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Review of bacteria water quality objectives And bacteria data for coastal watersheds

Prepared for

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Overview of bacteria water quality objectives

The Water Quality Control Plan (Basin Plan) for the Santa Ana Region establishes beneficial uses and water quality objectives for waters within the Santa Ana Region. The Santa Ana Basin Plan contains fecal coliform water quality objectives for inland surface waters that apply to the beneficial uses of water contact recreation (REC-1)[1] and non-water contact recreation (REC-2)[2]. As discussed below, these water quality objectives will likely be modified in the future.

Although not enforceable as water quality objectives, Orange County beaches and bays are "posted" and access may be restricted when exceedances of certain bacteria levels are observed.[3]

Origin of and basis for bacteria water quality standards

The Basin Plan bacteria objectives currently contained in the Santa Ana Basin Plan were originally developed by the National Technical Advisory Committee (NTAC) to the Federal Water Pollution Control Administration in 1968.[4] These recommendations

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[1] See Basin Plan at p. 4-6: "REC-1 Fecal coliform: log mean less than 200 organisms/100 mL based on five or more samples/30 day period, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period."

[2] See Basin Plan at p. 4-6: "REC-2 Fecal coliform: average less than 2000 organisms/100 mL and not more than 10% of samples exceed 4000 organisms/100 mL for any 30-day period."

[3] From Title 17 of the California Code of Regulations, Section 7958 (Bacteriological Standards): The minimum protective bacteriological standards for waters adjacent to public beaches and public water-contact sports areas shall be as follows:
(1) Based on a single sample, the density of bacteria in water from each sampling station at a public beach or public water contact sports area shall not exceed:

- (A) 1,000 total coliform bacteria per 100 milliliters, if the ratio of fecal/total coliform bacteria exceeds 0.1; or
- (B) 10,000 total coliform bacteria per 100 milliliters; or
- (C) 400 fecal coliform bacteria per 100 milliliters; or
- (D) 104 enterococcus bacteria per 100 milliliters.

(2) Based on the mean of the logarithms of the results of at least five weekly samples during any 30-day sampling period, the density of bacteria in water from any sampling station at a public beach or public water contact sports area, shall not exceed:

- (A) 1,000 total coliform bacteria per 100 milliliters; or
- (B) 200 fecal coliform bacteria per 100 milliliters; or
- (C) 35 enterococcus bacteria per 100 milliliters.

[4] See *Water Quality Criteria, a Report of the National Technical Advisory Committee to the Secretary of the Interior*, Federal Water Pollution Control Administration: Washington, D.C., April 1, 1968, at p. 8 and p. 12:

were based upon prospective epidemiological studies conducted by the United States Public Health Service in 1948, 1949, and 1950. These studies found an "epidemiologically detectable health effect" at levels of 2300 to 2400 coliforms per 100 ml at bathing beaching on Lake Michigan (at Chicago) and in the Ohio River. Later work showed that approximately 18% of the coliforms present in the mid-1960s at the Ohio location belonged to the fecal coliform subgroup. The recreational contact water quality criteria suggested by the committee were based upon the fraction of coliforms present as fecal coliforms and a factor of safety of two.

The fecal coliform standards recommended in 1968 were adopted by many states and municipalities and remain in use in many locations (including in the Santa Ana Region). Several studies conducted since 1968 have questioned these criteria and recommended use of alternatives.[5] As early as 1972, a Committee formed by the National Academy of Science-National Academy of Engineers noted the deficiencies in the study design and data used to establish the recreational fecal coliform criteria, and stated that it could not recommend a recreational water quality criterion because of a paucity of valid epidemiological data.[6]

In response to these concerns, EPA in 1972 initiated studies at marine and freshwater bathing beaches that were designed to correct the deficiencies in the earlier studies and analyses. These studies were conducted at sites contaminated either with pollution from multiple point sources (usually treated effluents that had been disinfected) or by effluents discharged from single point sources. The studies examined three bacterial indicators of fecal pollution (*E. coli*, enterococci, and fecal coliforms) and found that fecal coliform densities showed "little or no correlation" to gastrointestinal illness rates in swimmers. In contrast, a good correlation was found between swimming-associated gastrointestinal

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"Surface waters should be suitable for use in "secondary contact" recreation – activities not involving significant risks of ingestion – without reference to official designation of recreation as a water use. For this purpose, in addition to aesthetic criteria, surface waters should be maintained in a condition to minimize potential health hazards by utilizing fecal coliform criteria. In the absence of local epidemiological experience, the Subcommittee recommends an average not exceeding 2,000 fecal coliforms per 100 ml and a maximum of 4,000 per 100 ml, except in specified mixing zones adjacent to outfalls."

"Fecal coliforms should be used as the indicator organism for evaluating the microbiological suitability of recreation waters. As determined by multiple-tube fermentation or membrane filter procedures and based on a minimum of not less than five samples taken over not more than a 30-day period, the fecal coliform content of primary contact recreation waters shall not exceed a log mean of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml."

[5] For a summary of these studies, see the discussion provided on pages 1-3 of the *Ambient Water Quality Criteria for Bacteria – 1986*, USEPA 440/5-84-001, January 1986.

[6] Committee on Water Quality Criteria. National Academy of Sciences-National Academy of Engineering. *Water Quality Criteria*. USEPA R3-73-033, Washington, D.C., 1972.

symptoms and either *E. coli* or enterococci in swimming waters.[7] Based on these studies, EPA in 1986 proposed section 304(a) criteria for full body contact recreation based upon *E. coli* and/or enterococci but noted that "it is not until their adoption as part of the State water quality standards that the criteria become regulatory."[8]

EPA's current recommendations for bacteria water quality objectives[9] include the use of *E. coli* and or enterococci as the basis of water quality criteria to protect fresh recreational waters and the use of enterococci as the basis of marine water quality criteria. (Note that EPA recommends that the use of fecal and total coliform be discontinued for both freshwater and marine waters.) EPA's current recommendations further specify that compliance should be based upon geometric means (i.e., long-term averages) and "upper percentile values." This represents a change from previous recommendations to determine compliance using "single sample maximum" values. Upper percentile values are calculated bacteria densities that are intended to correspond to a known risk level, and are intended to be used to interpret any single measurement. EPA recommends that states acquire enough sample data to calculate site-specific upper percentile values to characterize water quality for waters where exposure is greatest (e.g., bathing beaches). EPA's recommended water quality criteria for freshwater and marine waters are presented in Tables 1 and 2.

Table 1. Water quality criteria for bacteria recommended by EPA for fresh recreational waters

Risk level[a] [% of swimmers]	Geometric mean density [per 100 ml]	Upper Percentile Value Allowable Density [per 100 ml]			
		75th percentile	82nd percentile	90th percentile	95th percentile
Enterococci criteria					
0.8	33	62	79	107	151
0.9	42	79	100	137	193
1.0	54	101	128	175	247
E. coli criteria					
0.8	126	236	299	409	576
0.9	161	301	382	523	736
1.0	206	385	489	668	940

[7] See Dufour, A. P., *Health Effects Criteria for Fresh Recreational Waters.* USEPA 600/1-84-004, August 1984.

[8] *Ambient Water Quality Criteria for Bacteria – 1986*, USEPA 440/5-84-002, January 1986.

[9] *Implementation Guidance for Ambient Water Quality Criteria for Bacteria. DRAFT.* USEPA-823-B-03-XXX, November 2003.

