# LOS ANGELES COUNTY AND ORANGE COUNTY BEACH WATER QUALITY: A RE-EVALUATION OF THE 3-DAY RULE


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**Abstract**
Exceedances of fecal indicator bacteria (FIB) beach water quality standards are correlated with storm events, which result from an influx of urban runoff containing high densities of FIB. In an effort to protect public health, the "3-Day Rule" warning is issued by public health agencies following a rain event to advise beachgoers to avoid water contact for a minimum of 72 hours. The intent of the 3-day period is to allow the bacteria enough time to decay or dissipate to safe levels. Current research fails to justify the validity of the 3-Day Rule for different beach types and rain intensities. In this study, *Enterococcus* densities in the water were examined at 32 beach sites within Los Angeles and Orange counties for a given rain day and its subsequent 10 dry runoff days for seven years of beach water quality data. These 32 beach sites are the most frequently monitored beaches in California. The beaches are categorized into three types: open, enclosed, and storm drain impacted. Rainfall intensity also has an effect on *Enterococcus* densities. Rainfall is categorized into four categories: light, medium, heavy, and very heavy. Based on the results, the 3-Day Rule is neither appropriate for enclosed beaches nor storm drain impacted beaches. An extension of the 3-Day Rule is needed for these two beach types to better protect the public health of swimmers and surfers. Open beaches do not exceed the *Enterococcus* standard until very heavy rainfall intensities occur. Additionally, the discrepancies in classifying storm drain impacted beaches and allotment of water quality monitoring resources across the two counties are significant findings. This study provides some recommendations for standardizing statewide beach classifications as well as to the California Department of Public Health regarding the efficacy of the 3-Day Rule to better protect beachgoer safety.

## <u>Introduction</u>

Beach water quality decreases after storm events, causing a concern for public health (Noble et al. 2003, Schiff et al. 2003). There is a correlation between rainfall and elevated levels of fecal indicator bacteria (FIB) in beach water; this connection varies with storm variables and beach type. Public agencies currently use FIB to evaluate beach water quality because FIB densities suggest the presence of pathogenic microbes, increased public health risk, and recent contamination in the water. Since California beaches receive millions of visitors annually, it is important to notify the public about potential beach water contamination to avoid exposure to pathogens. When there is a significant rainfall over 0.1 inch, public health agencies often issue an advisory for beachgoers to avoid water contact for a period of 72 hours after the rainfall.

This 3-Day Rule suggests that FIB levels will fall below the permissible contamination standard on the fourth day after a rainstorm, implying safe water contact. The 3-Day Rule is a risk communication statement not specific to beach type or storm intensity, and may not be appropriate for all beach types. Some beaches may require a longer advisory period for the microbial contamination to dissipate, while other beaches may need less than 72 hours. There is a gap in the literature reaffirming the appropriateness of the 3-Day Rule in California. For this study, FIB levels were examined during rainstorms and the following 10 dry runoff days to determine how long it takes for bacteria levels to drop below the standard. The study researchers sought to re-evaluate the 3-Day Rule at different beach types and with different storm intensities with the purpose to inform policy makers about the most effective way to protect public health and improve beachgoer safety.

## Background

Fecal indicator bacteria are found in the intestinal tracts of warm-blooded animals and are used to indicate the likelihood that the beach water harbors fecal-related pathogens. While most FIB themselves are harmless, they serve as indicators for human pathogenic bacteria and other microorganisms that pose a potential risk for beachgoers to contract enteric problems, such as gastroenteritis, diarrhea, or nausea (Griffith et al. 2009). Pathogens, viruses, and their corresponding fecal indicator bacteria are introduced to coastal beaches via runoff during rain storms. California beach water quality monitoring programs test for three indicator bacteria: total coliform, fecal coliform, and *Enterococcus.* The bacteria single sample standards in California are 10,000 CFU/100ml for total coliform, 400 CFU/100ml for fecal coliform, and 104 CFU/100ml for *Enterococcus*. Total coliforms include all coliforms from plants, soil, and animal sources. Fecal coliform and *Enterococcus* are found only in the fecal matter of mammals and birds. This study focuses on *Enterococcus* because it is an indicator of warm blooded animal contamination and is also the bacteria on which national beach water quality criteria are based.

According to the California Department of Public Health (CDPH) and California Assembly Bill 411, a beach must be tested at least once per week if it receives more than 50,000 people annually and if it is adjacent to a storm drain that flows in the summer (C.A. AB 411 1997). If the sample exceeds the FIB standards, the public must be notified and advised to avoid water contact. However, there is a lag between the sampling time and the posting of an advisory. It takes approximately 18-24 hours after a site is sampled to receive the test results. Therefore, it takes at least 24 hours for the public to receive the water quality information. In order to create a preemptive warning system, the CDPH issues a rain advisory in the event of a storm greater than one-tenth of an inch (0.10 inch). Elevated bacteria levels may continue for up to three days after a rain event. Consequently, the CDPH advises that beachgoers avoid water contact during these three days, especially near storm drains or creeks that discharge into the ocean (L.A. County DPH 2012).

Multiple studies have confirmed that swimmers are more prone to health risks as the density of certain FIB increases in the water (Halliday and Gast 2010, Haile et al 1999). Wade et al. (2008) interviewed beachgoers and surveyed their health conditions during a 10-12 day period. Coupled with water monitoring data at each study site, they concluded that *Enterococcus* densities, compared to other FIBs, were most strongly associated with gastrointestinal illness, especially among children. According to Halliday and Gast (2011), *Enterococcus* was best correlated with adverse health effects in marine beaches, whereas *E. coli* was best correlated with health effects in freshwater beaches. Additionally, Haile et al. (1999) found a significant difference in risk for those who swam at 0 yards versus 400+ yards from runoff flows into Santa Monica Bay, suggesting that location of recreational activity relative to a storm drain is important in understanding the extent of potential pathogen exposure to swimmers. Also, the bacteria levels and their dissipation times are dependent on a wide variety of factors including runoff flows, swell height, current direction and other factors, potentially necessitating a differentiation by beach type.

In this study, beaches were categorized into three types based on degree of water circulation and exposure to stormwater input. These categories were enclosed, open, and storm drain impacted, all with different retention times of storm runoff and corresponding FIB. Enclosed beaches were located inside a harbor. These beaches have limited water circulation, as there is no direct exposure to the open ocean or wave action. Families and young children often frequent enclosed beaches because of the calm waters and easy swimming conditions. Open beaches were defined as having no enclosing jetties or creeks or storm drains and with consistent ocean circulation and wave action. The final category, storm drain or creek impacted, included beaches that had storm drains with an outfall located on the beach. These beaches receive direct input of urban runoff and bacterial contamination. The fate and transport of FIB differed significantly between these three types, leading us to hypothesize that FIB levels and degradation time will differ for each beach category.

An advisory is issued for every rain event greater than or equal to 0.10 inch, however the impacts of rain intensity on FIB densities at recreational beaches has not been previously assessed. Although storm drain flow is the parameter that measures the amount of storm runoff that reaches a beach, rainfall intensity was used as a proxy since outfall flow data was unavailable.

## Methods

The correlation between fecal indicator bacteria and runoff day following a rain event greater than or equal to 0.10 inch was examined in order to re-evaluate the 3-Day Rule. This study was conducted using the beach water quality database compiled by Heal the Bay and later refined using specific parameters. The project focused on a seven-year period, from April 2005 to March 2012, and included over 87,000 data points. Each rain year was defined from April 1st to March 31st. Beaches within Los Angeles County and Orange County were selected for analysis if they were sampled two or more times per week; there were a total of 32 selected beach sampling locations. Sites 1-14 were Los Angeles County beaches and 15-32 were Orange County beaches.

The rainfall data was based on information collected by four rain gauges, one located in each of the following locations: Pepperdine University in Malibu (MBU), Los Angeles International Airport (LAX), Long Beach International Airport (LGB), and John Wayne International Airport (SNA) in Orange County. For sites 1-2, data from the LAX gauge was used for 2005-2006 and then the MBU gauge was used for 2007-2012; there was no access to MBU rain gauge data prior to 2007. Sites 3-14 were designated to the LAX gauge, sites 15-20 to the LGB gauge, and sites 21-32 to the SNA gauge. The rain gauges were assigned to the beach sites based on their proximity to the rain gauge. While LGB gauge is in LA County, its rain data was delegated to some of the Orange County beaches for its proximity to those beaches. Names, locations, and other relevant details about these 32 beach sites are listed in Table 1.

