximately 20 feet further east, then turned 90 degrees to the north, following the road. Aside from several small root intrusions in the clay pipe there were no structural problems observed in the run.

Facility 10096 – Ventura Point

This facility is located on Ventura Point on the western shore of Ventura Cove (Figure 3). It was investigated on October 10, 2002. The line was accessed from inside the restroom on the south side of the building. The four inch cast iron pipe ran south from the restroom toward the parking lot. At 23 feet there was a service connection. At 109 feet there were some “large roots” observed in the pipe and a possible blockage. At 138 feet, the line transitioned to clay pipe and the run ended at 140 feet due to an inability to push the camera. A lateral tie in was observed at this point. The large root intrusion may be an area of concern. At the time of the investigation, the engineer from Affordable Pipeline Services suggested that the root mass was not a likely source of sewage leakage to the surround area. He explained that very small root hairs often invade the interior of the pipe and expand once inside. Thus, although a root mass may appear large inside the pipe, the opening to the outside is usually very small. This was verified by the engineer who reviewed the video tape. In addition, the area of the root intrusion is approximately 200 m from the Bay and approximately half a mile from the County sampling site at Bahia Point.

Facility 579 – El Carmel Point

This facility is located on El Carmel Point on the east side of Mission Bay (Figure 3). It was investigated on October 10, 2002. The site was accessed from a toilet drain inside the restroom. The four inch cast iron pipe ran south from the restroom toward the street. There were several laterals entering the pipe at 30 feet from the restroom and a buried clean out observed at 51 feet from the restroom. The pipe transitioned to clay at 67 feet and terminated in a manhole at 71 feet. From here, the line headed west, down the middle of El Carmel Street. Aside from light corrosion of the cast iron pipe there were no structural problems observed in the run.

Facility 9939 – Santa Clara Point

This facility is located on Santa Clara Point on the east side of Mission Bay (Figure 3). It was investigated on October 10, 2002. Two runs were conducted here. The first was initiated inside the restroom. From here the four inch line ran west, towards the Bay, for a distance of approximately 37 feet where it was blocked by a 90 degree bend in the pipe to the left (south). The second run was initiated at the clean out at this point. Here, the line from the bathroom joins another line running south from commercial buildings on the northern tip of the peninsula. From the clean out, the 4 inch cast iron pipe runs south. At 38 feet there is another clean out and the pipe transitions to ABS at 82 feet. The pipe terminates at a manhole at 84 feet where the run was ended. Analysis of the video tape suggests that there is “severe corrosion” of the pipe observed in run 2. There was no evidence that the corrosion had perforated the pipe, which would lead to a leakage of sewage, but it may be beneficial to further examine this line.

Facility 1091 – South of Visitor’s Center

This facility is located at Site 8, just south of the Visitor’s Center (Figure 3). It was investigated on October 17, 2002. This restroom has a pump station associated with it because it is below the level of the water main. To access the line, the pump was disconnected and the line cleared. The line runs east from the restroom towards the street. The line was examined for a length of 204 feet. There were no clean outs observed in the run and the integrity of the pipe appeared to be intact.

Facility 1092 – Leisure Lagoon North

This facility is located at Site 9, at the northeast end of Leisure Lagoon (Figure 3). It was investigated on October 24, 2002. This restroom has a pump station associated with it because it is below the level of the water main. To access the line, the pump was disconnected and the line cleared. From the restroom, the line runs east for approximately 10 feet, then heads southeast toward East Mission Bay Blvd. The line was examined for a length of 275 feet. For the first 20 feet, the pipe is composed of clay, the transitions to cast iron for the rest of the run to the sewer main. The pipe was in good condition throughout its length and there were no structural problems observed in the run.

Facility 1093 – Leisure Lagoon South

This facility is located at Site 9 at the southern end of Leisure Lagoon (Figure 3). It was investigated on October 24, 2002. From the restroom, the line runs southeast to the main line intersection in the parking lot approximately 625 feet from the restroom. The line was examined for a length of 332 feet. The pipe was composed of clay for the first 30 feet, then transitioned to cast iron for the rest of the run. The pipe was in good condition throughout its length and there were no structural problems observed in the run.

Facility 1094 – North Pacific Passage

This facility is located at Site 10 at the southern end of Leisure Lagoon (Figure 3). It was investigated on October 31, 2002. From the restroom, the line runs east, then southeast towards the parking lot behind the facility. The line was examined for a length of 122 feet. For the first 20 feet, the line was cast iron, then transitioned to PVC for the remainder of the run. The pipe was in good condition throughout its length and there were no structural problems observed in the run.

CONCLUSIONS

The results of the CCTV investigations suggest that the lateral lines of the Mission Bay Park restroom facilities are an unlikely source of sewage to Mission Bay. Aside from some corrosion of the cast iron pipes and root intrusions of the clay pipes at some sites, the integrity of most of the lines investigated was intact. However, there are two facilities that may warrant further investigation: Facility 10096 – Ventura Point and Facility 9939 at Santa Clara Point.

At Facility 10096, a root mass was observed approximately 109 feet south of the restroom. As discussed in the results, the area is an unlikely source of high bacterial counts at Bahia Point (the closest monitoring station). However, the root mass does represent a potential source of sewage in Mission Bay Park and this facility may be a candidate for further investigation.

At Facility 9939 at Santa Clara Point, corrosion of the cast iron pipe between 38 and 84 feet from the restroom was observed. Although perforations of the pipe could not be observed due to the buildup of material lining the pipe, there is a potential for leakage to the surrounding area at this location. Although Santa Clara Point is not one of the sites monitored in this study, the potential for sewage leakage may warrant further investigation.

RECOMMENDATIONS

The infrastructure investigation indicated that the lateral lines of the Mission Bay Park restrooms were an unlikely source of sewage to the Bay. However, the City may wish to further investigate two restrooms that appeared to have some potential problems: Facility 10096 on Ventura Point and Facility 9939 at Santa Clara Point. Although neither facility is a likely source of sewage to the Bay, the following recommendations are presented to verify the integrity of these lines:

1. **Facility 10096 – Ventura Point.** The simplest way to determine if the root mass in this line is acting as a potential conveyance of sewage to the surrounding area is to remove the root mass with a snake and visualize the area of intrusion using a CCTV system. If a hole or separation of the pipe is evident, the pipe should replaced or patched a soon as possible.

2. **Facility 9939 – Santa Clara Point.** The "severe corrosion" observed in one section of this line suggests that the integrity of the cast iron wall of the pipe may have been compromised. Unfortunately, the only way to positively determine if sewage is escaping from the pipe is to view it externally. Excavating the pipe for visual inspection and subsequent replacement if necessary is recommended.

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City of San Diego, 1987. Mission Bay Sewage Interceptor System, Phase II Report, Final Master Plan. City of San Diego Water Utilities Department, 107 p.

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APPENDIX C

Sources of Human Sewage from Moored Boats

Interim Report for

Mission Bay Clean Beaches Initiative Source Identification Surveys

Task 2: Sources of Human Sewage from County Beach Boat Moorings

Prepared For:
State Water Resources Control Board

Prepared By:

City of San Diego

and

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October 30, 2002

INTRODUCTION

Historical Background

Mission Bay is an enclosed, recreational water body in San Diego, California that is used by twelve million people each year. Numerous recreational activities take place in Mission Bay, including swimming, diving, boating, fishing, kayaking, and water skiing. Water quality in the Bay has been monitored since the mid-1960s and exceedances of bacterial standards have been recorded from surface waters of the Bay since the early 1970s. Poor tidal flushing, contamination from storm drains, and periodic overflows from the City of San Diego sewage system were thought to the primary causes of most of the bacterial problems in the Bay.

In 1987, the City of San Diego built the East Mission Bay Sewer Interceptor System (MBSIS) to divert dry weather flow from storm drains that emptied into Mission Bay. MBSIS also reduced the incidence of sewage spills that periodically impacted the Bay. In 1993, the City completed the Mission Bay Peripheral Sewage Interceptor System (MBPSIS). Together, these two systems intercept and divert dry weather flows from 66 of the 89 storm drains that enter into the Bay. The 23 drains that are not included in the EBISS or MBPSIS were considered in the Sewage Interceptor System Master Plan to have no sewage spill potential (City of San Diego, 1987).

Although the interceptor system dramatically reduced the major sources of bacterial contamination to Mission Bay, exceedances of bacterial standards remain a persistent problem at several beach areas throughout the Bay. Water quality monitoring data from weekly sampling at 20 shoreline stations provided by the County of San Diego Department of Environmental Health showed that areas of Mission Bay were posted or closed a total of 1,453 days in the Year 2000 based on AB411 (the Beach Safety Bill) criteria. Greater than fifty percent of the total days that Mission Bay was posted in 2000 was due to bacterial exceedances at four shoreline areas: Bahia Point and Bonita Cove in the southwestern portion of the Bay, and De Anza Cove and the Visitor's Center in the northeastern portion of the Bay (Figure 1). The beaches adjacent to the mouths of Rose Creek on the north side of the Bay and Tecolote Creek on the east side of the Bay contributed to 20% of the postings. Swimming areas around Leisure Lagoon, the Wildlife Refuge, and north Pacific Passage (all on the northeastern portion of the Bay) contributed to an additional 22% of the postings.

Figure 1. Map of Mission Bay.

The City of San Diego contracted with MEC Analytical Systems, Inc. (MEC) to investigate the potential sources of bacterial contamination to Mission Bay. As part of the contract with the City, MEC produced a Quality Assurance Project Plan (QAPP), which identified three main tasks designed to investigate those sources:

1) Investigate and identify sources of human sewage from Park restroom infrastructure;
2) Investigate sources of human sewage from the discharge of boat holding tanks; and
3) Conduct visual observations of other potential sources of bacterial contamination.

This report summarizes the information collected in Task 2 - Investigate sources of human sewage from the discharge of boat holding tanks.

In Mission Bay, the largest harbor area is Quivira Basin, located in the southwestern portion of the Bay (Figure 1), which has numerous boat slips and two sewage pump-out stations. In addition, owners of boats up to 25 feet in length may use moorings in three locations in the southwest portion of the Bay: Mariners Basin, Santa Barbara Cove, and San Juan Cove. On the northwestern portion of Mission Bay, boat mooring/anchorage and dock facilities are available at Campland Marina and De Anza Cove. Although Mission Bay has been designated a “No-Discharge” area and no human waste (treated or untreated) may be discharged to the Bay, fecal contamination problems persist in some areas associated with boat moorings and anchorages. Three of these areas historically have had high bacterial counts: Bonita Cove, Bahia Point (adjacent to Santa Barbara Cove) and De Anza Cove. Thus, these areas were the focus of the boat mooring portion of this investigation. A photograph of the boat mooring facility at De Anza Cove is presented in Figure 2.

Figure 2. Boat mooring facility at De Anza Cove.

Study Objectives

The primary goal of this study was to examine the possibility of boat mooring areas in Mission Bay as sources of bacterial contamination to nearby beaches. The study had the following objectives:

1) Determine levels of indicator bacteria (total coliforms, fecal coliforms, and *Enterococci*) in and around boat mooring areas at three locations in Mission Bay: Bonita Cove, Santa Barbara Cove, and De Anza Cove.
2) Determine bacterial levels at beaches adjacent to Bonita Cove, Santa Barbara Cove, and De Anza Cove boat moorings.
3) Map, analyze, and report data, and make recommendations for future actions.

Site Locations

The investigation took place around boats moored at three sites in Mission Bay: Bonita Cove and Santa Barbara Cove in the southwestern portion of the Bay and De Anza Cove in the northeastern part of the Bay (Figure 3, Table 1). Bonita Cove is the only 72-hour boat anchorage in Mission Bay. Boats are allowed to anchor here for a maximum of 72 hours. Thus, the number of boats anchored in Bonita Cove at any one time is variable, depending on the time of year or special events. Typically, there are five to 25 boats anchored at this site at any time. The beach sampling location is at the northern end of Bonita Cove in front of a Park restroom.

Santa Barbara Cove houses numerous boats (estimated at around 60 boats) in the southern portion of the Bay, just south of Bahia Point (Figure 3, Table 1). It is also home to the Mission Bay Yacht Club, which contains boats and dock facilities on the northern portion of the Cove. The beach sampling point for this site is at the end of Bahia Point. High levels of indicator bacteria have been measured at Bahia Point, which is directly across the Bay from the Mission Bay Yacht Club.

The moored boats in De Anza Cove are located along the southwestern portion of the Cove (Figure 3, Table 1). Typically, there are 10 to 20 boats moored here, most of which are owned by residents of De Anza Harbor Resort. The beach sampling site for De Anza Cove is approximately 200 meters from the moored boats on the north shore of the Cove in front of a large storm drain.

Figure 3. Map of Mission Bay showing boat mooring investigation sites.

Table 1. Sampling sites and description for Mission Bay boat mooring investigation.

Site Location	Site Description	Latitude[1]	Longitude
Bonita Cove	At the swimming beach at the North end of Mariner's Basin, across the street from Belmont Park	32.7717	-117.2467
Santa Barbara Cove	On Bahia Point on the northeast shoreline	32.7750	-117.245
De Anza Cove	On North shore of Cove between the swim beach and first storm drain outlet east of restrooms	32.7933	-117.2117

[1] GPS coordinates in decimal degree format (HDDD.DDDD) and NAD 83 datum

MATERIALS AND METHODS

Sampling Protocol

At each site, the boat mooring investigation took place over three consecutive days. Bonita Cove was sampled on August 13, 14, and 15 (Tuesday through Thursday). Santa Barbara Cove and De Anza Cove were sampled on August 19, 20, and 21 (Monday through Wednesday). On each sampling day, five samples were collected at each site: one from the beach adjacent to the moorings and four along the perimeter of the moored boats, between the boats and the beach sampling site. The beach samples were collected from the same site location as that sampled by the San Diego County Department of Environmental Health (personal communication, Clay Clifton, County of San Diego Department of Environmental Health), as well as the samples collected during the Visual Observations Task (Task 3) of this study. The protocol for the boat mooring sampling is detailed below.

To assure consistency among results, the protocol for samples collected at the beach sites was the same as that employed by the San Diego County of Environmental Health. Samples were collected in sterile, 100-ml plastic bottles containing sodium thiosulfate. The bottles were sealed in clear plastic bags until use. The sampling technician first rinsed his hands with a waterless sanitizing gel, then put on a pair of Nitrile gloves. The sample bottle was removed from the plastic bag, labeled, and placed into a clamp attached to the end of four foot long PVC pole. The sampling technician waded into the water to a depth of approximately 12 inches and removed the lid from the sample bottle. The bottle was extended in front of the sampler (away from shore) with the sampling pole, then inverted and submerged four to six inches below the water surface. In a sweeping motion, the pole was rotated so the opening of the bottle was facing to the side. The pole was then swept sideways to take the water sample. The bottle was filled once, drained to the desired volume so that a small amount of air remained in the container, and capped. No surface residue, sediment, or debris was allowed to enter the sample bottle. If debris or sediment was evident in the bottle, the sample was discarded and the site was re-sampled with a new, sterile bottle. After collection, the sample was re-sealed in the plastic bag. All samples were kept on ice in the dark from the time of sample collection until delivery to the analytical laboratory.

The samples from the perimeter of the moored boats were taken from a kayak paddled around the perimeter of the boats. Four samples around the boats were taken at each site. The sampling locations were evenly distributed on a visual transect along the perimeter of the boats that was representative of the number of boats present. The transect was positioned approximately 10 meters from the boats, between the boats and the beach sampling site. Samples were taken from the side of the kayak, approximately six inches below the surface of the water. The aseptic technique described above for the beach sites was also employed for each of the four boat sampling locations. Because the purpose of these samples was to determine if illegal dumping was occurring, the sampling technician was as discrete as possible when taking samples, attempting to appear to be a recreational boater. All samples were kept on ice in the dark from the time of sample collection until delivery to the analytical laboratory.

The timing of sample collection was coordinated with tides, using tide charts. Because the focus of this portion of the study was to determine if indicator bacteria measured on the beach originate from moored boats, samples were collected when the tide was most likely to be moving bacteria from the boats (if present) to the shore. In Bonita Cove, sampling took place during a flood tide because the moored boats are seaward of the beach sampling site (Figure 3). However, in Santa Barbara Cove and De Anza Cove, samples were collected on an ebb tide because the beach sampling sites are seaward of the moored boats.

In addition to the bacteria samples, field data and observation sheets were completed at each site by the sampling technician to document basic information on weather and water quality conditions at the time of sample collection.

Laboratory Analyses

All bacteria samples were analyzed at the MEC Analytical Systems Microbiology Laboratory. The three indicator bacteria enumerated in this study were total coliform, fecal coliform, and Enterococcus. In the laboratory, total and fecal coliforms were analyzed using multiple tube fermentation based on Standard Methods 9221B&E. *Enterococci* were analyzed using a chromogenic technique (Enterolert), based on Standard Method 9223.

RESULTS

The results of the bacterial analyses for Bonita Cove, Santa Barbara Cove, and De Anza Cove are presented in Tables 2 through 4, respectively, below.

Table 2. Results of bacteria testing for the Mission Bay boat mooring investigation at Bonita Cove.

Site Number	Site Type	Sampling Date	Total Coliform[1]	Fecal Coliform	Enterococcus
1A	Beach	13 August, 2002	<20	<20	20
1B	Boat	13 August, 2002	<20	<20	<10
1C	Boat	13 August, 2002	20	20	10
1D	Boat	13 August, 2002	<20	<20	<10
1E	Boat	13 August, 2002	20	<20	31
1A	Beach	14 August, 2002	<20	<20	<10
1B	Boat	14 August, 2002	<20	<20	<10
1C	Boat	14 August, 2002	<20	<20	<10
1D	Boat	14 August, 2002	<20	<20	<10
1E	Boat	14 August, 2002	80	20	63
1A	Beach	15 August, 2002	<20	<20	<10
1B	Boat	15 August, 2002	<20	<20	10
1C	Boat	15 August, 2002	<20	<20	<10
1D	Boat	15 August, 2002	20	<20	<10
1E	Boat	15 August, 2002	40	<20	63

[1] All results in MPN/100 ml

Table 3. Results of bacteria testing for the Mission Bay boat mooring investigation at Santa Barbara Cove.

Site Number	Site Type	Sampling Date	Total Coliform[1]	Fecal Coliform	Enterococcus
2A	Beach	19 August, 2002	<20	<20	<10
2B	Boat	19 August, 2002	<20	<20	<10
2C	Boat	19 August, 2002	<20	<20	<10
2D	Boat	19 August, 2002	<20	<20	<10
2E	Boat	19 August, 2002	<20	<20	<10
2A	Beach	20 August, 2002	<20	<20	<10
2B	Boat	20 August, 2002	<20	<20	<10
2C	Boat	20 August, 2002	<20	<20	<10
2D	Boat	20 August, 2002	<20	<20	10
2E	Boat	20 August, 2002	20	<20	200
2A	Beach	21 August, 2002	20	20	10
2B	Boat	21 August, 2002	<20	<20	<10
2C	Boat	21 August, 2002	<20	<20	<10
2D	Boat	21 August, 2002	80	20	<10
2E	Boat	21 August, 2002	20	<20	<10

[1] All results in MPN/100 ml

Table 4. Results of bacteria testing for the Mission Bay boat mooring investigation at De Anza Cove.

Site Number	Site Type	Sampling Date	Total Coliform[1]	Fecal Coliform	Enterococcus
7A	Beach	19 August, 2002	<20	<20	41
7B	Boat	19 August, 2002	<20	<20	<10
7C	Boat	19 August, 2002	<20	<20	<10
7D	Boat	19 August, 2002	<20	<20	<10
7E	Boat	19 August, 2002	<20	<20	<10
7A	Beach	20 August, 2002	20	<20	10
7B	Boat	20 August, 2002	<20	<20	<10
7C	Boat	20 August, 2002	<20	<20	30
7D	Boat	20 August, 2002	20	<20	<10
7E	Boat	20 August, 2002	<20	<20	<10
7A	Beach	21 August, 2002	1300	140	20
7B	Boat	21 August, 2002	<20	<20	10
7C	Boat	21 August, 2002	<20	<20	<10
7D	Boat	21 August, 2002	20	<20	<10
7E	Boat	21 August, 2002	<20	<20	10

[1] All results in MPN/100 ml

Because the project was based on exceedances of AB411 criteria, the data collect were compared to those standards. For single sample limits, the AB411 criteria are as follows:

- Total Coliform of 1,000 MPN/100 ml (if fecal > 10% of Total) or 10,000 MPN/100 ml;
- Fecal Coliform of 400 MPN/100 ml;
- Enterococcus of 104 MPN/100 ml.

Very low concentrations of all three bacterial indicators were detected throughout the study at all three sites (Tables 2-4). In most cases, the concentrations were below or just above the detection limits. The only exception was the beach sample taken at De Anza Cove (Site 7A) on 21 August. The concentration of total coliforms in this sample was 1,300 MPN/100 ml, which is just slightly above the AB411 criteria. However, concentrations of fecal coliform and Enterococcus bacteria at this site were well below AB411 criteria. High levels of total coliforms, in the absence of fecal coliforms or Enterococci, may have been caused by elevated levels of suspended solids in the sample. It is very unlikely that the cause of the elevated total coliforms at this site was discharge from the moored boats.

CONCLUSIONS

This study was designed to determine if illegal dumping of holding tanks from boats moored in the three study areas was a persistent source of indicator bacteria on the beach. The lack of elevated levels of indicator bacteria from any of the samples at all sites indicates that illegal discharge of sewage from moored boats was not occurring during the time of sampling. The results also suggest that illegal sewage dumping from moored boats is not a chronic source of bacterial contamination at the beach.

However, it is important to remember that this study covered only a single sampling series over a three day period at each site. Although this is a reasonable study design for determining potential sources of human sewage from moored boats, the potential for illegal dumping from moored boats still exists and this study is by no means a comprehensive assessment of that potential. The illegal discharge of sewage holding tanks from moored boats is inherently episodic. If illegal dumping is occurring, it is likely only from a limited number of boats and only for a limited duration. For instance, if an individual is living on a boat in Mission Bay and illegally dumping the contents of the holding tank into the Bay, that dumping may be occurring at night or during the early morning. In order to capture this type of event, the sample would need to be taken soon after the discharge occurred (probably within hours).

The results of this study suggest that this type of dumping is not a chronic, persistent problem in Mission Bay, but it does not rule out the potential for episodic events.

RECOMMENDATIONS

The results of this study suggest that the illegal dumping of sewage from moored boats was not a source of bacteria at the sites monitored during the sampling period. However, since the sampling duration was limited, and illegally dumping is likely episodic (if it is occurring), the potential for moored boats as a source of bacterial contamination to adjacent beaches can not be ruled out.

To help verify and extend the data from this study, we submit the following recommendations for consideration by the City.

> **Re-sample during a high use time period.** It is reasonable to assume that the most likely time for illegal discharges from boat holding tanks will be when the greatest number of boats are using the anchorages and moorings. Therefore, repeating the sampling protocol during a high use weekend (e.g., Memorial Day, 2003) would have the greatest likelihood of collecting a sample during a discharge event. Sampling at night or early morning when illegal discharges are most likely to occur would also increase the chances of capturing an illegal discharge.
>
> **Conduct dye tab study.** One way of determining if illegal dumping from boats is occurring in the Bay is to place dye tabs in the holding tanks of boats that moor or anchor there. If the head is illegally flushed into the Bay, the dye would be released into the surrounding area. Local lifeguards and other boaters could be asked to help look for the dye and identify boats that may be discharging to the Bay. Dye tabs may also help in identifying chronic leaks from holding tanks if present. Although a permanent dye tab program may be difficult to institute, the program could be tested over a short period of time to test its efficacy. Dye tab programs have been successful in other bay areas in southern California (e.g., Newport Bay and Avalon Harbor on Catalina Island).
>
> **Follow up on anecdotal information.** There is some information that suggests that individuals may be using some boats moored in Mission Bay as semi-permanent residences. For instance, results of the 2000 census suggested that some individuals may be using moored boats in Mission Bay as a permanent residence (personal communication with Gary Stromberg, City of San Diego). If some boats are being lived on for extended periods of time, there is a greater likelihood that there is illegal discharge coming from these boats. Reducing this potential source of sewage to the Bay may help in reducing some high bacterial levels on adjacent beaches.

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City of San Diego, 1987. Mission Bay Sewage Interceptor System, Phase II Report, Final Master Plan. City of San Diego Water Utilities Department, 107 p.

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APPENDIX D

Visual Observations Study

TASK 3 – VISUAL OBSERVATIONS

INTRODUCTION

The City of San Diego contracted with MEC Analytical Systems, Inc. (MEC) to investigate the potential sources of bacterial contamination to Mission Bay. As part of the contract with the City, MEC produced a Quality Assurance Project Plan (QAPP), which identified three main tasks designed to investigate those sources:

1) Investigate and identify sources of human sewage from Park restroom infrastructure;
2) Investigate sources of human sewage from the discharge of boat holding tanks; and
3) Conduct visual observations of other potential sources of bacterial contamination.

This report summarizes the information collected in Task 3.

This report summarizes the information collected in Task 3 - Conduct visual observations of potential sources of bacterial contamination other than boat holding tanks and leaking restroom infrastructure. It was submitted to the City on January 20, 2003 and is reproduced here as part of the final report.

The potential sources that may be contributing to the bacterial problem in the Bay are manifold and diffuse and include fecal matter from birds and feral and wild animals that inhabit the Park, the homeless population, and the behavior of some Park visitors. In addition, Park management practices may contribute to the influx of indicator bacteria to the Bay from these and other sources. A photograph of a typical investigation site is presented in Figure 2.

Figure 1. Map of Mission Bay.

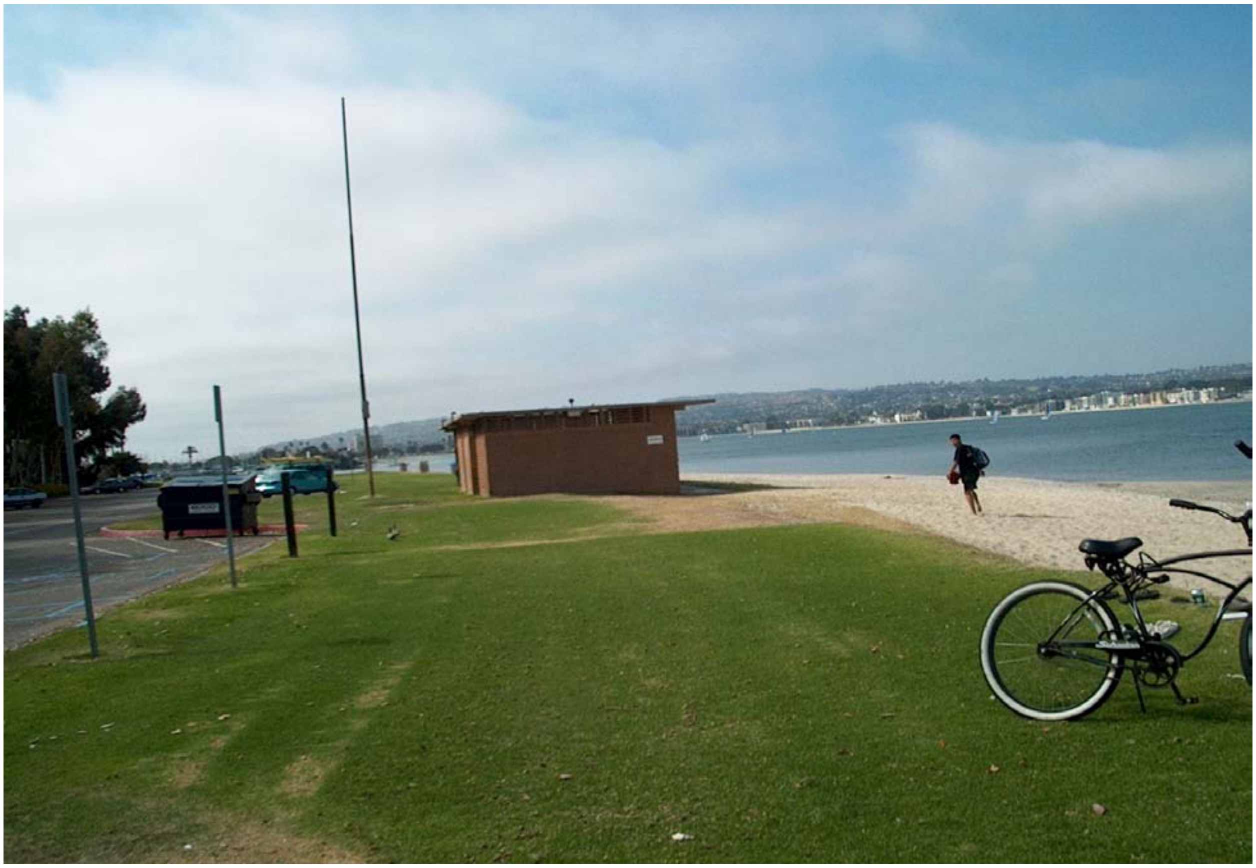


Figure 2. Typical investigation site for the visual observations study.

STUDY OBJECTIVES

The primary goal of this study was to assess the numerous potential sources of bacterial contamination to Mission Bay other than Park restroom infrastructure and boat moorings. The study had the following objectives:

1) Through visual observations, record the behavior and activities of Park visitors and wildlife as well as management practices within Mission Bay Park that may be contributing to bacterial contamination of the Bay.
2) During the observation period, sample those sources of potential bacterial influx to the Bay.
3) Summarize the results of the study with a description of potential bacterial sources at each of the 12 sites.

MATERIALS AND METHODS

SITE LOCATIONS

To facilitate a more complete spatial coverage of potential contamination areas in Mission Bay, the Bay was divided into four quadrants for investigation activities: Northeast, Northwest, Southeast, and Southwest Mission Bay (Figure 3). A total of 12 sites within the Bay were selected for the observational investigation, with a minimum of two sites within each quadrant. Sites were selected based on a review of dry weather exceedances of bacterial counts and a statistical review of seven years of sampling data (MEC, 2001).

Samples for bacterial analyses were taken from the same location as the San Diego Department of Environmental Health (DEH) beach monitoring sites. The Department of Health samples numerous sites in Mission Bay on a weekly basis for indicator bacteria (personal communication, Clay Clifton, County of San Diego Department of Environmental Health). Eleven of these sites are the same as the beach sites that were sampled in the visual observations investigation (Table 1). One site, Hidden Anchorage, was sampled in the visual observations study, but is not monitored by Department of Environmental Health. The sampling sites are described in Table 1 and shown in Figure 3.

Table 1. Sampling sites and descriptions for Mission Bay visual observations investigation.

MEC Site #	DEH[1] Site #	Site Name	Site Description	Lat.[2]	Long.
1	MB-170	Bonita Cove	At swimming beach at North end of Mariner's Basin, across from Belmont Park	32.7717	-117.2467
2	MB-160	Bahia Point	Northeast shoreline of Bahia Point near stormdrain	32.7750	-117.2450
3	MB-120	Fanual Park	At swimming beach in front of playground	32.7917	-117.2450
4	MB-110	Riviera Shores	La Cima at Riviera Shores, just north of Cima Street	32.7833	-117.2400
5	MB-090	Northern Wildlife Preserve	At swimming beach on northern Crown Point next to wildlife refuge fence	32.7883	-117.2317
6	MB-080	Campland	At beach at Campland resort, just west of Rose Creek entrance	32.7950	-117.2217
7	MB-070	De Anza Cove	On north shore, between swim beach & 1st stormwater outlet, east of restrooms	32.7933	-117.2117
8	MB-060	Visitor's Center	On sandy shore near stormdrain outlet, south of Visitor's Center	32.7883	-117.2100
9	MB-050	Leisure Lagoon	Semi-enclosed sandy beach, northeast of Hilton Hotel	32.7850	-117.2083
10	MB-042	North Pacific Passage	To the west of Hilton Hotel, between stormdrain outlets, near launch area	nd	nd
11	MB-030	Tecolote Creek	West of the playground, next to the PWC area	32.7717	-117.2083
12	na	Hidden Anchorage	On east shore, near stormdrain outlet	nd	nd

[1] County of San Diego County Department of Environmental Health

[2] GPS coordinates are in decimal degree format (HDDD.DDDD) and NAD 83 datum

Figure 3. Map of Mission Bay showing investigation and sampling sites.

SAMPLING REGIME

To determine the extent to which visitor behavior, Park maintenance procedures, and wildlife distribution patterns are contributing to the bacterial contamination of Mission Bay, a comprehensive visual observation program was implemented. The visual observation monitoring was conducted in conjunction with samples taken at the observation areas and analyzed for indicator bacteria. Observations and sampling took place during three periods between mid-August and mid-October, 2002: low-use, medium-use, and high-use. Within each of these periods, the study included three days of observation. During each day of observation, samples were taken at each of the 12 sampling locations, three times per day. In addition, “spot sampling” was conducted at areas where bacterial influx to the Bay was expected (e.g., flowing storm drains).

Three shifts of six individual samplers per day covered the 12 stations. The first shift began just before sunrise and the last shift ended at sunset. Thus, the period of observation included all Park maintenance activities and the majority of visitor activities. Within a shift, each sampler monitored two adjacent sampling areas and completed two observation packets per site. Samplers made every effort to be discrete in their observations so as not to influence the behavior of Park visitors or maintenance crews.

VISUAL OBSERVATIONS

Field crews were dressed as park-goers to be as discrete as possible so as not to influence the behavior of Park visitors or maintenance crews. Each sampler was equipped with a camera to photograph any potential bacteria sources, bacterial sampling equipment, Visual Observation Field Data Forms to document their observations, and a cell phone to communicate with each other, the couriers, and the project task leader. All observations were recorded on the Visual Observation Field Data Forms. Visual observations were split into three categories: visitor behavior, Park maintenance procedures, and wildlife distribution patterns.

> Visitor behaviors being observed and documented included: approximate number of people involved in specific activities, including swimming and boating; illegal discharges into the storm drains, including illegal dumping of recreational vehicle sewage holding tanks; proper use of the recreational vehicle sewage holding tank pump-out stations, including runoff observations; failure of pet-owners to pick-up pet wastes; trash and food disposal behaviors; and number of homeless persons present.
>
> Park maintenance operations being observed and documented included: restroom cleaning and wash-down operations, including any associated runoff; sump pump-out operations at comfort stations, including any associated runoff; trash disposal methods; and landscape irrigation patterns (e.g., are sprinklers hitting trash cans and/or restrooms areas and generating runoff).
>
> Wildlife distribution patterns were observed and documented to include abundance and number of different species present, including birds, animals, and rodents; and wildlife activities.

Field crews made additional observations of any flowing or ponded water visible in storm drains and/or on surface areas. Observations will include water quality information such as color, clarity, odor, and floatables. In addition, any flowing or ponded water observed during the period of observation was sampled for bacterial analysis (sample details are discussed below).

BACTERIAL SAMPLING

Two types of samples for bacterial analyses were collected during the study: site samples and spot samples. Site samples were collected at each of the 12 pre-determined sites at the beginning of each shift (i.e., three times per day). Spot samples were taken from any other potential source of bacteria to the Bay observed during the observational study (e.g., flowing storm drains, runoff from restrooms during cleaning, ponded water in grass, etc.).

To assure consistency among results, the protocol for collection of the site samples was the same as that employed by the San Diego County of Environmental Health. Samples were collected in sterile, 100-ml plastic bottles containing sodium thiosulfate. The bottles were sealed in clear plastic bags until use. The sampling technician first rinsed his hands with a waterless sanitizing gel, then put on a pair of Nitrile gloves. The sample bottle was removed from the plastic bag, labeled, and placed into a clamp attached to the end of four foot long PVC pole. The sampling technician waded into the water to a depth of approximately 12 inches and removed the lid from the sample bottle. The bottle was extended in front of the sampler (away from shore) with the sampling pole, then inverted and submerged four to six inches below the water surface. In a sweeping motion, the pole was rotated so the opening of the bottle was facing to the side. The pole was then swept sideways to take the water sample. The bottle was filled once, drained to the desired volume so that a small amount of air remained in the container, and capped. No surface residue, sediment, or debris was allowed to enter the sample bottle. If debris or sediment was evident in the bottle, the sample was discarded and the site was re-sampled with a new, sterile bottle. After collection, the sample was re-sealed in the plastic bag.

Spot samples were collected using the same aseptic technique as employed for the site samples, but in most cases the sampling pole was not used. Couriers picked up the bacterial samples from the field and delivered them to the laboratory within the required holding time. All samples were kept on ice in the dark from the time of sample collection until delivery to the analytical laboratory.

LABORATORY ANALYSES

All bacteria samples were analyzed at the MEC Analytical Systems Microbiology Laboratory in Carlsbad, California or at Environmental Engineering Laboratories in San Diego, California. The three indicator bacteria enumerated in this study were total coliform, fecal coliform, and Enterococcus. In the laboratory, total and fecal coliforms were analyzed using multiple tube fermentation based on Standard Methods 9221B&E. *Enterococci* were analyzed using a chromogenic technique (Enterolert), based on Standard Method 9223.

RESULTS

MONITORING SCHEDULE

The visual observations study occurred on a total of 10 days between the end of August and mid-October, 2002 (Table 2). The field work was originally scheduled to be completed by the end of September, but the last sampling day originally scheduled for September 30 had to be postponed due to rain. It was re-scheduled on October 8. In addition, the sampling that occurred on September 8 had to be repeated because it took place less than 72 hours after a storm event. It was re-scheduled and completed on October 9. Although October 9 was in the middle of the week and considered a low-use day, it was considered an appropriate candidate to replace September 8 (a medium-use day) because the results indicated that there was no discernable difference in bacterial counts between low and high-use days. The results summarized in this report do not include the September 8 data.

Table 2. Visual Observation Monitoring Days, 2002.

Sampling Date	Day of Week	Sampling Category
August 25	Sunday	High Use
August 29	Thursday	Medium Use
August 31	Saturday	High Use
September 2	Monday	High Use
September 8 *	Sunday	Medium Use
September 13	Friday	Medium Use
September 18	Wednesday	Low Use
September 24	Tuesday	Low Use
October 8	Tuesday	Low Use
October 9	Wednesday	Low Use

* The sampling that occurred on September 8 occurred less than 72 hours after a storm event and was therefore repeated on October 9.

VISUAL OBSERVATIONS

Overview

A total of approximately 1,300 man-hours of visual observations were made during the nine days of the study (over 100 hours per site). The results of the observations suggested that numerical assessments would not be meaningful for some of the observations. For instance, rodents and wildlife other than birds were observed at only two sites throughout the study area and were not considered to be a meaningful source of bacterial contamination of Mission Bay. Similar results were found for other sections of the Field Data Forms, such as trash/food disposal, number of boats in the water, illicit boat discharge, and improper use of recreational vehicle pumpouts.

The homeless population was also assessed in the Field Data Forms. Prior to the investigation, the homeless population was considered to be a potential source of bacterial contamination in some areas of Mission Bay. Homeless individuals were found at several sites or associated drainages throughout the study area, including Site 1, (Bonita Cove), Site 2 (Bahia Point), Site 3 (Fanuel Park), Site 5 (Wildlife Refuge), Site 8 (Visitor's Center), Site 9 (Leisure Lagoon), and Site 11 (Tecolote Creek). However, in all cases, there was no evidence that these individuals were contributing fecal contamination to the Bay. In fact, at most sites, the homeless population appeared to be attracted to the area because of the public comfort stations (among other reasons). Although the potential for fecal contamination from the homeless population in and around Mission Bay remains a possibility, the results of the visual observations suggest that the potential is very low. One possible exception to that is Site 11 (Tecolote Creek). Several homeless people were observed living under the Interstate 5 bridge just upstream of the sampling point. Although there was no evidence of human feces in the area, the close proximity of these individuals to the sampling point increases the potential for elevated levels of indicator bacteria.

Three sections of the Field Data Forms lent themselves to a numerical assessment: number of birds, number of swimmers, and number of dogs on the beach. These data are summarized in Table 3, below. It is important to note that the values presented in Table 3 are the summed values of the six observations (two observations for each of three shifts) made per day for each of the categories. The values from each of the observations were derived from the midpoint of a range of values presented in the Field Data Forms. For instance, for the number of swimmers category, the Field Data Forms provided four choices: none, <10, 10-50, and other. If the 10-50 choice was circled, the middle value of that range (30) was used for tabulation. This value was added to the other 5 observations made on that day arrived at in the same manner to yield the values in Table 3. Using the mid-point of a range of values is not an accurate assessment of the actual number of individuals in each category, and in most cases here will tend to over-estimate the actual number. Thus, the values listed in Table 3 should be viewed in terms of relative abundance rather than actual number.

Although the data summarized in Table 3 does not represent actual numbers in each category, some interesting patterns are apparent. For instance, the mean relative abundance of birds at Site 12 (Hidden Anchorage; 78) is much lower than at any of the other sites. Bird abundance was also low at Site 3 (Fanuel Park; mean of 156) and Site 4 (Riviera Shores; mean of 182) on the northwestern end of Mission Bay. In contrast, the mean relative abundance at Site 5 (Wildlife Refuge; 732) was much higher than any of the other sites. This is to be expected because, although the sampling area for site 5 is south of the Wildlife Refuge (Figure 3), an estimate of bird abundance was made in the Wildlife Refuge. Relative bird abundance was also high at Site 1 (Bonita Cove; mean of 501), Site 6 (Campland; mean of 521) and Site 9 (Leisure Lagoon; mean of 559).

Table 3. Summary of major visual observations (birds, swimmers, and dogs on beach) by site and sampling date.

Beach Site	8/25/2002	8/29/2002	8/31/2002	9/2/2002	9/13/2002	9/18/2002	9/24/2002	10/8/2002	10/9/2002	Mean
Birds										
1 - Bonita Cove	455	400	495	420	305	520	785	460	665	501
2 - Bahia Point	155	260	330	280	130	230	240	245	290	240
3 - Fanuel Park	60	135	175	305	270	45	110	180	125	156
4 - Riviera Shores	345	130	135	275	190	105	75	270	115	182
5 Wildlife Preserve	730	790	885	940	795	695	465	725	565	732
6 - Campland	380	490	320	475	475	470	860	620	600	521
7 - De Anza Cove	450	425	315	500	430	445	480	390	480	435
8 - Visitor’s Center	330	510	360	250	400	615	775	515	555	479
9 - Leisure Lagoon	340	345	425	230	540	695	1030	655	775	559
10 - North Pacific Passage	155	125	135	165	255	300	365	425	320	249
11 - Tecolote Creek	285	435	490	335	205	760	470	175	280	382
12 - Hidden Anchorage	45	55	55	100	35	155	80	35	145	78
Swimmers										
1 - Bonita Cove	130	0	40	210	5	0	0	5	15	45
2 - Bahia Point	100	40	105	100	10	5	0	10	10	42
3 - Fanuel Park	15	0	45	120	25	0	0	0	30	26
4 - Riviera Shores	0	0	5	70	0	0	0	0	0	8
5 Wildlife Preserve	60	45	45	210	20	5	5	5	0	44
6 - Campland	65	95	185	95	45	5	20	0	0	57
7 - De Anza Cove	40	5	10	125	0	0	0	5	5	21
8 - Visitor’s Center	15	0	20	125	0	0	0	5	0	18
9 - Leisure Lagoon	155	70	155	270	20	40	20	15	5	83
10 - North Pacific Passage	15	20	70	100	5	10	0	0	0	24
11 - Tecolote Creek	40	10	125	125	0	5	0	0	0	34
12 - Hidden Anchorage	25	5	20	20	15	5	50	0	0	16
Dogs on beach										
1 - Bonita Cove	48	48	24	60	0	0	0	0	36	24
2 - Bahia Point	60	24	36	24	0	12	0	0	12	19
3 - Fanuel Park	24	12	48	85	36	36	36	60	48	43
4 - Riviera Shores	48	0	48	36	36	12	24	36	36	31
5 Wildlife Preserve	36	36	36	36	48	60	60	72	48	48
6 - Campland	48	48	97	48	48	48	24	36	36	48
7 - De Anza Cove	48	24	12	60	12	48	24	48	24	33
8 - Visitor’s Center	36	24	24	72	60	0	24	36	36	35
9 - Leisure Lagoon	48	60	36	48	48	60	60	24	48	48
10 - North Pacific Passage	60	60	36	36	48	48	48	24	48	45
11 - Tecolote Creek	48	24	24	72	24	36	36	12	0	31
12 - Hidden Anchorage	60	60	60	72	60	60	72	48	60	61

The relative number of people observed swimming in Mission Bay was lowest at Site 4 (Riviera Shores; mean of 8). The observations suggested that very few people used the beach area of Rivera Shores, although a substantial number of people were observed on the bike path and in boats offshore. The site with the greatest number of swimmers was Site 9 (Leisure Lagoon), with a mean relative abundance of 83. Site 6 (Campland) had the second greatest number of swimmers, followed by Site 1 (Bonita Cove), Site 5 (Wildlife Preserve), and Site 2 (Bahia Point). It is interesting to note that for all sites except Site 12 (Hidden Anchorage), the number of swimmers was greatest during the two days that coincided with the Labor Day weekend (August 31 and September 2). This was particularly dramatic at Site 4 (Riviera Shores) where people were observed swimming only over the Labor Day weekend. After Labor Day, the number of swimmers in Mission Bay decreased dramatically at all sites except Site 12 (Hidden Anchorage).

The number of dogs on the beach (Table 3) was greatest at Site 12 (Hidden Anchorage; relative mean of 61). This is to be expected since Hidden Anchorage is the only site among the 12 monitored where dogs are allowed to be off leash. Numerous observations were made throughout the study of dogs running loose on the beach at Hidden Anchorage on the west side of the cove. More pet waste was also observed on the beach more frequently at this site than any other in the study. The relative abundance of dogs on the beach was similar among the other 11 sites.

Several sections of the Field Data Forms incorporated areas of elevated potential bacterial contamination to the Bay. These included restroom irrigation, comfort station washdown, flowing storm drains, and washdown of boats and vehicles. Each of these potential sources was associated with spot samples taken during the observation period. The visual observations and associated bacterial levels associated with those sources are summarized by site in the Bacteriology section, below.

BACTERIOLOGY

Overview

Two kinds of bacterial samples were taken during the course of the study: 1) site samples, which were taken at the sampling site on the beach monitored by the Department of Environmental Health; and 2) spot samples, which were taken from a variety of areas within Mission Bay Park where surface or groundwater was evident (flowing storm drains, ponded water in grass, comfort station washdown, etc.). The results of the bacterial analyses for the site samples and spot samples are presented in the site-specific assessments, below. These data are summarized graphically in Figures 4, 5, and 6 for total coliforms, fecal coliforms, and Enterococcus, respectively, to illustrate the overall trends.

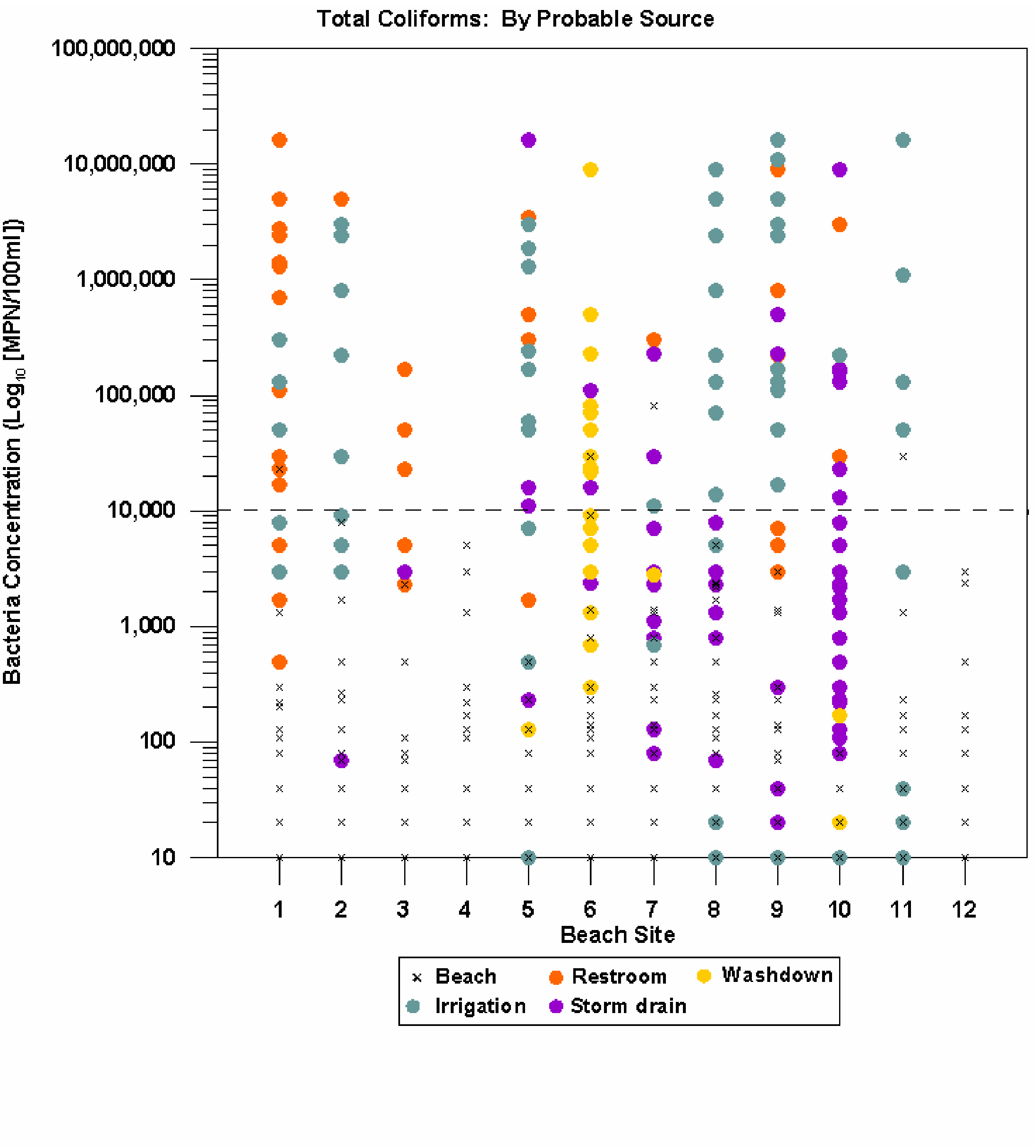


Figure 4. Plot of total coliform concentration by site and probable source. The dashed line represents the AB411 single sample criteria of 10,000 MPN/100 ml.

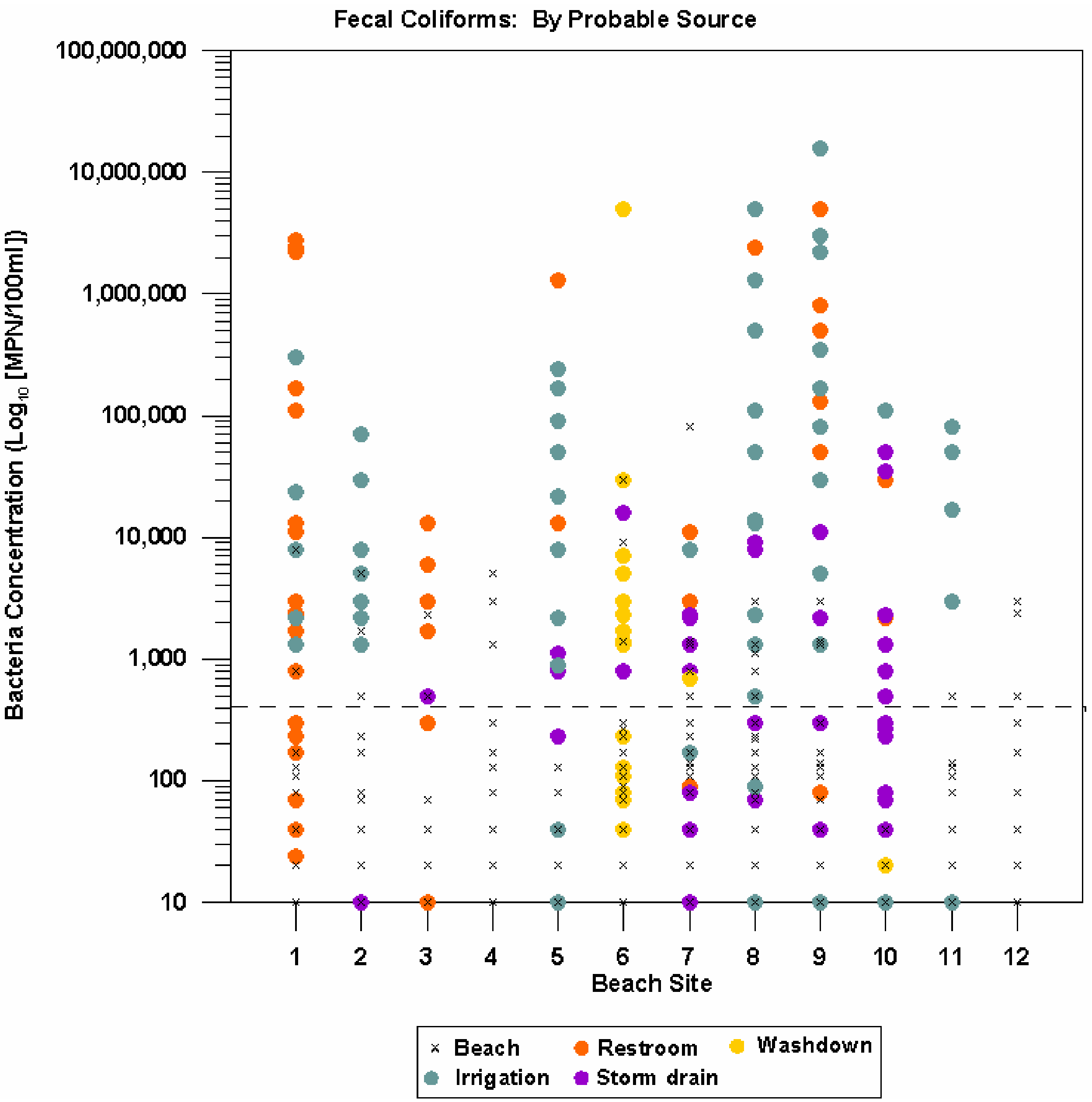


Figure 5. Plot of fecal coliform concentration by site and probable source. The dashed line represents the AB411 single sample criteria of 400 MPN/100 ml.

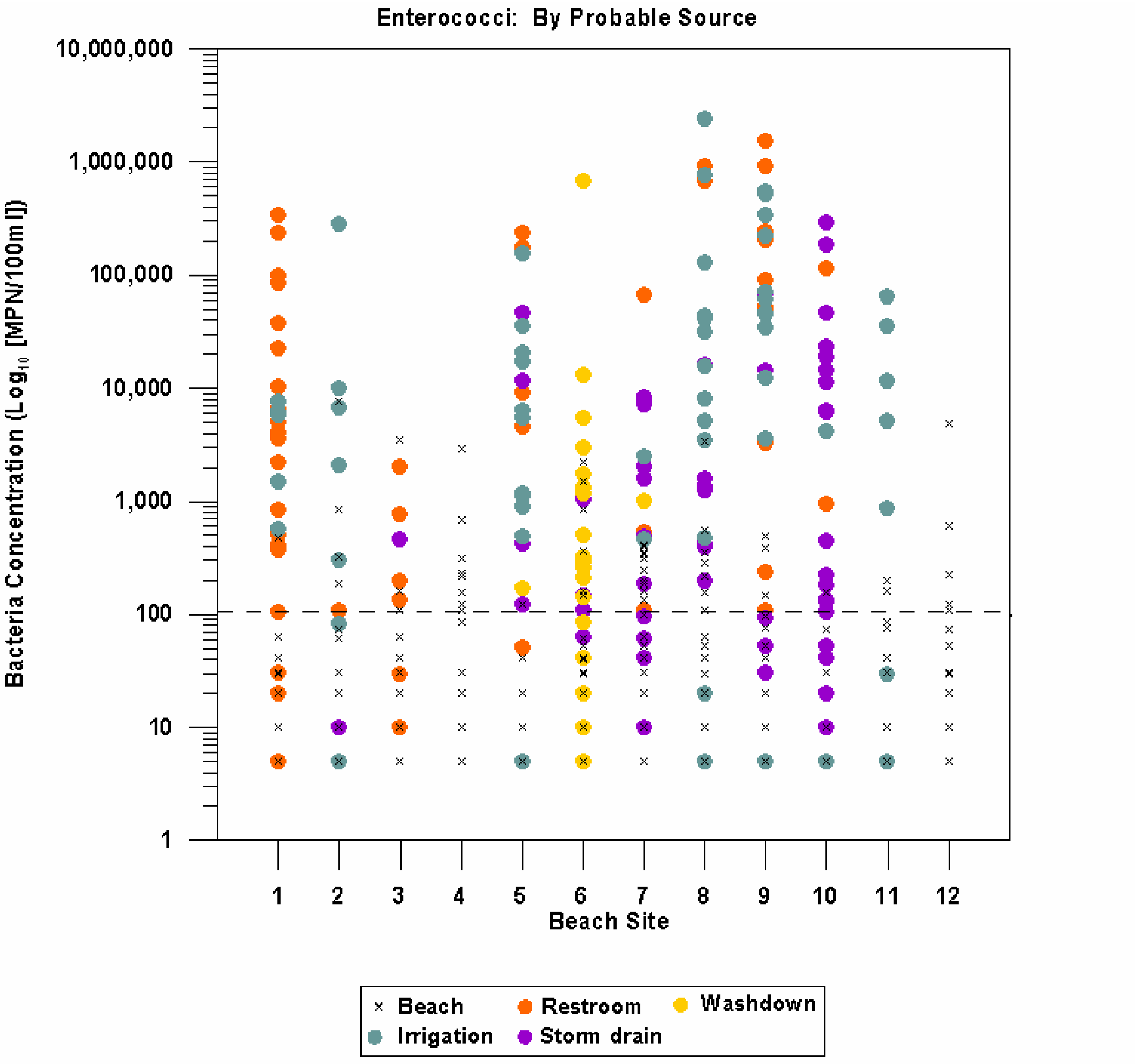


Figure 6. Plot of Enterococcus concentration by site and probable source. The dashed line represents the AB411 single sample criteria of 104 MPN/100 ml.

A total of 324 site samples and 198 spot samples were analyzed in the study. After all of the spot samples had been assessed, the data were categorized by the following probable sources: 1) irrigation; 2) comfort station washdown; 3) storm drain; and 4) boat or vehicle washdown. Figure 4 shows the results of the total coliform concentrations for the site samples and categorized spot samples by site. It is clear from Figure 4 that each of the 12 sites had a unique set of potential bacterial sources. For instance, most of the samples taken at Site 1 were from comfort station washdown, most samples at Site 10 were from flowing storm drains, and most samples from Site 6 were from boat washdown. The other sites had a mixture of potential sources. No spot samples were taken at Sites 4 and 12.

The dashed line in Figure 4 at 10,000 MPN/100 ml represents the AB411 criteria single sample limit for total coliform bacteria. The AB411 criterion for total coliforms is also exceeded if the fecal coliform concentration is greater than 10% of the total coliform concentration. Exceedances of this standard are highlighted for the site samples in Table 4 and for the spot samples in the site descriptions below. It is clear from Figure 4 that the majority of the spot samples exceeded the AB411 criteria for total coliforms. This is particularly true for samples taken from restroom washdown and irrigation. In contrast, most of the storm drain samples as well as the site samples were below the AB411 criteria.

The fecal coliform data are presented graphically in Figure 5. The site sample values are presented in Table 5. The dashed line at 400 MPN/100 ml in Figure 5 represents the AB411 criteria single sample limit for fecal coliform bacteria. The general pattern observed for total coliforms (Figure 4) is also evident for the fecal coliform levels. However, a larger proportion of the spot samples exceeded the AB411 criteria. The criterion was also exceeded in the site samples at least once for all sites except Sites 5 and 10.

The Enterococcus data are presented in Figure 6. The site sample values are presented in Table 6. The dashed line in Figure 6 at 104 MPN/100 ml represents the AB411 criteria single sample limit for Enterococci bacteria. Of the three indicators, Enterococcus exceeded the standard most frequently in this study in both spot samples and site samples. The AB411 criterion for Enterococcus was exceeded at least once at all 12 sites.

Table 4. Results of bacterial analysis of site samples for total coliform by site and date. Bacterial values are in MPN/100 ml. Values that exceeded AB411 criteria are highlighted in bold.

Beach Site	Shift	8/25/2002	8/29/2002	8/31/2002	9/2/2002	9/13/2002	9/18/2002	9/24/2002	10/8/2002	10/9/2002
1 - Bonita Cove	A	110	20	20	**23,000**	10	nd	**1,300**	199	220
	B	20	20	10	130	10	10	40	10	110
	C	40	10	20	300	80	20	80	10	130
2 - Bahia Point	A	20	20	10	230	130	80	270	20	**1,700**
	B	10	10	10	40	500	230	**8,000**	40	70
	C	10	10	20	20	20	10	500	20	10
3 - Fanuel Park	A	10	20	10	20	10	10	10	20	10
	B	20	40	10	10	10	80	**2,300**	500	10
	C	10	10	110	10	10	10	70	10	10
4 - Riviera Shores	A	10	10	10	20	20	20	10	40	40
	B	40	170	220	10	300	130	**3,000**	170	300
	C	20	**1,300**	**5,000**	10	40	10	10	110	10
5 - Wildlife Preserve	A	10	10	10	10	10	40	40	80	10
	B	10	40	10	20	20	10	230	10	500
	C	10	10	130	40	10	10	80	10	40
6 - Campland	A	40	10	20	130	230	80	800	170	110
	B	80	20	80	40	230	80	300	170	10
	C	230	170	10	10	110	140	**30,000**	**9,000**	**1,400**
7 - De Anza Cove	A	40	40	20	1,300	80	40	300	10	140
	B	230	500	10	20	300	230	20	**1,300**	**80,000**
	C	800	130	300	300	130	**1,300**	**1,400**	80	**1,300**
8 - Visitor's Center	A	170	2,200	230	500	**2,300**	10	10	230	80
	B	**1,700**	40	110	170	130	40	800	130	500
	C	170	10	20	500	10	260	500	**2,400**	**5,000**
9 - Leisure Lagoon	A	20	80	10	300	300	10	40	70	40
	B	10	140	10	40	10	**1,400**	20	10	10
	C	300	230	**3,000**	**1,300**	10	20	20	40	130
10 – North Pacific Passage	A	10	10	20	10	80	10	40	10	10
	B	10	10	10	40	10	10	10	10	10
	C	10	10	10	80	10	20	20	10	40
11 – Tecolote Creek	A	20	20	170	80	**1,300**	**30,000**	40	10	230
	B	20	20	10	10	10	1,300	40	10	10
	C	10	80	80	130	130	170	130	170	130
12 Hidden Anchorage	A	10	10	10	10	130	40	80	10	10
	B	10	10	10	40	10	40	40	**2,400**	500
	C	10	10	20	130	**3,000**	20	10	170	500

Table 5. Results of bacterial analysis of site samples for fecal coliform by site and date. Bacterial values are in MPN/100 ml. Values that exceeded AB411 criteria are highlighted in bold.

Beach Site	Shift	8/25/2002	8/29/2002	8/31/2002	9/2/2002	9/13/2002	9/18/2002	9/24/2002	10/8/2002	10/9/2002
1 - Bonita Cove	A	40	20	20	**8,000**	10	nd	**800**	170	170
	B	20	20	10	130	10	10	40	10	110
	C	40	10	20	40	40	10	80	10	130
2 - Bahia Point	A	20	20	10	230	80	40	170	20	**1,700**
	B	10	10	10	40	**500**	80	**5,000**	40	70
	C	10	10	20	20	20	10	500	20	10
3 - Fanuel Park	A	10	20	10	20	10	10	10	20	10
	B	20	40	10	10	10	10	**2,300**	**500**	10
	C	10	10	40	10	10	10	70	10	10
4 - Riviera Shores	A	10	10	10	20	10	20	10	40	40
	B	40	170	130	10	300	80	**3,000**	130	300
	C	20	**1,300**	**5,000**	10	40	10	10	40	10
5 -Wildlife Preserve	A	10	10	10	10	10	40	40	80	10
	B	10	20	10	20	10	10	40	10	130
	C	10	10	130	40	10	10	40	10	40
6 - Campland	A	40	10	20	130	230	80	270	170	110
	B	40	10	20	40	230	80	300	130	10
	C	130	110	10	10	70	90	**30,000**	**9,000**	**1,400**
7 - De Anza Cove	A	40	20	20	110	80	40	170	10	140
	B	80	**500**	10	10	300	230	20	**1,300**	**80,000**
	C	**800**	130	170	300	80	**800**	**1,400**	80	**1,300**
8 - Visitor's Center	A	170	300	230	**500**	**500**	10	10	130	80
	B	**1,100**	40	70	170	80	20	**800**	80	**500**
	C	110	10	20	300	10	220	**500**	**1,300**	**3,000**
9 - Leisure Lagoon	A	20	20	10	110	170	10	40	70	20
	B	10	140	10	40	10	**1,400**	20	10	10
	C	300	130	**3,000**	**1,300**	10	10	20	40	20
10 - North Pacific Passage	A	10	10	20	10	10	10	40	10	10
	B	10	10	10	10	10	10	10	10	10
	C	10	10	10	40	10	10	20	10	40
11 - Tecolote Creek	A	20	20	20	20	10	**500**	10	10	10
	B	20	20	10	10	10	110	20	10	10
	C	10	80	80	130	130	140	40	20	20
12 Hidden Anchorage	A	10	10	10	10	10	40	40	10	10
	B	10	10	10	20	10	40	40	**2,400**	300
	C	10	10	20	80	**3,000**	20	10	170	**500**

Table 6. Results of bacterial analysis of site samples for Enterococcus by site and date. Bacterial values are in MPN/100 ml. Values that exceeded AB411 criteria are highlighted in bold.

Beach Site	Shift	8/25/2002	8/29/2002	8/31/2002	9/2/2002	9/13/2002	9/18/2002	9/24/2002	10/8/2002	10/9/2002
1 - Bonita Cove	A	63	20	20	**471**	5	nd	5	31	10
	B	5	10	10	20	5	5	10	5	5
	C	5	5	41	30	5	5	20	20	41
2 - Bahia Point	A	5	74	10	73	5	20	31	62	**185**
	B	5	**7,701**	5	20	10	10	**860**	20	31
	C	5	31	5	5	10	5	**327**	5	10
3 - Fanuel Park	A	5	10	5	5	5	20	5	63	20
	B	5	5	10	5	5	**160**	**3,448**	5	**109**
	C	5	5	41	31	20	5	5	5	5
4 - Riviera Shores	A	10	5	5	20	10	20	**315**	20	85
	B	31	10	**216**	5	**231**	**158**	**122**	5	**110**
	C	5	**691**	**2,902**	5	10	5	5	5	5
5 - Wildlife Preserve	A	5	5	5	10	5	10	5	5	5
	B	10	**122**	5	5	5	5	20	5	41
	C	10	5	41	20	5	10	5	5	5
6 - Campland	A	30	5	5	52	10	20	**146**	31	20
	B	10	41	30	5	62	52	**364**	**161**	10
	C	10	20	5	20	40	30	**1,515**	**2,247**	**836**
7 - De Anza Cove	A	10	5	41	**414**	41	5	41	5	20
	B	31	**160**	5	**350**	**246**	31	10	98	**185**
	C	52	**199**	10	**399**	63	**134**	**315**	20	**341**
8 - Visitor's Center	A	**158**	**350**	20	**218**	**288**	5	5	5	41
	B	63	5	20	52	10	10	**110**	5	**548**
	C	41	5	5	63	5	10	52	30	**3,410**
9 - Leisure Lagoon	A	10	41	5	20	75	5	52	10	5
	B	5	52	5	5	10	10	5	5	5
	C	97	41	**384**	**496**	20	5	20	5	**146**
10 - North Pacific Passage	A	5	5	73	5	10	5	10	5	5
	B	5	5	74	10	10	5	5	5	5
	C	5	31	5	5	10	5	5	5	**155**
11 - Tecolote Creek	A	5	5	5	10	**199**	**161**	5	5	41
	B	5	10	5	5	10	10	5	5	5
	C	10	41	41	31	75	10	10	5	85
12 Hidden Anchorage	A	5	5	30	20	20	31	5	5	5
	B	5	5	5	73	5	10	5	**609**	**4,884**
	C	5	5	52	31	**226**	74	5	**109**	**122**

Site-Specific Assessments

The results of the visual observations study indicate that each of the 12 sites have a unique set of potential bacterial sources. Therefore, the results of the bacterial spot sampling and corresponding visual observations are summarized below by site.

Site 1 – Bonita Cove.

The spot sample data for Site 1 (Bonita Cove) are presented in Table 7. The majority of spot samples were taken from the washdown of comfort station 521 on the north end of the Cove and comfort station 1056 on the east side of the Cove. Several samples were also taken from ponded water in the grassy areas of Mission Bay Park resulting from irrigation. Nearly all of the samples taken from the comfort station washdown exceeded AB411 criteria for all three indicators. One exception to this appears to be the samples taken from the outdoor shower areas, where values were typically much lower. The comfort stations in Mission Bay were usually washed down with high pressure hoses in the early morning during the study period. At Bonita Cove, on almost all of the observation days, excess water was observed coming out of the restrooms and spilling onto the concrete pad. Pools of water were often observed where the concrete met the grassy area of the Park, even late in the afternoon hours after the wash down had occurred. French drains are present on the Bay side of Comfort Station 521 on the North end of Bonita Cove, but they appeared to be draining very slowly. The drains lead to a leach field that is approximately 20 m from the beach. The high levels of bacteria found in the ponded water resulting from daily cleaning of both restrooms on Bonita Cove represents a fairly large potential source of bacteria to the Bay. However, there was no evidence of a direct pathway on the surface of the grass from the comfort stations to the receiving waters.

High levels of all three indicator bacteria were also observed in samples of ponded water in the grassy areas of the Park (Table 7). In all cases, these samples were removed from any direct influence of the comfort station washing described above. During the visual observations, there were no obvious human fecal sources that could account for the high levels. However, fecal matter from bird waste is a possibility. Bonita Cove has a fairly large bird population, particularly on the eastern side of the Cove and birds were frequently observed in the grassy areas of the Park.

Other potential sources of bacteria in Bonita Cove include storm drains and the illicit discharge of sewage from boats that periodically anchor there. There are three storm drains that terminate in Bonita Cove. However, all three were submerged during the sampling period, even during the lowest tides, and could not be sampled. However, one sample was taken from ponded water on the street at Deal Court near the entrance to one of the storm drains. Levels of all three indicators were elevated (Table 7), suggesting that the source of water for the Bonita Cove storm drains needs to be further investigated. In Task 1 of this study, the illicit discharge of sewage from boats in Bonita Cove was investigated. Although the results suggested that there was no likely source of chronic discharge from this source, episodic discharge remains a potential source of bacteria on the beach at Bonita Cove.

Table 7. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 1 (Bonita Cove). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
29-Aug	0855	**3,000**	**1,300**	**7,701**	Irrigation flow in grass S. of CS 521	I
31-Aug	1350	**50,000**	**24,000**	**1,523**	Ponded water in grass at drinking fountain	I
18-Sep	0621	**130,000**	**2,200**	**5,794**	Ponded water in grass by trash can	I
18-Sep	0815	**5,000,000**	**8,000**	**10,220**	Ponded water in grass at drinking fountain	I
9-Oct	1540	**300,000**	**300,000**	**6,170**	Ponded water in grass at drinking fountain	I
9-Oct	1707	**8,000**	**8,000**	**565**	Ponded water in grass	I
25-Aug	0600	**1,400,000**	**170,000**	**6,500**	Runoff from washdown of CS 521	CS
25-Aug	1138	**23,000**	**13,000**	**4,960**	Runoff from washdown of CS 521	CS
29-Aug	1119	**2,800,000**	**2,800,000**	**98,700**	Runoff from washdown of CS 521	CS
29-Aug	1445	**5,000**	**3,000**	**379**	Runoff from washdown of CS 1056	CS
29-Aug	1501	3,000	300	31	Runoff from washdown of CS 521	CS
31-Aug	1118	**110,000**	230	**379**	Runoff from washdown of CS 521	CS
31-Aug	1334	**17,000**	**2,400**	**4,106**	Runoff from washdown of CS 1056	CS
2-Sep	0720	**300,000**	**300,000**	**22,470**	Runoff from washdown of CS 1056	CS
18-Sep	0621	**1,700**	**800**	**408**	Runoff from washdown of CS 1056	CS
18-Sep	0650	**300,000**	**110,000**	**235,900**	Runoff from washdown of CS 1056	CS
18-Sep	0650	**300,000**	**3,000**	5	Ponded water on beach in front of restroom	CS
18-Sep	1109	**300,000**	**1,700**	5	Ponded water in shower of CS 1056	CS
13-Sep	0800	**30,000**	**8,000**	**2,254**	Runoff from washdown of CS 1056	CS
13-Sep	1105	**30,000**	40	20	Ponded water in shower of CS 1056	CS
13-Sep	1327	500	70	104	Runoff from washdown of CS 1056	CS

Date	Time	TC	FC	ENT	Location	Type[1]
24-Sep	0730	**700,000**	**110,000**	**38,100**	Runoff from washdown of CS 521	CS
8-Oct	0710	**16,000,000**	**2,200,000**	**344,800**	Runoff from washdown of CS 1056	CS
8-Oct	0840	**2,400,000**	24	**3,654**	Runoff from washdown of CS 521	CS
8-Oct	1606	3,000	170	**512**	Ponded water in shower of CS 521	CS
9-Oct	0715	**16,000,000**	**2,200,000**	**344,800**	Runoff from washdown of CS 521	CS
9-Oct	1106	**5,000,000**	**2,400,000**	**86,500**	Ponded water in restroom, CS 1056	CS
9-Oct	1106	**1,300,000**	**11,000**	**842**	Ponded water in shower of CS 1056	CS
9-Oct	1542	**130,000**	300	31	Ponded water in shower of CS 521	CS
24-Sep	1053	**130,000**	**1,700**	**3,410**	Ponded water at Deal Ct. at SD	SD

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 2 – Bahia Point

A total of ten spot samples were taken at Bahia Point during the sampling period (Table 8). Seven of these were from suspected irrigation sources. Those from ponded water in the grass were generally higher than those taken from the parking lots. The one sample that was taken from the storm drain had very high levels of all three indicators. The drainage area for the storm drains at Bahia Point are all small, mostly draining the parking lots and a small area of grass above the beach. Thus, bacterial levels in the storm drains are directly related to those from irrigation.

Several observers noted excessive water from the wash down of Comfort Station 10086 at Bahia Point. However, only one sample was taken. Total coliform levels were very high in this sample, possibly reflecting the large amounts of sand and debris on the restroom floor, but levels of fecal coliforms and Enterococci were low. There is no grass buffer strip between the comfort station and the water at Bahia Point. Any bacteria washed out of the restroom drains directly to the sand beach and is therefore a potential source of bacteria to the Bay.

Aside from irrigation and comfort station wash down, other potential sources of bacteria at Bahia Point include illicit discharge from moored boats and the storm drains that discharge to Santa Barbara Cove. As with Bonita Cove, there was no evidence of a chronic source of bacteria from the boats moored in Santa Barbara Cove during the boat mooring study. However, there are approximately 25 boats moored on the south end of Santa Barbara Cove and approximately 50 more docked at the Mission Bay Yacht Club on the north end. Episodic discharge of sewage from these boats remains a potential source of bacteria at Bahia Point.

Table 8. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 2 (Bahia Point). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
18-Sep	0748	**3,000,000**	**70,000**	**2,070**	Ponded water in grass	I
18-Sep	0748	**800,000**	**2,200**	**6,820**	Irrigation flow in grass	I
18-Sep	0748	**220,000**	**1,300**	**10,140**	Ponded water in grass	I
25-Aug	1418	**3,000**	**3,000**	84	Ponded water at N. end of Hotel lot	I
29-Aug	1213	**30,000**	**30,000**	5	Ponded water in NW lot	I
31-Aug	1218	**9,000**	**3,000**	5	Ponded water at NE lot	I
9-Oct	1204	**5,000**	**5,000**	**307**	Ponded water on beach near entrance	I
8-Oct	1502	70	10	10	Ponded water in street near SD outlet	I
8-Oct	0720	**5,000,000**	10	**108**	Runoff from washdown of CS 834	CS
18-Sep	0841	**2,400,000**	**8,000**	**285,100**	Flow from storm drain near CS 10086	SD

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 3 – Fanuel Park

A total of seven spot samples were taken at Fanuel Park on the northwest end of Mission Bay (Figure 2); six from washdown of Comfort Station 9950 and one from a flowing storm drain (Table 9). The comfort station at Fanuel is positioned with restrooms on either side of an outdoor shower and rinse area. The outdoor shower area has two drains where the concrete pad meets the grass on the east and west side of the comfort station. During wash down of the restrooms, excess water would be flushed towards the drains and pool over them. Pooled water was observed over the drains during all the observation days. All six comfort station samples were taken from the pooled water over the drains. Most of these had elevated levels of all three bacterial indicators. Because the pooled water over the restroom drains sits at the edge of the grass at Fanuel Park, there is a potential for bacterial contamination from restroom washdown at this site via groundwater transport.

The other potential source of bacteria at Fanuel Park is the discharge of water via the Fanuel Street storm drain. Flow in the storm drain could be seen from the storm drain entrance on the street and it appeared to be flowing during all nine observation days during all shifts at a rate of approximately 2-5 gallons per minute. One sample was taken from this storm drain with an extended sampling rod. Levels of all three indicator bacteria from this sample exceeded AB411 criteria (Table 9). The suspected source of the chronic flow in the Fanuel Street storm drain is dewatering of underground parking structures in the area. Several apartment buildings and condominiums at the north end of Sail Bay are known to discharge groundwater to Mission Bay during de-watering operations. There is an interceptor station at the end of Fanuel Street that is designed to divert water from the Fanuel Street storm drain to the sewer system. However, water from unknown sources could be heard downstream (i.e., on the Bay side) of the diversion unit, which suggests that it may be discharged to the Bay. In addition, evidence of de-watering was apparent from condominiums along Pacific Beach Drive during the visual observations. The water appeared to be flowing to Mission Bay through a storm drain on Everts Street, just west of Fanuel Park. This discharge of groundwater to Mission Bay in the Fanuel Park area represents a potential source of bacterial contamination. The extent of the de-watering operations, locations of the discharge, and bacterial levels of the groundwater need to be further investigated to assess the potential impacts to water quality in the area.

Table 9. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 3 (Fanuel Park). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
31-Aug	0830	5,000	10	30	Runoff from washdown of CS 9950	CS
2-Sep	0715	**3,000**	**1,700**	10	Runoff from washdown of CS 9950	CS
2-Sep	0715	2,300	300	**199**	Runoff from washdown of CS 9950	CS
13-Sep	0645	**170,000**	**3,000**	**2,014**	Runoff from washdown of CS 9950	CS
24-Sep	1500	**23,000**	**13,000**	**134**	Ponded water in shower at CS 9950	CS
8-Oct	nd	**50,000**	**6,000**	**766**	Runoff from washdown of CS 9950	CS
29-Aug	0800	**3,000**	**500**	**459**	Flow from inlet to Fanuel Street SD	SD

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 4 – Riviera Shores

During the visual observations, no spot samples were taken at Riviera Shores. This reflects the lack of potential bacterial sources observed in this part of Mission Bay. There are no comfort stations at this site, no flowing storm drains, no irrigation, and no grassy park areas for the accumulation of water. Pets were never observed off leash at Riviera Shores and there was no pet waste observed on the beach. In addition, Rivera Shores, along with Fanuel Park and Hidden Anchorage, had the lowest relative number of birds of any of the sites (Table 3). However, the lack of obvious bacterial sources at Riviera Shores are confounded by the high number of bacterial exceedances from the site samples. The AB411 criteria were exceeded in site samples three times for total and fecal coliforms (Tables 4 and 5) and seven times for Enterococcus (Table 6) during the course of the study. The number of exceedances in site samples for Enterococcus at Riviera Shores was second only to De Anza Cove.

The high number of bacterial exceedances at Riviera Shores site samples is difficult to explain. Further investigations on the storm drain system and de-watering operations in the area should be pursued to better understand this problem. Contamination from sources outside of the area (e.g., transport of bacteria via currents from Fanuel Park) is also a possibility.

Site 5 – Wildlife Refuge

A total of 18 spot samples were taken at Site 5 (Wildlife Refuge; Table 10). Most of these (12) were samples of the irrigation water in the grassy park area west of the sampling site. Two of these samples had very low levels of indicator bacteria. Both were taken directly from the sprinkler head before the water hit the ground. The remainder of the irrigation samples were taken from ponded water in the grass and parking lot just upstream of the sampling site and from the flowing storm drain. There is only one storm drain at this site and it terminates on the beach where the samples for enforcement of the AB411 criteria are taken by the County. All of the samples from the grass, adjacent parking lots, and the storm drain had high levels of indicator bacteria suggesting that irrigation water that is transported to the beach via the storm drain at Site 5 is a potential source of bacterial contamination at Mission Bay.

In addition to the irrigation samples taken at the Wildlife Refuge, four spot sample were taken from the washdown of Comfort Station 522 (Table 10). Three of the four had high levels of all three bacterial indicators, suggesting that the runoff from comfort station wash down is a potential source of bacteria at this site via groundwater transport. However, that potential is likely small because the comfort station is far from the beach at this site (> 100 m).

The low bacterial levels observed from the Park sprinklers at the Wildlife Refuge and the high levels observed in the grass, adjacent lots, and terminus of the storm drain suggests that irrigation water transports bacteria generated in the Park area of this site to the beach. However, site samples taken at the Wildlife Refuge were generally low (Table 6). During the nine days of visual observations, AB411 criteria were exceeded in the site samples only once (Enterococcus of 122 MPN/100 ml on August 29, Shift B). The terminus of the storm drain in located high on the beach close to the park area at this site. In addition, the slope of the beach is very low, so that there is often a large distance between the end of the storm drain and the water's edge, particularly at low tide. That distance may account for the low number of exceedances observed in the site samples at the Wildlife Refuge.

Table 10. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 5 (Wildlife Refuge). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
13-Sep	0705	**7,000**	**900**	**5,475**	Irrigation flow at lot before SD	I
13-Sep	0705	**50,000**	**2,200**	**155,300**	Irrigation flow at lot before SD	I
13-Sep	0705	**1,300,000**	**90,000**	**20,640**	Irrigation flow at lot before SD	I
13-Sep	1404	**16,000,000**	**1,300,000**	**238,200**	Ponded water in grass at barbecue pit	I
8-Oct	0730	10	10	5	Flow from sprinkler	I
8-Oct	0730	**60,000**	40	**1,178**	Ponded water in grass around sprinkler	I
8-Oct	0730	**500**	10	**495**	Irrigation flow dripping off dumpster	I
8-Oct	0730	**1,880,000**	**50,000**	**1,119**	Irrigation flow in gutter before SD	I
9-Oct	0726	**3,000,000**	**170,000**	**886**	Irrigation flow at parking lot gutter	I
9-Oct	0726	10	10	5	Flow from sprinkler	I
9-Oct	0850	**1,300,000**	**8,000**	**6,450**	Flow at storm drain from irrigation	I
9-Oct	1108	**170,000**	**22,000**	**17,250**	Ponded water in grass at barbecue pit	I
25-Aug	0702	**3,500,000**	**170,000**	**177,200**	Runoff from washdown of CS 522	CS
29-Aug	0700	1,700	10	51	Runoff from washdown of CS 522	CS
13-Sep	0705	**300,000**	**13,000**	**4,611**	Runoff from washdown of CS 522	CS
18-Sep	0710	**500,000**	**50,000**	**9,090**	Runoff from washdown of CS 522	CS
13-Sep	0920	230	**230**	**11,620**	Ponded water inside SD	SD
13-Sep	0920	**16,000,000**	**50,000**	**47,300**	Ponded water at beach in front of SD	SD
24-Sep	1139	**11,000**	**1,100**	**122**	Flow from SD	SD
8-Oct	1226	**16,000**	**800**	**422**	Flow from SD	SD
8-Oct	0730	**240,000**	**240,000**	**35,400**	Flow from SD from irrigation	SD
18-Sep	1430	130	40	**173**	Washdown from hydroboats	W

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 6 – Campland

A total of 23 spot samples were taken at Site 6 (Campland; Table 11). The majority of these were runoff from the wash down of boats and vehicles near the boat ramp on the west end of the Campland property (Figure 3). The wash down area is approximately 25 m from the edge of the water at the boat ramp. Runoff from the wash down of boats and vehicles is conveyed to the Bay through a surface gutter and an underground drain pipe. The wash down area was used extensively by Campland guests during the visual observation period. Bacterial levels in runoff generated from the wash down were extremely variable; Enterococcus levels in these samples ranged from 10 MPN/100 ml to 686,700 MPN/100 ml. However, AB411 criteria were exceeded frequently. Due to the elevated bacterial levels, high frequency of use, and close proximity to the site sample location, the boat wash down area at Campland represents a potential source of bacteria to Mission Bay that needs to be further investigated.

Several other samples were taken from a drainage area located between the jetty that forms the west end of Campland and the wetland of the Wildlife Refuge. At the mouth of the drainage area is a diversion box where two large storm drains (approximately 72 inch diameter) terminate. One of the storm drains had a tide flex on it at the time of sampling, but the other did not. The storm drains drain the residential neighborhood to the north and west of Campland. To investigate the potential for this system to impact the beach at Campland, samples were taken from the drainage ditch upstream of the catch basin, in and around the catch basin, and from the creek that channels the drainage to the Bay (Table 11). Of these, the sample taken in the drainage ditch had the highest bacterial levels (Enterococcus of 1,047 MPN/100 ml), but the other samples were relatively low. These results and the long distance between this drainage and the Campland sampling point suggest that the drainage area is not a likely source of elevated bacterial levels observed at Campland.

