Public Health Risk Assessment for the Newport Bay Watershed: Recreational Contact and Microbiological Risk

Final Report

September 2001

Prepared for:

California Regional Water Quality Control Board, Santa Ana Region
Water Environment Research Foundation
County of Orange
Irvine Ranch Water District
The Irvine Company
City of Costa Mesa
City of Irvine
City of Lake Forest
City of Newport Beach
City of Santa Ana
City of Tustin

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Acknowledgements

The work described herein was sponsored by the California Regional Water Quality Control Board, the Water Environment Research Foundation, the County of Orange, Irvine Ranch Water District, the Irvine Company, the City of Costa Mesa, the City of Irvine, the City of Lake Forest, the City of Newport Beach, the City of Santa Ana, and the City of Tustin.

Project Management for the funding agencies was provided by Ken Thompson and Debbi Clark at the Irvine Ranch Water District, and Ken Theisen and Dr. Linda Candelaria at the California Regional Water Quality Control Board, Santa Ana Region. Technical guidance was provided by the Health Advisory Committee, whose members included Drs. Edwin Lennette, George Tchobanoglous, Robert Cooper, and Jack Colford. Substantial staff resources were provided to this investigation by the Irvine Ranch Water District and Orange County Health Care Agency. The data generated for and employed in this investigation were provided by those agencies. This report is dedicated to the memory of Dr. Lennette, who passed away during the course of the investigation.

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C Selected Comments from the HAC, and Comments and Responses on the Draft Report

D Newport Bay Watershed Management Committee Meeting (March 29, 2000): Review Panel Questions and Responses

E Beneficial Use Assessment Program Data

F Vessel Waste and Ambient Monitoring Program Data and Documentation

G Water Quality Modeling Report (Prepared by RMA)

H Overview of Disease Transmission Model: Simulink

ABBREVIATIONS

AB411 .....California Assembly Bill 411
CART.....Classification and Regression Tree Algorithm
CDC .....Centers for Disease Control
EPA .....Environmental Protection Agency
DAL .....Double Agar Overlay Method
HAC .....Health Advisory Committee
HRA .....Health Risk Assessment
ILSI .....International Life Sciences Institute
IRWD.....Irvine Ranch Water District
ISP .....Initial Susceptible Population
Mgal/d.....Million Gallons per Day
mL .....milliliter
MEP .....Maximum Extent Practicable
MPN.....Most Probable Number
MWRP .....Michelson Water Reclamation Plant
NTAC.....National Technical Advisory Committee
OCHCA.....Orange County Health Care Agency
OCSD.....Orange County Sanitation District
PE.....Professional Engineer
PHS .....Public Health Service
QA/QC .....Quality Assurance / Quality Control
REC-1 .....Body Contact Recreation Beneficial Use
RMA .....Resource Management Associates
RWQCB.....Regional Water Quality Control Board
SHEL.....Shellfish Harvesting Beneficial Use
SIR .....Susceptible – Infected – Recovered Model
SPON .....Stop Polluting Our Newport
SWRCB .....State Water Resources Control Board
TMDL .....Total Maximum Daily Load
TSS.....Total Suspended Solids
UCI.....University of California at Irvine
VFF .....Vortex Flow Filtration Method
WERF .....Water Environment Research Foundation
WHO.....World Health Organization

EXECUTIVE SUMMARY

ES.1 HEALTH RISK ASSESSMENT FINDINGS AND RISK MANAGEMENT CONSIDERATIONS

The California Regional Water Quality Control Board, Santa Ana Region (RWQCB), identified and listed (Lower and Upper) Newport Bay as a water quality limited receiving water body in accordance with Section 303(d) of the Clean Water Act. This designation indicates that applicable water quality standards are not being attained or expected to be attained with the implementation of technology based controls. The 303(d) List identifies pathogens as a stressor of water quality impairment and indicates that urban runoff and/or storm sewers are the source of the pathogens. On April 9, 1998, the RWQCB adopted a Total Maximum Daily Load (TMDL) for fecal coliform in Newport Bay[1].

ES.1.1 303(d) Listing of Newport Bay for Fecal Coliform

The analysis conducted as part of this public health risk assessment investigation indicates that the exceedances of the Basin Plan fecal coliform objectives for the REC-1 beneficial use[2] are temporally sporadic, geographically limited, and generally occur during the time of the year when REC-1 use is low and/or in areas of the Bay where the level of body contact recreation is low or is prohibited (i.e. within the ecological reserve in the Upper Bay).

ES.1.2 Relative Risk to Public Health from REC-1 Contact in Newport Bay

The health risk assessment was carried out employing a number of health protective assumptions (for example, the model organism was assumed to be as infectious as rotavirus and as prevalent and persistent in the environment as male specific coliphage, boundary conditions in the water quality model were developed based on the maximum concentrations observed, and all bacteriological observations reported below the detection limits were assumed to correspond to concentrations at the detection limit). Given the conservative nature of the assumptions that were employed, it is extremely likely that the estimated risk levels presented herein are higher than the "actual" levels of risk encountered by the population. Nevertheless, it was found that the risk of enteric virus disease from body contact recreation in Newport Bay, is well below EPA's "accepted illness rate" of 19 illnesses per 1,000 swimmers for recreation in marine waters[3].

ES.1.3 Controllable Sources

Urban runoff and/or storm sewers are identified in the 303(d) listing as the likely source of pathogens in Newport Bay. However, based on the analyses presented in this report neither of those sources substantially impact the risk to public health from body contact recreation in Newport Bay during the time of the year that the vast majority of the recreation occurs. Viral loading from vessel sanitary waste and from swimmers were also investigated as two potential sources of pathogen loading in Newport Bay.

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[1] A TMDL is a method for implementing water quality standards based on the relation between sources of pollutants and in-stream water quality conditions.
[2] log mean 200 MPN/100mL and 90th percentile 400 MPN/100mL.
[3] US EPA, Ambient Water Quality Criteria for Bacteria – 1986, EPA/440/5-84-002.

Based on the estimated costs to implement a public outreach program and the estimated benefit in terms of reducing enteric virus disease, it is suggested that reduction of vessel sanitary waste may be a control measure worth further consideration if risk managers feel that reduction of public health risk below the current levels is warranted. It should however be emphasized that limited data were available to characterize loading from vessels and the uncertainty in the estimate is substantial.

ES.1.4 Interpretation of the Basin Plan Fecal Coliform Objective

Based on the results of this investigation, it is suggested that interpreting the impairment of the REC-1 beneficial use in Newport Bay requires a more rigorous and comprehensive health risk evaluation and sanitary survey approach than the pass/fail test (i.e. simple comparison of water quality indicator data against water quality objectives / standards regardless of exposure conditions and sources) that has evolved to regulate the quality of recreational waters.

A more comprehensive approach is consistent with a health based monitoring approach for recreational waters recently outlined by the World Health Organization (WHO) (WHO 1999) in which experts called for "an improved approach to the regulation of recreational water that better reflects health risk and provides enhanced scope for effective management intervention". The WHO approach is to classify health risk as a function of both degree of overall fecal contamination and susceptibility to human contamination. In a similar manner, EPA's strategy for setting water quality criteria was to vary the maximum allowable density based on the level of recreational use that a particular site receives (i.e. designated beaches have lower allowable maximum values than moderately, lightly, or infrequently used areas).

Based on the information presented herein, a reasonable course of action to address the question of REC-1 beneficial use impairment in Newport Bay would be to apply the principles set forth by US EPA in 1986, the WHO in 1999, and the basic principles of public health engineering regarding the use of sanitary surveys to identify and control potential sources to the maximum extent practicable.

A site by site summary is provided in Table ES.1 demonstrating how the information presented herein may be used to facilitate interpretation of the Basin Plan Objective for fecal coliform with respect to risk to public health. The summary provided in Table ES.1 uses observed fecal coliform concentrations, levels of exposure, and seasonality to derive a relative level of public health concern associated with each of the monitoring sites. Using a similar approach, data presented in this report may be used to interpret observed fecal coliform observations with respect to whether it is reasonable to infer impairment of the REC-1 beneficial use in Newport Bay from exceedances in the Basin Plan fecal coliform objectives that occur in Newport Bay during the winter season, in low use areas, and/or in areas where body contact recreation is prohibited.

ES.2 BACKGROUND AND OBJECTIVES

The RWQCB fecal coliform TMDL is based on a phased approach for controlling the bacterial quality in Newport Bay and ensuring that the beneficial uses in the Bay are protected. The complexity of this fecal coliform TMDL derives primarily in interpreting the following question: "Do occasional exceedances of the fecal coliform objective for body contact recreation

necessarily imply an impairment to the beneficial use?". The answer to this question is difficult for several reasons: (1) The linkage between the fecal coliform concentrations and adverse health effects is weak; (2) There are significant temporal and spatial variations in water quality in Newport Bay; and (3) Limited data were available to identify controllable sources of coliform and to evaluate the potential human health related benefits by reducing coliform loading from those sources.

In addition to the Clean Water Act requirements, in California a TMDL must also be conducted within the context and requirements of the Porter-Cologne Act (California Water Code). Therefore, the framework of this investigation encompasses developing sufficient information to assist the RWQCB balance the benefits and costs associated with ensuring the reasonable protection of the REC-1 beneficial use. Consistent with that goal, this investigation focused on distinguishing between factors that potentially impact water quality and are controllable, from those factors that are uncontrollable and may have a significant water quality impact.

Based on meetings and discussions with the RWQCB, Orange County Health Care Agency (OCHCA), CA Department of Health Services, members of the Health Advisory Committee[4] (HAC), and Irvine Ranch Water District, this investigation was formulated to assist the RWQCB address the reasonable protection of the body contact recreation (REC-1) beneficial use in Newport Bay. The objectives of the investigation were:

- To characterize the existing relative risk to public health posed by exposure to pathogens derived from human sources via recreational contact in Newport Bay;
- To provide estimates of the relative risk associated with alternative levels of exposure and/or water quality (due to structural or programmatic changes), and to compare those results with the results representing existing conditions; and
- To integrate the results of the health risk assessment with planning level costs for implementing control alternatives that may lead to water quality improvements and reductions in public health risk.

ES.3 Overview of Bacteriological Water Quality in Newport Bay

The basic reason for carrying out microbiological water analysis is to safeguard the health of a community by testing for possible fecal pollution, the source of microorganisms causing waterborne disease. Pathogenic microorganisms usually appear in recreational waters intermittently and in low concentrations (Borrego et al. 1987). Indicator organisms are organisms that coexist with pathogens in the fecal environment and are easier and less expensive to test for than pathogens. For these reasons, indicator organisms are often the focus of water analyses rather than pathogen analysis. Ideally, an indicator organism will be present when the pathogen is present, be present in equal or higher numbers than the pathogen of interest, be easy and inexpensive to assay, and would serve as an indicator of human fecal contamination (as opposed to animal contributions). Within Newport Bay several of the potential important sources of fecal contamination include tributary inflows, food wastes, discharge of sanitary waste from vessels, fecal waste of wildlife (including waterfowl that inhabit the Bay and its environs), leakage of sewer lines, swimmers, domestic animal waste, and illegal waste discharges.

[4] The HAC was composed of internationally recognized members with expertise in the fields of public health, microbiology, environmental engineering, epidemiology, and virology.

To monitor potential human exposure to pathogens in Newport Bay, the OCHCA has monitored total and fecal coliform on (approximately) a weekly basis in Newport Bay for approximately the last 30 years. From the beginning of this effort through approximately 1998, total and fecal coliform data were collected, and starting in 1999 and continuing through the present, total coliform, *E. Coli*, and enterococcus data have been collected. Between 1990 and 2000, over 26,500 samples were collected and analyzed by OCHCA for these bacterial indicator organisms in Newport Bay locations. To provide an overview of the bacteriological water quality in Newport Bay for this investigation, the OCHCA data from 1990 through 2000 are summarized in tabular and graphical format.

ES.4 HEALTH RISK ASSESSMENT

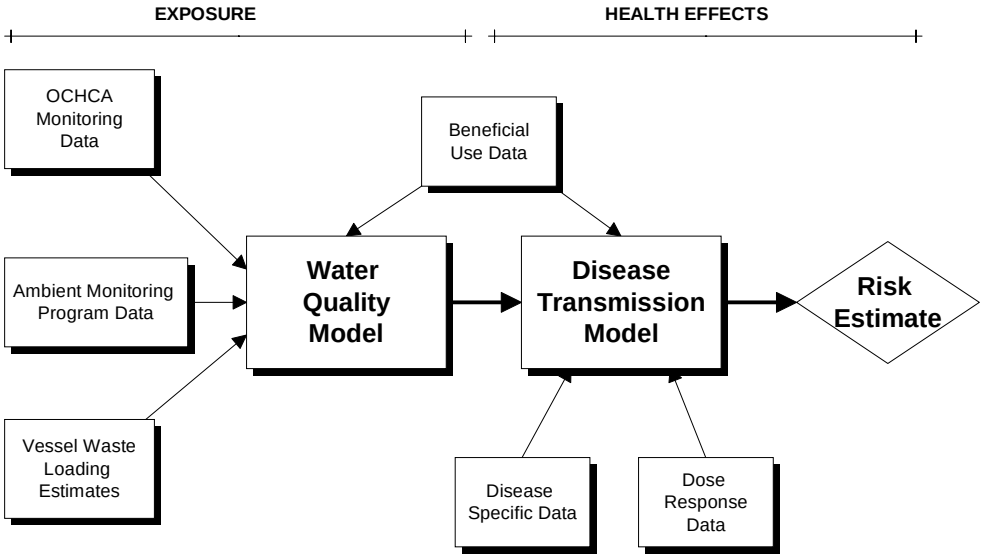
The health risk assessment approach was to take advantage of the available infectious disease and dose-response data to develop a dynamic population based mathematical model that characterizes the human disease risk of waterborne pathogen exposure. This approach makes explicit the mechanistic aspects of the infectious disease process and provides a transparent structure for clinical data to be incorporated into the mathematical model. The health risk model emphasizes the importance of how the epidemiological status (susceptible, infected, diseased, and immune) of individuals within a population varies over time, implicitly accounting for person to person spread of disease. The risk assessment methodology is consistent with the 1996 ILSI/EPA framework for microbial risk assessment and further extends work previously carried out in this field by characterizing the population based risk from recreational activity in a metric that is comparable to U.S. EPA water quality criteria endpoints, specified as risk to individual swimmers.

A schematic diagram of the investigation is presented in Figure ES.1. As shown, the investigation included site specific data collection efforts, water quality modeling, and a disease transmission modeling component.

Data that were collected and/or generated for this investigation included: (1) Estimates of the frequency and duration of recreational use of Newport Bay (i.e. how many people visit beaches in Newport Bay and when); (2) An estimate of virus and coliform loading to the Bay from bathers; (3) A characterization of the size of the population that is most likely to recreate in Newport Bay; (4) An estimate of virus and fecal coliform loading to the Bay from vessel waste; (5) An ambient monitoring program which augmented existing bacteriological data in the Bay; and (6) A comprehensive review of the literature related to indicator organisms, microbial risk assessment, and related investigations.

The purpose of the water quality modeling was to provide temporally and spatially varying concentrations of fecal coliform and coliphage to the disease transmission model. These temporally and spatially varying concentrations of coliform and coliphage are used in the disease transmission model in conjunction with site specific patterns of beneficial use in Newport Bay, to define exposure from recreational contact. A second goal of the water quality modeling was to evaluate alternative control strategies that may affect viral loading.

Figure ES.1
Schematic Diagram of Health Risk Assessment Investigation



The disease transmission modeling component of the health risk assessment required defining a route of exposure (ingestion of water from recreational activity), a specific pathogen of interest (enteric viruses), and a method to characterize the relation between the exposure and the pathogen of interest (use of an indicator organism). A population based model for disease transmission was developed to characterize risk from exposure to enteric viruses via recreational contact with Newport Bay water. A schematic diagram illustrating the disease transmission model is presented in Figure ES.2.

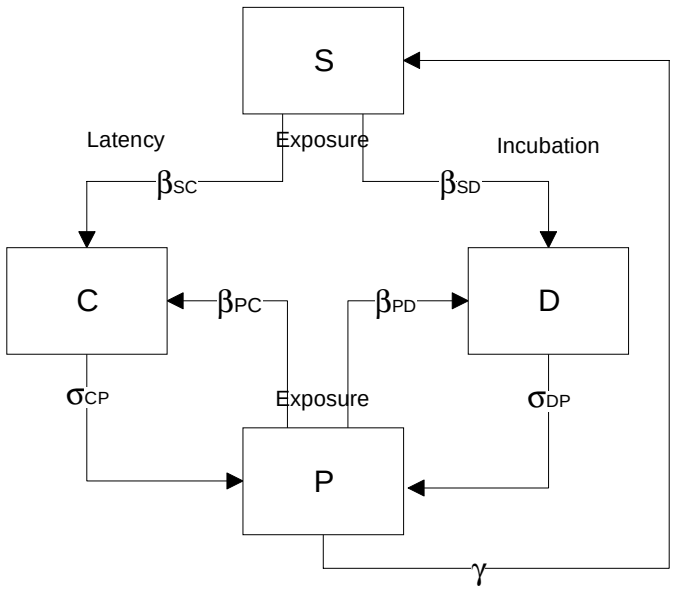
For the modeling effort in this investigation, the epidemiological states of the population are characterized as follows: (1) Those susceptible to disease (S), (2) Carriers of the disease, defined as those who are infectious but not symptomatic (C), (3) Diseased individuals, defined as those who are symptomatic and infectious (D), and (4) Those in a post-infection state who are not infectious and not fully susceptible due to (limited and short-term) immunity (P). Members of the population move from state to state based on rates specified by clinical or epidemiological data and exposure to pathogens.

The results of the disease transmission modeling indicate that the entire distribution of the number of predicted cases of enteric virus disease per swimming event falls below EPA's tolerable disease rate[1] for both marine and fresh waters. A comparison was also carried out with the predicted illness rate based on enterococcus data collected by OCHCA in the Newport Dunes area. The results from the disease transmission modeling were lower than the predicted illness rates based on enterococcus data by approximately a factor of ten, however the enterococcus concentrations were limited by the analytical detection limit and would have been lower had an analytical methodology been available to quantify enterococcus concentrations at lower levels.

Sensitivity and uncertainty analyses were also carried out on the disease transmission modeling results. Those studies included investigating (1) The impact of changing the size of the

population under study; (2) The impact of increased concentrations of enteric viruses in the Bay; (3) The impact of increased viral loading from vessels; (4) The impact of increased viral loading from bathers; (5) A multiple linear regression to determine what variables are most important in determining the background exposure to enteric viruses; and (6) Regional sensitivity analysis to identify which variables are most important in identifying high levels of disease prevalence in the community.

Figure ES.2
Schematic Diagram of Disease Transmission Model



ES.5 COMPARATIVE ASSESSMENT AND PLANNING LEVEL COSTS

Six alternative management scenarios (theoretical or potential options for reducing the viral loading to Newport Bay) were developed and simulated employing the water quality and disease transmission models. Planning level costs estimates were also developed for the alterative scenarios. Those scenarios included diverting dry weather viral loading from San Diego Creek, Santa Ana Delhi, and the Upper Bay storm drains, and reducing viral loading from vessels and recreators. The results of the alternative analyses indicate: (1) Eliminating dry weather viral loading from San Diego Creek, Santa Ana Delhi, or Big Canyon Wash to Upper Newport Bay would be more expensive than other options and would not substantially reduce the existing risk to swimmers; and (2) Reducing pathogen loading from vessels may be more effective (in terms of avoided diseased cases per swim event) than the other alternatives considered[5].

[5] Vessel loading is a highly uncertain parameter and the actual benefit to be realized from minimizing this component may be less than that predicted herein. Further, the probability of effectively implementing a public outreach campaign to reduce loading from vessels or swimmers is unknown

Table ES.1
Summary of Relative Public Health Concern Related to Fecal Coliform Exceedances in Newport Bay

Site Name	Recreational Use Level [1]	Exceedances of FC Standard During Dry Season [2]		Level of Public Health Concern Dry Season [7]	Exceedances of FC Standard During Wet Season [3]		Level of Public Health Concern Wet Season [7]	Potential Future Controls [4]			
		Log Mean	90th %ile		Log Mean	90th %ile		Vessel Waste	Swimmer Loading	Tributary Inflow	Others [9]
Vaughn's Launch	Use Prohibited		Ö	Very Low	Ö	Ö	Low	-	-	-	-
Ski Zone				Very Low		Ö	Very Low	-	-	-	-
Big Canyon Creek			Ö	Very Low	Ö	Ö	Low	-	-	-	-
San Diego Creek - Campus Dr.			Ö	Very Low	Ö	Ö	Low	-	-	-	-
Backbay Drive Pipe [5]			Ö	Very Low		Ö	Very Low	-	-	-	-
Santa Ana Delhi Channel		Ö	Ö	Low	Ö	Ö	Low	-	-	-	-
43rd Street Beach	Low Use	Ö	Ö	Medium		Ö	Low	Ö	-	-	Flushing
38th Street Beach			Ö	Low		Ö	Low	-	-	-	Flushing
33rd Street Channel			Ö	Low		Ö	Low	-	-	-	Flushing
Rhine Channel				Very Low		Ö	Low	-	-	-	Flushing
Sapphire Avenue Beach				Very Low			Very Low	-	-	-	-
N Street Beach				Very Low		Ö	Low	-	-	-	-
Promontory Point Channel				Very Low			Very Low	-	-	-	-
De Anza				Very Low		Ö	Low	-	-	-	-
Grand Canal				Very Low			Very Low	-	-	-	-
Newport Blvd. Bridge			Ö	Low		Ö	Low	-	-	-	Flushing
Park Avenue Beach	Medium Use			Very Low			Very Low	-	-	-	-
Onyx Avenue Beach				Very Low		Ö	Low	-	-	-	-
Ruby Avenue Beach				Very Low		Ö	Low	-	-	-	-
Bayshore Beach [6]			Ö	Medium		Ö	Low	Ö	-	-	-
Via Genoa Beach				Very Low		Ö	Low	-	-	-	-
15th Street Beach			Ö	Low		Ö	Low	-	-	-	-
10th Street Beach				Very Low		Ö	Low	-	-	-	-
Alvarado/ Bay Isle Beach				Very Low		Ö	Low	-	-	-	-
Abalone Avenue Beach				Very Low		Ö	Low	-	-	-	-
Garnet Avenue Beach				Very Low		Ö	Low	-	-	-	-
Harbor Patrol Beach				Very Low		Ö	Low	-	-	-	-
19th Street Beach	High Use			Very Low		Ö	Low	-	-	-	-
Rocky Point Beach				Very Low			Very Low	-	-	-	-
North Star Beach				Very Low		Ö	Low	-	-	-	-
Lido Yacht Club Beach				Very Low		Ö	Low	-	-	-	-
Newport Dunes - Middle	Extra High Use			Low		Ö	Medium	Ö	Ö	-	Flushing
Newport Dunes - West				Low		Ö	Medium	Ö	Ö	-	Flushing
Newport Dunes - North [8]			Ö	High		Ö	Medium	Ö	Ö	-	Flushing
Newport Dunes - East				Low		Ö	Medium	Ö	Ö	-	Flushing

1. Use Levels are defined in Chapter 3, Refer to Table 3.4
2. Dry Season defined as May through September
3. Wet Season defined as October through April
4. Controls were defined and evaluated in Chapter 8.
5. Dry weather flow is now diverted to sanitary sewer
6. High Use on holidays
7. Level of Public Health Concern is derived as shown to the right
8. Exceedances may have been linked to flow from the Backbay Drive Pipe, see note 5.
9. Other potential control measures not investigated as part of the HRA

Level of Public Health Concern
Dry Season

Indicator Concentration	Exposure None	Low	Medium	High	Extra high
Low	Very Low	Very Low	Very Low	Very Low	Low
Medium	Very Low	Low	Low	Medium	High
High	Low	Medium	Medium	High	High

Level of Public Health Concern
Wet Season

Indicator Concentration	Exposure None	Low	Medium	High	Extra high
Low	Very Low	Very Low	Very Low	Very Low	Low
Medium	Very Low	Low	Low	Low	Medium
High	Low	Low	Low	Medium	High

Note: The relative level of Public Health Concern shown in these tables is based on the combination of exposure level, indicator concentration, basic principles of sanitary engineering, and professional judgement. Concern at a given site changes seasonally, with the relative use that the site receives.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The California Regional Water Quality Control Board, Santa Ana Region (RWQCB), identified the Lower and Upper Newport Bay as a water quality limited receiving water body and listed Newport Bay in accordance with Section 303(d) of the Clean Water Act. This designation indicates that applicable water quality standards are not being attained or expected to be attained with the implementation of technology based controls. In addition to other pollutants, pathogens are identified in the 303(d) List as a stressor of actual and/or threatened water quality impairment and indicates that urban runoff and/or storm sewers are the source of the pathogens. The RWQCB has indicated that the bacterial contamination in the Bay has resulted in a shellfish harvesting ban and sporadic water contact recreation bans in some areas of the Bay (CA RWQCB 1999).

On April 9, 1998, the RWQCB adopted Resolution No.99-10 which amended the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) to establish a Total Maximum Daily Load (TMDL) for fecal coliform in Newport Bay, Orange County, California. A TMDL is a method for implementing water quality standards based on the relation between sources of pollutants and in-stream water quality conditions. The TMDL was approved by the State Water Resources Control Board (SWRCB) on July 15, 1999 and by the Office of Administrative Law on December 30, 1999. Resolution 99-10 and other related documentation are attached to this report as Appendix A.

The RWQCB TMDL is based on a phased approach for controlling the bacterial quality in Newport Bay and ensuring that the beneficial uses in the Bay are protected. In the phased approach additional monitoring and assessment are undertaken to address areas of uncertainty and to allow for future revision and refinement of the TMDL, as warranted. The added flexibility to refine the regulation, based on the future acquisition of data, is appropriate given the complexity of the problem, the limited data on bacterial sources and their fate in the environment, and the potential difficulties in identifying and implementing appropriate control measures. Moreover, this approach is consistent with United States Environmental Protection Agency (EPA) guidance which allows states to use specific factors to list and design the schedule for establishing the TMDL. Two key factors that are being considered as part of the fecal coliform TMDL for Newport Bay are: (1) the relative significance of the environmental harm or threat and (2) the relative complexity of the TMDL.

The complexity of the Newport Bay fecal coliform TMDL derives primarily in interpreting the following question: “Do occasional exceedances of the fecal coliform objective for body contact recreation, necessarily imply an impairment to the beneficial use?”. The answer to this question is difficult for several reasons: (1) The linkage between the fecal coliform indicator and adverse health effects is weak; (2) There are significant temporal and spatial variations in water quality in Newport Bay; and (3) Limited data were available to identify controllable sources of coliform and to evaluate

the potential human health related benefits by reducing coliform loading from those sources.

Based on meetings and discussions with the RWQCB, Orange County Health Care Agency, CA Department of Health Services, members of the Health Advisory Committee[6] (HAC), and Irvine Ranch Water District (IRWD), a Work Plan was developed to carry out an investigation to assist the RWQCB to address the reasonable protection of the REC-1 (body contact recreation) beneficial use in Newport Bay. The findings of that investigation are summarized in this report. The final Work Plan for this investigation is attached to this report as Appendix B.

In addition to the Clean Water Act requirements, in California, a TMDL must also be conducted within the context and requirements of the Porter-Cologne Act (California Water Code). Therefore, the framework of this investigation encompasses developing sufficient information to assist the RWQCB balance the benefits and costs associated with ensuring the reasonable protection of beneficial uses (i.e., body contact recreation). Consistent with that goal, a methodology was employed in this investigation that focused on distinguishing between factors that potentially impact water quality and are controllable, from those factors that are uncontrollable and may have a significant water quality impact. As such, the focus of the investigation is to prioritize areas within Newport Bay for the purposes of evaluation and implementation of cost-effective and reasonable control actions. The overall approach described herein including the methodology for the Health Risk Assessment is also applicable to other watersheds where the fundamental question involves the assessment of the public health impairment of beneficial uses due to observed levels of microbial indicators above water quality criteria and/or objectives.

Regulatory actions are based on two very distinct elements, **risk assessment**, the primary focus of this investigation, and **risk management**. Within the context of this investigation, risk assessment may be defined as the use of factual data to define the health effects of exposure for individuals or a population to infectious agents. Risk management, on the other hand, is the process of weighing policy alternatives and selecting the most reasonable regulatory actions based on integrating the results of the risk assessment with engineering data and with social, economic, and political concerns. While focused primarily on a technically defensible risk assessment, this investigation also included the development of information to facilitate risk management decisions with respect to the fecal coliform TMDL. The goal of the risk management component of this investigation is to present the findings of the risk assessment in an appropriate format that will allow the RWQCB to make an informed risk management decision consistent with the Clean Water Act and within the context of Porter-Cologne.

[6] The HAC was composed of internationally recognized experts to ensure that local and state regulatory staff understood and accepted the technical basis for the health risk assessment. Refer to section 1.4.

1.2 OBJECTIVES

The primary objectives of the investigation described herein are as follows:

- To characterize the existing relative risk to public health posed by exposure to pathogens derived from human sources via recreational contact in Newport Bay;
- To provide estimates of the relative risk associated with alternative levels of exposure and/or water quality (due to structural or programmatic changes), and to compare those results with the results representing existing conditions; and
- To integrate the results of the health risk assessment with the potential costs associated with implementing control alternatives that may lead to water quality improvements and reductions in public health risk.

1.3 APPROACH

1.3.1 Risk Assessment Methodology

Risk assessment involves the use of factual data to define the potential health effects of exposure for individuals or populations to hazardous materials and situations. Attempts to provide a quantitative assessment of human health risks associated with the ingestion of waterborne pathogens have historically been conducted within the framework developed for chemical risk assessments (National Research Council 1983) and for the most part have focused on the probability of infection or disease to an individual as a result of a single exposure event (Dudley et al. 1976; Haas 1983; Regli et al. 1991; Rose 1999).

A drawback to the chemical risk assessment paradigm with respect to infectious disease transmission is that there are issues unique to infectious disease transmission that the chemical risk paradigm does not incorporate , such as: secondary (person to person) spread of disease; and immunity (EOA, 1995, ILSI, 1996, Chick et al. 2001). The limitations of treating infectious disease transmission as a static disease process, with no interaction between those infected or diseased and those at risk, has been illustrated in studies of Giardia (Eisenberg et al. 1996), dengue (Koopman and Longini 1994), and sexually transmitted diseases (Koopman et al. 1991). Moreover, from a public health perspective, the probable number of people infected in an exposed population provides more insight and is more meaningful than the probability of individual infection. To address this public health perspective, the probability of individual infection has sometimes been multiplied by the number of exposed individuals in an attempt to predict the disease burden in the population (Anderson et al. 1998). Such a simple approach, however, may not lead to accurate risk forecasts for the population if immunity from infection and/or person to person transmission are important factors for the pathogen of interest (Eisenberg et al. 1998; Chick et al. 2001; McDonald et al. 2001).

In 1996, the U.S. EPA Office of Water and the American Water Works Association Research Foundation contracted the International Life Sciences Institute to convene a panel of experts to develop a conceptual framework to assess the risks of human disease associated with exposure to waterborne pathogenic microorganisms. The panel

acknowledged drawbacks to the chemical risk assessment framework when applied to microorganisms, and developed a generalized framework applicable for pathogens (International Life Sciences Institute - Risk Science Institute 1996). In 1999, the expert panel re-convened to review case study risk assessments carried out to test the applicability of the framework (EOA Inc. and U.C. Berkeley School of Public Health 1999; Teunis and Havelaar 1999), and found that the framework was generally appropriate for the conduct of microbial risk assessments.

The approach employed for this investigation is to take advantage of the available infectious disease and dose-response data in the development of a mathematical model that characterizes the human disease risk of waterborne pathogen exposure (EOA Inc. 1995; EOA Inc. and U.C. Berkeley School of Public Health 1995; Eisenberg et al. 1996; EOA Inc. et al. 1996; Eisenberg et al. 1998). Based on the host/microbe interaction, this approach makes explicit the mechanistic aspects of the infectious disease process and provides a transparent structure from which clinical data are incorporated into the disease transmission model. An existing dose-response model (Haas 1983; Regli et al. 1991) is embedded into an epidemiological framework, relying on a large base of literature describing the use of dynamic population models in the study of epidemics (Anderson and May 1991). These dynamic population models emphasize the importance of how the epidemiological status (susceptible, infected, diseased, and immune) of individuals within a defined population group varies over time, implicitly accounting for secondary (person to person) spread of disease. In addition to these epidemiological-based variables, the model used in this investigation incorporates an additional water quality modeling component (refer to Chapter 5) to account for the dynamics of pathogen concentration at the each of the exposure sites (body contact recreation). Thus, the risk assessment methodology is consistent with the 1996 ILSI/EPA framework and further extends work previously carried out in the field of microbial risk assessment by characterizing the population based risk from recreational activity in a metric that is comparable to U.S. EPA water quality criteria endpoints, specified as risk to individual recreators.

1.3.2 Components in the Health Risk Assessment

The following fundamental steps were required to carry out the Health Risk Assessment (HRA) for water contact recreation in Newport Bay:

- Specify a route of exposure;
- Specify the pathogen to be investigated;
- Estimate the size of the population that may be exposed to the pathogen of interest through the specified route of exposure;
- Estimate the dose(s) of the pathogen to which members of the population are exposed;
- Develop or modify an existing epidemiological model for microbial risk capable of determining the number of infected individuals in the population for the specified exposure scenario(s);
- Characterize the relative risk and uncertainty associated with existing and alternative exposure scenarios; and

- Provide planning level estimates of the costs associated with implementing alternative controls to improve water quality and thereby reduce the risk to public health.

1.3.3 Use of Health Protective Assumptions When Data Were not Available

In every investigation, assumptions must be made where data are not available. An important aspect of this investigation was that health protective assumptions were made when data were not available, either through monitoring efforts or via literature review. The use of health protective assumptions is consistent with other microbial risk assessments that have been carried out in the past (Haas et al. 1996).

1.4 HEALTH ADVISORY COMMITTEE AND INDEPENDENT REVIEW OF THE INVESTIGATION

An important element of this investigations was to ensure that appropriate RWQCB, Orange County Health Care Agency, and State Department of Health staff understood and accepted the technical data, health information, and interpretation that supported the technical basis for the TMDL and the methodology to be used to carry out the HRA. To this end, a Health Advisory Committee (HAC) was formed. The HAC is composed of internationally recognized experts in the fields of public health, microbiology, environmental engineering, epidemiology, and virology. Staff from the RWQCB, State Department of Health, the Water Environment Research Foundation (WERF), and local stakeholders were also invited to participate in the HAC process as ex-officio participants. The following experts served on the Health Advisory Committee:

Health Advisory Committee Member	Field of Expertise
Robert C. Cooper, Ph.D., Emeritus Professor, UCB	Microbiology, Public Health
George Tchobanoglous, Ph.D., P.E., Emeritus Professor, UCD	Environmental Engineering
Jack Colford, M.D., Ph.D., Professor UCB[7]	Epidemiology
Edwin H. Lennette, M.D., Ph.D.*	Virology, Public Health

* Passed away during the course of the investigation

Ex-Officio participants in the HAC process included: Ken Theisen and Linda Candelaria, Ph.D. (RWQCB), Larry Honeybourne (OCHCA), Robert Hultquist and Richard Sakaji, Ph.D. (CA DHS), James Crook, Ph.D. (WERF), Dr. Jack Skinner (Stop Polluting Our Newport), and David Dilks, Ph.D., Charles Haas, Ph.D., and Richard Gersberg, Ph.D. (representing Defend the Bay).

During the course of this investigation two HAC meetings were held and periodic status reports were submitted to the HAC and all ex-officio participants. Copies of the status reports are available under separate cover. All written correspondences from HAC or ex-officio participants were responded to. A summary of the most pertinent correspondences is attached to this report as Appendix C.

In addition to HAC review of this investigation, the Newport Bay Watershed Management Committee convened an independent Review Panel (March 29th, 2000) to

[7] Dr. Colford's primary role was to provide guidance and oversight related to the study design.

assess the technical merit of the indicator organism employed during the investigation. That review panel was composed of the following experts: Dr. Roy Wolfe (Metropolitan Water District of Southern California), Dr. April Garcia (Los Angeles County Sanitation Districts), Dr. Roger Fujioka (Univ. Hawaii), Dr. Sunny Jiang (UCI), and Dr. Stanley Grant (UCI). As a result of this independent review process, the HRA team was asked to respond to a series of questions. Those questions and the subsequent responses are attached to this report as Appendix D.

1.5 REPORT ORGANIZATION

This report is organized into 10 chapters: Chapter 1 provides information on the background and the problem definition. Data collection efforts used to support the HRA are considered in Chapters 2 through 4; the focus of Chapters 5 through 8 is on the risk assessment portion of the investigation; and risk management considerations are addressed in Chapters 9 and 10.

Water quality data from Newport Bay for the time period of 1990 through 2000 are summarized in Chapter 2. The data collected to characterize the frequency and duration of recreational exposure in Newport Bay, as well as the size of the population that may recreate in Newport Bay (potentially exposed population) are described in Chapter 3. Additional data that were collected as part of this investigation for the water quality modeling effort are summarized in Chapter 4. Those data include the ambient monitoring program (water quality indicator data) and an estimation of pathogen loading to Newport Bay from vessel waste.

The water quality modeling efforts carried out for this investigation are summarized in Chapter 5. The Health Risk Assessment, uncertainty and sensitivity analyses, and comparative analyses are summarized in Chapters 6, 7 and 8 respectively.

The integration of the HRA with benefits and planning level costs for the comparative analyses carried out in Chapter 8 is described in Chapter 9; and the important aspects of the investigation are condensed and refined into key risk management considerations and conclusions from the investigation in Chapter 10. The citations used throughout this report are documented at the end of the report..

CHAPTER 2: THE BACTERIOLOGICAL WATER QUALITY IN NEWPORT BAY: 1990 – 2000.

The purpose of this chapter is to provide an overview of the bacteriological water quality in Newport Bay by summarizing data collected over the last ten years. Water quality bacteriological monitoring is carried out within Orange County by the Orange County Health Care Agency (OCHCA). The OCHCA water quality monitoring program includes the collection of bacterial indicator data throughout the County on a weekly basis. Specific to this investigation, total coliform, Escherichia coli (*E. coli*), and enterococcus data are collected weekly at 35 stations within Newport Bay. The locations of the monitoring stations in Newport Bay are shown in Figure 2.1.

2.1 WATER QUALITY MONITORING AND INDICATOR ORGANISMS

The basic reason for carrying out microbiological water analysis is to safeguard the health of a community by testing for possible fecal pollution, the source of microorganisms causing waterborne disease. Pathogenic microorganisms usually appear in recreational waters intermittently and in low concentrations (Borrego et al. 1987). Indicator organisms are organisms that coexist with pathogens in the fecal environment and are easier and less expensive to test for than pathogens. For these reasons, indicator organisms are often the focus of water analyses rather than pathogen analysis. Ideally, an indicator organism will be present when the pathogen is present, be present in equal or higher numbers than the pathogen of interest, be easy and inexpensive to assay, and would serve as an indicator of human fecal contamination (as opposed to animal contributions). The most commonly employed indicator organisms in the United States are total coliform, fecal coliform, enterococcus, and *E. coli*. Fecal streptococcus is also commonly employed in Europe and coliphages have gained increased acceptability as a viable alternative as an indicator for viral contamination (Jagals et al. 1995; Sobsey et al. 1995; Paul et al. 1997). In some cases pathogens, particularly giardia and cryptosporidium have also been included in water quality monitoring programs, although quantitative monitoring of viruses in recreational waters is still rare and is expensive.

2.2 POTENTIAL SOURCES OF MICROBIAL POLLUTION IN NEWPORT BAY

Within the Newport Bay watershed there are a number of potential sources of fecal coliform. Based on RWQCB staff reports, those sources include the following for Newport Bay (CA RWQCB 1999):

- Tributary inflows (composed of urban and agricultural runoff, including stormwater);
- Food wastes;
- Discharge of sanitary vessel waste; and
- Fecal waste of wildlife, including waterfowl that inhabit the Bay and its environs;

Based on a review of the literature, the following are additional potential sources of fecal coliform loading to Newport Bay:

- Leakage of sewer lines (Metcalf and Eddy 1981);
- Recreators (EOA Inc. 1995; Yates et al. 1997);

- Animal wastes (from domestic animals) (Young and Thackston 1999); and
- Illegal and/or illicit waste discharges (from industrial, commercial, and/or residential sources).

2.3 Bacterial Water Quality Objectives, Standards, and Criteria

A water quality standard is comprised of the beneficial use or uses to be made of the water body or segment and the water quality criteria necessary to protect that use or uses (U.S. EPA 1983). Water quality criteria for bacteria may be defined as concentrations of indicator organisms that should not be exceeded to protect human health from pathogen-caused illness (U.S. EPA 2000). The Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) designates Water Contact Recreation (REC-1)[8] and shellfish harvesting (SHEL) as beneficial uses for Newport Bay.

With respect to the protection of the REC-1 beneficial use, there are several applicable sources of water quality objectives and criteria for bacterial constituents for Newport Bay, all of which are based on indicator organisms rather than pathogen concentrations. Those sources include the State Water Resources Control Board (SWRCB), the California State legislature, and U.S. EPA.

The Basin Plan includes numeric water quality objectives for total and fecal coliform bacteria in Newport Bay. Assembly Bill 411 (AB411) approved by the California State legislature in 1999, amended California State Health and Safety Codes 115880, 115885, and 115915. The amended codes specify water quality objectives in terms of enterococcus levels for ocean beaches. EPA has also specified bacteriological criteria for fresh and saltwater water contact recreation (U.S. EPA 1986). For water contact recreation in Newport Bay, the Santa Ana RWQCB Basin Plan Objectives and other potentially applicable water quality criteria are summarized in Table 2-1.

2.4 Summary of Historic Bacterial Indicator Data in Newport Bay

The OCHCA has monitored total and fecal coliform on (approximately) a weekly basis in Newport Bay for approximately the last 30 years. From the beginning of the monitoring effort through approximately 1998, total and fecal coliform data were collected (using the multiple tube fermentation methodology). Starting in 1999 and continuing through 2000, total coliform, *E. Coli*, and enterococcus data were collected[9] (Multiple tube fermentation was used for total coliform, Colilert was used for *E. Coli* analyses, and Enteroalert was used for enterococcus analyses. The Colilert analyses are used for compliance evaluation purposes with the fecal coliform objective).