| Site | Name | Type | Rain Gauge | County | Typical Samples/week | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| 1 | Surfrider Beach (breach point) (aka SMB-MC-2) | S | MBU/LAX | LA | 5 | 34.034304 | -118.67838 |
| 2 | Topanga State Beach at creek mouth (aka SMB-1-18) | S | MBU/LAX | LA | 5 | 34.037813 | -118.58261 |
| 3 | Will Rogers State Beach at Santa Monica Canyon drain (point zero) | S | LAX | LA | 5 | 34.026854 | -118.52061 |
| 4 | Santa Monica Municipal Pier (point zero) | S | LAX | LA | 5 | 34.00827 | -118.49738 |
| 5 | Santa Monica Beach at Pico/Kenter storm drain (point zero) | S | LAX | LA | 5 | 34.005087 | -118.49338 |
| 6 | Ocean Park Beach at Ashland Ave. drain (point zero) | S | LAX | LA | 5 | 33.9965 | -118.48527 |
| 7 | Marina del Rey, Mothers' Beach-Playground area (aka MdRH-1) | E | LAX | LA | 6 | 33.979872 | -118.45749 |
| 8 | Marina del Rey, Mothers' Beach-lifeguard tower (aka MdRH-2) | E | LAX | LA | 6 | 33.980758 | -118.45779 |
| 9 | Dockweiler State Beach at Ballona Creek mouth (point zero) | S | LAX | LA | 5 | 33.960747 | -118.45761 |
| 10 | Manhattan Beach at 28th St. drain (aka SMB-5-2) | S | LAX | LA | 5 | 33.894457 | -118.41893 |
| 11 | Herondo Street storm drain- (in front of the drain) (aka SMB-6-1) | S | LAX | LA | 5 | 33.851911 | -118.39971 |
| 12 | Redondo Municipal Pier - south side | S | LAX | LA | 5 | 33.838682 | -118.39125 |
| 13 | Cabrillo Beach - harborside at restrooms | E | LAX | LA | 5 | 33.71116 | -118.28294 |
| 14 | Cabrillo Beach - harborside at boat launch | E | LAX | LA | 5 | 33.713392 | -118.28388 |
| 15 | Bolsa Chica Beach across from the Reserve Flood Gates | O | LGB | OC | 4.5 | 33.701814 | -118.05523 |
| 16 | Bolsa Chica Reserve at the downcoast end of the State Beach | O | LGB | OC | 4.5 | 33.688065 | -118.04218 |
| 17 | Huntington City Beach, Bluffs | O | LGB | OC | 4.5 | 33.67565 | -118.02853 |
| 18 | Huntington City Beach, projection of 17th Street | S | LGB | OC | 4.5 | 33.663642 | -118.01346 |
| 19 | Huntington City Beach, Jack's Snack Bar at Huntington St. | S* | LGB | OC | 4.5 | 33.65118 | -117.99691 |
| 20 | Huntington City Beach, projection of Beach Blvd. | O | LGB | OC | 4.5 | 33.645938 | -117.98811 |
| 21 | Huntington State Beach, projection of Newland St. (SCE Plant) | S* | SNA | OC | 4.5 | 33.6417 | -117.98126 |
| 22 | Huntington State Beach, projection of Magnolia Street | S* | SNA | OC | 4.5 | 33.638235 | -117.97555 |
| 23 | Huntington State Beach, projection of Brookhurst Street | S* | SNA | OC | 4.5 | 33.632909 | -117.96624 |
| 24 | Santa Ana River Mouth | S | SNA | OC | 4 | 33.62929 | -117.95968 |
| 25 | Newport Beach, projection of Orange Street | S* | SNA | OC | 4.5 | 33.626291 | -117.954 |
| 26 | Newport Beach, projection of 52nd/53rd Street | S* | SNA | OC | 4.5 | 33.622048 | -117.94444 |
| 27 | Newport Beach, projection of 38th Street | S* | SNA | OC | 4.5 | 33.6166 | -117.937 |
| 28 | Balboa Beach, projection of 15th/16th Street | S* | SNA | OC | 4.5 | 33.605207 | -117.92196 |
| 29 | Balboa Beach Pier | O | SNA | OC | 4.5 | 33.60085 | -117.90285 |
| 30 | Balboa Beach, The Wedge | O | SNA | OC | 4.5 | 33.59369 | -117.88166 |
| 31 | Corona Del Mar (CSDOC) | O | SNA | OC | 4.5 | 33.59303 | -117.87557 |
| 32 | Crystal Cove (CSDOC) | S | SNA | OC | 4.5 | 33.582088 | -117.85678 |

**Table 1**. This table lists all 32 beach sample sites. Type designates the site's structure as enclosed (E), open (O), and storm drain impacted (S). S* designates Orange County beaches not impacted by local storm drains that were classified as storm drain impacted before the study. Rain gauge designates the location of the site's rainfall measurement; Pepperdine University in Malibu (MBU), Los Angeles International Airport (LAX), Long Beach

International Airport (LGB), and John Wayne International Airport (SNA). Typical samples/week designates how often the beach site is typically sampled per week from April 2005 to March 2012.

The effects of rainfall were analyzed for storm events and their following 10 dry days. A wet day was defined as any day with a rainfall amount greater than or equal to 0.10 inch; anything below a 0.10 inch is considered a dry day. A storm was defined as the sum of consecutive days of rainfall. In order to examine the FIB levels after a rainstorm, the last rain day of a storm was designated as "Runoff Day 0". The 10 consecutive dry days, or runoff days, were labeled "Runoff Days 1-10". If a rainstorm occurs within the 10 days, the dry runoff period is shortened. Storms without a full 10-day dry runoff period were included in the analysis as storms with shorter runoff periods. Sample sizes for each runoff day are listed in Table 2.

| | | **Runoff Day** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| **Rain Gauge** | **MBU/LAX** | 147 | 96 | 82 | 72 | 67 | 65 | 58 | 56 | 51 | 49 | 47 |
| | **LAX** | 151 | 98 | 90 | 80 | 72 | 70 | 65 | 62 | 55 | 53 | 50 |
| | **LGB** | 141 | 92 | 83 | 71 | 64 | 63 | 58 | 55 | 52 | 50 | 49 |
| | **SNA** | 148 | 101 | 90 | 82 | 74 | 71 | 65 | 58 | 53 | 52 | 44 |

**Table 2.** This table shows the sample size by runoff day for each rain gauge. Runoff day 0 is the day of the storm.

Each sampling location was categorized into the three different beach types: enclosed, open, and storm drain impacted. Based on the beach monitoring frequency parameter, Los Angeles had 4 enclosed beaches and 10 storm drain impacted beaches. Orange County had 3 storm drain impacted beaches and 15 open beaches. Los Angeles had no open beaches and Orange County had no enclosed beaches that were sampled at least two times per week. Sample sizes for each beach type are listed in Table 3.

| | | | **Runoff Day** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beach Type** | **Rain Gauge** | **# of Sites** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| Enclosed | LAX | 4 | 604 | 392 | 360 | 320 | 288 | 280 | 260 | 248 | 220 | 212 | 204 |
| Storm Drain (Original) | MBU/LAX | 2 | 294 | 194 | 166 | 146 | 136 | 132 | 118 | 114 | 104 | 100 | 96 |
| | LAX | 8 | 1208 | 792 | 728 | 648 | 584 | 568 | 528 | 504 | 448 | 432 | 408 |
| | LGB | 2 | 282 | 186 | 168 | 144 | 130 | 128 | 118 | 112 | 106 | 102 | 100 |
| | SNA | 9 | 1332 | 918 | 819 | 747 | 675 | 648 | 594 | 531 | 486 | 477 | 405 |
| Storm Drain (Revised) | MBU/LAX | 2 | 294 | 194 | 166 | 146 | 136 | 132 | 118 | 114 | 104 | 100 | 96 |
| | LAX | 8 | 1208 | 792 | 728 | 648 | 584 | 568 | 528 | 504 | 448 | 432 | 408 |
| | LGB | 1 | 141 | 93 | 84 | 72 | 65 | 64 | 59 | 56 | 53 | 51 | 50 |
| | SNA | 2 | 296 | 204 | 182 | 166 | 150 | 144 | 132 | 118 | 108 | 106 | 90 |
| Open (Original) | LGB | 4 | 564 | 372 | 336 | 288 | 260 | 256 | 236 | 224 | 212 | 204 | 200 |
| | SNA | 3 | 444 | 306 | 273 | 249 | 225 | 216 | 198 | 177 | 162 | 159 | 135 |
| Open (Revised) | LGB | 5 | 705 | 465 | 420 | 360 | 325 | 320 | 295 | 280 | 265 | 255 | 250 |
| | SNA | 10 | 1480 | 1020 | 910 | 830 | 750 | 720 | 660 | 590 | 540 | 530 | 450 |

**Table 3.** This table shows the sample size by runoff day for each beach type and the corresponding rain gauge. Runoff day 0 is the day of the storm.

Los Angeles and Orange counties have different monitoring location designation protocols for their storm drain impacted beaches. Los Angeles County designates a storm drain impacted beach as any beach with a local storm drain that empties onto the sand. This county also standardizes monitoring locations at point zero, or where the outflow directly meets the ocean. Orange County designates a storm drain impacted beach based on the influence of the Santa Ana River, and sample sites are assigned at equidistant points north and south of the river mouth. For the purpose of this study, however, only beach sites with local storm drain outfalls were classified as storm drain impacted beaches. A comparison of the average beach *Enterococcus* density by runoff day was made between Los Angeles and Orange County storm drain impacted beaches since it is the beach type shared by both counties. In addition, the *Enterococcus* densities were differentiated between the counties to determine if sampling location had an impact on bacteria levels.

The daily maximum *Enterococcus* single sample standard in California is 104 CFU/100ml. For this study, the standard was referred to as the "*Enterococcus* standard". Some dates did not have a monitoring sample taken, and these null days were not included in our analysis. Using the *Enterococcus* density standard, a binary exceedance value was issued. A "0" indicated that a sample site's *Enterococcus* density measured less than the standard, whereas a "1" exceeded the standard. The mean empirical probability was calculated by averaging every "0" (non-exceedance) and "1" (exceedance) for each sample site. This yielded the likelihood a sample site will exceed the *Enterococcus* standard for a particular day.

Stata was the statistical software used to analyze the data. In order to compare between the three beach types, an average of each *Enterococcus* density for each runoff day was taken for each beach type. This yielded the average empirical *Enterococcus* density. The binary exceedance values were also averaged to determine the probability of exceedance. Both of these analyses were based on the data collected over the past seven years. Using the data, a predictive model was generated for *Enterococcus* density and binary values.

Two aspects of rainfall were focused on: first flush and rainfall intensity. A first flush is the first significant rainfall after the dry season. For the purpose of the study, rainfall after September 30$^{th}$ was deemed to be a first flush storm. A first flush storm was defined as the first 0.25 inch or greater storm after the dry summer season and any other 0.25 storm with a 30-day antecedent dry period. This produced a sample size for each rain gauge: 14 first flushes for Malibu/LAX, 13 for LAX, 20 for Long Beach, and 14 for Santa Ana. This totaled to 840 first flushes for all 32 beaches. A three-level linear mixed model was used to show the interaction between first flush by site type by runoff day, and the chi-squared test was used to determine the statistical significance of this interaction. Sample sizes for first flush storms are listed in Table 4.

| | 60-day | 30-day |
|---|---|---|
| MBU/LAX | 11 | 14 |
| LAX | 9 | 13 |
| LGB | 14 | 20 |
| SNA | 12 | 14 |
| Total | 358 | 472 |
| Total w/ Runoff Days | 2640 | 4422 |

**Table 4.** This chart shows the sample size for first flushes (both the 60-day and 30-day definitions) for each rain gauge. “Total” sums the number of first flushes for all beach sites. “Total w/ Runoff Days” includes the number of subsequent runoff days (maximum of 10 days) after a first flush.

Rainfall was divided into four categories: light (0.1–0.25 inch), moderate (0.25–0.5 inch), heavy (0.5–0.75 inch), and very heavy (0.75 inch and above). Sample sizes for rain intensity are listed in Table 5.

| | | Rain Intensity | | | |
|---|---|---|---|---|---|
| | | Light | Moderate | Heavy | Very Heavy |
| Rain Gauge | MBU/LAX | 50 | 36 | 16 | 80 |
| | LAX | 53 | 35 | 31 | 51 |
| | LGB | 40 | 36 | 30 | 55 |
| | SNA | 55 | 39 | 15 | 65 |

**Table 5.** This chart shows the sample size by rain intensity for each rain gauge. Light rain is 0.1 to 0.25 inches. Moderate rain is >0.25 to 0.5 inches. Heavy rain is >0.5 to 0.75 inches. Very heavy rain is >0.75 inches.

