State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review – Staff Memorandum

Technical Memorandum #3:
Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

By

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November 5, 2009

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Los Angeles Region

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To: Wendy Phillips, C.E.G., C.H.G.,
Chief of Groundwater Permitting and Landfills Section
Rebecca Chou, Ph.D. P.E., Chief of Groundwater Permitting Unit

From Elizabeth Erickson, P.G. Groundwater Permitting Unit

Date: October 21, 2009

Subject: Peer Review Response to Comments - Technical Memo #3: Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

Attachments:

1. Comments dated October 5, 2009 from Dr. Robert Arnold, Arizona State University
2. Comments dated October 7, 2009 from Dr. Jörg Drewes, Colorado School of Mines
3. Comments dated September 10, 2009 from Dr. JoAnn Silverstein, University of Colorado at Boulder

To ensure that the proposed amendment to the *Basin Plan*[1] is based on sound science and engineering principles, the scientific elements of Technical Memorandum #3: "Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation" dated September 9, 2009, was peer reviewed. This peer review was conducted in accordance with requirements and guidelines from the Cal/EPA Scientific Peer Review Program, Office of Research, Planning and Performance.

Summary

Dr. Robert Arnold of Arizona State University, Dr. Jörge Drewes of Colorado School of Mines, and Dr. JoAnn Silverstein of the University of Colorado at Boulder agreed that the approach and methods used in Tech Memo #3 incorporate sound scientific and engineering principles. Although some suggestions were made to improve staff's discussion, none of the comments materially altered the conclusion of Tech Memo #3. That is: OWDSs in the Malibu Civic Center area cumulatively release bacteria to Malibu Beaches, where the enterococcus densities exceed the water quality criteria for the protection of human health.

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[1] Proposed amendment to the *Water Quality Control Plan for Coastal Watersheds of Los Angeles and Ventura Counties (Basin Plan)* to prohibit on-site subsurface disposal systems (OWDSs) in the Malibu Civic Center area.

New Material Added

Dr. Bob Arnold asked for additional material to be added. Statistical support for the findings were added on page T3-17 and summarized in Appendix 1.

Dr. Arnold: "The contention here is that the correlations among annual frequency distribution provides evidence of annual similarities at each beach for which data were provided and thus an indication that fluctuation in enterococcus numbers is probably the result of some regular pattern of events as opposed to random odd events like direct communication with bathers, etc. I am unable to provide a convincing statistical analysis as part of this review..." (page 3).

Response: The enterococcus interval frequencies calculated for the beaches for four summers were compared using the Pearson's correlation coefficient. The number of measures were counted in each of eight intervals: (1) values less than or equal to ten; (2) more than ten but less than or equal to 25; (3) more than 25 but less than or equal to 50; (4) more than 50 but less than or equal to 100; (5) more than 100 but less than or equal to 250; (6) more than 250 but less than or equal to 500; (7) more than 500 but less than or equal to 1,000; and (8) more than 1,000. The intervals approximate a logarithmic distribution, but include more intervals between 25 and 100 and between 250 and 1,000, ranges in which the beaches contrasted most sharply. Pearson's correlation coefficient was applied following EPA's "Ambient Water Quality Criteria for Bacteria, 1986" as described in the following quote:

> "The examination of a number of potential indicators, including the ones most commonly used in the United States (total coliforms and fecal coliforms), was included in the study. Furthermore, the selection of the best indicator [enterococcus] was based on the strength of the relationship between the rate of gastroenteritis and the indicator density, *as measured with the Pearson's Correlation Coefficient. This coefficient varies between minus one and plus one. A value of one indicates a perfect relationship, that is, all of the paired points lie directly on the line which defines the relationship. A value of zero means that there is not linear relationship. A positive value indicates that the relationship is direct, one variable increases as the other increases. A negative value indicates the relationship is inverse, one variable decreases as the other increases.* The correlation coefficients for gastroenteritis rates are related to the various indicators of water quality from both marine and fresh bathing water as shown in Table 2" (page 5).

Staff also conducted an additional study to determine if evidence for groundwater contributions to beach bacteria could be statistically linked to existing water quality and hydrology data. Early technical reviewers commented that the approach had not been used before and asked for additional time to evaluate the study. The analysis is provided in Attachment #1.

Requests for Clarification

Dr. Arnold, Dr. Jorge Drewes and Dr. JoAnn Silverstein asked for clarification on three topics. Dr. Arnold requested clarification on how the scientific process was used. Dr. Drewes' inquiry on non-human sources for enterococcus and Dr. Silverstein's query about bacteria transport in groundwater have been resolved with clarifying language in the memo.

Dr. Arnold: "I feel that this is a weak argument, primarily because the statement does not seem to rest on statistically valid hypothesis testing. That is, do the calculated correlation coefficients in fact justify the conclusion that the distribution of values observed is derived from the same population of actual values each year - that the distribution of MPNs does not change from year to year. Even if that distribution of concentrations is time invariant (as suggested) it seems that the population of enterococcus concentrations in the waters tested may take on a distribution of this sort for any number of reasons, including a somewhat randomly generated source of contamination due to bathing and so forth. It seems difficult to justify the elimination of such an explanation based on the data provided."

Response: Material has been added on pages T3-2 and T3-25 to clarify the hypothesis testing process which led to the results.

Dr. Drewes: "The author neglects to state that there are also non-human sources for enterococcus, which could potentially contribute to the concentrations observed in beach samples, although the likelihood for non-human contributions is small in the given settings (page 1)."

Response: Enterococcus has been attributed by some researchers to feces from warm-blooded animals such as raccoons, a source which may be present at the Malibu beaches. See the additional clarifying material included on page T3-23 and in Attachment 2.

Dr. Silverstein: "..the Haile et. al. epidemiology study was based on illness resulting from swimming at or near storm drain outfalls. The 1983 EPA document, Health Effects Criteria for Marine Recreational Waters, was based on studies of illness linked with treated wastewater outfalls. These are both point sources at beaches. The mechanism for transport of septic tanks and subsurface infiltration such as those in Malibu is thorough porous media, which may lessen the risk of these discharges. One source of difference resulting from subsurface discharge is the removal of particulate matter and attached bacteria. The 1983 EPA Health Effects document noted that removal of suspended solids during wastewater treatment reduced the density of Salmonella."

Response: Both the Haile and EPA epidemiology studies measured illnesses associated with enterococcus from point and non-point sources. Additional clarifying discussion was added at T3-24 and in Attachment 3.

Recommendations Not Incorporated

Staff appreciated comments from Dr. Drewes and Dr. Silverstein and provides further explanation, but did not incorporate two recommendations. Dr. Drewes requested that more surface water information should be provided in the memo. Staff chose to rely on existing surface water documents. Dr. Silverstein commented that the end-of-pipe enterococcus measures were not consistent with average raw sewage densities. Staff agrees, but inserted additional discussion describing why a change was not made.

Dr. Drewes: "Data presented in this Technical Memorandum provide support that beach water quality in the vicinity of the Malibu Creek watershed repeatedly fails to meet water quality objectives. The data presented would not support that the water quality "persistently" fails to meet the water quality objectives since only a limited data set is presented. For some tables, information is missing regarding the size of the data set considered. For example, regarding Table 2, what is the total number of samples collected? Exceedances reported for the Surfrider Beach (2006 and 2007) in Table 2 seems to be based on data collected during six weeks in 2006 only, whereas the 2007 data set represents data collected over a four-month period. Are results presented in Tables 3-5 all data that is available for these sampling locations? At a minimum, a clarification should be provided in the Memorandum" (page 3).

Response: Sufficient evidence of a persistent problem has already been made available to the public in EPA's 2002 303(d) list, Santa Monica Bay Bacteria, Malibu Creek and Lagoon bacteria and Malibu Creek and Lagoon nutrient TMDLs and the 2008 NOV on stormwater exceedances in Malibu, but additional discussion was provided on page T3-7.

Dr. Silverstein: "Some of the data in Table 1 (page T3-3) seem questionable. For the Malibu Colony Plaza, the numbers of total and fecal coliform are identical, and typically fecal coliform are a log unit less than total. Also the number of Enterococci is higher than either total or fecal coliform, which is atypical in general, and not consistent with the other samples. For Fire Station 8, the data are more puzzling. In all samples, the MPN for enterococcus is equal to or greater than either total or fecal MPNs. .....these data should be questioned by anyone familiar with typical trends for these three indicators reported in the literature and therefore some explanation of the differences should be offered."

Response: The end-of-pipe data were provided to document that enterococcus can be discharged from OWDSs into groundwater. The bacteria densities and proportions are not consistent with sewage or non-sewage related waters. Inconsistencies within these samples is attributed to the wide range of data reported for OWDS effluent where disinfection has failed and different detection methods are used on serial grab samples of samples of partially treated sewage. See discussion added on page T3-4.

Dr. Silverstein: "The scientific basis for Figure 11 is weak..."

Response: The end-of-pipe values included in this figure show the wide variation in enterococcus densities entering the groundwater at the location indicated and discussed above. Staff questions if 'average' range of enterococcus in raw sewage concentrations from homogenized municipal waste is an appropriate criteria for well testing or septic tank outlet to a seepage pit. Numerous reported enterococcus values in the Malibu Civic Center wells and at end-of-pipe range up to 1×10^8 MPN/100 mL, suggesting that any one high value is not a computational, sampling or reporting error.

Comments in Support

Dr. Arnold: "Considering the entire argument presented and supporting information provided, the staff has made an adequate case for improving the microbial quality (indicators of fecal contamination) in Malibu ground water in order to improve the water quality in the near shore marine area off the Malibu coastline in order to reduce associated threats to human health (page 4)."

Dr. Arnold: "There are somewhat speculative, but increasingly accepted, mechanisms for the transport of bacteria and viruses from proximate ground waters, through the near-surface beach sand and into the surf zone. Observations regarding transport through the beach front were derived from studies outside the Malibu area, but in southern California, from multiple lines of experimentation. These have been described in peer-reviewed archival journals, adding to their credibility (page 4)."

Dr. Drewes: "The reviewer concurs with the interpretation of the key literature considering in this Technical Memorandum indentifying factors that increase the levels of pathogen indicators and risk to human health. The reviewer also concurs with the selection of enterococcus bacteria, since it is more persistent in water and sediments as compared to coliforms, as a recreational water quality indicator illustrating the presence of human waste at the sites studied "(page 1).

Dr. Drewes: "The reviewer agrees with staff's determination of impairment through pathogenic organisms and the conclusion that groundwater in this area is a source of impairment to lagoon and beaches (page 3)."

Dr. Drewes: "Plotting enterococcus occurrence data as frequency graphs is appropriate to illustrate distribution changes over several years for May-October summer time periods. (page 3)"

Dr. Drewes: "Correlation coefficients between annual enterococcus frequency distributions are reported for the Surfrider Beach (MC-2) data set only and they demonstrate that the variability of the distribution is small from year to year (page 3)."

Dr. Silverstein: "Overall, the movement of groundwater from the area served by OWDSs is well documented in other reports (Tech Memo 4). Literature cited confirms that pathogens, especially viruses, are transported in the subsurface from OWDSs, and would therefore reach the ocean water, especially in a sandy aquifer with short travel time. The presence of enterococcus in septic tank effluent, nearby groundwater, and the beaches is credible support for the contribution of OWDSs to contamination of the Malibu beaches by bacteria."