The sewage infrastructure at Campland is designed to accommodate hundreds of RVs. Each individual RV site has its own sewage clean out area in addition to two large dump stations located on the northwest side of the property. There are also several public restrooms on the site. Waste from all of these facilities is conveyed to the City sewer system. Two spot samples were taken from Dump Station F (Table 11). The sample taken after the dump station had been used had high bacterial levels (Enterococcus of 5,475 MPN/100 ml) as would be expected. However, the dump station is located several hundred meters from the county sampling point on the beach and it is unlikely that bacteria from this area is transported to the Bay. One restroom is located close to the sampling point. However, the visual observations suggest that it was very well maintained and was an unlikely source of bacteria to Mission Bay.

Bacterial levels from the site samples taken at Campland were below AB411 criteria for all three indicators during the study from August 25 through September 18 (Tables 4, 5, and 6). However, from September 24 through October 9, levels of all three indicators exceeded criteria in at least one sample per day. One possible explanation for these results is the increase in birds and associated fecal matter. The relative number of birds at Campland increased from 470 on September 18 to 860 On September 24 (Table 3) and remained high through October 9. At about the same time, the relative number of swimmers on the beach decreased dramatically. These results suggest that fecal matter from birds should be investigated as a potential source of bacteria at Campland.

Table 11. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 6 (Campland). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
24-Sep	1355	**500,000**	**30,000**	**259**	Ponded water @ Dump station F	CS
24-Sep	1634	**70,000**	**7,000**	**5,475**	Ponded water @ Dump station F after use	CS
8-Oct	1135	**50,000**	**16,000**	**148**	Mouth of diversion box W. of Campland	SD
8-Oct	1135	**16,000**	**800**	**110**	Ponded water -catch basin W. of Campland	SD
8-Oct	1135	2,400	110	63	Inside Creek West of Campland	SD
8-Oct	1135	**110,000**	**5,000**	**1,047**	Across Pacific Beach Dr in drainage ditch	SD
25-Aug	1117	700	230	20	"Fresh water" dump from RV	W
25-Aug	1603	300	80	5	Drain on west side of boat ramp	W
29-Aug	1100	**80,000**	**5,000**	**2,987**	Drain on west side of boat ramp	W
29-Aug	1300	**3,000**	**1,300**	**211**	Runoff from boat rinse area	W
29-Aug	1706	**23,000**	**2,300**	**1,334**	Runoff from boat rinse area	W
29-Aug	1800	1,300	70	nd	Runoff from boat rinse area	W
31-Aug	0750	**9,000**	**3,000**	10	Runoff from boat rinse area	W
31-Aug	0750	**24,000**	**3,000**	86	Runoff from boat rinse area	W
31-Aug	1120	**50,000**	230	**1,166**	Runoff from boat rinse area	W
31-Aug	1120	7,000	110	**295**	Runoff from boat rinse area	W
31-Aug	nd	**30,000**	**5,000**	**12,997**	Runoff from boat rinse area	W
2-Sep	0920	**9,000,000**	**5,000,000**	**686,700**	Runoff from boat rinse area	W
2-Sep	1620	5,000	40	**512**	Runoff from boat rinse area	W
18-Sep	0800	**230,000**	**1,700**	41	Runoff from boat rinse area	W
18-Sep	1327	**23,000**	**1,400**	**1,726**	Runoff from boat rinse area	W
18-Sep	1327	**22,000**	**1,700**	**142**	Drain on west side of boat ramp	W
8-Oct	1135	5,000	130	**321**	Drain on west side of boat ramp	W

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 7 – De Anza Cove

A total of 17 spot samples were taken at De Anza Cove, located on the northeast end of Mission Bay (Table 12). The majority of these (12) were taken from flowing storm drains. There are seven storm drains that terminate in De Anza Cove. The site samples and samples taken by the County are taken in front of the largest of these (approximately 60 inch diameter), which terminates approximately in the center of the north shore of the Cove (Figure 3). Dry weather flow from this storm drain is diverted approximately 100 m upstream of the discharge terminus and there was no flow observed from this storm drain during any of the nine days of visual observations. The second storm drain is located at the western end of De Anza Cove. It is undiverted and drains the parking lots on the west side of the Cove as well as parts of the Harbor Resort. Four spot samples were taken from this storm drain and surrounding Bay water. Bacterial levels were variable. Enterococcus levels ranged from 41 MPN/100 ml to over 7,000 MPN/100 ml. On August 29, one sample was taken from the flowing storm drain and another from Bay water directly in front of the discharge point. Bacterial levels in the storm drain were high (Enterococcus of 7,701 MPN/100 ml), but levels in the Bay water sample were very low.

Two storm drains terminate close together just south of the sampling point in the northeast corner of De Anza Cove (Figure 3). Both are diverted. The first (one south of the sampling point) drains a small area near the I-5 freeway on ramp. Four samples were taken from this storm drain and three of them had bacteria levels below or slightly above AB411 criteria (Table 12). However, one sample taken on August 25 had a fecal coliform concentration of 2,300 MPN/100 ml and an Enterococcus concentration of 2,046 MPN/100 ml. The second storm drain south of the sampling point also contained levels of indicator bacteria that exceeded AB411 criteria. The third storm drain south of the sampling point terminates on the east side of De Anza Cove, just north of the pump station. It is undiverted and drains a small area on the east side of Interstate 5. Two samples were taken from this storm drain (August 25 and August 31) and both had high levels of indicator bacteria. The sample taken on August 25 had an Enterococcus concentration of over 8,000 MPN/100 ml. No samples were taken from the other two storm drains that terminate in De Anza Cove.

The fact that storm drains that are part of the diversion system have flowing water during the dry season, suggests that the diversion system may not be completely effective in preventing dry weather flow from entering De Anza Cove. Flow from most of these storm drains discussed above was fairly low. However, the high bacterial concentrations found in some of them suggest that they may be a source of elevated bacterial levels in De Anza Cove. An investigation of the source of the water for each of the storm drains and an evaluation of the effectiveness of the diversion system would help determine the impact that storm drain flow has on water quality in the area.

In addition to samples from flowing storm drains, five samples were taken from ponded water in the grass or on the sidewalk as a result of irrigation in De Anza Cove (Table 12). Bacterial levels exceeded AB411 criteria in all of the samples and in one case reached extremely high levels (October 9 Enterococcus concentration of 67,600). None of the sites sampled were close to any obvious source of human fecal contamination. Bacteria in the park area of De Anza Cove represents a potential source to Mission Bay. Although no direct surface transport of water from the park to the Bay was observed, eroded banks near the site sampling point suggest that surface transport does take place. Bacteria may also be transported to Mission Bay via groundwater.

The potential for bacterial contamination from other sources examined during the visual observations (comfort station wash down, pet waste etc.) appeared to be low at this site.

Table 12. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 7 (De Anza Cove). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
2-Sep	0840	**3,000**	**3,000**	**536**	Ponded water in grass E. of CS 10087	I
24-Sep	1705	700	170	**465**	Ponded water in grass W. of sampling point	I
9-Oct	0800	**11,000**	**8,000**	**2,495**	Ponded water on walkway NE of CS 10087	I
24-Sep	0824	3,000	90	**108**	Ponded water in grass W. of pump station	I
9-Oct	0800	**300,000**	**11,000**	**67,600**	Ponded water in grass NE of CS 10087	I
18-Sep	1225	**1,100**	**800**	**185**	Ponded water in SD 1 S. of sampling point	SD
25-Aug	0800	**7,000**	**2,300**	**2,046**	Flow from SD one S. of sampling point	SD
25-Aug	0812	**2,300**	**2,300**	**8,390**	Flow from SD three S. of sampling point	SD
29-Aug	1745	**30,000**	**2,200**	**7,701**	Flow from SD at NW end of Cove	SD
29-Aug	1745	130	10	10	Bay water at SD at NW end of Cove	SD
31-Aug	8000	800	**800**	**1,597**	Flow from SD three S. of sampling point	SD
2-Sep	1110	**230,000**	**2,300**	**7,230**	Flow from SD at NW end of Cove	SD
24-Sep	1641	80	40	41	Flow from SD at NW end of Cove	SD
24-Sep	1650	80	10	61	Flow from SD one S. of sampling point	SD
24-Sep	1700	80	80	96	Flow from SD one S. of sampling point	SD
8-Oct	nd	**3,000**	**1,300**	**495**	Flow from SD two S. of sampling point	SD
9-Oct	1730	**2,800**	**700**	**1,017**	Flow from SD two S. of sampling point	SD

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 8 – Visitor's Center

A total of 24 spot samples were taken at Visitor's Center (Table 13) during the visual observations. The majority of these were taken from ponded water in the grass or parking lot as a result of irrigation. Ponded water was common in the park area of Visitor's Center throughout the study period. As with irrigation samples taken at other sites, the bacterial levels in these samples were variable. Enterococcus levels ranged from 5 MPN/100 ml to over 2 million MPN/100 ml. Bacteria in the park area of Visitor's Center may be conveyed to the Bay through surface runoff or possibly groundwater transport. The County sampling point and the site sampling point for this study is located in front of two large (approximately 60 inch diameter) storm drains at Visitor's Center. Severely eroded banks adjacent to this point observed during this study suggest that surface water from the park is transported to the Bay and may be a source of elevated bacterial levels. Groundwater transport of bacteria from the Park to the Bay also remains a possible pathway.

In addition to samples taken in the park at Visitor's Center, seven samples were taken from one of two storm drains located at the County sampling point (Table 13). The northern most storm drain was flowing at a rate of approximately 5 gallons per minute throughout the entire study period. Bacterial levels in samples taken from this storm drain were all above AB411 criteria. Since the county monitoring site at Visitor's Center is located directly in front of this storm drain, discharge from it is a likely source of bacterial exceedances of AB411 criteria.

Flow from Cudahy Creek on the south end of the Visitor's Center site was also consistent throughout the study period. One sample was taken from this area and the values were above AB411 criteria. However, the impact on water quality at the sampling point from Cudahy Creek discharge needs to be investigated further. The potential for bacterial contamination from other sources examined during the visual observations (RV dump station, comfort station wash down, pet waste etc.) appeared to be low at this site.

Table 13. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 8 (Visitor's Center). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
2-Sep	0930	**2,400,000**	**2,400,000**	**686,700**	Ponded water in grass S. of CS 1091	I
2-Sep	0930	**2,400,000**	**1,300,000**	**920,800**	Ponded water in grass S. of CS 1091	I
24-Sep	0752	**14,000**	**1,300**	**5,172**	Ponded water in grass near disposal area	I
24-Sep	0915	**800,000**	**500,000**	**770,100**	Ponded water in grass south of CS 1091	I
24-Sep	0915	**130,000**	**2,300**	**31,800**	Ponded water in parking lot	I
24-Sep	0915	**2,400,000**	**1,300,000**	**44,100**	Ponded water in grass near SD	I
24-Sep	0915	**2,400,000**	**50,000**	**15,850**	Ponded water in grass near SD	I
24-Sep	0915	**5,000,000**	**5,000,000**	**2,419,600**	Ponded water in parking lot	I
24-Sep	0915	**9,000,000**	**1,300,000**	**130,500**	Ponded water in grass near SD	I
8-Oct	0925	10	10	5	Ponded water in grass near RV pumpout	I
8-Oct	0715	5,000	**500**	**479**	Ponded water in grass N. of Cudahy Creek	I
8-Oct	0925	**14,000**	90	20	Irrigation flow entering SD NE of CS 1091	I
9-Oct	0725	**70,000**	**13,000**	**3,448**	Irrigation flow entering SD	I
9-Oct	0725	20	10	5	Ponded water in grass	I
9-Oct	0725	**130,000**	**14,000**	**41,060**	Irrigation flow entering SD at RV pumpout	I
9-Oct	1105	**220,000**	**110,000**	**8,230**	Ponded water in grass near storm drain	I
24-Sep	1750	70	70	**199**	Flow from SD at sampling point	SD
25-Aug	0650	**8,000**	**8,000**	**1,616**	Flow from SD at sampling point	SD
25-Aug	0830	800	300	**1,236**	Flow from SD at sampling point	SD
25-Aug	1740	**3,000**	**500**	**1,376**	Flow from SD at sampling point	SD

Date	Time	TC	FC	ENT	Location	Type[1]
29-Aug	1945	**2,400,000**	**9,000**	**16,310**	Flow from SD at sampling point	SD
2-Sep	0950	**1,300**	**500**	**201**	Flow from SD at sampling point	SD
18-Sep	1410	**3,000**	**1,300**	**402**	Flow from SD at sampling point	SD
9-Oct	1645	**2,300**	**1,300**	**422**	Flow from Cudahy Creek	SD

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 9 – Leisure Lagoon

A total of 28 spot samples were taken at Leisure Lagoon (Table 14). Fifteen of these were from suspected irrigation sources. Over-watering appears to be a potential problem at Leisure Lagoon. During nearly all of the nine days of this study, excessive water was observed in the park area during the morning watering, particularly at the south end of the Lagoon near Comfort Station 1093. There was also evidence of erosion and sheet transport of irrigation water in this area. Similar to Site 5 (Wildlife Refuge), water exiting the sprinkler head appeared to be very low in bacteria. However, bacterial levels in all of the samples taken from the grass and parking lot areas of the site exceeded AB411 criteria. Compared to other sites, surface runoff at Leisure Lagoon may be a more important pathway for the conveyance of bacteria from the park to the Bay. Groundwater transport also remains a possibility.

Runoff from the cleaning of the comfort stations is also an important potential source of bacterial contamination at Leisure Lagoon. Numerous observations were made of maintenance crews sweeping water from the restrooms during cleaning directly to the concrete pad outside. The water would typically pool at the edge of the grass. Bacteria levels in all of the samples taken from these areas exceeded AB411 criteria (Table 14). One sample taken on September 2 had an Enterococcus level of over 1.5 million. Runoff from comfort station wash down is thus a potential source of bacteria in Mission Bay at Leisure Lagoon.

Two storm drains terminate on the east side of Leisure Lagoon: one at the north end of the sampling area by Comfort Station 1092 and one approximately 200 m south of there. The County sampling point is at the southern-most storm drain. Flow from this storm drain had bacterial levels that ranged from 52 MPN/100 ml to 68,670 MPN/100 ml (Tale 14). However, samples taken from the northern storm drain had low bacteria levels. The sources and flow characteristics of both storm drains need to be further investigated to determine the potential impacts on water quality at this site.

Table 14. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 9 (Leisure Lagoon). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
13-Sep	0605	10	10	5	Flow from sprinkler	I
13-Sep	0605	**110,000**	**30,000**	**12,460**	Ponded water in grass at S. end of Lagoon	I
13-Sep	0605	**130,000**	**5,000**	**70,800**	Irrigation flow at lot at S. end of Lagoon	I
18-Sep	0645	**17,000**	**5,000**	**3,654**	Ponded water in grass at W. end of Lagoon	I
18-Sep	0645	**16,000,000**	**16,000,000**	**344,800**	Ponded water in grass at W. end of Lagoon	I
18-Sep	0645	**170,000**	**170,000**	**61,310**	Irrigation flow from W. parking lot before SD	I
18-Sep	1620	**3,000,000**	**3,000,000**	**224,700**	Ponded water in grass at W. end of Lagoon	I
24-Sep	0615	**5,000**	**1,300**	**110**	Ponded water in grass N. of CS 1093	I
24-Sep	0630	**5,000,000**	**2,200,000**	**46,200**	Ponded water in lot next to dumpster	I
24-Sep	1135	**16,000,000**	**16,000,000**	**547,500**	Ponded water in grass on W. side of lagoon	I
8-Oct	0720	**50,000**	**1,300**	**34,500**	Ponded water in lot next to dumpster	I
8-Oct	0720	**2,400,000**	**350,000**	**45,700**	Ponded water in grass	I
8-Oct	0720	**11,000,000**	**80,000**	**517,200**	Irrigation flow on S. side of Lagoon at table	I
9-Oct	0720	**220,000**	**50,000**	**48,700**	Irrigation flow on S. side of Lagoon at table	I
9-Oct	0745	**800,000**	**500,000**	**34,360**	Ponded water in grass south of CS 1092	I
25-Aug	0629	**7,000**	**5,000**	**3,255**	Runoff from washdown of CS 1092	CS
31-Aug	0723	3,000	80	**242**	Runoff from washdown of CS 1093	CS
2-Sep	0930	**16,000,000**	**5,000,000**	**1,553,100**	Ponded water near CS 1092	CS
13-Sep	0645	**2,400,000**	**50,000**	**920,800**	Ponded water in grass at N. end of Lagoon	CS
24-Sep	0630	**800,000**	**800,000**	**248,900**	Ponded water in grass just W. of CS 1093	CS
24-Sep	0615	**5,000,000**	**30,000**	**52,800**	Runoff from washdown of CS 1092	CS
24-Sep	1020	**9,000,000**	**800,000**	**205,100**	Ponded water in grass N. of CS 1093	CS
9-Oct	0720	**230,000**	**130,000**	**91,100**	Runoff from washdown of CS 1093	CS
25-Aug	0629	**500,000**	**11,000**	**14,390**	Flow from SD at sampling point	SD
25-Aug	1615	40	40	94	Flow from SD at N. end of Lagoon	SD
29-Aug	0610	**230,000**	**2,200**	**68,670**	Flow from SD at sampling point	SD
8-Oct	1605	300	300	52	Flow from SD at sampling point	SD
8-Oct	1630	20	10	31	Flow from SD at N. end of lagoon	SD

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 10 – North Pacific Passage

A total of 29 spot samples were taken at Site 10 (North Pacific Passage; Table 15). The majority of these were taken from three pipes (designated north, middle, and south) that discharge under the Hilton Hotel boat dock. These pipes were discharging a slow but steady flow of water consistently throughout the study. Bacterial levels in samples taken from these pipes were extremely variable (Enterococcus levels ranged from 5 to almost 300,000 MPN/100 ml). In most cases, the northern pipe had the highest bacterial levels. Although the flow from these pipes was low, the high bacterial levels associated with them and the close proximity to the sampling point suggest that they should be further investigated to determine the source and possible abatement actions. Two additional storm drains terminate at North Pacific Passage: one directly in front of the Hilton Hotel and one south of the hotel. The one in front of the Hilton is the designated County sampling point. Only a few spot samples were taken from these storm drains because they are typically inundated during all but the lowest tides. Bacterial levels were moderate from the storm drain in front of the Hilton (Enterococcus levels of 223 and 446 MPN/100 ml), but high from the storm drain south of the hotel (Enterococcus of 14,390 MPN/100 ml).

In addition to storm drain samples, several samples of irrigation water were taken at North Pacific Passage (Table 15). As with other sites, bacterial levels in the sprinkler flow were very low. However, samples of ponded water in the grass and in the gutters flowing toward storm drains had high levels of all three indicators. There was little evidence of erosion at North pacific Passage, suggesting that sheet flow of water from the Park to the Bay is unlikely. However, groundwater transport of this bacteria remains a possibility. The potential for bacterial contamination from other sources examined during the visual observations (comfort station wash down, pet waste etc.) appeared to be low at this site.

Bacterial levels in site samples at North Pacific Passage exceeded AB411 criteria only once during the study (Table 6).

Table 15. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 10 (North Pacific Passage). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
13-Sep	0920	**220,000**	**110,000**	**4,200**	Irrigation flow to SD at N. lot	I
9-Oct	0815	10	10	5	Sprinkler flow N. of CS 1094	I
9-Oct	0815	**30,000**	**2,200**	**957**	Ponded water in grass E. of CS 1094	I
9-Oct	0815	**170,000**	230	**46,110**	Flow from gutter on M. Bay Dr. E before SD	I
9-Oct	0815	**3,000,000**	**30,000**	**116,900**	Ponded water in grass N. of CS 1094	I
25-Aug	0720	**130,000**	**35,000**	**14,390**	Flow from storm drain S. of sampling point	SD
25-Aug	1715	**3,000**	**1,300**	**6,370**	Hilton Hotel boat dock - N. pipe	SD
25-Aug	1758	2,200	40	**106**	Hilton Hotel boat dock - S. pipe	SD
25-Aug	1810	**1,300**	**800**	**446**	Flow from SD at sampling point	SD
29-Aug	0707	8,000	20	**6,131**	Hilton Hotel boat dock – pooled water	SD
29-Aug	1750	**9,000,000**	**50,000**	**186,000**	Hilton Hotel boat dock – pooled water	SD
29-Aug	1210	8,000	80	**290,900**	Hilton Hotel boat dock – N. pipe	SD
29-Aug	1750	**13,000**	300	**11,190**	Hilton Hotel boat dock – N. pipe	SD
29-Aug	1750	2,200	70	5	Hilton Hotel boat dock – mid. pipe	SD
31-Aug	0815	**160,000**	40	20	Hilton Hotel boat dock - N. pipe	SD
2-Sep	0705	300	10	41	Hilton Hotel boat dock - mid. pipe	SD
2-Sep	0707	**2,300**	**2,300**	5	Hilton Hotel boat dock - N. pipe	SD
2-Sep	0709	80	10	5	Hilton Hotel boat dock - S. pipe	SD
13-Sep	0730	5,000	**500**	183	Hilton Hotel boat dock - gray pipe	SD
13-Sep	0740	**23,000**	**500**	**19,180**	Hilton Hotel boat dock - N. pipe	SD
13-Sep	0740	230	20	5	Hilton Hotel boat dock - S. pipe	SD
18-Sep	0745	3,000	20	**23,590**	Hilton Hotel boat dock - N. pipe	SD
18-Sep	0745	800	**500**	10	Hilton Hotel boat dock - mid. pipe	SD
18-Sep	1020	2,300	20	**134**	Hilton Hotel boat dock - pooled water	SD
24-Sep	1700	3,000	270	**223**	Flow from SD at sampling point	SD
8-Oct	0740	1,700	20	5	Hilton Hotel boat dock - mid. pipe	SD
8-Oct	0740	2,200	10	5	Hilton Hotel boat dock - S. pipe	SD
29-Aug	0935	20	20	5	RV washdown in lot between sites 9&10	W
29-Aug	1415	170	10	5	Hilton Hotel boat dock - jetski washdown	W

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 11 – Tecolote Creek

A total of eight spot samples were taken at Teoclote Creek (Table 16). All of them were from suspected irrigation sources. As with other sites, bacteria levels in samples taken directly from the sprinklers were very low, but samples of ponded water in the grass and parking lots were high (Enterococcus concentrations ranged from 882 65,000 MPN/100 ml). There was no evidence of bank erosion at this site, so surface flow of irrigation water in the Park to the Bay appears unlikely. However, groundwater transport remains a potential conveyance.

The only other potential source noted during the visual observations at this site was Tecolote Creek. Homeless people were observed frequently under the Interstate 5 bridge, at the mouth of Tecolote Creek. Because the county sampling point for this site is located just downstream of that area, fecal contamination from the homeless population is more likely here than at other sites in the study. The potential for bacterial contamination from other sources examined during the visual observations (comfort station wash down, pet waste etc.) appeared to be low at this site.

Table 16. Results of bacterial analyses of spot samples for total coliform (TC), fecal coliform (FC), and Enterococcus (ENT) at Site 11 (Tecolote Creek). Bacterial values are in MPN/100 ml. Values that exceeded AB 411 criteria are highlighted in bold.

Date	Time	TC	FC	ENT	Location	Type[1]
25-Aug	0922	**3,000**	**3,000**	**882**	Ponded water in grass near sprinkler	I
25-Aug	1401	10	10	5	Flow from sprinkler	I
13-Sep	1630	40	10	30	Flow from broken sprinkler head	I
18-Sep	0834	**50,000**	**50,000**	**11,640**	Ponded water in lot	I
24-Sep	0716	**1,100,000**	**80,000**	**5,200**	Ponded water at playground picnic table	I
24-Sep	0716	**130,000**	**17,000**	**65,000**	Ponded water at trash can S. of playground	I
8-Oct	0900	20	10	5	Flow from sprinkler	I
31-Aug	0900	**16,000,000**	**3,000**	**35,900**	Ponded water in grass south of CS 1094	I

[1] Type: I = Irrigation, CS = Comfort Station, SD = storm drain, W = washdown

Site 12 – Hidden Anchorage

There were no spot samples taken at Hidden Anchorage because this site has very few potential sources of bacteria. Hidden Anchorage has no comfort stations, irrigation, or grassy park areas. The bird population is also low relative to the other sites in the study (Table 3). However, Hidden Anchorage is unique among the sites because it is the only site where dogs are allowed to run leash free. Numerous observations were made of dogs and dog waste on the beach at Hidden Anchorage, particularly on the west side of the Cove.

The dog waste on the beach is likely the largest potential source of bacteria at this site. During high tides, the waste may be washed into the water column resulting in elevated bacterial levels in the area. Removing the pet waste or eliminating its deposition would help in reducing high bacterial counts at this site.

CONCLUSIONS

It is clear from the results of the visual observations that each of the 12 sites examined in this study has a unique set of characteristics related to potential bacterial sources. These characteristics are summarized by site in Table 17.

Table 17. Summary of potential bacterial sources in Mission Bay by site.

Site No.	Site Name	Birds	Storm drains	Groundwater	Irrigation	Boat Discharge	Creek Drainage	Restroom Washdown	Homeless	Pet Waste	Boat Cleaning	RV Pumpouts
1	**Bonita Cove**	**X**	**X**	**X**	**X**	**X**		**X**				
2	**Bahia Point**	**X**	**X**	**X**	**X**	**X**		**X**				
3	**Fanuel Park**	**X**	**X**	**X**				**X**				
4	**Riviera Shores**	**X**	**X**	**X**								
5	**Wildlife Refuge**	**X**	**X**	**X**	**X**			**X**				
6	**Camp land**	**X**		**X**			**X**				**X**	
7	**De Anza Cove**	**X**	**X**	**X**	**X**	**X**						
8	**Visitor's Center**	**X**	**X**	**X**	**X**		**X**					
9	**Leisure Lagoon**	**X**	**X**	**X**	**X**			**X**				
10	**N. Pacific Passage**	**X**	**X**	**X**	**X**							
11	**Tecolote Creek**	**X**		**X**	**X**		**X**		**X**			
12	**Hidden Anchorage**	**X**		**X**						**X**		

RECOMMENDATIONS

A list of recommendations based on the results of the visual observations study is presented below.

- Investigate the potential for groundwater contamination through de-watering at Fanuel Park and Riviera Shores.
- Contact the City's Real Estate Division (or appropriate group) regarding boat and car washdown areas at Campland and investigate the causes of the elevated bacteria levels in this area.
- Develop a program to reduce the potential for bacterial contamination from birds at Campland. Possible actions include: remove the swim platform in front of the swimming beach during low use periods; encourage Campland residents and guests to stop feeding the birds; and remove the bird waste from the intertidal area of the Campland beach.
- Install a tide flex on the storm drain terminus between the Wildlife Refuge and Campland.
- Investigate the source of the water discharged from the Visitor's Center storm drain and remediate where possible.
- Contact the City's Real Estate Division (or appropriate group) about the four PVC pipes that are contributing bacteria to the Bay at the Hilton Hotel boat dock and investigate the source(s) of the drainage to these pipes as appropriate.
- Investigate the extent of the homeless population and potential for fecal contamination at suspected sites, particularly Tecolote Creek.
- Investigate the possibility of additional trash cans, signs, and bags etc. at Hidden Anchorage to reduce bacterial loading from pet waste.

- Remove the chain link fence at Hidden Anchorage on Fiesta Island to help reduce the number of dogs (and dog waste) in the area.

- Contact the appropriate City Division about the irrigation procedures in Mission Bay Park and determine the appropriate procedures that could help reduce irrigation flow to the Bay.

- Contact the appropriate City Division regarding the washdown of the Mission Bay Park comfort stations and possible procedures to reduce runoff from the restrooms during cleaning.

- Consider re-examining the potential discharge from boats at Bonita Cove, Santa Barbara Cove, and De Anza Cove during a high use weekend, such as Memorial Day, 2003.

- Where possible, determine the drainage area of all storm drains in Mission Bay where high bacterial levels in storm drains were measured or suspected (Sites 1, 2, 3, 4, 7, 8, 9, 10,and 11) and assess the effectiveness of the interceptor system in these areas.

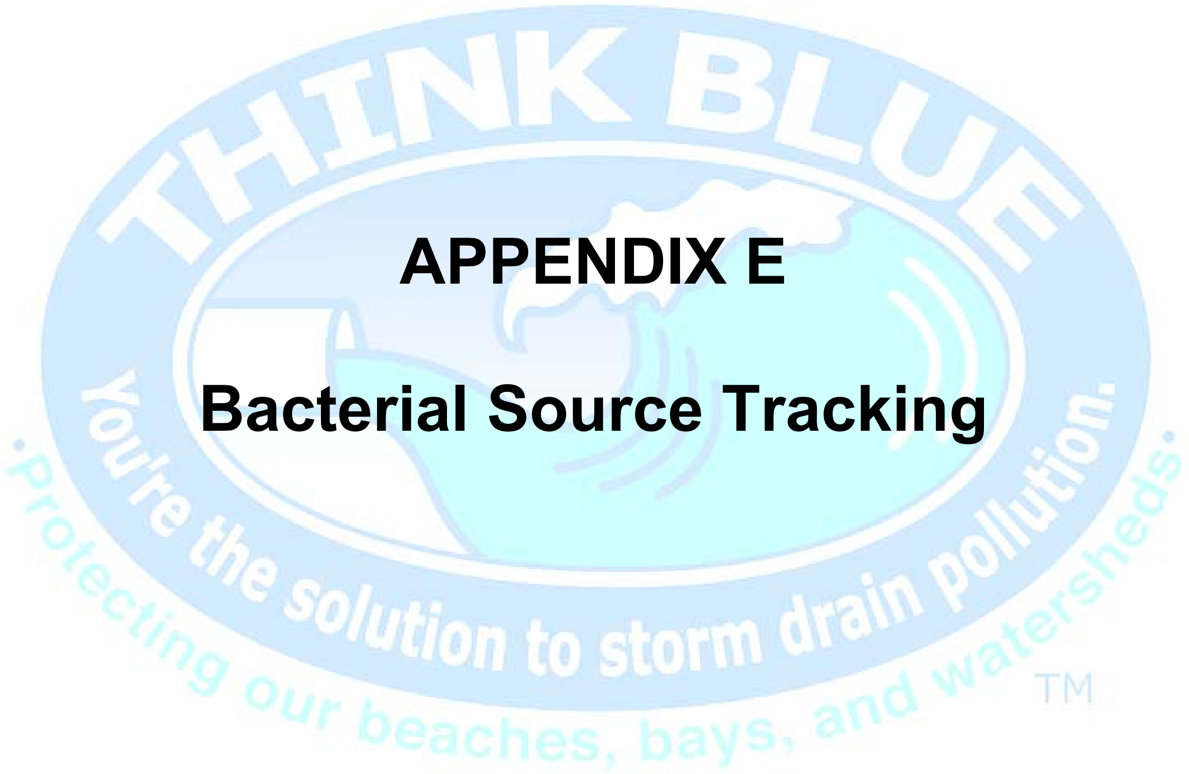
- Develop a process to communicate ALL diversion system status changes promptly to the City Storm Water Pollution Prevent Program. Currently, two different groups manage the diversion systems; the Streets Division and the MWWD Department. Both groups need to accurately and promptly provide information to the City Storm Water Pollution Prevention Program.

For all of the recommendations listed, it will be important to fully document what remedial actions have taken place in regards to the specific problem and when the action was initiated. In addition, a monitoring plan will need to be put in place after remedial actions have been initiated to verify that the appropriate actions are being continued.

Progress on the tasks will be discussed at the bi-weekly meeting between the City and MEC.

APPENDIX E

Bacterial Source Tracking



Interim Report for

Mission Bay Clean Beaches Initiative
Bacterial Source Identification Study (Phase II)

Microbial Source Tracking

Prepared For:

State Water Resources Control Board
1001 I Street
Sacramento, California 95814

THE CITY OF SAN DIEGO · STATE OF CALIFORNIA
SEMPER VIGILANS

MEC
ANALYTICAL SYSTEMS

WESTON
SOLUTIONS

Interim Report for

Mission Bay Clean Beaches Initiative Bacterial Source Identification Study (Phase II)

Microbial Source Tracking

Prepared For:
State Water Resources Control Board

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June 30, 2004

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INTRODUCTION

Project Overview

The Mission Bay Bacterial Source Identification Study was designed to identify sources of bacterial contamination in Mission Bay and recommend appropriate actions and activities to eliminate the input of those sources to the Bay receiving waters. The study is being conducted in two phases. The first phase was completed at the end of June, 2003.

Three major questions emerged from Phase I that were identified for assessment in Phase II to understand the nature and sources of bacteria in Mission Bay:

1) What is the origin (human, avian, etc.) of high bacterial levels measured in Phase I?
2) How much bacteria is transported from the grass surface of Mission Bay Park to the Bay via groundwater?
3) Is sediment in Mission Bay serving as an on-going source of bacteria in the water column through resuspension?

Three investigative tasks were identified in Phase II to complete this project. In the scope of the overall project, these tasks have been designated Investigative Tasks 4, 5, and 6:

Investigative Task 4. Identify the origins of bacteria using microbial source tracking (MST) techniques;

Investigative Task 5. Investigate the transportation mechanisms of bacteria from the surface of Mission Bay Park to the Bay receiving waters (i.e., fate and transport study);

Investigative Task 6. Investigate bacteria levels in sediments at the Bay's major depositional areas.

This report summarizes Task 4, the microbial source tracking investigation.

Historical Background

In Phase I of this study, high bacterial levels were measured from samples originating from numerous sources. In some cases, the host origin (human, avian, etc.) of the bacteria was fairly obvious and easily remediated (e.g., bacteria found in restroom washdown originate from humans). However, in the majority of cases, the origin of bacteria was unknown. Flowing storm drains, for example, can convey bacteria from human, avian, and other wildlife sources. In addition, most of the 12 sites studied had several potential sources. Identifying the origin of bacteria to a waterbody is a critical component in understanding the contaminant problem and, ultimately, in remediating that problem. In recent years, microbial source tracking methods have been developed for discriminating between human and non-human sources of fecal contamination. These methods have proven to be powerful tools for tracking bacterial sources and have been used successfully for studies (e.g., TMDLs) where common bacterial indicators (total coliform, fecal coliform, and enterococcus) have provided limited results. One recent study used an MST technique and other source tracking tools to assess the origins of bacteria in Avalon Bay on Catalina Island (Boehm et al. 2003). MST was critical in identifying and eventually remediating a leaking sewage line that was one of several bacterial sources in the local watershed. In this study, we used two separate molecular typing techniques to identify the host origin of the bacteria in Mission Bay.

Study Objectives

This study had two primary objectives: 1) determine the host origin of bacteria in the Mission Bay receiving waters; and 2) identify potential sources or pathways (e.g., storm drains, groundwater, irrigation, etc.) that may contribute to elevated bacterial levels in the Bay. The study employed two molecular biology techniques to address these objectives:

1) **Host-Specific PCR** – The polymerase chain reaction (PCR) technique takes advantage of host-specific genetic differences in the 16S rRNA gene of the anaerobic bacteria, *Bacteroides*, a major bacterial resident present in feces (Bernhard and Field 2000a, Bernhard and Field 2000b). The HS-PCR assay provides a rapid first step in tracking bacterial host origin and allows us to determine the presence or absence of human fecal contamination in a particular water sample.
2) **Ribotyping** – Ribotyping analysis relies on a comparison of the DNA fingerprint within *Escherichia coli* isolates derived from the waterbody in question (i.e., Mission Bay receiving waters) to a library database of DNA fingerprints derived from known or confirmed host animal fecal specimens (Field et al. 2003). The results of the Ribotyping assessment allow us to determine the host origin (human, avian, canine, etc.) of the bacteria in the receiving waters as well as the suspected conduit or reservoir from which the bacteria were derived (e.g., storm drains, sediments, organic debris, etc.).

MATERIALS AND METHODS

Site Locations

The following sites were assessed in the MST Task (Figure 1): Bonita Cove (Site 1), Fanuel Park (Site 3), Wildlife Refuge (Site 5), Campland (Site 6), De Anza Cove (Site 7), Visitor's Center (Site 8), and Leisure Lagoon (Site 9).

Sampling Protocol

The sampling protocol was designed to maximize spatial and temporal coverage within the constraints of the study. Maximal spatial coverage was achieved by sampling several stations at each site. Samples were taken from the receiving waters at stations centered around the San Diego County Department of Environmental Health (DEH) AB411 monitoring location and extending approximately 500 feet on either side, as indicated by the red hatching in Figure 1. For the PCR analyses, four to five stations were sampled at each site and the samples were analyzed individually. For the Ribotyping analyses, ten stations were sampled at each site and the samples were composited in the MEC Microbiology laboratory. Sampling and laboratory techniques are discussed in detail below.

Temporal coverage was maximized by sampling each site several times throughout each designated time period (dry weather or wet weather). Within a season, each site was sampled four to five times except Bonita Cove. The results of Phase I indicated that bacterial densities at Bonita Cove were greater during summer weekend days compared to weekdays. To investigate this observation, Bonita Cove was sampled on six summer holiday days and 5 non-holiday weekdays.

Because the results of Phase I indicated distinct site-specific differences relative to bacterial sources, the sampling protocol for each site was unique. The protocol for each site is summarized in Table 1.

Figure 1. Map of Mission Bay showing investigation and sampling sites for the Microbial Source Tracking Task.

Table 1. Microbial Source Tracking study design by site. For this study, Dry Weather was from July 1 to November 10, 2003 and Wet Weather was from November 11, 2003 to April 7, 2004.

Site	Season	Technique	Water Type
Bonita Cove (Site 1)	Dry Weather (Holiday and non-Holiday)	HS-PCR Ribotyping	Receiving Water Storm Drains Groundwater
Fanuel Park (Site 3)	Dry Weather	HS-PCR Ribotyping	Receiving Water Storm Drains
Wildlife Refuge (Site 5)	Dry Weather	HS-PCR	Receiving Water Groundwater
Campland (Site 6)	Dry Weather	HS-PCR Ribotyping	Receiving Water
	Wet Weather	HS-PCR Ribotyping	Receiving Water
De Anza Cove (Site 7)	Dry Weather	HS-PCR Ribotyping	Receiving Water Storm Drains Groundwater
	Wet Weather	HS-PCR Ribotyping	Receiving Water Storm Drains Groundwater
Visitor's Center (Site 8)	**Wet Weather**	PCR Ribotyping	Receiving Water Storm Drains Groundwater Spring Cudahy Creek
Leisure Lagoon (Site 9)	Dry Weather	PCR Ribotyping	Receiving Water Storm Drains Groundwater

The sampling locations for each of the sites are identified in Figure 1.

Receiving Water Sampling. To assure consistency among results, we used the same sampling protocols as the DEH. Samples were collected in sterile, plastic bottles (100-ml volume for Ribotyping samples and 250-ml volume for PCR samples). At each station, the sampler first rinsed his hands with a sterilizing ethanol gel then put on a pair of Nitrile gloves. Using sterile technique, the sample bottle was secured inside a clamp attached to the end of a four foot long PVC pole. The sampler waded into the water to a depth of about 12 to 18 inches (ankle to knee depth). The opened bottle was submerged open-end down to a depth of 4 to 6 inches below the water's surface. Then the bottle was turned face-up and allowed to fill. The bottle was filled, drained to the desired volume so that a small amount of air remained in the container, and capped. No surface residue, sediment, or debris was allowed to enter the sample bottle. If debris or sediment was evident in the bottle, the sample was discarded and the site was re-sampled with a new, sterile bottle. Each field sample was labeled (using indelible ink) and identified with the project title, appropriate identification number, the date and time of sample collection, and preservation method. All samples were kept on ice in the dark from the time of sample collection until delivery to the analytical laboratory.

Host Specific PCR. Samples collected for HS-PCR analysis were initially processed at the MEC laboratory according to the published protocol established in the contracted laboratory of Dr. Katharine Field at Oregon State University (Bernhard and Field, 2000a). Briefly, samples were concentrated onto Supor200 0.2 µM filters (Pall Life Sciences). For each collection date, filtration negative controls were included. Filters were stored at – 80º C in Guanidine isothiocyanate (GITC) buffer (5M GITC, 100mM EDTA, pH 8.0, 0.5% Sarkosyl). Preserved filters were shipped to the contracted laboratory on dry ice. The contracted laboratory then extracted DNA from the filters with a Qiagen 96-well DNeasy kit. All reagents and buffers were made according to quality control protocols described in Dr. Field's laboratory SOPs, which include making reagents in a separate laboratory in order to avoid contamination. Extraction negative controls were processed at the same time filters were extracted.

Extracted DNAs were analyzed by polymerase chain reaction (PCR) according to published protocols (Bernhard and Field, 2000b; Bernhard et al., 2003) using three primer sets that amplify targets from the Bacteroidetes group of fecal bacteria. These included a general primer set that assays for the presence of fecal contamination from any source (GB marker), and two human-specific primer sets that assay specifically for the presence of human fecal contamination (HF134 and HF183 markers). PCR reactions were set up in UV-treated PCR hoods in a separate laboratory according to quality control protocols described in Dr. Field's laboratory SOPs. Extraction, filtration, and PCR negative controls and the appropriate positive controls were included on each 96-well amplification assay plate.

PCR products were separated by electrophoresis in 96-well agarose gels containing ethidium bromide, utilizing a Ready-To-Run Separation Unit (Amersham Biosciences, San Francisco, CA), and photographed with a UVP gel documentation unit under ultraviolet irradiation. Gel electrophoresis and documentation took place in another separate laboratory, in order to avoid contamination by amplification products.

Sensitivity of the general marker is approximately 10 copies per reaction, which is somewhat more sensitive than the standard assay for *E. coli*. Sensitivity of the two human markers is approximately 10 to 100 copies per reaction, which would be approximately equal to the sensitivity of the standard assay for *E. co*li. If either of both of the two human markers amplified, a sample was scored as positive for the presence of human fecal contamination.

Source Animal Feces Collection. The contracted laboratory for Ribotype analysis at the Institute for Environmental Health maintains a Source Ribotype Library Database that consists of >110,000 Ribotypes characterized from *E. coli* isolates derived from known animal fecal specimens collected from hundreds of watersheds throughout North America. For the purpose of generating local Ribotype Library entries, it was necessary to collect fecal samples from suspected host animals from the Mission Bay watershed. MEC field technicians aseptically collected fresh animal fecal samples over the course of the study in and around the Mission Bay Park and watershed only from positively identified sources. No more than five samples were collected from members of the same animal species from a given location, and only a single sample was collected from an individual animal. Additionally, raw sewage grabs from manhole lifts and primary effluent samples from Point Loma wastewater treatment plant were obtained in lieu of individual human fecal samples. All sample containers were labeled with the following information: sample type, host species, sample date and time, sample location, and sampler's initials. Samples were transported to the MEC Microbiology Laboratory on wet or blue ice in the dark. All sample information was subsequently logged into a field log. Fecal samples were refrigerated (< 48hours) until they were shipped on blue ice to the contracted laboratory at the Institute for Environmental Health.

***E. coli* Isolates**. Isolates from fecal specimens were obtained at the Institute for Environmental Health. Once fecal specimens arrived at the contracted laboratory, samples were plated on MacConkey agar and were allowed to incubate at 35º C overnight in a conventional air incubator. The next day, 3-5 lactose fermenting, non-mucoid colonies were picked and replated on MacConkey agar for purification. A single, well-isolated non-mucoid colony was then plated on Trypticase Soy Agar and allowed to grow overnight at 35º C. Each culture was then tested by Spot Indol testing using the appropriate positive and negative controls. Indol positive cultures were then tested for their ability to utilize citrate using Simon Citrate media. Indol positive, citrate negative colonies were then given final confirmation as *E. coli* and assigned isolate numbers. A portion of each *E. coli* strain isolated from each sample was stored at -80ºC, in nutrient broth plus 15% glycerol.

In order to obtain *E coli* isolates from the Cudahy Creek, Spring, and Storm Drain water samples, three aliquots from each sample (1 ml, 5 ml and 25 ml) were concentrated onto 0.45 µm, 47 mm sterile membrane filters (Millipore Corporation) using a Microfil Filtration vacuum manifold system (Millipore Corporation) connected to a vacuum pump. Membrane filters were then placed in 47 mm Petri dishes with absorbent pads (Millipore Corporation) pre-soaked in Coliscan MF media (Micrology Laboratories) according to the manufactures directions. Plates were allowed to grow at 44.5º C overnight in a conventional air incubator, and blue colonies were initially scored as *E. coli* according to the manufactures specifications Coliscan MF plates were then shipped on blue ice to the contracted laboratory at the Institute for Environmental Health for purification and confirmation of *E. coli* as follows: well isolated blue colonies were picked and plated on Trypticase Soy Agar and allowed to grow overnight at 35º C. Each culture was then tested by Spot Indol testing using the appropriate positive and negative controls. Indol positive cultures were subsequently tested for their ability to utilize citrate using Simon Citrate media. Indol positive, citrate negative colonies were then given final confirmation as *E. coli* and assigned isolate numbers. A portion of each *E. coli* strain isolated from each sample was stored at -80ºC, in nutrient broth plus 15% glycerol. Genomic DNA was extracted according to the contracted laboratory's protocol.

To obtain *E. coli* isolates from the receiving waters, three volumes for each sample (5 ml, 25 ml and 75 ml aliquots) were concentrated onto sterile membrane filters, incubated with Coliscan MF media, and blue colonies were initially scored as *E. coli*. Coliscan MF plates were shipped to the contracted laboratory on blue ice, and blue colonies were processed for purification and storage as described above.

Ribotyping Analysis. Genomic DNA was isolated from each *E. coli* strain using a standard protocol. All reagents and buffers were made according to formulas described in the Institute for Environmental Health's laboratory SOPs. Reagents and buffers were tested for sterility. Every batch of restriction enzyme reaction contains two reactions with a positive control strain which were included on two lanes per gel. Agarose gel electrophoresis was conducted under standard conditions, agarose gel concentration, and volume, buffer strength, pH, mA, V, and electrophoresis time were controlled for. Each agarose gel was assigned a number, and when more than one gel was run, the position of the first standard reference strain was changed in each gel (1st lane on the first gel, to the Nth lane on the Nth gel). After electrophoresis, gels were stained in ethidium bromide. Two gels were typically stained in a single container; of the two gels placed in the same container, one corner of the gel of the higher number was clipped. Labels for each gel were also transferred to the staining container. Each gel was then photographed and a hard copy of the print was labeled with the gel sheet (containing the isolates numbers loaded on each lane, and the enzyme used to cut the DNA, plus date, gel number, voltage, mA, gel strength, buffer strength, and electrophoresis time information). Southern blotting was performed according to the protocol detailed in the contracted laboratory's SOP. After photography, each gel was returned to the same staining container. Gels were denatured for Southern blotting in the same container. Each blotting apparatus was constructed in a separate container which was labeled with the gel number. Each membrane filter was then labeled with the gel number, restriction enzyme designation, date, and technician's initials.

The genetic fingerprints (or Ribotypes) were analyzed manually using an algorithm developed by researchers at the Institute for Environmental Health. Type patterns are cut and catalogued, and every pattern was compared side by side to the type pattern. New patterns were given appropriate identifiers and catalogued accordingly. The criterion for data analysis was one hundred percent identity of the Ribotype patterns.

RESULTS

Bacterial Host Origin

For each site examined in Phase II of the study, a unique Microbial Source Tracking (MST) sampling regimen was employed, both in terms of season (e.g. dry weather vs. wet weather, holiday vs. non-holiday) and of methods (e.g. HS-PCR only, Ribotyping only or both). Table 2 summarizes, for each site examined, the season, water type, number of sampling events and the number of isolates analyzed by the Ribotyping assay. In total, 1,097 receiving water isolates, 646 storm drain isolates, 96 Cudahy Creek isolates and 85 Spring isolates were analyzed. Table 2 also summarizes, by site, the season, water type, number of sampling events and the total number of samples analyzed by the HS-PCR assay. Across the entire study, 223 receiving water samples, 111 storm drain samples, eight Cudahy Creek samples, and eight Spring samples were analyzed.

Table 2. Summary of sampling events and samples analyzed by MST according to site, season, and method. For this study, Dry Weather was from July 1 to November 10, 2003 and Wet Weather was from November 11, 2003 to April 7, 2004.

Site	Season	Water Type	Ribotyping Sampling Events	Total # of Isolates	HS-PCR Sampling Events	Total # of Samples
Bonita Cove (Site 1)	Holiday	Receiving Water	6	74	6	24
		Storm Drains	3	4	3	6
	Non-Holiday	Receiving Water	6	104	6	24
		Storm Drains	5	88	5	18
Fanuel Park (Site 3)	Dry Weather	Receiving Water	5	115	3	15
		Storm Drains	5	117	3	34
Wildlife Refuge (Site 5)	Dry Weather	Receiving Water	nd[a]	nd[a]	4	19
Campland (Site 6)	Dry Weather	Receiving Water	6	138	5	24
	Wet Weather	Receiving Water	9	124	5	25
De Anza Cove (Site 7)	Dry Weather	Receiving Water	6	137	5	25
		Storm Drains	4	52	2	9
	Wet Weather	Receiving Water	10	124	3	15
		Storm Drains	6	172	5	28
Visitor's Center (Site 8)	Wet Weather	Receiving Water	10	135	4	20
		Storm Drains	6	115	4	8
		Spring	6	85	4	8
		Cudahy Creek	6	96	4	8
Leisure Lagoon (Site 9)	Dry Weather	Receiving Water	5	146	5	32
		Storm Drains	7	98	4	8
		Total	111	1924	80	350

[a]nd = no data

It should be noted that while groundwater samples were taken for analysis at sites Bonita Cove, Wildlife Refuge, De Anza Cove, Visitor's Center, and Leisure Lagoon, bacteria levels were found to be either undetectable or at the detection limit of the assay employed. A summary of Microbial Source Tracking results from each site is presented below.

Bonita Cove

Microbial Source Tracking at Bonita Cove was performed on samples taken from storm drain effluent and the receiving waters. Since the results from Phase I of the study suggested that indicator bacterial densities in receiving water were greater during summer holidays than non-holidays. The sampling design accounted for this apparent difference: Ribotypes derived from receiving water samples taken on the July 4th and Labor Day Holiday weekends were analyzed separately from those samples taken on non-holiday sampling events. Upon searching the Institute for Environmental Health's Source Ribotype Library Database for matches using these discrete data sets, we found that Avian sources could be attributed to 74% and 75% of the Holiday and non-Holiday receiving water-derived Ribotypes, respectively (Figure 2A and B). The next largest animal source, the Canine group of Ribotypes, shared very similar proportions of the Ribotypes identified in the receiving water between the two sampling groups (6% Holiday, 9% non-Holiday). Thus, an analysis of the data indicates that differences in host animal contributions between holiday and non-holiday periods were insignificant. In addition, the lack of Ribotypes of human origin in the receiving water suggests that anthropogenic sources (e.g., illicit discharge of sewage from boats, leaking sewer lines, etc.), are not the source of the elevated densities observed on summer holidays at Bonita Cove.

Holiday vs. Non-Holiday
Ribotyping Results at Bonita Cove

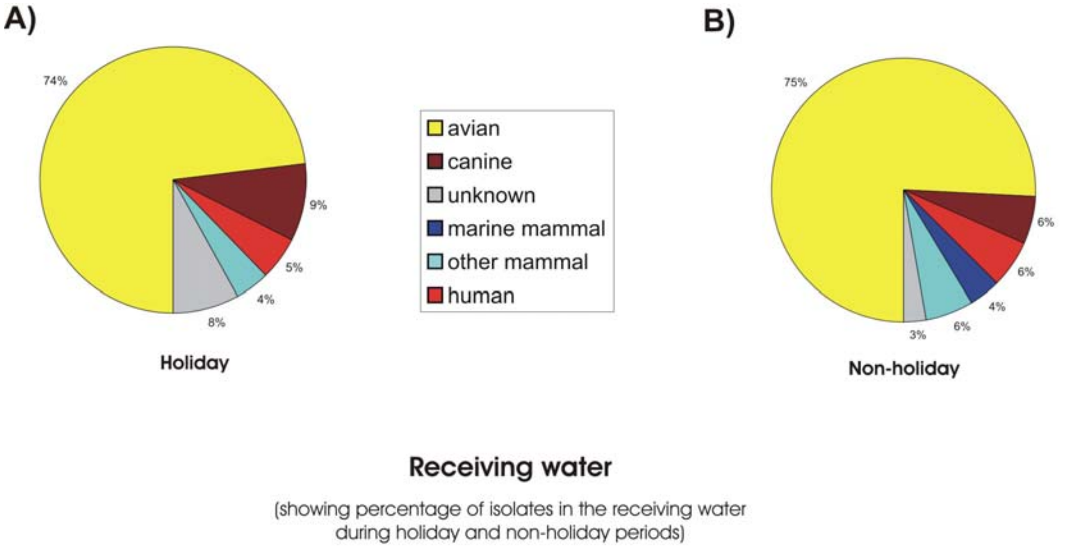


Figure 2. Results of Ribotyping analysis at Bonita Cove showing the origin of bacterial isolates during Holiday (A) and Non-Holiday (B) periods from samples collected in the receiving water.

Over the course of the study (Holiday and Non-Holiday combined), 92 storm drain *E. coli* isolates were obtained from storm drains at Bonita Cove for Ribotyping from a total of eight sampling events. Upon completing the Ribotype analysis of these 92 isolates, the Institute for Environmental Health's Source Ribotype Library Database was searched for matches. We found that 68% (or 63 out of 92) of the storm drain-derived Ribotypes matched those of Avian origin (Figure 3A). A mixture of other mammalian animal sources comprised the next largest group of Ribotypes (12%, or 11 out of 92), while Canine sources accounted for 10% of the Bonita Cove storm drain-derived Ribotypes. Finally, Ribotypes with unknown animal sources were found for 10% (or 9 out of 92) of the *E. coli* Ribotypes isolated from storm drain effluents at Bonita Cove (Unknown).

Receiving Water and Storm Drain Ribotyping Results at Bonita Cove

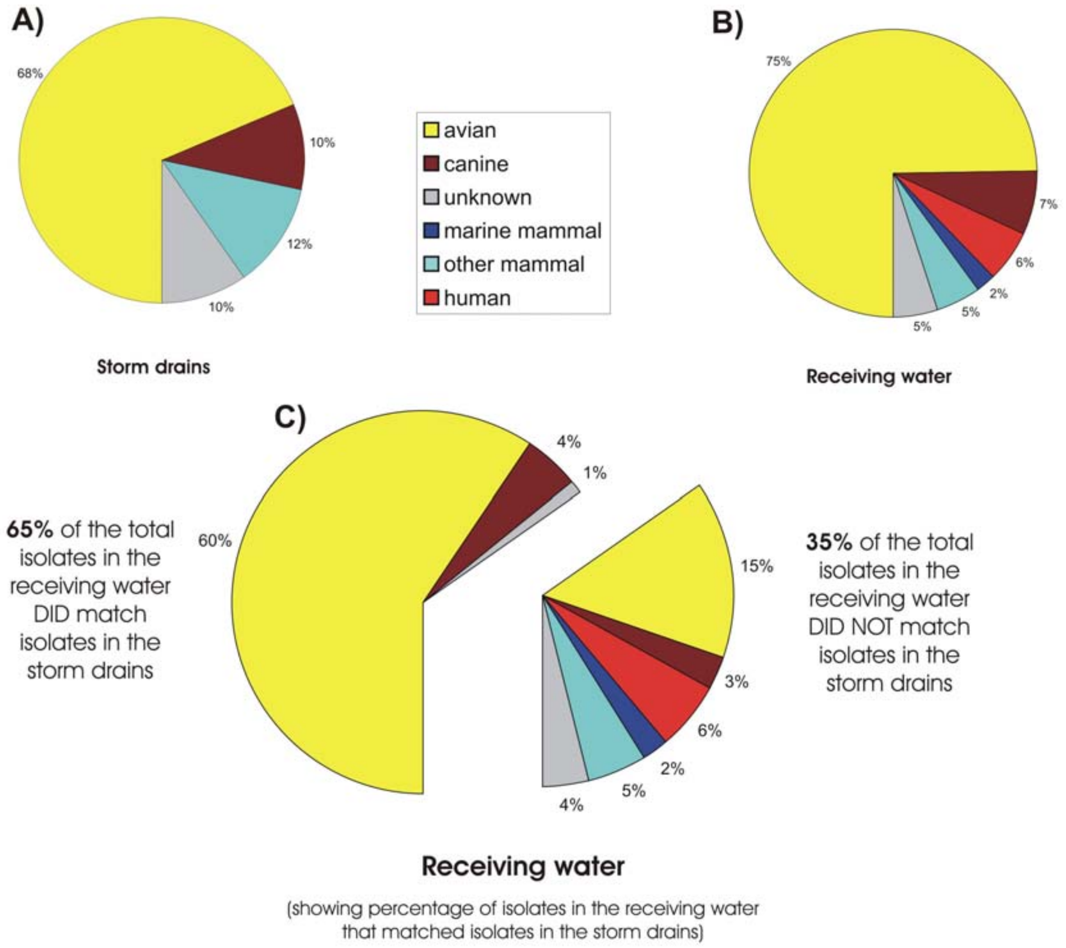


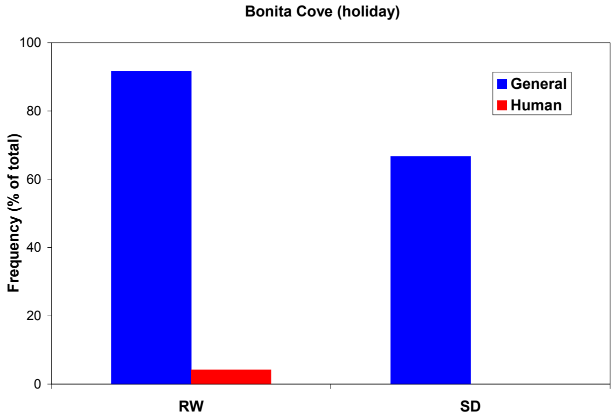
Figure 3. Results of Ribotyping analysis at Bonita Cove. The pie charts show the origin of bacterial isolates in storm drains (A), receiving water (B), and the proportion of isolates in receiving water that matched those in storm drains (C).

As eluded to above, when Bonita Cove receiving water-derived Ribotypes from both Holiday and Non-Holiday sampling events were analyzed together, we found that a large majority (75% or 133 out of 178) matched Avian Ribotypes in the Library Database (Figure 3B). Besides Avian, Canine Ribotype matched 13 out of 178 (or 7%) of the Ribotypes, and Ribotypes from Human sources were identified for 10 out of 178 (or 6%). The remaining 12% of the Ribotypes obtained from the Bonita Cove receiving waters were found to be distributed between a variety of mammalian sources (marine mammal or other mammal), or could not be matched to any sources whatsoever in the Institute for Environmental Health's Source Ribotype Library Database (Unknown).

We next asked whether any of the receiving water-derived Ribotypes were shared with those derived from storm drain effluent-derived Ribotypes. As presented in Figure 3C, 65% (or 116 out of 178) of the water Ribotypes were found to be common with Ribotypes present in the storm drain data set. Nearly all of these receiving water-storm drain Ribotype matches could be traced to Avian upstream sources (106 out of 116).

HS-PCR analysis was next performed on receiving water and storm drain samples taken from the Holiday sampling survey. As can be seen in Figure 4, we found that 22 out of 24 receiving water and four out of six storm drain samples were positive for the general *Bacteroides* marker, indicating the presence of fecal contamination by warm blooded animals. While none of the Holiday storm drain samples were positive, one of 24 receiving water samples indicated the presence for the Human marker.

HS-PCR Results at Bonita Cove - Holiday

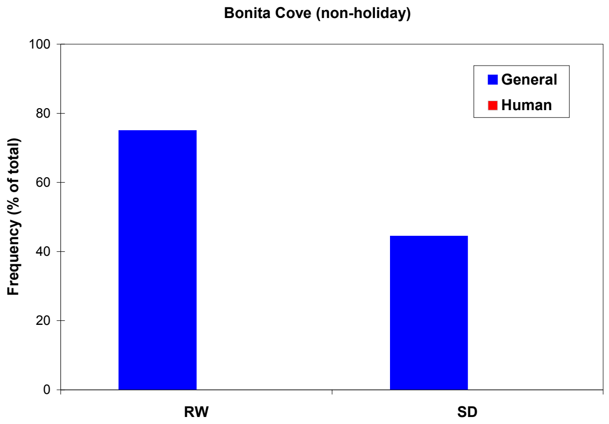


	Holiday	
Bonita Cove	**RW**	**SD**
General	22	4
Human	1	0
Total	24	6

Figure 4. Results of HS-PCR analyses on samples collected at Bonita Cove.

HS-PCR analysis on samples collected during the Non-Holiday survey showed that 18 out of 24 receiving water samples and eight out of 18 storm drain samples were positive for the general *Bacteroides* marker. On the other hand, when these water samples were analyzed by HS-PCR for the presence of the Human marker, neither receiving water nor storm drain samples were positive (Figure 5).

HS-PCR Results at Bonita Cove – Non-Holiday



Bonita Cove	Non Holiday	
	RW	SD
General	18	8
Human	0	0
Total	24	18

Figure 5. Results of HS-PCR analyses on samples collected at Bonita Cove.

Fanuel Park

At Fanuel Park, MST was performed only during the dry season on both storm drain effluent and receiving waters. Ribotyping analysis showed that over the five sampling events, a majority (60%, or 70 out of 117) of the storm drain-derived *E. coli* isolates produced Ribotypes that matched Avian Ribotypes in the Institute for Environmental Health's Source Ribotype Library Database (Figure 6A). Interestingly, a significant proportion of the storm drain-derived Ribotypes were found to match Ribotypes of Canine origin (20%, or 23 out of 117). A variety of other mammals comprised 15% of the Ribotypes from the storm drain effluent Ribotypes, while 5% could not be identified (Unknown).

Receiving water-derived isolates were analyzed by the Ribotyping assay, and upon searching the Institute for Environmental Health's Source Ribotype Library Database, we found that 69% (or 79 out of 115) of these Ribotypes matched Ribotypes of Avian origin (Figure 6B). Several much smaller groups of animal hosts contributed to the remainder of the water-derived Ribotypes, including 10% from Marine Mammal, 7% from Canine and 7% from Human sources.

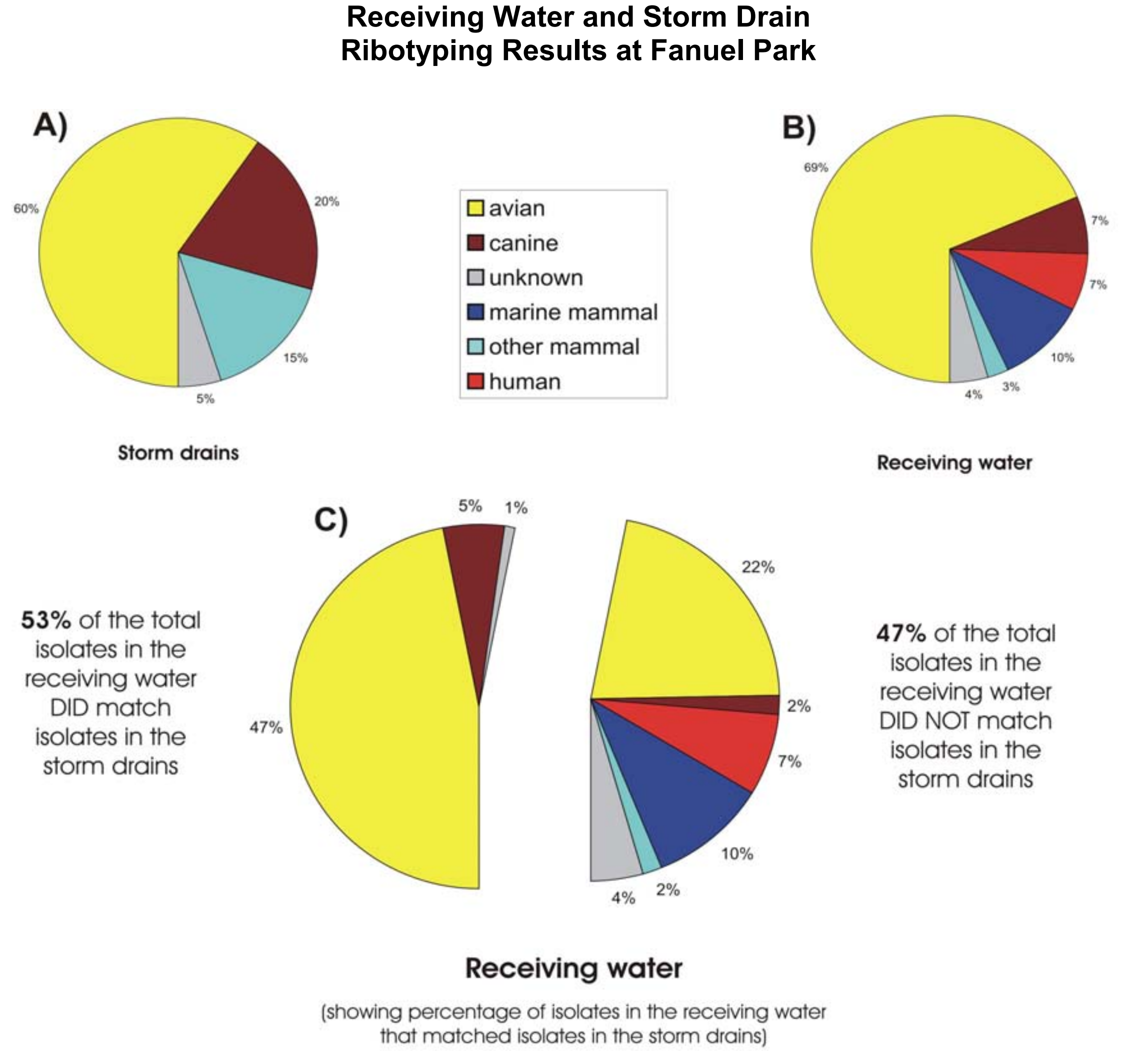
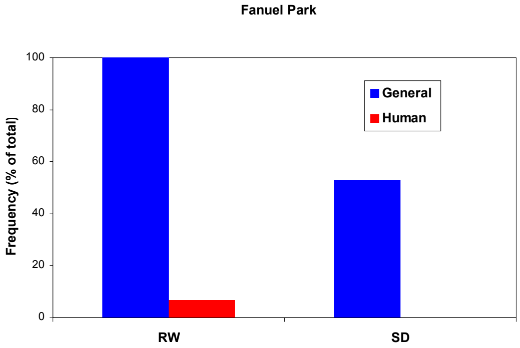


Figure 6. Results of Ribotyping analysis at Fanuel Park. The pie charts show the origin of bacterial isolates in storm drains (A), receiving water (B), and the proportion of isolates in receiving water that matched those in storm drains (C).

We next asked what proportion of the Fanuel Park receiving water-derived Ribotypes could be matched to those Ribotypes derived from the storm drain samples. Importantly, this analysis showed that over half (53% or 61 of 115) of those Fanuel Park water-derived Ribotypes were also found in the Fanuel Park storm drain-derived Ribotypes obtained over the course of the study, with virtually all of these (54 out of 61) matching Ribotypes stemming from Avian upstream sources (Figure 6C).

Fifteen Fanuel Park receiving water and 34 storm drain samples were analyzed by HS-PCR. The results are summarized in Figure 7. While all of the receiving water samples were positive for the General *Bacteroides* marker, only one was positive for the Human marker. Of the storm drain samples, 18 out of 34 were positive for the General marker and none were found to be positive for the Human marker.

HS-PCR Results at Fanuel Park



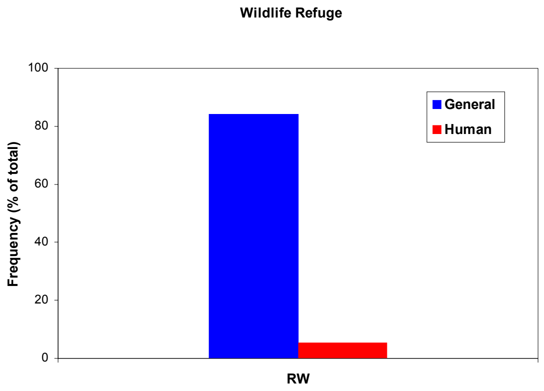
Fanuel Park	RW	SD
General	15	18
Human	1	0
Total	15	34

Figure 7. Results of HS-PCR analyses on samples collected at Fanuel Park.

Wildlife Refuge

HS-PCR was the only Microbial Source Tracking technique performed at the Wildlife Refuge site. Over the Dry Weather season, 19 receiving water samples were taken over four sampling events. HS-PCR analysis revealed that 80% (16 out of 19) of the samples were positive for the General *Bacteroides* marker (Figure 8), but only one sample was positive for the Human marker.

HS-PCR Results at Wildlife Refuge



Wildlife Refuge	RW
General	16
Human	1
Total	19

Figure 8. Results of HS-PCR analyses on samples collected at Wildlife Refuge.

Campland

Historically, Campland receiving water bacterial densities increase significantly during the winter months. However, transient spikes are also frequently observed during the summer. There are no storm drains or other suspected sources of bacteria that could be easily monitored at this site. Therefore, MST was used to assess the only the receiving waters at Campland during both dry and wet weather seasons.

The Dry Weather survey yielded 138 receiving water *E. coli* isolates collected over six sampling events. Ribotyping analysis was completed on these isolates, and upon searching the Institute for Environmental Health's Source Ribotype Library Database, we found that greater that 79% (or 110 out of 138) matched Ribotypes of Avian origin (Figure 9A). Of the remaining 28 Ribotypes, 11 were found to match Canine, five were found the match Human, 10 were found a variety of mammals, and two could not be identified in the Library Database (Unknown).

During the Wet Weather survey at Campland, we obtained 124 isolates from the receiving waters over nine sampling events. Upon Ribotyping these and searching the Institute for Environmental Health's Source Ribotype Library Database, we found that 69% (or 87 out of 124) of these matched Avian Ribotypes (Figure 9B). The next largest group (13% or 16 out 124) was comprised of Ribotypes that could not be identified in the Library Database (Unknown). Ribotypes of Canine origin were found to match 10% of the Ribotypes, while the remaining 8% of the Ribotypes were distributed between Marine Mammals (5%), Human (2%), and Other Mammals (1%).

Wet and Dry Weather Ribotyping Results at Campland

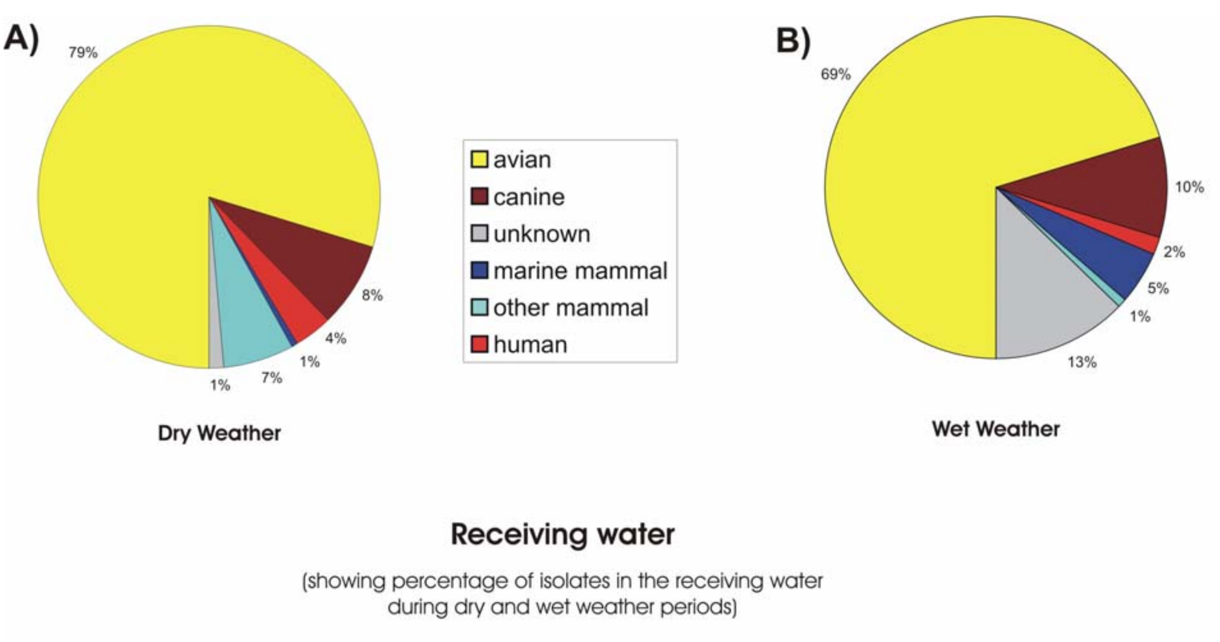
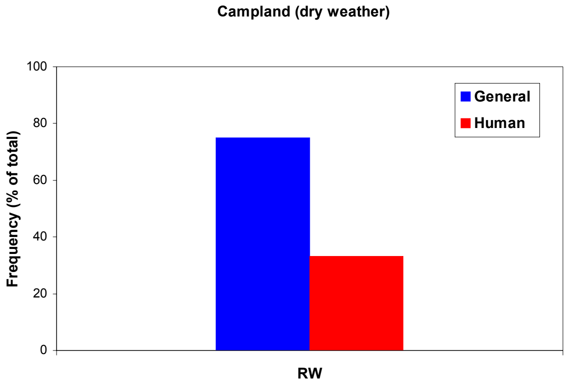


Figure 9. Results of Ribotyping analysis from receiving water samples collected at Campland during wet weather (A) and dry weather (B). The pie charts show the origin of bacterial isolates.

HS-PCR analysis of samples taken during the Dry Weather Survey showed that 18 out of 24 were positive for the General *Bacteroides* marker. Interestingly, eight of 24 samples tested positive for the presence of the Human *Bacteroides* marker. The results are summarized in Figure 10.

HS-PCR Results at Campland during Dry Weather

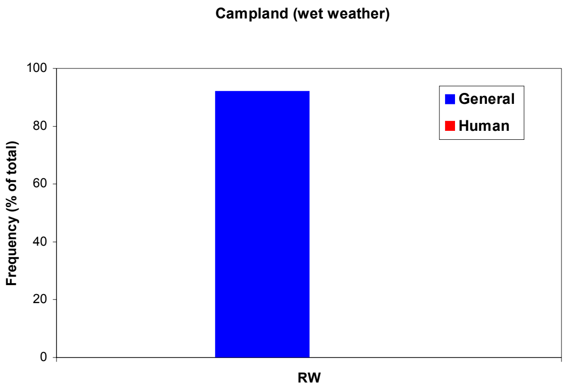


Campland	Dry Weather
	RW
General	18
Human	8
Total	24

Figure 10. Results of HS-PCR analyses on samples collected at Campland during dry weather monitoring.

Figure 11 summarizes the results of our HS-PCR analysis on wet weather samples. In summary, 23 out of 25 receiving water samples were positive for the General *Bacteroides* marker, while no samples were positive for the Human marker.

HS-PCR Results at Campland during Wet Weather



Campland	Wet Weather
	RW
General	23
Human	0
Total	25

Figure 11. Results of HS-PCR analyses on samples collected at Campland during wet weather monitoring.

De Anza Cove

At De Anza Cove, samples were collected for MST analyses during both Dry and Wet Weather Surveys. Over the course of four dry weather sampling events, 52 storm drain *E. coli* isolates were obtained for Ribotyping analysis. When these Ribotypes were used to query the Institute for Environmental Health's Source Ribotype Library Database, 48% (or 25 out of 52) were found to match those of Avian sources (Figure 12A). A rather large Ribotype group (29%, or 15 out of 52) was found to match Ribotypes from a variety of other mammals (12 rodents, 2 feline, 1 raccoon). While 19% (or 10 of 52) of the Dry season, storm drain Ribotypes were identified as being of Canine origin, only 4% could be identified as having a Human source (two out of 52).

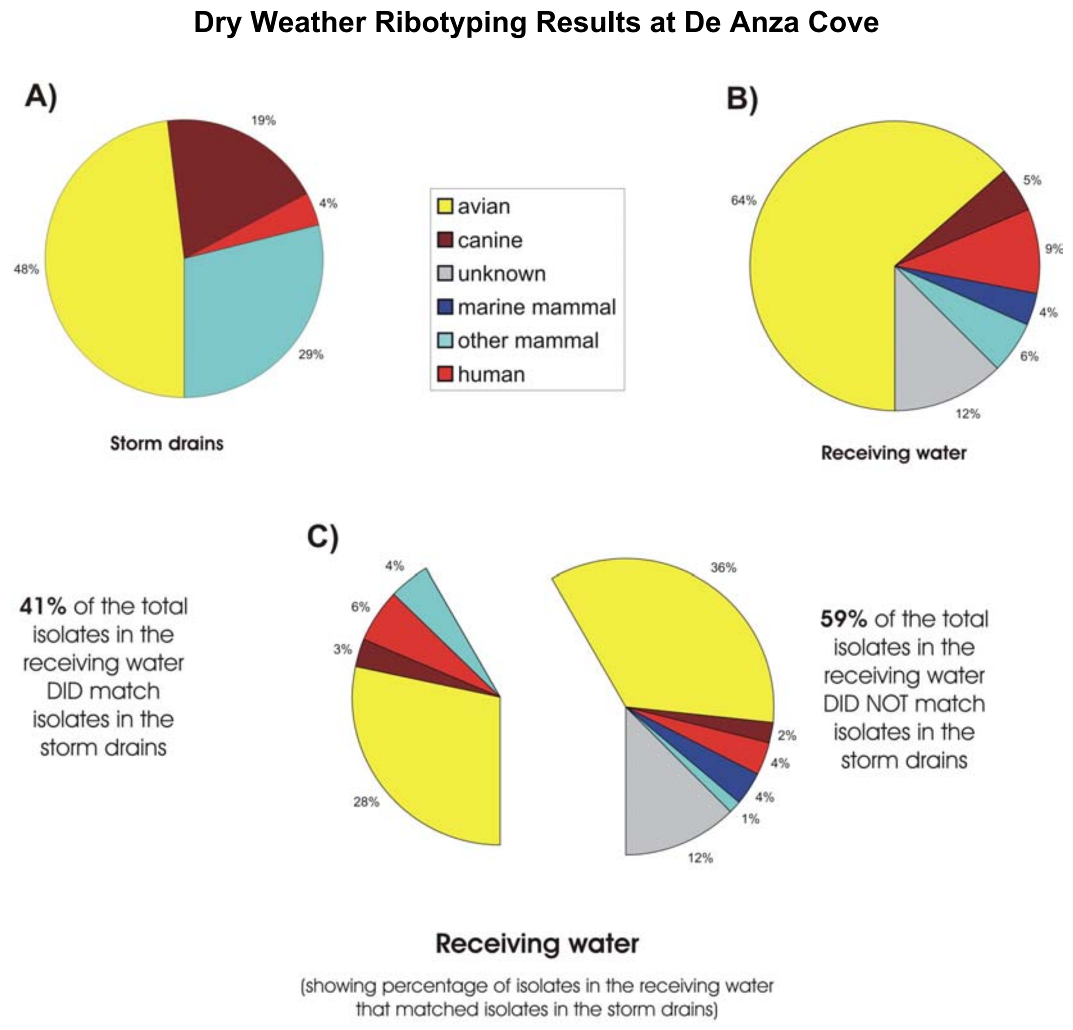


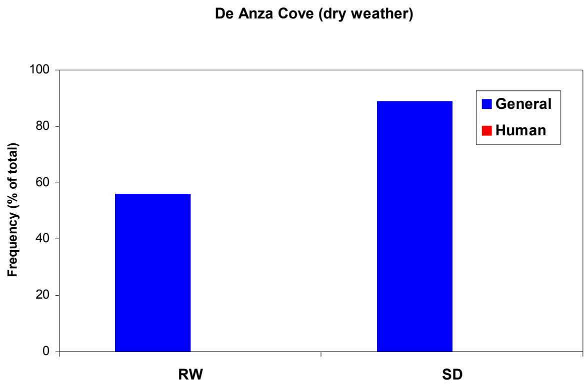
Figure 12. Results of Ribotyping analysis at De Anza Cove during dry weather. The pie charts show the origin of bacterial isolates in storm drains (A), receiving water (B), and the proportion of isolates in receiving water that matched those in storm drains (C).

Dry Weather sampling (6 events) produced 137 receiving water isolates at De Anza Cove. When these were analyzed by Ribotyping and a majority (64%, or 87 out of 137) of these Ribotypes were shown to match Avian Ribotypes upon searching the Source Ribotype Library (Figure 12B). The next largest group (Unknown) accounted for 12%, or 17 of 137 of the Dry Weather Ribotypes. Interestingly, 9% (or 13 of 137) were found to match Human Ribotypes. A variety of other animals, including the Canine family, were found to take up the remaining 15% of the Dry Weather receiving water-derived Ribotypes.

We next looked for matches between De Anza Cove Dry Weather receiving water and storm drain Ribotypes (Figure 12C). We found that between the two sample sets, 57 of 137 (41%) of the Ribotypes were in common. Of these common Ribotypes, 39 were of Avian upstream sources and eight were of Human origin. Canine and Other Mammals rounded out the remaining 10 shared receiving water/storm drain Ribotypes.

Twenty-five Receiving water and nine storm drain samples were taken during Dry Weather survey for Host-Specific PCR analysis. As summarized in Figure 13, 14 out of 25 receiving water and eight out of nine storm drain samples were positive for the General *Bacteroides* marker, whereas none of these samples were positive for the Human marker.

HS-PCR Results at De Anza Cove during Dry Weather



DeAnza Cove	Dry Weather	
	RW	SD
General	14	8
Human	0	0
Total	25	9

Figure 13. Results of HS-PCR analyses on samples collected at De Anza Cove during dry weather monitoring.

Ribotyping analysis was next performed on isolates derived from storm drain effluent samples obtained during the Wet Weather survey at De Anza Cove (6 sampling events), and data generated from the analysis overlaid well with the data obtained from the Dry Weather survey. Specifically, we found that of the 172 storm drain-derived Ribotypes, 49% matched Avian Ribotypes present in the Institute for Environmental Health's Source Ribotype Library Database (Figure 14A). The next largest animal source, Canine, was found to account for 29% (or 50 out of 172) of the storm drain Ribotypes, while 19% (or 33 of 172) of the Ribotype matches were comprised of various other mammals (20 rodent, 9 raccoon and 4 feline source Ribotypes). Finally, 3% (or 6 of 172) of the Ribotypes could not be matched to any animal sources (Unknown).

Wet Weather Ribotyping Results at De Anza Cove

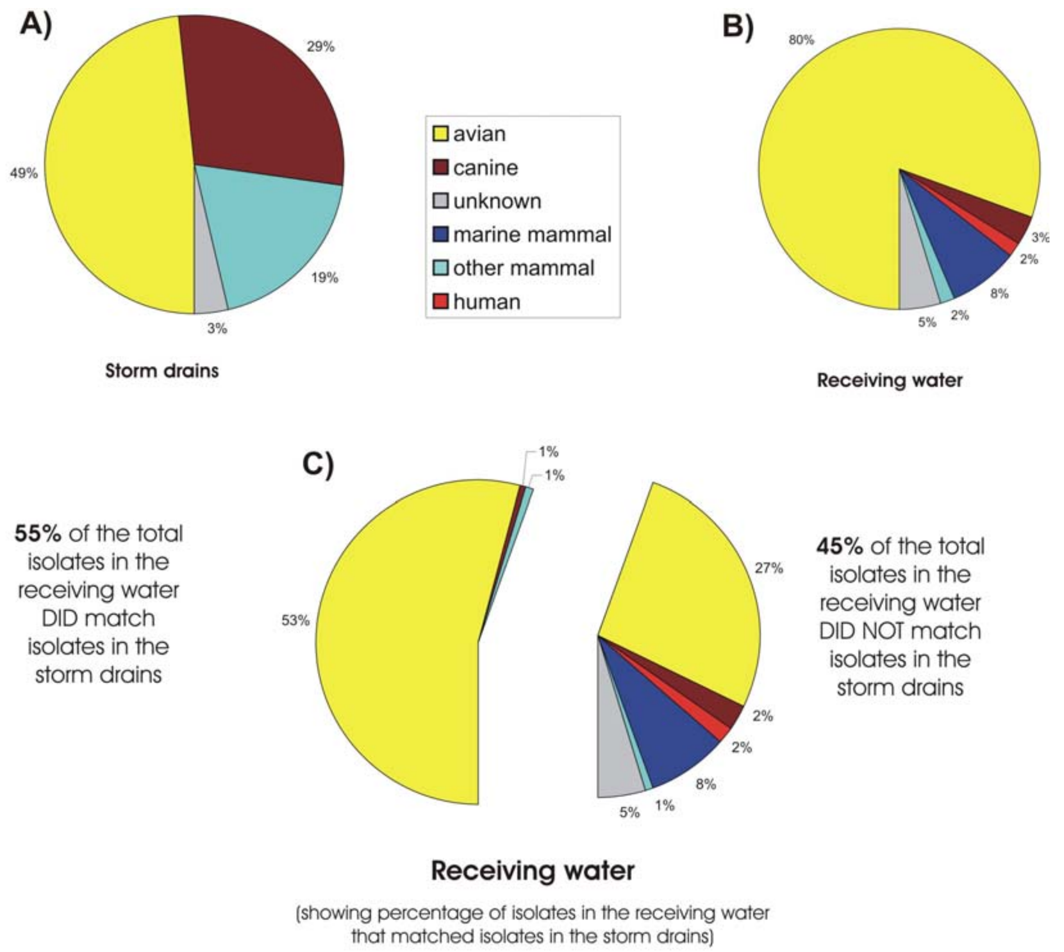


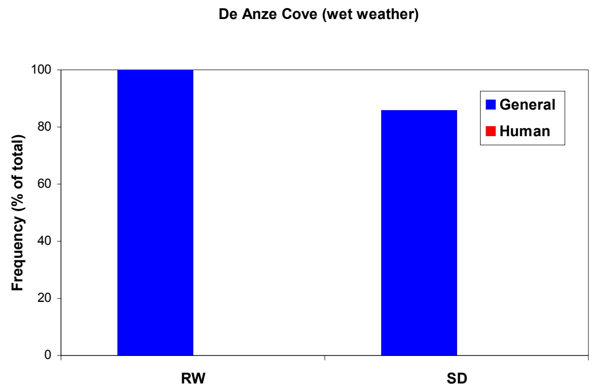
Figure 14. Results of Ribotyping analysis at De Anza Cove during wet weather. The pie charts show the origin of bacterial isolates in storm drains (A), receiving water (B), and the proportion of isolates in receiving water that matched those in storm drains (C).

