APPENDIX A: MODELING REPORT

1.0 Introduction

Water quality data indicate that Alamitos Bay, Colorado Lagoon, and Los Cerritos Channel do not meet water quality standards. Alamitos Bay and Colorado Lagoon are identified as impaired for indicator bacteria on the 2006, 2010 and 2016 Clean Water Act Section 303(d) lists. Los Cerritos Channel is identified as impaired for indicator bacteria on the 1996, 1998, 2002, 2006, 2008, 2010, 2012, and 2016 303(d) lists. Los Cerritos Channel discharges into Alamitos Bay, and water is exchanged between Alamitos Bay and Colorado Lagoon through tidal flow. In addition, there are two power plants connected to Alamitos Bay. The plants require cooling water, for which the plant on the west side - Alamitos Generating Station (AGS) draws water from Los Cerritos Channel (LCC), and the plant on the east side - Haynes Generating Station (HGS) draws water from Alamitos Bay through closed conduits under the San Gabriel River Estuary (SGRE). The cooling water is subsequently discharged into the SGRE at several points. Pumping and discharging by the power plants affect water movement throughout the Alamitos Bay and SGRE.

This report describes the development of a model for simulating bacteria loading and transport in the Alamitos Bay and Los Cerritos Channel flow system (Alamitos Bay Bacteria Model) and presents the simulation results of different input scenarios from Los Cerritos Channel, Colorado Lagoon, and the two power plants pumping and discharging. To represent the linkage between source contributions and in-stream and bay responses, a dynamic water quality model was developed to simulate source loadings and transport of bacteria concentrations in the Alamitos Bay and Los Cerritos Channel flow system. This model simulates bacteria concentrations in the receiving water to evaluate potential management scenarios for the bacteria total maximum daily load (Bacteria TMDL) for Alamitos Bay and Los Cerritos Channel, including Colorado Lagoon.

The Environmental Fluid Dynamics Code (EFDC) was selected to model bacteria loading and transport in the Alamitos Bay and Los Cerritos Channel flow system. In this report, the fundamentals of theory, model development, model calibration, and model results for different management scenarios for the Bacteria TMDL will be presented and discussed.

2.0 Theoretical Background of EFDC Model

EFDC is a multidimensional hydrodynamic and water quality model that has been used by the U.S. Environmental Protection Agency (EPA) for TMDL development in rivers, lakes, estuaries, wetlands, and coastal regions throughout the United States. The model has three primary components (hydrodynamics, sediment-toxic transport and fate, and water quality) integrated into a single model. The hydrodynamic component is dynamically coupled to salinity and temperature transport as well as to sediment-toxic transport and water quality components.

EFDC was originally developed by Dr. John Hamrick at the Virginia Institute of Marine Science. At present, the EFDC model is a public domain model, maintained by Tetra Tech, Inc. for EPA with continuing research and development to expand the capabilities of the model. The EFDC model has been integrated into the EPA's TMDL Modeling Toolbox for supporting TMDL development. EFDC solves the 3-D Reynold-averaged Navier-Stokes equations assuming incompressible flow and hydrostatic pressure distribution with dynamically coupled salinity and temperature transport, which accounts for density variations. Turbulent closure via horizontal and vertical eddy viscosities is based on the Mellor-Yamada level 2.5 turbulence closure scheme (see EFDC Technical Memorandum 2002).

The numerical scheme employed in EFDC to solve the equations of motion uses a second order accurate spatial finite difference approach on a staggered or C grid. The model's time integration employs a second order accurate three-time level, finite difference scheme with an internal-external mode splitting procedure to separate the internal shear or baroclinic mode from the external or barotropic mode. The external mode solution is semi-implicit and simultaneously computes the two-dimensional surface elevation field by a preconditioned conjugate gradient procedure. The external solution is completed by the calculation of the depth-averaged barotropic velocities using the new surface elevation field.

The model's semi-implicit external solution allows large time steps that are constrained only by the stability criteria of the explicit central difference or high-order upwind advection scheme used for the nonlinear accelerations. The EFDC model's internal momentum equation solution, at the same time step as the external solution, is implicit with respect to vertical diffusion. Time splitting inherent in the three-time level scheme is controlled by periodic insertion of a second order accurate two-time level trapezoidal step.

Water column transport is based on the same advection-diffusion scheme used for salinity and temperature. EFDC includes an internal sub-model to simulate the transport and fate of an arbitrary number of reacting contaminants in water columns and sediment beds. In this mode, the contaminant transport and fate simulation are functionally similar to the WASP TOXIC model with the added flexibility of simulating an arbitrary number of contaminants. EFDC can simulate multiple classes of cohesive and non-cohesive sediment as suspended load and bed load as well as sediment deposition and re-suspension. The sediment transport is linked to toxic or contaminant transport and fate components. EFDC can simulate an arbitrary number of contaminants, including bacteria, metals and hydrophobic organics, sorbed onto any sediments class.

The bacteria in estuarine and coastal waters can be transported and diffused within the water column in their free-living form, or they can be adsorbed onto the sediments and then transported and diffused with the sediments. However, in this study, due to the lack of extensive observed bacteria data in the sediments, the interaction between bacteria and the sediments is not taken into account in the model and only the transport and fate of the bacteria in the water column is considered hereafter in this report.

3.0 Model Development

The model used in the hydrodynamic and water quality simulation, including grid set-up and model parameters, will be described in this section. For this study, the developed model will be used to evaluate the bacteria water quality under the existing condition and potential management scenarios to meet bacteria water quality standards in the Alamitos Bay and Los Cerritos Channel flow system.

3.1 Hydrodynamic Model Set-up

3.1.1 Computational Grid and Model Parameters

A computational grid layout was set up for hydrodynamic and water quality simulations for the flow system, including the inflow from Los Cerritos Channel and the withdrawals from the power plant cooling water intakes. The computational grid system shown in Figure 3.1 covers the Alamitos Bay area including a 4 kilometer-long segment of Los Cerritos Channel and a 6 kilometer-long segment of the San Gabriel River Estuary, an alongshore distance of about 4 kilometers, and an offshore distance of about 2 kilometers. The estuarine portion of the model extended from the end of the concrete apron below the confluence of San Gabriel River and Coyote Creek to the mouth of the SGRE. In the offshore area, a grid spaced 125m by 125m was made of 32 cells parallel to the shoreline and 15 cells perpendicular to the shoreline. The vertical cells were spaced at 25% of the total depth. The mesh size of the grid was chosen in such a way as to provide a satisfactory resolution of the water elevation and water quality distribution in the computational flow system. The bathymetry used in the model is shown in Figure 3.2. Offshore bathymetry and topography of the coastal area were obtained from a mapping survey performed by the National Oceanic and Atmospheric Administration (NOAA) in 1988. Initial bottom elevations of Alamitos Bay, Los Cerritos Channel, and SGRE were obtained from the Los Angeles Department of Public Works (LADPW) 1951 as-build drawings.

The values of Manning's n used in the hydrodynamic simulation to calculate the bottom friction were from 0.02 in the offshore area to 0.025 in the estuary area. These values are well documented in the literature for a concrete type of channel. The computation time step Δt was 6 seconds for the computational grid. Wind induced surface stresses are of less importance, so their effects were not simulated.

3.1.2 Boundary Conditions of the Hydrodynamic Model

For initial conditions, velocities u, v (x and y components) and water elevations must be specified for every point in the model region. The model may be started from either a cold condition or a pre-starting function. The simulations adopted a cold start, which means that the water elevations were level and velocities were zero everywhere in the computational grid system.

At the solid boundaries, zero normal flow was assumed as a corresponding boundary condition except for the upstream boundary which was specified as a flow rate using measured data for each simulation case. The measured flow data and precipitation data (2001-2018) at Los Cerritos Channel were used to determine the relationship between flow and precipitation and provide the flow input from Los Cerritos Channel into the computational flow system by using the predicted relationship as shown in Figure 3.3 and Figure 3.4.

In addition, the computational grid system has three open boundaries, all of which were implemented as water-level boundaries, i.e., water elevations were specified at boundary nodal points to drive the simulation of tidal circulation within the Alamitos Bay and Los Cerritos Channel flow system.

No tidal elevation data was available at the open boundaries of the study area, so the predicated tidal elevations were used. The tide data predicted by NOAA at Los Angeles Harbor outer breakwater (NOAA, 2010) were used as the basis of water elevations along the open boundaries.

There are two major streams (Los Cerritos Channel and San Gabriel River) and two Generating Stations (AGS and HGS), which withdraw water from Los Cerritos Channel and Alamitos Bay and then discharge to the SGRE, that affect circulation in the Alamitos Bay and Los Cerritos Channel flow system. In addition, predicted flow from Colorado Lagoon as shown in Figure 3.5 is considered as a tidal flow into the Alamitos Bay.

3.2 Water Quality Model Set-up

3.2.1 Water Quality Model Parameters

The computation time step used in the water quality simulation was the same as that used in the hydrodynamic model.

The turbulent diffusion coefficients are among the major controlling factors in solving the pollutant transport equation. It is important to take into consideration their physical meanings and numerical implications when values are selected for the modeling. In general, the diffusion coefficients vary locally according to velocity distribution, water depth, bottom roughness, etc. For this model, the turbulent diffusion coefficients were calibrated through salinity and temperature results obtained by the U.S. Geological Survey (USGS, 2005) and compared with those used in the hydrodynamic model performed by the Southern California Coastal Water Research Project (SCCWRP, 2007). The turbulent diffusion coefficient for horizontal eddy viscosity is 50m^2/sec, vertical kinematic viscosity 3.0E-5 m^2/sec, and vertical eddy diffusivity 5.0E-5 m^2/sec.

3.2.2 Boundary Conditions of the Water Quality Model

Water quality simulation was based on the flow field resulting from the hydrodynamic simulation using the same computational grid system. The model requires a proper initial condition, which will specify water quality at every nodal point in the simulation domain at time zero. Usually, the model starts with a uniform water quality distribution with a typical value for the modeling area. At the land boundary nodes, perpendicular flux was assumed to be zero except for the upstream boundary which was specified as a constant flux with a measured flow rate and concentration for each simulation case.

4.0 Calibration of the Model

4.1 Calibration of the Hydrodynamic Model

After the model was set-up, model calibration was performed. Upon completion of the calibration at selected locations, a calibrated dataset containing parameter values was developed.

Hydrodynamics was the first model component calibrated because simulation of water quality loading relies heavily on flow prediction. The calibration involves a comparison of model results to water movement observations at selected locations. After comparing the results, key parameters were adjusted, and additional model simulations were performed. This iterative process was repeated until the simulated results closely represented the system.

The hydrodynamic model was calibrated against the data collected at the USGS sampling locations throughout July 2005. A summary of the selected calibration parameters is provided in Table 4.1. The calibrated water depths compared to the field data at three USGS stations are shown in Figure 4.1 through Figure 4.3. The field data is represented in red and model predicted results in blue. As shown in these figures, the model predicted water surface depths are in good agreement with the field data over the 30-day calibration period.

As indicated in the previous section, the hydrodynamic component of the EFDC model is dynamically coupled to temperature and salinity transport. Therefore, the temperature and salinity prediction can be considered as one of hydrodynamic calibration. The calibrated surface water temperatures and salinity at three USGS stations are presented in Figure 4.4 through Figure 4.9. In general, the predicted surface water temperature and salinity over the 30-day calibration period agree well with the field data. It should be noted that the hourly temperature data from the power plants enabled the model to simulate measured data in the lower portion of the estuary well, but temperature data for the upstream creek discharge were only available at weekly time intervals, which hindered the model's ability to simulate observed values in the upper estuary.

From the above calibration results, the hydrodynamic model developed for the Alamitos Bay Bacteria model accurately simulates flow field and water movement patterns. As such, it provides a good foundation for the simulation of water quality for the Alamitos Bay and Los Cerritos Channel flow system.

4.2 Calibration of the Water Quality Model

The water quality portion of the Alamitos Bay Bacteria Model was calibrated following the calibration of the hydrodynamics and using the same time step for simulation. Initial concentrations and boundary conditions for bacteria were required for the modeling. In the model, these concentrations were specified based on available data. The initial concentration of 0.0 cfu/100 mL for fecal coliform and enterococcus in the water column was used in the model. This concentration was also used as the ocean boundary condition.

To calibrate the bacteria water quality model, the model results were compared with the observed data sets at four sampling stations (B-22, B-67, B-14 and B-31) for the first 120 days of the year of 2010. The year 2010 represents the 90th percentile storm year and was used as the reference year. The 90th percentile storm year was identified by constructing a cumulative frequency distribution of annual wet-weather days (0.5 inch of rain and the following 24 hours) using historical rainfall data from Long Beach Airport (Los Angeles County Department of Public Works Gauge Station 662D). The sampling locations are shown in Figure 3.1.

The decay rate or die-off rate of bacteria is an important parameter necessary to determine the decrease of bacteria populations in surface water. To calibrate the model, simulations were conducted for the existing condition with various decay rates, including a decay rate of zero to represent the condition of no bacteria die-off, and a range of decay rates to represent the bacteria die off condition, which typically ranges from 0.6 to 6.0 /day for fecal coliform and 0.56-9.4 /day for enterococcus (EPA, 2007 and 2010). The decay rate is generally much higher in marine and estuarine waters than in freshwater.

The model results of water quality simulations for fecal coliform at four calibration locations for different decay rates are presented in Figure 4.10 through Figure 4.13. In these figures, time series of measured fecal coliform data at four measured locations are shown for comparison. Comparisons of measured data and modeled values for enterococcus concentrations are presented in Figure 4.14 through Figure 4.17. The decay rates of 4.0/day for fecal coliform and 6.0/day for enterococcus are selected for the model simulation runs in this study. It can be seen from these figures that the agreement between modeled bacteria results and measured values at four stations during the 2010 sampling events is good. It should be noted that the measured data of bacteria concentrations obtained from Alamitos Bay were limited during wet-weather conditions.

Overall, the calibration results of bacteria concentrations showed a good comparison between modeled and observed values, thus confirming the applicability of the calibrated hydrodynamic and water quality parameters to the Alamitos Bay and Los Cerritos Channel flow system.

5.0 Model Results

After completing model calibration for hydrodynamics and water quality, the model can be applied to the existing condition of bacteria (Baseline Scenario) and the selected load reduction conditions (Reduction Scenarios). The major sources contributing bacteria to the Alamitos Bay and Los Cerritos Channel flow system are Los Cerritos Channel and Colorado Lagoon (during ebb tide). The San Gabriel River was not a major source of bacteria loads to Alamitos Bay (see Figures 5.13 and 5.14). In general, it is expected that the upstream flows and loads from Los Cerritos Channel vary substantially between wet-weather and dry-weather conditions. In this study, predicted flow rates and bacteria concentrations from Los Cerritos Channel during the 90th percentile storm year reference year, 2010, were used in the Baseline Scenario and Reduction Scenario runs to consider a full year variation of weather conditions. The daily rainfall for the year 2010 at the Long Beach Airport (Los Angeles County Department of Public Works Gauge Station 662D) is shown in Figure 5.1. The tidal elevations specified as the ocean boundary along the ocean portion of the model grid are shown in Figure 5.2. The input data of flow rate from Los Cerritos Channel and the AGS and HGS Power Plants during the 2010 period are presented in Figure 5.3 through Figure 5.6.

5.1 Modeling Results of Baseline Scenario

The Alamitos Bay Bacteria model was run for a 365-day period from January 1, 2010 through December 31, 2010. Daily average bacteria concentrations were simulated at four locations within Alamitos Bay (B-22, B-67, B-14, and B-31).

