

Santa Monica Pier Bacterial Source Identification Study

Performed for the City of Santa Monica

by

Heal the Bay

7/10/06 – 8/10/06



Heal the Bay – SM Pier Bacterial Source Identification Study
7/10/06 – 8/10/06

As part of the Santa Monica Bay Beaches Bacteria TMDL monitoring requirements, the ocean water quality monitoring location at the Santa Monica Pier was moved from 50 yards southeast of the pier to directly in front of the pier stormdrain. Despite the diversion implemented to eliminate flow from the stormdrain to the beach during the summer months, water quality has chronically exceeded state water quality thresholds at this location (SMB-3-3). Exceedances at this location have been of such frequency and magnitude as to result in the Santa Monica Pier having the fifth worst water quality in the state according to Heal the Bay’s 2005-2006 Annual Beach Report Card. In order to determine the sources and possible remedies to such poor water quality at the pier, the City of Santa Monica partnered with Heal the Bay to conduct this bacterial source identification study. The five week study was designed to determine if fecal bacteria sources were offshore or onshore, were related to tidal cycle or current direction, and/or were localized near the stormdrain, leaky pipes, bird populations, or other sources.

Data Collection

Heal the Bay obtained and analyzed ocean water samples from 10 sites under and adjacent to the Santa Monica pier three times per week for the five weeks from 7/10/06 through 8/10/06. Time of samples ranged from 8:22 AM to 10:20 AM. All samples were immediately put on ice, and analyzed with the Idexx method (for Total Coliform, E. Coli, and Enterococcus) within 6 hours of collection.

The 10 sample locations included eight in the swash zone at ankle depth from 100 yards south of the pier to 100 yards north of the pier. Two additional samples were collected at waist depth on either side of the pier (see Appendix 1 Map). Field observations were also recorded each sample morning to note water temperature, the presence of birds and/or transients, leaking pipes or drains, and any other pertinent information. Table 1 contains site IDs and description of all ten sample locations.

Table 1: (see also Appendix 1 Map)

| Site ID | Description |
|---------|--|
| 100S | 100 yards south of pier - ankle depth incoming wave |
| 50S | 50 yards south of pier - ankle depth incoming wave |
| 0SW | 0 yards south of pier - waist depth incoming wave |
| 0S | 0 yards south of pier - ankle depth incoming wave |
| 1/3S | 100ft north of south end of pier (1/3 width of pier) - ankle depth incoming wave |
| 1/3N | 100ft south of north end of pier (1/3 width of pier) - ankle depth incoming wave |
| 0N | 0 yards north of pier - ankle depth incoming wave |
| 0NW | 0 yards north of pier - waist depth incoming wave |
| 50N | 50 yards north of pier - ankle depth incoming wave |
| 100N | 100 yards north of pier - ankle depth incoming wave |

Observations

A moderate amount of pigeons were witnessed almost every sample day. On 7/10/06 approximately 40 pigeons were observed on the sand, on the catwalk, and on overhead pipes and other pier structures on the south side of the pier. The estimated daily average of pigeons in this area over the entire study was less than 20. The majority of pigeons in this area were either picking through trash on the beach or roosting in the overhead structures underneath the south side of the pier. On two occasions, large numbers of birds were present due to human feeding. On 7/20/06, more than 100 birds were witnessed on the north side of the pier

at the high tide line as someone from the pier was throwing bread. On 8/7/06, large amounts of bird seed and pigeon tracks were found near the ponded storm drain area on the south side of the pier.

A few transients were witnessed during the first week of the study sleeping above the high tide line under the pier. On 8/8/06, a man was witnessed coming through the fenced-off area with a backpack. Overall, the number of transients observed under the pier was less than one per day.

