May 2007

Ventura County

Channel Islands Harbor Beach Park Dry Weather Runoff Diversion Characterization Study

Prepared by:

LARRY WALKER ASSOCIATES

Funding for this project has been provided in full or in part through a contract with the State Water Resources Control Board (SWRCB) pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) and any amendments thereto for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsements or recommendation for use.

Introduction

Channel Island Harbor Beach Park, herein referred to as Kiddie Beach, is an enclosed beach in Channel Islands Harbor in Ventura County, CA. The designated beneficial uses of Kiddie Beach include contact and non-contact recreation, fishing, and marine and wildlife habitat. The enclosed nature of the beach makes it popular for swimming with families with small children because it is protected from large waves. While the enclosed nature of Kiddie Beach encourages water contact, it also poses water quality problems due to reduced circulation with the open ocean, and near-shore water samples have historically exhibited bacteria concentrations that exceed water quality objectives (WQOs) for recreational water contact more frequently than any other beach in Ventura County. These WQO exceedances have resulted in beach postings, which advise the public to avoid contact with water due to possible bacterial contamination. In addition, Kiddie Beach has been listed as impaired on the 2006 California 303(d) list. As a result, along with other harbors in the Ventura County area, the Los Angeles Regional Water Quality Control Board is currently developing a bacteria total maximum daily load (TMDL) for Kiddie Beach, which is scheduled for public review in spring 2007.

Identifying sources of bacteria to beaches is a challenging task, and source identification efforts have been performed at Kiddie Beach in the past (URS, 2004). Birds are one of the major candidates identified as a potentially significant source of fecal indicator bacteria to Kiddie Beach, as discussed in a companion report (LWA, 2007). Urban runoff has been identified as another potential source of bacteria to Kiddie Beach. An urban runoff outfall, maintained by the Ventura County Watershed Protection Division (VCWPD), is located at the southern end of Kiddie Beach at the intersection of Victoria Avenue and San Nicholas Avenue. Runoff from this pump station, often referred to as the Silver Strand Pump Station, has been diverted to the sanitary sewer during the dry season since October 1999 in order to eliminate urban runoff discharges to Kiddie Beach. Prior to 2006, the VCWPD used a portable submersible pump for runoff diversion. In 2006, using Proposition 50 funds, the County of Ventura installed a permanent diversion structure to divert dry season urban runoff to the sanitary sewer. **Figure 1** shows the pump station and manhole to the wet well in the foreground, and Kiddie Beach in the background. The pump in the diversion structure was in operation from June 1 to late September 2006. A total of over 3 million gallons were diverted from Kiddie Beach during this time period. The purpose of this report is to quantify the loading of bacteria diverted from Kiddie Beach due to the implementation of the permanent diversion structure.

Figure 1. Silver Strand Pump Station at Kiddie Beach

Figure 2. Kiddie Beach Diversion into the Sanitary Sewer

Monitoring of Diverted Runoff

Dry weather monitoring was conducted at the Silver Strand diversion structure, from the end of the pipe that discharges to the sanitary sewer system, which is shown in **Figure 2**. Indicator bacteria samples were collected on six dates between November 20, 2006 and the December 6, 2006. These samples were tested (within the 6-hour holding times) for enterococcus, fecal coliform and total coliform by the Ventura County Public Health Department Laboratory. It is noted that fecal coliform was measured using an *E. coli* test (Colilert®) using a 1:1 translator, just as is done with regular receiving water monitoring. Water samples were also analyzed for field parameters, including pH, temperature, turbidity, and electrical conductivity (EC), as shown in **Appendix 1.**

It should be noted that the runoff monitoring was conducted outside of the dry season (which is normally defined as ending on October 15), but observed concentrations are considered to be representative of dry weather bacteria concentrations due to the lack of any significant rainfall prior to, or during, the sampling period (i.e. the wet season had a “late start” in 2006). The National Weather Service’s Oxnard location recorded only trace precipitation for the month of September, 0.12 inches for the month of October, and 0.07 inches for the month of November (http://newweb.wrh.noaa.gov/lox/local/LAXRR1VTU).

Data Analysis

AVAILABLE DATASETS AND APPLICABLE WATER QUALITY OBJECTIVES

The only available datasets containing measurements of the water quality of runoff from the Silver Strand pump station are monitoring data collected during this study, and from monitoring conducted during a separate study in late 1999 and early 2000. The historic bacteria data were analyzed using multiple tube fermentation or chromogenic substrate (Colilert®, or Enterolert®) methods, which are generally considered comparable with one another, particularly in the case of fecal coliform, *E. coli* and enterococcus (Griffith et al., 2006). As discussed in the following sections, this older dataset was used to analyze whether the data collected during this study are representative of “typical” runoff water quality.

With respect to receiving water data, in accordance with state law AB411, extensive bacteria sampling has been conducted at Kiddie Beach by the County of Ventura Environmental Health Division (EHD). Per AB411 requirements, all samples were tested for enterococcus, fecal coliform and total coliform. The water quality objectives (WQOs) for these indicator bacteria are shown in **Table 1**. The single sample density limits are emphasized in this report. For this report, the term “bacteria” is generally used to describe total coliform, fecal coliform, and enterococcus, while these species are referred to individually as “indicators”. It is noted that fecal coliform was measured using an *E. coli* test (Colilert®) using a 1:1 translator. The beach sampling dataset covers the time period between September 30, 1998 and November 13, 2006. Bacteria samples were generally taken at least once per week and usually multiple samples were taken on each day. There are three sampling site locations named “regular” (R), “north” (N), and "south" (S). These locations of these sites, along with the Silver Strand Pump Station outfall, are shown in **Figure 3.**

Table 1. Bacteria Water Quality Objectives for Marine Waters in the Los Angeles Region Basin Plan and as Prescribed by State Legislation AB411

Beneficial Use	Single Sample Density Limits†			Geometric Mean Density Limits‡		
	Enterococcus	Fecal Coliform	Total Coliform	Enterococcus	Fecal Coliform	Total Coliform
Water Contact Recreation (REC-1)	≤ 104/ 100mL	≤ 400 /100mL	≤ 10,000 /100mL	≤ 35 /100mL	≤ 200 /100mL	≤1,000 /100mL

† Maximum value of a single grab sample
‡ Geometric mean values are calculated based on at least five samples equally-spaced over a 30-day period