[8] Definition of REC-1: , DHS recommended (10/24/1990) that REC-1 be defined as "recreational uses that involve contact with water with substantial likelihood of ingesting water" (swimming, wading by children, etc.), and that REC-2 be defined as "Recreation uses where limited contact with water is reasonably possible (fishing, boating, etc.).

[9] In addition to these data, additional data were also collected as part of this investigation. Those monitoring efforts and analyses were carried out as a collaboration between OCHCA and IRWD, and are described in Chapter 4.

Table 2.1
Summary of Applicable REC-1 Water Quality Limitations for Newport Bay

Souce	Organism	Criteria	Value	Units
Basin Plan	Total Coliform	median	240 [1]	MPN/100mL
		maximum	10,000	MPN/100mL
	Fecal Coliform	log mean	200 [1]	MPN/100mL
		90th percentile	400	MPN/100mL
EPA Salt Water Criteria	Enterococcus	geometric mean	35 [1]	colonies/100mL
		designated beach - max	104	colonies/100mL
		Moderately used site - max	158	colonies/100mL
		Lightly used site - max	276	colonies/100mL
		Infrequently used site - max	500	colonies/100mL
EPA 1976 [2]	Fecal Coliform	geometric mean	200	MPN/100mL
CA State Health and Safety Code	Total Coliform	log mean	1000 [1]	MPN/100mL
		maximum	10,000	MPN/100mL
	Fecal Coliform	log mean	200 [1]	MPN/100mL
		maximum	400	MPN/100mL
	Enterococcus	log mean	35 [1]	colonies/100mL
		maximum	104	colonies/100mL

1. Based on a minimum of 5 equally spaced samples in any 30 day period
2. EPA's salt water criteria supercede this limitation, however many states have yet to adopt the new criteria

Between 1990 and 2000, a total of approximately 26,625 analyses for total coliform, fecal coliform, *E. Coli*, and enterococcus were analyzed for Newport Bay locations by OCHCA. Six summary tables and six figures have been prepared based on the data to present a general overview of bacterial water quality in Newport Bay during the time period of 1990 through 2000[10,11].

2.4.1 1990 through 1998

Total and fecal coliform data for May through October (dry season) of 1990 through 1998 are presented in Table 2.2. Data corresponding to the months of November through April (rainy season) 1990 through (April) 1999 are summarized in Table 2.3. For each monitored site in Newport Bay, Tables 2.2 and 2.3 present the number of samples collected for total and fecal coliform, the median total coliform value, the percent that the median is above 240 MPN/100mL ((median – 240) / 240*100%), the number of total coliform observations above 10,000 MPN/100mL, the percent of samples above 10,000 MPN/100mL total coliform, the log mean of the fecal coliform observations, the percent the log mean is above 200 MPN/100mL (if it is above that value), the 90th percentile, and the percent that the 90th percentile is above 400 MPN/100mL (if it is above that value). Graphical summaries of these data illustrating the percent of observations above 400 MPN/100mL fecal coliform are presented in Figures 2.2 and 2.3 for the time periods of May through October 1990 – 1998, and November through April 1990 – 1999, respectively.

It should be noted that although the summaries correspond to the Basin Plan objectives, the Basin Plan and AB411 objectives require that summary statistics be computed on a

[10] Fecal coliform data presented in Tables 2.2 through 2.6 are consistent with those used for compliance purposes.
[11] Data prior to 1998 are data that were used to establish the fecal coliform TMDL, and 1999 through 2000 data were collected during the course of this investigation.

monthly basis. The data presented in the summary tables in this chapter should, therefore, be interpreted as a general overview of water quality, rather than as a summary of compliance with the applicable water quality objectives.

2.4.2 1999 through 2000

Similar to that presented above, summary tables for total and fecal coliform data for May through October 1999, November 1999 through April 2000, and May through October 2000, are presented in Tables 2.4, 2.5, and 2.6, respectively. Graphical summaries for fecal coliform and those respective dates are presented in Figures 2.4, 2.5, and 2.6 respectively. Enterococcus data for May 1999 through October 2000 are presented in Table 2.7, and May 2000 through October 2000 enterococcus data are presented graphically in Figure 2.7.

2.4.3 Indicator Data – General Observations

From a review of the data and information presented in the summary data tables and figures the following general observations can be made:

General observations Regarding Fecal Coliform Limitations:

- With the exception of the Upper Bay tributaries and the Back Bay Drain, most sites have a log mean fecal coliform value that is less than the limitation of 200 MPN/100mL for both wet and dry seasons for all times periods summarized (1990 – 2000);
- The 90th percentile values of the reported fecal coliform observations were above the objective of 400 MPN/100mL at most sites during the wet seasons;
- The percent of sites with fecal coliform 90th percentile values above 400 MPN/100mL during wet seasons, was similar for the time periods of 1990 – 1998 and 1999 – 2000;
- Approximately one half of the sites had 90th percentile values for fecal coliform observations above the objective of 400 MPN/100mL during the dry seasons of 1990 – 1998. The number of sites with 90th percentile exceedances was reduced to approximately one third (12 sites) during 1999 and 2000;
- Of the 12 sites with fecal coliform 90th percentile values above 400 MPN/100mL during 1999 and 2000, four are located in areas where recreational activities (REC-1) are prohibited (Santa Ana Delhi Channel, San Diego Creek @ Campus, Big Canyon Wash, and Vaughn's Launch), and three are near areas which receive substantial recreational use (15th Street, Bayshore Beach, and Newport Dunes North). The other sites are areas that are used infrequently for recreational activity (43rd, 38th, and 33rd Street beaches, Backbay Drain and Newport Blvd Bridge) (Refer to Section 3.1.2);
- Dry season fecal coliform observations are comparable for 1999 and 2000. During both years 43rd Street beach and Santa Ana Delhi had log mean values above 200 MPN/100mL, and 8 of the 12 sites that had 90th percentile values above 400 MPN/100mL during those years, were above that value during both years;

- Dry season log mean fecal coliform values were similar or lower in 1999 and 2000 than from 1990 – 1998. Between 1990 and 1998, 4 Upper Bay tributary sites (Big Canyon Creek, San Diego Creek, Back Bay Drain, and Santa Ana Delhi Channel) had log mean values greater than 200 MPN/100mL. During 1999 and 2000, 43rd Street Beach and Santa Ana Delhi Channel log mean values greater than 200 MPN/100mL;
- Fecal coliform concentrations at the 43rd Street Beach were below the log mean limitation prior to the 1999 dry season, and appear to be somewhat higher since that time;

General observations Regarding Enterococcus Limitations:

- The percent of observations above EPA's marine enterococcus water quality criteria (104 colonies/100mL) for the time period of November 1999 – April 2000 is similar to those above 400 MPN/100mL fecal coliform for that time period; and
- The number of sites with log mean enterococcus concentrations above EPA's marine criteria of 35/100mL was higher than the number of sites above the fecal coliform log mean objective for the time period of 1999 – 2000 for both wet and dry periods.

Table 2.4

Summary of Newport Bay Monitoring Data for Total and Fecal Coliform *

May - October 1999

		Total Coilform [1]					Fecal Coliform [5]				
Station [10]	Station Name	# samples	median	% median > 240 [2]	# > 10,000 [3]	% > 10,000 [4]	# samples	log mean	% log mean > 200 [6]	90th percentile [7]	% 90th > 400 [8,9]
BNB01	Park Avenue Beach	26	20		0	0	30	17		61	
BNB02	Onyx Avenue Beach	25	20		0	0	29	28		158	
BNB03	Ruby Avenue Beach	26	20		0	0	30	17		96	
BNB05	Bayshore Beach	26	30		2	8	30	55		598	50
BNB07	Via Genoa Beach	26	20		0	0	30	13		28	
BNB09	43rd Street Beach	26	120		1	4	30	257	29	8075	1919
BNB10	38th Street Beach	26	100		0	0	30	71		700	75
BNB11	33rd Street Channel	26	265	10	1	4	30	87		2473	518
BNB12	Rhine Channel	26	120		0	0	30	44		329	
BNB14	19th Street Beach	26	30		0	0	30	26		208	
BNB15	15th Street Beach	26	20		0	0	30	17		51	
BNB17	10th Street Beach	26	20		0	0	30	13		30	
BNB18	Alvarado/ Bay Isle Beach	27	20		0	0	30	20		52	
BNB20	Sapphire Avenue Beach	24	20		0	0	28	19		68	
BNB21	Abalone Avenue Beach	26	20		0	0	30	19		63	
BNB22	N Street Beach	26	20		0	0	29	13		31	
BNB23	Rocky Point Beach	25	20		0	0	29	19		98	
BNB24	Newport Dunes - Middle	26	20		0	0	30	23		176	
BNB24	Newport Dunes - West	26	20		0	0	30	21		115	
BNB24	Newport Dunes - North	26	80		0	0	30	66		624	56
BNB24	Newport Dunes - East	26	20		0	0	30	33		237	
BNB25	Vaughn's Launch	25	20		1	4	26	45		1117	179
BNB26	Ski Zone	21	20		0	0	22	34		249	
BNB28	North Star Beach	26	20		1	4	30	14		50	
BNB29	Promontory Point Channel	26	20		0	0	30	10		10	
BNB30	De Anza	26	20		0	0	30	22		118	
BNB31	Garnet Avenue Beach	28	20		0	0	31	24		235	
BNB32	Lido Yacht Club Beach	26	20		0	0	30	16		108	
BNB33	Harbor Patrol Beach	26	30		0	0	30	33		156	
BNB34	Grand Canal	25	20		0	0	29	16		52	
BNB35	Newport Blvd. Bridge	26	350	46	2	8	30	71		597	49
CNBBC	Big Canyon Creek	0	-	-	-	-	26	166		699	75
CNBCD	San Diego Creek - Campus Dr.	0	-	-	-	-	30	117		1098	175
CNBND	Backbay Drive Pipe	0	-	-	-	-	29	186		2950	638
CNBSA	Santa Ana Delhi Channel	0	-	-	-	-	30	501	151	5424	1256

*. Data Source :OCHCA

1. Water Quality Objectives for Total Coliform: median < 240 MPN/100mL, no sample > 10,000 MPN/100mL

2. Percent that the median value is above 240 MPN/100mL

3. Number of samples > 10,000 MPN/100mL

4. Percent of samples > 10,000 MPN/100mL

5. Water Quality Objective for Fecal Coliform: log mean < 200 MPN/100mL, 90th percentile < 400 MPN/100mL, summary is of colilert samples

6. Percent that the log mean is above 200 MPN/100/mL

7. 90th Percentile of observed data

8. Percent that the 90% percentile is above 400 MPN/100mL

9.Shown only for sites with > 10 samples

10. Stations are referred to by name and the last portion of the name code on Figure 2.1

Table 2.5

Summary of Newport Bay Monitoring Data for Total and Fecal Coliform*

November 1999 - April 2000

		Total Coilform [1]					Fecal Coliform [5]				
Station	Station Name	# samples	median	% median > 240 [2]	# > 10,000 [3]	% > 10,000 [4]	# samples	log mean	% log mean > 200 [6]	90th percentile [7]	% 90th > 400 [8,9]
BNB01	Park Avenue Beach	27	20		3	11	26	19		241	
BNB02	Onyx Avenue Beach	27	20		2	7	26	35		716	79
BNB03	Ruby Avenue Beach	26	20		3	12	26	22		525	31
BNB05	Bayshore Beach	28	55		2	7	26	38		1158	190
BNB07	Via Genoa Beach	27	20		3	11	26	31		1337	234
BNB09	43rd Street Beach	27	300	25	4	15	26	89		2334	484
BNB10	38th Street Beach	27	20		3	11	26	37		902	126
BNB11	33rd Street Channel	27	500	108	5	19	26	44		2700	575
BNB12	Rhine Channel	27	130		3	11	26	71		1348	237
BNB14	19th Street Beach	29	40		5	17	28	47		2894	624
BNB15	15th Street Beach	28	20		3	11	27	24		1300	225
BNB17	10th Street Beach	27	20		2	7	26	35		3126	681
BNB18	Alvarado/ Bay Isle Beach	27	20		3	11	26	32		6364	1491
BNB20	Sapphire Avenue Beach	26	20		2	8	26	22		312	
BNB21	Abalone Avenue Beach	27	40		3	11	26	27		539	35
BNB22	N Street Beach	27	40		3	11	26	38		912	128
BNB23	Rocky Point Beach	27	20		2	7	26	22		201	
BNB24	Newport Dunes - Middle	26	75		4	15	26	56		1409	252
BNB24	Newport Dunes - West	28	125		4	14	27	89		1766	342
BNB24	Newport Dunes - North	27	140		4	15	26	76		1714	328
BNB24	Newport Dunes - East	26	105		5	19	26	78		1515	279
BNB25	Vaughn's Launch	25	400	67	4	16	24	224	12	4642	1061
BNB26	Ski Zone	19	130		4	21	18	69		1419	255
BNB28	North Star Beach	26	40		5	19	26	60		2615	554
BNB29	Promontory Point Channel	27	20		0	0	26	13		70	
BNB30	De Anza	27	70		6	22	26	62		1800	350
BNB31	Garnet Avenue Beach	26	20		4	15	25	30		883	121
BNB32	Lido Yacht Club Beach	27	20		3	11	26	25		1437	259
BNB33	Harbor Patrol Beach	27	40		1	4	27	44		908	127
BNB34	Grand Canal	27	20		1	4	26	19		308	
BNB35	Newport Blvd. Bridge	27	230		5	19	26	52		878	120
CNBBC	Big Canyon Creek	0	-	-	-	-	26	380	90	1994	398
CNBCD	San Diego Creek - Campus Dr.	0	-	-	-	-	25	263	32	8547	2037
CNBND	Backbay Drive Pipe	0	-	-	-	-	26	78		490	23
CNBSA	Santa Ana Delhi Channel	0	-	-	-	-	26	447	123	15681	3820

*. Data Source :OCHCA

1. Water Quality Objectives for Total Coliform: median < 240 MPN/100mL, no sample > 10,000 MPN/100mL

2. Percent that the median value is above 240 MPN/100mL

3. Number of samples > 10,000 MPN/100mL

4. Percent of samples > 10,000 MPN/100mL

5. Water Quality Objective for Fecal Coliform: log mean < 200 MPN/100mL, 90th percentile < 400 MPN/100mL, summary is of colilert samples

6. Percent that the log mean is above 200 MPN/100/mL

7. 90th Percentile of observed data

8. Percent that the 90% percentile is above 400 MPN/100mL

9.Shown only for sites with > 10 samples

10. Stations are referred to by name and the last portion of the name code on Figure 2.1

Table 2.6

Summary of Newport Bay Monitoring Data for Total and Fecal Coliform*

May - October 2000

		Total Coilform [1]					Fecal Coliform [5]				
Station [10]	Station Name	# samples	median	% median > 240 [2]	# > 10,000 [3]	% > 10,000 [4]	# samples	log mean	% log mean > 200 [6]	90th percentile [7]	% 90th > 400 [8,9]
BNB01	Park Avenue Beach	54	41		0	0	27	18		73	
BNB02	Onyx Avenue Beach	54	126		0	0	27	32		208	
BNB03	Ruby Avenue Beach	52	40		0	0	26	14		44	
BNB05	Bayshore Beach	66	170		1	2	33	42		200	
BNB07	Via Genoa Beach	50	41		0	0	25	13		41	
BNB09	43rd Street Beach	63	1,246	419	13	21	31	288	44	4171	943
BNB10	38th Street Beach	89	1,334	456	21	24	45	174		1022	155
BNB11	33rd Street Channel	52	2,862	1,092	21	40	26	141		1560	290
BNB12	Rhine Channel	56	353	47	1	2	28	47		326	
BNB14	19th Street Beach	52	137		2	4	27	28		163	
BNB15	15th Street Beach	58	116		1	2	29	32		536	34
BNB17	10th Street Beach	53	41		2	4	27	16		58	
BNB18	Alvarado/ Bay Isle Beach	53	84		0	0	26	30		155	
BNB20	Sapphire Avenue Beach	54	74		0	0	27	44		327	
BNB21	Abalone Avenue Beach	58	74		1	2	29	23		108	
BNB22	N Street Beach	52	31		0	0	26	16		62	
BNB23	Rocky Point Beach	54	40		0	0	27	21		114	
BNB24	Newport Dunes - Middle	54	119		2	4	27	19		138	
BNB24	Newport Dunes - West	56	222		1	2	28	34		244	
BNB24	Newport Dunes - North	115	300	25	5	4	58	138		1233	208
BNB24	Newport Dunes - East	64	296	23	4	6	32	62		263	
BNB25	Vaughn's Launch	50	177		4	8	25	37		356	
BNB26	Ski Zone	44	110		6	14	22	30		363	
BNB28	North Star Beach	52	77		0	0	26	13		44	
BNB29	Promontory Point Channel	61	20		1	2	30	20		170	
BNB30	De Anza	57	63		0	0	28	28		211	
BNB31	Garnet Avenue Beach	60	67		0	0	30	41		269	
BNB32	Lido Yacht Club Beach	54	57		2	4	27	16		80	
BNB33	Harbor Patrol Beach	63	110		0	0	31	39		227	
BNB34	Grand Canal	56	67		0	0	28	27		98	
BNB35	Newport Blvd. Bridge	50	256	7	5	10	25	35		1534	284
CNBBC	Big Canyon Creek	0	-	-	-	-	26	200		785	96
CNBCD	San Diego Creek - Campus Dr.	0	-	-	-	-	27	138		773	93
CNBND	Backbay Drive Pipe	0	-	-	-	-	28	60		352	
CNBSA	Santa Ana Delhi Channel	0	-	-	-	-	31	355	77	6831	1608

*. Data Source :OCHCA

1. Water Quality Objectives for Total Coliform: median < 240 MPN/100mL, no sample > 10,000 MPN/100mL
2. Percent that the median value is above 240 MPN/100mL
3. Number of samples > 10,000 MPN/100mL
4. Percent of samples > 10,000 MPN/100mL
5. Water Quality Objective for Fecal Coliform: log mean < 200 MPN/100mL, 90th percentile < 400 MPN/100mL, summary is of colilert samples
6. Percent that the log mean is above 200 MPN/100/mL
7. 90th Percentile of observed data
8. Percent that the 90% percentile is above 400 MPN/100mL
9.Shown only for sites with > 10 samples
10. Stations are referred to by name and the last portion of the name code on Figure 2.1

Table 2.7

Summary of Newport Bay Enterococcus Monitoring Data [1,2]

May 1999 - October 2000

		May - October 1999					November 1999 - April 2000					May - October 2000				
Station	Station Name	# samples	log mean	% log mean > 35 [3]	# > 104 [4]	% > 104 [5]	# samples	log mean	% log mean > 35 [3]	# > 104 [4]	% > 104 [5]	# samples	log mean	% log mean > 35 [3]	# > 104 [4]	% > 104 [5]
BNB01	Park Avenue Beach	26	12		0	0	26	15		2	8	26	15		2	8
BNB02	Onyx Avenue Beach	25	12		0	0	25	17		2	8	27	13		1	4
BNB03	Ruby Avenue Beach	26	13		1	4	26	18		2	8	26	10			0
BNB05	Bayshore Beach	26	31		4	15	25	26		3	12	33	22		5	15
BNB07	Via Genoa Beach	26	11		0	0	26	26		6	23	25	13			0
BNB09	43rd Street Beach	26	26		4	15	26	65	84	7	27	33	26		5	15
BNB10	38th Street Beach	26	12		1	4	26	23		5	19	45	25		6	13
BNB11	33rd Street Channel	26	25		4	15	26	66	89	11	42	26	36	4	6	23
BNB12	Rhine Channel	26	17		2	8	26	26		4	15	27	17		4	15
BNB14	19th Street Beach	26	17		3	12	28	32		6	21	25	11		1	4
BNB15	15th Street Beach	26	10		0	0	27	23		4	15	28	13			0
BNB17	10th Street Beach	26	11		0	0	26	22		4	15	28	16		1	4
BNB18	Alvarado/ Bay Isle Beach	26	16		1	4	25	32		4	16	26	14			0
BNB20	Sapphire Avenue Beach	24	11		0	0	27	16		3	11	27	12			0
BNB21	Abalone Avenue Beach	26	11		0	0	26	17		1	4	29	15		2	7
BNB22	N Street Beach	25	11		0	0	26	20		5	19	26	11			0
BNB23	Rocky Point Beach	25	12		0	0	26	25		1	4	27	15		1	4
BNB24	Newport Dunes - Middle	26	12		0	0	27	39	11	7	26	27	14		1	4
BNB24	Newport Dunes - West	26	12		0	0	28	54	53	10	36	28	15		1	4
BNB24	Newport Dunes - North	26	13		1	4	25	31		5	20	55	24		7	13
BNB24	Newport Dunes - East	26	13		0	0	26	26		5	19	32	24		4	13
BNB25	Vaughn's Launch	25	24		3	12	24	110	213	10	42	24	19		2	8
BNB26	Ski Zone	21	110	213	8	38	18	110	213	8	44	22	47	34	3	14
BNB28	North Star Beach	26	10		0	0	26	43	22	7	27	26	12			0
BNB29	Promontory Point Channel	26	10		0	0	26	11		0	0	30	13		1	3
BNB30	De Anza	26	19		3	12	26	40	14	7	27	27	17		2	7
BNB31	Garnet Avenue Beach	27	13		1	4	25	23		4	16	30	19		3	10
BNB32	Lido Yacht Club Beach	26	14		1	4	26	23		4	15	27	14		1	4
BNB33	Harbor Patrol Beach	26	15		2	8	27	25		3	11	30	26		5	17
BNB34	Grand Canal	25	13		1	4	26	14		2	8	28	11			0
BNB35	Newport Blvd. Bridge	26	46	31	7	27	26	37	6	5	19	25	32		5	20
CNBBC	Big Canyon Creek	25	83	138	6	24	26	100	186	13	50	26	151	332	19	73
CNBCD	San Diego Creek - Campus Dr.	26	83	138	6	23	25	186	432	11	44	26	79	127	14	54
CNBND	Backbay Drive Pipe	25	603	1,622	24	96	26	288	724	22	85	28	501	1,332	23	82
CNBSA	Santa Ana Delhi Channel	26	209	497	13	50	26	251	618	14	54	31	407	1,064	26	84

1. Data Source: OCHCA
2. Bacteriological Criteria for Enterococcus: log mean < 35/100mL,max < 104/100mL
3. Percent that log mean is greater than 35 colonies / 100mL
4. Number of samples > 104/100mL
5. Percent of samples > 104 /100mL

CHAPTER 3: EXPOSED POPULATION

The purpose of this chapter is to describe qualitatively and quantitatively the population that may be exposed to pathogenic microorganisms through body contact recreation in Newport Bay. For that purpose, a beneficial use assessment program was designed and carried out for this investigation.

The beneficial use assessment program was designed to gather data on the levels and patterns of recreational use in Newport Bay to estimate: (1) The frequency and duration of recreational exposure in Newport Bay, (2) The size of the population most likely to recreate in Newport Bay, and (3) The virus and fecal coliform loading to the Bay from bathers. The beneficial use assessment program was conducted between June 24th, 1999 and May 31st, 2000. Details describing the design of the beneficial use assessment program, results of the program, and how those results were employed in the Health Risk Assessment investigation are described below.

3.1 Frequency and Duration of Recreational Exposure

The beneficial use assessment program was composed of two parts: monitoring use patterns (counting number of recreators) and surveying recreators (asking recreators a series of questions). The beneficial use program was based on a purposeful sampling design in which recreational use in the Bay was monitored during 36 days (representing approximately 10% of the year). Monitoring occurred on a randomized sampling plan stratified by season and type of day (weekday, weekend, holiday). Further, the monitoring program was purposely weighted to emphasize data collection during the summer (high use) period. The numbers of recreators at representative recreational sites were documented during the summer, fall, winter, and spring seasons. A summary of the sampling schedule from the final work plan and the actual sampling schedule is presented below in Table 3.1. Due to logistical difficulties, one fewer day was monitored than originally intended. A detailed summary of the days in which monitoring occurred is included as Appendix E.

Table 3.1
Experimental Design for Beneficial Use Monitoring

Intended Sampling Schedule

	Summer Samples	Spring/Fall Samples	Winter Samples
Weekday	10	3	2
Weekend	6	4	3
Holiday	4	3	2
Season Totals	20	10	7
Annual Total	37		

Actual Sampling

	Summer Samples	Spring/Fall Samples	Winter Samples
Weekday	10	2	2
Weekend	6	4	3
Holiday	4	3	2
Season Totals	20	9	7
Annual Total	36		

In addition to counting recreators at selected recreational sites, a portion of recreators who were present at those sites were surveyed to determine where they reside, how often they recreate in Newport Bay, and how much swimming occurs during those times of recreation. The overall goal of the survey effort was to interview a representative sample

of recreators at each of the recreational sites on each survey day. Surveys were conducted on approximately 20% of the days monitored, and recreators were selected at random subject to requirements for obtaining a minimum number of survey responses. A total of approximately 150 interviews were conducted during the course of the program. A copy of the survey form used to obtain this information is included in Appendix E.

3.1.1 Daily Use Trend

The first part of the beneficial use assessment program involved determining a "Daily Use Trend" for recreational activity. The purpose of this aspect of the program was to document the use trend of recreators throughout the day. The Daily Use Trend monitoring was conducted on June 24, 25, and 26, 1999 at the Newport Dunes in the City of Newport Beach. The number of people recreating at the beach was recorded once per hour between 9am and 6pm. Based on the monitoring data, the times of highest use are between 11am and 3pm. All subsequent beneficial use monitoring was conducted during this high use time period. A summary of the Daily Use Trend monitoring results is presented in Table 3.2.

Table 3.2
Results of Beneficial Use Monitoring:
June 24 – 26, 1999 Newport Dunes

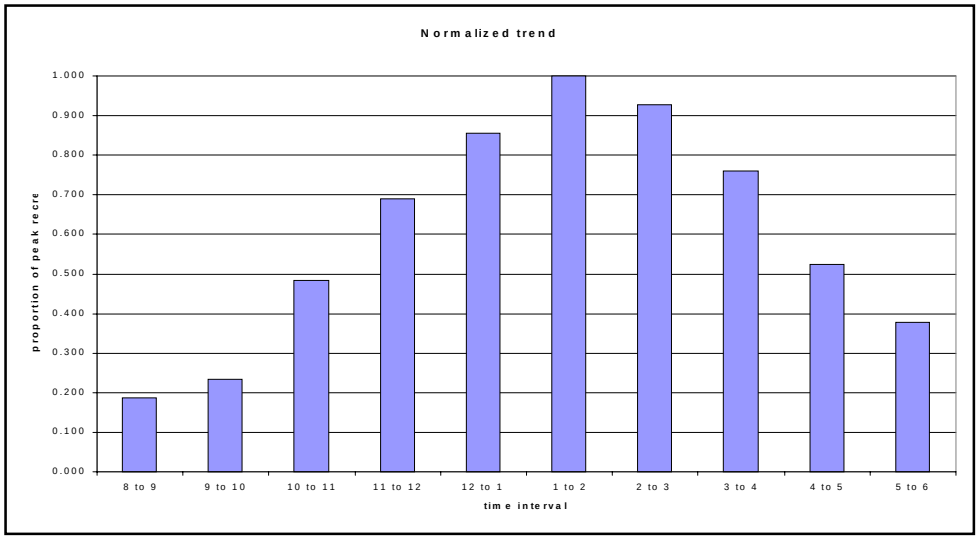
Date:	Thursday 6/24/1999	Friday 6/25/1999	Saturday 6/26/1999
Weather:	clear /sunny	clear/ sunny	mostly sunny
Temperature:	63-76 F	63-77 F	62-74 F

Time	# Recreators			Average
9:00AM	24	76	170	90
10:00AM	85	110	210	135
11:00AM	180	330	485	332
12:00PM	175	318	510	334
1:00PM	247	310	920	492
2:00PM	168	340	910	473
3:00PM	165	364	740	423
4:00PM	147	160	625	311
5:00PM	152	171	265	196
6:00PM	98	120	290	169

Several special events were held at the beach during the time period that was monitored, including field trips, group overnight camping, and catered lunches with music. Most of the catered events took place on Saturday between the hours of 12PM and 3PM. Field trips (excluding overnight trips) took place on Thursday and Friday, June 24th and 25th, 1999.

The daily use trend data presented in Table 3.2 were used to generate a normalized use trend by averaging the data over discreet time intervals. The resultant normalized use trend is presented in Figure 3.1. The trend shown in Figure 3.1 was used establish the peak period of use (11 A.M. – 3 P.M.) and the daily use pattern.

Figure 3.1
Normalized Daily Use Trend for Recreational Activity



3.1.2 Beneficial Use Assessment Monitoring

After the daily use trend was established, the beneficial use monitoring and survey program was carried out. Beneficial use monitoring sites were selected based on those sites currently monitored by the OCHCA and on discussions with Larry Honeybourne (OCHCA), Ken Theisen (RWQCB), and Dr. Jack Skinnner (SPON). Each of the sites was categorized preliminarily by level of use (low, medium, high). It was assumed that each of the sites categorized as a particular use level received similar recreational activity. Representative sites for each use level were selected for beneficial use monitoring and surveying.

After examining the results of the summer monitoring and surveying results, site categorizations were adjusted where obvious miscategorizations had occurred. The original categorization of monitored sites and the modified use level categorizations based on collected data, are presented in Table 3.3. A complete list of the 27 recreational sites and their use categorizations is included as Appendix E.

Table 3.3
Beneficial Use Levels of Monitored Sites

Site	Original Use Level Categorizations	Modified Use Level Categorizations
Balboa Island/Onyx-Coral Ave	M	M
10th Street	H	M
19th Street	H	H
Lido Isle Yacht Club	M	H
De Anza Pier	L	L
Newport Dunes	H	X-H
Bay Shore Drive	M	M (H on holidays)

Note: L = Low, M = Medium, H = High, and X-H = Extra-high

Recreational use was categorized originally into three seasons: Summer, Winter, and Spring/Fall. However, from an analysis of the beneficial use survey data it was concluded that actual use patterns were better represented by two seasons: high season and low season. As a result, use was recategorized into high season and low season, where high season encompasses May through September, and low season includes October through April.

The results of the beneficial use assessment are summarized below in Table 3.4. Raw data collected for the Beneficial Use Assessment program are included in Appendix E.

Table 3.4
Results of Beneficial Use Assessment:
Average Number of Recreators During Peak Time of Day[1]
June 1999 – May 2000

HIGH SEASON - May through September

Day	Use Level											
	Low			Medium			High			Extra High		
	mean	med	sd	mean	med	sd	mean	med	sd	mean	med	sd
Weekday	**2.3**	0.0	4.0	**14.3**	15.5	11.1	**25.6**	23.0	18.5	**256.8**	241.0	145.1
Weekend	**3.8**	3.0	4.8	**18.3**	14.0	13.4	**24.3**	28.0	16.1	**410.3**	380.0	207.3
Holiday	**7.0**	7.0	--	**18.0**	18.0	25.5	**59.0**	38.0	39.9	**1300.0**	1300.0	--

LOW SEASON - October through April

Day	Use Level											
	Low			Medium			High			Extra High		
	mean	med	sd	mean	med	sd	mean	med	sd	mean	med	sd
Weekday	**1.0**	0.0	2.4	**3.0**	1.0	5.1	**3.7**	0.5	8.0	**8.3**	5.0	9.5
Weekend	**0.3**	0.0	0.5	**2.4**	0.0	4.9	**4.1**	0.0	11.7	**6.3**	2.0	9.9
Holiday	**0.8**	0.0	1.1	**2.2**	2.0	1.9	**0.7**	0.0	1.0	**18.2**	16.0	17.0

1. As defined in Section 3.1.1 (11 A.M. – 3 P.M.

Low:
43rd Street
38th Street
33rd Street Rhine Channel
Sapphire Avenue
N Street Beach
Promontory Point
DeAnza Pier
Grand Canal

Medium:
Park Avenue
Onyx Avenue
Ruby Avenue
Via Genoa
15th Street
10th Street
Bayshore Beach
Alvarado/Bay Island
Abalone Avenue
Garnet Avenue
Harbor Patrol Beach

High:
19th Street (17th)
Rocky Point
Dunes North
North Star Beach
Lido Island Yacht Club
Bayshore (holidays)

Extra-High:
Dunes

3.1.3 Beneficial Use Assessment Survey Results

A copy of form used for the Beneficial Use Survey is included in Appendix E. The survey included the following questions:

- In which City do you live?
- On an annual basis, how frequently do you come to one of the Newport Bay beaches?
- How long will you spend on the beach today? and

- On average, how much time do you spend in the water when you come to one of the Newport Bay beaches?

Summary results from the Beneficial Use Surveying are presented in Tables 3.5, 3.6, and 3.7. As shown in Table 3.5, approximately 85% of recreators surveyed came from outside the City of Newport Beach. Of those, the majority were on a one time visit. On the July 4th holiday, 97% of those surveyed came from outside of the City of Newport Beach.

Table 3.5
Origin of Newport Bay Recreators

City of Newport Beach	16%
Nearby Cities*	20%
Other	64%

*based on the nine nearby cities included on survey: Anaheim, Corona del Mar, Costa Mesa, Irvine, Fountain Valley, Fullerton, Santa Ana, Tustin, Yorba Linda

Table 3.6
Frequency of Visits by Origin

City of Newport Beach

more than once a week	12	50%
2-4 per month	4	17%
once per month	5	21%
2-5 per year	1	4%
once per year	2	8%

Nearby Cities*

more than once a week	3	10%
2-4 per month	2	7%
once per month	4	14%
2-5 per year	12	41%
once per year	8	28%

OTHER

more than once a week	6	6%
2-4 per month	6	6%
once per month	5	5%
2-5 per year	33	35%
once per year	44	47%

Based on the results presented in Table 3.6, the frequency of visits appears to be strongly tied to how close recreators live to Newport Bay. Half of those recreators from the City of Newport Beach reported visiting Newport Bay beaches more than once a week. About forty percent of recreators from nearby towns came 2-5 times per year. The majority of those visiting Newport Bay from other cities responded that they come to Newport Bay once a year.

Based on the data presented above, the important inference is that the further away people live from Newport Bay, the less likely they are to visit Newport Bay beaches. The most frequent recreators at Newport Bay beaches live in the City of Newport Beach or otherwise live nearby Newport Bay.

Based on the fourth survey question, data for swimming recreators was compiled and grouped based on the amount of time those recreators spend in the water. Approximately 30% of those surveyed said that they do not go in the water. Responses were given in ranges, the midpoint of the time range was used as a point estimate for the time spent in the water (i.e. 1-2 hrs becomes 1.5 hrs). For those recreators that do go into the water, the time they spend in the water is summarized in Table 3.7.

Table 3.7
Summary of the Time Swimmers Spend in Water

Time in Water - swimmers	# swimmers	% swimmers
7.5 minutes	13	12
37 minutes	35	31
90 minutes	33	29
150 minutes	31	28
Total swimmers	112	100

3.1.4 Beneficial Use Assessment Program Observations

Some general observations that can be made from the beneficial use assessment program are as follows:

- Substantially more recreation occurs at the Newport Dunes than any other recreational site in Newport Bay. During high season at any given time it is estimated that the Dunes has more than one hundred times as many recreators as a typical low use beach and more than ten times as many recreators as a typical high use beach.
- There was little difference between holidays and weekend days, except for July 4th which had by far the highest number of recreators. It was anticipated that weekdays would have the lowest number of recreators, followed by weekends, and then holidays with the most. However, the numbers for Monday, July 5th were similar to the typical weekend range. Thus, the usage peak is steep and centered around the holiday for a holiday weekend. It may be the case that holidays which fall on the weekend will have the highest number of recreators, and holidays which fall on weekdays will more closely resemble weekend days than holidays. Therefore, only July 4th was categorized as a holiday. Weekday holidays during high season were counted as weekend days. Thus, Monday July 5th, and Monday September 6 (Labor Day) were counted as weekend days;
- The majority of recreators, on both weekdays and weekends, spend between 2 and 3 hours at the beach. However, on July 4th, most recreators surveyed were planning on staying 6 hrs or more;
- About 30% of recreators surveyed reported that they do not swim when they visit Newport Bay beaches. An additional 10% reported that they swim for less than 15 minutes. Responses were fairly evenly distributed among the survey ranges 15 min to

1 hr, 1-2 hrs, and greater than 2 hrs, with about 20% of the responses falling in each range;

- Anecdotally, it is estimated that the majority of those recreating in Newport Bay were children. One surveyor estimated that of those observed recreating, approximately two-thirds were children (data not shown in tables); and
- The most frequent recreators at Newport Bay beaches live in the City of Newport Beach or otherwise live nearby Newport Bay. The further away people live from Newport Bay, the less likely they are to visit Newport Bay beaches.

3.2 USE OF THE BENEFICIAL USE ASSESSMENT PROGRAM RESULTS

The data collected as part of the Beneficial Use Assessment Program is incorporated into the Health Risk Assessment (described in detail in Chapter 6) in three different ways: exposure profile, bather loading, and initial susceptible population.

3.2.1 Exposure Profile

The daily use trend monitoring in combination with the beneficial use monitoring were used to develop a profile of recreator use of Newport Bay beaches by time of year, type of day (weekday, weekend or holiday), and use level of beach. The daily use monitoring provided information about the distribution of use throughout a day which was then used in estimating the number of recreators at beaches relative to the peak hours (as shown in Figure 3.1). Data on the number of people at surveyed beaches during peak hours was used to develop expected numbers of recreators at beaches for each type of beach use level (low, medium, high, extra-high) and each type of day (weekday, weekend, holiday).

The number of recreators at each of the beaches on each day was used in conjunction with the percent of recreators that swim, the time that recreators that do swim spend in the water, and literature based values for water ingestion rates during swimming. These data were used to characterize primary exposure within the disease transmission model in time series format for each of the 27 recreational sites.

3.2.2 Bather Loading

Information on swimming behavior was used to develop an estimate of virus and coliform loading to the Bay from bathers. Loading to the Bay from bathers was estimated based on the percentage of recreators swimming during a given interval (from survey responses), the expected number of recreators at a given time (from beneficial use assessment monitoring), the expected duration distribution for swim events (from survey data), and values for virus and coliform loading per time swimming (from literature). Loading values were originally calculated for all beaches. However, based on the results of the water quality modeling (Chapter 5) it was found that the impact of loading from beaches was negligible except from the Dunes which is an extra-high use site. The loading estimate was therefore revised to include only bather loading at the Dunes. A summary description of the bather loading estimate is provided in Appendix F.

3.2.3 Initial Susceptible Population

A necessary piece of data for any population based health risk assessment is an estimate of the size of the potentially exposed population or equivalently the initial susceptible

population (ISP). The exposed population is a subset of the ISP. For the purposes of this investigation, the exposed population is defined to be those persons that engage in body contact recreation in Newport Bay (and therefore may be exposed to pathogenic microorganisms through ingestion of Bay water). The ISP includes the exposed population plus those people who are likely to come into contact with those who recreate at Newport Bay beaches, and thus might experience person to person transmission of disease (secondary exposure).

Information gathered regarding the origin and frequency of visits to Newport Bay beaches served as the basis for the estimate of the ISP. Specifically, the ISP was estimated based on the two beneficial use survey questions: In which city do you live? and, On an annual basis, how frequently do you come to one of the Newport Bay beaches?

To develop an estimate of the ISP, a list of the cities for which there were survey responses of "once a month" or greater frequency was compiled. Using that list of cities, the median distance recreators travel to Newport Bay was calculated. The travel distance, 15 miles, is considered the most likely distance frequent recreators are expected to travel to recreate at Newport Bay beaches. The ISP was estimated by summing the populations of the major cities and towns within 15 miles of Newport Bay. The result is an ISP of approximately 1.2 million.

Some cities were included in the ISP even though there were few "once a month" or greater responses from those cities. This approach was taken based on the assumption that recreators from different cities are willing to travel comparable distances to recreate in Newport Bay. Given the scope of the beneficial use assessment sampling program, it is reasonable to expect that the survey may not have captured respondents from every city that Newport Bay recreators come from. A summary of the cities that make up the ISP for the purposes of this investigation is presented in Table 3.8.

Table 3.8

Cities Making Up the Initial Susceptible Population for the HRA

City	Population	Distance from Newport Beach (mi)	Total Survey Responses*
Newport Beach	**66,643**	**0**	**24**
Cities within 15 mi radius			
Aliso Viejo	7,612	13.8	**1**
Costa Mesa	96,357	1.9	**5**
Fountain Valley	53,691	9.8	**5**
Garden Grove	143,050	13.9	**3**
Huntington Beach	181,519	5.9	**8**
Irvine	110,330	9.2	**8**
Laguna Beach	23,170	10.8	**2**
Orange	110,658	15.1	**8**
Santa Ana	293,742	10.7	**1**
Tustin	50,689	11.5	**2**
Westminster	78,118	14.9	**3**
Total	**1,215,579**		**70**

* Reflects all survey responses from respondents in the Cities shown, not just "once a month or greater"

CHAPTER 4: AMBIENT MONITORING PROGRAM AND VESSEL WASTE LOADING

The purpose of this chapter is to summarize the water quality data that were collected specifically for this investigation and to summarize the estimate of fecal coliform and enteric virus loading to Newport Bay from vessel waste. Both of those components were developed for and used in the water quality monitoring efforts described in detail in Chapter 5 and Appendix G.

4.1 SANITARY WASTE FROM VESSELS

4.1.1 Overview of Existing Vessel Waste Prohibition

The fecal coliform TMDL states that the Newport Bay has been designated by as a No-Discharge harbor for vessel sanitary wastes since 1976. Despite this prohibition, it has been suggested in the TMDL that some discharge of fecal waste from vessels does occur. Because these wastes are of human origin, they are a potential source of pathogens (and indicator organisms), and thus they may pose a potential public health threat. The Regional Board, the City of Newport Beach, and the County of Orange, have taken action to enforce the vessel waste discharge prohibition. The principal focus of these efforts has been to make compliance with the prohibition convenient. In this regard, vessel waste pumpouts have been installed at key locations around the Bay and are inspected routinely by the OCHCA. A City of Newport Beach ordinance addresses boating activities to ensure that sanitary wastes are disposed of appropriately. The ordinance requires that sailing clubs, harbor tours, and boat charter operations install harbor based pumpouts for their vessels. Another City of Newport Beach ordinance addresses the proper disposal of sanitary waste from persons living on their boats. Efforts have also been made to ensure that there are adequate public rest rooms onshore. Newport Beach also sponsors a public education campaign designed to advise both residents and visitors of the discharge prohibition, the significance of violations, and of the location of pumpouts and rest room facilities. Despite all of these efforts, the effectiveness of the controls is unknown.