The Baseline Scenario is the existing condition of bacteria loads that contribute to the Alamitos Bay and Los Cerritos Channel flow system. The Baseline Scenario includes the discharge from Los Cerritos Channel at LCC1 and LBE1, the discharge from Colorado Lagoon during ebb tide, and the withdrawal from three intake pumps from Alamitos Bay by the two power plants that discharge to SGRE. The bacteria concentration inputs from Los Cerritos Channel and Colorado Lagoon are shown in Figure 5.7 through Figure 5.12. The bacteria concentration inputs from the two power plants to SGRE for fecal coliform are assumed to be constant values of 30 cfu/100mL for AES and 12 cfu/100mL for HGS. The enterococcus inputs from the power plants to SGRE are assumed to be 0.0 cfu/100mL. These are the average values of the sampling data from 2010.

The spatial distribution of fecal coliform at ebb tide and flood tide are presented in Figure 5.13 and Figure 5.14 to show the bacteria concentration pattern and how bacteria can be transported through the Alamitos Bay flow system in wet-weather. In the year 2010, the first significant rain event peaked on day 20 (Figure 5.1), so day 20 is represented in Figure 5.13 to simulate the baseline spatial distribution of fecal coliform during the ebb tide in wet weather. Figure 5.14 depicts the spatial distribution of fecal coliform on day 20.5 of the year 2010, as the flood tide occurs approximately 12 hours (0.5 days) after the ebb tide. It can be seen from these two figures that the bacteria concentrations in Alamitos Bay are separated into two parts near the intake of the Haynes Generating Station. The higher concentrations of bacteria upstream appear diluted by tidal effects and the circulation of water from the intake pumping.

The computed time series of fecal coliform concentrations at four specified locations are presented in Figure 5.15 through Figure 5.18. The measured fecal coliform concentrations are shown in the same graph for comparison. As can be seen from these figures, the predicted fecal coliform concentrations exceed the Statistical Threshold Value (STV) water quality objective of 320 cfu/100mL for storm events with rainfall greater than 0.5 inches when compared with the rainfall histogram shown in Figure 5.1. Similarly, for enterococcus, as shown in Figure 5.19 through Figure 5.22, it can also be seen that the model results exceed the STV of 110 cfu/100mL for storms with rainfall greater than 0.5 inches.

For the Baseline Scenario, the model results indicate that the bacteria concentrations cannot meet the water quality objectives during storm events greater than 0.5 inches for the 2010 simulation period and load reductions are required.

5.2 Modeling Results of Reduction Scenarios

The following three Reduction Scenarios were performed to evaluate the response of bacteria concentrations in Alamitos Bay to reduction in bacteria loads from Los Cerritos Channel. In order to simulate a reduction in bacteria loads from Los Cerritos Channel, the flow from LCC1 and LBE1 were reduced in the following scenarios:

1. 50% Reduction Scenario - existing loads from Los Cerritos Channel are reduced by 50%.

2. 75% Reduction Scenario - existing loads from Los Cerritos Channel are reduced by 75%.

3. 85% Reduction Scenario - existing loads from Los Cerritos Channel are reduced by 85%.

Although Colorado Lagoon is a source of bacteria loads to Alamitos Bay, a load reduction from Colorado Lagoon was not considered because it is only a source of bacteria during ebb tides.

To find out which load reduction scenario will meet the geometric mean and STV water quality objectives in the Basin Plan, the time series of fecal coliform and enterococci concentrations at four specified locations over the 2010 simulation period were computed. The STV results are presented in Figure 5.23 through

Figure 5.30. In these figures, the measured data and the model results of the Baseline Scenario are also presented in the same graph for comparison.

The geometric mean results are presented in Figure 5.31 through Figure 5.38. In these figures, the geometric mean results for the Baseline Scenario and measured data are also shown in the same graph for comparison.

The summary of model results is provided in Table 5.1 and Table 5.2 to assess attainment of the geometric mean and STV water quality objectives under the Baseline Scenario and the Reduction Scenarios. It can be seen from the time series in Figures 5.23 through Figure 5.38 and the summary in Tables 5.1 and 5.2 that the concentrations of fecal coliform and enterococcus at the four specified locations will only be able to meet the STV and geometric mean objectives for the 85% load reduction scenario. It can also be seen from the contour plots shown in Figure 5.13 and Figure 5.14 that Alamitos Bay is never fully mixed during storm events and the plume of bacteria is carried downstream and exits to the ocean from the mouth of Alamitos Bay. Based on the model results, the loading of bacteria from Los Cerritos Channel must be reduced by at least 85% in order to attain both the geometric mean and STV water quality objectives in Alamitos Bay.

5.3 Modeling Results for Cessation of Power Plant Withdrawals

Since all of the plants using coastal and estuarine waters for power plant cooling are required to come into compliance with Water Quality Control Policy (Resolution No. 2010-0020), the two Generating Stations (AGS and HGS) will stop withdrawing water from the Alamitos Bay and Los Cerritos Channel in the near future. In this report, the calibrated model was used to investigate the water quality impacts of ceasing the withdrawal of water and the model results are presented in this Section.

To evaluate the effects on water quality due to power plant intake pumping, residence time (i.e. average time a pollutant particle resides in a dynamic flow system) of fecal coliform is used as a means for indirectly assessing the water quality in the Alamitos Bay and Los Cerritos Channel flow system. Although the bacteria water quality objective for enterococcus applies in Alamitos Bay, residence time analysis was performed using fecal coliform concentrations. The decay rates for fecal coliform and enterococcus used in the model were 4/day and 6/day, respectively. The decay rate for fecal coliform is lower (and therefore slower) than that of enterococcus, so this approach is deemed conservative.

Consider a tracer concentration in a tidal flow system due to tidal flushing after being released, for which C_0 is initial concentration and $C(t)$ is the concentration at time t. The residence time T_r of the tracer in the Alamitos Bay and Los Cerritos Channel flow system can be calculated from the model results of the tracer concentration time series as follows:

$$T_r = \frac{\int tC(t)\,dt}{\int C(t)\,dt}$$

The residence times obtained by using the bacteria concentrations from the computed model results (for the January 1 – December 31, 2010 simulation period) for different scenarios of the power plants withdrawing water are shown in Tables 5.3a through 5.3c. Table 5.3a shows the residence times of bacteria at four locations in Alamitos Bay for the baseline scenario and three pump cessation scenarios during wet-weather, and Tables 5.3b shows the residence times for the same locations and scenarios during dry- weather. Table 5.3c shows the overall increase in residence times between the baseline scenario and the cessation of all pumping at four locations in Alamitos Bay during wet- and dry-weather. The three pump cessation scenarios were:

1. HGS intake pump is shut off, and only AGS is withdrawing water from Alamitos Bay.
2. AGS intake pumps are shut off, and only HGS is withdrawing water from Alamitos Bay.
3. All intake pumps are shut off, and neither power plant is withdrawing water from Alamitos Bay.

It can be seen from Table 5.3a that the residence times of fecal coliform concentrations at B-22 will increase from the baseline in wet-weather for the low pumping rate scenarios (Case 1 and 2) and no pumping scenario (Case 3) by 0.5 days and 0.8 days, respectively. For example, the residence time for the baseline scenario at location B-22 is 6.0 days. When the intake pumps are shut off at either AGS or HGS (Case 1 or Case 2), the residence time at location B-22 increases to an average of 6.5 days. Therefore, the residence time increases by an average of 0.5 days with one power plant shut down. If all of the intake pumps from AGS and HGS are shut off (Case 3), the residence time at B-22 increases from the baseline of 6.0 days to 6.8 days (an increase of 0.8 days).

The same increases of the residence times by 0.5 days for Case 1 and Case 2 and 0.8 days for Case 3 are seen at location B-67, as well. At locations B-14 and B-31, the residence times also increase from the baseline scenario, however the increase in residence times are smaller than they are at B-22 and B-67.

The increase in residence times indicate that intake pumping from the power plants enhances circulation in Alamitos Bay by an average of 11% at all four locations, and a maximum of 15% (at B-67) during wet-weather when comparing the highest intake pumping condition (Baseline) with the no intake pumping condition (Case 3). However, the enhancement in circulation from intake pumping is not very significant when compared to the flow flushing due to the first major storm event on day 20 of the year 2010. It can be seen in Figure 5.3 that the flow rate at LCC1 during the storm peaks on day 20 at approximately 80 m^3/sec, whereas Figures 5.5 and 5.6 show that the maximum flow rate at AES and HGS during the same storm event is approximately 10 m^3/sec.

Table 5.3b shows that the residence times of fecal coliform concentrations in dry-weather at locations B-22, B-67, and B-14 increase from the baseline scenario for the low pumping rate scenarios (Case 1 and 2) and no pumping scenario (Case 3) by 0.3 days and 0.6 days, respectively. The increase in residence times at B-31 for the low pumping rate scenarios and no pumping scenario are by 0.2 days and 0.5 days, respectively. The increase in residence times suggest that intake pumping from the power plants augments circulation in Alamitos Bay by an average of 155% at all four locations, and a maximum of 250% (at B-31) during dry-weather when comparing the baseline to the no intake pumping condition (Case 3). Although these percentages are relatively high, it must be considered that the actual residence times in the baseline scenario for dry-weather are smaller (ranging from 0.2 days to 0.6 days) than the residence times in the baseline scenario for wet-weather. Therefore, a small increase in residence time may reflect a large percent difference in total residence time during dry weather. For example, at location B-31, the 250% increase reflects an increase from a baseline residence time of 0.2 days to 0.7 days when all pumping ceases.

Table 5.3c compares the overall increases in residence times during wet- and dry-weather from the baseline scenario to the cessation of all pumping (Case 3) at the four locations in Alamitos Bay.

To evaluate the impact of power plant intake pumping on water quality in Alamitos Bay, model simulations were performed with intake pumping and without intake pumping under the baseline, 75% Reduction Scenario, and 85% Reduction Scenario. Comparisons of the geometric mean exceedances and STV exceedances at four locations in Alamitos Bay (B-22, B-67, B-14, and B-31) for the two power plant withdrawal cases (with and without power plant intake pumping) are presented in Tables 5.4 and 5.5.

As seen in Table 5.4, in the with and without power plant intake pumping cases, there are exceedances of the geometric mean and STV for fecal coliform at all locations for the baseline scenarios. In the 75% Reduction Scenario of the power plant pumping case, there is one geometric mean exceedance at B-67, and two STV exceedances at both B-22 and B-67. In comparison, in the 75% Reduction Scenario for the without power plant pumping case, there are exceedances of the geometric mean and STV at locations B-22, B-67, and B-14. In the 85% Reduction Scenario of the power plant pumping case, there are no geometric mean or STV exceedances. In the 85% Reduction Scenario of the without power plant pumping case, although there are no geometric mean exceedances, there are two STV exceedances at B-22.

Table 5.5 shows the with and without power plant pumping cases with the same baseline and reduction scenarios for enterococcus. In the 75% reduction scenario of the with power plant pumping case, there are exceedances of the geometric mean and STV at B-22. Alternatively, in the 75% Reduction Scenario of the without power plant pumping case, there are geometric mean and STV exceedances at B-22 and B-67, and an exceedance of the geometric mean at B-14. In the 85% Reduction Scenario for both the with and without power plant pumping cases, there are no geometric mean or STV exceedances for enterococcus.

It can be seen from Tables 5.4 and 5.5 that without power plant pumping, even with an 85% reduction there are still exceedances of the STV for fecal coliform. Therefore, the power plant intake pumping affects the ability of Alamitos Bay to meet the water quality objectives for fecal coliform under the 85% Load Reduction Scenario at B-22.

5.4 Modeling Results of Water Quality Impacts of High Flow Suspension

A high flow suspension is the suspension of bacteria water quality objectives on days with rainfall greater than or equal to 0.5 inches and the 24 hours following the end of the 0.5 inch or greater rain event. Because the Los Cerritos Channel meets the channel requirements for a high flow suspension, a Basin Plan amendment to add a high flow suspension for the Los Cerritos Channel could be considered by the Los Angeles Water Board. To take into account the effect of a high flow suspension applied in Los Cerritos Channel on water quality in the Alamitos Bay Los Cerritos Channel flow system, the results from the baseline, 50%, 75%, and 85% Reduction Scenarios (Tables 5.1 and 5.2) were evaluated to determine whether exceedances of the STV and geometric mean occurred during a rainfall event of greater than or equal to 0.5 inches or the following 24 hour period.

Since the STV exceedances are based on a period of one month, staff reviewed data for each month that exceeded the STV, and determined if that specific month's exceedance was due to a rainfall event of greater than or equal to 0.5 inches of rain or the following 24 hour period. Tables 5.6a and 5.7a show the total number of exceedances of the STV for fecal coliform and enterococcus in the year 2010, and whether those exceedances were due to a rainfall event that would trigger a high flow suspension, if one was applied in Los Cerritos Channel. As seen in Table 5.6a and 5.7a, all of the STV exceedances that occur in the baseline, 50%, and 75% reduction scenarios for fecal coliform and enterococcus are due to a rainfall event of greater than or equal to 0.5 inches or the following 24 hour period. In the 75% reduction scenario, there are two STV exceedances for fecal coliform at locations B-22 and B-67 that occur during what would be considered a high flow suspension period if a high flow suspension was applied. Similarly, in the 75% reduction scenario, there is one STV exceedance for enterococcus at B-22 during what would be considered a high flow suspension period. There are no STV exceedances for fecal coliform or enterococcus in the 85% reduction scenario. Since all of the STV exceedances in the baseline, 50%, and 75% reduction scenarios are due to a rainfall event that would trigger a high flow suspension scenario, it can be seen that Alamitos Bay does not meet water quality objectives if a high flow suspension is applied in Los Cerritos Channel, even in a 75% reduction scenario.

Similar to STV exceedances, the geometric mean exceedances for fecal coliform and enterococcus were also analyzed to determine whether the exceedances were related to a rainfall event greater than or equal to 0.5 inches, or the following 24-hour period. However, because the geometric mean is calculated as a six-week rolling average, a geometric mean exceedance could not be directly correlated with one specific rainfall event. In order to make a more general comparison of geometric mean exceedances to rainfall events of 0.5 inches or greater, staff determined whether a rainfall event (0.5 inches or greater) or the 24 hours following that rainfall event occurred during the six-week period.

Tables 5.6b and 5.7b show the total number of geometric mean exceedances for fecal coliform and enterococcus in the year 2010, and whether those exceedances were considered to be related to a rainfall event greater than or equal to 0.5 inches or the following 24 hours. As seen in Tables 5.6b and 5.7b, all of the geometric mean exceedances that occur in the baseline, 50%, and 75% reduction scenarios for fecal coliform and enterococcus are related to a rainfall event of greater than or equal to 0.5 inches or the following 24 hour period. In the 75% reduction scenario, there is one geometric mean exceedance for fecal coliform at B-67 that occurs during what would be considered a high flow suspension period if a high flow suspension was applied. Similarly, in the 75% reduction scenario, there are two geometric mean exceedances for enterococcus at B-22 during what would be considered a high flow suspension period. There are no geometric mean exceedances for fecal coliform or enterococcus in the 85% reduction scenario. Since all of the geometric mean exceedances in the baseline, 50%, and 75% reduction scenarios are related to a rainfall event that would trigger a high flow suspension scenario, it can be seen that Alamitos Bay does not meet water quality objectives if a high flow suspension is applied in Los Cerritos Channel, even in a 75% reduction scenario. In an 85% reduction scenario, there are no geometric mean or STV exceedances, and Alamitos Bay meets water quality objectives.

6.0 Summary

The water quality model developed for the Bacteria TMDL has been calibrated and closely predicts observed data. The model is capable of simulating bacteria transport in the Alamitos Bay and Los Cerritos Channel flow system and demonstrates that the flow flushing from storm water is stronger than the power plant intake flow and discharge flow during storm events.