These categories indicate intensity of the storm by rainfall amount. An empirical and a predictive model were used to determine the effect of rainfall intensity on the *Enterococcus* density for the three beach types. A three-level model was used to incorporate rainfall intensity: rain category, beach type, and *Enterococcus* density for Days 0-10. The p-value was used to determine statistical significance. The predictive model incorporated these averages into a three level linear regression model and generated a predicted *Enterococcus* density for a specific beach type for a given rainfall intensity.

## Results

### *Beach Type*

*Average Empirical Enterococcus Density by Beach Type*

On rain day 0, average *Enterococcu*s densities exceeded the *Enterococcu*s standard for both enclosed and storm drain impacted beaches (Figures 1-2). Storm drain impacted beaches had the highest exceedance on day 0. These bacteria levels then decreased significantly during the first three runoff days, falling below the Enterococcus standard on the fifth runoff day. For enclosed beaches, the *Enterococcu*s density peaked on the first runoff day and continued to violate safe levels, except for a slight decrease below the standard on the eighth runoff day.

Open beaches never exceeded the standard for either rain day 0 or the subsequent 10 runoff days. For all beach types, the average densities demonstrated the greatest decrease between days one and three. The chi-squared value was 701.88 with a P>chi-squared equal to 0.00.

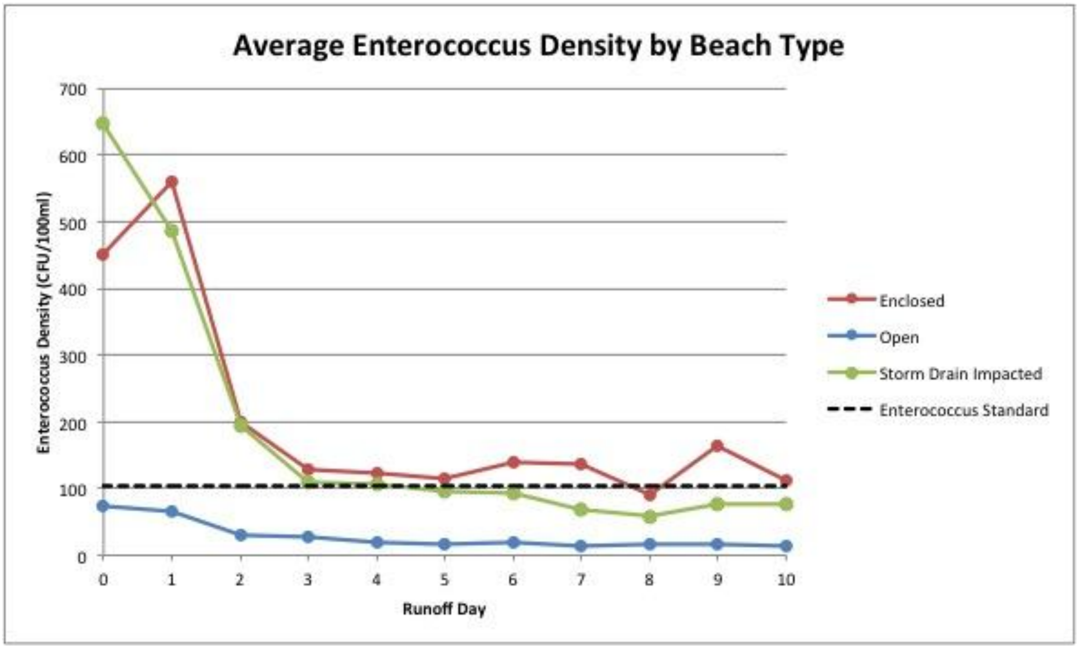


**Figure 1: Average Empirical *Enterococcus* Density by Beach Type** graph shows the average *Enterococcus* density for a particular runoff day for each beach category: enclosed, open, and storm drain impacted. The averages are derived from the raw *Enterococcus* data. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

*Average Empirical Exceedance Probability by Beach Type*

The empirical binary test produced average probabilities that a beach will exceed the *Enterococcu*s standard based on the raw data (Figure 2). These probabilities were calculated for rain day 0 and runoff days 1-10 for each of our three beach types. The probability of an exceedance for open beaches exhibited a downward trend from days 0-2. For enclosed and storm drain impacted beaches, the probability increased between days 0 and 1 but then continued to decrease until day 3 for enclosed beaches and day 5 for storm drain impacted beaches. The probability of an open beach to exceed state standards was always below 20%. In contrast, the probability of an enclosed beach to exceed these standards was always above 20%.

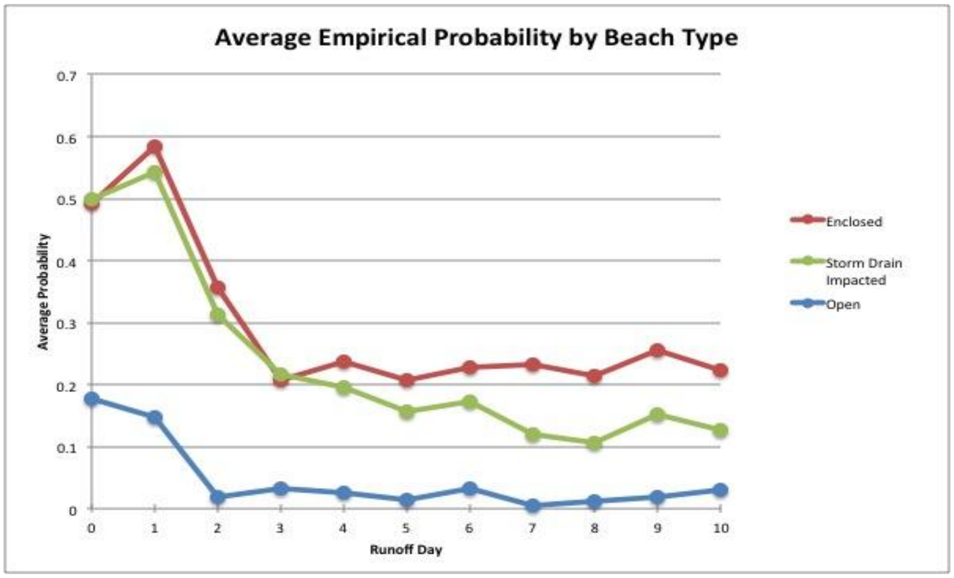


**Figure 2: Average Empirical Probability by Beach Type** graph shows the average probability that the *Enterococcus* density will exceed the *Enterococcus* safety standard of 104 CFU/100ml for a particular runoff day for each beach category: enclosed, open, and storm drain impacted. Runoff day "0" indicates the last rain day.

*Predicted Enterococcus Density by Beach Type*

The results for the predicted *Enterococcus* density by beach type (Figure 3) were similar to the empirical results (Figure 1). For rain day 0, enclosed beaches had a predicted density of nearly 500 CFU/100ml and then the predicted density further increased on the first runoff day, approaching 600 CFU/100ml. The predicted *Enterococcus* density dramatically decreased to 200 CFU/100ml by the second runoff day and then generally plateaued at around 150 CFU/100ml. The predicted density never fell below the *Enterococcus* standard during the 10 day period. The *Enterococcus* density for open beaches remained below the *Enterococcus* standard for rain day 0 and runoff days 1-10. The storm drain impacted beaches behaved more closely to the enclosed beaches after storms, however they eventually decreased below the *Enterococcus* standard. These beaches started near a predicted density of 700 CFU/100ml and then dropped significantly over the sequential runoff days. By the third runoff day, the *Enterococcus* density was just above the standard. By the seventh runoff day, the density of *Enterococcus* fell below the standard and continued to do so for runoff days 7-10.

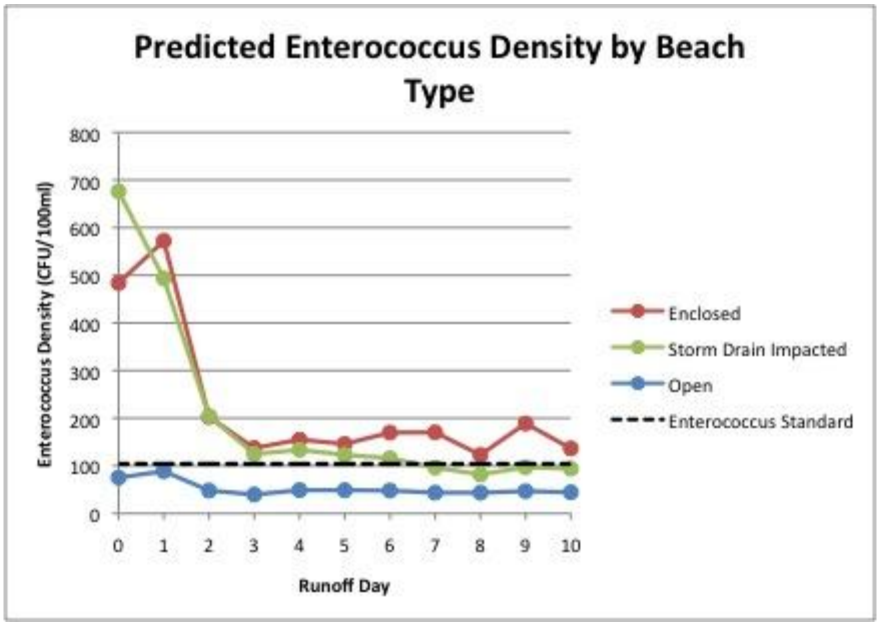


**FIgure 3: Predicted *Enterococcus* Density by Beach Type** graph shows the *Enterococcus* density for each beach type predicted by the binary model. The dashed line marks the 104 CFU/100ml *Enterococcus* standard safety level. Runoff day "0" indicates the last rain day that precedes the following 10 runoff days.

### *Los Angeles County versus Orange County Storm Drain Sampling Location*

The average empirical *Enterococcus* density was calculated for Orange County (OC) and Los Angeles County (LA) storm drain impacted beaches for rain day 0 and runoff days 1-10 using the Orange County Environmental Monitoring Division designations for storm drain impacted beaches. LA storm drain impacted beaches had significantly higher *Enterococcus* densities compared to OC storm drain impacted beaches throughout days 0-10. The *Enterococcus* density for the LA beaches surpassed the *Enterococcus* standard until the sixth day where it fell slightly below for the remainder of the runoff period. The *Enterococcus* density for OC storm drain impacted beaches remained below the standard for the entire duration of the monitored runoff period.