4.1.2 Methodology Used to Compute Vessel Waste Loading

One component of this investigation was to provide an initial estimate of enteric virus loading to Newport Bay from vessels. The virus loading estimate was used in the water quality modeling component of the investigation as one of the sources of viruses in Newport Bay. Information used to estimate the loading was collected from various sources including:

- City of Newport Beach Marine Department;
- Discussions with representatives from private and public harbors in Newport Bay;
- Orange County Harbor Master and Sheriff;
- A survey of boaters conducted specifically for this investigation;
- Discussions with boat cleaners and holding tank pumpout services in Newport Bay; and
- Aerial photos.

The estimate of viral loading from vessel sanitary waste was based specifically on the following pieces of data:

- The estimated percent of boaters who discharge their waste into Newport Bay;
- The average number of hours spent aboard boats berthed in Newport Bay per unit time (day or week);
- The average number of people on board each boat;
- The total number of boats berthed in Newport Bay; and
- The average amount of human waste generated per person per time unit.

The total number of boats resident in Newport Bay was based on information provided by the Harbor Master and the City of Newport Beach. Estimates of average number of people on board each boat, average number of hours spent aboard boats in Newport Bay, and the percentage of boaters that are discharging into the Bay are based on boat cleaner and boater surveys (refer to sections 4.1.3, 4.1.4, and 4.1.5). The average amount of human waste generated per person per time was based on values found in the literature.

In using data from the boat cleaner and boater surveys to develop the vessel waste loading estimate, several assumptions were necessary. Where assumptions were necessary, conservative (health protective) assumptions were employed. The assumptions employed for this component of the investigation are as follows:

- Months were considered to have 21 weekdays and 9 weekend days;
- All of the time spent on boats was assumed to be spent in Newport Bay – a conservative assumption as many boats are taken out of the Bay and waste discharge may occur legally in the open ocean;
- For answers that were given to survey questions as ranges, the average value was used. (i.e. if a survey respondent gave an answer such as 4-5, 4.5 was used as the response);
- For answers that were given as less than a specified number, that number was used. (i.e. if a survey respondent gave an answer such as <1%, 1% was used as the response). For the response "very small", 5% was used. Respondents were always encouraged to give numerical answers, but not all complied; and
- Boater behavior is assumed to be the constant per unit time spent on a boat. Thus, for the purposes of this preliminary estimate, no distinction is made between weekend and weekday boater discharge behavior. Nor is a distinction made among boaters who live aboard their boats, boaters using moorings, and boaters using commercial marinas. Because it is assumed that even those that are on board for relatively short periods of time discharge a proportionate level waste, the approach used is conservative.

4.1.3 Boat Cleaner Survey

Before initiating the boater survey, telephone interviews were conducted with boat cleaners. Boat cleaners provide services including pumping out holding tanks. Many have standing contracts with clients for routine cleaning and also operate on a request basis. It

was assumed that boat cleaners would have knowledge of boater practices in the Bay and boater attitudes. A copy of the survey form used to interview the boat cleaners is shown below:

Boat Cleaner Survey	
"We are conducting a survey authorized by the Orange County Health Care Agency concerning recreational boating practices in the Bay. If you do not mind, I would like to ask you a few short questions."	
Question	Response
1. How many boats (in Newport Bay) do you clean per week/month/year	
2. How long have you been cleaning boats in Newport Bay?	
3. Would you say emptying holding tanks into the bay is: a. Rare b. Occasional c. Common	
4. Based on your cleaning experience, what percentage of boaters to you think empty their holding tanks into the Bay?	
5. Are there areas in Newport Bay where boaters are more likely to discharge?	
6. Is the situation improving? Are boaters becoming more responsible?	

The responses from the boat cleaners were remarkably consistent. EOA interviewed representatives from 6 boat cleaning companies during August 1999. Their experience in Newport Bay ranged from 7 to 20 years. Together their companies clean well over 400 boats per week in Newport Bay. The boat cleaners characterized the release of holding tank contents into the Bay as rare or occasional. The majority estimated 5% or fewer boaters were discharging their waste into the Bay. The cleaners, in general, felt that boaters were fairly aware and responsible and that behavior is improving. A few speculated that the public moorings might be a problem area. Others speculated that there was some accidental discharge and some problems caused by boaters too lazy to use pumpout stations. Overall the boat cleaner's responses suggest that vessel waste discharge into Newport Bay is infrequent.

4.1.4 Boater Survey: Design

After information was collected from boat cleaners, a survey was developed to interview and gather information from boaters in Newport Bay. The boater survey questions were designed to capture the information required while encouraging honest responses. Because Newport Bay is designated No-Discharge for vessel sanitary wastes, it was assumed that boaters would be reluctant to admit their own discharging. With this in mind, rather than asking boaters whether they themselves discharged waste into the Bay, boaters were asked to estimate the percentage of boaters they thought discharged their

waste into Newport Bay. Surveys were also administered in an anonymous manner. A copy of the boater survey form is shown below.

Boater Survey	
"We are conducting a survey authorized by the Santa Ana RWQCB to determine the extent to which Newport Bay is used for boating activities. If you do not mind, I would like to ask you a few short questions. The answers will be kept completely anonymous and will be only used for the stated purpose."	
Question	Response
1. How many days per month are you on your boat? (# days)	
2. When you use your boat, how many hours do you spend on it per day? (#hrs)	
3. What percent of the time you spend on your boat is on the weekend? (%)	
4. What percent of the time you spend on your boat is in Newport Bay? (%)	
5. On average, how many people are on your boat per use? (# people)	
6. Does your boat have a holding tank?	
Do you use it?	
7. Do you use the Newport Bay pumpout stations?	
How Often?	
Where?	
8. Do you use a holding tank pumpout service?	
9. What percentage of boaters do you think empty their fecal waste into Newport Bay? (%)	

A randomized study design was used to determine survey days, and a geographically representative cross-section of the Bay was surveyed to the extent practical. Surveys were conducted at marinas in Newport Bay. Survey administrators were instructed to approach people on or around boats in the marina areas and only to survey those who indicated they were boat owners or users.

In the Work Plan, it was estimated that 150 surveys would be sufficient to estimate the percentage of boaters who discharge waste into Newport Bay with reasonable confidence. During the first few days of surveying it became apparent that collecting survey data from boaters would be much more difficult than anticipated. Difficulties encountered included not being able to gain access to all marinas, not being able to find boaters at marinas to survey, and reluctance by some boaters that were approached to complete the survey. A total of seventy-three surveys were collected. Based on the analysis presented below and consultation with the HAC, it was decided that collection of additional surveys

would not likely provide additional insight worth the effort and cost involved in procuring those data.

The impacts on risk to human health from sanitary waste loading to Newport Bay from vessels is addressed further in this report in Chapter 5 (Water Quality Modeling), Chapter 7 (Sensitivity and Uncertainty Analyses), and Chapter 8 (Comparative Analyses). Should it be desired, future work could focus improving the estimate of vessel waste provided herein. Nevertheless, the information summarized below provides a valuable initial estimate of the viral loading to the Bay from discharge of fecal waste from vessels.

4.1.5 Boater Survey Results

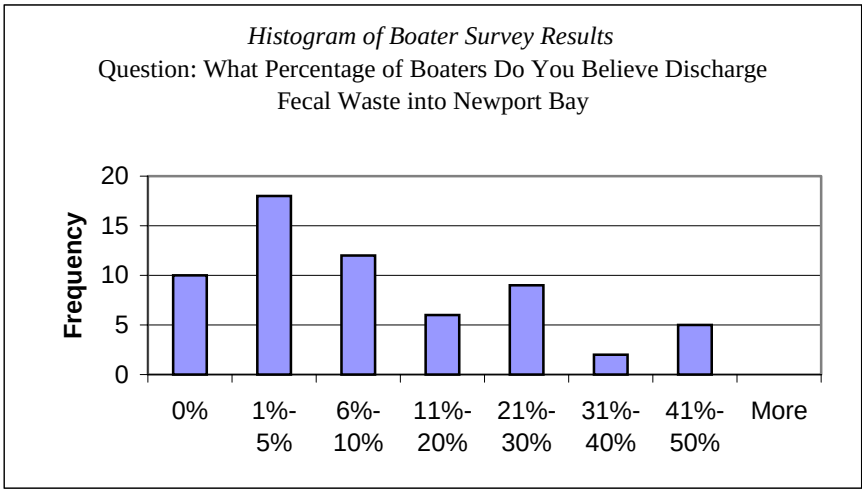
Results of the boater survey are summarized in Table 4.1.

Table 4.1
Summary of Boater Survey Results

	Median	Standard Deviation
Days/month on boat	8	8.4
Hours/day on boat	8	7.9
Average number of people on boat	3.5	2.2
Percent of time on boat that is weekend	50%	33%
Percent of boaters that discharge waste into the Bay	10%	15%

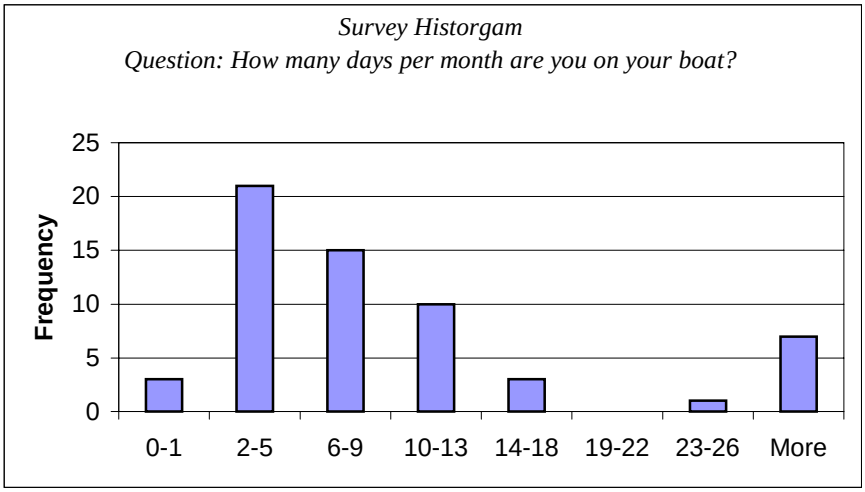
The Estimated Percent of Boaters Who Discharge Their Waste Into Newport Bay:
Responses for the percent of boaters that discharge their waste into the Bay ranged from a 0% to 50%. The median response was 10%. A histogram of survey responses is presented in Figure 4.1. Several respondents said they know that some boaters discharge their waste into the Bay because they have seen or smelled it. Some blamed "weekenders" (people that live outside Newport Bay, but berth boats in the marinas and visit Newport Bay on the weekend to use them). Others expressed concern about "live-aboards" (people that live on boats, including those with and without a permit to do so).

Figure 4.1



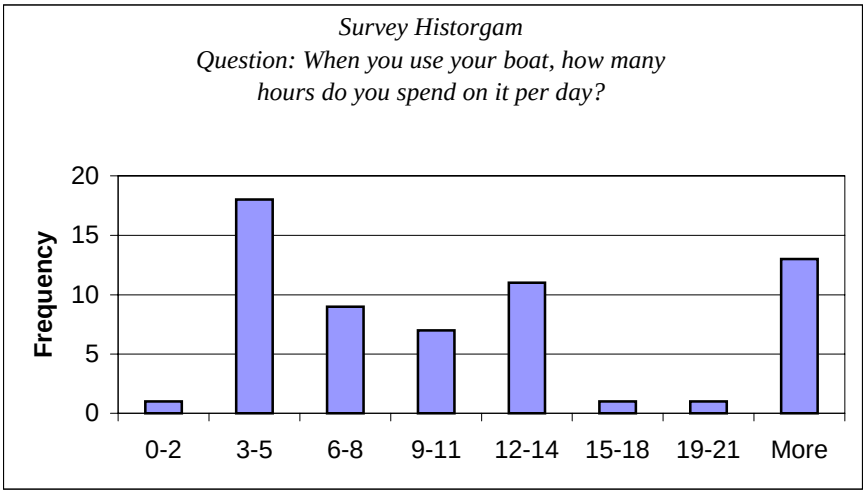
Number of Hours Spent Aboard Boats Resident in Newport Bay per Unit Time: Boaters were asked how many days per month they spent on their boats, how many hours/day, and how much of that time was on the weekend. Responses to these questions varied considerably. The variability in responses might reflect different types of boat users participating in the survey (e.g. live-aboards, weekenders, weekday users, etc.). Responses ranged from 1 day/month to 30 days/month. The median response was 8 days per month. A histogram of responses to this question is presented in Figure 4.2.

Figure 4.2



The responses to the question about the number of hours spent on boats per day ranged from 1 hour/day to 24hrs/day. The median value was 8 hours/day. A histogram of the responses to this questions is presented in Figure 4.3.

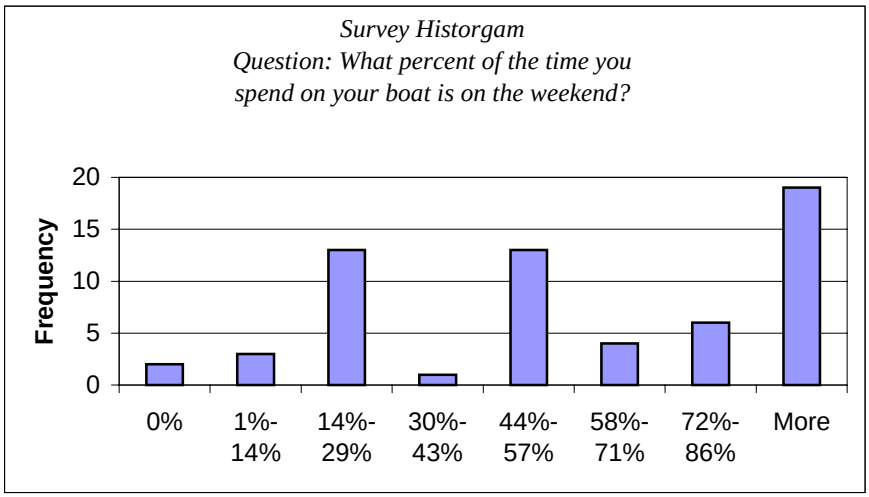
Figure 4.3



Percent of Time Spent on Boat on a Weekend: The 'percent of time on boat that is weekend' responses appear to fall into broad categories: 14-29%, 44-57%,> 86%, and

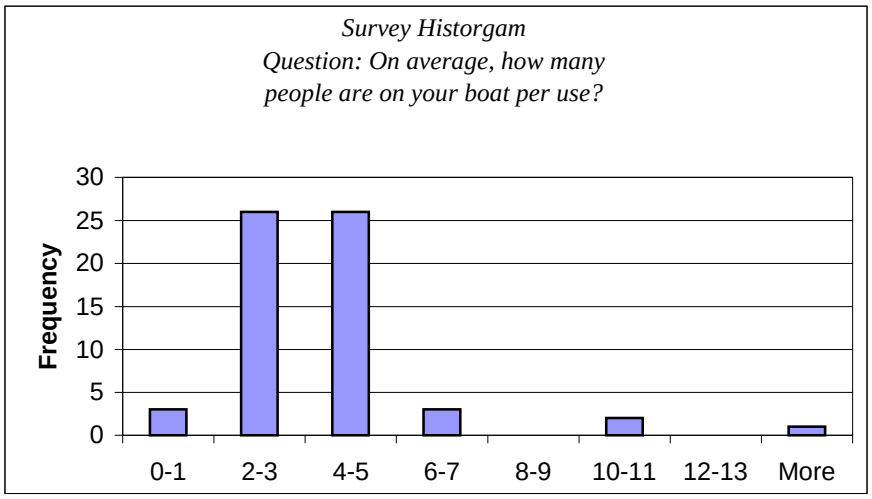
others. The 29% category probably captures live-aboards, for whom 2 days out of 7 they are on board of their boats on the weekend. The category "greater than 86%" likely captures “weekenders” for whom almost all the time on their boat is spent on weekends. The median response was 50%. A histogram of the results for this survey question is presented in Figure 4.4.

Figure 4.4



<u>The Average Number of People on Board Each Boat:</u> The average number of people on board ranged from 1 to 15. The median response was 3.5 people. As shown in Figure 4.5, there is a clear peak range of responses between 2 and 5 people.

Figure 4.5



<u>Holding Tank Use</u>: Almost all the boaters interviewed owned boats with holding tanks. Many of the boaters that indicated they did not spend much time in Newport Bay also indicated that they discharge their waste at sea. Of those boaters that indicated their boats have holding tanks, the majority said that they use Newport Bay pumpout stations. Those who do not use the pumpout stations, cited discharging at sea or not using the heads on

their boats at all as their reason for not using pumpouts. About a quarter of those surveyed said they use a pumpout service.

4.1.6 The Total Number of Boats Resident in Newport Bay;

Information on the number of boats in Newport Bay was provided by the Harbor Master and the City of Newport Beach. The information obtained included an estimate of the number of boats at moorings, residential piers, commercial marinas, and the number of permitted live-aboards.

For the waste loading estimate, the total number of boats was based on the number of permitted live-aboards (30), mooring sites (1220), and slips occupied at commercial marinas within Newport Bay (3000)(Sources: City of Newport Beach Marine Department and Orange County Harbor Master). Other boats were not included because it was assumed that boaters with residential piers were much less likely to discharge waste into Newport Bay (in general, with a boat docked at their residence, it is assumed that boaters are much less likely to use the head on the boat). Further, the survey was conducted primarily at marinas, as accessing private residences is difficult logistically. One possible exception would be unpermitted live-aboards leasing a slip at a private residence. Based on the methodology employed, the survey results are therefore most representative of the behavior of boaters using commercial marinas.

4.1.7 Estimate of Fecal Coliform and Viral Loading From Vessel Waste

Conceptually it may be understood that the estimate of fecal coliform and viral loading from vessel waste may be computed as follows:

Fecal Coliform or Virus[12] loading/day = L * P * B * D

where

L = loading/(person hour)

P = person hrs / (boat day) = 2.86 for weekdays and 11.43 for weekends

B = # boats = 4250

D = The percent of boats discharging waste to the Bay= 10%

The first term is derived below from literature values, and the second through fourth terms are derived from the site specific survey data described above.

Fecal Coliform Loading: Based on a coliform loading rate of 1.95×10^9 coliforms per day per capita [13] (Geldreich 1962; Hilton and Stotzky 1973; Feachem et al. 1983; Gerba 2000), and the formula presented above, the estimated fecal coliform loadings to Newport Bay from sanitary waste are summarized below:

Estimated weekday loading= 9.9×10^{10} fecal coliforms / day

Estimated weekend loading = 4.0×10^{11} fecal coliforms / day.

[12] This calculation is based on point estimates values that are a combination of conservative estimates and estimates of central tendency for each variable. The sensitivity of the modeling efforts to this loading estimate is explored in Chapter 7.

[13] Note that this value needs to be divided by 24 to yield units of per hour, to be consistent with the formula shown above.

Virus Loading[14]: Due to the available data in the literature, an estimation of virus loading is slightly more involved than that presented above for coliform. Data required are the grams of stool per capita per day, infective virus particles per gram of stool, and the percent of the population shedding viruses at a given time. The first two of these three values are obtained directly from the literature: 150 grams stool/day per capita (Feachem et al. 1983) and 10^8 infective rotavirus particles per gram stool from infectious persons shedding viruses in their feces (Flewett and Woode 1978).

The final piece of data (percent of the population shedding viruses at a given time) was derived from literature based data. To estimate percent of the population shedding viruses at a given time, some previously published studies have used incidence levels of infection (proportion of new cases to the total population for given time period) to estimate the loading from recreational activity (Anderson et al. 1998; Gerba 2000). However, it is the prevalence of enteric virus infection (proportion of the population that is infected at a given time) that is needed for this particular calculation.

Based on an epidemiological study reporting an estimated 5 symptomatic cases per 100 person years (Rodriquez et al. 1987), and another reporting 234 symptomatic cases per 3311 person years (Koopman et al. 1989), a duration of shedding of 10 days (Gomez-Barreto et al. 1976; Lycke et al. 1978; Gurwith et al. 1981; Ward et al. 1986), and by making the conservative assumption that enteric virus infections occur equally throughout the year, it may be conservatively estimated that 0.4% of the population is shedding rotavirus at any given time (prevalence)[15]. Based on the fact that rotavirus appears to be the most infectious of the probable waterborne viruses for which data are available (Haas et al. 1996), it is reasonable to use rotavirus as representative of enteric viruses in this component of the investigation. The value derived above may be corroborated by employing CDC's estimated illness rate of 3.9 million cases of rotavirus annually in the United States (Mead et al. 1999) and an estimated population in the U.S of 275 million, to yield an estimate of 0.1% shedding at any given time.

With the values presented above, the virus loading to Newport Bay from vessel sanitary waste is estimated as 2.5×10^6 infective virus particles / (person *hr) (derived as 150 grams per person per day * 10^8infective particles per gram * 0.4% of the population shedding). Using this estimate as described above, the estimated viral loadings to Newport Bay from sanitary waste are summarized below:

Estimated weekday loading =	3.0×10^9 infective virus particles/ day
Estimated weekend loading =	1.2×10^{10} infective virus particles / day

[14] Note that the risk model described in Chapter 6 is based on risk to enteric viruses and to that end employs the dose response for rotavirus and the occurrence of coliphage as health protective assumptions.

[15] For comparative purposes, Anderson et al. (1998) report an infection rate of 5-20% for rotavirus, and based on work by Monto et al. (1983), Gerba (2000) reports an annual rate of clinical infection of 10%.

4.2 AMBIENT MONITORING PROGRAM

The purpose of the ambient monitoring program was to augment the existing available information with additional data to support the water quality modeling efforts. As described in Chapter 2, the historic data collection efforts in Newport Bay focused primarily on total and fecal coliform. Recent efforts also include enterococcus. Based on discussions between RWQCB, IRWD, RMA, and EOA, Inc. staff, draft recommendations for the Ambient Monitoring Program were developed and distributed to the HAC and ex-officio participants for review. A summary of the documentation sent to the HAC and ex-officio participants during the development of the Ambient Monitoring Program is included in Appendix F.

The recommended Ambient Monitoring Program was composed of the following three components:

4.2.1 Ambient Monitoring Program : Phase I

The Ambient Monitoring Program Phase I was a screening phase in which limited male specific coliphage monitoring was amended to the existing OCHCA monitoring program. The purpose of this Phase of the investigation was to establish a preliminary set of data, covering Newport Bay and tributaries that could be used to assess the relative levels of indicator organisms present. This phase of work was carried out as a collaboration between IRWD and OCHCA. Samples were split in the field, with one set going to OCHCA for analysis of total coliform, *E. coli*, and enterococci, and the other set sent to IRWD for male specific coliphage analyses. Standard QA/QC was followed in both laboratories.

During Phase I, IRWD analyzed the water samples employing the membrane filtration method for recovery of coliphages form surface water. A copy of the protocol used during this Phase of the investigation is included in Appendix F. Approximately 135 samples were collected and analyzed for male specific coliphage for this effort. A summary of the results of those analyses are included in Appendix F. Reviewing the results from this Phase indicates that most the coliphage analyses were reported to be below the detection limit of 1 pfu/100mL.

Laboratory staff at IRWD expressed concerns that the low levels of coliphage found in the samples may have been related to interference from debris and algae. Alternative phage methods were investigated to address this concern. The methods investigated included using the Standard Double Agar Overlay Method (DAL) and the Vortex Flow Filtration Method (VFF). Staff felt that using VFF for concentration would improve the methodology by enabling larger volumes (1 to 20 liters) of samples to be processed, thereby increasing sensitivity. A small side by side study of DAL and VFF indicated good correlation between the two methods. Further method validation was carried out until IRWD laboratory staff had sufficient confidence in the VFF method to move forward with Phase II. Because the VFF required more processing time per sample, the initial scope of the Ambient Monitoring Program Phase II had to be scaled back to

accommodate the daily sample limitations. (Documentation regarding this change is included in Appendix F)[16].

4.2.2 Ambient Monitoring Program: Phase II

The purpose of Phase II of the Ambient Monitoring Program was to collect boundary condition data for the water quality model and in-Bay coliphage data for calibration of the water quality model. This phase of the investigation was also carried out as a collaboration between IRWD and OCHCA.

Samples collected during this phase of the investigation, were analyzed for *E. coli*, fecal coliform, total coliform, enterococcus, male specific coliphage, electrical conductivity, flow (major inflows and storm drains), salinity, and temperature. Samples were collected at three distinct types of sites for this Phase of the investigation: Upper Bay Inflows, Lower Bay Inflows, and In-Bay Stations. A summary of the stations included in this phase of the investigation is presented in Table 4.2

Table 4.2
Summary of Stations Inluded in Phase II

Upper Bay Inflows	
	San Diego Creek
	Santa Ana Delhi
	Big Canyon Wash Drain
	Back Bay Drain
	Santa Isabella Channel
	East Costa Mesa Drain
Lower Bay Inflows	
	Arches Drain
	43rd St Drain
	33rd St Drain
	Fashion Island Drain
	Corona del Mar Drain
In-Bay Stations	
	Newport Dunes
	Via Genoa
	Lido Island Yacht Club
	Sapphire Island
	Onyx Avenue
	Northstar Beach
	DeAnza Pier
	Vaughn's Launch

A total of approximately 260 samples were collected and analyzed during this phase of the investigation. A summary of the results from this Phase of the work is included in Appendix F.

4.2.3 Indicator Distribution Changes Through A Tidal Cycle (Phase IIb)

The final component of the Ambient Monitoring Program was to investigate how the distribution of indicator organism density changes throughout the course of a tidal cycle. To achieve this goal, total coliform, fecal coliform, male specific coliphage, and

[16] For more information on this phase of the investigation, please contact Ms. Debbi Clark at IRWD.

enterococcus samples were analyzed on two days throughout the course of a full tidal cycle. The monitoring included "slack after flood" and "slack after ebb" samples. On each day monitored, 8 sites were monitored no more than three hours apart throughout the tidal cycle. The sites included in this Phase included: the Dunes, De Anza pier, Northstar beach, Lido Island Yacht Club beach, Via Genoa, Onyx Avenue, Sapphire Avenue, and Vaughns Launch. The results from this phase of the investigation are included in Appendix F.

Upon completion of both phases of the Ambient Monitoring Program data collection efforts, the results were forwarded to RMA (along with the results previously described in section 4.1), so that the water quality modeling efforts could be carried out.

CHAPTER 5: WATER QUALITY MODELING

5.1 OVERVIEW

The purpose of this chapter is to summarize the water quality modeling efforts that were carried out for this investigation. Water quality modeling was carried out by Resource Management Associates (RMA) as a subcontractor to EOA, Inc. The water quality modeling efforts are described in detail in the RMA final report included in Appendix G. Readers interested in details regarding the water quality component of this investigation are strongly encouraged to review the full water quality modeling final report. A brief overview of the final report is presented below.

In previous work, the existing RMA finite element model of Newport Bay was calibrated for simulation of hydrodynamics, sediment transport, and basic water quality parameters including salinity, temperature, dissolved oxygen, nutrients, phytoplankton, and macrophytes. For the current investigation, the proven model was applied to model the fate and transport of fecal coliform and coliphage in Newport Bay during dry season conditions.

5.2 OBJECTIVES

The goal of the water quality modeling component of this investigation was to extend the existing water quality modeling capability for Newport Bay to include simulation of fecal coliform and coliphage in support of the fecal coliform TMDL for the Newport Bay watershed. The water quality model provides temporally and spatially varying concentrations of fecal coliform and coliphage for use by the disease transmission (health risk) model (described in detail in Chapter 6). These temporally and spatially varying concentrations of coliform and coliphage are used in the disease transmission model to define exposure from REC-1 contact along with site specific patterns of beneficial use in Newport Bay. A second goal was to evaluate alternative control strategies that may affect viral loading. Specific objectives of this component of the investigation included the following:

- Configure and calibrate a fecal coliform and coliphage transport model based on the existing RMA water quality model of Upper Newport Bay;
- Perform uncertainty analysis on the modeling results;
- Develop the linkage between the RMA model and the microbial risk model; and
- Perform simulations for a set of alternative control strategies and provide the resulting coliphage concentration results to the microbial risk model.

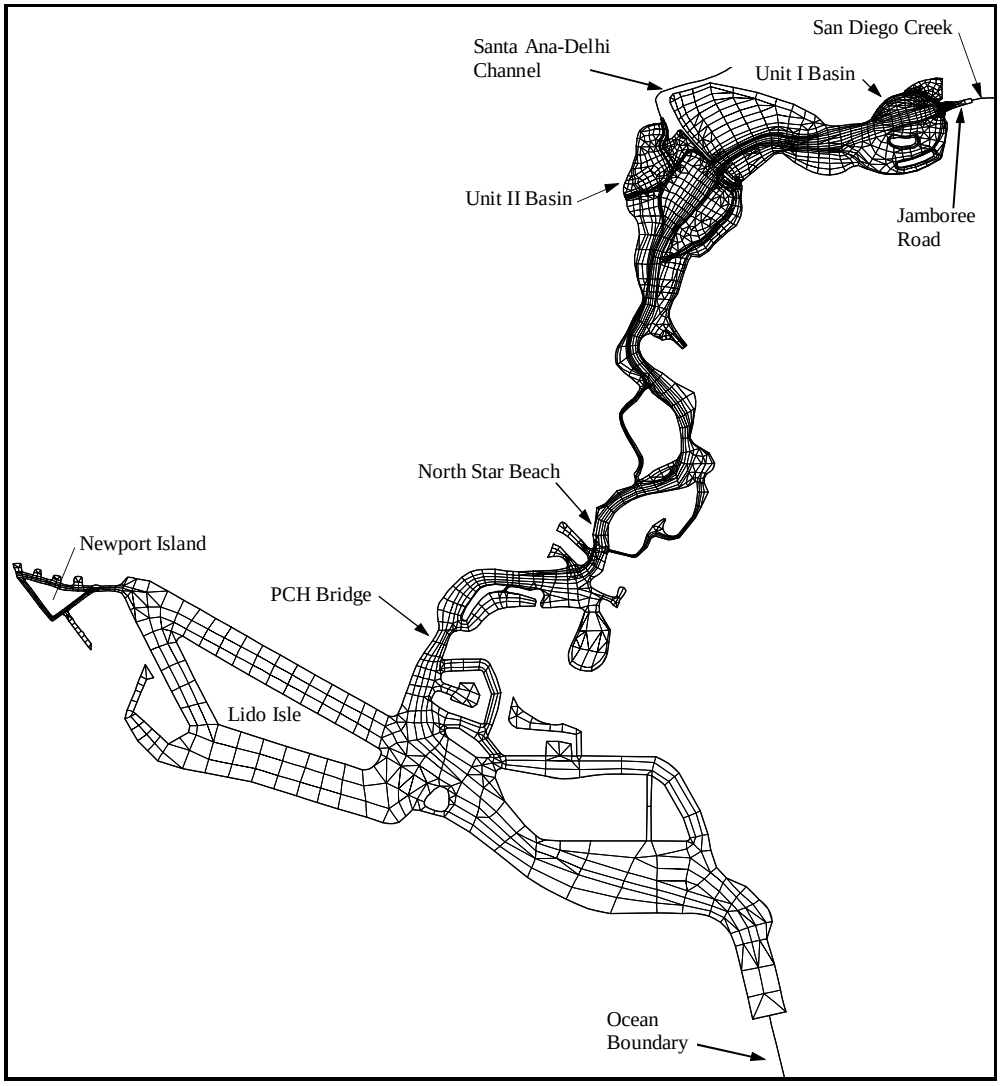
5.3 MODEL CONFIGURATION

The RMA finite element model of Newport Bay extends from the entrance of the Lower Bay to San Diego Creek just upstream from Jamboree Bridge. Tributary inflows are specified at San Diego Creek, Santa Ana Delhi Channel, Big Canyon Wash, Back Bay Drain (calibration periods only), East Costa Mesa Drain, Fashion Island Drain, and Arches Drain. The Bay is represented using a two-dimensional depth averaged

approximation, with short one-dimensional cross-sectionally averaged segments at the tidal boundary, San Diego Creek, and Santa Ana Delhi Channel.

An overview of the finite element mesh is provided in Figure 5.1. The finite element mesh includes the area of the Bay up to approximately +1m MSL. Because the bed elevations (bottom) in the Bay change over time, several bathymetric data sets have been developed for the model. Bathymetric data representing current conditions, including the recent Unit III dredging, were used for this study. These data are based on the 1997 comprehensive survey performed by the County of Orange and the Unit III dredging design plans (County of Orange Public Facilities and Resources Department, 1997). Model mixing coefficients were first calibrated during the Upper Newport Bay salinity study to best match observed salinity gradients in the Bay. These mixing coefficients were used for this investigation.

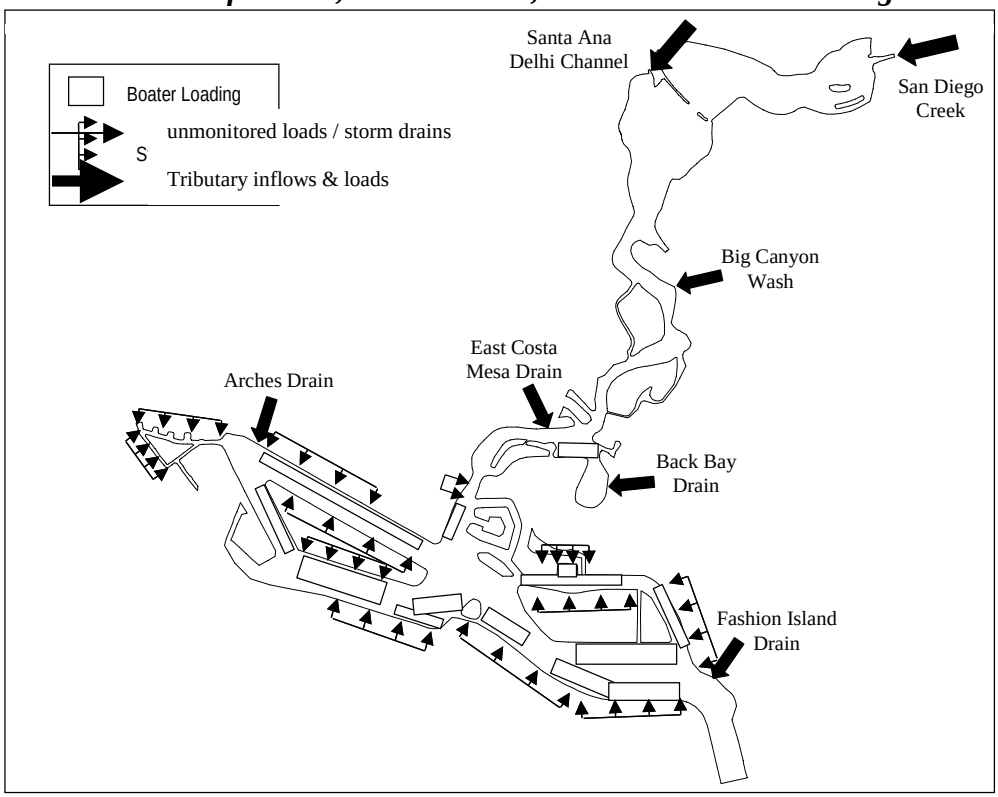
Figure 5.1
Finite Element Configuration for Newport Bay



5.4 FECAL COLIFORM MODELING

The difficulty in coliform and coliphage modeling is the uncertainty in loading rates. For the fecal coliform calibration, available data were used to estimate loads from the creeks and monitored storm drains, and literature values and site specific data were used to estimate loading from vessel waste and bathers. A graphical summary of the principal loading locations is provided in Figure 5.2. Literature values were used to estimate die-off rates in darkness and sunlight. To bring computed concentrations into agreement with observed data, loading estimates were made for the small, unmonitored storm drains in the lower Bay, and a distributed load was applied to represent undocumented non-point sources. The calibration method produced computed fecal coliform concentrations that are in good agreement with observed data throughout most of the Bay.

Figure 5.2
Locations of Creeks, Storm Drains, and Vessel Waste Loading



At the Dunes East site (area downstream of the Back Bay Drain), the known loads were not sufficient to produce coliform concentrations as high as those observed. It is possible that die-off rates from the literature are not applicable to Newport Bay. If lower die-off rates could be justified for use in the model, concentrations in the Dunes would increase while concentrations throughout the rest of the Bay could be kept near currently calibrated levels by reducing the distributed load. Another possible and more plausible explanation for the noted discrepancy at the Dunes East is the historic intermittent flow of the Back Bay drain. It appears, based on limited evidence, that the drain is a potential source of fecal contamination. Dry weather flow from the Back Bay drain is currently

diverted[17] to the sanitary sewer, and the concentrations of fecal coliform at the Dunes East site under current conditions are in good agreement with the water quality modeling results.

5.5 COLIPHAGE MODELING

Boundary conditions for the coliphage water quality modeling included inflow, temperature and coliphage concentration at San Diego Creek, Santa Ana Delhi and the major drains, and temperature and tidal elevation at the ocean boundary (coliphage concentration assumed to be zero at the ocean boundary). The hydrodynamics used in the fecal coliform simulation were also used for the coliphage simulation. Bather virus loads are applied at perimeter elements in the Dunes where swimming occurs, and vessel waste loads were applied at the marina locations as shown in Figure 5.2.

Two temperature dependent coliphage loss parameters were applied: die-off in darkness, and light sensitive die-off. The die-off rate in darkness range from approximately 0.0024 to 0.0045 hr^{-1}, with temperature dependence. The depth-averaged light sensitive die-off at peak sunlight ranges from approximately 0.0028 to 0.041 hr^{-1}, varying with depth and temperature. Literature values indicate die-off rates ranging from 0.0028 hr^{-1} to 0.096 hr^{-1} (Fujioka et al., 1980, Hurst and Gerba, 1980, and Raphael et al., 1985).

Boundary coliphage concentrations were set to the maximum of all available dry season coliphage data at each location. Based on monitoring carried out specifically for this investigation (Refer to Chapter 4), 1 to 12 dry season coliphage observations were available for each of the creeks and drains. The majority of the data were reported to be below detectable limits. The maximum values were chosen for boundary concentrations as a conservative and health protective assumption. If no data were above the detection limit (1 pfu/100mL) for a particular site, the boundary was set at the detection limit.

The goal of the coliphage simulation was to configure the coliphage model to match predicted coliphage concentrations with observed concentrations throughout the Bay as closely as possible. From the ambient monitoring program (Chapter 4) 2 to 5 dry season coliphage observations were available at each station. Almost all of the in-Bay data were reported to be below detectable limits (<1 pfu/100mL). Median values of the observed data at all stations were below the detection limit. Based on the limited amount of quantifiable data from the site specific monitoring program, rigorous calibration of the coliphage model was not possible. However it should be noted that in previous applications, the RMA model has been shown to simulate successfully the transport of dissolved and suspended constituents when the loading of those constituents are known. Thus, configuration of the coliphage model involved ensuring that the predicted coliphage concentrations at the sampling sites were consistent with the observed data. Should a new methodology become available in the future, with the capability of detecting organisms at a much lower level, a more rigorous calibration could be carried out. Based on these simulations, coliphage time series were generated for each of the water quality monitoring sites specified in Chapter 2.

[17] Personal correspondence with Larry Honeybourne, OCHCA, May 2001.

5.6 LOADING AND UNCERTAINTY ANALYSIS

The RMA model of Newport Bay has been used successfully to simulate transport of dissolved and suspended constituents. Fecal coliform and coliphage simulations are somewhat different than previous work, because the primary sources of uncertainty in the modeling results are the estimates of loading and die-off rates. With respect to uncertainty analysis, the important issues are as follows:

- What is the contribution of each individual source of loading to the fecal coliform and coliphage concentration at each of the OCHCA monitoring sites;
- What is the expected distribution of the fecal coliform and coliphage concentration at each of the OCHCA monitoring sites given the uncertainty in the estimate of each load, and
- What is the impact of the die-off rates on individual load contributions and expected distribution?

Because die-off is a first order decay process, linear superposition can be used to calculate the sum of all coliform or coliphage concentrations at any site. That is, the total concentration at any site is equal to the sum of the concentrations resulting from each of the loading sources (i.e. creeks, storm drains, etc.). To examine the contribution of individual loads for a given die-off rate, separate simulations were performed tracking the concentration response of individual loadings throughout the bay. The response is directly proportional to the individual loadings, so scaling the base response can generate the response for alternate individual loadings. A Monte Carlo scheme was used to develop the distribution of the total concentration at a particular site by summing the response for each load scaled by the estimated load distribution. The impact of the die-off rate is bracketed by developing concentration responses to individual loads with different values for the die-off rates.