The model results that show the spatial distribution of bacteria in wet-weather and demonstrate that bacteria concentrations in Alamitos Bay are not fully mixed and are separated into two parts near the intake of the Haynes Generating Station. The higher concentrations of bacteria upstream appear to be diluted by tidal effects and the circulation from intake pumping during storm events.

The model results indicate that the bacteria concentrations in water from Los Cerritos Channel cannot obtain the mixing benefit from the downstream tidal effect in the Alamitos Bay waterbody system during ebb tide, although some dilution benefit can be obtained during flood tide, even under the condition of no power plant intake pumping and outfall discharge.

Therefore, based on the model results, it is recommended that the bacteria loads from Los Cerritos Channel be reduced by greater than 85% of the existing bacteria condition (Baseline Scenario as discussed previously) in order to meet the geometric mean and STV water quality objectives for bacteria.

The model results demonstrate that intake pumping from the power plants enhances circulation within Alamitos Bay by an average of 11% at all four locations, and a maximum of 15% (at B-67) during wet-weather when comparing the highest intake pumping condition and the no intake pumping condition. However, the enhancement is not very significant when compared to the flow flushing due to the storm event specifically in 2010. The model results also indicate that the power plant intake pumping will affect the bacteria quality to meet water quality standard under 75% Load Reduction Scenario at B-22 and B-67.

In addition, the model results show that the high flow suspension in Los Cerritos Channel, if not otherwise accompanied by an 85% reduction in loading, has a significant impact on water quality. Exceedances of the geometric mean and STV are related to rainfall events that would trigger a high flow suspension, if one were applied to Los Cerritos Channel. However, under the 85% Reduction Scenario, there were no exceedances of the geometric mean or STV. Therefore, Alamitos Bay meets water quality objectives under the 85% Reduction Scenario in the high flow suspension scenario for Los Cerritos Channel.

7.0 References

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TABLE 4.1 SELECTED CALIBRATION PARAMETERS OF HYDRODYNAMIC SIMULATION FOR ALAMITOS BAY BACTERIA MODEL

MODEL PARAMETER	UNITS	VALUE
Roughness Height – San Gabriel River Estuary	m	0.025
Roughness Height – Offshore Area	m	0.02
Horizontal Eddy Viscosity	m^2/sec	50
Maximum Vertical Kinematic Viscosity	m^2/sec	3E-5
Maximum Vertical Eddy Diffusivity	m^2/sec	5E-5
Anti-Diffusion Correction for Hydrodynamics	--	Off
Anti-Diffusion Correction for Metals	--	On

Table 5.1 Summary of Model Results of Fecal Coliform for Baseline Scenario and Different Reduction Scenarios Based on January 1-December 31, 2010 Simulation Year

Location and Parameter			Baseline Scenario	50% Reduction Scenario	75% Reduction Scenario	85% Reduction Scenario
B-22	GM	NE_{GM}	7	4	0	0
		N_{GM}	9	7	4	4
	STV	NE_{STV}	3	3	2	0
		NM_{STV}	7	6	4	3
B-67	GM	NE_{GM}	7	4	1	0
		N_{GM}	8	7	4	1
	STV	NE_{STV}	3	3	2	0
		NM_{STV}	7	4	3	2
B-14	GM	NE_{GM}	6	4	0	0
		N_{GM}	7	7	4	1
	STV	NE_{STV}	3	3	0	0
		NM_{STV}	7	4	3	2
B-31	GM	NE_{GM}	5	0	0	0
		N_{GM}	7	4	0	0
	STV	NE_{STV}	3	2	0	0
		NM_{STV}	4	3	2	0

GM: Geometric Mean; STV: Statistical Threshold Value.

NE_{GM}: Number of exceedances for Geometric Mean calculation (calculated weekly) in six-week interval.

N_{GM}: Number of times a geometric mean was able to be calculated with a minimum of five samples and values greater than detection limits (1 cfu/100mL, dilution factor of 10).

NE_{STV}: Number of exceedances for Statistical Threshold Value calculation (calculated monthly) and more than 10% of samples calculated.

NM_{STV}: Number of months with calculated values greater than detection limit (1 cfu/100mL, dilution factor of 10).

Table 5.2 Summary of Model Results of Enterococci for Baseline Scenario and Different Reduction Scenarios Based on January 1-December 31, 2010 Simulation Year

Location and Parameter			Baseline Scenario	50% Reduction Scenario	75% Reduction Scenario	85% Reduction Scenario
B-22	GM	NE_{GM}	8	4	1	0
		N_{GM}	8	7	4	1
	STV	NE_{STV}	3	3	2	0
		NS_{STV}	7	4	3	2
B-67	GM	NE_{GM}	7	4	0	0
		N_{GM}	7	6	1	0
	STV	NE_{STV}	3	3	0	0
		NS_{STV}	5	3	3	2
B-14	GM	NE_{GM}	7	4	0	0
		N_{GM}	7	4	1	0
	STV	NE_{STV}	3	2	0	0
		NS_{STV}	5	3	2	1
B-31	GM	NE_{GM}	6	0	0	0
		N_{GM}	6	4	0	0
	STV	NE_{STV}	3	0	0	0
		NS_{STV}	4	3	1	0

GM: Geometric Mean; STV: Statistical Threshold Value.

NE_{GM}: Number of exceedances for Geometric Mean calculation (calculated weekly) in six-week interval.

N_{GM}: Number of times a geometric mean was able to be calculated with a minimum of five samples and values greater than detection limits (1 cfu/100mL, dilution factor of 10).

NE_{STV}: Number of exceedances for Statistical Threshold Value calculation (calculated monthly) and more than 10% of samples calculated.

NM_{STV}: Number of months with calculated values greater than detection limit (1 cfu/100mL, dilution factor of 10).

TABLE 5.3A RESIDENCE TIME RESULTS OF FECAL COLIFORM FOR BASELINE SCENARIO AND DIFFERENT POWER PLANT WITHDRAWING WATER CASES UNDER WET-WEATHER CONDITION FOR ALAMITOS BAY BACTERIA MODEL BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

LOCATIONS	PARTICLE TRAVEL	BASELINE SCENARIO	CASE 1	CASE 2	CASE 3
B-22	Start Time (day)	17.0	17.0	17.0	17.0
	End Time (day)	23.0	23.4	23.6	23.8
	Residence Time (day)	6.0	6.4	6.6	6.8
B-67	Start Time (day)	17.5	17.5	17.3	17.2
	End Time (day)	23.0	23.4	23.4	23.5
	Residence Time (day)	5.5	5.9	6.1	6.3
B-14	Start Time (day)	18.0	18.0	18.0	18.0
	End Time (day)	23.1	23.3	23.4	23.5
	Residence Time (day)	5.1	5.3	5.4	5.5
B-31	Start Time (day)	18.1	18.1	18.1	18.1
	End Time (day)	22.3	22.4	22.5	22.6
	Residence Time (day)	4.2	4.3	4.4	4.5

Baseline Scenario: Existing condition that both AGS and HGS are withdrawing water from Alamitos Bay
Case 1: Only AGS is withdrawing water from Alamitos Bay
Case 2: Only HGS is withdrawing water from Alamitos Bay
Case 3: No power plant withdrawing water from Alamitos Bay
Note: These model results are based on the wet-weather condition under the first storm event in 2010 indicated in Figure 5.1, Figure 5.3, Figure 5.5, and Figure 5.6.

TABLE 5.3B RESIDENCE TIME RESULTS OF FECAL COLIFORM FOR BASELINE SCENARIO AND DIFFERENT POWER PLANT WITHDRAWING WATER CASES UNDER DRY-WEATHER CONDITION FOR ALAMITOS BAY BACTERIA MODEL BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

LOCATIONS	PARTICLE TRAVEL	BASELINE SCENARIO	CASE 1	CASE 2	CASE 3
B-22	Start Time (day)	0.0	0.0	0.0	0.0
	End Time (day)	0.6	0.8	1.0	1.2
	Residence Time (day)	0.6	0.8	1.0	1.2
B-67	Start Time (day)	0.0	0.0	0.0	0.0
	End Time (day)	0.5	0.7	0.9	1.1
	Residence Time (day)	0.5	0.7	0.9	1.1
B-14	Start Time (day)	0.0	0.0	0.0	0.0
	End Time (day)	0.4	0.6	0.8	1.0
	Residence Time (day)	0.4	0.6	0.8	1.0
B-31	Start Time (day)	0.0	0.0	0.0	0.0
	End Time (day)	0.2	0.3	0.5	0.7
	Residence Time (day)	0.2	0.3	0.5	0.7

Baseline Scenario: Existing condition that both AGS and HGS are withdrawing water from Alamitos Bay

Case 1: Only AGS is withdrawing water from Alamitos Bay

Case 2: Only HGS is withdrawing water from Alamitos Bay

Case 3: No power plant withdrawing water from Alamitos Bay

Note: These model results are based on the dry-weather condition under the flow measured data in 2010 indicated in Figure 5.3, Figure 5.5, and Figure 5.6.

TABLE 5.3C INCREASE IN FECAL COLIFORM RESIDENCE TIMES FROM THE BASELINE SCENARIO FOR NO POWER PLANTS WITHDRAWING WATER (CASE 3) DURING WET- AND DRY-WEATHER CONDITIONS BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

LOCATIONS	INCREASE IN RESIDENCE TIME (DAYS) FOR WET-WEATHER (% INCREASE)	INCREASE IN RESIDENCE TIME (DAYS) FOR DRY-WEATHER (% INCREASE)
B-22	0.8 (13.3%)	0.6 (100%)
B-67	0.8 (14.5%)	0.6 (120%)
B-14	0.4 (7.8%)	0.6 (150%)
B-31	0.3 (7.1%)	0.5 (250%)

TABLE 5.4 COMPARISON OF MODEL RESULTS OF FECAL COLIFORM FOR WITH POWER PLANT INTAKE PUMPING AND WITHOUT POWER PLANT INTAKE PUMPING BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

LOCATION AND PARAMETER			WITH POWER PLANT INTAKE PUMPING			WITHOUT POWER PLANT INTAKE PUMPING		
			BASELINE SCENARIO	75% REDUCTION SCENARIO	85% REDUCTION SCENARIO	BASELINE SCENARIO	75% REDUCTION SCENARIO	85% REDUCTION SCENARIO
B-22	GM	NE_{GM}	7	0	0	7	1	0
		N_{GM}	9	4	4	20	7	7
	STV	NE_{STV}	3	2	0	4	3	2
		NM_{STV}	7	4	3	7	6	4
B-67	GM	NE_{GM}	7	1	0	9	1	0
		N_{GM}	8	4	1	18	7	6
	STV	NE_{STV}	3	2	0	3	2	0
		NM_{STV}	7	3	2	7	4	4
B-14	GM	NE_{GM}	6	0	0	6	1	0
		N_{GM}	7	4	1	16	7	6
	STV	NE_{STV}	3	0	0	3	2	0
		NM_{STV}	7	3	2	7	4	4
B-31	GM	NE_{GM}	5	0	0	4	0	0
		N_{GM}	7	0	0	7	4	1
	STV	NE_{STV}	3	0	0	3	0	0
		NM_{STV}	4	2	0	6	3	2

GM: Geometric Mean; STV: Statistical Threshold Value.

NE_{GM}: Number of exceedances for Geometric Mean calculation (calculated weekly) in six-week interval.

N_{GM}: Number of times a geometric mean was able to be calculated with a minimum of five samples and values greater than detection limits (1 cfu/100mL, dilution factor of 10).

NE_{STV}: Number of exceedances for Statistical Threshold Value calculation (calculated monthly) and more than 10% of samples calculated.

$NM_{\mathbf{STV}}$: Number of months with calculated values greater than detection limit (1 cfu/100mL, dilution factor of 10).

Table 5.5 Comparison of Model Results of Enterococci for with Power Plant Intake Pumping and without Power Plant Intake Pumping Based on January 1-December 31, 2010 Simulation Year

Location and Parameter			With Power Plant Intake Pumping			Without Power Plant Intake Pumping		
			Baseline Scenario	75% Reduction Scenario	85% Reduction Scenario	Baseline Scenario	75% Reduction Scenario	85% Reduction Scenario
B-22	GM	NE_{GM}	8	1	0	9	4	0
		N_{GM}	8	4	1	16	7	4
	STV	NE_{STV}	3	2	0	5	2	0
		NM_{STV}	7	3	2	7	4	3
B-67	GM	NE_{GM}	7	0	0	8	1	0
		N_{GM}	7	1	0	14	6	4
	STV	NE_{STV}	3	0	0	4	2	0
		NM_{STV}	5	3	2	7	4	3
B-14	GM	NE_{GM}	7	0	0	8	1	0
		N_{GM}	7	1	0	8	4	1
	STV	NE_{STV}	3	0	0	3	0	0
		NM_{STV}	5	2	1	7	3	2
B-31	GM	NE_{GM}	6	0	0	7	0	0
		N_{GM}	6	0	0	7	0	0
	STV	NE_{STV}	3	0	0	3	0	0
		NM_{STV}	4	1	0	6	2	1

GM: Geometric Mean; STV: Statistical Threshold Value.

NE_{GM}: Number of exceedances for Geometric Mean calculation (calculated weekly) in six-week interval.

N_{GM}: Number of times a geometric mean was able to be calculated with a minimum of five samples and values greater than detection limits (1 cfu/100mL, dilution factor of 10).

NE_{STV}: Number of exceedances for Statistical Threshold Value calculation (calculated monthly) and more than 10% of samples calculated.

NM_{STV}: Number of months with calculated values greater than detection limit (1 cfu/100mL, dilution factor of 10).