[a] The risk level corresponds to the anticipated excess illness rate. For example, a risk level of 0.8% is believed to correspond to an illness rate of 8 gastrointestinal illnesses per 1,000 swimmers in excess of background illness rates.

Table 2. Water quality criteria for enterococci recommended by EPA for marine recreational waters

Risk level[a] [% of swimmers]	Geometric mean density [per 100 ml]	Upper Percentile Value Allowable Density [per 100 ml]			
		75th percentile	82nd percentile	90th percentile	95th percentile
0.8	4	13	20	35	63
0.9	5	16	24	42	76
1.0	6	19	29	50	91
1.1	8	23	35	61	110
1.2	9	28	42	73	133
1.3	11	34	51	89	161
1.4	14	41	62	107	195
1.5	17	49	75	130	235
1.6	20	60	91	157	284
1.7	24	72	109	189	344
1.8	29	87	132	229	415
1.9	35	105	160	276	502

[a] The risk level corresponds to the anticipated excess illness rate. For example, a risk level of 0.8% is believed to correspond to an illness rate of 8 gastrointestinal illnesses per 1,000 swimmers in excess of background illness rates.

The Santa Ana Region (within which the proposed Pelican Hill Inn project is located) currently continues to utilize fecal coliform bacteria to assess water quality applicable to recreational beneficial uses. However, the Santa Ana Regional Board is currently conducting a triennial review of its Basin Plan, and is including an evaluation of recreational beneficial use designations and water quality objectives as part of the Basin Plan update process. In addition and as required by the Beaches Environmental Assessment and Health Act (BEACH Act) of 2000, each State must update water quality criteria for coastal recreation waters during 2004. We currently anticipate that the Santa Ana Regional Board will likely update fresh water bacteria water quality objectives in accordance with the recommendations contained in EPA's November 2003 Implementation Guidance (see Tables 1 and 2) (Joanne Schneider, personal communication, March 24, 2004).

Discussion of monitoring data and results

A number of recent studies in southern California have shown that high concentrations of indicator bacteria are present in runoff from pristine, undeveloped areas that have little potential for human bacterial contamination.[10] For example, storm water runoff from the head of the Rose Creek watershed in the San Diego Region contained levels of indicator bacteria well in excess of water quality objectives even though this area is nonurban, contains no sewer lines or lift stations, and is restricted from public access. Recent data collected within the Los Angeles Basin also show high levels of bacteria from natural sources. As noted by the Los Angeles County Department of Public Works:

> "Natural conditions often exceed the Basin Plan objectives by several orders of magnitude. Samples from Public Works' NPDES monitoring program during the 2000-01 storm season show that runoff from undeveloped land can reflect total coliform levels ranging up to 240,000 MPN/100 ml, fecal coliform levels ranging up to 1,700 MPN/100 ml, and fecal enterococcus levels ranging up to 160,000 MPN/100 ml…"[11]

Bacteria data (including total coliforms, E. coli, and enterococci) from creeks and coastal waters within Orange County were reviewed by PBS&J in a report prepared for The Irvine Company in November 1999. These data were collected by the Orange County Division of Environmental Health between November 1996 and October 1999. From the available data, discussed in greater detail below, PBS&J reached three major conclusions:

1. Little difference was observed in the mean concentration of bacteria between different sites.
2. Creek waters (fresh water) exhibited consistently high bacteria concentrations, while samples collected from the surf zone (marine waters) exhibited significantly lower concentrations. For the fresh water creek samples, no relationship was found between the level of development within the watershed and either long-term mean or single sample bacteria concentrations. In fact, PBS&J concluded that bacteria concentrations in some of the more developed drainages tended to be less than concentrations in drainages with minimal levels of development.
3. Even though creek waters contained high concentrations of indicator bacteria, it did not appear that these waters had a significant impact on bacteria concentrations in the surf zone.

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[10] See, for example, Schiff, K., and P. Kinney. *Tracking sources of bacterial contamination in stormwater discharges to Mission Bay*, California, 2001. Water Environment Research 73(5):534-542, and Moore, D., *Bacteriological Survey of San Juan Creek Watershed*, Task 3 report for the San Juan Creek Watershed Bacteriological Study, November 14, 2001.

[11] Comment letter from the County of Los Angeles Department of Public Works to the Los Angeles RWQCB on September 18, 2001.

The data examined in the PBS&J report were collected by the Orange County Division of Environmental Health between November 1996 and October 1999. These data included several coastal catchments and surf zone areas along the Newport Coast, as shown in Figure 1. Additional detail on the catchment areas, including the watershed size and the percent development, has been collated from the PBS&J report and is provided in Figure 2.

Although not strictly applicable to fresh waters, PBS&J in the November 1999 report compared bacteria measurements to the Title 17 "beach posting" bacteria levels (see footnote 3). (Note that PBS&J apparently did not have fecal coliform data to compare to Basin Plan water quality objectives for bacteria.) As shown in Figures 3 and 4 (Figures 8 and 10 from the PBS&J report), long-term geometric mean bacteria concentrations for total coliform and enterococci exceeded marine water "beach posting" bacteria levels. Figure 5 (PBS&J Figure 9) presents E. coli data from the creeks. As shown in Figure 4, long-term mean enterococci concentrations for all creeks within the study area exceed EPA's recommended bacteria criteria for freshwater by up to two orders of magnitude. Similarly, Figure 5 demonstrates that long-term mean E. coli concentrations exceed EPA's recommended E. coli bacteria criteria, again by a significant margin, in all but two creeks.

Figures 6, 7, and 8 (PBS&J Figures 12, 13, and 14) present the relationship between long-term mean bacteria concentrations and the percent of development within a given watershed. As concluded by PBS&J, these data demonstrate no clear relationship between the amount of development within the watershed and bacteria concentrations. (Note that the "standards" presented in these plots are the Title 17 "beach posting" bacteria levels.)

Flow Science has gathered data from 1999 to present to update and confirm the results presented by PBS&J.[12] Figures 9 through 11 present long-term geometric means for enterococci, fecal coliforms, and total coliforms. As shown in Figure 9, long-term geometric mean concentrations of enterococci exceed EPA's proposed freshwater enterococci water quality criteria in all the coastal creeks for which data were available. Similarly, long-term geometric mean concentrations of fecal coliform in most Newport Coast creeks exceed existing Santa Ana Basin Plan REC-1 fecal coliform water quality criteria. No E. coli data were available for the time period 1999- present for in Newport Coast area creeks. Figures 12 through 14 present long-term geometric means for enterococci, fecal coliform, and total coliforms plotted against the percent of development within each watershed. As with the 1999 PBS&J report, there is no apparent trend for any of the three indicator bacteria presented in these figures

[12] Data were obtained from http://www.ocbeachinfo.com/downloads/data/index.htm on March 16, 2004.

with amount of the watershed that has been developed. Note that Figures 12 through 14 utilize the percent development for each watershed as measured by PBS&J (1999), and thus may underestimate the percent development in those watersheds where development has occurred in the previous four years.

The coastal creek data from 1999-present, as shown in these figures, are very similar to the data presented by PBS&J in their November 1999 report. The more recent data clearly demonstrate that, for creeks within the coastal watershed, there is no apparent correlation between the amount of development and concentrations of indicator bacteria in creek waters. Similarly, plots of bacteria within the surfzone, not shown here, are similar to those presented by PBS&J, and indicate that surf zone concentrations of indicator bacteria are significantly lower than and apparently unrelated to concentrations of indicator bacteria in creek waters.