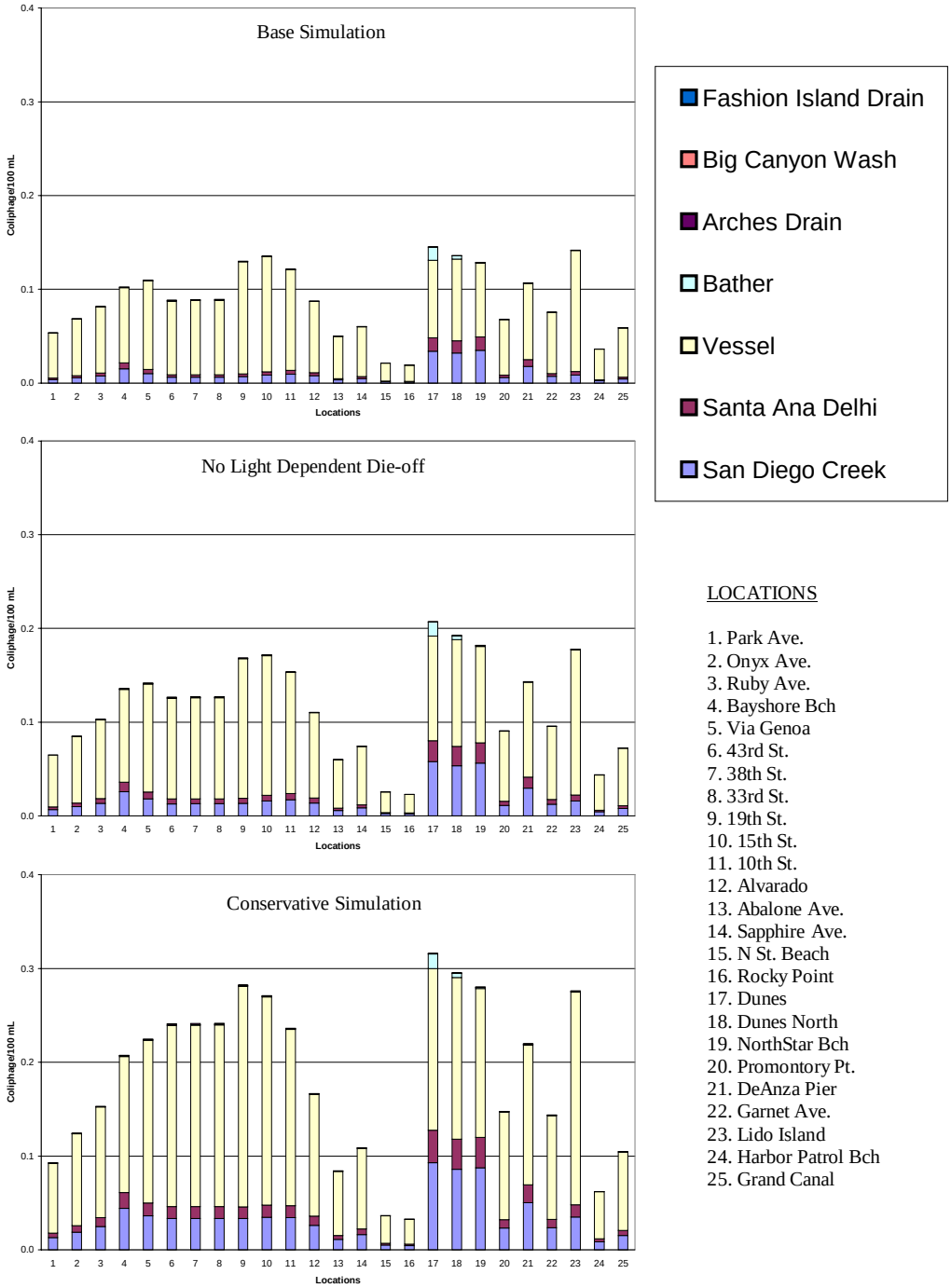
A post-processing routine was developed to determine the contribution from each load to fecal coliform and coliphage concentrations at the 25 specified locations throughout the Bay, and to analyze the uncertainty of the model results based on the probability distributions of input data and uncertainty in die-off rates. Individual load simulations were performed for each constituent using: (1) die-off rates from the respective calibration/configuration simulations, (2) no light dependent die-off, and (3) no die-off. Throughout the Bay the distributed load was found to be the largest contributor to fecal coliform concentrations using the calibrated die-off rates. With no die-off and the distributed load eliminated, San Diego Creek becomes the largest contributor to fecal coliform concentrations. For the coliphage simulations, the vessel loading was the most important load, regardless of the die-off rate. The importance of the vessel loading contribution for the total coliphage concentration is illustrated in Figure 5.3 which is a summary of the coliphage loading analysis.

To examine the importance of the uncertainty in the input data, Monte Carlo analyses were performed using the simulation scenarios described above. These analyses resulted with probability distributions of concentrations at 25 locations throughout the Bay based

on the probability distributions of data and uncertainty in die-off rates. The Monte Carlo results indicated that for fecal coliform simulations, the maximum expected concentration ranges at each site were up to 4 times the maximum computed values for the base simulation, up to 24 times the maximum computed values for the no light dependent die-off simulation, and up to 108 times the computed values for the conservative simulation. With no light dependent die-off the most probable fecal coliform values are increased by up to 3.6 times the base simulation.

For coliphage, the large uncertainty in the coliphage loading from vessel waste dominates the maximum expected concentration range calculated in the Monte Carlo uncertainty analysis. The maximum coliphage concentration ranges were up to 600 times the maximum computed value. Representative results are illustrated in Figure 5.4 for the Newport Dunes. With no light dependent die-off the most probable coliphage concentrations are increased by up to 2 times the base simulation, and with no die-off the most probable coliphage concentrations are increased by up to 4.7 times the base simulation.

Figure 5.3
Contribution of Individual Loads to Coliphage Concentrations at 25 Sites for Three Decay Scenarios



LOCATIONS

1. Park Ave.
2. Onyx Ave.
3. Ruby Ave.
4. Bayshore Bch
5. Via Genoa
6. 43rd St.
7. 38th St.
8. 33rd St.
9. 19th St.
10. 15th St.
11. 10th St.
12. Alvarado
13. Abalone Ave.
14. Sapphire Ave.
15. N St. Beach
16. Rocky Point
17. Dunes
18. Dunes North
19. NorthStar Bch
20. Promontory Pt.
21. DeAnza Pier
22. Garnet Ave.
23. Lido Island
24. Harbor Patrol Bch
25. Grand Canal

5.6 ALTERNATIVE SCENARIOS

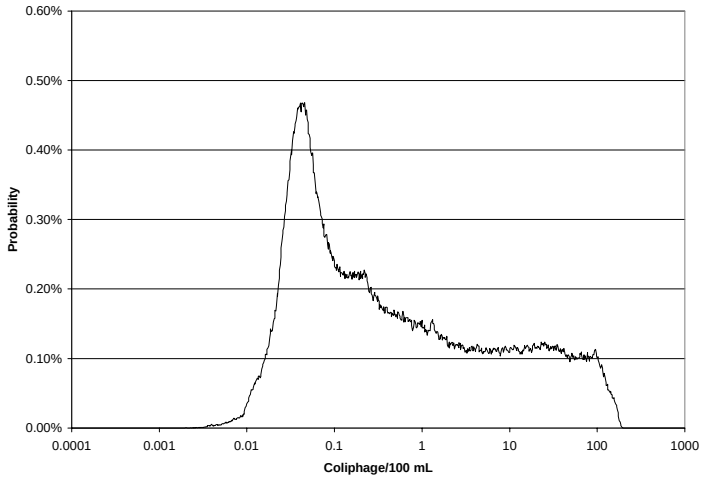
Simulations were performed for the following five alternatives:

1. Existing model with no input from San Diego Creek;
2. Existing model with no input from Santa Ana Delhi Channel;
3. Existing model with no input from Big Canyon Wash;
4. Existing model with decreased loading from vessels to 10% of its current level; and
5. Existing model with decreased loading from bathers to 50% of its current level.

Each simulation was run for a 9-month period using a 13-day repeating tide and the same boundary conditions as the coliphage calibration, with the exception of the changed parameter for each alternative as noted above. The Back Bay Drain was not included in the alternative simulations, because dry weather flow was permanently diverted from the Bay in March 2001. Boundary conditions were held constant (or used the same weekly or hourly variation) throughout the 9-month period. Meteorological data from the Irvine CIMIS station were used from March through November 1998.

Results indicated that with the elimination of coliphage loading from San Diego Creek, concentrations at the 25 sites would reduce from 6 to 30% on average. Elimination of Santa Ana Delhi channel coliphage loads would reduce concentrations at the 25 sites by 2 to 11% on average. Reduction of bather loading by 50% and elimination of the Big Canyon Wash coliphage load would have no significant impact on concentrations. The largest impact was from reduction of the vessel loads to 10% of the current level. The alternative in which the vessel load was reduced resulted in average concentration reductions ranging from 50 to 80% at the 25 sites. These are all independent results, if the load reductions from any of the alternatives were combined, the concentration deceases would be expected to be cumulative.

Figure 5.4
Uncertainty Analysis: Coliphage Probability Distribution at the Dunes for Three Decay Scenarios



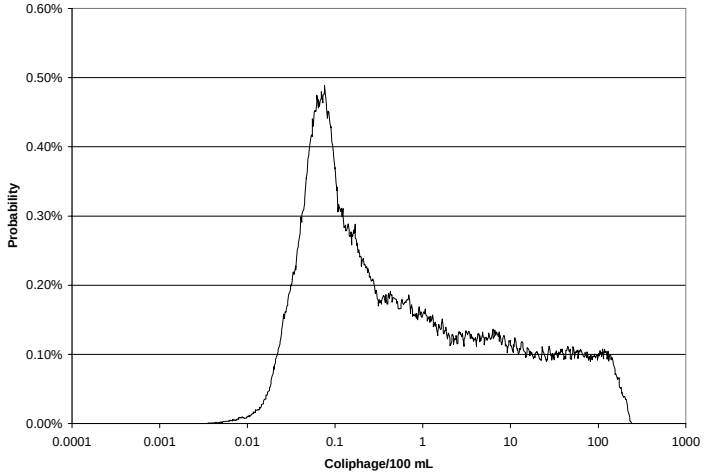
Base Simulation

Most Probable Concentration = 4.6E-2 coliphage/100mL

Median Concentration = 2.4E-1 coliphage/100mL

Max Concentration = 1.9E+2 coliphage/100 mL

Min Concentration = 1.8E-3 coliphage/100 mL



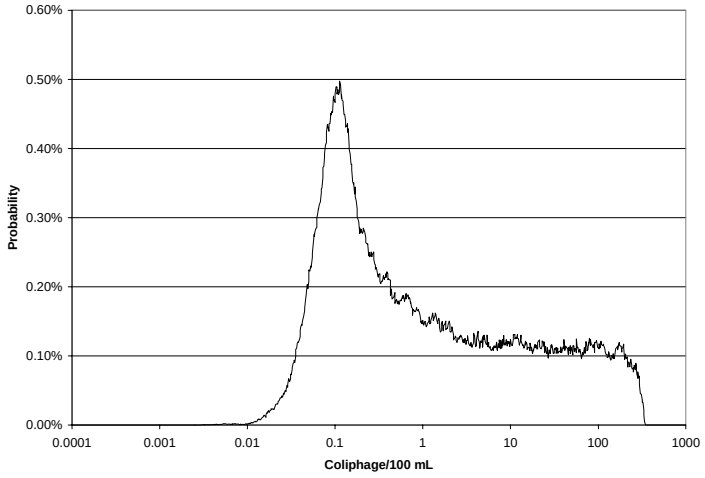
No Light Dependent Die-off

Most Probable Concentration = 7.8E-2 coliphage/100mL

Median Concentration = 2.9E-1 coliphage/100mL

Max Concentration = 2.4E+2 coliphage/100 mL

Min Concentration = 2.5E-3 coliphage/100 mL



Conservative

Most Probable Concentration = 1.2E-1 coliphage/100mL

Median Concentration = 4.6E-1 coliphage/100mL

Max Concentration = 3.5E+2 coliphage/100 mL

Min Concentration = 3.0E-3 coliphage/100 mL

CHAPTER 6: HEALTH RISK ASSESSMENT

6.1 OVERVIEW

The purpose of this chapter is to describe the approach taken to carry out the health risk assessment (HRA) and subsequently present a characterization of the level of relative risk to public health from water contact recreation in Newport Bay under the existing conditions (1999-2000).

To describe the HRA approach and results, the rationale for the route of exposure investigated in the HRA, the pathogen of interest, and the indicator organism used to characterize pathogen exposure are documented first. A model for infectious disease transmission is then presented for exposure to the pathogen. Several different types of data, developed and presented in previous Chapters, are then used, along with data derived through literature review as input to the disease transmission model. Representative output from the model is then presented followed by a characterization of relative risk from recreational contact for the existing conditions in Newport Bay.

6.1.1 Route of Exposure

The exposure pathway is the course that the microorganism takes from its source to a given receptor (U.S. EPA 1989). Each exposure pathway includes a source, a point of contact, and an exposure route. All members of a population are exposed to low levels of microorganisms through their daily activities. For the purposes of this assessment, that low-level exposure will be referred to as a "background" level of exposure. It is assumed that background exposure to microorganisms is manifested in a community as the endemic level of disease in that community.

People may be exposed to additional microorganisms above background levels through a variety of activities. Those individuals exposed to above background levels of microorganisms in the Newport Bay watershed include those persons who use the Bay for recreational activities such as swimming, scuba diving, kayaking, and fishing, as well as those that collect and consume shellfish. Given that the first phase of the TMDL is focused on the protection of the REC-1 beneficial use, it is assumed for this health risk assessment that above background exposure to pathogens occurs through body contact recreation in Newport Bay. Although, it is recognized that microorganisms come into contact with the body through a variety of exposure routes (i.e. ingestion, skin contact, inhalation), ingestion will be the only route of exposure addressed in this risk assessment. The ingestion assumption is consistent with the available epidemiological data from which it can be concluded that this route of exposure is the most significant (Mead et al. 1999) for waterborne pathogens.

6.1.2 Pathogen of Interest

Conducting a risk assessment to establish the relative health risk associated with body contact recreation in Newport Bay requires the selection of a representative pathogen on which to conduct the assessment. Based on research conducted over the last 20 years by a number of researchers and federal agencies (Cabelli 1983; Levine and Stephenson 1990; Palmeteer et al. 1991; Sobsey et al. 1995; Fankhauser et al. 1998), the primary risk

associated with recreational exposure to waterborne pathogens is most likely from viral agents. Further corroborating evidence is available from the World Health Organization (WHO 1999) and a recent report from the Centers for Disease Control (Mead et al. 1999). From the data presented in that CDC report it may be estimated that approximately between 85 and 90% of all waterborne infections in the United States are due to viral pathogens. It should be noted that the above statement does not mean that outbreaks do not occur from exposure to parasites and/or bacteria, but rather that the vast majority of infections throughout the United States from waterborne pathogens, and specifically from recreational exposure are likely to be viral.

Given the abundance of evidence gathered on the importance of enteric viruses with respect to recreational exposure to waterborne pathogens, it was assumed for this assessment that public health risk to enteric viruses are conservatively representative of the overall health risk associated with exposure to pathogens derived from human sources via recreational contact in Newport Bay. The appropriateness of this approach was addressed at the project's first advisory committee meeting, where HAC members and ex-officio participants agreed unanimously with the reasonableness of the approach and the proposed course of action to characterize health risks associated with body contact recreation in Newport Bay. The proposed course of action is further supported by the fact that "sources other than human fecal contamination present a significantly lesser risk to human health" (WHO 1999), and is consistent with previous related work in this field (EOA Inc. 1995; EOA Inc. and U.C. Berkeley School of Public Health 1995; EOA Inc. et al. 1996; Haas et al. 1996).

6.1.3 An Epidemiological Model for Disease Transmission

Based on available dose-response and clinical data, and on relative public health importance of pathogens for which sufficient data are available, rotavirus was selected as the representative virus for enteric virus infections and disease (Kapikian et al. 1980; Gurwith et al. 1981; Champsaur et al. 1983; Black et al. 1984; Mead et al. 1999). Because rotavirus appears to be the most infective virus for which dose response studies are available[18] (Haas et al. 1999), the modeling approach taken in this investigation should be seen as health protective (i.e. this investigation models a pathogenic agent as prevalent as coliphage in the environment and as infectious as rotavirus). Rotavirus also exhibits the critical epidemiological properties associated with other enteric viruses, including person to person transmission and (short term) protection from reinfection.

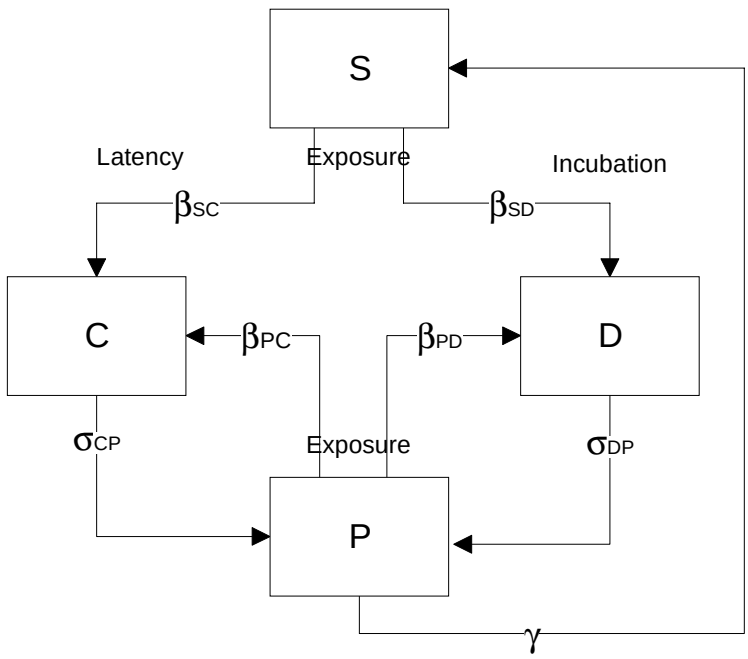
From an epidemiological point of view, the population can be considered to be divided into distinct states with respect to enteric viruses. In general, members of a population could be susceptible, infected, or protected (immune) from disease. However given what is known about enteric viruses from a review of the epidemiological literature (Gomez-Barreto et al. 1976; Champsaur et al. 1983; Koopman and Monto 1989; Ansari et al. 1991; Molyneaux 1995), it can be demonstrated that a simple "susceptible – infected – recovered" (SIR) type model may not be sufficient to characterize the movement of the

[18] Dose response data for Norwalk-like (caliciviruses) viruses are currently under development. Those viruses may be similar to rotavirus in infectivity. However, the dose response research was not completed sufficiently at the time this investigation was carried out to be considered.

population between states (Hethcote 1976; Anderson and May 1991). For example, it is known that (1) some protective immunity can be attained after recovery from enteric virus disease(rotavirus or Norwalk like viruses are examples), however, this immunity may be neither absolute nor long-term; and (2) it is possible (and in fact is common) to have an enteric virus infection without demonstrating the symptoms of disease.

For the modeling effort in this investigation, the epidemiological states of the population are characterized as follows: (1) Those susceptible to disease (S), (2) Carriers of the disease, defined as those who are infectious but not symptomatic (C), (3) Diseased individuals, defined as those who are symptomatic and infectious (D), and (4) Those in a post-infection state who are not infectious and not fully susceptible due to (limited and short-term) immunity (P). A schematic diagram illustrating the disease transmission model is presented in Figure 6.1.

Figure 6.1
Schematic Diagram of Disease Transmission Model



State Variables	***Rate Parameters***
S :Not Infectious, not symptomatic	B_{sc}: Fraction of individuals in state S that move to state C per hour
C: Infectious and not symptomatic	B_{sd}: Fraction of individuals in state S that move to state D per hour
D: Infectious, symptomatic	B_{pc}: Fraction of individuals in state P that move to state C per hour
P: Not Infectious, not symptomatic	B_{pd}: Fraction of individuals in state S that move to state D per hour
with short-term or partial immunity	σ_{cp}: Fraction of individuals in state C that move to state P per hour
	σ_{dp}: Fraction of individuals in state D that move to state P per hour
	γ:Fraction of individuals in state P that move to state S per hour

To describe the transmission of enteric virus infection and disease within a population, the conceptual model includes both state variables and rate parameters. State variables (S, C, D, and P) are used to track the number of people that are in each of the states at any

given point in time, and are defined such that the sum of the state variables equals the total population. Rate parameters determine the movement of the population from one state to another. In general, the rate parameters are denoted as Greek letters with appropriate subscripts: β (rate of acquiring infection) , σ (rate of recovery from infectious states), and γ (rate of decline in immunity). Rate parameters may be determined directly through literature review or may be more complicated functions of other variables which are determined through literature review.

To illustrate how the model calculates movement of population members between states, consider the susceptible portion of the population during a particular point in time. From Figure 6.1 it can be seen that upon exposure, three processes affect the number of susceptible individuals within the population: 1) some members of the population will move from the susceptible state S to the carrier state C (this happens at rate β_{SC}), 2) some members will move from the susceptible state S to the diseased state D (this happens at rate β_{SD}), and 3) other members of the population will move from the post-infection state P back to the susceptible state S (at rate γ). This same approach can be employed to account for movement of the population between any two states[19].

For this investigation, two routes of transmission are considered: primary transmission in which the exposure vehicle is either background exposure or recreational contact in Newport Bay, and secondary transmission which includes all other routes of transmission including person-to-person transmission.

Rate parameters describe the movement between states due to both primary and secondary transmission routes. Mathematically, the movement of the population between states may be modeled as a series of ordinary differential equations. Using this approach and assuming that each of the transmission processes described above are independent (Hethcote 1976), the change in the fraction of the population in any state from one time period to the next is modeled as a first order differential equation. For example, the relative change in state S from one time period to the next due to primary infection can be described as:

$$dS_1/dt = -\beta_{SC1}\, S - \beta_{SD1}\, S + \gamma\, P$$

β_{SC1} is the rate at which the population moves from State S to State C due to primary exposure,
β_{SD1} is the rate at which the population moves from State S to State D due to primary exposure, and
γ is the rate at which the population moves from State P to State S.

Similarly, the relative change in state S from one time period to the next due to secondary (person to person) infections can be described as the change in the number of individuals who move out of State S due to secondary infection, which is directly related to the number of individuals who are in States S, C and D during that time period.

$$dS_2/dt = -(\beta_{SC2} + \beta_{SD2})\, S\, (D+C)$$

[19] For this model, the distribution of time spent in each state is exponential with the rate based on literature based data. Adaptations of this model are possible in which the distribution of time spent in each state is skewed (lognormal or gamma, for example) (Eisenberg, et. Al., 1998), however for this investigation, a priori evidence that additional complexity was warranted, was not sufficient to include this modification.

β_{SC2} is the rate at which the population moves from State S to State C due to secondary exposure,
β_{SD2} is the rate at which the population moves from State S to State D due to secondary exposure, and
$\beta_{SC} = \beta_{SC1} + \beta_{SC2}$,
$\beta_{SD} = \beta_{SD1} + \beta_{SD2}$.

Primary and secondary transmissions are assumed to be independent processes (Hethcote 1976). Therefore, the overall change in the number of susceptible individuals from one time period to the next is simply:

$$dS/dt = dS_1/dt + dS_2/dt$$

6.1.4 Indicator Organism for Investigation

The concentration of pathogenic organisms present in environmental waters is generally low as well as highly varied in characteristic or type and, hence, difficult to identify, enumerate, and isolate. Therefore, scientists and public health officials typically monitor nonpathogenic organisms that are associated with fecal contamination, but are more easily sampled and measured[20] (indicator organisms). Although indicator organisms are employed in this investigation to estimate virus concentrations in Newport Bay, the HRA methodology employed could easily be modified to take advantage of quantitative virus monitoring data, should such data become available in the future.

Although EPA states that "The selection of fecal indicator organisms is a difficult and controversial process", they nevertheless recommend that an appropriate fecal indicator be selected based on the information known about the waterbody and the potential impairment (U.S. EPA 2001). Moreover, EPA states that consideration in the selection of an indicator organism should be given to established water quality standard(s), alternative indicators, and designated beneficial uses. Consistent with these criteria, male specific coliphage was selected as the indicator organism for this investigation. The basis for the selection of male specific coliphage as the indicator organism is delineated in the following discussion. Interested readers are referred to Appendix D in which an independent Review Panel's comments on the selection of indicator organism for this investigation are summarized and responded to.

6.1.4a: Bacterial Indicators: Total coliform, fecal coliform, *Escherichia coli*, *Klebsiella spp*., *Streptococcus faecalis*, *Streptococcus faecium*, *Clostridium perfingens*, and enterococcus are bacteria that are/have been used as indicator organisms for pathogens (U.S. EPA 2001). Coliform bacteria, for example have been used since 1914 to determine the sanitary quality (Hazen 1988) of drinking waters. From a review of the literature, numerous studies have been published over the past 85 years supporting the use of bacterial indicators. At the same time many other studies have been published describing the limitations in the use of indicators under various circumstances.

[20] According to Feachem (1983), the ideal fecal indicator should be: (1) A member of the intestinal flora of healthy people, (2) Exclusively intestinal in habitat, (3) Absent from nonhuman animals, (4) Present whenever fecal pathogens are present, and present only when fecal pathogens might reasonable be expected to be present, (5) Present in higher numbers than fecal pathogens, (6) Unable to grow outside of the intestine, with a die-off slightly less than fecal pathogens, (7) Resistant to natural antagonistic factors and to water and waste treatment processes to a degree equal to or greater than that of fecal pathogens, (8) Easy to detect and count, and (9) Nonpathogenic.

Federal water quality criteria recommendations were first proposed in 1968 by the National Technical Advisory Committee (NTAC) of the Department of the Interior. The microbiological criterion suggested by the NTAC for bathing waters was based on a series of studies conducted in the 1940s and 1950s by the United States Public Health Service (PHS). The studies were conducted at bathing beaches located on Lake Michigan in Chicago, IL, on the Ohio River in Dayton, KY, and on Long Island Sound, NY. In each case, two beaches with different water quality were selected, cooperating families recorded their swimming activity and illnesses on a daily basis for the entire summer.

Data from the Ohio River study indicated that swimmers who swam in water with a median coliform density of 2300 total coliform/100mL had an excess of gastrointestinal illness when compared to an expected rate calculated from the total study population. An analysis of the Lake Michigan study comparing a one week time period following three days of high coliform density, with a corresponding time period following three days of low coliform density corroborated the Ohio River study results. The results of the two marine bathing beach studies showed no association between illness and swimming in water containing approximately 400 and 800 total coliforms/100mL.

The coliform water quality index used during the studies noted above was translated into a fecal coliform index in the mid-1960s by using a ratio of fecal coliform to total coliform at the location on the Ohio River where the original study had been conducted in 1949. About 18% of the coliforms were found to be fecal coliforms and this proportion was used to transform the density at which a statistically significant swimming-associated gastrointestinal illness was observed to a fecal coliform standard (400/100mL). The NTAC suggested that a detectable risk was undesirable, and, therefore, one half of the density at which a health risk occurred, 200/100mL was proposed. The recommended criterion for fecal coliform was thus generated. Although the criterion adopted was criticized on a number of technical issues, it was again recommended by the US EPA in 1976.

In 1972 EPA initiated a series of studies at marine and fresh water bathing beaches which were designed to correct the perceived deficiencies of the PHS studies. One goal of these EPA studies was to determine if swimming in sewage-contaminated water carries a health risk for bathers, and if so, to what type of illness. If a quantitative relationship between water quality and health risk was obtained, two additional goals were to determine which bacterial indicator is best correlated to swimming associated health effects and if the relationship is strong enough, to provide a criterion.

The results of the EPA bathing beach studies are described by Cabelli (1983) and Dufour (1984). In those studies it was found that elevated levels of enterococci bacteria were more strongly correlated with gastroenteritis in both fresh and marine recreational waters than any of the other indicators investigated. In fresh water, *E. Coli* was also found to correlate with gastroenteritis, but total coliform and fecal coliform were uncorrelated or weakly correlated with this adverse health effect (Cabelli et al. 1982; Cabelli et al. 1983; U.S. EPA 1986). A review by Pruess (Pruess 1998) of 22 studies of recreational waters

showed that the indicator that best correlated with illness for marine water was the ratio of enterococci/fecal streptococci. It is however, noteworthy to consider that Pruess (1998) reports that randomized control trials (Kay et al. 1994; Fleisher et al. 1996) permit more accurate assignment of exposure, and probably are the most accurate of the studies investigated, and that the randomized control studies found fecal streptococcus to be the only indicator that correlated with gastroenteritis. The Pruess investigation was used by US EPA as a basis for their Implementation Guidance for Ambient Water Quality Criteria for Bacteria (U.S. EPA 2000).

Contrary to the above studies there are many studies indicating that bacterial indicators are marginal or inappropriate for use as indicators for viral pathogens. The following are representative of such research:

- "Relating indicator organism densities to the individual bather is an extremely important aspect of study design. This (Fleisher, et al., 1993) is the first epidemiological study to relate indicator organism density to the individual bather….The lack of adequate control for the possible confounding effect of non-water related risk factors, coupled with imprecise measurement of exposure among bathers contained in all previous epidemiological studies, question the validity of previous findings, and thus the appropriateness of current marine water criteria" (Fleisher et al. 1993).
- "Our failure to correlate the occurrence of enterovirus in marine waters with indicator bacteria, and the frequent occurrence of enterovirus in water which met current bacteriological standards, indicates that these standards do not reflect the occurrence of enteroviruses and perhaps other human pathogenic viruses in marine waters" (Gerba et al. 1979);
- The "Results of this analysis show the mathematical relationship between enterococci density and swimming associated gastroenteritis derived by Cabelli to be of questionable validity so that current federal bacteriological water quality criteria governing marine recreational waters are not based on strong enough evidence to support their continued use" (Fleisher 1991);
- "Coliforms seem to have little value of indicators of risks of gastroenteritis" (Kay et al. 1994)
- "*E. Coli* and enterococci are unreliable as indicators of viral pathogens, because they may be less persistent than viruses" (Sobsey et al. 1995);
- "It is now agreed that the bacterial indicators do not reflect the behavior of viruses" (Gantzer et al. 2000); and
- "Fecal coliform have been found to be severely limited in determining the significance and sources of fecal contamination in ambient waters" (McLaughlin and Rose 2000).

<u>6.1.4.b: Coliphages as Indicator Organisms:</u> In recent literature it has been reported that male specific F^+ RNA coliphages (FRNA coliphages), a group of small icosahedral bacteriophages infecting male strains of *E. Coli*, may fulfill many of the essential requirements of a viral indicator (Havelaar et al. 1984; Havelaar et al. 1986; Havelaar 1987; IAWPRC Study Group 1991; Havelaar et al. 1993; Sobsey et al. 1995; Paul et al. 1997). Moreover, it is reported that "Bacteriophages are physically and chemically

related more closely to human enteric viruses and are more similar to them in such characteristics as environmental persistence and resistance to treatment than are indicator bacteria" (Sobsey et al. 1995). Coliphages are also listed as potential indicator organisms for TMDL development by EPA's Office of Water (U.S. EPA 2001).

A review of the literature indicates that numerous studies have been carried out suggesting that the use of FRNA phages may be appropriate for this investigation of health risk associated with body contact recreation in Newport Bay. A summary of the most relevant studies follows:

- Vaughn and Metcalf (Vaughn and Metcalf 1975) studied the occurrence of coliphage and enteric viruses in estuarine waters over 3 years. In water samples, they found coliphage occurred more often than virus, although the ratios varied wildly. Later work (Gerba 1987) indicated that the recovery method used in the Vaughn and Metcalf study may have been partly at fault for the variation in the observed ratios. In only 1 out of 53 samples collected were viruses found when no coliphage were present;
- Simkova and Cervenka found agreement between enteric viruses and phages in terms of presence and absence and noted that their seasonal variations followed the same pattern (Simkova and Cervenka 1981);
- Borrego and co-workers carried out an investigation to determine the relation between coliphage, their bacterial hosts, and pathogenic microorganisms in natural waters. The results indicated that the coliphages are good indicators of the presence of pathogenic microorganisms. They reported that "The results suggest that coliphages are better indicators of fecal pollution that the classical indicator systems employed" (Borrego et al. 1987);
- Geldenhuys and Pretorius (Geldenhuys and Pretorius 1989) compared phages, enteric viruses, and bacterial indicators in South African freshwater, and found the strongest correlation between phages and enteric viruses;
- In summarizing work carried out by Stetler (1984) and Wentsel and co-workers (Wentsel et al. 1982), Paul and co-workers state that "The abundance of coliphages has been correlated with the presence of enteric viruses and has been considered an indicator of virological and general hygienic water quality" (Paul et al. 1993);
- Havelaar and co-workers summarized data on fate of human viruses and model organisms, and addressed the relationship between virus and phage concentrations in freshwater. In this study they conclude that the "Results confirm the effectiveness of F+RNA phages as model organisms for human viruses in a wide range of environments and treatment processes (including rivers and lake waters)" (Havelaar et al. 1993). Further, they state that "The strong relation between virus and F^+RNA phage concentrations in surface waters makes the organisms a suitable alternative for direct detection of viruses in recreational waters". It should be noted that there were several occasions when they did find enteroviruses in absence of F+RNA phage. The authors were not overly concerned with this finding however, and conclude that "These cases were exceptional and the concentrations were less than 0.01 particle/100mL". Finally, it should be noted that in this study they found significant correlations (at 99%

C.L) between FRNA phages and both enteroviruses and enteric viruses at ratios of approximately ~1000:1;

- Sobsey and co-workers found that the presence of F^+RNA phages appears to coincide with the presence of *E. coli* and enterococci. Based on this observation they stated that "This supports (the) hypothesis that F specific phages are found typically in surface waters impacted by fecal wastes and are not typically found in the absence of fecal contamination. The results of this study provide clear evidence that F-specific phages … appear to be reliable and useful indicators of fecal contamination" (Sobsey et al. 1995);
- Jagals and co-workers found that male specific coliphages met the required characteristics of a good indicator organism for enteric viruses and was only detected in water exposed to human fecal pollution. This finding led them to conclude that male specific coliphages are more likely to indicate fecal pollution of human than animal origin (Jagals et al. 1995);
- "Because of viral stability compared to its host, coliphage appear to be better indicators of marine water quality than fecal coliform. Evidence suggests that coliphage are the best indicators to date of human enteric viruses … and based on the isolation of phages at various bathing beaches should be used for continuing evaluation of recreational waters" (Paul et al. 1997);
- Chung and co-workers carried out an investigation to evaluate F^+RNA phage as an indicator of viral and fecal contamination in estuarine water (using new assay methods). They concluded that "F^+RNA coliphages were reliable indicators of enteric viruses and fecal contamination in oysters. *B. fragilis*, salmonella, fecal coliform, *E. coli*, and enterococcus did not represent fecal contamination" (Chung et al. 1998);
- "We found (that) male specific coliphages recovered from environmental waters can be presumed to be of anthropogenic origin. As such, male specific bacteriophage may be a reliable indicator of enteric viral pathogens in environmental waters….The results strongly support the use of male specific bacteriophage as the indicator of choice for assessing the potential presence of human enteric viruses in estuarine and marine environments impacted by wastewater sources" (Calci et al. 1998); and
- Grabow and co-workers recently published an update on bacteriophages as models for viruses in water (Grabow 2001). In that manuscript they report the following: In a survey of a range of waste waters and raw water sources, FRNA phages have been found to outnumber cytopathogenic enteric viruses by a factor of about 100. This implies that the absence of FRNA phages from raw and treated water supplies offers a meaningful indication of the absence of human enteric viruses". The use of phages as models/surrogates for enteric viruses is "based particularly on structure, composition, size, and mode of replication which resemble enteric viruses much closer than commonly used bacterial indicator of faecal pollution such as coliforms and enterococci". In addition, phages closely meet the requirements of models/surrogates for enteric viruses, survive longer in natural waters than enteric viruses, and (FRNA) phages fail to multiply in the environment".

Further evidence supporting the use of coliphage as an indicator for this investigation is provided by studies that indicate that the survival of FRNA phages more closely resembles that of viruses as compared to bacterial indicators (Baldini et al. 1978; Borrego et al. 1987; IAWPRC Study Group 1991; Armon and Kott 1996; Wommack et al. 1996; Paul et al. 1997; Griffin et al. 1999; Sinton et al. 1999; McLaughlin and Rose 2000).

In addition to the studies summarized above, a close review of the literature also indicates that FRNA coliphage satisfies the criteria for an indicator organism that it is present in equal or higher numbers compared to the pathogen of interest. Studies illustrating this indicator criterion include those published by Havelaar (Havelaar et al. 1993), the Santa Monica Bay Restoration Project (Gold et al. 1992), the American Water Works Research Foundation (AWWARF 1999), Dutka (Dutka et al. 1987), Kott (Kott et al. 1974), Stetler (Stetler 1984), Morinigo (Morinigo et al. 1992), and Jagals (Jagals et al. 1995). In these studies, the ratio of coliphage to viruses varied significantly, both between and within investigations. However, in all of these studies it was suggested that coliphage were found in equal or greater numbers than viruses.

The ratio of coliphage to viruses reported in the investigations cited above ranged from ~1:1 to ~1,000,000:1, with levels most commonly reported between 100:1 and 1000:1. A ratio of 1:1 was selected for this investigation to be protective of public health. By assuming that each coliphage enumerated represents a viable virus, the health risk assessment assumes the "worst case" scenario currently reported in the literature[21]. Therefore, by using observed coliphage concentrations as a surrogate for enteric viruses, it can be inferred that the approach employed in this investigation most likely overestimates the actual presence of viruses of more public health concern, such as rotavirus which are more pernicious but occur at lower frequency (Rao and Melnick 1986; Haas et al. 1996).

6.2 Conceptual Model for Exposure and Transmission of Disease

A schematic representation showing the relation between key data sources, the water quality modeling component, and the disease transmission model is presented in Figure 6.2. As illustrated in Figure 6.2, the water quality model and disease transmission model incorporate several components of data that were presented previously in this report.

The water quality model incorporates OCHCA water quality monitoring data (Chapter 2), the ambient monitoring program data (Chapter 4), estimates of vessel waste loading (Chapter 4), and results of the beneficial use monitoring and survey (Chapter 3) (to estimate loading from swimmers). The water quality model computes hourly concentrations of FRNA coliphage (as an indicator for enteric virus concentrations) at each of the recreational sites in Newport Bay, and that information is transferred to the disease transmission model.

[21] This was an issue that was raised during the Newport Bay Watershed Management Committee independent review on March 29, 2000 A written response was provided to the expert Review Panel. Refer to Appendix D.

The disease transmission model takes as input the concentrations from the water quality model, beneficial use monitoring and survey data, and disease specific data derived via literature review, and outputs a characterization of risk to public health. To develop the characterization of risk, it is necessary to account for the variability and uncertainty associated with each of the variables in the models. The variability and uncertainty is carried forward in the disease transmission model by employing a probabilistic simulation technique known as Monte Carlo simulation, whereby the feasible values of each variable are sampled randomly and the model simulations are run many (thousands of) times. The resultant output, therefore, conveys not only an estimate of risk, but also a measure of the variability and uncertainty in that estimate of risk.

6.3 EXPOSURE

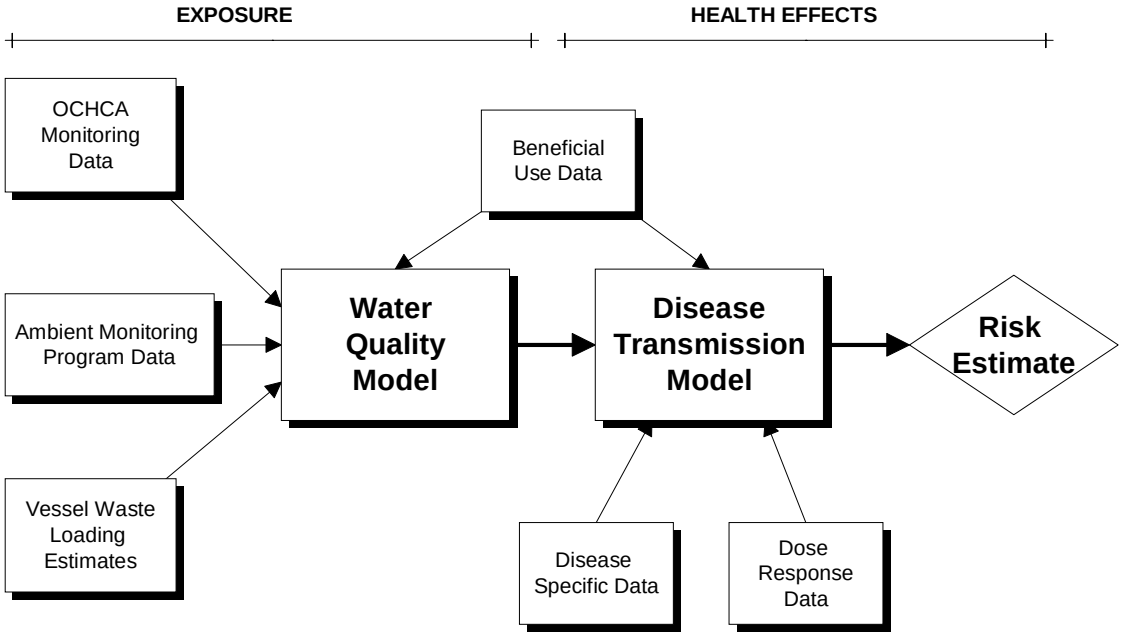
The schematic diagram presented in the previous section may be interpreted to be composed of two distinct components: exposure and health effects. Those components roughly correspond to the water quality modeling (along with the linkage to the disease transmission model), and the disease transmission modeling components of this investigation, respectively. In this section, the data and assumptions used to characterize the exposure to enteric viruses through recreational activity in Newport Bay are discussed.

6.3.1 Exposure Scenario

The exposure scenario for this investigation is defined as body contact recreation in Newport Bay. To characterize this exposure scenario to enteric viruses quantitatively, the following assumptions and caveats were employed:

- The exposure is assumed to occur during the dry season (this assumption was discussed with the HAC and determined to be reasonable: Refer to the project status reports for correspondences related to this assumption);
- Concentrations of male specific coliphage are assumed to be a conservative (health protective) surrogate for enteric viruses. Refer to Appendix D;
- The frequency and spatial distribution of recreational use within Newport Bay follow the patterns described in Chapter 3;
- Within any given day, recreational use occurs following the daily use pattern described in Chapter 3;
- The proportion of people engaging in body contact recreation compared to the total number of recreators is consistent with that described in Chapter 3;
- For those engaging in body contact recreation, the length of swimming events is distributed in a manner consistent with that reported in Chapter 3; and
- The total size of the population that includes those most likely to be recreating in Newport Bay is consistent with that described in Chapter 3.

Figure 6.2
Schematic Diagram of Health Risk Assessment Investigation

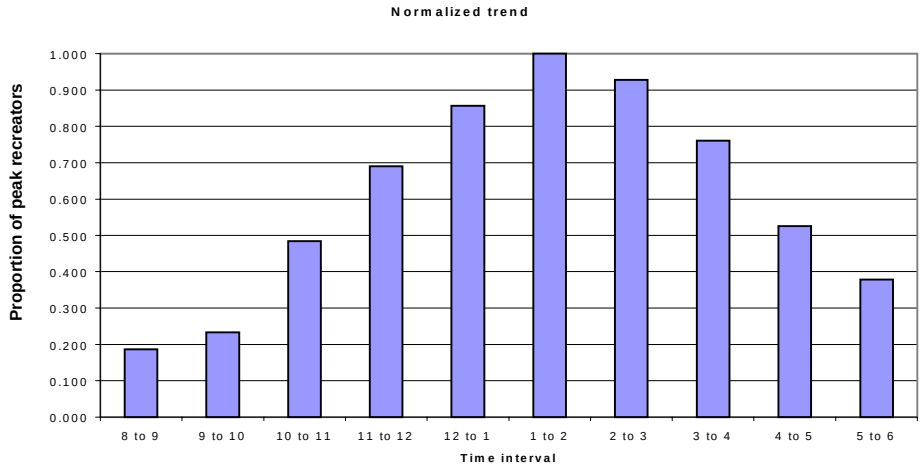


6.3.2. Linkage Between the Water Quality and Disease Transmission Models
The output from the water quality modeling effort corresponds to expected concentrations of enteric viruses in Newport Bay. Specifically, the water quality model outputs hourly concentrations at each of the recreational sites. These water quality data along with information specifying recreational use patterns in Newport Bay are used to generate a profile of virus exposure for the disease transmission model. How recreational use patterns in Newport Bay are used to specify the linkage between the water quality and disease transmission models is described in this section.