To assist with analysis of available datasets, summary statistics were calculated for each indicator over the course of the study. Calculation of summary statistics was accomplished by using an Excel add-in statistical package developed for California Department of Transportation (Caltrans) known as the Data Analysis Tool (DAT). The DAT is based on regression on order (ROS) statistics, assumes a log-normal distribution, and applies a best-fit regression equation ($\ln(y) = a*Z + b$) to the dataset to estimate summary statistics. The DAT is especially useful for datasets that include non-detects because it estimates non-detect concentrations based on (i) the sample limit of detection and (ii) the distribution of the detected data points. Several of the fecal coliform results were non-detect. Another useful function of DAT for this study was the ability to estimate the log-normal distribution and extrapolate higher order percentile values (e.g. 90^{th} percentile), as only 12 environmental measurements were collected from each site. All sites fit a log-normal distribution reasonably well, and most fit exceptionally well, as demonstrated by the correlation coefficients (R values) presented in the summary statistics tables in **Appendix 2**.

Figure 3. Map of Kiddie Beach with Locations of Monitoring Sites and Pump Station Outfall

DISCHARGE RATE AND VOLUME OF DIVERTED RUNOFF

Prior to 2006, there are no readily-available records regarding the volume of diverted runoff or the diversion rate (e.g. pump capacity). One of the improvements associated with the installation of the permanent diversion structure was the installation of a flow meter that records the cumulative volume of runoff diverted and also a meter that records the cumulative hours of pump operation. Shown in **Table 2** is the record for the summer of 2006, including pump hours and total runoff diverted. A total of over 3.3 million gallons of runoff were diverted during this time period. As further discussed below, it should be noted that total volume of water discharged through the diversion structure is likely not entirely urban runoff, but rather a combination of urban runoff, seawater, and groundwater. Based on the data in **Table 2**, a pump discharge rate of 182 gallons per minute (gpm) can be calculated.

Table 2. Volume of Runoff Diverted from Kiddie Beach and Pump Operation Hours during 2006

Date	Cumulative Pump Operation (Hours)	Cumulative Runoff Diverted (Gallons)#
6/1/2006	3.5	19436
6/8/2006	21	228,328
6/15/2006	52.2	504,984
6/22/2006	59.6	580,854
6/29/2006	78	N/A*
7/6/2006	89.2	849,646
7/13/2006	106.4	1,061,047
7/13/2006	126	1,283,002
7/27/2006	146.4	1,510,476
8/2/2006	162.4	1,704,179
8/10/2006	186.5	2,005,159
8/17/2006	211.4	2,311,945
8/24/2006	231.2	N/A*
9/7/2006	260.9	2,921,908
9/14/2006	277.6	3,125,953
9/21/2006	295.5	3,346,805

- Diverted water is likely a combination of urban runoff and seawater-influenced groundwater

* - Cumulative runoff value not available for these dates

CONCENTRATIONS OF BACTERIA IN DIVERTED RUNOFF

Twelve samples were collected between November 20 and December 6, 2006 from the wet well at the diversion structure to characterize the concentration and loading of bacteria in the diverted dry weather runoff. Two samples were collected during each sampling event – the first immediately after the pump in the diversion structure began to run and the second approximately five minutes later. This was done to capture any influences of the pumping on the concentration of bacteria (e.g. by stirring up sediments in the wet well). The results of these samples are presented in **Table 3**, and summary statistics are shown in **Appendix 2**.

The results presented in **Table 3** show that total coliform exceeded the single sample limit in nine of the twelve samples (75%), and enterococcus exceeded the single sample limit in ten out of the twelve samples (83%), while fecal coliform did not exceed the limit in any of the samples (0%). Statistics for the concentrations of each indicator are presented in **Table 4**. The geometric mean concentrations of the total coliform and enterococcus samples exceeded the single sample and geometric mean limits, while the geometric mean of the fecal coliform samples was well below the corresponding limits.

Table 3. Bacteria Samples Collected at the Diversion Structure at Kiddie Beach

Sample Date	Sample Time	Total Coliform (MPN/100 mL)	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)
11/20/2006	12:30	***19,863***	108	***560***
11/20/2006	12:36	***17,329***	74	***659***
11/21/2006	11:15	***12,033***	41	***478***
11/21/2006	11:20	6,488	52	***453***
11/30/2006	13:10	***155,310***	226	***344***
11/30/2006	13:15	***104,620***	368	***364***
12/4/2006	13:55	***17,329***	<10	***124***
12/4/2006	14:00	***15,531***	<10	***124***
12/5/2006	8:15	***12,997***	10	***178***
12/5/2006	8:20	***24,192***	10	***238***
12/6/2006	9:15	9,804	<10	87
12/6/2006	9:20	9,208	<10	99
AB411 Single Sample Density Limit (MPN/100 mL)		**10,000**	**400**	**104**

"<" denotes constituent not detected above specified detection limit.

Bold **denotes samples above the single sample maximum WQOs**

Table 4. Statistics of the Indicator Concentrations Sampled from the Diversion at Kiddie Beach as Measured in November and December 2006

	Total Coliform (MPN/100 mL)	**Fecal Coliform** (MPN/100 mL)	**Enterococcus** (MPN/100 mL)
10th percentile	5,376	1	86
25th percentile	9,941	4	143
Geometric Mean	**19,661**	**19**	**249**
Arithmetic Mean	**33,735**	**75**	**309**
75th percentile	38,885	87	434
90th percentile	71,895	340	717

Box plots are a visual tool used to depict the typical range (or statistics) of concentrations of collected water samples. Boxes that are higher along the y-axis represent higher concentrations, and vice versa. In detail, the boxes span 25^{th} to 75^{th} percentile values, with the estimated median (50th percentile) represented as a line in between. The whiskers represent the 10^{th} and 90^{th} percentile values, and the dots represent the 5^{th} and 95^{th} percentile values. **Figure 4** is a box plot of the indicator bacteria concentrations sampled from the diversion at Kiddie Beach during this study. The red dotted lines indicate the single sample water quality standards for each indicator (also see **Table 1**).