Perhaps more importantly, the fact that bacteria concentrations in runoff from the Pelican Hill watershed and from adjacent watersheds along the Newport Coast are not related to the amount of development within the tributary watershed areas clearly indicates that high bacteria concentrations can and do result from natural sources. Particularly for newer development, where sewer lines and related facilities are unlikely to leak and therefore unlikely to contribute to high bacteria concentrations within the watershed, natural sources of bacteria likely contribute most of the observed bacteria loads. As discussed below, there is little epidemiological information to suggest that natural sources of bacteria, particularly wildlife sources, do or do not contribute to a human health risk.

Use of indicator bacteria to predict human health risks

It is clear from the data gathered along the Newport Coast that high concentrations of indicator bacteria do not necessarily indicate human sources of contamination. Unfortunately, the literature on the health risks associated with exposure to indicator bacteria is largely silent on the issue of whether non-human sources of bacteria pose as great a health risk as human-derived bacteria to humans who might be exposed to those bacteria while recreating.

Bacteria indicator organisms are commonly used as water quality objectives for recreational waters because they are believed to demonstrate the presence of fecal pollution and associated pathogens that may cause human illness. Indeed, many of the epidemiological studies relating bacteria concentrations to human illness rates have been conducted in the vicinity of known sources of human-derived bacteria (e.g., downstream of sewage treatment plant effluents).[13] While indicator bacteria organisms generally do not cause illness directly, they may often be present when pathogens are present, and detection and measurement of indicator bacteria is easier, faster, and more cost-efficient than direct measurement of actual disease-causing pathogens. Of course, an ideal indicator would be one with the best correlation between density and the health hazards associated with a given type of pollution. Sources of pollution and indicator bacteria may include municipal or industrial effluents or sludge, sanitary wastes, fecal wastes from boats, drainage from landfills, storm water runoff, and animal waste, including waste from wildlife. Some infectious agents may also be native to the aquatic environment. Although indicator bacteria are imperfect measures of public health risk associated with bathing in recreational waters, analytical methods for direct, rapid, and cost-effective pathogen detection have significant limitations.

Because measurements of indicator bacteria are not direct measurements of pathogens (and associated human health risk), many epidemiological studies have found conflicting results, and often fail to indicate a consistent relationship between a given bacteria indicator and a given human health endpoint (e.g., gastrointestinal illness, or acute febrile respiratory illness).[14] In a recent comprehensive survey of the epidemiological literature, Wade et al. (2003)[15] found that viral indicators were significantly stronger predictors of gastrointestinal illness in both fresh and marine environments than bacteria indicators, but that, if bacteria are to be used, the literature generally supports EPA's recommended bacteria criteria. Wade et al. also concluded that "it is evident that no single [bacteria] indicator can predict illness consistently in all environments at all times, perhaps because of the wide array of pathogens that have been associated with GI [gastrointestinal] illness in recreational water environments as well as natural variability in pathogen-indicator associations."

Many researchers explicitly acknowledge that the source of bacteria (human or non-human) likely plays a significant role in the relationship between the presence of bacteria and the presence of pathogens. For example, the most recent bacteria guidelines

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[13] See, e.g., Dufour, A. P., 1984. Health effects criteria for fresh recreational waters. EPA-600/1-84-004, August 1984. This document, and the epidemiological studies described therein, form the basis for EPA's recommended fresh water bacteria criteria.

[14] See, e.g., Fleisher, J.M., D. Kay, R.L. Salmon, F. Jones, M.D. Wyer, and A.F. Godfree, 1996. Marine waters contaminated with domestic sewage: nonenteric illnesses associated with bather exposure in the United Kingdom. Am. J. Public Health, 86(9):1228-1234.

[15] Wade, T.J., N. Pai, J.N.S. Eisenberg, and J.M. Colford, Jr. 2003. Do U.S. Environmental Protection Agency Water Quality Guidelines for Recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis. Environmental Health Perspectives 111(8): 1102-1109.

developed by the World Health Organization (WHO) for recreational waters[16] recommend two components in assessing recreational water quality: a sanitary survey, which would indicate the potential for human – as opposed to non-human – sources of bacteria and pathogens, and the use of indicator bacteria. As noted by WHO,

> "It was fully appreciated that the more stringent of these [bacteria] water quality standards would be difficult to achieve in many locations. This is particularly true where non-sewage contributions of faecal indicators from diffuse sources elevate the background faecal indicator concentrations in recreational waters or, more commonly, produce short-term episodes of faecal indicator loadings after rainfall events. For this reason, the Guidelines include a process of ascribing a beach to a sanitary inspection category, which is designed to underpin appropriate application of the 'health-based' microbiological criteria to the range of socio-cultural and economic environment…"

As noted in WHO (2003)[17], the WHO classification scheme places emphasis on pollution from human sources, noting that "due to the 'species barrier,' the density of pathogens of public health importance is generally assumed to be less in aggregate in animal excreta than in human excreta which may therefore represent a significantly lower risk to human health." WHO have been unable to identify any studies differentiating between zoonotic (animal) and human-derived illnesses in recreational waters.[18] However, because animal fecal matter can, in some cases, transmit human pathogens (e.g., cryptosporidium, *E. coli* O157:H7), WHO emphasizes local knowledge of possible sources and environmental pathways from animals to humans as part of a sanitary inspection that would complement and be used with measurements of indicator bacteria density.

Within Orange County, substantial research into the sources of indicator bacteria at local coastal beaches has been conducted and indicates that enterococci bacteria can be present at high concentrations in waters from multiple sources, including urban runoff, bird feces, marsh sediments, and on marine vegetation.[19] Grant et al. suggest that an

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[16] Kay, D., J. Bartram, A. Pruss, N. Ashbolt, M.D. Wyer, J.M. Fleisher, L. Fewtrell, A. Rogers, and G. Rees, 2004. Derivation of numerical values for the World Health Organization guidelines for recreational waters. Water Research 38:1296-1304.

[17] World Health Organization, 2003. Guidelines for safe recreational water environments. Volume 1, Coastal and Fresh Waters. Includes Chapter 4: Faecal Pollution and Water Quality. WHO, Geneva, 2003.

[18] David Kay, Professor of Environment and Health, Centre for Research into Environment and Health, University of Wales, personal communication, April 21, 2004.

[19] Grant, S.B., B.F. Sanders, A.B. Boehm, J.A. Redman, J.H. Kim, R.D. Mrse, A.K. Chu, M. Gouldin, C.D. McGee, N.A. Gardiner, B.H. Jones, J. Svejdovsky, G.V. Leipzig, and A. Brown, 2001. Generation of

epidemiological study could be conducted to help define the human health risks associated with recreational exposures to non-human sources of indicator bacteria, such as effluent from coastal wetlands, and further suggest that these research results "call into question" the use of water quality standards based upon indicator bacteria in locations with significant non-human bacterial contributions.

Jiang et al. (2001)[20] used advanced analytical techniques to detect the presence of human adenovirus, a member of the human enteric virus group implicated in causing gastrointestinal and respiratory illnesses, in waters collected from twelve southern California beach locations. This study found adenoviruses in four of the twelve samples examined. The study also found exceedances of California's recreational water quality limits (see footnote 3) for three bacteria indicators (total coliforms, fecal coliforms, and enterococci) at five of the twelve sites examined. However, exceedances of bacterial water quality indicators did not correlate with the presence of human adenoviruses and thus may not have indicated a human health risk. Jiang et al. concluded that "the results of this study call for both a reevaluation of our current recreational water quality standards to reflect the viral quality of recreational waters and monitoring of recreational waters for human viruses on a regular basis."