Using a standardized approach for both counties, storm drain impacted beaches were defined as a beach with a local storm drain outfall. The average empirical *Enterococcus* density for the three reclassified OC storm drain beaches for rain day 0 and runoff days 1-10 were consistently below the *Enterococcus* standard. Also, one of the three reclassified OC beaches, Crystal Cove, was a natural watershed drainage, so we ran another analysis including only the two urbanized storm drain impacted beaches. The results of this analysis indicated that the *Enterococcus* density for these beaches did not fall below the *Enterococcus* standard until runoff day two (Figure 4).

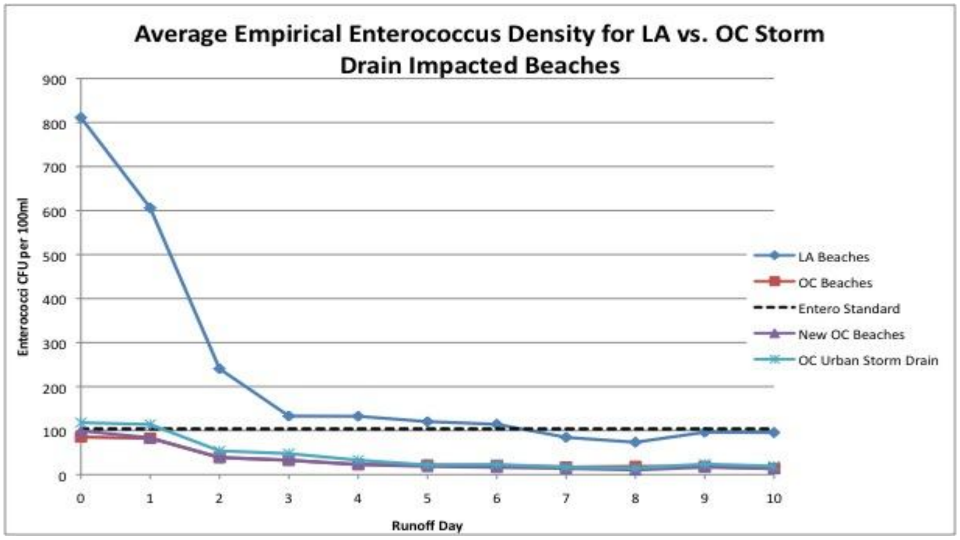


**Figure 4: Average Empirical Enterococcus Density for LA vs OC storm drain Impacted Beaches** graph illustrates the relationship between runoff days following a rain event and *Enterococcus* densities. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

### *First Flush*

The influence of first flushes on *Enterococcus* densities was considered for a 30-day dry period. In the absence of a first flush influence, storm drain impacted beaches (Figure 5), on average, displayed the highest exceedances for all runoff days including the day of the rain event. Both storm drain impacted and enclosed beaches peaked on the first runoff day and exceeded well beyond the standard for runoff days 0-10. While open beaches experienced their highest *Enterococcus* levels on runoff day 0 and the first runoff day, densities were still below the standard from day 0 through the 10th runoff day.

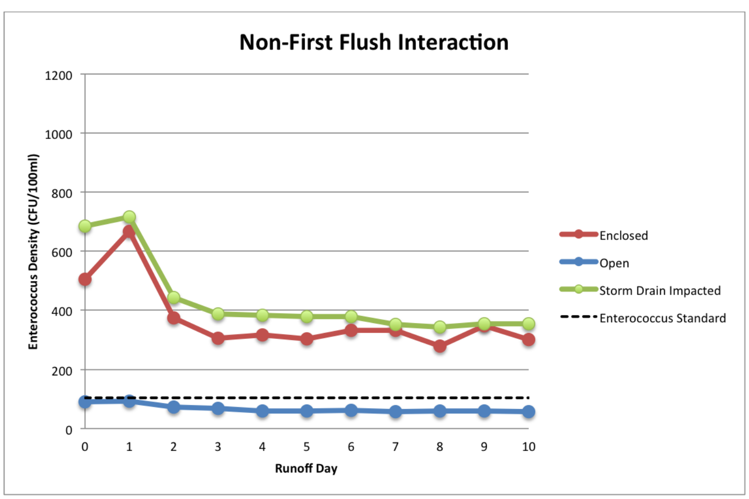

**Figure 5: Non-First Flush Interaction** graph is not adjusted for first flush rainstorm defined by 30 dry days. The interaction yields predicted *Enterococcus* levels for each beach type on a particular runoff day. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

The 3-level linear mixed model interaction between 30-day first flush, site type, and runoff day was shown to be statistically significant, as evidenced by its chi-squared value of 69.24 and p-value of 0.000. Significance for this 30-day analysis was achieved when the chi-squared value of the nested variables was at least 60. The site type by runoff day interaction effect, in this case, was not the same for non-first flush and first flush events. The sample size of first flush storms in the same 8-year term (i.e. 472) was 0.005% of the total sample data. Although the sample size was only 0.001% greater than that of the 60-day scenario, it was large enough to create a statistically significant relationship between the variables. After a first flush storm, storm drain impacted and enclosed beaches remained above the *Enterococcus* standard (Figure 6). Open beaches fell beneath the threshold standard but slightly exceeded on the first runoff day. For enclosed and storm drain impacted beaches, the rainy day and the first two runoff days differed the most between non-first flush and first flush storms. The *Enterococcus* density for both beach types was higher on these days following a first flush storm. In addition, while the densities at enclosed beaches peaked on the first runoff day in both storm scenarios, storm drain impacted beaches exhibited its highest density on the actual rain day for first flush storms but the first runoff day following a non-first flush storm.

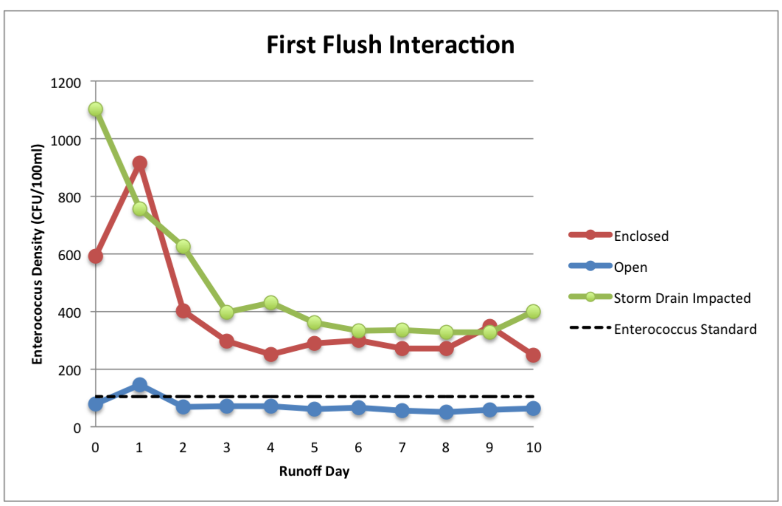


**Figure 6: Graph of the Site Type by Runoff Day Interaction** shows a three-way interaction between site type and runoff days and is adjusted for first flush as defined by 30 dry days. Enclosed and storm drain impacted beaches show the highest exceedances for any given runoff day when compared to open beaches.

### *Rainfall Intensity*

*Empirical Enterococcus Density by Site Type for Rainfall Intensity*

The empirical *Enterococcus* density was calculated by site type for rainfall intensity (Figures 7-10). For light (0.1-0.25 inch) rainfall (Figure 7) the *Enterococcus* density for enclosed beaches remained above the *Enterococcus* standard for a total of 9 days out of the 11 days that were monitored. Open beaches never exceeded the *Enterococcus* standard for light rainfall. Storm drain impacted beaches maintained bacteria densities above *Enterococcus* standard for three days.

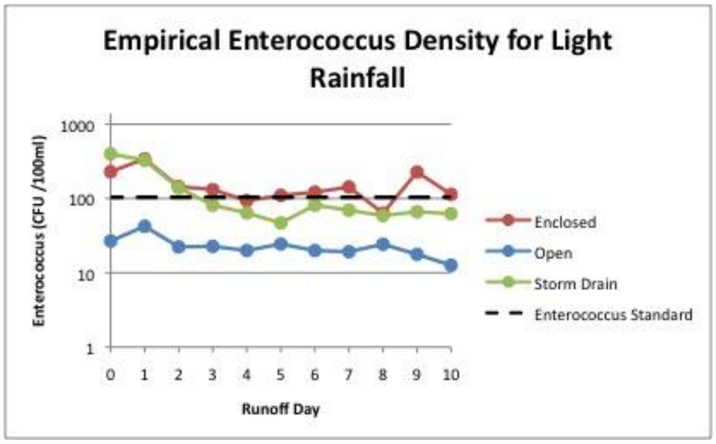


**Figure 7: Empirical *Enterococcus* Density for Light Rainfall** graph depicts the relationship between *Enterococcus* densities (CFU/100ml) and runoff day; this graph is adjusted for light rainfall intensity. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

The *Enterococcus* density for enclosed beaches for moderate (0.25 to 0.5 inch) intensity rainfall (Figure 8) exceeded the *Enterococcus* standard for a total of eight days following rain day 0. Open beaches never exceeded the *Enterococcus* standard for moderate rainfall. Storm drain impacted beaches kept above *Enterococcus* standard for seven runoff days following the light rainstorm.

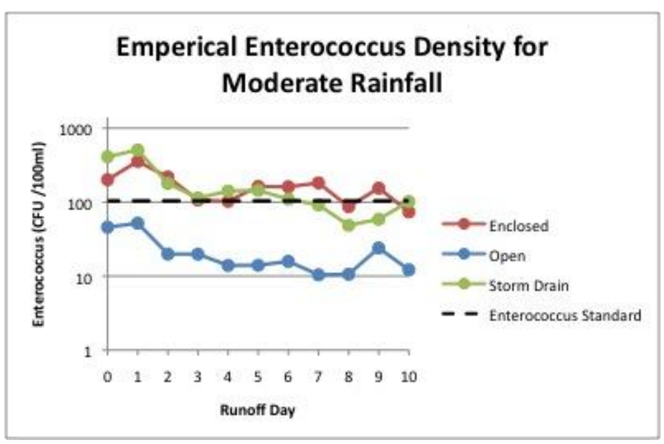


**Figure 8: Empirical *Enterococcus* Density for Moderate Rainfall** graph depicts the relationship between *Enterococcus* densities (CFU/100ml) and runoff day; this graph is adjusted for moderate rainfall intensity. The black

dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

The *Enterococcus* density for enclosed beaches for heavy (0.5 to 0.75 inch) intensity rainfall (Figure 9) was above the Enterococcus standard up until the fifth runoff day. Open beaches never exceeded the *Enterococcus* standard for heavy rainfall.   Storm drain impacted beaches kept above *Enterococcus* standard until the sixth runoff day.