TABLE 5.6A ASSESSMENT OF MODEL RESULTS FOR THE BASELINE AND REDUCTION SCENARIOS FOR FECAL COLIFORM STV EXCEEDANCES DURING > 0.5" OF RAIN BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

ALAMITOS BAY LOCATION AND PARAMETER	TOTAL NUMBER OF STV EXCEEDANCES FOR ALL FECAL COLIFORM DATA (2010)	NUMBER OF STV EXCEEDANCES OCCURRING DURING ≥ 0.5" OF RAIN OR THE FOLLOWING 24 HOUR PERIOD
BASELINE SCENARIO		
B-22	3	3
B-67	3	3
B-14	3	3
B-31	3	3
50% REDUCTION SCENARIO		
B-22	3	3
B-67	3	3
B-14	3	3
B-31	2	2
75% REDUCTION SCENARIO		
B-22	2	2
B-67	2	2
B-14	0	0
B-31	0	0
85% REDUCTION SCENARIO		
B-22	0	0
B-67	0	0
B-14	0	0
B-31	0	0

TABLE 5.6B ASSESSMENT OF MODEL RESULTS FOR THE BASELINE AND REDUCTION SCENARIOS FOR FECAL COLIFORM GEOMETRIC MEAN EXCEEDANCES DURING > 0.5” OF RAIN BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

ALAMITOS BAY LOCATION AND PARAMETER	**TOTAL NUMBER OF GEOMETRIC MEAN EXCEEDANCES FOR ALL FECAL COLIFORM DATA (2010)**	**NUMBER OF EXCEEDANCES OCCURRING DURING ≥ 0.5” OF RAIN OR THE FOLLOWING 24 HOUR PERIOD**
BASELINE SCENARIO		
B-22	7	7
B-67	7	7
B-14	6	6
B-31	5	5
50% REDUCTION SCENARIO		
B-22	4	4
B-67	4	4
B-14	4	4
B-31	0	0
75% REDUCTION SCENARIO		
B-22	0	0
B-67	1	1
B-14	0	0
B-31	0	0
85% REDUCTION SCENARIO		
B-22	0	0
B-67	0	0
B-14	0	0
B-31	0	0

TABLE 5.7A ASSESSMENT OF MODEL RESULTS FOR THE BASELINE AND REDUCTION SCENARIOS FOR ENTEROCOCCUS STV EXCEEDANCES DURING > 0.5" OF RAIN BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

ALAMITOS BAY LOCATION AND PARAMETER	TOTAL NUMBER OF STV EXCEEDANCES FOR ALL ENTEROCOCCUS DATA (2010)	NUMBER OF STV EXCEEDANCES OCCURRING DURING ≥ 0.5" OF RAIN OR THE FOLLOWING 24-HOUR PERIOD
BASELINE SCENARIO		
B-22	3	3
B-67	3	3
B-14	3	3
B-31	3	3
50% REDUCTION SCENARIO		
B-22	3	3
B-67	3	3
B-14	2	2
B-31	0	0
75% REDUCTION SCENARIO		
B-22	2	2
B-67	0	0
B-14	0	0
B-31	0	0
85% REDUCTION SCENARIO		
B-22	0	0
B-67	0	0
B-14	0	0
B-31	0	0

TABLE 5.7B ASSESSMENT OF MODEL RESULTS FOR THE BASELINE AND REDUCTION SCENARIOS FOR ENTEROCOCCUS GEOMETRIC MEAN EXCEEDANCES DURING > 0.5” OF RAIN BASED ON JANUARY 1-DECEMBER 31, 2010 SIMULATION YEAR

ALAMITOS BAY LOCATION AND PARAMETER	TOTAL NUMBER OF GEOMETRIC MEAN EXCEEDANCES FOR ALL ENTEROCOCCUS DATA (2010)	NUMBER OF EXCEEDANCES OCCURRING DURING ≥ 0.5” OF RAIN OR THE FOLLOWING 24-HOUR PERIOD
BASELINE SCENARIO		
B-22	8	8
B-67	7	7
B-14	7	7
B-31	6	6
50% REDUCTION SCENARIO		
B-22	4	4
B-67	4	4
B-14	4	4
B-31	0	0
75% REDUCTION SCENARIO		
B-22	1	1
B-67	0	0
B-14	0	0
B-31	0	0
85% REDUCTION SCENARIO		
B-22	0	0
B-67	0	0
B-14	0	0
B-31	0	0