Ten Wet Weather survey sampling events produced 124 receiving water *E. coli* isolates. Upon searching the Institute for Environmental Health's Source Ribotype Library Database for matches, we found that an overwhelming majority (80%, or 100 out of 124) could be matched to Avian Ribotypes (Figure 14B). Interestingly, Ribotypes matching those of marine mammals (8%, or 10 out of 124) made up the next largest group of receiving water-derived Ribotypes. Several smaller animal groups, including 5% which could not be identified in the Library Database (Unknown, 5%) accounted for the rest of the Ribotypes analyzed.

We next asked what proportion of the De Anza Cove Wet Weather receiving water-derived Ribotypes could be matched to Ribotypes obtained from the storm drain effluent. We found that 69 out of 124 of the water-derived Ribotypes were also found in the storm drain effluent Ribotype data set (Figure 14C). Nearly all of the common Ribotypes (67 of 69) were identified as having an Avian origin.

HS-PCR analysis was performed on samples collected during the Wet Weather survey. As summarized in Figure 15, all of the receiving water samples (15 out of 15) were positive for the general *Bacteroides* marker, yet none were positive for the Human marker. Likewise, a majority of the storm drain samples analyzed for the general marker were positive (24 out of 28), yet none of these were found to possess the Human maker as well.

HS-PCR Results at De Anza Cove during Wet Weather



DeAnza Cove	Wet Weather	
	RW	SD
General	15	24
Human	0	0
Total	15	28

Figure 15. Results of HS-PCR analyses on samples collected at De Anza Cove during wet weather monitoring.

Visitor's Center

Visitor's Center is not only one historically of the most contaminated AB411 monitoring sites in Mission Bay, but one of the most complex in terms of potential input sources to the beach area. Not only does the bird population grow exceedingly high, but two major drainages empty directly into the beach area itself: storm drain SD8-1 and Cudahy Creek. To complicate matters even further, the Spring East of Interstate 5 feeds directly into the storm drain, allow fresh water to flow in the form of ground water seepage. Cudahy Creek is also complicated insofar as its specific drainages are unknown. Further, we have recently shown that Cudahy Creek is highly susceptible to tidal influences that can create bacterial breeding ground. Therefore, we chose an extensive sampling regimen at Visitor's Center, not only of the receiving waters, but of the three potential source water inputs (the Spring East of I-5, the storm drain to which the Spring flows into, and the mouth of Cudahy Creek). All water types were analyzed by both Microbial Source Tracking methods during the Wet Weather season only, employing both the Ribotyping and HS-PCR techniques.

We first obtained *E. coli* 85 isolates over six sampling events from the Spring East of I-5 for Ribotyping. Upon searching the Institute for Environmental Health's Source Ribotype Library Database for matches, we found that 72% (or 61 out of 85) matched Ribotypes of Avian origin (Figure 16A). Eleven of 85 (or 13%) Spring-derived Ribotypes were not able to be matched to any Ribotypes present in the Library Database (Unknown), while 7 of 85 (or 8%) were identified as having Canine origin and the remaining 6 Ribotypes had other mammalian upstream sources.

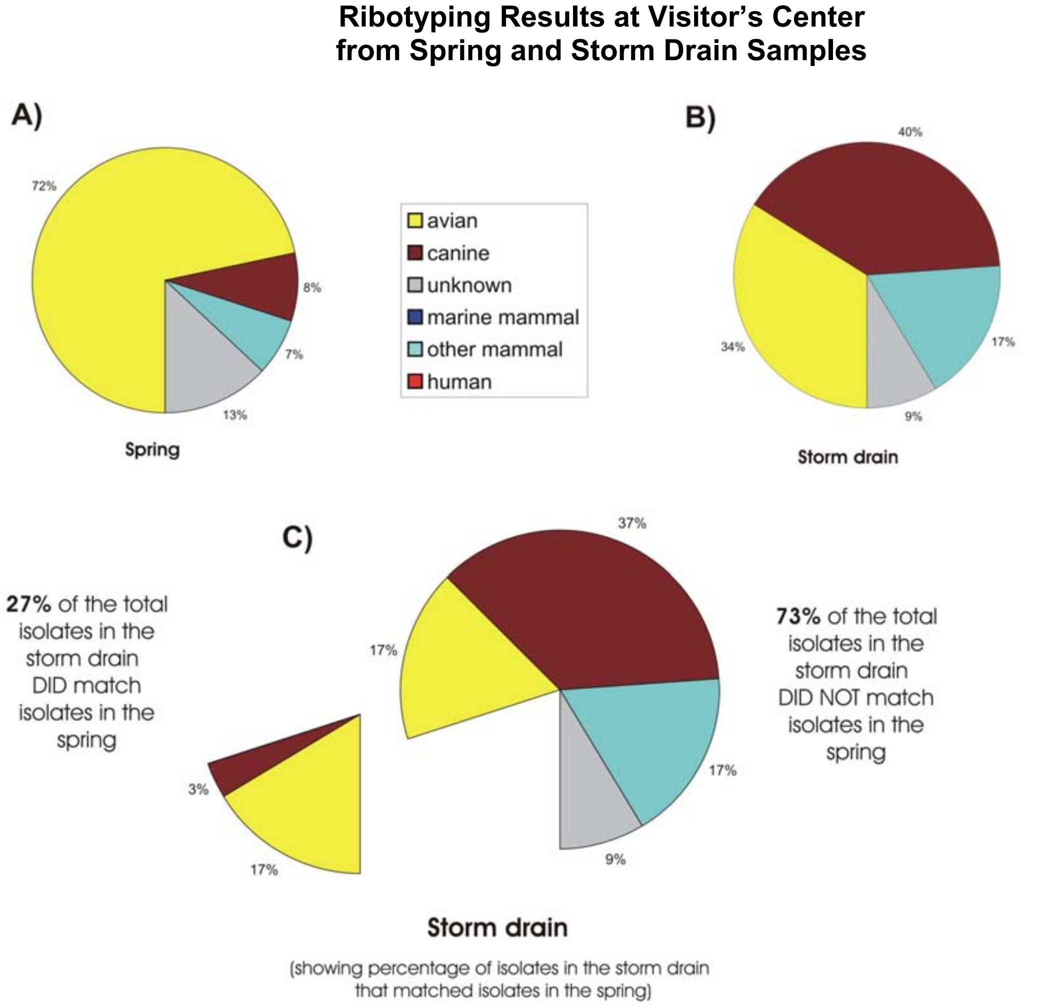


Figure 16. Results of Spring and storm drain Ribotyping analysis at Visitor's Center. The pie charts shows the origin of bacterial isolates from the Spring (A), the storm drain (B), and the proportion of isolates in storm drain effluent that matched those in Spring (C).

The storm drain at Visitor's Center was sampled over six events, and here we collected 115 isolates for Ribotyping analysis. Interestingly, we found that a majority (40% or 46 out of 115) of the storm drain-derived Ribotypes matched those of Canine origin (Figure 16B). The next largest animal host group was found to be Avian, whose Ribotypes accounted for 39 out of 115, or 34%, of the storm drain-derived Ribotype set. Ribotypes of other mammalian sources were found to account for 17% (or 20 of 115) of these, while Ribotypes with no identifiable animal source accounted for 9% of the storm drain-derived Ribotypes (Unknown).

In order to determine what proportion of the Spring Ribotypes could be traced to those Ribotypes found in the storm drain. Interestingly, we found that only 23 of 115 (or 27%) of these were shared (Figure 16C). A majority of these (19 of 23) had Avian upstream sources, while the remaining were shown to be of Canine origin (four of 24).

Since the Spring East of I-5 and the storm drain into which it feeds combine to a single source water to the receiving water at Visitor's Center, we next combined these Ribotype data sets (Spring/storm drain) in order to obtain a cumulative Ribotype data set. The Spring/storm drain data set would then accurately represent the total possible bacterial input from this single point into the receiving waters at Visitor's Center, and the combined data set would later be used to determine the impact these source waters had on the receiving water at Visitor's Center (see below). The merging of the two data sets resulted in a total of 200 Ribotypes (85 from the Spring and 115 from the storm drain), and the combined distribution of animal origin can be seen in Figure 17A. Specifically, we found that 50% of the total Spring/SD Ribotypes were of Avian origin, 27% were of Canine origin, 13% were of mixed mammalian sources and 11% remained unknown.

Six receiving water sampling events at Visitor's Center produced 135 *E. coli* isolates for Ribotyping analysis. Upon searching the Institute for Environmental Health's Source Ribotype Library Database for matches, we found that a majority of these (66% or 88 out of 135) were of Avian origin (Figure 17B). Canine sources were identified for 14% (or 19 of 135) of these, while marine mammal sources were attributed to 8% (or 11 of 135). Ribotypes that did not match any of those in the Library Database accounted for 6% of the receiving water-derived Ribotypes (Unknown), while other mammalian sources and Human sources accounted for 4% and 2% of the Ribotypes, respectively.

We next asked what proportion of the combined Spring/storm drain Ribotypes could be traced to the receiving water Ribotype data set. Interestingly, we found that 86 out of 135 (or 64%) of the water-derived Ribotypes were shared with those found in the Spring/storm drain Ribotype data set (Figure 17C). Of the 86 common Ribotypes, 64 were identified as having Avian upstream sources, 18 were of Canine sources, and 4 were of other mammalian hosts.

Ribotyping Results at Visitor's Center from Spring/Storm Drain and Receiving Water Samples

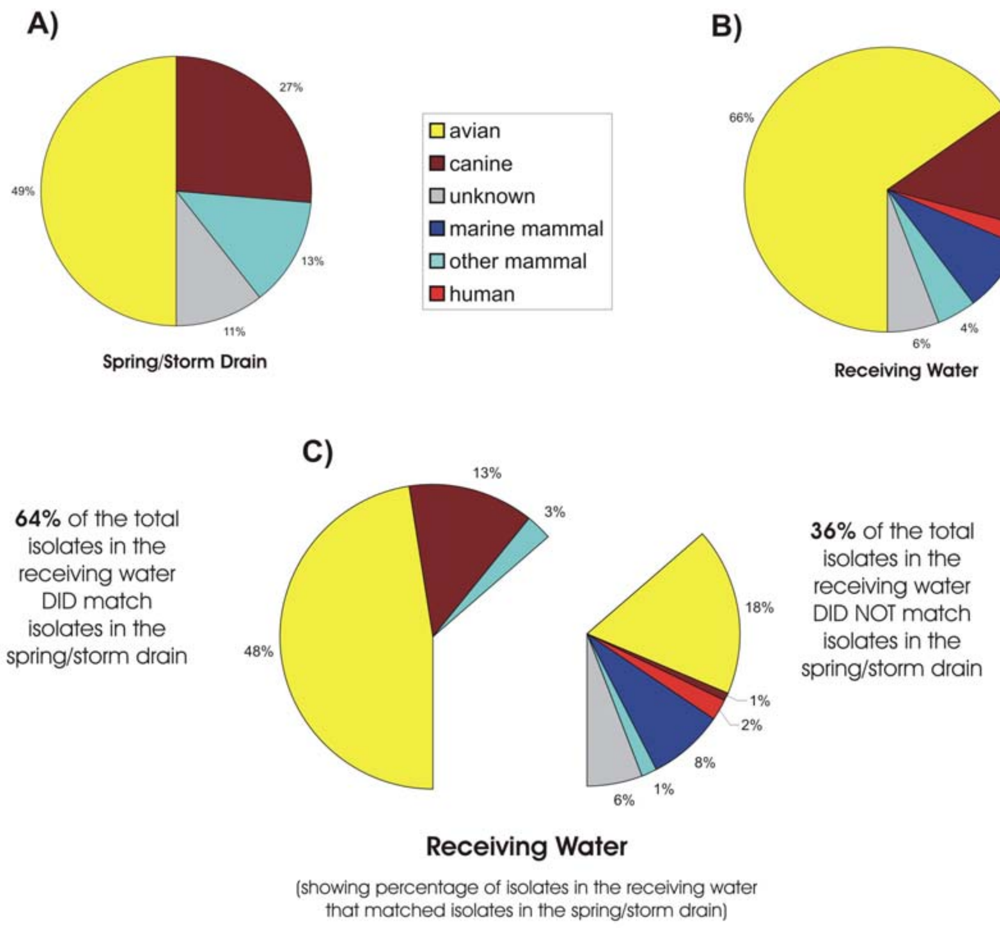


Figure 17. Results of Spring/storm drain and receiving water Ribotyping analysis at Visitor's Center. The pie charts shows the origin of bacterial isolates from the Spring/storm drain (A), the receiving water (B), and the proportion of isolates in Spring/storm drain effluent that matched those in receiving water (C).

The second input into Visitor's Center receiving waters, Cudahy Creek, was sampled 6 times, and 96 *E. coli* isolates were obtained for Ribotyping analysis. This Cudahy Creek Ribotype data set was used to query the Institute for Environmental Health's Source Ribotype Library Database for host matches, and we found that 66% (or 63 out of 96) matched Ribotypes of Avian origin (Figure 18). Canine sources comprised the next largest group, accounting for 22 out of 96, or 23%, of the Cudahy Creek-derived Ribotypes. Ribotypes that could not be identified in the Library Database accounted for 7% of the Cudahy Creek Ribotypes (Unknown), while 2% and 1% were attributed to other mammal and Human sources, respectively.

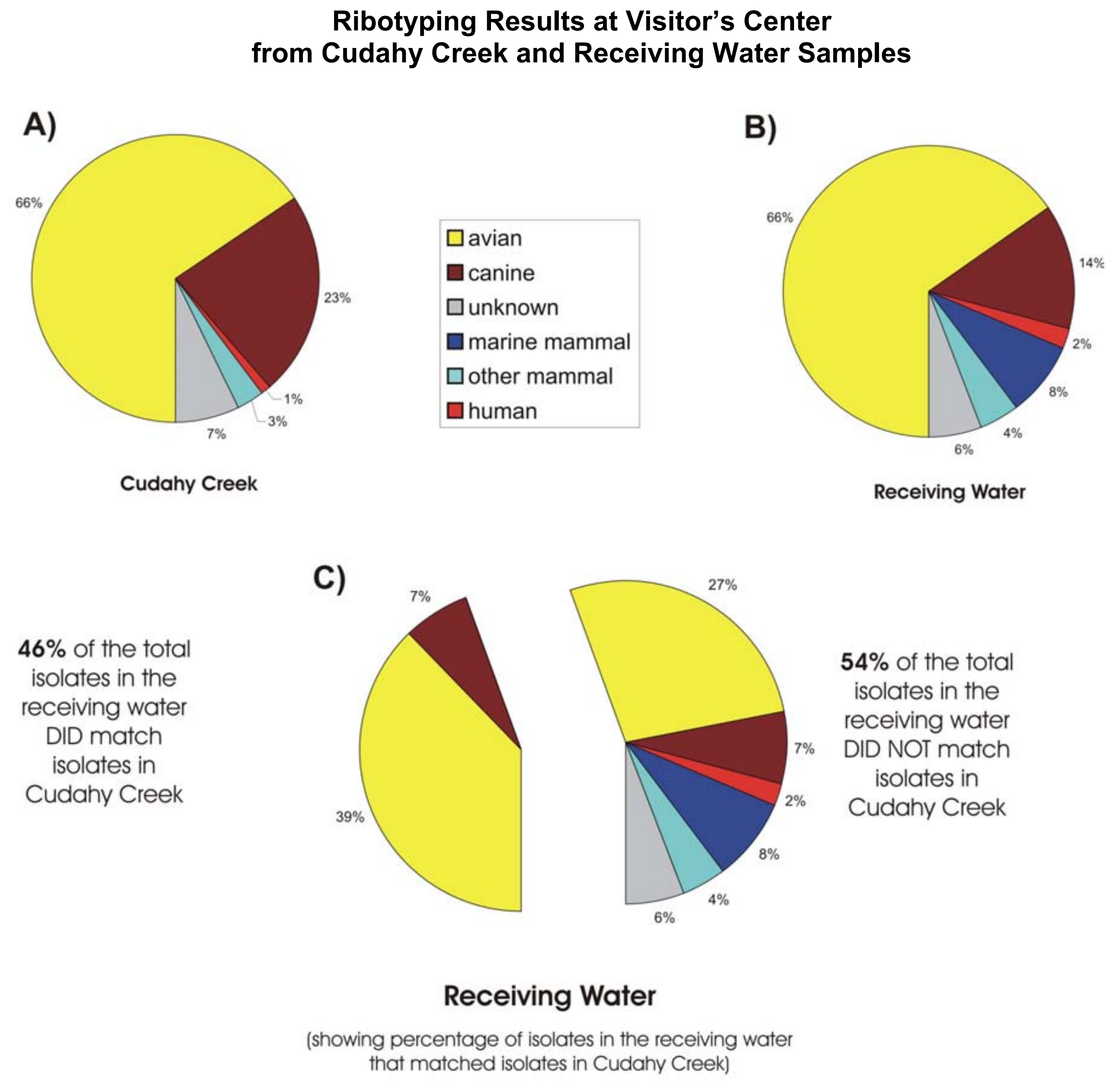
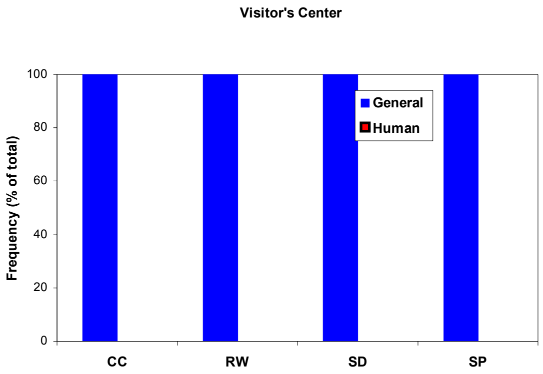


Figure 18. Results of Cudahy Creek and receiving water Ribotyping analysis at Visitor's Center. The pie charts shows the origin of bacterial isolates from Cudahy Creek (A), the receiving water (B), and the proportion of isolates in Cudahy Creek that matched those in receiving water (C).

We next asked what proportion of the Cudahy Creek Ribotypes were in common with those found in the receiving water at this site (see above and Figure 18C). We found that 60 out of 135 (or 46%) of the Visitor's Center receiving water-derived Ribotypes were also identified in the Cudahy Creek Ribotype data set. Of these common Ribotypes, 51 were attributed to Avian upstream sources, while 9 were identified as having Canine sources.

Over the course of the study, Visitor's Center receiving water, storm drain, Cudahy Creek, and Spring samples were analyzed by HS-PCR. As summarized in Figure 19, we found that every sample, 20 out of 20 receiving water, 8 out of 8 storm drain, 8 out of 8 Cudahy Creek, and 8 out of 8 Spring samples, were positive for the general *Bacteroides* marker. Importantly, not any of these samples were identified to be positive for the Human Bacteroides marker.

HS-PCR Results at Visitor's Center



Visitor's Center	CC	RW	SD	SP
General	8	20	8	8
Human	0	0	0	0
Total	8	20	8	8

Figure 19. Results of HS-PCR analyses on samples collected at Visitor's Center from receiving water and suspected sources.

Leisure Lagoon

Microbial Source Tracking at Leisure Lagoon included both Ribotyping and HS-PCR analysis of storm drain effluent and receiving water samples. Since results from Phase I of the Study suggested that bacterial exceedances were primarily an issue during the summer months, sampling for MST was completed only during the dry season.

First, Ribotyping was completed on 98 isolates obtained from seven storm drain sampling events. Upon searching the Institute for Environmental Health's Source Ribotype Library Database for matches, we found that 58% (or 56 out of 98) of these matched Avian Ribotypes (Figure 20). Other mammalian sources, which consisted of rodent (20 Ribotypes) and raccoon (2 Ribotypes), accounted for 22% of the storm drain Ribotype matches. Canine Ribotypes were identified for 16% (or 16 out of 98) of the storm drain-derived Ribotypes, while 4% of these Ribotypes could not be associated with any animal (Unknown).

Ribotyping Results at Leisure Lagoon from Storm Drain and Receiving Water Samples

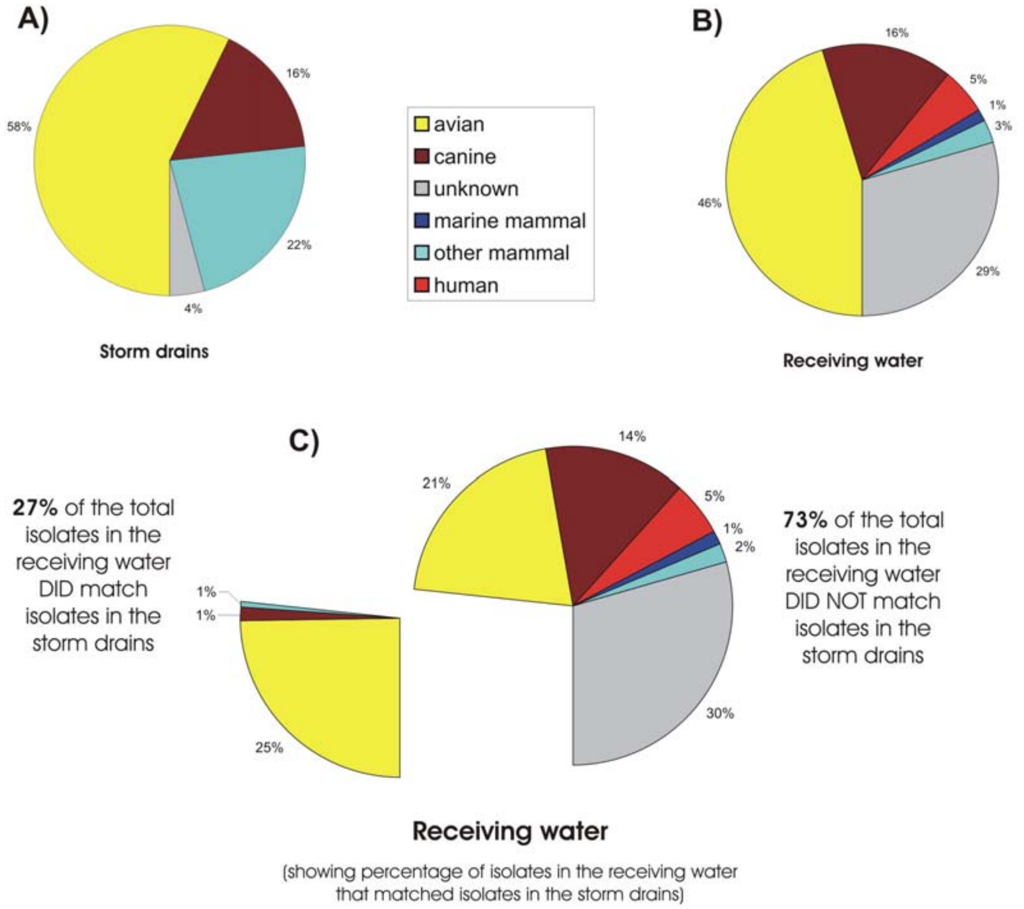


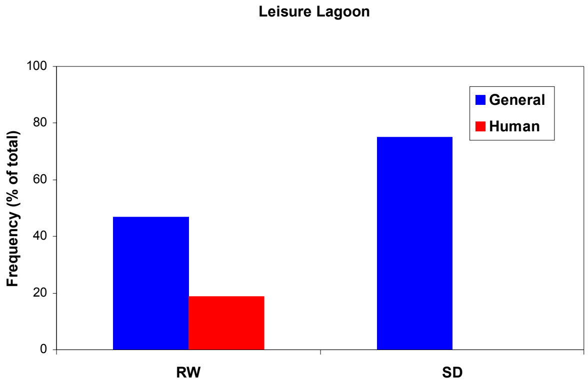
Figure 20. Results of storm drain and receiving water Ribotyping analysis at Leisure Lagoon. The pie charts shows the origin of bacterial isolates from the storm drain (A), the receiving water (B), and the proportion of isolates in the storm drain that matched those in receiving water (C).

Next, Leisure Lagoon receiving water isolates were analyzed by Ribotyping. Avian and Canine sources were identified for 45% (or 66 out of 146) and 16% (23 of 146) of the receiving water-derived Ribotypes, respectively (Figure 20B). Human matches were found for 5% (or 8 out of 146) of the receiving water Ribotypes. Most interesting, however, was an unusually large group (29%, or 43 out of 146) of receiving water Ribotypes for which no host animal matches could be found in the Institute for Environmental Health's Source Ribotype Library Database (Unknown).

Finally, we asked whether any of the Leisure Lagoon receiving water-derived Ribotypes could be matched to those obtained from storm drain effluent. We found that 39 out of 146 of the receiving water Ribotypes could be traced to Ribotypes found in the storm drain effluent samples (Figure 20C), nearly all of which (36 of 39) were found to have Avian upstream sources.

Host-Specific PCR analysis was completed on receiving water and storm drain samples taken at Leisure Lagoon. As seen in Figure 21, 15 out of 32 receiving water and 6 out of 8 storm drain samples were positive for the general *Bacteroides* marker. Interestingly, 6 of 32 receiving water samples were positive for the Human marker. None of the storm drain samples analyzed were positive for the Human marker.

HS-PCR Results at Leisure Lagoon



Leisure Lagoon	RW	SD
General	15	6
Human	6	0
Total	32	8

Figure 21. Results of HS-PCR analyses on samples collected at Leisure Lagoon from receiving water and suspected sources.

DISCUSSION

At Mission Bay Park, swimming beach sites and the accompanying recreational waters have historically been plagued with beach closures due to exceedances in AB411 criterion for fecal indicator bacteria. The goal of Phase I of this Study was to gain a better understanding of the possible sources (i.e., input from storm drains, faulty sewage lines, wildlife, illicit discharge from boats, etc) that covey fecal indicator bacteria contamination to the Mission Bay receiving waters. It was reasoned that, with this crucial source information, BMPs could be implemented in an effort to reduce the number of annual beach closures. Work from Phase I of the Study helped to narrow the myriad of potential sources. Specifically, closed circuit television scoping showed that comfort station laterals in tact at every site in which they were inspected, and water quality monitoring near boat moorings all but eliminated illicit discharge from boats as a possible source of bacterial contamination to the Bay. In some instances, efforts from Phase I of the Study provided successful management action solutions that helped to eliminate suspected sources. While Phase I facilitated the elimination in number of suspected bacterial inputs to the Bay, the findings from Phase I did not address the origin of bacteria to the Bay. Thus, in the microbial source tracking task of Phase II of the Study we sought to learn the specific host animals from which the enteric bacteria in the receiving water originate.

In recent years, water quality managers and policy makers have begun to recognize the importance of developing methods to help the host origin of bacterial contamination (i.e., contamination from irrigation runoff, domestic pets/dogs, horses, birds and pleasure boats). Specific source identification for a particular watershed provides the most effective and direct means of implementing of BMPs. While early studies incorporated phenotypic methods for bacterial source identification of bacteria (i.e., multiple antibiotic resistance and carbon utilization profiles), several more accurate molecular genetic methods have recently emerged in the nascent field of microbial source tracking (MST). These methods include such techniques as rep-PCR, Host-Specific PCR, Ribotyping and PFGE (see Simpson et al. 2002 for review of current methods). A majority of case studies where such methods have been employed across North America and Europe have been successful in identifying sources of bacterial contamination (Bernhard and Field 2000a, Boehm et al. 2003, Kitts et al. 2002, Seurinck et al. 2003, Tippets et al. 2001).

For the microbial source tracking efforts during Phase II of this Study, the two leading molecular assays were chosen for the analysis of water at Mission Bay: the Library-based Ribotyping method and the Human presence/absence HS-PCR method (Griffith et al. 2003). Given the large size of Mission Bay and the great diversity of potential bacterial inputs, microbial source tracking efforts during Phase II of the Study required a site specific sampling regimen, including in some cases sampling in a seasonal fashion.

For our MST efforts that utilized the Ribotyping technique, a total of 1,097 receiving water *E. coli* isolates were analyzed. In Figure 22, the Ribotyping analyses for receiving water from all sites were combined. It is clear that the dominant source of enteric bacteria in the receiving waters of Mission Bay originate from birds. HS-PCR results strongly support these findings as well. Given that each site individually has a unique suite of bacterial contamination issues, a site-by-site discussion is presented below.

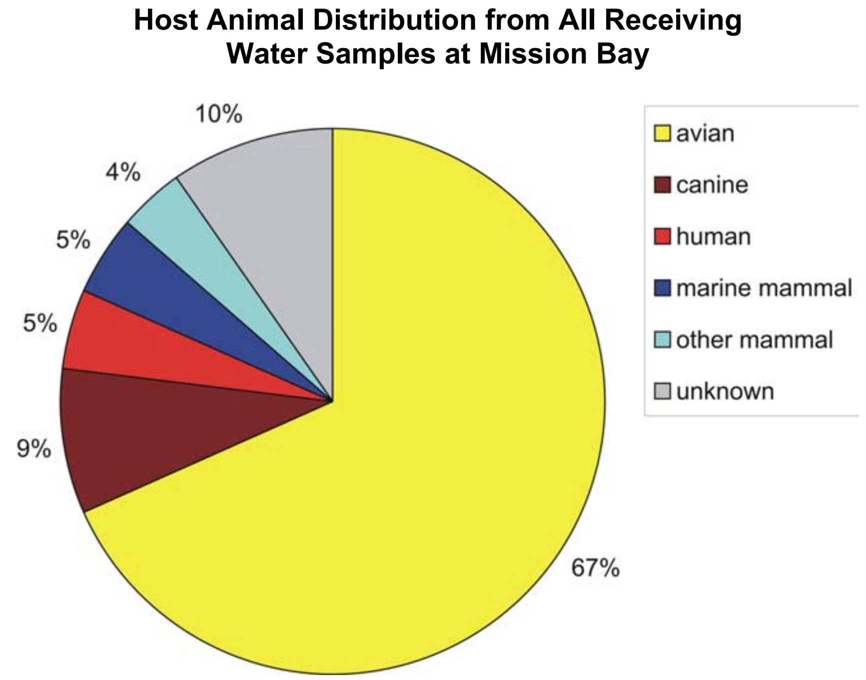


Figure 22. Results of Ribotyping analysis for the receiving waters of all sites studied at Mission Bay between July 2003 and March 2004.

Bonita Cove

Bonita Cove is somewhat unique in that there are no strong seasonal trends in densities of indicator bacteria in the receiving waters. While other sites at Mission Bay, mostly on the east side of the Park, experience significant seasonal changes in their bird populations, Bonita Cove seems to maintain a rather constant populace. Somewhat expectedly, we found that a majority (>74%) of the bacteria isolated from the Bonita Cove receiving waters were found to be of Avian origin. However, since Bonita Cove experiences dramatic increases in swimmer populations during Holiday weekends, it was somewhat unexpected that there was not a significant increase in the proportion of Human bacteria in the water samples collected during Holiday vs. non-Holiday sampling events. Results from the HS-PCR assay are consistent with these findings as well insofar as no samples tested positive for the Human *Bacteroides* marker.

A majority (>68%) of the bacteria isolated from Bonita Cove storm drain effluents was found to be contributed from Avian sources. These findings were not surprising given the fact that storm drain SD1-1 may be a mechanism for bacterial transport from irrigation run-off. When we compared the Ribotypes derived from the storm drain samples with those from receiving water samples, we found that 65% of the bacteria were in common. This connection strongly suggests that, in addition to direct deposition of feces to the receiving water by birds themselves, the storm drains can act as a constant supply of Avian-derived bacteria to the receiving waters at Bonita Cove.

Fanuel Park

At Fanuel Park, microbial source tracking performed only during the Dry season. Consistent with all other sites at Mission Bay, we found that a majority (69%) of the bacteria in the receiving water at this site was identified as having an Avian origin. While it was thought initially that such a high Avian bacteria level in the receiving water was due to the direct influence of birds at this site, we found a strong and unique connection between the storm drain bacteria. Specifically, 65% of the storm drain-derived isolates were found to match those isolates derived from the receiving water. It is important to note that the storm drain samples were taken from storm drain diversion structures that are not tidally influenced as opposed to other sites where storm drain samples were taken from the end of the storm drain. Thus, the connection observed between the storm drain and receiving water bacteria at Fanuel Park is unlike all other sites at Mission Bay. Here more than any other site the contribution of bacteria from the storm drain has a direct influence on the receiving waters.

Wildlife Refuge

At Wildlife Refuge, four potential nonpoint sources of bacteria (other than wildlife) presented themselves in Phase I: un-diverted irrigation run-off via storm drain SD5-2, groundwater transport of bacteria from ponded water on the grassy area of the park to freshwater springs on the beach face, direct swimmer input, and birds populating the beach. Storm drain SD5-2 was found to be plugged by sand during the Wildlife Refuge sampling events and was therefore determined to be non-influential. During the Fate and Transport Task, we found that groundwater taken from freshwater springs on the beach face at Wildlife Refuge (as well as all other sites at Mission Bay) to be virtually free of indicator bacteria; therefore, groundwater can not be acting as a mechanism for bacterial transport the receiving waters. Thus, we deduced that direct human input or bird waste on the beach were the most likely sources. To this end, we performed the HS-PCR analysis on receiving water samples taken from Wildlife Refuge. While 80% of the samples were shown to be positive for the General *Bacteroides* marker, only one single sample (5%) was found to contain the genetic marker for Human fecal contamination. Therefore, we can conclude that at Wildlife Refuge, bacteria from human sources does not play a significant role in the receiving waters at this site. However, since Ribotype analysis was not conducted at this site, we can only infer that the bacteria found here is due to direct input from wildlife sources.

Campland

Historically, Campland experiences a significant increase in bird population during the fall and winter months. Correlated with the increase in birds is an increase in fecal indicator bacteria levels in the receiving water. Therefore, in order to determine if there was a seasonal change in hosts for the bacteria input at Campland, sampling for microbial source tracking was separated into dry and wet weather seasons. During both seasons, we found that a majority of the bacteria in the receiving water was of Avian origin. Surprisingly, however, we found a higher incidence of bacteria from Avian sources during the dry season (79%) as opposed to during the wet season (69%). While Ribotype analysis of receiving water isolates obtained in the dry season indicated that only a very small proportion of the bacteria was of Human origin (4%), HS-PCR results suggested up to 33% of the samples were contaminated with Human feces. It remains possible that bacteria of Human origin may be the result of swimmer input, and that the difference in results is a consequence of sensitivity between the two MST techniques (see detailed discussion below for Leisure Lagoon).

De Anza Cove

De Anza Cove was also studied in a seasonal fashion. We found that during both the dry and wet seasons, a majority (64% dry, 80% wet) of the receiving water bacteria was from Avian sources. Interestingly, however, we observed a minor (9%) contribution of Human bacteria to the receiving water only during the dry season. It is unclear where these Human bacteria originated from as the storm drain effluents analyzed during the dry season showed only a very slight (4%, 2 out of 52 isolates) presence of Human bacteria. Nonetheless, the contribution of Human bacteria to the De Anza Cove receiving waters is only a minor proportion of the bacterial consortium at this site. A lack of significant Human contamination was confirmed by our HS-PCR analysis of both receiving water and storm drain samples, where all samples were found to be negative for the Human marker.

A comparison of the receiving water and storm drain Ribotypes derived from the Dry weather at De Anza Cove indicate a 41% overlap between the two. An even greater connection (55%) was observed when Wet weather receiving water and storm drain Ribotypes were compared. This strong connection between the Ribotypes suggests that, year-round, the storm drain effluents flowing to at De Anza Cove provide a constant means of conveying bacteria to the receiving water.

Visitor’s Center

Visitor’s Center is historically one of Mission Bay’s worst sites for exceedances in fecal indicator bacteria. As with every site at Mission Bay, we found that a majority (66%) of the bacteria in the receiving water stems from Avian sources. Unlike other sites, however, the potential bacterial inputs to the receiving waters at Visitor’s Center are rather complex.

The first potential nonpoint bacterial source at Visitor's Center is Cudahy Creek, which drains into the southern portion of the site. Isolates taken from Cudahy Creek effluent for Ribotype analysis indicated that, here too, a majority (66%) of the bacteria are of Avian origin. Interestingly, we found a 46% match between the bacteria identified in the receiving water at Visitor's Center and those found in the Cudahy Creek effluent.

The second input source at Visitor's Center is storm drain SD8-2. This storm drain is directly influenced by flow from a freshwater Spring located east of Interstate 5. Thus, when we combine the host origin data from the Spring and storm drain samples, we are left with a more accurate representation of the potential bacterial input to the Visitor's Center receiving waters. We found that, together, enteric bacteria from this source were comprised of two major host groups: Avian (49%) and Canine (27%). Strikingly, 64% of Visitor's Center receiving water Ribotypes were found to match those in the Spring/storm drain samples, suggesting a strong connection between the Spring/storm drain effluent and the receiving water.

Taken together, these data strongly suggest that the bacteria present in both Cudahy Creek and the storm drain have a direct influence to the receiving waters at Visitor's Center. It should also be noted that, during our *in vitro* investigations, unique conditions which simulate storm drain environments were identified that provide an ideal scenario for fecal indicator bacteria propagation. Similar re-growth conditions exist at Visitor's Center, providing yet another mechanism by which Cudahy Creek and storm drain SD8-1 can influence the receiving waters at this site.

Results from our HS-PCR analysis carried out on all water types at Visitor's Center (receiving water, storm drain, Cudahy Creek, and Spring) were all negative for the Human *Bacteroides* marker, which further supports a mechanism by which Cudahy Creek and storm drain SD8-1 directly convey Avian-derived bacteria to the receiving waters at this site.

Leisure Lagoon

While the majority (46%) of *E. coli* isolates found in the receiving water at Leisure Lagoon were shown to be of Avian sources, it is interesting to consider the possibility that input from human sources may play a significant role at this site as well. First, results from Phase I suggest that the young children swimmer population during summer months at Leisure Lagoon is exceedingly high, indicating that Leisure Lagoon may be the most susceptible site at Mission Bay to human contamination via direct swimmer input. While this first point is suggestive, our recent Microbial Source Tracking data may be interpreted as more direct. It has recently been proposed that acquiring proper Human Ribotype representation in the Ribotype Library Database may be an insurmountable task (M. Samadpour, personal communication) given the enormous diversity in human cultural traditions, culinary preferences, and geographical mobility. Thus, the unusually large Leisure Lagoon "Unknown" group found in the receiving water may indeed be comprised of Human Ribotypes which are simply not present in the Institute for

Environmental Health's Source Ribotype Library Database. It should be noted that the receiving water samples taken at Leisure Lagoon produced, overwhelmingly, the largest "Unknown" group in the entire study. It is also noteworthy to mention that no Human Ribotypes were found in the storm drain samples, further support of a mechanism by which young swimmers contribute fecal contamination directly to the receiving waters at this site.

Additional direct evidence of human fecal contamination in receiving waters at Leisure Lagoon is illustrated by results of the HS-PCR analysis, which showed that nearly half of the samples which were positive for the General *Bacteroides* positive samples were also positive for the Human marker (see above, Figure 21). It should be noted that this site and Campland were the only sites examined over the course of the Study that yielded significant HS-PCR Human positive results.

It should be emphasized once again that while the arguments presented above provide strong suggestive evidence that indicates that a significant proportion (up to 34%) of the *E. coli* isolated from the receiving waters at Leisure Lagoon may be contributed by direct swimmer input or other Human sources, the majority of bacteria is of an Avian origin (46%).

CONCLUSIONS

The molecular genetic techniques employed throughout the Microbial Source Tracking Task provide us with the most direct and accurate insight as to the host origin of enteric bacteria found in the many water types sampled at Mission Bay. Results from both MST methods utilized in Phase II helped to confirm the suspicion raised in Phase I that birds were the leading source of bacteria to Mission Bay. The wealth of data generated from the MST portion of the study, however, allows us to draw unique conclusions for each site examined as presented below.

Bonita Cove – A majority of the bacteria isolated from the receiving water at Bonita Cove was of Avian origin, and no difference was found between Holiday versus non-Holiday samples. A large percentage of the bacteria isolated from the storm drains at this site matched the bacteria isolated in the receiving water, suggesting that the storm drains convey these bacterial strains in addition to direct deposition from birds themselves. No significant human contamination was observed.

Fanuel Park – Avian sources were identified for a majority of the bacteria isolated from the receiving waters at Fanuel Park. A majority of the bacteria isolated from the storm drain samples at this site was also of Avian origin. Given the unique configuration of the storm drain system at Fanuel Park, the connection between the bacteria in the receiving water and the bacteria in the storm drain is much more direct than other sites; therefore, the storm drains are believed to be a direct source of bacteria to the receiving waters. Significant human contamination was not observed at Fanuel Park.

Wildlife Refuge – While receiving water samples at Wildlife Refuge were found to be contaminated with fecal bacteria, they were not found to contain a significant proportion of human contamination.

Campland – A majority of the receiving water bacteria was contaminated with bacteria of Avian origin, and the proportion of Avian bacteria did not change between the dry weather and wet weather surveys. While the Ribotyping technique did not implicate Human sources during the wet weather or dry weather surveys, Human contamination was detected during dry weather by the HS-PCR assay. Therefore, human sources remain a possibility at the receiving water at Campland.

De Anza Cove – A majority of the receiving water bacteria was contaminated with bacteria of Avian origin, both during wet and dry weather monitoring. A connection between the storm drain bacteria and the receiving water was made, and this connection was observed to be slightly higher during the wet weather survey. The connection suggests that the storm drains at De Anza Cove can act as a bacteria source to the receiving waters. Human contamination was not observed in storm drain samples collected from De Anza Cove.

Visitor's Center – A majority of the receiving water bacteria at Visitor's Center is of Avian origin. Two drainage sources surveyed were found to also be contaminated with a large percentage of Avian-derived bacteria: the Spring/storm drain effluent and the Cudahy Creek effluent. A significant proportion of the bacteria from the receiving water at Visitor's Center matched bacteria from these effluent sources, suggesting that these effluents can have an effect on the receiving waters. No significant Human contamination was observed at Visitor's Center.

Leisure Lagoon – A majority of the receiving water was contaminated with Avian-derived bacteria. However, the host origin of a significant percentage of the bacteria could not be identified due to suspected limitations of the Ribotyping assay. The HS-PCR method, on the other hand, suggests that a significant proportion of the samples were contaminated with Human bacteria. Only a modest connection between the receiving water bacteria and the bacteria present in the storm drain at Leisure Lagoon was observed. Thus it remains a formal possibility that Human bacteria was contaminating the receiving waters at the time of the study from sources other than the storm drain.

RECOMMENDATIONS

The results of the Molecular Source Tracking Task indicate that the majority of the enteric bacteria in Mission Bay originates from birds and that contributions of bacteria from human origin are insignificant. Because little can be done about the number of birds in Mission Bay, we believe that the most effective management solutions in reducing indicator bacterial densities should focus on four areas where we believe the initial load generated from avian sources can be amplified:

1. intertidal sediments,
2. the wrack line,
3. irrigation runoff, and
4. storm drains.

Intertidal Sediments

There are relatively few management actions related to intertidal sediments that have been implemented to reduce loading of indicator bacteria on the beach. At Campland, simply removing the fecal matter from the beach face proved to be a very effective means of reducing indicator bacterial densities in the receiving waters. However, this type of program is very labor intensive and likely impractical on a large scale. In addition, replacing the sand on the beach is likely impractical, as studies have shown that bacterial densities can return to initial levels within two weeks of sand replacement. Since we know of no BMPs that have been applied specifically to reducing bacterial densities in intertidal sediments, we believe that creative BMPs should be designed and tested to determine their ability to reduce bacterial loading in this area. For instance, grooming practices should be evaluated to assess their effectiveness in reducing bacterial loads on the beach. Initial work conducted on beaches in the Great Lakes region suggests that bacterial densities in beach sediments increase after certain types of grooming.

The results of the MST study in Mission Bay, the sediment investigation, and the laboratory study suggest that sediments in the lower intertidal zone are less likely to contain elevated indicator bacterial densities partially because bacterial survival is limited by the effects of seawater. Thus, one possible way to reduce bacterial densities in the upper intertidal sediments is to periodically spray that area with seawater during the grooming process. This procedure is likely to be most effective during neap tides when the upper intertidal zone is exposed to bird feces for the greatest period of time. To our knowledge, this type of BMP has never been initiated and would thus require monitoring to assess its effectiveness.

Wrack Line

Accumulation of organic debris that forms the wrack line is a persistent phenomenon in Mission Bay. The results of the wrack line study suggested that the wrack acts as a bacterial reservoir that maintains the initial load for prolonged periods of time before releasing it back to the receiving waters. This process is likely to be most problematic on the east side of Sail Bay (Fanuel Park and Riviera Shores) and the east side of Mission Bay (primarily De Anza Cove to Visitor's Center), although wrack accumulates at all sites to a limited extent. Since the origin of the bacteria in the wrack is predominantly Avian, it is possible that this process had some influence on the results from the receiving water samples collected as part of the MST study. Thus, removal of the wrack from the beach face in Mission Bay would likely be an effective means of reducing indicator bacterial densities in the receiving water. We believe removal of the wrack during neap tides would be the most efficient way to manage this problem. However, as with the recommendations made for the intertidal sediments above, beach grooming practices utilized by the City should be evaluated to determine their effectiveness in reducing bacterial densities in the intertidal zone. For instance, one grooming practice currently in place utilizes a rake structure that tends to grind the wrack into the sediment rather than removing it, thus leaving the source of the bacteria on the beach. Other, more effective means of removing the wrack line should be considered and evaluated.

Irrigation Runoff

The results of the Fate and Transport study indicate that there is a large reservoir of bacteria in the upper soil strata within the grassy areas of Mission Bay Park. MST techniques established that the origin of that bacteria is Avian. Although the Fate and Transport study indicates that the bacteria are not impacting the receiving waters via groundwater transport, the potential exists for other transport mechanisms, such as soil erosion and excess irrigation. In Phase I of the Mission Bay Bacterial Source Identification Study, excessive irrigation at several sites was shown to be a potential bacterial transport pathway from the park to the bay receiving waters. The excess irrigation water transported bacteria to the bay through storm drains (downstream of the Mission Bay Sewage Interceptor System) and via overland transport, which results in erosion of the banks. To prevent bacterial transport via these mechanisms, the following actions are recommended to the City.

To the extent possible, reduce excessive irrigation throughout the park to eliminate or minimize flow to the bay from the storm drains. This might be accomplished through a variety of turf management techniques, such as redirecting sprinklers to prevent overflow to the gutters, installing sensors to assess the water content of the soil, and automating the sprinkler system to increase watering efficiency.

Minimize erosion by maintaining stable banks. This could be accomplished by reducing excessive irrigation as mentioned above, fixing and maintaining sprinkler heads near banks where erosion occurs, and eliminating flow from concrete ramps associated with park comfort stations. In areas where bank erosion is particularly problematic, permanent edge structures could be installed to further prevent erosion.

Storm Drains

The most common source of indicator bacteria to the receiving waters of Mission Bay identified in this two–year study was storm drain effluent. Storm drains were determined to be a potential source of bacteria at several sites examined, although at some sites such as Bahia Point their impact has been minimized. Storm drain runoff was found to be particularly problematic at Bonita Cove, Fanuel Park, Wildlife Refuge, De Anza Cove, Visitor's Center, and Leisure Lagoon. At all of these sites, except Leisure Lagoon and Bonita Cove, the problematic storm drains are part of the MBSIS. However, several mechanisms were identified through the course of this study that indicate that these storm drains convey indicator bacteria to the receiving waters, including:

1. poor maintenance of storm drain diversion structures,
2. bacterial amplification that occurs within the storm drains and diversion structures.
3. bacterial influx downstream of the diversion system, primarily from irrigation runoff, and

Proper maintenance of the storm drains and storm drain diversion structures is the most important recommendation that we have for the City for reducing bacterial loads from the storm drains to the receiving waters of Mission Bay. During Phase I of this study, numerous storm drain diversion structures (tide flex valves, check valves, etc.) were found to be broken or completely dysfunctional. In most cases, this allowed organic debris from the bay to be deposited in the diversion vaults, creating an environment conducive to the growth of indicator bacteria, which we have shown to be dramatic. In addition, when the diversion vaults are not properly cleaned, the diversion structures can be rapidly overwhelmed, allowing un-diverted water from the watershed to flow directly to the bay. Thus, the importance of proper maintenance of the MBSIS in reducing bacterial loads to Mission Bay can not be over-emphasized.

In addition to proper maintenance of the storm drains, we believe that the City should consider installing tide gates (or other similar hardware) at the ends of the storm drains to prevent bay water from entering the storm drain system during high tides. The monitoring results of Phase I and the results of the laboratory follow-up study conducted as part of Phase II showed that even storm drains that are not part of the MBSIS (such as SD9-2 at Leisure Lagoon) can act as bacterial amplifiers. The influx of organic debris and water from the bay combined with the environmental conditions inside the storm drains can produce dramatic growth of indicator bacteria. Preventing the influx of organic debris to the storm drains would likely be an effective means of minimizing this process. Tide gates are in place at some sites on the west side of Mission Bay and are currently being installed on storm drains in the lower San Diego River drainage. We recommend that these systems be assessed as potential models for storm drains throughout Mission Bay.

The results of this two-year study and on-going monitoring conducted by the City indicate that the storm drains that convey the most indicator bacteria to Mission Bay are storm drain SD8-1 and Cudahy Creek located at Visitor's Center. Both these storm drain systems have a continual flow of freshwater that contains high densities of indicator bacteria. The results of the MST Task indicate that runoff from these storm drains impacts the bacterial densities in the receiving water at Visitor's Center. One problem associated with these storm drains is that the diversion structures are located on the east side of Interstate 5. Although inspections of the diversion structures indicate that they typically function properly in diverting dry weather flow to the sewer system, there is a large influx of freshwater from the upstream watershed and organic debris from the bay that enters the storm drain system downstream of the diversion structures. This combination produces a large amount of bacteria that is subsequently conveyed to the bay. We recommend that the City consider installing secondary diversion structures on the west side of Interstate 5 (i.e., within Mission Bay Park) for both these storm drain systems to divert the flow that is produced between the diversion structures currently in place and the bay. These secondary diversion structures combined with tide gates or other exclusion systems at the ends of the storm drains would be an effective means of reducing the flow from these storm drains to Mission Bay. Alternative engineering solutions should also be considered. The results of this study suggest that if the dry weather effluent from these storm drains is not addressed, reducing bacterial densities in the receiving waters of Visitor's Center is unlikely.

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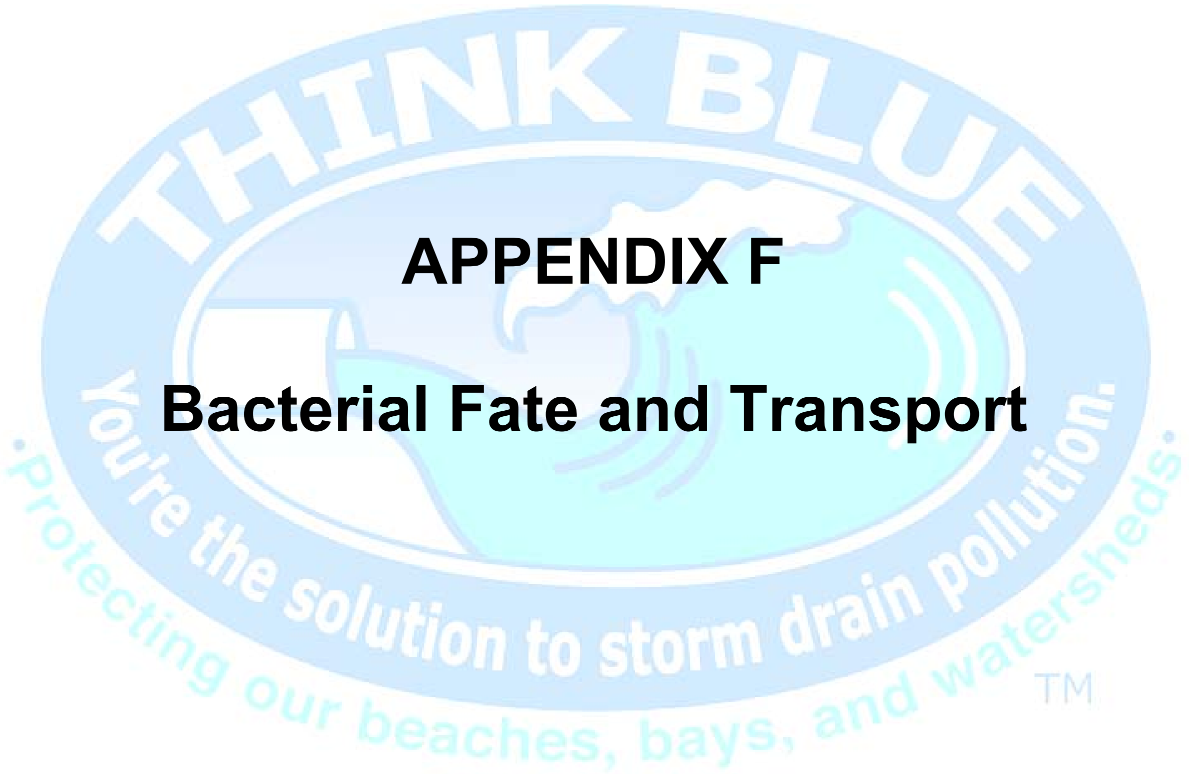
APPENDIX F

Bacterial Fate and Transport



FINAL
Interim Report for

Mission Bay Clean Beaches Initiative Bacterial Source Identification Study (Phase II)

Bacterial Fate and Transport

Prepared For:

State Water Resources Control Board
1001 I Street
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INTRODUCTION

Project Overview

The Mission Bay Bacterial Source Identification Study was designed to identify sources of bacterial contamination in Mission Bay and recommend appropriate actions and activities to eliminate the input of those sources to the bay receiving waters. The study is being conducted in two phases. The first phase was completed at the end of June, 2003 and Phase II was completed 12 months later.

Three major questions emerged from Phase I that were identified for assessment in Phase II to understand the nature and sources of bacteria in Mission Bay:

1) What is the origin (human, avian, etc.) of high bacterial levels measured in Phase I?
2) How much bacteria is transported from the grass surface of Mission Bay Park to the bay via groundwater?
3) Is sediment in Mission Bay serving as an on-going source of bacteria in the water column through re-suspension?

Three investigative tasks were identified in Phase II to complete this project. In the scope of the overall project, these tasks have been designated Investigative Tasks 4, 5, and 6:

Investigative Task 4. Identify the origins of bacteria using molecular bacterial source tracking (BST);

Investigative Task 5. Investigate the transportation mechanisms of bacteria from the surface of Mission Bay Park to the bay receiving waters (i.e., fate and transport study);

Investigative Task 6. Investigate bacteria levels in sediments at the bay's major depositional areas.

This report summarizes Task 5, bacterial fate and transport.

Historical Background

There is increasing research on the fate and transport of pathogenic microorganisms related to environmental and public health concerns (Lo et al. 2002, Abu-Ashour et al. 1998, Sinton et al. 1997). Numerous studies have demonstrated that bacteria are transported via groundwater from areas of intensive deposition (e.g., livestock operations and septic tank leach field) to local surface waters (Lo et al. 2002, Viraraghavan and Ionescu 2002, Jenkins et al. 1994, Joy et al. 1998). Moreover, tracer studies have demonstrated that human enteric pathogens are capable of moving rapidly from septic tanks into nearby coastal waters, particularly in areas with sandy soils (Harvey and George 1989, Lipp et al. 2001, Paul et al. 1995). Movement of pathogens from depositional areas to surface waters may be particularly high during wet seasons when seasonal recharge results in an elevated water table (Cable et al. 1997). In coastal areas, tidal influences result in daily fluctuations in groundwater levels (Li and Barry 2000, Sun 1997, Inouchi et al. 1990), which may facilitate the transport of microbes that are able to penetrate the subsurface during saturated conditions (Bicki and Brown 1991).

Many of the conditions described in the studies that facilitate the groundwater transport of microorganisms to local surface waters are found at several sites in Mission Bay. One of the most striking results of the Visual Observations Task of Phase I was the high bacteria levels that were observed in the grassy areas of Mission Bay Park surrounding the bay. Water samples taken from grassy areas within the park (i.e., puddles from irrigation) exceeded AB411 criteria at all sites where a sample was collected. These beaches included Bonita Cove, Bahia Point, Wildlife Refuge, De Anza Cove, Visitor's Center, Leisure Lagoon, North Pacific Passage, and Tecolote Creek. Bacterial levels from samples taken directly from the sprinkler heads were very low at all of these sites, except Bonita Cove and De Anza Cove, where no sprinkler sample was taken. The analytical results were typically at or just above the detection limit. However, bacteria levels in ponded irrigation water in the grassy areas adjacent to the sprinkler head were typically very high. In most cases, ponded water adjacent to the sprinkler head had enterococcu*s* levels of approximately 1,000 MPN/100 mL, whereas the AB411 criteria for enterococcus is 104 MPN/100 mL. As water from the sprinklers moved across the grass towards the storm drains, bacterial densities increased one to two orders of magnitude. The extent to which these bacteria are transported to the bay receiving waters is unclear. During the Visual Observations Task, there was some evidence of sheet transport of irrigation water from the grassy areas of the park directly to the bay (i.e., eroded banks). However, most grassy areas of the park were wet from irrigation on all days of observation, even during late afternoon shifts well after lawn irrigation was completed. The combination of high bacterial levels in the grass, a moist environment from irrigation, sandy soils, and shallow groundwater suggest that bacteria may be conveyed from the park to the bay receiving waters via groundwater transport. In this way, some sites in the bay may act similarly to leach fields associated with septic systems with regard to bacterial transport.

Study Objectives

The primary goal of this study was to determine if bacteria are being transported from the grassy areas of Mission Bay Park to the receiving waters of the bay via groundwater. Two types of assessments were conducted:

1) An assessment of bacterial densities in soil beneath the grassy areas of Mission Bay Park; and
2) An assessment of bacterial densities in groundwater at the same locations and at the beach face springs.

MATERIALS AND METHODS

Site Locations

There are several locations along the east side of the bay where groundwater exfiltration sites (springs) have been observed along the beach face. These areas were targeted for sampling because they are the most likely places where bacteria in groundwater (if present) will be transported to the bay receiving waters. Fate and transport studies were conducted at the following three sites (Table 1, Figure 1): De Anza Cove, Visitor's Center, and Leisure Lagoon. These sites were chosen because they all have grassy areas where high bacterial levels were measured in Phase I and they have groundwater springs on the beach face adjacent to these areas. If bacteria is being transported from Mission Bay Park to the bay receiving waters via groundwater springs, it is most likely to occur at these sites.

Table 1. Sampling sites and descriptions for Mission Bay fate and transport study.

Site Number	Site Name	Site Description	Lat.[2]	Long.
7	De Anza Cove	Along the east side of the Cove between storm drains SD7-2 and SD7-3	32.7933N	-117.2117W
8	Visitor's Center	South of Visitor's Center building between storm drain SD8-1 and Cudahy Creek	32.7883N	-117.2100W
9	Leisure Lagoon	Along the east side of the Lagoon near storm drain SD9-2	32.7850N	-117.2083W

[1] County of San Diego Department of Environmental Health
[2] GPS coordinates are in decimal degree format (HDDD.DDDD) and NAD 83 datum

Figure 1. Map of Mission Bay. Sampling sites for the Fate and Transport Study are De Anza Cove (Site 7), Visitor's Center (Site 8), and Leisure Lagoon (Site 9).

Sampling Protocol

Well Installation

At each of the three sites, a series of three wells was drilled along a transect in line with the beach face spring, perpendicular to the bay receiving waters (Figure 2). Well 1 was positioned 25 feet from the edge of the grass/sand interface, Well 2 was positioned 12.5 feet from the edge of the grass, and Well 3 was positioned at the edge of the grass adjacent to the beach face.

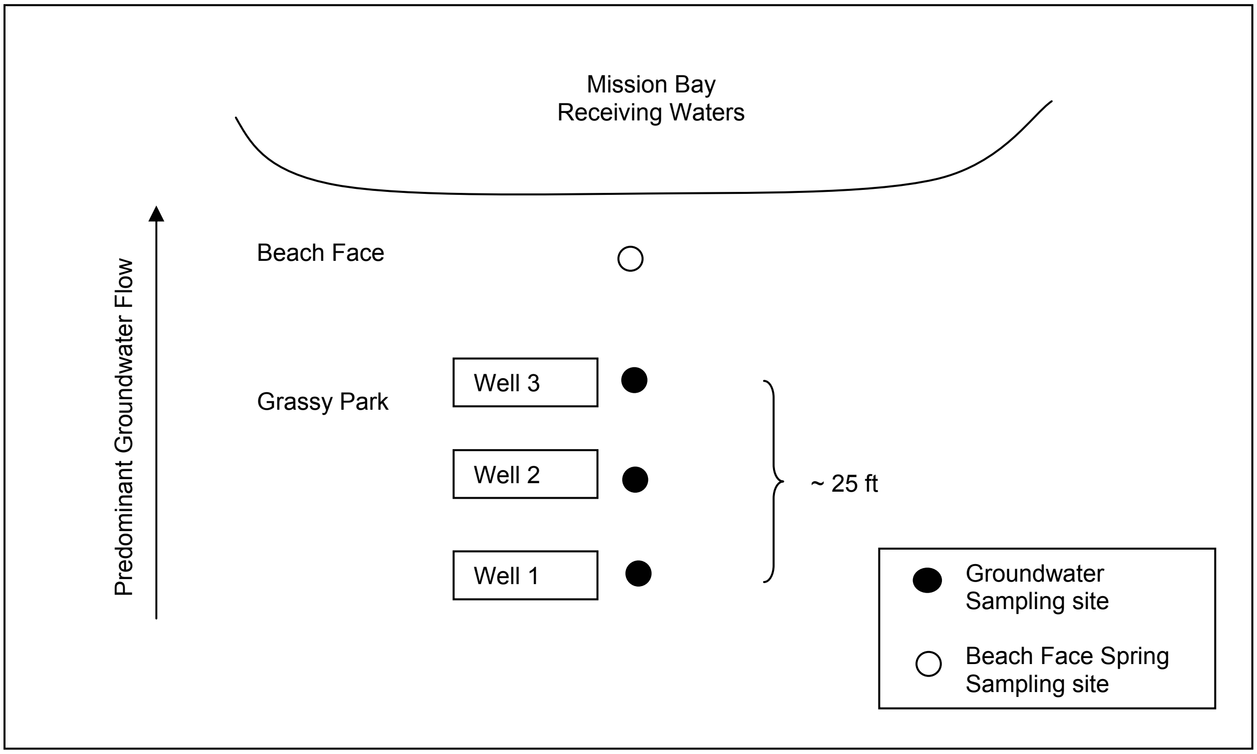


Figure 2. Plan view schematic showing fate and transport sampling array.

Drilling groundwater wells.

The wells were drilled using a 3-inch auger and a hammer drill powered by a portable generator. Each well was drilled to a depth of ten feet. Once the desired depth was reached, the auger was removed and a small, sterile, approximately one inch long, stainless steel, screened probe (AMS, American Falls, ID, part #211.00) was inserted into the soil an additional two feet using a push rod and slide hammer. The upper end of the probe was attached to a length of 3/16 inch sterile plastic tubing, which was inserted inside the push rod and protruded above the surface of the ground. The lower end of the push rod covered the screened portion of the probe as it was being inserted into the soil. Once the probe had reached the final depth of 12 feet, the push rod was removed, leaving the probe at a depth of 12 feet connected to sterile tubing that extended up to the surface of the ground. After the first probe was inserted, approximately six inches of fine-grained sand was poured on top of it, followed by six inches of bentonite clay, followed again by an additional six feet of sand. The bentonite forms a hydraulic seal, which prevents water from entering the probe from above. Two additional probes were inserted similarly in the same hole at depths of 7 and 4 feet below the surface of the ground. In this way, groundwater probes were set at three discrete depths in each of three wells at each site (Figure 3). The tubing from each probe that protruded above the surface of the ground was marked with the appropriate depth.

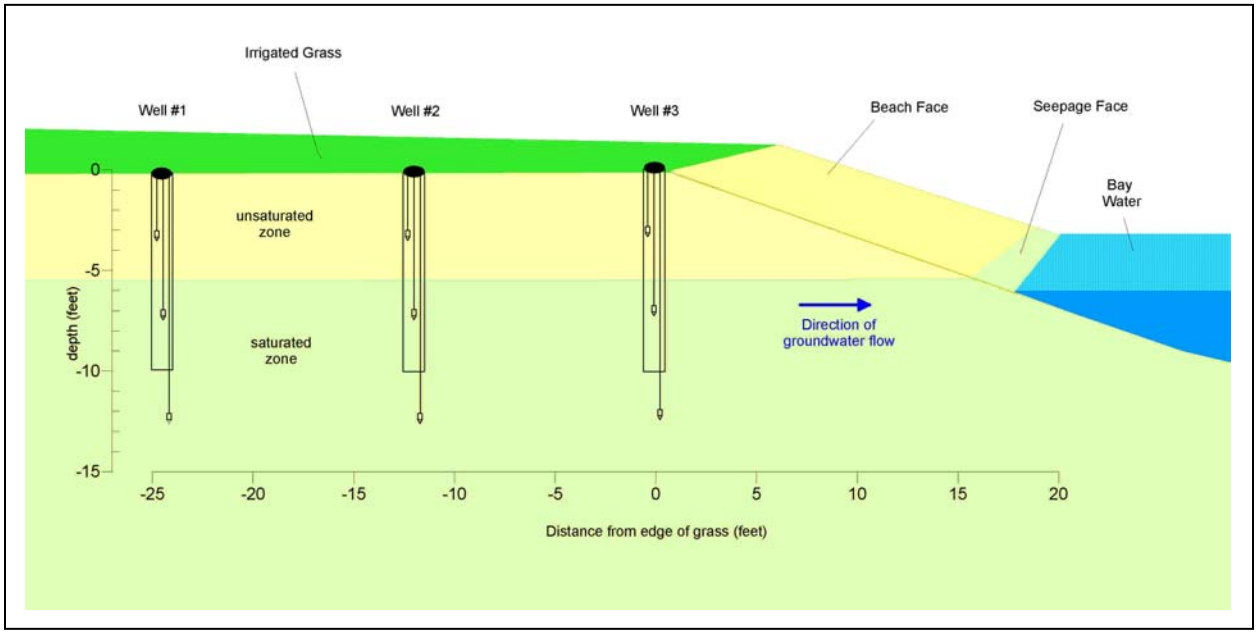


Figure 3. Elevation view schematic showing fate and transport sampling array.

To extract the groundwater, tubing from each of the groundwater wells was inserted into a short length (approximately 10-inches) of sterile, flexible tubing (0.25-inch outside diameter). The flexible tubing was inserted into a battery-operated peristaltic pump (Geotech, Geopump 2) for water extraction. At depths where groundwater could be extracted, the lines were initially purged for at least two minutes prior to taking a sample to remove any sediment or organic material present around the sampling probe. Groundwater was then pumped directly into 100-mL sterile sample bottles, capped, and labeled with the appropriate site and depth information. All samples were kept in a cooler on ice for transport to the laboratory for bacterial analyses. After the samples were collected for bacterial analyses, an additional sample was collected for water quality. In the field, the water quality samples were analyzed for pH and temperature using a hand-held water quality meter (Oakten water quality meter, model # WD-35630-62). The water quality samples were then brought back to the laboratory and analyzed for salinity using a bench top salinity meter (Orion salinity meter, model # 142).

In addition to the samples extracted from the wells, groundwater was also sampled from the beach face spring at each site. Groundwater samples from the beach were taken approximately ten feet above the top edge of the spring, measured along the beach face, at a depth of 12 to 24 inches below the surface of the beach face. Samples were taken using a four-foot long, 0.5 inch diameter sampling rod connected to a six inch long, sterilized probe (AMS, Inc., American Falls, ID, part # 210.01). At the bottom of the probe is a 1.5-inch long pointed, conical tip for insertion into the ground. The probe encases a retractable sampling port surrounded by a stainless steel screen. The top of the sampling port is connected to an eight foot length of 3/16 inch sterile tubing that was inserted inside the sampling rod and out the top.

Beach spring groundwater sampler showing screened, retractable sampling port

To take a groundwater sample, the probe was inserted to the appropriate depth with a slide hammer. Then, the rod was pulled up approximately two inches, exposing the screened sampling port. The tubing from the top of the sampling rod was inserted inside a short length (approximately 12 inches) of sterile, flexible tubing and samples were collected with a peristaltic pump as described above.

Groundwater sampling from beach face spring

Soil Cores

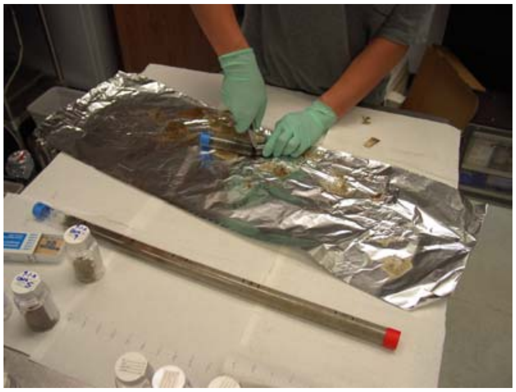

Push core soil probe with sterile butyrate liner

In addition to the groundwater monitoring wells, two soil cores were also taken at each site adjacent to Wells 1 and 3. The cores were taken with a 24-inch long chrome plated push core soil probe (AMS, Inc., American Falls, ID, part # 424.23) fitted with a cross handle and sterile butyrate liner. The sampler was pushed manually through the turf and into the soil to a depth of approximately eight inches. A slide hammer was then used to pound the sampler to a depth of approximately 22 inches below the ground surface. The sampler was then extracted from the soil and the liner containing the soil core was removed using sterile technique, capped on both ends, and labeled with the appropriate site information. After extraction, the cores were kept on ice in a cooler for transport to the laboratory.

Laboratory Analyses

Water samples from the park and beach groundwater probes were analyzed at the MEC Analytical Systems Microbiology Laboratory in Carlsbad, California. Fecal coliform bacteria were enumerated using multiple tube fermentation based on Standard Methods 9221B&E. Enterococcus bacteria were enumerated using a chromogenic technique (Enterolert), based on Standard Method 9223. All samples were analyzed within six hours of extraction.

The soil cores were also processed at the MEC Microbiology Laboratory. In the laboratory, the cores were visually inspected for distinct soil strata. The strata were delineated with a marker, numbered, photographed, and catalogued with a visual description of the color, consistency, and depth from surface of each stratum in the core. Four to five strata were identified in all the cores. A sterilized utility knife was then used to cut the cores at each of the identified strata so that representative soil samples from each stratum could be removed for three separate analyses: bacterial indicators, moisture content, and soil grain size. The soil extracted for bacteria and moisture content analyses (typically 30 – 60 grams each) were placed into separate, sterile, pre-weighed, 100-mL


Processing cores in the laboratory

plastic bottles labeled with the appropriate site and soil strata information. The soil extracted for grain size assessment was placed into a labeled plastic bag.

For the bacterial analyses, the weight of the sample bottle was subtracted from the total weight of the sample bottle and the sediment to determine the sediment wet weight. A total of 50-75 mL of sterile dilution water (phosphate buffered saline) was then added to the weighed sample, shaken, and allowed to settle for 2 minutes. The bacteria suspended in the overlying water was then extracted and analyzed for fecal coliform and enterococcus densities as described above for groundwater samples. The results of the initial assessment were in units of MPN/100 mL of sample; however, because only 50-75 mL of water was used in the initial dilutions, the result was multiplied by this factor to correct for the amount of water used. The MPN result was then divided by the weight of sediment tested to yield results in bacteria per gram wet weight.

To determine the moisture content of the sample, the representative section of the core was added to a pre-weighed porcelain dish and weighed. The weight of the dish was then subtracted from the total weight to determine the wet weight of the sediment. The sediment and dish were dried in an oven overnight at 80º C and re-weighed. The weight of the dish was then subtracted to determine the dry weight of the sediment. The dry weight was subtracted from the wet weight to determine the percentage of dry sediment to the overall sediment. This percentage was multiplied by the initial bacterial count of the sample to produce the final result in bacteria MPN per gram of dry sediment.

Sediment grain size was analyzed using a technique employed by Plumb (1981) based on procedures for Handling and Chemical Analysis of Sediment and Water Samples.

The host origin (human, avian, etc.) of the bacteria found in puddles in the grassy areas of Mission Bay Park was determined using a ribotyping technique. To perform the ribotyping analysis, water samples from ponded water or grassy puddles were collected from Bonita Cove and Tecolote Creek using a 60cc sterile syringe. Puddle water samples were transported to the MEC laboratory on ice where they were then processed as follows: 1mL, 5mL and 25mL aliquots of puddle water was concentrated onto .45uM, 47mm sterile membrane filters (Millipore Corporation) using a Microfil Filtration vacuum manifold system (Millipore Corporation) connected to a vacuum pump. Membrane filters were placed in 47mm Petri dishes with absorbent pads (Millipore Corporation) pre-soaked in Coliscan MF media according to the manufactures directions (Micrology Laboratories). Plates were allowed to grow at 44.5º C overnight in a conventional air incubator, and blue colonies were scored as *E. coli* according to the manufactures specifications. *E. coli* isolates derived from concentrated puddle water plates were grown in liquid culture and genomic DNA was extracted according to the protocols developed by a contractor at the University of Washington. These DNAs were then analyzed by the ribotyping assay. Resultant ribotypes were then assigned an identifier code and ribotype matching analysis was performed against the University of Washington's General ribotype Library.

RESULTS

Groundwater Monitoring

At each site, samples were collected from the groundwater wells three times during an ebbing spring tide. Wells at Visitor Center and Leisure Lagoon were monitored on March 18, 2004 and wells at De Anza Cove were monitored on March 19, 2004. At each site, samples were attempted from each of the three depths per well a total of three times (i.e., a total of 27 sampling events per site). In addition, a groundwater sample was also taken from the beach spring at the same times the wells were sampled. Sampling times covered approximately one half of a tidal cycle during an ebbing spring tide. In estuarian conditions such as Mission Bay, this part of the tidal cycle has been shown to produce the greatest overheight of the groundwater above the still water of the bay, resulting in maximal groundwater flow towards the receiving waters (Nielsen 1990, Kang et al. 1994, Jackson et al. 1999).

The sampling times are shown graphically in Figure 4. Groundwater could not be obtained at any of the sites from the probes located four feet below the surface. Apparently, the saturated zone is below this depth. At depths of 7 feet and 12 feet, groundwater was pumped easily to the surface at a rate of approximately 150 to 500 mL/min. In all cases, the extracted water appeared clear after the initial purge.

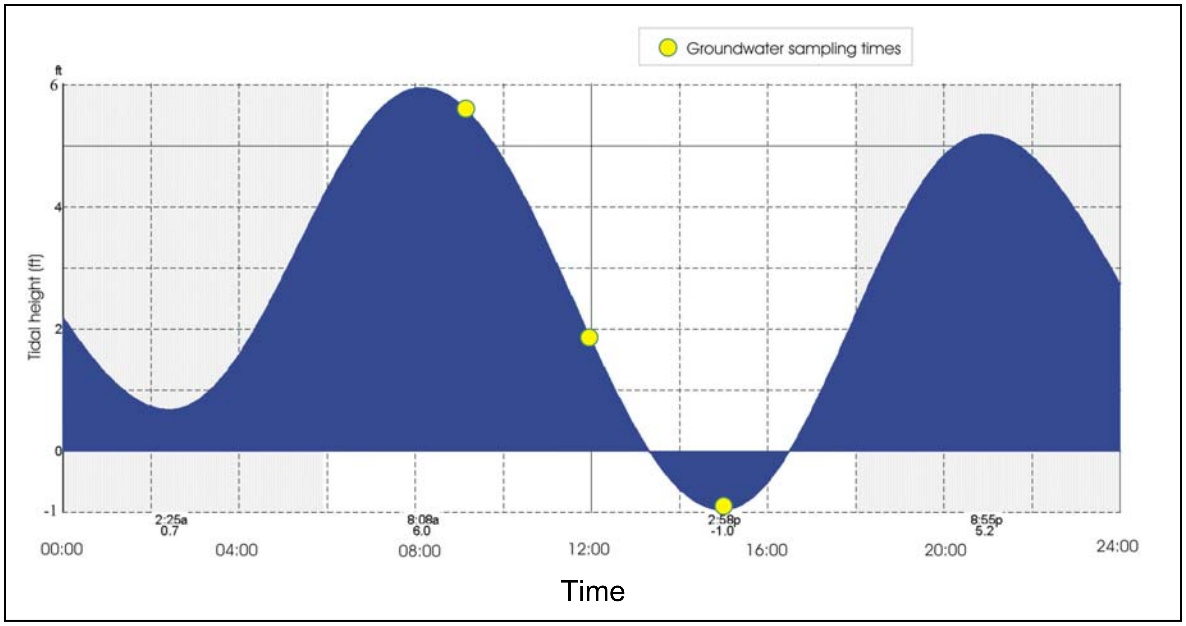


Figure 4. Groundwater sampling times during ebbing spring tide.

Bacterial densities were very low in all of the samples collected (Tables 2 through 4). At Visitor's Center, there was only one sample that tested positive for fecal coliforms (Well 1 at 12 feet at 1200 hrs) and this density was at the detection limit of 20 MPN/100 mL (Table 2). Enterococcus densities were also low at Visitor's Center. Four samples had enterococcus densities that exceeded the detection limit of 10 MPN/100 mL, ranging from 10 to 41 MPN/100 mL. All of these samples were collected from the 7-foot sampling probes and three of the four occurred at Well 3, closest to the beach. Groundwater salinity at Visitor's Center was fairly constant throughout the study period, ranging from 1.1 to 1.4 parts per thousand (ppt) at seven feet below the surface and from 7.8 to 8.7 ppt at 12 feet. The higher salinity values at the 12-foot depth most likely reflect saltwater intrusion from Mission Bay. Lower salinity values at 7 feet suggest the presence of a freshwater lens on top of the more saline groundwater below it. In contrast to salinity, values of groundwater pH and temperature did not show any patterns of stratification. Groundwater pH values at Visitor's Center ranged from 7.33 to 7.86 at all depths and groundwater temperature ranged from 18.3 to 18.9° C at all depths. None of the groundwater samples taken from the beach spring contained indicator bacteria. Values for salinity, pH, and temperature from the beach spring groundwater were all slightly higher than the corresponding values in the park groundwater samples, likely reflecting the influence of bay water mixing with groundwater.

Table 2. Results of groundwater sampling at Visitor's Center. For each well, sample collection was attempted three times (0900, 1200, and 1500 hr) at each depth (4, 7, and 12 feet). Bacterial densities in red were greater than the detection limit, nd = no data available.

Depth (feet)	Sample Time	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	Salinity (ppt)	pH	Temperature (degrees C)
WELL #1 (25 feet from beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	1.3	7.47	18.4
12	0900	<20	<10	8.7	7.65	18.8
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	1.3	7.26	18.4
12	1200	20	<10	8.1	7.54	18.3
4	1500	nd	nd	nd	nd	nd
7	1500	<20	<10	1.3	7.81	18.7
12	1500	<20	<10	7.8	7.84	18.7
WELL #2 (12.5 feet from beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	1.2	7.38	18.1
12	0900	<20	<10	8.2	7.33	18.6
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	1.1	7.65	18.5
12	1200	<20	<10	7.9	7.86	18.5
4	1500	nd	nd	nd	nd	nd
7	1500	<20	41	1.1	7.22	18.3
12	1500	<20	<10	7.8	7.43	18.9
WELL #3 (adjacent to beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	10	1.4	7.72	18.4
12	0900	<20	<10	8.4	7.67	18.4
4	1200	nd	nd	nd	nd	nd
7	1200	<20	10	1.1	7.34	18.7
12	1200	<20	<10	7.8	7.29	18.8
4	1500	nd	nd	nd	nd	nd
7	1500	<20	20	1.2	7.87	18.3
12	1500	<20	<10	7.9	7.41	18.9
SPRING (at Beach Face)						
Beach	0900	<20	<10	11.2	7.96	18.3
Beach	1200	<20	<10	10.6	8.02	19.6
Beach	1500	<20	<10	11.8	7.93	20.1

At Leisure Lagoon, none of the park groundwater samples contained fecal coliform or enterococcus bacteria (Table 3). As with the Visitor's Center, groundwater salinities at Leisure Lagoon showed some stratification. Salinity values at 7 feet below the surface ranged from 2.5 to 2.8 ppt, while salinities at a depth of 12 feet ranged from 5.6 to 6.1 ppt. There were no clear differences between sampling depths in either pH or temperature and values were similar to those recorded at Visitor's Center. Among the three groundwater samples taken from the beach spring, only one contained indicator bacteria. A fecal coliform density of 20 MPN/100 mL was measured from the beach spring at 1200 hours. Values of salinity, pH, and temperature in groundwater from the beach spring were slightly higher than those recorded in the park groundwater samples.

Table 3. Results of groundwater sampling at Leisure Lagoon. For each well, sample collection was attempted three times (0900, 1200, and 1500 hr) at each depth (4, 7, and 12 feet). Bacterial densities in red were greater than the detection limit, nd = no data available.

Depth (feet)	Sample Time	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	Salinity (ppt)	pH	Temperature (degrees C)
WELL #1 (25 feet from beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	2.6	7.62	18.5
12	0900	<20	<10	5.6	7.75	18.7
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	2.5	7.81	18.3
12	1200	<20	<10	5.7	7.62	18.4
4	1500	nd	nd	nd	nd	nd
7	1500	<20	<10	2.7	7.59	18.9
12	1500	<20	<10	5.7	7.64	19.0
WELL #2 (12.5 feet from beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	2.6	7.67	18.6
12	0900	<20	<10	5.9	7.84	18.6
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	2.6	7.65	18.8
12	1200	<20	<10	5.7	7.66	18.4
4	1500	nd	nd	nd	nd	nd
7	1500	<20	<10	2.6	7.89	18.3
12	1500	<20	<10	5.9	7.90	18.6
WELL #3 (adjacent to beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	2.8	7.77	18.1
12	0900	<20	<10	5.9	7.73	18.2
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	2.8	7.69	18.1
12	1200	<20	<10	5.7	7.61	18.1
4	1500	nd	nd	nd	nd	nd
7	1500	<20	<10	2.8	7.85	18.4
12	1500	<20	<10	6.1	7.78	18.7
SPRING (at Beach Face)						
Beach	0900	<20	<10	7.9	8.10	18.4
Beach	1200	20	<10	7.5	8.28	19.5
Beach	1500	<20	<10	7.4	8.14	19.7

At De Anza Cove, only one of 27 groundwater samples taken from the park contained detectable levels of indicator bacteria: 20 MPN/100 mL from Well 1 at a depth of 12 feet at 0900 hrs (Table 4). Groundwater salinities at De Anza Cove were lower in samples from the probes at 7 feet (1.3 to 1.6 ppt) than those at 12 feet (8.5 to 9.0 ppt), which is similar to the stratification seen at Visitor's Center and Leisure Lagoon. Values of pH in the park groundwater samples ranged from 7.48 to 7.79 and showed no discernable patterns with depth or distance from the beach. Temperature was consistent among the park groundwater samples, ranging from 18.7 to 19.3° C. Groundwater samples taken at the De Anza Cove beach face spring contained no measurable levels of indicator bacteria. Values of salinity, pH, and temperature were slightly higher than the corresponding park groundwater samples, likely reflecting the influence of the bay water.

Table 4. Results of groundwater sampling at De Anza Cove. For each well, sample collection was attempted three times (0900, 1200, and 1500 hr) at each depth (4, 7, and 12 feet). Bacterial densities in red were greater than the detection limit, nd = no data available.

Depth (feet)	Sample Time	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	Salinity (ppt)	pH	Temperature (degrees C)
WELL #1 (25 feet from beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	1.3	7.65	18.8
12	0900	20	<10	8.5	7.71	18.9
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	1.4	7.54	19.3
12	1200	<20	<10	8.6	7.77	19.1
4	1500	nd	nd	nd	nd	nd
7	1500	<20	<10	1.3	7.48	18.8
12	1500	<20	<10	8.5	7.52	19.0
WELL #2 (12.5 feet from beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	1.6	7.67	18.7
12	0900	<20	<10	8.9	7.69	18.7
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	1.5	7.53	18.8
12	1200	<20	<10	9.0	7.51	18.8
4	1500	nd	nd	nd	nd	nd
7	1500	<20	<10	1.2	7.54	18.7
12	1500	<20	<10	8.9	7.55	18.9
WELL #3 (adjacent to beach)						
4	0900	nd	nd	nd	nd	nd
7	0900	<20	<10	1.5	7.72	18.8
12	0900	<20	<10	8.7	7.75	18.9
4	1200	nd	nd	nd	nd	nd
7	1200	<20	<10	1.4	7.59	18.8
12	1200	<20	<10	8.7	7.55	18.8
4	1500	nd	nd	nd	nd	nd
7	1500	<20	<10	1.5	7.79	18.9
12	1500	<20	<10	8.6	7.63	18.9
SPRING (at Beach Face)						
Beach	0900	<20	<10	10.4	8.11	19.3
Beach	1200	<20	<10	10.7	7.95	19.8
Beach	1500	<20	<10	9.9	7.78	19.9

Soil Cores

The results of the soil core grain size and bacterial analyses are presented by depth interval in Table 5. At each of the three sites, two soil cores were taken: one adjacent to Well 1, 25 feet from the park/beach interface, and one adjacent to Well 3, at the park/beach interface. At De Anza Cove, the distribution of indicator bacteria was similar in both cores. Fecal coliform bacteria were found only in the upper-most stratum (surface to five inches below the surface). Enterococcus densities were also highest in the top strata (surface to ten inches below the surface) and decreased sharply with depth. At a depth of 18 inches, densities of both indicators were un-detectable.