Leaks through the pier decking and/or active drain spouts were also recorded. On our first sample day, 7/10/06, a Pacific Park employee was observed hosing off the miniature golf course. Runoff from this activity was flowing through the decking near a drain grate and making contact with the beach. Non-pipe related deck leaks were not seen after 7/25/06. The three most common water sources under the pier were all associated with what appeared to be 1" metal downspouts. Two of these three were sampled by Heal the Bay and tested negative for any of the three indicator bacteria. SM Pier staff determined that these drips were associated with condensation from air-conditioning units, and has taken action to connect all of the condensation lines to a sewer line by 9/1/06. Table 2 contains results from the sampled drain pipes under the pier.

Table 2:

| | | drain pipe at 1/3N | | | drain pipe near 1/3N | | | | |
|-----------|--|--------------------|----------|---------|----------------------|----------|---------|-----------|--|
| Date | | Total* | E. Coli* | Entero* | Total* | E. Coli* | Entero* | Date | |
| 7/27/2006 | | <10 | <10 | <10 | <10 | <10 | <10 | 7/31/2006 | |

* cfu/100ml

Single Sample Exceeds State Health Standards when:

- Total Coliform: $\geq 10,000$ cfu/100ml
- Fecal Coliform: ≥ 400 cfu/100ml
- Enterococcus: ≥ 104 cfu/100ml
- Total Coliform/Fecal Coliform ratio is ≤ 10 when Total Coliform count exceeds 1,000 cfu/100ml

30 Day Geometric Mean Exceeds State Health Standards when:

- Total Coliform Geometric Mean: $\geq 1,000$ cfu/100ml
- Fecal Coliform Geometric Mean: ≥ 200 cfu/100ml
- Enterococcus Geometric Mean: ≥ 35 cfu/100ml

Surfzone Results:

Over the duration of Heal the Bay's study, the four sampling locations closest to the pier exceeded the state geometric mean standards for E. Coli. The location 100 feet from the south end (1/3S) exceeded the geometric mean for all three indicator bacteria. This location exceeded state single sample standards 80% of Heal the Bay's sample days. 1/3N exceeded single sample standards 47% of the time followed by OS with 33% and ON with 20%. (see appendix 2) Heal the Bay used E. coli as a surrogate for fecal coliforms when calculating the Total to Fecal Ratio (T/F). As E. coli densities are a subset of fecal coliform densities, Total to Fecal Ratios using E. coli are more conservative than those using fecal coliforms. Numerous exceedances of state standards for T/F were found at the three most problematic sample locations, and reflect a serious health risk. T/F exceedances are demarcated in Appendix 2 with a red border around the table cell.

On 8/7/06, while investigating an area underneath the south side of the pier with birdseed and multiple pigeons present, Heal the Bay noticed that the water level in the ponded area at the outlet of the stormdrain had risen dramatically. A large tidal swell event had been occurring for more than a week (high tide debris line approaching pond), and either ocean water had reached over the sand berm, or there had been flow

activity from the drain. The source of the water was likely the high tide because high flows from the stormdrain were not observed. The ponded area extended beyond the fenced area, and samples were taken directly from the stagnant water on 8/8/06 and 8/10/06. Both of these samples had extremely high densities of the three indicator bacteria (see Table 3). The monitoring locations closest to this ponded area are 0S and the site with the worst water quality, 1/3S.

Table 3:

| Date | pond/pool | | |
|-----------|-----------|----------|---------|
| | Total* | E. Coli* | Entero* |
| 8/8/2006 | 72700 | 23820 | 850 |
| 8/10/2006 | 22470 | 16580 | 630 |

* cfu/100ml

Heal the Bay investigated the ponded area and found other leaks under the pier in the fenced-off area. There were a number of leaky areas, some of which the source was undeterminable. These leaks not only appear to be affecting the integrity of the wood decking, but are also possible sources of bacteria. The diversion of the under-pier storm drain appears to be inadequate. Plywood and sandbags are in place at the mouth of the pipe, but the pipe is cracked and broken and a ‘trickle’ sound was heard on the morning of 8/8/06. It appears that the pipe is still discharging to the ponded area, but at a rate slow enough not to directly cause water flow to the beach. Photos 1 and 2 show the diversion and the broken storm drain. Photos 3 and 4 show the extent of the ponded area at the mouth of the storm drain. Photos 5 and 6 show an example of a leak found under the pier in the fenced-off area.