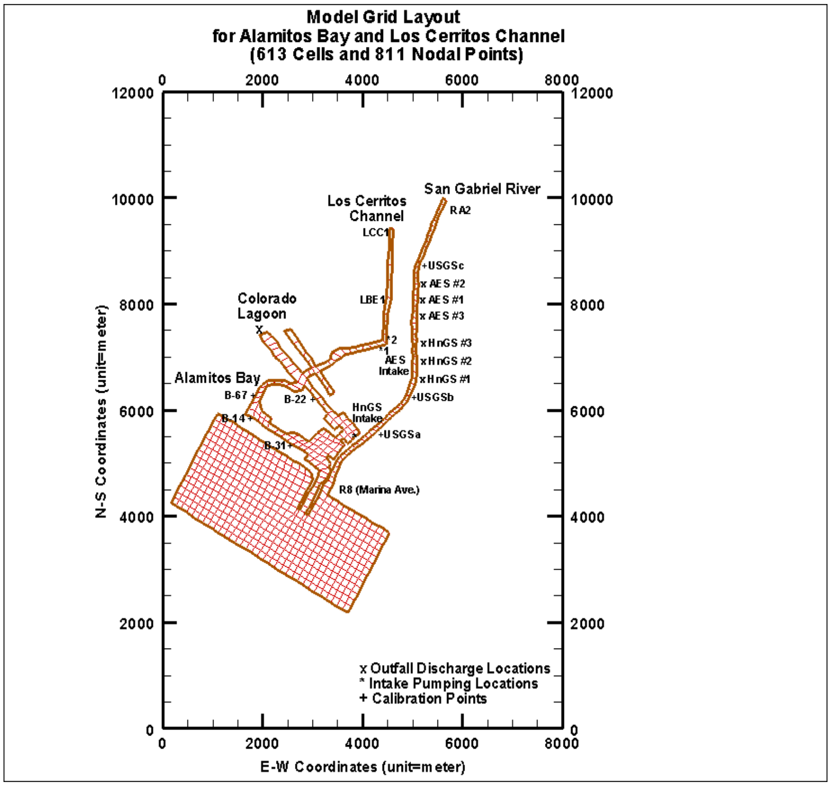

FIGURE 3.1 GRID SET-UP FOR THE ALAMITOS BAY BACTERIA MODEL

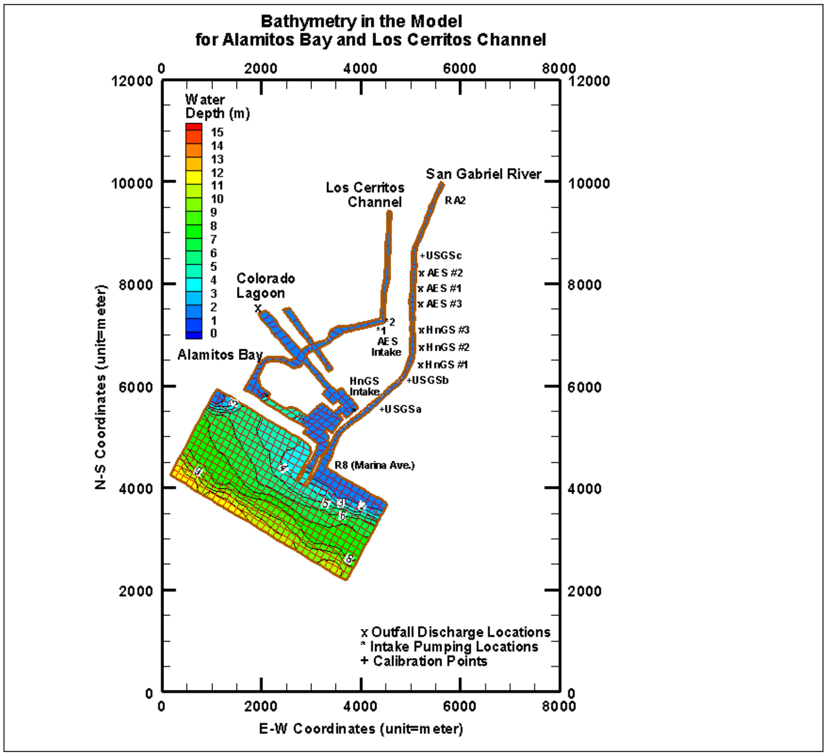

FIGURE 3.2 BATHYMETRY USED IN THE ALAMITOS BAY BACTERIA MODEL

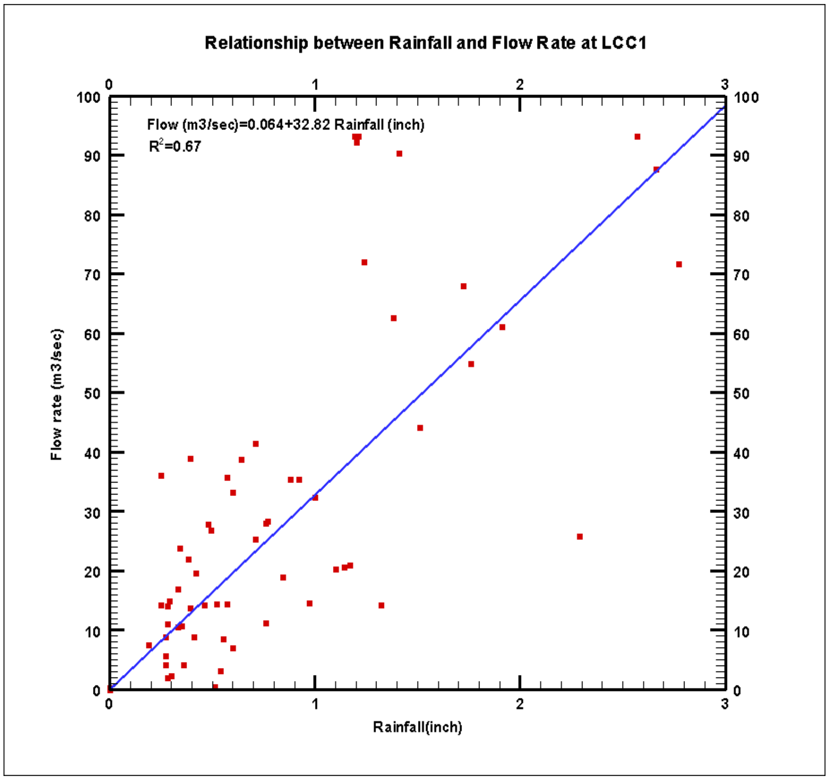

FIGURE 3.3 RELATIONSHIP BETWEEN FLOW RATE AND PRECIPITATION AT LCC1 USED IN THE ALAMITOS BAY BACTERIA MODEL

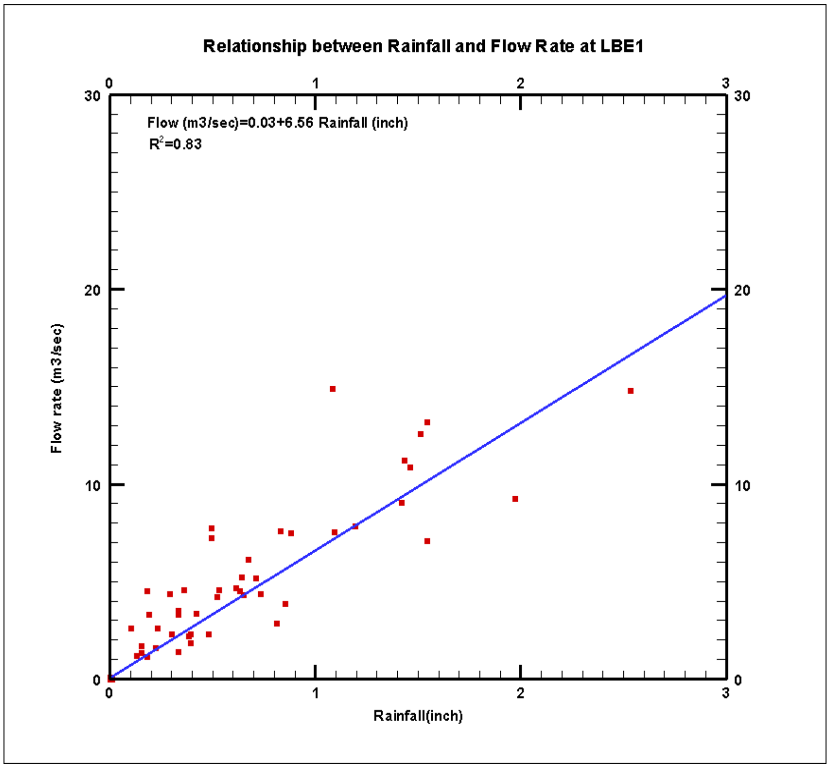

FIGURE 3.4 RELATIONSHIP BETWEEN FLOW RATE AND PRECIPITATION AT LBE1 USED IN THE ALAMITOS BAY BACTERIA MODEL

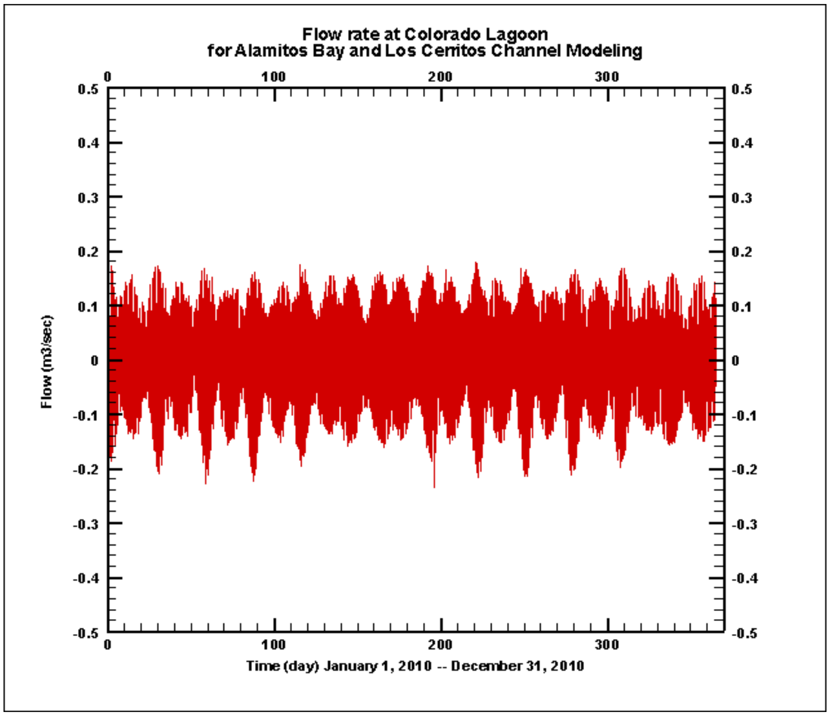

FIGURE 3.5 PREDICTED FLOW RATE AT COLORADO LAGOON USED FOR THE ALAMITOS BAY BACTERIA MODEL

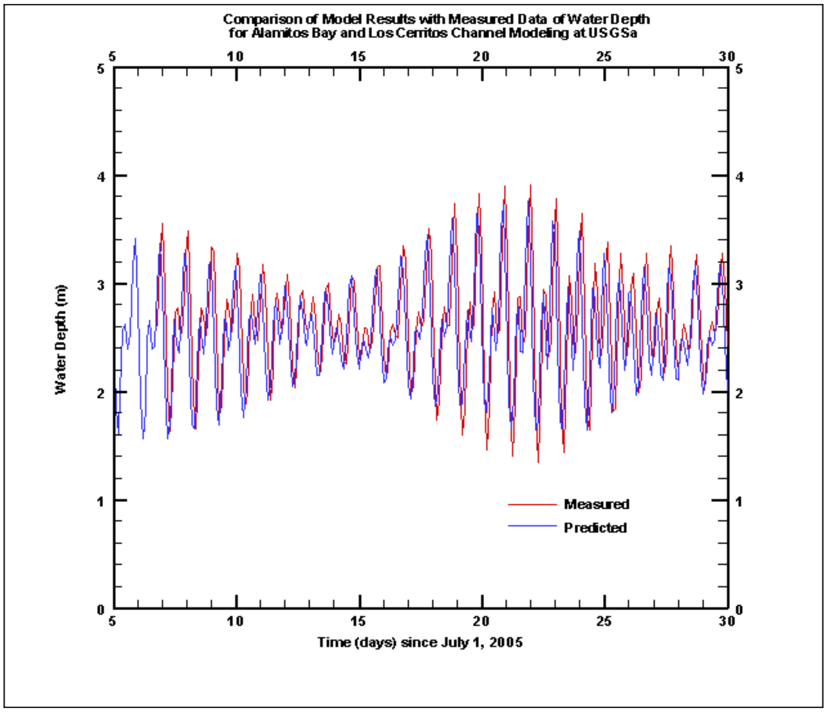

FIGURE 4.1 COMPARISON OF WATER DEPTH AT STATION USGSA FOR THE ALAMITOS BAY BACTERIA MODEL

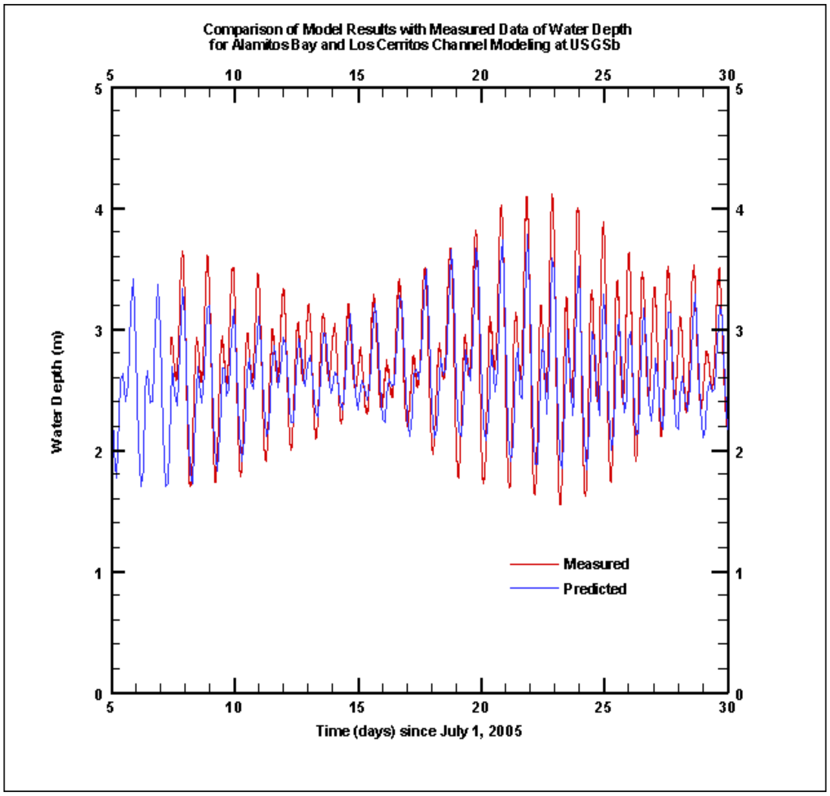

FIGURE 4.2 COMPARISON OF WATER DEPTH AT STATION USGSB FOR THE ALAMITOS BAY BACTERIA MODEL

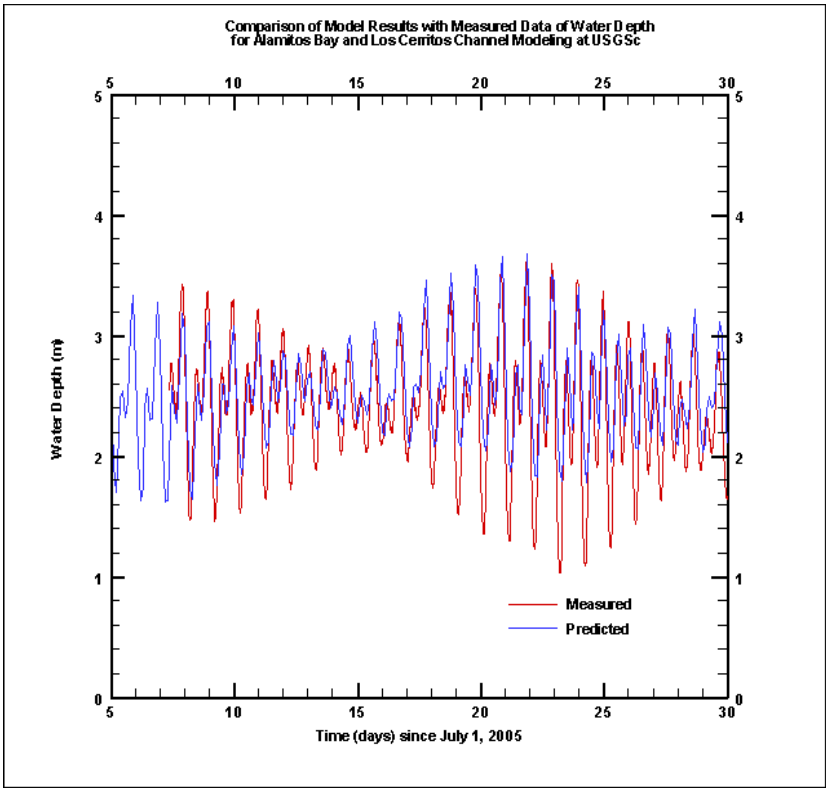

FIGURE 4.3 COMPARISON OF WATER DEPTH AT STATION USGSC FOR THE ALAMITOS BAY BACTERIA MODEL

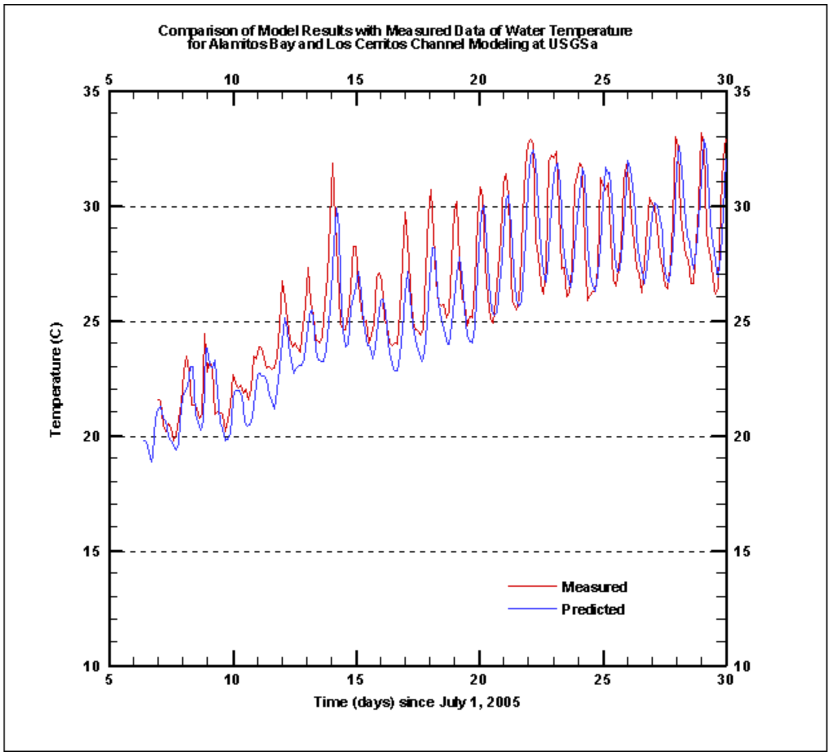

FIGURE 4.4 COMPARISON OF SURFACE WATER TEMPERATURE AT STATION USGSA FOR THE ALAMITOS BAY BACTERIA MODEL

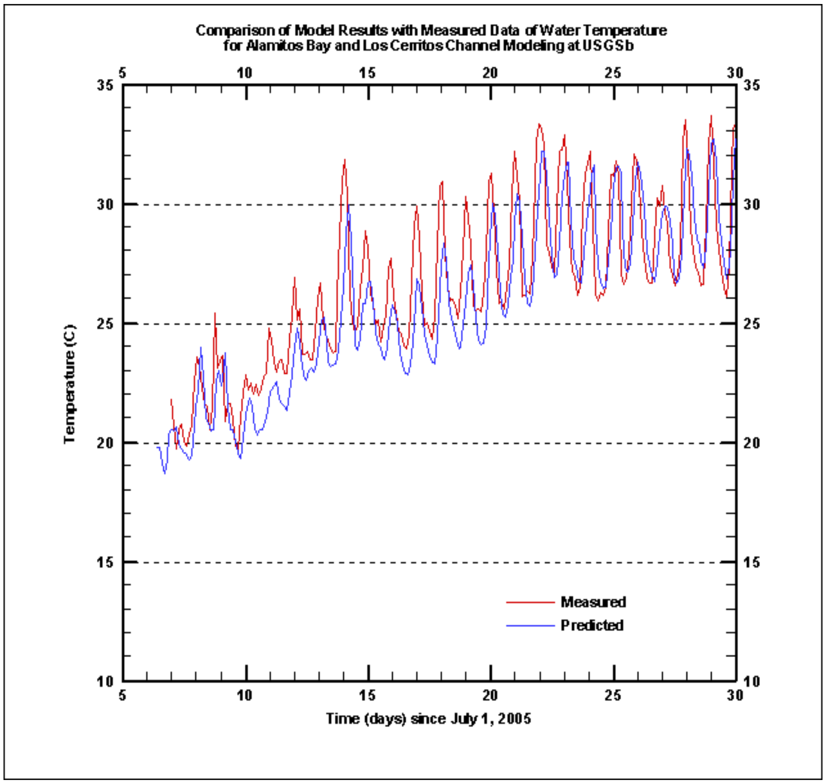

FIGURE 4.5 COMPARISON OF SURFACE WATER TEMPERATURE AT STATION USGSB FOR THE ALAMITOS BAY BACTERIA MODEL

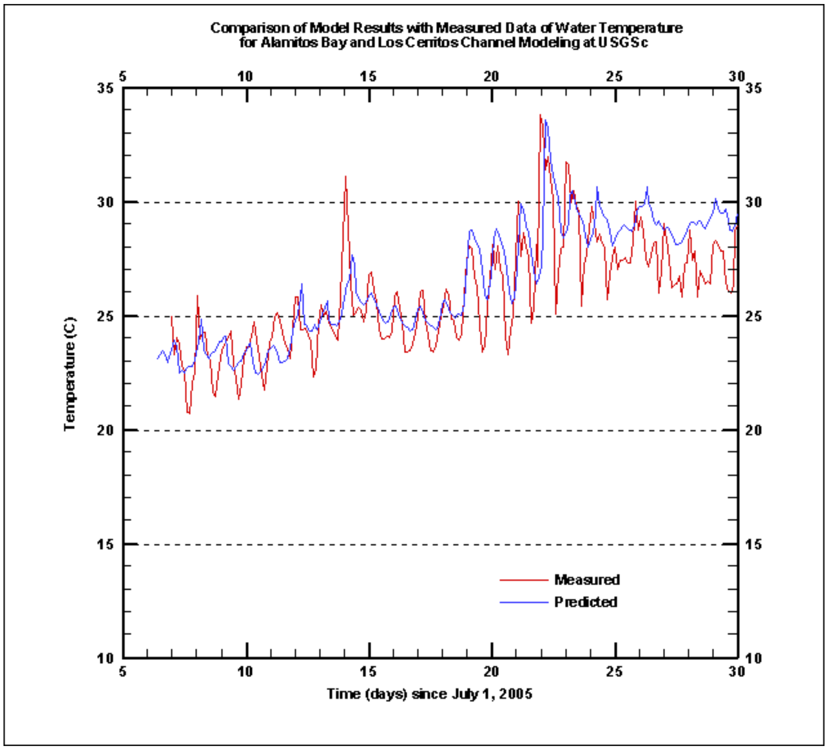

FIGURE 4.6 COMPARISON OF SURFACE WATER TEMPERATURE AT STATION USGSC FOR THE ALAMITOS BAY BACTERIA MODEL

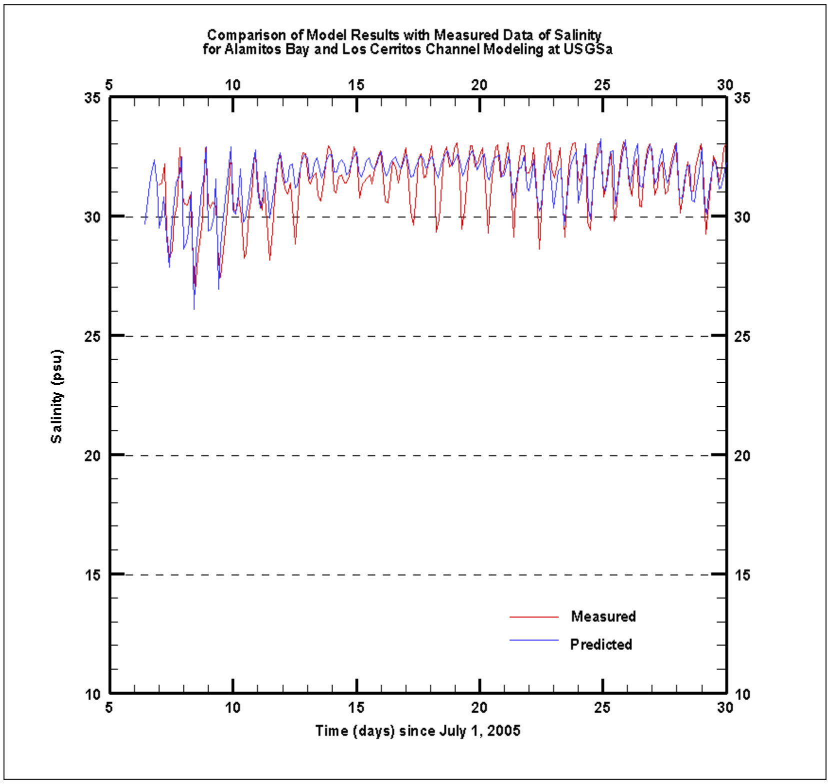