Although it would be desirable to readily differentiate between various sources of pollution and to use this information to inform decision-making related to the protection of public health, the science to allow such differentiation is in development and is not anticipated to be ready for widespread use for a number of years. As part of ongoing research, SCCWRP has investigated various methods for differentiating between bacterial sources. In a recent comparative study, SCCWRP evaluated twelve different methods employed by 22 different researchers to differentiate five different fecal sources in blind water samples.[21] One method (host-specific PCR) performed best at differentiating between human and non-human sources, but this method is not yet quantitative and could not reliably differentiate between the various non-human sources. Most other methods tested failed to distinguish reliably and reproducibly between sources. None of the methods is considered ready for widespread use, although several of the techniques evaluated in this study are promising and may be very useful after additional development and evaluation.

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enterococci bacteria in a coastal saltwater marsh and its impact on surfzone water quality. Environmental Science & Technology 35(12):2407-2416.

[20] Jiang, S., R. Noble, and W. Chu, 2001. Human adenoviruses and coliphages in urban runoff-impacted coastal waters of Southern California. Applied and Environmental Microbiology, 67(1):179-184.

[21] Griffith, J.F., S.B. Weisberg, and C.D. McGee, 2003. Evaluation of microbial source tracking methods using mixed fecal sources in aqueous test samples. J. Water Health 01:141-151.

Summary

Although indicator bacteria have been in widespread use for many years to indicate human health risk in recreational waters, it is clear that there are many sources of these bacteria to the environment, and that many of these sources may not correlate with the presence of human pathogens. Thus, indicator bacteria may or may not be reliable indicators of risks to human health, depending upon the source of the bacteria, the proximity to sources of human pathogens, and a variety of environmental factors.

Available data from Orange County coastal watersheds demonstrate that both existing and EPA-recommended bacteria water quality criteria are routinely exceeded in fresh water creek flows. Exceedances of criteria occur even for flows from largely natural, undeveloped watersheds, indicating that human sources of bacteria are not the likely cause of these exceedances. Available epidemiological data, which have been used to establish recommended bacteria water quality criteria, have often been collected in the vicinity of known sources of human fecal matter and thus are likely not representative of the human health risks that may be posed by non-human bacteria sources. Finally, available data from southern California indicate a wide variety of bacteria sources to the environment and demonstrate clearly that more reliable measures of human health risk (e.g., the presence of human adenoviruses) do not necessarily correlate with the presence of indicator bacteria.

Scientific methods and techniques that may help evaluate and manage human health risks in recreational waters are currently under development, including techniques to differentiate between various sources of bacteria and methods for the rapid and direct detection of human pathogens. None of these advances are expected to be ready for widespread use for at least several years. Thus, the regulatory environment is somewhat in a state of flux, and changes in the way human health risks are managed are anticipated in the future.

Figure 1: Location of coastal catchments and surf zone areas along the Newport Coast.

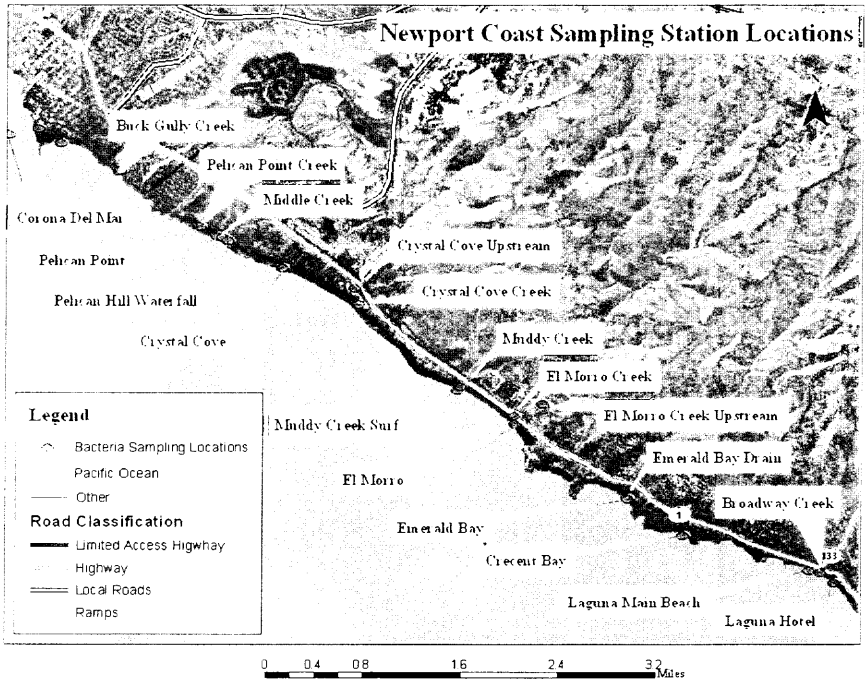

Figure 2: Additional detail on the catchment areas (information collated from the PBS&J report, November 1999.

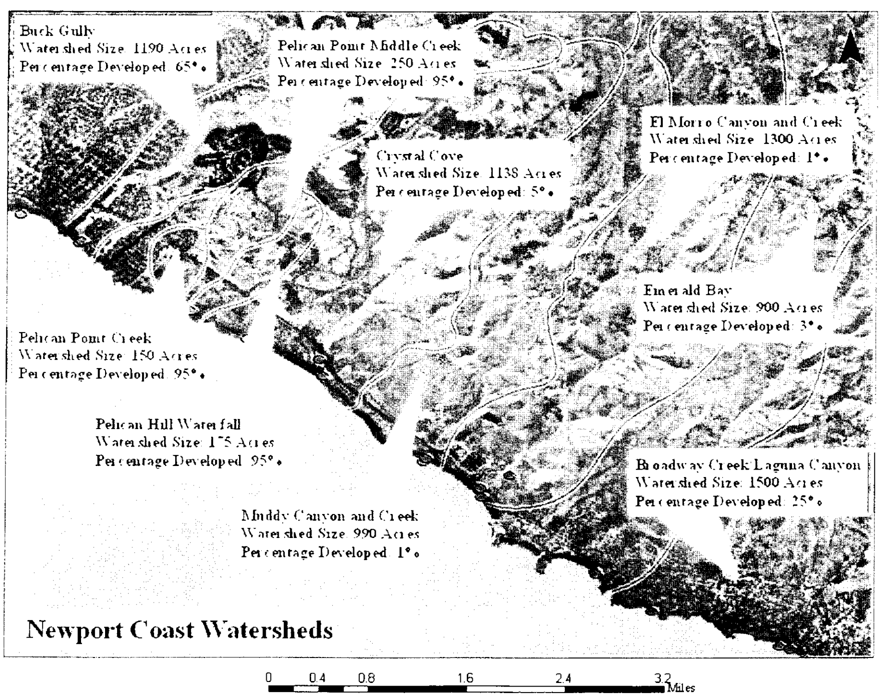

Figure 3: Long-term geometric mean concentration for total coliform (data from November 1996 to October 1999). Plots from PBS&J (1999).