6.3.2.a Recreational Site Use Level: Based on data collected during this investigation and feedback from OCHCA and HAC ex-officio participants, each recreational site was classified in terms of recreational use as either low, medium, high, or extra high. A summary of the classifications for each site and the numbers of recreators associated with each site classification (for weekdays, weekends, and holidays) is described in Chapter 3.

6.3.2.b Daily Use Trend: Based on data collected during this investigation (Chapter 3), recreation is assumed to occur in Newport Bay between 8 A.M. and 6 P.M. A summary of the "daily use trend" is shown in Figure 6.3.

Figure 6.3
Daily Use Trend for Recreational Activity in Newport Bay



6.3.2.c REC-1 Profile Summary: Data were also collected during this investigation to characterize the percent of the population visiting Newport Bay beaches that recreate in the water, and the length of time those members of the population spend in the water. A summary of those results is presented in Table 6.1.

6.3.2.d Volume of Water Ingested During Recreational Activity: The volume of water ingested per time swimming is assumed to be 50 mL/hr based on commonly accepted rates for risk assessment set forth by US EPA (U.S. EPA 1989).

Table 6.1
REC-1 Profile Summary for Newort Bay Beaches [1]

Description	% of Recreators Surveyed	Median Swim Time (mins)
Do not go into the water	30	0
Spend less than 15 minutes in the water	8	7.5
Spend between 15 minutes and 1 hour in the water	22	37
Spend between 1 and 2 hours in the water	21	90
Spend more than 2 hours in the water	20	150

1. Based on data collected between June 1999 and May 2000

6.3.2.e Summary of Linkage Between Water Quality and Disease Transmission Models: Exposure to enteric viruses through recreational activities in Newport Bay may be characterized using the data summarized above. Specifically, for each hour in the simulation time period, the linkage between the water quality model and the disease transmission model is based on the expected number of people participating in recreational activities at each site in Newport Bay (based on the use level of each site, the hour in the day, the day of the week, and the REC-1 profile). The above information along with the output from the water quality model (concentration data at each site) and the volume of water ingested during recreational activity comprises the exposure of enteric viruses for recreators during that time step (hour). The exposure is then transferred to the disease transmission model. At each hourly time step, the disease transmission model takes the exposure data and tracks the rate of movement among the population between relevant epidemiological states.

6.4 HEALTH EFFECTS: PARAMETERIZATION OF THE DISEASE TRANSMISSION MODEL

All of the variables used in the disease transmission model are summarized in this section. Variables related to the water quality model were described previously and result in concentrations which are used as input to the disease transmission model. The variables in the disease transmission model may be divided into two groups: biological, and community. The biological variables are based on properties of the microorganism under study. Community variables are based on properties of the community and the exposure scenario under study. A summary of the disease transmission model variables, along with the ranges of those variables sampled as part of the Monte Carlo simulation procedure is presented in Table 6.2. A brief description of each of the variables employed in the disease transmission model and a summary of the rationale for the ranges employed in this investigation is presented following Table 6.2.

Table 6.2
Summary of Disease Transmission Model Parameters

Description	Parameter	Units	Range	Comment
Dose Response Parameters	Alpha	Unitless	0.125 - 0.5	alpha, beta, and the dose ingested during
	Beta	Unitless	0.21 - 0.84	recreational activity are used to compute Pdose
Probability of Symptomatic Response	Psym	Unitless	0.1 - 0.45	Used to compute βSD, and βPD
Previous Exposure Factor	ε	Unitless	0.1 - 0.9	Used to compute βPD, and βPC
Reciprocal of Incubation	tauI	day^{-1}	0.33 -1.0	Used to compute βSD, and βPD
Reciprocal of Latency	tauL	day^{-1}	0.143 - .333	Used to compute βSC, and βPC
Rate Diseased move to Post infection State	σdp	day^{-1}	0.09 - 0.5	σdp is also used to compute Pcontact
Rate Carriers move to Post infection State	σcp	day^{-1}	0.05 - 0.125	σcp is also used to compute Pcontact
Rate of susceptible re-establishment	γ	day^{-1}	0.0009 - 0.0027	

6.4.1 Biological Parameters

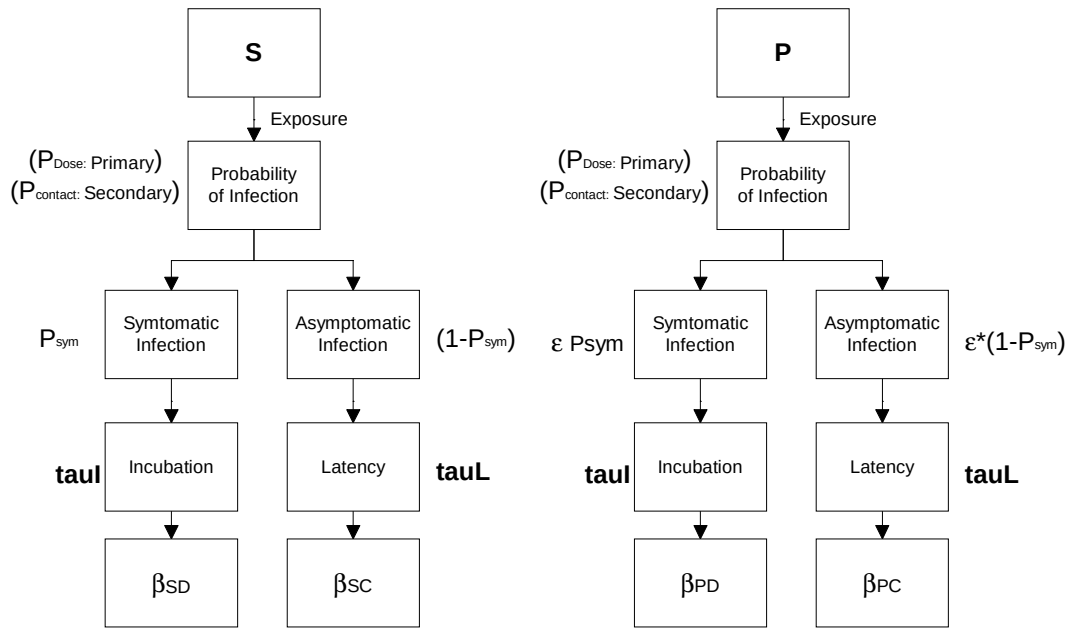
The derivation for rate parameters B_{SC}, B_{SD}, B_{PC}, and B_{PD} is presented graphically in Figure 6.4 along with the equations describing how those rates are computed in the disease transmission model.

6.4.1.a Probability of Infection (Pdose) and Dose Response Parameters (alpha and beta): Based on a Beta-Poisson model (Regli et al. 1991) and dose response data (Ward et al. 1986), the probability of infection due to primary rotavirus exposure (*Pdose*) is $1-(1+d/B)^{-\alpha}$ where the ranges for the dose response parameters α and β are {0.126, 0.5} and {0.21, 0.84}, respectively. The dose (*d*) ingested by recreators is determined by multiplying the volume of water ingested during recreational contact (refer to section 6.3.2) by the concentration of viruses at the recreational site (output from the water quality model).

6.4.1.b Probability of Symptomatic Infection (P_{sym}). The probability of a symptomatic infection is based on data from Wenman (40% symptomatic), Tufvesson (46% symptomatic), and Haffejee (11-70%). Based on these data, a uniform distribution between 0.1 and 0.45 {10 to 45%} was assumed (Tufvesson et al. 1977; Wenman et al. 1979; Haffejee 1995).

6.4.1.c Incubation (tauI): The incubation period from infection to diarrheal symptoms has been estimated to range from 1-3 days (Shepard and et. al 1975; Flewett and Woode 1978).

Figure 6.4
Quantifying the Rate Parameters
for Susceptible and Post-Infection States



$$\beta_{SC} = \beta_{SC1} + \beta_{SC2} = (P_{dose} + P_{contact}) \cdot (1 - P_{sym}) \cdot tauL$$
$$\beta_{SD} = \beta_{SD1} + \beta_{SD2} = (P_{dose} + P_{contact}) \cdot (P_{sym}) \cdot tauI$$
$$\beta_{PC} = \beta_{PC1} + \beta_{PC2} = (P_{dose} + P_{contact}) \cdot \varepsilon \cdot (1 - P_{sym}) \cdot tauL$$
$$\beta_{PD} = \beta_{PD1} + \beta_{PD2} = (P_{dose} + P_{contact}) \cdot \varepsilon \cdot (P_{sym}) \cdot tauI$$

6.4.1.d Latency (tauL): Based on data from Ward (3-7 days) and Gomez-Barreto (median 3 days), shedding of virus is estimated to occur between 3 and 7 days after exposure (Gomez-Barreto et al. 1976; Ward et al. 1986).

6.4.1.e Previous exposure factor (ε): It has been reported that intestinal antibody levels may correlate with protection against severe disease, not infection, and that there is a poor correlation between serum antibodies and protection (Chanock et al. 1978; Wenman et al. 1979, Bishop, 1983 #6912; Kapikian et al. 1980; Molyneaux 1995). However, some potential confounding factors were also present in these studies, such as: (1) the possible presence of more than one serotype; and (2) the possibility that protection was only temporary. Little data are available to characterize the rate of movement from a protected state directly to a diseased or carrier state. The previous exposure factor (ε) in the disease transmission model accounts for previous exposure to a pathogenic agent and provides a means to account for the rate difference between movement from S to C or D, when compared to that from P to C or D. ε ranges between 0.1 and 0.9 in the disease transmission model to account for the inherent uncertainty in the parameter and the

relative rate of movement of the population to State C or D directly from State P, compared to similar movement from State S.

6.4.1.f Probability of Disease Transmission due to Person to Person Contact (Pcontact): Secondary transmission is defined as infection due to exposure to infected individuals, caused by either person-to-person or person-object-person contact. A viable method to estimate secondary transmission is to assume that it is directly proportional to the number of contacts from infected individuals. Such a mass action assumption is used widely and accepted in the modeling of infectious disease transmission processes (Hethcote, 1976). Assumptions necessary to estimate the secondary transmission parameters are as follows: (1) The probability of contact and infection are independent of C or D status; (2) The probability of infection is dependent on S or P status; and (3) The probability of contact is age independent.

For the purpose of this investigation it is assumed that outbreaks in day care centers are primarily due to secondary transmission. By assuming that on average 50% of the children become diseased (O'Ryan et al. 1993), and that the process can be characterized as an SIR infectious process, the following derivation can be used Hethcote (1976):

$$1 - S(\infty) + \frac{\log[S(\infty)/S_0]}{P_{contact} N / \sigma} = 0$$

Based on the above discussion, it is be assumed that $S(\infty) = 0.5$ and $S_0 = 1.0$. Therefore, the probability of contact can be estimated as a function of disease duration, σ. From the above equation

$$P_{\text{contact}} = 1.38 \text{ x } \sigma/N$$

where σ is estimated below, and N is the population level for the scenario under study (section 6.4.2). Finally, to account for uncertainty in P_{contact}, a random variable was incorporated into the disease transmission model allowing the lower and upper bounds of P_{contact} to span an order of magnitude.

6.4.1.g Rate of Movement from State D to P (σdp): The rate of movement from State D to P is the reciprocal of the length of time it takes for recovery from disease (or equivalently the duration of shedding). Based on data from Gomez-Barreto (1986) and Gurwith et al. (1981) this parameter is the reciprocal of 2-11 days.

6.4.1.h Rate of Movement from State C to P (σcp): The rate of movement from State D to C is the reciprocal of the length of time it takes for carriers to recover from infection (or equivalently the duration of shedding), and is the reciprocal of 8-20 days based on data from Ward et al. (Ward et al. 1986) and Ansari (Ansari et al. 1991).

6.4.1.i Duration of post infection status (γ): The duration of protection from future infection varies considerably in the literature. Based on a review of the pertinent literature, it may be inferred that protection against rotavirus seems to be generally serotype specific, and the protection may be age specific (adults seem to have longer protection than children). For the purposes of this investigation, it is assumed that

protection from future infection varies between 1 and 3 years (γ is the reciprocal of that duration) (Bernstein et al. 1991; Ward and Bernstein 1994).

6.4.2 Community Parameter: Population Size (N):

The size of the population that may potentially be exposed to enteric viruses through recreational contact in Newport Bay was discussed previously in Chapter 3. Based on data collected during this investigation, it is estimated that the size of the population most likely to recreate in Newport Bay is approximately 1,200,000 people. This population estimate includes residents of the following cities: Aliso Viejo, Costa Mesa, Fountain Valley, Garden Grove, Huntington Beach, Irvine, Laguna Honda, Orange, Santa Ana, Tustin, and Westminster.

6.4.3 Disease Transmission Model Output

Output from the disease transmission model includes the final number of people in each of the states (Susceptible, Diseased, Carrier, and Post-Infection) as well as the average point prevalence for the simulation. Average point prevalence is defined as the proportion of the population (per 100,00) that is symptomatic (in state D) during each one hour time step of the simulation averaged over the whole simulation period. Average point prevalence incorporates both the number of cases and the duration of disease, resulting in a measure of disease intensity. Average point prevalence can be compared with incidence by the following approximation (Eisenberg et al. 1996) (with appropriate unit conversion factors):

$$\text{Average Point Prevalence} \approx \text{Incidence} * \text{Duration of disease}$$

6.5 MODEL IMPLEMENTATION AND INITIALIZATION

6.5.1 Implementation:

As described in the previous section, for this investigation the transmission of infectious disease is modeled as a series of first order differential equations. The model was implemented using Matlab 5.3 and Simulink 3.0 . Matlab is a high performance language for technical computing which integrates computation, visualization, and programming (Mathworks Inc. 1998). Simulink is a software package for modeling, simulating, and analyzing dynamic systems which provides an intuitive graphical user interface for model development. A printout of the Simulink model for this investigation's disease transmission model is included with this report as Attachment G.

6.5.2 Initialization of the Disease Transmission Model

The purpose of the model initialization phase was to ensure that the parameter sets employed during the Monte Carlo simulations would yield results consistent with data reported in the literature for non-outbreak conditions. The concept of background exposure was introduced in Section 6.1.1 and was defined as the (low) level of microorganism exposure that members of a population receive through their daily activities. For the model initialization in this investigation, the levels of background rotavirus disease reported in the literature were used as the acceptable range of disease from exposure to microorganisms in the community without the additional exposure from

recreational activities in Newport Bay (Eisenberg et al. 1996; Eisenberg et al. 1998). The model initialization approach which is consistent with previous related work, was composed of the following components:

- Endemic disease levels of rotavirus were estimated based on data from the literature (Koopman et al. 1989; Mead et al. 1999). Based on the reported data, it is estimated that level of diseased (infectious and symptomatic) individuals in a community from rotavirus ranges from 0.04 to 0.55% at a given point in time (non-outbreak conditions);
- A series of Monte Carlo simulation sets (each set composed of 1000 simulations) were run employing the disease transmission model with variable levels of background exposure until a background exposure level was found that resulted in an average disease prevalence of 0.3% (the average of the range described above). During all of the simulations, parameter sets were selected randomly from the ranges specified previously for those variables (Table 6.2);
- The background level of exposure identified in the previous step was used in all subsequent simulations to ensure that the proportion of the population in each epidemiological state in the disease transmission model was an accurate reflection of the conditions in the community prior to additional exposure through recreational activity; and
- Exposure to enteric viruses in the Newport Bay watershed was simulated including background exposure and exposure through recreational activities. For each simulation a set of values was selected randomly for each of the variables (from the feasible ranges specified), and the prevalence of disease due to background exposure was checked to ensure that it fell within the accepted range. If the prevalence fell outside of the feasible range, the parameter set was discarded and another set was randomly selected. If background exposure with the random variable set fell within the feasible range, disease prevalence was computed for background exposure plus exposure through recreational activities.

6.6 General Properties of the Disease Transmission Model

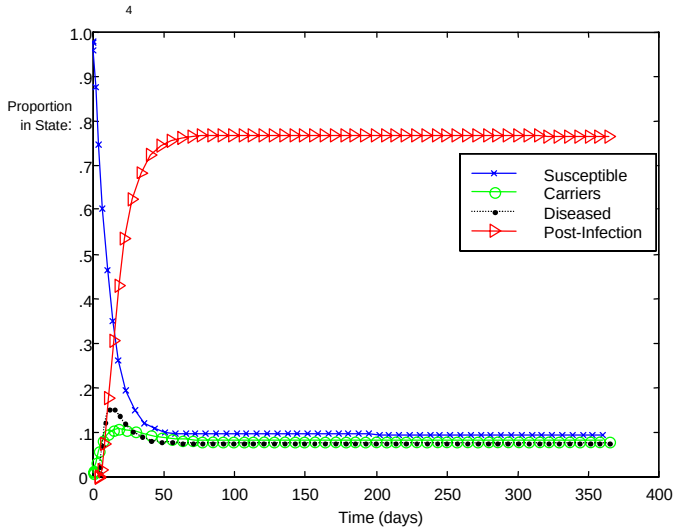
Each simulation represents an assumed 270 day time period during the dry season in the Newport Bay watershed. For each simulation, a set of variable values is selected randomly from the ranges specified in Table 6.2. Given the following data, it should be understood that the modeled system is dynamic and deterministic: (1) Output from the water quality model, (2) Data specifying the exposure linkage between the water quality model and the disease transmission model, and (3) The (randomly) selected values for the disease transmission model variables. Monte Carlo simulations are carried out to account for the variability and uncertainty associated with each of the variables in the model. The result from this probabilistic methodology is that the output from the model includes an estimate of the associated variability and uncertainty.

The general properties of the rotavirus disease transmission model are explored in this section via a representative simulation (EOA Inc. and U.C. Berkeley School of Public Health 1999) to demonstrate that (1) the model is well behaved, (2) a steady

(equilibrium) state is reached relatively quickly in the simulation, and (3) at the end of the simulation a substantial proportion of the population resides in the "post-infection" state.

Results of a representative simulation from the disease transmission model are presented in Figure 6.5. As illustrated in Figure 6.5 the whole population was assumed to be "susceptible" with respect to disease at the beginning of the simulation, and that an equilibrium state was achieved relatively quickly. It will also be noted that a relatively low proportion of the population is in the susceptible state once equilibrium has been achieved.

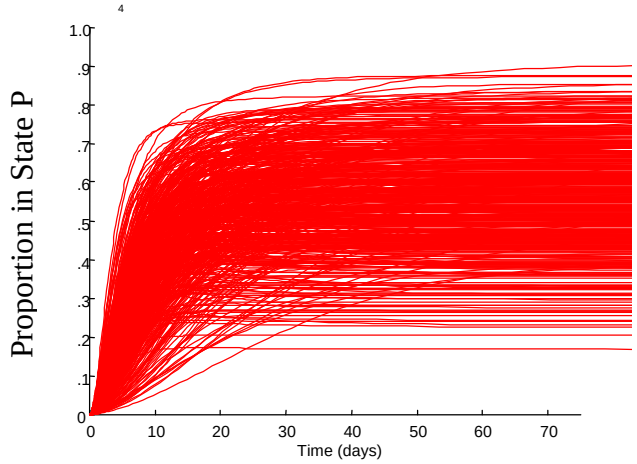
Figure 6.5
Representative Output from One Simulation of the Disease Transmission Model



By allowing each of the variables in the disease transmission model to vary within their specified ranges, the proportion of the population residing in each of the epidemiological states at the end of the simulation will vary. Considering a series of results from the disease transmission model demonstrates the variability associated with the state variables. The proportion of the population in the post-infection state at the end of 500 representative simulations is presented in Figure 6.6.

As shown in Figure 6.6 the proportion of the population in the post-infection state varies considerably and depends greatly on the combination of variable values used to carry out the simulation. The finding concerning variability is important because it highlights the limitations of microbial risk techniques that do not account for (1) the variability or uncertainty in variables, and (2) the existence of a post-infective state. Based on the results of these representative simulations, it can be concluded that estimating risk without consideration of the epidemiological status of the population, may lead to biased estimates. Further, it should be clear that variability and uncertainty exist in the components used to model the transmission of infectious diseases. If these components are used in a model, the associated variability and uncertainty in those components will propagate to the model's output. If the variability and uncertainty in these components is not modeled, it does not mean that the results are more certain, but rather that their effects are simply not accounted for in the output.

Figure 6.6
Representative Output for the Post-Infection State (P) from 500 Simulations



6.7 RELATIVE PUBLIC HEALTH RISK FROM REC-1 EXPOSURE TO ENTERIC VIRUSES IN NEWPORT BAY

6.7.1 Number of Simulations Required

The disease transmission model is composed of a series of ordinary differential equations based on ten random variables. A priori it is not possible to know which of those variables or combinations of variables may be important with respect to the prevalence of disease in the community.

With a potentially vast experimental space to explore (10 dimensions – 1 for each parameter), an important aspect of the simulation procedure was to determine a reasonable number of simulations from which the evaluation could be based. To that end, a numerical experiment was carried out in which a series of Monte Carlo simulations was run to determine how the results (in terms of proportion of the population residing in each epidemiological state) varied with the number of simulations.

From the results of the simulation experiment it was found that the relative change in the average number of people residing in each state at the end of the simulations varied very little when comparing 1,000 to 15,000 simulations. The previous statement is true for background exposure and for background plus recreational exposure. The relative changes in the number of people in each state when 1,000 simulations were compared to 15,000 simulations were as follows: Susceptible (0.5%), Carrier (1.4%), Diseased (1.2%), and Post-Infection (0.3%). Based on the results of this numerical experiment, 1,000 simulations were deemed to be sufficient to carry out the ensuing simulations and risk characterization .

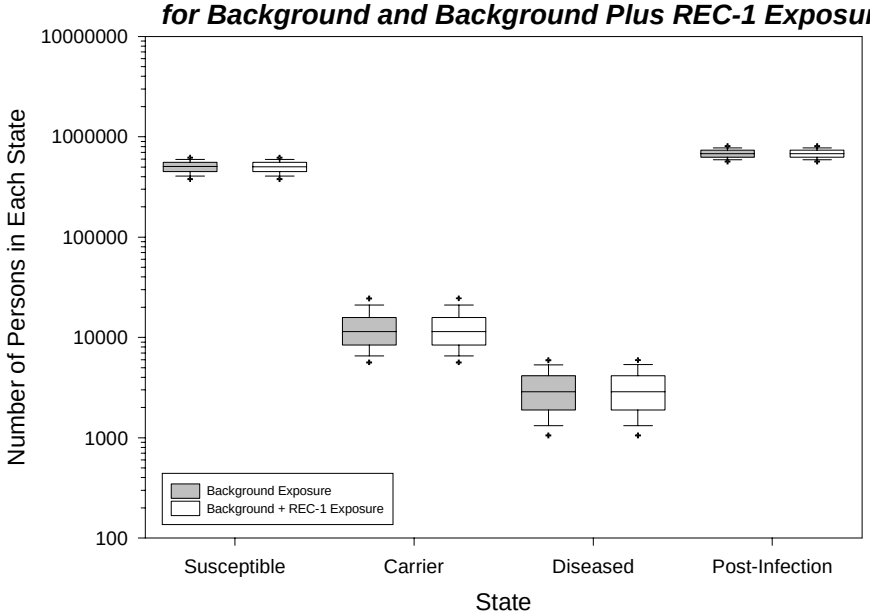
6.7.2 Simulation Results

The results from 1000 simulations modeling the relative public health risk from exposure to enteric viruses in the Newport Bay Watershed based on the exposure scenario

described previously, are presented in Figures 6.7 through 6.9. Figures 6.7 through 6.9 are boxplots in which the median (line in the middle of the box), the 25th and 75th percentile values (edges of the boxes), and the 5th and 95th percentile values (circles above and below the boxes), of the data are presented in each figure.

The number of individuals in each of the epidemiological states at the end of the simulations[22] is presented in Figure 6.7. Note that two sets of 1000 simulations are summarized in Figure 6.7, one for background exposure and the second for background plus REC-1 exposure. Both sets of simulations employed the same sets of variable values. Inspecting Figure 6.7, it will be observed that the number of people in each of the states under both exposure conditions (background and background plus REC-1exposure) appears to be very similar, and that the number of people in the Carrier and Diseased states is substantially lower than those in the Susceptible and Post-Infection States.

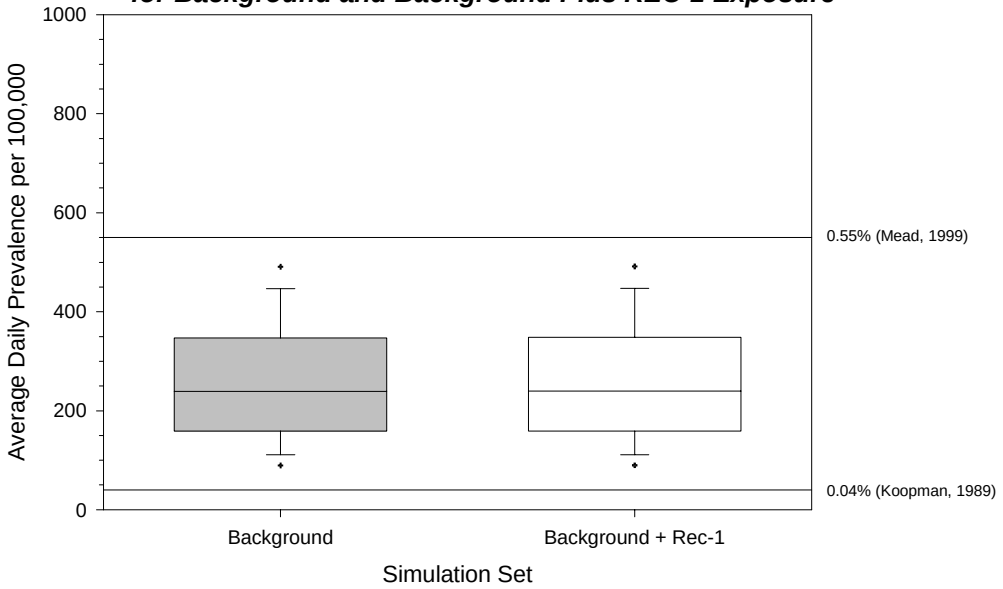
Figure 6.7
Output From Disease Transmission Model
for Background and Background Plus REC-1 Exposure



Average Daily Prevalence (number of individuals in the Diseased State) for the exposure conditions described above is presented in Figure 6.8. Also presented in Figure 6.8, for comparative purposes, are the literature based endemic disease levels (non-outbreak conditions). As illustrated Figure 6.8, both the background and the background plus REC-1 exposure scenario falls within the ranges of endemic disease reported in the literature.

[22] The median value is represented by the bar in the center of the box, the 25th and 75th percentiles are represented by the lower and upper edges of the box, the 10th and 90th percentiles are represented by the short lines parallel to the box, and the 5th and 95th percentiles are represented by the symbols below and above the box, respectively.

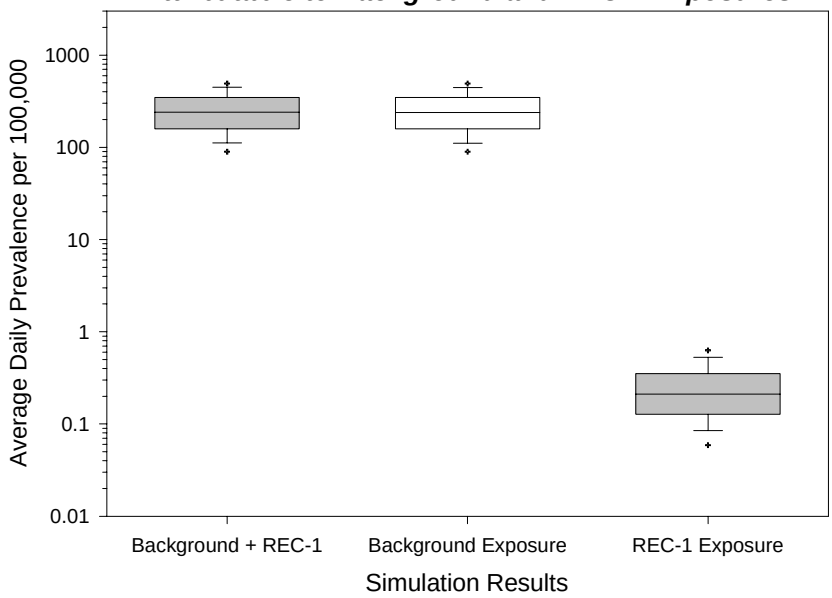
Figure 6.8
Average Daily Prevalence per 100,000
for Background and Background Plus REC-1 Exposure



To understand the incremental risk that may be posed by body contact recreation in Newport Bay above background exposure, the number of individuals in the diseased state due to background exposure at the end of each simulation was subtracted from those in the diseased state from background plus REC-1 exposure. This difference accounts for the number of individuals in the diseased state that is attributable to REC-1 exposure in Newport Bay (including subsequent secondary transmission of disease). The prevalence of enteric virus disease attributable to REC-1 contact in the Newport Bay watershed is presented in Figure 6.9 along with that for background exposure.

The number of individuals in the diseased state at any given time attributable to REC-1 exposure, as illustrated in Figure 6.9, is substantially lower than the number in the diseased state from background exposure. It should, however, be understood that all members of the population (1.2 million in this investigation) are subjected to background levels of viruses, and only those individuals who recreate in Newport Bay receive the incremental exposure from REC-1 contact. The profile of individuals at each of the recreational sites was presented previously in Chapter 3.

Figure 6.9
Average Daily Prevalence in the Newport Bay Watershed Attributable to Background and REC-1 Exposures



6.7.3 Comparison of Model Output with EPA's Accepted Risk Level

The applicable water quality criteria for REC-1 exposure are all derived directly or indirectly from EPA's best estimate of the accepted illness rates for the fecal coliform criteria (U.S. EPA 1986) which are 8 illnesses per 1,000 swimmers for fresh water beaches and 19 illnesses per 1,000 swimmers at marine beaches.

To compare the output from the disease transmission model to those levels, the following approximation was employed:

$$\text{Risk of disease per swim event} = \Delta P * \text{sigma}_{dp} / N_s$$

where

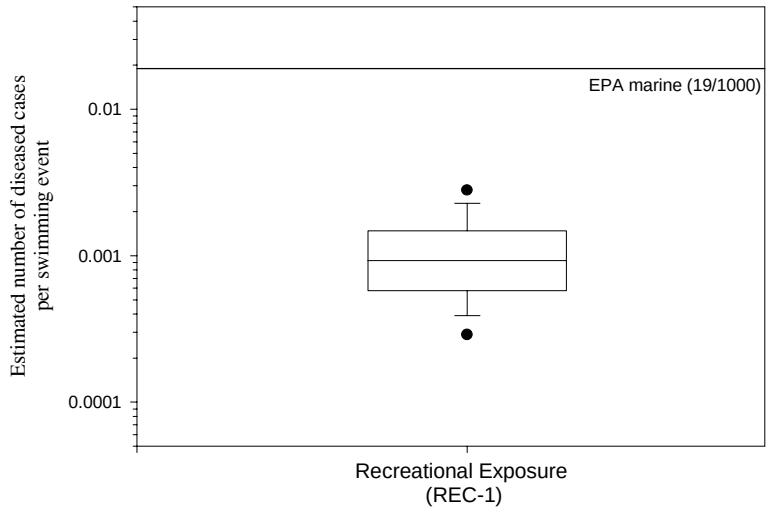
ΔP = Disease Prevalence attributable to REC-1 exposure

sigma_{dp} = Rate of Diseased individuals that move to Post infection state

N_s = Average number of swimmers per day (Note that this number is estimated based on data collected as part of the beneficial use survey described in Chapter 3. Calculations are provided in Appendix E).

A boxplot comparing the simulation results in the metric described above to appropriate benchmarks, is presented in Figure 6.10. As shown in Figure 6.10, the entire distribution of predicted diseased cases per swimming event falls below EPA's accepted illness per swimmer ratios (based on median values) for both marine (19/1000) and fresh (8/1000) waters (U.S. EPA 1986; U.S. EPA 2000).

Figure 6.10
Comparison of Risk of Disease per Swimming Event
With Benchmark Levels



6.7.4 Comparison of Model Output with Enterococci Data

As a method to corroborate the data evaluation presented above, one may apply the chemical risk assessment framework (National Research Council 1983) along with EPA's recommended dose response function for enterococcus and use them to evaluate data collected in the Newport Bay watershed. Based on data presented previously, it is clear that the Newport Dunes areas host more body contact recreation in Newport Bay than any other site. Therefore, enterococcus data collected during the high use seasons of 1999 and 2000 (May through October) at the Newport Dunes monitoring stations were evaluated and are compared to the results presented above.

A total of 246 enterococcus observations were collected and analyzed by OCHCA at Newport Dunes monitoring stations during the time period of May – October 1999 and May – October 2000. The enterococcus data were grouped together and assumed to be representative of the bacterial water quality at the Newport Dunes monitoring sites during that time period. A summary of these data is presented in Table 6.3.

Table 6.3
Summary of OCHCA Enterococcus Monitoring Data for Newport Dunes Sites
May - October 1999 and 2000

# Samples	Median	Mean	Std Dev	Min	Max
246	10	28	48	<10	384

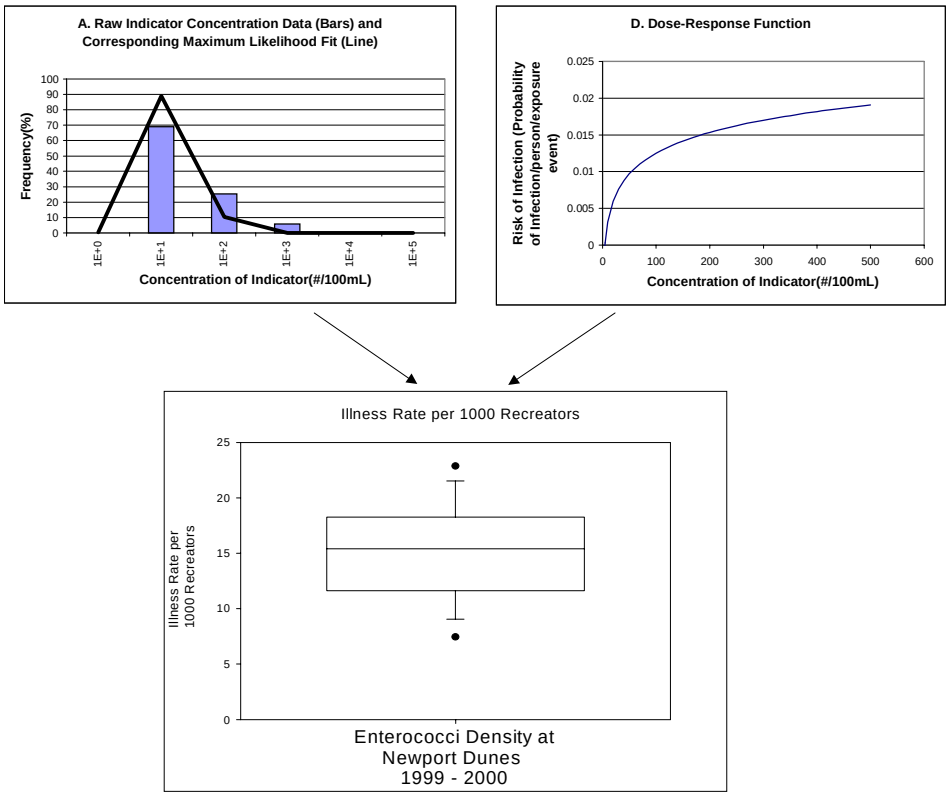
Concentration units are MPN/100mL

The data in Table 6.3 were fit to a lognormal distribution via the method of maximum likelihood. Based on the resultant distribution and EPA's equation relating enterococci density in marine water to illness rate (U.S. EPA 1986), a series of Monte Carlo

simulations were performed to estimate the expected distribution of (infectious and symptomatic) illness. The results of those simulations are presented in Figure 6.11.

As illustrated in Figure 6.11, the median estimate of illness (or equivalently risk of disease) is approximately 15/1000, which is slightly less than the median of 19/1000 used by EPA as the acceptable level of illness. The 25th and 75th percentile values are approximately 12/1000 and 18/1000, respectively.

Figure 6.11
Characterization of Risk Based on Enterococcus Data
Newport Dunes 1999 - 2000

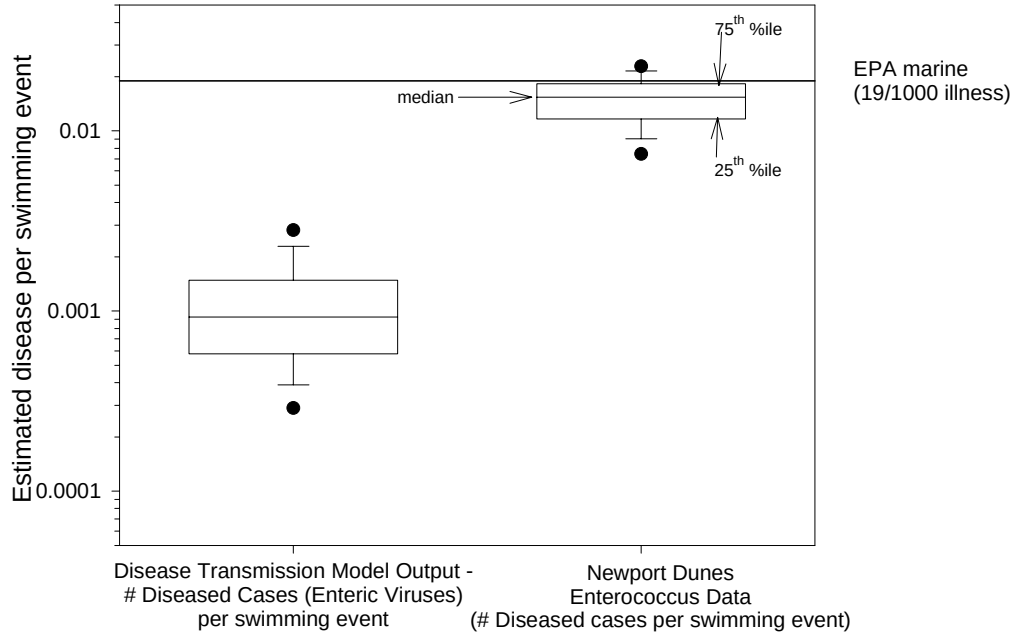


The final step in this comparative evaluation of enterococcus data and output from the disease transmission model is to compare the results presented in Figure 6.11 with those presented in the previous section. To do so, several considerations are necessary:

- It should be noted that the enterococci dose response function is based on a compilation of several epidemiological studies; and
- It is necessary to scale the units used in the two sections to make them as comparable as possible (Note Figure 6.12 shows the results in terms of estimated disease per swimming event).

A comparison of the predicted illness rate based on enterococcus data collected at the Newport Dunes with the output from the disease transmission model for the Newport Bay watershed is presented in Figure 6.12.

Figure 6.12
Comparison of Disease Transmission Model Output with Estimated Risk Based on Newport Dunes Enterococcus Data



From a review of the information presented in Figure 6.12 it can be concluded that (1) the levels of disease predicted by both enterococcus and the disease transmission model are below the EPA's accepted levels as estimated by the median values[23], and (2) the levels of disease attributable to body contact recreation estimated by the disease transmission model are somewhat lower than those estimated by using enterococcus data. Several possible explanations for this second observation are as follows:

- The importance of a post-infective (protected or immune) state for enteric viruses may not be sufficiently captured in the concentration-response function for enterococcus;
- 118 out of the 246 (~48%) enterococcus observations used in the analysis presented above were reported to be below the detection limit of 10 colonies per 100mL. For the purposes of the analysis, those observations were assumed to be present at a concentration equal to the detection limit. If a more rigorous approach were used to estimate the distribution of enterococcus concentration at the Newport Dunes location which accounted for observations below detectable limits, the resultant estimate of risk would be lower than that shown above;
- The uncertainty associated with the enterococcus analysis is not captured in a manner commensurate with the uncertainty embedded in the disease transmission model output. For example, the enterococcus data employed in the analysis only

[23] Note that the log mean and median are the same for log normally distributed data.

represent the reported values for enterococcus not the 95% confidence intervals about the reported values. For the membrane filtration method, a reported concentration of 10 colonies per 100mL has upper and lower 95% confidence limits of 4.7 and 18.4 colonies per 100mL, respectively[24]. Incorporating this uncertainty into the analysis presented above would have the effect of increasing the distance between the reported median value and other reported percentiles. Thus, the difference between the enterococcus data and the disease transmission output would appear less than is shown above; and

- Use of enterococcus as an indicator organism for human health risk from body contact recreation may not be appropriate in this particular watershed for assessing risk from recreational contact with Newport Bay waters: (1) It is possible that the enterococcus sources to Newport Bay are more abundant than sources contributing viruses relative to those in the studies used to generate the enterococcus concentration-response relation[25]; and (2) A reanalysis of the data supporting the U.S. federal bacteriological water quality criteria for enterococcus in marine waters with similar salinity to Newport Bay, found significant differences in the mathematical relationship between swimming-associated gastroenteritis and enterococcus density at the two locations used in the study (Fleisher, 1991)[26].

[24] APHA, AWWA, and WEF, "Standard Methods for the Examination of Water and Wastewater", 19th ed, p. 9-58, 1995.

[25] For example, it is possible that birds and other wildlife contribute more enterococcus in this Watershed than similar sources did in the studies used to generate the concentration – response function.

[26] That study concludes by questioning the appropriateness of the use of a universal enterococci density to govern all marine recreational water locations in the U.S.

CHAPTER 7: SENSITIVITY AND UNCERTAINTY ANALYSES

7.1 OVERVIEW

The purpose of this chapter is to describe the approach taken to characterize the sensitivity and uncertainty analyses that were carried out as part of this investigation. Uncertainty refers to a lack of knowledge about specific factors, parameters, or models, and sensitivity generally refers to the variation in output of a mathematical model with respect to changes in the values of the model's input (US EPA 1997). A sensitivity analysis attempts to provide a ranking of the model's assumptions with respect to their contribution to model output variability and uncertainty (U.S. EPA 1988). In a broader sense, sensitivity can also refer to how inferences or conclusions may change if models, data, or assumptions are changed.

The results from three simulation studies, a multiple linear regression, and a parametric uncertainty analysis are presented and discussed in this chapter. The combination of these analyses provides a robust interpretation and understanding of the results of the HRA presented in Chapter 6. As a starting point for this discussion, recall that the simulations discussed in Chapter 6 incorporated the variability and uncertainty associated with ten random variables. The variability and uncertainty in each of those variables was quantified based on a review of the literature. In this chapter, the sensitivity of the output is explored further with respect to those variables and several other potentially important variables such as the size of the population most likely to recreate in Newport Bay, the concentration of viruses estimated to be in Newport Bay waters, and loading contributions from swimmers and vessels.