FIGURE 4.7 COMPARISON OF SURFACE WATER SALINITY AT STATION USGSA FOR THE ALAMITOS BAY BACTERIA MODEL

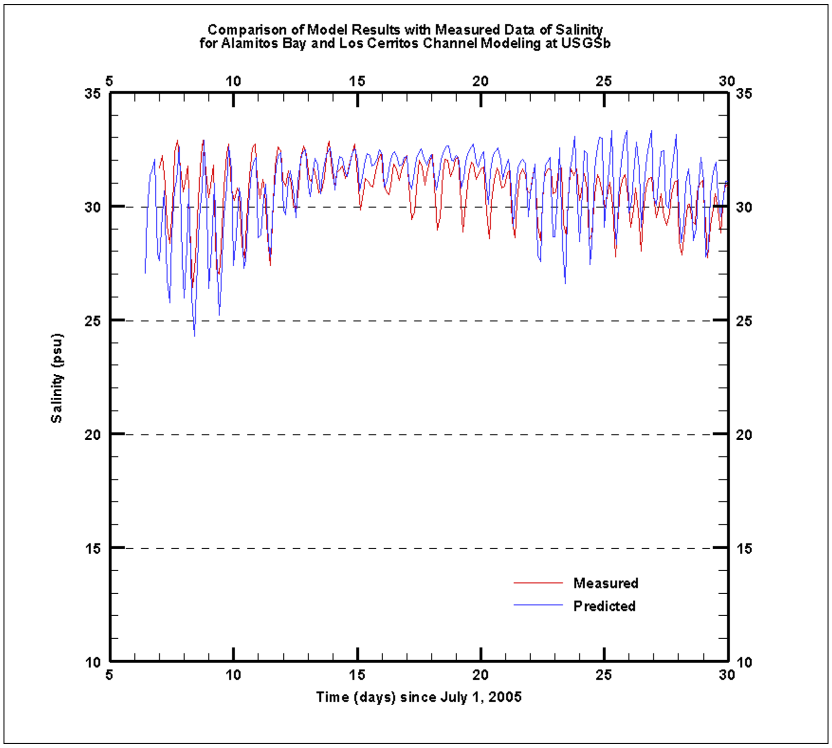

FIGURE 4.8 COMPARISON OF SURFACE WATER SALINITY AT STATION USGSB FOR THE ALAMITOS BAY BACTERIA MODEL

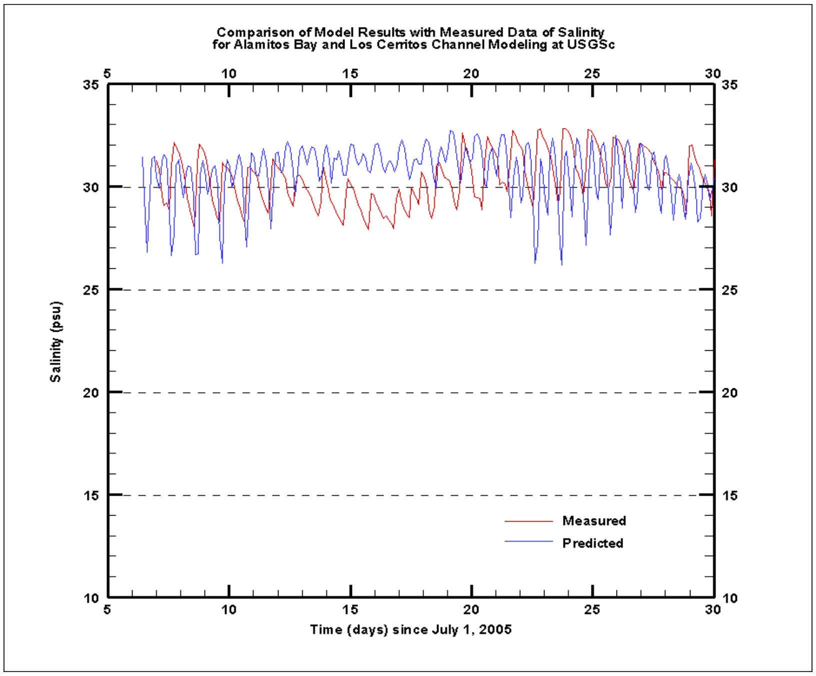

FIGURE 4.9 COMPARISON OF SURFACE WATER SALINITY AT STATION USGSC FOR THE ALAMITOS BAY BACTERIA MODEL

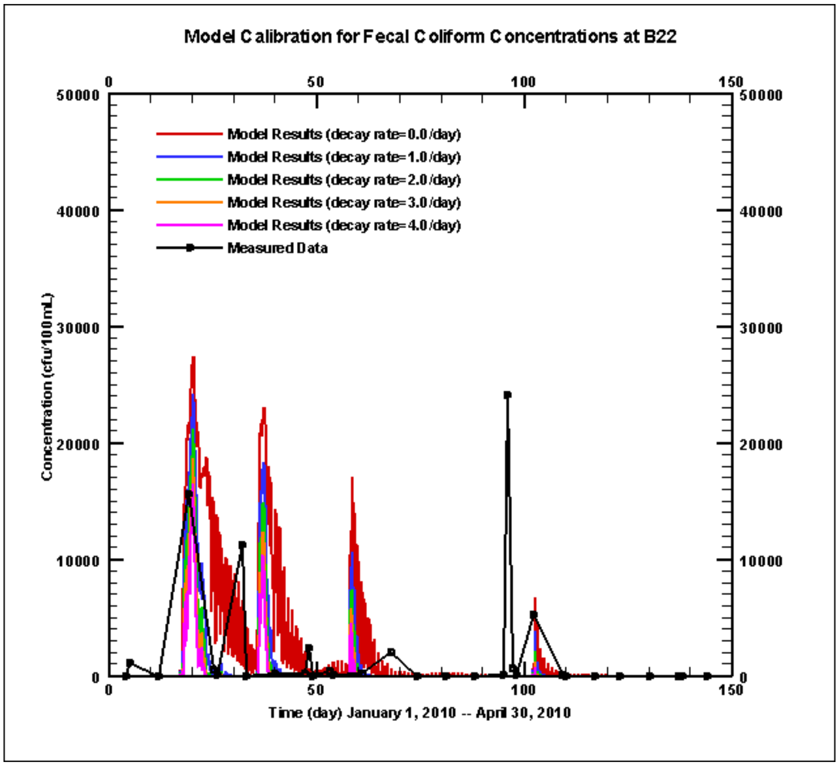

FIGURE 4.10 MODEL CALIBRATION FOR FECAL COLIFORM CONCENTRATION AT B-22 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

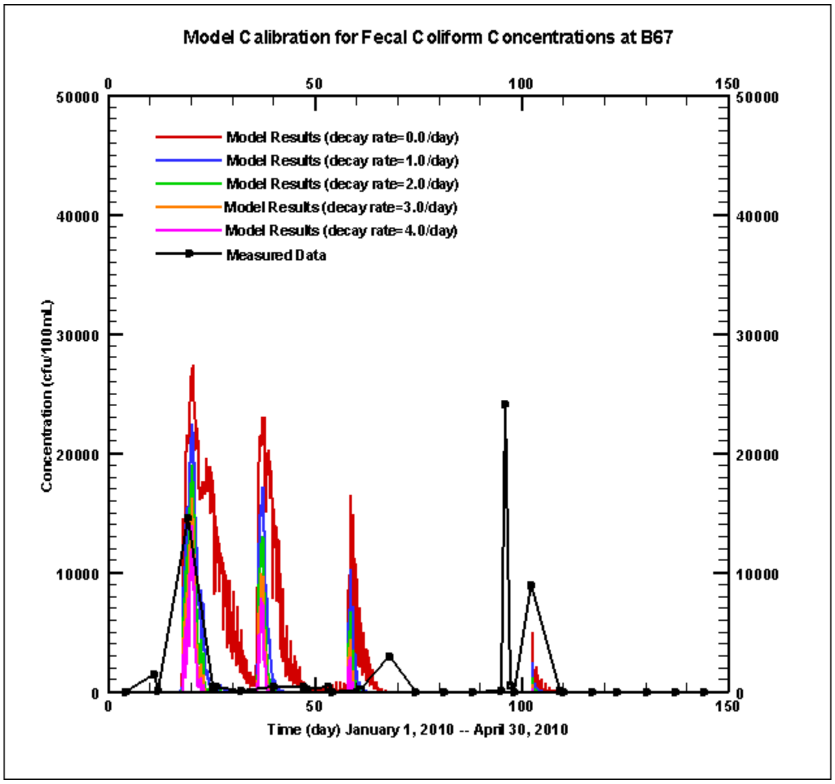

FIGURE 4.11 MODEL CALIBRATION FOR FECAL COLIFORM CONCENTRATION AT B-67 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

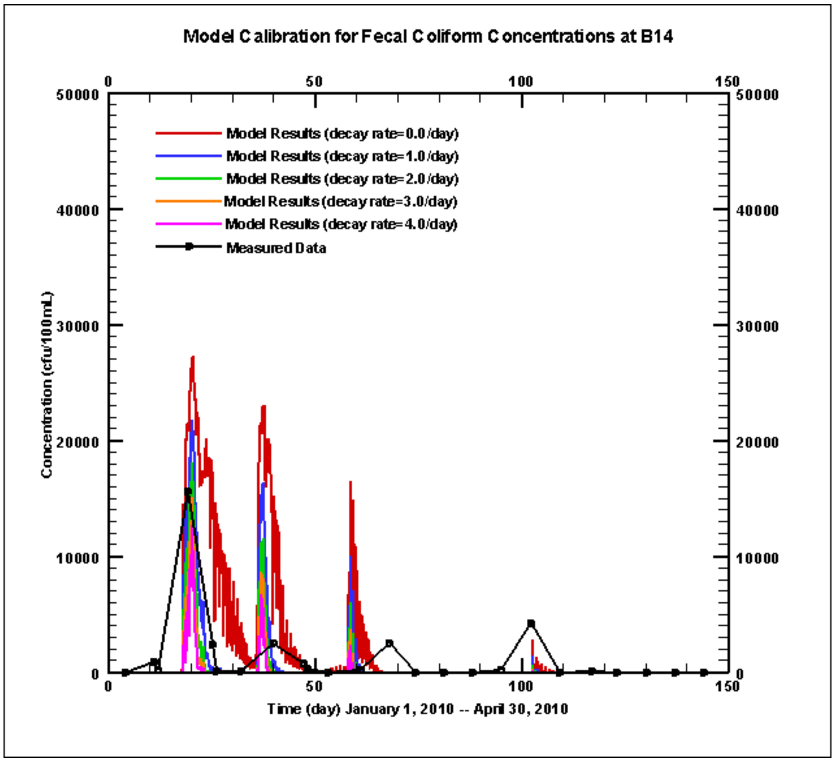

FIGURE 4.12 MODEL CALIBRATION FOR FECAL COLIFORM CONCENTRATION AT B-14 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

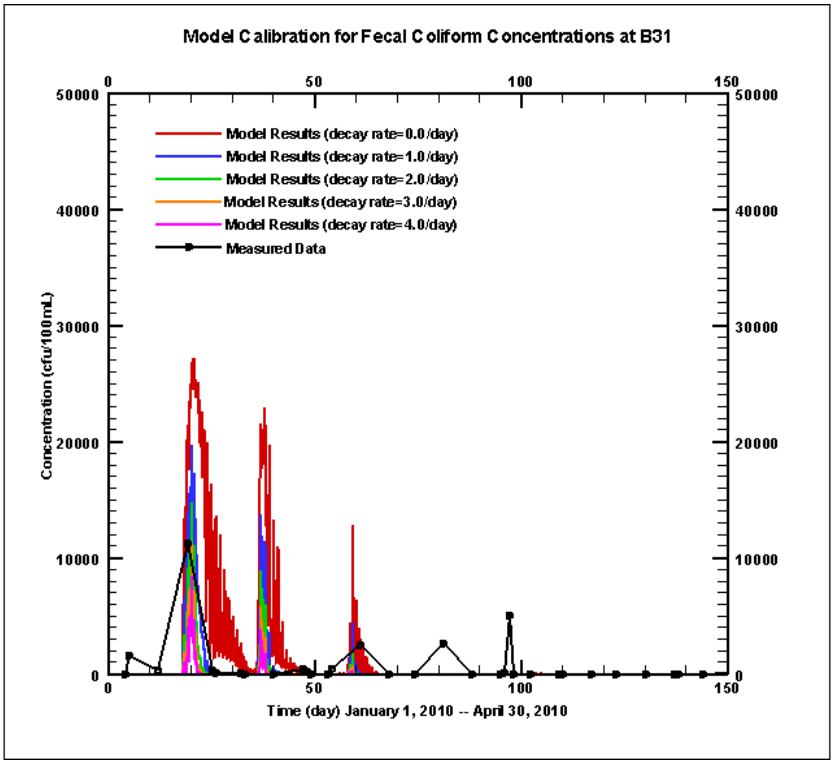

FIGURE 4.13 MODEL CALIBRATION FOR FECAL COLIFORM CONCENTRATION AT B-31 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

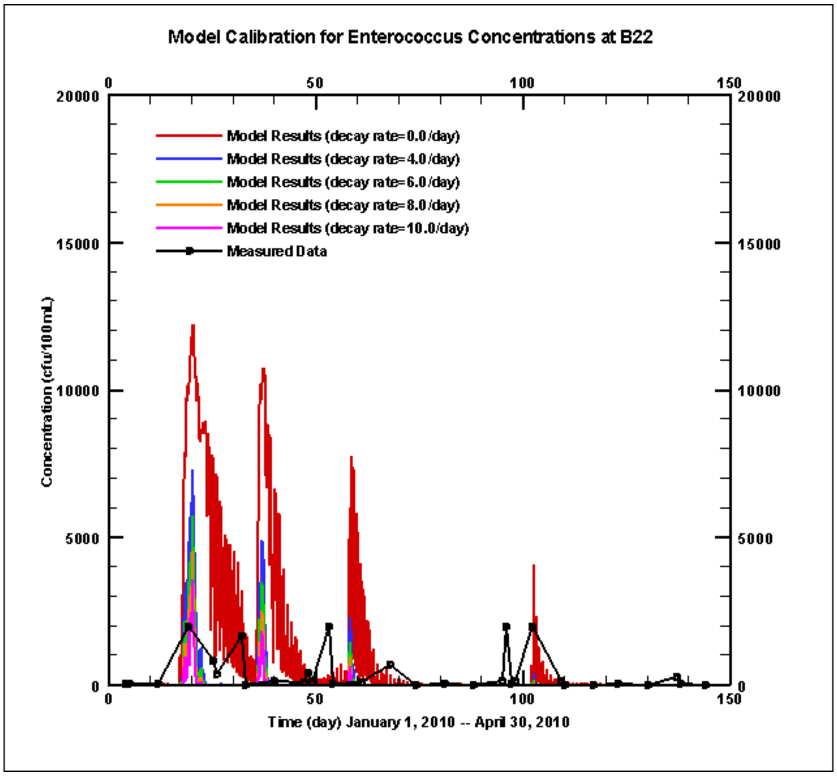

FIGURE 4.14 MODEL CALIBRATION FOR ENTEROCOCCI CONCENTRATION AT B-22 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

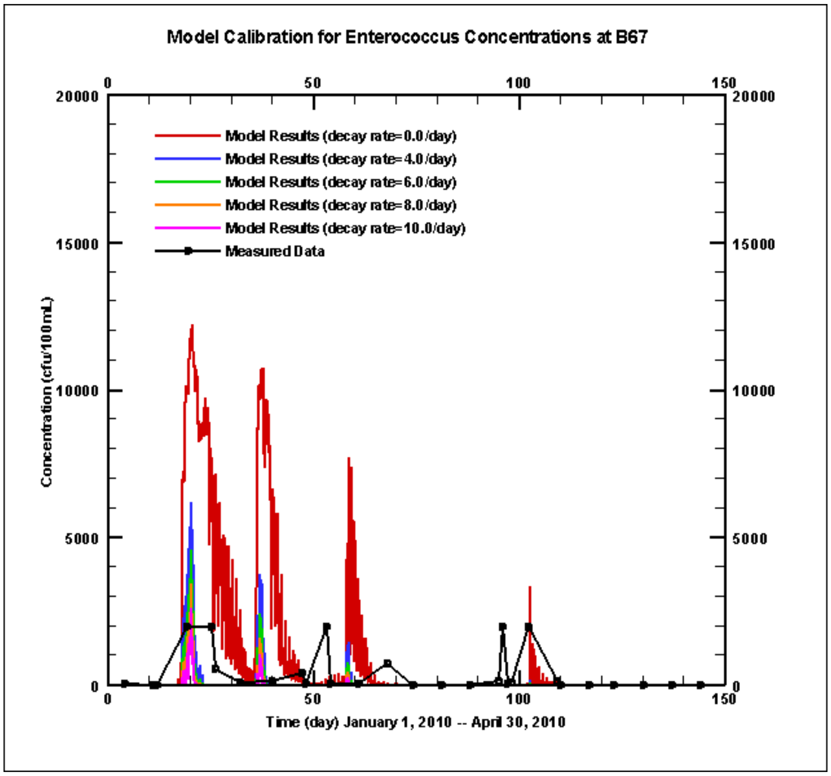

FIGURE 4.15 MODEL CALIBRATION FOR ENTEROCOCCI CONCENTRATION AT B-67 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

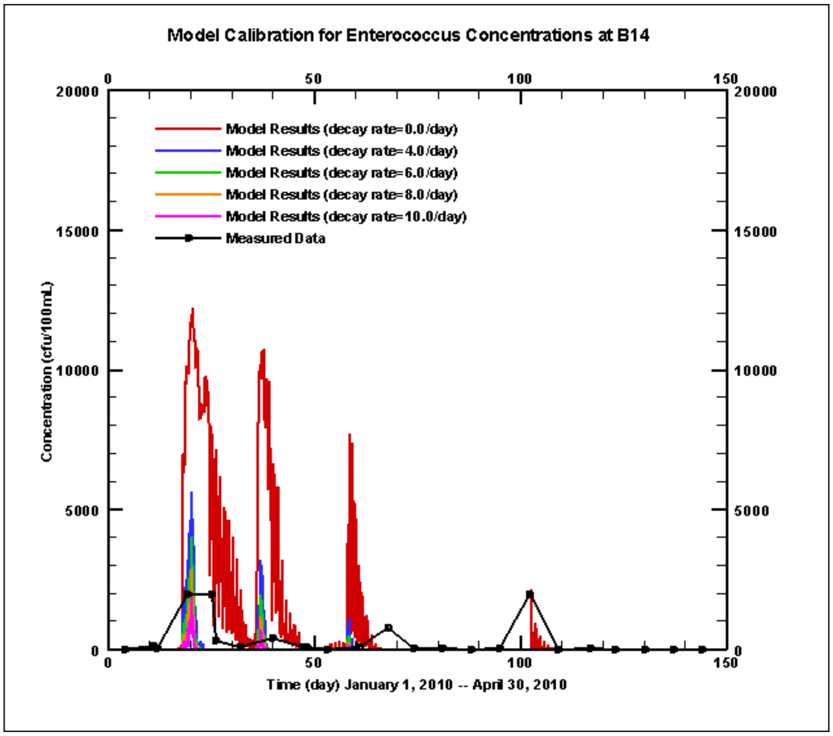

FIGURE 4.16 MODEL CALIBRATION FOR ENTEROCOCCI CONCENTRATION AT B-14 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