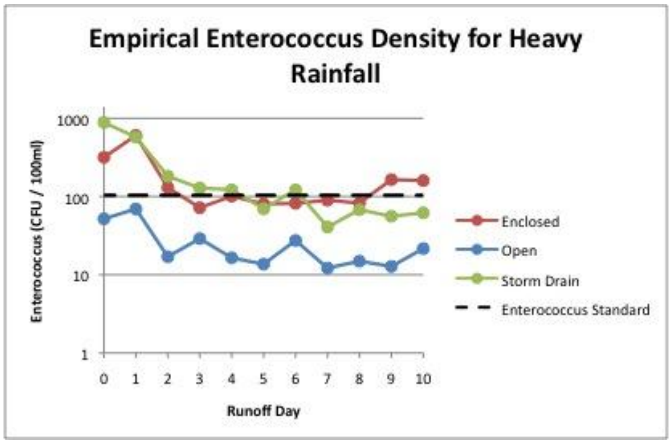


**Figure 9: Empirical *Enterococcus* Density for Heavy Rainfall** graph depicts the relationship between *Enterococcus* densities (CFU/100ml) and runoff day; this graph is adjusted for heavy rainfall intensity. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

For *Enterococcus* density adjusted for very heavy (over 0.75 inch) intensity rainfall (Figure 10), enclosed beaches were above the *Enterococcus* standard until the sixth runoff day. Open beaches only exceeded the *Enterococcus* standard for rain day 0. Storm drain impacted beaches kept above *Enterococcus* standard until the seventh runoff day.

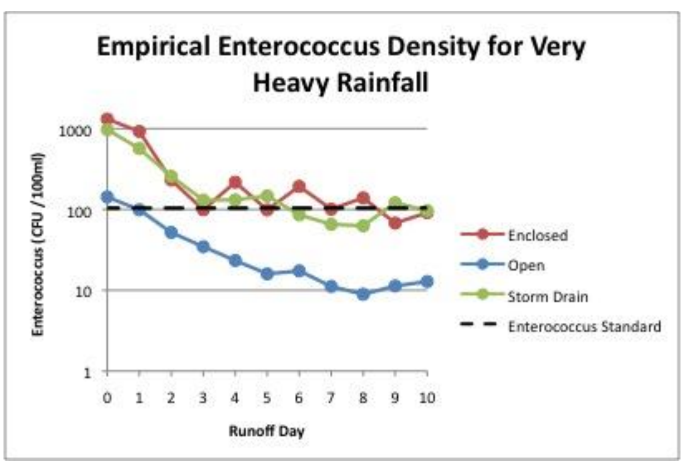


**Figure 10: Empirical *Enterococcus* Density for Very Heavy Rainfall** graph depicts the relationship between *Enterococcus* densities (CFU/100ml) and runoff day; this graph is adjusted for very heavy rainfall intensity. The

black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

The *Enterococcus* density for the rain day 0 for each beach type were calculated for all of the four storm categories (Table 2). For light, moderate, and heavy rainfall, storm drain impacted beaches had the highest *Enterococcus* density, whereas for very heavy rainfall enclosed beaches had the highest *Enterococcus* density. For storm drain impacted beaches and open beaches, the *Enterococcus* density on rain day 0 grew with increasing rainfall intensity. For enclosed beaches, a moderate rainfall produced the lowest *Enterococcus* density on rain day 0 but for all other rainfall intensities, the density grew with increasing rainfall intensity. All beach types exceeded the permissible standard for very heavy rainfall.

| DAY ZERO | Light | Moderate | Heavy | Very Heavy |
|---|---|---|---|---|
| Enclosed | 229.56 | 200.81 | 316.97 | 1311.74 |
| Open | 26.76 | 45.79 | 51.88 | 142.43 |
| Storm | 398.96 | 411.49 | 885.03 | 973.14 |

**Table 2.** This table lists the average *Enterococcus* densities on rain day 0 for each beach category (ie. enclosed, open, storm) during the four separate storm intensity categories (ie. Light (0.1–0.25 inch), Moderate (0.25–0.5 inch), Heavy (0.5–0.75 inch), and Very Heavy (0.75 inch and above).

## Discussion

### *Beach Type*

In re-evaluating the 3-Day Rule, the most critical results were found when comparing beach types. The *Enterococcus* density exceedances following a storm for all three beach types ranged from highest *Enterococcus* densities at enclosed beaches to lowest densities at open beaches. Enclosed beaches are not exposed to wave action or currents from the open ocean, which dissipate bacterial densities at open beaches. Storm drain impacted beaches generally had *Enterococcus* concentrations in between the values of enclosed and open beaches. Based on the densities of *Enterococcus* after a storm, enclosed beaches are of the greatest concern for beachgoers. Following a storm event, *Enterococcus* levels exceeded the standard on rain day 0 and for most of the following 10 runoff days after the storm. Even on days that met the single sample *Enterococcus* standard, they were often followed immediately by an exceedance day. This inconsistency does not mean that there are certain "safe" days in between the exceedances, and in order to be as protective of public health as possible the advisory period should be extended. Unlike storm drain impacted and open beaches with *Enterococcus* densities that dropped rapidly after a storm, enclosed beaches had a gradual slope of decreasing *Enterococcus* concentrations to below standards. Upon individual examination of the enclosed sample sites (see appendix figures A-7 - A-18), it was observed that only the Cabrillo harborside beach near the restrooms consistently exceeded standards for over a week after a storm; Cabrillo Beach has a history of having high levels of FIB and was listed on Heal the Bay's 2013 Beach Bummer list (Heal the Bay 2013). This beach most likely increased the overall *Enterococcus* density averages for enclosed beaches, however, these averages are still significant for overall policy recommendations. The other three sites (two at Mother's Beach in Marina del Rey and the third also at Cabrillo) fell below the standard between the third and seventh runoff days.

Many families seek enclosed beaches for young children because there are little to no currents or waves. However, a 3-Day Rule would not suffice and would have to be extended to at least 5 days to achieve safe levels for enclosed beaches. There are only a few enclosed beaches along the California coastline, making it easier to notify beach visitors of exceedances at these beach types. Lifeguards and other public health officials should be notified of these results to keep the public safe.

Open beaches had the lowest *Enterococcu*s densities. On rain days, open beaches did not exceed the *Enterococcus* standard for all rainfall intensities except the very heavy category. After the rain day, *Enterococcus* densities remained below the exceedance value, and consistently decreased during the subsequent 10 runoff days. Three days proved to be an appropriate advisory period for this beach type.

Storm drain beaches and *Enterococcus* exceedances were dependent on their location in either Los Angeles or Orange Counties, which is further discussed below.

### ***Orange County vs. Los Angeles County Beaches storm drain Impacted Beaches***

The initial results from *Enterococcus* densities for storm drain impacted beaches indicated that there were significant differences between the storm drain impacted beaches in Los Angeles (LA) and Orange County (OC). The *Enterococcus* densities for LA storm drain impacted beaches did not fall below the *Enterococcus* standard until the seventh runoff day, while *Enterococcus* densities for OC storm drain impacted beaches never exceeded the *Enterococcus* standard; these results implied that OC storm drain impacted beaches had lower *Enterococcus* densities and are, therefore, safer for beachgoers. After discussing the issue of beach categorization with public health officials in LA and OC, however, it was discovered that OC does not classify their storm drain beaches based on the distance from the closest storm drain like LA (Honeybourne 2013, Sharp 2013). In OC, the largest storm drain is the Santa Ana

River Mouth, and as stated in the NPDES Permit and water discharge requirements for the County of Orange and Santa Ana Region, sampling locations designated in equidistant points north and south from the Santa Ana River mouth were also categorized as storm drain impacted (C.A. RWQCB 2013). These 11 beaches are as far as three miles away from the river mouth, and only three have local storm drains (two urbanized drainages and one natural watershed). The remaining eight sites also had similar results to open beaches in the data analysis of *Enterococcus* densities in that they never exceeded the *Enterococcus* standard after a rain.

Even with the reclassification of the OC storm drain impacted beaches, there was still a noticeable difference in regards to the *Enterococcus* densities between OC and LA County beaches. In LA storm drain impacted beaches, bacteria levels did not meet water quality standards until at least the third day following a rain event, while it only took one day for OC storm drain impacted beaches to meet standards. It should be noted, however, that this observation is based off of the *Enterococcu*s densities for only two storm drain impacted beaches in Orange County, an extremely small sample size. One storm drain impacted beach, Crystal Cove, was classified as having a natural watershed. This beach had no exceedances on rain day 0 or runoff days 1-10 and, therefore, was safe for beachgoers to enter the water at all times during or after a rain event. These results suggested that beaches with natural watershed discharges may behave more similarly to open ocean beaches and be safer earlier for beachgoers than urban storm drain impacted beaches. To implement a successful beach advisory period by beach type and to gain more accurate analyses of beach water quality data, it is important to standardize how beaches are classified throughout the state.

As a result of the reclassification, it is recommended that Orange County reallocate their monitoring resources. Only 3 of the 11 original storm drain impacted beaches were found to be true storm drain impacted beaches using the local storm drain criteria. Heal the Bay also recommended to the OC Monitoring Program that "any decrease in monitoring frequency should be accompanied by a requirement to move beach sample sites to point zero in front of storm drains" (Heal the Bay 2013). If OC chooses to monitor less frequently at certain sample sites, it is best to move these resources to point zero. Monitoring beaches at point zero is a protective measure of public health-- if the beach is below the *Enterococcus* standard at point zero, it will also be below the standard further away from the outflow. Future research should include a comprehensive analysis of storm drain maps, watershed size, flows and discharge locations in OC and eventually, the entire state of California. This would identify any additional storm drain impacted beaches such as Huntington Pier, the outfall of Talbert Marsh, or other locations that need consistent monitoring. The cost of this increased monitoring would come from reallocating resources. For example, decreasing the monitoring at the reclassified open beaches to only once per week would make resources available for monitoring additional storm drain impacted beaches. We agree that the overall cost of the monitoring program should not increase based on these proposed changes.

### ***First Flush***

Prior to data analysis, first flush storms were speculated to generate higher *Enterococcus* levels for all beach types in comparison to the non-first flush storms. First flush storms are correlated with higher levels of metals and petroleum hydrocarbons in urban runoff due to accumulation during the dry season. Therefore, it was hypothesized that a similar outcome would occur with fecal bacteria.