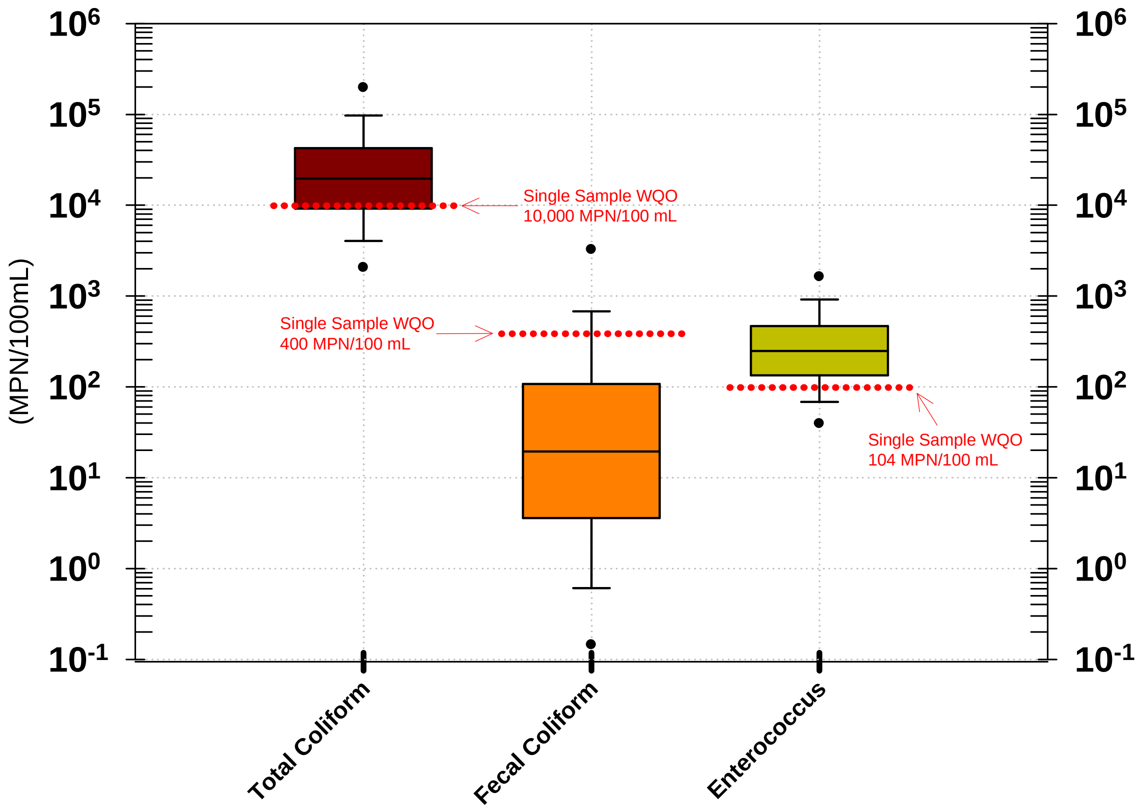

Figure 4. Indicator Bacteria Concentrations from the Diversion Structure at Kiddie Beach as Measured in November and December 2006

Between June and September of 1999, nine indicator bacteria samples were collected from a manhole in the vicinity of the present diversion structure. For comparison, **Figure 5** is a box plot showing statistics of the concentrations of indicators from these 1999 samples (in orange) to the concentrations of indicators as sampled during 2006 (in green). Only one enterococcus sample was collected in the 1999 data set and is represented in the figure as a single horizontal line. The single sample water quality standards for each indicator are shown as red dotted lines. The box plot does not show any clear trend in bacteria concentrations in dry weather runoff in 1999 versus 2006. Total coliform concentrations were generally higher in 2006 when compared to 1999, while fecal coliform concentrations were generally higher in 1999 then 2006. Based on **Figure 5**, it is reasonable to assume that the data collected during 2006 (and used for loading rate calculations herein) are representative of "typical" urban runoff.

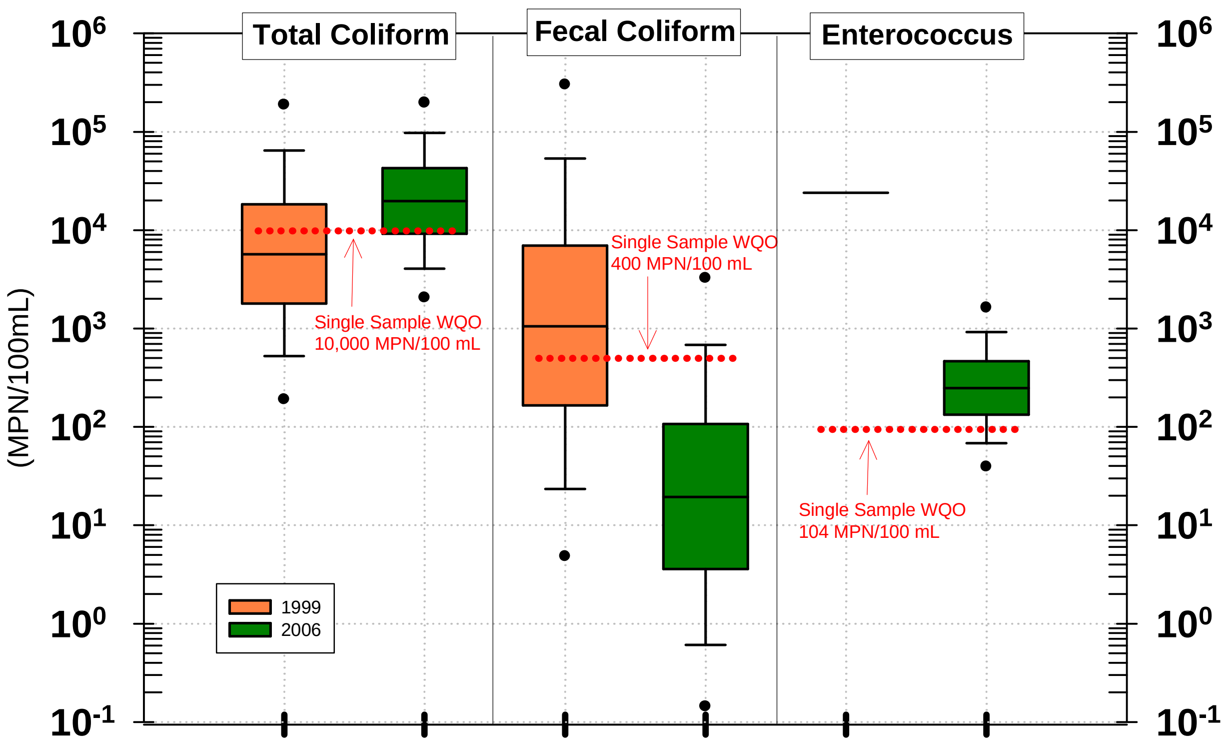

Figure 5. Indicator Bacteria Concentrations in Dry Weather Runoff Near Kiddie Beach 1999 versus 2006