Dr. Silverstein: "a particular source of pathogen risk is associated with the fact that OWDSs serve a small number of people. This was discussed in the EPA Health Effects Criteria for Marin Recreational Waters (1983, page 49). That document notes that when the number of individuals who are sources of fecal waste becomes smaller, the ratio of pathogen-to-indicator density will vary highly from numbers based on aggregate wastes from a large population. If one or a small number of individuals in these small systems have an infectious disease, the ratio could approach 1, making the risk a significantly higher than that addressed by the water quality standard. The EPA document advises in that case, which may include OWDSs : " The solution is administrative action prohibiting such discharges into recreational waters."

Dr. Silverstein: "Taken as a whole, the conclusions of Technical Memos #3 and #4 are based on sound scientific principles and reasoning. Epidemiologic studies cited provide a strong basis for increased health risks to swimmers and the presence of indicator bacteria measured at the beaches, especially enterococcus, at concentrations higher than marine recreational water quality standards. There are some relatively minor concerns about interpretations of literature and some of the reported data as discussed above and in previous comments on Tech Memo #4. Addressing these will acknowledge real uncertainties that always exist with environmental studies, but will not weaken the conclusions."

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Other Revisions

Dr. Arnold: "I feel that the case is well made for construction of sewerage in the Malibu area, but I was convinced in part by information from the supporting documents that might be included directly in the technical memorandum. The epidemiological case in particular requires supporting information. In my opinion, further studies are not required to justify Board action, so that recommendations specific to such studies are unnecessary. The complexity of the hydrology conditions, microbiological transport mechanisms and so forth are sufficiently plain (page 4)."

Response: The supporting documents have been included as part of the administrative record and posted on the website for the use of the public in considering Technical Memo #3. Specifically, we included Haile et. al, "An epidemiological study of possible adverse health effects of swimming in Santa Monica Bay", 1996; Haile et. al. "The health effects of swimming in ocean water contaminated by storm drain runoff", 1999; Gold, M.A. "What are the health risks of swimming in Santa Monica bay", 1994; and EPA "Health Effects Criteria for Marine recreational waters", 1983.

Dr. Silverstein: "Caution should be used in associated the bacteria indicator with human waste."

Response: Corrections in the text are made as per your recommendations emphasizing that enterococcus can also be associated with non-human waste.

Editorial and grammatical suggestions have been followed as appropriate, but are not specifically listed here. Staff wishes to express appreciation for the contributions of the peer reviewers.

Attachment #1

Comparison of Santa Monica Bay Beaches Adjacent to OWDS and to Sewers with Winter Rainfall using Gehan Statistical Test.

Dr. Arnold asked for additional statistical support for staff's findings.

Data

Beach data were collected as part of the "Santa Monica Bay Beaches Bacteria Total Maximum Daily Load Coordinated Site Monitoring Plan, April 7, 2004" (CSMP) and can be found at http://ladpw.org/wmd/npdes/beachplan.cfm.

Sampling procedures are standardized, including morning sampling in ankle-deep water at fixed points with testing in State certified laboratories. The study focused on records for June through August in 2005, May through October in 2006, April through October in 2007, and May through October in 2008, on a total of 58 beaches, 36 of which receive freshwater drainage (with MS-4 stormwater permits) and 22 of which do not. The beaches stretch from El Pescador Beach in the northwest to Redondo Beach in the southeast.

The sample sites were sorted according to characteristics, such as watershed size, land-use, fecal-indicator-bacteria concentrations, septic system presence, wave strength and beach visitor population. A full array of site characteristics were found to be represented: sewage or septic system waste treatments, adjacent groundwater levels of enterococcus levels above 1 MPN/100mL, watershed sizes ranging from 813 acres to 81,980 acres, urban acres ranging from 128 acres to 68,700 acres, and wave action identified from surf web-sites ranging from none to persistent. Some beaches had adjacent lagoons, tidally influenced pools, stormwater containments and low flow diversions.

Results

Enterococcus on Malibu Civic Center Beaches and all Santa Monica Bay Beaches

The enterococcus measures recorded on CSMP beaches over the summers 2005 to 2008 were sorted by interval frequency and plotted against the concentrations of Enterococcus (MPN/100mL). The method was chosen to minimize the impact of varying sample sizes and simplify large variations in the measures.

The beaches were found to have the most measures at 10 MPN/100 mL and some additional measures above 1,000 MPN/100 mL Figures A to D and Tables A to D of all Santa Monica Bay beaches for 2005 through 2008 show that these general characteristics are present for all the studied beaches.

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Figure A. 40 Santa Monica Bay Beaches 2005 (All MS-4 beaches) Enterococcus Interval Frequency for June-August Single Measures[2]

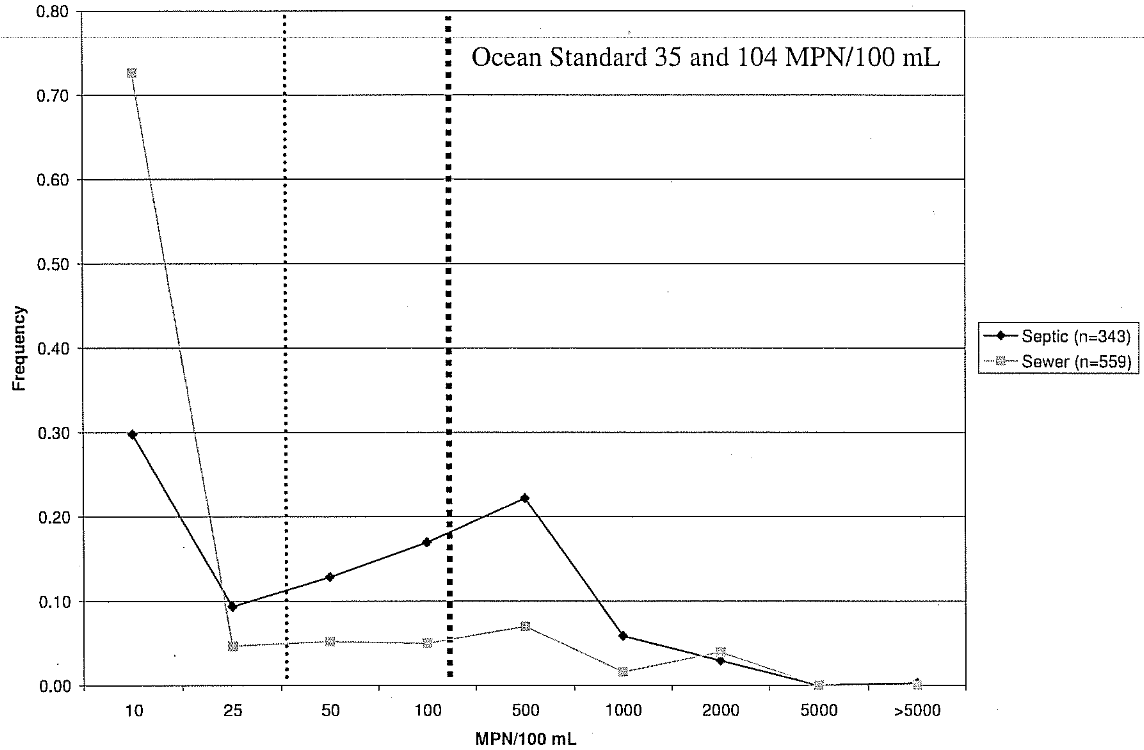

Table A: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2005.

In MPN/100mL	all beaches in 2005			
Enterococcus	Septic (n=466)	% total days reported at septic sites	Sewer (n=859)	% total days reported at sewer sites
Days above 35	206	44%	207	24%
Days above 104	108	23%	126	15%

[2] For the purposes of this study, the following site definitions were made: MS-4 Septic (19) 1-01, 1-03, 1-04, 1-05, 1-06, 1-07, 1-08, 1-09, 1-10, 1-11, 1-12, 1-13, 1-14,1-16,1-18, 4-01, MC-01, MC-02, MC-03; MS-4 Sewer (21) 2-01, 2-02, 2-06, 2-07, 2-10, 2-11, 2-13, 2-15, 3-01, 3-02, 3-03,3-04, 3-05, 3-06, 3-07, 3-08, 5-02, 5-03,6-01,6-05, BC-01; Non MS-4 Septic (3)1-02,1-15,1-17;
Non MS-4 Sewer (15) 2-03,2-04,2-05,2-08,2-09,2-12,2-14,3-09,5-01,5-04,5-05,6-02,6-03,6-04,6-06

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Figure B. 40 Santa Monica Bay Beaches 2006 (All MS-4 beaches) 1nterococcus Interval Frequency for May-October Single Measures

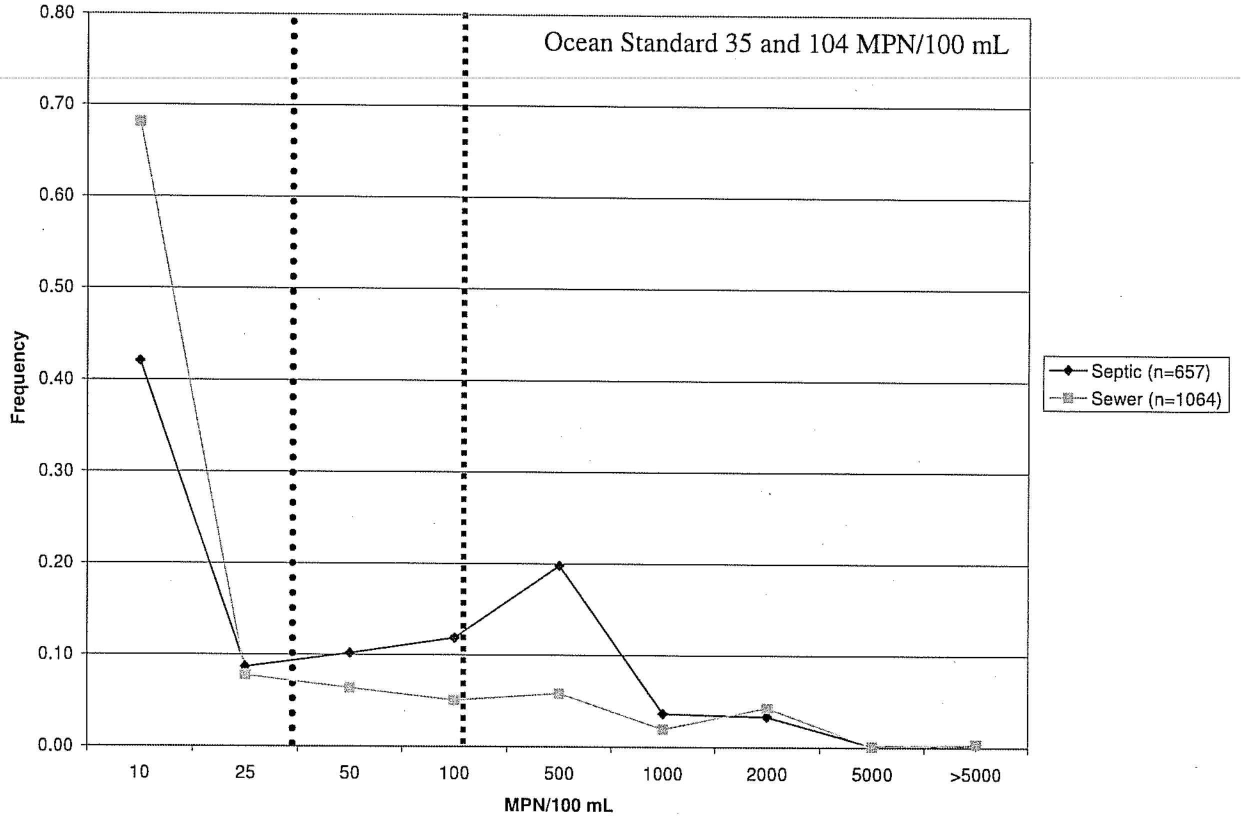

Table B: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2006. Sewered beaches were tested about one and a half times as often, in this year, as septic beaches, yet more days were recorded when enterococcus densities on septic beaches were higher than the Ocean single sample and geometric mean objectives.