The first flush variable was statistically insignificant using a 60-day definition, so the antecedent dry period was decreased to 30 days to obtain a larger sample size in hopes of yielding more statistical certainty. A separate chi-squared test was used to compare the influence of storm conditions with a 30 day antecedent dry period. The results of this modified analysis did, in fact, support a statistically significant relationship. The peak seen on runoff day 0 for storm drain impacted beaches may reflect the direct discharge of highly concentrated urban runoff. The noticeable spike on the first runoff day for enclosed beaches may be due to lag associated with runoff flow rate as well as the day on which the water sample was taken. These results support the influential effect of first flush storm events on *Enterococcus* densities, demonstrating more exceedances and poorer water quality after a first flush than non-first flush storms.

### ***Rainfall Intensity***

It was evident that rainfall intensity had different effects on the advisory period at different beach types. For enclosed beaches, heightened rainfall intensity did not correlate to an increased advisory period for beachgoers; this beach type generally had high concentrations of FIB regardless of rainfall intensity**.** Therefore, beachgoers are recommended to stay out of the water for at least 5 days following a rain. Increased rainfall intensity, however, did correlate to an increased advisory period for open beaches and storm drain impacted beaches. For open beaches, very heavy rainfall caused an *Enterococcus* exceedance, and this exceedance was only on rain day 0. This result indicates that for light, moderate, and heavy rainstorms beachgoers at open beaches are less likely to become ill after entering the water following rain day 0. However, during very heavy rainfalls, beachgoers should avoid entering the water during the rain event. Open beaches may exceed the *Enterococcus* standard on rain day 0 because a runoff plume for higher intensity storms covers a much larger area than that for lower intensity storms. The runoff plume will, therefore, also affect non-storm drain impacted beaches, including open beaches. Because of the high number of storm drain impacted beaches in Los Angeles County near less frequently monitored open ocean beaches, further analysis on rainfall intensity impacts on FIB densities and runoff plumes at open ocean beaches in Los Angeles County could demonstrate a longer water quality impact than seen in Orange County. For storm drain impacted beaches, rainfall impacts on FIB densities were associated with rainfall intensity. Light rains caused exceedances of standards for an average of two days and five to six days for moderate, heavy and very heavy rainfall intensities. Beachgoers are advised to avoid ocean water contact for a minimum of five days following a rain event.

The predicted probability trends of an *Enterococcus* exceedance by site type for rainfall amount were very similar to the empirical model. Enclosed beaches had the highest probability of an exceedance for rain day 0 and runoff days 1-10, while open beaches had the lowest probability of an exceedance for rain day 0 and runoff days 1-10. The purpose of this component of the study was to provide public health officials with a predicted probability model that could be used to warn beachgoers of the probability of an exceedance at a particular beach type based on the storm size.

## Conclusion

The results of this study indicated that FIB levels in beach water were affected by rainfall intensity and by beach type and the 3-Day Rule is not adequate to protect the health of beachgoers after a rain at enclosed and storm drain impacted beaches. To best protect public health against pathogens found in recreational water, public notification policy should be amended to include these factors. Although the 3-Day Rule is simple, it is not applicable to all beaches and is not the best protection of public health. The rule provides a sufficient advisory period for open beaches. It is not adequate, however, for storm drain and enclosed beaches. Public health agencies should warn beachgoers to avoid water contact at enclosed and storm drain, creek or river impacted beaches for at least 5 days after a significant rain.

Standardized monitoring techniques and beach classifications are also essential, especially on a regional and statewide basis. Collecting water samples at “point zero” in front of a pollution point source, such as a storm drain, gives the most protective representation of FIB concentrations for water quality purposes. Monitoring at point zero is already mandated throughout Los Angeles County, and this practice should be standardized throughout the state and region to best protect beachgoers’ health. In addition, beach classification also should be consistent across counties and throughout the state. Standardized beach classifications and water sampling locations will make it easier for future comparisons of beach water quality data. Monitoring locations for storm drain impacted beaches should be located in front of local storm drain outflows and not by proximity to river mouths or other single, large point sources, such as the current technique used in Orange County. Also, all bathing and surfing beaches in front of creeks and storm drains should be monitored on a weekly basis. Establishing a uniform set of guidance for beach classifications statewide will provide a better allocation of monitoring time and resources.

Further research should focus on the impacts of the Santa Ana River mouth on Orange County beach sites in order to determine the extent of the effects of the outfall plume. In order to do this, upstream flow from the Prado Dam must be studied and correlated with exceedances near the Santa Ana River mouth. Also, storm drain flow data is a more accurate predictor of beach exceedance than rain gauge data. Rainfall amount serves as a surrogate, however, due to the lack of storm drain data. Further investigations on flow impacts on beach water quality are needed after the installation of flow meters on all Los Angeles and Orange County storm drains. Better beach usage data could be a valuable tool in ensuring that the most frequented beaches near pollution sources are consistently monitored. Knowledge of beach usage and visitation is valuable in determining if certain beaches should be sampled more often than others. While we focused on *Enterococcus* densities because it is the indicator bacteria used on a national level, completing the same analysis on the impacts of rain on Total Coliform and Fecal Coliform densities in beach water would provide further insight into protecting public health.

## Recommendations

- Enclosed beaches and storm drain impacted beaches in California should have at least a 5-day rule for risk communication
- The 3-day rule is appropriate for open beaches
- California should develop a uniform statewide storm drain impacted beach classification and monitoring protocol

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**Appendix**

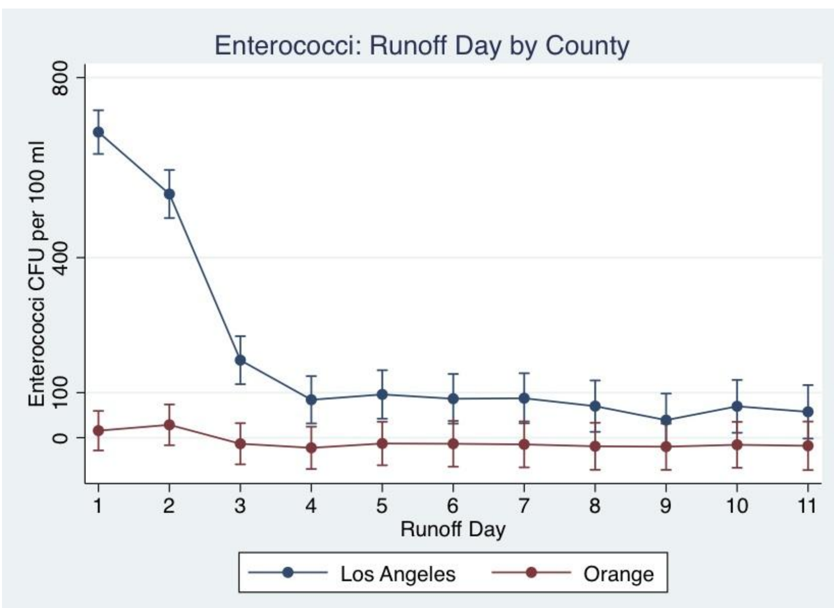


**Figure A-1.** This graph represents the *Enterococcus* density (CFU/100ml) for beaches in Los Angeles and Orange County. Los Angeles county beaches show the greatest density of Enterococci during and after a rain event. Error bars are included for the appropriate range of values that exist for different beach types within the county. Overlap of the error range occurs on the 6th runoff day. Note that this graph shows the rain day as the 1st runoff day and the actual 10th runoff day as the 11th runoff day.

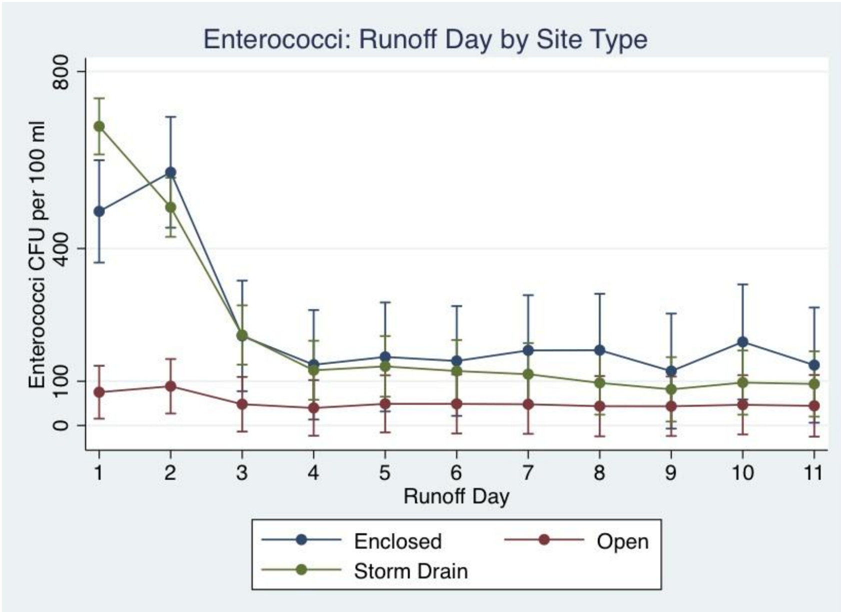


**FIgure A-2.** This graph shows the *Enterococcus* density (CFU/100ml) for each beach type. Enclosed and storm drain impacted beaches have relatively high exceedances until about the 3rd runoff day. Note that this graph shows the rain day as the 1st runoff day and the actual 10th runoff day as the 11th runoff day. The open beaches stay below the 104 CFU/100ml standard, but the error bars do show that in extreme cases the open beaches could have exceedances on the storm day and first runoff day.