Full view and close up images of sediment cores showing various strata

At Visitor's Center, densities of fecal coliform bacteria were highest at the surface in both cores and appeared in general to decrease with depth (Table 5). Isolated pockets of bacteria were present at a depth of 16-18 inches in Core 1 (1,300 MPN/g) and at 20-22 inches in Core 3 (200 MPN/g). Enterococcus density also decreased with depth at Visitor's Center. Core 1 contained the highest enterococcus levels of any sample in the study (78,900 MPN/100 g). At a depth of 18 inches, enterococcus had decreased to un-detectable levels. Enterococcus density in Core 3 was lower at the surface (800 MPN/100 g sediment) than Core 1, but higher levels were measured at a depth of 6 inches. Enterococci in Core 3 had decreased to un-detectable levels at a depth of 16 inches.

At Leisure Lagoon, fecal coliform densities were highest at the surface (Table 5). The upper five inch stratum contained the highest fecal coliform density of any core in the study (59,700 MPN/g). In contrast, fecal coliforms were un-detectable in the upper six inch stratum of Core 3 at Leisure Lagoon. In both cores, fecal coliform densities decreased dramatically with depth and were not detected from 9 to 11 inches below the ground surface. Enterococcus densities also decreased with depth. Levels were highest from the surface to a depth of 9 to 11 inches. There was an isolated pocket of elevated levels at a depth of 17 to 19 inches in Core 3. Enterococci were un-detectable below 9 inches in Core 1 and below 19 inches in Core 3.

The sediment grain size results at different levels throughout the cores are also presented in Table 5. In addition to generating the median grain size, the grain size analysis produced results for each of the core sections as four fractions or classifications of sediments: gravel, sand, silt, and clay. In Table 5 the percentages of silt and clay have been combined into a single measure.

Table 5. Results of soil core sampling at De Anza Cove, Visitor's Center, and Leisure Lagoon. Highlighted areas represent the strata with the highest proportion of silt and clay.

Core Number	Depth (inches)	Median Grain Size (microns)	Percent Gravel	Percent Sand	Percent Silt & Clay	Fecal Coliform* (MPN/ 100 g)	Enterococcus* (MPN/100 g)
De Anza Cove (Site 7)							
1	0-5	174.5	5.63	70.8	23.5	4,000	14,900
	5-10	162.8	0.31	72.5	27.2	<1	6,400
	10-14	237.4	0.24	97.0	2.75	<1	900
	14-18	241.3	0.00	97.6	2.40	<1	<1
	18-22	229.2	0.09	97.1	2.79	<1	<1
3	0-5	nd	nd	nd	nd	400	3,000
	5-10	nd	nd	nd	nd	<1	7,900
	10-14	nd	nd	nd	nd	<1	800
	14-18	nd	nd	nd	nd	<1	100
	18-22	nd	nd	nd	nd	<1	<1
Visitor's Center (Site 8)							
1	0-4	322.7	13.93	63.9	22.1	4,300	78,900
	4-9	255.6	6.21	79.6	14.2	200	1,300
	9-16	209.1	0.07	88.9	11.1	<1	19,900
	16-18	240.7	0.08	96.2	3.67	1,300	400
	18-22	nd	nd	nd	nd	<1	<1
3	0-1	179.3	0.39	89.5	10.1	11,200	800
	6-12	148.0	1.10	82.9	16.0	<1	10,700
	12-16	139.7	5.28	60.8	33.9	<1	3,900
	16-20	212.0	0.06	94.1	5.86	<1	<1
	20-22	197.4	0.08	92.4	7.55	200	<1
Leisure Lagoon (Site 9)							
1	0-5	249.0	1.95	91.6	6.44	59,700	9,000
	5-9	209.8	2.17	80.4	17.42	2,700	6,800
	9-14	240.3	0.00	98.0	2.03	<1	<1
	14-20	245.7	0.01	98.2	1.77	<1	<1
	20-22	325.0	0.92	97.2	1.90	<1	<1
3	0-6	201.3	0.16	95.2	4.69	<1	12,600
	6-11	199.1	0.33	96.4	3.32	1,800	500
	11-17	223.1	0.01	96.4	3.55	<1	200
	17-19	187.7	1.85	72.9	25.3	<1	3,600
	19-22	nd	nd	nd	nd	<1	<1

* Bacterial densities are in dry weight

The gravel fraction from the soil core sections was low at all sites (generally less than 5%) except in Core 1 at Visitor's Center, where the top soil layer (0-4 inches below ground surface) contained 13.93% gravel (Table 5). Sand was the dominant soil type at all three sites assessed in this study, ranging from 63.9% in Core 1 at Visitor's Center to 98.2% in Core 1 at Leisure Lagoon. Finer grained sediments consisting of silt and clay were present in all of the cores, but appeared to be present in isolated strata. For instance, at De Anza Cove, fined grained sediments (23.5 to 27.2% silt and clay) were found in the top two strata (0 to 5 and 5 to 10 inches below ground surface). Similarly, at Visitor's Center, the top three strata of both cores contained higher proportions of silt and clay (ranging from 10.1 to 33.9% for both cores) than the lower strata. At Leisure Lagoon, there appears to be one stratum in each core that contains higher proportions of fine grained sediments. In Core 1 this stratum was located 5 to 9 inches below ground surface (17.4% silt and clay) and in Core 2 the stratum was located 17 to 19 inches below ground surface (25.3% silt and clay).

For each core, the strata containing the highest proportion of silt and clay has been highlighted in Table 5 because these areas typically contained the highest bacterial densities, particularly enterococcus. The relationship between enterococcus density and percent silt and clay is shown in Figure 5. For this graph, the enterococcus data were Log_{10} transformed and the percent silt and clay were ArcSine transformed (this is a common statistical transformation for data consisting of proportions or frequencies). The linear regression applied to the data produced an R^2 value of 0.45. The data suggest that the highest enterococcus densities are associated with the strata containing the greatest percentage of silt and clay. Below this level in each of the cores enterococcus densities drop off sharply.

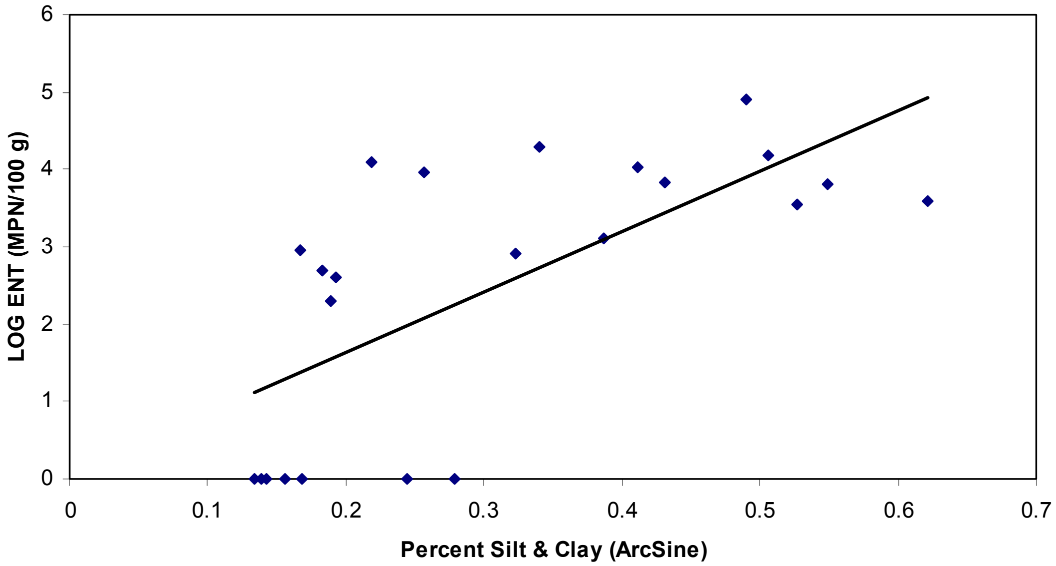


Figure 5. Plot of enterococcus density (Log_{10} transformed) verses percent silt and clay (ArcSine transformed) for soil cores collected at three sites in Mission Bay.

DISCUSSION

It is apparent from data collected in Phase I and Phase II of this study that the grassy areas of Mission Bay Park contain some of the highest bacterial densities assessed throughout the study. Levels of fecal coliform and enterococcus bacteria associated with puddles in the grassy areas of the park in Phase I and II are presented in Figure 6. The data are highly variable in space and time and cover a broad range. For instance, fecal coliform densities ranged from 40 to 16,000,000 MPN/100 mL. Enterococcus densities ranged from 5 to 2,500,000 MPN/100 mL. It is clear from the data that there is a large load of fecal indicator bacteria in the grassy areas of Mission Bay Park.

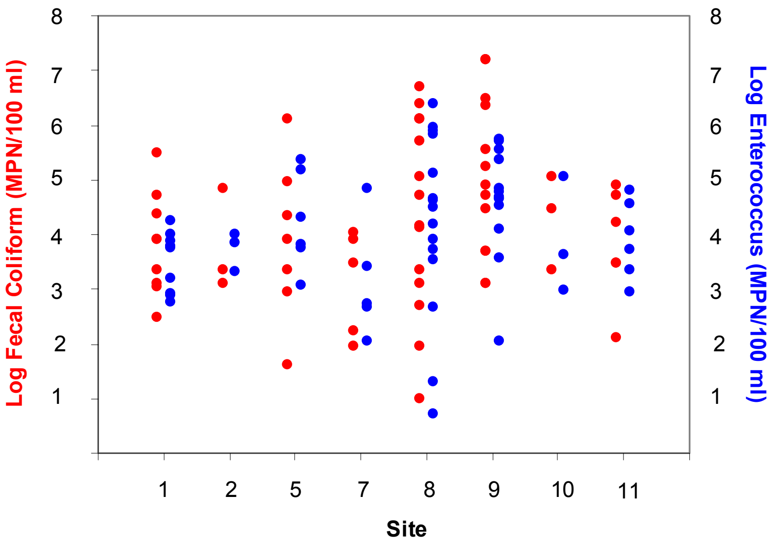


Figure 6. Densities of fecal coliform (red dots) and enterococcus (blue dots) bacteria in grass puddles at several sites throughout Mission Bay. AB411 criteria are shown for reference as a red line for fecal coliform (400 MPN/100 mL) and a blue line for enterococcus (104 MPN/100 mL).

Observations made throughout the study showed that large numbers of birds congregate in the grassy areas of the park, particularly American coots (*Fulica Americana*), western gulls (*Larus occidentalis*), and pigeons (*Columba livia*). These observations suggested that the birds were a major source of the elevated bacteria levels found in the grass. To test this assumption, *E. coli* bacteria (a member of the fecal coliform group) were isolated from several of these puddles as part of the Bacterial Source Tracking portion of this study (Task 4) and analyzed to determine the bacterial host of origin. The results of the analysis are presented in Figure 7.

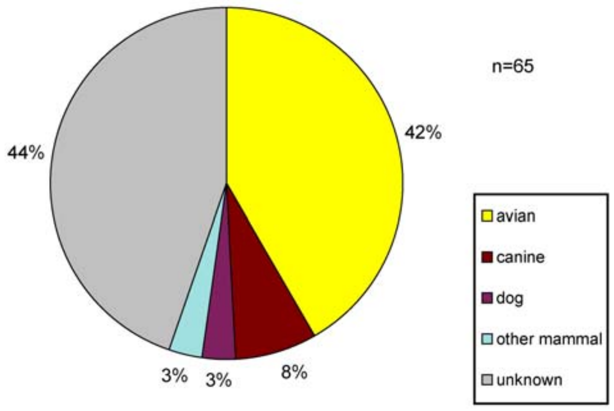


Figure 7. Pie chart showing host origin of *E. coli* bacteria collected from puddles within grassy areas of Mission Bay Park.

Although There was a large proportion of the total number of isolates in the grass that were from an unknown origin (44%), the analysis presented in Figure 7 indicates that the identifiable bacteria found in the grassy areas of Mission Bay Park originate primarily from birds (42%). Smaller proportions of canine (8%), dog (3%), and other mammal isolates were also identified. In this case, canine represents canine species that were not included in the library of domestic dog (e.g., coyotes or wild dogs). The large proportion of isolates originating from birds is consistent with observations of large numbers of birds and bird fecal matter in the grassy areas of the park. This is particularly true at Visitor's Center where large amounts of bird feces are found throughout the area.

Birds on grass at Visitor's Center

Bird waste in grass

The original objective of this study was to determine if the bacteria identified in the grassy areas of the park was being transported via groundwater and beach face springs to the bay receiving waters. Studies of subsurface microbial transport show that bacteria migration through soil is highly variable, with transport distances ranging from zero to thousands of feet (Yates and Yates 1988, Bitton and Harvey 1992, Pieper et al. 1997). The potential for bacterial transport is mediated by several factors. In both the unsaturated and saturated zones bacterial migration is primarily influenced by three processes (Beavers and Gardner 1993):

1. adsorption of bacteria to soil particles;
2. filtering of aggregate lumps of bacteria; and
3. inactivation (die-off) due to chemical reactions and microbial antagonism within the soil environment.

The results of this study suggest that all of these mechanisms may be at work in Mission Bay. The well monitoring data indicate that the unsaturated zone at the sites studied in Mission Bay extends to a depth of at least four feet. No groundwater was obtained at this depth from any of the wells (Tables 2 through 4). Within this zone, the highest bacteria levels in the soil were found closest to the surface (from 0 to approximately 10 inches below ground surface). The grass surface is treated with fertilizer and irrigated regularly. Thus, the upper strata likely contain the environmental conditions most conducive to bacterial growth, such as abundant nutrients and water. In addition, the results of the grain size analysis (Table 5) indicate that the top strata in nearly all the soil cores contain the greatest proportion of fine grained material (highest proportion of silt and clay). For a given volume of soil, fine grained particles allow for a larger overall surface area than course grained particles (i.e., higher surface to volume ratio). Higher bacterial levels are typically associated with finer grained sediments because the larger overall surface area provides a greater potential for adsorption of bacteria to soil particles. The correlation between increasing bacterial density with decreasing grain size has been reported in several papers (Harvey et al. 1993, Silliman et al. 2001, Lo et al. 2002).

In the case of the grassy area in Mission Bay Park, the small grain size associated with the silt and clay fractions of the upper soil strata appear to act as a barrier for the downward vertical migration of the high bacterial levels found at the ground surface. In all of the soil cores examined, the highest bacterial densities were associated with the strata containing the greatest percentage of silt and clay. Below this level, the sand fraction predominated and bacterial levels were undetectable or very low. These results are similar to those of other studies that have examined bacterial migration patterns. For instance, Lo et al. (2002) examined the movement of bacteria through columns containing various mixtures of sand and bentonite clay. They found that the deepest migration (maximum of 10 cm) occurred in columns with 100% coarse sand (median grain size of 300 to 600 µm). With the addition of 5 and 10% clay, the depth of penetration decreased to 8 cm and 6 cm, respectively. The soil core data from Mission Bay suggest that bacterial penetration is deeper than those discussed by Lo et al. (2002). However, at all sites downward migration is essentially halted by layers of silt and clay at a maximal depth of approximately 18 inches (Table 5).

The data collected from the groundwater wells supports the assertion that clay layers in the soil effectively block the vertical migration of bacteria from the grassy areas of Mission Bay Park. Of the 108 bacterial analyses conducted at all three sites from groundwater well samples, 102 had undetectable levels of indicator bacteria and the six analyses that were above the detection limit were all at very low levels. The low densities of indicator bacteria in groundwater reflect the lack of bacteria found in the beach face springs. Groundwater emanating from the beach face springs have been analyzed for indicator bacteria in the Fate and Transport study at De Anza Cove, Visitor's Center, and Leisure Lagoon as well as in the Bacterial Source Tracking Task (Investigative Task 4) at these and two additional sites (Bonita Cove and Wildlife Refuge). The results of the beach face spring groundwater analyses for both studies are summarized in Table 6. The sites sampled provide good spatial coverage throughout the bay and represent the most likely areas where groundwater transport of bacteria was thought to occur (based on the results of Phase I). Samples were collected during both dry and wet seasons providing good temporal coverage as well. Of the 40 groundwater samples collected in these studies, only five had levels for either indicator (fecal coliform and enterococcus) greater than the detection limit. Measurable densities were very low, typically at or just above the detection limit.

Table 6. Results of shallow groundwater sampling at beach face springs in Mission Bay taken during the bacterial source tracking study (Investigative Task 4) and the fate and transport study (Task 5). Densities for fecal coliform (FC) and enterococcus (ENT) are in units of MPN/100 mL. All densities were less than the detection limit except those highlighted in red.

Site	Date	FC	ENT	Site	Date	FC	ENT
Bonita Cove (Site 1)	9/9/03	<20	<10	**Visitor's Center (Site 8)**	8/26/03	<20	10
	10/8/03	<20	<10		8/26/03	<20	<10
	10/22/03	<20	<10		8/26/03	<20	<10
	10/28/03	<20	<10		10/7/03	<20	<10
					12/10/03	<20	<10
Wildlife Refuge (Site 5)	9/11/03	<20	<10		12/18/03	<20	<10
	10/7/03	<20	20		1/29/04	<20	<10
	10/21/03	<20	<10		2/12/04	<20	<10
	10/29/03	<20	<10		3/18/04	<20	<10
					3/18/04	<20	<10
De Anza Cove (Site 7)	9/10/03	<20	<10		3/18/04	<20	<10
	10/8/03	<20	<10				
	10/21/03	<20	<10	**Leisure Lagoon (Site 9)**	9/12/03	<20	<10
	11/5/03	<20	<10		10/7/03	<20	<10
	11/5/03	20	31		10/22/03	<20	<10
	12/18/03	<20	<10		11/6/03	<20	<10
	1/30/04	<20	<10		3/18/04	<20	<10
	2/6/04	<20	<10		3/18/04	20	<10
	3/5/04	<20	<10		3/18/04	<20	<10
	3/11/04	<20	<10				
	3/12/04	<20	<10	**Field Control**	10/8/03	<20	<10
	3/19/04	<20	<10		3/5/04	<20	<10
	3/19/04	<20	<10		10/7/03	<20	<10
	3/19/04	<20	<10		10/22/03	<20	<10
					10/7/03	<20	<10
					10/7/03	<20	<10
					10/29/03	<20	<10

In Figure 8, we constructed a simple conceptual model to demonstrate the mechanisms of bacterial fate and transport assessed in this study. The results of the study suggest that enterococci and, to a lesser extent, fecal coliform bacteria emanating from the original host animals (birds and dogs) are able to survive and possibly reproduce in the grass and upper sediment layers of Mission Bay Park. In this way, the upper 18 inches of soil beneath grassy areas of the park (red zone in Figure 8) acts as a large reservoir for fecal indicator bacteria that has the potential of impacting the receiving waters of Mission Bay. This reservoir appears to be trapped by layers of clay in the soil that prevent the bacteria from migrating to the saturated groundwater zone, which is at a depth of approximately 5 to 6 feet. Groundwater springs on the beach face at Mission Bay Park appear to be hydrologically connected to the groundwater beneath the surface bacterial reservoir. The lack of bacteria collected from these springs during the fate and transport task and the groundwater portion of the BST task suggest that shallow groundwater is not a source of fecal indicator bacteria to Mission Bay from either the high bacterial load in the grassy areas of Mission Bay Park or from other potential sources.

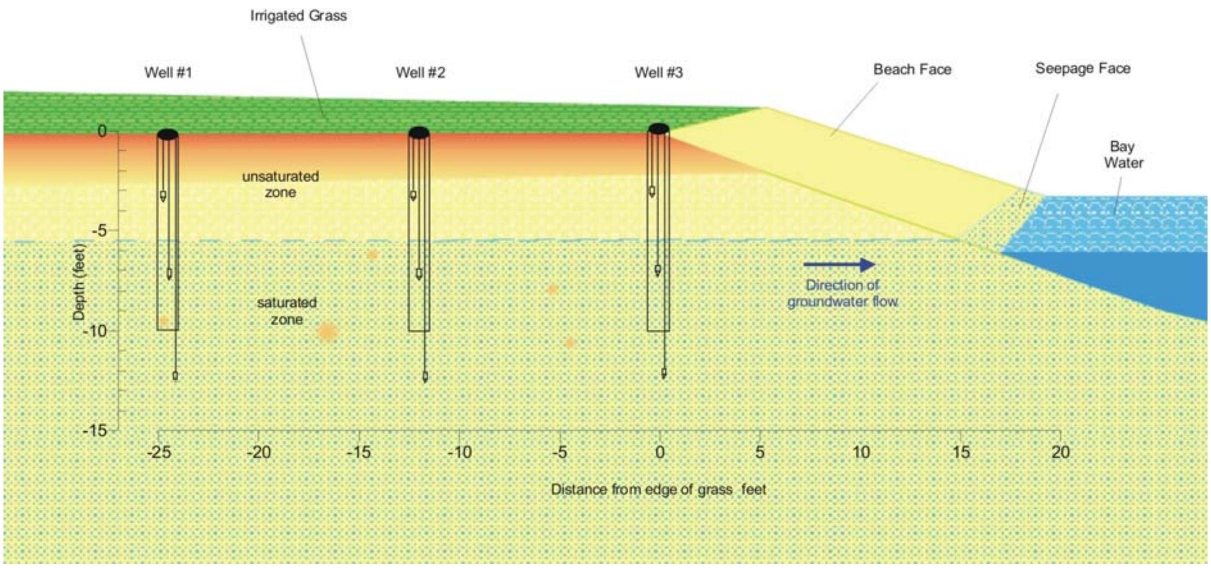


Figure 8. Conceptual model of bacterial fate and transport in Mission Bay Park. The red zone from the surface to a depth of approximately 18 inches represents the area of elevated indicator bacterial densities.

CONCLUSIONS

The objective of the Fate and Transport Study revealed several important factors about the migration of indicator bacteria from the grassy areas of Mission Bay Park to the bay's receiving waters. The conclusions of the study are summarized below.

- The grassy areas of Mission Bay Park contain a large reservoir of indicator bacteria. Samples collected in Phase I and Phase II from irrigated portions of the park contained fecal coliform densities ranging from 40 to 16,000,000 MPN/100 mL. Enterococcus densities ranged from 5 to 2,500,000 MPN/100 mL. High levels were observed throughout the park during both dry and wet seasons.

- Molecular analyses of the bacteria in the grassy areas of the park reveal that the majority of the identified isolates originate primarily from birds.

- Data from soil cores from three areas in the park, De Anza Cove, Visitor's Center, and Leisure Lagoon, revealed high bacterial densities near the ground surface. Densities of both indicators decreased with depth and appeared to be negligible at a maximal depth of approximately 18 inches.

- Bacterial densities appear to be related to soil grain size, with the highest levels associated with the silt and clay soil fractions. Soil strata with a silt and clay fraction of between approximately 10 and 34% appeared to act as a barrier to the vertical migration of bacteria from the grassy areas of the park.

- The saturated zone is though to be at a depth of approximately 5 to 6 feet below ground surface. At depths of seven and 12 feet below ground surface, levels of indicator bacteria in groundwater were below the detection limit in nearly all cases.

- Groundwater samples collected from beach face springs also contained negligible levels of indicator bacteria.

- Overall, the results of this study indicate that the bacteria associated with the grassy areas of the park are trapped within the top 18 inches of soil and are not likely to be transported via groundwater to the receiving waters of Mission Bay.

RECOMMENDATIONS

The results of this study indicate that there is a large reservoir of bacteria in the upper soil strata within the grassy areas of Mission Bay Park. Although the study indicates that the bacteria are not impacting the receiving waters via groundwater transport, the potential exists for other transport mechanisms, such as soil erosion and excess irrigation. In Phase I of the Mission Bay Bacterial Source Identification Study, excessive irrigation at several sites was shown to be a potential bacterial transport pathway from the park to the bay receiving waters. The excess irrigation water transported bacteria to the bay through storm drains (downstream of the Mission Bay Sewage Interceptor System) and via overland transport, which results in erosion of the banks. To prevent bacterial transport via these mechanisms, the following actions are recommended to the City.

To the extent possible, reduce excessive irrigation throughout the park to eliminate or minimize flow to the bay from the storm drains. This might be accomplished through a variety of turf management techniques, such as redirecting sprinklers to prevent overflow to the gutters, installing sensors to assess the water content of the soil, and automating the sprinkler system to increase watering efficiency.

Minimize erosion by maintaining stable banks. This could be accomplished by reducing excessive irrigation as mentioned above, fixing and maintaining sprinkler heads near banks where erosion occurs, and eliminating flow from concrete ramps associated with park comfort stations. In areas where bank erosion is particularly problematic, permanent edge structures could be installed to further prevent erosion.

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APPENDIX G

Sediment Studies

Interim Report for

Mission Bay Clean Beaches Initiative Bacterial Source Identification Study (Phase II)

Sediment Investigation

Prepared For:

State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Interim Report for

Mission Bay Clean Beaches Initiative Bacterial Source Identification Study (Phase II)

Sediment Investigation

Prepared For:
State Water Resources Control Board

Prepared By:

City of San Diego

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September 15, 2004

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INTRODUCTION

Project Overview

The Mission Bay Bacterial Source Identification Study was designed to identify sources of bacterial contamination in Mission Bay and recommend appropriate actions and activities to eliminate the input of those sources to the Bay receiving waters. The study is being conducted in two phases. The first phase was completed at the end of June, 2003.

Three major questions emerged from Phase I that were identified for assessment in Phase II to understand the nature and sources of bacteria in Mission Bay:

1) What is the origin (human, avian, etc.) of high bacterial levels measured in Phase I?
2) How much bacteria is transported from the grass surface of Mission Bay Park to the Bay via groundwater?
3) Is sediment in Mission Bay serving as an on-going source of bacteria in the water column through resuspension?

Three investigative tasks were identified in Phase II to complete this project. In the scope of the overall project, these tasks have been designated Investigative Tasks 4, 5, and 6:

Investigative Task 4. Identify the origins of bacteria using molecular microbial source tracking (MST) techniques;

Investigative Task 5. Investigate the transportation mechanisms of bacteria from the surface of Mission Bay Park to the Bay receiving waters (i.e., fate and transport study);

Investigative Task 6. Investigate bacteria levels in sediments at the Bay's major depositional areas.

This report summarizes Task 6, the sediment investigation.

Historical Background

Numerous studies have suggested that beach sediments often contain higher densities of fecal indicator bacteria than the overlying water column (An et al. 2002, Grant et al. 2001, Obiri-Danso and Jones 2000, Solo-Gabrielle et al. 2000, Howell et al. 1996). In addition, studies on the survival of bacteria indicate that sediments present an environment favorable for growth. Enteric bacteria have been shown to survive and, to a certain extent, even to grow in both freshwater and marine sediments (Grant et al. 2001, Solo-Gabriele et al. 2000, Davies et al.

1995, Hood and Ness 1982). During summer months, this bacteria may be resuspended in the water column by swimmers, resulting in exceedances of water quality standards and the potential for increased exposure of swimmers to waterborne pathogens. One recent study conducted in Southern California found a seasonal pattern of fecal coliform storage in sediments during low-flow conditions and subsequent resuspension of bacteria to the water column when the sediments were disturbed (Steets and Holden 2003). A similar study conducted in Florida suggested that *E. coli* bacteria multiplied in tidal riverbank soils after their initial deposition during storms and were resuspended and carried to the river mouth during ebbing tides (Solo-Gabriele et al 2000).

The extent to which bacteria is stored in the sediments of Mission Bay is unknown, but given the small grain size at some sites and numerous bacterial sources close to area beaches, the potential for bacterial storage is present at some locations. This is particularly true at sites located near the mouths of creeks where sediment transported during winter storms is deposited in the delta.

Study Objectives

The primary goal of this study was to determine if the sediments in Mission Bay act as a source of bacteria to the receiving waters at area beaches. Investigations were conducted to determine the potential for receiving water bacterial contamination originating from two types of sediments in Mission Bay:

1. Sediments in deltas at the mouths of the three major drainages that discharge to Mission Bay, which may contaminate adjacent beaches via tidal currents; and
2. Intertidal sediments, which may contaminate receiving water via resuspension when the sediments are disturbed.

The delta sediment investigation was conducted by taking sediment cores within the deltas of each of the three major drainages to Mission Bay (Rose Creek, Cudahy Creek, and Tecolote Creek). Sediment and receiving water samples were analyzed to determine the densities of indicator bacteria (fecal coliform and enterococcus). Molecular techniques were then used to determine the similarity between the bacteria in the sediments and those in the receiving waters.

The intertidal sediment investigation was conducted by measuring bacterial levels in intertidal sediments at three sites in Mission Bay (Bonita Cove, De Anza Cove, and Leisure Lagoon). A comparison was then made between bacterial levels in the receiving water before and after resuspension of the sediments.

MATERIALS AND METHODS

Site Locations

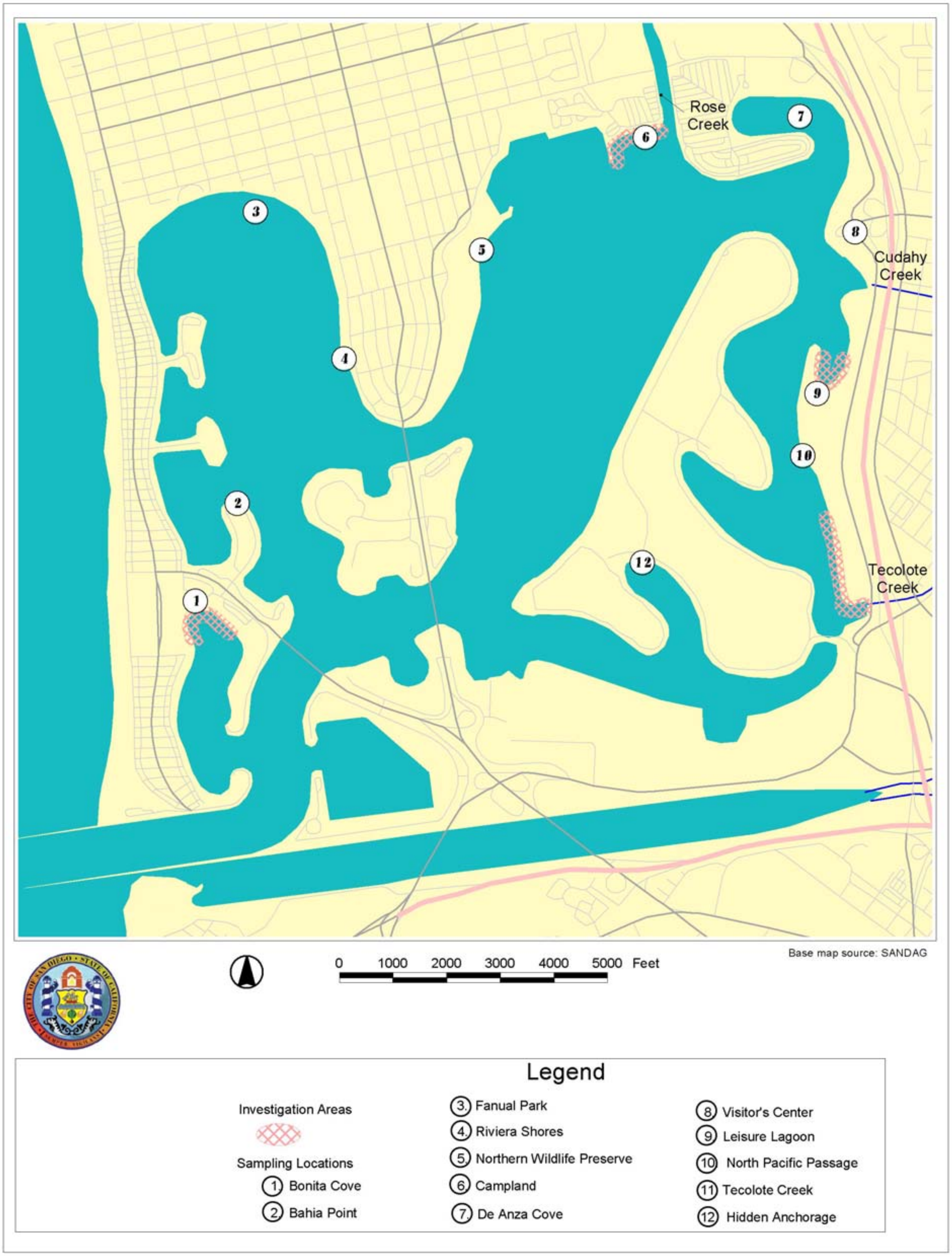
The three major creeks that discharge to Mission Bay terminate near three receiving water sites that were sampled in Phase I of this study. For the delta sediment Investigation, sediment from the deltas of these creeks and water from the adjacent receiving water sites were sampled. The sites are shown in Figure 1:

1. Rose Creek, which discharges near Campland (Site 6)
2. Cudahy Creek, which discharges near Visitor's Center (Site 8); and
3. Tecolote Creek, which discharges near the Tecolote Creek site (Site 11).

Intertidal sediments were also investigated at three sites (Figure 1):

1. Bonita Cove (Site 1),
2. De Anza Cove (Site 7), and
3. Leisure Lagoon (Site 9).

These sites were chosen because they tend to be used most frequently by swimmers during the summer months. If bacteria associated with intertidal sediments is resuspended during swimming activity, it is most likely occurring at these sites.



Base map source: SANDAG

Figure 1. Map of Mission Bay showing investigation and sampling sites for the sediment investigation.

Sampling Protocol for Delta Sediments

The delta sediment study was conducted during two separate surveys:

1) A dry season survey, conducted on October 24, 2003, prior to the first rains of the wet season; and
2) A wet season survey, conducted on January 14, 2004 after substantial runoff had entered the Bay from wet season storms.

Sampling Locations. The approximate location of the deltas of each of the three creek outlets were digitized using the GIS program ArcView and aerial photographs of the area. Within the polygon representing each delta, six random points were selected using a random points generator, an extension of ArcView that generates a user specified number of random points within polygons. A minimum distance of 20 feet was specified between points. The latitude and longitude coordinates of each of the six points were also generated.

Sediment Cores. Sediment cores were taken from an inflatable raft (Zodiac) equipped with an 8 horse outboard motor. The coordinates of each of the sampling locations were located in the field using a hand-held GPS. Once in position, the inflatable was anchored on site. Sediment cores were taken with a hand core that consisted of 10-foot long aluminum push rod attached to an aluminum block. The block consisted of a six cubic inch head connected to a six inch long, 3 inch diameter cylinder. At the bottom of the cylinder was a rubber stopper that was held in place with a line that passed through the aluminum block and out of a port near the top of the push rod. The stopper was secured inside the bottom of a 3-inch diameter, sterile, plastic tube approximately 20 inches long. The sterile tube was then attached to the outside of the aluminum cylinder with hose clamps.

Collecting sediment cores from Tecolote Creek delta

To remove a sediment core, the plastic tube was inserted into the sediment from the inflatable boat and pushed into the sediment using the push rod. A slide hammer was then used to pound the tube into the sediment until refusal. The stopper, located at the sediment water interface, was pushed up the plastic tube as the tube was inserted into the sediment. When the appropriate depth was reached, the whole apparatus was removed from the sediment with the sediment core in tact within the plastic tube. The stopper creates suction within the tube that holds the sediment core in place. As the core was lifted to the surface of the water, a sterile plastic cap was placed on the bottom of the plastic tube. The tube was then removed from the push rod and the aluminum cylinder and sealed with another sterile cap on top of the core. The self-contained cylinder was stored upright on ice in a cooler for further processing.

Between sampling sites, the entire apparatus was cleaned with biodegradable soap (Alconox) and de-ionized water, then rinsed in 90% ethanol and air dried.


Cutting sediment core to remove sediment sample

Sediment Core Processing. After the cores had been removed and capped, they were stored in the dark on ice, then transferred to shore for processing. The top cap was removed and any excess water on top of the sediment (typically less than 1 cm) was removed with a sterile pipette. The tube was then cut with a reciprocating saw equipped with a sterilized blade, approximately 2 cm above the top of the sediment layer. The top 1 cm of the sediment core was then removed with a sterile spoon and placed into a sterile 100-ml plastic bottle and capped. Surficial sediments from each of these cores were analyzed for indicator bacteria (fecal coliform and enterococcus). In addition, bacteria from the sediment were analyzed to determine the bacteria's host origin (e.g., human, avian, etc.) using two molecular techniques referred to in this document as HS-PCR and Ribotyping. The techniques are described briefly below under Laboratory Analyses.

Three of the six cores at each site were also processed to determine enterococcus and fecal coliform concentrations in the sediment core at a depth of approximately four inches from the surface. At all three sites, the first three randomly selected sites were chosen for this analysis. To sample the sediment at depth, the reciprocating saw with a new, sterilized blade was used to cut the tube and sediment at a depth of four inches from the sediment surface. Approximately 1 cm of sediment from this section of the core was removed as described above. All samples were transported to the laboratory on ice for processing. Samples from depth were analyzed for enterococcus and fecal coliform bacteria, but not for bacterial host origin.

After the delta sediment samples were collected for bacterial analyses, sub-samples of surficial sediment from the same six cores were also collected for grain size analysis. Approximately 100 g was collected from each core with a stainless steel spoon. The cores were then homogenized in a stainless steel bowl and placed into a labeled plastic bag for transport to the laboratory. Surficial sediment composites were collected for grain size analyses in both the dry and wet weather surveys.

Receiving Water Monitoring. Adjacent to the deltas in Mission Bay that were sampled for sediment, there are three receiving water sites that are routinely monitored by the County Department of Environmental Health (DEH) for bacterial indicators: Campland, Visitor's Center, and Tecolote Creek (Figure 1). During the wet season survey, fecal coliform bacteria were present in the deltas sediments at high enough densities at Site 8 and 11 to allow for a molecular comparison between bacteria in the sediments to those in the receiving water. Samples for the receiving water analysis were collected at each site from five stations centered on the DEH sampling site with a spatial extent of approximately 300 feet. At each station, a single receiving water sample was collected in a 100-ml sterile plastic bottle. The samples were composited in the laboratory for assessment by the Ribotyping technique (see Laboratory Analyses below). Samples were collected in this way on two consecutive days (January 20 and 21, 2004) during an ebbing spring tide when current velocities were maximal. The receiving water sites are located down current from the deltas during ebbing tides. Thus, bacteria associated with the delta sediments were most likely to be found in the receiving water during these conditions if the sediments are acting as a source.

Sampling Protocol for Intertidal Sediments

Bacterial levels in intertidal sediments were characterized at three locations in Mission Bay (Figure 1):

- Bonita Cove (Site 1),
- De Anza Cove (Site 7), and
- Leisure Lagoon (Site 9).

Two types of assessments were conducted:

1. Beach face transects, which provided a profile of bacterial densities in the intertidal sediments from the high to low tide marks.

2. Sediment resuspension analysis, which provided a measure of the extent to which resuspension of beach sediments contributed to bacterial levels in the receiving water.

Aerial photographs of each site showing sampling locations are shown in Figures 2 through 4.

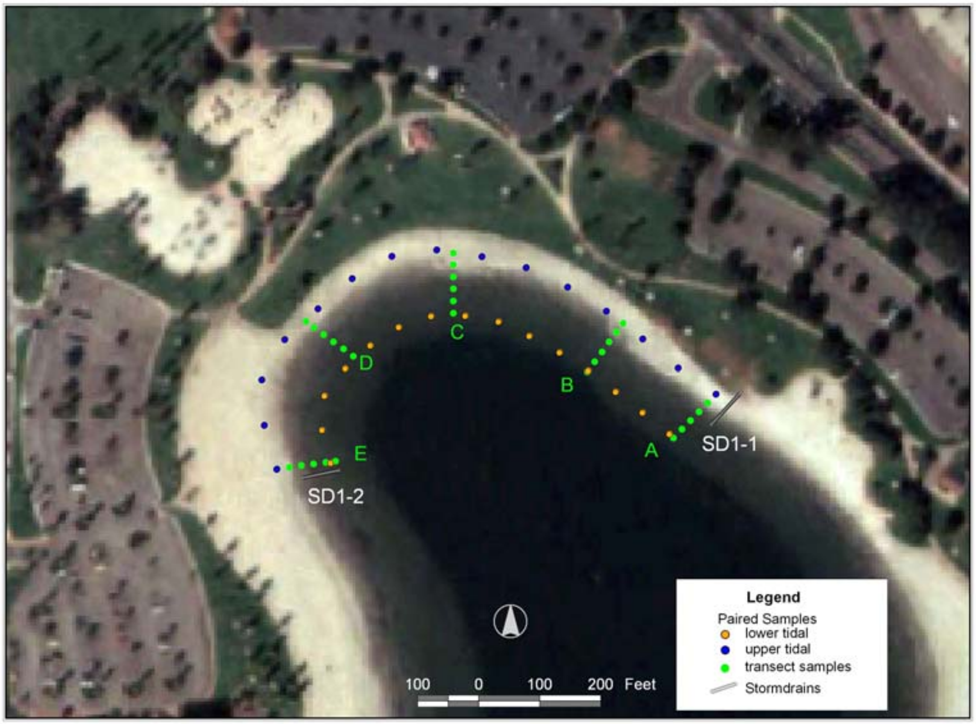


Figure 2. Aerial photograph of Bonita Cove showing sampling stations for the sediment investigation.

Figure 3. Aerial photograph of De Anza Cove showing sampling stations for the sediment investigation.

Figure 4. Aerial photograph of Leisure Lagoon showing sampling stations for the sediment investigation.

Beach face transect at Bonita Cove

Beach Face Transects. Bacterial densities were measured along beach face transects at Bonita Cove and Leisure Lagoon (De Anza Cove was not included in this assessment). At each of the three sites, five transects were positioned along the beach face. At Bonita Cove and Leisure Lagoon, the transects were centered around the AB411 receiving water monitoring site (Figures 2 and 3). Each transect, which consisted of a measuring tape secured at either end with a metal pin, ran perpendicular to the Bay from a tidal height of 0 to +6 feet above Mean Lower Low Water (MLLW). The transects were put in place during a low tide (below 0 MLLW). The position of the tidal height on the beach face was determined using tide charts and the measuring tape. Along each transect, six stations representing tidal height positions from 0 to +6 feet above MLLW were identified with survey flags. The transect stations were: 0, +1, +2, +4, +5, and +6 feet above MLLW. At each of the transect points, one surficial (approximately 1 cm deep) sediment sample consisting of approximately 50 g of sediment was taken using a sterile 100-ml plastic bottle. At each of the two sites assessed, a total of 30 sediment samples were taken (5 transects x 6 stations).

Sediment Resuspension. Sediment resuspension studies were conducted at three sites: Bonita Cove, De Anza Cove, and Leisure Lagoon. At each site, the study protocol was slightly different as summarized in Table 1.

Table 1. Sediment resuspension studies conducted by site in Mission Bay.

Site	Date of Study	Tidal Condition	Sampling Time	Indicators Assessed*
Site 1 Bonita Cove	May 19, 2003	Low Tide (- 1.5 feet)	0730 hrs	ENT
	April 16, 2004	High Tide (+ 5.1 feet)	0800 hrs	ENT and FC
Site 7 De Anza Cove	May 21, 2003	Low Tide (- 0.5 feet)	0930 hrs	ENT
Site 9 Leisure Lagoon	April 29, 2004	High Tide (+ 4.4 feet)	0530 hrs	ENT and FC

*** ENT = enterococcus, FC = fecal coliform**

At each site, a total of 15 stations were positioned along the beach face parallel to the water and identified with survey flags. The sites were equidistant from each other and located within an area covering the same spatial extent as the beach face transects described above (Figures 2 through 4).

At each of the 15 stations, two consecutive water samples were taken. The first was a "clear-water" sample, which was taken using DEH protocol in which the underlying sediments were not disturbed. Immediately after the clear-water sample had been collected, the sampler disturbed the sediments at that location by mixing the beach sediment into the water column with his feet (similar to what a swimmer would do). A sample was then taken from the water column that contained the resuspended sediment. We refer to this as the resuspended sediment sample.

Sediment Grain Size. In addition to the samples described above, a composite sediment sample was taken at each site for grain size analysis. The composite consisted of approximately equal volumes of beach face sediment collected from each of the 15 sites assessed in the sediment resuspension study. The samples were collected with a stainless steel spoon and composited in a stainless steel bowl at each site.

Laboratory Analyses

Receiving Water Bacteria. All receiving water samples were analyzed at the MEC Analytical Systems Microbiology Laboratory in Carlsbad, California. Fecal coliforms were analyzed using multiple tube fermentation based on Standard Methods 9221E. Enterococcus bacteria were enumerated using a chromogenic technique (IDEXX Enterolert), based on Standard Methods 9223.

Sediment Bacteria. All sediment bacterial densities are presented as Most Probable Number (MPN) of bacteria per gram dry weight using the following procedure. The weight of the sample bottle was subtracted from the total weight of the sample bottle plus the sediment in the sample to determine the sediment wet weight. A total of 50-75 ml of sterile dilution water (phosphate buffered saline) was then added to the weighed sample, shaken, and allowed to settle for two minutes. The bacteria suspended in the overlying water was then extracted and analyzed for fecal coliform and enterococcus concentrations as described above. The results of the initial assessment were in units of MPN/100 ml of sample, however, because only 50-75 ml of water was used in the initial dilutions, the result was multiplied by this factor to correct for the amount of water used. The MPN result was then divided by the weight of sediment tested to yield results in bacteria per gram wet weight.

To determine the moisture content of the sample, the representative section of the core was added to a pre-weighed porcelain dish and weighed. The weight of the dish was then subtracted from the total weight to determine the wet weight of the sediment. The sediment and dish were dried in an oven overnight at 80° C and re-weighed. The weight of the dish was then subtracted to determine the dry weight of the sediment. The dry weight was subtracted from the wet weight to determine the percentage of dry sediment to the overall sediment. This percentage was multiplied by the initial bacterial concentration of the sample to produce the final result in bacteria MPN per gram of dry sediment.

Sediment Grain Size. Sediment grain size was analyzed using a technique employed by Plumb (1981) based on procedures for Handling and Chemical Analysis of Sediment and Water Samples.

Host Specific PCR. Samples collected for HS-PCR analysis were initially processed at the MEC Microbial Source Tracking Laboratory. Sediment samples collected for HS-PCR analysis were processed using the FastDNA SPIN Kit for Soil (Qbiogene) according to manufacturer's directions. Approximately 0.5g from each surficial sediment core was used to extract total genomic DNA. Purified DNA samples were then shipped to a contracted laboratory at Oregon State University on dry ice. Extracted DNAs were analyzed by polymerase chain reaction (PCR) according to published protocols (Bernhard and Field, 2000b; Bernhard et al., 2003) using three primer sets that amplify targets from the Bacteroidetes group of fecal bacteria. These included a general primer set that assays for the presence of fecal contamination from any source (GB marker), and two human-specific primer sets that assay specifically for the presence of human fecal contamination (HF134 and HF183 markers). PCR reactions were set up in UV-treated PCR hoods in a separate laboratory according to quality control protocols described in the contracted laboratory's SOPs. Extraction, filtration, and PCR negative controls and the appropriate positive controls were included on each 96-well amplification assay plate.

PCR products were separated by electrophoresis in 96-well agarose gels containing ethidium bromide, utilizing a Ready-To-Run Separation Unit (Amersham Biosciences, San Francisco, CA), and photographed with a UVP gel documentation unit under ultraviolet irradiation. Gel electrophoresis and documentation took place in another separate laboratory, in order to avoid contamination by amplification products.

Sensitivity of the general marker is approximately 10 copies per reaction, while the sensitivity of the two human markers is approximately 10 to 100 copies per reaction. If either or both of the two human markers amplified, a sample was scored as positive for the presence of human fecal contamination.

***E. coli* Isolates.** To isolate *E. coli* from delta sediments for Ribotyping analysis, two 50 mL aliquots from each surficial sediment core resuspension were first clarified using filter paper to remove large particulate matter. Resulting filtrates were then concentrated onto .45 µm, 47 mm sterile membrane filters (Millipore Corporation) using a Microfil Filtration vacuum manifold system (Millipore Corporation) connected to a vacuum pump. Membrane filters were placed in 47mm Petri dishes with absorbent pads (Millipore Corporation) pre-soaked in Coliscan MF media (Micrology Laboratories) according to the manufactures directions. Plates were allowed to grow at 44.5º C overnight in a conventional air incubator, and blue colonies were initially scored as *E. coli* according to the manufactures specifications. Coliscan MF plates were then shipped on blue ice to the contracted laboratory at the Institute for Environmental Health for purification and confirmation of *E. coli* as follows: well isolated blue colonies were picked and plated on Trypticase Soy Agar and allowed to grow overnight at 35ºC. Each culture was then tested by Spot Indol testing using the appropriate positive and negative controls. Indol positive cultures were subsequently tested for their ability to utilize citrate using Simon Citrate media. Indol positive, citrate negative colonies were then given final confirmation as *E. coli* and assigned isolate. A portion of each *E. coli* strain isolated from each sample was stored at -80ºC, in nutrient broth plus 15% glycerol. Genomic DNA was extracted according to the contracted laboratory's protocol.

To isolate *E. coli* bacteria from receiving waters for Ribotyping analysis, three volumes of each receiving water sample (5ml, 20ml and 40ml aliquots) were concentrated onto sterile membrane filters, incubated with Coliscan MF media, and blue colonies were initially scored as *E. coli*. Coliscan MF plates were shipped to the contracted laboratory on blue ice, and blue colonies were processed for purification and storage as described above.

Ribotyping Analysis. Genomic DNA was isolated from each *E. coli* strain using a standard protocol. All reagents and buffers were made according to formulas described in the Institute for Environmental Health's laboratory SOPs. Reagents and buffers were tested for sterility. Every batch of restriction enzyme reaction contains two reactions with a positive control strain which were included on two lanes per gel. Agarose gel electrophoresis was conducted under standard conditions, agarose gel concentration, and volume, buffer strength, pH, mA, V, and electrophoresis time were controlled for. Each agarose gel was assigned a number, and when more than one gel was run, the position of the first standard reference strain was changed in each gel (1st lane on the first gel, to the Nth lane on the Nth gel). After electrophoresis, gels were stained in ethidium bromide. Two gels were typically stained in a single container; of the two gels placed in the same container, one corner of the gel of the higher number was clipped. Labels for each gel were also transferred to the staining container. Each gel was then photographed and a hard copy of the print was labeled with the gel sheet (containing the isolates numbers loaded on each lane, and the enzyme used to cut the DNA, plus date, gel number, voltage, mA, gel strength, buffer strength, and electrophoresis time information). Southern blotting was performed according to the protocol detailed in the contracted laboratory's SOP. After photography, each gel was returned to the same staining container. Gels were denatured for Southern blotting in the same container. Each blotting apparatus was constructed in a separate container which was labeled with the gel number. Each membrane filter was then labeled with the gel number, restriction enzyme designation, date, and technician's initials.

The genetic fingerprints (or Ribotypes) were analyzed manually using an algorithm developed by researchers at the Institute for Environmental Health. Type patterns are cut and catalogued, and every pattern was compared side by side to the type pattern. New patterns were given appropriate identifiers and catalogued accordingly. The criterion for data analysis was one hundred percent identity of the Ribotype patterns.

Statistical Analyses. As is typical with bacterial data from environmental samples, bacterial densities were approximately log-normal. Thus, geometric means are used to display the results. For hypothesis testing, all bacterial data were log-transformed prior to analysis. Hypothesis testing (ANOVA) was used to compare mean bacterial densities using a p value of 0.5 as the level of significance. Tukey's Multiple Comparison Test was used for comparisons of more than two means. All statistical analyses were performed using the statistical software SAS (Version 8).

RESULTS

Delta Sediments

Sediment samples were collected from the three deltas during the dry weather survey on October 24, 2003 and a wet weather survey on January 14, 2004. The dry weather survey was conducted at the end of the dry season. Prior to the sampling date, there had been no measurable rainfall > 0.2 inches in the area (measured at Lindbergh Field) since May 2, 2003 (175 days). Prior to the wet weather survey, several storms had impacted Mission Bay (Figure 5). From the date of the dry weather survey (October 24, 2003) through the wet weather survey (January 14, 2004), five storms with a total rainfall greater than 0.2 inches had impacted Mission Bay, including one larger storm (0.6 inches of rainfall) that occurred on December 25, 2003. No more than a trace of rain (< 0.1 inches) had fallen on the Mission Bay watershed within a 12-day period prior to the wet weather survey.

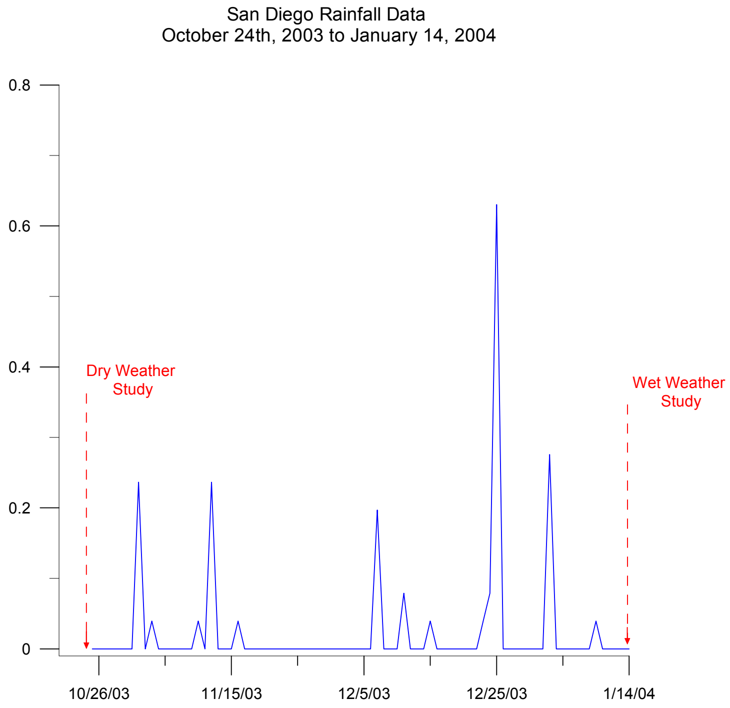


Figure 5. Daily rainfall in Mission Bay.

Bacterial Densities. The results of the bacterial monitoring in the Mission Bay deltas are presented in Table 2 and Figure 6. During the dry weather survey, fecal coliform densities were low at all three sites in samples taken from the sediment surface as well as at depth (four inches below the surface). Fecal coliform densities in all of the samples collected at Rose Creek and Tecolote Creek were below the detection limit. At Cudahy Creek, fecal coliform bacteria were present in surficial sediments at five of the six stations and at depth at one station. Densities were low, ranging from < 1 to 16 MPN/g. Enterococcus densities were also low in the dry weather survey. At Rose Creek, enterococcus densities in surficial sediments ranged from < 1 to 35 MPN/g. However, sediment samples taken at depth at Rose Creek contained surprisingly higher levels of enterococcus, ranging form 9 to 72 MPN/g. At Cudahy Creek and Tecolote Creek, enterococcus densities in surficial sediments and those at depth were below or slightly above the detection limit, ranging from < 1 to 3 MPN/g.

During the wet weather survey, surficial sediment fecal coliform densities at Rose Creek and Cudahy Creek were similar to those taken during the dry weather survey (Table 2, Figure 6A). However, at Tecolote Creek, the mean surficial fecal coliform density in the wet weather survey (20 MPN/g) was significantly greater than that of the dry weather survey (< 1 MPN/g) ($p < 0.0001$). Fecal coliform densities at depth in the wet weather survey were below detection limit in all samples (Figure 6B).

Enterococcus densities in the delta sediments changed the most between the dry and wet weather surveys (Table 2, Figures 6C and D). The mean enterococcus density in surficial sediments during the wet weather survey was 38 times higher than the mean dry weather density at Cudahy Creek (p 0.0006) and over 100 times higher at Tecolote Creek ($p < 0.0001$) (Figure 6C). At Rose Creek, the mean surficial enterococcus density during the wet weather survey was twice that of the dry weather survey, but the difference was not statistically significant. The most remarkable differences between the two surveys were in enterococcus densities at depth (Figure 6D). At Rose Creek, the mean enterococcus density at depth (4,703 MPN/g) was significantly greater than the dry weather mean at depth ($p < 0.0016$) and an order of magnitude higher than any other value measured in either survey. Enterococcus densities at two of the three samples collected at depth from Cudahy Creek were also extremely high (3,047 and 1,375 MPN/g) and similar in magnitude to samples collected at depth at Rose Creek.

Table 2. Fecal coliform (FC) and enterococcus (ENT) densities in sediment samples from deltas at Rose Creek, Cudahy Creek, and Tecolote Creek. All data are presented as MPN per gram of dry sediment. Surface refers to surficial sediment (top 1 cm), Depth refers to four inches below the surface, and Mean is the geometric mean of the data. Bacterial densities > 1,000 MPN/g are highlighted in red.

Strata	FC (MPN/g)	ENT (MPN/g)	Strata	FC (MPN/g)	ENT (MPN/g)
Rose Creek – 10/24/2003			**Rose Creek – 1/14/2004**		
Surface	<1	8	Surface	<1	<1
Surface	<1	2	Surface	<1	7
Surface	<1	<1	Surface	<1	33
Surface	<1	10	Surface	<1	11
Surface	<1	2	Surface	<1	15
Surface	<1	35	Surface	5	55
Mean	<1	**4.2**	**Mean**	**0.7**	**10.0**
Depth	<1	9	Depth	<1	2,496
Depth	<1	72	Depth	<1	5,897
Depth	<1	18	Depth	<1	7,066
Mean	<1	**22.3**	**Mean**	<1	**4,703**
Cudahy Creek – 10/24/2003			**Cudahy Creek – 1/14/2004**		
Surface	16	<1	Surface	12	20
Surface	6	2	Surface	<1	397
Surface	7	<1	Surface	<1	53
Surface	<1	<1	Surface	6	25
Surface	2	3	Surface	23	41
Surface	2	1	Surface	1	4
Mean	**3.3**	**0.94**	**Mean**	**2.8**	**35.6**
Depth	2	3	Depth	<1	1
Depth	<1	<1	Depth	<1	3,047
Depth	<1	<1	Depth	<1	1,375
Mean	**0.82**	**0.95**	**Mean**	<1	**176**
Tecolote Creek – 10/24/2003			**Tecolote Creek – 1/14/2004**		
Surface	<1	<1	Surface	11	45
Surface	<1	1	Surface	420	223
Surface	<1	<1	Surface	14	8
Surface	<1	<1	Surface	6	8
Surface	<1	<1	Surface	10	128
Surface	<1	<1	Surface	17	712
Mean	<1	**0.55**	**Mean**	**20**	**62.2**
Depth	<1	1	Depth	<1	3
Depth	<1	3	Depth	<1	<1
Depth	<1	<1	Depth	<1	<1
Mean	<1	**1.1**	**Mean**	<1	**0.95**

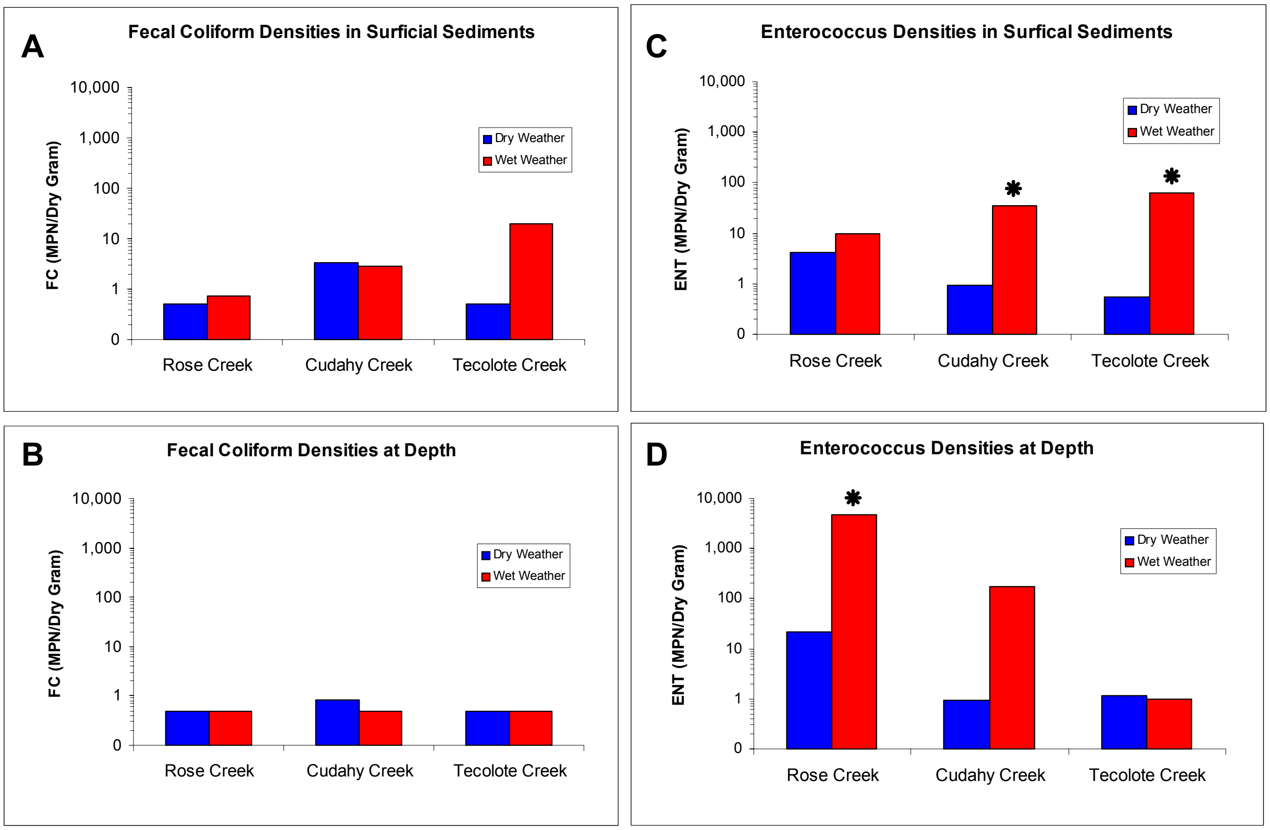


Figure 6. Graphs of fecal coliform and enterococcus densities in surficial sediments (top 1 cm) and at a depth of four inches from deltas at Rose Creek, Cudahy Creek, and Tecolote Creek. Bars represent the geometric means of bacterial densities collected during the dry and wet weather surveys (* represents statistical significance between survey means).

Grain Size. The results of the grain size analyses for the surficial sediment composites is presented for the dry and wet weather surveys in Table 3. The largest sediment grain size of the three deltas was found at Rose Creek. At this site, grain size characteristics were similar between dry weather and wet weather surveys. Sediments were composed primarily of sand-sized particles. At Cudahy Creek, grain size characteristics were also similar between dry and wet weather surveys. However, Cudahy Creek delta sediments contained a smaller percentage of sand and a larger percentage of silts and clays than the deltas at Rose Creek or Tecolote Creek. In contrast to Rose Creek and Cudahy Creek, the characteristics of the delta sediments at Tecolote Creek differed between the dry and wet weather surveys. The median grain size in the dry weather survey (147 µm) was nearly three times greater than that observed in the wet weather survey (54 µm). This pattern was reflected by the percent silt and clay fraction, which changed from 15% in the dry weather survey to 54% in the wet weather survey.

Table 3. Grain size characteristics of surficial sediments from composite samples taken from deltas at Rose Creek, Cudahy Creek, and Tecolote Creek.

	Dry Weather Survey – October 2003				Wet Weather Survey – January 2004			
	Median (microns)	Percent Gravel	Percent Sand	Percent Silt/Clay	Median (microns)	Percent Gravel	Percent Sand	Percent Silt/Clay
Rose Creek	256	1.2	90	8.5	209	0.12	91	9.0
Cudahy Creek	85	0.70	63	36	76	0.65	60	39
Tecolote Creek	147	1.0	84	15	54	0.13	45	54

Bacterial Host Origin

The molecular analysis used to identify bacterial host origin utilizes isolates of *E. coli* bacteria, which are part of the fecal coliform bacterial group. Since fecal coliform bacteria were found in surficial sediments only at Cudahy Creek during the dry weather survey, isolates for MST analysis were obtained only from this site. During the wet weather survey, fecal coliform bacteria in surficial sediments were present at densities high enough for isolation of *E. coli* only at Cudahy Creek and Tecolote Creek. The total number of bacterial isolates taken from each site for Ribotyping analyses is presented in Table 4.

Table 4. Number of bacterial isolates obtained from sediment and receiving water for Ribotyping Analyses during dry and wet weather surveys.

Site	Dry Weather Survey – October 2003		Wet Weather Survey – January 2004		Total
	Sediment	Receiving Water	Sediment	Receiving Water	
Rose Creek	0	0	0	0	0
Cudahy Creek	103	0	59	79	138
Tecolote Creek	0	0	69	86	155
Total	103	0	128	165	293

Cudahy Creek

During the dry weather survey, a total of 103 *E. coli* isolates from surficial delta sediments were analyzed to determine the DNA Ribotype. All of the isolates were taken from samples collected at Cudahy Creek. The analysis revealed that a majority (56%, or 58 out of 103) of the sediment-derived Ribotypes were identified as having an Avian source (Figure 7). The next largest group accounted for 24% (or 25 out of 103) of the sediment-derived Ribotypes and was comprised of Ribotypes that could not be matched to any of the animal host Ribotypes present in the Institute for Environmental Health’s Source Ribotype Library Database (Unknown). Human sources matched 10% of the sediment-derived Ribotypes, while the remaining 10% of the isolates were found to have a mixed mammalian origin.

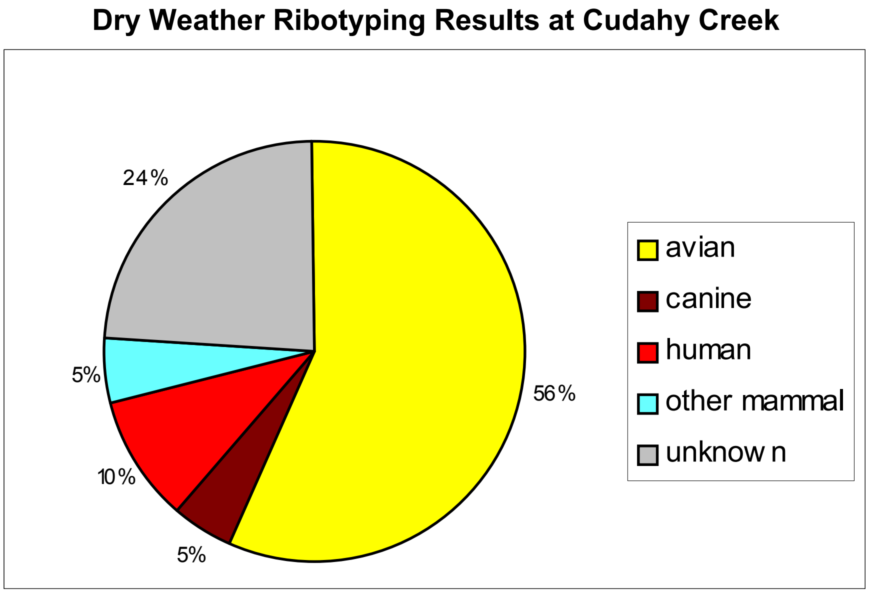


Figure 7. Results of Ribotyping analysis at Cudahy Creek during the dry weather survey. The pie charts show the origin of bacterial isolates in delta sediments.

The results of the HS-PCR analysis of samples collected at Cudahy Creek during the dry weather survey are shown in Table 5. While the general *Bacteroides* marker appeared in two out of three sediment samples analyzed, no human marker was detected.

Table 5. Results of PCR analysis of delta sediments at Cudahy Creek during dry weather.

Location	General Marker	Human Marker	Total # of Samples
Site 8	2	0	3

During the wet weather survey, a total of 59 *E. coli* isolates were obtained from Cudahy Creek sediments. Upon querying the Institute for Environmental Health's Source Ribotype Library Database, we found that 42 out of 59 (or 71%) of the sediment-derived Ribotypes matched Ribotypes of Avian origin (Figure 8A). Sediment-derived Ribotypes that matched Canine Ribotypes comprised the next largest host animal source group (9 of 59, or 15%) The remaining 8 sediment-derived Ribotypes (or 14%) could not be matched to any Ribotypes present in the Institute for Environmental Health's Source Ribotype Library Database and therefore no upstream animal sources could be identified (Unknown, Figure 8A).

In receiving water samples collected at Cudahy Creek during wet weather, a total of 79 isolates were obtained (Figure 8B). Of these, 66% (52 out of 79) were of Avian origin. Bacteria of Canine origin accounted for 14% (11 out 79) of the total. Of the remaining isolates, 14% (or 11 out of 79) were found to match Ribotypes from a variety of mammalian hosts, while 6% (5 out of 79) could not be matched to any animal host (Unknown, Figure 8B).

To assess the extent to which sediments act as a source of bacteria to the receiving waters, we next asked what percentage of Ribotypes in the sediments were also found in the receiving waters. To answer this question, we searched the sediment-derived Ribotype data set for Ribotype identifier codes that matched those Ribotype identifier codes from the water-derived data set. Results from this analysis are shown in Figure 8C. This analysis showed that only 17% (14 out of 79 isolates) of the Ribotypes in the receiving water matched those in the sediment at Cudahy Creek.

Wet Weather Ribotyping Results at Cudahy Creek

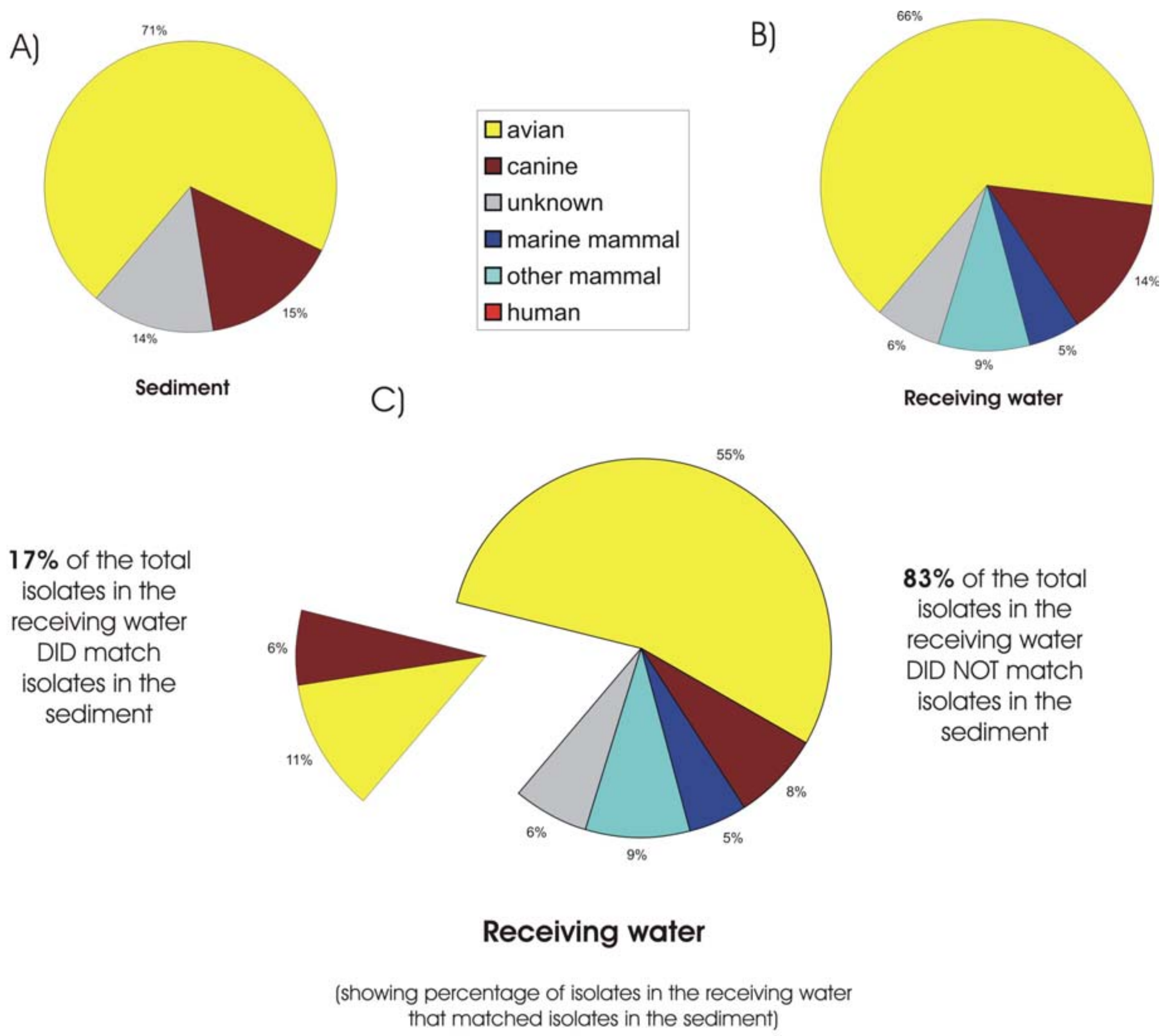


Figure 8. Results of Ribotyping analysis at Cudahy Creek during the wet weather survey. The pie charts show the origin of bacterial isolates in delta sediments (A), receiving water (B), and the proportion of isolates in receiving water that matched those in sediment (C).

As with sediments collected during the dry weather survey, a sub-set of samples collected during the wet weather survey at Cudahy Creek were subjected to the HS-PCR assay. Interestingly, results from these samples indicated that all samples were positive for the general maker, and that two out of three samples were positive for the Human *Bacteroides* marker (Table 6).

Table 6. Results of PCR analysis of delta sediments at Cudahy Creek during wet weather.

Location	General Marker	Human Marker	Total # of Samples
Site 8	3	2	3

At Tecolote Creek, *E. coli* isolates were obtained only during the wet weather survey. In the sediment, a total of 69 isolates were obtained (Figure 9A). Ribotyping analyses revealed that of these, 55% (38 out of 69) were of Avian origin, 26% were of Canine origin, and 15% were from other mammalian sources. A total of 4% of the Ribotypes could not be identified in the Institute for Environmental Health's Source Ribotype Library Database (Unknown, Figure 9A).

In the receiving water at Tecolote Creek, 86 isolates were obtained (Figure 9B). Ribotyping analysis determined that they were primarily of avian origin (72 out of 86, or 84%). Canine sources were identified for six out of 86 water-derived Ribotypes and the remaining eight Ribotypes were distributed among a variety of animal sources.

We next searched for matches between the Tecolote Creek sediment and receiving water-derived Ribotype data sets (Figure 9C). Strikingly, we found that 45% (39 out of 86) of the isolates obtained from the receiving water did match isolates identified in the sediments.

Wet Weather Ribotyping Results at Tecolote Creek

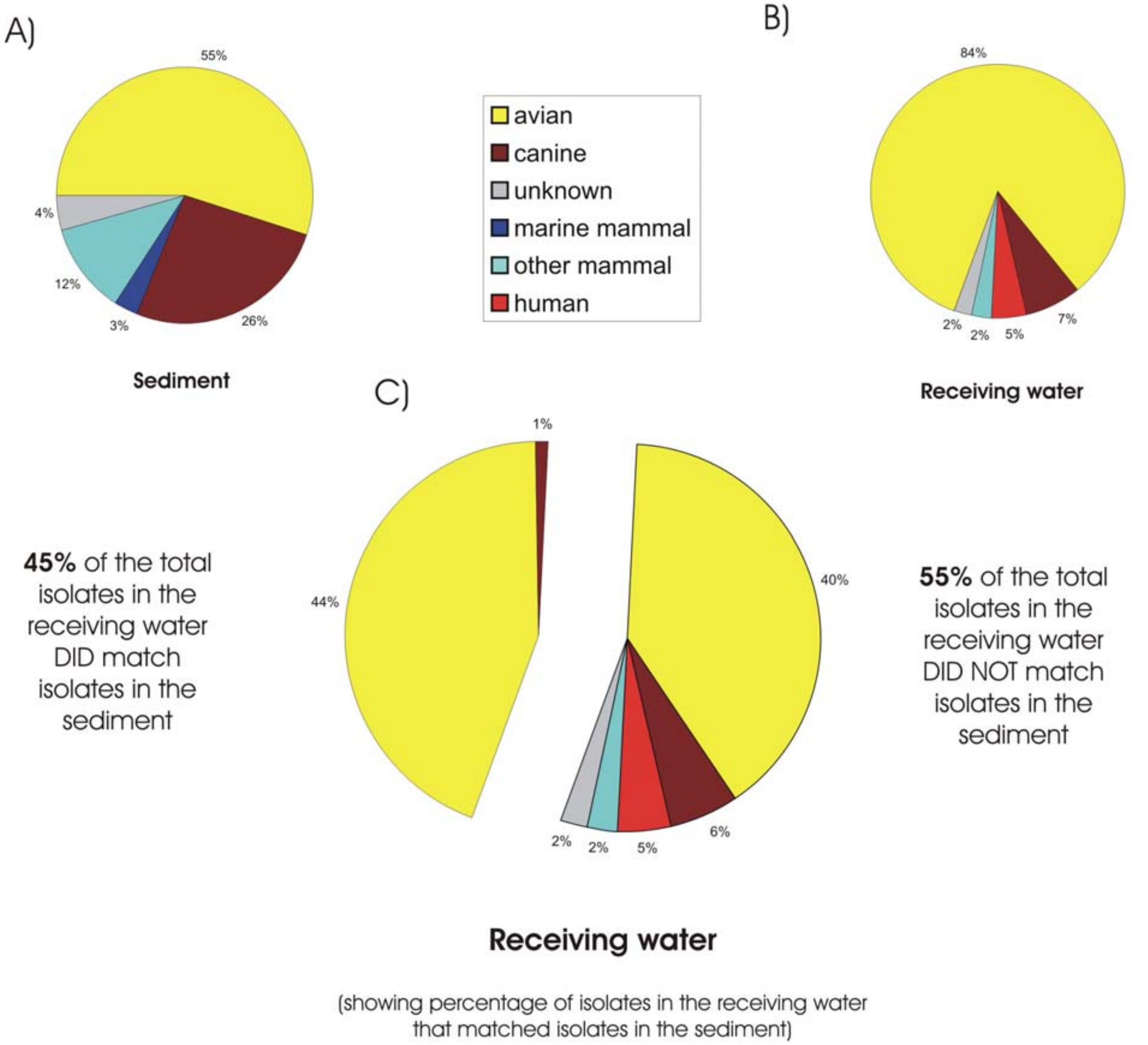


Figure 9. Results of Ribotyping analysis at Tecolote Creek during the wet weather survey. The pie charts show the origin of bacterial isolates in delta sediments (A), receiving water (B), and the proportion of isolates in receiving water that matched those in sediment (C).

The results of the HS-PCR analysis of surficial sediment samples collected from Tecolote Creek during the wet weather survey revealed that two out of the three samples were positive for both the General and the Human *Bacteroides* marker (Table 7).

Table 7. Results of PCR analysis of delta sediments at Tecolote Creek during wet weather.

Location	General Marker	Human Marker	Total # of Samples
Site 11	2	2	3

Intertidal Sediments

Two types of assessments involving intertidal sediments were conducted: Beach face transects and sediment resuspension studies. Enumeration of bacteria along the beach face was conducted at two sites: Site 1 (Bonita Cove) and Site 9 (Leisure Lagoon). Sediment resuspension studies were conducted at three sites: Site 1 (Bonita Cove), Site 7 (De Anza Cove), and Site 9 (Leisure Lagoon). The results of the intertidal sediment studies are presented below by site.

Bonita Cove. At Bonita Cove, the assessments of bacterial densities in the intertidal sediments were conducted on April 14, 2004. The results are presented in Table 8. Fecal coliform densities in intertidal sediments were similar at tidal heights of +6, +5, +4, and +2 feet above MLLW, with geometric means of the five transects ranging from 32.5 to 101 MPN/g dry sediment. At tidal heights of +1 and 0 feet above MLLW, fecal coliform densities dropped dramatically, with geometric means of 1.4 and 2.6 MPN/g, respectively. Mean fecal coliform densities in the upper intertidal sediments (+6, +5, +4, and +2 feet above MLLW) were significantly greater ($p < 0.0001$) than those in the lower intertidal sediments (+1 and 0 feet above MLLW). These results are presented graphically in Figure 10.

Densities of enterococci in intertidal sediments showed a similar pattern to that observed for fecal coliforms (Table 8). Mean enterococcus densities were similar between the upper intertidal sampling locations (+6, +5, +4, and +2 feet above MLLW) and were significantly greater ($p < 0.0001$) than those in the lower intertidal sediments (one and zero feet above MLLW) (Figure 10).

Table 8. Fecal coliform and enterococcus densities in intertidal sediments at Bonita Cove. All data are presented as MPN per gram of dry sediment.

Transect	Tidal Height on Beach Face (in feet above MLLW)					
	6	**5**	**4**	**2**	**1**	**0**
Fecal Coliform						
A	16	406	65	60	1	3
B	12	60	60	61	4	15
C	109	51	56	6	2	1
D	27	191	49	29	1	1
E	64	45	21	109	1	7
Geometric Mean	**32.5**	**101**	**46.6**	**37.1**	**1.4**	**2.6**
Enterococcus						
A	17	52	39	21	5	3
B	11	37	47	18	2	3
C	12	26	47	20	2	0
D	14	45	55	25	2	0
E	29	18	29	75	11	7
Geometric Mean	**15.5**	**33.0**	**42.3**	**26.7**	**3.1**	**1.2**

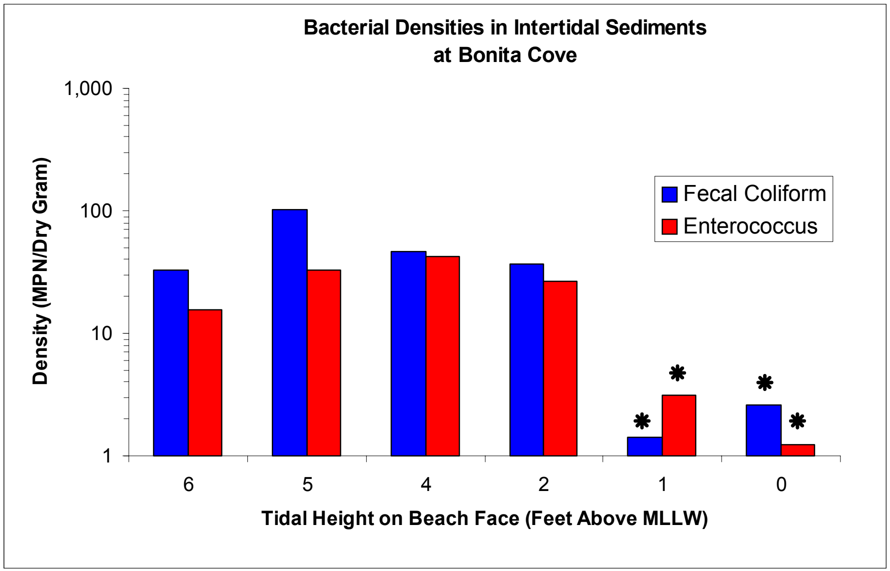


Figure 10. Fecal coliform and enterococcus densities in intertidal sediments at Bonita Cove. Bars represent the geometric means of 5 samples, * represents significant differences between upper and lower intertidal sediments.

The fecal coliform and enterococcus data for the resuspension studies conducted at Bonita Cove are presented in Tables 9 and 10. During the Low Tide study, there was no significant difference ($p > 0.05$) between the mean clear water and resuspended sediment bacterial densities for either fecal coliform or enterococcus. In contrast, when the study was repeated during high tide, there was a marked difference in bacterial densities between the clear water and resuspended sediment samples. For enterococcus, the geometric mean density of the Clear Water samples was low at high tide (9.1 MPN/100 ml), similar to the results observed during low tide. However, after sediment resuspension at high tide, the enterococcus geometric mean density had increased two orders of magnitude to 1,096 MPN/100 ml. At all 15 stations the resuspended sediment samples at high tide were one to two orders of magnitude greater than the corresponding Clear Water samples. The mean enterococcus density of the resuspended sediment sample was significantly greater than that of the clear water samples ($p < 0.0001$). These results are shown graphically in Figure 11.

Fecal coliform bacteria were enumerated at Bonita Cove only in the High Tide resuspension study conducted in April 2004. The results are presented in Table 10. The results are similar to those seen for enterococcus at high tide. Mean fecal coliform density of the resuspended sediment samples was significantly greater than that of the clear water samples ($p < 0.0001$). These results are presented in Figure 12.

Table 9. Enterococcus densities at Site 1 Bonita Cove from clear water sample (taken prior to sediment resuspension) and resuspended sediment samples (taken while sediments had been resuspended in the water column). Bacterial densities are presented as MPN/100 ml. Values in red exceeded the AB411 standard for enterococcus of 104 MPN/100 ml.