In MPN/100mL	all beaches in 2006			
Enterococcus	Septic (n=903)	% total days reported at septic sites	Sewer (n=1669)	% total days reported at sewer sites
Days above 35	326	36%	295	18%
Days above 104	183	20%	156	9%

Figure C. 40 Santa Monica Bay Beaches 2007 (All MS-4 beaches) Enterococcus Interval Frequency for May-October Single Measures

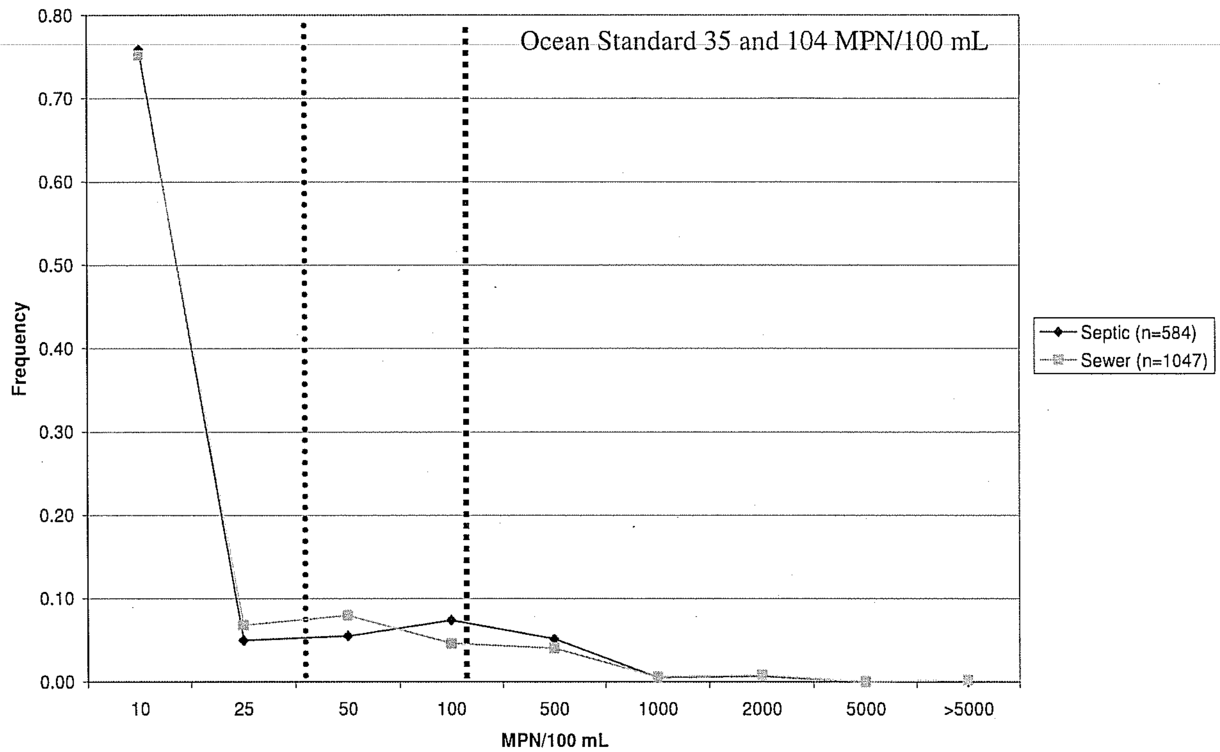

Table C: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2007. Sewered beaches were tested about twice as often, in this year, as septic beaches, and both had the same frequency of exceedances.

In MPN/100mL	all beaches in 2007			
Enterococcus	Septic (n=816)	% total days reported at septic sites	Sewer (n=1705)	% total days reported at sewer sites
Days above 35	106	13%	215	13%
Days above 104	38	5%	79	5%

Figure D. 40 Santa Monica Bay Beaches 2008 (All MS-4 beaches) Enterococcus Interval Frequency for May-October Single Measures

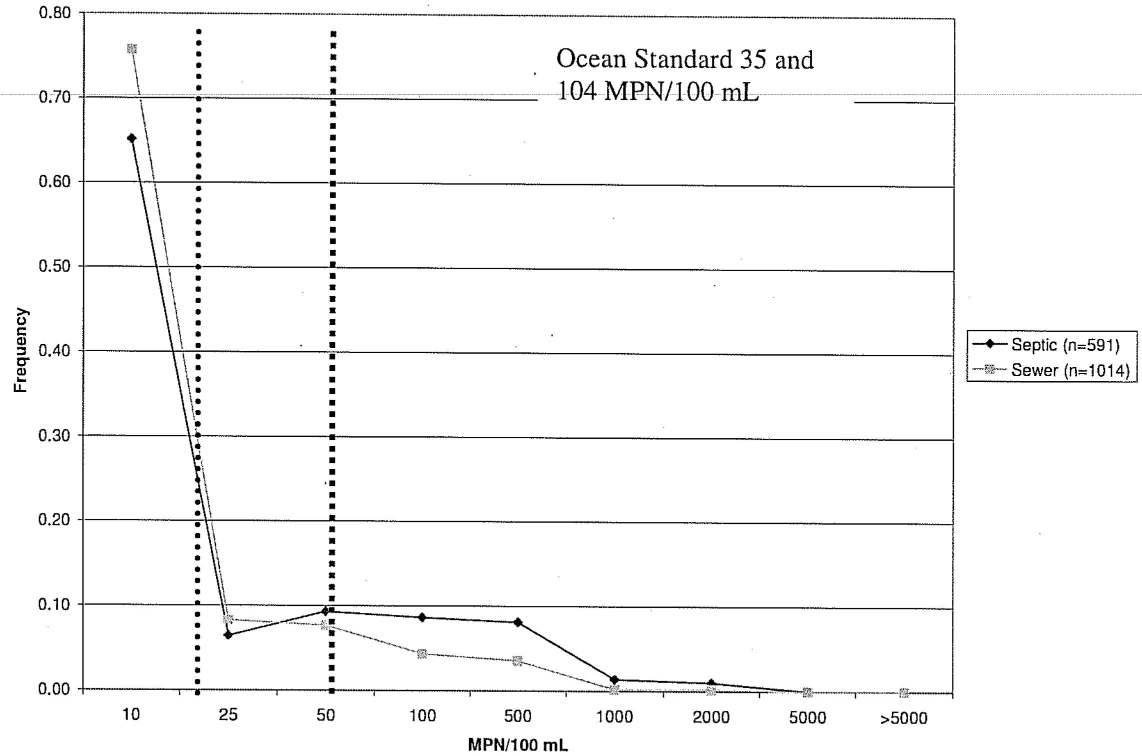

Table D: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2008.

In MPN/100mL	all beaches in 2008			
Enterococcus	Septic (n=813)	% total days reported at septic sites	Sewer (n=1644)	% total days reported at sewer sites
Days above 35	145	18%	176	11%
Days above 104	59	7%	54	3%

This annual comparison of all Santa Monica Bay beaches is consistent with the hypothesis that the mechanism(s) supplying enterococcus bacteria to beaches during the summer months does not operate uniformly every year. Further, the mechanism which supplies enterococcus bacteria to the beaches at levels of 10 MPN/100 mL, and to a lesser extent at levels above 1,000 MPN, must operate on all beaches regardless of the year or the method of waste treatment in the adjacent area.

The difference between the septic and sewered data sets for 2005, 2006 and 2008 is statistically significant.

Statistic analysis was performed for the same data sets of 2005-2008 using a t-test, and a Chi-square test. The use of these tools to measure the significance of enterococcus distributions was found to produce variable results depending on the size of the population and any truncation of the population. This observation is attributed to the non-normal and non-Chi-square shape of the distributions with a predominance of very low values and wide variations in the number and size of the largest values.

Consistent statistical results were obtained for the entire population of over 8,000 measures using the Gehan Test (a non-parametric Statistical Program) from USEPA ProUCL Statistical Program in conjunction with the Wilcoxsin and Quartile tests. All results confirmed hypothesis that enterococcus concentrations at septic beaches are greater than sewered beaches with 95% confidence level except for 2007 data. Gehan Test results and a discussion of the discarded methods are provided below.

This examination of all Santa Monica Bay beaches over four years provides evidence that bacteria may be transported by groundwater to the beach face as other mechanisms such as stormwater flow, overland urban flow, storm surge are minimal in the summer and the only other major source present only at septic beaches in groundwater discharge. Because bacteria must be transported by the groundwater between the septic systems and surface receiving waters and groundwater gradients increase after rain, a correlation between the number of enterococcus measures per site and the rainfall is expected at beaches where groundwater movement of the bacteria takes place.

Rainfall and Enterococcus

The highest monthly volume of rain fell in 2005 (wet year), among the years evaluated here, when 6.95 inches were recorded. The lowest was reported in 2007 (dry year) when less than one inch was recorded. However, the average annual rain fall in this area is 12 inches per year, significantly larger than the rain received in this study's "wet" year of 2005. Rain gauge reports from Los Angeles International Airport reported by the Department of Water Resources confirm annual variations in precipitation by year and are shown in Figure E.

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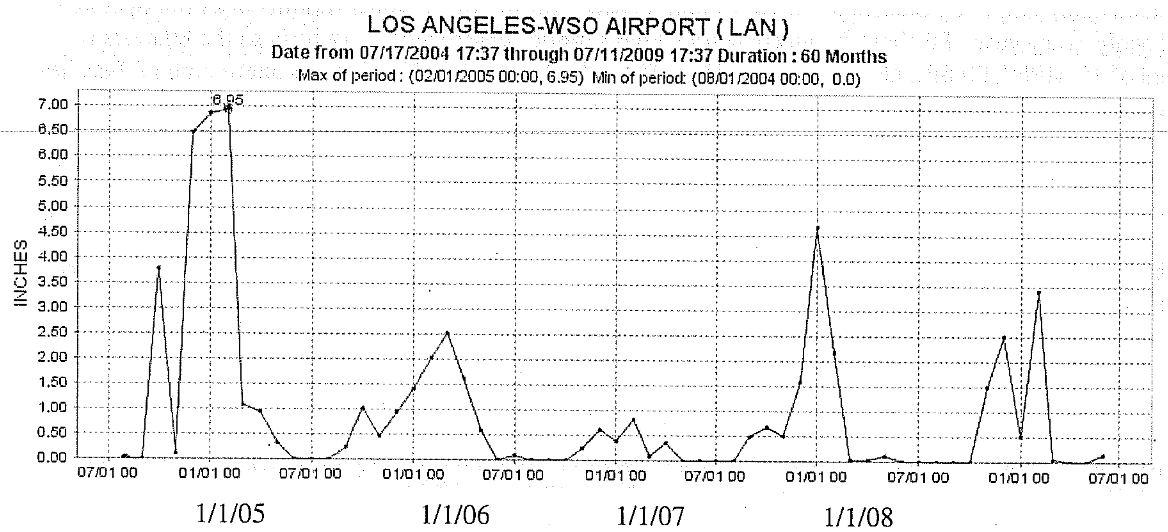
Figure E. Rain gauge information for Los Angeles International Airport



Septic beaches are more distinct from sewered beaches in summers preceeded by rainy winters. The relative frequency of bacteria densities above 35 MPN/100mL on the beaches during the summer are seen to decrease between 2005 and 2007 in Tables A through D. The rainfall also decreases during this period as shown in Figure E.