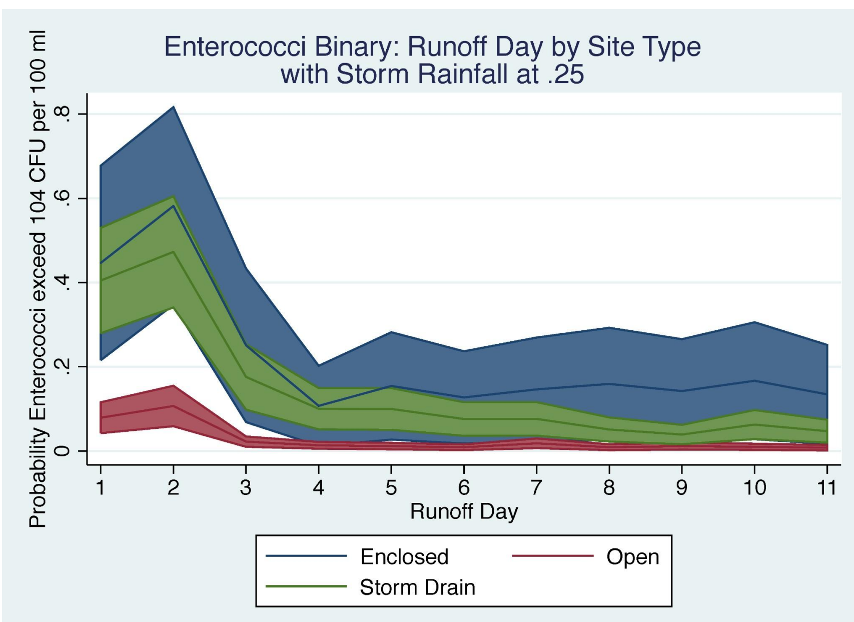


**FIgure A-3.** This graph shows the probability of *Enterococcus* density (CFU/100ml) exceeding the 104 CFU/100ml standard for each beach type, given a rainfall amount of 0.25 inches. There is a range of error highlighted along the central line. Enclosed and storm drain impacted beaches both tend to have high probability of exceedance until about the 3rd runoff day. Note that this graph shows the rain day as the 1st runoff day and the actual 10th runoff day as the 11th runoff day. The range of error for enclosed beaches is largest, ranging from a less than 40% chance of exceedance to as high as over 70% for the rain day. For open beach sites, the range of error is small, within 10%, for all 11 days.

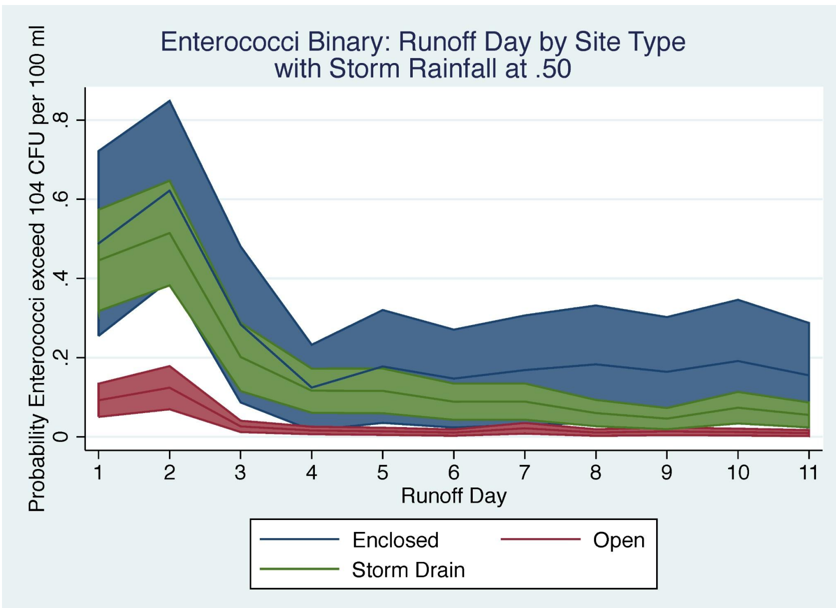


**Figure A-4.** This graph shows the probability of *Enterococcus* density (CFU/100ml) exceeding the 104 CFU/100ml standard for each beach type, given a rainfall amount of 0.50 inches. There is a range of error highlighted along the central line. Enclosed and storm drain impacted beaches both tend to have high probability of exceedance until about the 3rd runoff day. Note that this graph shows the rain day as the 1st runoff day and the actual 10th runoff day as the 11th runoff day. For open beach sites, the range of error is small, within 10%, for all 11 days.

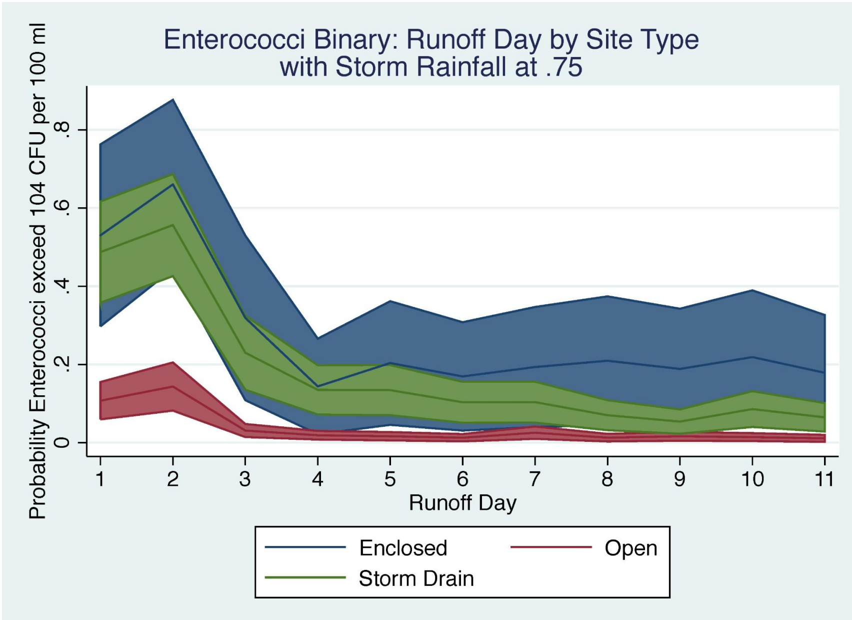


**Figure A-5.** This graph shows the probability of *Enterococcus* density (CFU/100ml) exceeding the 104 CFU/100ml standard for each beach type, given a rainfall amount of 0.75 inches. There is a range of error highlighted along the central line. Enclosed and storm drain impacted beaches both tend to have high probability of exceedance until about the 3rd runoff day. Note that this graph shows the rain day as the 1st runoff day and the actual 10th runoff day as the 11th runoff day. Open beaches have very small range of error by runoff day 2 where it is less than 5% error for the rest of the runoff days. Overall predictions for exceedances are highest for 0.75 inch storms.

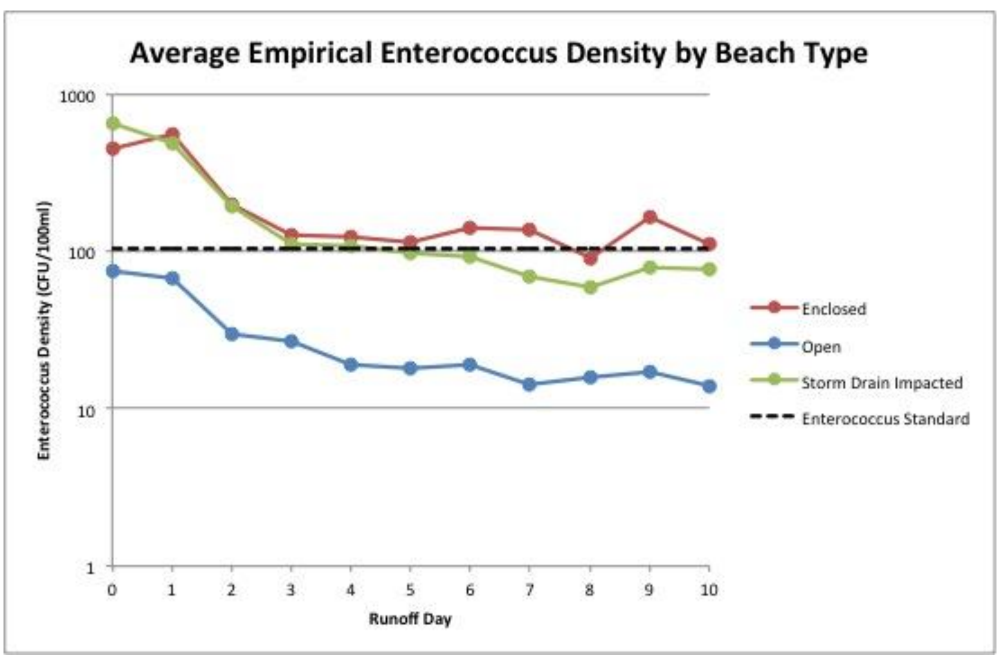


**Figure A-6: Average Empirical *Enterococcus* Density by Beach Type (Log Scale)** graph shows the average *Enterococcus* density for a particular runoff day for each beach category: enclosed, open, and storm drain impacted. The averages are based from the raw *Enterococcus* data. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day “0” indicates the last rain day. Enclosed beaches remain above the *Enterococcus* density standard, except for the eighth runoff day. Storm drain impacted beaches fall below the standard by the sixth runoff day. Open beaches never exceed the *Enterococcus* density standard.

### *Enterococcus Density for Individual Enclosed Beaches*

There are four enclosed beach sample sites; there are two enclosed beaches, Marina Del Rey Mothers’ Beach and Cabrillo Beach, each with two sampling locations, leading to four total sample sites. The average *Enterococcus* density between the four sites were always in exceedance of the permissible standard (Figures A-7 and A-8). Average densities for each sample site were analyzed to observe individual beach trends. Both of the Marina Del Rey sites eventually fell below the standard. The bacteria density fell below the standard on third runoff day for the beach at the playground area and on fifth runoff day for the beach at the lifeguard tower. The Cabrillo site at the boat launch also fell below the standard but on seventh runoff day. The Cabrillo beach harborside at the restrooms, however, never fell below the standard.

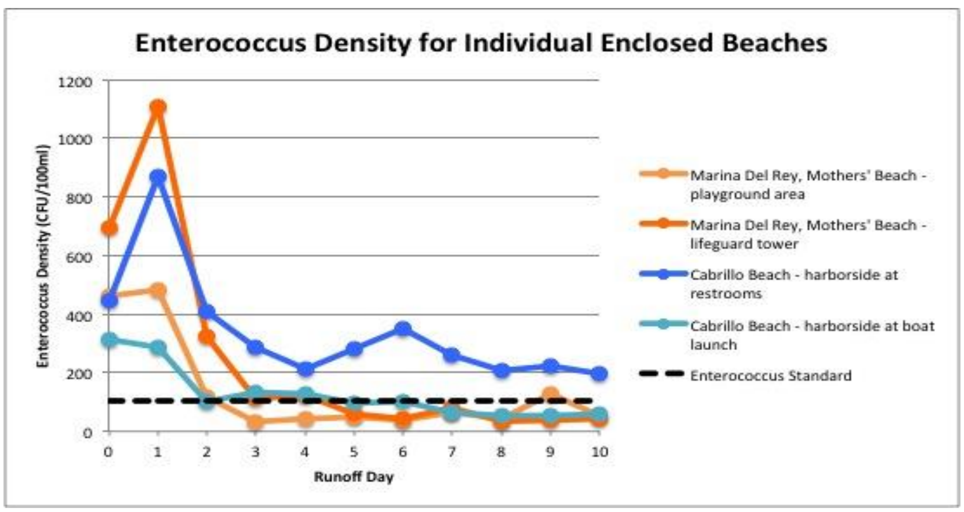


**Figure A-7: Enterococcus Density for Individual Enclosed Beaches** graph shows the average *Enterococcus* density for a particular runoff day for each enclosed beach. These averages are based off the empirical *Enterococcus* data. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day “0” indicates the last rain day.