Discussion -

The five week study provided information critical to Santa Monica on beach water quality near the Santa Monica Pier. Water quality 100 yards north or south of the pier rarely exceeded beach water quality standards. A public health recommendation for the public to swim over 100 yards away from the pier would be protective of the public the vast majority of the time. This was especially true 100 yards south of the pier where the indicator densities were well below water quality standards. The water quality 100 yards north of the pier, although still in compliance with water quality standards the vast majority of the time, had a geometric mean for E. coli that was nearly (166 cfu/100ml) equal to the state geometric mean standard (200 cfu/100ml) for fecal coliforms.

The study also demonstrated that the source of fecal bacteria in the surfzone was likely an onshore source. Samples collected at waist depth on the south side of the pier never exceeded water quality standards, while samples collected at waist depth on the north side of the pier seldom exceeded standards, and had lower densities than samples collected nearby at ankle depth.

One interesting trend was that the bacteria densities north of the pier from point zero to 100 yards north were generally higher than samples collected from point zero to 100 yards south of the pier. One possible reason for this difference is that the breakwater north of the pier may have dampened the effects of swell height and currents on diluting bacteria densities in the surfzone.

The clearest trend observed in the data was that the bacteria densities in the surfzone at ankle depth were much higher underneath the pier than 50 to 100 yards north or south of the pier. This trend was expected and demonstrates that the predominant source of fecal bacteria in the surfzone is coming from under the pier. The most polluted sites were 1/3S and 1/3N under the pier with 1/3S as the most polluted site. The stormdrain pond is immediately inland from the 1/3S site, which strongly implicated the pond as a major

source of bacterial contamination on the beach. Other sources of fecal bacteria to the beach, including pigeons and leaky pipes, were distributed relatively evenly under the pier, so their distribution does not provide evidence on why the 1/3S site was the most polluted.

As a favor to Heal the Bay, Professor Jenny Jay of the Department of Environmental and Civil Engineering at UCLA had her students collect and analyze numerous surface sand samples from the area adjacent to the ponded water to the high tide line (see Appendix 4 and 5). At each location, triplicate samples of sand were collected. A 50 mL Falcon tube was skimmed along the surface of the sand such that the top 1 cm was collected. Deeper samples up to 6 inches were collected by using a gloved hand to push sand away to expose the desired depth. Samples were held on ice and analyzed immediately upon return to the lab. Subsamples from each Falcon tube were weighed into a vial, and extracted with phosphate buffered saline (pH 8). Vials were vigorously hand-shaken for one minute, and allowed to settle for two minutes. The supernatant from two serial washes was decanted and pooled. Each of the extractions from triplicate sand samples was analyzed in triplicate for viable total coliform, E. coli and enterococci using defined substrate technology (Colilert and Enterolert, IDEXX). Water samples were also analyzed for the same organisms using IDEXX. Additional subsamples from each vial were weighed into aluminum drying dishes, and heated at 60 °C overnight. The difference in weights was used to calculate the wet to dry ratio for each sample. Results for each test were reported in Most Probable Number (MPN) per gram dry sediment.

The results were compelling. Sand samples directly adjacent to the ponded area had high densities of fecal bacteria, while those samples between the pond and the high tide zone followed a decreasing gradient. Control samples collected north and south of the pond at the high tide zone had very low densities of fecal bacteria.