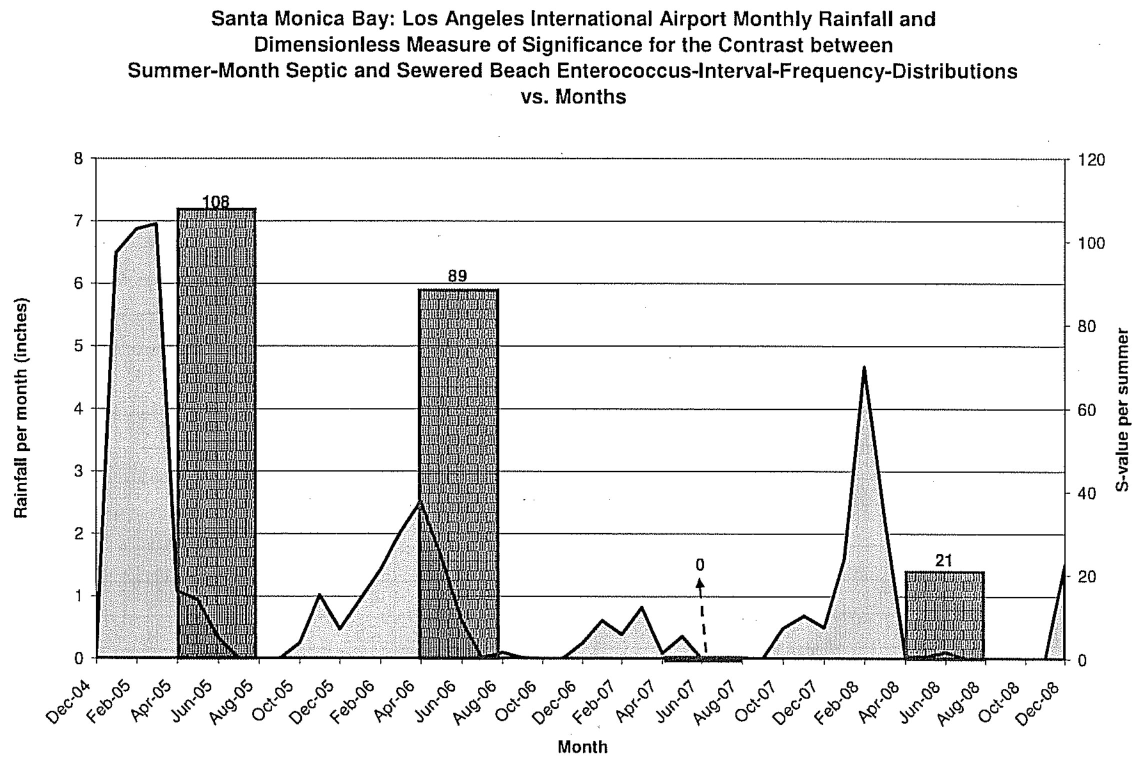
Non parametric statistical tools were applied to the enterococcus beach data sets using Gehan Test from EPA's ProUCL statistical program. Using Form 1 Test, the Null Hypothesis is "Septic Beach Mean/Median Less Than or Equal to Sewer Beach Mean/Median;" and the Alternative Hypothesis is "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median". The result of the Gehan Test for 2005, 2006 and 2008 shows that the Null Hypothesis is rejected by a low P-value with an alpha value of 0.05 (a confidence level of 95%) , which rejects the Null Hypothesis and supports the Alternative Hypothesis "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median".

The statistical assessments of the 2007 enterococcus data are not consistent with the statistical results for 2005, 2006, and 2008. The same results were also obtained with an alpha value of 0.01 (a confidence level of 99%); enterococcus concentrations at septic beaches are higher than concentrations at sewered beaches statistically. Form 2 Test is also performed using the Gehan Test to verify the above conclusions.

The "Substantial Difference" (S) is used to estimate the difference in enterococcus concentration between septic and sewered beaches and is shown in Figure F. The rainfall was low in 2007, as is the S value. The S increases as the winter rains increase in 2008.

Because septic or sewered beach have little stormwater discharge for June to September, these observations document a supply and transport mechansim. Ground water discharge with elevated enterococcocus densities after wet winters is affecting septic beaches to a greater extent than is occuring on sewered beaches. In the summer of 2008, the frequency of enterococcus densities above 35 MPN/100mL does not increase to the 2006 summer levels, despite increasing rainfall in the winter of 2007-2008, nor does the S value increase to 2006 levels. This observation is attributed to short term rain events in February 2008 when discharge was via stormwater and not groundwater recharge.

Figure F.



Septic Density

Septic Density did not show a strong correlation with enterococcus measures or interval frequencies.

The number of septic systems at a beach within 1000 feet of the CSMP monitoring location was estimated by counting roofs on air photos dating after 2004 and available for coastal areas on Google for the area northwest of Castlerock Mesa, where no sewer hook up is available. The counts are as follows:

Table E.

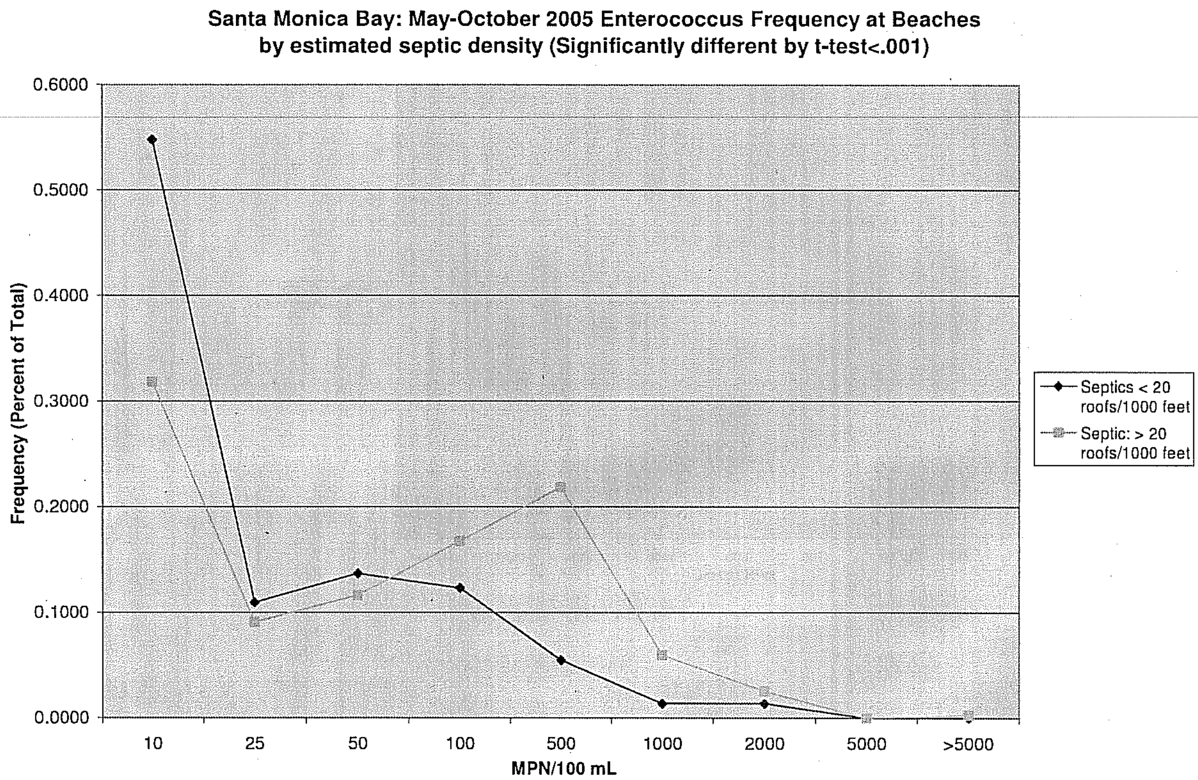
Beach with Lower Septic System Density	Sampling Point	Number of roofs within 1000 feet
Zuma Beach	1-05	3
Malibu Pier	MC-3	4
Leo Carrilo	1-01	5
San Nicholas Canyon	4-01	10
Solstice Creek an Dan Blocker Beach	1-10	10

Table F.

Beach with Higher Septic System Density	Sampling Point	Number of roofs within 1000 feet
Latigo Canyon	1-09	20
Surfrider Beach	MC-2	21
Trancas Creek	1-04	22
Walnut Creek	1-06	29
Sweetwater Canyon on Carbon Beach	1-13	32
Corral Canyon	1-11	34
Escondido Creek	1-08	34
Pena Creek on Las Tunas County Beach	1-16	36
Topanga Beach	1-18	41
Marie Canyon	1-12	43
Malibu Colony	MC-1	45
Las Flores Creek	1-14	58
Tuna Canyon	1-17	93
Ramirez Creek	1-07	120

Six beaches with no sewer connections and less than 20 roofs within 1000 feet of the CSMP monitoring point were compared with 14 beaches with no sewer connections and more than 20 roofs, as shown in Tables E and F and Figures G, H, J, and K. The plots below demonstrate that significant differences, as measured by the less reliable student t-test, were found on beaches in 2005 and 2006, when some rain fell. The following two years, a significant difference was not found. A weather related summer month difference, when direct discharge across the beaches is limited, is most likely attributed to groundwater flows.

Figure G.



Santa Monica Bay: May-October 2005 Enterococcus Frequency at Beaches
by estimated septic density (Significantly different by t-test<.001)
Frequency (Percent of Total)
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
10
25
50
100
500
1000
2000
5000
>5000
MPN/100 mL
Septics < 20 roofs/1000 feet
Septic: > 20 roofs/1000 feet

Figure H.

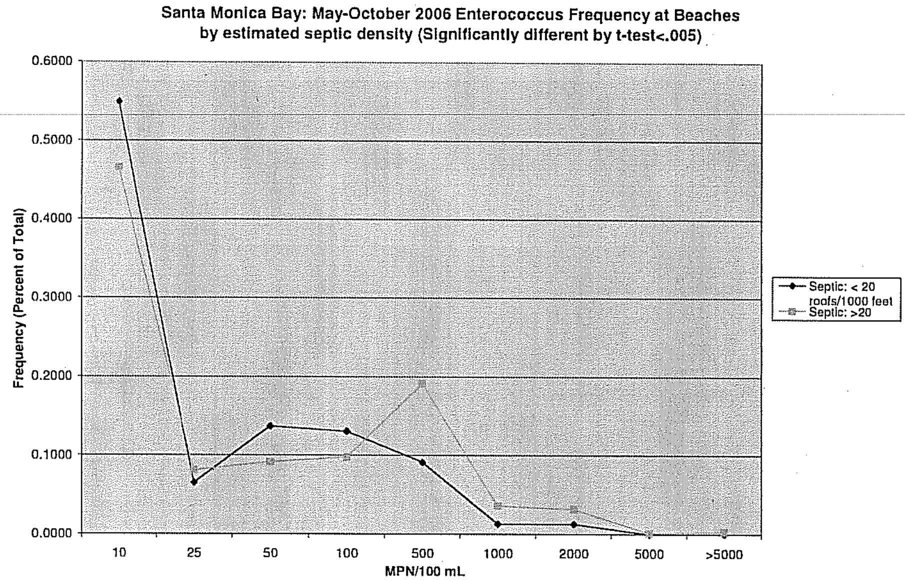


Figure J.