Station	Low Tide Study - May 2003		High Tide Study - April 2004	
	Clear Water Sample	Resuspended Sediment Sample	Clear Water Sample	Resuspended Sediment Sample
1	31	74	5	909
2	20	41	10	1,145
3	10	20	20	776
4	41	31	10	650
5	20	86	10	512
6	20	20	10	1,414
7	41	31	10	1,187
8	20	41	5	1,119
9	31	10	5	2,014
10	30	30	5	2,755
11	74	30	10	2,613
12	62	51	10	1,723
13	31	20	20	1,354
14	20	197	10	886
15	146	109	10	262
Geometric Mean	**31.7**	**39.3**	**9.1**	**1,096**

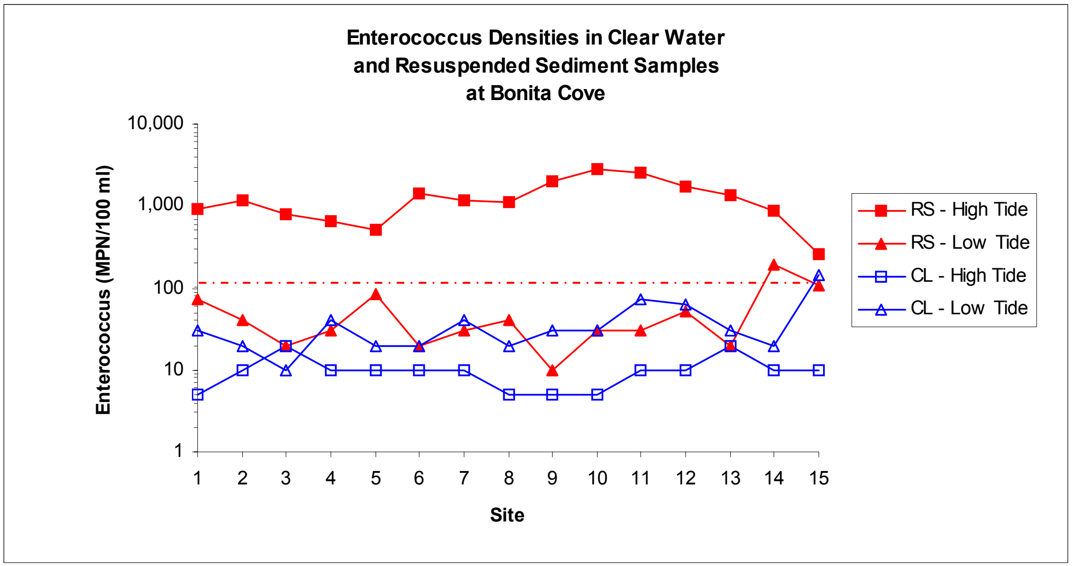


Figure 11. Graph of enterococcus densities in receiving water at Bonita Cove. CL refers to clear water samples and RS refers to samples taken after sediment resuspension. The dashed red line represents the AB411 standard for enterococcus of 104 MPN/100 ml.

Table 10. Fecal coliform densities at Bonita Cove from clear water sample (taken prior to sediment resuspension) and resuspended sediment samples (taken while sediments had been resuspended in the water column). Bacterial densities are presented as MPN/100 ml. Values in red exceeded the AB411 standard for fecal coliform of 400 MPN/100 ml.

Station	Low Tide Study - May 2003	
	Clear Water Sample	Resuspended Sediment Sample
1	20	1,700
2	< 20	5,000
3	< 20	2,200
4	70	3,000
5	40	11,000
6	40	2,300
7	20	3,000
8	< 20	3,000
9	20	14,000
10	20	8,000
11	20	11,000
12	20	5,000
13	80	3,000
14	20	5,000
15	40	2,300
Geometric Mean	**23.8**	**4,255**

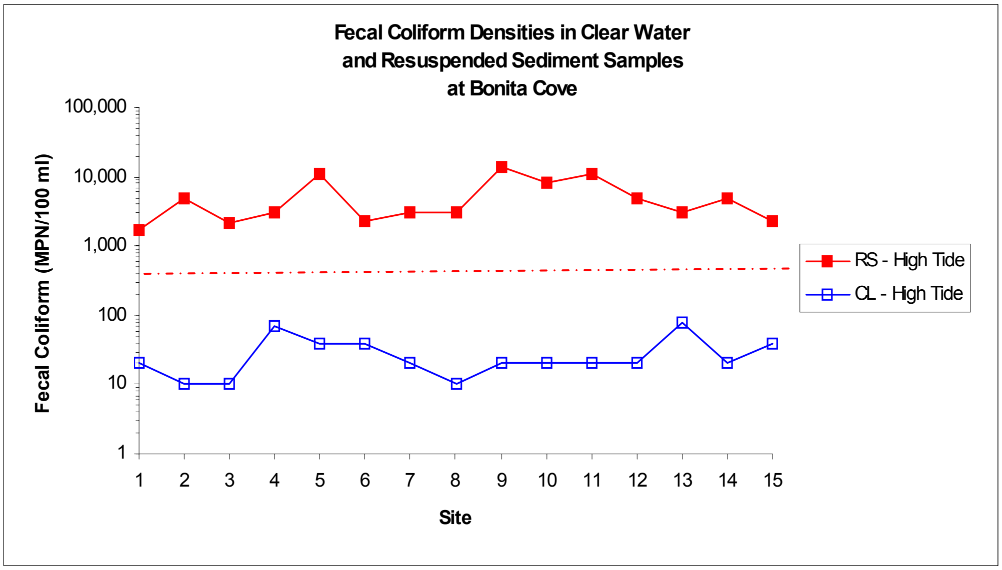


Figure 12. Fecal coliform densities in receiving water at Bonita Cove. CL refers to clear water samples and RS refers to samples taken after sediment resuspension. The dashed red line represents the AB411 standard for fecal coliform of 400 MPN/100 ml.

De Anza Cove. At De Anza Cove, a single, Low Tide resuspension study was conducted on May 21, 2003. Only enterococcus was enumerated (Table 11). In contrast to the Low Tide study conducted at Bonita Cove, the mean resuspended sediment enterococcus density of 38.1 MPN/100 ml was significantly greater than the mean clear water density of 12.3 MPN/100 ml (p = 0.0004). The data are presented graphically in Figure 13.

Table 11. Enterococcus densities at De Anza Cove from clear water sample (taken prior to sediment resuspension) and resuspended sediment samples (taken while sediments had been resuspended in the water column). Bacterial densities are presented as MPN/100 ml. Values in red exceeded the AB411 standard for enterococcus of 104 MPN/100 ml.

Station	Low Tide Study - May 2003	
	Clear Water Sample	Resuspended Sediment Sample
1	10	20
2	10	52
3	10	30
4	30	110
5	10	41
6	10	84
7	10	10
8	10	20
9	74	108
10	10	153
11	10	10
12	10	30
13	10	10
14	10	106
15	10	41
Geometric Mean	**12.3**	**38.1**

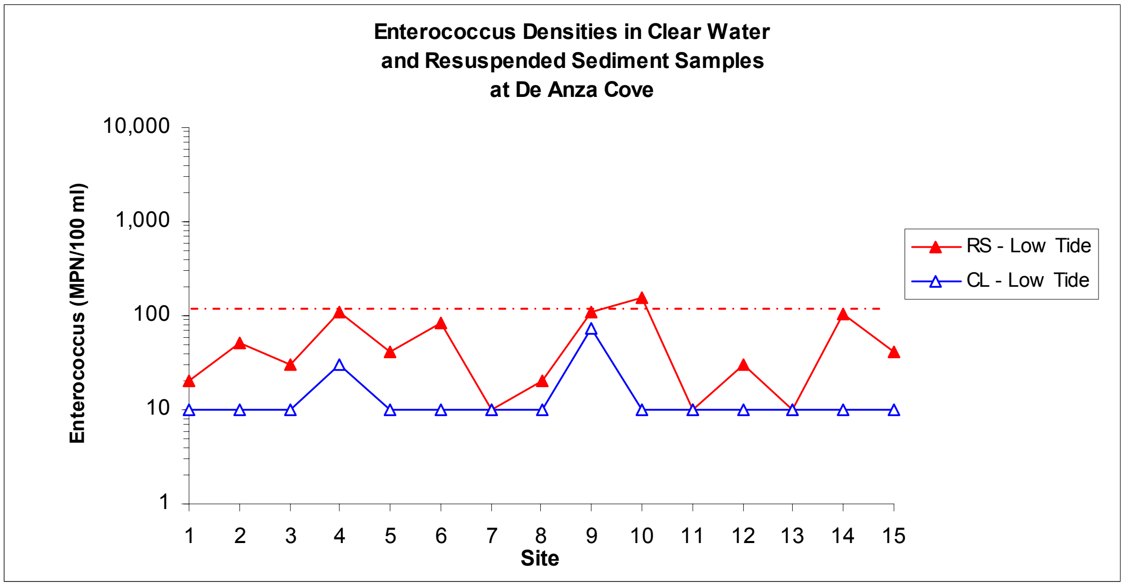


Figure 13. Graph of enterococcus densities in receiving water at De Anza Cove. CL refers to clear water samples and RS refers to samples taken after sediment re-suspension. The dashed red line represents the AB411 standard for enterococcus of 104 MPN/100 ml.

Leisure Lagoon. At Leisure Lagoon, bacterial densities in intertidal sediments were similar to those found at Bonita Cove (Table 12). Fecal coliform geometric mean densities in intertidal sediments at Leisure Lagoon ranged from 10.8 to 2.9 MPN/g and enterococcus geometric mean densities ranged from 5.0 to 10.6 MPN/g. In contrast to Bonita Cove, there were no significant differences for either bacterial indicator between mean sediment densities by tidal height (Figure 14). However, samples taken at Transect C at tidal heights of +2, +1, and 0 feet above MLLW contained bacterial densities that were one to two orders of magnitude greater than samples collected from other transects at the same tidal height. These samples are highlighted in red in Table 12. Transect C was located adjacent to storm drain SD9-2 in Leisure Lagoon. The terminus of this storm drain is located at a tidal height of approximately +2 feet above MLLW. Thus, sediment samples collected at tidal heights of 0, +1, and +2 feet above MLLW at Transect C were directly in front of the discharge point of the storm drain outfall, which apparently greatly influenced bacterial densities. The values for these three samples were removed from the data set, and the data were re-plotted, as shown in Figure 15. With the storm drain influenced samples removed, it is apparent that the bacterial densities in the upper intertidal sediments at Leisure Lagoon (+6, +5, and +4 feet above MLLW) are greater than those in the lower Intertidal sediments (+2, +1, and 0 feet above MLLW). When data from the upper intertidal sediments are pooled and compared to those in the lower intertidal sediments (without the samples collected in front of the storm drain outfall), there was a significant difference between the two means for both fecal coliform (p=0.0043) and enterococcus (p = 0.0028).

Table 12. Fecal coliform and enterococcus densities in intertidal sediments at Leisure Lagoon. All data are presented as MPN per gram of dry sediment. Densities in red are from samples taken directly in front of storm drain SD9-2.

Transect	Tidal Height on Beach Face (in feet above MLLW)					
	6	5	4	2	1	0
Fecal Coliform						
A	9	5	1	0	1	1
B	14	6	57	1	2	0
C	2	36	49	**107**	**86**	**15**
D	42	13	20	4	1	7
E	14	1	3	4	24	4
Geometric Mean	**10.8**	**6.8**	**11.1**	**3.9**	**5.3**	**2.9**
Enterococcus						
A	2	7	4	2	5	3
B	3	4	3	2	0	2
C	4	16	33	**> 517**	**> 418**	**> 338**
D	45	7	24	2	1	3
E	7	1	14	3	4	1
Geometric Mean	**6.0**	**5.0**	**10.6**	**6.6**	**5.3**	**5.7**

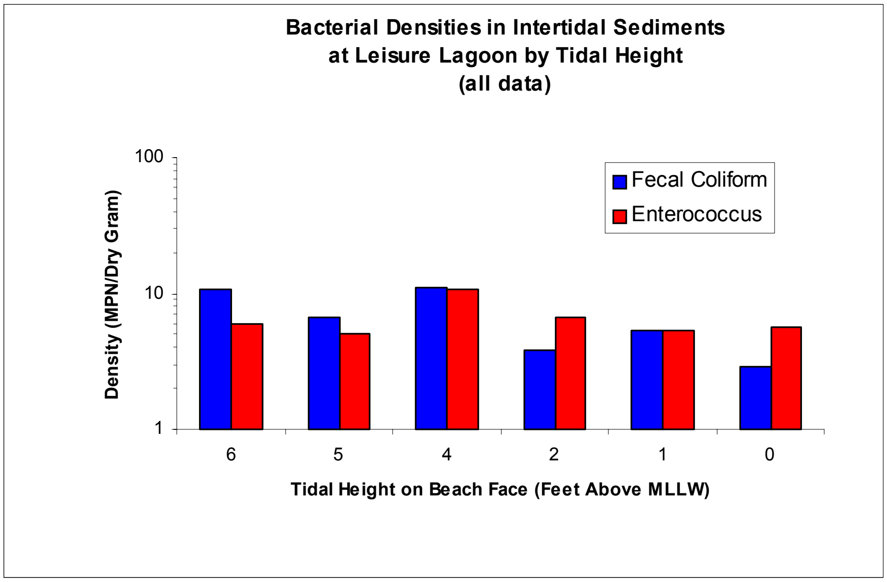


Figure 14. Fecal coliform and enterococcus densities in intertidal sediments at Site 9 (Leisure Lagoon) by tidal height. Bars represent the geometric means of 5 samples.

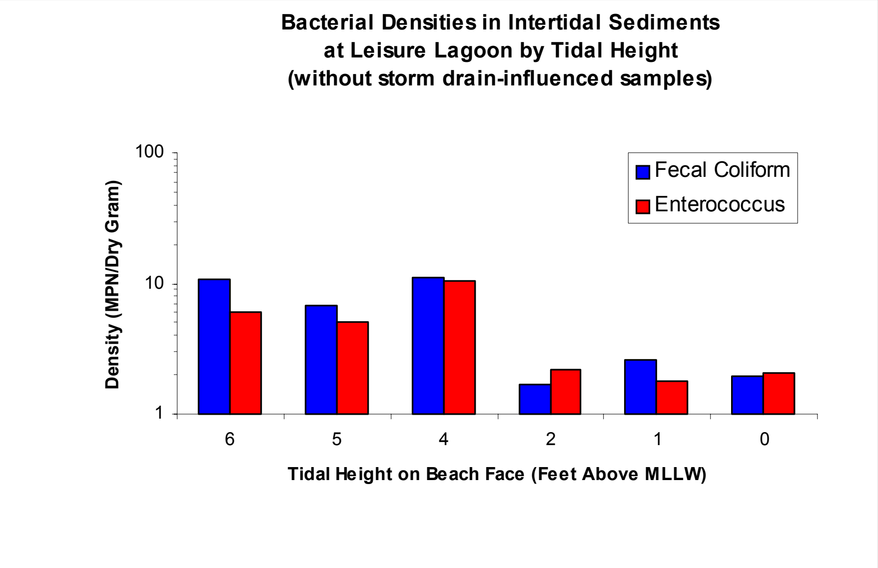


Figure 15. Fecal coliform and enterococcus densities in intertidal sediments at Site 9 (Leisure Lagoon) by tidal height with storm drain-influenced samples removed. Bars represent the geometric means of 4 to 5 samples.

The sediment resuspension study was conducted at Leisure Lagoon during a high tide in April 2004. The results are presented in Table 13. Mean fecal coliform density for resuspended sediment samples (574 MPN/100 ml) was an order of magnitude greater than the mean of clear water samples (21.9 MPN/100 ml). The difference was statistically significant ($p < 0.0001$). The pattern for enterococcus was similar to that of fecal coliforms. The mean enterococcus density of resuspended sediment samples (384 MPN/100 ml) was significantly greater than the mean of clear water samples (7.9 MPN/100 ml) ($p = < 0.0001$). Graphical representations of the data (Figure 16) clearly demonstrate the difference in bacterial densities in clear water verses water containing resuspended sediment.

Table 13. Fecal coliform and enterococcus densities at Leisure Lagoon from clear water sample (taken prior to sediment resuspension) and resuspended sediment samples (taken while sediments had been resuspended in the water column). Bacterial densities are presented as MPN/100 ml. Values in red exceeded the AB411 criteria for fecal coliform and enterococcus of 400 and 104 MPN/100 ml, respectively.

Station	Fecal Coliform (MPN/100 ml)		Enterococcus (MPN/100 ml)	
	Clear Water Sample	Resuspended Sediment Sample	Clear Sample	Resuspended Sediment Sample
1	20	110	< 10	41
2	< 20	140	< 10	85
3	< 20	110	< 10	120
4	20	300	10	292
5	20	300	20	74
6	20	5,000	10	1,616
7	40	3,500	< 10	213
8	20	5,000	10	19,863
9	20	5,000	10	682
10	40	1,300	< 10	441
11	20	800	10	1,014
12	40	80	20	146
13	20	110	< 10	262
14	20	500	10	1,112
15	40	800	< 10	733
Geometric Mean	**21.9**	**574**	**7.9**	**384**

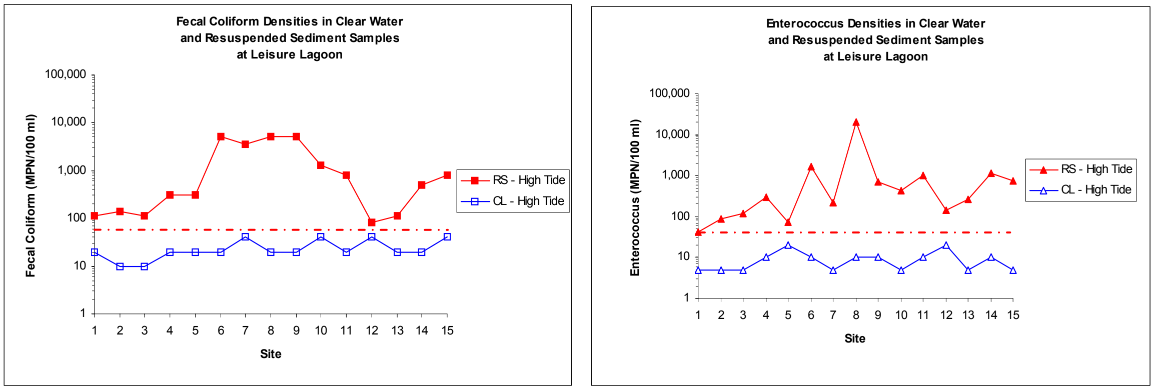


Figure 16. Fecal coliform and enterococcus densities in receiving water at Leisure Lagoon. CL refers to clear water samples and RS refers to samples taken after sediment re-suspension. The dashed red lines represents the AB411 standards of 400 MPN/100 ml for fecal coliform and 104 MPN/100 ml for enterococcus.

Grain Size. In addition to the bacterial assessments, sediment grain size was determined from composite samples taken along the beach face at each of the three sites (Table 14). Sediments at all three sites were composed primarily of sand (90.1 to 97.0 %). However, the median grain size at Bonita Cove (237 microns) was larger than that at the other sites. Sediments at De Anza Cove were smaller (median grain size of 163 microns) and contained a larger proportion of fine-grained sediments (9.53 % silt and clay) than the other sites. Sediment characteristics at Leisure Lagoon were intermediate between Bonita Cove and De Anza Cove.

Table 14. Grain size characteristics of surficial sediments from composite samples taken along the beach face at Bonita Cove, De Anza Cove, and Leisure Lagoon.

Site	Median (microns)	Percent Gravel	Percent Sand	Percent Silt/Clay
Bonita Cove	237	0.14	97.0	2.89
De Anza Cove	163	0.48	90.1	9.53
Leisure Lagoon	209	0.11	96.6	3.30

DISCUSSION

Delta Sediments

The goal of the delta sediment investigation was to determine the extent to which sediments at the mouths of the major freshwater drainages to Mission Bay affect indicator bacterial levels in the receiving waters. Several studies have suggested that freshwater sediments can harbor enteric bacteria for prolonged periods of time, particularly in warmer climates (Solo-Gabriele et al 2000). However, fewer studies have been published that address the survival of enteric bacteria in sediments that are influenced by the harsher conditions found in marine waters (Steets and Holden 2003, Grant et al. 2001). Coastal embayments are often complex environments due to temporal changes in salinity, DO, pH, and other water quality variables. In addition, organic enrichment, which enhances the survival and growth of bacteria in the environment can be extremely variable and site-specific. The coastal zone of southern California is arid and receives on average less than 10 to 13 inches of rainfall annually (MEC 2004) and many streams draining to the coast are intermittent. In Mission Bay, freshwater is even less available because of the Mission Bay Sewage Interceptor System (MBSIS), which diverts dry weather flows to the sewer. Thus, there are a variety of factors that affect the extent to which the delta sediments in Mission Bay act as a reservoir for enteric bacteria. The results of this study suggest that seasonal and site-specific conditions at each of the three deltas greatly influenced the extent to which the delta sediments impacted bacterial levels in the receiving waters.

Rose Creek

The bacteriological results from samples collected from Rose Creek indicate that the delta sediments are an unlikely source of bacteria to the receiving waters at Campland. There were virtually no fecal coliform bacteria in either the dry or wet weather surveys in surficial sediments and the Rose Creek delta does not appear to be a reservoir for this indictor bacteria. Enterococcus densities were patchy in both the dry and wet weather surveys and densities were low to moderate. One surprising result from the study was the very high densities of enterococcus bacteria from samples at a depth of four inches below the surface, which ranged from 2,400 to over 7,000 MPN/g during the wet weather survey. Densities in this range reflect the resiliency of enterococcus bacteria to survive and possibly reproduce under harsh environmental conditions. However, due to the low current velocities in this part of Mission Bay (Largier et al. 2003) we think it is unlikely that bacteria from this depth are transported to the receiving waters at Campland.

The lack of fecal coliform bacteria in the Rose Creek delta prevented us from assessing the connection between bacteria in the sediments and those in the receiving water using the

Ribotyping technique. However, a review of historical bacterial data from receiving waters collected at Campland provided ancillary information that suggests the sediments are an unlikely source of bacteria. Receiving water monitoring data collected at Campland from 2001 through 2003 are plotted against the tidal stage at the time of collection in Figure 17. The Rose Creek delta lies outside of the entrance to the Campland beach. In this location, sediment (and any bacteria associated with it) would be transported from the delta to the beach only during flooding tides. Thus, if the delta sediments were a substantial source of bacteria to the receiving waters at the beach, bacterial densities would be expected to be greater during flooding tides than ebbing tides. The data presented in Figure 17 suggest that there is no such pattern in bacterial densities at Campland. Exceedances of the enterococcus AB411 criterion for enterococcus (shown in red) appear to be randomly distributed among samples taken throughout the tidal cycle. These results provide indirect evidence that the delta sediments at Rose Creek are not a source of indicator bacteria to the receiving waters at Campland.

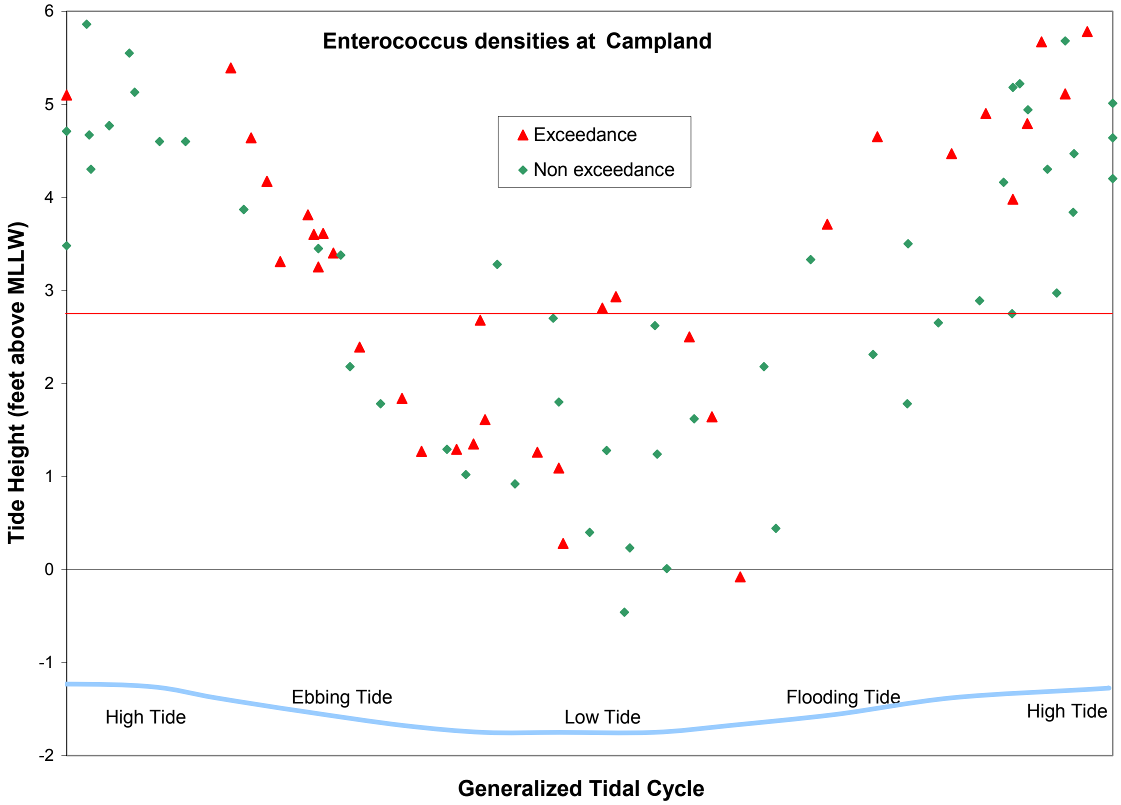


Figure 17. Enterococcus densities verses tidal height at Campland, adjacent to the Rose Creek delta, from 2001 through 2003. Samples shown in red exceeded the AB411 criteria for enterococcus of 104 MPN/100 ml. The red line separates samples taken in the upper intertidal from the lower intertidal zones.

In addition to the receiving water monitoring data collected at Campland, receiving water samples are also collected for bacterial analyses from Rose Creek, approximately 2,000 feet north (upstream) of the Campland beach as part of a Supplemental Environmental Program (SEP) conducted by the City. In Figure 18, enterococcus densities are plotted over time for receiving water samples collected from Rose Creek and from the Campland beach from October 2002 through January, 2003. Data from the receiving water monitoring support the assertion that indicator bacteria associated with Rose Creek have little impact on the receiving waters at Campland. Enterococcus densities at Campland show periodic spikes throughout the sampling period (Figure 18A). However, enterococcus densities in Rose Creek were very low throughout the sampling period except over several days at the end of December (days 80-100) when enterococcus densities increased dramatically. The spike in enterococcus density was due to a sewage spill that occurred in Rose Creek during this time. Remarkably, during the same time period, enterococcus densities at Campland remained very low. When the data from the Rose Creek sewage spill are removed from the data set and re-plotted (Figure 18B), it is apparent that enterococcus densities were very low in Rose Creek throughout the sampling period and there was no apparent correlation between densities measured in Rose Creek and those at Campland. These results combined with other observations at Campland suggest that Rose Creek effluent does not affect indicator bacterial densities in receiving waters at the Campland beach.

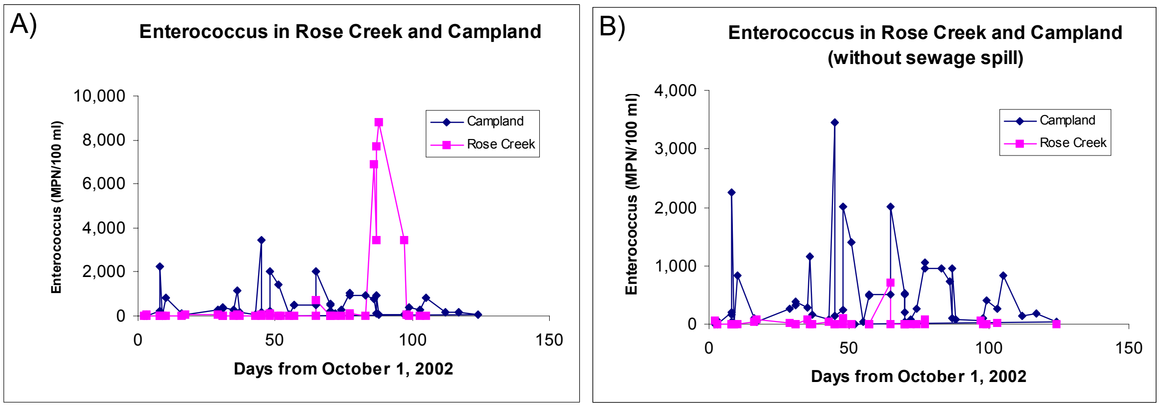


Figure 18. Comparison of enterococcus densities in receiving waters collected from Rose Creek and from the Campland AB411 monitoring site with (Graph A) and without (Graph B) data from a sewage spill in Rose Creek in late December 2002.

Cudahy Creek

The results of the bacterial analysis conducted on sediments from the Cudahy Creek delta suggest that there is a strong seasonal pattern in indicator bacterial densities in the sediments. During the dry weather survey, fecal coliform and enterococcus densities in nearly all of the samples collected were low, suggesting that the sediments are an unlikely source of bacteria to the receiving waters during dry weather. The Ribotypiing analysis suggested that the majority of the isolates obtained from the sediments during this survey originated from birds, which is consistent with other Ribotyping assessments conducted at this site and elsewhere in Mission Bay.

During the wet weather survey, fecal coliform densities were similar in magnitude to those measured during dry weather. However, enterococcus densities had increased by an order of magnitude during the wet weather survey. These results suggest an input of enterococcus bacteria to the site during the winter months, most likely due to runoff from Cudahy Creek and two large storm drains at Visitor's Center. The results also indicate that, during the wet season, the sediments of the Cudahy Creek delta act as a reservoir for enterococcus bacteria. The results of the Ribotyping assay indicate that the majority of the bacteria originate from birds. However, the Ribotyping results also suggest that there is not a strong connection between the enteric bacteria in the sediments and those in the receiving water at this site. Of the 79 receiving water isolates analyzed, only 17% had Ribotypes that matched those of isolates in the sediment.

The lack of a strong connection between bacteria in the sediments and those in the receiving water may be due to the high densities of indicator bacteria present at this site and the numerous bacterial sources that have been identified, including effluent from storm drains and Cudahy Creek, excessive irrigation, and organic debris on the beach. In addition, this area typically has the highest concentration of birds of any site in Mission Bay. One of the largest sources of bacteria to this area is flow from Cudahy Creek. The number of exceedances of bacterial standards is greater at this site than any other site in Mission Bay. The number of exceedances of the enterococcus standard at Cudahy Creek is illustrated in Figure 19.

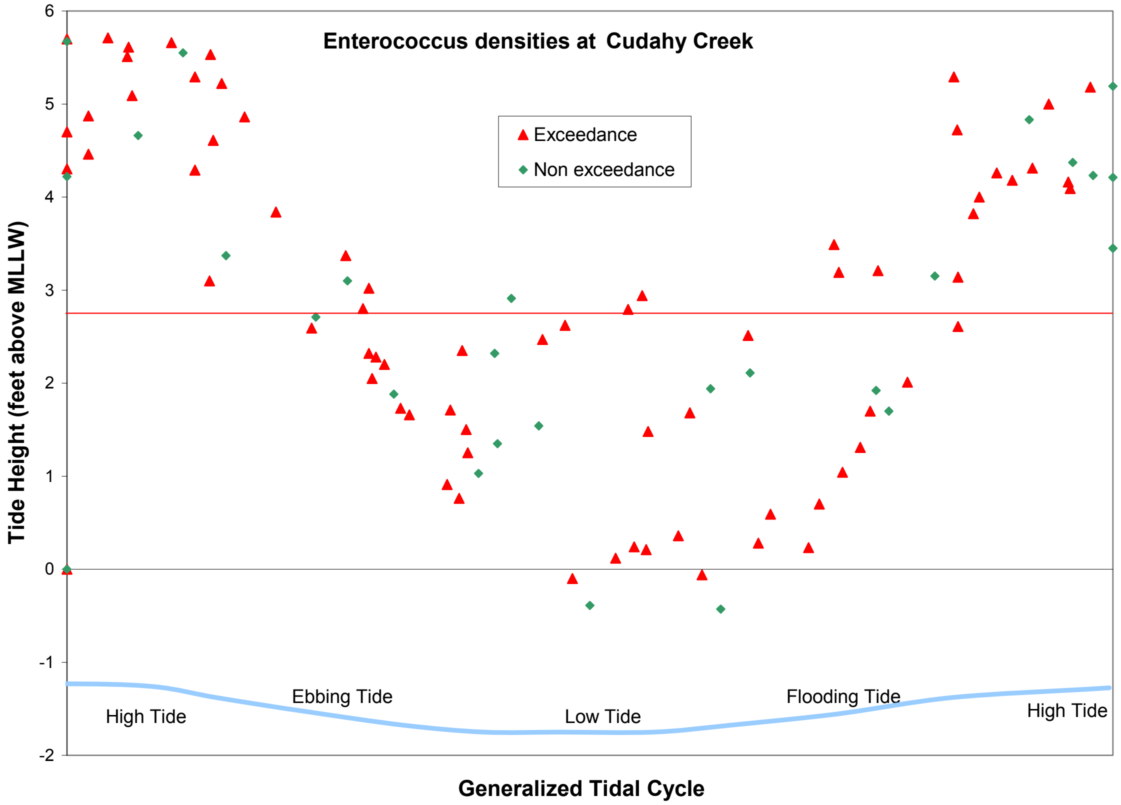


Figure 19. Enterococcus densities verses tidal height at Cudahy Creek from 2001 through 2003. Samples shown in red exceeded the AB411 criteria for enterococcus of 104 MPN/100 ml. The red line separates samples taken in the upper intertidal from the lower intertidal zones.

The results of the sediment investigation suggest that, although the sediments at the mouth of Cudahy Creek appear to be a reservoir for indicator bacteria, the extent to which that reservoir contributes to elevated bacterial densities in the receiving water appears to be small.

Tecolote Creek

The results of the sediment assessment at Tecolote Creek suggest that there is a pronounced seasonal difference in the ability for the delta sediments at Tecolote Creek to act as a reservoir for indicator bacteria. During dry weather, Tecolote Creek sediments contained virtually no indicator bacteria. However, in wet weather, both indictor bacteria were found in surficial sediments at this site and at some stations densities were very high. Ribotyping analysis showed that a majority of the bacterial isolates originated from birds, which is consistent with other Ribotyping assessments conducted elsewhere in Mission Bay. The most striking result at Tecolote Creek was that nearly half (45%) of the Ribotypes of bacteria collected in the receiving water matched those found in the sediment.

These results suggest that a large proportion of the enteric bacteria found in the receiving waters are also found in the delta sediments. However, sediments can only impact the receiving waters if they are lifted from the delta at the mouth of the creek into the water column and transported via currents to the receiving water monitoring site. There are many variables that affect the extent to which sediment will be transported through a water column. However, two factors play a major role: current velocity and sediment grain size. A recent study on current velocities in Mission Bay suggested that tidally induced current velocities are low in the back portions of Mission Bay near Tecolote Creek, with maximal velocities of approximately of 0.15 m/s (Largier et al. 2003). During the wet season, a large proportion of the surficial sediments in the Tecolote Creek delta were composed of fine-grained particles typical of silts and clays. Sediment grain size is plotted against the current velocities measured at Tecolote Creek in Figure 20.

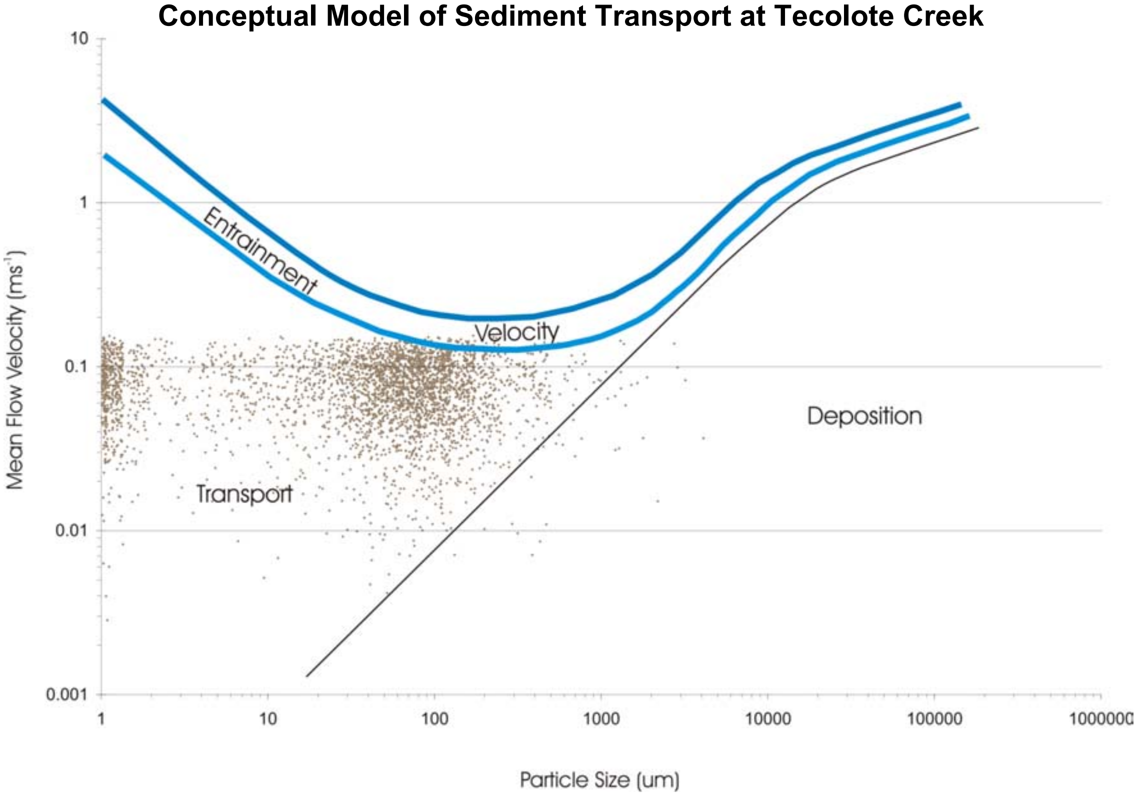


Figure 20. Conceptual model of sediment transport at Tecolote Creek showing grain size distribution of delta sediments plotted against current velocities at this site.

In this figure, the wet weather sediment grain size and current velocity data collected at Tecolote Creek were entered into a conceptual model of sediment transport proposed in Summerfield (1993). The model is based on over 30 empirical studies on sediment transport with a wide range of physical characteristics. In this simplified conceptual model, the Entrainment Velocity is the current speed needed to lift a particle of a given size off a horizontal surface into the water column. Largier et al. (2003) found that current velocities at Tecolote Creek typically average approximately 0.05 m/s, which is well below the entrainment velocity used in the model. However, during the largest spring tides, maximal current velocities can reach up to 0.15 m/s at Tecolote Creek. Under these conditions, the velocity is sufficient to lift particles of a grain size measured in the Tecolote Creek sediments into the water column. Bacteria adhered to these sediment particles can be transported from the delta to the receiving waters. In this way the reservoir of bacteria contained in the delta sediments at Tecolote Creek during the wet season can act as a source of bacteria to the receiving water monitoring site. This interpretation agrees with the degree of connectivity between the sediments and the receiving water indicated by the Ribotyping analysis.

However, it is important to remember that the vast majority of the tidally-induced current velocities at Tecolote Creek are below the entrainment velocity used in this model. Thus, under the majority of conditions, bacteria adhered to the sediments deposited at the mouth of Tecolote Creek are unlikely to have a large impact on the receiving waters at the AB411 monitoring site. Historical enterococcus data collected at Tecolote Playground (adjacent to the Tecolote Creek delta) appear to support this conclusion. Figure 21 shows the number of samples that exceeded the AB411 criterion for enterococcus at this site. Although the data set used to create the graph is small, there is no apparent connection between tidal stage and enterococcus density at this site that would suggest a strong connection between the sediments and the receiving water during typical tidal stages.

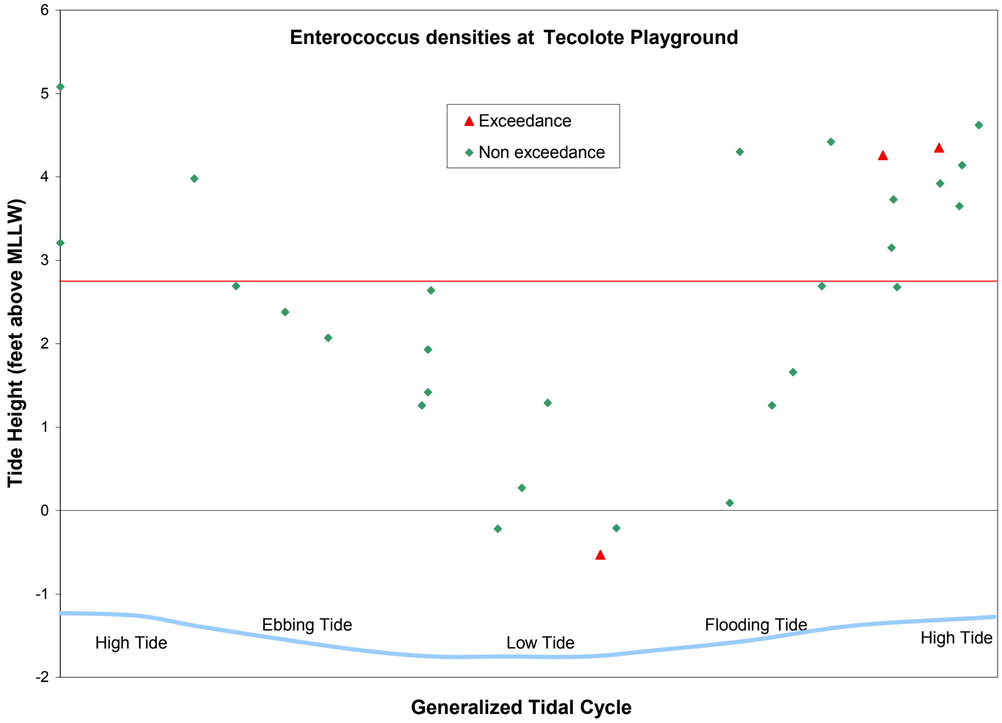


Figure 21. Enterococcus densities verses tidal height at Tecolote Playground from 2001 through 2003. Samples shown in red exceeded the AB411 criteria for enterococcus of 104 MPN/100 ml. The red line separates samples taken in the upper intertidal from the lower intertidal zones.

Intertidal Sediments

One of the major results of the Microbial Source Tracking Task of the Mission Bay Source Identification Study was that the majority of the enteric bacteria in the receiving waters originates from birds. The results of the sediment investigation presented in this report indicate that intertidal sediments act as a reservoir for indicator bacteria. Although Microbial Source Tracking was not applied to the intertidal sediments, the most likely origin of the bacteria found there is also the birds. The deposition of bacteria from avian sources to the intertidal sediments can occur from fecal matter suspended in the water column or through direct deposition on the beach face. During the course of this study we observed numerous birds on the beach, primarily gulls and shorebirds, and found that bird feces on the beach face was common. Although the magnitude of the fecal matter on the beach was not quantified, it was clear that the vast majority of the fecal matter was found in the upper intertidal zone. To better understand the relationship between fecal deposition and tidal stage, we graphed the tidal pattern in Mission Bay and graphically separated the upper and the lower intertidal zones. The graphs for spring and neap tides are presented in Figure 22. In this figure, red represents the proportion of the upper intertidal zone that is exposed over time (i.e., not covered with water), yellow represents the proportion of the lower intertidal zone that is exposed over time, and blue represents sea water. The graph demonstrates that the upper intertidal zone on Mission Bay beaches is exposed for a much greater period of time than the lower intertidal zone. When the tidal cycle in Mission Bay was examined over an entire year, we found that the upper intertidal zone was exposed 86% of the time throughout the year and the lower intertidal zone was exposed 14% of the time.

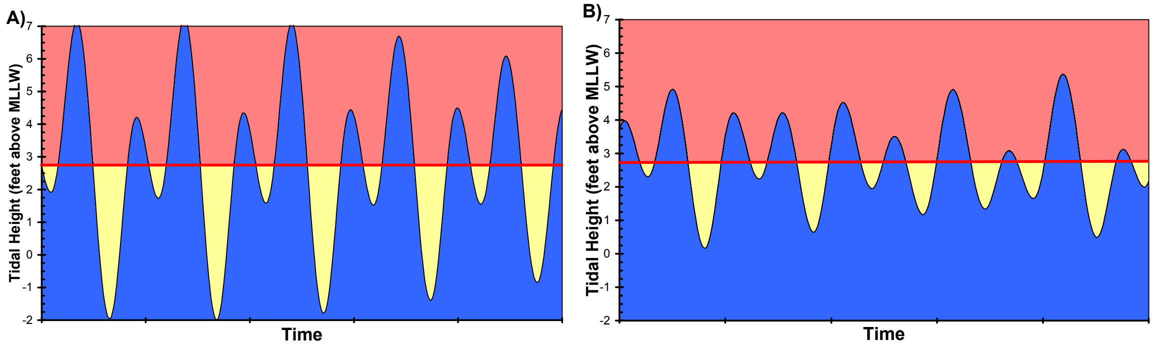


Figure 22. Relative amount of time that the upper intertidal zone (red) and the lower intertidal zone (yellow) is exposed (e.g., not under water) during spring (A) and neap tides (B).

A greater period of exposure in the upper intertidal zone allows for a greater period of time for the birds to populate and defecate on that area of the beach. We believe this simple relationship accounts for the large amount of fecal matter observed in the upper intertidal zone as well as the greater bacterial densities found in the upper intertidal zones at Bonita Cove and Leisure Lagoon. In addition, several studies have suggested that enterococcus and fecal coliform bacteria do not survive well in the presence of seawater. During neap tides, the lower intertidal zone in Mission Bay is covered with seawater the majority of the time, which would act to limit bacterial survival. During the same period, the upper intertidal zone is exposed, allowing for the accumulation of fecal matter from the birds.

Bonita Cove

The results of the sediment resuspension study clearly indicate that the sediments in the upper intertidal zone at Bonita Cove act as a reservoir for indicator bacteria. If the sediments are left undisturbed, then the bacteria sorbed to them do not tend to make their way into the water column. However, when these sediments are disturbed and resuspended in the water column, as a result of swimming activity for instance, then bacterial densities in the water column can increase dramatically. The same pattern was not observed in the lower intertidal zone. We believe this can be explained by the fact that the beach face in the upper intertidal zone is exposed (i.e., not inundated by seawater) to a much greater extent than the lower intertidal zone, which allows for a greater period of time for the accumulation of fecal matter. A review of the historical data at Bonita Cove suggests that exceedances of bacterial standards occur more often when samples are collected in the upper intertidal zone. The data from Bonita Cove from 2001 through 2003 for which sampling times were available are graphed in Figure 23. Although the sample size was small, the five exceedances that occurred during this period all took place when the water at the time of sampling was over the upper intertidal zone of the beach.

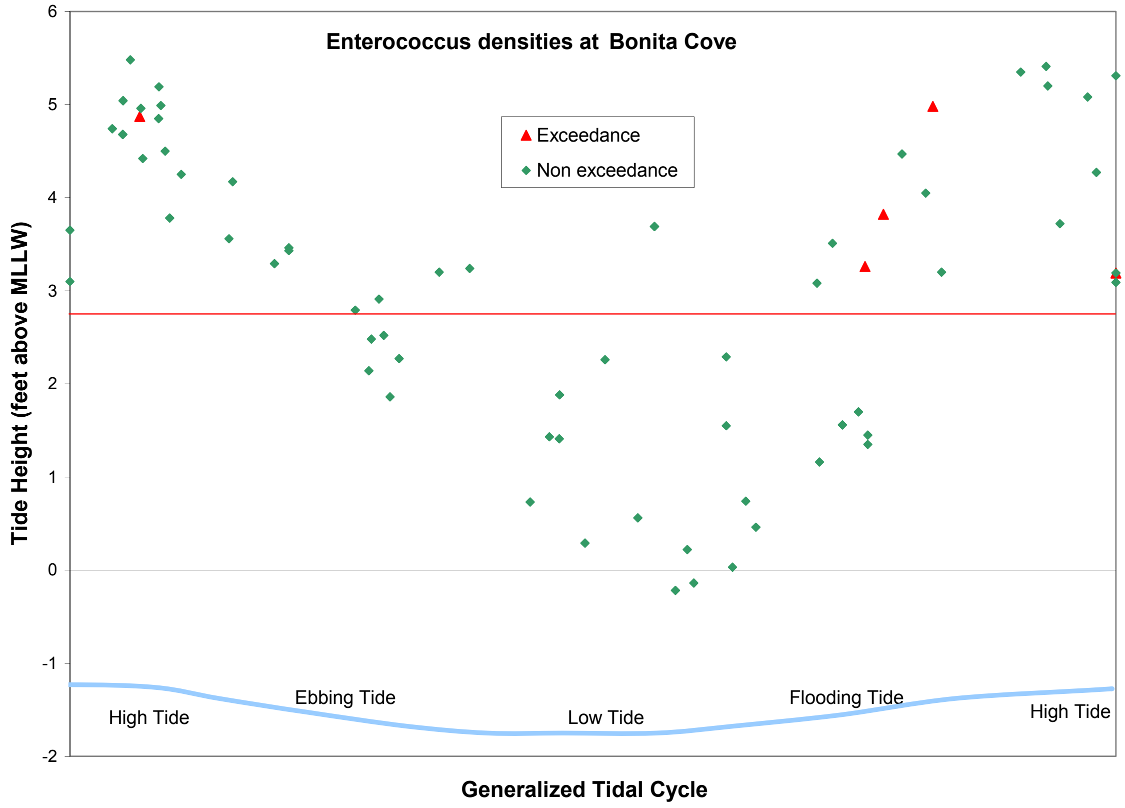


Figure 23. Enterococcus densities verses tidal height at Bonita Cove from 2001 through 2003. Samples shown in red exceeded the AB411 criteria for enterococcus of 104 MPN/100 ml. The red line separates samples taken in the upper intertidal from the lower intertidal zones.

The results of the intertidal sediment study provide the most reasonable explanation for the observed increase in bacterial densities during summer holiday weekends at Bonita Cove. Initially, this increase was thought to be due to a greater number of boats at Bonita Cove on holidays and a greater potential for illicit sewage discharge. However, the results of the Molecular Source Tracking Task indicate that there is very little enteric bacteria from human origin in the receiving waters at this site. In addition, there are no management actions that take place only on holidays that would account for the difference. However, during summer holidays, the number of swimmers at Bonita Cove increases dramatically. As a result, the intertidal sediments on summer holidays are disturbed to a greater extent than on non-holidays, resulting in greater sediment resuspension and subsequent release of the bacteria to the water column.

Leisure Lagoon

At Leisure Lagoon, bacterial densities in intertidal sediments were similar to those found at Bonita Cove. However, at Leisure Lagoon, the sediments directly in front of storm drain SD9-2 contained much higher indicator bacterial levels than sediments in other areas of the site at the same tidal height. This is most likely a result of the storm drain effluent originating from irrigation runoff that discharges to this area. During the Visual Observations Task of this study, very high bacterial densities were measured from effluent samples taken from this storm drain. The results from the sediment investigation suggest that the effluent from storm drain SD9-2 had inoculated the sediments in the area directly below the storm drain discharge with fecal coliform and enterococcus bacteria.

Similar to Bonita Cove, the results of the sediment resuspension study at Leisure Lagoon clearly indicate that the sediments in the upper intertidal zone act as a reservoir for indicator bacteria at this site. A graph of the enterococcus data from Leisure Lagoon samples indicate that all of the exceedances of the AB411 criterion occurred when samples were collected when the bay water was over the upper intertidal zone (Figure 24).

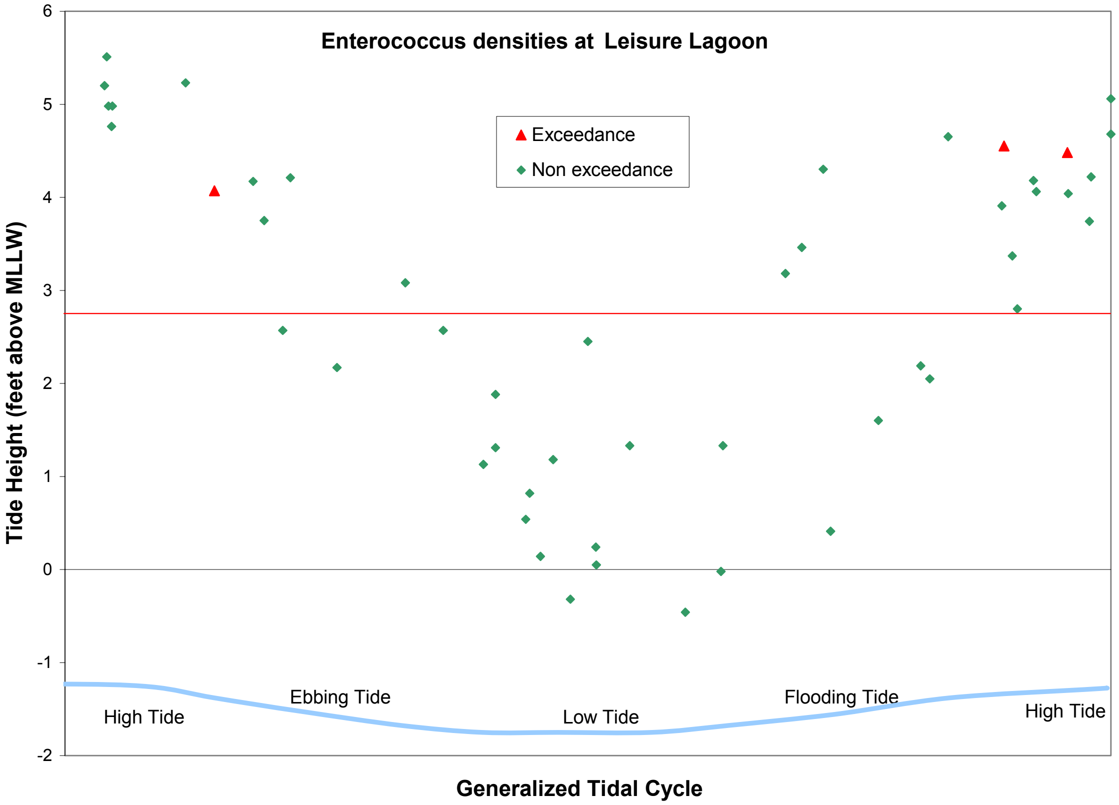


Figure 24. Enterococcus densities verses tidal height at Leisure Lagoon from 2001 through 2003. Samples shown in red exceeded the AB411 criteria for enterococcus of 104 MPN/100 ml. The red line separates samples taken in the upper intertidal from the lower intertidal zones.

De Anza Cove

At De Anza Cove, the sediment investigation was conducted only during low tide. Although there was a three-fold difference between mean enterococcus densities in the clear water and resuspended sediment samples, the difference between the two sample types was less clear than that seen at Bonita Cove and Leisure Lagoon during high tide. For instance, at De Anza Cove, three of the 15 resuspended sediment samples were below the detection limit of 10

MPN/100 ml. In addition, only one of the resuspended sediment samples exceeded the AB411 criteria of 104 MPN/100 ml. This is in contrast to the High Tide studies conducted at Bonita Cove and Leisure Lagoon where all of the resuspended sediment samples exceeded AB411 criteria.

More storm drains discharge to De Anza Cove than any other site in Mission Bay. The storm drains terminate in the lower intertidal zone at a tidal height of approximately +1 to +2 feet above MLLW. Thus, discharge from the storm drains may inoculate the sediments in the lower intertidal zone at De Anza Cove, which would account for the greater bacterial densities in resuspended sediment samples observed at this site. In addition, the median grain size of sediments at De Anza Cove is much finer than that found at Bonita Cove, where there was no difference in resuspended and clear water samples collected during low tide. Smaller grain size is typically correlated with greater bacterial densities, which may explain the difference in the results of the low tide studies between the two sites. A wrack line tends to accumulate at De Anza Cove and the bird population is fairly high compared to other sites on the bay, which suggest that sediments in the upper intertidal zone at this site also act as a reservoir for indicator bacteria. This is also suggested by the receiving water monitoring data at this site, which shows no apparent pattern relative to the tidal height at the time of sample collection (Figure 25).

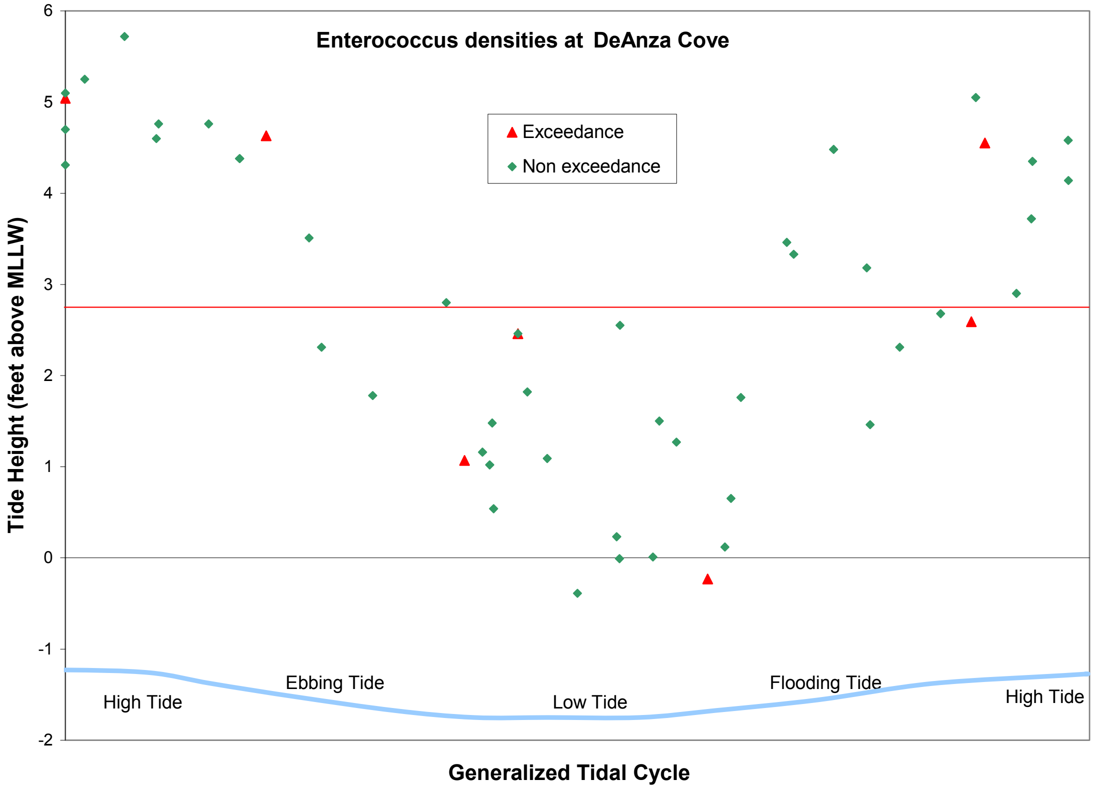


Figure 25. Enterococcus densities verses tidal height at De Anza Cove from 2001 through 2003. Samples shown in red exceeded the AB411 criteria for enterococcus of 104 MPN/100 ml. The red line separates samples taken in the upper intertidal from the lower intertidal zones.

CONCLUSIONS

The results of the sediment investigation allow us to reach several conclusions about the extent to which sediments influence bacterial densities in the receiving water of Mission Bay. The results of both the delta sediment investigation and the sediment resuspension study suggest that the relationship between sediments and receiving water is dependent on the specific characteristics of each site. The conclusions of the two studies are summarized by site below.

Rose Creek – Sediments in the Rose Creek delta do not appear to have an impact on bacterial densities in the receiving waters at Campland in either dry or wet weather periods.

Cudahy Creek – Sediments in the Cudahy Creek delta act as a reservoir for indicator bacteria, particularly during the wet season. However, the extent to which bacteria in the sediment impact the receiving waters appears to be relatively minor.

Tecolote Creek – Sediments in the Tecolote Creek delta contain low bacterial densities in the dry season and high bacterial densities in the wet season. During the wet season, it is likely that bacteria in the sediment are transported to the receiving waters only during periods of maximal tidal currents. The majority of time, the sediments are not a source of bacteria to the receiving waters.

Bonita Cove – Sediments in the upper intertidal zone at Bonita Cove act as a reservoir for indicator bacteria. When the sediments are disturbed (e.g., through swimmer activity), the bacteria is released to the water column resulting in elevated bacterial densities. Sediments in the lower intertidal zone do not act as a reservoir for indicator bacteria.

Leisure Lagoon – As with Bonita Cove, sediments in the upper intertidal zone at Leisure Lagoon act as a reservoir for indicator bacteria that can be released to the water column when the sediments are disturbed. In addition, effluent from storm drain SD9-2 appears to have elevated the bacterial densities in the nearby sediments.

De Anza Cove – Sediments in the lower intertidal zone at De Anza Cove act as a reservoir for indicator bacteria that can be released to the water column when the sediments are disturbed. In addition, it is likely that sediments in the upper intertidal zone at De Anza Cove play the same role.

RECOMMENDATIONS

Overall, the sediments that form the deltas of the three major drainages to Mission Bay do not appear to impact bacterial densities in the receiving waters. However, they can act as a reservoir for indicator bacteria and should be studied thoroughly before any management actions that could disturb them are initiated.

We recommend that that the City consider limiting recreational boating activities to areas where nearshore sediments are least likely to be disturbed.

Creative BMPs related to beach grooming practices should be studied for their potential to reduce bacterial levels in the upper intertidal sediments.

Storm drain diversion structures, when present, should be cleaned and maintained on a regular basis to prevent storm drain effluent from inoculating beach sediments. In addition, we recommend that the City consider placing flap valves at the ends of storm drains, where appropriate, to prevent seawater intrusion.

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APPENDIX H

Bacterial Amplifiers

Follow-Up Study for

Mission Bay Clean Beaches Initiative
Bacterial Source Identification Study (Phase II)

Bacterial Amplifiers

INTRODUCTION

Observations made through the course of the investigative studies suggested that there were two areas in Mission Bay that may provide conditions conducive to bacterial growth: 1) the wrack line, which is formed from organic debris that washes up on the beach faces in some areas of the bay; and 2) coastal storm drains, which harbor organic debris from the bay and the upstream watershed. This report summarizes the results of two studies designed to assess the potential for bacterial amplification from these two areas.

Study Objectives

The objective of the wrack line investigation was:

- Determine the extent to which bacterial densities increase or are maintained within the wrack line environment and assess its potential for contributing bacteria to the receiving waters.

The objective of the storm drain study was:

- Utilizing a laboratory microcosm, assess the potential for bacterial amplification under conditions typically found inside a coastal storm drain.

MATERIALS AND METHODS

WRACK LINE

Site Locations

Two locations in Mission Bay were assessed as part of the wrack line investigation: Riviera Shores (Site 4), which represents an area with minimal impacts related to indicator bacteria and Visitor’s Center (Site 8), which is one of the worst sites in Mission Bay for exceedances of AB411 criteria (Figure 1).

Figure 1. Map of Mission Bay showing sampling sites for the wrack line investigation: Site 4 (Riviera Shores), and Site 8 (Visitor's Center).

Sampling Protocol

At each location, wrack samples were collected along a 100-m length of continuous wrack line that was deposited on the beach face during a high, spring tide that occurred on February 6, 2004. Five stations were identified at random along the wrack line and marked. Approximately 100 g of wrack (consisting primarily of decaying algae) was collected daily from each station in sterile plastic bags using aseptic technique over a period of eleven days. The wrack samples were analyzed for fecal coliform and enterococcus bacteria. On the 11th day, wrack samples were also analyzed for bacterial host origin (see below).

After the initial wrack line collection, receiving water samples were collected over a tidal cycle during a spring tide that came in contact with the wrack line. At each site, samples were collected every two hours at each of the five stations from just after midnight until 2:00 p.m.

Laboratory Procedures

Indicator Bacteria Enumeration. Wrack line samples were transported to the laboratory on ice for analysis. Upon arrival at the laboratory, the pre-weighed bags were re-weighed with the eel grass and bag weight subtracted to provide actual weight of eel grass. A total of 500 ml of sterile buffered water was added to the bags. The bags were sealed and shaken vigorously to remove as much bacteria from the surfaces as possible. Aliquots from the overlying water were then removed for sampling. Enterococci bacteria were enumerated using IDEXX Enterolert™, while fecal coliforms were enumerated using multiple tube fermentation (SM 9221E). In cases where isolates were needed for Ribotype analysis, membrane filtration (SM 9222D) was used to enumerate fecal coliforms. Initial results were given in units of enterococci/fecal coliforms per 100 ml. However, the results were then multiplied by 5 to adjust for the 500 ml of water present in the bag. These results were then divided by the weight of eel grass present in the bag in order to attain counts of bacteria per gram of eel grass.

***E. coli* Isolates.** Bacterial Isolates from the resuspended wrack were prepared as follows: for each transect, three 100 ml aliquots were clarified using filter paper to remove large particulate matter. Resulting filtrates were then concentrated onto 0.45 µm, 47mm sterile membrane filters (Millipore Corporation) using a Microfil Filtration vacuum manifold system (Millipore Corporation) connected to a vacuum pump. Membrane filters were placed in 47mm Petri dishes with absorbent pads (Millipore Corporation) pre-soaked in Coliscan MF media (Micrology Laboratories) according to the manufactures directions. Plates were allowed to grow at 44.5º C overnight in a conventional air incubator, and blue colonies were initially scored as *E. coli* according to the manufactures specifications Coliscan MF plates were then shipped on blue ice to the contracted laboratory at the Institute for Environmental Health for purification and confirmation of *E. coli* as follows: well isolated blue colonies were picked and plated on Trypticase Soy Agar and allowed to grow overnight at 35º C. Each culture was then tested by Spot Indol testing using the appropriate positive and negative controls. Indol positive cultures were subsequently tested for their ability to utilize citrate using Simon Citrate media. Indol positive, citrate negative colonies were then given final confirmation as *E. coli* and assigned isolate numbers. A portion of each *E. coli* strain isolated from each sample was stored at -80º C, in nutrient broth plus 15% glycerol. Genomic DNA was extracted according to the contracted laboratory's protocol.

To obtain *E. coli* isolates from the receiving waters, three volumes for each sample (5 ml, 25 ml and 75 ml aliquots) were concentrated onto sterile membrane filters, incubated with Coliscan MF media, and blue colonies were initially scored as *E. coli*. Coliscan MF plates were shipped to the contracted laboratory on blue ice, and blue colonies were processed for purification and storage as described above.

Ribotyping Analysis. Genomic DNA was isolated from each *E. coli* strain using a standard protocol. All reagents and buffers were made according to formulas described in the Institute for Environmental Health's laboratory SOPs. Reagents and buffers were tested for sterility. Every batch of restriction enzyme reaction contains two reactions with a positive control strain which were included on two lanes per gel. Agarose gel electrophoresis was conducted under standard conditions, agarose gel concentration, and volume, buffer strength, pH, mA, V, and electrophoresis time were controlled for. Each agarose gel was assigned a number, and when more than one gel was run, the position of the first standard reference strain was changed in each gel (1st lane on the first gel, to the Nth lane on the Nth gel). After electrophoresis, gels were stained in ethidium bromide. Two gels were typically stained in a single container; of the two gels placed in the same container, one corner of the gel of the higher number was clipped. Labels for each gel were also transferred to the staining container. Each gel was then photographed and a hard copy of the print was labeled with the gel sheet (containing the isolates numbers loaded on each lane, and the enzyme used to cut the DNA, plus date, gel number, voltage, mA, gel strength, buffer strength, and electrophoresis time information).

Southern blotting was performed according to the protocol detailed in the contracted laboratory's SOP. After photography, each gel was returned to the same staining container. Gels were denatured for Southern blotting in the same container. Each blotting apparatus was constructed in a separate container which was labeled with the gel number. Each membrane filter was then labeled with the gel number, restriction enzyme designation, date, and technician's initials.

The genetic fingerprints (or Ribotypes) were analyzed manually using an algorithm developed by researchers at the Institute for Environmental Health. Type patterns are cut and catalogued, and every pattern was compared side by side to the type pattern. New patterns were given appropriate identifiers and catalogued accordingly. The criterion for data analysis was one hundred percent identity of the Ribotype patterns.

STORM DRAIN SIMULATION

Retrieval of indicator bacteria

Two 500 ml samples were taken from effluent at the mouth of Cudahy Creek and filtered down to concentrate the bacteria present. Filters were placed on m-FC agar (Difco) and BEA agar (Difco) plates in order to select for fecal coliforms and enterococci, respectively. Plates were allowed to incubate overnight to allow growth of colonies. Bacterial colonies were then randomly scraped from the filters and fecal coliforms and enterococci were re-suspended in separate containers of sterile dilution water (phosphate buffered saline). Using standard enumeration methods, concentrations of each organism per milliliter were derived.

Experimental Microcosms

500 ml of laboratory created sterile water was added to each of fourteen 2-liter Erlenmeyer flasks comprising the study microcosm. The water was added in various concentrations of salinity, representing three environments. Four flasks received 15% saline water, representing a fresh water environment. Four flasks received 100% saline water to represent marine receiving waters and four flasks received 70% saline water representing storm drains of interest in the Mission Bay studies.

Eelgrass obtained from a clean beach was rinsed and soaked in sterile de-ionized water and UV irradiated for ten minutes. A total of 25 g was then aseptically transferred to two flasks of each water type, leaving two flasks from each water type with sterile water only (see table below). Two negative controls of 15% salinity were also created, one with eelgrass and one without. The microcosm design is summarized in Table 1.

Table 1. Summary of storm drain simulation microcosm. Percentages refer to the salinity in each flask.

15% Seawater	70% Seawater)	100% Seawater	Negative Controls
2 replicates w/eelgrass	2 replicates w/eelgrass	2 replicates w/eelgrass	1 with eelgrass
2 replicates without	2 replicates without	2 replicates without	1 sterile water only

Fecal coliform and enterococci were added to all flasks except the negative controls in the following approximate concentrations:

Fecal coliform: 10,000 MPN/100mL (Approximately 50,000 MPN/flask)
Enterococci: 1,000 MPN/100mL (Approximately 5,000 MPN/flask)

All flasks were wrapped in tin-foil to block out ultraviolet light. Lids were then fitted with one small hole to allow a sterile air tube to be inserted. Prepared flasks were placed randomly in a 15º C controlled environment and allowed to acclimate.

Testing and Analysis

Bacterial testing commenced immediately after inoculation (time/day 0), twelve hours later, then each 24 hours thereafter for the first five days, and every 2-4 days for the remainder of the 32-day study. Samples were taken after swirling the flasks vigorously in order to free the bacteria from surfaces as much as possible. All flasks in the microcosm were sampled simultaneously, for a total of fifteen times throughout the study. Water quality (salinity, DO, pH) was monitored weekly.

RESULTS

WRACK LINE

Wrack Line Bacterial Densities

The densities of fecal coliform and enterococcus in the wrack line at Riviera Shores are presented in Figure 2. The bars represent the daily mean densities from the five stations over the 11-day study period. Bacterial densities in the wrack were maintained in the wrack during this time, suggesting that the wrack line provides an environment conducive to the maintenance and possibly the growth of both enterococcus and fecal coliform bacteria.

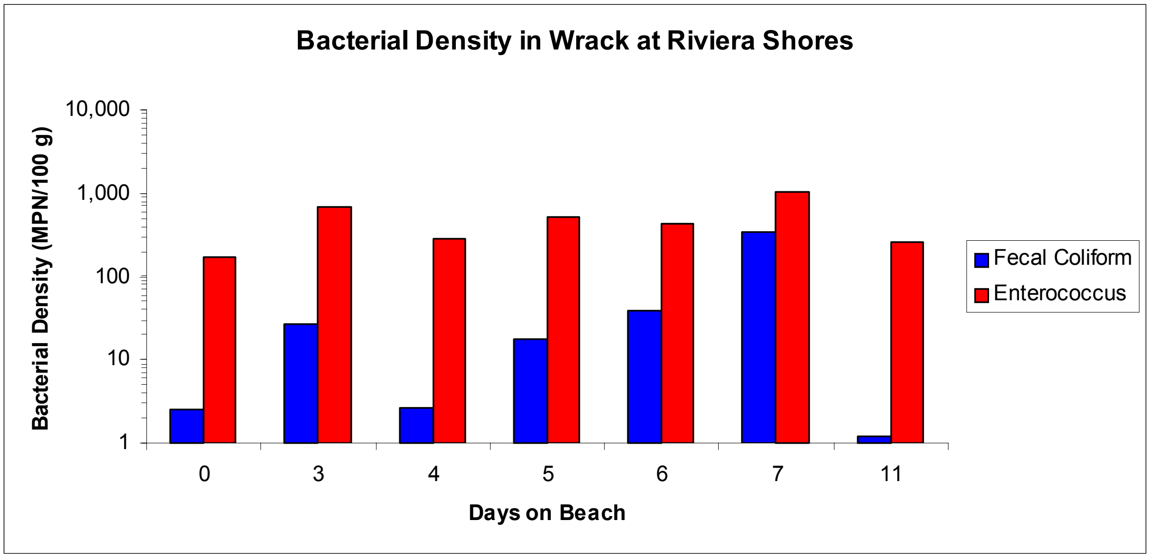

Figure 2. Mean Fecal coliform and enterococcus densities in wrack at Riviera Shores from February 6 through 17, 2004. The bars represent the daily mean densities from the five stations over the 11-day study period.

The densities of fecal coliform and enterococcus in the wrack line at Visitor's Center are presented in Figure 3. As with Riviera Shores, bacterial densities in the wrack were maintained in the wrack during the study period, however, the densities were much greater than those at Riviera Shores.

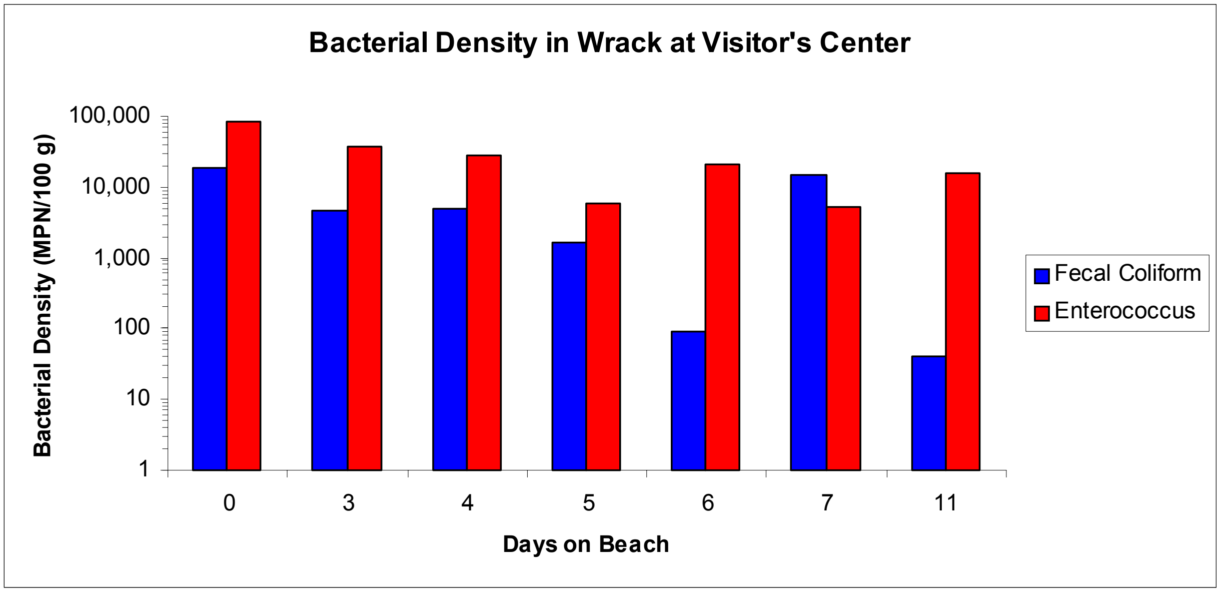

Figure 3. Mean Fecal coliform and enterococcus densities in wrack at Visitor's Center from February 6 through 17, 2004. The bars represent the daily mean densities from the five stations over the 11-day study period.

Receiving Water Bacterial Densities

After the bacteria in the wrack line had been enumerated, we took samples of the receiving water during the subsequent spring tide as the water level rose and made contact with the wrack line on the beach. The results of this part of the study are shown in Figure 4. Here, bacterial densities were low in the early morning when the edge of the receiving waters were in the lower intertidal zone. Densities increased dramatically at 0600 hours when the receiving waters first made contact with the upper intertidal zone and peaked at 0800 hours when the receiving waters were in contact with the wrack material. As the tide receded into the lower intertidal zone starting at about 1000 hours, bacterial densities decreased. Thus, greater bacterial densities occur in the upper intertidal zone on the beach when the receiving water comes in contact with the wrack line.

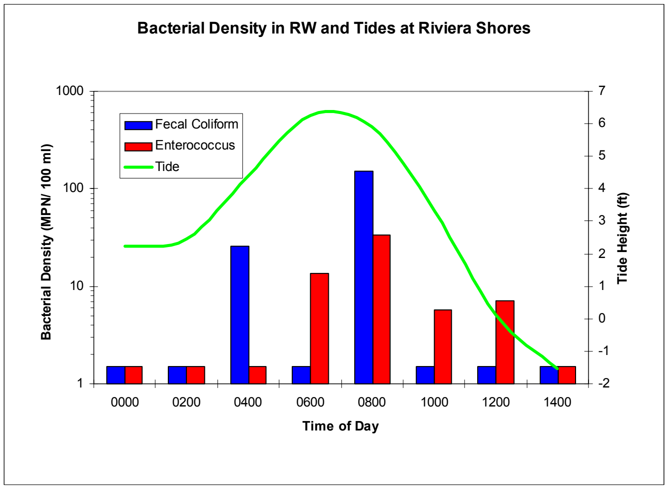

Figure 4. Densities of enterococcus and fecal coliform bacteria in receiving water verses tidal height at Riviera Shores. Each bar represents the geometric mean of five samples.

Results of the receiving water sampling conducted at Visitor's Center are shown in Figure 5. As with Riviera Shores, bacterial densities were low in the early morning, increased as the tide rose, and peaked around 0800 as the water made contact with the wrack line. Enterococcus densities declined as the tide receded, however, fecal coliform densities remained high throughout the ebbing tide.

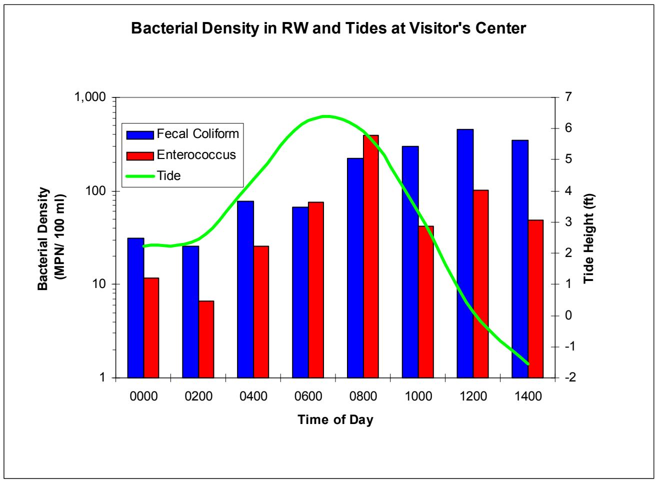

Figure 5. Densities of enterococcus and fecal coliform bacteria in receiving water verses tidal height at Riviera Shores. Each bar represents the geometric mean of five samples.

Ribotyping

In order to determine the animal hosts that contributed bacteria to the receiving waters at Riviera Shores, microbial source tracking via *E. coli* Ribotyping was completed by a contracted laboratory at The Institute for Environmental Health at the University of Washington. To accomplish this, wrack-derived *E. coli* isolates were analyzed by the Ribotyping assay, and identifier codes based on the genetic fingerprint pattern were assigned to each Ribotype derived from the sample (Figure 6). A total of 80% of the isolates obtained originated from Avian sources. Smaller proportions of other mammals and bacteria from unknown origin were also present. These results suggest that the birds are the primary source of bacteria in the receiving waters at Riviera Shores. Birds are also the likely dominant source of bacteria found in the wrack line.

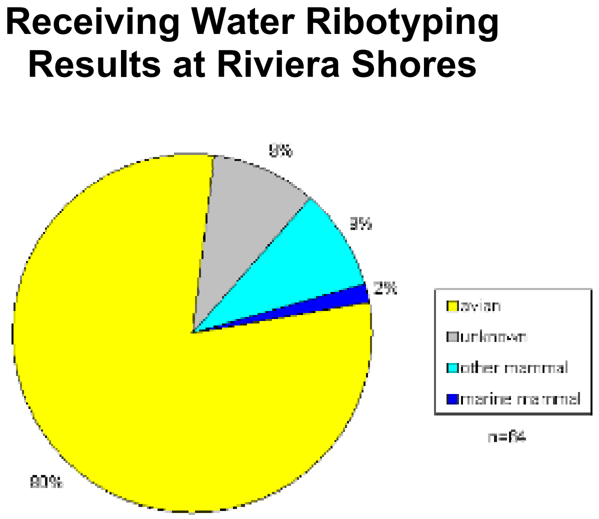

Figure 6. Results of Ribotyping analysis of receiving water samples collected at Riviera Shores showing relative percentage of bacterial host origin.

Unfortunately, no isolates were obtained from the wrack at Riviera Shores, however, a total of 66 Ribotypes were analyzed from the wrack at Visitor's Center. A pair-wise comparison between the wrack-derived Ribotype data set and the Institute for Environmental Health's Source Ribotype Library Database was then completed. We found that 30 out of 66 (or 45%) of the wrack-derived Ribotypes matched Ribotypes of Avian origin (Figure 7A). Wrack-derived Ribotypes that matched Canine Ribotypes comprised the next largest host animal source group, accounting for 17 of 66 (or 26%) of the wrack-derived Ribotypes. Interestingly, 15 out of 66 (or 23%) of the wrack-derived Ribotypes were found to match Ribotypes derived from other wrack line isolates. Since upstream animal hosts could not be identified for this, we refer to these matches as Unknown. A small group (4 of 66, or 6%) of the wrack-derived Ribotypes were found to match Ribotypes from a variety of mammalian hosts.

Wrack Line and Receiving Water Ribotyping Results at Visitor's Center

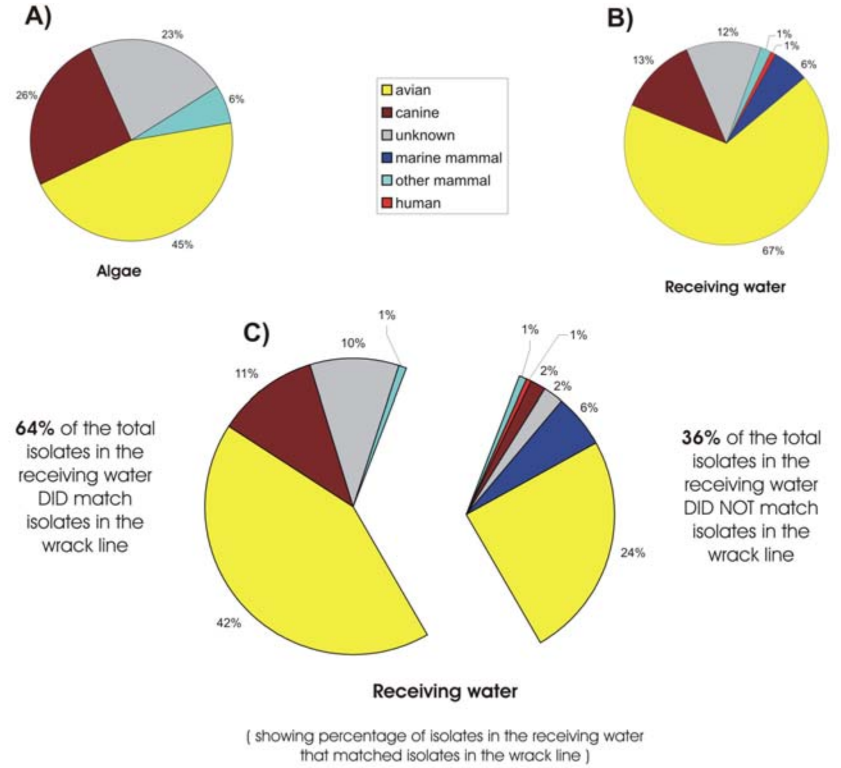

Figure 7. Results of Ribotyping analysis at Visitor's Center showing the origin of bacterial isolates in the wrack (A), receiving water (B), and the proportion of isolates in receiving water that matched those in wrack (C).

Ribotype analysis was next performed on the isolates derived from the receiving water (134 total). As with the wrack-derived isolates, identifier codes were assigned to each of the Ribotypes individually. Upon querying the Institute for Environmental Health's Source Ribotype Library Database, we found that 67% (or 90 out of 134) of the water-derived Ribotypes had their origin from Avian sources (Figure 7B), a result that is consistent with the results obtained from the broader source tracking analysis for this site. Bacteria of Canine origin were found to account for 17 out of 134 (or 13%) of the receiving water-derived isolates. Of the remaining isolates, 12% (or 16 out of 134) could not be matched to any animal host (Unknown), while 8% (or 10 out of 134) matched a variety of mammalian hosts.

We next asked what proportion of the isolates found in the receiving water taken at Visitor's Center could be matched to the isolates obtained from the accompanying wrack line. To answer this question, it was first necessary to treat the wrack line as a bacterial source; therefore, the wrack-derived Ribotype data set (see above) was included in the Institute for

Environmental Health's Source Ribotype Library Database. Strikingly, when a pair-wise comparison of the receiving water-derived Ribotype data set was made against the amended Source Ribotype Library Database, we found that the majority of receiving water Ribotypes (64%, or 86 out of 134) matched Ribotypes identified in the wrack line (see Figure 7C). A closer examination of the 86 wrack-matching Ribotypes revealed that 63 of these were "transient" insofar as they shared identical Ribotypes from Avian, Canine or other host animal-derived isolates, suggesting these hosts as the original input of bacteria for the wrack line. Interestingly, 13 out of 86 of the Ribotypes were identified exclusively from wrack line-derived isolates and did not match Ribotypes from any other animal host. Since upstream animal hosts could not be identified for these water-derived isolates, we refer to these isolates as Unknown. Overall, a total of 90 out of 134 (or 67%) of the water-derived Ribotypes have their origin from either Avian or Avian/wrack line sources, a result that is consistent with the results obtained in the broader source tracking analysis at this site.