These results demonstrate that the sand is a potential sink for fecal bacteria in the area near the pond, while the sand is not a sink for fecal bacteria in the control areas. In addition, the fecal bacteria gradient in the sand, in conjunction with the high bacteria densities in the pond and the fecal bacteria pattern in the surfzone, strongly suggests that the pond is a major source of fecal bacteria to the ocean under the pier. The warm, sheltered water in the pond may allow extensive fecal bacteria regrowth, thereby acting as a chronic source of fecal bacteria to the sand and surfzone.

In conclusion, it is Heal the Bay's best professional judgment that the predominant source of fecal bacteria to the Santa Monica Pier beach is the pond in front of the pier stormdrain. Although pigeons, leaky pipes and homeless people are potential fecal bacteria sources, Heal the Bay believes that the evidence (extremely high bacteria densities in the pond, the impact of a high-high tide on the pond size and depth, and the fecal bacteria gradient from the pond to the mean high tide zone) demonstrates that the pond is the most likely major source of fecal bacteria to the beach.

Recommendations -

1) Install a flap gate at the terminus of the stormdrain under the pier. The flap gate should be constructed so that no sea water enters the stormdrain, and the flapgate only opens when a certain head builds up behind it. In addition, the City should investigate and abate the sources of dry weather flow to the stormdrain. With the pier stormdrain runoff diversion in place, there should not be flow in that drain. Finally, construct and maintain a sand berm similar to the one at the Pico-Kenter drain that plugs the drain during the April through October time period. A pond should not be allowed to form in front of the drain. Heal the Bay observed that even a small pond can grow dramatically in size after a very high tide.

2) Spike roosting perches above the intertidal zone under the pier. Pigeons are a definite source of fecal bacteria and the elimination or reduction of roosting sites in the intertidal zone area would help reduce fecal

bacteria densities in the surfzone.

- 3) Continue to deter the homeless from taking residence under the pier. Although this was not a major problem, clearly some homeless people occasionally live under the pier near the pond and the high tide line. Heal the Bay did not observe any direct human sources of fecal bacteria, but that is still a concern. Also, as stated previously, a homeless person was observed providing food to resident pigeons under the pier. Repair and strengthen the fence under the pier in front of the ponded area.
- 4) Begin compliance assurance and enforcement actions against pier tenants that discharge nuisance runoff. Clearly, the tenant education effort has not been completely effective and a compliance assurance deterrent like the issuance of Notices of Violations and fines for repeat offenders is needed at this point. Santa Monica must take into consideration the new beach bacteria TMDL requirements that could hold the City responsible for beach water quality violations. Make it clear in the NOV's that dischargers may be held liable for any Clean Water Act fines incurred because of TMDL violations at the beach near the pier.
- 5) Eliminate leaks from the pier infrastructure. Although the bacteria densities in the leaks from the pier piping were extremely low, leaks should not be occurring and should be repaired.
- 6) Until the stormdrain ponding issues are remedied, request for the lifeguards to post beach warning signs up to 100 yards from the pier. Provide some clear delineation like a buoy for the 100 yard distance.

Summary and Follow-Up (10/19/06)

Heal the Bay completed a five week study on fecal bacteria at the beach adjacent to SM Pier. Heal the Bay found that the source of the fecal bacteria was coming from on shore, and likely to be from a leaky stormdrain that ponds underneath the pier. Sand analysis by Dr. Jenny Jay of UCLA showed that the polluted pond was the likely source of high fecal bacteria densities in the water. Heal the Bay provided extensive recommendations to the city of Santa Monica to clean up the beaches and Santa Monica has started to implement those recommendations.

The city pumped the polluted water out of the pond and filled in the pond with clean sand. Also, they will soon hire a contractor to complete a thorough investigation of the stormdrain infrastructure, the runoff diversions and the Santa Monica Urban Runoff Reuse Facility to identify problems and solutions to the water quality problems.