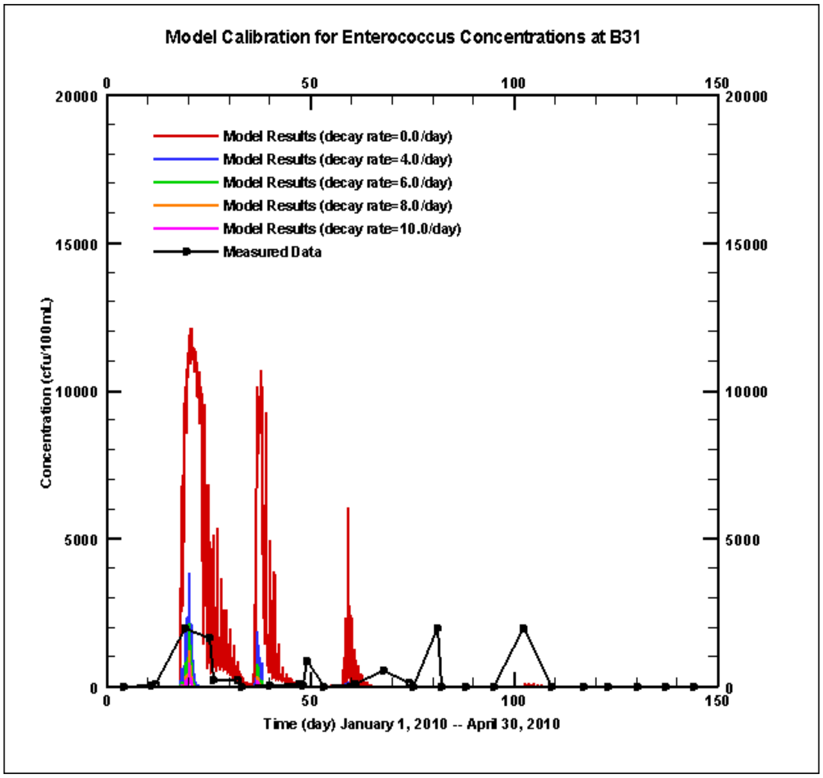

FIGURE 4.17 MODEL CALIBRATION FOR ENTEROCOCCI CONCENTRATION AT B-31 FOR THE ALAMITOS BAY BACTERIA MODEL IN JANUARY 1-APRIL 30, 2010

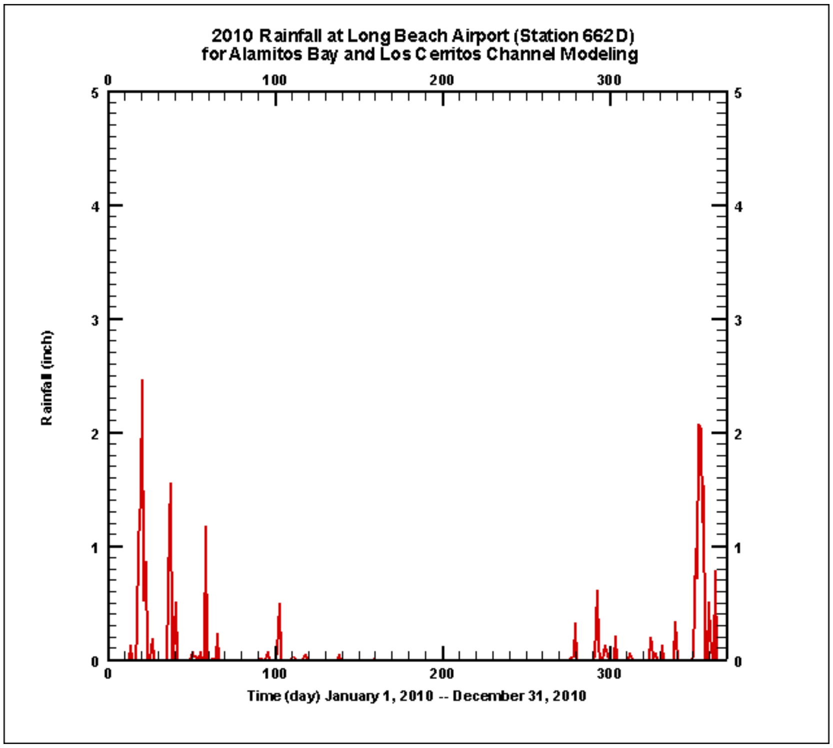

FIGURE 5.1 TIME SERIES OF RAINFALL AT LONG BEACH AIRPORT (LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS STATION 662D) USED FOR THE ALAMITOS BAY BACTERIA MODEL IN 2010.

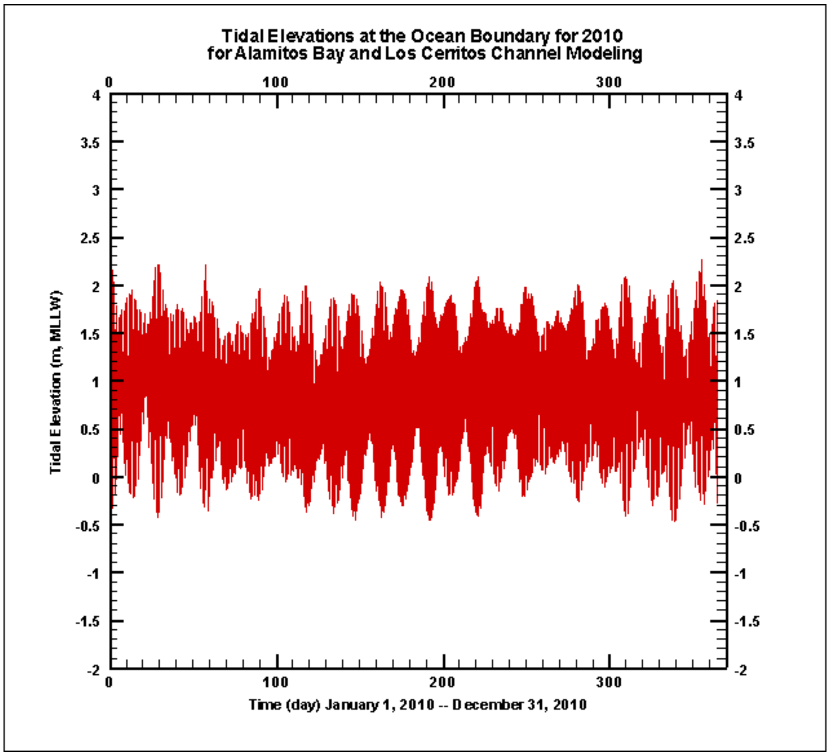

FIGURE 5.2 TIME SERIES OF TIDAL ELEVATION AT THE OCEAN BOUNDARIES FOR THE ALAMITOS BAY BACTERIA MODEL IN 2010.

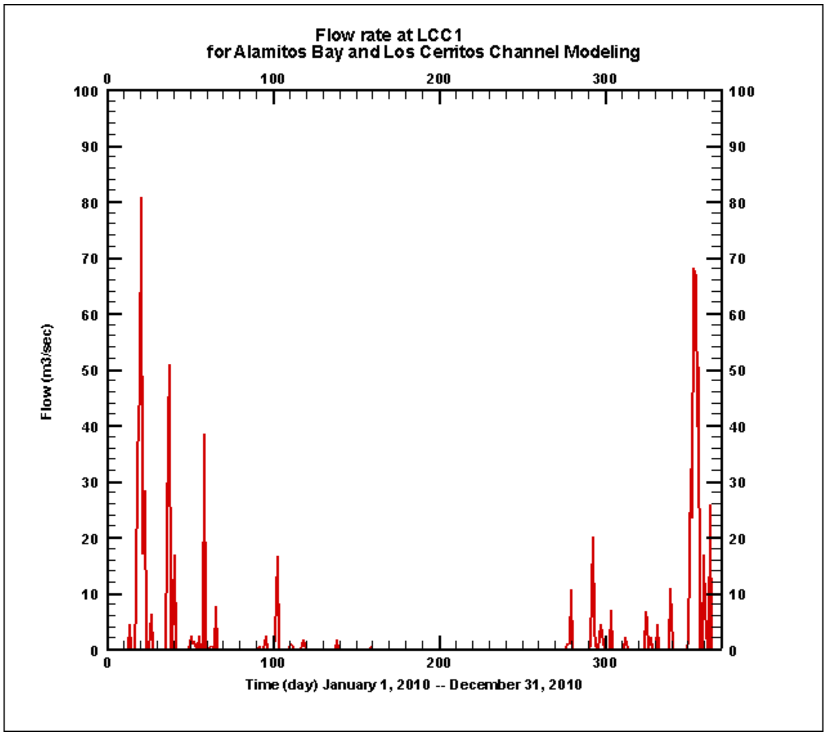

FIGURE 5.3 TIME SERIES OF FLOW RATE AT LOS CERRITOS CHANNEL LCC1 LOCATION FOR THE ALAMITOS BAY BACTERIA MODEL.

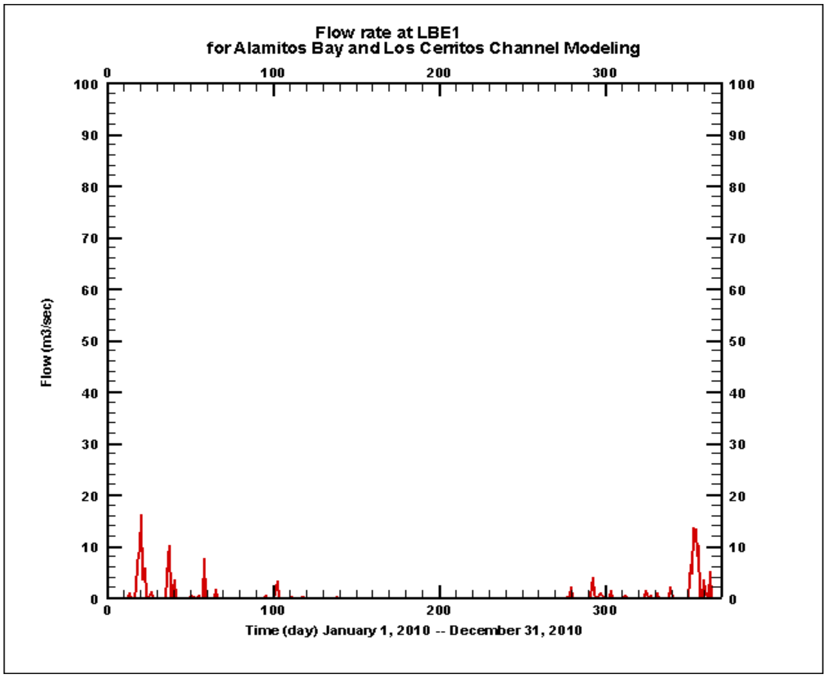

FIGURE 5.4 TIME SERIES OF FLOW RATE AT LOS CERRITOS CHANNEL LBE1 LOCATION FOR THE ALAMITOS BAY BACTERIA MODEL.

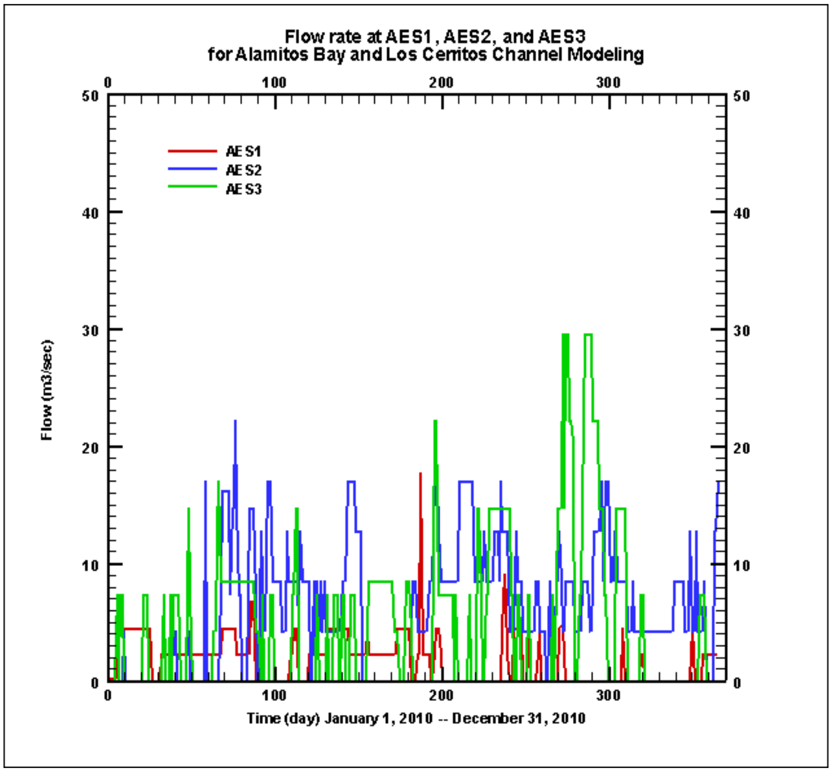

FIGURE 5.5 TIME SERIES OF FLOW RATE FROM AES GENERATING STATION FOR THE ALAMITOS BAY BACTERIA MODEL.

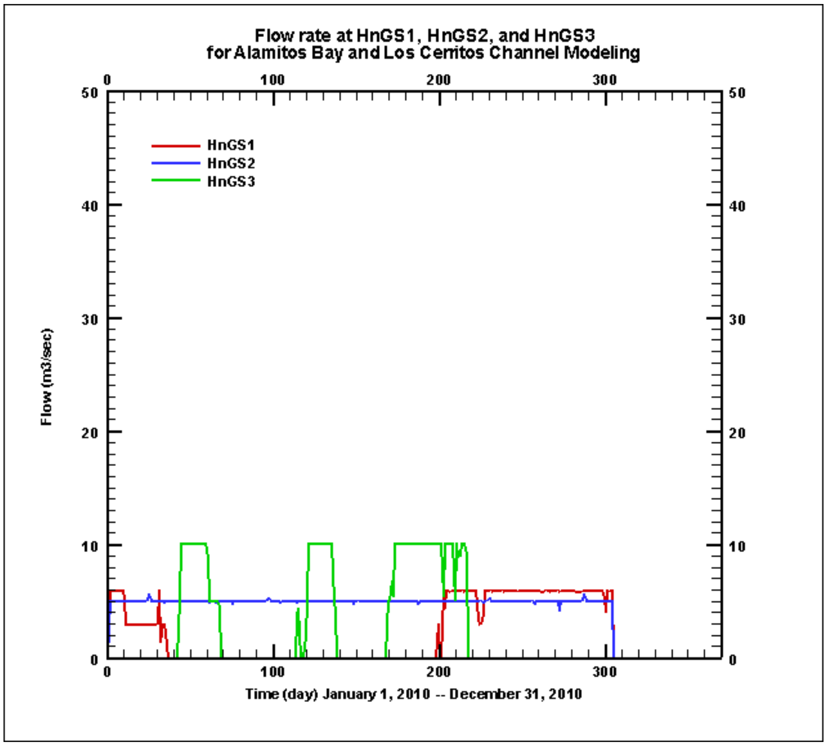

FIGURE 5.6 TIME SERIES OF FLOW RATE FROM HAYNES GENERATING STATION FOR THE ALAMITOS BAY BACTERIA MODEL.