7.2 SENSITIVITY STUDY: IMPACT OF CHANGING THE POPULATION SIZE

In Chapter 3, the size of the population that is most likely to participate in body contact recreation in Newport Bay was estimated to be 1.2 million. That estimate was based on data collected during 1999 and 2000, as part of the beneficial use survey carried out specifically for this investigation.

With respect to the results of the HRA presented in Chapter 6, an important topic to be considered is whether the prevalence of disease attributable to body contact recreation in Newport Bay is sensitive to the overall size of the population of those likely to be recreating in Newport Bay, i.e., the initial susceptible population (ISP). For example, it is possible that person to person transmission of disease may be a more important factor for the prevalence of disease attributable to body contact recreation when the ISP is lower, because there may a greater probability of interpersonal contact with an infected individual. Continuing with that logic, a smaller ISP could result in an increased disease prevalence in the community. To address this potentially important factor, a simulation study was carried out.

For the purpose of this simulation study, it was assumed that the smallest ISP worthy of consideration is equal to the population of the City of Newport Beach. This assumption

would mean that all those who recreate in Newport Bay live in the City of Newport Beach. Based on the beneficial use survey data collected as part of this investigation, it is known that this assumption is incorrect, nevertheless it serves as a reasonable worst case scenario worthy of exploration. The population of the City of Newport Beach is approximately 67,000, based on the 1990 census data.

Using the same variable ranges as were used for the simulations presented in Chapter 6, 1000 simulations were run assuming a population size of 67,000 rather than 1.2 million as was assumed in Chapter 6. A comparative summary of the results of those simulations along with those from Chapter 6 is presented in Table 7.1.

Table 7.1
Summary of Size of Population Sensitivity Study

Exposure	Population = 1,200,000 Average Number in State (%)				Population = 67,000 Number in State (%)			
	S	C	D	P	S	C	D	P
Background	501020	12705	3097	683178	27743	727	174	38355
	42%	1.1%	0.3%	57%	41%	1.1%	0.3%	57%
Background + REC-1	500796	12719	3100	683385	27523	741	177	38559
	42%	1.1%	0.3%	57%	41%	1.1%	0.3%	58%
Average Point Prevelance /100,000	Background		258.7				260.7	
	Background + REC-1		259.0				265.5	
Average Change in APP due to REC-1 Exposure			0.3				4.8	

As reported in Table 7.1, changing the size of the ISP from 1.2 million to 67,000 changes the estimate of average point prevalence /100,000 for background and background plus REC-1 exposure scenarios by 0.8% and 2.5%, respectively. Moreover, the change in the portion of the estimate of disease prevalence in the community attributable to recreational contact in Newport Bay is on the order of 5/100,000 for an ISP of 67,000 compared to 0.3/100,000 for an ISP of 1,200,000. It should however be noted that, on average there are expected to be 3 individuals in the Diseased State attributable to REC-1 exposure regardless of whether the population is 1.2 million or 67,000 (3,100 – 3,097 for ISP = 1,200,000 and 177 – 174 for ISP – 67,000). Based on these results, it may be inferred that on average, person to person transmission of disease is a relatively minor factor when considering the incremental health risk to enteric virus disease from body contact recreation in Newport Bay. It should however be understood that the epidemiological status of the population (number of people in each state at any given time) is a critical aspect of this inference.

The number of individuals in the diseased state attributable to REC-1 exposure at the end of each of the 1000 simulations when the size of the ISP was assumed to be 1.2 million and 67,000, is summarized in Figures 7.1 and 7.2, respectively. Figure 7.1 and 7.2 are probability plots showing the distribution of the number of individuals in the diseased state attributable to REC-1 exposure at the end of the simulations. Comparing the data in Figures 7.1 and 7.2 it can be concluded that the attributable number of individuals in the diseased state at the end of the simulations was relatively independent of the size of the ISP. This observation corroborates the inference noted above regarding the relative

importance of person to person transmission of disease attributable to body contact recreation for this particular investigation.

Figure 7.1
Lognormal Probability Plot for Number of Individuals in Diseased State when ISP = 1.2 Million

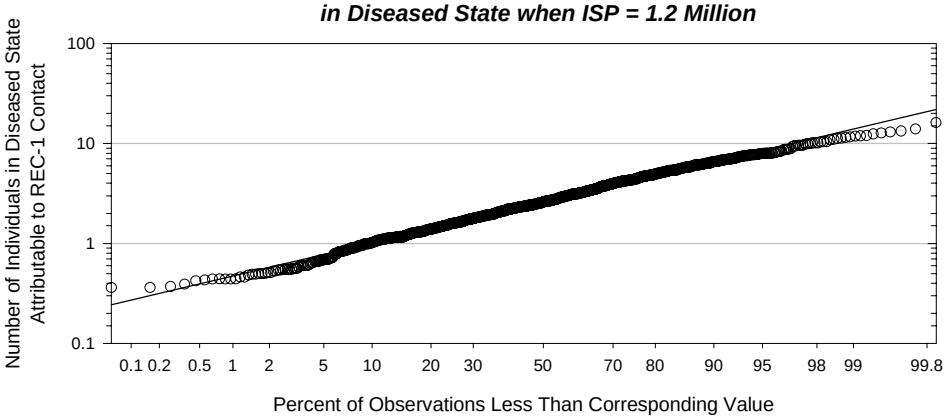
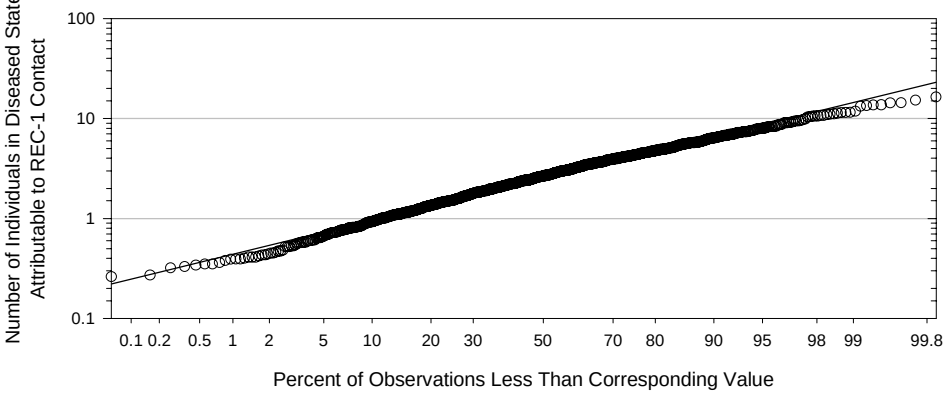


Figure 7.2
Lognormal Probability Plot for Number of Individuals in Diseased State when ISP = 67,000



7.3 SENSITIVITY STUDY: IMPACT OF BAY-WIDE INCREASES IN CONCENTRATION OF ENTERIC VIRUSES

In this section, changes in Bay-wide concentrations of enteric viruses in Newport Bay are explored to determine how those hypothetical changes in virus concentrations in Newport Bay would impact levels of disease prevalence in the community, given the known level of body contact recreation in the Bay. Specifically, increased levels of viruses in Newport Bay are examined to determine how substantially those increased levels would increase the levels of disease prevalence in the community attributable to body contact recreation.

Concentration levels of viruses in Newport Bay were increased above those used in Chapter 6 by levels of 10, 100, and 10,000. These levels were selected to bracket conservatively the unlikely but possible underestimation of enteric viruses in Newport Bay due to analytical inefficiencies, variability in the ratio of MS coliphage to viruses, and other factors that may not be unaccounted for. Sets of simulations were run using those new concentration levels along with the same variable ranges as those used in

Chapter 6. The ISP was assumed to be 1.2 million for all simulations. A comparative summary of the results of the simulations employing the various increased levels of virus concentrations is presented in Table 7.2.

The average number of individuals in States C, D, and P, as reported in Table 7.2 increases as the estimated concentration of enteric viruses increases in Newport Bay. Moreover, it can be seen that as the concentration of enteric viruses increases in Newport Bay, the average daily prevalence per 100,000 associated with Background plus REC-1 exposure also increases incrementally. Those increases however are smaller than may be anticipated. For example, the average daily prevalence under background exposure is approximately 259 per 100,000, and the expected average daily prevalence with virus concentrations 100 times higher than current estimates, is approximately 261 per 100,000.

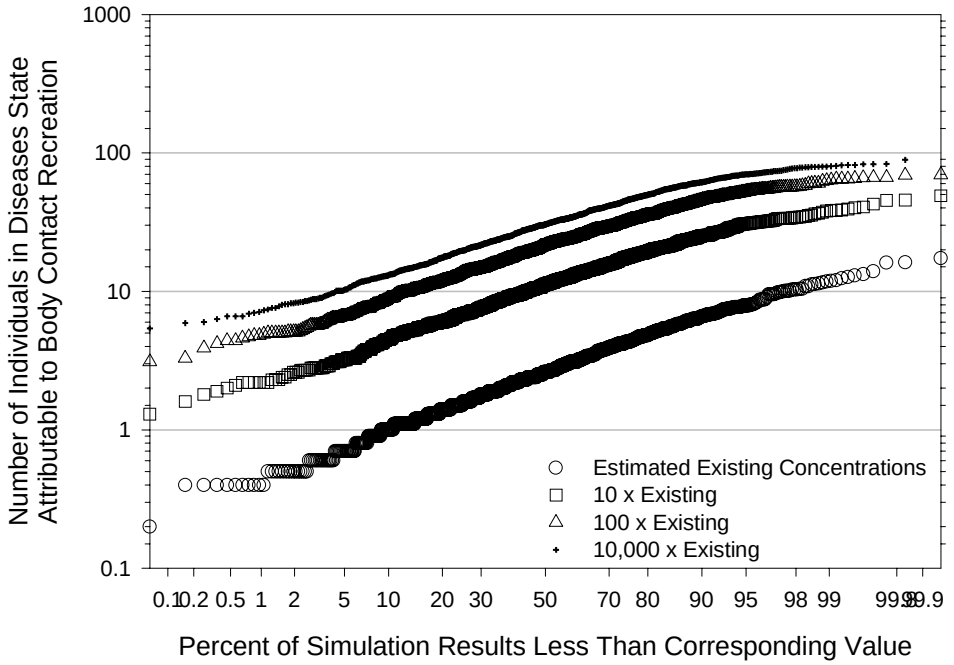
Table 7.2
Summary of Sensitivity Study for Increased Concentrations of Enteric Viruses in Newport Bay

	Avg # Individuals in Each State			Average Daily Prevalence /100,000	
Conditions	Background	Background +Rec 1	Difference	Background	Background + REC-1
Existing Estimate of Concentration					
S	501,020	500,796	(224)		
C	12,705	12,719	14		
D	3,097	3,100	3	258.7	259
P	683,178	683,385	207		
10 x Existing Estimate of Concentration					
S	501,020	500,079	(941)		
C	12,705	12,761	56		
D	3,097	3,110	13	258.7	259.8
P	683,178	684,051	873		
100 x Existing Estimate of Concentration					
S	501,020	499,212	(1,808)		
C	12,705	12,809	104		
D	3,097	3,121	24	258.7	260.9
P	683,178	684,858	1,680		
10,000 x Existing Estimate of Concentration					
S	501,020	498,383	(2,637)		
C	12,705	12,853	148		
D	3,097	3,131	34	258.7	261.9
P	683,178	685,633	2,455		

To characterize the change in the epidemiological status of the population attributable to body contact recreation for the scenarios described above, effects from background levels of exposure were subtracted from the results obtained for background plus REC-1 exposure. A summary of the distribution of the number of individuals in the diseased state attributable to REC-1 exposure is presented in Figure 7.3. From a review of the plots in Figure 7.3 it is clear that virus concentration levels in Newport Bay impact the disease prevalence in the community, however those impacts are less than may be expected. From the data presented in Figure 7.3 it may be inferred that a 10,000 fold increase in the existing concentration of viruses in the Bay would increase the median

number of individuals in the diseased state attributable to body contact recreation from approximately 3 to 40.

Figure 7.3
Distribution of Number of Individuals in Diseased State
For Increased Levels of Enteric Viruses In Newport Bay



A comparison of the predicted number of disease cases per swimming event for the increased levels of enteric viruses in Newport Bay described previously, is presented in Figure 7.4. Based on the data presented in Figure 7.4, it may be inferred that even if the estimated concentrations of enteric viruses in Newport Bay were several orders of magnitude (factors of ten) higher than they are estimated to be in this investigation, the predicted number of diseased cases per swimming event would be within the level of risk considered acceptable by EPA for recreational activities. A likely explanation for the trend shown in Figure 7.4 derives directly from the shape of the dose response function for rotavirus. In that function, the probability of infection increases (in a sigmoidal shape) with the log of concentration, and at low concentrations the function is linear (Regli et al. 1991). At concentrations similar to those in this investigation, the probability of infection increases linearly with log increases (factors of ten) in dose. Close inspection of Figure 7.4 indicates that the increase in the number of disease cases per swimming event with increased concentration of viruses in the Bay, is consistent with an increase in probability of infection from the dose response function.

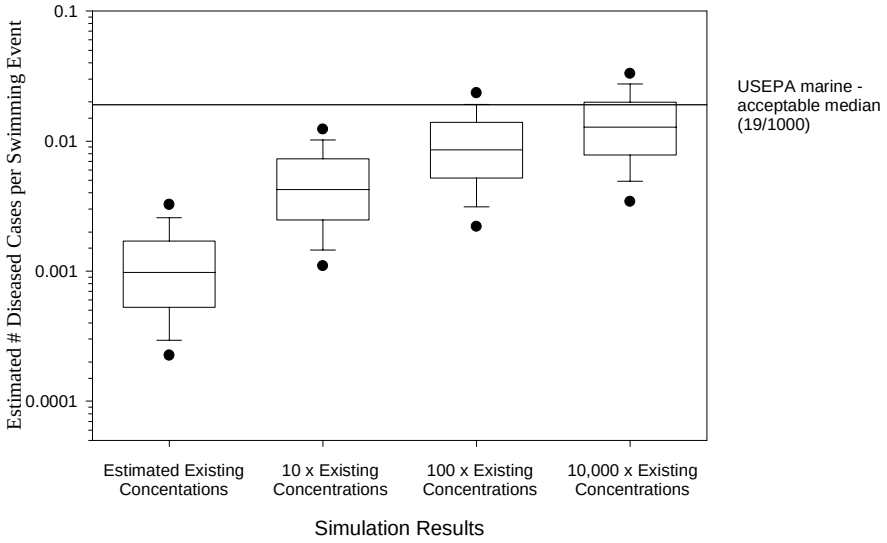
7.4 SENSITIVITY STUDY: IMPACT OF SPECIFIC INCREASED VIRUS LOADINGS

In the previous section, Bay-wide increases of enteric virus concentrations were investigated. In this section, the impacts of increased loadings from two specific viral loading sources are investigated to determine how such increases may impact levels of disease prevalence in the community. The sources investigated included loading from vessels and from recreators. Similar to the previous section, these sensitivity studies

were undertaken to bracket conservatively the unlikely but possible undercounting of enteric viruses in Newport Bay.

Loadings from vessels and swimmers were discussed in detail in Chapter 4 and Chapter 3, respectively. The loading contribution from vessels was increased by a factor of 100 over that specified previously, and that from recreators by a factor of 200. The vessel waste loading estimate discussed in Chapter 4 is based on a number of factors including an estimate of 10^8 infective virus particles per gram of feces and an estimated 10% of the vessels discharging waste to the Bay. The estimation for virus particle per gram of feces was the median value from literature sources, and the proportion of vessels discharging waste to the Bay was estimated as the median of the collected data. The increase presented in this section accounts for the upper feasible ranges of these variables (i.e. increasing the estimate of infective virus particles per gram of feces to the upper end of the range of values reported in the literature (10^{10} infective virus particles per gram) or the 100% of the boats discharging waste to the Bay.

Figure 7.4
Comparison of Estimated Number of Diseased Cases per Swimming Event for Increased Levels of Enteric Viruses in Newport Bay

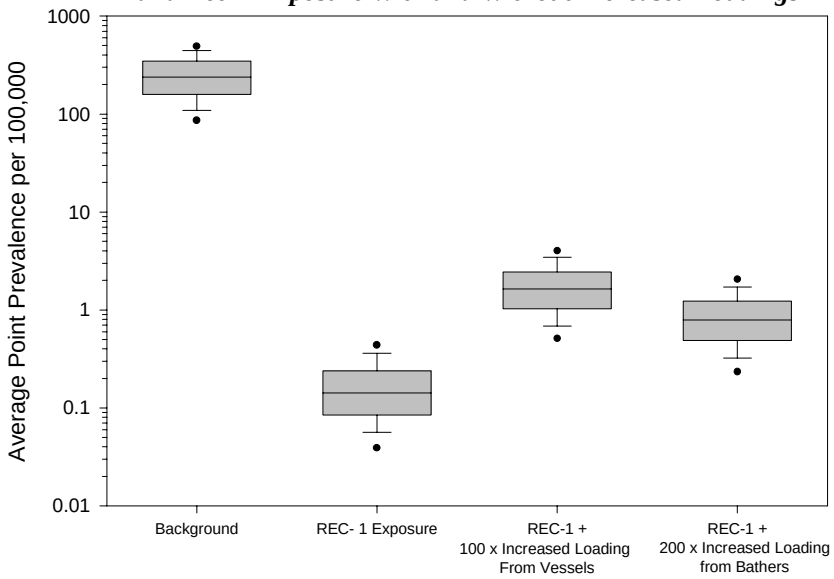


For bather loading, a distributional estimate of loading per person was generated and is based on the proportion of the population shedding viruses, the grams of feces shed per person during recreational activity, and the number of infective particles per gram of feces. The bather loading estimate used to generate the results presented in Chapter 6 was based on the median value of the resultant distribution (Refer to Appendix E). For this sensitivity study, the 99th percentile value from the distribution was used (increase of a factor of 200).

For each of the cases investigated in this section, (increase of vessel loading and increase of swimmer loading), the water quality model was rerun based on the increased loadings, and the output from those runs was used as input to the disease transmission model. The average point prevalence attributable to background exposure, and body contact

recreation with and without the increased loadings are presented in Figure 7.5. As illustrated in Figure 7.5, a 100 fold increase in vessel waste loading results in a slightly larger increase in disease prevalence than a 200 fold increase in bather loading. These results are consistent with those reported in Chapter 5 with respect to the importance of various source loadings.

Figure 7.5
Average Point Prevalence Attributable to Background and Rec-1 Exposure With and Without Increased Loadings



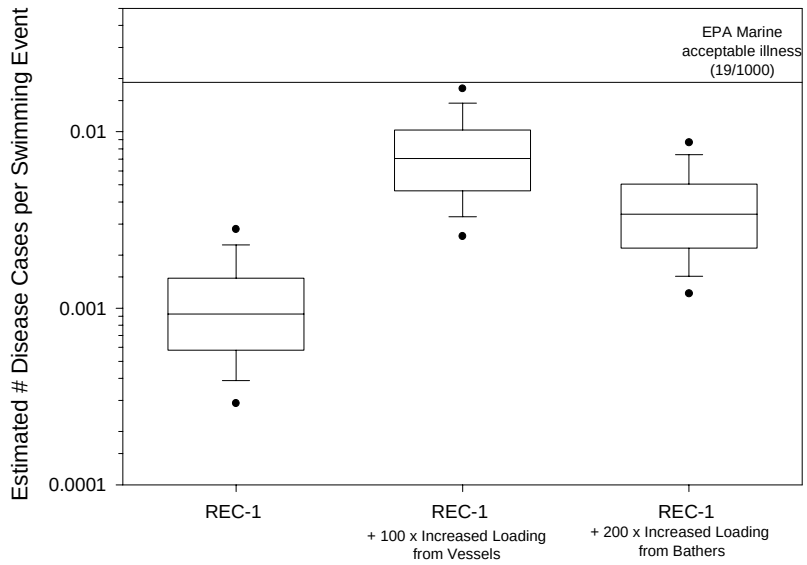
Using the data evaluation method described in Section 6.7.4, the results presented in Figure 7.5 were transformed into an estimate of individual risk based on the number of diseased cases per swimming event. Those results are presented in Figure 7.6 and are compared to EPA's accepted level of illness for body contact recreation. It can be concluded from an inspection of Figure 7.6 that even if the levels of viruses contributed to Newport Bay via vessel waste loading were 100 times higher than estimated in Chapter 4, or if bather loading were 200 times higher than estimated, the estimated risk to an individual per swimming event would still be within the levels considered acceptable by EPA (19 illness per 1000 swimming events).

7.5 MULTIPLE LINEAR REGRESSION FOR BACKGROUND EXPOSURE

The result of the Monte Carlo simulations of a given model is an ensemble of models, each of similar structure with a corresponding parameter vector. All of the parameter vectors taken together constitute a multivariate distribution, sampled from the feasible region of the n dimensional parameter space. The goal of a sensitivity analysis is to ascertain which elements of the multivariate distribution are important in producing simulations that mimic the essential features of the system being studied, as reflected by the output vector. To this end, a criterion function may be defined, which can be used to classify the output (e.g. feasible or infeasible). In this investigation, average daily prevalence per 100,000 is the output vector, and the criterion is the feasible background range of disease in the community as defined by literature values. (i.e. a random set of variable values are selected from the ranges identified in the literature, a simulation is run with background exposure only, the output is compared to the reported endemic level of

disease and the variable set is declared feasible or infeasible based on the result of the comparison.)

Figure 7.6
Estimated Individual Risk per Swim Event
for REC-1 Exposure With and Without Increased Loadings



To understand which parameters may be important with respect to background exposure, a multiple linear regression analysis was performed using the ten variables sampled in the background exposure scenario. Using those variables with average prevalence per 100,000 as the dependant variable, a linear model resulted in a regression equation with a correlation coefficient of $R^2 = 0.89$. The most important determinants of the level of disease prevalence were the parameters *Psym* (probability of symptomatic response), $sigma_{dp}$ (the rate at which individuals move from state D to P), and *TauI* (reciprocal of incubation period), and to a lesser extent *TauL* (reciprocal of latency period) and *Pe* (previous exposure factor). A linear regression model composed of only the three most important parameters resulted in an $R^2 = 0.78$.

7.6 CART ANALYSIS

Multivariate analysis is motivated by the fact that various types of parametric interactions may be important with respect to the output vector and would not be observable from analysis of univariate marginal distributions. In this investigation, a technique known as Regional Sensitivity Analysis is employed (Spear and Hornberger 1980). This robust technique has been applied successfully to other water quality investigations (Van Straten 1981; Whitehead and Hornberger 1984; Jakeman et al. 1990; Eisenberg et al. 1996), as well as investigations in other fields such as toxicology and control engineering, among others (Tsai and Auslander 1988; Spear et al. 1991; Eisenberg et al. 1995).

To define the regions in the feasible multidimensional parameter space most likely to impact the level of disease prevalence attributable to body contact recreation, an implementation of Regional Sensitivity Analysis known as CART analysis was employed (Breiman et al. 1984). CART is a computer intensive procedure that leads to

classification rules based on inequality constraints applied to individual parameter values or to linear combinations of parameters. CART analysis produces a tree structure in which at each node a parametric division is made by an inequality. Observations that satisfy the condition are sent to the left node, otherwise they are sent to the right node. When a specific split is chosen that minimizes the classification error, the node is replaced by two daughter nodes. Splitting continues until a stopping rule is satisfied. Revisitation of higher nodes occurs if necessary to readjust lower level errors. Based on this procedure an exhaustive list of subtrees is created. The optimal tree is the one that minimizes total classification error. The objective is to find an optimal combination of tree size and error (Eisenberg et al. 1996).

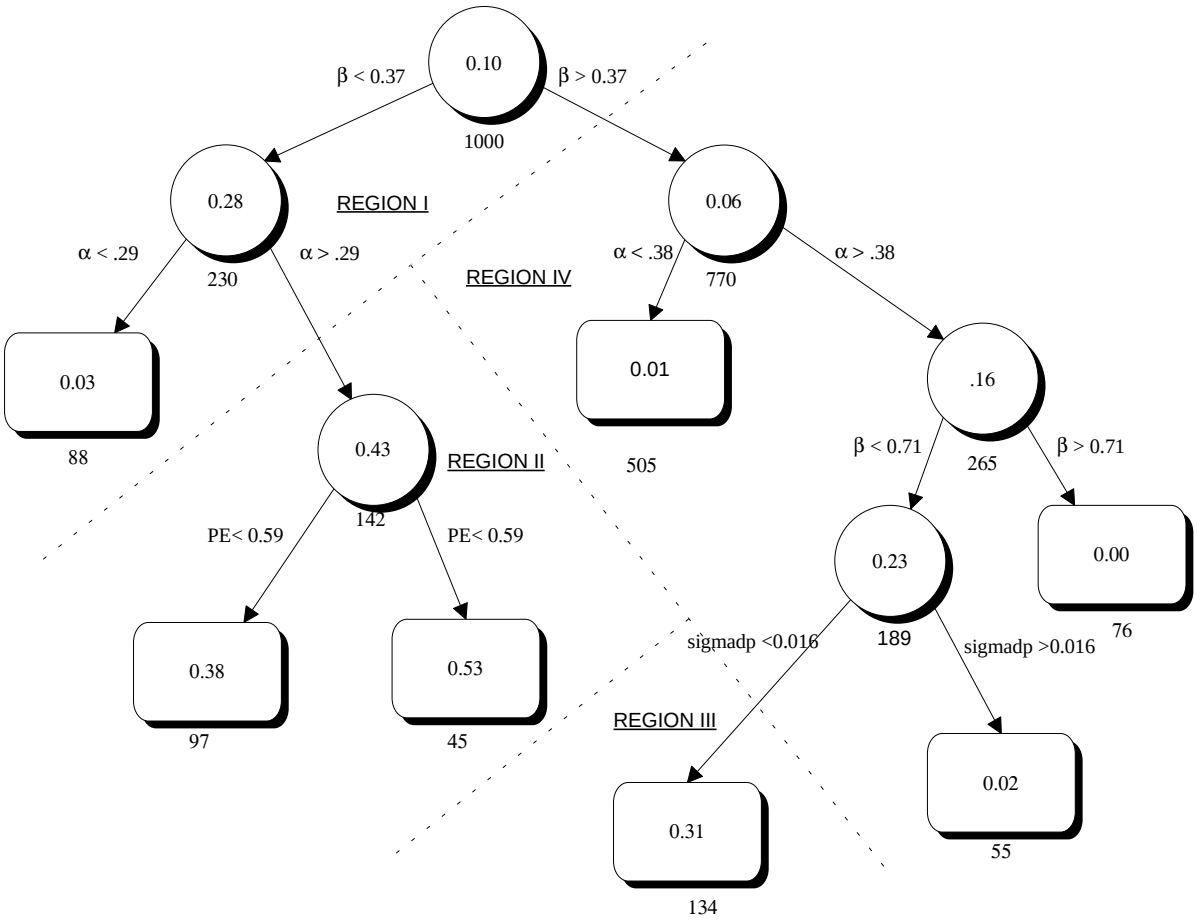
Presented in Figure 7.7, is the decision tree built by the CART procedure to identify the parametric conditions necessary to classify a particular parameter set yielding data in the upper 10th percentile of the dataset defining disease prevalence attributable to body contact recreation (The simulations described in Chapter 6 for the background plus REC-1 exposure scenario were the simulations investigated). The figure may be interpreted as follows: At each node, the number within the circle is the proportion of the simulations falling within the top decile of the simulations with respect to prevalence attributable to body contact recreation; the inequality between the nodes is the parametric constraint necessary to move down one node; and the number below the circle is the total number of simulations satisfying the higher level parametric conditions.

Based on the CART procedure, the classification of an upper decile disease prevalence attributable to REC-1 exposure was primarily determined by the dose response parameters α and β. $Sigma_{dp}$ (the rate at which members of the population move from the diseased state to the post-infection state) and to a lesser extent PE (previous exposure factor) were also found to be important factors. Four distinct regions were identified during the CART analysis, as shown in Figure 7.5. Regions I and IV result in a low probability of an upper decile observation, and Regions II and III correspond to a higher probability of an upper decile observation. Those regions may be summarized as follows:

- Region I: $\beta < 0.37$ and $\alpha < 0.29$;
- Region II: $\beta < 0.37$ and $\alpha > 0.29$;
- Region III: $0.37 < \beta < 0.71$, $\alpha > 0.38$, and $sigma_{dp} < 0.016$; and
- Region IV: $\beta > 0.37$ all cases not included in Region III.

Relevant to this investigation, the insight gained by this analysis is that the primary variability and uncertainty associated with the relative risk to enteric virus disease from body contact recreation in Newport Bay, is driven by the uncertainty in the dose response parameters rather than other epidemiological factors. Based on these results, it could be demonstrated that the uncertainty in the output from the disease transmission model could be reduced (1) If one were to assume that the optimal values for the dose response parameters α and β, achieved via the method of maximum likelihood (Regli et al. 1991) are reasonable estimates for those parameters, or (2) If estimates for α and β could be generated with less uncertainty.

FIGURE 7.7
Decision Tree Produced by CART Procedure



CHAPTER 8: COMPARATIVE ASSESSMENT

8.1 OVERVIEW

The purpose of this chapter is to describe the alternative management scenarios that were examined, to characterize the relative microbial risk to public health associated with each of the alternative management scenarios, and to present the relative risk to public health for those alternatives in a concise manner. The alternative management scenarios are theoretical or potential options for reducing the viral loading to Newport Bay. The alternative management scenarios considered in this chapter were developed based on consultation with the HAC and ex-officio participants[27].

The following management alternatives were explored:

1) Existing conditions as described in Chapter 6;
2) Back Bay storm drain diverted;
3) Back Bay storm drain diverted and no viral loading from San Diego Creek;
4) Back Bay storm drain diverted and no viral loading from Santa Ana Delhi;
5) Back Bay storm drain diverted and no viral loading from Upper Bay storm drains;
6) Back Bay storm drain diverted and viral loading from vessels decreased to 10% of its current level; and
7) Back Bay storm drain diverted and viral loading from bathers decreased to 50% of its current level.

Included in this chapter are: (1) A brief description and rationale for each of the management scenarios investigated, and (2) Summary results of water quality and disease transmission risk modeling under each management alternative.

8.2 DESCRIPTION OF ALTERNATIVE MANAGEMENT SCENARIOS

Developing management alternatives involved identifying the sources of pathogen loading to Newport Bay and determining which of those sources are potentially controllable. Six management alternatives were developed (in addition to the two "alternative scenarios" that were carried out as sensitivity studies and discussed in section 7.4). Each alternative scenario involves reduction in virus loading to the Bay through the reduction or elimination of a specific source. The first four alternatives focus on point source loadings to the Upper Bay (storm drains and creeks). The last two alternative focus on bathers and boaters as sources of pathogen loading to the Bay.

The results of the health risk assessment, as described in Chapter 6, were based on the best available estimates for loading and exposure at the time that this investigation commenced. Recently however (as of March 2001), dry weather flow from the Back Bay storm drain was permanently diverted from the Bay in an effort to reduce pathogen

[27] The alternative management scenarios considered in this investigation focused on identifying factors that potentially affect water quality and are controllable. Factors that are uncontrollable, (such as contributions from wildlife, for example) yet may have a significant impact on water quality, were not the focus of this aspect of the investigation.

loading to Newport Bay[28]. The Back Bay storm drain carries stormwater into Newport Bay at the east end of the Newport Dunes and has been considered a potential "management alternative" for some time. Because of this permanent diversion, loading from the Back Bay Drain was not included in any of the alternative scenario simulations carried out in this analysis.

The first management alternative considered is the existing conditions as described in Chapter 6 with no loading from the Back Bay drain (Alternative 1) . As explained above, this is an alternative that was implemented in March 2001. In all of the other alternatives, diversion of Back Bay Drain is assumed plus additional load reductions corresponding to the alternative under consideration.

How relative risk to public health would change if pathogen loadings from Upper Bay creeks and storm drains were removed is investigated in Alternatives 2, 3, and 4. It is understood that a reduction to zero pathogen loading from these sources is not possible in a practical sense, however these scenarios bracket the range of potential benefit that may be gained by reducing the loading from the specified sources. In Alternative 2 the reduction of pathogen loading from San Diego Creek is considered. In Alternative 3 the loading from Santa Ana Delhi is removed, and in Alternative 4 the relative changes to public health risk where there is no loading from the upper bay storm drains is examined.

Different types of loading to the Bay are addressed in Alternatives 5 and 6. In Alternative 5 it is assumed that the loading from vessels decreases to 10% of its currently estimated level (refer to Chapter 4). Alternative 5 is designed to explore the reduction in risk possible by improving enforcement of Newport Bay's "No discharge" requirement. In Alternative 6 it is assumed that the virus loading from swimmers is reduced to half of its current level, and explores the potential for reduction in public health risk associated with improved sanitary behavior at beaches.

8.3 Results of Comparative Assessment

Water quality in Newport Bay was modeled under each of the six alternatives. The results of this modeling were then input into the disease transmission model, with an assumed exposure as was defined previously for Chapter 6. For each alternative scenario, one thousand Monte Carlo simulations were carried out in the same manner as described in Chapter 6. The ISP was assumed to be 1,200,000 for each of the simulations.

8.3.1 Population Based Results

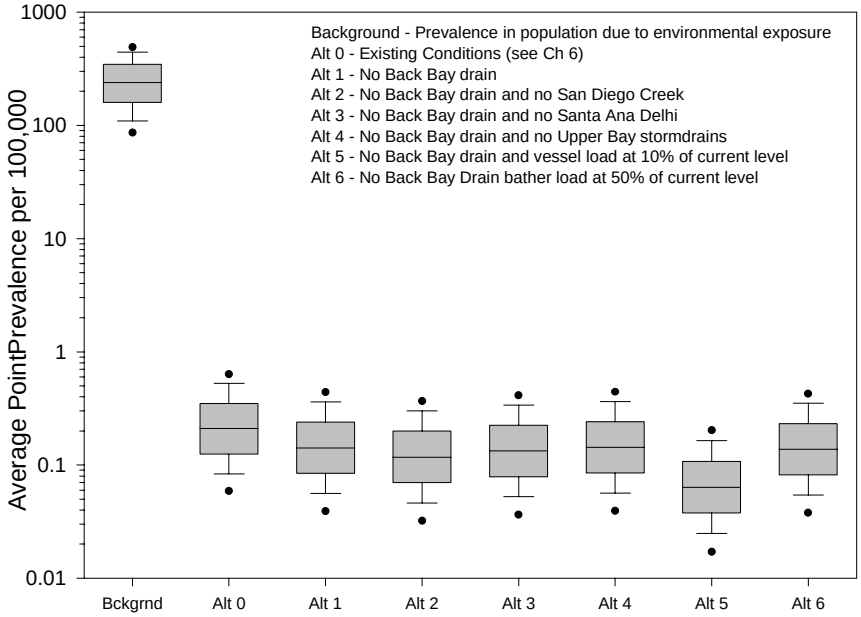
The average point prevalence attributable to background exposure and to REC-1 exposure under each of the management alternatives is presented in Figures 8.1 and 8.2 . The same data as that shown in Figure 8.1 are shown in Figure 8.2, except the background exposure is not shown so that a tighter scaling may be used to investigate the differences between the alternatives.

[28] Personal correspondence with Larry Honeybourne, OCHCA.

Consistent with the results presented previously in Chapters 6 and 7, the median point prevalence due to background exposure is 239 per 100,000 as illustrated in Figure 8.1. (Recall that background exposure represents the environmental exposure that produces the endemic disease prevalence in the population)

Figure 8.1

Average Point Prevalence Attributable to Background and to REC-1 Exposure Under Alternative Scenarios



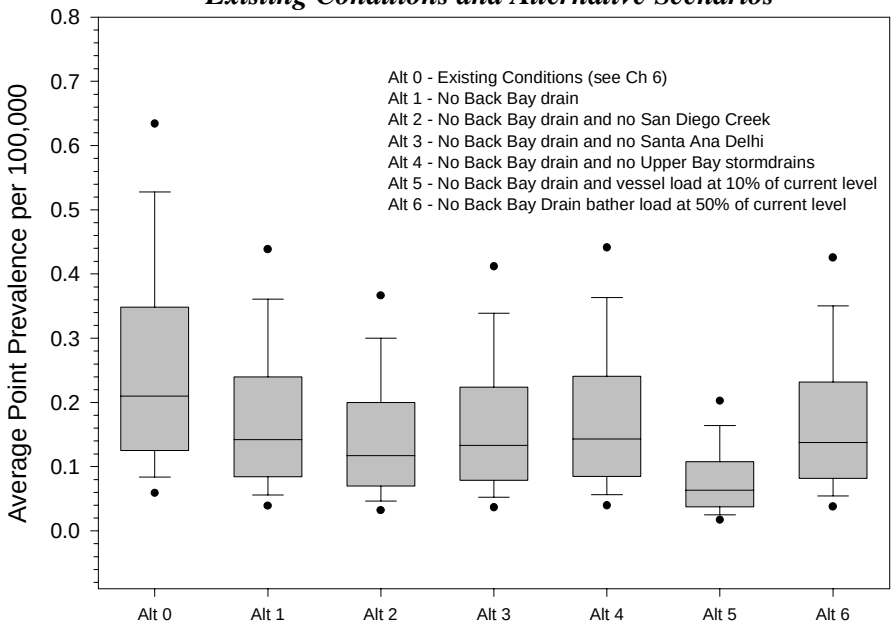
From an inspection of Figure 8.2, it is possible to detect differences in the disease prevalence attributable to body contact recreation in Newport Bay under each of the management scenarios. By comparing the Alternative 0 and 1, the reduction in disease prevalence gained by diverting the Back Bay storm drain can be quantified. By diverting flow from Back Bay Drain to the sanitary sewer, the median prevalence decreased from 0.21 to 0.14 per 100,000. The upper 90% confidence limit about the estimate also decreased from 0.52 to 0.36 per 100,000.

Among the point source reductions alternatives (Alternatives 2, 3, and 4), Alternative 2, elimination of loading from San Diego Creek, yields the greatest reduction in disease prevalence. However none of these options produces a substantial reduction in the disease prevalence in the community.

Alternative 5, reduction of vessel waste loading to 10% of current levels, yields the greatest risk reduction of any of the management scenarios considered. Comparing to Alternative 1, the median prevalence decreases from 0.21 to 0.06 per 100,000, and the upper 90% confidence interval decreases by approximately a factor of about 3, from 0.52 to 0.16 per 100,000. Alternative 6, reduction of bather loading to 50% of its current level, results in a small reduction in disease prevalence, comparable to the reductions of Alternatives 2, 3, and 4.

Figure 8.2

Average Point Prevalence Attributable to Rec-1 Exposure Under Existing Conditions and Alternative Scenarios



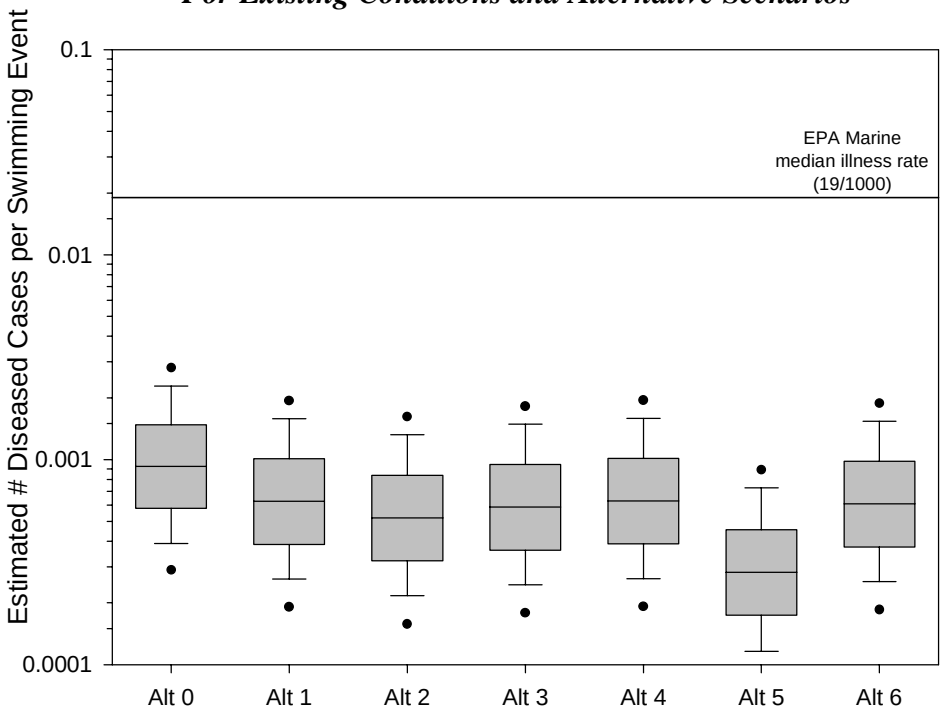
8.3.2 Individual Based Results

Average Point Prevalence was defined as the proportion of the population (per 100,000) that was symptomatic (in the diseased state) during each time step in the simulation. The metric of disease intensity was transformed to risk of disease per swimming event in Chapter 6 (section 6.7.3) so that the results from the disease transmission model could be compared to EPA's accepted illness rates for body contact recreation (median of 19 cases per 1000 swim events).

Using the same approximation as was applied in section 6.7.3, the estimated risk per swimming event for each of the management alternatives is presented in Figure 8.3. Consistent with that shown previously in Chapters 6 and 7, the risk attributable to body contact recreation in Newport Bay under existing conditions (Alternatives 0 and 1) is below EPA's criterion for marine waters.

The median estimated number of diseased cases per swim event under Alternative 0 (existing conditions) is approximately 1 per 1000. With flow from the Back Bay drain diverted, the median estimated number of diseased cases per swim event is reduced to 0.6 per 1000 swimmers (6 in 10,000). Implementation of Alternatives 2, 3, 4, or 6 would result in a reduction of 1 in 10,000 or less, in the estimated number of diseased cases per swim event. Under Alternative 5, the median estimated number of diseased cases per swim event decreases from approximately 6 in 10,000 to approximately 3 in 10,000.