Photo 1: Storm Drain Diversion



Photo 2: Broken Storm Drain (from above)



Photo 3: Poned area east end (looking west)



Photo 4: Poned area west end



Photo 5: Basin leak



Photo 6: Basin leak puddle



Appendix 1 Map



Appendix 2: Indicator Bacteria Monitoring Data

| Date | 100S | | | 50S | | | 0SW | | | 0S | | | 1/3S | | | 1/3N | | | 0N | | | 0NW | | | 50N | | | 100N | | |
|-----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|--------|----------|----------|
| | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* | Total* | E. Coli* | Enteroc* |
| 7/10/2006 | 86 | 52 | 10 | 135 | 74 | < 10 | 218 | 107 | 41 | 441 | 317 | 63 | 464 | 327 | 110 | 323 | 201 | 30 | 457 | 327 | 41 | 547 | 313 | 20 | 173 | 122 | 10 | 85 | 31 | < 10 |
| 7/11/2006 | 52 | 10 | 10 | 95 | 51 | 20 | 135 | 86 | < 10 | 185 | 146 | < 10 | 1081 | 860 | 20 | 345 | 218 | 31 | 520 | 345 | 74 | 364 | 262 | 10 | 281 | 265 | 10 | 341 | 288 | 20 |
| 7/13/2006 | 233 | 109 | 31 | 860 | 860 | 41 | 350 | 295 | 10 | 2014 | 1658 | 52 | 1172 | 878 | 41 | 262 | 187 | 52 | 98 | 52 | 74 | 74 | 31 | < 10 | 74 | 31 | < 10 | 231 | 121 | < 10 |
| 7/17/2006 | 121 | < 10 | 20 | 199 | 52 | 359 | 74 | 20 | < 10 | 309 | < 10 | 63 | 933 | 703 | 73 | 624 | 295 | 20 | 246 | 160 | 10 | 211 | 185 | 20 | 249 | 122 | 20 | 305 | 201 | < 10 |
| 7/18/2006 | 10 | < 10 | < 10 | 31 | < 10 | 20 | 20 | < 10 | < 10 | 309 | 201 | < 10 | 1553 | 1250 | < 10 | 1291 | 836 | 31 | 9208 | 9208 | < 10 | 479 | 278 | 10 | 379 | 256 | 20 | 472 | 318 | < 10 |
| 7/20/2006 | 31 | 10 | < 10 | 31 | 20 | < 10 | 121 | 98 | < 10 | 265 | 218 | 10 | 5475 | 5475 | 63 | 556 | 373 | 20 | 677 | 393 | 41 | 448 | 175 | 10 | 295 | 218 | 31 | 465 | 305 | 10 |
| 7/24/2006 | 41 | 31 | < 10 | 30 | 10 | 10 | 30 | 10 | 10 | 1119 | 86 | 20 | 644 | 457 | < 10 | 984 | 959 | 41 | 160 | 52 | < 10 | 63 | 10 | < 10 | 231 | 74 | 10 | 6131 | 5794 | 52 |
| 7/25/2006 | 31 | < 10 | < 10 | 156 | 73 | 20 | 63 | 52 | < 10 | 813 | 547 | 63 | 3076 | 2098 | 52 | 3076 | 1860 | 30 | 4106 | 3873 | 10 | 591 | 408 | 20 | 364 | 171 | 20 | 368 | 195 | 10 |
| 7/27/2006 | 240 | 160 | 20 | 776 | 512 | 10 | 465 | 231 | 20 | 1500 | 1236 | 31 | 4352 | 2987 | 86 | 2481 | 1723 | < 10 | 359 | 199 | 10 | 384 | 278 | 10 | 288 | 185 | 30 | 63 | 20 | < 10 |
| 7/31/2006 | 97 | < 10 | < 10 | 63 | 10 | < 10 | 10 | < 10 | 10 | 199 | 121 | 41 | 717 | 373 | 20 | 1076 | 697 | 41 | 216 | 98 | 20 | 203 | 148 | 10 | 278 | 110 | 20 | 262 | 146 | 10 |
| 8/1/2006 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | 63 | 63 | < 10 | 1046 | 350 | 52 | 855 | 538 | < 10 | 1785 | 1785 | 10 | 121 | 85 | < 10 | 185 | 109 | < 10 | 146 | 121 | < 10 | 183 | 132 | 10 |
| 8/3/2006 | 52 | 10 | < 10 | 41 | < 10 | < 10 | 10 | < 10 | < 10 | 41 | 20 | 20 | 240 | 30 | < 10 | 158 | 97 | < 10 | 74 | 41 | 10 | 86 | 20 | < 10 | 520 | 336 | < 10 | 74 | 41 | < 10 |
| 8/7/2006 | 10 | < 10 | < 10 | 41 | < 10 | 20 | 10 | 10 | 10 | 201 | 110 | 41 | 743 | 598 | 20 | 295 | 203 | 52 | 228 | 134 | 41 | 213 | 146 | < 10 | 223 | 145 | < 10 | 203 | 122 | 10 |
| 8/8/2006 | 10 | 10 | < 10 | 74 | 41 | 10 | 10 | < 10 | < 10 | 231 | 146 | 41 | 226 | 169 | 161 | 298 | 168 | < 10 | 282 | 203 | < 10 | 199 | 96 | < 10 | 441 | 262 | 10 | 388 | 240 | < 10 |
| 8/10/2006 | 20 | 20 | 10 | 148 | 63 | 20 | 120 | 31 | 31 | 1565 | 1081 | 10 | 2481 | 1664 | 41 | 2046 | 1187 | 31 | 2359 | 1076 | 83 | 1046 | 419 | 31 | 256 | 199 | 10 | 240 | 183 | < 10 |
| geomeans | 45 | 26 | 15 | 99 | 59 | 23 | 55 | 54 | 16 | 433 | 245 | 33 | 1062 | 685 | 50 | 706 | 468 | 30 | 423 | 256 | 27 | 256 | 130 | 14 | 255 | 152 | 16 | 277 | 166 | 14 |
| %exceed | 0% | | | 20% | | | 0% | | | 33% | | | 80% | | | 47% | | | 20% | | | 13% | | | 0% | | | 7% | | |