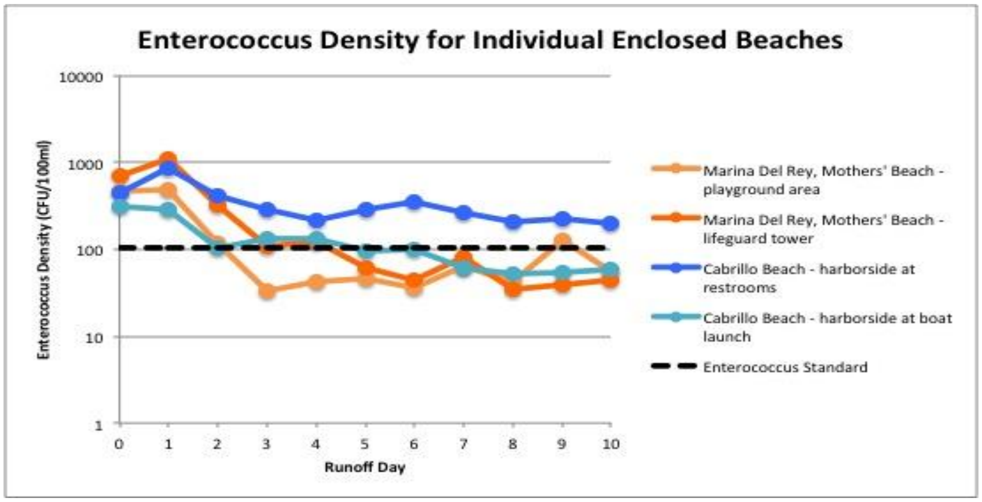


**Figure A-8: Enterococcus Density for Individual Enclosed Beaches (Log Scale)** graph shows the average *Enterococcus* density for a particular runoff day on a log-based 10 scale for each enclosed beach. These averages are based off the empirical *Enterococcus* data. The black dashed line represents the *Enterococcus* safety standard of 104 CFU/100ml. Runoff day "0" indicates the last rain day.

*Predicted Probability of Enterococcus Exceedance by Site Type for Rainfall Intensity*

The likelihood of an *Enterococcus* exceedance was predicted for different rainfall intensities (Graphs A-9 through A-11). Overall, the probability of an exceedance rose with increasing rain intensity for all beach types. For rain day 0, the probability of an exceedance for enclosed beaches was 0.45, 0.50 and 0.75 for 0.25, 0.5 and 0.75 inch storms, respectively. For open beaches, the probability of an exceedance on rain day 0 was 0.08, 0.01 and 0.11 for 0.25, 0.5 and 0.75 inch storms respectively. For rain day 0, the probability for storm drain impacted beaches was 0.40, 0.45, and 0.50 for 0.25, 0.5, and 0.75 inch storms, respectively.

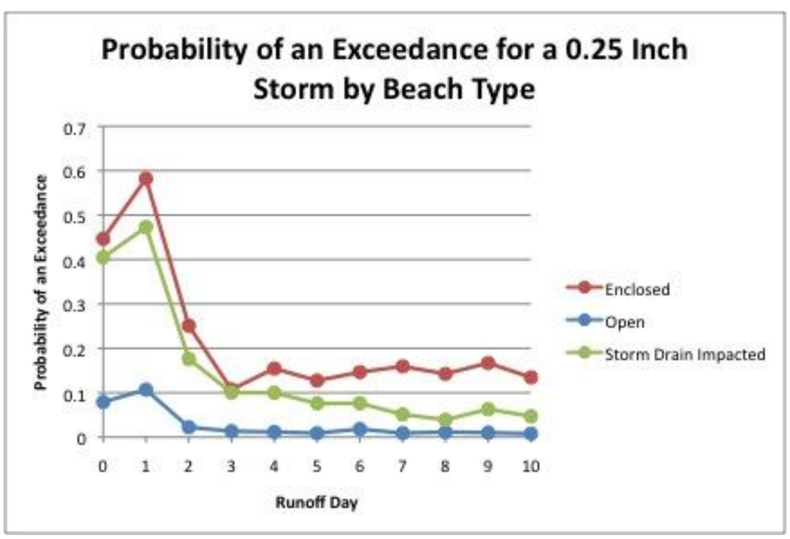

**Figure A-9: Predicted Probability of an Exceedance for a 0.25 Inch Storm by Beach Type** is shown in this graph. The Enclosed beaches are most likely to have an *Enterococcus* exceedance with the chance never dropping below 10% for the rain day and all 10 runoff days. Storm drain beaches show a high chance of exceedance, not dropping below 10% until the fifth runoff day. The open beaches have low likelihood of exceeding with the only the first runoff day exceeding a 10% probability.

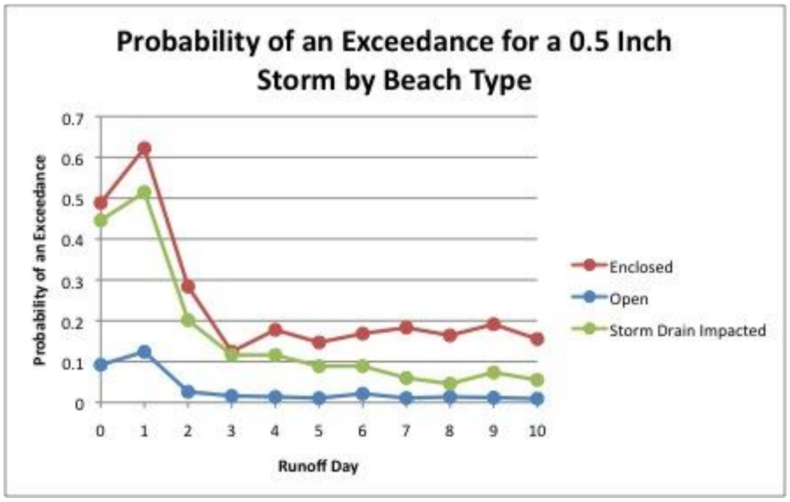


**FIgure A-10: Predicted Probability of an Exceedance for a 0.5 Inch Storm by Beach Type** is shown in this graph. Enclosed beaches are most likely to exceed the *Enterococcus* standard, and the likelihood never drops below 10%. Storm drain impacted beaches have a high chance of exceeding until two runoff days after the storm. The probability does not drop below 10% until the fifth runoff day. Open beaches only have 10% a chance of exceeding on the rain day and first runoff day, while all other days have much lower than 10% likelihood of exceeding the *Enterococcus* standard.

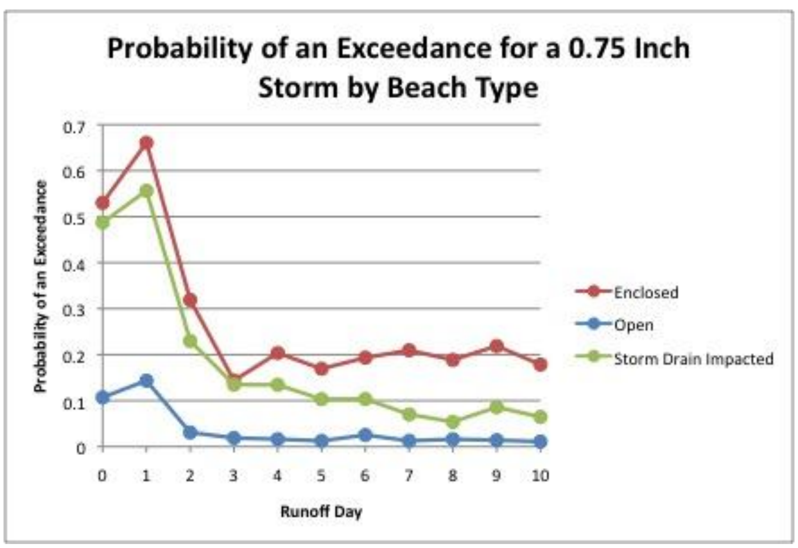


**Figure A-11: Predicted Probability of an Exceedance for a 0.75 Inch Storm by Beach Type** is shown in this graph. Enclosed beach have the highest chance of an *Enterococcus* exceedance with only the third runoff day having a 15% likelihood of exceeding; all other rain and runoff days are well above 15% likelihood of exceedance. Storm drain impacted beaches stay above the 10% chance of *Enterococcus* exceedance until the seventh runoff day. Open beaches only surpass a 10% chance of exceedance on the rain day and first runoff day.

One example of a beach that was reclassified as an open beach was the 15th/16th Street in Newport Beach on Balboa Island, which was a storm drain impacted beach according to the Orange County Environmental Monitoring Division. The storm drains, however, discharge into Newport Bay and not the western side of the peninsula where the beach sampling site was located. This site was 2.67 miles away from the Santa Ana River mouth. Categorizing this site as a storm drain impacted beach led to skewed results. It was more appropriate to classify it as an open beach. This beach was tested 5-6 times per week, however Huntington Pier, a locally storm drain impacted beach with heavy visitation is not regularly monitored and instead only has permanently posted warning signs regarding swimming near the drainage (Honeybourne 2013). A consistent monitoring program would greatly increase public health protection. Also, Doheny and Poche beaches in southern Orange County should be monitored more than once per week because both beaches are among the top 10 polluted beaches in California. According to the Beach Bummer list of 2013 from Heal the Bay’s Annual Beach Report Card, Doheny was ranked seventh and Poche was ranked third (Heal the Bay 2013). Talbert Marsh discharge, located roughly 400 meters (0.25 miles) north of the Santa Ana River mouth is not a monitoring site and should be because it is a known FIB source. During dry weather (summer), all flows into the marsh (except tidal) are diverted into the sanitary sewer; however, during storm events, some drainages from Huntington Beach and Fountain Valley flow into the marsh (Honeybourne 2013). The Talbert marsh discharge should be monitored at point zero.