It is also worth noting that the electrical conductivity (EC) values measured in the diversion structure wet well were very high, which suggests that seawater, or at least seawater-dominated groundwater, is entering the wet well of the Silver Strand pump station. High salinity water is likely entering the storm drain system via infiltration of shallow groundwater from the surrounding area. This shallow groundwater may have been naturally discharged to Kiddie Beach as runoff prior to construction of the stormwater conveyance system, or the stormwater infrastructure may have been constructed below the shallow table, leading to increased groundwater discharges. As mentioned above, this suggests that the total volume of water discharged through the diversion structure is not urban runoff in its entirety, but rather a combination of urban runoff/seawater/groundwater. It should be noted that the high conductivity could affect the concentration of bacteria in the diversion, as salinity affects the survival rate of indicator bacteria (Bordalo et al., 2002). Conductivity values measured in the wet well at the Kiddie Beach diversion structure are presented in **Table 5.**

Table 5. Electrical Conductivity in the Diversion Structure at Kiddie Beach

Sample Date	Sample Time	Electrical Conductivity (µS/cm)
11/20/2006	12:30	29,916
11/20/2006	12:36	28,854
11/21/2006	11:15	34,752
11/21/2006	11:20	32,838
11/30/2006	13:10	18,388
11/30/2006	13:15	18,288
12/4/2006	13:55	29,480
12/4/2006	14:00	29,816
12/5/2006	8:15	28,122
12/5/2006	8:20	28,363
12/6/2006	9:15	32,096
12/6/2006	9:20	32,144

Conductivity measurements were also collected from urban runoff at Kiddie Beach between October 1999 and February 2000. Shown in **Figure 6** is a box plot of these measurements compared to the 2006 measurements. The plot demonstrates that EC values measured in 1999 were also very high, further suggesting that 2006 data are representative. The 1999-2000 samples were collected between October and February, which are typically wet months in Ventura County. Dilution from precipitation may account for the lower conductivity values sampled in 1999-2000 versus 2006.

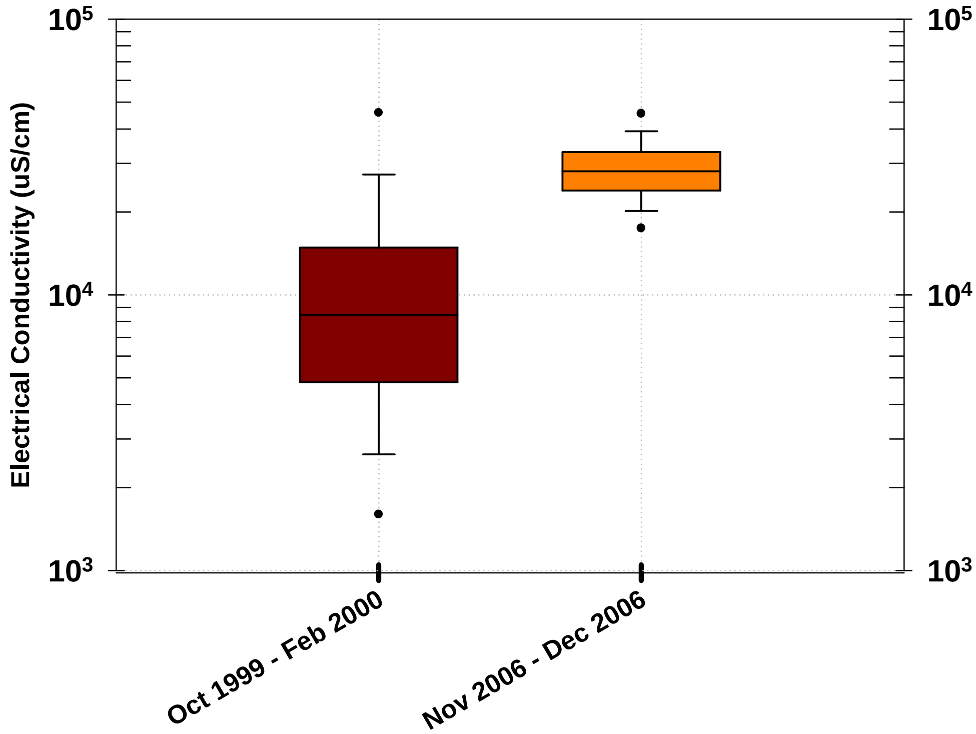

Figure 6. Conductivity at the Kiddie Beach Pump Station in 1999-2000 and 2006

BACTERIA LOADING REMOVED BY DIVERSION

The ultimate goal of the Silver Strand diversion structure is to prevent bacteria loads associated with urban runoff from impacting Kiddie Beach. To quantify the bacteria that was diverted from Kiddie Beach, bacteria loading rates were calculated as follows:

$$L_{BacT} = 5.45 \cdot 10^4 \cdot C_{BacT} \cdot Q \qquad \text{(Equation 1)},$$

where:

L_{BacT} = Calculated loading rate of indicator bacteria (MPN/day)
C_{BacT} = Measured concentration of indicator bacteria in runoff (MPN/100mL)
Q = Measured volumetric flow rate of runoff (GPM)

Based on Equation 1, three parameters were used to evaluate bacteria loading that was removed by the diversion structure:

1) **Instantaneous loading rate** – this is the bacteria discharge rate when the diversion structure was actually pumping. Note that during a majority of the time, the pump is not running.

2) **Average dry season loading rate –** this is the estimated total load of bacteria diverted over the dry season divided by the length of the dry season.

3) **Cumulative load –** this is the total number of bacteria cells that were estimated to be diverted over the course of the dry season.

In each case, a range of values from the 10th percentile to the 90th percentile is given (based on the measured concentrations), which may be used as a "range" of the estimate (i.e. estimates ranging from very low [10th percentile] to very high [90th percentile]), while the geometric mean may provide an estimate of the "mid-range" value.