* cfu/100ml

Single Sample Exceeds State Health Standards when:

Total Coliform: $\geq 10,000$ cfu/100ml

Fecal Coliform: ≥ 400 cfu/100ml

Enterococcus: ≥ 104 cfu/100ml

Total Coliform/Fecal Coliform ratio is ≤ 10 when Total Coliform count exceeds 1,000 cfu/100ml

30 Day Geometric Mean Exceeds State Health Standards when:

Total Coliform Geometric Mean: $\geq 1,000$ cfu/100ml

Fecal Coliform Geometric Mean: ≥ 200 cfu/100ml

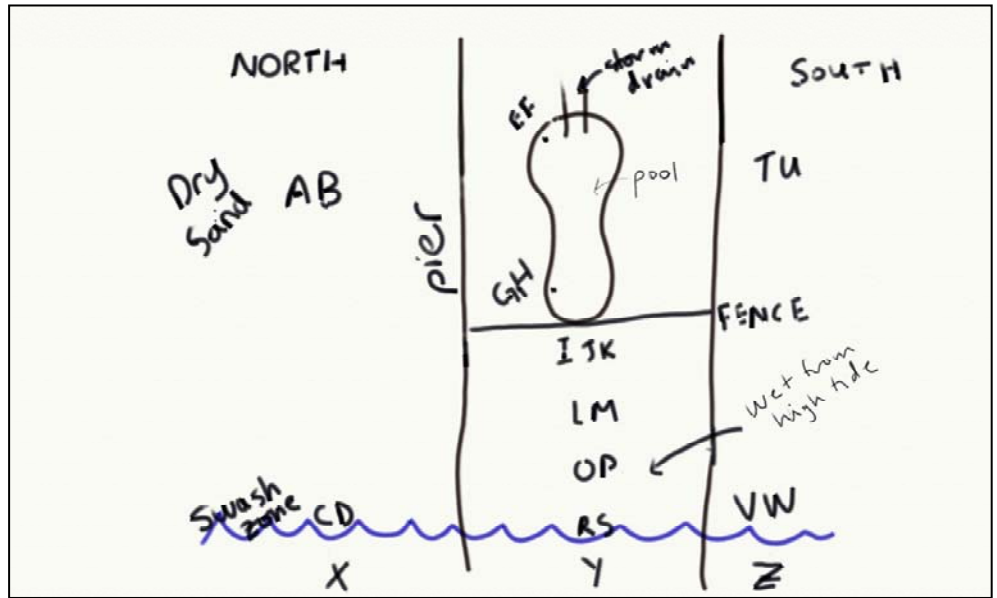
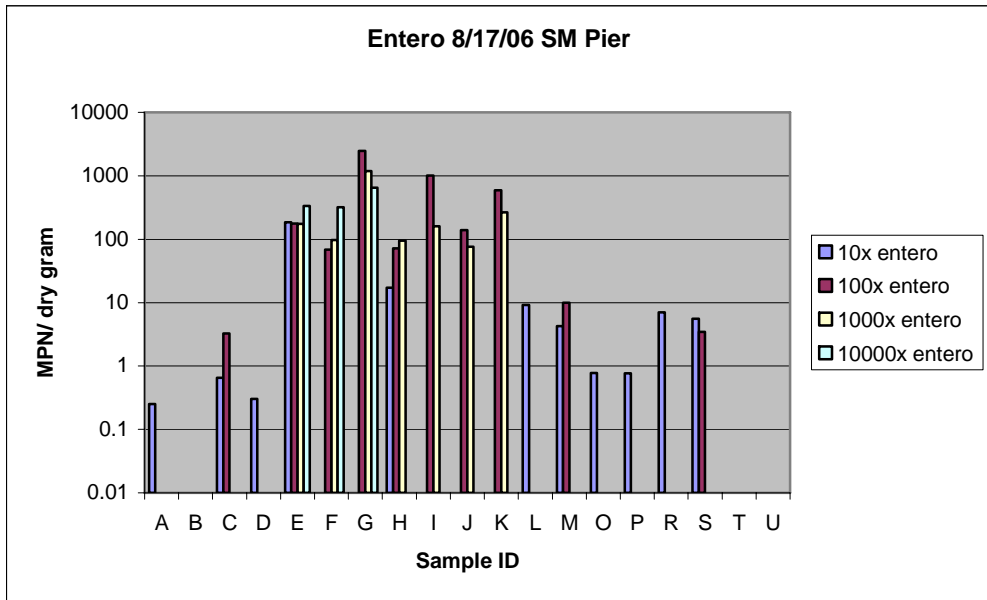
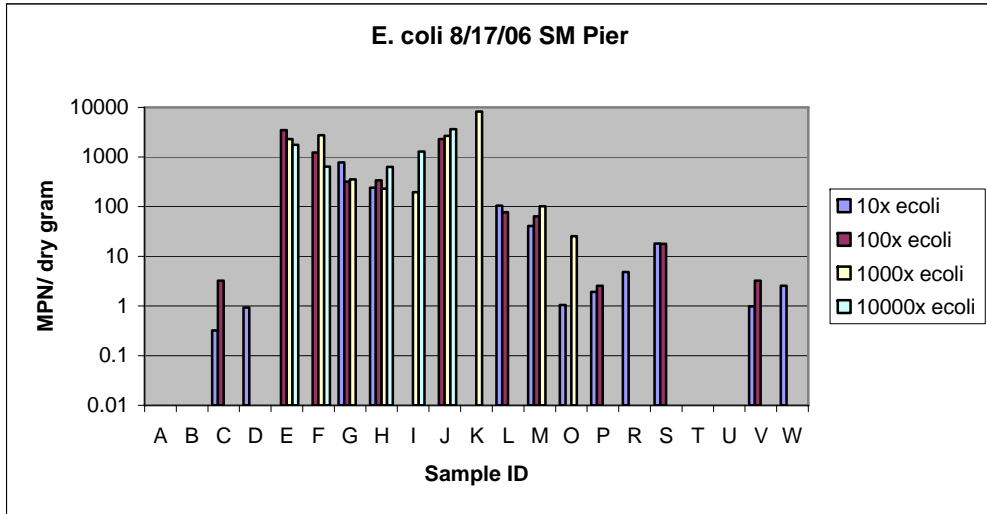
Enterococcus Geometric Mean: ≥ 35 cfu/100ml