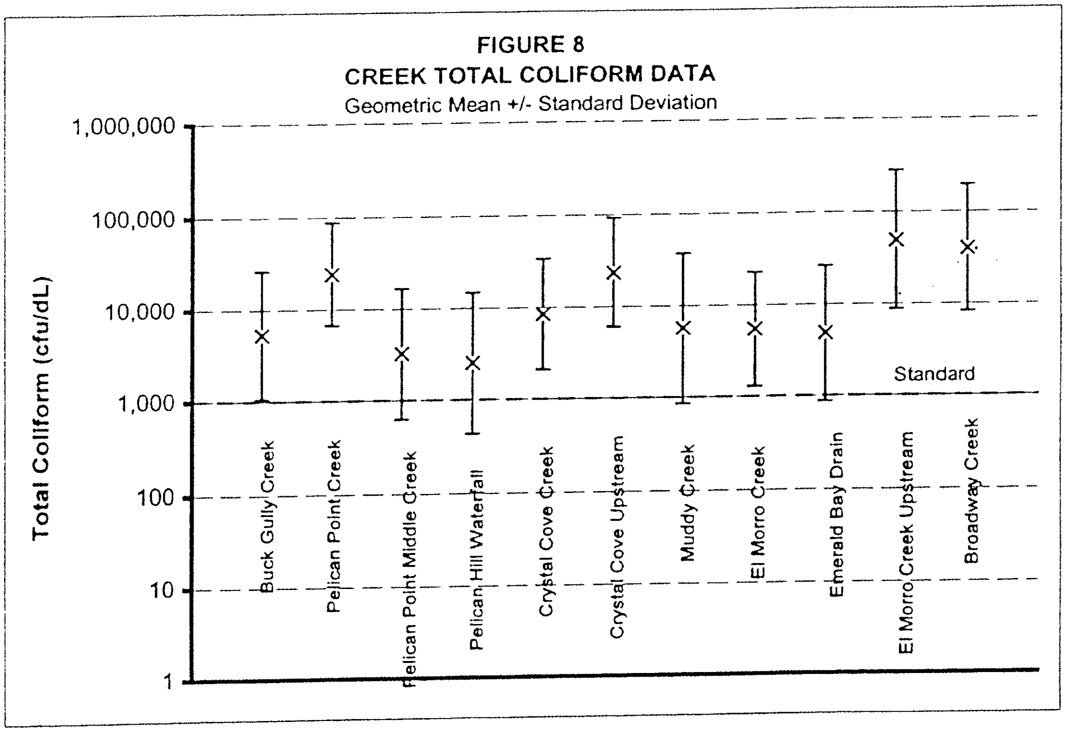

Figure 4: Long-term geometric mean concentration for enterococci. (data from March 1999 to October 1999). Plots from PBS&J (1999).

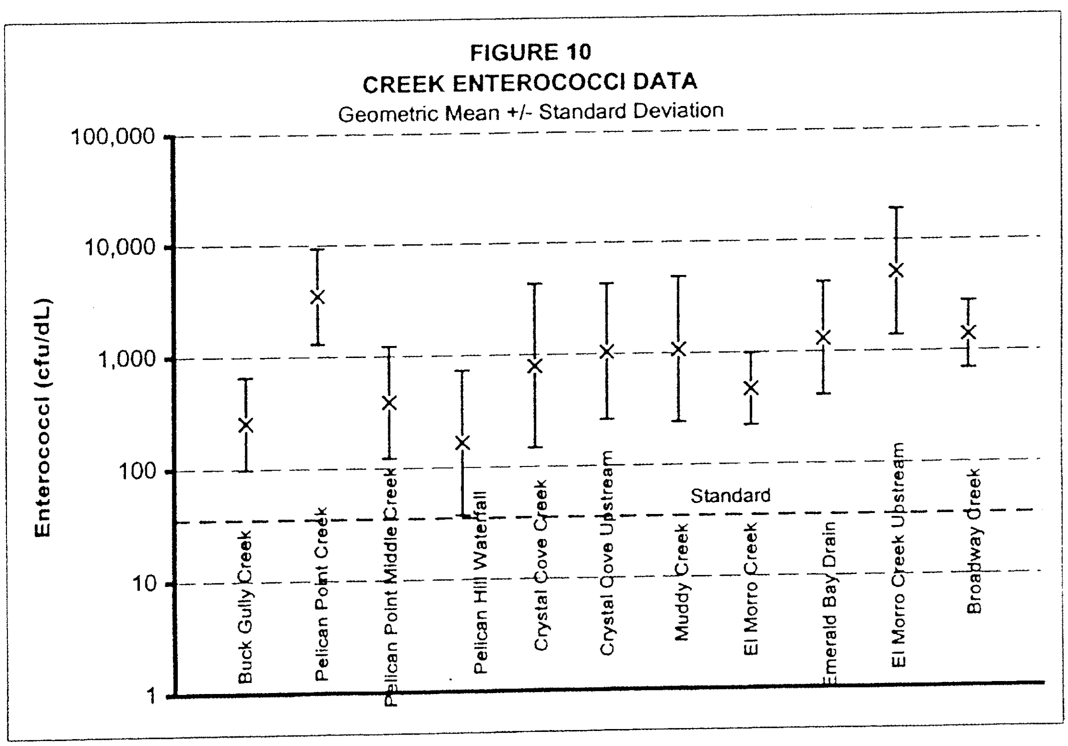

Figure 5: Long-term mean E. coli concentrations (data from November 1996 to October 1999). Plots from PBS&J (1999).

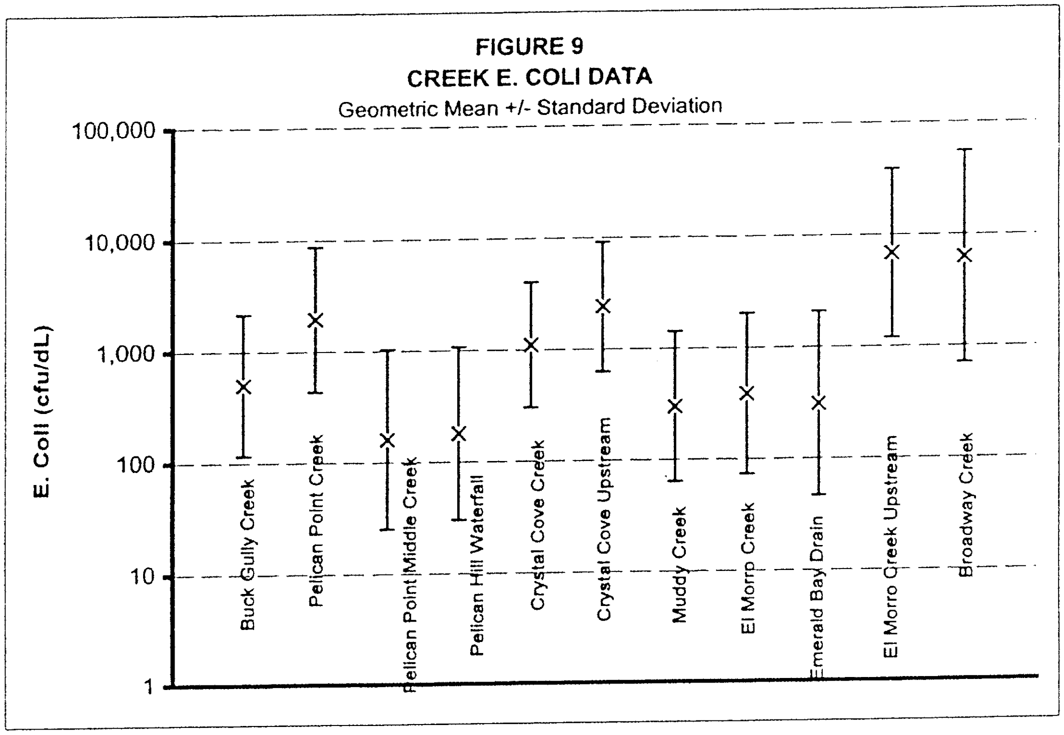

Figure 6: Relationship between % development and the mean total coliform concentration (data from November 1996 to October 1999). Plots from PBS&J (1999).