Instantaneous Loading Rate

Loading rates for each indicator were calculated using the concentrations of the diversion structure samples collected in 2006 and the recorded rate of the pump discharging runoff into the diversion. The estimated instantaneous loading rates of each indicator being removed by the diversion are shown in **Table 6**. Recall that the pump operated for approximately 300 hours in 2006.

Table 6. Estimated Instantaneous Loading Rates of Bacteria Removed by the Diversion Structure when Operating in 2006

	Total Coliform (MPN/Day)	**Fecal Coliform** (MPN/Day)	**Enterococcus** (MPN/Day)
Very Low Estimate (10th percentile)	$5.35 \bullet 10^{10}$	$1.09 \bullet 10^{7}$	$8.58 \bullet 10^{8}$
Low Estimate (25th percentile)	$9.88 \bullet 10^{10}$	$4.24 \bullet 10^{7}$	$1.42 \bullet 10^{9}$
Mid-Range Estimate (Geometric Mean)	$\mathbf{1.95 \bullet 10^{11}}$	$\mathbf{1.88 \bullet 10^{8}}$	$\mathbf{2.47 \bullet 10^{9}}$
Mid-Range Estimate (Arithmetic Mean)	$\mathbf{3.35 \bullet 10^{11}}$	$\mathbf{7.45 \bullet 10^{8}}$	$\mathbf{3.07 \bullet 10^{9}}$
High Estimate (75th percentile)	$3.87 \bullet 10^{11}$	$8.68 \bullet 10^{8}$	$4.31 \bullet 10^{9}$
Very High Estimate (90th percentile)	$7.15 \bullet 10^{11}$	$3.38 \bullet 10^{9}$	$7.12 \bullet 10^{9}$

Average Dry Season Loading Rate

The estimated average dry weather loading rate of each indicator is shown in **Table 7**. The average loading rate is the average of the total bacteria load discharged during the time the diversion structure and pump were in operation (June 1, 2006 to September 21, 2006).

Table 7. Estimated Average Dry Weather Loading Rate of Bacteria Removed by the Diversion Structure from June 1, 2006 to September 21, 2006

	Total Coliform (MPN/Day)	**Fecal Coliform** (MPN/Day)	**Enterococcus** (MPN/Day)
Very Low Estimate (10th percentile)	$6.03 \cdot 10^{9}$	$1.23 \cdot 10^{6}$	$9.68 \cdot 10^{7}$
Low Estimate (25th percentile)	$1.11 \cdot 10^{10}$	$4.78 \cdot 10^{6}$	$1.60 \cdot 10^{8}$
Mid-Range Estimate (Geometric Mean)	$\mathbf{2.20 \cdot 10^{10}}$	$\mathbf{2.16 \cdot 10^{7}}$	$\mathbf{2.79 \cdot 10^{8}}$
Mid-Range Estimate (Arithmetic Mean)	$\mathbf{3.78 \cdot 10^{10}}$	$\mathbf{8.40 \cdot 10^{7}}$	$\mathbf{3.46 \cdot 10^{8}}$
High Estimate (75th percentile)	$4.36 \cdot 10^{10}$	$9.79 \cdot 10^{7}$	$4.87 \cdot 10^{8}$
Very High Estimate (90th percentile)	$8.06 \cdot 10^{10}$	$3.81 \cdot 10^{8}$	$8.03 \cdot 10^{8}$

Cumulative Load

The estimated cumulative load of each indicator removed from Kiddie Beach by the diversion structure is shown in **Table 8**. The cumulative load is the total amount of bacteria removed from the beach while the diversion structure and pump were in operation (June 1, 2006 to September 21, 2006). These values represent the estimated total number of bacteria diverted from Kiddie Beach.

Table 8. Estimated Total Number of Bacteria Diverted From Kiddie Beach by the Diversion Structure in 2006

	Total Coliform (MPN)	**Fecal Coliform** (MPN)	**Enterococcus** (MPN)
Very Low Estimate (10th percentile)	$6.81 \cdot 10^{11}$	$1.39 \cdot 10^{8}$	$1.09 \cdot 10^{10}$
Low Estimate (25th percentile)	$1.26 \cdot 10^{12}$	$5.40 \cdot 10^{8}$	$1.81 \cdot 10^{10}$
Mid-Range Estimate (Geometric Mean)	$\mathbf{2.49 \cdot 10^{12}}$	$\mathbf{2.44 \cdot 10^{9}}$	$\mathbf{3.15 \cdot 10^{10}}$
Mid-Range Estimate (Arithmetic Mean)	$\mathbf{4.27 \cdot 10^{12}}$	$\mathbf{9.49 \cdot 10^{9}}$	$\mathbf{3.91 \cdot 10^{10}}$
High Estimate (75th percentile)	$4.93 \cdot 10^{12}$	$1.11 \cdot 10^{10}$	$5.50 \cdot 10^{10}$
Very High Estimate (90th percentile)	$9.11 \cdot 10^{12}$	$4.30 \cdot 10^{10}$	$9.08 \cdot 10^{10}$

EFFECT OF RUNOFF DIVERSION ON KIDDIE BEACH

Previous work by LWA (2001) found that dry weather runoff diversion at Kiddie Beach significantly decreased the concentrations of total and fecal coliform, along with the rate of WQO exceedances for enterococcus, at site S, the southern-most sampling site. Sampling site S is located closest to the runoff outfall location, while sites R and N are located further away along the beach (see **Figure 3**). To evaluate whether during wet weather, when runoff is not diverted, site S exhibits higher concentration of bacteria than sites R and N, concentrations at each site were analyzed and compared to one another (**Figure 7**). While site S did not show relative differences when compared to the other sites, **Figure 7** does demonstrate that Kiddie Beach (all sites) has higher bacteria concentrations during the wet season when compared to the dry season. This indicates that when runoff is not diverted, the concentrations of total and fecal coliform and enterococcus increase. The trend is less distinct for fecal coliform due to the high number of non-detects measured. Increased bacteria concentrations during the wet season are likely due to a combination of hydrological conditions (i.e. bacteria concentrations are generally higher in runoff and receiving water when it rains) and the positive effect of diversion during the dry season, though the relative effect of these two factors cannot be determined. The lack of spatial bacteria distribution along the beach may be related to complex circulation/dispersion patterns found at enclosed beaches in general and Kiddie Beach in particular (Everest International Consultants, 2003).