STORM DRAIN SIMULATION

The results of the storm drain simulation experiment are shown graphically in Figure 8 for fecal coliforms and Figure 9 for enterococcus. The trends in bacterial densities demonstrate the effects of two variables on bacterial survival and growth: salinity and the presence of a nutrient source. In the 70% and 100% salinities, no bacterial growth was observed. In the absence of eel grass, both fecal coliform and enterococcus densities decreased dramatically to near zero in two to four days, reflecting the harsh effects of seawater on indicator bacteria. Both indicator bacteria survived for a longer period of time in 70% and 100% seawater in the presence of eel grass and a similar pattern was observed for bacteria in 15% seawater without eel grass.

The most compelling results of the study, however, were for bacteria in 15% seawater in the presence of eel grass. Both fecal coliform and enterococcus densities increased dramatically in this environment by several orders of magnitude within the first few days of the experiment. Extremely high densities were maintained for nearly a week, before leveling off, but elevated densities continued to be maintained throughout the course of the 27-day study. It is also interesting to note that the prolonged survival of enterococcus in the presence of eel grass in all three salinities tested was maintained at a density slightly above the AB411 criteria of 104 MPN/100 ml (see dashed red line in Figure 9). Although further studies are needed to assess the strength of this relationship, these results suggest that enterococcus, in the presence of an organic substrate, can survive for prolonged periods of time in storm drains at densities that exceed the AB411 criteria for receiving waters.

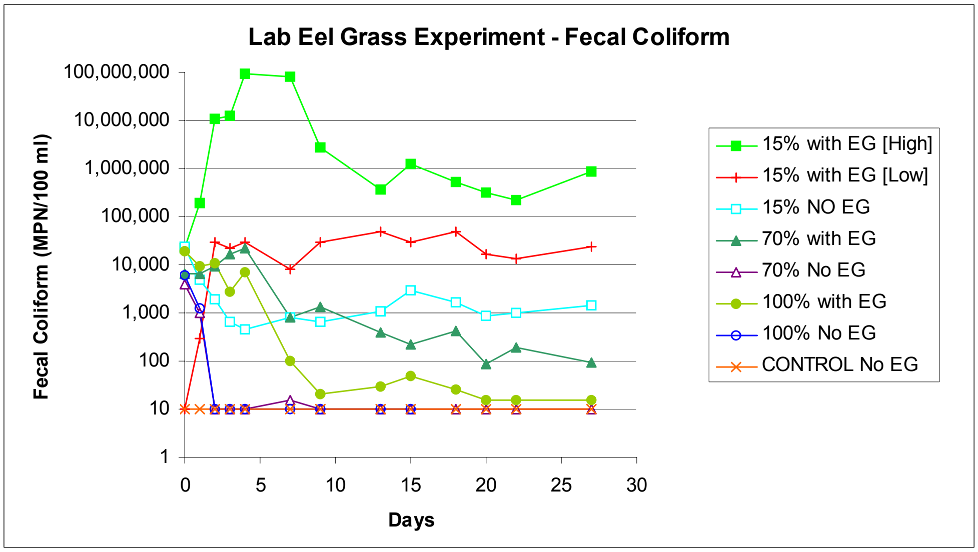

Figure 8. Fecal coliform densities over time under simulated storm drain conditions.

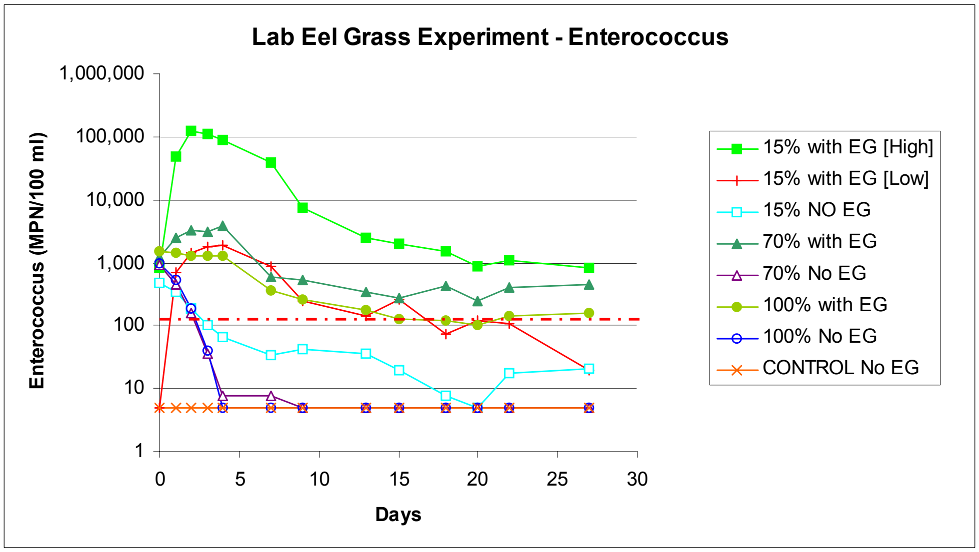

Figure 9. Fecal coliform densities over time under simulated storm drain conditions. The dashed red line represents the AB411 criterion for enterococcus of 104 MPN/100 ml.

DISCUSSION

WRACK LINE

Historically, fecal coliforms and enterococcus bacteria have been used as indicators of contamination originating from domestic sewage or pollution events. In order to set guidelines for water quality managers to indicate when waters pose a public health risk, numerical criteria for fecal indicator bacteria densities have been established. Invariably, exceedances in fecal indicator bacteria standards directly results in the annual closure of marine and freshwater recreational beaches nationwide.

Perhaps more common than sewage discharges to recreational water bodies are bacterial inputs from nonpoint sources, which include direct feces deposition by wildlife, surface water flow via storms, and groundwater transport. While these ubiquitous nonpoint sources often lead to bacterial exceedences and effectively have the same end result (beach closures), the health risk associated with non-sewage-derived indicator bacteria to human health is not well understood. To exacerbate matters, several environmental bacterial reservoirs have recently been identified whereby fecal indicator bacterial amplification has been observed, both within the water column and along the shoreline. Such “amplifiers” include: decaying vegetation (wrack) present on the beach, algae mats (*Cladophora*), delta sediments, and intertidal sediments (Weiskel, et al. 1996, Anderson et al. 1997, Muller et al. 2001, Haack et al. 2003, Shiaris et al. 1987, Whitman et al. 2003). These findings challenge the general assumption that fecal indicator bacteria do not multiply in the environment. Further, it has been suggested that amplification of enteric bacteria in the environment can artificially degrade water quality estimates in situations were fecal waste is not the primary influence (Anderson et al. 1997, Whitman et al. 2003).

Visual observations made during Phase I and Phase II of the Study led to the hypothesis that decaying eel grass and kelp deposited during peak flooding spring tides on the faces of several beaches throughout Mission Bay Park may be acting as amplifiers and could potentially be contributing to indicator bacteria exceedences to the accompanying receiving water. The design of the wrack line microbial source tracking investigation allowed us to ask whether the bacteria present in the wrack were contributing directly to the receiving water after making contact with the 2 week old wrack line. The fact that a 64% Ribotype match was found between the bacteria identified in the wrack and the bacteria isolated from the receiving waters immediately adjacent to the wrack after a tide cycle made contact strongly supports a mechanism by which bacterial shedding/washing occurs. While our wrack line experiment included only one trial over one spring tidal cycle, the data provides evidence that enteric bacteria, originally deposited by avian sources, can be amplified in the wrack, can survive under a range of environmental conditions, and can lead to elevated bacterial densities in the receiving water.

Our findings here are consistent with other reports which indicate that indicator bacterial amplifiers, such as intertidal sand, wrack line deposits on the beach, or wrack and other organic matter trapped in storm drains, function by providing a growth-permissive substrate and environment which allows for the environmental propagation of enteric bacteria. While experts in the field believe that indicator bacteria resuspension by sediment entrainment or aquatic macrophyte shedding may lead to misinterpretation of water quality tests (Anderson et al. 1997, Whitman et al. 2003), water quality managers, nevertheless, must adhere to established guidelines and regulations governing recreational waters.

STORM DRAIN SIMULATION

It has long been known that the total and fecal coliform families grow readily in various environmental settings. Often only moisture and a nutrient source are required for growth, even in a wide range of moderate temperatures. No studies, however, have shown how readily members of the enterococci family can grow in the same environment. Three questions were to be answered in the storm drain simulation study.

1. What effect does eel grass have as a nutrient source and as protection for indicator bacteria?

2. What effect does salinity have on the growth and survival of these organisms?

3. How do these two factors affect each other in an environmental setting?

In consideration of the saline aspect of this study and in reviewing the results, both indicator species show an ability to grow on eel grass in freshwater. A 2-3 log growth under these conditions for fecal coliforms was not unexpected. Although interestingly the growth occurred in a 15º C environment (fecal coliforms are grown in the laboratory at 44º C). However, exponential growth of enterococci in fresh water and modest growth of both organisms in the 70% saline environment was unanticipated. Studies have shown the ability for enterococci to withstand high saline environments. However, while enterococci lasted only approximately 3-4 days without the presence of eel grass in high salinity, it displayed less than a one-log drop-off throughout the one-month study. Fecal coliform did not fare as well in 100%. In the flasks with no eel grass, no fecal coliforms were present after only 36 hours. Even in the presence of eel grass, greater than a 2-log drop-off was noted within the first week. This reaction to high salinity is consistent with previous studies performed on these organisms.

Bacteria in general survive substantially longer attached to a surface than free-floating in water. This is as true for indicator bacteria. By day seven of this study, nutrients had been depleted from the flasks containing eel grass, as can be seen by the significant drop off of all organisms in the study at that point. It can be predicted that with limited nutrients and space, bacterial growth will eventually cease and die-off will ensue. However, note a comparison between the bacterial counts in the flasks with eel grass toward the end of the study, as compared to the counts in the flasks with no eel grass. Even in the absence of nutrients and the presence of high amounts of bacterial waste (produced from the previous significant growth) there was survival in all flasks containing eel grass. In addition, due to evaporation, all flasks in the study were considerably higher in salinity than a month previous. This knowledge and the fact that the indicator organisms maintained counts through day 32 represents the ability for all organisms in the study to survive on surfaces, even in the highest saline environments.

CONCLUSIONS

Saline environments can have a dramatic affect on all indicator organisms. It is well studied that higher salinity represents greater die-off with time. This is true especially for free-floating microorganisms. However, bacteria that have adsorbed to surfaces show a significantly greater ability to survive such harsh environments. In this study, the presence of surfaces such as eel grass allowed for long-term survival of both fecal coliforms and enterococci even in the highest salinities. In addition, the issue of eel grass as a significant growth source for both bacterial indicators was reviewed. This study found that in both fresh water and brackish environments (such as storm drains), growth of fecal coliforms and enterococci was significant. This represents serious concern for storm drains and beaches with such organic matter present. In an environmental example, eel grass present in a tidally influenced fresh water or brackish storm drain could be contaminated with indicator bacteria from urban runoff. With the eel grass as a nutrient source, this bacteria could reach very high densities. Tides entering and exiting the drain would wash these organisms from their present surfaces, carrying them into the marine environment where they could potentially settle out onto growing eel grass or into sediments and survive for extended periods.

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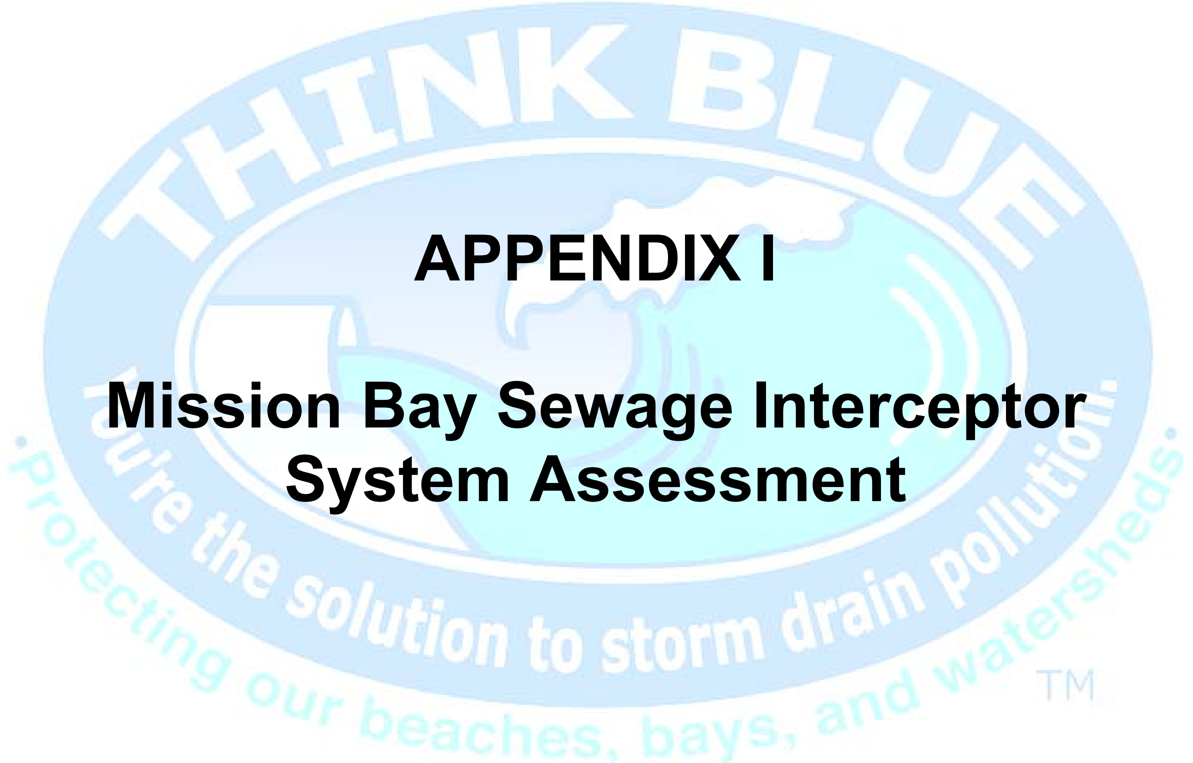


APPENDIX I

Mission Bay Sewage Interceptor System Assessment

Mission Bay Sewage Interceptor System

Introduction

The area encompassed by Mission Bay is the final receiving waters for a large drainage area in the City of San Diego. There are approximately 100 storm drains, serving 80 square miles of the City of San Diego that carry urban runoff to Mission Bay. These storm drains and the urban runoff they convey to the Bay have been suspected sources of bacteria to the receiving waters since monitoring began in the late 1960s. The Mission Bay Sewage Interceptor System (MBSIS) is a particularly important feature in preventing dry weather runoff, and associated bacterial loads, from reaching the Bay. The system is reviewed briefly here, including background on the basis for constructing the system and a general description of how it operates. More detailed descriptions of the system can be found in Hirsch (1987) and AIS (2001).

The storm drain system can convey a variety of pollutants to Mission Bay from numerous sources, including residential irrigation runoff, industrial waste, and the effluent from sewage spills and chronic sewer leaks. Historically, many of the high bacterial counts in Mission Bay have been attributed to sewer overflows and other sources conveyed to the Bay by the storm drain system. To respond to this problem the City of San Diego constructed the MBSIS that encircles the Bay. The overall purpose of the MBSIS is to protect the water quality of Mission Bay by diverting pollutants that flow through the storm drains to the sewer system before they enter the Bay.

In 1987 a Mission Bay Interceptor Master Plan was developed (Hirsch 1987) for the City of San Diego, which provided a blueprint for constructing the MBSIS. The first step of the Master Plan was to prioritize the storm drains in Mission Bay relative to their potential for carrying human sewage to the Bay. The criteria used for this prioritization included the size of the storm drain, whether it was an outlet for a sanitary sewage pump station, its proximity to a trunk sewer, and its potential for collecting sewage spills. Based on the prioritization, 23 storm drains were ranked with a priority of 0, indicting that they had no sewage spill potential.

It is important to note that potential sources of bacteria other than human sewage (e.g., urban runoff, bird fecal matter, etc.) were not included in this prioritization. These storm drains were subsequently removed from the Master Plan and are not part of the current MBSIS. In addition, there are several storm drains that were identified in Phase I that are not discussed in the Master Plan and are not included in other City storm drain maps. Although the potential for these storm drains to convey human sewage to the Bay was considered low in the Master Plan and are therefore un-diverted, they can convey bacteria to the Bay from other sources, such as bird waste or urban runoff from areas within Mission Bay Park.

In constructing the interceptor system, several types of diversion structures were considered, including vacuum, low pressure, air lift, and conventional gravity pumping systems (Hirsch 1987). Conventional gravity and pumping systems were chosen due to their simplicity, City maintenance staff familiarity, and the large distance between interceptor systems. A typical diversion system consists of a concrete diversion vault (variable in size, ranging from approximately 3 to 12 square feet), which is typically located at the downstream end of a drainage area, before the storm drain pipe discharges to the Bay. Inside the vault near the Bay side is a diversion weir or berm. The berm consists of a six-inch raised concrete structure that diverts dry weather flows from the upstream drainage to a pipe located in the side of the vault that diverts water to the sewer system.

The diversion pipe is typically a six-inch line that is covered in the diversion vault with a metal grate to prevent debris from entering the sewer system. A typical diversion structure is shown in Figure I-1. Those storm drains that are influenced by tide water are fitted with a metal flap valve (Figure I-2), a tide flex valve (Figure I-3), or a manually operated tide gate. These structures are designed to protect the system from salt water intrusion at high tides. The valves are typically located at the base (Bay side) of the diversion box.

Figure I-1. Photograph of water entering a storm drain diversion vault (on the right side of the photograph), the diversion berm (on the left side of the photograph), and grate. The vault shown here is filled with sediment that had washed up from the Bay.

Figure I-2. Photograph of a typical flap valve used to prevent salt water intrusion of the diversion system.

Figure I-3. Photograph of a typical tide flex valve used to prevent salt water intrusion of the diversion system. This tide flex has been bowed open and is ineffective in preventing tidal backflow.

The MBSIS was installed in five phases. The first phase involved construction of the East Mission Bay Interceptor System, which encompasses the area between Rose Creek and Tecolote Creek on the east side of Mission Bay. The system is made up of seven storm drain interceptor pump stations and 12 diversion sites (Figure I-4). The system was constructed in three main phases in 1985 and 1987 (AIS 2001). Phase I was completed in 1985 and involved the storm drain interceptors in the northeast side of the Bay, including construction of the De Anza Cove storm drain diversion and three diversion valves associated with Interceptor I-6. Phase 2 was also completed in 1985. It involved the construction of Interceptor Pump Stations I-5 south of De Anza Cove, I-4 at Tecolote Shores, I-2 at Morena Blvd. and Lister Street, and V-5 at Morena Blvd. and Ingulf Street. Phase 3 was completed in 1986. It included the Rose Creek and Tecolote Creek interceptor pump stations. A second interceptor pump station (I-9) was constructed for Rose Creek south of Garnet Street in 1992. The remainder of the MBSIS was completed by 1993.

In 2001, a study was completed by Advanced Infrastructure Systems (AIS) on the effectiveness of the MBSIS (AIS 2001). The purpose of the study was to assess the reliability and operational effectiveness of the interceptor pump stations and their associated facilities on the east side of Mission Bay. The study concluded that the interceptor pump stations were in good operating condition, especially considering the age and volume of water that is pumped. During the two month study (May and June, 2001), no urban runoff flows were observed bypassing the diversion system. Based on the research conducted in the study, the authors concluded that the pump stations have sufficient capacity to effectively pump the diverted urban runoff flows, plus other extraneous flows, such as the salt water backflow that occurs at high tides. The study recommended that the flap valve seals should be repaired or replaced because they were leaking at high tides.

In the spring of 2003, the storm drain system and MBSIS were inspected at the 12 sites identified in this study. The results are presented by site below.

Figure I-4. Map of Mission Bay storm drain diversion system showing diverted areas in blue and un-diverted areas in red.

Bonita Cove

Because storm drain runoff was identified as a potential source of indicator bacteria at Bonita Cove during the Visual Observations Task, the storm drains and the Mission Bay Sewage Interceptor System (MBSIS) were inspected at this site and others throughout the Bay with the help of City staff. There are seven storm drains that discharge to Bonita Cove (Figure I-5). The storm drains and the diversion system associated with them were inspected on April 2, 2003. The results are reviewed below.

Figure I-5. Map of storm drain system at Bonita Cove showing diverted (in blue) and un-diverted areas (in red).

The storm drain located at the southern end of the peninsula on the west side of Bonita Cove (SD1-7), at Mission Blvd. and San Diego Place, discharges to the Mission Bay Channel through a tide flex in the channel rip rap. Dry weather flows are diverted via a diversion box and a motorized plug valve (V-15). The entrance to the storm drain directly upstream of the tide flex was flooded with seawater from the Mission Bay Channel that was flowing into the sewer system. The tide flex was partially submerged and could not be inspected, but the large volume of seawater in the storm drain inlet suggests that it was not functioning properly, particularly during high tides.

The majority of the peninsula on the west side of Bonita Cove is drained to the Cove by storm drain diversion boxes and motorized plug valves located at Balboa Court (V-30), Cohasset Court (V-32), and Deal Court (V-33). The storm drain at Balboa Court (V-30) was completely clogged with debris and sediment during the inspection (Figure I-6). There were no flows at the time of the inspection, but the clogged diversion rack suggested that dry weather flows are not properly diverted at this site. Diversion structures at Balboa Court and Cohasset Court appeared to be functioning properly. Tide gates are in place at the Balboa Court and Deal Court storm drains. Both appeared to be in good condition and functioning properly. The storm drain at Cohasset Court has a tide flex that apparently is submerged and could not be inspected.

Figure I-6. Diversion rack clogged with debris.

The storm drain at San Fernando Place (SD1-3) drains a fairly large area on the west side of Mission Blvd. The diversion structure consists of a tide flex and diversion box located in the parking lot just west of the beach at San Fernando Place. Dry weather flow is diverted to Interceptor Pump Station I-13 located at the southern end of the parking lot on the west side of Bonita Cove. During the inspection, the diversion box was completed flooded with seawater that was flowing directly to I-13. The tide flex was re-inspected at low tide. The Bay side of the tide flex had been closed with a large C-clamp (Figure I-7). However, water was clearly entering the diversion box at high tide, either through the clamped opening or the band that

Figure I-7. Clamped tide flex valve.

connects the upstream end of the tide flex to the perimeter of the storm drain. During high tides, it is likely that Bay water and urban runoff mix. If the diversion rack has a large quantity of debris on it, there is a potential for the urban runoff to be carried to the Bay during ebb tides.

Figure I-8. Broken Bonita Cove tide flex valve stuck open.

The storm drain located at the northwestern corner of Bonita Cove (SD1-2) conveys flow from the parking lot on the west side of the Cove. The diversion structure consists of a diversion box and a tide flex valve. At the time of the inspection, the Bay side of the tide flex was permanently bowed with a large opening in the center (approximately eight inches wide), resulting in a substantial volume of Bay water flowing to Interceptor Pump Station I-13 (Figure I-8). As with storm drain SD1-3, it is likely that Bay water and urban runoff mix during high tide allowing for urban runoff contamination of the Bay when the tide ebbs.

The last storm drain that conveys water to Bonita Cove is located on the northeast side of the Cove (SD1-1). There is no diversion structure associated with this storm drain. The drainage area for this storm drain is fairly large. It drains the parking lot on the northeast side of Bonita Cove, approximately half of the parking lot on the north side of Bonita Cove, and street runoff from a large portion of Mission Bay Drive. Because there is no diversion structure for this storm drain, irrigation water in the grass associated with high bacterial levels may reach the receiving waters of Bonita Cove via the storm drain conduit.

Bahia Point

Because storm drain runoff was identified as a potential source of indicator bacteria at Bahia Point during the Visual Observations Task, the storm drains and the Mission Bay Sewage Interceptor System (MBSIS) were inspected at this site and others throughout the Bay with the help of City staff. There are eight storm drains that drain to the area between Carmel Point in Santa Barbara Cove and the eastern side of Ventura Cove, which surround Bahia Point (Figure I-9). These storm drains were examined on April 3, 2003 to map out areas of the storm drain conveyance system at this site. The results are reviewed below.

Figure I-9. Map of storm drain system at Bahia Point showing diverted (in blue) and un-diverted areas (in red).

The first two storm drains (SD2-1 and SD2-2) are located off of Liverpool Court (V-42) and just south of San Luis Obispo Place (V-40). Each consists of a storm drain diversion box, a motorized plug valve, and a manual tide gate. The diversion grates in both diversion boxes were small (approximately eight inches square) and had some debris in them. A local resident was there at the time of the assessment. He said that he cleans them regularly because they are easily clogged with litter and debris. At the time of the inspection, the diversion boxes and tide gates appeared to functioning as designed.

The third storm drain is located in the southwest corner of Santa Barbara Cove (SD2-3). This storm drain is diverted in a diversion box upstream of the discharge point to the sewer via a motorized plug valve (V-38). This system appeared to be diverting storm drain system flows to the sewer.

There are two storm drains that drain the northern half of the Bahia Point Peninsula (SD2-4 and SD2-5). Both are undiverted and drain surface runoff to Ventura Cove on the east side of the Peninsula. During the Visual Observations Task of this study, elevated bacterial levels were measured from the discharge of both storm drains and from water samples taken before the water entered these storm drains. Weekly monitoring was conducted in the receiving water adjacent to SD2-4 (Figure I-10).

Figure I-10. Curb inlet upstream of Storm Drain

The southern half of the Bahia Point peninsula is drained by a storm drain located on the southwestern end of Ventura Cove (SD2-6). Dry weather flow is diverted in a diversion box upstream of the discharge point to the sewer via a motorized plug valve (V-38). This system appeared to be functioning as designed.

The last two storm drains in this area are located at the southeastern end of Ventura Cove (SD2-7 and SD2-8). They drain the parking lots and some surface street runoff on the southeast side of Ventura Cove. Both are un-diverted, but no bacterial data is available for these sites.

Fanuel Park

There are five storm drains that drain to the Fanuel Park area (Figure I-11). These storm drains were examined on February 27, 2003 to map out areas of the site that were un-diverted and to assess the effectiveness of the diversion system.

The first storm drain in the area (SD3-1) is located at the end of Dawes Street. It consists of a storm drain diversion box, a motorized plug valve (V-55), and a tide flex. The entrance to the diversion box is located approximately 15 feet from the end of Dawes Street, where a second storm drain inlet is located. Minor dry weather flows typically flow into the diversion box and are diverted to the sewer. However, heavier flows, which have been observed during dry weather from de-watering operations, will overwhelm the diversion box and flow to the second storm drain entrance and then directly to the Bay. One sample of de-watering flow that was bypassing the diversion system had very high levels of fecal indicator bacteria (the enterococcus concentration was nearly 6,000 MPN/100 ml). In addition, there is a second line that connects to this storm drain from the west. This line drains Briarfield Drive and several surface streets up-gradient. This line does not have a tide flex and connects to the Dawes Street storm drain downstream of the diversion. High tides have been observed inundating the lower portions of Briarfield Drive. Flow from this area goes directly to the Bay.

Figure I-11. Map of storm drain system at Fanuel Park showing diverted (in blue) and un-diverted areas (in red).

The second storm drain (SD3-2) is located at Everts Street, just west of Fanuel Park. It consists of a storm drain diversion box and motorized plug valve (V-56). The layout of the diversion system (and problems associated with it) is similar to that described for the Dawes Street storm drain. In addition, the Everts Street storm drain receives un-diverted flow from surface runoff of condominiums and apartment buildings in the area.

The third storm drain is located at the end of Fanuel Street. It consists of a storm drain diversion box that diverts water to an Interceptor Pump Station (I-7), which pumps diverted flow to the sewer. The Fanuel Park storm drain is also designed to have an associated tide flex or check valve. However, neither structure was in place at the time of the inspection and had not been since at least January 30, 2003. Thus, high tides inundate the diversion box, sending large volume of seawater to the diversion system. In addition, it is likely that flows from Fanuel Street are also delivered to the Bay during ebbing tides. The storm drain entrance in Fanuel Street has had consistent flow (approximately 1-2 gallons per minute) since the study began in August, 2002. Although the flow is low, samples taken from this storm drain have had bacteria levels that consistently exceed AB411 criteria.

In addition to the problems mentioned above, there are other concerns associated with the Fanuel Park storm drain system. There are two pipes that connect to the storm drain downstream of the diversion system. Both are thought to carry water from de-watering activities and sumps associated with the condominiums and apartment buildings in the area (Figure I-12). The results of an investigation that was recently conducted to assess bacterial levels from these sources is discussed below.

Figure I-12. De-watering sump pump located at Fanuel Park.

Interceptor Pump Station I-7 (which receives flow from the Fanuel Park storm drain) also receives flow from the fourth storm drain in the area, located at Roosevelt Street, east of Fanuel Park (SD3-4). This storm drain consists of a storm drain diversion box and tide flex valve. Diverted water flows west from the diversion to Fanuel Park where it turns north and flows into Pump Station I-7. On March 11 2003, the line was inspected where the flow moves north to I-7. The line was filled with several feet of water, which was removed by a vactor truck. Inside the line, an inflatable plug had been inserted, which had completely blocked flow (Figure I-13). The plug was removed and normal flow resumed.

Figure I-13. Plug found after vactor truck cleaning of storm drain system.

The last storm drain in the Fanuel Park area is located at Moorland Drive and Riviera Drive. It consists of a diversion box and motorized plug valve and appeared to be functioning as designed.

Sail Bay Storm Drain Conveyance System Investigation and Study

On Monday April 28, 2003, a follow-up study was conducted at Fanuel Park to investigate the effectiveness of the Mission Bay Sewer Interceptor System and several potential sources of fecal indicator bacteria (the complete report is located in Appendix E). The Fanuel Park area is unique in Mission Bay because it contains several residential properties with underground parking structures. Four of these structures require a de-watering system to prevent the structures from flooding. The de-watering systems pump ground water from sumps located within the structure to the storm drain system. Twelve of these structures in the Fanuel Park area require a de-watering system to prevent the rainwater from flooding underground parking structures. Much of the water from both these systems is un-diverted. The investigation was initiated to determine if the de-watering operations and other sources of water in the area had an impact on the bacteria levels in the receiving waters at Fanuel Park (Table I-1).

Table I-1. Indicator bacteria sample results from April 28, 2003.

Site	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)	Enterococcus (MPN/100ml)
V3-1	230	<20	<10
V3-4	800	70	**241**
V3-4*	**110,000**	20	**2,613**
V3-5	5,000	70	**216**
V3-5*	**>350,000**	80	**3,255**
V3-6	<20	<20	<10
MH3-2	**160,000**	**30,000**	**6,131**
MH3-3	800	<20	20
MH3-4	3,000	<20	**275**
MH3-8	2,200	<20	**241**
SD3-3A	**50,000**	**3,000**	**1,054**
SD3-3B	<20	<20	<10
R3-2	20	<20	<10
R3-3	**30,000**	<20	<10
R3-6A	<20	<20	<10
R3-6B	20	<20	10
R3-8	**80,000**	**80,000**	nd
R3-9	8,000	140	**435**
R3-11	<20	<20	<10
R3-14	800	<20	**109**

*Samples taken on 3/11/03.
Values that exceeded AB411 criteria are highlighted in bold

Prior to the study, extensive research and investigations were conducted to collect information on locations of de-watering sump pumps and their characteristics. Two distinct types of sump pumps have been found in the area. The de-watering sump pumps (DSP) are found at locations that have very large underground garage structures; the DSP collects groundwater and tidally influenced water and sends it out to the storm drain conveyance system. Some of these systems pump over 200,000 gallons of water per day. The second type of sump pumps, rainwater sump pumps (RSP), are found at locations that have a parking structure below the street surface. During high rainfall events these locations send water from the parking structure back onto the street surface. The discharge rate from these pumps is dependent on the volume of rainfall and any washing activity that occurs within the parking structures.

During the field investigations, samples were collected from several of the de-watering sump pumps, manhole inlets and vaults of the storm drain conveyance system (Figure I-14), and storm drain effluent. Samples were analyzed for fecal indicator bacteria to determine potential sources of contamination within the storm drain conveyance system.

Figure I-14. Storm drain vault with connected rainwater sump pump drainage pipe.

Three of the four storm drain conveyance manholes had an exceedance of at least one of the indicator bacteria. Two of the four vaults had an exceedance for only enterococcus. Three of the eight rainwater/dewatering sump pumps had an exceedance for at least one of the indicator bacteria. The highest bacteria levels were found in the storm drain manhole at the terminus of Dawes Street and the manhole at the terminus of Fanuel Street. In addition, large volumes of water were observed from the de-watering operations entering the storm drains downstream of the diversion system at Fanuel Street (SD3-3) and at Graham and Gresham Streets (SD3-4). During the weekly monitoring, Fanuel Park had the second lowest average salinity of any of the 12 sites monitored in Mission Bay. The lack of any obvious freshwater discharges in the area (e.g., creek drainage), suggests that the de-watering operations may have been the source of the lower salinity values. Bacterial levels in effluent from the de-watering operations measured during the follow-up study at Fanuel Park were low. However, given the large volumes of water (estimated at over 260,000 gallons per day for all dewatering sump pumps) and the fact that the water is un-diverted, suggests that these operations should be monitored in the future when Fanuel Park is experiencing elevated bacterial levels.

Riviera Shores

There are four storm drains that discharge to the Riviera Shores area (Figure I-15). All of them except storm drain SD4-4, which has a very small drainage, are diverted. None of the storm drains were flowing any time during the Visual Observations Task or weekly monitoring. On February 27, 2003 the storm drain diversion system was inspected. Three of the four storm drains at Riviera Shores are located at the ends of the following streets: La Mancha Drive (SD4-1), La Cima Drive (SD4-2), and Edge Cliff Drive (SD4-3) (Figure I-16). Dry weather flow from all three of the storm drains is diverted to the sewer via Interceptor Pump Station I-14 located at the western end of La Cima Drive. All of the storm drains drain small, residential neighborhoods and the diversion system appeared to be diverting storm drain system flows to

Figure I-15. Map of storm drain diversion system at Site 4 (Riviera Shores) showing diverted (in blue) and un-diverted areas (in red).

the sewer system. The fourth storm drain in the area (SD4-4) is located at the southern tip of Crown Point and drains a small area on the north side of the Ingraham Street Bridge. It is un-diverted, but no flows have been observed emanating from it during this study.

Figure I-16. La Cima Drive storm drain (SD4-2) and sampling site location.

Wildlife Refuge

There are four storm drains that discharge along the east side of the Crown Point peninsula (Figure I-17). They terminate at the ends of La Cima Drive (SD5-1), Moorland Drive (SD5-2), south of Roosevelt Avenue (SD5-3), and south of Fortuna Avenue (SD5-4). All of them are diverted as part of the MBSIS. On April 28, 2003 the storm drain diversion system was inspected. All of the diversion structures were free of debris and the system appeared to be functioning as designed.

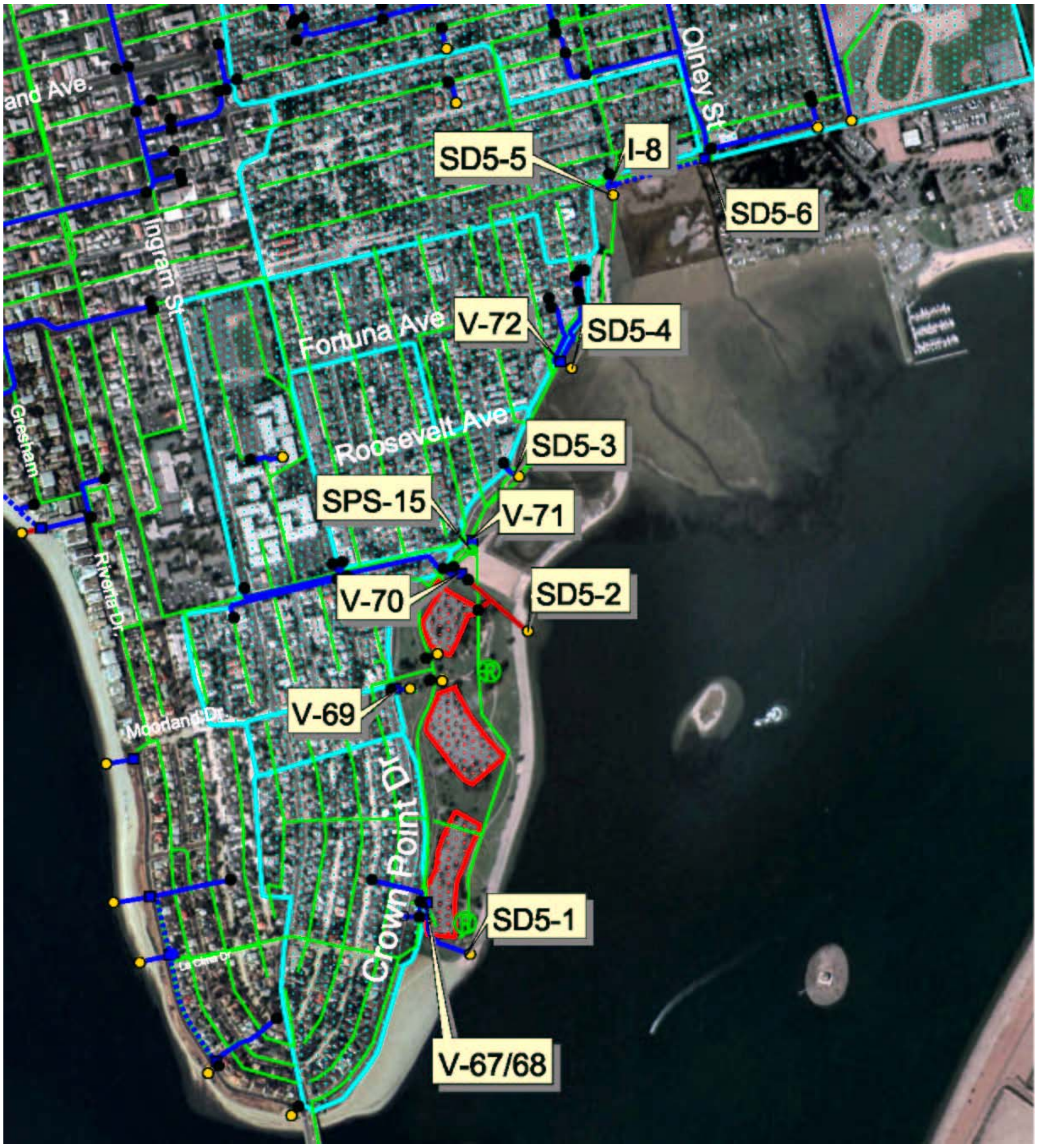


Figure I-17. Map of storm drain system at Wildlife Refuge showing diverted (in blue) and un-diverted areas (in red).

Campland

Aside from the diversion structure at Rose Creek, which is upstream of the Creek's mouth, there are no storm drain diversion outfalls near the Campland beach (Figure I-18). However, two storm drains terminate just west of Campland into the northern end of the Kendall Frost Marsh Reserve. They were inspected on November 11, 2002 and April 28, 2003.

Figure I-18. Map of storm drain system at Campland showing diverted (in blue) and un-diverted areas (in red).

Figure I-19. Facing south of the storm drain outlet located at Olney Street and Pacific Beach Drive.

The first is located just west of the Campland property at the intersection of Olney Street and Pacific Beach Drive (SD5-6 in Figure I-19). It consists of two large culverts that discharge to a storm drain diversion box. Each culvert is supposed to contain a tide flex valve, however one of the storm drains is missing a tide flex and has been since at least November 11, 2002. It was recommended to the Streets Division that a tide flex be replaced at this site. Bacterial levels that exceeded AB411 criteria have been measured in the storm drain diversion box and from areas downstream. Dry weather flow from these storm drains is diverted to Interceptor Pump Station I-8, located west of the storm drain at Pacific Beach Drive and Noyes Street. There are two manholes in the line that connects the storm drain with the diversion box. Both were completely flooded with stagnant water during the inspection, suggesting that the diversion system was not working properly. A second investigation was conducted on May 1, 2003. During this inspection it appeared that the clogged line had been cleared and that the storm drain conveyance system for I-8 was functioning properly.

The second storm drain in this area is located at Interceptor Pump Station I-8 (SD5-5). It receives flow from a large urban sub-watershed and has a diversion box located at Noyes Street and Oliver Avenue. The diversion boxes have not yet been inspected. However, the storm drain entrance located across the street from Interceptor Pump Station I-8 and down-gradient from the diversion box was completely flooded with stagnant water on the day of the investigation. Further investigations conducted on May 1, 2003 found that the storm drain conveyance system had been cleared and was functioning properly.

De Anza Cove

There are eight storm drains that terminate in De Anza Cove (Figure I-20), more than any other area in Mission Bay. Several of these were flowing during the Visual Observations Task and during the weekly monitoring and several have had consistently high bacterial levels. On January 31 and February 5, 2003, the condition of the storm drains and the diversion system at De Anza Cove were inspected.

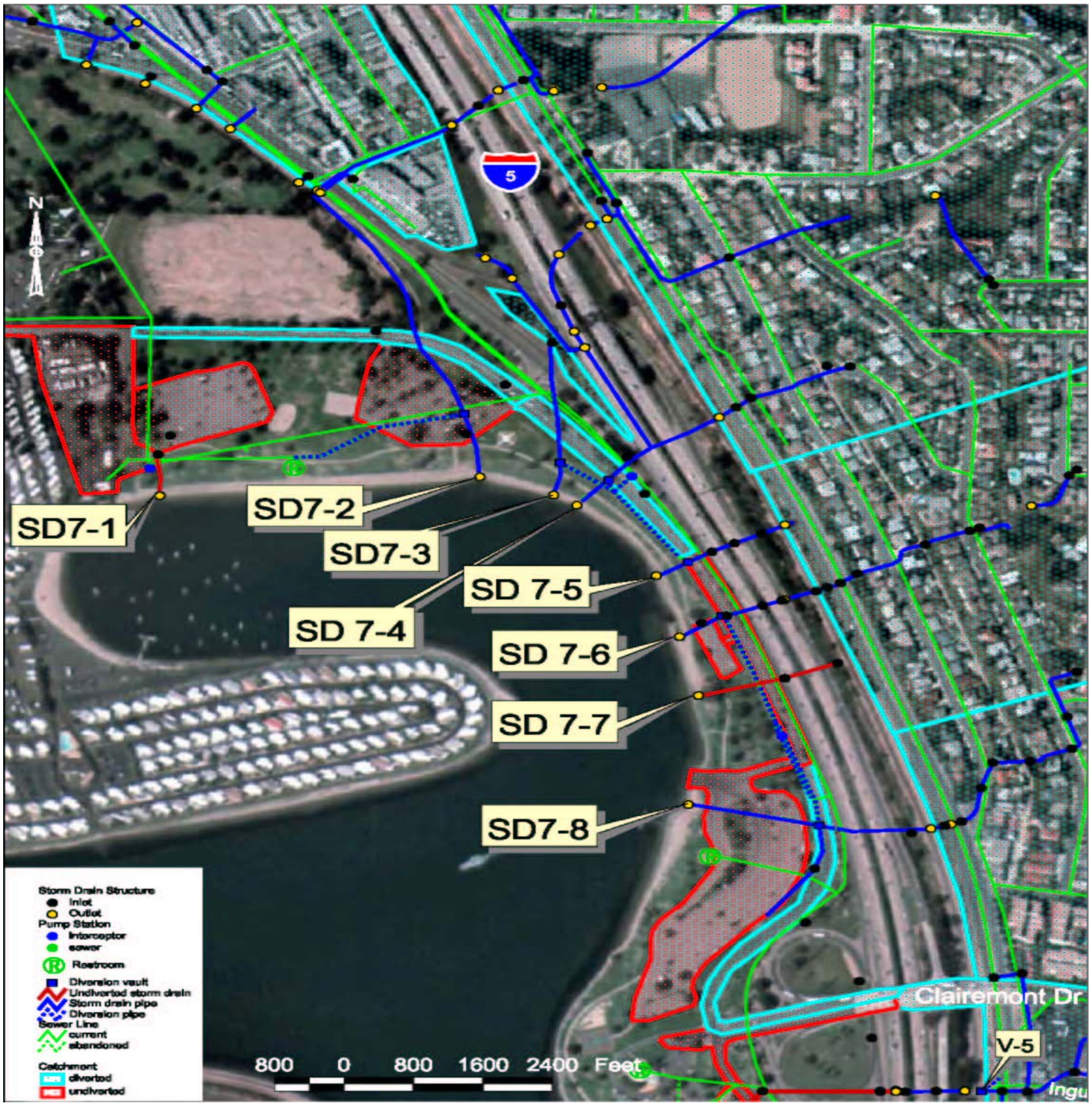


Figure I-20. Map of storm drain system at De Anza Cove showing diverted (in blue) and un-diverted areas (in red).

SD7-1 is un-diverted and drains the west parking lot of De Anza Cove and small number of surface streets. High bacterial levels (enterococcus concentration of 7,701 MPN/100 ml) have been measured from this storm drain, but flow is minimal and it is unlikely that it has a large impact on bacterial levels in the receiving waters.

SD7-2 drains a large area north of De Anza Cove that includes the Mission Bay Golf Course north of the site. The diversion system consists of a diversion box and motorized plug valve (V-6). Since this study was initiated, no dry weather flow has been observed from SD7-2 and it appears to be functioning as designed.

Storm drains SD7-3, SD7-4, and SD7-5 each consist of a diversion box, a motorized plug valve, and a check valve. Dry weather flow from each of these storm drains flows to a single manhole, then across East Mission Bay Drive to Interceptor Pump Station I-6. The diversion boxes for all three storm drains and the manhole that they drained into were all filled with sediment, organic matter (primarily eel grass), and trash (Figure I-21). The check valves were propped open with the debris so that dry weather flow was not diverted and flowed directly to the Bay. Samples collected from the ends of each of the three storm drains had elevated bacterial levels on the day of the investigation as well as during the Visual Observations Task of this study. During the Visual Observations Task and subsequent weekly sampling, flow was observed from all three storm drains, suggesting that urban runoff flows had been reaching the Bay since at least August 2002. Flow from SD7-4 and SD7-5 is consistent and fairly heavy and a well-formed delta and braided channel can be seen at the storm drain terminus. In addition SD7-5 is badly cracked near the terminus.

Figure I-21. Eelgrass surrounding storm drain SD7-5.

The diversion system at storm drains SD7-6 and SD7-8 also consist of a diversion box, a motorized plug valve, and a check valve. Diverted flow from these storm drains flows into Interceptor Pump Station I-5, which is located approximately half way in between the two storm drains on the west side of East Mission Bay Drive. The diversion boxes of both SD7-6 and SD7-8 were filled with sediment during the inspection and the check valves were propped open with debris (Figure I-22). It was apparent that during high tides a large volume of seawater was flowing up the storm drains, through the diversion boxes, and into Interceptor Pump Station I-5. Dry weather flows in these storm drains flow directly to the Bay when the diversion structure is filled with debris.

Figure I-22. Sediment and debris clogging the diversion rack at storm drain SD7-6.

In between storm drains SD7-6 and SD7-8 is SD7-7 – a buried storm drain that has apparently been abandoned. There is an obvious spring located on the beach where the end of the storm drain should be. Discharge from the spring is copper colored and has elevated levels of bacteria.

Visitor's Center

As with other sites throughout the Bay, storm drain runoff was identified as a potential source of indicator bacteria at Visitor's Center during the Visual Observations Task of this study. Therefore, an investigation of the storm drains and the MBSIS at this site was initiated on January 31 and February 5, 2003. There are three storm drains that discharge at the Visitor's Center area (Figure I-23). The results of these infrastructure investigations are reviewed below.

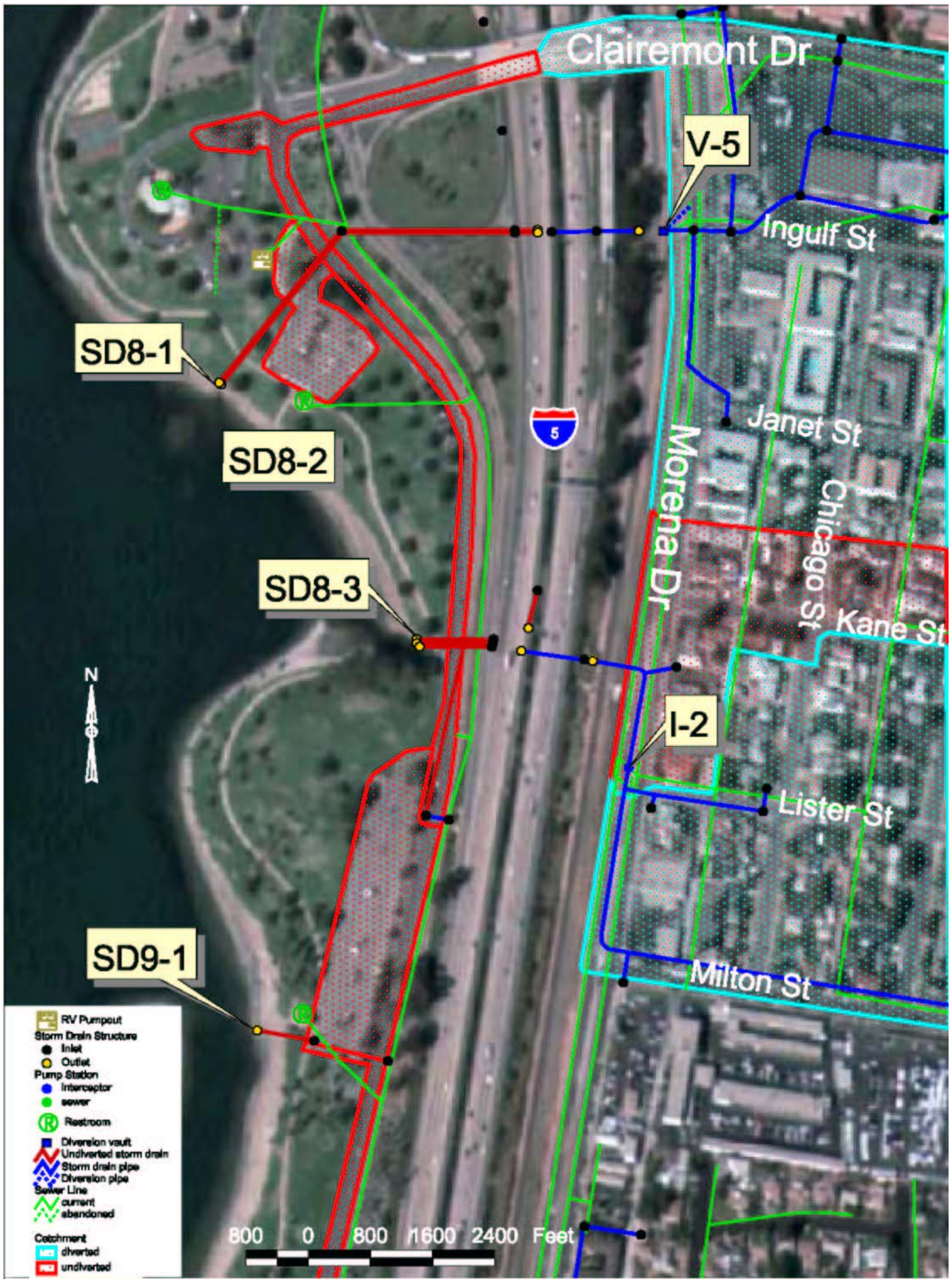


Figure I-23. Map of storm drain system at Visitor's Center showing diverted (in blue) and un-diverted areas (in red).

The first two storm drains (SD8-1 and SD8-2) are located just south of the Visitor's Center building (Figure I-24). SD8-1 is a 60-inch diameter reinforced concrete pipe (RCP). Although there are no maps currently available for the storm drains at Visitor's Center, SD8-1 is thought to originate on the east side of Interstate 5, west of the railroad tracks at Ingulf Street. East of the railroad tracks at Ingulf Street is Diversion Box V-2. The diversion box consists of an approximately 12-inch tall concrete berm that directs upstream flow to the sewer line by gravity. Above the diversion box, this storm drain conveys runoff from a large residential and commercial area on the east side of Interstate 5 north of Ingulf Street. All dry weather flow from this area should be diverted at diversion box V-2. Although the diversion box is not tidally influenced, directly downstream of the diversion and just east of the Interstate 5 off ramp at Clairemont Drive is a groundwater spring. There is perennial vegetation at this location and evidence of one homeless person encampment. During a site reconnaissance performed on January 16, 2003, the salinity of this water was measured at 3.6 parts per thousand (ppt), which is typical of freshwater. From here, the groundwater flows under Intestate 5 towards Mission Bay. It is not known if runoff from the Interstate enters storm drain SD8-1.

Figure I-24. Storm drains 8-1 (on left) and 8-2 (on right), located just south of the Visitor's Center building.

It is suspected that SD8-1 can be accessed west of Interstate 5 from a drain inlet located on the east side of East Mission Bay Drive, directly across the street from the entrance to the parking lot just south of the Visitor's Center. This inlet is directly in line with the storm drain east of Interstate 5 described above (for which maps are available). During the site reconnaissance on January 16, 2003, this drain was filled with water that appeared to be flowing towards Mission Bay. The salinity of the water was 24 ppt, suggesting a mixture of fresh and salt water. From this point, the storm drain is thought to turn to the left, at an approximate 45° angle to the termination point northwest of Comfort Station 1091. The salinity of the water coming out of the pipe was 29 ppt, also suggesting a mixture of saltwater (salinity of at least 30 ppt) and freshwater.

SD8-2 is also a 60-inch diameter RCP, and its terminus located directly adjacent to SD8-1. There are no maps available for this storm drain. Thus, the source is unknown. It is possible that the pipe parallels SD8-1 for all or a portion of its length. One map that is available shows a single storm drain originating on the east side of Interstate 5 that changes to two parallel storm drains on the west side. However, the map or the storm drains stop at that point and no further information is available. During the visual observations, water was not observed flowing from SD8-2 during any of the observation days except immediately after a high tide. Thus, no samples were taken. This suggests that SD8-1 and SD8-2 may not originate from the same source.

Figure I-25. Outlet of Cudahy Creek at Mission Bay.

The third storm drain that discharges to the Visitor's Center area is the mouth of Cudahy Creek (SD8-3), which lies at the southern end of the Visitor's Center beach (Figure I-25). At the mouth, the creek consists of a triple 48-inch by 72-inch box culvert. Just upstream of the mouth, the southern culvert receives undiverted surface flow from street drains along both sides of East Mission Bay Drive. SD8-3 also receives undiverted flow from Interstate 5. The culverts extend under Interstate 5 and surface on the east side of the Intestate, just west of Morena Boulevard between Kane and Lister Streets. At this location, the entire width of the channel is covered with decaying eelgrass and kelp to a depth of approximately one foot. The decaying vegetation extends west under the Interstate as far as can be seen and presumably to the mouth (the source of the vegetation). Upstream of the open channel is a 72-inch culvert. Small amounts of decaying vegetation could be seen approximately 50 feet up the culvert during the January 31, 2003 investigation, indicating the maximal extent of the tidal intrusion. At Morena Boulevard, the culvert forms a Y. The south leg of the Y heads south along the west side of Morena Boulevard and continues one-half block to Lister Street where Diversion Unit I-2 is located. Diversion Unit I-2 diverts dry weather flows from a large residential area south of Lister Street and east of Denver Street. Flow is diverted by a berm in the I-2 diversion box that directs water via a pump to the sewer main running along the west side of Morena Boulevard. The east leg of the Y runs east under Morena Boulevard, draining a small area between Morena Boulevard and Denver Street, and between Jellet Street and Lister Street. Surface water in this area flows undiverted to the mouth of Cudahy Creek.

Leisure Lagoon

Figure I-26. Map of storm drain system at Leisure Lagoon showing diverted (in blue) and un-diverted areas (in red).

There are three storm drains that terminate in the Leisure Lagoon area (Figure I-26). Two of them (SD9-1 and SD9-2) discharge directly to the east side of Leisure Lagoon. The third discharges to Mission Bay west of the Lagoon and is unlikely to affect water quality at this site. Storm drain SD9-1 is located at the north end of the sampling area by Comfort Station 1092 and storm drain SD9-2 is located approximately 6,000 feet to the south.

Storm Drain SD9-1 is located on the northeast end of the Lagoon adjacent to the comfort station 1092 (Figure I-27). This storm drain drains the parking lot adjacent to the restroom, a small portion of the surface runoff from Each Mission Bay Drive, and unknown area east of Interstate 5. The storm drain is un-diverted. Samples taken from this storm drain during the Visual Observations Task had bacterial levels that were below AB411 criteria.

The County AB411 monitoring site is located directly in front of the southern-most storm drain, SD9-2 (Figure I-28). The drainage area of storm drain SD9-2 is small, encompassing a parking lot and grassy areas of the Park. It is not part of the MBSIS and directs runoff directly to the Bay. Enterococcus levels in samples taken from this storm drain during the Visual Observations Task were extremely variable, but ranged as high as 68,000 MPN/100 ml. The most likely source of the high concentrations is runoff from the grassy areas of the Park during irrigation. Only two samples were taken from the northern storm drain (SD9-1). Both had very low levels of all three bacterial indicators.

Figure I-27. Photograph of storm drain SD9-1 on the northeast side of Leisure Lagoon.

Figure I-28. Photograph of storm drain SD9-2 on the east side of Leisure Lagoon.

North Pacific Passage

There are three storm drains that discharge within the North Pacific Passage sampling area (Figure I-29). The storm drains and the diversion system at this site were inspected on March 27, 2003.

Figure I-29. Map of storm drain system at North Pacific Passage showing

Storm drains SD10-1 and SD10-2 are located directly in front of the Hilton Hotel to the north of the Hilton boat ramp (Figure I-30). The County Department of Environmental Health AB411 sampling site is located directly in front of the discharge of these storm drains. The drainage area for both storm drains is small and is limited to portions of the Hilton Hotel property. Neither storm drain is part of the MBSIS. Elevated levels of enterococcus were recorded from samples taken from this storm drain during the Visual Observations Task. However, flow was always very limited.

Figure I-30. Storm drain SD10-1 and SD10-2 at North Pacific Passage.

The third storm drain at this site (SD10-3) is located just south of the Hilton Hotel west of East Mission Bay Drive (Figure I-31). The drainage area of the storm drain consists of portions of East Mission Bay Drive and two parking lots at the south end of Tecolote Shores. The diversion system consists of a diversion box, a check valve, and an Interceptor Pump Station. The system was assessed in March 2003. The diversion box was obviously tidally influenced, but at the time of the inspection it was free from debris. However, the check valve was propped open by a water bottle, allowing tidal water to enter the diversion system at high tide and dry weather flow to enter the Bay (Figure I-32). During the Visual Observations Task, a single sample was taken from this storm drain. The sample had an enterococcus concentration of over 14,000 MPN/100 ml. At the storm drain terminus, the beach had been eroded away.

Figure I-31. Storm drains SD10-3 at North Pacific Passage.

Figure I-32. Storm drain SD10-3 at North Pacific Passage showing debris in check valve.

Tecolote Creek

There are no storm drains that discharge to the Tecolote Creek site (Figure I-33). Currently dry weather flow is directed to a slough on the east side of East Mission Bay Drive, opposite the Tecolote playground parking lot.

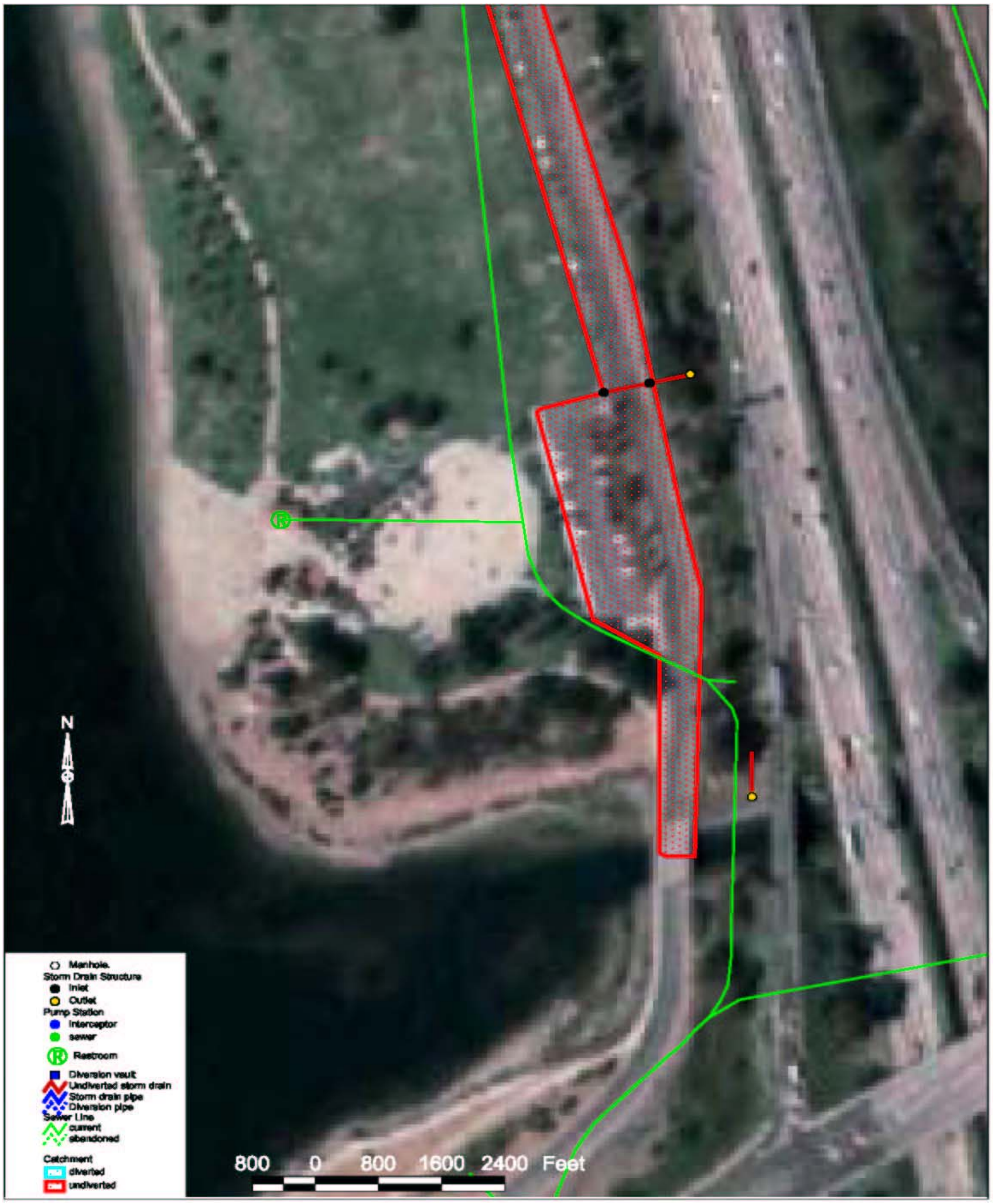


Figure I-33. Map of storm drain system at Tecolote Creek showing diverted (in blue) and un-diverted areas (in red).

The MBSIS diversion for Tecolote Creek is located east of Morena Boulevard, directly north of the Tecolote Community Park building. The diversion was inspected on March 27, 2003. At the time of the inspection, the ability of the diversion berm to direct water to the pump station was overwhelmed and urban runoff was flowing directly to Mission Bay (Figure I-34). Although the interceptor pump system was considered operational at the time, one of the pumps in the system was not functioning properly and the system was unable to keep up with the flow.

Figure I-34. Dry weather urban runoff overflowing the diversion berm at Tecolote Creek. On this date the MBSIS pump station was identified as operational, however one pump was offline and was unable to keep up with the flow.

Hidden Anchorage

There are four storm drains that discharge to the Hidden Anchorage area (Figure I-35). All of them drain a large basin on the opposite side of a berm that surrounds the north and west sides of the site. None of the storm drains are diverted and none of them were flowing during the Visual Observations Task or the weekly monitoring. During rain events, these storm drains have the potential for impacting bacterial standards at Hidden Anchorage by delivering dog fecal matter from the basin to the receiving waters.

Figure I-35. Map of storm drains at Hidden Anchorage.

APPENDIX J

Results of Weekly Monitoring

J.1

Water Quality Data

APPENDIX J

Results of Weekly Monitoring

Appendix J.1. Results of weekly monitoring for water temperature, pH, turbidity, and salinity by site and date.

Sample Date	Physical Parameter	Bonita Cove	Bahia Point	Fanuel Park	Riviera Shores	Wildlife Refuge	Campland	De Anza Cove	Visitor's Center	Leisure Lagoon	N. Pacific Passage	Tecolote Creek	Hidden Anchorage
11/4/2002	Temperature	17.7	17.5	19.4	18.3	19.3	19.5	NS	NS	NS	NS	NS	NS
	pH	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Turbidity	13.92	2.92	9.01	1.26	6.38	8.14	27.38	2.74	1.34	3.98	14.99	0.64
	Salinity	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
11/13/2002	Temperature	18.2	17.2	18	19	18.2	18.5	18	17.9	17.2	17.9	17	17
	pH	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Turbidity	0.72	2.15	4.04	1.31	1.9	3.64	0.86	0.87	0.97	0.85	2.18	0.43
	Salinity	31.005	27.3	31.005	29.055	33.15	28.665	28.86	29.055	32.76	26.325	28.275	29.055
11/18/2002	Temperature	15.8	16	17	16.2	16.9	17.3	18.5	18	18.2	19.1	19	18
	pH	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Turbidity	1.37	0.78	0.51	0.58	2.33	2.05	0.52	0.83	1.23	2.28	2.59	1.2
	Salinity	32.955	33.54	32.955	34.125	30.225	31.59	33.345	33.345	32.76	31.98	33.345	31.98
11/25/2002	Temperature	15.2	15	15.8	15.5	15.5	16	15.9	15.8	16.3	16	16.2	16
	pH	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Turbidity	1.05	3.04	0.43	0.55	2.41	0.69	1.66	1.05	0.82	0.79	4.88	1.1
	Salinity	33.735	34.32	32.175	31.005	34.32	33.54	32.955	34.125	33.15	33.93	32.175	33.15
12/3/2002	Temperature	18.7	18.3	18.5	18.7	18.6	18.6	17.1	17.6	17	18.6	18.4	18.3
	pH	8	7.8	8.1	7.6	8.1	7.9	8	7.7	8	8	7.9	8
	Turbidity	3.27	0.76	1.52	2.13	0.57	2.85	2.39	1.27	0.84	1.02	4.1	3.82
	Salinity	33.345	33.54	33.15	32.955	32.955	31.98	32.37	32.955	33.345	32.76	31.98	33.15
12/9/2002	Temperature	14	16.5	16	15.5	16.9	16.2	16	15.5	15	14.5	15	13
	pH	8.1	8.3	8.4	8.3	8.2	8	8.3	8.2	8.2	8.3	8.3	8.3
	Turbidity	2.11	4.34	2.39	4.96	1.49	1.65	2.65	1.37	0.84	0.82	10.72	3.05
	Salinity	30.42	34.125	29.64	32.76	31.2	31.98	30.42	30.615	34.32	27.105	29.25	31.2
12/13/2002	Temperature	17.8	16.3	17.8	17.2	17	18.2	18.5	16	16	16	16.2	15.9
	pH	8.2	8.5	8.4	8.5	8.5	8.6	8.6	8.1	8.3	8.2	8.2	8.3
	Turbidity	1.28	1.63	3.02	2.66	3.17	7.23	2.71	1.78	9.47	27.3	3.39	2.69
	Salinity	30.81	32.955	28.275	32.955	32.76	30.03	31.98	31.98	31.98	32.37	31.59	31.59

Sample Date	Physical Parameter	Bonita Cove	Bahia Point	Fanuel Park	Riviera Shores	Wildlife Refuge	Campland	De Anza Cove	Visitor's Center	Leisure Lagoon	N. Pacific Passage	Tecolote Creek	Hidden Anchorage
12/24/2002	Temperature	16.5	15.8	16	16.1	15.7	16.4	14	14.4	14.7	14.6	14.9	15.4
	pH	8.9	8.9	8.9	9	8.9	8.9	8.9	8.8	8.9	8.6	8.8	8.9
	Turbidity	9.04	1.74	2.47	2.5	9.01	7.68	5.61	16.21	1.75	2.31	2.4	6.63
	Salinity	33.345	31.59	32.955	34.71	29.445	29.445	27.885	29.445	30.81	29.055	34.125	31.785
12/30/2002	Temperature	14.5	14.8	15.8	16.2	14	16	16.8	15.3	14	14	14.2	13
	pH	NS	NS	NS	NS	NS	NS	NS	NS	9.4	8.9	9	8.9
	Turbidity	2.78	2.58	1.48	10.01	4.49	3.42	3.86	5.13	8.62	3.46	2.72	0.84
	Salinity	29.64	34.32	31.98	31.59	29.835	30.615	29.64	27.3	31.59	27.3	25.74	30.225
1/6/2003	Temperature	13.55	14.2	13.95	13.75	14.15	14.7	14.1	14.7	14.9	15.3	14.9	14.4
	pH	7.7	7.2	7.9	7.9	7.9	7.9	7.5	8.26	7.6	8.2	8.2	8
	Turbidity	6.1	4.85	0	0.05	3.72	11.22	3.75	0.54	4.12	0.91	1.5	4.77
	Salinity	27.69	31.98	32.175	32.955	29.25	31.59	36.075	31.785	34.905	34.125	28.275	30.81
1/8/2003	Temperature	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	pH	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Turbidity	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Salinity	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/13/2003	Temperature	14.9	15.2	15.5	15.1	15.5	16.6	17.5	16.5	17.2	16.3	17	16
	pH	8.16	8.22	8.18	8.29	8.24	8.4	8.48	8.34	8.35	8.37	8.22	8.37
	Turbidity	3.16	1.13	2.46	0.71	2.23	0	0.89	0.8	2.61	0	1.3	0
	Salinity	30.03	33.345	28.665	30.81	31.98	30.42	30.81	32.565	33.345	31.59	33.54	35.295
1/22/2003	Temperature	15.65	15.65	16.2	15.65	16.45	16.7	16.85	16.65	17.1	18.05	17.75	16.15
	pH	8.1	8.1	8	8.1	7.9	7.9	8	7.9	8	7.9	8	8.1
	Turbidity	1.73	1.12	2.42	2.03	1.26	0.12	3.09	1.02	0	0	0.35	2.91
	Salinity	33.54	30.03	29.835	34.32	34.125	32.175	31.59	25.74	29.64	30.03	31.005	29.64
1/27/2003	Temperature	15.65	16	16.95	16.65	17.3	17.85	18.7	17.75	18.3	17.3	19.3	19.3
	pH	7.9	7.9	7.9	7.9	7.9	8.1	8.1	8	8	8.2	7.9	7.9
	Turbidity	1	0.8	0	0	1.07	19.34	0	3.26	0	0	0.4	0.4
	Salinity	30.03	32.37	29.25	31.59	32.76	33.15	31.395	32.175	29.055	27.885	29.64	29.64
2/3/2003	Temperature	15.5	15.55	16.65	15.65	16.75	17.6	17.7	17.8	17.65	18.1	17.55	17.5
	pH	8.42	7.91	7.59	8.02	7.58	7.5	7.66	7.44	7.54	7.68	7.04	7.74
	Turbidity	4.42	1.72	0.23	0.06	2.35	2.6	3.15	6.32	0	0	2.33	0
	Salinity	31.59	34.32	28.275	33.15	27.69	30.03	31.59	31.59	34.32	31.59	29.055	30.225

Results of Weekly Monitoring

Sample Date	Physical Parameter	Bonita Cove	Bahia Point	Fanuel Park	Riviera Shores	Wildlife Refuge	Campland	De Anza Cove	Visitor's Center	Leisure Lagoon	N. Pacific Passage	Tecolote Creek	Hidden Anchorage
2/10/2003	Temperature	14.45	14.6	14.6	14.5	14.25	14.55	15.8	16.3	16.1	16.1	16.25	16
	pH	8.46	8.1	7.49	7.48	7.28	7.58	NS	8.62	9.24	NS	8.34	NS
	Turbidity	0	0	0	1.71	1.7	0.8	9.88	3.08	2.68	1.23	4.43	2.58
	Salinity	29.64	29.835	29.055	31.395	30.03	29.64	27.3	30.225	35.49	29.835	27.3	29.25
2/19/2003	Temperature	16.5	15.9	15.2	15.2	15.1	15.7	16.1	18	18.1	18.8	17.9	17
	pH	6.75	9.8	6.56	6.5	6.65	6.87	7.44	6.5	6.84	6.78	6.89	7.49
	Turbidity	1.17	2.37	22.65	2	2.72	2.81	1.67	0	2.77	0	2.73	1.14
	Salinity	29.64	31.2	26.52	28.275	29.055	29.25	26.325	32.565	31.785	27.69	29.25	32.37
2/24/2003	Temperature	15.7	15.95	15.7	15.7	16.1	16.35	16.95	18.1	17.5	17.2	16.85	18.15
	pH	7.26	6.87	6.49	6.54	6.58	6.7	6.51	6.75	6.71	6.65	6.57	6.64
	Turbidity	0.43	0	1.83	0	0	4.2	8.26	1.51	0	0	12.87	17.96
	Salinity	29.835	31.59	29.64	33.54	28.86	24.765	24.765	24.57	31.005	32.955	29.25	27.885
3/3/2003	Temperature	NS	15	15.1	15	14.85	16.15	15.75	15.8	16.95	16.05	16.85	16
	pH	NS	8.91	9.14	9.1	8.67	9.98	8.96	8.65	9.03	8.94	8.55	8.72
	Turbidity	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Salinity	NS	28.86	27.105	29.445	29.835	28.86	25.155	24.57	28.47	25.155	23.01	25.74
3/10/2003	Temperature	13.5	14.7	15	14.4	14.9	16.2	16.6	17.4	18	17.2	17.4	16.4
	pH	8	8.15	8.34	8.31	8.42	8.37	8.23	8.06	8.22	8.33	8.2	8.49
	Turbidity	2.71	8.32	8.14	5.24	3.69	0.71	0.42	2.22	1.13	0.85	7.92	5.1
	Salinity	27.3	29.055	30.42	29.835	26.13	29.64	28.275	25.74	29.64	29.25	31.59	27.69
3/20/2003	Temperature	15.35	15.35	16.95	16.5	16.85	16.9	18.3	18.3	18.6	NS	NS	NS
	pH	8.93	8.95	9.18	7.34	9.52	9.12	9.13	NS	7.94	7.92	8.09	8.11
	Turbidity	3.79	6.78	7.85	2.86	8.76	24	62	13.07	3.07	3.19	6.64	2.4
	Salinity	22.815	25.74	25.155	23.01	21.255	24.18	27.495	27.69	27.885	31.2	15.21	31.2
3/24/2003	Temperature	18	18.2	17	17.2	17	18.2	17	18.5	18	18.1	18	17.4
	pH	8.5	8.3	8.9	9.9	8.6	8.6	8.2	8.7	8.6	8.8	8.3	8.7
	Turbidity	3.16	1.14	8.54	12.86	7.26	7.96	9.63	1.7	0.81	1.51	4.69	3.93
	Salinity	24.765	23.205	23.595	23.01	22.62	20.865	24.18	25.155	25.545	21.645	22.62	25.155

J.2

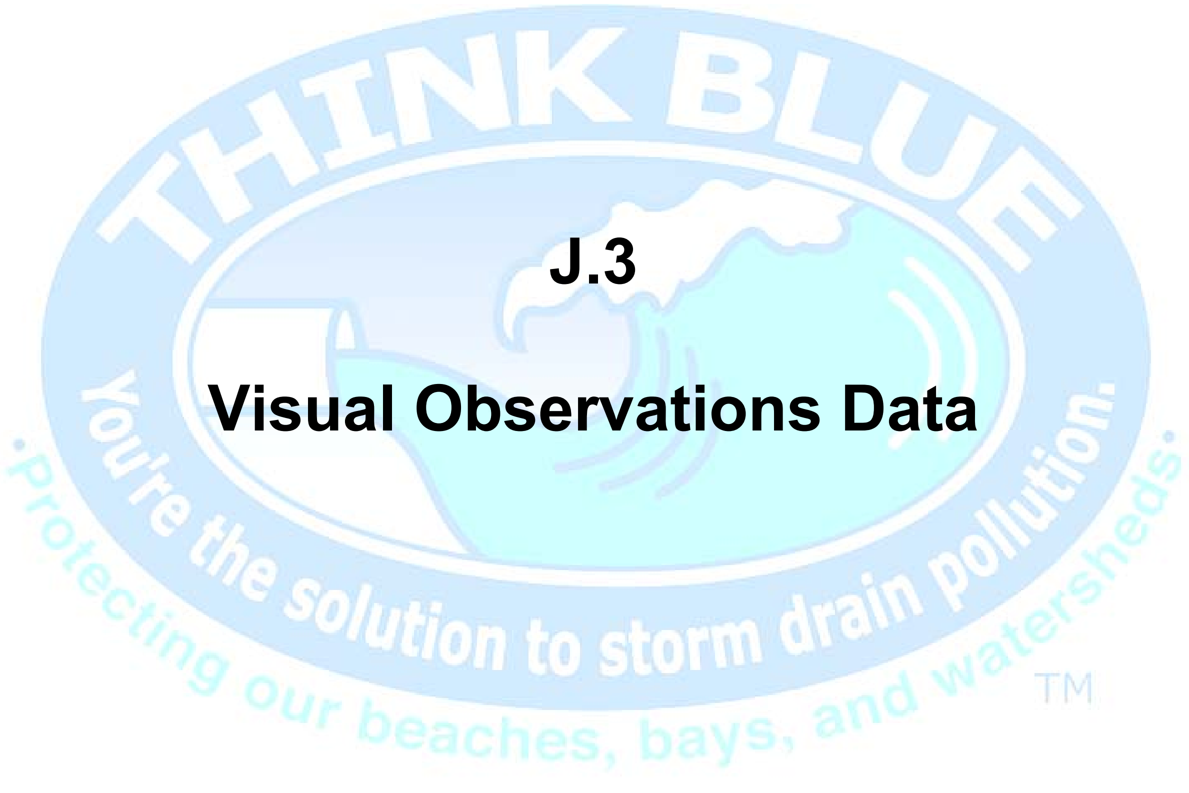
Bacterial Indicator Data

Appendix J.2. Results of weekly monitoring for total coliform (TC), fecal coliform (FC), and enterococcus (EC) concentrations by site and date. Bacterial values are in MPN/100ml. Values that exceeded AB411 criteria are highlighted in bold.

Sampling Date	Indicator Bacteria	Bonita Cove	Bahia Point	Fanuel Park	Riviera Shores	Wildlife Refuge	Campland	De Anza Cove	Visitor's Center	Leisure Lagoon	N. Pacific Passage	Tecolote Creek	Hidden Anchorage
11/4/2002	TC	40	40	<20	<20	40	5,000	80	230	<20	80	1230	140
	FC	<20	40	<20	<20	40	**3,000**	80	230	<20	40	80	90
	EC	10	20	10	<10	10	**1,153**	**130**	**355**	10	10	31	20
11/13/2002	TC	20	20	40	70	40	7,000	170	1,3000	230	300	5,000	80
	FC	<20	20	40	<20	40	**7,000**	<20	230	80	<20	**500**	80
	EC	<10	20	<10	<10	<10	**3,448**	<10	52	<10	<10	**2,098**	<10
11/18/2002	TC	40	<20	80	<20	3,000	800	40	3,000	130	80	500	<20
	FC	40	<20	40	<20	20	**500**	<20	60	<20	40	40	<20
	EC	<10	<10	<10	<10	20	**1,401**	<10	75	20	<10	63	30
11/25/2002	TC	40	<20	800	40	<20	230	<20	140	40	80	170	<20
	FC	20	<20	**800**	40	<20	230	<20	40	20	<20	<20	<20
	EC	31	<10	<10	<10	20	**496**	<10	10	<10	<10	10	20
12/3/2002	TC	110	<20	2,300	80	170	8,000	40	5,000	3,000	40	3,000	70
	FC	110	<20	**800**	40	170	**8,000**	20	**500**	130	20	300	40
	EC	31	<10	**211**	40	52	**4,352**	10	**457**	**121**	52	**183**	74
12/9/2002	TC	<20	40	40	20	2,300	500	230	40	110	20	40	<20
	FC	<20	40	20	20	**1,300**	300	230	40	80	<20	20	<20
	EC	<10	<10	98	10	**185**	**201**	41	52	<10	20	41	20
12/13/2002	TC	<20	130	40	<20	<20	3,000	80	300	20	40	20	20
	FC	<20	130	40	<20	<20	**1,100**	40	230	<20	40	<20	20
	EC	<10	20	**110**	10	10	**1,050**	<10	41	10	20	52	98
1/08/2003	TC	80	20	<20	<20	<20	20	<20	2,200	40	<20	**110,00**	<20
	FC	80	20	<20	<20	<20	20	<20	170	40	<20	**110,000**	<20
	EC	<10	20	<10	<10	<10	**399**	<10	86	<10	<10	**1,354**	31
1/13/2003	TC	20	<20	700	<20	<20	300	110	170	20	<20	700	<20
	FC	20	<20	**700**	<20	<20	300	110	130	20	<20	170	<20
	EC	<10	<10	**2,382**	20	<10	**379**	31	62	<10	<10	31	31
1/22/2003	TC	20	2,200	20	<20	500	500	3,000	<20	40	20	3,000	20
	FC	20	130	<20	<20	**500**	**500**	80	<20	40	<20	140	20
	EC	10	10	<10	<10	<10	**185**	<10	41	<10	10	31	20
1/27/2003	TC	40	<20	<20	<20	<20	40	40	<20	<20	<20	<20	<20
	FC	20	<20	<20	<20	<20	40	<20	<20	<20	<20	<20	<20
	EC	10	<10	10	<10	<10	31	20	<10	20	<10	10	10
2/3/2003	TC	20	80	<20	<20	20	40	<20	<20	40	<20	<20	<20
	FC	20	80	<20	<20	20	40	<20	<20	40	<20	<20	<20
	EC	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	30	<10

Results of Weekly Monitoring

Sampling Date	Indicator Bacteria	Bonita Cove	Bahia Point	Fanuel Park	Riviera Shores	Wildlife Refuge	Campland	De Anza Cove	Visitor's Center	Leisure Lagoon	N. Pacific Passage	Tecolote Creek	Hidden Anchorage
2/10/2003	TC	20	<20	<20	<20	40	300	230	170	20	20	20	20
	FC	20	<20	<20	<20	40	300	230	170	20	20	20	20
	EC	<10	<10	<10	<10	10	**173**	<10	63	10	30	10	<10
2/19/2003	TC	40	40	500	<20	500	500	110	340	20	<20	40	20
	FC	40	20	**500**	<20	230	230	40	90	20	<20	20	20
	EC	<10	10	30	10	**132**	52	41	98	41	10	41	**160**
2/24/2003	TC	130	20	500	80	80	800	800	300	130	40	230	110
	FC	130	<20	**500**	80	80	**800**	140	230	130	<20	40	110
	EC	10	<10	75	<10	10	**327**	**110**	**233**	<10	<10	**171**	**203**
3/3/2003	TC	<20	40	<20	20	40	130	170	800	80	20	2,300	500
	FC	<20	40	<20	20	20	20	20	**500**	40	<20	300	220
	EC	<10	10	<10	<10	20	63	<10	**110**	10	<10	**158**	**313**
3/10/2003	TC	20	<20	300	<20	<20	80	70	500	110	<20	40	<20
	FC	20	<20	300	<20	<20	40	20	**500**	110	<20	20	<20
	EC	<10	<10	<10	<10	20	<10	<10	97	10	<10	20	10
3/20/2003	TC	20	210	70	<20	140	500	5,000	700	40	80	300	20
	FC	20	20	70	<20	40	170	**700**	**700**	20	80	40	20
	EC	<10	20	10	10	63	10	**435**	30	41	20	75	10
3/24/2003	TC	20	<20	<20	20	20	220	<20	170	40	70	130	<20
	FC	<20	<20	<20	20	20	170	<20	110	40	70	40	<20
	EC	20	<10	<10	<10	20	86	10	10	10	10	**218**	<10



J.3

Visual Observations Data

Appendix J.3. Summary of major visual observations (birds, swimmers, and dogs on beach) by site and date during weekly sampling.