Figure 8.3
Estimated Number of Diseased Cases per Swim Event
For Existing Conditions and Alternative Scenarios



A tabular summary presenting the results of the Comparative Assessment is provided in Table 8.1

Table 8.1
Summary of Comparative Assessment

Exposure Scenario	Median Number in Diseased State at end Simulation (ISP = 1,200,000)	Median Average Point Prevalence per 100,000	Estimated # of Diseased Cases per Swim Event
Background	2865	239	--
Alternative 0	2870	0.21	9.3 / 10,000
Alternative 1	2868	0.14	6.3 / 10,000
Alternative 2	2868	0.12	5.2 / 10,000
Alternative 3	2868	0.13	5.9 / 10,000
Alternative 4	2868	0.14	6.3 / 10,000
Alternative 5	2866	0.06	2.8 / 10,000
Alternative 6	2868	0.14	6.1 / 10,000

Alternative 0. Existing conditions as described in Chapter 6
Alternative 1. Back Bay storm drain diverted
Alternative 2. Back Bay storm drain diverted and no loading from San Diego Creek
Alternative 3. Back Bay storm drain diverted and no loading from Santa Ana Delhi
Alternative 4. Back Bay storm drain diverted and no loading from upper Bay storm drains
Alternative 5. Back Bay storm drain diverted and loading from vessels decreased to 10% current level
Alternative 6. Back Bay storm drain diverted and loading from bathers decreased to 50% current level

CHAPTER 9: INTEGRATE HEALTH RISK ASSESSMENT RESULTS, BENEFITS, AND PLANNING LEVEL COSTS

9.1 OVERVIEW

In this chapter, the results of the Health Risk Assessment (Chapter 6) and the Comparative Assessment (Chapter 8) are integrated with estimated planning level costs for each of the Alternative Management Scenarios described in Chapter 8.

Alternative exposure scenarios corresponding to potential management options or control measures were investigated in Chapter 8 with respect to the potential reduction in health risk that may be achieved by implementing each of those control measures. The Alternatives considered were as follows:

Alternative	Summary
0	Existing conditions as described in Chapter 6
1	Back Bay storm drain diverted
2	Back Bay storm drain diverted and no viral loading from San Diego Creek
3	Back Bay storm drain diverted and no viral loading from Santa Ana Delhi
4	Back Bay storm drain diverted and no viral loading from upper Bay storm drains
5	Back Bay storm drain diverted and loading from vessels decreased to 10% current level
6	Back Bay storm drain diverted and loading from bathers decreased to 50% current level

The results from Chapter 8 are paired with estimated planning level costs that may be required to implement those control measures. Planning level costs were developed for each of the Alternatives described in Chapter 8, and are discussed in two sections in this Chapter: Planning level costs associated with treating Upper Bay inflows (for Alternatives 2, 3, and 4); and Planning level costs associated with implementing new public outreach programs (for Alternatives 5, and 6). A cost benefit analysis is then presented comparing the estimated implementation cost of each of the Alternatives with the projected effectiveness of those Alternatives to reduce risk to public health from body contact recreation in Newport Bay.

9.2 PLANNING LEVEL COSTS FOR ALTERNATIVES 2, 3, AND 4

One possible approach to reduce the viral and/or bacteriological loading in Newport Bay is to treat the water entering the Upper Bay (creeks and storm drains). In support of that approach and to investigate the feasibility of the treatment alternative, planning level cost estimates for treatment of creeks and storm drain discharges were developed. Political, social, or regulatory constraints associated with diverting creeks and/or storm drain discharge, sighting treatment facilities, or discharging treated water to creeks, Newport Bay, or the sanitary sewer system are not considered in this analysis.

These planning level costs include estimates of capital costs, annual operation and maintenance costs and life cycle costs, and are only intended to provide a rough estimate of the costs that may be associated with the specified options. These costs do not take into account site specific conditions that may increase costs, i.e. property values, condition of land, ease of construction, and other special conditions. In addition,

treatment options were chosen based on limited water quality and flow data. A more detailed analysis of data may show different treatment processes or sizes are needed.

9.2.1 Selection of Flow Streams for Treatment

The approach taken was to identify those sources, which if treated, would have the greatest potential for improving viral and/or bacteriological water quality in the Bay. To do so, water quality data for the San Diego Creek, Santa Ana Delhi Channel and a number of storm drain discharge locations presented in Chapter 2, along with the limited flow data[29] available for these sources were reviewed. Because it is not economically practical to divert every potential influent source of microorganisms to the Bay (or to consolidate the relatively dispersed sources for centralized treatment), sources with the highest percent of coliform samples greater than 400 MPN/100mL in the summer months (as presented in Chapter 2) and the highest estimated summer discharge flows were identified for possible treatment. Because the REC-1 beneficial use occurs primarily in the summer months, and because the size (and cost) of facilities for treating wet seasons flows would likely be prohibitive, the dry season flows were used as the basis for estimating treatment costs.

Consistent with the criteria specified above, San Diego Creek and Santa Ana Delhi Channel were considered for treatment (Alternatives 2 and 3, respectively). Based on available data for storm drains, Big Canyon Wash was identified as having the highest summertime flow and some of the highest fecal coliform concentrations of the storm drains sampled. The Big Canyon discharge was therefore chosen for treatment (Alternative 4). There is undeveloped land around the Big Canyon Wash outfall next to the Bay. However, as this land is sometimes inundated with water at high tide, the design of a treatment facility would therefore, involve special (and potentially costly) considerations.

The data (and anecdotal information from County staff) indicate that flow from all the other storm drains is significantly less than from Big Canyon Wash. Of these smaller storm drains, the Back Bay Drive storm drain was selected for treatment because the coliform concentrations were among the highest[30]. In addition, the outfall is located on County owned land (i.e. a park), which might facilitate siting a treatment facility.

In summary, the following treatment strategies were identified as having the greatest potential for reducing microbiological inflows to Newport Bay, and correspond to the Alternatives discussed in Chapter 8. In all cases, the proposed strategy calls for treatment of flows during the during summer months (May – October).

1. Treat Santa Ana Delhi Channel flow, and return treated water to the Channel.

[29] Discussions with County staff added anecdotal information about the relative flow from different storm drains.

[30] Note that this analysis was carried out prior to the permanent diversion of dry weather Back Bay drain flows to the sanitary sewer, and is included in this analysis for completeness. The relative costs associated with treating or diverting a different storm drain with similar flows, water qualities, and siting issues could be estimated based on the data presented herein for Back Bay drain.

2. Treat San Diego Creek, and return treated water to the Creek.
3. Divert Big Canyon Wash storm drain discharge for treatment, and return treated water back to the wash.
4. Divert Back Bay storm drain discharge for treatment, and return treated water back to the storm drain.

Because the flows associated with Big Canyon Wash and Back Bay storm drain are relatively low, diversion of these flows to the sanitary sewer system is considered in Section 9.2.4.

9.2.2 Treatment Options

The flow and water quality data used in the treatment analysis are presented in Table 9.1. The proposed treatment train would to reduce bacteriological concentrations to a total coliform of <2.2 MPN/100mL. The proposed level of treatment is equivalent to that required under California's Title 22 for "disinfected tertiary recycled water". These criteria were selected because (1) it would provide a high level of coliform removal, and (2) performance and costs for providing this level of treatment are well documented in the literature. Although the literature costs are based upon treatment of domestic wastewater, not all of the unit processes typically found in a wastewater treatment plant (or reclamation plant) would be required when treating creek and/or storm drain flows, and the analysis which follows reflects such a "reduced" treatment train.

It is assumed that any treatment train would require facilities for diversion, pumping, coarse screening and possibly grit removal. These operations are analogous to the headworks of a wastewater treatment plant.

As reported in Table 9.1, the coliform and total suspended solids (TSS) concentrations for the selected sources are roughly equivalent to that of secondary effluent from a wastewater plant (prior to disinfection). Therefore, neither primary sedimentation nor secondary (biological) treatment are included in the proposed treatment train. However, TSS concentrations in the discharges are at a level that filtration would be most likely required. Although the filters themselves provide only minimal coliform removals (typically 0.5 to 1 log removal assuming coagulation and flocculation), they are necessary to ensure effective coliform removal in the subsequent disinfection process. High rate sand filters (or pressure filters, which have a smaller footprint) are standard components of a Title 22 treatment process.

To reduce coliform concentrations, two disinfection options were considered, chlorination and UV disinfection. Chlorine is the most widely used disinfectant, and is highly effective in reducing coliform concentrations to very low levels. For large flows (>10 Mgal/d), gaseous chlorine is often used, whereas for smaller flows, liquid chlorine (sodium hypochlorite) is more common. (Chlorine can be generated on-site electrolytically, reducing chemical storage and handling requirements, although this alternative is very expensive). Chlorinated water can be discharged to the sanitary sewer, however, if discharged back to a creek or Bay, it must first be dechlorinated. Liquid sodium bisulfite is normally used for this purpose. For both chlorination and

dechlorination using liquid chemicals, a system of metering pumps and residual analyzers is used to control the rate of chemical injection into the flow stream, and to verify that the correct levels are achieved.

Table 9.1
Water Quality and Flow Data for Treatment Options

Discharge Source	
Treatment criteria	**Data Source**
Santa Ana Delhi Channel	
Average flow = 2.4 Mgal/d Max flow = 13.4 Mgal/d Min flow = 1.1 Mgal/d	July 95 – June 97 monthly means for May – October only; OCHCA
Average TSS = 24 mg/L Max TSS = 46 mg/L Min TSS = 10 mg/L	4 samples collected from May – October (1998-2000); County of Orange Public Facilities and Resource Department
Total Coliform median = 9,000 MPN/100mL	1990-1998 (May – October only), 90 samples, OCHCA
Fecal Coliform log mean = 501 MPN/100mL	May – October 1999, 30 samples, OCHCA
Fecal Coliform log mean = 355 MPN/100mL	May – October 2000, 31 samples, OCHCA
San Diego Creek	
Average flow = 9.8 Mgal/d Max flow = 18.4 Mgal/d Min flow = 7.4 Mgal/d	July 95 – June 97 monthly means for May – October only; OCHCA
Average TSS = 109 mg/L Max TSS = 1600 mg/L Min TSS = 18 mg/L	72 samples collected from May – October (1998-2000); County of Orange Public Facilities and Resource Department
Total Coliform median = 7,000 MPN/100mL	1990-1998 (May – October only), 57 samples, OCHCA
Fecal Coliform log mean = 117 MPN/100mL	May – October 1999, 30 samples, OCHCA
Fecal Coliform log mean = 138 MPN/100mL	May – October 2000, 27 samples, OCHCA
Big Canyon Wash Storm Drain	
Flow = 1.1 Mgal/d	1 data point in May 2000; IRWD
Average TSS = 58 mg/L Max TSS = 270 mg/L Min TSS = 4 mg/L	45 samples collected from May – October (1998-2000) at Costa Mesa storm drain[1]; County of Orange Public Facilities and Resource Department
Total Coliform median = 3,000 MPN/100mL	1990-1998 (May – October only), 17 samples, OCHCA
Fecal Coliform log mean = 166 MPN/100mL	May – October 1999, 26 samples, OCHCA
Fecal Coliform log mean = 200 MPN/100mL	May – October 2000, 26 samples, OCHCA
Back Bay Storm Drain	
Flow = 0.04 Mgal/d	1 data point in May 2000; IRWD
Average TSS = 58 mg/L Max TSS = 270 mg/L Min TSS = 4 mg/L	45 samples collected from May – October (1998-2000) at Costa Mesa storm drain[1];
Total Coliform median = 9,000 MPN/100mL	1990-1998 (May – October only), 150 samples, OCHCA
Fecal Coliform log mean = 186 MPN/100mL	May – October 1999, 29 samples, OCHCA
Fecal Coliform log mean = 60 MPN/100mL	May – October 2000, 28 samples, OCHCA

Notes:
1. Total Suspended Solids data were not available for Big Canyon or Back Bay storm drain discharges, so it was assumed that Costa Mesa storm drain water quality data would be representative.

Ultraviolet (UV) light is a second option for disinfection. Although capital and operating costs for UV disinfection may be higher than for chlorination (particularly when disinfecting to low coliform concentrations), the use of UV eliminates both the need to store and handle hazardous chemicals, and concerns about chlorinated byproducts in the treated water. For these reasons, UV is becoming an increasingly popular disinfectant in the wastewater treatment industry.

9.2.3 Treatment Cost Estimates

Treatment costs were derived primarily from "The Cost of Wastewater Reclamation in California" (Richard, et. al November 1992). In this reference, detailed estimates are presented for 12 different treatment trains at three flow rates (1, 5, and 10 Mgal/d). Capital costs are presented for the individual unit processes that make up the treatment train (e.g., headworks, primary sedimentation, filtration, chlorination, etc) as well as for the "site-wide" costs that are a necessary part of any treatment process (site development, process-yard piping, instrumentation, electrical distribution controls, electrical services, operations/maintenance buildings). For the present analysis, it was noted that the site development, process piping, instrumentation, electrical distribution and controls, and electrical service generally amounted to 50% of the total cost of the unit processes. Therefore, this factor is applied to the unit process costs selected from the reference document. The costs for support buildings (also from the reference document) and plus design/administrative/legal costs are in addition to the above costs. The latter are estimated at 35% of total capital costs.

A range of unit capital costs for the selected unit processes is presented in Table 9.2, along with the other components that contribute to total capital costs. The variation in unit costs for filters reflects different types of filters considered in the study. Actual filter costs will depend on the type of unit selected and the unit loading rates, which are typically determined through pilot studies. Dechlorination costs were estimated at 50% of chlorination costs. For purposes of this analysis, the high end of the capital cost range will be used to estimate treatment costs for the selected discharges. Initial UV costs were estimated as twice the corresponding cost for chlorine disinfection, adding approximately 10% to the total capital cost estimates.

Table 9.2
Range of Estimated Capital Costs

	Costs in Million Dollars		
Component	**1 Mgal/d**	**5 Mgal/d**	**10 Mgal/d**
Headworks[1]	0.620 - 0.650	1.06 – 1.115	1.640 – 1.730
Filters[1]	0.170 - 0.340	0.56 – 1.215	1.095 – 1.920
Chlorination[1]	0.270 – 0.295	0.60 - 0.585	0.820 - 1.125
Dechlorination	0.135 – 0.148	0.300 – 0.293	0.410 – 0.563
Support Buildings[1]	0.355	0.510	0.705
Site-wide Costs (50% of above) [1]	0.775 – 0.894	1.515 – 1.859	2.335 – 3.022
Total Construction Cost	2.325 – 2.682	4.545 – 5.577	7.005 – 9.065
Engineering/Administrative/Legal (35% of construction costs)	0.813 – 0.939	1.591 – 1.952	2.452 – 3.173
Total Capital Cost	3.138 – 3.621	6.136 – 7.529	9.457 – 12.238

1. Reference: "The Cost of Wastewater Reclamation in California" (Richard, et. Al November 1992)

"The Cost of Wastewater Reclamation in California" also provides estimates of annual operating costs, which include personnel charges, power costs, spare parts, chemicals, and solids handling fees. Because the proposed treatment train is a subset of those in the reference document, the values presented in Table 9.3 were estimated from the incremental operation and maintenance costs associated with upgrading a wastewater treatment plant with filtration and chlorination.

Table 9.3.
Estimated O&M Costs

	Costs in Million Dollars		
Component	1 Mgal/d	5 Mgal/d	10 Mgal/d
Labor[1]	0.011 – 0.017	0.023 – 0.026	0.035 – 0.042
Power[1]	0.009 – 0.017	0.012 – 0.017	0.024 – 0.030
Maintenance[1]	0.011	0.020 – 0.022	0.031 – 0.045
Chemicals[1]	0.024	0.122	0.244
Sludge handling and disposal[1]	0.001	0.003	0.005
Total O&M Costs	**0.056 – 0.070**	**0.180 – 0.190**	**0.339 – 0.366**

1. Reference: "The Cost of Wastewater Reclamation in California" (Richard, et. Al November 1992). Note that these costs may be somewhat low because the cost data is from 1992.

Estimated treatment costs for the selected discharge streams are presented in Table 9.4. These costs are presented as January 2001 dollars. The costs from the cited reference above were in January 1990 dollars and were adjusted using a 20 city average ENRCCI. The first row of values represent the total capital costs, based on the unit costs presented in Table 9.2. These costs are then annualized using a 10% interest rate over 20 years. The estimated annual O&M cost, and the total annual cost (capital + operating) are also presented.

Table 9.4
Estimated Total Costs for Treating Newport Bay Inflows

	Santa Ana Delhi	San Diego Creek	Big Canyon Wash	Back Bay Storm Drain
Average Flow (Mgal/d)	2.4	9.8	1.1	0.04
Design Flow for estimate (Mgal/d)	5	10	1	0.04[2]
Capital Cost (million $)	9,849,000	16,009,000	4,737,000	498,000
Annualized Capital Cost ($/yr)[1]	1,157,000	1,880,000	556,000	58,000
Operating Cost ($/yr)	249,000	479,000	92,000	10,000
Total Annual Cost ($/yr)	1,405,000	2,359,000	648,000	68,000

1. Annualized capital cost is based on a design life of 20 years and a return rate of 10%.
2. The average flow of this discharge stream was determined to be too low to estimate the cost based on the 1 Mgal/d design flow costs. Therefore, costs for this discharge flow were calculated using the known costs of a 1 Mgal/d plant and assuming a cost-plant size curve of power 0.7 (due to economies of scale the cost to size relationship is not linear).

Site acquisition costs are not included in the capital costs presented in Table 9.4. The cost of land acquisition is variable and site specific. Siting a treatment facility near these discharges was determined to be feasible based on the presence of undeveloped land

shown on a standard street map. The actual possibility of acquiring land or the costs of acquiring land were not included in the above cost estimates.

9.2.4 Diversion of Storm Sewers to Sanitary Sewer

Diversion of creek flow and dry weather base flow from storm drains to the sanitary sewer was also considered. The Michelson Water Reclamation Plant (MWRP) has a 15 Mgal/d plant capacity, and currently treats an average flow of 13 Mgal/d. The nearest water source considered for treatment is San Diego Creek. The average flow of San Diego Creek during the summer months is 9.8 Mgal/d. Therefore, the MWRP currently would not have the capacity to treat this water source. Permit conditions and high salinity concentrations would also prevent them from excepting these flows.

Diversion of the smaller flows (Big Canyon Wash and/or Back Bay Storm drain) would be more feasible, as it may be possible to pump these flows to an existing sanitary sewer for transport to the Orange County Sanitation District (OCSD) Treatment Plant #2 (Huntington Beach). Discussions with District staff revealed that some dry weather urban runoff flow is currently being diverted to the sanitary sewer. A special cooperative agreement was reached between the treatment plant and storm drain discharge responsible agencies. Currently, there is no charge from the treatment plant for treating these urban runoff flows because the cumulative flows are below a threshold target (4 Mgal/d monthly average). Once that target is passed there will be a fee assessed to each discharge based on the relative plant treatment costs for the flow. As discussed previously, Back Bay storm drain is one of the discharges that is currently being diverted (as of March 2001). Although there is no fee assessed to the responsible agency there is a cost associated with diverting and treating this discharge. The cost estimates below are based on discussions with OCSD staff. The capital costs are an estimated cost for building a diversion structure at the storm drain outfall. The annual costs include the plant operational costs for treating the flow and an annual permit fee.

Table 9.5
Range of Costs for Diverting Dry Weather Urban Runoff

Component	Range of Cost Estimates
Capital Cost (diversion structure)	$50,000 - $250,000
Annual treatment plant costs	$320 - $900 per million gallon
Annual permit fee	$250

The total costs for diverting the storm drain discharges for Big Canyon Wash and Back Bay are presented in Table 9.6. The capital costs were based on the minimum and maximum estimates in the range for the low and high average flows of the storm drain discharges, respectively. The design/administrative/legal costs were again estimated as 35% of the capital costs. The operating costs were based on the maximum cost for treatment multiplied by the average flow per day (Mgal/d) for the six month dry season (May – October). There are many additional costs that were not accounted for in these estimates, including land costs, maintenance of diversion structure and sampling and

analysis costs. Further, it is not known whether there is capacity in the existing pipeline for the flows shown in Table 9.6

Table 9.6
Estimated Total Costs for Diverting Small Dry Weather Urban Runoff Flows

	Big Canyon Wash	**Back Bay Storm Drain**
Average Flow (Mgal/d)	1.1	0.04
Capital Cost ($)	338,000	68,000
Annualized Capital Cost ($/yr)[1]	40,000	8,000
Operating Cost ($/yr)	179,000	7,000
Total Annual Cost ($/yr)	219,000	15,000

1. Annualized capital cost is based on a design life of 20 years and a return rate of 10%.

9.3 PLANNING LEVEL COSTS FOR ALTERNATIVES 5 AND 6

One second possible approach to reduce the microbiological loading in Newport Bay is to develop public outreach programs that may be effective in changing human behavior (loading from boaters and recreators) and thereby reducing the loading to the Bay. In support of that approach, planning level cost estimates for the implementation of public outreach programs were developed. These estimated planning level costs are meant to investigate the feasibility of implementing Alternatives 5 (reduction of vessel waste loading) and 6 (reduction of bather loading)[31], but again are only intended to provide a rough estimate of the costs that may be associated with the specified options.

The goal of a public outreach campaign is to repeatedly reach the appropriate audience with a clear and consistent message. The sender needs to communicate the message at a time and in a format which will encourage listener receptivity. For example, individuals relaxing at a beach may have a limited attention span for an outreach campaign, particularly pre-occupied parents distracted from a public health message by their excited children. Consequently if the message is to reach a receptive audience, the public outreach program may want to include options beyond message delivery at the beach or at a boat dock during a holiday weekend. In addition, the degree to which the audience is known and can be targeted will affect the complexity and cost of an outreach campaign. The planning level costs described below include estimates of costs to develop flyers, posters and signs, targeted mailing campaigns, media placement, and professional services.

One potential drawback to this approach for minimizing microbiological loading to Newport Bay is the difficulty in measuring the effectiveness of the programs. For example, Alternative 6 is based on an assumed reduction of loading from bathers to 50% of the currently estimated level. Actually measuring the effectiveness of a program implemented to achieve that goal would be very challenging and perhaps expensive.

[31] Implementing a public outreach campaign to control recreational vessel sewage discharge is an approach that is consistent with that set forth by US EPA. Interested readers are referred to EPA 842-B-94-005, U.S. EPA. "Recreational Vessel Sewage Discharge Control: A Primer for State and Local Outreach Campaigns." EPA 842-B-95-005, August 1994..

Similarly, it would be a challenge to design a program to measure the effectiveness of an outreach program designed to reduce the loading from boats to 10% of the currently estimated level (Alternative 5). Outreach programs are described below covering the general components which may need to be included to achieve the goal of the respective Alternatives. If any such programs are implemented in the future or are considered for implementation, it is recommended that program evaluation be considered carefully.

9.3.1 Planning Level Costs Associated with Decreasing Loading from Recreators

Recreators at Newport Bay beaches are a specific, easily defined audience, whereas the category of potential Newport Bay recreators is quite broad and more challenging to target (Refer to discussion on ISP in Chapter 3). A broad-based, multi-media campaign designed to reach a wide variety of people residing in neighboring communities, as well as the City of Newport Beach, may be worth consideration to reach people before they visit Newport Bay beaches.

The following four public outreach program options are listed from the simplest and least costly to the most complex and expensive. The dollars figures are based on conversations with media production consultants, as well as a review of existing public outreach budgets or public relations/marketing consultant proposals for local government agencies or consortiums of several local governments. The analysis included an advertising firm in the Los Angeles area (Woodland Hills) and a small consulting firm based in Orange County, who has created videos for CalTrans.

Minimum On-Site Communication Program

1. Distribute flyers at the beach on select days, such as holidays and weekends at the 6 most heavily used beaches during the high recreational use season. It is estimated that this approach would reach between 15,000 and 20,000 people;
2. Post signs at some or all beach entry points. Sign maybe permanent or a poster/flyer tacked onto an existing bulletin board or temporary sandwich board.

Potential costs

- $1,000 - $12,000 to print ~18,000 flyers without or with graphic design, respectively;
- $315 - $2100 to print 30 posters with graphic design; OR
- $50/permanent sign + installation costs (assuming design regulations equivalent to permanent traffic sign);
- Assumes In kind Agency labor costs to develop message;
- Assumes In-kind Agency labor costs to write flyer/poster text;
- Assumes In-kind Agency labor costs to deliver flyers/posters to beach sites; and
- Assumes parking lot attendant or In-kind Agency labor is available to handout flyers or safeguard the sandwich board at no additional cost.

Community Outreach Campaign Program

1. Targeted mailing campaign to pediatricians/family practice doctors, swimming teachers, and others who have direct contact and influence with the targeted audience; and

2. Education outreach at community fairs, classrooms and other grass-roots level activities.

Potential costs[32]

- $5,000 - $20,000 in graphic design, printing for brochures, other information pieces; and
- 1/4 time-experienced person (app. 550 hours) to develop new brochures, research and implementation of one major targeted campaign, coordination of mailing or physical displays, attends 6 community fairs per year, keep doctor offices stocked with brochures.

Minimal Media Program

1. Develop image/identity, implementation strategy, and possibly oversee production of media pieces.
2. Expand outreach to include newspaper print and 30/60 second public service announcements (PSA's) on radio and broadcast media.
3. Media relations – obtain in-depth coverage of issue on local television, radio and newspaper by actively pursuing radio interviews, public affairs programming, and other.

Potential Costs

- $15,000 - $40,000 Create identity, implementation strategy, and oversee development;
- $3,500 - $30,000 Write newspaper copy and produce Public Service Announcements (PSA); and
- $10,000 - $15,000 – Media relations. Cost does **not** include any media buys or advertising. Radio and TV stations are required to run public service announcements, but there is no control over the time, day and number of times the PSA will be played.

Local government agencies' familiarity using local media and in-house technical ability to produce their own video products varies greatly. An agency with a proactive public information office and/or their own cable TV studio, camera equipment, and technicians will do more in-house, then those without these resources who may want assistance from an outside consultant.

Professional Campaign Program

The elements of the above Minimal Media Program plus the following additions:

1. Perform surveys and conduct focus group interviews to determine who the prospective audience is, learn how to best reach them, and evaluate how well messages were communicated;
2. Produce commercials for print, radio and television;
3. Buy media placements/advertising; and

[32] Contra Costa County Public Works contracted yearly at the cost of $20,000-$30,000 with the County Health Services Department to receive similar services. Examples of annual targeted campaigns were self-employed painters / paint stores and boaters / marinas.

4. Provide overall coordination to research, creative, production, and advertising activities that will probably be performed by either a full service public relations firm or a cooperating network of consultants and sub-consultants

Potential Costs

- $4,000 - $12,000 Focus Group;
- $15,000 - 80,000 Surveys;
- The cost of producing and placing paid advertising ranges widely depending on the media chosen, number of spots per week, length of time the commercial runs, vagaries of the local advertising market, and other factors. Example of sample campaigns include:
  - $30,000 Spring television campaign for San Francisco Water Pollution Prevention Program. (This amount does not include production costs.);
  - $90,000 Radio media campaign for San Bernardino and Riverside Counties' Storm Water Public Education programs;
  - $102,000 Cable television fall campaign for 5 (five) San Francisco Bay Counties' Oil Recycling Programs (No production costs included.); and
  - $400,000 Multi-media Spring campaign for a regional storm water organization (BASMAA) representing more than 5 Counties

9.3.2 Planning Level Costs Associated with Decreasing Loading from Vessels

Unlike the Programs discussed above in section 9.3.1, the audience of boaters and boat owners with boats docked in Newport Bay is a narrow, clearly defined group that can be more easily targeted. Expensive, broad-based, multi-media communication may not be necessary. Precise audience identification and the creation of potential mailing lists can be created from County Tax Assessor records, the City's dock rental agreements, yachting, sailing, and other clubs or associations catering to boat owners. Public outreach messages could be crafted to fit each of these sources. Some examples include the following:

1. Information flyers can be inserted into the property tax bills of boat owners residing in the City of Newport Beach;
2. Rental agreements in Newport Bay marinas could be amended to include wording forbidding the use of sanitary facilities on boats without holding tanks and forbidding discharging human waste while in Newport Bay. At a minimum, information could be distributed to everyone when they rent public dock space; and
3. Make presentations, including videos regarding health problems of sanitary discharges, at sailing and yachting clubs or to classes where sailing is taught.

Potential Costs

- $2,500 - $20,000 production of flyers, brochures, other printed information pieces with or without graphic design;
- Minimal - $3,000 Mailing costs (will vary depending on method used). There are instances where County Tax Offices have agreed to insert public information flyers with property tax bill for no charge. For large mailings, a professional mailing service can copy, fold, and insert at competitive rates and then mail at the

lower bulk rates. Local governments can also take advantage of bulk mailing rates and often have an in-house office that handles copying and mail preparation services;

- $5,000 - $25,000 Develop a video. Range is based on amounts budgeted or proposed for video production in several local government public outreach programs in the San Francisco Bay area. The quality of the video and ability to provide services in-house, (e.g. cable TV studio, camera equipment, and technicians) will affect the cost;
- 100 hours of In-kind services to research and develop one information piece, and provide the coordination, scheduling and other administrative tasks to ensure that the information then reaches its audience. The in-kind figure is a rough average based on several outreach projects performed by a local government employee experienced in public outreach. Besides development of the brochure, the projects involved 1) coordination with county tax departments to develop mailing list and arrange for mailing, 2) coordination with 15 marinas to disseminate hazardous waste prevention information when either a launch ticket was purchased or a rental agreement was signed; and
- 8 – 10 hours Schedule and speak at clubs and associations frequented by boaters. These hours assume minimum time for preparation of material. Add time if power point presentations, slides, and overheads are to be developed.

9.4 INTEGRATE COMPARATIVE ASSESSMENT AND PLANNING LEVEL COSTS

Based on information presented in Sections 9.2. and 9.3, planning level cost estimates for Alternatives 2 through 6 are summarized in Table 9.7. Also presented in Table 9.7 is a summary of the likelihood that the alternative would achieve the goal of each alternative[33]. Consistent with that described previously, Table 9.7 indicates that Alternative 2, 3, and 4 are more costly and more likely to achieve success, than Alternative 5 and 6, for which the probability of success is unknown.

Table 9.7
Planning Level Costs for Alternatives Considered in Comparative Assessment

Alternative	Summary	Estimated Annual Cost ($)	Probability of Achieving Goal
0	Existing conditions as described in Chapter 6	-	
1	Back Bay storm drain diverted	$15,000[1]	
2	Alt.1 and no viral loading from San Diego Creek	$2,359,000	High
3	Alt 1 and no viral loading from Santa Ana Delhi	$1,405,000	High
4	Alt 1 and no viral loading from upper Bay storm drains	$219,000[2]	High
5	Alt 1 and loading from vessels decreased to 10% current level	$25,000 - $70,000[3]	Unknown
6	Alt 1 and loading from bathers decreased to 50% current level	$25,000 - $50,000	Unknown

1. Currently in place
2. Assumes drain diversion to sanitary sewer rather than treatment option;
3. Assumes Community Outreach Campaign and Minimal Media Program with mid-ranges used for estimated costs.

[33] For alternatives 2,3, and 4, the loading reduction would correspond to the description in section 9.2.2

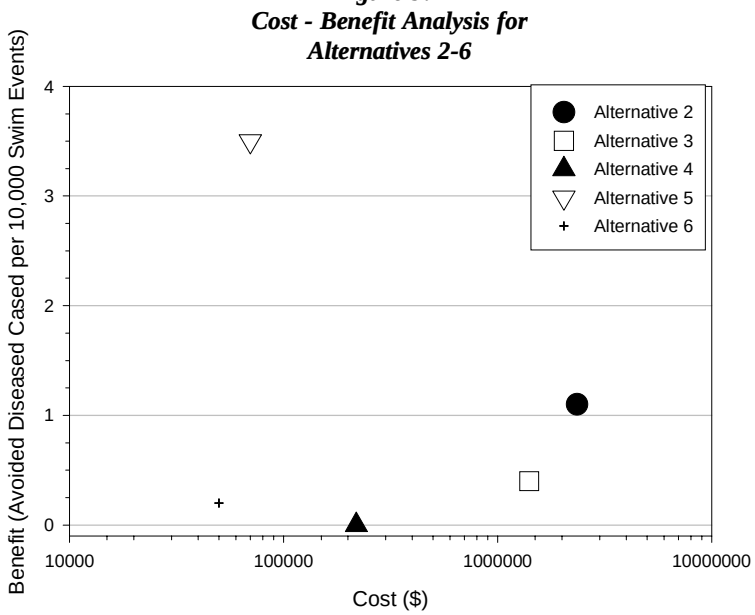
The results from the comparative assessment in Chapter 8 are integrated with those planning level costs in Table 9.8 and shown graphically in Figure 9.1. The estimated benefits in terms of the reduction of disease per 10,000 swim events, and the estimated annual costs to implement each alternative are presented in Table 9.8. Note that the benefits shown in Table 9.8 are relative to Alternative 1 as Alternative 1 most closely resembles the current status (with Back Bay drain dry weather flow diverted).

A graphical summary of the estimated cost of implementing each alternative as a function of the diseased cases avoided is illustrated in Figure 9.1. The estimated cost of implementing Alternative 5 and 6 as a function of the diseased cases avoided, is based on the assumption that the public outreach campaigns would be effective in reducing the loading to the specified levels.

Table 9.8
Estimated Benefits and Planning Level Costs for Alternatives Considered in Comparative Assessment

Exposure Scenario	Estimated # of Diseased Cases per Swim Event	Estimated Benefit: Reduction of Disease Cases per 10,000 Swim Events	Estimated Annual Cost	Probability of Achieving Goal
Alternative 0	9.3 / 10,000	-	-	
Alternative 1	6.3 / 10,000	-	$15,000	
Alternative 2	5.2 / 10,000	1.1	$2,359,000	High
Alternative 3	5.9 / 10,000	0.4	$1,405,000	High
Alternative 4	6.3 / 10,000	0.0	$219,000	High
Alternative 5	2.8 / 10,000	3.5	$25,000-70,000	Unknown
Alternative 6	6.1 / 10,000	0.2	$25,000-50,000	Unknown

Figure 9.1
Cost - Benefit Analysis for Alternatives 2-6



Note: Probability of Success for Alternative 2, 3, 4 - High
Probability of Success for Alternatives 5, 6 - Unknown

The following observations may be made from the data presented in Table 9.8 and Figure 9.1:

- The effectiveness (avoided diseased cases per swim event) of eliminating viral loading from San Diego Creek, Santa Ana Delhi, or Big Canyon Wash to Upper Newport Bay with respect to minimizing risk to public health from body contact recreation in Newport Bay is predicted to be approximately 1/10,000 or less;
- Reducing pathogen loading from vessels to 10% of the currently estimated level would be at lest three times more effective in terms of avoided diseased cases per swim event than any other Alternative considered. It should however be understood that vessel loading is a highly uncertain parameter, and that the actual benefit to be realized from minimizing this component may be less than that predicted herein;
- Eliminating pathogen loading to Newport Bay from Big Canyon Wash would have no measurable effect on public health;
- Treating dry weather flow from the San Diego Creek or Santa Ana Delhi (Alternatives 2 and 3) is likely to be substantially more expensive than implementing public outreach campaigns (Alternatives 5 and 6);
- The probability of effectively implementing a public outreach campaign to reduce loading from vessels or recreators, is unknown; and
- In terms of cost of each Alternative per diseased case avoided, Alternative 5 is estimated to be the most effective (provided that the public outreach program would be effective). Alternative 6 would cost approximately 10 times more per diseased case avoided than would Alternative 5 (with the same caveat that the outreach program is effective), and Alternatives 2 and 3 would cost approximately 200 to 250 times more per diseased case avoided.

CHAPTER 10: HRA FINDINGS AND RISK MANAGEMENT CONSIDERATIONS

10.1 INTRODUCTION

Risk Management is a decision making process which involves weighing policy alternatives with respect to social, economic, political, engineering, and risk related information to select the most reasonable regulatory action(s) or response(s) to a potential health hazard (National Research Council 1983).

In Chapters 1 through 9 of this report, a detailed health risk assessment was presented along with appropriate supporting information and data. Key elements of this investigation included: an extensive review of relevant literature, a summary of bacteriological water quality in Newport Bay, beneficial use data collection, water quality modeling, development of a population based disease transmission model to estimate risk to human health, characterization of model parameter sensitivity and uncertainty, and consideration of a series of control (management) options to reduce risk to public health.

The purpose of this chapter is to highlight critical findings from this investigation, and to describe the relation between those findings and risk management within the context of the fecal coliform TMDL.

10.2 HRA FINDINGS

10.2.1 303(d) Listing of Newport Bay for Fecal Coliform

Newport Bay is a Section 303(d) listed waterbody consistent with the Clean Water Act. Pathogens are identified as a stressor of actual and/or threatened water quality impairment, and urban runoff and/or storm sewers are identified as likely sources of the pathogens. The actual and/or threatened water quality impairment was evaluated using the fecal coliform water quality objectives (as indicators of risk from pathogenic microorganisms) for the body contact recreation (REC-1) beneficial use.

The analysis conducted as part of this public health risk assessment investigation indicates the following:

1. Although the whole Bay is listed, the Basin Plan fecal coliform objectives for the REC-1 beneficial use[34] are met in much of the Bay for much of the year. Data supporting this finding are presented graphically in Figures 10.1 and 10.2 in which Newport Bay fecal coliform data for the time period of 1999 – 2000 are summarized, by monitoring station and levels of observed recreational use;
2. Exceedances of the Basin Plan fecal coliform objectives for the REC-1 beneficial use are temporally sporadic, geographically limited, and generally occur where level of body contact recreation is low or is prohibited (i.e. within the ecological reserve in the Upper Bay) and /or during the time of the year when REC-1 use is low; and

[34] log mean 200 MPN/100mL and 90th percentile 400 MPN/100mL.

Figure 10.1
Summary of Log Mean Fecal Coliform Data
For Newport Bay Sites: 1999 - 2000

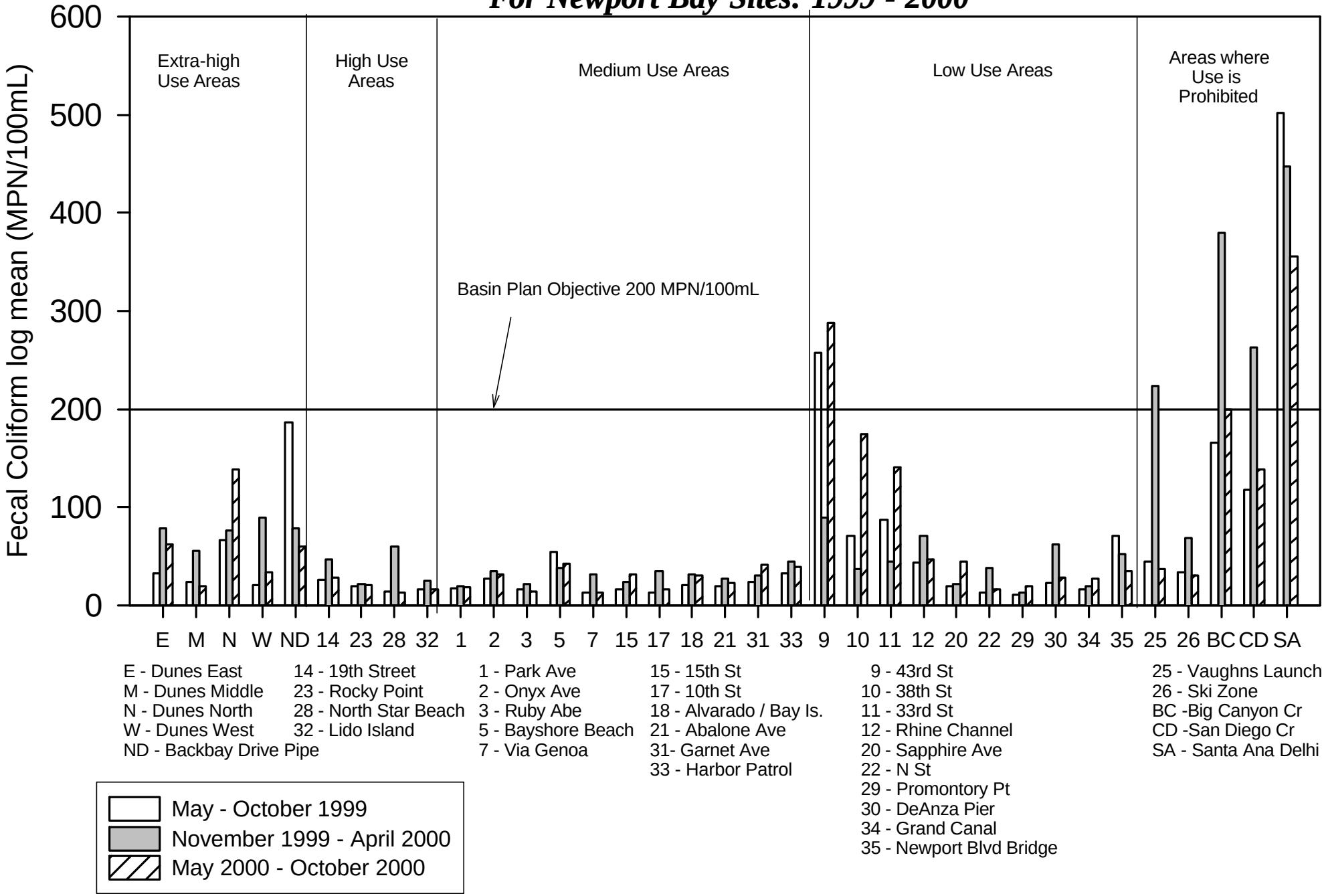
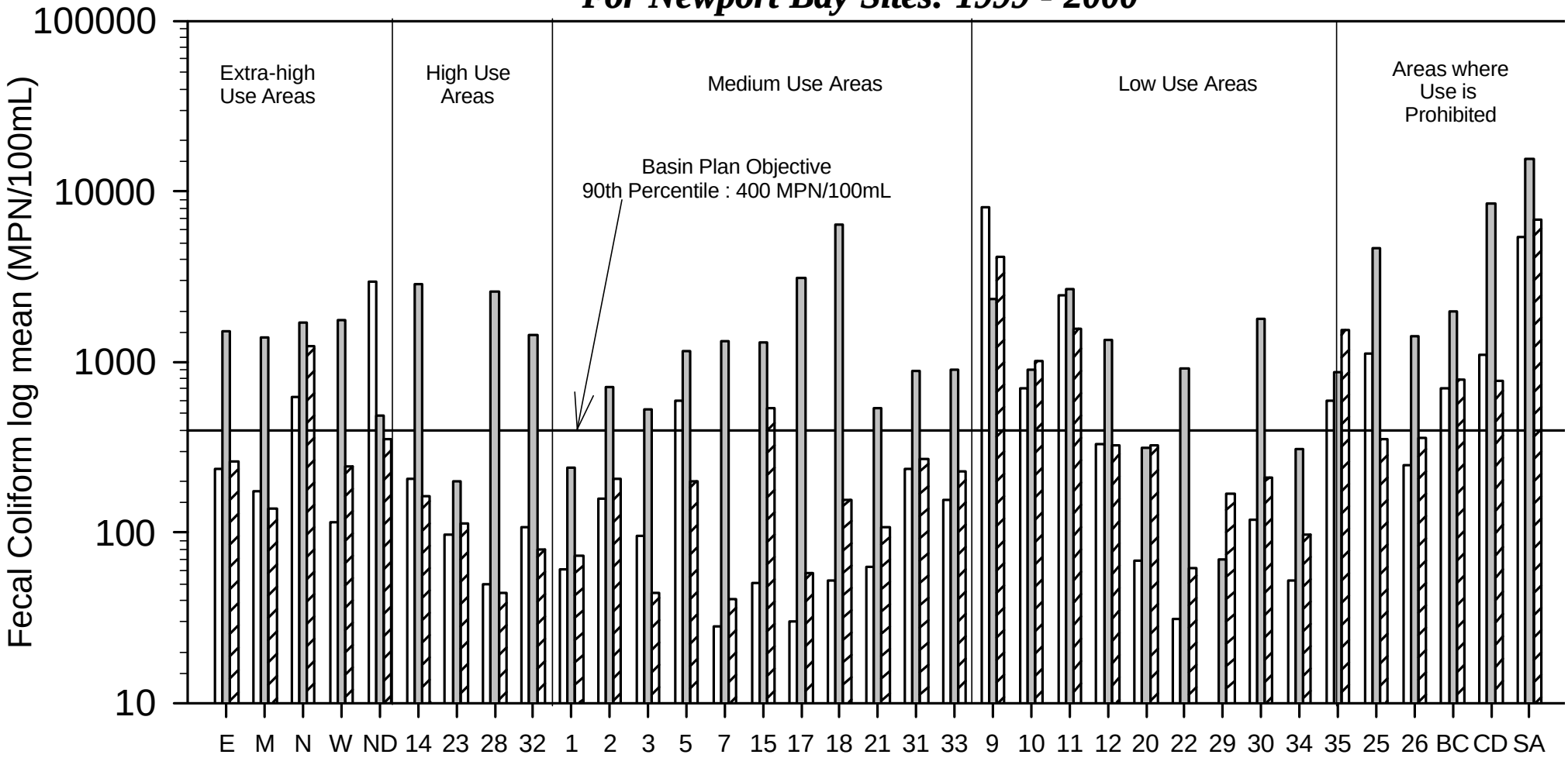


Figure 10.2
Summary of 90th Percentile Fecal Coliform Data For Newport Bay Sites: 1999 - 2000



E - Dunes East
M - Dunes Middle
N - Dunes North
W - Dunes West
ND - Backbay Drive Pipe

14 - 19th Street
23 - Rocky Point
28 - North Star Beach
32 - Lido Island

1 - Park Ave
2 - Onyx Ave
3 - Ruby Abe
5 - Bayshore Beach
7 - Via Genoa
9 - 43rd St

15 - 15th St
17 - 10th St
18 - Alvarado / Bay Isl
21 - Abalone Ave
31- Garnet Ave
33 - Harbor Patrol

10 - 38th St
11 - 33rd St
12 - Rhine Channel
20 - Sapphire Ave
22 - N St
29 - Promontory Pt
30 - DeAnza Pier
34 - Grand Canal
35 - Newport Blvd Bridge

25 - Vaughns Launch
26 - Ski Zone
BC -Big Canyon Cr
CD -San Diego Cr
SA - Santa Ana Delhi

May - October 1999
November 1999 - April 2000
May - October 2000

3. Body contact recreation is very limited in Newport Bay during the wet season (November through April).

10.2.2 Relative Risk to Public Health from REC-1 Contact in Newport Bay

A health risk assessment was carried out for this investigation to characterize the relative risk of enteric virus disease from body contact recreation in Newport Bay. To that end, a number of conservative (health protective) assumptions were employed in this investigation including:

- The assessment was carried out for an organism as prevalent and persistent as coliphage in the environment and as infectious as rotavirus;
- The rate of viral loading from swimmers and vessels is independent of length of use;
- The boundary conditions in the water quality modeling component were developed based on the maximum concentrations observed during the investigation;
- The ingestion rate during recreation is based on swimming but is assumed to be independent of activity; and
- Members of the population are equally likely to recreate in Newport Bay independent of their epidemiological state.