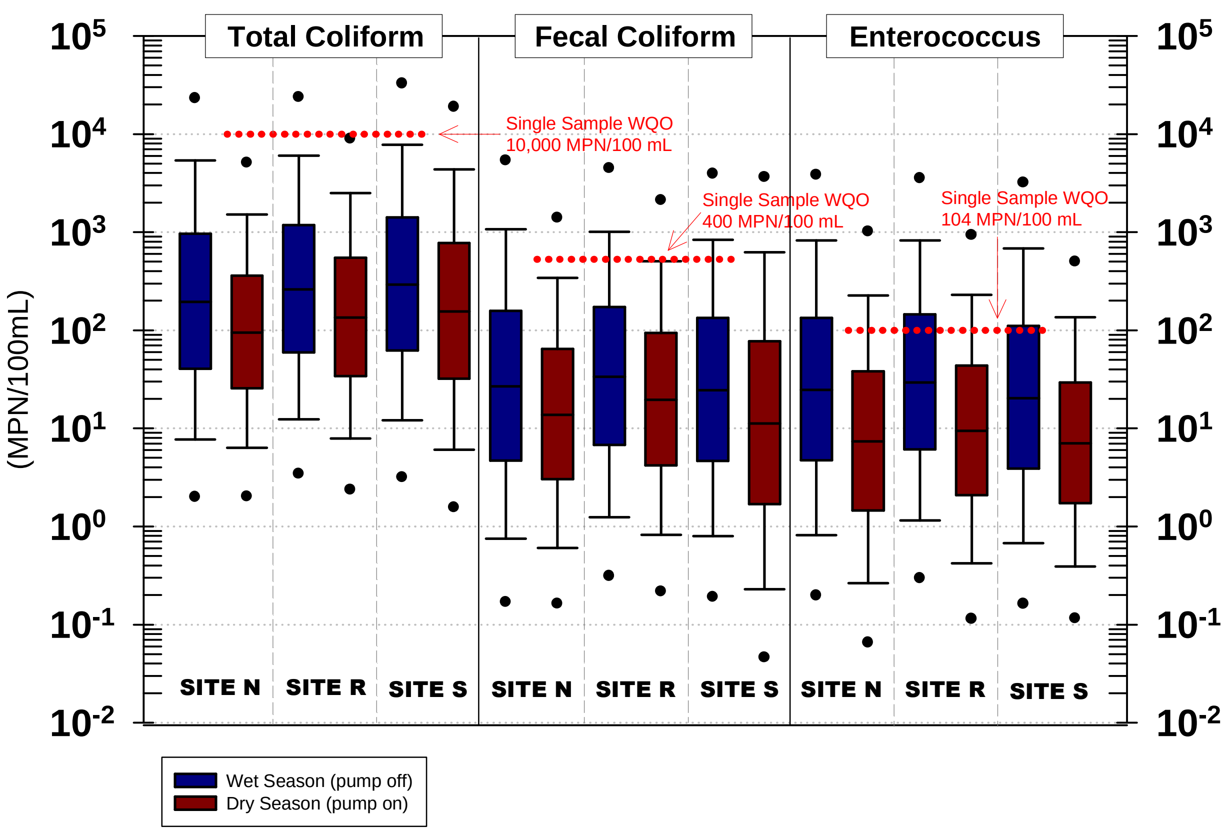

Figure 7. Concentrations of Bacteria at Kiddie Beach in the Wet and Dry Seasons 1999-2006

Previous monitoring by EHD and analysis by LWA (2001) determined that Kiddie Beach bacteria concentrations generally increase from low to rising tide, reach a peak at high tide, and then decrease during falling tides. Analysis of historic EHD-collected bacteria data, as shown in **Figure 8** and as discussed in a companion report (LWA, 2007), further suggests that tide levels may affect bacteria concentrations on Kiddie Beach. Using the time at which bacteria samples were collected, and data from available tide charts, tide heights were determined for each sampled bacteria concentration. These were then grouped into categories of low (-1.7 – 1.5 ft), medium (1.5 – 4.5 ft), and high (4.5 – 7 ft) tide levels as reported by a tide gage at Rincon Beach. Bacteria statistics were calculated for each tide group and plotted in box plots. As shown in **Figure 8**, at low and medium tide heights average bacteria concentrations are comparable, while the high tide bacteria concentrations are significantly elevated (at the 95% confidence limits). Note that the data presented in **Figure 7** differ from the data presented in the aforementioned companion study (LWA, 2007) in that for this report, tidal conditions at the time of sampling were estimated based on tidal levels reported by the tide gage at the time of sampling, instead of simply relying on tidal range information (i.e., either low [<3 ft], medium [3-5 ft], or high [>5 ft]) recorded by field personnel.

Previous work by EHD and LWA (2001) was somewhat inconclusive regarding the effect of beach sand on bacteria concentrations in the water samples collected from Kiddie Beach. However, as discussed in LWA, 2007, recent studies of other southern California beaches found that tidal levels may affect bacteria concentrations due to flushing of sediments. A study of 60 beaches in southern California has shown that tides greatly affect enterococcus concentrations (Boehm and Weisberg, 2005). The study concluded that high tides may increase bacteria concentrations in water by flushing sources of bacteria present on the beach into the water column. Possible beach sources include groundwater or animal feces (including deposits from cats and birds) along the high tide line. In addition, the beach sand itself may also act an important source. A study of Santa Monica beach sediments asserts that sand may encourage bacterial growth by, “reducing sunlight inactivation, protecting against predators, and providing colonizable surfaces” (Lee et al., 2006). The study also found that fecal indicator bacteria including enterococcus and *E. coli* were typically two orders of magnitude higher in sand from enclosed versus exposed beaches, perhaps due to reduced flushing, which suggest that the overall layout of Kiddie Beach may contribute to bacteria growth and persistence in beach sand.