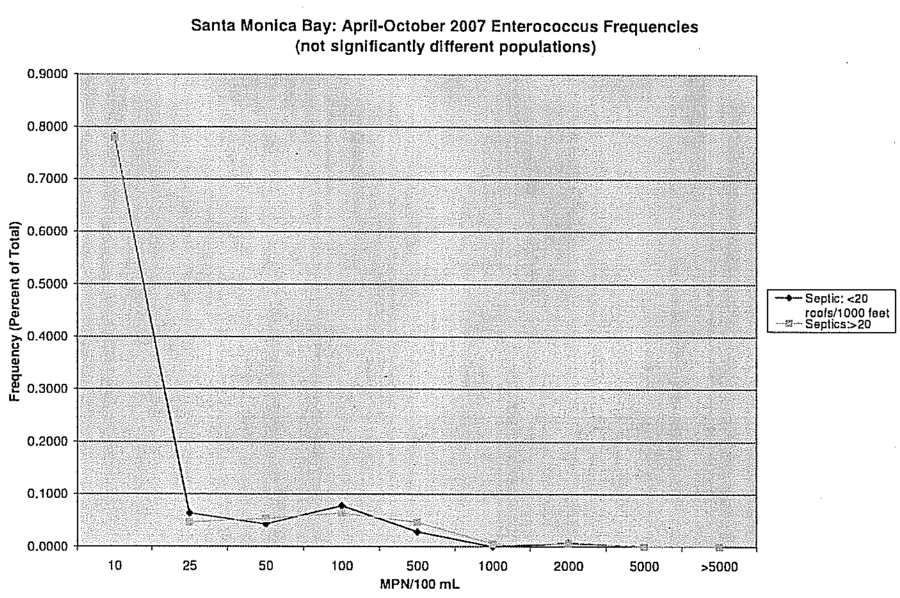
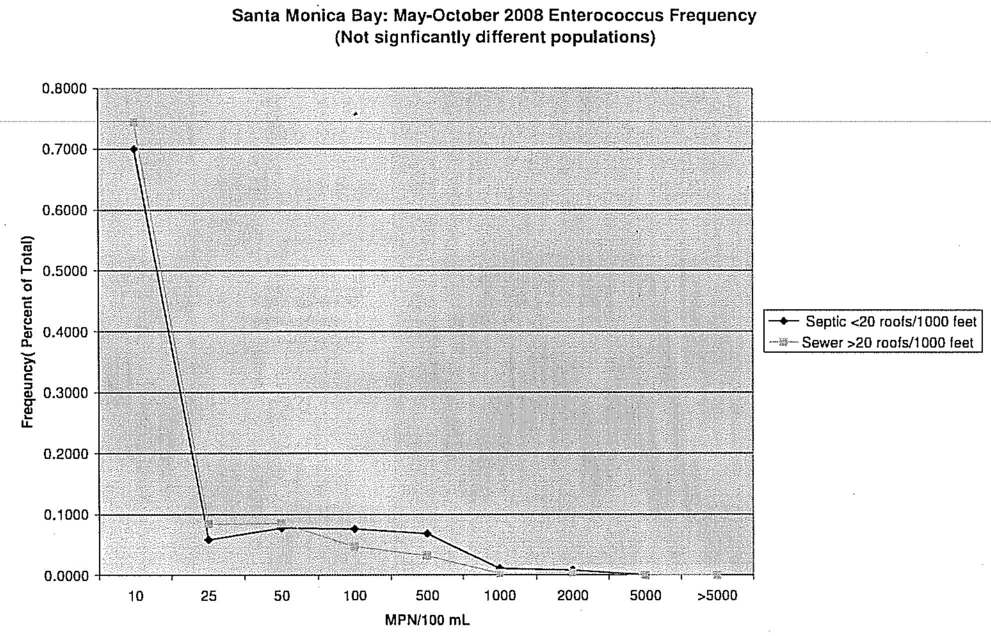


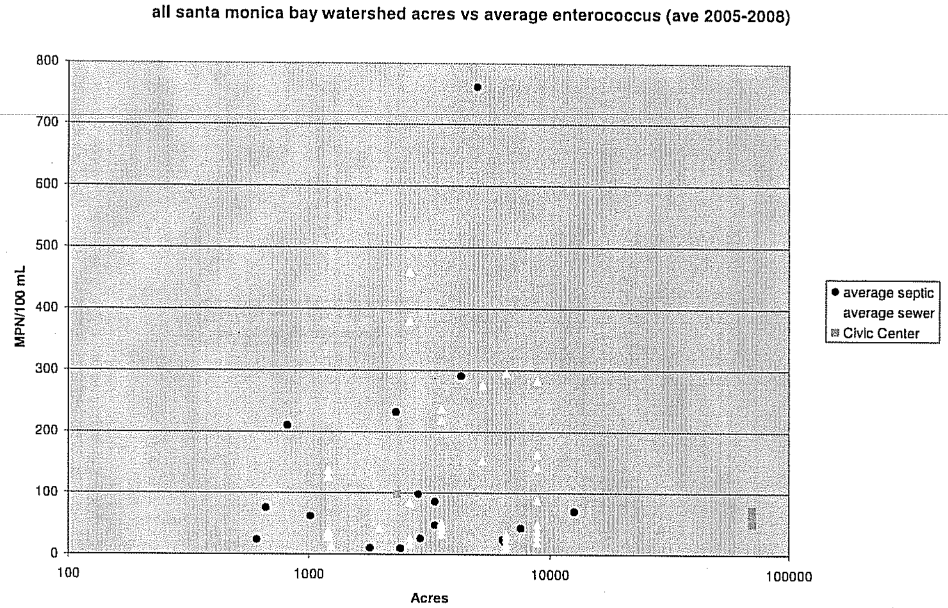
Figure K.



Watershed Area, Urban development and Beach populations

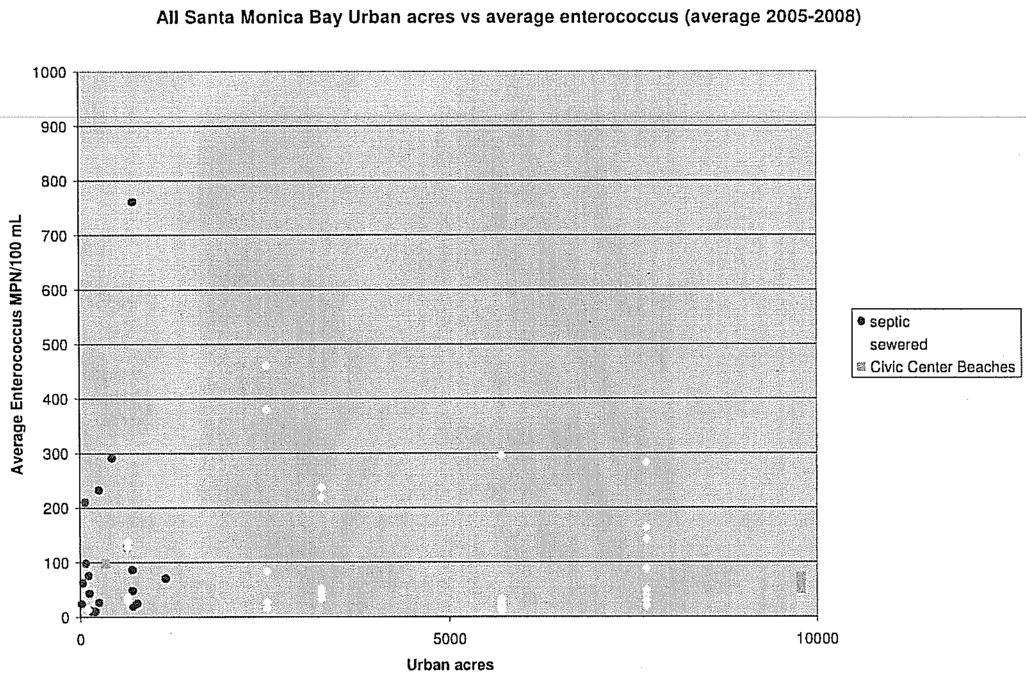
Watershed area, urban acreage and beach populations were not found to correlate with variations in enterococcus density distributions in Figure K. The following charts were prepared to show that the average enterococcus density on beaches with or without adjacent sewers is not seen to vary with these potentially confounding factors.

Figure L.



The Surfrider, Malibu Colony and Malibu Pier septic beaches appear on the right side of Figure L (greater than 10,000 acres) and a nearby beach, Sweetwater Canyon at Carbon beach, appears in the center (less than 5,000 acres). The acreage values come from the Santa Monica Bay bacteria Total Maximum Daily Load documents, and staff notes that three Civic Center beaches share the same high value for acreage. This may incorrectly suggest that the watershed size for is much greater than other beaches. Further evidence that watershed size does not correlate with enterococcus average comes from the two largest watersheds: Santa Monica Canyon with an average of 117.42 MPN/100 mL and acreage of 10,088; and, Ballona Creek with an average of 47.42b MPN/100 mL and acreage of 81,980.

Figure M.



No strong correlation is seen in Figure M above between urban acreage and average enterococcus densities for beaches with or without sewers. The Surfrider, Malibu Colony and Malibu Pier septic beaches appear on the right side of the chart (at 10,000 acres) and Sweetwater Canyon at Carbon beach appears on the left (at less than 1,000 acres). The acreage values come from the Santa Monica Bay bacteria Total Maximum Daily Load documents.

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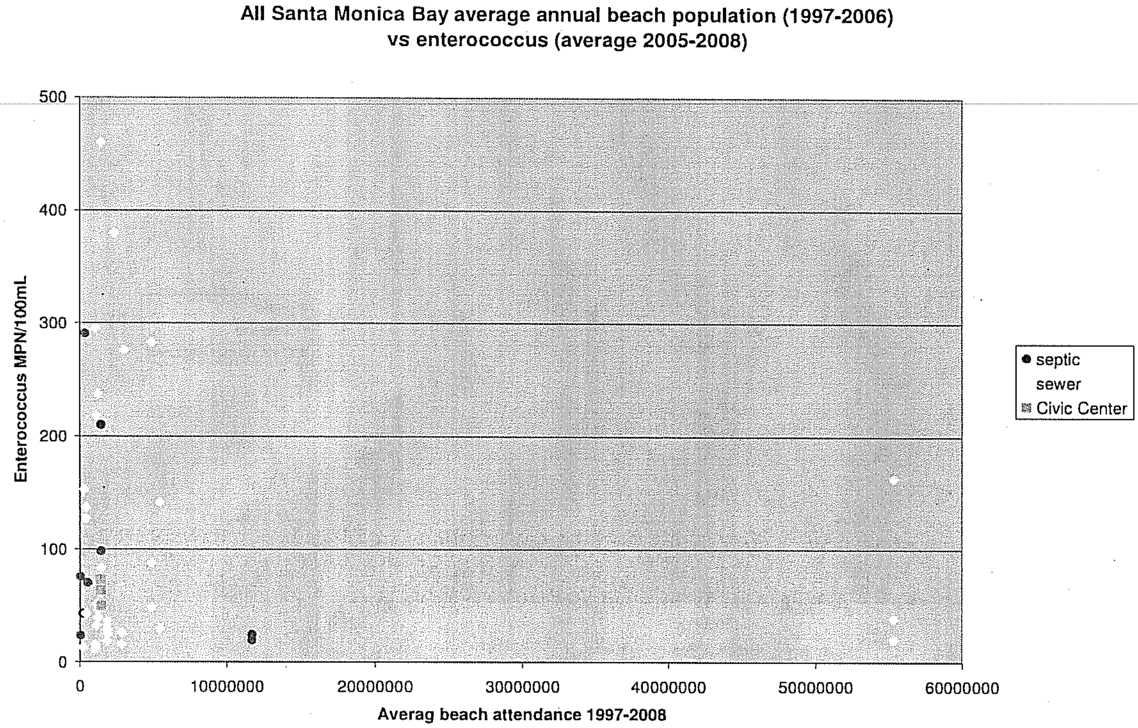
Figure N.