Sample Date	Bonita Cove	Bahia Point	Fanuel Park	Riviera Shores	Wildlife Refuge	Camp land	De Anza Cove	Visitor's Center	Leisure Lagoon	N. Pacific Passage	Tecolote Creek	Hidden Anchorage	Mean
Birds													
11/4/02	35	30	0	0	0	8	30	135	65	0	35	5	
11/13/02	35	30	60	0	35	90	30	110	60	65	105	0	
11/18/02	80	10	30	0	75	5	5	335	35	30	75	5	
11/25/02	265	5	30	10	0	120	150	335	285	0	60	5	
12/3/02	305	40	35	10	265	60	30	480	105	35	75	30	
12/9/02	5	5	30	5	30	75	60	290	165	0	35	5	
12/13/02	105	10	65	5	90	35	80	260	30	30	30	35	
12/24/02	280	60	30	5	60	30	85	285	180	0	75	5	
12/30/02	80	35	30	5	325	165	150	340	305	30	510	10	
1/6/03	135	35	30	5	75	315	305	400	65	5	75	0	
1/8/03	5	35	30	5	35	210	35	40	205	0	30	0	
1/13/03	165	30	5	75	30	180	80	535	65	5	75	5	
1/22/03	35	35	30	150	5	5	60	260	78	0	80	5	
1/27/03	110	35	30	30	30	165	150	360	35	75	80	5	
2/3/03	35	5	5	5	230	5	160	105	35	0	30	0	
2/10/03	35	5	30	30	30	80	60	430	35	5	105	30	
2/19/03	35	5	75	0	80	35	105	40	75	0	75	0	
2/24/03	40	5	0	30	180	130	105	510	90	0	115	30	
3/3/03	30	10	35	30	30	110	95	675	120	5	110	40	
3/10/03	65	5	75	5	15	15	20	340	140	0	60	5	
3/20/03	35	0	35	15	10	40	0	130	140	5	40	5	
3/24/03	65	10	0	5	180	8	5	365	85	10	30	5	
Mean	90	20	60	19	82	86	82	307	109	14	87	10	
Swimmers													
11/4/02	0	0	0	0	0	0	0	0	0	0	0	0	
11/13/02	0	0	0	0	0	0	0	0	0	0	0	0	
11/18/02	0	0	0	0	0	0	0	0	0	0	0	0	
11/25/02	0	0	0	0	0	0	0	0	0	0	0	0	
12/3/02	0	0	0	0	0	0	0	0	0	0	0	0	
12/9/02	0	0	0	0	0	0	0	0	0	0	0	0	
12/13/02	0	0	0	0	0	0	0	0	0	0	0	0	
12/24/02	0	0	0	0	0	0	0	0	0	0	0	0	
12/30/02	0	0	0	0	0	0	0	0	0	0	0	0	
1/6/03	0	0	0	0	0	0	0	0	0	0	0	0	

Results of Weekly Monitoring

Sample Date	Bonita Cove	Bahia Point	Fanuel Park	Riviera Shores	Wildlife Refuge	Camp land	De Anza Cove	Visitor's Center	Leisure Lagoon	N. Pacific Passage	Tecolote Creek	Hidden Anchorage	Mean
1/8/03	0	0	0	0	0	0	0	0	0	0	0	0	
1/13/03	0	0	0	0	0	0	0	0	0	0	0	0	
1/22/03	0	0	0	0	0	0	0	0	0	0	0	0	
1/27/03	0	0	0	0	0	0	0	0	0	0	0	0	
2/3/03	0	0	0	0	0	0	0	0	0	0	0	0	
2/10/03	0	0	0	0	0	0	0	0	0	0	0	0	
2/19/03	0	0	0	0	0	0	0	0	0	0	0	0	
2/24/03	0	0	0	0	0	0	0	0	0	0	0	0	
3/3/03	0	0	0	0	0	0	0	0	0	0	0	0	
3/10/03	0	0	0	0	0	0	0	0	0	0	0	0	
3/20/03	0	0	0	0	0	0	0	0	0	0	0	0	
3/24/03	0	0	0	0	0	0	0	0	0	0	0	0	
Mean	0	0	0	0	0	0	0	0	0	0	0	0	
Dogs on beach													
11/4/02	0	0	0	0	0	0	0	0	0	0	0	12	
11/13/02	0	0	0	0	0	0	0	0	0	0	0	12	
11/18/02	0	0	0	0	0	0	0	0	0	0	0	12	
11/25/02	0	0	0	0	0	0	0	0	0	0	0	12	
12/3/02	0	0	0	0	0	0	0	0	0	0	0	12	
12/9/02	0	0	0	0	0	0	0	12	0	0	0	12	
12/13/02	0	0	0	0	0	0	0	0	0	0	0	12	
12/24/02	0	0	0	0	0	0	0	12	0	0	0	12	
12/30/02	0	0	0	0	0	0	0	12	0	0	0	12	
1/6/03	0	0	0	0	0	0	0	12	0	0	0	12	
1/8/03	0	0	0	0	0	0	0	0	0	0	0	12	
1/13/03	0	0	0	0	0	0	0	0	0	0	0	0	
1/22/03	0	0	0	0	0	0	0	0	0	0	0	12	
1/27/03	0	0	0	0	0	0	0	12	0	0	0	12	
2/3/03	0	0	0	0	0	0	0	0	0	0	0	12	
2/10/03	0	0	12	0	0	0	0	0	0	0	0	12	
2/19/03	0	0	12	0	0	12	12	0	0	0	0	12	
2/24/03	0	0	12	0	0	0	0	0	0	12	0	12	
3/3/03	0	0	12	0	0	0	0	0	0	0	0	12	
3/10/03	0	0	0	12	12	0	0	0	0	0	0	0	
3/20/03	0	0	0	0	0	12	0	0	0	0	0	12	
3/24/03	0	0	0	0	0	0	0	0	12	0	0	12	

APPENDIX K

Follow-Up Studies

K.1

Bonita Cove Boat Anchorage Study

INVESTIGATION OF ILLICIT BOAT DISCHARGE AT BONTIA COVE

BACKGROUND / CAUSE OF INVESTIGATION

An assessment of historical data of bacterial levels in Mission Bay (1993 through 2000) collected by the City of San Diego and the San Diego County Department of Environmental Health (DEH) suggest that there are differences between the concentrations of indicator bacteria on summer holidays (Memorial Day, Fourth of July, and Labor Day) verses non-holiday days at some beach sites. For this assessment, the holiday period included a seven day period centered around the actual holiday date and the non-holiday period was all other days after Memorial Day and before Labor Day. At Bonita Cove the mean concentration of enterococcus during summer holidays (105 MPN/100 ml) was significantly different than the concentration during non-holiday days (49 MPN/100 ml) ($p = 0.027$). The large difference in enterococcus levels between holidays and non-holidays, suggests that there may be different mechanisms at work during these two time periods related to bacterial levels in the water column.

There are two scenarios that would most likely explain the observed differences in enterococcus levels between holiday and non-holiday periods: 1) Beach sediments act as a source of bacteria and high bacterial levels observed during holiday periods are associated with re-suspended sediments that develop with the increase in swimmers during holidays; and 2) Illicit discharge of sewage holding tanks of boats that anchor or moor at Bonita Cove during holidays is the source of the bacteria. This study was designed to assess the second scenario.

Objectives

There are three major objectives of this study:

1) Determine levels of indicator bacteria (enterococcus) in and around boat anchoraged areas at Bonita Cove

2) Determine bacterial levels at beaches adjacent to Bonita Cove. The boat anchoraged and beach investigations will be concurrent.

3) Map, analyze, and report data, and make recommendations for future actions.

Materials and Methods

Bonita Cove is the only boat anchorage station within Mission Bay. Therefore, boaters can anchor at Bonita Cove for a 72-hour time period. The study was conducted over the Memorial Day weekend on two days with two different time periods, May 24th at 9:00pm and May 26th at 5:30am. These dates and times were selected to determine if illegal dumping was occurring from the anchoraged boats at Bonita Cove. On each sampling day, five samples were collected along each transect and one sample was collected from the beach (Figure 1). The beach samples were collected from the same site location as that sampled by the San Diego County Department of Environmental Health (personal communication, Clay Clifton, County of San Diego Department of Environmental Health), as well as the samples collected during the Visual Observations Task (Task 3) of this study.

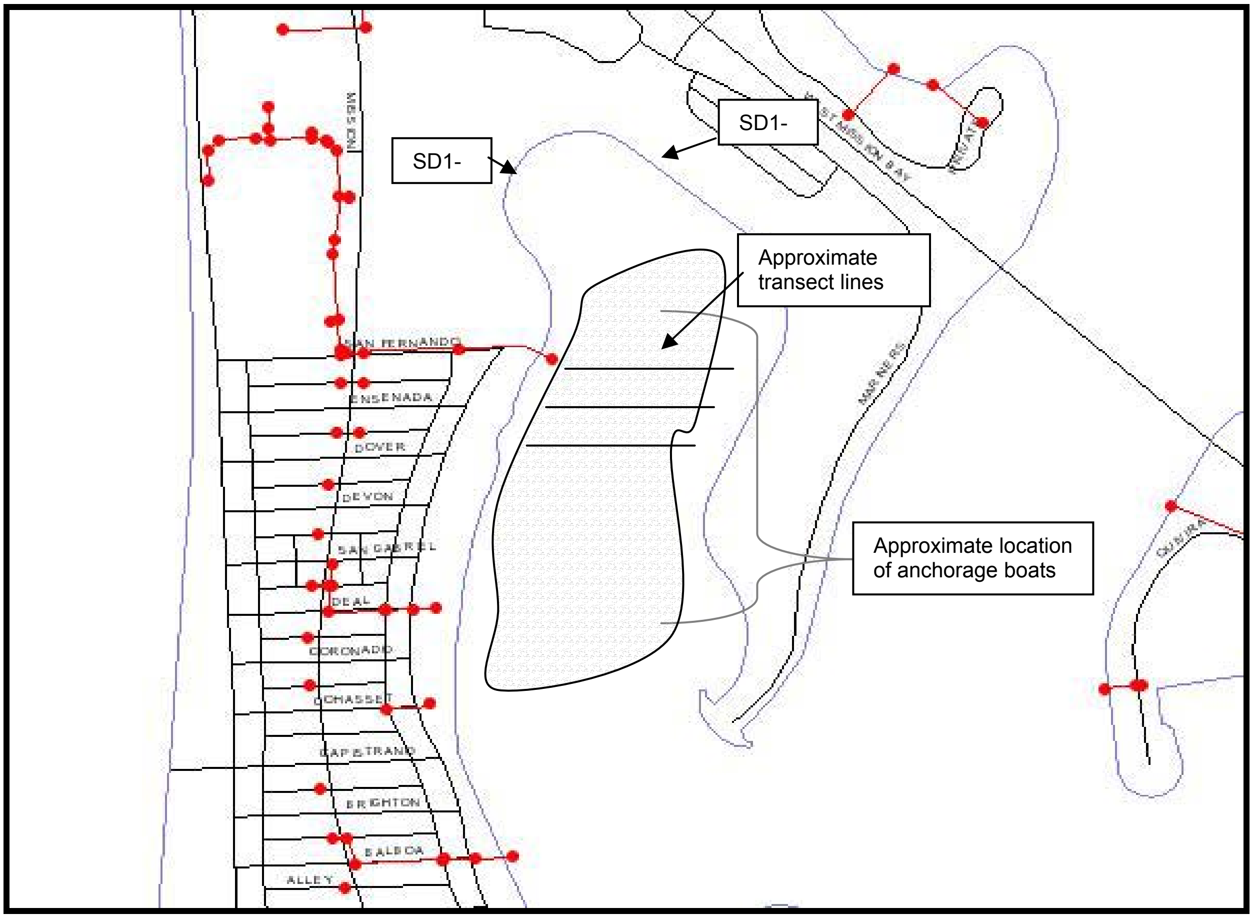


Figure 1. Map of the Bonita Cove boat anchorage location.

To assure consistency among results, the protocol for samples collected at the beach sites was the same as that employed by the San Diego County Department of Environmental Health. Samples were collected in sterile, 100-ml plastic bottles containing sodium thiosulfate. The bottles were sealed in clear plastic bags until use. The sampling technician first rinsed his hands with a waterless sanitizing gel, then put on a pair of Nitrile gloves. The sample bottle was removed from the plastic bag, labeled, and placed into a clamp attached to the end of four foot long PVC pole. The sampling technician waded into the water to a depth of approximately 12 inches and removed the lid from the sample bottle. The bottle was extended in front of the sampler (away from shore) with the sampling pole, then inverted and submerged four to six inches below the water surface. In a sweeping motion, the pole was rotated so the opening of the bottle was facing to the side. The pole was then swept sideways to take the water sample. The bottle was filled once, drained to the desired volume so that a small amount of air remained in the container, and capped. No surface residue, sediment, or debris was allowed to enter the sample bottle. If debris or sediment was evident in the bottle, the sample was discarded and the site was re-sampled with a new, sterile bottle. After collection, the sample was re-sealed in the plastic bag. All samples were kept on ice in the dark from the time of sample collection until delivery to the analytical laboratory.

The samples from the transects were taken from a kayak paddled through the anchoraged boat locations. Five samples around the boats were taken at each site. The sampling locations were evenly distributed on a visual transect between the anchoraged boats. Samples were taken from the side of the kayak, approximately six inches below the surface of the water. The aseptic technique described above for the beach sites was also employed for each of the four boat sampling locations. Because the purpose of these samples was to determine if illegal dumping was occurring, the sampling technician was as discrete as possible when taking samples, attempting to appear to be a recreational boater. All samples were kept on ice in the dark from the time of sample collection until delivery to the analytical laboratory.

The timing of sample collection was coordinated with the potential to sample during a discharge event from the anchoraged boats.

Laboratory Analyses

All bacteria samples were analyzed at the MEC Analytical Systems Microbiology Laboratory. The three indicator bacteria enumerated in this study were total coliform, fecal coliform, and enterococcus. In the laboratory, total and fecal coliforms were analyzed using multiple tube fermentation based on Standard Methods 9221B&E. Enterococcus were analyzed using a chromogenic technique (Enterolert), based on Standard Method 9223.

Results

Data from the two sampling dates and times indicated no direct source of enterococcus from the anchored boats at Bonita Cove. One sample on May 24, 2003 at the Bonita Cove beach just exceeded the single sampling standard. All other samples taken on both dates had values of enterococcus less than ten MPN/100ml (Table 1).

Discussion

It is obvious that the anchored boats during the two sampling time periods did not contribute to the bacterial exceedances normally found at Bonita Cove during the summer holiday time frame. The exceedance on the 24th at the beach may be due to several sources including irrigation run-off, birds, residual from earlier park goers activities and/or run-off from a storm drain that is undiverted. Interestingly, all of the samples taken away from the beach had no variability in enterococcus values. This same trend had been noted in other field studies conducted by the City of San Diego.

Previous statistical analysis on this time period has indicated a strong correlation with increase of bacteria indicator values and the summer holiday time frame from 1993-2000 (Table 2). Further studies investigating this potential source may employee a remote sensor (SONDE) which can collect water samples for various parameters including ammonia. The samples can be taken at ten minute intervals and the data can be collected over an extended period of time. This type of sampling will greatly increase the temporal data and the probability of noticing an illegal discharge from the anchorage boats.

Table 1. Sampling results from the Bonita Cove boat study.

Date	Sample Id	Sample Time	Tidal Height (ft)	*Enterococcus*
5/24/2003	1-T1-A	2105	3.88, E	<10
5/24/2003	1-T1-B	2108	3.84, E	<10
5/24/2003	1-T1-C	2111	3.81, E	<10
5/24/2003	1-T1-D	2114	3.77, E	<10
5/24/2003	1-T1-E	2116	3.77, E	<10
5/24/2003	1-T2-A	2122	3.69, E	<10
5/24/2003	1-T2-B	2125	3.65, E	<10
5/24/2003	1-T2-C	2127	3.65, E	<10
5/24/2003	1-T2-D	2129	3.58, E	<10
5/24/2003	1-T2-E	2131	3.58, E	<10
5/24/2003	1-T3-A	2139	3.46, E	<10
5/24/2003	1-T3-B	2141	3.42, E	<10
5/24/2003	1-T3-C	2144	3.38, E	10
5/24/2003	1-T3-D	2147	3.34, E	<10
5/24/2003	1-T3-E	2149	3.34, E	<10
5/24/2003	BEACH 1	2145	3.38, E	109
5/26/2003	1-T1-A	540	3.05, F	<10
5/26/2003	1-T1-B	542	3.08, F	<10
5/26/2003	1-T1-C	543	3.08, F	<10
5/26/2003	1-T1-D	545	3.12, F	<10
5/26/2003	1-T1-E	548	3.15, F	<10
5/26/2003	1-T2-A	554	3.22, F	<10
5/26/2003	1-T2-B	555	3.22, F	<10
5/26/2003	1-T2-C	557	3.26, F	<10
5/26/2003	1-T2-D	559	3.29, F	<10
5/26/2003	1-T2-E	601	3.29, F	<10
5/26/2003	1-T3-A	607	3.35, F	<10
5/26/2003	1-T3-B	609	3.38, F	<10
5/26/2003	1-T3-C	610	3.38, F	<10
5/26/2003	1-T3-D	611	3.14, F	<10
5/26/2003	1-T3-E	614	3.44, F	<10
5/26/2003	BEACH 1	545	3.12, F	<10

E = Ebbing tide
F = Flooding tide

Table 2. Bonita Cove single factor ANOVA for beach samples during the summer months between 1993 to 2000.

Anova: Single Factor Bonita Cove (no outliers)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Holiday	22	2328	105.8182	42175.58
Non-Holiday	118	5800	49.15254	6640.37

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	59541.02	1	59541.02	4.942023	0.027838	3.909733
Within Groups	1662611	138	12047.9			
Total	1722152	139				

Therefore, Accept Ha

Ho: There is no difference of enterococcus values between/among holiday dates and non-holiday dates

Ha: There is a difference of enterococcus values between/among holiday dates and non-holiday dates

K.2

Fanuel Park/Riviera Shores ICID

INVESTIGATION OF BACTERIAL SOURCES
Sail Bay

INTRODUCTION

On Monday April 28, 2003, City Storm Water staff Shaun Flater and Jayna Nystrom and MEC Analytical Systems, Inc. (MEC) staff Steve Gruber initiated a bacterial source identification investigation at the Sail Bay area on Mission Bay in response to elevated bacteria levels. High densities of enterococcus bacteria have been recorded during weekly sampling at the Fanuel Park storm drain outlet, located at the terminus of Fanuel Street. These high densities were also observed during the Visual Observations component of the Mission Bay Source Identification study conducted by the City and MEC from August through October of 2002. In order to locate potential sources of bacteria and to determine the possible influence of freshwater discharges adjacent to the site area, physical parameter measurements and residential investigations were conducted in conjunction with the collection of water samples at various selected residential and storm drain locations within the Sail Bay area. The study design identified three specific objectives to accomplish this goal:

1. Determine the sources and extent of the water discharged from dewatering sump pumps, and identify the locations of unmapped connections within the storm drain conveyance system.
2. Collect water samples from residential dewatering systems and the storm drain conveyance system for bacteriological analysis to assist in identifying potential sources of indicator bacteria.
3. Determine the influence of urban runoff flow to the Fanuel Park storm drain conveyance system on water quality in Sail Bay.

This report provides a summary of the study design and results of the field investigation that was undertaken on April 28, 2003.

FIELD SITE

Sail Bay is located on the west side of Mission Bay between Riviera Drive and Pacific Beach Drive. The site is characterized by multiple three to four story condominiums and townhouses that surround the majority of Sail Bay. There are no creeks or natural freshwater sources that enter into Sail Bay. Sail Bay is frequently used as a recreational area for boaters and water-skiers.

There are two major potential point sources of bacteria at this site (Figure 1):

1. Five total storm drains enter into Sail Bay each of these maybe a potential source of indicator bacteria due to upstream sources. One storm drain (SD3-3) terminates just offshore of Fanuel Park, approximately 100 feet southeast of the public restroom (Comfort Station 9950). Four additional storm drains are found within the Sail Bay area from Dawes Street to La Cima Drive.

2. Several of the condominiums and townhouses have dewatering sump pumps to prevent tidally influenced groundwater or rainwater from flooding the underground parking structures. Some of these pumps are connected to the storm drain conveyance system and are known to discharge a large quantity of water per day. Because the connections to the storm drain system are downstream of the sewer interceptor system, the discharged water flows directly into the bay.

The entire storm drain conveyance system for the watershed of Sail Bay also acts as a potential source of indicator bacteria. Each of the five storm drains has been assigned a number based on the location of its terminus in Sail Bay. The characteristics of each storm drain are summarized briefly below based on two separate field investigation dates, March 11, 2003 and April 28, 2003. The focus of the March 11, 2003 investigation was to ground truth existing storm drain conveyance system maps. On April 28, 2003 the investigation focused on determining the sources of indicator bacteria within the storm drain conveyance system.

SD3-1 is a 42-inch diameter reinforced concrete pipe (RCP) that terminates approximately 20 feet from the shoreline. The storm drain system for SD3-1 starts at the intersection of Gresham Street and Garnet Avenue, and conveys street surface flow from East Briarfield Drive. The sewer interceptor system and adjoining diversion box (DV-55) are located just prior to the terminus of Dawes Street. The diversion box consists of an approximately 12-inch tall concrete berm that directs upstream flow to the sewer line via the sewer interceptor system. Two curb inlets drop into the diversion box thus allowing low flow street surface runoff to the sewer system. Directly downstream of the diversion box and tide flex is a connection to the storm drain inlet at the terminus of Briarfield Street. Thus, street surface runoff from Briarfield Street enters the bay undiverted.

SD3-2 is a 30-inch diameter RCP that terminates approximately 30 feet from the shoreline. The SD3-2 conveyance system starts at the intersection of Pacific Beach Drive and Everts Street. The sewer interceptor system and adjoining diversion box (DV-56) is located just prior to the terminus of Everts Street. The diversion box consists of an approximately 12-inch tall concrete berm that directs upstream flow to the sewer line via the sewer interceptor system. Two curb inlets drop into the diversion box thus allowing low flow street surface runoff to the sewer system. Directly downstream of the diversion box is a pipeline connection to three vaults, located south of several condominiums on Pacific Beach Drive. The westernmost vault (V3-1) is a 2-foot by 3-foot vault that connects to a 4-inch PVC pipe. This pipe discharges a large volume of water and investigations have found that the discharge water is from an underground garage structure sump pump in one of the condominium units located on Pacific Beach Drive. It was not possible to open the second vault (V3-2) on both investigation dates. The third vault (V3-3) is also a 2-foot by 3-foot vault that connects to a 4-inch PVC pipe. During both investigation dates this vault was dry however, sediment was found at the bottom.

SD3-3 is a 48-inch diameter RCP that terminates approximately 30 feet from the shoreline. The SD3-3 conveyance system starts at the intersection of Ingraham Street and Garnett Avenue. The sewer interceptor system (IPS-7) and adjoining diversion box are located directly south of the terminus of Fanuel Street. The diversion box consists of an approximately 12-inch tall concrete berm that directs upstream flow to the sewer line via the sewer interceptor system. Upstream of the diversion box is a storm drain inlet that collects runoff from a large residential area on the west side of Ingraham Street and north of La Playa Street. The diversion system is designed to divert all dry weather flow from this area at the sewer interceptor system (IPS-7) and adjoining diversion box. Directly downstream of the diversion are two pipeline connections. The first connection is located approximately 60 feet from the diversion box. This pipeline is a 6-inch PVC pipe from which a large volume of water flows at specific time intervals. Strong evidence suggests that this pipeline is connected to a dewatering sump pump system located at a condominium complex on Fanuel Street. The second pipeline intersection is an 18-inch PVC pipe that is connected to two sources. Each source is comprised of a 2-foot by 3-foot vault that is connected into via a PVC pipe. Both vaults contained either ponded or low flow water at the time of the investigations. The first vault has a 4-inch PVC pipe that conveys surface runoff from a condominium located on La Palma Street (V3-4). This vault had sediment at the bottom and had a salinity of 20.28 ppt during the investigation. The second vault has a 12-inch concrete pipe that originates from a condominium located on Gresham Street (V3-5). The 12-inch pipe collects water from the condominium’s floor drains, rainwater sump pump and roof drains. A dead animal was found within this vault and salinity was measured to be 2.11 ppt during the investigation on March 11, 2003.

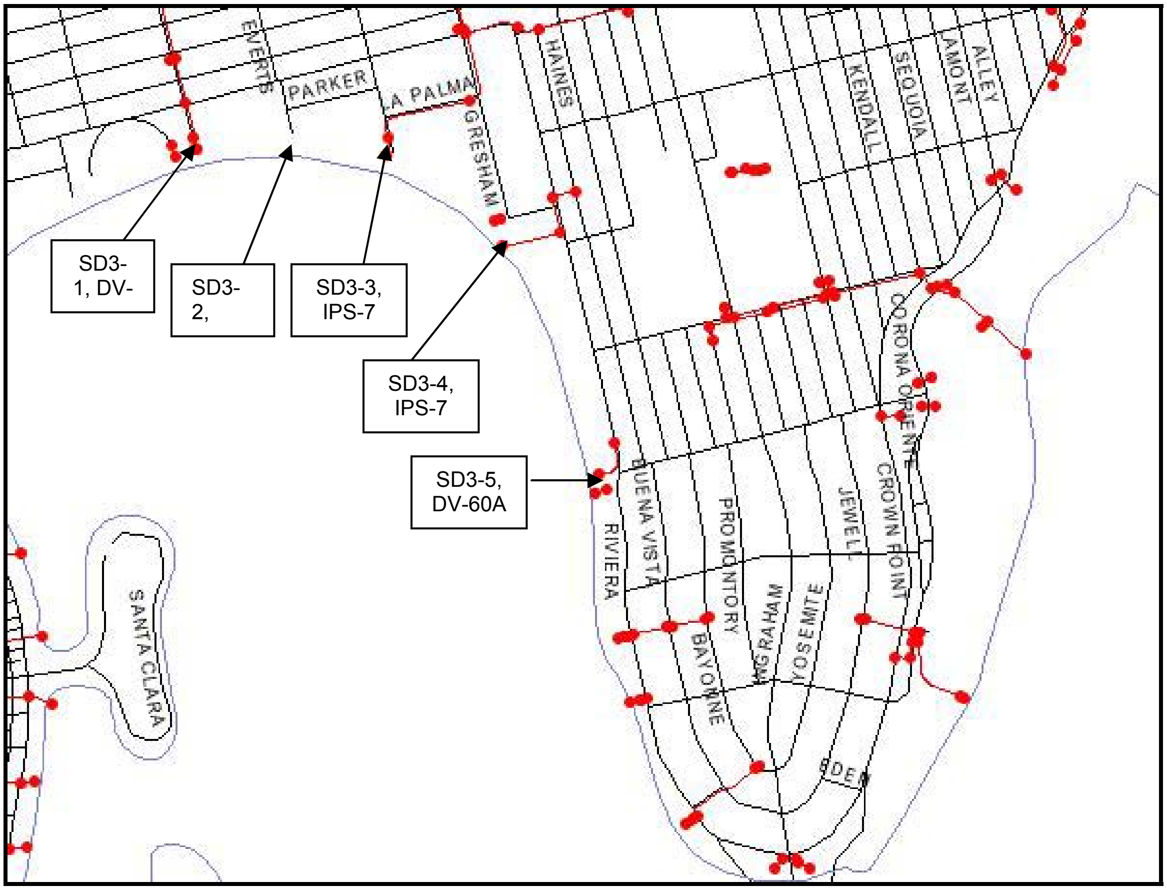
SD3-4: Is a 30-inch diameter RCP that terminates approximately 20 feet from the shoreline. The SD3-4 conveyance system starts at the intersection of Graham Street and Gresham Street. The diversion box and adjoining tide flex are located directly southwest of the Graham Street and Gresham Street intersection. The diversion box consists of an approximately 12-inch tall concrete berm that directs upstream flow to the sewer line via the sewer interceptor system. At this location the sewer interceptor system pipeline runs parallel to the shoreline and connects to IPS-7 located at Fanuel Street (as described above). Directly downstream of the diversion is a tide flex and a 12-inch pipe. The 12-inch pipe discharges a high quantity of water downstream of the diversion unit and tide flex, flowing directly into Mission Bay. Investigations by Storm Water biologists have discovered the source of the discharge water to be a dewatering sump pump system from a condominium unit located on Riviera Drive. Upstream of the diversion box at SD3-4 are numerous sources of flow. The first is a manhole found within the planter at the end of Graham Street. This manhole receives urban runoff from the street surface at the Graham and Gresham intersection via a PVC pipe, and also conveys runoff (i.e., pool surface drains and roof drains) from a condominium located at Graham Street via a concrete pipe. The second source is a series of manholes that collect street surface flow or rainwater within underground garage structures from Riviera Drive and several condominiums located on Riviera Drive. The third source is a series of three vaults. The two most southern vaults collect flow from the grassy area east of the sidewalk and runoff from an outdoor shower head.

SD3-5 is a 30-inch diameter RCP that terminates approximately 30 feet from the shoreline. The SD3-5 conveyance system collects flow on Riviera Drive from Moorland Street to La Cima Street. The sewer interceptor system and adjoining diversion box (DV-60A) are located directly west of the terminus of Moorland Street. The diversion box consists of an approximately 12-inch tall concrete berm that directs upstream flow to the sewer line via the sewer interceptor system. No additional pipeline connections are located downstream of the diversion box.

Table 1. Summary of storm drains in Fanuel Park/Sail Bay

Number	Latitude	Longitude	Terminus Diameter	Diversion Status[1]	Diversion Type	Drainage Description
SD3-1	32º 47.485	117º 14.880	42”	D; V	Berm in Diversion Box, gravity feed to sewer	Residential area on the south side of Pacific beach Drive and Dawes Street. A portion of East Briarfield Street flows to bay undiverted
SD3-2	32º 47.501	117º 14.765	30”	D; V	Berm in Diversion Box, gravity feed to sewer	Residential area on the south side of Pacific Beach Drive and Everts Street
SD3-3	32º 47.475	117º 14.658	48”	D; I	Berm in Diversion Box, pumped to sewer	Large Residential and commercial area from the intersection of Ingraham Street and Garnett Avenue to the end of Fanuel Street
SD3-4	32º 47.409	117º 14.524	30”	D; V	Berm in Diversion Box, gravity feed to sewer	Residential area at the intersection of Graham Street and Gresham Street
SD3-5	32º 47.140	117º 14.419	30”	D; V	Berm in Diversion Box, gravity feed to sewer	Residential area on the north side of La Cima Street to Moorland Street on Riviera Drive

[1] D = Diverted, I = Interceptor consists of a diversion berm and a gravity feed to a pump station, V = Diverted water flows to sewer by gravity, no pump involved.



Red dots = storm drain inlets/manholes/junctions
Red lines = storm drain conveyance system

Figure 1. Map of the Sail Bay Storm Drain System.

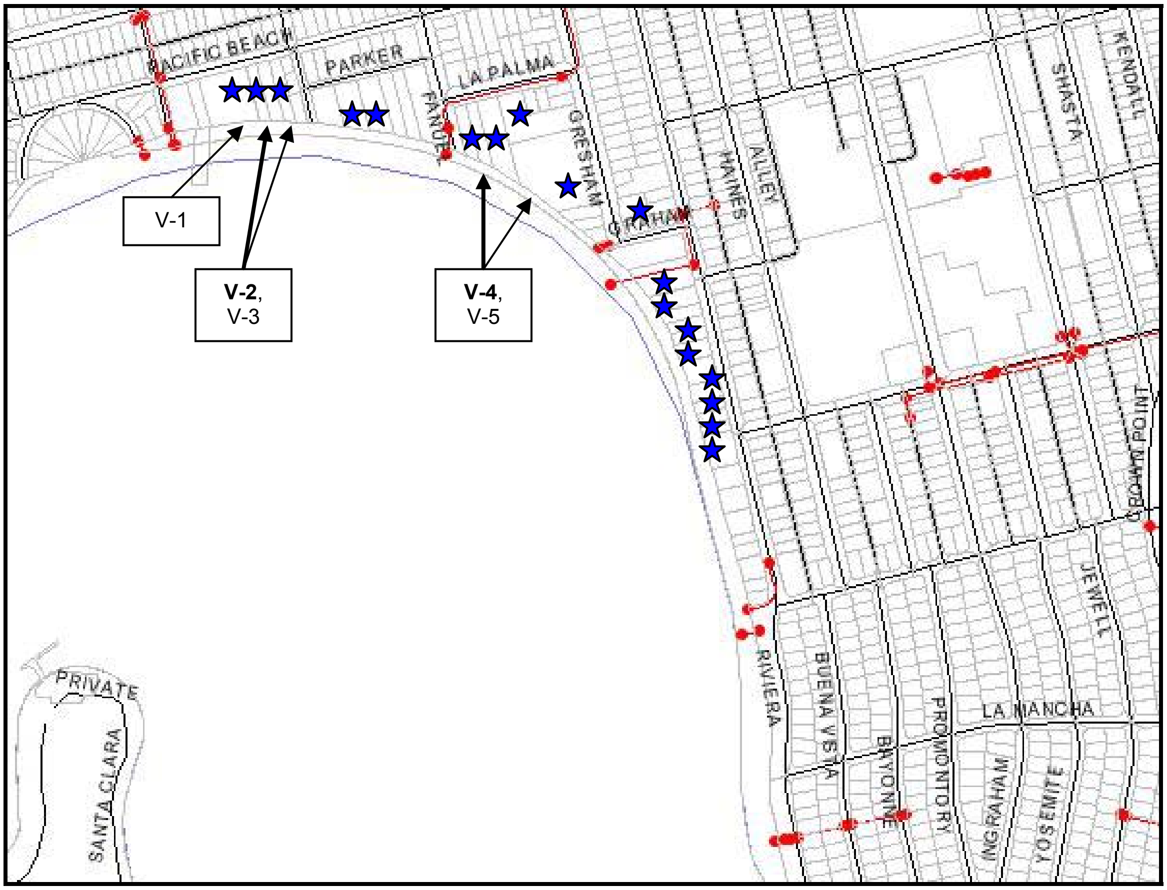
METHODS

The primary goal of this study, as identified in the Introduction, was accomplished through the identification of three main objectives. These objectives were achieved via several tasks, as described below.

Objectives 1: Determine the extent of the water discharge from dewatering sump pumps.

Extensive research and investigations have been conducted collecting information on locations that have dewatering sump pumps and the characteristics of the sump pumps. Two distinct types of sump pumps have been found in the Sail Bay area. The dewatering sump pump (DSP) are found at locations that have very large underground garage structures; the DSP collects groundwater and tidally influenced water and sends it out to the storm drain conveyance system. Some of these pumps have been identified to pump approximately 100,000 gallons of water per 24-hour period. The second type of sump pump, rainwater sump pump (RSP), is found at locations that have a parking structure below the street surface. During high rainfall events these locations send water from the parking structure back onto the street surface via a sump pump. These pumps have been identified to pump approximately 10 gallons per discharge. However, the discharge rate is strictly dependent upon the rainfall quantity and any washing activity that occurs within the parking structures.

- Using investigational information a water sample was taken, April 28th 2003, from the DSP or the RSP at each location that has been identified to discharge in the Sail Bay sub-watershed. In addition, a sample was obtained at the discharge outlet from four DSP or RSP.



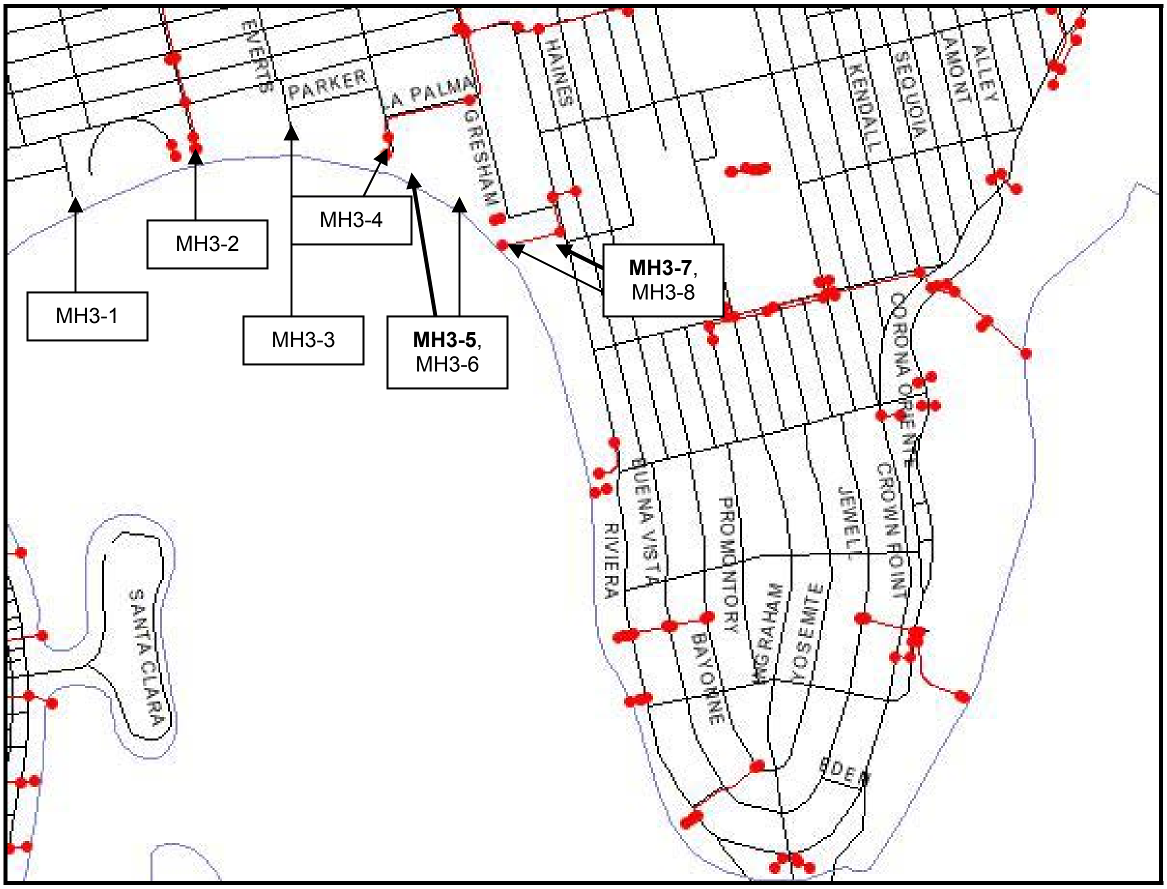
Red dots = storm drain inlets/manholes/junctions
Red lines = storm drain conveyance system
V = vault (potential locations of sump pump discharge)
★ = DSP or RSP at specific locations

Figure 2. Locations of DSP, RSP and sump pump discharge vaults within Sail Bay.

Objective 2: Determine the sources of potential bacterial sources within the storm drain conveyance system at Sail Bay.

Samples were collected from manhole inlets of the storm drain conveyance system and Mission Bay Sewer Interceptor System within the Sail Bay area. Samples were analyzed to determine potential sources of bacteria and the quantity of bacterial indicators within the storm drain conveyance system. The sampling event also helped to assess the operational functioning of the Mission Bay Sewer Interceptor System.

- Flow from all flowing storm drains were measured and recorded on the water quality data sheets. GPS coordinates of all sites of interest were also recorded on the data sheets.



Red dots = storm drain inlets/manholes/junctions
Red lines = storm drain conveyance system
MH = manhole locations

Figure 3. Locations of manhole inlets of the storm drain conveyance system and Mission Bay Sewer Interceptor System within Sail Bay.

Bacteriological Sampling and Analyses

Field Sampling

To assure consistency among results, the protocol for collection of the site samples was the same as that employed by the San Diego County of Environmental Health. Samples were collected in sterile, 100-ml plastic bottles containing sodium thiosulfate. The bottles were sealed in clear plastic bags until use. The sampling technician first applied a waterless sanitizing gel and then put on a pair of Nitrile gloves. The sample bottle was removed from the plastic bag, labeled, and placed into a clamp attached to the end of four foot long PVC pole. The sampling technician carefully waded into the water to a depth of approximately 12 inches and removed the lid from the sample bottle. The bottle was extended in front of the sampler (away from shore) with the sampling pole, then inverted and submerged four to six inches below the water surface. In a sweeping motion, the pole was rotated so the opening of the bottle was facing to the side. The pole was then swept sideways to take the water sample. Samples taken within waist deep water were obtained using a paddleboard and following the standard sampling procedures discussed above. The bottle was filled once, drained to the desired volume so that a small amount of air remained in the container, and capped. No surface residue, sediment, or debris was allowed to enter the sample bottle. If debris or sediment was evident in the bottle, the sample was discarded and the site was re-sampled with a new, sterile bottle. After collection, the sample was re-sealed in the plastic bag and placed on “Blue Ice” packs.

Spot samples were collected using the same aseptic technique as employed for the site samples, but in most cases the sampling pole was not used. A courier picked up the bacterial samples from the field and delivered them to the laboratory within the required holding time. All samples were kept on blue ice in the dark from the time of sample collection until delivery to the analytical laboratory.

Laboratory Analyses

All bacteria samples were analyzed at the MEC Analytical Systems Microbiology Laboratory in Carlsbad, California. The three indicator bacteria enumerated in this study were total coliform, fecal coliform, and enterococcus. In the laboratory, total and fecal coliforms were analyzed using multiple tube fermentation based on Standard Methods 9221B&E. Enterococcus were analyzed by using a chromogenic technique (Enterolert), based on Standard Method 9223.

RESULTS

Water quality measurements for bacteria indicators occurred at several different kinds of locations around Sail Bay. These locations included the storm drain conveyance system manholes, storm drain vaults and rainwater/dewatering sump pumps. Three of the four storm drain conveyance manholes had an exceedance of at least one of the indicator bacteria. Two of the four vaults had an exceedance for only enterococcus. Three of the eight rainwater/dewatering sump pumps had an exceedance for at least one of the indicator bacteria. The highest bacteria levels were found in the storm drain manhole at the terminus of Dawes Street (MH3-2) and the manhole at the terminus of Fanuel Street (SD3-3A)(Table 2). In general, the storm drain conveyance system had the highest level of indicator bacteria. The dewatering sump pumps did not indicate a potential source of bacteria within Sail Bay.

Overall, the indicator bacteria levels were relatively low compared to dry weather bacteria levels within the greater Mission Bay watershed. However, two samples were an exception to this.

MH3-2 and SD3-3A both had elevated levels above the average of samples taken from these systems. An additional sample, R3-8, had elevated levels of total and fecal coliform. This site is has an 18 x 18 inch rainwater sump pump. The discharge outlet is currently believed to be a 2 inch PVC pipe on La Palma Street. However, the Triton Realty Service (property manager) has been unable to confirm this to date.

DISCUSSION

Several suspected sources were sampled and evaluated for indicator bacteria during the field investigation on April 28, 2003. The dewatering sump pump located at 4015 Fanuel Street (R3-6A) had very low bacteria levels similar to the connecting discharge pipe outlet (SD3-3B) (Table 2). The dewatering sump pump at 4015 Fanuel Street discharges approximately 50,000 gallons/24hr period downstream of the interceptor system and thus directly into Mission Bay. Therefore, a high amount of bacteria found within either system would be a strong potential source of the bacteria exceedances at Fanuel Park. However, as stated above this does not seem to be the source of bacteria exceedances at Fanuel Park.

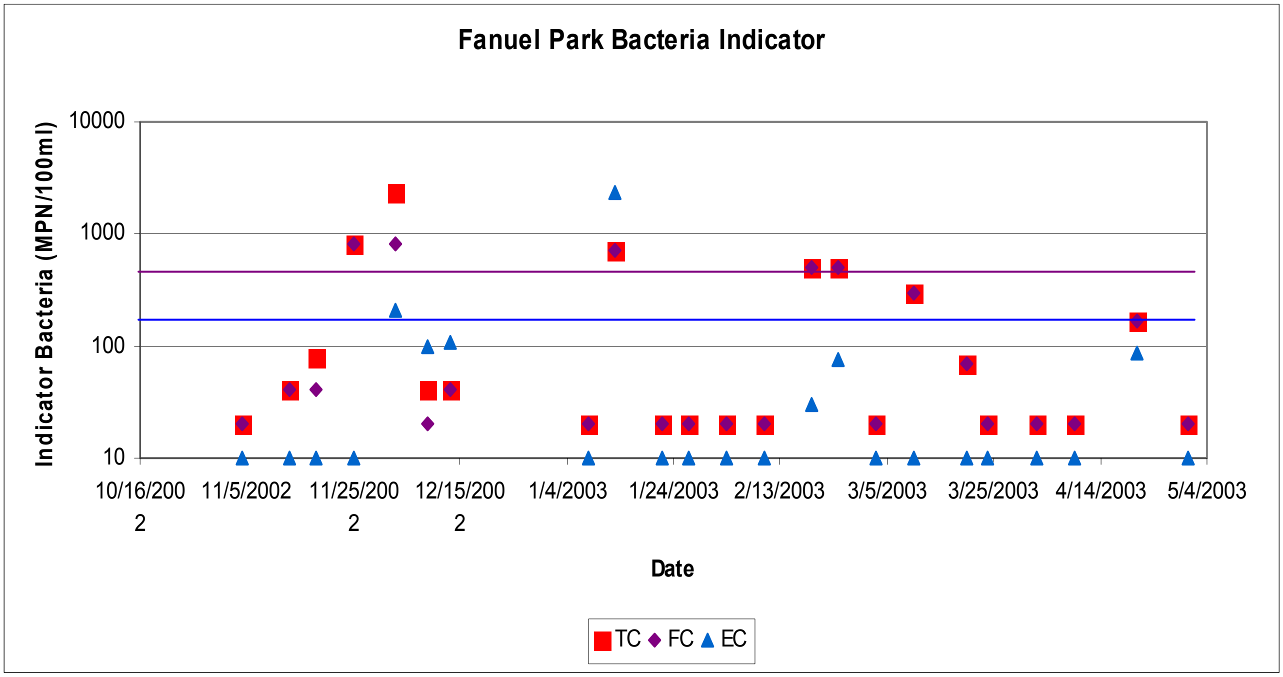
A similar scenario is found at the dewatering sump pump located at 3916 Riviera Drive (R3-11) and the connecting discharge pipe outlet (V3-5). Both systems had very low levels of bacteria. The dewatering sump pump at 3916 Riviera Drive discharges approximately 216,000 gallons/24hr period downstream of the interceptor system and thus directly into Mission Bay. However, at current conditions neither of these two potential sources (R3-6A and R3-11) are likely contributors to the bacteria exceedances at Fanuel Park.

The rainwater sump pump located on 3916 Gresham Street (R3-9) and the adjacent storm drain vault (V3-5) had exceedances for enterococcus (Table 2). R3-9 is a 3 x 2 x 8 foot rainwater sump pump that collects rainwater and cash wash-off. Once the sump fills the water is discharged into V3-5, this occurs sporadically depending upon rainfall levels and residential car washing. R3-9 had an exceedance for enterococcus (435 MPN/100ml) as did V3-5 (216 MPN/100ml). The source of the bacteria within the rainwater sump pump may be from leaking trash bins, animals or urban runoff. The trash bins are located approximately 100 feet from the inlet of the sump pump thus they do not seem to a source. The maintenance manager stated that in terms of rainfall the pumps activate during heavy rainfall events. The last large rainfall event was on April 8, 2003 (1.08 inches) considering the time frame between the rainfall event and the sample date urban runoff does not seem a likely source. Domestic or non-domestic animals maybe a potential source however quantifying the population that can obtain access into the underground parking structure is not possible. An investigation of the sewage pipeline confirmed that the pipeline was in good condition and properly functioning. Thus, direct influences from sewage does not seem likely. It is our current belief that animals can obtain access into the sump pump due to the finding of an animal in the receiving vault. Residential car washing may be a potential vector for transporting bacteria into the sump pump again quantification of this activity is not possible. Interestingly, on March 11, 2003 a decomposing animal was found in V3-5 which resulted in dramatically elevated levels of bacteria within V3-4 and V3-5 (Table 2). The animal was removed however enterococcus levels on April 28, 2003 were elevated. Therefore, the combination of residual bacteria from the decomposing animal and flow from the sump pump may be the potential sources of bacteria within V3-5. The vault (V3-4) downstream of V3-5 had similar bacteria levels. This vault takes in rainfall runoff from 1327 La Palma Street and flow from V3-5. Since the bacteria numbers between V3-4 and V3-5 are similar it maybe inferred that the source of bacteria at V3-4 was derived from V3-5 and not rainfall runoff from 1327 La Palma Street. Again, the last large rainfall event was on April 8, 2003 (1.08 inches) considering the time frame between the rainfall event and the sample date rainfall runoff does not seem a likely source. It is very likely that the roof drains may have acted as a vector for bird feces on the roof of 1327 La Palma Street however, current data indicates that bird feces has a much higher value of enterococcus and fecal coliform than what was found within the sample taken on April 28, 2003. Again, the combination of residual bacteria from the decomposing animal and flow from V3-5 may be the potential sources of bacteria within V3-4.

Samples taken from the storm drain conveyance system manholes (MH3-4 & MH3-8) of IPS-7 (interceptor pump system) had exceedances for enterococcus (Table 2). The exceedances are relatively low and are potential non-issue if IPS-7 is properly functioning. On April 28, 2003 it was confirmed that the interceptor system was properly functioning. The potential sources and mechanisms for decreased die-off rates of the bacteria maybe derived from several dependent and independent systems. For example, these systems maybe include urban runoff, supply of nutrients (washed in eel grass via a warped tide flex-has been confirmed), low flow conditions and the absence of Ultraviolet light may combine to allow potential re-grow of enterococcus within the pipeline system.

Two samples (MH3-2 & SD3-3A) taken on April 28, 2003 had high exceedances of all three indicator bacteria (Table 2). These two locations receive urban runoff from a large watershed located north of the site. Multiple sources may have caused the exceedance however bacteria data does not indicate that sewage is a likely source. City of San Diego personnel conducted an investigation into the potential sources of the bacteria within the Fanuel Street and Dawes Street watershed on May 15, 2003. The investigation found that several locations within the watershed had irrigation runoff flowing into the storm drain conveyance system. It was concluded that the combination of these multiple locations greatly increases the urban runoff flow into MH3-2 and SD3-3A. The runoff from these locations may act as a transport mechanism thus, transporting and concentrating upstream bacteria into a central location. No specific source of the bacteria was found within the surface drainage area or the underground storm drain conveyance system. With the exception of identifying a citizen washing off a barbeque grill within the Dawes Street watershed. The location of the incident was only one block away from where the MH3-2 sample was taken. It is known that grease can increase the concentration of indicator bacteria by acting a nutrient resource.

In summary, dewatering systems do not seem to be a likely source of bacteria exceedances at the Fanuel Park sampling site. Urban runoff has been identified as a potential source of bacteria within storm drain conveyance system. Therefore, if the storm drains are not diverted or the diversion system is not functioning properly urban runoff can flow directly into Sail Bay. Finally, the storm drain vaults appear to be a potential source of enterococcus at Sail Bay since the discharge outlet is downstream of the diversion system thus flows travel directly into Mission Bay.



*Data from 11/4/02-3/24/03 is City of San Diego (MEC Analytical Laboratory)
Data from 4/2/03-4/30/03 is County of San Diego
Blue line indicates enterococcus standard limit
Violet line indicates fecal coliform standard limit
Total coliform did not exceed the standard limit (10,000 MPN/100ml)

Figure 4. Temporal trend of bacteria levels at Fanuel Park.

Table 2. Indicator bacteria sample results from April 28, 2003.

Site	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)	Enterococcus (MPN/100ml)
V3-1	230	<20	<10
V3-4	800	70	**241**
V3-4*	**110,000**	20	**2,613**
V3-5	5,000	70	**216**
V3-5*	**>350,000**	80	**3,255**
V3-6	<20	<20	<10
MH3-2	**160,000**	**30,000**	**6,131**
MH3-3	800	<20	20
MH3-4	3,000	<20	**275**
MH3-8	2,200	<20	**241**
SD3-3A	**50,000**	**3,000**	**1,054**
SD3-3B	<20	<20	<10
R3-2	20	<20	<10
R3-3	**30,000**	<20	<10
R3-6A	<20	<20	<10
R3-6B	20	<20	10
R3-8	**80,000**	**80,000**	nd
R3-9	8,000	140	**435**
R3-11	<20	<20	<10
R3-14	800	<20	**109**

*Samples taken on 3/11/03.
Values that exceeded AB411 criteria are highlighted in bold

Table 3. Residential bacteria sampling location by address.

Site	Address
R3-2	1165 Pacific Beach Drive
R3-3	4007 Parker Place
R3-6A	4005-4015 Fanuel Street
R3-6B	4005-4015 Fanuel Street
R3-8	1335 La Palma Street
R3-9	3940 Gresham Street
R3-11	3916 Riviera Drive
R3-14	3868 Riviera Drive

Water quality data.

Date	Site	Time	Sample Number	Site Description/Comments
4/28/03	MH3-1	N/A	MH3-1	Unable to open
4/28/03	MH3-2	14:21	MH3-2	Ponded water, strong odor, yellowish in color, no surface flow
4/28/03	MH3-3	14:40	MH3-3	Trickle flow from west and north pipelines, sediment at bottom
4/28/03	MH3-4	15:05	MH3-4	Flowing clear water
4/28/03	MH3-5	N/A	MH3-5	Unable to sample due to low volume of ponded water
4/28/03	MH3-6	N/A	MH3-6	Flow, no odor observed
4/28/03	MH3-7	N/A	MH3-7	Unable to sample
4/28/03	MH3-8	15:47	MH3-8	Flow from west and north pipelines, organic debris, tide flex not functioning properly
4/28/03	V3-1	14:30	V3-1	Ponded water, clear, odorless, sediment on bottom
4/28/03	V3-2	N/A	V3-2	Unable to open
4/28/03	V3-3	N/A	V3-3	Dry
4/28/03	V3-4	15:25	V3-4	Ponded water in vault
4/28/03	V3-5	15:15	V3-5	Ponded water in vault
4/28/03	V3-6	15:42	V3-6	Dewatering pipeline outlet from 3916 Riviera Drive
4/28/03	SD3-3A	14:35	SD3-3A	Storm drain inlet at the terminus of Fanuel Street
4/28/03	SD3-3B	14:40	SD3-3B	Dewatering pipeline outlet from 4005 Fanuel Street
4/28/03	SD3-3C	N/A	SD3-3C	Unable to sample
4/28/03	R3-1	N/A	R3-1	Unable to sample
4/28/03	R3-2	11:57	R3-2	3 x 4 foot dewatering sump pump, approximately half full of water
4/28/03	R3-3	10:36	R3-3	Rainwater sump pump located in underground parking structure, ponded water, no flow
4/28/03	R3-4	N/A	R3-4	Unable to sample
4/28/03	R3-5	N/A	R3-5	Unable to sample
4/28/03	R3-6A	9:30	R3-6A	Dewatering sump pump inside underground garage at 4005 Fanuel Street
4/28/03	R3-6B	9:35	R3-6B	Rainwater sump pump inside underground garage at 4005 Fanuel Street
4/28/03	R3-7	N/A	R3-7	No sample
4/28/03	R3-8	10:45	R3-8	Rainwater sump pump inside underground garage at 1335 La Palma Street
4/28/03	R3-9	9:44	R3-9	Rainwater sump pump inside underground garage at 3940 Gresham Street
1/31/03	R3-10	N/A	R3-10	Unable to sample

Fanuel Park/Riviera Shores ICID

Date	Site	Time	Sample Number	Site Description/Comments
1/31/03	R3-11	11:03	R3-11	Dewatering sump pump inside underground garage at 3916 Riviera Drive
1/31/03	R3-12	N/A	R3-12	Dry, flow would go directly to beach
1/31/03	R3-13	N/A	R3-13	Dry, flow would go directly to beach
1/31/03	R3-14	9:30	R3-14	Washing down of underground parking structure, sample taken from flow exiting on to street outlet pipe (~1 gal/min for 2 minutes of flow)
1/31/03	R3-15	N/A	R3-15	Dry, flow would go to bayside storm drain conveyance system
1/31/03	R3-16	N/A	R3-16	Dry, flow would go to bayside storm drain conveyance system
1/31/03	R3-17	N/A	R3-17	Dry, flow would go to bayside storm drain conveyance system
1/31/03	R3-18	N/A	R3-18	Dry, flow would go to bayside storm drain conveyance system

K.3

Campland ICID

Campland, 2211 Pacific Beach Dr., Site Investigation

BACKGROUND / CAUSE OF INVESTIGATION

City Storm Water staff initiated an investigation at 2211 Pacific Beach Dr. in the Campland RV Park in response to an increase in bacteria levels. Campland was monitored weekly by the San Diego County Department of Environmental Health (DEH) from April 1, 2002 to October 31, 2002 and by the City of San Diego from November 1, 2002 to March 31, 2003. The beach at Campland has been closed for 99 days as of March 5, 2003. The geometric mean AB411 standard for enterococcus is 35 MPN/100 ml. However; as of October 29, 2002, the geometric mean at Campland was 371 MPN/100 ml.

The San Diego Metro Waste Water Division (MWWD) developed a Supplemental Environmental Project (SEP) for monitoring the Mission Bay Watershed in lieu of paying fines for a sanitary sewer leakage to Tecolote Creek that occurred on 2/18/01. As part of this program, several sites in the for Mission Bay watershed are routinely monitored, including Rose Creek, Tecolote Creek, and San Clemente Canyon.

This investigation was conducted to determine the extent of potential sources of bacteria within and around Campland, located on the north side of Mission Bay. The investigation site is bordered by Rose Creek on the east and Kendall Frost Marsh Reserve on the west. There are several potential sources that may be contributing to elevated bacteria levels. This investigation consisted of visual observations, eleven samples for bacterial analyses, and documentation that included photographs and field notes. All samples were obtained during an ebbing tide, approximately 30 minutes after a high tide of 6.1ft.

Bacteriological Sampling and Analyses

Field Sampling

To assure consistency among results, the protocol for collection of the site samples was the same as that employed by the San Diego County of Environmental Health. Samples were collected in sterile, 100-ml plastic bottles containing sodium thiosulfate. The bottles were sealed in clear plastic bags until use. The sampling technician first applied a waterless sanitizing gel and then put on a pair of Nitrile gloves. The sample bottle was removed from the plastic bag, labeled, and placed into a clamp attached to the end of four foot long PVC pole. The sampling technician carefully waded into the water to a depth of approximately 12 inches and removed the lid from the sample bottle. The bottle was extended in front of the sampler (away from shore) with the sampling pole, then inverted and submerged four to six inches below the water surface. In a sweeping motion, the pole was rotated so the opening of the bottle was facing to the side. The pole was then swept sideways to take the water sample. Samples taken at offshore sites were obtained using the City of San Diego Safety & Lifeguard Services patrol boat and following the standard sampling procedures discussed above. The bottle was filled once, drained to the desired volume so that a small amount of air remained in the container, and capped. No surface residue, sediment, or debris was allowed to enter the sample bottle. If debris or sediment was evident in the bottle, the sample was discarded and the site was re-sampled with a new, sterile bottle. After collection, the sample was re-sealed in the plastic bag and placed on "Blue Ice" packs.

Spot samples were collected using the same aseptic technique as employed for the site samples, but in most cases the sampling pole was not used. A courier picked up the bacterial samples from the field and delivered them to the laboratory within the required holding time. All samples were kept on blue ice in the dark from the time of sample collection until delivery to the analytical laboratory.

Laboratory Analyses

All bacteria samples were analyzed at the MEC Analytical Systems Microbiology Laboratory in Carlsbad, California. The three indicator bacteria enumerated in this study were total coliform, fecal coliform, and enterococcus. In the laboratory, total and fecal coliforms were analyzed using multiple tube fermentation based on Standard Methods 9221B&E. Enterococcus were analyzed by using a chromogenic technique (Enterolert), based on Standard Method 9223.

Notes / Findings

- Rose Creek discharges into Mission Bay directly east of the Campland beach. A SEP monitoring site (MBW 21) is located approximately one half-mile up stream of the investigation site (Figure 1). The enterococcus levels at this site have been consistently low since September 2002 (Table 1). The average enterococcus single sample value from August 21st to November 18th was 34.7 MPN/100 ml. This value is well below the AB411 single sample limit of 104 MPN/100 ml for enterococcus. Additional field investigation of Rose Creek found four large homeless encampments located downstream of the diversion system. In addition, the diversion unit contains approximately 25 ft. of heavy vegetation upstream of the diversion. The heavy vegetation may be greatly decreasing the effectiveness of the diversion unit (Figure 2). No flow was observed due to the heavy amount of vegetation in the diversion area (Figure 3a,b).
- The Illegal Connection and Illicit Discharge (ICID) investigation took place on November 21, 2002. Three samples (6A-1, 6A-3, 6A-4) were obtained within Rose Creek using a Lifeguard Safety patrol craft (Figure 1). Travis Gleason from San Diego Fire and Life Safety assisted with obtaining the samples. All three of these sties had very low bacteria levels (Table 2).
- Three samples (6A-2, 6A-5, 6A-6) were taken within Mission Bay directly south of the Campland beach and boat dock (Figure 1). All three of these sites had very low bacteria levels (Table 2). Sites 6A-5 and 6A-6 were taken near the abandoned dock that contained a large number of birds and fecal matter. Bacterial indicator levels at these sites were also low. Based on this preliminary effort, this area does not appear to be a major source of bacteria to the beach.
- One sample (6A-9) was taken in the Rose Creek south of the diversion system (IPS I-1) (Figure 2). This site contains heavy vegetation and is not tidally influenced. However, slight flow was observed. It is hypothesized that groundwater from Rose Creek flows underneath the concrete channel (where the diversion unit is located) and surfaced downstream of the diversion system. The location of the surfacing groundwater is directly west of the Mission Bay Drive Bridge. The bacteria levels for enterococcus at this location were above AB411 standards (Table 2). However, the bacteria levels were relatively low considering the environmental conditions at the location. The source of the enterococcus may be due to the wildlife in the area. The ammonia-nitrogen level at this location was < 1.0 mg/L.

- One sample (6A-8) was taken within a channel that flows from a diversion unit into the eastern side of Kendal Frost Marsh Reserve (Figure 4). The diversion unit is missing one tide flex and is tidally influenced during high tides ($\geq$ 5.5). No birds or animals were observed during the time of the sample. The water flowing from this location may be transported to Campland once it enters Mission Bay due to the tidal effects or movement from currents (Figure 1). However, samples taken at this location had low bacteria levels (Table 2). It may be hypothesized that this location does not contribute to the bacteria levels found at Campland. The ammonia-nitrogen level at this location was < 1.0 mg/L.

- Sample 6A-7 was taken from the jetty on the west side of the Campland Marina. This location separates the Marina from the Kendal Frost Marsh Reserve. Several pieces of dog fecal matter were observed here. Approximately ten Willets where observed on the west side of the jetty. The ammonia-nitrogen level at this location was < 1.0 mg/L. Bacteria levels at this site were very low (Table 2). Therefore, it may be hypothesized that the influence of birds at the Kendal Frost Marsh Reserve does not contribute to the bacteria levels at Campland.

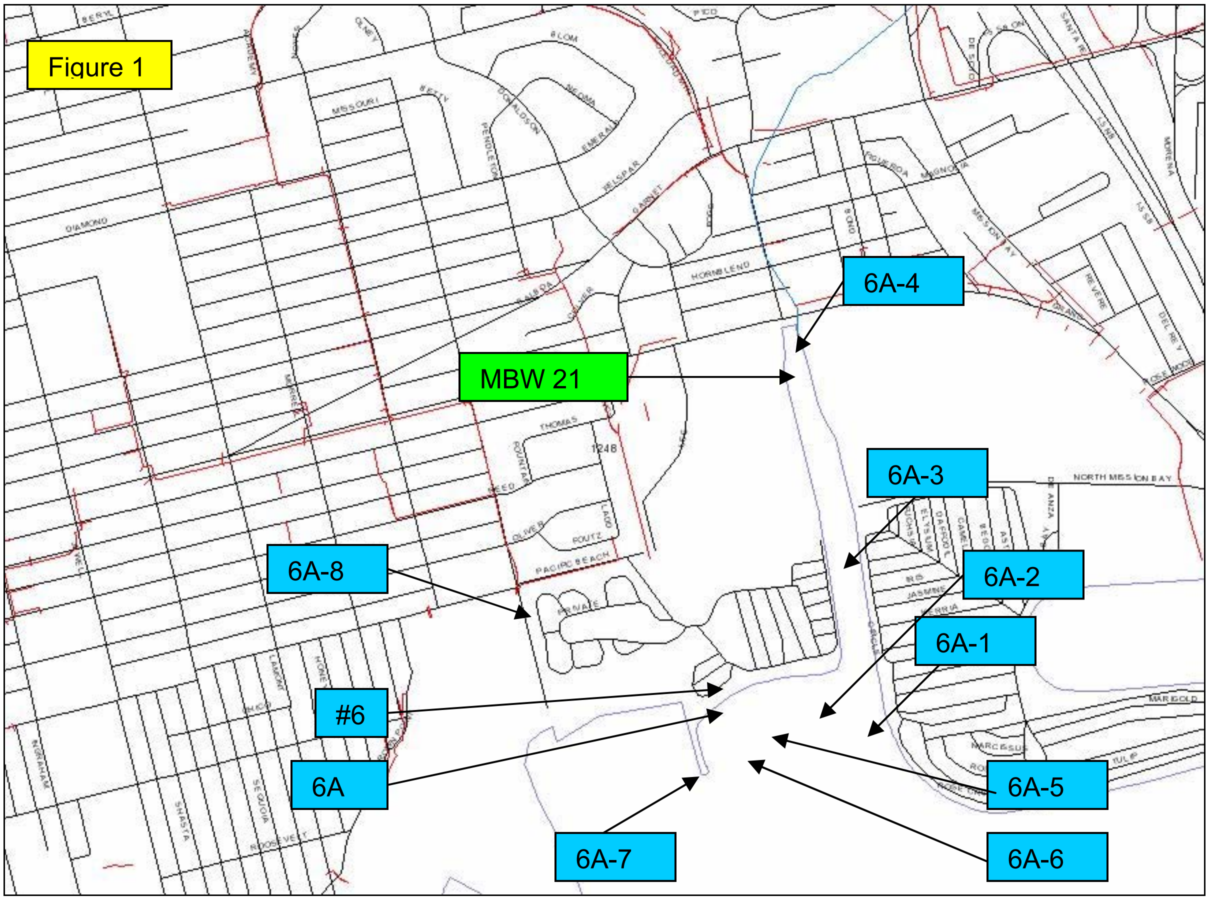
- From early August to October, 2002 a field investigation was conducted by MEC Analytical Systems and the City of San Diego. During this time period several samples were taken out of a pipe located on the west side of the Campland boat launch (Figure 1) (Table 3). This pipe is connected to an inlet where campers can wash off their boats and cars using potable water. The outlet pipe is located on the western side of the boat ramp. Campland Marina Manager, Dave Rohl, explained to us that the pipe was blocked for some period of time in the summer. Campland Facilities Maintenance Manager, Travor Taguacta, also told us that a couple of times camp visitors were found washing out their RV sewage discharge pipes on the wash rack. They stopped the visitors immediately and educated the visitors on the proper location to wash off the pipes. The wash off of these pipes and conditions in the drainpipe may have lead to growth of bacteria colonies within the pipe thus causing an increase in the bacteria levels. On Nov. 21st Travor Taguacta told us that they have cleaned out the debris within the pipe and hyper-chlorinated the pipeline. Minimal debris was found within the pipe during the cleaning. Specific debris was not reported.

- One sample (#6) was taken outside of the pipe outlet on the boat ramp. The sample was taken by running the potable water from the wash off location down the pipe. After a couple of minutes several ducks came over to the end of the boat ramp and began drinking the freshwater. An additional sample (6A) was taken where the ducks where drinking within the water column just off the boat ramp. The ammonia-nitrogen level at this location was < 1.0 mg/L. Sample #6 had very high levels of both total coliform and enterococcus (Table 2). In addition, sample 6A had high levels of fecal coliform and enterococcus (Table 2).

- Several additional sources have been identified around the Campland location.
    1. Approximately thirty 4-inch pipes were observed coming from the De Anza Point trailer park (Figure 5). These pipes appear to allow over watering from lawns to run-off into the bay. No water was observed flowing during a field investigation using a patrol boat from the Lifeguard Boating Safety Unit on November 20th. Further analysis will be conducted to determine the inlet of these pipes and the potential bacteria contribution. Site 6A-1, was sampled on the western end of De Anza Point, had very low bacteria levels. Also, De Anza Point is approximately 300meters from the Campland beach. Therefore, it can be concluded that De Anza Point is not a source of the high bacteria levels at Campland.

2. A large number of ducks can be found within Campland. It has been observed during several times that in the morning ducks will come up on the Campland beach from Rose Creek by passing directly through the weekly sampling location. During daytime the ducks are found within the Campland park and underneath the beached boats on the west end of the beach (Figure 6).
3. A large number of birds were also found on an abandoned dock directly south of the Marina docks. Samples 6A-6 and 6A-5 were taken on the north side of the abandoned dock located between the abandoned dock and the Marina docks. Dave Rohl informed us that during the spring a sprinkler system was used to rid the birds from the location (Figure 7). However, the system has not been used since late spring.
4. Several statistical analyses have been conducted at this site for bacteria variations during tidal heights. Statistical analyses were conducted by using regression analysis for all three of the indicator bacteria. Each of the samples were taken from on the Campland beach (location where County of San Diego DEH samples) from November 4, 2002 to February 19, 2003. The trend-line analysis is separated for tidal height and ebbing/flooding actions of the tide. Results indicated that bacteria levels are independent of the tidal height and/or the effects of an ebbing or flooding tide ($r^2 = 0.016$ and $r^2 = 0.0691$ respectively).
5. Several homeless encampments have been found downstream of the diversion (Figure 2). However, SEP site MBW 21 has no history of high bacteria levels. Suggesting that the homeless are not increasing fecal bacteria levels at site MBW 21.

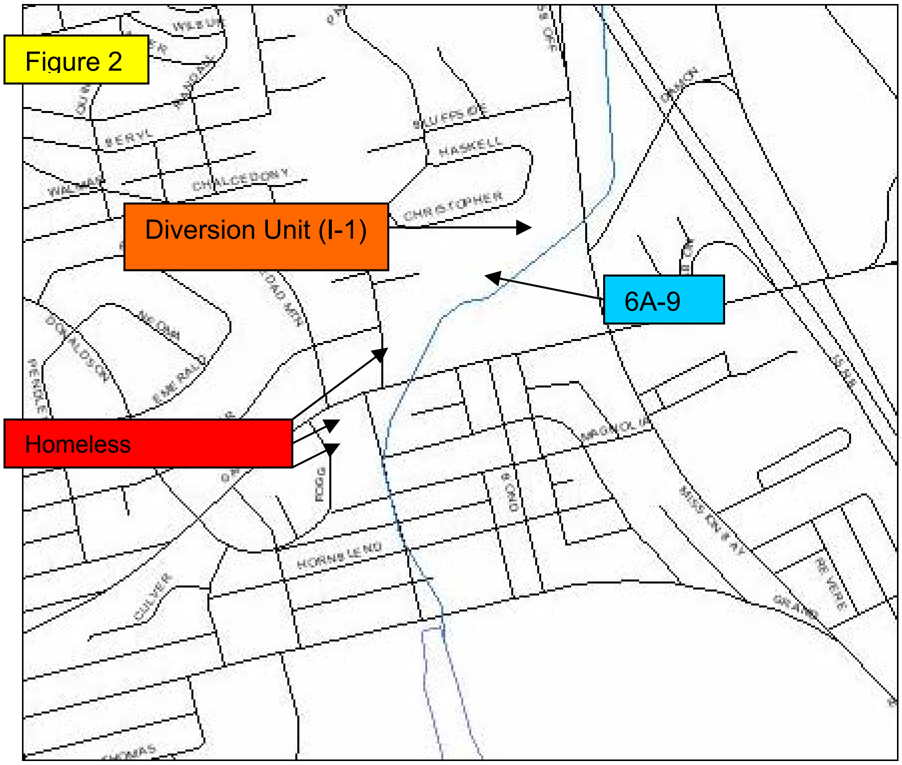
Map of Campland and Site of Interest



Samples and points of interest around Campland

Legend:
Blue = ICID Spot Samples
Green = SEP Site Location

Map of Campland and Site of Interest



Samples and points of interest around Campland

Legend:
Blue = ICID Spot Samples
Red = Homeless encampments
Orange = Diversion Unit

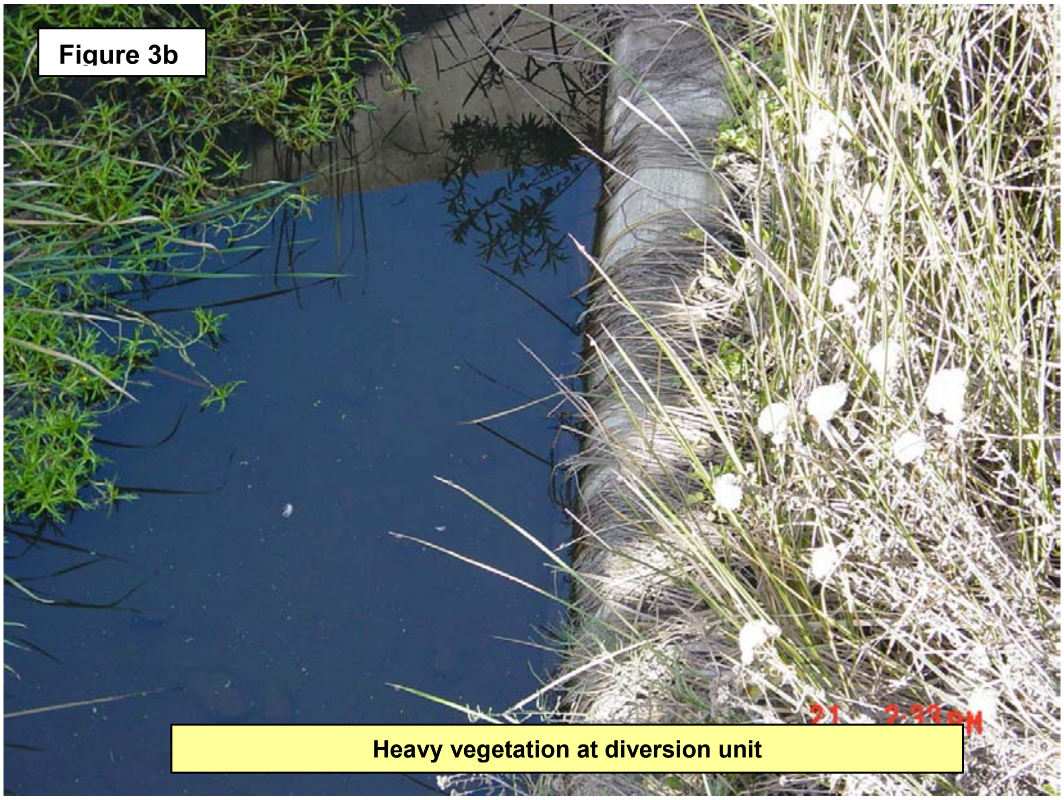
Pictures of 2211 Pacific Beach Dr.

Figure 3a

Heavy vegetation at diversion unit

Campland ICID

Figure 3b



Heavy vegetation at diversion unit

Figure 4

Eastern end of Kendall Frost Marsh Reserve

Figure 5

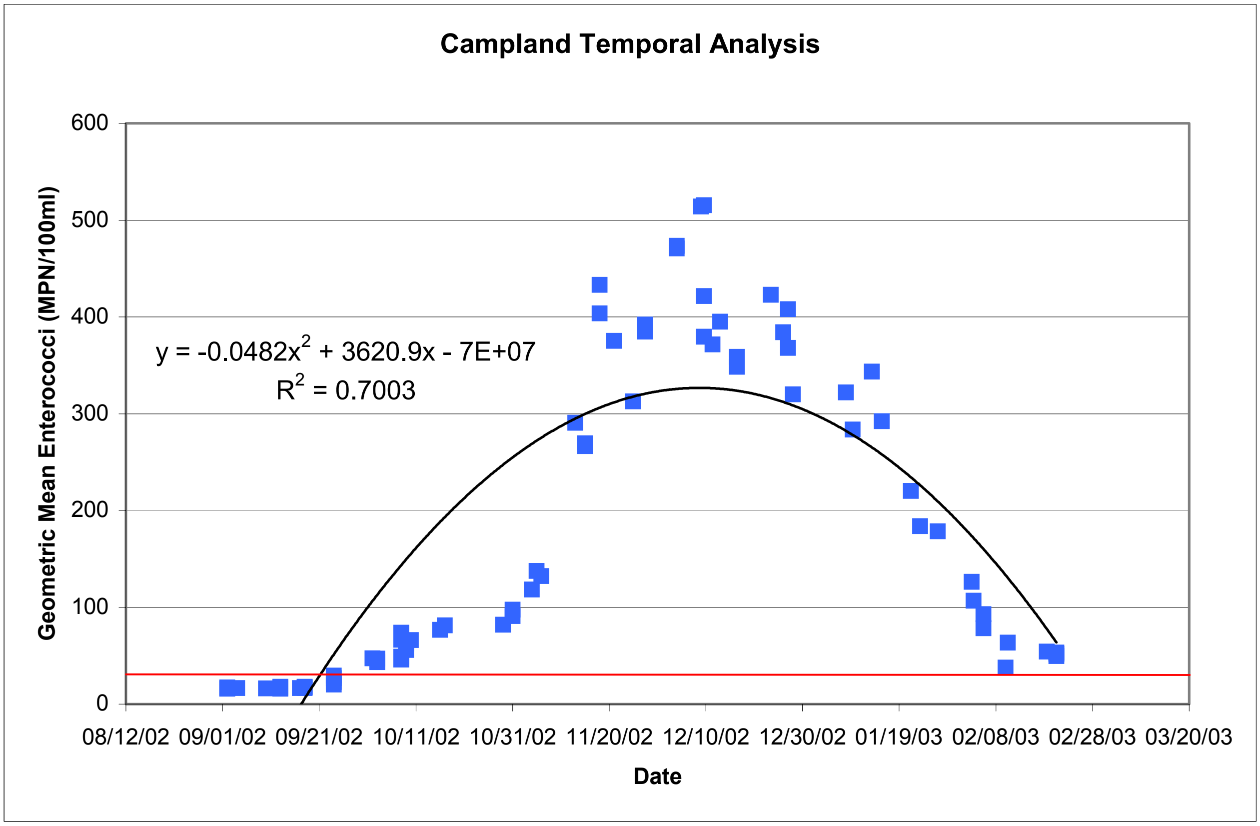
4-inch pipes found on De Anza Point

Figure 6

Ducks during daytime under docked boats at Campland

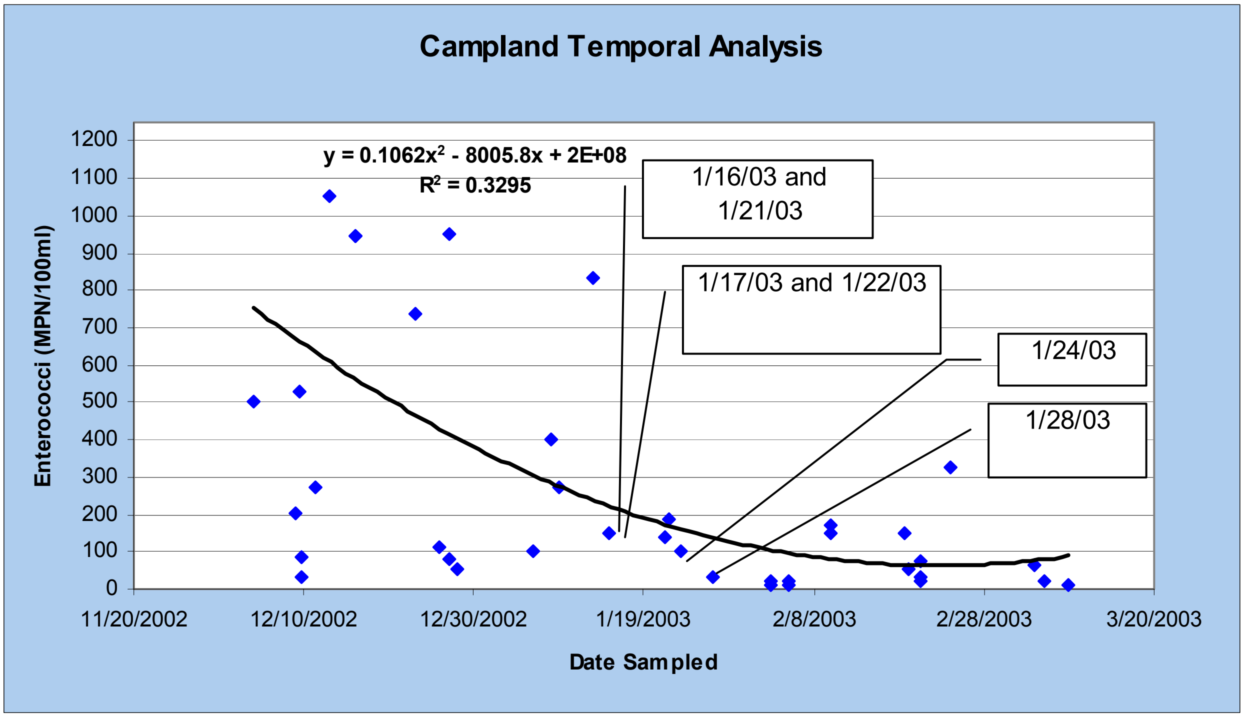
Figure 7

Birds on abandoned dock at Campland



Red-line is standard geometric mean for enterococcus (35 MPN/100ml).

Figure 8a. Campland temporal analysis, data from 9/2/02 to 2/20/03.



Note:
1/16/2003 – 1) Plugged and capped off line from Marine to Boat Ramp w/ a retrievable spout (ball valve and hose bib). 2) Same was done from the wash area to the storm catch located inside the bike area. Hyperchlorinate both lines with two gallons of chlorine each and water for twenty-four hours.
1/17/2003 – 1) collected chlorinated water from lines into trash can and poured into sewer. 2) high pressure wash with 240˚ water using Hotsy power washer for 15 minutes on each line. 3) Power rinse both lines with two hydrant hose for 15 minutes on each line segment.
1/21/2003 – repeat process performed on 1/16/2003
1/22/2003 – repeat process performed on 1/17/2003
Weekly basis (starting 1/24/03):

- Monday, Wednesday, Fridays shovel up the bird fecal matter and dispose of it from the west and east side of the launch ramp
- Tuesday, Thursday flush boat ramp pipeline out with clean hydrant water
- Once a month hyperchlorinate the pipeline using the dilution documented above.

Figure 8b. Campland temporal analysis, data from 12/4/02 to 3/10/03.

Campland ICID

Table 1. SEP Monitoring Data for Site MBW 21

DATE	TOTAL	E COLI	ENTERO
09/09/2002	3,873	318	31
09/16/2002	620	63	10
09/24/2002	1,674	85	51
10/02/2002	1,281	175	52
10/07/2002	2,932	243	10
10/28/2002	24,000	1,232	20
11/13/2002	3,255	97	41
11/18/2002	3,725	512	98
11/25/2002	NS	NS	NS
12/9/2002	74	10	10
12/16/2002	2,382	63	85
12/23/2002	224,700	21,870	6,867
1/13/2003	368	41	20
2/3/2003	462	65	10
2/10/2003	733	10	20
2/19/2003	9,100	350	228
2/24/2003	959	41	30

*Units are in MPN Index/ 100mL for all bacteria

Table 2. Data from ICID field investigation conducted on 11/21/02

DATE	SAMP ID	TOTAL	FECAL	ENTERO	SAMPLE TIME	SITE DESCRIPTION
11/21/2002	6	130,000	300	1,529	1240	Boat ramp pipe outlet
11/21/2002	6A	1,700	800	695	1242	End of boat ramp
11/21/2002	6A-1	1,300	<20	10	1133	Offshore west of De Anza Point
11/21/2002	6A-2	40	40	10	1137	Offshore south of Campland beach
11/21/2002	6A-3	40	<20	<10	1145	Offshore at the mouth of Rose Creek
11/21/2002	6A-4	60	20	85	1150	Offshore directly south of Grand Ave. bridge
11/21/2002	6A-5	230	230	<10	1208	Offshore at the eastern end of abandoned dock
11/21/2002	6A-6	70	40	10	1207	Offshore at the western end of abandoned dock
11/21/2002	6A-7	40	20	10	1232	West side of jetty, directly west of marina
11/21/2002	6A-8	1,300	40	86	1318	Eastern end of Kendal Frost Marsh Reserve
11/21/2002	6A-9	3,000	230	209	1347	¾ mile downstream of diversion unit/pump station I-1

*Units are in MPN Index/ 100mL for all bacteria

Table 3. MEC samples taken directly from the boat ramp pipe outlet from August to October, 2002.

DATE	SITE	TIME	TOTAL	FECAL	ENTERO
8/25/2002	6	1117	700	230	20
8/25/2002	6	1603	300	80	5
8/29/2002	6	1100	80,000	5,000	2,987
8/29/2002	6	1300	3,000	1,300	211
8/29/2002	6	1706	2,3000	2,300	1,334
8/31/2002	6	750	9,000	3,000	10
8/31/2002	6	750	24,000	3,000	86
8/31/2002	6	1120	50,000	230	1,166
8/31/2002	6	1120	7,000	110	295
9/2/2002	6	920	9,000,000	500,0000	686,700
9/2/2002	6	1620	5,000	40	512
9/8/2002	6	1130	70,000	5,000	105
9/8/2002	6	1130	23,000	140	98
9/18/2002	6	800	230,000	1,700	41
9/18/2002	6	1,327	23,000	1,400	1,726
9/18/2002	6	1,327	22,000	1,700	142
9/24/2002	6	1,355	500,000	30,000	259
10/8/2002	6	1,135	5,000	130	321

*Units are in MPN Index/ 100mL for all bacteria

Table 4. MEC samples taken directly from the boat ramp pipe outlet before and after hyper-chlorination activities were performed.

DATE	SITE	TIME	TOTAL	FECAL	ENTERO
1/8/2003	6	1109	22,000	1,700	1,892
1/8/2003	6	1115	500	500	259
1/22/2003	6	1100	2200	40	350

*Units are in MPN Index/ 100mL for all bacteria

Table 5. Bird observation during the pellet count conducted on 12-16-02 between 1:27pm to 2:45pm

Bird (common name)	Quantity
Sea Gull	20
Heron	1
Pelican	13
Duck	75
Cormorant	100
Willet	25

Table 6. Campland beach samples (data includes County of San Diego DEH samples) compared to SEP Site MBW21 in Rose Creek. Bold datum points are AB411 single sample exceedances.