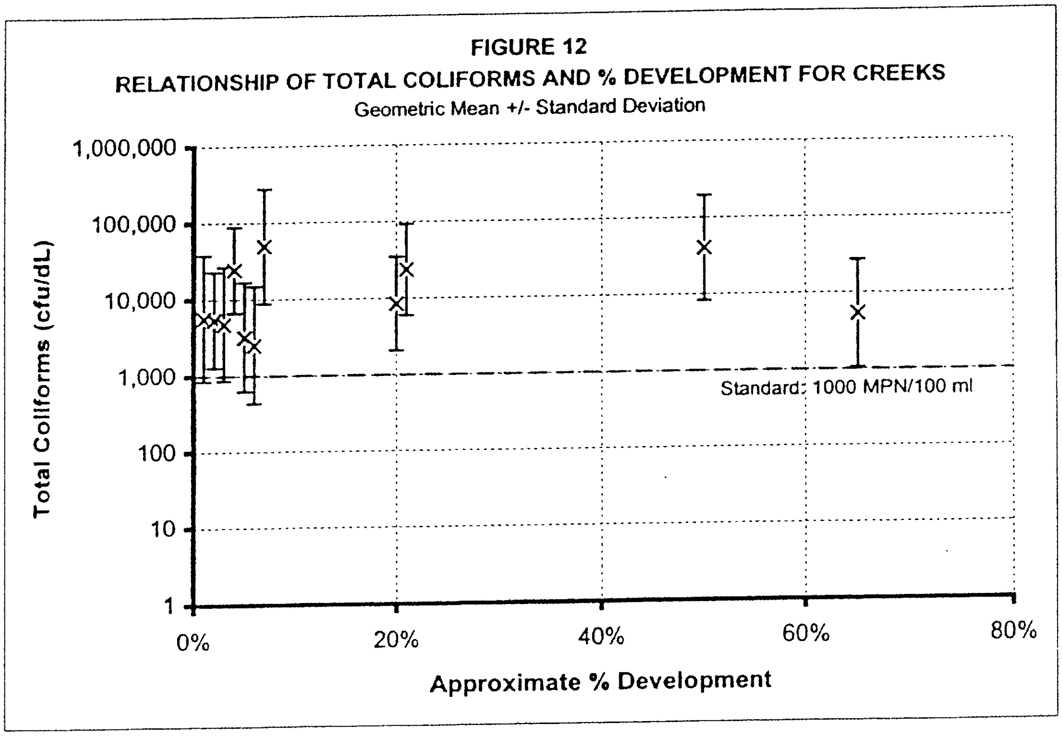

Figure 7: Relationship between % development and the mean E. coli concentration (data from November 1996 to October 1999). Plots from PBS&J (1999).

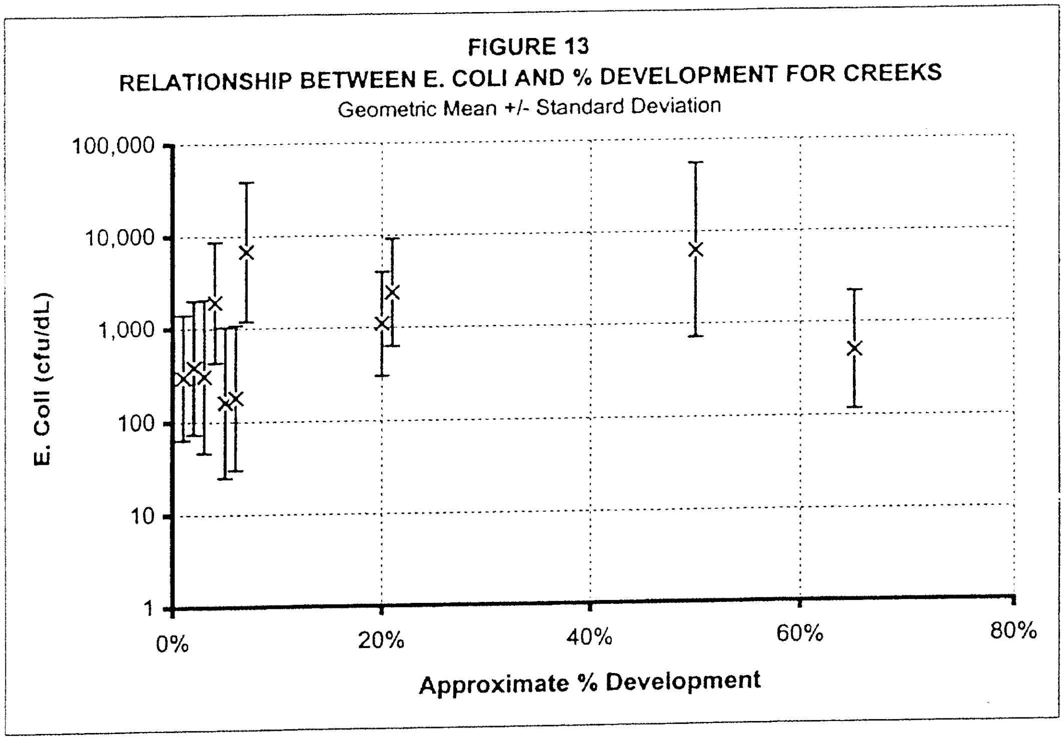

Figure 8: Relationship between % development and the mean enterococci concentration(data from March 1999 to October 1999). Plots from PBS&J (1999).