Given the assumptions employed, it is reasonable to infer that it is extremely likely that the estimated risk levels presented herein are higher than the "actual" levels of risk encountered by the population. Nevertheless, when the population based values generated by the assessment are transformed to individual risk values for a swimming event, it was found that the risk of enteric virus disease from body contact recreation in Newport Bay, is well below EPA's acceptable threshold rate of 19 illnesses per 1,000 swimmers[35] for recreation in marine waters.

10.2.3 Controllable Sources

Urban runoff and/or storm sewers are identified in the 303(d) listing as the likely source of pathogens in Newport Bay. However, based on the analyses presented in this report neither of those sources substantially impact the risk to public health from body contact recreation in Newport Bay. Moreover, reduction or elimination of the estimated dry weather viral loading from those sources (San Diego Creek, Santa Ana Delhi, and/or Big Canyon Wash) would result in an estimated maximum benefit (on an individual basis) of reducing approximately 1 case of disease per 10,000 swim events (from ~6/10,000 to ~5/10,000, as compared to EPA's acceptable risk level of 19/1,000).

Viral loading from vessel sanitary waste and from recreators (shedding pathogens) were also investigated as two potential sources of pathogen loading in Newport Bay. In the analyses it was assumed that these loadings may be controllable sources, which if

[35] EPA's evaluation of fecal coliform data indicated that a geometric mean of 200 MPN/100mL would cause an estimated 19 illnesses per 1,000 swimmers at marine beaches. That accepted rate was used in 1986 (EPA, 1986) to derive an equally stringent enterococci criteria (35/100mL). California has not yet adopted the enterococci criteria, but the stringency (19/1000) was used to list the Bay using the existing fecal coliform standard.

reduced may reduce the risk to enteric virus infection (and disease) from body contact recreation in Newport Bay. Because limited data are available to characterize loading from vessels and the variability reported in the literature is substantial, the loading from vessels was a highly uncertain parameter in the modeling efforts.

The analyses presented herein indicate that reducing loading from bathers to 50% of the currently estimated level would result in an estimated benefit of reducing less than 1 case of enteric virus disease per 10,000 swim events. It is possible that the benefit associated with the control alternative is less of an overestimate than other values presented in this report, because concentrations of indicator organisms (and pathogens) could vary substantially over short time periods when the density of recreators is high. Estimating those potential short time period changes in water quality due to high recreator density and shedding was beyond the scope of this investigation.

Using the best available estimates of vessel waste loading, it was found that the reduction of this viral source (to 10% of its currently estimated level) may result in an estimated benefit of reducing approximately 3.5 cases of enteric virus disease per 10,000 swim events (from 6/10,000 to <3/10,000). Moreover, based on the estimated costs to implement a public outreach program, it is suggested that reduction of vessel sanitary waste may be a control measure worth further consideration if risk managers feel that reduction of public health risk below the current levels (~6/10,000) is warranted. However, it should be emphasized that the likelihood of success for such a program is unknown.

10.2.4 Interpretation of the Basin Plan Fecal Coliform Objective

Interpretation of the Basin Plan Fecal Coliform Objective for Body Contact Recreation is difficult for a number of reasons including: (1) The etiological agents most likely to be of interest from a public health perspective in protecting the REC-1 beneficial use in Newport Bay are human enteric viruses; (2) Use of fecal coliform as an indicator of human enteric viruses is questionable, at best; (3) Uncontrollable and non-human sources contribute to the fecal coliform loading to the Bay, but may not contribute substantially to the risk to recreators, and (4) The inherent variability of microbial constituents in the environment is considerable. Based on the results of this investigation, it is suggested that interpreting the impairment of the REC-1 beneficial use in Newport Bay requires a more rigorous and comprehensive health risk evaluation and sanitary survey approach than the pass/fail test that has evolved to regulate the quality of recreational waters.

A more comprehensive approach is consistent with a health based monitoring approach for recreational waters recently outlined by the World Health Organization (WHO) (WHO 1999) in which experts called for "an improved approach to the regulation of recreational water that better reflects health risk and provides enhanced scope for effective management intervention"[36]. The WHO approach is to classify health risk as a

[36] According to this new approach for health based monitoring of recreational waters, the most robust, accurate, and feasible index of health risk is provided by a combination of a measure of microbiological indicator of fecal contamination with an inspection based assessment of the susceptibility of an area to direct influence from human fecal contamination (because "sources other than human fecal contamination

function of both degree of overall fecal contamination and susceptibility to human contamination.

From a careful review of the US EPA's 1986 bacterial water quality criteria document (U.S. EPA 1986), it is clear that a strategy consistent with that set forth by the WHO in 1999, was employed for specifying the maximum allowable density of indicator organisms at a given recreational site. EPA's strategy was to vary the maximum allowable density based on the level of recreational use that a particular site receives (i.e. designated beaches have lower allowable maximum values than moderately, lightly, or infrequently used areas).

Based on the information presented herein, a reasonable course of action to address the question of REC-1 impairment in Newport Bay would be to apply the principles set forth by US EPA in 1986, the WHO in 1999, and the basic principles of public health engineering regarding the use of sanitary surveys to identify and control potential sources to the maximum extent practicable. Using those general principles, the following examples illustrate how the relation between exceedances of the fecal coliform objective and impairment of the REC-1 beneficial use in Newport Bay may be interpreted:

- Based on the data presented in this report, the general the risk associated with body contact recreation in Newport Bay is below the US EPA acceptable threshold for marine waters (as well as below the freshwater threshold). Further, it has been noted that there are sites in the ecological reserve portion of the Upper Bay (where body contact recreation is prohibited), that have fecal coliform levels that sporadically to regularly exceed (varies from site to site) the Basin Plan (log mean and 90th percentile) objectives for fecal coliform. Given the lack of correlation between the fecal coliform concentrations in those areas and the risk to recreators in areas where recreation does occur, it is reasonable to assume that an impairment of the REC-1 use from these exceedances is unlikely. For example, for the time period of 1999 – 2000, the log mean values of fecal coliform at the Big Canyon monitoring site were below 200MPN/100mL during the dry seasons and above during the wet season. The 90th percentile values were above 400 MPN/100mL during both dry seasons (700 – 900 MPN/100mL) and the wet season (3000 MPN/100mL). Given that body contact recreation is prohibited in this area, that body contact recreation levels throughout the Bay are low during the wet season, and that the objectives are met in areas where REC-1 activity does occur, it is reasonable to assume that these observed concentrations of fecal coliform are unlikely to cause an impairment of the REC-1 use;
- Log mean values of fecal coliform at the De Anza monitoring site (a low use site) were below 200 MPN/100mL between 1999 and 2000 during both wet and dry seasons. The 90th percentile values were below 400 MPN/100mL during both dry seasons, and was ~2000 MPN/100mL during the wet season (between November 1999 – April 2000). Given that body contact recreation use is extremely low at

present a significantly lesser risk to human health and by adopting a combined classification it is possible to reflect this modified risk").

this site, particularly during the wet season and that the impact on risk from controllable sources is minimal, it is reasonable to assume that these observations are unlikely to cause an impairment of the REC-1 beneficial use in Newport Bay; and

- Log mean values of fecal coliform at the 43rd Street monitoring site were above the 200 MPN/100mL objective during the 1999 and 2000 dry seasons. The 90th percentile of the observed data were above the 400 MPN/100mL objective during both dry seasons (1999 and 2000) and the wet season. Although the level of recreational use at this site is low, inferring that the REC-1 use is impaired at this area may be reasonable, and pursuing control measures commensurate with the projected (or potential) use level at this site, may be a reasonable course of action.

A site by site summary is provided in Table 10.1 demonstrating how the information presented herein may be used to facilitate interpretation of the Basin Plan Objective for fecal coliform with respect to risk to public health. The summary provided in Table 10.1 uses observed fecal coliform concentrations, levels of exposure, and seasonality to derive a relative level of public health concern associated with each of the monitoring sites. Using a similar approach, data presented in this report may be used to interpret observed fecal coliform observations with respect to whether it is reasonable to infer impairment of the REC-1 beneficial use in Newport Bay from exceedances in the Basin Plan fecal coliform objectives that occur in Newport Bay during the winter season, in low use areas, and/or in areas where body contact recreation is prohibited.

Table 10.1
Summary of Relative Public Health Concern Related to Fecal Coliform Exceedances in Newport Bay

Site Name	Recreational Use Level [1]	Exceedances of FC Standard During Dry Season [2]		Level of Public Health Concern Dry Season [7]	Exceedances of FC Standard During Wet Season [3]		Level of Public Health Concern Wet Season [7]	Potential Future Controls [4]			
		Log Mean	90th %ile		Log Mean	90th %ile		Vessel Waste	Swimmer Loading	Tributary Inflow	Others [9]
Vaughn's Launch	Use Prohibited		Ö	Very Low	Ö	Ö	Low	-	-	-	-
Ski Zone				Very Low		Ö	Very Low	-	-	-	-
Big Canyon Creek			Ö	Very Low	Ö	Ö	Low	-	-	-	-
San Diego Creek - Campus Dr.			Ö	Very Low	Ö	Ö	Low	-	-	-	-
Backbay Drive Pipe [5]			Ö	Very Low		Ö	Very Low	-	-	-	-
Santa Ana Delhi Channel		Ö	Ö	Low	Ö	Ö	Low	-	-	-	-
43rd Street Beach	Low Use	Ö	Ö	Medium		Ö	Low	Ö	-	-	Flushing
38th Street Beach			Ö	Low		Ö	Low	-	-	-	Flushing
33rd Street Channel			Ö	Low		Ö	Low	-	-	-	Flushing
Rhine Channel				Very Low		Ö	Low	-	-	-	Flushing
Sapphire Avenue Beach				Very Low			Very Low	-	-	-	-
N Street Beach				Very Low		Ö	Low	-	-	-	-
Promontory Point Channel				Very Low			Very Low	-	-	-	-
De Anza				Very Low		Ö	Low	-	-	-	-
Grand Canal				Very Low			Very Low	-	-	-	-
Newport Blvd. Bridge			Ö	Low		Ö	Low	-	-	-	Flushing
Park Avenue Beach	Medium Use			Very Low			Very Low	-	-	-	-
Onyx Avenue Beach				Very Low		Ö	Low	-	-	-	-
Ruby Avenue Beach				Very Low		Ö	Low	-	-	-	-
Bayshore Beach [6]			Ö	Medium		Ö	Low	Ö	-	-	-
Via Genoa Beach				Very Low		Ö	Low	-	-	-	-
15th Street Beach			Ö	Low		Ö	Low	-	-	-	-
10th Street Beach				Very Low		Ö	Low	-	-	-	-
Alvarado/ Bay Isle Beach				Very Low		Ö	Low	-	-	-	-
Abalone Avenue Beach				Very Low		Ö	Low	-	-	-	-
Garnet Avenue Beach				Very Low		Ö	Low	-	-	-	-
Harbor Patrol Beach				Very Low		Ö	Low	-	-	-	-
19th Street Beach	High Use			Very Low		Ö	Low	-	-	-	-
Rocky Point Beach				Very Low			Very Low	-	-	-	-
North Star Beach				Very Low		Ö	Low	-	-	-	-
Lido Yacht Club Beach				Very Low		Ö	Low	-	-	-	-
Newport Dunes - Middle	Extra High Use			Low		Ö	Medium	Ö	Ö	-	Flushing
Newport Dunes - West				Low		Ö	Medium	Ö	Ö	-	Flushing
Newport Dunes - North [8]			Ö	High		Ö	Medium	Ö	Ö	-	Flushing
Newport Dunes - East				Low		Ö	Medium	Ö	Ö	-	Flushing

1. Use Levels are defined in Chapter 3, Refer to Table 3.4
2. Dry Season defined as May through September
3. Wet Season defined as October through April
4. Controls were defined and evaluated in Chapter 8.
5. Dry weather flow is now diverted to sanitary sewer
6. High Use on holidays
7. Level of Public Health Concern is derived as shown to the right
8. Exceedances may have been linked to flow from the Backbay Drive Pipe, see note 5.
9. Other potential control measures not investigated as part of the HRA

Level of Public Health Concern
Dry Season

	Exposure				
Indicator Concentration	None	Low	Medium	High	Extra high
Low	Very Low	Very Low	Very Low	Very Low	Low
Medium	Very Low	Low	Low	Medium	High
High	Low	Medium	Medium	High	High

Level of Public Health Concern
Wet Season

	Exposure				
Indicator Concentration	None	Low	Medium	High	Extra high
Low	Very Low	Very Low	Very Low	Very Low	Low
Medium	Very Low	Low	Low	Low	Medium
High	Low	Low	Low	Medium	High

Note: The relative level of Public Health Concern shown in these tables is based on the combination of exposure level, indicator concentration, basic principles of sanitary engineering, and professional judgement. Concern at a given site changes seasonally, with the relative use that the site receives.

REFERENCES

Anderson, M. A., M. Stewart, M. V. Yates, and C. P. Gerba. "Modeling the impact of body-contact recreation on pathogen concentrations in a source drinking water reservoir." Water Res 32,3293-3306, 1998.

Anderson, R. M., and R. May. "Infectious Diseases of Humans: Dynamics and Control." New York: Oxford University Press, 1991.

Ansari, S. A., S. Springthorpe, and S. A. Sattar. "Survival and Vehicular Spread of Human Rotaviruses: Possible Relation to Seasonality of Outbreaks." Reviews of Infectious Diseases. Reviews of Infectious Diseases 1991:13 (May-June) pp.448-461.

Armon, R., and Y. Kott. "Bacteriophages as Indicators of Pollution." Critical Reviews in Environmental Science and Technology, 1996, Vol. 26, No. 4, pp. 299-335.

AWWARF. "Using Microbial Indicators in Optimization of Treatment Plant Performance." E. Nieminski, Presented at the International Symposium on Waterborne Pathogens, AWWA, Milwaukee, WI.

Baldini, I., E. Scandelari, and E. Cacciabue. "Research of the RNA-coliphages, in comparison with usual microbial and chemical indexes of biological pollution for hygienic and sanitary evaluations of coast waters." Ann Sclavo, July-August 1978, Vol. 20, No. 4, pp. 588-598.

Bernstein, D. I., D. S. Sander, V. E. Smith, G. M. Schiff, and R. L. Ward. "Protection from Rotavirus Reinfection : 2-Year Prospective Study." The Journal of Infectious Diseases. JID 1991:164 (August).

Black, S. A., D. N. Graveland, W. Nicholaichuk, D. W. Smith, and R. S. Tobin. "Manual for Land Application of Treated Municipal Wastewater and Sludge." Environmental Protection Service, Ottawa (Ontario). Environmental Protection Programs Directorate. Manual EPS 6-EP-84-1, March, 1984. p 216, 29 Fig, 70 Tab, 142 Ref, 4 Append., Journal Announcement: SWRA1808.

Borrego, J. J., M. A. Morinigo, A. De Vincente, C, R. Ornax, and P. Romero. "Coliphages as an indicator of faecal pollution in water, its relationship with indicator and pathogenic microorganisms." Water Res. 21(12): 1473-1480, 1987.

Breiman, L., J. Friedman, and R. Olshen. "Classification and Regression Trees." Wadsworth International Group, Pacific Grove, CA, 1984.

CA RWQCB. "A Resolution Amending the Water Quality Control Plan for the Santa Ana River Basin To Establish a Total Maximum Daily Load for Fecal Coliform Bacteria in Newport Bay." Resolution 99-10, 1999.

Cabelli, V. J. "Public health and water quality significance of viral diseases transmitted by drinking water and recreational water." In: Water Virology, W.O. Grabow (ed.); Water Sci. Tech. 15(5): 1-15, 1983.

Cabelli, V. J., A. P. Dufour, L. J. McCabe, and M. A. Levin. "Swimming-Associated Gastroenteritis and Water Quality." American Journal Of Epidemiology, Vol. 115, pp. 606-616.

Cabelli, V. J., A. P. Dufour, L. J. McCabe, and M. A. Levin. "A Marine Recreational Water Quality Criterion Consistent with Indicator Concepts and Risk Analysis." Journal WPCF, Vol. 55, No. 10, October 1983, pp. 1306-1314.

Calci, K. R., W. Burkhardt III, W. D. Watkins, and S. R. Rippey. “Occurrence of Male-Specific Bacteriophage in Feral and Domestic Animal Wastes, Human Feces, and Human-Associated Wastewaters.” Applied and Environmental Microbiology, Vol. 64, No. 12, pp. 5027-5029.

Champsaur, H., E. Questiaux, J. Prevot, M. Henry-Amar, D. Goldszmidt, M. Bourjouane, and C. Bach. “Rotavirus Carriage, Asymptomatic Infection and Disease in the First Two Years of Life. I. Virus Shedding.” The Journal of Infectious Diseases. The Journal of Infectious Diseases, Vol. 149, No.5, May 1984 pp. 667-674.

Chanock, R. M., R. G. Wyatt, and A. Z. Kapikian. “Immunization of Infants and Young Children Against Rotaviral Gastroenteritis - Prospects and Problems.” JAVMA. JAVMA, Vol. 173, No. 5 pp. 570- 572.

Chick, S. E., J. S. Koopman, S. Soorapanth, and M. E. Brown. “Infection Transmission System Models for Microbial Risk Assessment.” Science of the Total Environment, 2001, in press.

Chung, H., L. A. Jaykus, G. Lovelace, and M. D. Sobsey. “Bacteriophages and Bacteria as Indicators on Enteric Viruses in Oysters and their Harvest Waters.” Water Science Technology, Vol. 38, pp. 37-44.

Dudley, R. H., K. K. Hekimian, and B. J. Michalas. “A Scientific Basis for Determining Recreational Water Quality Criteria.” Journal WPCF. Vol. 48, No. 12, December 1976.

Dutka, B. J., A. E. Shaarawi, M. T. Martins, and P. S. Sanchez. “North and South American Studies on the Potential of Coliphage as a Water Quality Indicator.” Water Research, 1987, Vol. 21, No. 9, pp. 1127-1134.

Eisenberg, J., W. K. Reisen, and R. C. Spear. “Dynamic Model Comparing the Bionomics of Two Isolated Culex Tarsalis Populations: Sensitivity Analysis.” J. Med. Entomol. 32, 98-106. 1995.

Eisenberg, J. N., E. Y. W. Seto, A. Olivieri, and R. C. Spear. “Quantifying Water Pathogen Risk in an Epidemiological Framework.” Risk Analysis, Vol. 16, No.4, pp.549-563, 1996.

Eisenberg, J. N. S., E. Y. W. Seto, J. M. Colford, Jr., A. Olivieri, and R. C. Spear. “An Analysis of the Milwaukee Cryptosporidiosis Outbreak Based on a Dynamic Model of the Infection Process.” Epidemiology. Vol. 9, No. 3, May 1998.

EOA Inc. “Mamala Bay Study Infectious Disease Public Health Risk Assessment.” Prepared for the Mamala Bay Study Commission, 1995.

EOA Inc., Systech Engineering, BioVir Laboratories, and U.C. Berkeley School of Public Health. “City of Stockton NPDES Studies Health Risk Assessment.” Prepared for the City of Stockton, 1996.

EOA Inc., and U.C. Berkeley School of Public Health. “Microbial Risk Assessment for Reclaimed Water.” Prepared for the Irvine Ranch Water District and the National Water Resource Association, 1995.

EOA Inc., and U.C. Berkeley School of Public Health. “Evaluation of Pathogen Risk Assessment Framework.” Prepared by J.A. Soller, J.N.Eisenberg, and A.W. Olivieri for ILSI Risk Science Institute, 1999.

Fankhauser, R. L., J. S. Noel, S. S. Monroe, T. Ando, and R. I. Glass. “Molecular epidemiology of "Norwalk -like viruses" in outbreaks of gastroenteritis in the

United States." Journal of Infectious Diseases, Dec. 1998, Vol. 178, No. 6, pp. 1571-1578.

Feachem, R. G., D. J. Bradley, H. Garelick, and D. D. Mara. "Sanitation and disease - Health aspects of excreta and wastewater management. (Book)." In: Sanitation and Disease - Health Aspects of Excreta and Wastewater Management, World Bank Publications, 1983.

Fleisher, J. M. "A Reanalysis of Data Supporting U.S. Federal Bacteriological Water Quality Criteria Governing Marine Recreational Waters." Water Pollution Control Federation Research Journal, Vol. 63, No. 3, pp. 259-265.

Fleisher, J. M., F. Jones, D. Kay, R. Stanwell-Smith, M. D. Wyer, and R. Morano. "Water and Non-water Related Risk Factors for Gastroenteritis Among Bathers Exposed toSsewage-Contaminated Marine Waters." International Journal of Epidemiology, Vol. 22, No. 4, pp. 698-708, 1993.

Fleisher, J. M., D. Kay, R. L. Salmon, F. Jones, M. D. Wyer, and A. F. Godfree. "Marine waters contaminated with domestic sewage: nonenteric illnesses associated with bather exposure in the United Kingdom." American Journal of Public Health, Sept. 1996, Vol. 86, Vo. 9, pp. 1228-1234.

Flewett, T. H., and G. N. Woode. "The Rotaviruses: Brief Review." Archives of Virology. Archives of Virology 57, 1-23 (1978).

Gantzer, C., L. Gillerman, M. Kuznetsov, and G. Oron. "Adsorption and survival of faecal coliforms, somatic coliphages and F-specific RNA phages in soil irrigated with wastewater." 1st World Water Congress of the International Water Association, Health Related Water Microbiology, July 3-7, 2000, Paris, France.

Geldenhuys, J. C., and P. D. Pretorius. "The Occurrence of Enteric Viruses in Polluted Water, Correlation to Indicator Organisms and Factors Influencing Their Numbers." Wat. Sci. Technol., 21(3):105-109, 1989.

Geldreich, E. E. "Type distribution of coliform bacteria in feces of warm-blooded animals." J. Water Pollution Control Federation, 34: 295-301. 1962.

Gerba, C. P. "Recovering viruses from sewage, effluents, and water." In: Methods for Recovering Viruses from the Environment, G. Berg (ed.), CRC Press, Inc., Florida, chapter 1: 1-23, 1987.

Gerba, C. P. "Assessment of Enteric Pathogen Shedding by Bathers during Recreatina Activity and its Impact on Water Quality." Quantitative Microbiology, 2,55-68, 2000.

Gerba, C. P., S. M. Goyal, R. L. LaBelle, I. Cech, and G. F. Bodgan. "Failure of indicator bacteria to reflect the occurrence of enteroviruses in marine waters." American Journal of Public Health, November 1979, Vol. 69, No. 11, pp. 1116-1119.

Gold, M., M. Bartlett, C. McGee, and G. Deets (1992). Pathogens and Indicators in Storm Drains Within the Santa Monica Bay Watershed. Santa Monica.

Gomez-Barreto, J., E. L. Plamer, A. J. Nahmias, and M. H. Hatch. "Acute Enteritis Associated with Reovirus-Like Agents." JAMA. JAMA 235:1857-1860, 1976.

Grabow, W. O. K. "Bacteriophages: Update on application as models for viruses in water." Water SA, Vol 27, No.2, 251:68, 2001.

Griffin, D. W., C. J. Gibson, E. K. Lipp, K. RILEY, J. H. Paul, and J. B. Rose. "Detection of Viral Pathogens by Reverse Transcriptase PCR and of Microbial Indicators by

Standard Methods in the Canals of the Florida Keys." Applied and Environmental Microbiology, Sept. 1999, Vol. 65, No. 9, pp. 4118-4125.

Gurwith, M., W. Wenman, D. Hinde, S. Heltham, and H. Greenberg. "A Prospective Study of Rotavirus Infection in Infants and Young Children." The Journal of Infectious Diseases. The Journal of Infectious Diseases, Vol. 144., No.3, September 1981.

Haas, C. N. "Estimation of Risk Due to Low Doses of Microorganisms: A Comparison of Alternative Methodologies." Am. J. Epidemiol, 55:573-582, 1983.

Haas, C. N., J. Anotai, and R. S. Engelbrecht. "Monte Carlo assessment of microbial risk associated with landfilling of fecal material." Water Environment Research, November/December 1996,Vol. 68, pp. 1123-1131.

Haas, C. N., J. B. Rose, and C. P. Gerba. "Quantitative Microbial Risk Assessment." J.W. Wiley, Inc., 1999.

Haffejee, I. E. "The Epidemiology of Rotavirus Infections: A Global Perspective." Journal of Pediatric Gastroenterology and Nutrition 20:275-86, 1995.

Havelaar, A. H. "Bacteriophages as model organisms in water treatment." Microbiological Science, December 1987, Vol. 4, No. 12, pp. 362-364.

Havelaar, A. H., K. Furuse, and W. M. Hogeboom. "Bacteriophages and indicator bacteria in human and animal faeces." Journal of Applied Bacteriology, March 1986, Vol. 60, No. 3, pp. 255-262.

Havelaar, A. H., W. M. Hogeboom, and R. Pot. "F specific RNA bacteriophages as model viruses in sewage: methodology and occurrence." Wat. Sci. Tech., Vol. 17, Amsterdam, pp. 645-655.

Havelaar, A. H., M. V. Olphen, and Y. C. Drost. "F-Specific RNA Bacteriophages Are Adequate Model Organisms for Enteric Viruses in Fresh Water." Applied and Environmental Microbiology, Sept. 1993, Vol. 59, No. 9, pp. 2956-2962.

Hazen, T. C. "Fecal coliforms as indicators in tropical waters: A review." Toxic. Assess.: An Int. J. 3(5): 461-477, 1988.

Hethcote, H. "Qualitative Analyses of Communicable Disease Models." Mathematical Biosciences 28:335-356, 1976.

Hilton, M. C., and G. Stotzky. "Use of Coliphages as Indicators of Water Pollution." Dept. of Biology, New York University, New York 10003, pp. 747-751.

IAWPRC Study Group. "Review Paper-Bacteriophages as Model Viruses in Water Quality Control." Water Research, Vol. 25, No. 5, pp. 529-545.

International Life Sciences Institute - Risk Science Institute. "A Conceptual Framework to Assess the Risks of Human Disease Following Exposure to Pathogens." Risk Analysis, Vol 16, 841:848, 1996.

Jagals, P., W. O. K. Grabow, and J. C. de Villiers. "Evaluation of Indicators for Assessment of Human and Animal Faecal Pollution of Surface Run-Off." Water Science Technology, 1995, Vol. 31, No. 5-6, pp. 235-241.

Jakeman, A. J., F. Ghassemi, and C. R. Dietrich. "Calibration and Reliability of an Aquifer System Model Using Generalized Sensitivity Analysis." IAHS 195,45-51, 1990.

Kapikian, A., R. G. Wyatt, H. B. Greenberg, A. R. Kalica, H. W. Kim, C. D. Brandt, W. J. Rodreigues, R. H. Parrott, and R. M. Chanock. "Approaches to Immunization of Infants and Young Children Against Gastroenteritis Due to Rotaviruses."

Reviews of Infectious Diseases. Reviews of Infectious Diseases, Vol. 2, No. 3 May-June 1980.

Kay, D., J. M. Fleisher, R. L. Salmon, F. Jones, M. D. Wyer, A. F. Godfree, Z. Zelenauch-Jacquotte, and R. Shore. "Predicting Likelihood of Gastroenteritis from Sea Bathing: Results from Randomized Exposure." The Lancet, Vol. 344, pp. 905-909, 1994.

Koopman, J. S., and I. M. Longini. "The Ecological Effects of Individual Exposures and Nonlinear Disease Dynamics in Populations." American Journal of Public Health, Vol.84, No.5:836-842, 1994.

Koopman, J. S., I. M. Longini, J. A. Jacquez, and C. P. Simon. "Assessing Risk Factors for Transmission of Infection." American Journal of Epidemiology, Vol. 133, No.12:1199-1209, 1991.

Koopman, J. S., and A. S. Monto. "The Tecumseh Study XV: Rotavirus infection and pathogenicity." American Journal of Epidemiology. American Journal of Epidemiology, Vol. 130, No.4, 1989.

Koopman, J. S., A. S. Monto, and I. M. Longini. "The Tecumseh Study XVI: Family and Community Sources of Rotavirus Infection." American Journal of Epidemiology. American Journal of Epidemiology, Vcol. 130, No.4, 1989 pp. 760 - 768.

Kott, Y., N. Rozi, S. Sperber, and N. Betzer. "Bacteriophages as viral pollution indicators." Water Research, Vol. 8, pp. 165-171.

Levine, W. C., and W. T. Stephenson. "Waterborne disease outbreaks, 1986-1988." Morb. Mort. Wkly. Rpt., Vol.39/No.SS-1 (1990).

Lycke, E., J. Blmber, G. Berg, A. Eriksson, and L. Madsen. "Epidemic Acute Diarrhoea in Adults Associated with Infantile Gastroenteritis Virus." The Lancet. The Lancet November 11, 1978.

Mathworks Inc. "Using MATLAB." The Mathworks, Inc., 1998.

McDonald, A. C., W. R. Mac Kenzie, D. G. Addiss, G. M.S., G. Linke, E. Zembrowski, M. R. Hurd, M. J. Arrowood, P. J. Lammie, and J. W. Priest. "Cryptosporidium parvum, Specific Antibody Responses among Children Residing in Milwaukee during the 1993 Waterborne Outbreak." The Journal of Infectious Diseases. vol 183: 1373:1379.

McLaughlin, M. R., and J. B. Rose. "Evaluation of the Bacteroides fragilis phage as an alternative indicator of sewage pollution." 1st World Water Congress of the International Water Association, Health Related Water Microbiology, July 3-7, 2000, Paris, France.

Mead, P. S., L. Slutsker, V. Dietz, L. F. McCaig, J. S. Bresee, C. Shapiro, P. M. Griffin, and R. V. Tauxe. "Food Related Illness and Death in the United States." Emerging Infectious Diseases, Vol. 5, 1999, No. 5, pp. 1-28.

Metcalf and Eddy. "Wastewater Engineering: Collection and Pumping of Wastewater." written and edited by G. Tchobanoglous, McGraw Hill publications, 1981.

Molyneaux, P. "Human immunity ot rotavirus." J. Med. Microbiol. J. Med. Microbiol. - Vol. 43 (1995), 397 - 404.

Morinigo, M. A., D. Wheeler, and C. Berry. "Evaluation of different bacteriophage groups as faecal indicators in contaminated natural waters in Southern England." Water Research, March 1992, Vol. 26, pp. 267-271.

National Research Council. “Risk Assessment in the Federal government, Managing the Process.” National Academy Press, Washington, D.C., 1983.

O'Ryan, M. L., D. O. Matson, M. K. Estes, and L. K. Pickering. “Anti-Rotavirus G Type - Specific and Isotype-Specific Antibodies in Children with Natural Rotavirus Infections.” Journal of Infectious Diseases. JID 1994: 169 (March) pp. 504-511.

Palmeteer, G. A., B. J. Dutka, E. M. Janzen, S. M. Meissner, and M. G. Sakellaris. “Coliphage and Bacteriophage as Indicators of Recreational Water Quality.” Water Research, 1991, Vol. 25, No. 3, pp. 355-357.

Paul, J. H., J. B. Rose, S. C. Jiang, C. A. Kellogg, and L. Dickson. “Distribution of Viral Abundance in the Reef Environment of Key Largo, Florida.” Applied and Environmental Microbiology, March 1993, Vol. 59, No. 3, pp. 718-724.

Paul, J. H., J. B. Rose, S. C. Jiang, P. London, X. Xhou, and C. A. Kellogg. “Coliphage and Indigenous Phage in Mamala Bay, Oahu, Hawaii.” Applied and Environmental Microbiology, Jan 1997, Vol. 63, No. 1, pp.133-138.

Pruess, A. “Review of Epidemiological Studies on Health Effects from Exposure to Recreational Water.” International Journal of Epidemiology, 27:1-9, 1998.

Rao, V., and J. L. Melnick. “Environmental Virology.” American Society of Microbiology, Washington, D.C., 1986.

Regli, S., J. B. Rose, C. N. Haas, and C. P. Gerba. “Modeling the Risk From Giardia and Viruses in Drinking Water.” Journal AWWA. November 1991, pp. 76-84.

Rodriquez, W. J., H. W. Kim, and C. D. Brandt. “Longitudinal study of rotavirus infection and gastroenteritis in families served by a pediatric medical practice: clinical and epidemiologic observations.” Pediatr Infect Dis J Feb;6(2):170-6, 1987.

Rose, J. B., et. al.,. “King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay, Appendix B-2: Risks to People.” Prepared for the Duwamish River and Elliott Bay Water Quality Assessment Team Working Draft, 1999.

Shepard, and et. al. Lancet, 2:1082, 1975.

Simkova, A., and J. Cervenka. “Coliphages as ecological indicators of enteroviruses in various water systems.” Bulletin of the World Health Organization, Vol. 59, No. 4, pp. 611-618.

Sinton, L. W., R. K. Finlay, and P. A. Lynch. “Sunlight Inactivation of Fecal Bacteriophages and Bacteria in Sewage Polluted Seawater.” Applied and Environmental Microbiology, Aug, 1999, Vol. 65, No. 8, pp. 3605-3613.

Sobsey, M., D. A. Battigelli, T. R. Handzel, and K. J. Schwab (1995). Male-Specific Coliphages as Indicators of Viral Contamination of Drinking Water, AWWA Research Foundation.

Spear, R. C., F. Bois, and T. Woodruff. “Modeling Benzene Pharmo-kinetics Across Three Sets of Animal Data: Parametric Sensitivity and Risk Implications.” Risk Analysis, 11, 641-654. 1991.

Spear, R. C., and G. M. Hornberger. “Eutrophication in Peel Inlet: II. Identification of Critical Uncertainties Via Generalized Sensitivity Analysis.” Water Research, 14,43-49. 1980.

Stetler, R. E. “Coliphages as Indicators of Enteroviruses.” Applied and Environmental Microbiology, Sept, 1984, Vol. 48, No. 3, pp. 668-670.

Teunis, P. F. M., and A. Havelaar. “Cryptosporidium in Drinking Water: Evaluation of the ISLI/RSI Quantitative Risk Assessment Framework.” Prepared for the International Life Sciences Institute, 1999.

Tsai, K. C., and D. M. Auslander. “A Statistical Methodology for the Design of Robust Process Controllers.” Trans. ASCE J. Dyn. Syst. Meas. Control 110(2),1-22, 1988.

Tufvesson, B., T. Johnsson, and B. Persson. “Family Infections by Reo-like Virus: Comparison of Antibody Titres by Complement Fixation and Immunoelectroosmophoresis.” Scand. J. Infect. Dis. Scand. J. Infect. Dis. (: 257-261, 1977.

U.S. EPA. “Questions and Answers on Water Quality Standards.” Office of Water, Regulations and Standards, Washington, D.C., 1983.

U.S. EPA. “Ambient Water Quality Criteria for Bacteria.” EPA440/5-84-002, 1986.

U.S. EPA. “Development of a qualitative pathogen risk assessment methodology for municipal sludge landfilling.” NTIS: PB88-198544/AS, EPA/600/6-88/006, Environmental Criteria and Assessment Office, Office of Research and Development, U.S.EPA, Cincinnati OH, 1988.

U.S. EPA. “Risk Assessment Guidance for Superfund: Volume 1 Human Health Evaluation Manual (part A).” EPA/540/1-89/002 December 1989, Office of Emergency and Remedial Response; Washington DC 20460.

U.S. EPA. “Recreational Vessel Sewage Discharge Control: A Primer for State and Local Outreach Campaigns.” EPA 842-B-95-005, August 1994.

U.S. EPA. “Draft Implementation Guidance for Ambient Water Quality Criteria for Bacteria - 1986.” EPA-823-D-00-001, 2000.

U.S. EPA. “Protocol for Developing Pathogen TMDLs.” Office of Water, EPA 841-R-00-002, 2001.

US EPA (1997). Guiding Principles for Monte Carlo Analysis.

Van Straten, G. “Analysis of Model and Parameter Uncertainty in Simple Phytoplankton Models for Lake Balaton.” Prog. Ecol. Eng. Management Mathematical Modeling, 107-134, 1984.

Vaughn, J. M., and T. G. Metcalf. “Coliphages as Indicators of Enteric Viruses in Shellfish and Shellfish Raising Estuarine Waters.” Water Research, 1975, Vol. 9, pp. 613-616.

Ward, R. L., and D. I. Bernstein. “Protection against Rotavirus Disease after Natural Rotavirus Infection.” The Journal of Infectious Diseases. Vol. 169, pp. 900-904, 1994.

Ward, R. L., D. I. Bernstein, E. C. Young, J. R. Sherwood, D. R. Knowlton, and G. M. Schiff. “Human Rotavirus Studies in Volunteers: Determination of Infectious Dose and Serological Response to Infection.” The Journal of Infectious Diseases. Vol. 154, No. 5 pp. 871-879, 1986.

Wenman, W., D. Hinde, S. Feltham, and M. Gurwith. “Rotavirus Infection in Adults.” New England Journal of Medicine. New Engl J Med 301: 303-306, 1979.

Wentsel, R. S., P. E. O'Neill, and J. F. Kitchens. “Evaluation of coliphage detection as a rapid indicator of water quality.” Applied Environmental Microbiology, February 1982, Vol. 43, No. 2, pp. 430-434.

Whitehead, P., and G. M. Hornberger. “Modeling Algal Behavior in River Thames.” Water Research, 18, 945-953, 1984.

WHO (1999). Health Based Monitoring of Recreational Waters: The Feasibility of a New Approach (The 'Annapolis Protocol'). Geneva, World Health Organization-Sustainable Development and Healthy Environments.

Wommack, K. E., R. T. Hill, T. A. Muller, and R. R. Colwell. “Effects of Sunlight on Bacteriophage Viability and Structure.” Applied and Environmental Microbiology, April 1996, Vol. 62, No. 4, pp. 1336-1341.

Yates, M. V., M. A. Anderson, C. P. Gerba, and J. B. Rose. “The Impact of Body-Contact Recreation in the Eastside Reservoir Project on 1) Pathogen Risk to Consumers and Recreators and 2) MTBE Contamination.” Final Report to the Metropolitan Water District of Southern California, 1997.

Young, K. D., and E. L. Thackston. “Housing Density and Bacterial Loading in Urban Streams.” Journal of Environmental Engineering, 1177-1180, 1999.