MEC SITE	DATE	TOTAL	FECAL	ENTERO	Station	Date	TOTAL	ENTERO
Campland	10/2/02	500	300	53	MBW21	10/2/02	1281	52
Campland	10/3/02	70	70	10				
Campland	10/3/02	2400	**2400**	**207**				
Campland	10/8/02	170	170	31	MBW21	10/7/02	2932	10
Campland	10/8/02	170	130	**161**				
Campland	10/8/02	9,000	**9,000**	**2,247**				
Campland	10/8/02	230	230	10				
Campland	10/9/02	110	110	20				
Campland	10/9/02	10	10	10				
Campland	10/9/02	1,400	**1,400**	**836**				
Campland	10/10/02	40	40	**111**				
Campland	10/16/02	300	300	31	MBW21	10/14/02	798	41
Campland	10/17/02	80	80	**271**	MBW21	10/21/02	272	74
Campland	10/29/02	700	**700**	**324**	MBW21	10/28/02	**24000**	20
Campland	10/31/02	300	300	**384**				
Campland	10/31/02	700	**700**	**288**				
Campland	11/4/02	5000	**3000**	**1,153**	MBW21	11/4/02	1860	74
Campland	11/5/02	140	90	**164**				
Campland	11/6/02	230	230	75				
Campland	11/13/02	7,000	**7,000**	**3,448**	MBW21	11/13/02	3255	41
Campland	11/15/02	170	170	**137**				
Campland	11/15/02	700	**700**	**238**				
Campland	11/18/02	9000	**9000**	**2005**	MBW21	11/18/02	3725	98
Campland	11/18/02	800	**500**	**1401**				
Campland	11/21/02	40	40	42				
Campland	11/25/02	230	230	**496**	MBW21	11/25/02	NS	NS
Campland	11/27/02	500	**500**	**504**				
Campland	11/27/02	300	300	**504**				
Campland	12/4/02	2400	**2400**	**2005**	MBW21	12/2/02	**23590**	**717**
Campland	12/4/02	500	210	**504**				
Campland	12/9/02	500	300	**201**	MBW21	12/9/02	74	10
Campland	12/9/02	800	**800**	**531**				
Campland	12/9/02	300	170	31				
Campland	12/9/02	230	230	87				
Campland	12/11/02	300	300	**271**				
Campland	12/13/02	3000	**1,100**	**1,050**				
Campland	12/16/02	3000	**3000**	**945**	MBW21	12/16/02	2382	85
Campland	12/16/02	3000	**3000**	**945**				
Campland	12/23/02	2400	**2400**	**738**	MBW21	12/23/02	**224700**	**6867**
Campland	12/26/02	1300	170	**110**	MBW21	12/24/02	**189200**	**3448**
Campland	12/27/02	140	78	**950**	MBW21	12/25/02	**488400**	**7710**
Campland	12/27/02	5200	140	78	MBW21	12/26/02	**410600**	**8820**
Campland	12/28/02	950	130	54	MBW21	12/30/02	**32550**	**3448**
Campland	1/6/03	110	80	**99**	MBW21	1/6/03	583	63
Campland	1/8/03	20	20	**399**				
Campland	1/9/03	230	230	271				

MEC SITE	DATE	TOTAL	FECAL	ENTERO	Station	Date	TOTAL	ENTERO
Campland	1/13/03	2400	**1300**	**831**	MBW21	1/13/03	368	20
Campland	1/15/03	300	230	**150**				
Campland	1/22/2003	500	**500**	**185**				
Campland	1/27/2003	40	40	31				
Campland	2/3/2003	40	40	<10	MBW21	2/3/03	462	10

*Units are in MPN Index/ 100mL for all bacteria

Table 7. Campland beach samples (data includes County of San Diego DEH samples) and estimated bird population.

12/4/02-1/15/03** Enterococcus **levels	
Mean	512.5
Standard Error	111.6567461
Median	335
Mode	271
Standard Deviation	499.3441488
Sample Variance	249344.5789
Kurtosis	2.758903854
Skewness	1.483610417
Range	1974
Minimum	31
Maximum	2005
Sum	10250
Count	20
Largest(1)	2005
Smallest(1)	31
Confidence Level(95.0%)	233.700328

1/21/03-3/10/03** Enterococcus **levels	
Mean	83.31578947
Standard Error	19.41273059
Median	52
Mode	20
Standard Deviation	84.61813086
Sample Variance	7160.22807
Kurtosis	2.349970263
Skewness	1.483019962
Range	317
Minimum	10
Maximum	327
Sum	1583
Count	19
Largest(1)	327
Smallest(1)	10
Confidence Level(95.0%)	40.78466512

12/4/02-1/15/03 Estimated Bird Population	
Mean	143.75
Standard Error	35.91594851
Median	110
Mode	70
Standard Deviation	101.585643
Sample Variance	10319.64286
Kurtosis	-0.36509283
Skewness	0.844729844
Range	290
Minimum	35
Maximum	325
Sum	1150
Count	8
Largest(1)	325
Smallest(1)	35
Confidence Level(95.0%)	84.9276621

1/21/03-3/10/03 Estimated Bird Population	
Mean	50
Standard Error	18.1757295
Median	27.5
Mode	5
Standard Deviation	51.40872633
Sample Variance	2642.857143
Kurtosis	-1.371018262
Skewness	0.733916835
Range	125
Minimum	5
Maximum	130
Sum	400
Count	8
Largest(1)	130
Smallest(1)	5
Confidence Level(95.0%)	42.97874002

Estimation Key for bird population:

<10 = 5	50-100 = 75
10-50 = 35	< 100 = calculated as number given or if range, then median used

Recommendations / Follow-up

~~1.~~ The bacteria levels within the pipe located on the Campland boat ramp are lower than those taken during the summer. However, it is suggested that additional hyper-chlorinating will further decrease the levels of bacteria within the pipe. A higher concentration and longer duration are suggested.
2. The high bacteria levels at Site 6A during the ICID investigation, in addition to high levels from this area during the weekly sampling indicates that the source of bacteria is located close to the beach. A large number of ducks have been observed during the daytime hours on the Campland beach and within the park. If the ducks are contributing to the bacteria levels it should be suggested that park goers are instructed not to feed the ducks. Educating park goers not to wash their RV sewage pipes at the wash rack will reduce further high bacteria levels within the pipe.
3. The City of San Diego and MEC Analytical will conduct further research on the potential impact of the sand at the Campland beach. This will include samples between the supralittoral zone to the infralittoral zone.
4. Contact the City of San Diego Streets Department to clean out the heavy vegetation at the diversion unit within Rose Creek, which should decrease the influence of urban run-off.
5. Placement of dye tablets in the holding tanks of the boats located on the boat dock. This procedure will further reduce and eliminate bacteria sources from boat discharges.

Follow-up

1. Campland management sent a closed circuit television (CCTV) into the pipeline that extends from the wash rack to the boat ramp. The CCTV monitoring was split into two runs; the first was conducted from the wash rack to a connection box found at the northwest end of the bicycle rental tent. The second run went from the bicycle rental tent to the boat ramp outfall. The first run showed no signs of broken piping, illegal connections or high amounts of organic debris. This second run found a heavy build-up of a bio-film on the top of the pipeline; a root intrusion on the bottom of the pipeline and a small sparrow that was found stuck between the pipeline and the root intrusion. The maintenance personnel removed the root intrusion using a rotor-rooter type system. Then a high-pressure wash was conducted using 240-degree water to remove the bio-film. The maintenance crew noticed a large amount of “organic matter and debris” during this activity. Finally, Campland management hyper-chlorinated the pipeline on two occasions. The first hyper-chlorination was conducted for eight hours. The following day the hyper-chlorination was conducted for 24 hours (1/17/2003). City of San Diego Biologists, Jayna Nystrom and Shaun Flater, took a sample for bacteria from the pipeline outfall five days after the hyper-chlorination was performed (Table 4).
2. Campland management transported the swim platform in front of the beach into Rose Creek, found of the northeastern end of the property.
3. On December 16, 2002 between the hours of 1:26 to 2:45 in the afternoon Andre Sonksen conducted a pellet count of the Campland beach. The tide height was an ebbing tide at 1.43 ft. and a flooding tide at 0.08 ft., respectively. The pellet count was performed within the supralittoral zone and infralittoral zone. The infralittoral zone had 98 pellets and the supralittoral zone had 127 pellets. The infralittoral zone had previous tidal influence prior to pellet count. Both of the zones where the pellets were observed would be tidally influenced during a tidal height greater than 2.5 ft. Several birds were observed during the pellet count however, no swimmers or dogs

were observed on the beach (Table 5). Starting on January 27, 2003 Campland management have been removing the bird pellets from the tidally influenced beach 5-7 days per week. This activity will continue for one month and may continue until further notice from the City of San Diego.

4. The Streets department is aware of the situation at the diversion unit in Rose Creek. The department is currently waiting for permit to remove the vegetation at the diversion unit.
5. SEP site MBW21 has had relatively low values since October 2, 2002. However, a sewage spill did occur, around December 25, 2002, downstream of the Rose Creek diversion unit (I-9). The spill site was at tidally influenced waters that connect to Mission Bay. The spill did not seem to increase the bacteria levels at Campland during the event time frame (Table 6).
6. Campland management will place dye tablets in the holding tanks of the boats located on the boat dock. This procedure will occur in mid-March after Dr. John Largier has completed dye studies in the area. The procedure will continue until further notice.
7. Campland management will CCTV the main sewage lines located on Campland property to determine if any structural deficiencies are observed. This activity will occur in late February and City of San Diego Biologists, Shaun Flater and Jayna Nystrom, will be notified of results.
8. Statistical analysis using raw data was performed on two time periods to determine a potential difference between time periods. Enterococcus levels and estimated bird population were averaged between 12/4/02 to 1/15/03 the values were 512.5 and 143.75, respectively. Enterococcus levels and estimated bird population were averaged between 1/21/02 to 3/10/03 the values were 83.3 and 50.0, respectively (Table 7). Bird population may have an influence on bacteria levels at Campland. However, to date this has not been tested for directly.
9. Samples taken after Campland remediation activities have indicated a significant decrease in bacteria levels within the receiving water (Figure 8a & 8b). Further analysis is needed to determine a true correlation between the two subjects.
10. To date recent samples are indicating a reduction in bacterial. Consistent remediation practices, public education and continued research will further pinpoint the source(s) of bacterial pollution at Campland.

K.4

Visitor’s Center Freshwater Dispersion Study

INVESTIGATION OF BACTERIAL SOURCES
Visitor's Center, 2590 East Mission Bay Drive

INTRODUCTION

On Friday, January 31 2003, City Storm Water staff Shaun Flater and Jayna Nystrom initiated a bacterial source identification investigation at the Visitor's Center on Mission Bay in response to elevated bacteria levels. High densities of enterococcus bacteria have been recorded during weekly sampling. These high densities were also observed during the Visual Observations component of the Mission Bay Source Identification study conducted by the City and MEC Analytical Systems, Inc. (MEC) from August through October of 2002. In order to locate potential sources of bacteria and to determine the possible influence of freshwater discharges adjacent to the site area, physical parameter measurements and water samples were collected at various selected upstream storm drain locations, pipe terminus, and offshore locations near the Visitor's Center. The study design identified three specific objectives to accomplish this goal:

1. Determine the sources and extent of the freshwater discharge at Visitor's Center.

2. Collect water samples for bacteriological analysis to identify potential sources.
3.
3. Assess the effectiveness of the upstream Mission Bay Sewage Interceptor System for each of the Visitor's Center storm drain pipes.

This report provides a summary of the study design and results of the field investigation that was undertaken on January 31, 2003.

FIELD SITE

The Visitor's Center is located on the east side of Mission Bay at Clairemont Drive. For this study, the northern end of the investigation site is defined as the area including the riprap that forms the point of the peninsula that is directly west of the Visitor's Center building. The mouth of Cudahy Creek defines the southern end of the investigation site.

There are two major potential point sources of bacteria at this site (Figure 1):

1. Two storm drains that terminate near the mid-point of the Visitor's Center beach, approximately 100 feet northwest of the public restroom (Comfort Station 1091). The storm drains are designated SD8-1 for the northern storm and SD8-2 for the southern storm drain.

2. The mouth of Cudahy Creek, which discharges on the far south end of the Visitor's Center beach. Cudahy Creek is designated SD8-3.

SD8-1: 60-inch diameter reinforced concrete pipe (RCP). There are no maps currently available for the storm drains at Visitor's Center. However, storm drain SD8-1 is thought to originate on the east side of Interstate 5, west of the railroad tracks at Ingulf Street. East of the railroad tracks at Ingulf Street is Diversion Box V-2. The diversion box consists of an approximately 12-inch tall concrete berm that directs upstream flow to the sewer line by gravity. Above the diversion box, this storm drain conveys runoff from a large residential and commercial area on the east side of Interstate 5 north of Ingulf Street. All dry weather flow from this area should be diverted at diversion box V-2. Directly downstream of the diversion and just east of the Interstate 5 off ramp at Clairemont Drive is a groundwater spring. There is perennial vegetation at this location and evidence of one homeless person encampment. During a site reconnaissance performed on January 16, 2003, the salinity of this water was measured at 3.575 parts per thousand (ppt), which is typical of freshwater. From here, the groundwater flows under Intestate 5 towards Mission Bay. It is not known if runoff from the Interstate enters SD8-1.

It is suspected that SD8-1 can be accessed west of Interstate 5 from a drain inlet located on the east side of East Mission Bay Drive, directly across the street from the entrance to the parking lot just south of the Visitor's Center. This inlet is directly in line with the storm drain east of Interstate 5 described above (for which maps are available). During the site reconnaissance on January 16, 2003, this drain was filled with water that appeared to be flowing towards Mission Bay. The salinity of the water was 24.57 ppt, suggesting a mixture of fresh and salt water. From this point, the storm drain is thought to turn to the left, at an approximate 45° angle to the termination point northwest of Comfort Station 1091. Seven samples were taken of water flowing from SD8-1 during the Visual Observations Task undertaken from August through October of 2002. Laboratory results indicated that AB411 criteria were exceeded in all of the samples. In one sample taken August 29, 2002, the enterococcus concentration was 16,310 MPN/100ml. Water was observed flowing during all of the visual observation days at a rate of approximately 5 gallons per minute (gpm). During the site reconnaissance on January 16, 2003, water was flowing from SD8-1 at about the same rate. The salinity of the water coming out of the pipe was 29.06 ppt, suggesting a mixture of saltwater (salinity of at least 30 ppt) and freshwater.

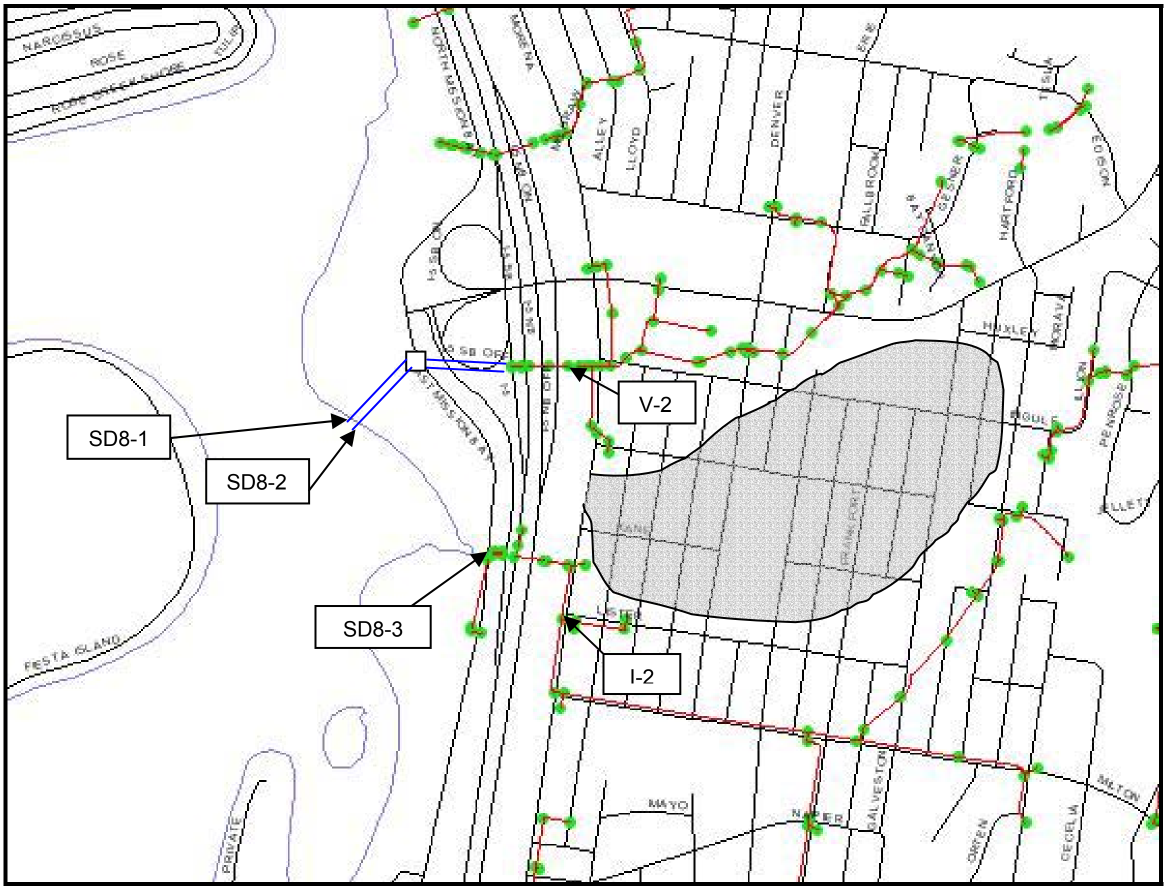
SD8-2: 60-inch diameter RCP, terminus located adjacent to SD8-1. There are no maps available for this storm drain. Thus, the source is unknown. It is possible that the pipe parallels SD8-1 for all or a portion of its length. One map that is available shows a single storm drain originating on the east side of Interstate 5 that changes to two parallel storm drains on the west side. However, the map or the storm drains stop at that point and no further information is available. During the visual observations, water was not observed flowing from SD8-2 during any of the observation days except immediately after a high tide. Thus, no samples were taken. This suggests that SD8-1 and SD8-2 may not originate from the same source.

SD8-3: SD8-3 is used to designate the mouth of Cudahy Creek. At the mouth, the drain consists of a triple 48-inch by 72-inch box culvert. Just upstream of the mouth, the southern culvert receives undiverted surface flow from street drains along both sides of East Mission Bay Drive. SD8-3 also receives undiverted flow from Interstate 5. The culverts extend under Interstate 5 and surface on the east side of the Intestate, just west of Morena Boulevard between Kane and Lister Streets. At this location, the entire width of the channel is covered with decaying eelgrass and kelp to a depth of approximately one foot. The decaying vegetation extends west under the Interstate as far as can be seen and presumably to the mouth (the source of the vegetation). Upstream of the open channel is a 72-inch culvert. Small amounts of decaying vegetation could be seen approximately 50 feet up the culvert, indicating the maximal extent of the tidal intrusion. At Morena Boulevard, the culvert forms a Y. The south leg of the Y heads south along the west side of Morena Boulevard and continues one-half block to Lister Street where Diversion Unit I-2 is located. Diversion Unit I-2 diverts dry weather flows from a large residential area south of Lister Street and east of Denver Street. Flow is diverted by a berm in the I-2 diversion box that directs water via a pump to the sewer main running along the west side of Morena Boulevard. The east leg of the Y runs east under Morena Boulevard, draining a small area between Morena Boulevard and Denver Street, and between Jellet Street and Lister Street. Surface water in this area flows undiverted to the mouth of Cudahy Creek. Characteristics of the storm drains that discharge to Visitor's Center are summarized in Table 1.

Table 1. Summary of storm drains in Visitor's Center.

Number	Latitude	Longitude	Terminus Diameter	Diversion Status[1]	Diversion Type	Drainage Description
SD8-1	32°47.312	117°12.574	60"	D; V-2	Berm in Diversion Box, gravity feed to sewer	large residential and commercial area on the east side of Interstate 5 north of Ingulf Street
SD8-2	32°47.313	117°12.571	60"	D; V-2	Berm in Diversion Box, gravity feed to sewer	unknown
SD8-3	32°47.219	117°12.485	48" x 72" triple box culvert	D; I-2	Berm in Diversion Box, pumped to sewer	Upstream: diverted dry weather flows from a large residential area south of Lister Street and east of Denver Street; also a small area between Morena Boulevard and Denver Street and between Jellet Street and Lister Street Downstream: undiverted surface flow from street drains along both sides of East Mission Bay Dr.; also undiverted flow from Interstate 5

[1] D = Diverted, I = Interceptor consists of a diversion berm and a gravity feed to a pump station, V = Diverted water flows to sewer by gravity, no pump involved.



Green dots = storm drain inlets/manholes/junctions
Red lines = storm drain conveyance system
Blue lines = suspected storm drain conveyance system
Shaded area = undiverted area of watershed
V-2 = Diversion Box, Morena Blvd. and Ingulf Street
I-2 = Interceptor Pump Station, Morena Blvd. and Lister Street

Figure 1. Map of the Visitor's Center Storm Drain System.

METHODS

The primary goal of this study, as identified in the Introduction, was accomplished through the identification of four main objectives. These objectives were achieved via several tasks, as described below.

Objectives 1: Determine the extent of the freshwater discharge at Visitor's Center.

The extent of the freshwater discharge at Visitor's Center was determined by measuring water quality physical parameters such as the salinity, temperature, and pH of the bay water surrounding the County sampling point for this site (SD8-1) and the outlet of Cudahy Creek (SD8-3). Temperature and pH were measured with a Sentron probe (Model 1001) and salinity was evaluated with a Spartan hand refractometer (Model A366ATC). All measurements were taken at a depth of approximately 6 inches below the water surface. Differences in salinity values were the main characteristic by which the extent of any freshwater discharges were delineated. Two assessments were conducted on January 31, 2002.

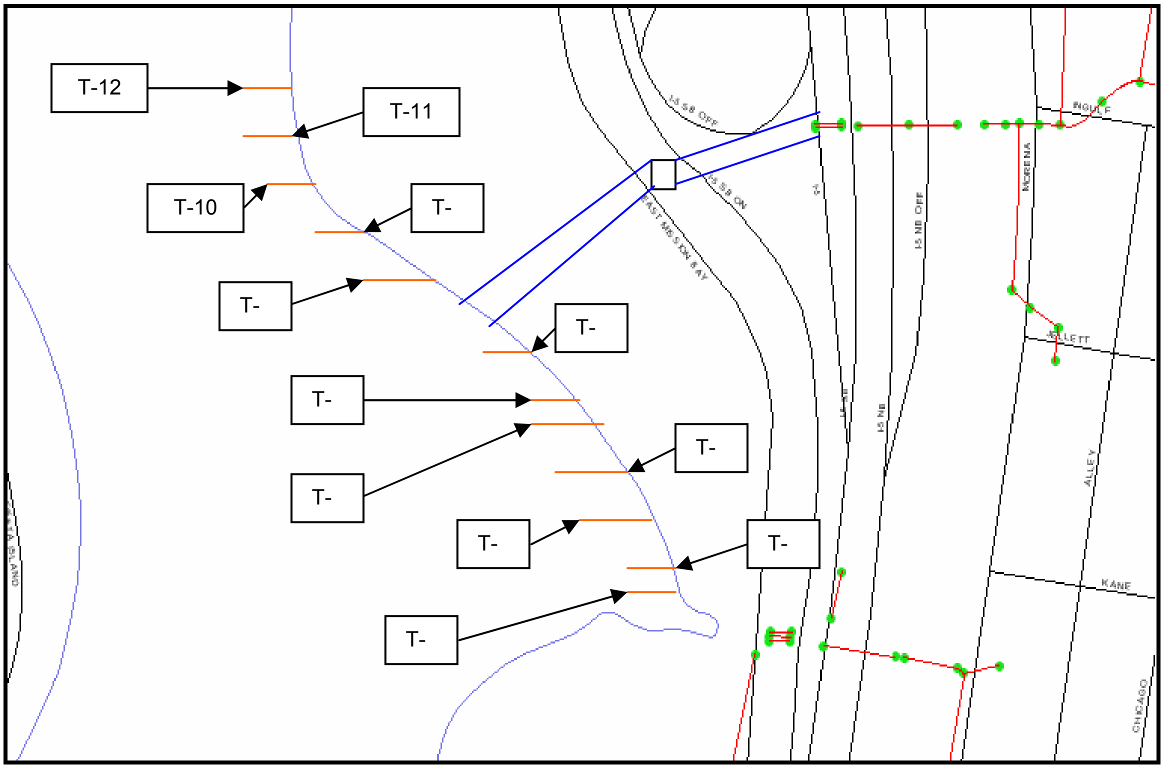
1. slack low tide (0814 hrs); and
2. slack high tide (1522 hrs)

During each assessment, physical parameter measurements were taken from pre-determined locations in Mission Bay. The following is a summary of the steps that were involved in this process:

Task 1 – Using a surveyor tape, the distance of the beach to be sampled was measured. Sampling took place from south to north, starting at the mouth of Cudahy Creek and continuing north to the tip of the peninsula formed by the riprap wall directly in front of the Visitor's Center building.

Task 2 – A survey flag was placed at the south end of the sampling area a few feet above the expected high tide mark. This site was designated T1 (for Transect 1). A flag was then placed every 100 feet along the shoreline to the other end of the sampling area, totaling 12 transects (Figure 2). These points were designated T2, T3, etc., and the latitude and longitude of the starting points of all transects were recorded.

Task 3 – At the first transect (T1), one end of the surveyor's tape was anchored to the shore at the water's edge with a spike. At this point, one person made measurements and one person recorded the data on the field data sheets. The measurer then waded into the water with the survey's tape and water quality probes along a visual transect perpendicular to the shore. The distance from the spike and the water quality parameters were recorded every five feet. Each location where a measurement was taken had a sample number designated by the transect number and distance from the spike. Measurements were continued until the water quality parameters were the same as those of ambient bay water. This process was repeated for all transects in the sampling area. Recorded data is included at the end of the report.



Orange lines = transect line locations

Figure 2. Map of the Visitor's Center transect line locations.

Objectives 2 and 3: Determine the sources of freshwater and potential bacterial contamination at Visitor's Center.

The sources of freshwater and potential bacteria were determined by taking water quality physical parameter measurements and water samples for bacterial analyses at all point and non-point sources. This task took place after the completion of Task 1, and microbiological samples were only collected during the afternoon low tide as to eliminate the effects of bay water dilution on bacterial densities in the storm drain runoff. Procedures used for field collection and laboratory analyses of bacteriological samples are discussed after the description of Objective 4. The activities that were involved in conducting Objectives 2 and 3 are summarized below:

- Water quality physical parameters were analyzed from SD8-1 at the terminus, from the drain on the east side of East Mission Bay Drive, and from the spring on the east side of Interstate 5. In addition, six samples were collected for analyses of total coliform (TC), fecal coliform (FC), and enterococcus (ENT). Sampling locations included SD8-1 at the pipe terminus (sample SD8-1), approximately 35 feet offshore from the pipe terminus in the Bay (sample SD8-1A), the drain on the east side of East Mission Bay Drive (sample SD8-1B), and three equally distributed locations within the spring on the east side of Interstate 5 (labeled SD8-1C, SD8-1D, and SD8-

1E from west to east within the spring, respectively). Results of water quality and bacteria analyses are included at the end of the report.

- Water quality parameters from SD8-2 were not analyzed and no samples were collected for bacterial analyses because flow was not observed from the outlet during the afternoon low tide sampling period.

- One sample (sample SD8-3) was collected for bacterial analyses (TC, FC, ENT) from SD8-3 at the mouth of Cudahy Creek before the flow entered the Bay. In addition, water quality physical parameters were analyzed at the spring upstream of SD8-3 on the east side of Interstate 5. The field crew was unable to collect a sample for bacterial analyses (TC, FC, ENT) at this spring location due to insufficient flow volume.

- Three samples were collected for bacterial analyses (TC, FC, ENT) from groundwater seeps located approximately 5 feet east of transects 11 and 12, near the northern end of the Visitor's Center investigation site in the area including the riprap that forms the point of the peninsula. These samples were labeled SD8-SPR-1, SD8-SPR-2, and SD8-SPR-3 from south to north, respectively.

- Flow from all flowing storm drains was measured and recorded on the water quality data sheets. GPS coordinates of all sites of interest were also recorded on the data sheets.

Objective 4: Assess the effectiveness of the dry weather diversion system at each site.

Concurrently with taking water quality physical parameter measurements at the two upstream spring locations for SD8-1 and SD8-3, the field crew attempted to assess the effectiveness of the diversion systems at both sites. The City biologists observed Diversion Box V-2, located upstream of SD8-1, to be functioning properly. All flowing water was stopped from traveling downstream in the storm water conveyance system by the diversion berm and was instead redirected into the grate directly in front of the pump unit. The flow entering the grate was not impeded by debris. It was not possible to visually confirm that the diversion system for SD8-3 was functioning properly as the diversion berm and grate are subsurface. However, confirmation was obtained from the City Metropolitan Wastewater Department (MWWD) that the aforementioned pump systems for both sites were operational on January 31, 2003 and that the flow was being pumped into the sanitary sewer system.

Bacteriological Sampling and Analyses

Field Sampling

To assure consistency among results, the protocol for collection of the site samples was the same as that employed by the San Diego County of Environmental Health. Samples were collected in sterile, 100-ml plastic bottles containing sodium thiosulfate. The bottles were sealed in clear plastic bags until use. The sampling technician first applied a waterless sanitizing gel and then put on a pair of Nitrile gloves. The sample bottle was removed from the plastic bag, labeled, and placed into a clamp attached to the end of four foot long PVC pole. The sampling technician carefully waded into the water to a depth of approximately 12 inches and removed the lid from the sample bottle. The bottle was extended in front of the sampler (away from shore) with the sampling pole, then inverted and submerged four to six inches below the water surface. In a sweeping motion, the pole was rotated so the opening of the bottle was facing to the side. The pole was then swept sideways to take the water sample. Samples taken within waist deep water were obtained using a paddleboard and following the standard sampling procedures discussed above. The bottle was filled once, drained to the desired volume so that a small amount of air remained in the container, and capped. No surface residue, sediment, or debris was allowed to enter the sample bottle. If debris or sediment was evident in the bottle, the sample was discarded and the site was re-sampled with a new, sterile bottle. After collection, the sample was re-sealed in the plastic bag and placed on “Blue Ice” packs.

Spot samples were collected using the same aseptic technique as employed for the site samples, but in most cases the sampling pole was not used. A courier picked up the bacterial samples from the field and delivered them to the laboratory within the required holding time. All samples were kept on blue ice in the dark from the time of sample collection until delivery to the analytical laboratory.

Laboratory Analyses

All bacteria samples were analyzed at the MEC Analytical Systems Microbiology Laboratory in Carlsbad, California. The three indicator bacteria enumerated in this study were total coliform, fecal coliform, and enterococcus. In the laboratory, total and fecal coliforms were analyzed using multiple tube fermentation based on Standard Methods 9221B&E. Enterococcus were analyzed by using a chromogenic technique (Enterolert), based on Standard Method 9223.

RESULTS

Water quality physical parameter measurements along the twelve transects during high and low tides did not demonstrate significant spatial or temporal trends in salinity, pH, or temperature. The salinity survey detected values typical of marine waters that were consistent with those measured during past sampling dates, with no evident spatial trends of freshwater discharges. The pH data obtained during the flooding tide had distinct differences in value from T1 to T12. However, the highly variable values may have been due to prolonged instrument usage. Variations in recorded temperatures appear to be normal for the winter season, and temperature data collected during the ebbing and flooding tidal periods demonstrate trends similar to those observed from past sampling dates. Transect water quality data is included at the end of the report.

However, water quality measurements at point sources and specified upstream locations did indicate variations in salinity values. Two freshwater springs were observed to the northwest and southwest of the mouth of Cudahy Creek (Figure 3). Salinity at both of these locations was 7 ppt and numerous birds where observed drinking from the springs. Salinity measurements were also taken at several locations along the SD8-1 pipeline. The rate of flow out of the SD8-1 pipe outlet during the ebbing tide was measured at 390 milliliters/minute (0.1 gpm) and the salinity was 30ppt. The water at sampling location SD8-1B (the inlet east of East Mission Bay Drive, upstream of the SD8-1 outlet) had a salinity value of 25ppt. Three additional samples (SD8-1C through E) were obtained in a culvert at the beginning of the pipeline for SD8-1, each of which had a salinity value between 5 and 5.5 ppt.

Spatial bacterial analysis resulted in the identification of specific locations where bacterial counts exceeded AB411 standards. Point sources of bacteria were generally associated with the storm water conveyance system, including outlets and associated upstream locations, rather than non-point offshore sampling locations. Bacteria samples taken in waist deep water offshore of SD8-1 and SD8-3, and from the springs within the riprap directly west of the Visitor's Center facility had low bacterial counts during both tidal stages. However, samples taken within and near the two storm drain outlets (SD8-1 & SD8-3) had significantly higher bacterial counts than the offshore samples (although the decrease in bacterial values sampled downstream of the pipe outlet may be due to the diluting effect of bay water). Similarly, bacterial densities detected upstream of the SD8-1 pipe outlet at sampling location SD8-1B were much greater than those recorded downstream of the pipe outlet. In the culvert at the beginning of the pipeline for SD8-1, bacterial values were significantly less than the two samples taken at SD8-1 and at SD8-1B. The diversion berm and interceptor pump station was observed and confirmed to be working correctly during the date of the field research.

Flow was not observed from the SD8-2 outlet during low tide and thus no bacteria samples were collected. One sample collected at the mouth of Cudahy Creek (SD8-3), where the flow rate was measured at 0.035 gal/min, indicated elevated bacteria densities. However, inadequate flow volume at the upstream spring prevented further sample collection at that location. Bacteria samples were also unobtainable at the two freshwater springs on either side of the creek mouth due to excessive sediment in the sample bottle and syringe, although samples collected just offshore of these springs resulted in low bacteria counts.

Current research on tidal fluctuations near Visitor's Center indicates ebbing water movement toward the west and north, whereas flooding water moves toward the east and south (Figure 4). The influence of these tidal movements on bacterial levels was analyzed for data collected at SD8-1, resulting in a strong relationship between rapid tidal movement and increased values of enterococcus (Figure 5). The data pool for this analysis was composed of weekly samples obtained by the City of San Diego since November 4, 2002 and by the County of San Diego Department of Environmental Health since December 16, 2002. A correlation was found between high tidal retreat rates (the difference of the peak tidal height and sample tidal height divided by the time frame [total minutes] between the two tidal heights) and elevated enterococcus values within the bay water. The correlation coefficient was 0.6369 for a samples size of 13. In addition, ebbing tides with a height greater than 5.5 feet had greater enterococcus values at the sampling site location.

Statistical analysis was conducted to determine any potential influence on bacteria levels from the localized bird population. Since November 4, 2002, thirteen samples were collected concurrently with performing visual bird surveys at Visitor's Center. Regression analysis was performed to determine if there is a correlation between enterococcus levels and bird populations. The regression analysis found no significant correlation between the bird population and enterococcus levels (Figure 6).

DISCUSSION

The results of the water quality physical parameter measurements conducted at each of the twelve transects during both tidal stages did not indicate the development of a freshwater lens during an ebbing tide. Several potential freshwater sources were identified, including the two springs to the northwest and southwest of the Cudahy Creek terminus and the spring upstream of SD8-1 (on the east side of Interstate 5). However, the magnitude of these freshwater flows appeared negligible. Brackish water (salinity of more than 5 ppt and less than 30) was found at sampling points SD8-1, SD8-1B, SD8-3, and the riprap at the northern end of the site area. But again, minimal flow rates combined with relatively high salinity values did not result in a freshwater discharge having a measurable extent.

Tidal analysis results conducted at SD8-1 indicate a strong relationship between rapid tidal movement and increased values of enterococcus. Ebbing spring high tides had statistically greater levels of enterococcus when compared to ebbing neap high tides (Figure 5). Three relationships are suggested for these results. The first is that enterococcus is surviving, growing and potentially reproducing in the high organic, dark and moist environmental conditions of the SD8-1 storm drain pipeline, somewhere adjacent to the SD8-1B sampling point. Thus, the spring high flooding tide picks-up bacteria within the pipeline, then when the tide ebbs, the sampler is obtaining bacteria that "originated" from within the storm drain pipeline.

The second relationship is that bacteria in samples collected from the storm drain actually originated from a warm-blooded source and the bacteria are present within the bay water. The spring flooding tide transports the bacteria into the pipeline, then during the spring ebbing tide when the sampler obtains a sample, the detected bacteria originated not from the pipeline but from the peripheral bay water that is retreating from the pipe. While samples taken within and near the outlets at SD8-1 and SD8-3 had elevated bacterial counts, samples taken offshore of these locations and additional locations within the Bay water did not exceed AB411 standards. Data obtained on January 31, 2003 indicated low enterococcus levels at distances greater than approximately ten feet from the SD8-1 terminus. These results indicate that the source of enterococcus does not appear to be from the offshore bay water. Rather, it can be deduced that the source of bacteria may be localized near shore and within the pipelines (SD8-1 & SD8-3). Sources of enterococcus located near the shore include bird fecal pellets on the beach sand and decomposing eel grass with the potential for bacterial re-growth located directly next to the terminus of both storm drain outlets. Enterococcus sources within the pipelines may include upstream sources and bacteria that are potentially surviving and re-growing within the pipeline.

The third relationship is a combination of the first and second scenarios. The source of bacteria within the SD8-1 pipeline is derived from warm-blooded sources located outside of the pipeline itself (i.e., birds, human sources, mammals and epiphytic relationships on plants) and/or upstream sources such as contaminated groundwater. However, according to data collected at Sites SD8-1C, SD8-1D, and SD8-1E, groundwater does not appear to be a significant source of bacterial pollution. In addition, the optimal environment of the SD8-1 pipeline allows for the transported bacteria to grow, survive and potentially reproduce. This activity may have been observed during other research conducted by City of San Diego Biologists. At one study location, a pipeline had a biofilm and a dead bird within the structure. Removal of the dead bird, hydro-jetting the pipeline using 240 degree high pressured water to remove the biofilm, in addition to several hyper-chlorination activities caused the enterococcus levels to decrease substantially from initial enterococcus values. Therefore, it is reasonable to conceive that the SD8-1 pipeline may have similar parameters thus leading to increased enterococcus levels when the sampler obtains water retreating from within the pipeline. It is our recommendation that the pipeline for SD8-1 be inspected via closed-circuit television (CCTV) to identify possible bacterial sources and cleaned in any manner possible to remove debris.

Temporal analyses over nine years indicate a potential correlation of bird population levels and the increase of bacteria levels. Since November 4, 2002, thirteen samples were collected concurrently with performing visual bird surveys at Visitor's Center. Regression analysis performed on this data pool found no significant correlation between the bird population and enterococcus levels. These results suggest that the population of the birds observed during the sampling event did not influence the detected enterococcus levels. This analysis may be complicated because of the frequent relocation of several of the bird species. It has been observed on multiple occasions that many of the birds will relocate in large groups around several locations near the sampling site at Visitor's Center. In addition, birds such as seagulls frequently fly onto and away from a beach depending upon the amount of people on the beach and park goers feeding the birds. However, for the time frame when these samples were taken, we may be able to deduce that bird population levels do not correlate with enterococcus values.

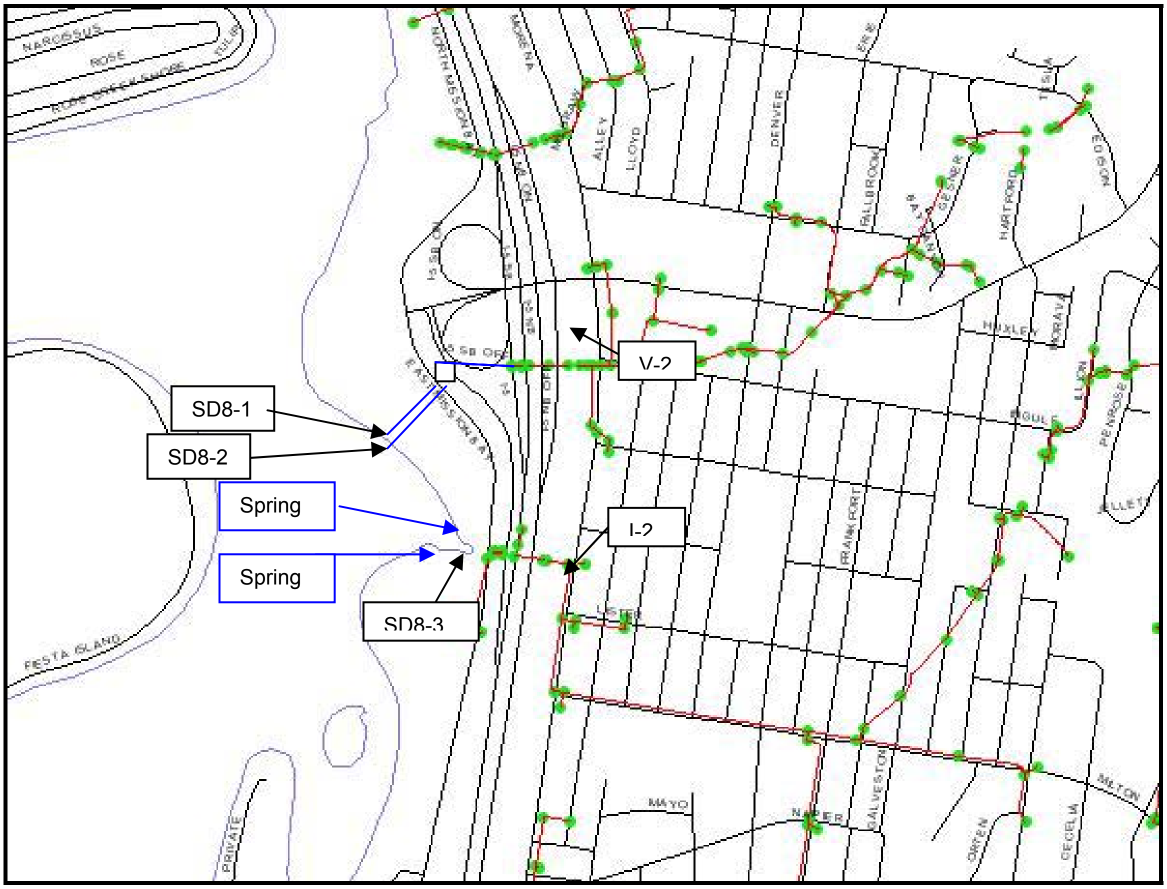


Figure 3. Freshwater springs located near Visitor's Center and Cudahy Creek.

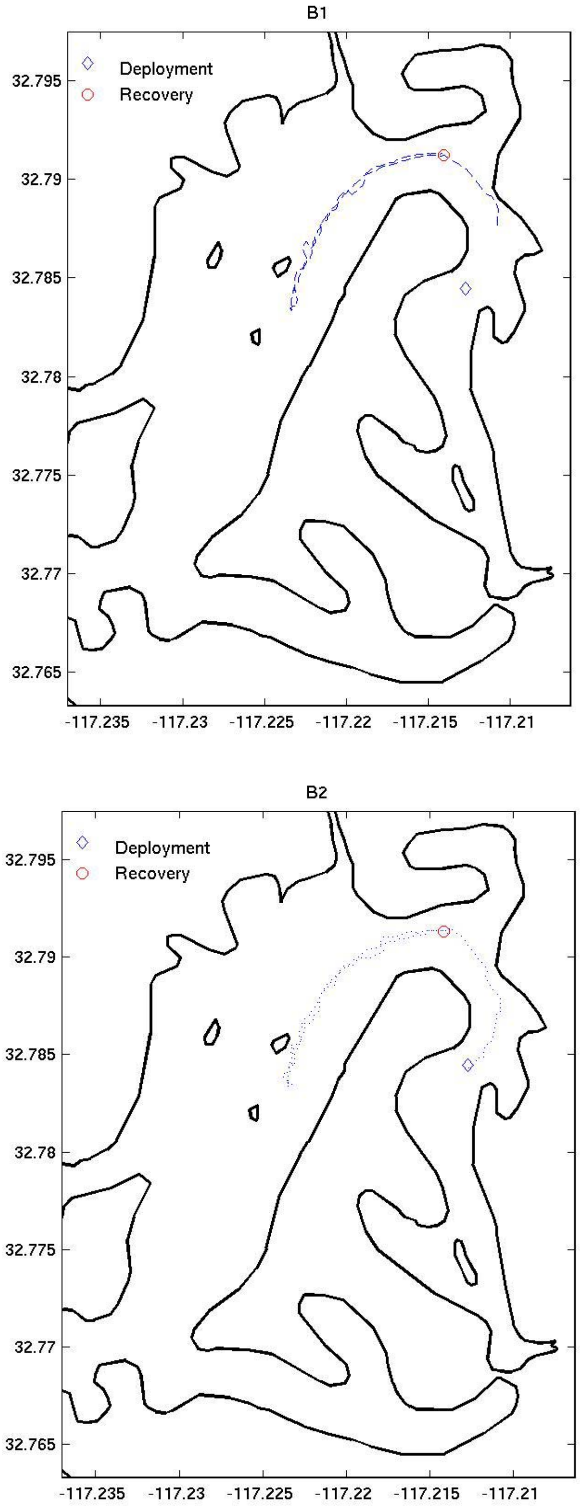
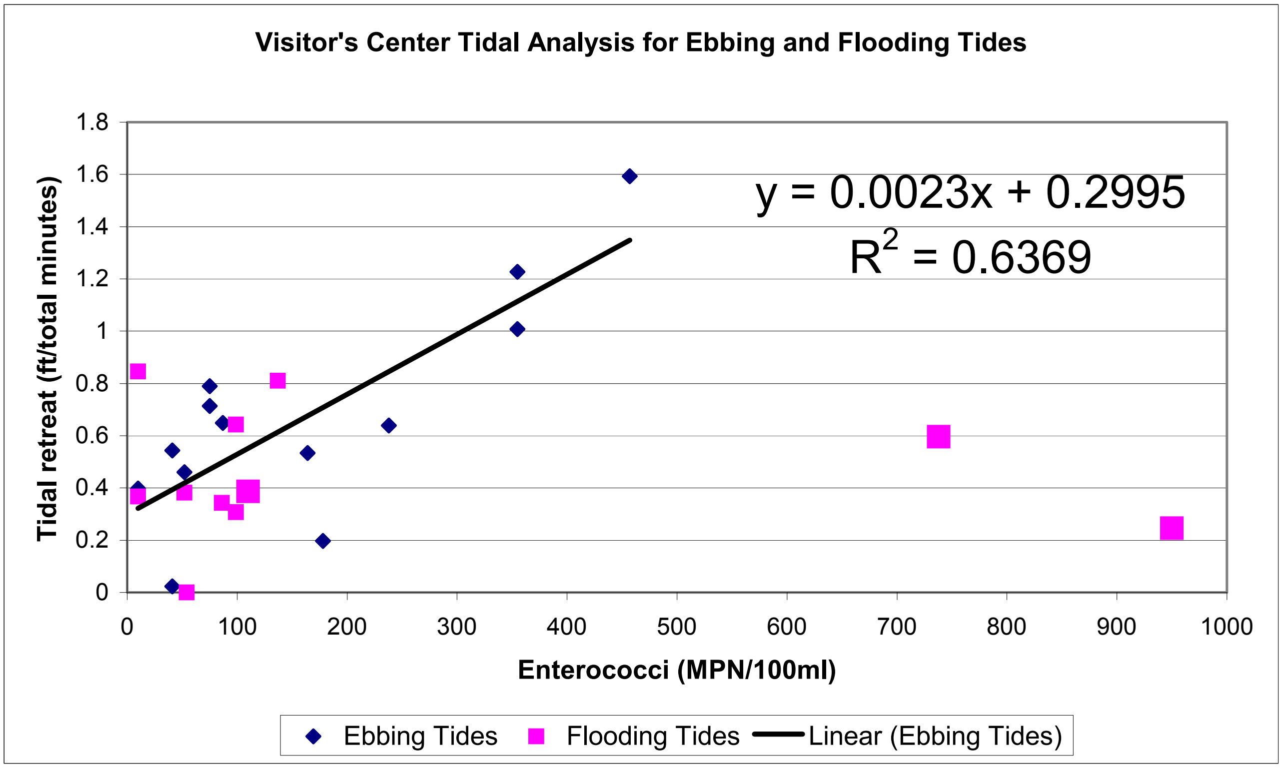
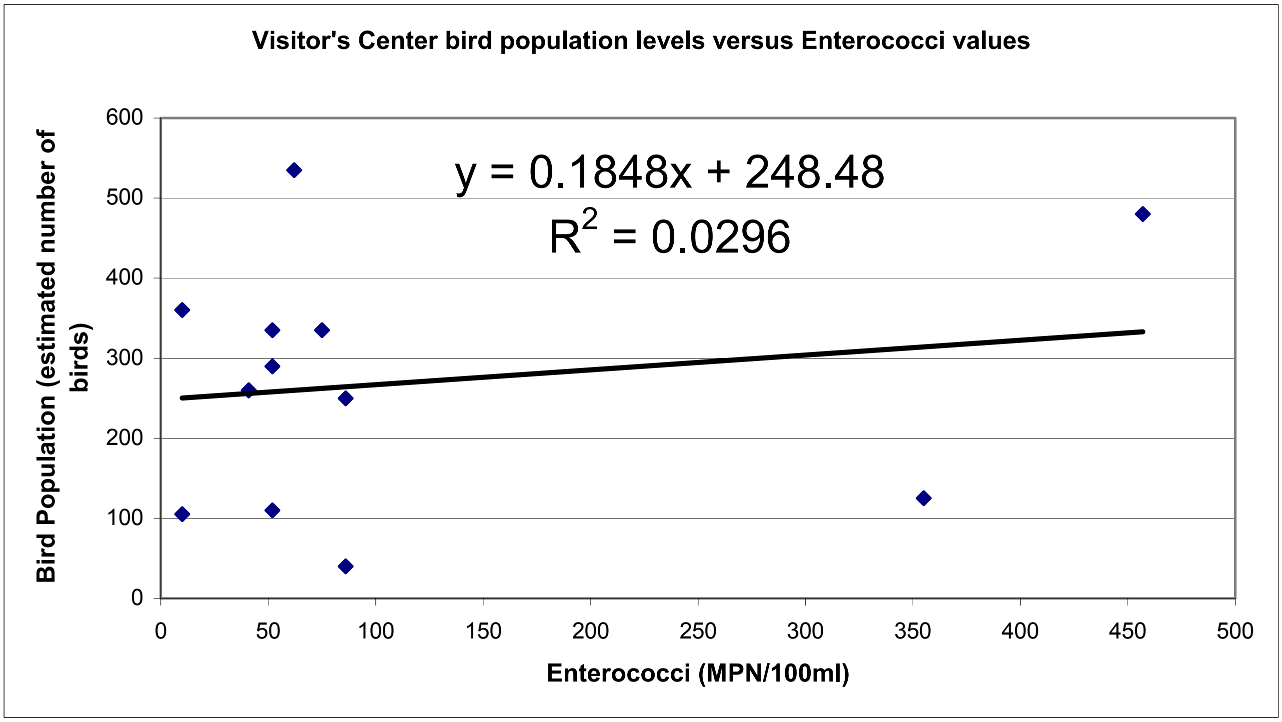


Figure 4. Current movement west of Visitor's Center during ebbing and flooding tidal variations.



Note: Data includes City of San Diego and County of San Diego samples. The County of San Diego samples were only analyzed if a sample time was present.
Note: The three larger datum points were taken during a sewer spill at a tidally influenced location of Rose Creek. In addition, rainfall levels during the weekend prior to the week of sampling was 1.25 inches.

Figure 5. Regression Analysis of flooding and ebbing tides of SD8-1, 2 outfalls.



Note: Data includes City of San Diego only.

Figure 6. Regression Analysis of bird population levels and enterococcus values.

Transect Water Quality Data.

Date	Site	Time	Sample Number	Temperature (°C)	pH	Salinity (ppt)	Site Description/Comments
High Tide Transects (high tide at 8:11am = 6.70ft.)							
1/31/03	T1	7:58	T1-0	16.3	8.3	29*	32 47.234N, 117 12.494W
1/31/03	T1	8:02	T1-5	16.5	8.3	29*	Note: Conductivity meter used to measure*
1/31/03	T1	8:06	T1-10	16.5	8.3	29*	salinity for T1-0 through T2-25
1/31/03	T2	8:10	T2-0	16.4	8.3	30*	32 47.248N, 117 12.501W
1/31/03	T2	8:14	T2-5	16.4	8.3	28*	
1/31/03	T2	8:16	T2-10	16.6	8.3	30*	
1/31/03	T2	8:20	T2-15	16.6	8.3	29*	
1/31/03	T2	8:23	T2-20	16.6	8.3	31*	
1/31/03	T2	8:26	T2-25	16.8	8.3	30*	
1/31/03	T3	8:34	T3-0	16.6	8.33	35	32 47.263N, 117 12.512W, salinity
1/31/03	T3	8:37	T3-5	16.8	8.34	36	Note: Refractometer used to measure
1/31/03	T3	8:40	T3-10	16.8	8.32	36	salinity for T3-0 through T12-5
1/31/03	T4	8:44	T4-0	16.7	8.33	35	32 47.277N, 117 12.524W
1/31/03	T4	8:45	T4-5	16.9	8.32	36	
1/31/03	T4	8:46	T4-10	16.9	8.32	36	
1/31/03	T5	8:48	T5-0	16.7	8.36	36	32 47.289N, 117 12.537W
1/31/03	T5	8:50	T5-5	16.9	8.32	37	
1/31/03	T5	8:52	T5-10	16.9	8.32	36	
1/31/03	T5	8:53	T5-15	16.9	8.33	36	
1/31/03	T6	8:56	T6-0	16.9	8.32	35	32 47.300N, 117 12.552W
1/31/03	T6	8:58	T6-5	16.9	8.33	36	
1/31/03	T6	8:59	T6-10	16.9	8.33	36	
1/31/03	T7	9:05	T7-0	16.9	8.32	35	32 47.301N, 117 12.568W
1/31/03	T7	9:08	T7-5	16.9	8.33	36	
1/31/03	T7	9:09	T7-10	16.9	8.33	36	
1/31/03	T8	9:11	T8-0	16.8	8.27	36	32 47.317N, 117 12.585W
1/31/03	T8	9:12	T8-5	17.0	8.28	36	Flow here moving east to west
1/31/03	T8	9:21	T8-10	17.0	8.31	35	
1/31/03	T8	9:23	T8-15	17.0	8.32	36	
1/31/03	T8	9:24	T8-20	17.0	8.32	36	
1/31/03	T9	9:26	T9-0	17.2	8.31	37	32 47.328N, 117 12.600W

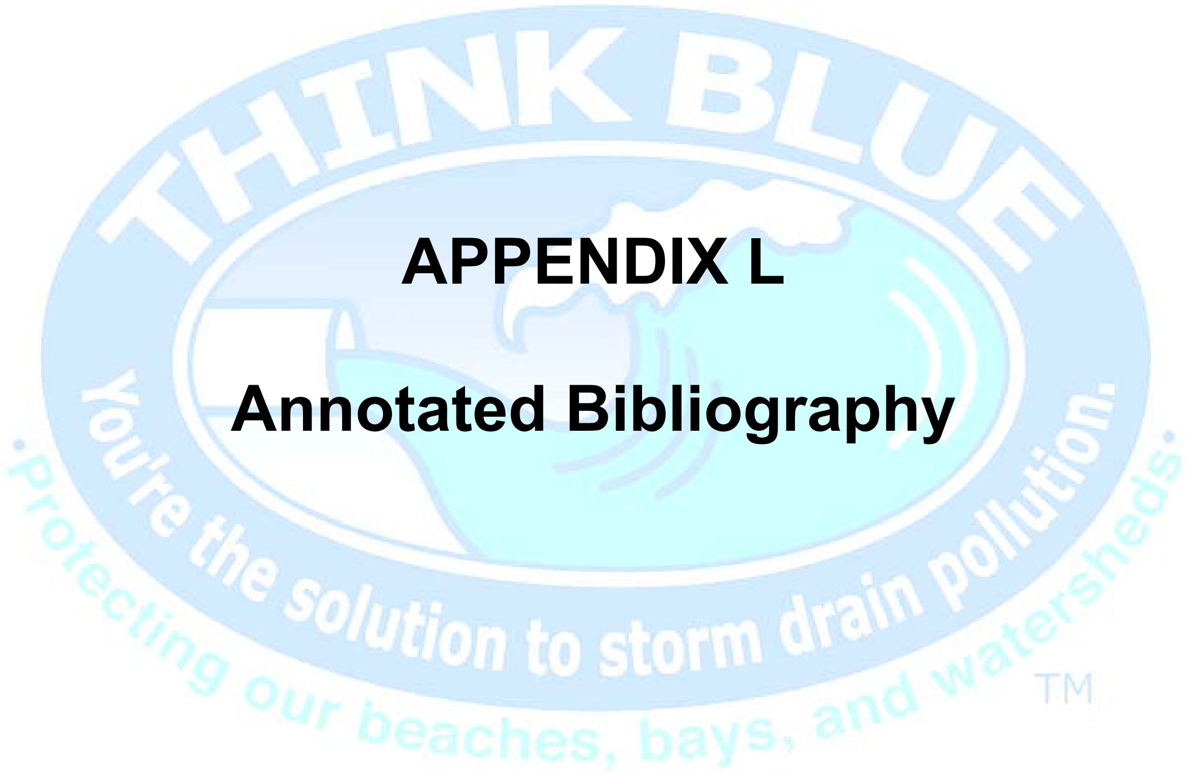
Date	Site	Time	Sample Number	Temperature (°C)	pH	Salinity (ppt)	Site Description/Comments
1/31/03	T9	9:29	T9-5	17.2	8.31	35	
1/31/03	T9	9:30	T9-10	17.2	8.32	36	
1/31/03	T9	9:31	T9-15	17.2	8.33	36	
1/31/03	T10	9:34	T10-0	17.0	8.30	36	32 47.338N, 117 12.616W
1/31/03	T10	9:36	T10-5	17.0	8.30	36	
1/31/03	T10	9:37	T10-10	17.2	8.32	36	
1/31/03	T11	9:41	T11-0	17.2	8.30	36	32 47.350N, 117 12.629W
1/31/03	T11	9:44	T11-5	17.2	8.33	36	
1/31/03	T11	9:46	T11-10	17.2	8.33	36	
1/31/03	T12	9:50	T12-0	16.9	8.29	36	32 47.361N, 117 12.644W
1/31/03	T12	9:51	T12-5	16.9	8.30	36	
1/31/03	T12	9:53	T12-10	16.9	8.29	36	
Low Tide Transects (low tide at 15:22 = -1.6ft.)							
1/31/03	T1	15:08	T1-0	20.5	8.7	35	214ft west of original site
1/31/03	T1	15:11	T1-5	20.5	8.7	35	
1/31/03	T2	15:20	T2-0	23.5	8.4	34	224ft west of original site
1/31/03	T2	15:22	T2-5	23.0	8.5	35	
1/31/03	T2	15:25	T2-10	19.5	8.5	35	
1/31/03	T3	15:28	T3-0	20.5	8.6	35	107ft west of original site
1/31/03	T3	15:30	T3-5	20.6	8.5	35	
1/31/03	T4	15:34	T4-0	19.4	8.2	35	85ft west of original site
1/31/03	T4	15:36	T4-5	19.4	8.5	35	
1/31/03	T5	15:38	T5-0	19.5	8.1	35	91.1ft west of original site
1/31/03	T5	15:39	T5-5	19.0	8.0	35	
1/31/03	T6	15:43	T6-0	19.3	7.7	35	91.2ft west of original site
1/31/03	T6	15:44	T6-5	19.0	7.9	35	
1/31/03	T7	15:47	T7-0	19.4	8.5	35	425ft south of original site
1/31/03	T7	15:49	T7-5	19.1	7.6	35	
1/31/03	T8	15:52	T8-0	20.0	7.3	35	300ft south of original site
1/31/03	T8	15:55	T8-5	20.6	7.3	35	
1/31/03	T9	15:57	T9-0	19.5	7.5	35	86ft south of original site
1/31/03	T9	15:59	T9-5	19.2	6.7	35	
1/31/03	T9	16:00	T9-10	19.0	6.7	35	
1/31/03	T10	16:03	T10-0	18.7	6.65	35	73ft south of original site
1/31/03	T10	16:05	T10-5	18.6	6.62	35	

Date	Site	Time	Sample Number	Temperature (^{o}C)	pH	Salinity (ppt)	Site Description/Comments
1/31/03	T11	16:08	T11-0	18.5	6.80	35	60ft south of original site
1/31/03	T11	16:10	T11-5	18.5	6.88	35	
1/31/03	T11	16:12	T11-10	18.0	6.81	35	
1/31/03	T12	16:16	T12-0	19.0	6.95	35	200ft south of original site
1/31/03	T12	16:18	T12-5	18.5	6.86	35	

Results of water quality and bacterial analyses.

Sample ID	Sample Description	Time	Tidal Stage[1]	Temp. (°C)	pH	Salinity (ppt)	TC (MPN/100ml)	FC (MPN/100ml)	ENT (MPN/100ml)
SD8-1	Outlet terminus 32 47.313N, 117 12.600W	13:10	E	ND	ND	ND	700	230	355
SD8-1A	35' offshore from SD8-1,2 outlet	12:54	E	19	8.3	35	170	170	86
SD8-1B	Inlet east of East Mission Bay Dr.	13:10	E	26	8.24	25	800	140	1043
SD8-1C	Spring upstream of SD8-1,2 (westernmost)	14:00	E	21.2	7.99	5	1,300	80	164
SD8-1D	Spring upstream of SD8-1C,E (middle)	14:03	E	21.0	8.03	5.5	170	80	52
SD8-1E	Spring upstream of SD8-1,2 (easternmost)	14:05	E	21.1	8.15	5	230	20	189
SD8-3	Mouth of Cudahy Creek 32 47.214N, 117 12.486W	13:50	E	ND	ND	ND	500	<20	262
SD8-SPR-1	Spring approx. 5 feet south of T11	13:35	E	ND	8.80	35.6	300	300	52
SD8-SPR-2	Spring approx. 5 feet east of T11	13:44	E	24.3	9.10	35	<20	<20	<10
SD8-SPR-3	Spring approx. 5 feet east of T12	13:47	E	21.3	8.9	31	<20	<20	<10
SD8-1 OUTLET	Outlet terminus 32 47.313N, 117 12.600W	16:20	F	ND	ND	ND	170	40	148
SD8-1 OFFSHORE	Offshore from outlet terminus 32 47.310N, 117 12.598W	16:35	F	ND	ND	ND	170	170	20
SD8-3 FIREPIT	Spring northwest of Cudahy Creek, 32 47.256N, 117 12.524W	16:40	F	ND	ND	ND	300	300	74
SD8-3 PALMTREE	Spring southwest of Cudahy Creek, 32 47.207N, 117 12.553W	16:45	F	ND	ND	ND	170	170	10

[1] E = ebbing tide, F = flooding tide
ND = no data



APPENDIX L

Annotated Bibliography

BIRDS

Alderisio, K.A. and N. DeLuca. 1999. Seasonal enumeration of fecal coliform bacteria from the feces of ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). Applied and Environmental Microbiology 65:5628-5630.

The New York City Department of Environmental Protection initiated a two-year study to investigate the relationship between waterfowl presence and fecal coliform concentrations in the Kensico Reservoir. It had been observed that elevated FC concentrations were detected in autumn and winter, which directly coincided with the increased roosting activities. Fecal samples were collected from 249 ring-billed gulls (*Larus delawarensis*) and 236 Canada geese (*Branta Canadensis*) between September 1995 and September 1997. The droppings were collected in situ immediately after defecation was observed, and sample analysis included average FC concentration, weight, and seasonal variation for both bird species. Results indicated that fecal matter from ring-billed gulls contains more FC per gram than that of the Canada geese. The 249 gull samples averaged 3.68×10^8 FC/g of feces while the 236 goose samples averaged 1.53×10^4 FC/g. Seasonal FC concentrations from the geese were variable, whereas the seasonal FC averages for gulls were fairly stable. It was calculated that the potential FC contribution to surface waters from gull and goose feces is approximately 1.77×10^8 and 1.28×10^5 FC per fecal deposit. Additionally, analysis of several old, sun-dried goose fecal samples yielded FC concentrations between 8.2×10^2 and 3.0×10^5/g. The results of this study suggest that localized bird populations can significantly impact bacteriological water quality.

Levesque, B., P. Brousseau, F. Bernier, E. Dewailly, and J. Joly. 2000. Study of the bacterial content of ring-billed gull droppings in relation to recreational water quality. Water Research 34:1089-1096.

Levesque *et al.* conducted a study of three colonies of ring-billed gulls (*Larus delawarensis*) in the freshwater portion of the St. Lawrence River valley, Canada. The authors' objective was to evaluate the risk for swimmers using recreational waters that are contaminated with gull droppings containing various pathogenic bacteria. A second aspect of the study was to verify the validity of Canada's recreational water quality standard of 200 FC/100ml for freshwater basins by calculating the relationship between the number of pathogens and FC concentrations in the gull droppings. Fecal samples were collected bi-weekly from late April to mid-July, 1996. They found the fecal coliform geometric mean was 2.1×10^8 g^{-1} for adult and juvenile ring-billed gulls, with minimal difference in bacteria concentrations as a function of age groups, colony, or sampling date. The authors concluded ring-billed gulls, along with many other species of gulls, contribute significantly to the microbiological contamination of recreational waters. Additionally, it was determined that the Canada recreational water quality guideline (200 FC/100ml) is sufficient in protecting bathers from gull-originated fecal pollution, based on calculations involving average FC and pathogen concentrations. Weaknesses of the study, as identified by the authors, included a limited sampling time (only one summer), the omission of impacts from soil or sand contamination, and a lack of qualifying the effects of direct contact by bathers (such as children) with gull droppings. The authors also suggest means of abating the problem, such as limiting anthropogenic food supplies by educating the public not to feed birds.

Kisner, D. 2002. Mission Bay Regional Park and flood control channel, bird usage survey: March 2000 to March 2001.

Kisner conducted a bird usage survey within the Mission Bay Regional Park and San Diego River flood control channel from March 2000 to March 2001. The information obtained by this study was then evaluated in the context of historic data, and will be used for comparison with future studies to determine long-term trends in avian diversity and abundance. The bay was divided into five main basins, including Fiesta Island (F), San Diego River Flood Control Channel (FC), Mariner's Basin (M), the Northern Basin (N), and the Western Basin (W). Bird populations were greatest between December and March (8,973 ± 547), and were the least abundant between April and July (1,580 ± 532). Over the study period the most common birds were the American coot (9,303 individuals), the leser scaup (6,506 individuals) and the western gull (6,330 individuals). Although there was no single basin that had the highest number of birds per survey period, the western portion of the bay (Mariner's Basin and Western Basin) typically had the fewest individuals. The author placed all of the birds into two of five sub-guilds. For all of the detected birds, the largest number of individuals belonged to the "ducks" and "shorebird" guilds with 37.4% and 36.0%, respectively.

Clemente, C. 1998. Birds as a source of fecal coliforms to mussels (*Mytilus galloprovincialis*) grown in the Agua Hedionda Lagoon, San Diego County, California. Prepared for the Degree Master in Public Health.

To examine the impacts of resident bird populations on water and shellfish quality, Clemente conducted bird counts and collected water samples from June 14 to June 29, 1998 at six locations in Agua Hedionda Lagoon, San Diego County, CA. The bird count study employed specific enumeration criteria and consisted of two daily bird counts: at sunset and again at 10:00pm. The sum average bird numbers were 434 ($s = 246$) with a corresponding fecal coliform geometric mean of 14.35 MPN/100ml ($s = 14$) for water samples and 1,207 CFU/100g for mussel tissue. The author found that the positive relationship between the water fecal coliform densities and bird numbers was not statistically significant ($R^2 = 0.2201$, $p < 0.05$). A bird exclusion study found that deterrent devices were successful in displacing birds from the northern portion of the mussel growing area. In the absence of birds, there was a 97% reduction in the geometric mean mussel coliform densities and an 82% reduction in the geometric mean FC densities of water samples in the northern growing area. However, the author concludes that available data does not show a statistically significant correlation between fecal coliform densities and the presence of birds, and therefore does not support the hypothesis that birds contribute significantly to bacteriological contamination in the lagoon water and mussels. The author also proposes further study involving a longer experimental duration in order to lessen the impacts of spatial and temporal variability.

PHYSICAL VARIABLES

Sinton, L.W., R.K. Finlay, and P.A. Lynch. 1999. Sunlight inactivation of fecal bacteriophages and bacteria in sewage-polluted seawater. Applied and Environmental Microbiology 65:3605-3613.

The authors conducted a 3-year study designed to quantify sunlight inactivation rates of enterococci and fecal bacteriophages (Somatic coliphage, F-RNA phage, Fecal coliform, F-DNA phage, *B. fragilis* phage) in seawater, using large chambers at an outdoor experimental area. According to the authors, solar radiation appears to be the most important factor affecting the survival of fecal indicator bacteria in seawater when compared with the influences of nutrient availability, salinity, temperature, pH, and microbial predation. Specifically, the UV-B portion of the solar spectrum is the most bacteriocidal, causing direct (photobiological) DNA damage. An earlier study by the authors (1994) showed that in seawater, greater sunlight exposure was required to inactivate enterococci than fecal coliforms, and inactivation of both indicators decreased with increasing seawater depth. The authors found that all test organisms were more rapidly inactivated in sunlight than in the dark. Fecal coliforms were inactivated by a wide range of solar wavelengths. Overall, the results indicate that penetration of shorter wavelengths, to which somatic coliphages are more susceptible, occurs in surface waters. However, F-RNA phages and fecal coliforms are more susceptible to the longer wavelengths that penetrate deeper waters. The principle finding in the study was that somatic coliphages exhibited consistently superior survival in sunlight-exposed seawater compared to fecal coliforms and F-RNA phages. Somatic coliphages were also more sunlight resistant than enterococci, F-DNA phages, and *B. fragilis* phages.

Mallin *et al*. 1999. Tidal stage variability of fecal coliform and chlorophyll a concentrations in coastal creeks. Marine Pollution Bulletin 38:414-422.

The authors investigated the influence of tidal variation on the concentrations of fecal coliforms. Sampling was conducted in three different creeks, and data was gathered during 14 tidal cycles from both euhaline and mesohaline locations. The authors found that tidal stages and sampling distance from the creek mouth appeared to have an effect on the abundance of fecal coliform such that abundance was high during low tide at the euhaline station, whereas maximal abundance at the more mesohaline upstream stations was between mid-and-low tide. The authors concluded that bacterial abundance in the studied tidal creek waters at or near low tide was probably influenced by several factors. Fecal coliform densities were higher in the fresher headwater areas, near potential sources such as small feeder creeks in the upper marsh areas. There is an inverse relationship between fecal coliform abundance and/or survival time and salinity. During the study, decreases in salinity greater than 20% occurred between high and low tides concurrently with sharp increases in fecal coliform concentrations. Finally, fecal coliform bacteria are often concentrated in sediments of water bodies, and their subsequent reintroduction to the water column by tidal stirring (tidal resuspension) can increase water column concentrations of such bacteria.

Mallin, M.A., S.H. Ensign, M.R. McIver, G.C. Shank, and P.K. Fowler. 2001. Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. Hydrobiologia 460:185-193.

The authors investigated the impacts of urban development and rainfall on receiving water quality, specifically evaluating the relationship between population density and impervious surface coverage on fecal coliform densities in several watersheds in New Hanover County, North Carolina. Water samples were taken on a monthly basis at five tidal creeks from 1993 through 1997. The authors found increasingly strong correlations between geometric mean fecal coliform abundance in receiving waters and watershed population, percent developed land, and percent impervious surface. Of the study areas, the watershed with greater than 20% impervious coverage was severely polluted, with all areas of the creek unsafe for shell fishing. In addition, results indicated that rain events were linked to both turbidity and fecal coliform increases, and also showed a strong correlation between fecal coliforms and turbidity. The authors concluded that increases in human population, domestic animals, and alterations of the natural landscape are all factors that can lead to increase in the amount of fecal coliform bacteria entering nearby waterways.

GROUNDWATER

Li, L. and D.A. Barry. 2000. Wave-induced beach groundwater flow. Advances in Water Resources 23:325-337.

Through numerical modeling, the authors simulated flow dynamics of wave-induced groundwater responses in a representative beach zone. Their modeling suggests that as waves propagate towards the shore they become steeper, leading to wave breaking and the formation of bores. The large slope of the sea surface in the vicinity of a bore results in significant hydraulic gradients that may cause considerable beach groundwater flows locally. Across the beach face, water infiltrates into the coastal aquifer at the upper part of the beach near the maximum run-up, and exfiltration occurs at the lower part of the beach face near the breaking point of the waves. The infiltration/exfiltration rates are determined by the bore amplitude, the water depth at the bore front, and the thickness of the underlying aquifer. The authors concluded several important features of groundwater circulation in the beach zone that are attributable to wave action. Firstly, the bore-induced infiltration and exfiltration rates can be relatively large. Secondly, a steady infiltration rate persists while the swash lens is present. Exfiltration occurs during the dry period (i.e., zero swash depth) for a short period of time. This research supports the concept that beach groundwater circulation contributes largely to submarine groundwater discharge and so affects chemical transfer, and possibly biological transfer, from the coastal aquifer to the coastal sea.

Horn, D.P. 2002. Beach groundwater dynamics. Geomorphology 48:121-146.

The author conducted a review of research on beach groundwater dynamics. A number of studies since the 1940s have described the shape and elevation of the beach water table as a function of beach morphology and tidal state. The elevation of the beach water table is not only dependent on prevailing hydrodynamic conditions such as tidal elevation, wave run-up, and rainfall, but also on beach sediment characteristics that determine hydraulic conductivity, including sediment size, sediment shape, sediment size sorting, and porosity. Decoupling between the tide and the beach watertable can occur when the groundwater exit point becomes separated from the shoreline. This occurs because the rate at which the beach drains is less than the rate at which the tide falls, so the tidal elevation generally drops more rapidly than the watertable elevation and decoupling occurs, with the watertable elevation higher than the tidal elevation. Once decoupling occurs a seepage face develops where the watertable coincides with the beachface. The seepage face is distinguished by a glassy surface, and is different from the watertable in that its shape is determined by beach topography. The extent of the seepage face depends on the tidal regime, the hydraulic properties of the beach sediment, and the geometry of the beachface. Thus, at a higher tide, a greater area of the beach is available for water to flow into the beach than at low tide, when the area of the beach from which groundwater flows is defined by the length of the beach under water (below the tide) and the extent of the seepage face. The exit point is generally assumed to mark the boundary between a lower section of the beach which is saturated and an upper section which is unsaturated. The author states that this assumption is probably an oversimplification.

Mahler, B.J., J.-C. Personne, G.F. Lods, and C. Drogue. 2000. Transport of free and particulate-associated bacteria in karst. Journal of Hydrobiology 238:179-193.

The authors investigated the event-based bacterial contamination of a heterogeneous karst aquifer, focusing on the importance of sediment-associated bacterial transport. The study site was located in the Lez Basin in southern France, near a stream that receives discharge from a wastewater treatment plant after rainfall. Samples were collected from two neighboring wells during a dry period (July 7-8, 1998) and after a rainfall (April 29 – May 11, 1998) for analysis of TSS, fecal coliforms, and enterococci. Results indicate that concentrations of fecal coliforms and enterococci increased in the first flush of surface waters and bacterial levels within the wells increased sharply within hours after the rainfall, then declined over the next 60 hours. The authors observed that 4-5 days after the rain event bacteria concentrations within the wells increased. The increase in levels occurred long after overland flow ceased and when flow in the creek had decreased to a trickle. They hypothesized that given the warm daytime temperatures and the almost stagnant condition of the water in the creek bed, it is possible that bacterial populations in the ponding water underwent explosive growth. Therefore, in this case the high concentrations of fecal coliforms and enterococci were no longer necessarily indicators of other non-bacterial fecal-associated pathogens but instead of conditions conducive to bacterial growth.

STORM WATER

Grant *et al*. 2001. Generation of enterococci bacteria in a coastal saltwater marsh and its impact on surf zone water quality. Environmental Science & Technology 35:2407-2416.

The purpose of this study was to determine if urban runoff from the Talbert Watershed was a source of fecal pollution at Huntington State and City beaches in southern California. The investigation was broken down into three components: a marsh study in which the flows of water and enterococci were measured between the marsh and ocean; a surf zone study encompassing a dye experiment and intensive surf zone water quality monitoring; and a source study to identify specific sources of enterococci in the marsh and watershed.

The marsh study was carried out for 15 days, starting on May 2, 2002. Enterococci data was segregated based on tidal stage at the time of sample collection, and whether storm water pump stations were on or offline. Results indicate that during ebb tides, the geometric mean of enterococci and the percentage of samples exceeding the single-sample standard approximately doubled as the water flowed through the marsh from the landward station to the seaward station. The trend was reversed during flood tides, with bacteria increasing as the water flowed through the marsh from the sea. Also, the highest levels of enterococci recorded at both stations occurred during spring tides when the mud flats were most likely to be washed by tidal action. Elevated enterococci values were generally not detected during periods when runoff from the drainage channels (as indicated by conductivity depressions) was present. Thus, urban runoff from the Talbert Watershed was not identified as the primary source of ENT.

Although the above study identified the marsh as a net source of enterococci, the extent to which this impacted the surf zone water quality was unclear. Therefore, two dye experiments were carried out during ebbing tides. Results indicated that effluent leaving the marsh suffers approximately a factor two dilution and is entrained in the surf zone. Interestingly, bacteriological monitoring conducted during this study showed a trend of marsh enterococci geometric means that are two times higher than those measured at the surf zone stations during ebbing tides.

The source study investigated the potential of enterococci contributions from urban runoff, marsh and surf zone sediments, marine vegetation, and bird feces. Although high levels of enterococci were detected in most urban runoff samples, the activation of pump stations did not appear to negatively impact downstream water quality. However, at least 50% of the runoff discharged to the marsh during the time in which pump stations were online was temporarily trapped in the channel network due to the tidally driven oscillation of water flow in the drainage channels. Die-off of enterococci and the relatively long residence time (1 week) of runoff in the drainage channels may have limited the downstream impact of urban runoff. Sediment cores were collected from May 22 to June 6, 2000 along transects placed in both the marsh and surf zone. Nineteen percent of the sediment samples from the marsh were positive for enterococci, compared to 2% of the sediment samples from the surf zone. Vertical profiles of enterococci in the marsh sediments indicate that the bacteria are concentrated in the top 1 cm of the cores. High levels of enterococci were also found on seaweed collected from the marsh. The fact that sediments and vegetation are enriched in enterococci suggests that these organisms are surviving, and perhaps even growing, in the marsh environment. The authors found that bird feces are also a significant source of enterococci in the marsh environment. When marsh water was exposed to sediment containing feces that were wet at the time of collection, the enterococci concentrations ranged from 9090 to 24,192,000 MPN/100ml. The majority of bird feces are deposited on low-lying mud flats in the marsh which become submerged to varying degrees during high tides.

Although the authors of this study found high concentrations of enterococci in urban runoff, bird feces, marsh sediments, and on marine vegetation, they assert that Talbert Marsh is the primary source of enterococci flowing into the ocean. This may be because coastal marshes are an important bird habitat, and the resulting abundance of bird feces is a potential source of enterococci, as is the environmental growth of these organisms in the sediments and on vegetation in the marsh.

Annotated Bibliography

Boehm, A.B., J.A. Fuhrman, R.D. Mrse, and S.B. Grant. 2003. Tiered approach for identification of a human fecal pollution source at a recreational beach: Case study at Avalon Bay, Catalina Island, California. Environmental Science and Technology, *In Press*.

The authors conducted a three-tiered approach for determining sources of human and nonhuman fecal indicator bacteria at Avalon Bay, a recreational beach on Catalina Island, California. The first and second tiers utilized standard fecal bacteria indicator tests to spatially isolate the bacteria indicator signal, to characterize the variability of the indicator bacteria over a range of temporal scales, and to measure indicator bacteria concentrations in potential source organisms. In the third tier, water samples from indicator bacteria “hot spots” and sources were tested for human-specific bacteria *Bacteriodes/Prevotella* (HF) and enterovirus (HV) to determine whether the fecal indicator bacteria originated from human sewage or from nonhuman sources such as bird feces. The authors concluded that most of the indicator bacteria contamination along the shoreline of the City of Avalon was due to sources inside the bay and, in particular, from the land side of the beach. Positive HF and HV results in the subsurface water samples were consistent with the extraordinarily high concentrations of fecal indicator bacteria in Avalon Bay, and together these results suggest that the subsurface water was contaminated with sewage, probably from a leaking sewer trunk line. Indeed, an earlier infiltration study commissioned by the City found that as much as 30% of sewage treated by the local sanitation district originated from the infiltration of saline subsurface water. It should be noted that sewer trunk lines run parallel to the Avalon Bay beach, approximately 20 meters from the shoreline.

Hanley, Y. 2002. Impact of rainfall on microbiological water quality of Mission Bay, California. Prepared for the Degree Master in Public Health, San Diego State University.

The author examined spatial and temporal bacterial contamination, statistical relationships between bacterial levels and several precipitation parameters, and statistically compared bacterial data before and after the final construction of the Mission Bay Sewage Interceptor System (MBSIS) in 1994 in San Diego, California.

Historic bacterial data from 20 stations in the bay was evaluated. Analysis consisted of total coliform and fecal coliform data recorded from 1987 through 1999, and enterococci data from 1991 through 1999. The data was categorized into dry and wet weather seasons based on rainfall patterns. The author found a statistically significant positive correlation between indicator bacteria levels and rainfall amount for the majority of the stations and all years combined, and concluded that rain events are strongly associated with increases in bacterial densities in Mission Bay waters. Additionally, it was observed that mean enterococci densities among east stations were notably higher then among the west bay stations. East stations had 1.5 and 4.5 times greater enterococci levels than west stations during dry and wet weather, respectively. Additional trend analysis was conducted on the relationship between cumulative precipitation and indicator bacteria for east bay stations during five wet seasons. The geometric means for these stations were described by a polynomial curve of convex shape, showing an increase in bacterial densities with cumulative precipitation reaching a maximum level between 60 and 100 mm, with a subsequent decrease in bacterial levels thereafter.

Mean bacterial levels were compared prior to and after final construction of the MBSIS to determine the statistical significance of the system’s effect on bacterial water quality. Results indicated that there was no improvement in fecal coliform bacteria water quality since 1994. The author presented two possible outcomes for these results: 1) the interceptor system is not effective in its design or construction to operate as intended, or 2) the source of fecal contamination in Mission Bay during dry weather is not storm water runoff. Possible other sources are increased beach/water activities from the influx of tourists, visitors and local residents, as well as animals and birds in the water.

Schiff, K. and P. Kinney. 2001. Tracking sources of bacterial contamination in storm water discharges to Mission Bay, California. Water Environment Research 73:534-542.

The authors investigated whether wet weather discharges were the predominant source of bacterial contamination in Mission Bay, San Diego, California between 1987 and 1994. Additionally, they sought to determine potential sources of indicator bacteria within the Mission Bay watershed. Samples were collected for microbiological analysis from flowing storm drains during non-storm conditions, in addition to sediment samples from 20 monitoring sites established by the City of San Diego. Samples were also collected from the watersheds of the two largest tributaries to Mission Bay, including Rose Creek and Tecolote Creek. These watersheds were first divided by subwatershed, and then by land use (including residential, commercial, industrial, and open space) in order to pinpoint specific sources of contamination. Surface flows from each of the land-use sites were sampled before they entered the storm sewer system.

Historical monitoring data were analyzed by assessing temporal and spatial trends to evaluate the magnitude of the effect from storm water discharges. By calculating the monthly geometric mean densities of total coliform, fecal coliform, and enterococci from more than 7300 samples taken between 1987 and 1994, it was observed that there were seasonal cycles of bacterial levels in Mission Bay with extremes peaking between December and March. Historically, these are the wettest months of the year in San Diego. During each year, the lowest monthly geometric mean densities occurred between May and August. The authors also found higher densities of fecal indicator bacteria on east bay than the west bay, especially during the winter months. Monthly geometric mean densities of fecal coliform and enterococcus in the east bay were as much as one order of magnitude higher than the west bay during the wet season. However, densities were comparable between the east and west bay during the dry season. Results of storm drain sampling indicated a negligible water quality impact from dry weather flows, but showed exceedances during wet weather conditions.

Levels of fecal indicator bacteria in sediments of Mission Bay responded to inputs of storm water runoff, but did not seem to represent a long-lasting source of fecal indicator bacteria to bay waters. In addition, upstream tracking along the Rose and Tecolote Creek watersheds indicated that no single sub-watershed or land-use type overwhelmingly contributed the majority of bacteria to total storm water discharge. The concentrations of indicator bacteria were as high at the headwaters of the creeks as they were at the mouths where they discharge into Mission Bay. This finding demonstrated that the high bacteria densities observed in the discharges were not the result of a point source (e.g., a broken sanitary sewer line). Rather, the densities of bacteria were high throughout the watershed indicating a diffuse, widespread source. In conclusion, the authors determined that exceedances of water quality objectives in San Diego can not be attributed to easily distinguishable locations such as broken sanitary sewer lines, sewer overflows, illicit connections, illegal discharges, leaking septic tanks, or contaminated sediments.

Baran, E.D. 1994. An evaluation of the relation between rainfall and water quality in Mission Bay, California. Prepared for the Degree Master in Public Health, San Diego State University.

The author studied the relationship between rainfall and bacterial indicator levels at shore stations in Mission Bay and bacterial indicator levels in two of the major tributaries at Mission Bay. Results indicated that the levels of bacterial indicators in Mission Bay, Rose and Tecolote Creek are not well correlated with rainfall; rather, there are many variables affecting indicator densities other than rainfall. The author suggested that the strongest factor that might influence coliform levels is the stirring of high bacterial levels in the sediments combined with regrowth of coliforms in the water column, with a resulting combined effect of a three to five order of magnitude increase in coliform density when resuspension occurs.

A study of bacteria in Mission Bay 1993-2000. MEC Analytical Systems, 2001.

This study evaluated weekly sampling data collected at 20 sites in Mission Bay from 1993 through 2000 for analysis of indicator bacteria. Data was segregated based on whether the sampling date fell within 72 hours of a rainfall event. From the data set, 320 weeks were determined to be dry weather conditions and 65 weeks were considered to be wet weather conditions. Researchers found that sampling stations with high averages of indicator bacteria per year were Tecolote Creek outlet, Visitor's Center, De Anza Cove, Campland, and Northern Crown Point on the east bay; and Fanuel Park, Bahia Point and Bonita Cove on the west bay. During rain events ($\geq$ .20 inches), virtually all of the stations on the eastern and northern shores were in exceedance of water quality standards equal to or greater than 50% of the time. One conclusion derived from this study is that, during the period of time that the data was collected, exceedances of AB411 bacterial water quality standards in Mission Bay were primarily due to concentrations of enterococci.