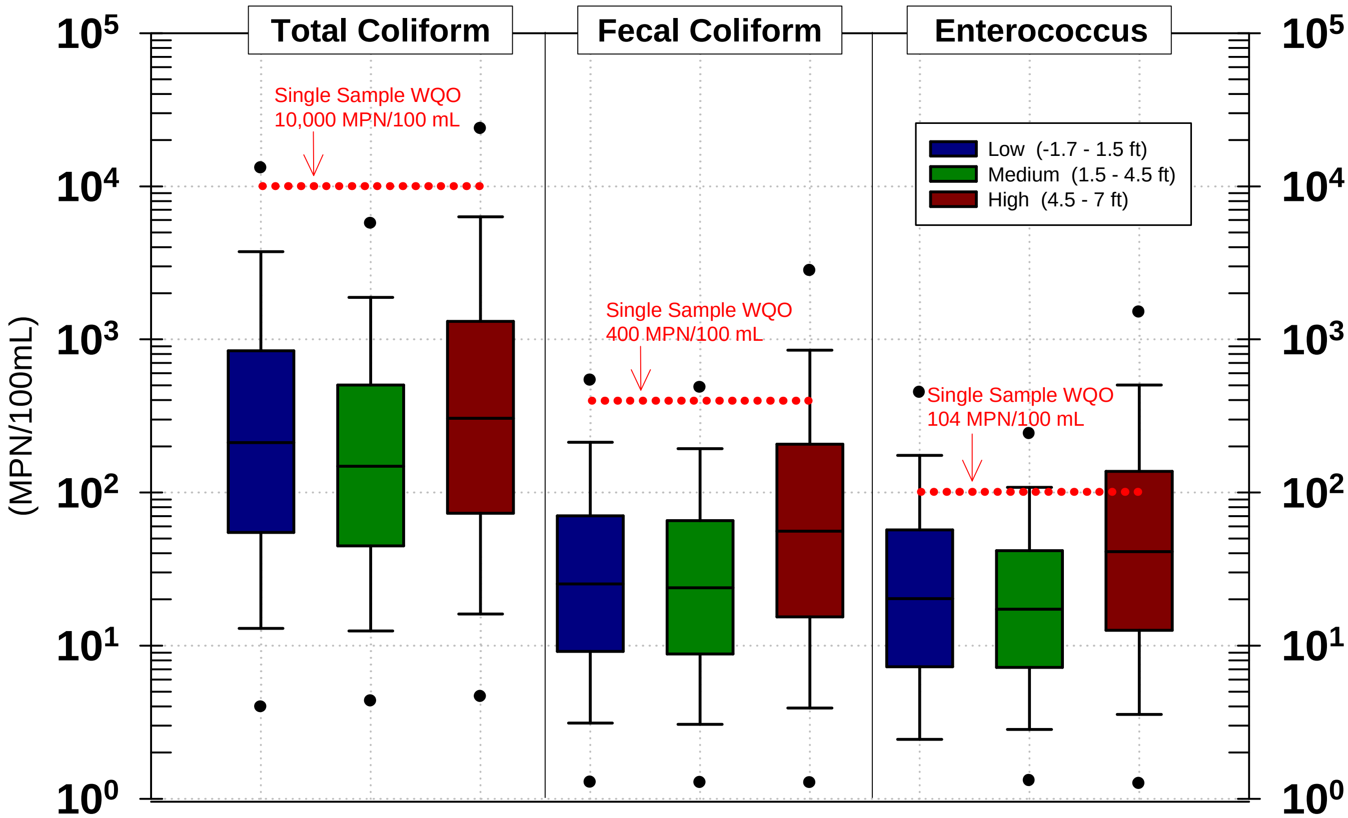

Figure 8. Concentrations of Bacteria at Kiddie Beach During Low, Medium, and High Tides 1999-2006 (both wet and dry seasons are represented)

Conclusions

Diversion of urban runoff discharges to Kiddie Beach likely reduces health risks associated with swimming during the dry season (Haile et al., 1996). Based on monitoring of the Silver Strand pump station in late 2006, concentrations of diverted runoff were typically well above the single sample water quality objectives (WQOs) for total coliform and enterococcus, but below the WQO for fecal coliform. Flow records suggest that over 3 million gallons of runoff was diverted from Kiddie Beach, though based on high the EC values, it is likely that this diverted water was not entirely urban runoff, but instead a combination of urban runoff and seawater-influenced groundwater that infiltrated into the storm drain system from the surrounding area. When the measured concentrations are combined with flow records, it is estimated that billions of bacteria were diverted from the beach over the course of the 2006 dry season – specifically 2490, 24, and 32 billion counts of total coliform, fecal coliform and enterococcus, respectively. It was determined that the concentrations of bacteria collected from three locations on Kiddie Beach did not demonstrate spatial patterns relative to the location of the urban runoff outfall during the wet season. However, the concentrations of bacteria were consistently higher along the beach during the wet season than during the dry season. Increased concentrations during the wet season are likely due to a combination of hydrological conditions (i.e. bacteria concentrations are generally higher in runoff and receiving water when it rains) and the positive effect of diversion during the dry season, though it was not possible to determine the relative effect of these factors. Furthermore, in line with other studies, it appears that tidal level affects the concentrations of bacteria found at Kiddie Beach. The mean concentrations of all three indicators at high tide were statistically-significantly higher than the mean concentrations of the indicators during low and medium tide levels. Overall, this suggests that WQO exceedances at Kiddie Beach may be due in part to phenomena such as flushing of bacteria from the sand surface by wave action during the rising tide, or a diffuse, large-scale source(s) – water quality may be a reflection of Channel Islands Harbor or the open ocean systems as opposed to localized sources near Kiddie Beach.

References

Boehm, A.B., S.B. Weisberg. (2005) Tidal forcing of enterococci at marine recreational beaches at fortnightly and semi-diurnal frequencies. *Environmental Science and Technology*. 39(14):5575-5583.

Bordalo, A.A., Onrassami, R., and C. Dechsakulwatana (2002) . Survival of fecal indicator bacteria in tropical estuarine waters. *Journal of Applied Microbiology* 93 (5), 864–871.

Everest International Consultants, Inc. (2003) Channel Islands Harbor Circulation Improvement Study. Prepared for Ventura County Harbor Department, July 2003.

Griffith et al., 2006. Comparison and verification of bacterial water quality indicator measurement methods using ambient coastal water samples. *Environmental Monitoring and Assessment*. 116: 335-344.

Haile RW, Witte JS, Gold M, et al. The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology*. 1999;10:355–363.