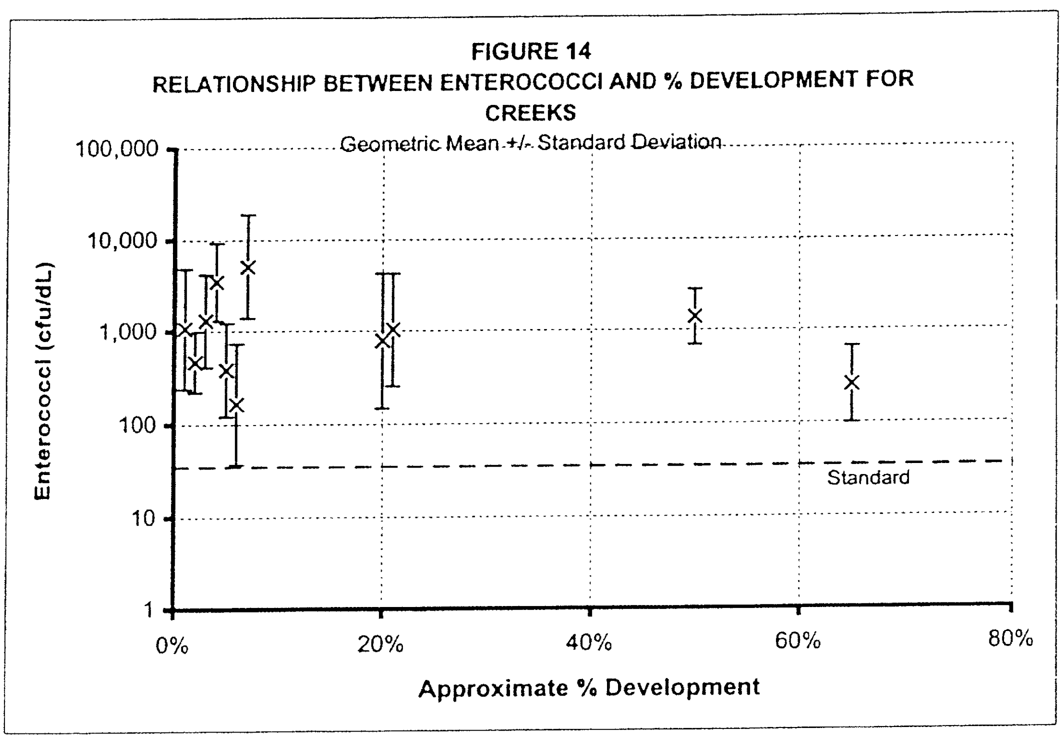

Figure 9: Long-term geometric mean concentration for enterococci (data from 3/30/99 to 1/13/04). Dashed line represtents EPA's suggested 30-day geometric mean water quality criterion for enterococci corresponding to a 1.0% risk level.

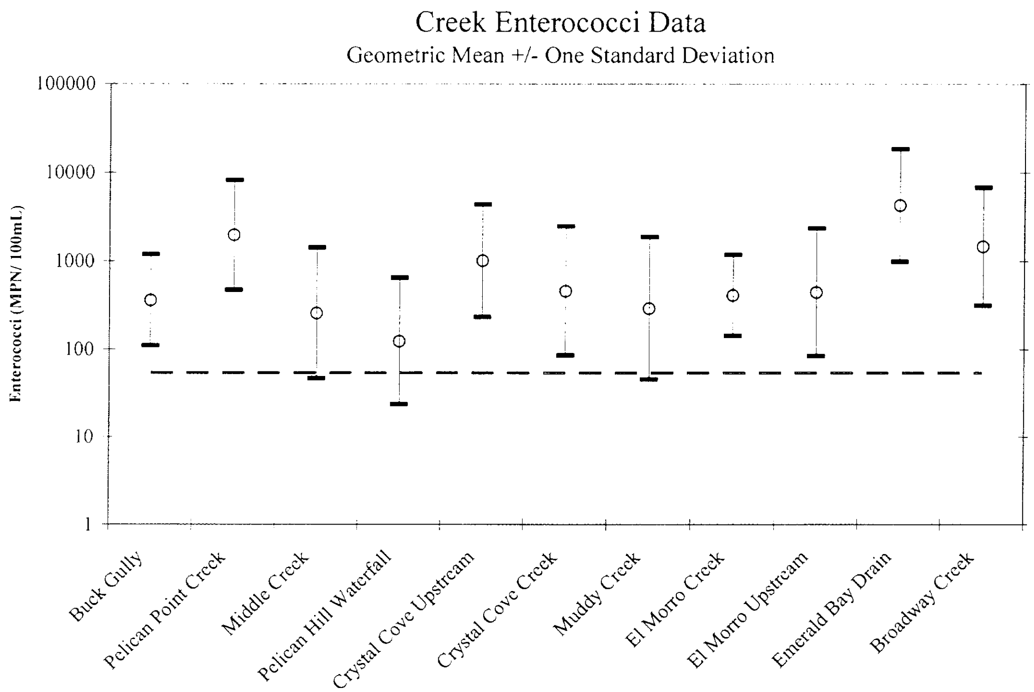

Figure 10: Long-term geometric mean fecal coliform concentrations (data from 1/5/99 to 1/13/04). Dashed line corresponds to the current Santa Ana Basin Plan water quality criterion for 30-day log mean (geometric mean) fecal coliform concentrations.

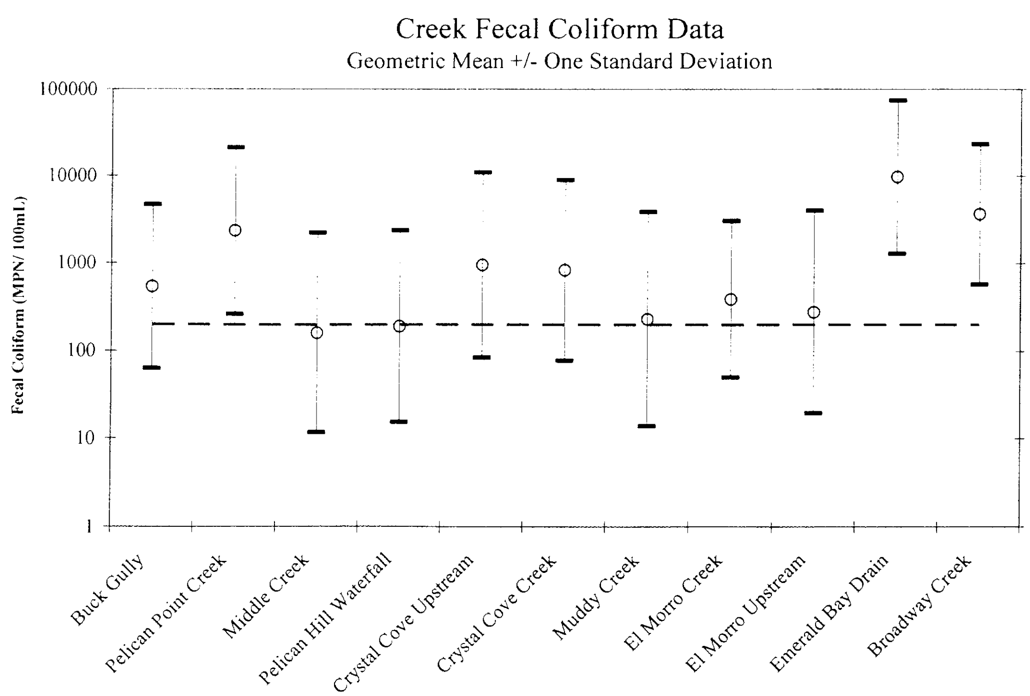

Figure 11: Long-term geometric mean concentrations for total coliform (data from 2/2/99 to 1/13/04)