No strong correlation is seen in Figure N between acreage beach attendance and average enterococcus densities for beaches with or without sewers. The Surfrider, Malibu Colony, and Malibu Pier beaches appear on the left (at less than 1,000,000 people).

Statistical Significance

The application of statistical tools to the beach bacteria data sets revealed that standard tests have a high potential to produce misleading results. Additional statistical tests were used to confirm a significant difference between enterococcus interval frequency distributions for septic and sewered beaches in 2005, 2006 and 2007 for non-MS-4 beaches not including beaches with direct discharge to beach wave wash. The examination of enterococcus on beaches requires the manipulation of very large data sets. As an example, 7,081 measures were collected from beaches receiving MS-4 discharge in the summers of 2005 through 2008. The measures were not all normally distributed and were dominated by densities at or below 10 Most Probable Number (MPN)/100 mL (considered to be non-detect), with the presence of occasional measures above 24,000 MPN/100mL. The majority of the bacteria measures in the beach data sets had low and high enterococcus densities which together constitute a log normal distribution, but with interval frequencies between 50 and 1,000 MPN/100 mL which were not consistent with a log normal distribution.

Statistics which rely on normal distributions may produce false positive measures of significance for the beach bacteria populations. Many single beach samples assembled through weekly sampling over 4

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summers did not have sufficiently large populations to allow statistical assessment with such tests. For example, an attempt to compare Surfrider and Manhattan (40th Street) beaches during the summer of 2007 was not successful because of the distribution of the measures for Manhattan Beach (9 measures below 10 MPN/100 mL, one of 24,000 MPN/100mL and 5 of 10 MPN/100mL). The resulting sample distribution was not normally distributed nor was the natural log of the sample distribution normally distributed. A comparison of the data with the larger sample at Surfrider Beach varied with the interval to which the statistical test was applied.

Where data sets are large, normal distributions can be created through repeated sampling. However, the largest data sets also had a few very large measurements and many small measurements, suggesting that population distribution is not improved with sampling. As an example, annual populations for all sewered and septic beaches had high correlation coefficients for large and small intervals, but not for the interval between 50 and 1,000 MPN/100 mL.

If normality was assumed and Student's t-tests and Correlation Coefficient were applied to the entire population, the results were repeatedly inconsistent. T-tests and t-tests of normal log values would show sewer and septic populations were distinct in a given year, but fail to provide this result if the data were truncated to remove high values or low values. The statistic package Minitab was used to apply the Chi-square test. When the chi square correlation was made on truncated populations of all beaches with some values below 10 MPN/100 ML removed, the results ($p<.05$) indicated that septic and sewered beaches did not belong to the same population. However, the removal of about half of the population was of concern.

Non parametric statistical tools were applied to the same data sets. When all septic and sewered beaches for the year 2005 - 2008 were contrasted using the non-parametric Quartile Hypothesis Test, the Wilcoxon-Mann-Whitney (WMW) Test and Gehan Test from EPA's ProUCL statistical program, the Quartile Test results recommend using the WMW Test. However, the WMW Test is only applicable for data set with less than 40% non-detect level of 10 MPN/100mL. Therefore, the Gehan Test is the most appropriate Test for this study. The Gehan test looks at all intervals and emphasizes the mean/median interval. The results are summarized in Tables 1 through 4.

The Null Hypothesis is termed "Septic Beach Mean/Median Less Than or Equal to Sewer Beach Mean/Median;" and the Alternative Hypothesis is "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median" using Gehan Form 1 Test.

The result of the Gehan Test for 2005, 2006 and 2008 shows that the Null Hypothesis is rejected by a low P-value with an alpha value of 0.05 (a confidence level of 95%) , which rejects the Null Hypothesis and supports the Alternative Hypothesis "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median". The 2007 data are not consistent with the results of 2005, 2006, and 2008 due to low groundwater discharge to beaches after dry winter. The same results were also obtained with an alpha value of 0.01 (a confidence level of 99%) that enterococcus concentration at septic beaches is higher than concentration at sewered beaches statistically.

	Table 1 - 2005 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects	
User Selected Options		
From File	WorkSheet.wst	
Full Precision	OFF	
Confidence Coefficient	95%	
Substantial Difference	0	
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)	
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median	
Area of Concern Data: septic		
Background Data: sewered		
Raw Statistics		
	Site	Background
Number of Valid Data	358	754
Number of Non-Detect Data	113	482
Number of Detect Data	245	272
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	31.56%	63.93%
Minimum Detected	20	20
Maximum Detected	9208	4200
Mean of Detected Data	261.7	368.9
Median of Detected Data	87	99
SD of Detected Data	661.3	591.3
Site vs Background Gehan Test		
H0: Mean/Median of Site or AOC <= Mean/Median of background		
Gehan z Test		
Value	9.461	
Critical z (0.95)	1.645	
P-Value	1.52E-21	
Conclusion with Alpha = 0.05		
Reject H0, Conclude Site > Background		
P-Value < alpha (0.05)		

Table 2 - 2006 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	685	1377
Number of Non-Detect Data	293	921
Number of Detect Data	392	456
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	42.77%	66.88%
Minimum Detected	20	20
Maximum Detected	24192	48010
Mean of Detected Data	324.9	532.3
Median of Detected Data	86.5	42
SD of Detected Data	1320	2701

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test

Value	11.74
Critical z (0.95)	1.645
P-Value	4.17E-32

Conclusion with Alpha = 0.05
Reject H0, Conclude Site > Background
P-Value < alpha (0.05)

Table 3 - 2007 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic

Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	731	1364
Number of Non-Detect Data	574	1023
Number of Detect Data	157	341
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	78.52%	75.00%
Minimum Detected	10	20
Maximum Detected	2000	24192
Mean of Detected Data	127.5	260
Median of Detected Data	52	41
SD of Detected Data	281	1713

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test	
Value	-1.226
Critical z (0.95)	1.645
P-Value	0.89

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Site <= Background

P-Value >= alpha (0.05)

Table 4 - 2008 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	734	1315
Number of Non-Detect Data	514	979
Number of Detect Data	220	336
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	70.03%	74.45%
Minimum Detected	20	20
Maximum Detected	2000	2000
Mean of Detected Data	146.8	90.55
Median of Detected Data	53	31
SD of Detected Data	290.3	226.3

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test	
Value	3.45
Critical z (0.95)	1.645
P-Value	2.81E-04

Conclusion with Alpha = 0.05

Reject H0, Conclude Site > Background

P-Value < alpha (0.05)

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An additional measurement of significance using the Gehan test can be achieved by adding an investigation value (i.e. enterococcus concentration) to the mean/median before assessing the Null hypothesis to demonstrate the magnitude of difference using Gehan Form 2 Test. The larger this value, called substantial difference, S, the greater the difference between the populations, i.e., the greater an S, the greater an enterococcus concentration for septic beaches versus sewered beaches. Definitions from EPA's ProUCl program are detailed follow.

> Δ (delta): The true difference between the mean concentration of X in one sample and the mean of X in a second sample. Delta is an unknown parameter which describes the true state of nature. Hypotheses about its value are evaluated using statistical hypothesis tests. In principle, we can select any specific value for Δ and then test if the observed difference is as large as Δ or not with a given confidence and power.
>
> S (substantial difference): A difference in mean concentrations that is sufficiently large to warrant additional interest based on health or ecological information. S is the investigation level. If Δ exceeds S, the difference in concentrations is judged to be sufficiently large to be of concern, for the purpose of the analysis. A hypothesis test uses measurements from the site and from background to determine if Δ exceeds S.

In the study cases, the S value was calculated to determine the significance of the contrast between sewered and septic beaches for the summers of 2005, 2006, 2007 and 2008. The resulting S values show that septic beaches were most distinct from sewered beaches in 2005 after wet winter and not distinct in 2007 after dry winter. A substantial difference exists between septic and sewered beaches for every year except 2007.

Year	2005	2006	2007	2008
S value MPN/100 mL	108	89	0	21

The Gehan calculation with S factor calculation for the 2005 - 2008 are shown in Tables 5 - 9.

Table 5 – 2005 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	108
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	358	754
Number of Non-Detect Data	113	482
Number of Detect Data	245	272
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	31.56%	63.93%
Minimum Detected	20	20
Maximum Detected	9208	4200
Mean of Detected Data	261.7	368.9
Median of Detected Data	87	99
SD of Detected Data	661.3	591.3

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 108

Gehan z Test Value	-1.631
Critical z (0.95)	-1.645
P-Value	0.0514

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 108.00
P-Value >= alpha (0.05)

Table 6 – 2006 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	89
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	685	1377
Number of Non-Detect Data	293	921
Number of Detect Data	392	456
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	42.77%	66.88%
Minimum Detected	20	20
Maximum Detected	24192	48010
Mean of Detected Data	324.9	532.3
Median of Detected Data	86.5	42
SD of Detected Data	1320	2701

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 89

Gehan z Test Value	-1.353
Critical z (0.95)	-1.645
P-Value	0.088

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Site >= Background + 89.00

P-Value >= alpha (0.05)

Table 7 – 2007 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	731	1364
Number of Non-Detect Data	574	1023
Number of Detect Data	157	341
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	78.52%	75.00%
Minimum Detected	10	20
Maximum Detected	2000	24192
Mean of Detected Data	127.5	260
Median of Detected Data	52	41
SD of Detected Data	281	1713

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 0

Gehan z Test Value	-1.226
Critical z (0.95)	-1.645
P-Value	0.11

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 0.00
P-Value >= alpha (0.05)

Table 8 – 2008 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	21
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	734	1315
Number of Non-Detect Data	514	979
Number of Detect Data	220	336
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	70.03%	74.45%
Minimum Detected	20	20
Maximum Detected	2000	2000
Mean of Detected Data	146.8	90.55
Median of Detected Data	53	31
SD of Detected Data	290.3	226.3

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 21

Gehan z Test Value	-0.305
Critical z (0.95)	-1.645
P-Value	0.38

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 21.00
P-Value >= alpha (0.05)

Attachment #2

Non-Human Sources for Enterococcus

Dr. Drewes asked Staff to include additional discussion on non-human sources for enterococcus

Staff finds that enterococcus densities exceeding the water quality objective are a sufficiently reliable indicator of human health risk despite research documenting non-human sources for the bacteria.