Appendix 3: Current and Tide data

| Date | Start | End | Temp °C | Tide | avgTide | previous HT | HT time | current at HT | avg current at sample | avg current since previous HT | Notes |
|-----------|---------|----------|---------|------|---------|-------------|----------|---------------|-----------------------|-------------------------------|--|
| 7/10/2006 | 9:25 AM | 9:59 AM | 20.7 | R | 3.73 | 6.88 | 8:24 PM | 273 | 260 | 263 | |
| 7/11/2006 | 8:22 AM | 8:57 AM | 20.4 | R | 2.35 | 7.09 | 9:06 PM | 261 | 262 | 265 | |
| 7/13/2006 | 9:44 AM | 10:20 AM | 20.9 | R | 2.66 | 6.82 | 11:06 PM | 267 | 270 | 267 | |
| 7/17/2006 | 9:36 AM | 10:14 AM | 21.4 | R | 1.62 | 3.96 | 3:12 AM | 214 | 253 | 249 | leak at Mariasol discovered |
| 7/18/2006 | 8:59 AM | 9:34 AM | 21.0 | W | 2.20 | 3.51 | 4:42 AM | 226 | 185 | 224 | leak at Mariasol determined freshwater (repair completed 8/8/06) |
| 7/20/2006 | 9:23 AM | 10:19 AM | 21.2 | W | 3.32 | 3.68 | 8:36 AM | 199 | 225 | 244 | |
| 7/24/2006 | 9:30 AM | 10:01 AM | 22.1 | R | 3.63 | 6.9 | 8:42 PM | 266 | 266 | 255 | |
| 7/25/2006 | 8:31 AM | 9:13 AM | 22.4 | R | 3.22 | 6.97 | 9:36 PM | 264 | 262 | 254 | |
| 7/27/2006 | 9:31 AM | 10:12 AM | 22.7 | R | 3.23 | 6.37 | 10:30 PM | 250 | 270 | 232 | |
| 7/31/2006 | 9:32 AM | 10:05 AM | 21.4 | R | 2.71 | 4.17 | 1:18 AM | 266 | 268 | 269 | |
| 8/1/2006 | 8:56 AM | 9:19 AM | 22.1 | R | 2.62 | 3.57 | 2:18 AM | 265 | 274 | 269 | |
| 8/3/2006 | 9:41 AM | 10:11 AM | 22.4 | R | 3.14 | 3.16 | 6:24 AM | 271 | 272 | 273 | West End Fish Cleaning Station repaired. |
| 8/7/2006 | 9:34 AM | 10:06 AM | 20.1 | P/R | 3.93 | 6.61 | 8:00 PM | 278 | 272 | 260 | ponded area water level has risen |
| 8/8/2006 | 8:50 AM | 9:13 AM | 19.1 | R | 3.88 | 6.9 | 8:12 PM | 286 | 241 | 275 | |
| 8/10/2006 | 9:41 AM | 10:06 AM | 21.3 | R | 4.25 | 7.11 | 10:00 PM | 263 | 260 | 255 | |



Appendix 4: Dry Sand Samples



Appendix 5: Wet Sand Samples