Lee, C.M., T. Lin, C.-C. Lin, G. A. Kohbodi, A. Bhatt, R. Lee, J.A. Jay. (2006) Persistence of fecal indicator bacteria in Santa Monica Bay beach sediments. *Water Research*. 40(14):2593-2606.

LWA, 2001. Channel Islands Beach Park, Draft Action Plan for Improving Water Quality.

LWA, 2007. Channel Islands Harbor Beach Park Bird Control Measure Efficacy Study. Prepared by Larry Walker Associates for Ventura County Environmental Health Division. January 2007.

URS Corporation (2004). Bacteria Source Study for Channel Islands Harbor: Kiddie Beach and Hobie Beach, Ventura County, California. Prepared for Ventura County Harbor Department, March 2004.

Water Quality Field Parameters

Sonde Measurements from Silver Strand Diversion Water Quality Sampling

Date (MMDDYY)	Time (HHMM)	Temp (°C)	pH (Units)	DO (mg/l)	DO (% Sat)	Turbidity (NTU)	CHLa (ug/l)	SpCond (uS/cm)	Sal (ppt)
11/20/2006	12:31	19.29	7.86	7.88	89.2	10.1	0.52	29916	18.50
11/20/2006	12:37	19.04	7.86	7.94	89.8	6.6	0.52	28854	17.78
11/21/2006	11:16	19.63	7.74	7.94	90.2	163.7	0.50	34752	20.41
11/21/2006	11:21	19.45	7.73	7.75	89.4	144.4	0.50	32838	19.87
11/30/2006	13:11	16.82	7.90	8.10	90.4	6.3	0.66	18388	10.85
11/30/2006	13:16	16.56	7.92	8.13	90.6	11.8	0.65	18288	10.79
12/4/2006	13:56	17.18	7.90	7.70	89.0	5.9	0.54	29480	17.20
12/4/2006	14:01	16.38	7.91	7.91	90.1	7.9	0.56	29816	17.39
12/5/2006	8:16	15.97	7.64	8.08	90.6	248.2	0.59	28122	17.28
12/5/2006	8:21	15.91	7.70	8.09	90.7	100.8	0.59	28363	17.44
12/6/2006	9:16	16.48	7.81	7.94	91.3	17.5	0.55	32096	18.79
12/6/2006	9:21	16.44	7.87	7.82	90.0	226.8	0.53	32144	18.82

Bacteria Summary Statistics

DAT-Generated Log-Normal Statistics for 2006 Silver Strand Diversion Bacteria Concentrations

Run ID	Total Coliform MPN/100 mL	E. Coli MPN/100 mL	Enterococcus MPN/100 mL
n	12	12	12
Percent detected	100.0%	66.7%	100.0%
n detected	12	8	12
Mean	33725.33333	74.91633474	309
Geometric Mean	19660.64699	18.94626719	248.7546333
Standard Deviation	50457.26912	122.1801763	198.5328099
Coefficient of Variation	1.496123659	1.630888333	0.642501003
Lower 95% Confidence Limit about Mean	5176.445781	5.786392248	196.6694882
Upper 95% Confidence Limit about Mean	62274.22089	144.0462772	421.3305118
10th percentile	5376.499523	1.094930848	86.34974457
25th percentile (Lower Quartile)	9940.500172	4.265525251	142.5833852
50th percentile (Median)	19660.64699	19.29069916	248.7546333
75th percentile (Upper Quartile)	38885.47189	87.24155923	433.9837177
90th percentile	71894.55488	339.8671931	716.6074189
Inter Quartile Range	28944.97172	82.97603398	291.4003325
Minimum Detected Value	6488	10	87
Maximum Detected Value	155310	368	659
Minimum Reporting Limit		10	
Maximum Reporting Limit		10	
Regression Equation	ln(y) = 9.88637430206468 + 1.01158806050063*Z	ln(y) = 2.95962307069269 + 2.23832994893434*Z	ln(y) = 5.51646700209826 + 0.825495371192111*Z
Beta_1 (slope)	1.011588061	2.238329949	0.825495371
Beta_0 (intercept)	9.886374302	2.959623071	5.516467002
Correlation Coefficient (r)	0.905324789	0.970296289	0.975293489
Note:	All data reported as detected.		All data reported as detected.

1999 Kiddie Beach Manhole Bacteria Concentrations and DAT-Generated Log-Normal Statistics

Date	Time	Total Coliform, MPN/100ml	Fecal Coliform, MPN/100ml	Enterococcus, MPN/100ml
6/3/1999	14:08	2400	2400	N/A
6/10/1999	12:12	24000	5000	24000
8/3/1999	14:55	13000	80	N/A
8/10/1999	11:34	16000	16000	N/A
8/17/1999	11:10	1400	700	N/A
8/24/1999	11:08	500	80	N/A
8/31/1999	11:05	16000	16000	N/A
9/7/1999	12:40	9000	500	N/A
9/14/1999	11:41	5000	220	N/A

DAT-Generated Log-Normal Statistics

	Total Coliform, MPN/100ml	Fecal Coliform, MPN/100ml	Enterococcus, MPN/100ml
n	9	9	NOT ENOUGH DATA TO GENERATE SUMMARY STATISTICS
Percent detected	100.0%	100.0%	
n detected	9	9	
Mean	9700	4553.333333	
Geometric Mean	5668.069288	1047.153171	
Standard Deviation	8280.62667	6921.216291	
Coefficient of Variation	0.853672853	1.52003286	
Lower 95% Confidence Limit about Mean	4289.990575	31.47202298	
Upper 95% Confidence Limit about Mean	15110.00942	9075.194644	
10th percentile	794.1796478	44.19750169	
25th percentile (Lower Quartile)	2015.977355	198.1363878	
50th percentile (Median)	5668.069288	1047.153171	
75th percentile (Upper Quartile)	15936.1956	5534.21699	
90th percentile	40453.07575	24809.76802	
Inter Quartile Range	13920.21825	5336.080602	
Minimum Detected Value	500	80	
Maximum Detected Value	24000	16000	
Regression Equation	ln(y) = 8.64260382514598 + 1.53331515958136*Z	ln(y) = 6.95383049548465 + 2.46944777890569*Z	
Beta_1 (slope)	1.53331516	2.469447779	
Beta_0 (intercept)	8.642603825	6.953830495	
Correlation Coefficient (r)	0.959210446	0.976897614	