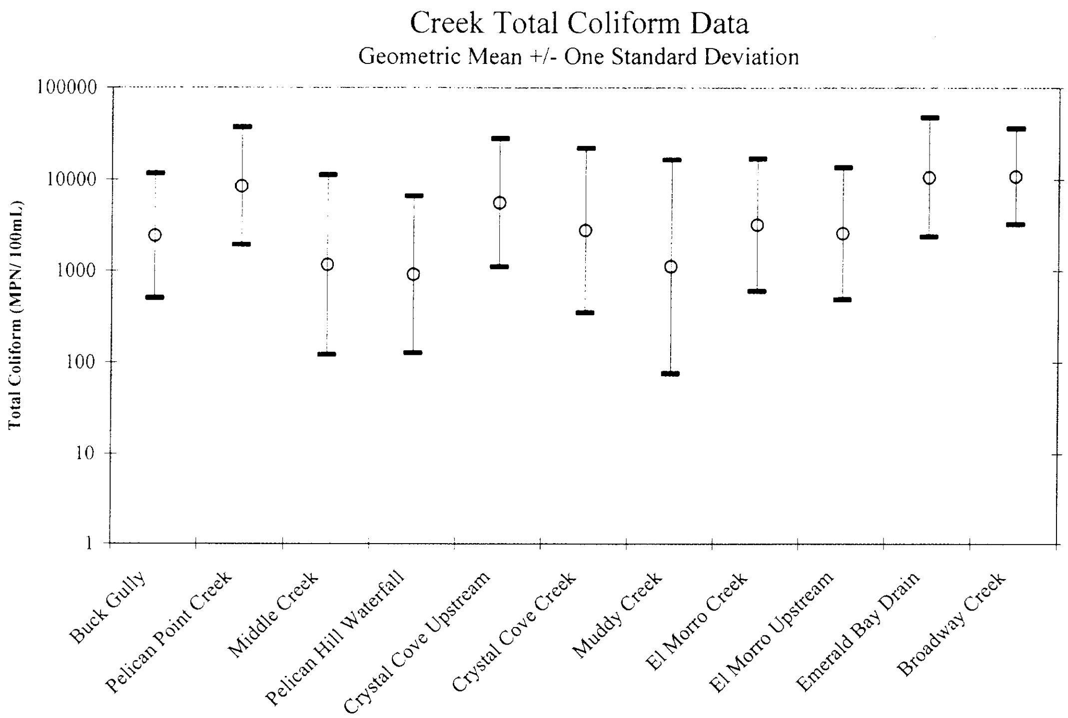

Figure 12: Relationship between % developed and the long-term geometric mean enterococci concentration (data from 3/30/99 to 1/13/04). Dashed line represents EPA's suggested 30-day geometric mean water quality criterion for enterococci corresponding to a 1.0% risk level.

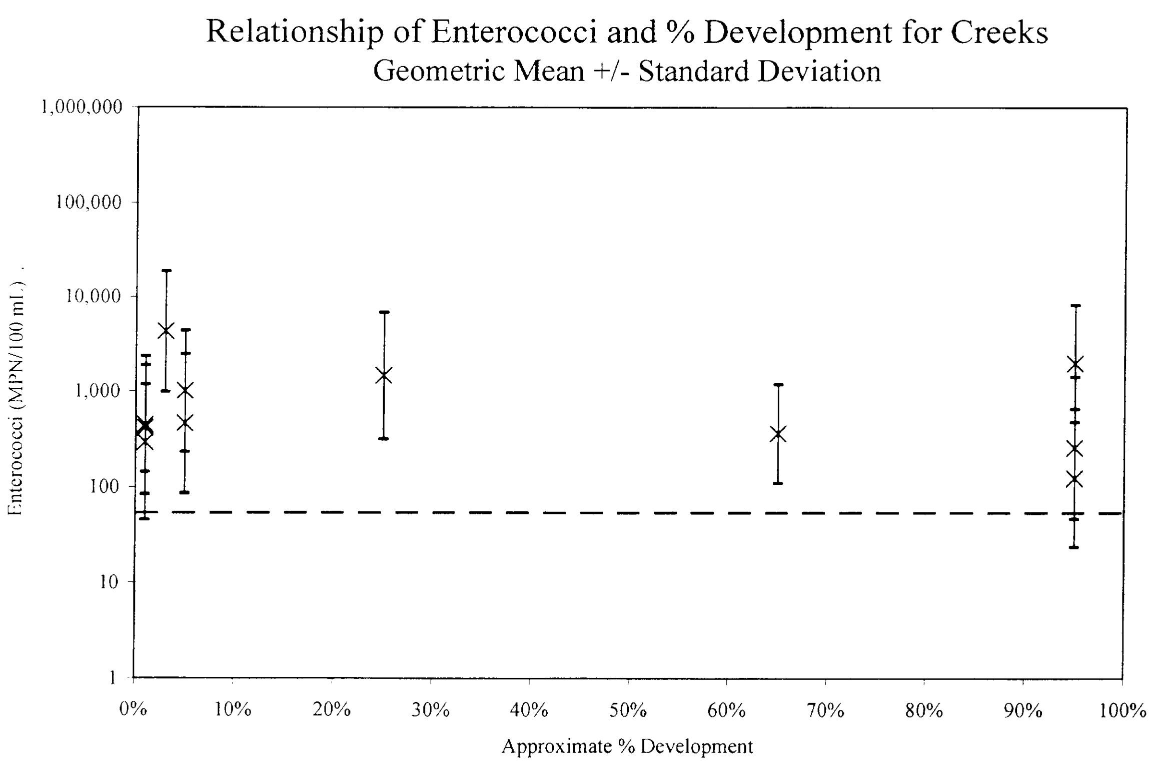

Figure 13: Relationship between % developed and the long-term geometric mean fecal coliform concentration (data from 1/5/99 to 1/13/04). Dashed line corresponds to the current Santa Ana Basin Plan water quality criterion for 30-day log mean (geometric mean) fecal coliform concentrations.

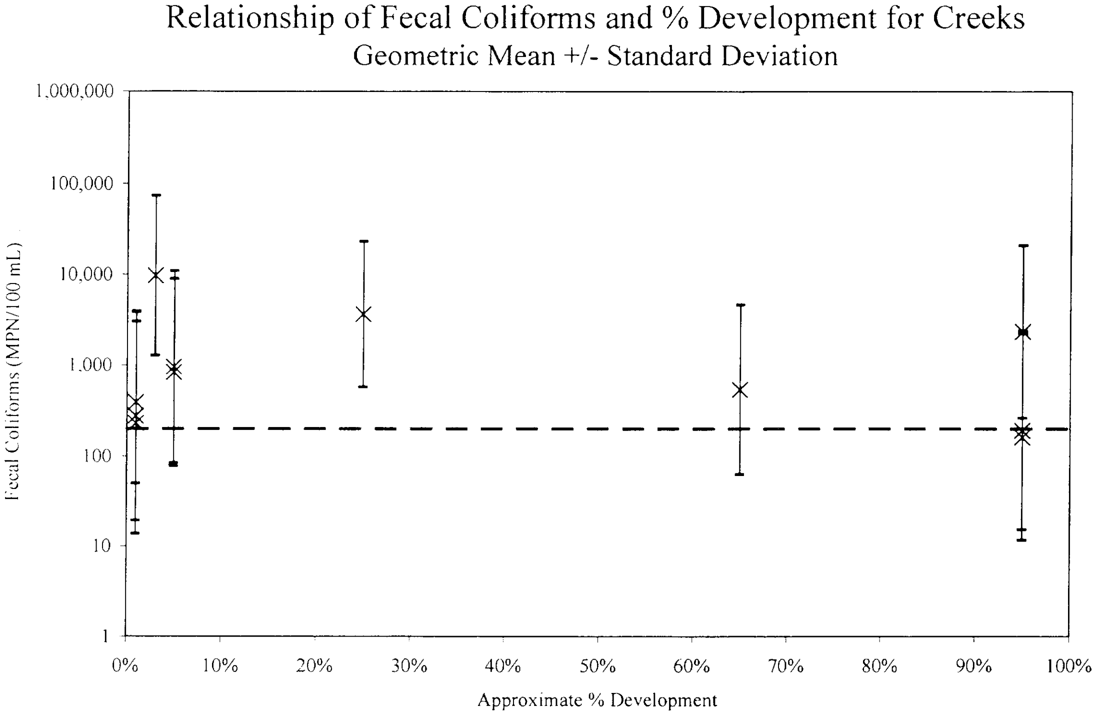

Figure 14: Relationship between % developed and the long-term geometric mean total coliform concentration (data from 2/2/99 to 1/13/04).