Enterococcus, a genus of bacterium, has been found in feces from humans and warm-blooded animals including marine birds. State and federal standards establish a water quality objective of 35 MPN/1000 mL enterococcus for any marine human-contact recreation, yet genetic typing of the enterococcus has been used to preferentially close beaches when human enterococcus was identified. The Vermont case, described below, resulted in fewer beach closures using this more sophisticated method when combined with a reduction of the human-sourced bacteria identified, a process which has not proved successful in Malibu.

> "The Vermont staff deployed Microbial Source Tracking (MST) to classify isolates of enterococcus as being from humans, birds, dogs, or wildlife sources, and flurometery (detection of optical brighteners in detergents from sewers and septic drain fields) was added as a chemical method to differentiate between human and non-human sources of pollution. Based on 2004 results that human sources of pollution were present at several beaches, investigations by officials from Hampton, Newport News and Hampton Road Sanitation Districts identified probable sources of the pollution and took steps to eliminate the problems. Sampling in 2005 and 2006 confirmed the success of these efforts (reduction in the level of pollution from human sources) and demonstrated improved water quality conditions at beaches....Hilton, King-Lincoln and Anderson Beaches all had advisories in 2004 and 2005, but none in 2006. This demonstrated the success of using MST to identify sources of fecal pollution in 2004, performing remediation to remove the origins of the pollution in 2005, and then follow-up with MST in 2006 to prove that the sources found in 2004 and 2005 were no longer present in 2006. This is the first report where MST results indicated pollution from a particular source was present (human-origin sewage), the origin of the pollution was then located, steps taken to eliminate the pollution, and subsequent MST results indicated the success of those remediation efforts. (Hagedorn, C., 2006, *Final Project Report: Microbial Source Tracking and Virginia Beach Monitoring Program.* Virginia Polytechnic Institutes and State University and Virginia Department of Health)"

Anti-biotic resistant enterococcus has been identified in bird waste and the proportion of antibiotic resistant species used to conclude that non-human sources generated entercoccus in densities exceeding water quality standards. In the Huntington Beach studies, garbage and an offshore sewage outfall were also identified the sources for anti-biotic resistant enterococcus to enter the food chain. The United States Fish and Wildlife provided the alternative explanation that the bird population, alone, was insufficient to explain the bacteria densities.

> "The Huntington Beach studies showed that the levels of bacteria generated within the marsh contributed to the bacteria population, but were not sufficient, in and of themselves, to account for the problem itself. Specifically, the studies showed that bacteria generated by birds in the Talbert Marsh could cause bacteria concentrations in the surf line near the marsh to briefly exceed criteria on outgoing nighttime or early morning tides. The study further concluded that fecal material deposited by western gulls is a significant source of indicator bacteria in the water flowing out of Talbert Marsh and that indicator bacteria growing on vegetation in the marsh and in marsh sediment may also contribute to the near shore loading of these microorganisms. The study additionally concluded that the levels of bacteria recorded along the beach were higher than could possibly have been generated by Talbert Marsh alone and that there has to be another source (page 47)…….data show that beaches near tidal wetlands do not have chronic beach postings. Postings on beaches near tidal wetlands had an average of about 2 postings for 12 days in 1999 while beaches not near wetlands had an average of about 3 posting for 32 days(page 49)." (US Fish and Wildlife Service, 2001 Staff Report and Recommendation on Consistency Determination: Bolsa Chica Lowlands, Orange County, California Coastal Commission Determination CD-061-01.)

Further, literature on non-human enterococcus sources does not include an epidemiology study linking decreased illness rates among swimmers exposed only to enterococcus species generated outside the human body. In fact, the 1983 Cabelli epidemiology study, upon which the 1983 EPA enterococcus criteria is based, states that the beaches studied did not all have an identifiable point source of human sewage. In addition, the 1999 Haile study looked at fecal, total, e. coli, and enterococcus and related human illness to the densities of each of these bacteria on the beach, even though both fecal and total bacteria are known to include bacteria species not related to human feces.

The literature on non-human sources of enterococcus reviewed by staff also fails to interpret a change to the enterococcus water quality objective, except to say in the most general way that the criteria may 'require revision.' Instead, Pruse's review in 1998 found that enterococcus was among the most reliable indicators of illness.

> "The indicator organism which correlate best with health outcome were enterococcus/fecal streptococci for both marine and freshwater (pg 3)." (Pruse, A, 1998, *Review of Epidemiological Studies on Health Effects from Exposure to Recreational Water*. International Epidemiological Association vol. 17, pages 1-9)

Future research is desirable to resolve these apparent contradictions in the application of the enterococcus standard. Staff offers the possible explanation that bacteria densities correlate with human illness because bacteria and virus densities are highest in microbiological and hydrological environments where bacteria are successfully transported and protected. The proximity and volume of a human fecal source would be the secondary variable controlling the infectious natural of the enterococcus observed. The 1998 Pruse summary confirms a correlation between illness and indicator bacteria in 19 of 22 studies.

Staff's explanation allows agreement with research showing enterococcus can exceed the water quality objective where no human fecal sources are present, without negating its use in protecting beaches where a proximal human fecal source is present. In the Malibu Civic Center, the three sources of human feces are stormwater, urban runoff and groundwater containing septic discharge. Further, concerns about an over-stringent application of the enterococcus standard are settled by the site specific epidemiology study linking illness rates at the Civic Center beach called Surfrider to bacteria density at approximately the published criteria rate for gastrointestinal symptoms which include a fever (HCGI 2). Staff notes that the enterococcus water quality standard is implemented nation-wide, has not been revised since 1983, and is the criteria upon which the Board must evaluate the exceedances shown.

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Attachment #3

Bacteria Transport in Groundwater

Dr Silverstein comments that a reduction in pathogen density is expected between the OWDSs and the ocean. In fact, the rate and manner of bacteria and virus transport is not fully understood. The hydraulic and microbiological setting of the Civic Center beaches contains characteristics which may prevent bacteria and viruses destruction in the subsurface and enhance transport through the beach sand to the ocean on occasion in some locations.

In 2007, Nathalie Tufenkji provided a survey of particulate transport in the groundwater and noted that the existing models are deficient in successfully predicting the movement of organic particles. The survey specifically notes that work predicting the subsurface slowing of bacteria movement has not been paralleled by equally vigorous exploration of the subsurface enhancement of bacteria movement.

> "A substantial research effort has been aimed at elucidating the role of various physical, chemical and biological factors on microbial transport and removal in natural subsurface environments. The major motivation of such studies is an enhanced mechanistic understanding of the processes for development of improved mathematical models of microbial transport and fate. In this review, traditional modeling approaches are systematically evaluated. A number of these methods have inherent weaknesses or inconsistencies (pg 1455)....For instance, calculations based on Tufenkji and Elimelech (TE) equation indicate that particles in the size range of [about] 2 um (e.g. many bacteria) are nearly twice as mobile in porous media than previously believed (pg 1461)....The release (detachment) of microorganisms from sediment grain surfaces can be of considerable importance in natural subsurface environments and engineered water treatment systems...an improved understanding of....factors controlling microbial release is required before practical incorporation of this process into mathematical transport models (pg 1646)... Future areas for fundamental research in this area have been identified and include (i) inactivation kinetics of microorganisms in soils, (ii) role of protozoan grazing in removal of bacteria, (iii) mechanisms of microbial detachment from sediment grain surfaces, (iv) interactions between cell/cyst surface biomolecules and mineral surfaces, and (v) the influence of physical and geochemical aquifer heterogeneity on microbial transport (page 1468) (Tufenkji, N. 2007, *Modeling Microbial Transport in Porous Media: Traditional Approaches and Recent Developments.* Advances in Water Resources vol. 30, pages 1455-1469)

Referred literature shows that colloids travel at elevated rates in discrete macro-pores instead of through uniform concentration fronts like dissolved species. Further, changes in colloidal movement have been attributed to chemistry, such as the difference between freshwater and saltwater, with more rapid colloid movement freshwater. As another example, a 2001 study showed that bacteria move more rapidly in 'dirty' packed sand than in clean sand.

> "We characterize the filtration and deposition profiles of a recombinant analog of Norwalk virus, an important waterborne pathogen, in packed beds of saturated quartz sand under both 'clean-bed' and 'dirty-bed' conditions. Under clean-bed conditions with

> NaCl as the electrolyte, the retained Norwalk virus particles decline like a power-law with depth. The power-law decay in retained particle concentration is consistent with the predictions of a recently proposed filtration model which assumes that microscale heterogeneity leads to particle filtration length scales of all sizes, i.e. the filtration is fractual in nature. However, under dirty-bed conditions with either groundwater or wastewater as the pore fluid, the deposited Norwalk virus particles profiles are considerably more complex. Analysis of these data using both the traditional filtration model and the fractal filtration model suggest that, under dirty-bed conditions, macroscale heterogeneity dominates virus removal rates. (Redman, J. A., Estes, M.K., and Grant, S.B, 2001, *Resolving macroscale and microscale heterogeneity in virus filtration*, Colloids and Surfaces A: Physicochemical and Engineering Aspects. Vol. 191, Issues 1-2, pg 57- 70)

Staff found literature both supporting and refuting the conclusion that the method and rate of groundwater well pumping may affect the reliability of bacteria samples collected. Higher pressure extraction rates are discussed as a possible mechanism for the destruction of bacteria. Staff proposes that well testing may not successfully sample the zones of preferential transport described above. Heterogeneity in aquifer properties and bacteria transport may not be represented by the homogeneous conditions assumed in traditional groundwater modeling.

Future research is desirable to resolve these challenges to existing groundwater modeling methods and introduce a measure of caution in predicting microbiological transport based solely on water movement. The prediction that variations in subsurface flow conditions can affect bacteria transport is consistent with Izbicki's recent studies at Santa Barbara, his ongoing hydrology at Surfrider Beach, as well as De Sieyes work which links episodic nutrients pulses correlated with tides, to septic systems, and Boehms work which links groundwater to bacteria.

Staff offers the comment that rapid change in the subsurface hydrology, such as with breaching of the lagoon, may create variations in the proportion of septic bacteria which are present at the beaches. Just as swimming next to a flowing storm drain is currently discouraged, additional study may identify an elevated risk with summer swimming during periods of increased septic discharge, such as during neap tides or during low ebb of a spring tide.

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State of California
California Regional Water Quality Control Board, Los Angeles Region

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Peer Review – Staff Memorandum

Technical Memorandum #4:
Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life

By

Toni Callaway, P.G., Engineering Geologist

November 5, 2009

California Regional Water Quality Control Board
Los Angeles Region

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Linda S. Adams
Cal/EPA Secretary

Arnold Schwarzenegger
Governor

Date: October 21, 2009

To: Rebecca Chou, Ph.D., P.E., Chief of Groundwater Permitting Unit
Wendy Phillips, PG, CHG, CEG, Chief of Groundwater Permitting and Landfill Section

From: Toni Callaway, P.G., Engineering Geologist, Groundwater Permitting Unit

Subject: **Peer Review Response to Comments - Technical Memorandum #4: Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life**

Attachments:

1. Comment dated September 5, 2009 from Dr. Robert Arnold of Arizona State University
2. Comments dated September 10, 2009 from Dr. Jörg Drewes of Colorado School of Mines
3. Comments dated September 12, 2009 from Dr. JoAnn Silverstein of the University of Colorado at Boulder

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To ensure that the proposed amendment to the *Basin Plan*[1] is based on sound science and engineering principles, the scientific elements of Technical Memorandum (Tech Memo) #4: *Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life,* draft dated August 5, 2009 (Tech Memo #4), were peer reviewed. This peer review was conducted in accordance with requirements and guidelines from the Cal/EPA Scientific Peer Review Program, Office of Research, Planning and Performance.

All three peer reviewers responded promptly and provided valuable comments. In summary, all three peer reviewers found that the basic approaches and methods used to calculate the nitrogen loading to Malibu Lagoon in Tech Memo #4 incorporated sound scientific and engineering principles.

Suggestions were made to clarify the assumptions made by staff. Staff responded to these suggestions and revised Tech Memo #4 as appropriate and noted that none of the changes materially altered the conclusion of Tech Memo #4. That is: On-site subsurface disposal systems (OWDSs) in the Malibu Civic Center area cumulatively release nitrogen to Malibu Lagoon at

1 Proposed amendment to the *Water Quality Control Plan for Coastal Watersheds of Los Angeles and Ventura Counties (Basin Plan)* to prohibit on-site subsurface disposal systems (OWDSs) in the Malibu Civic Center area.

rates that violated the total maximum daily limit (TMDL) adopted by the US Environmental Protection Agency in 2003 for the Malibu Lagoon (USEPA, 2003).

Comments have been summarized into three main issues and presented in *italics*, followed by staff's response. The main issues raised in the comments are: 1) Residential Loading - Is the 100 gallons per day per person (gpd/person) wastewater flow rate assumed in the Tech Memo for single-family homes realistic? 2) Commercial Loading - Are the flow rates estimated for un-permitted commercial properties in the Tech Memo accurate? and 3) TN/BOD Ratio - Is the TN/BOD Ratio of 0.20 in wastewater used in the Tech Memo an appropriate estimation for total nitrogen (TN) when biochemical oxygen demand (BOD_5) data is available while TN data is not available? Comments related to these issues are addressed in paragraphs 1 through 3 below:

1. ***Residential Loadings**: Comparing to the typical rate of wastewater generation per capital in the literature (40 to 90 gpd/person), the 100 gpd/person rate used in Tech Memo #4 for the Malibu Civic Center area may be too high.*

   Staff considers the residences in the Malibu Civic Center area luxury homes, because almost all the 392 residences in the area are large single family homes with more than 3.5 bath/bedrooms per house. Many studies have shown that luxury homes use more water than ordinary homes and therefore generate more wastewater. For example, Metcalf and Eddy (1991, Table 2-9, page 27) reported that the average water usage for luxury homes in residential areas was 75-150 gpd/person, while the water usage for the average home nationwide was 70 gpd/person. The higher than typical wastewater flow rate used in Tech Memo #4 is also supported by historical water use data of Malibu City. In 2008, the population of the Malibu City was 13,009 and the water consumption of the City was 2,200 million gallons for both commercial and residential usage. It has been estimated that approximately 54% of urban water usage is residential (Department of Water Resource in California) and that 50% of residential water usage is for irrigation (American Water Works Association). Assuming these percentages are applicable to the Malibu Civic Center area, the net per capita water consumption (excluding irrigation use) would be 125 gpd/person. Because the bulk of residential water consumption becomes wastewater at the end, the 100 gpd/person of wastewater flow rate used for the Malibu Civic Center area is a reasonable estimate. Tech Memo #4 has therefore not been modified in response to this comment.

2. ***Commercial Loading**: In Tech Memo #4, wastewater flow rates from small businesses were estimated using on-site population and business activity information. A few details or examples of the process by which wastewater flows were assigned might provide a feel for this work.*

A new column (category) has been added to Table 1 in Tech Memo #4 to characterize each commercial facility, including whether flow rate of the facility was estimated. New footnotes have also been added to Table 1 to better explain the data source for each facility. Of the 38 commercial facilities in the Malibu Civic Center area that discharge wastewater with OWDSs, the flow rates of 7 facilities were not available and had to be estimated. This constitutes 5.4% of the total commercial flow.

3. ***TN/BOD Ratio**: Staff assumed a constant fraction (0.20) of total nitrogen concentration to five-day biochemical oxygen demand (TN/BOD$_5$) to estimate nitrogen load of commercial sources where only BOD$_5$ measurements were available. More appropriate references should be used to provide the accurate representation of single source waste streams. TN/BOD ratios from single sources should be site-specific and highly depending on the types of dischargers (i.e. lower in restaurant effluents). If local data exist with which to make this distinction, they should be cited in the text. It is advisable that samples be taken to verify the TN:BOD ratio from specific dischargers with higher flow.*

BOD$_5$ is a measurement of the amount organic substances in wastewater. Because nitrogen in wastewater is mostly derived from organic substances (proteins), the concentration of total nitrogen generally increases with the increase of BOD$_5$. The 0.20 TN/BOD$_5$ ratio used in Tech Memo #4 is consistent with tables characterizing residential wastewater found in college textbooks, such as Metcalf and Eddy (1991) and Crites and Tchobanoglous (1998). Staff has added Table 4 which summarizes TN and BOD analytical data from 106 septic tank wastewater samples from large mixed usage commercial facilities located in the Malibu Civic Center area. The average TN/BOD$_5$ ratio for these samples was 20.4%, which is essentially the same as what was used in Tech Memo #4. The mixed use commercial properties include restaurants, but there are few stand-alone restaurant in the Malibu Civic Center area.

Staff responses to comments requiring minor clarification summarized in paragraphs A through H below:

A. Staff should provide more information regarding the OWDSs being used in the Malibu Civic Center area, such as a definition of "advanced" OWTS treatment. In the interest of defining the most significant sources of nitrogen load, the facilities that provide advanced treatment, the nature of the treatment provided, and typical BOD$_5$ and total nitrogen removal efficiencies might be added to the report. The credits between OWDSs and soil profile to the removal of nitrogen/BOD should be clarified.

"Advance OWTS treatment" is defined as more advanced than primary treatment, i.e. secondary and tertiary treatment with disinfection. The advanced systems in the Malibu

Civic Center area vary greatly, no two are alike, but a footnote (Footnote D) has been added to Table 1 to identify advanced OWTSs. As stated in Tech Memo #4, the Regional Board lacks site specific information for the hundreds of residential septic systems in the Malibu Civic Center area. When available, the effluent loads (nitrogen concentration) in Table 1 listed real "end-of-pipe" data.

In Table 3 of Tech Memo #4, credits for TN reduction in the soil profile are based on soil type (e.g. sandy loam), sufficient groundwater separation (e.g. 5 feet to 10 feet from bottom of leachfield to groundwater), and demonstrated unsaturated soil assimilative capacity. The high density of wastewater discharges in many of the commercial and residential areas of Malibu preclude adequate subsurface assimilative capacity. Available data indicates that site conditions in the coastal strips (high groundwater) and the highland residential area (fractured bedrock with the prevalent usage of seepage pits for disposal) do not warrant further reduction of nitrogen loads by soil treatment.

B. Because many calculations in the spreadsheet model were based on assumptions, a sensitivity analysis of the eventual nitrogen load estimates in response to the variation of key input parameters, such as flow rate, TN, and soil attenuation factor, is recommended.

Staff has conducted a sensitivity analysis to the spreadsheet model, but little impact was observed to the eventual nitrogen load estimates. Sensitivity analysis was made by changing the estimated flow rate and TN concentration in the spreadsheet model. All of the variations tried resulted in values much higher than the assigned TMDL load for septic systems in the lower Malibu Creek watershed).

C. Is it possible that seasonal effects are of importance to the average nitrogen load estimation in the Malibu Civic Center area?

Since most homes in the Malibu Civic Center area are owner occupied, little seasonal variation is expected on the wastewater flows from the single homes. Monitoring data large multi-family residences located in the area do not display seasonal significant variation. Wastewater flows from commercial sources do change by season as a function of the number of visitors. Staff observed slightly higher TN loads in the prime summer tourist season. Because the flow rate data in Tables 1 and 3 of Tech Memo #4 are annual averages over several years, seasonal variations were minimized.

D. Staff's judgment regarding the fate of nitrogen during on-site treatment and subsequent transport seems arbitrary. The discussion makes no distinction between ammonium ion absorption, which is both efficient and fast on soil particles, and *nitrification/de-nitrification reactions, which can lower the concentrations of available nitrogen forms and dramatically affect nitrogen transport in the subsurface.*

Because of variations of local site conditions, it is impractical to distinguish the form of nitrogen transport for all wastewater sources in the area. However, as detailed in Tech Memo #2, there are indications showing that natural attenuation (treatment of pollutants in soil) is not occurring in many areas of the Malibu Valley and the nearby Winter Canyon. There are numerous indications that the high density of subsurface wastewater discharges in the Malibu Civic Center Area has exceeded the natural assimilation capacity of the soil profiles. Because the goal of Tech Memo #4 is to determine the long term total nitrogen load of the Malibu Civic Center area to the Malibu Lagoon, the form of nitrogen transport should have little effect to the conclusion of the study. Both the numeric and spreadsheet models assume that total nitrogen is converted to nitrate after reaching surface waters.

E. Staff might comment on the form in which nitrogen is present in the Malibu Lagoon since this bears on the forms in which nitrogen is transferred from on-site disposal locations.

Malibu Lagoon is a unique aquatic system which opens to ocean during raining season and close during dry season. During dry seasons that nitrogen can be accumulated, significant breakthrough of nitrate or ammonia was not observed in the lagoon, but serious eutrophication has been observed. Staff assumes that total nitrogen in groundwater converts in the Lagoon to nitrate.

F. There are some inconsistencies between Tables 1 and 3. Since all the designed parameters are the same for all models, the calculated total nitrogen loads should be the same.

The inconsistencies between Tables 1 and 3 in Tech Memo #4 have been verified and corrected.

G. The non-point source nitrogen contributions to the Lagoon did not appear to have been considered. If these are available from the TMDL calculation, they should be considered as part of the total load.

The total load allocation of nitrogen in the Lagoon is 27 lbs/day. Because non-point sources have already been considered in the TMDL for Malibu Lagoon, they are not included in Tech Memo #4, which is to determine whether the total nitrogen load from OWDSs in the Malibu Civic Center area exceeds the 6 lbs/day allocation required in the TMDL for OWDSs sources. Details of total nitrogen load allocations from non-point sources in the larger Malibu Creek watershed are detailed in the TMDL (USEPA, 2003) and available on the Regional Board website at http:www.waterboards.ca.gov/losangeles.

H. How much a 6 lbs/day of nitrogen addition to the lagoon is likely to increase the available nitrogen levels in Malibu Lagoon?

An evaluation of nitrogen mass loading in Malibu Lagoon is given in Attachment 4-1 (by Dr. Lai) of Tech Memo #4. Figure 5 of Attachment 4-1 indicates that, assuming no other sources exist, a 6 lbs/day of total nitrogen load into the lagoon would bring the nitrogen concentration in the water from 0 to approximately 0.5 mg/L.

Editorial and grammatical suggestions have been followed as appropriate, but are not addressed here. A revised Tech Memo #4 that incorporates changes made in response to peer review comments is posted on the Regional Board website at http:www.waterboards.ca.gov/losangeles.

Staff would like to thank all three peer reviewers for their thoughtful review of Tech Memo #4 and providing their comments in a very timely, professional manner.

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******For a list of simple ways to reduce demand and cut your energy costs, see the tips at: http://www.swrcb.ca.gov/news/echallenge.html******

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