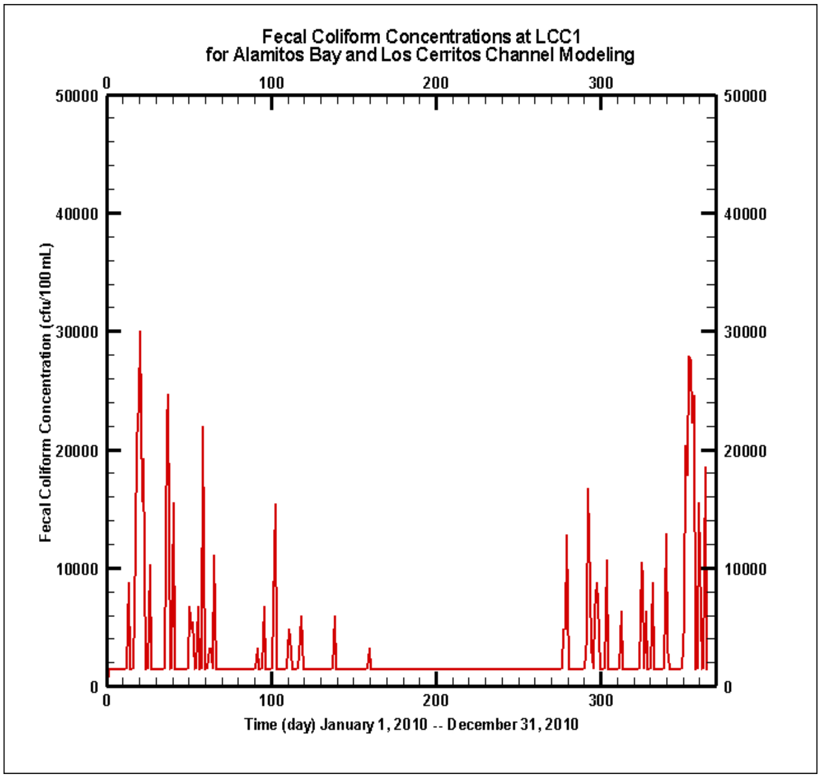

FIGURE 5.7 TIME SERIES OF FECAL COLIFORM CONCENTRATIONS AT LCC1 FOR THE ALAMITOS BAY BACTERIA MODEL.

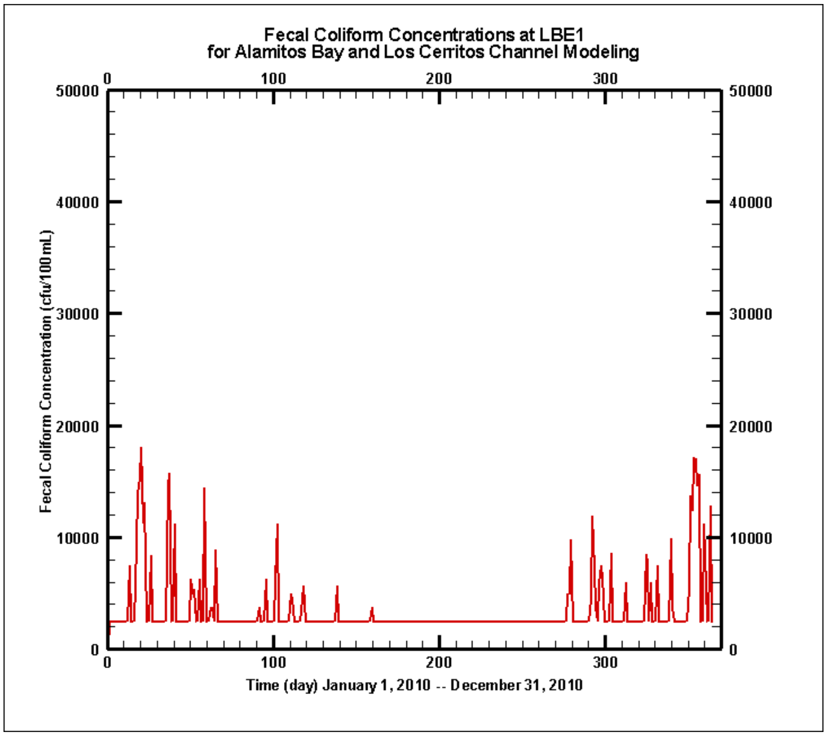

FIGURE 5.8 TIME SERIES OF FECAL COLIFORM CONCENTRATIONS AT LBE1 FOR THE ALAMITOS BAY BACTERIA MODEL.

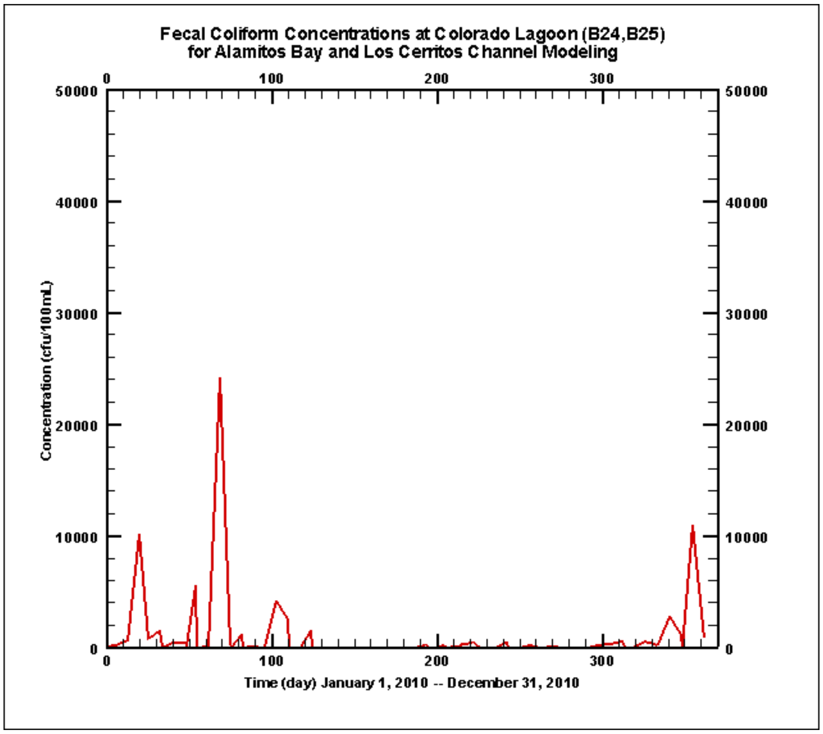

FIGURE 5.9 TIME SERIES OF FECAL COLIFORM CONCENTRATIONS AT COLORADO LAGOON FOR THE ALAMITOS BAY BACTERIA MODEL.

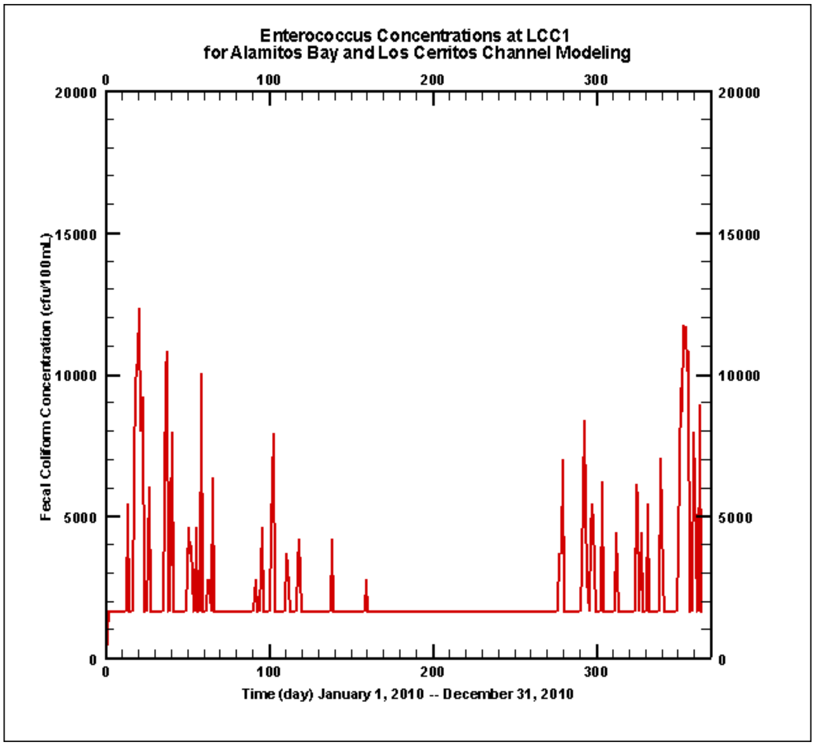

FIGURE 5.10 TIME SERIES OF ENTEROCOCCUS CONCENTRATIONS AT LCC1 FOR THE ALAMITOS BAY BACTERIA MODEL.

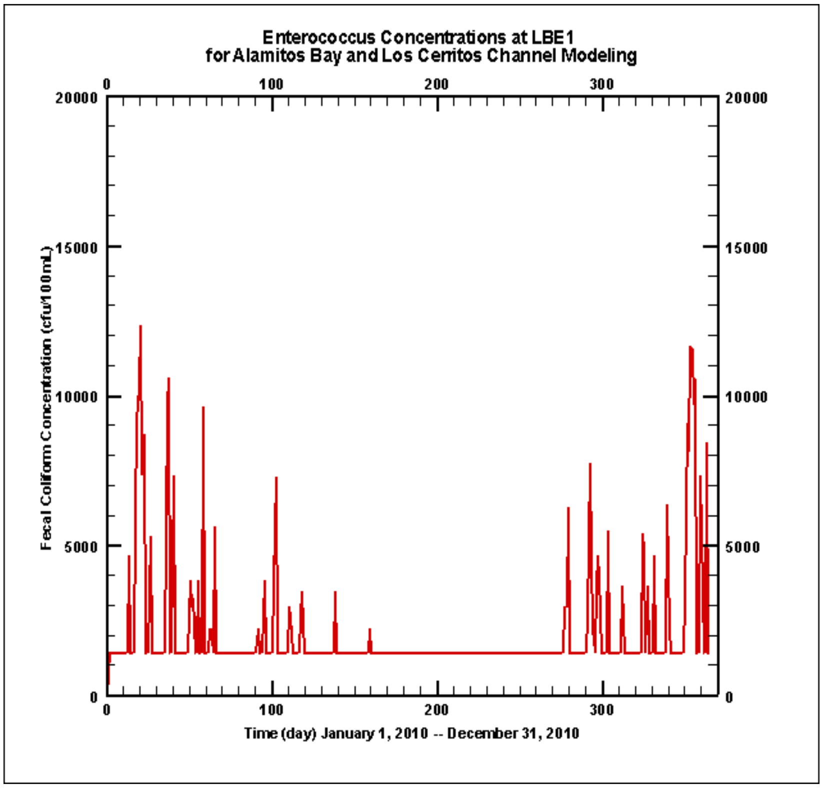

FIGURE 5.11 TIME SERIES OF ENTEROCOCCUS CONCENTRATIONS AT LBE1 FOR THE ALAMITOS BAY BACTERIA MODEL.

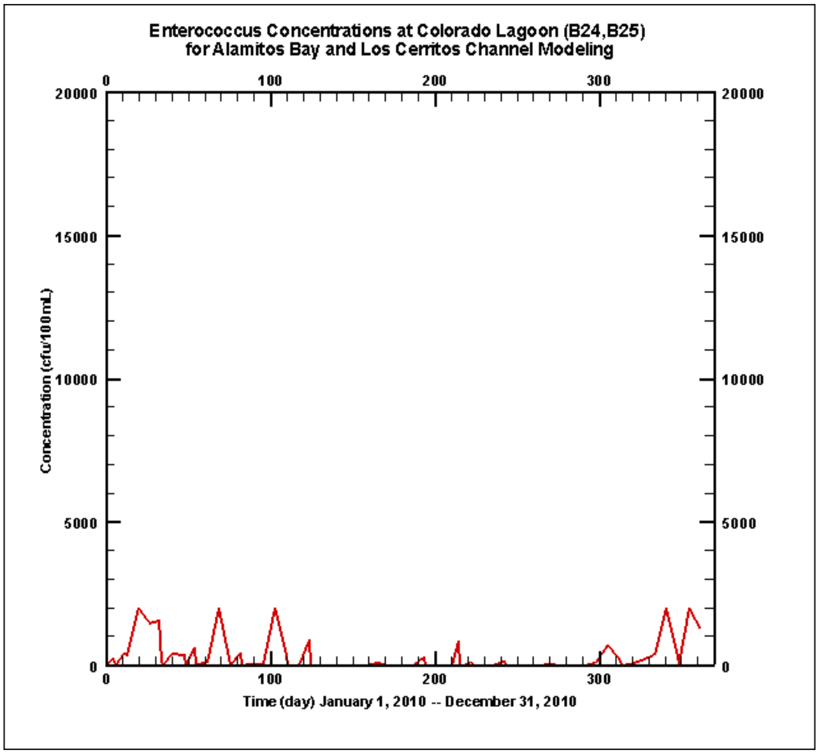

FIGURE 5.12 TIME SERIES OF ENTEROCOCCUS CONCENTRATIONS AT COLORADO LAGOON FOR THE ALAMITOS BAY BACTERIA MODEL

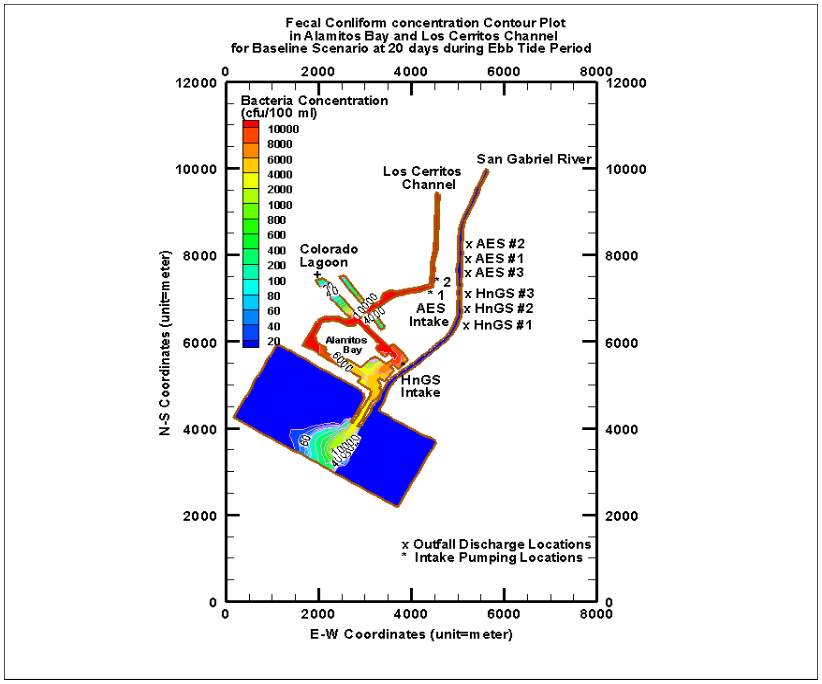

FIGURE 5.13 SPATIAL DISTRIBUTION OF FECAL COLIFORM CONCENTRATION AT DAY 20 SIMULATION DURING EBB TIDE FOR BASELINE SCENARIO

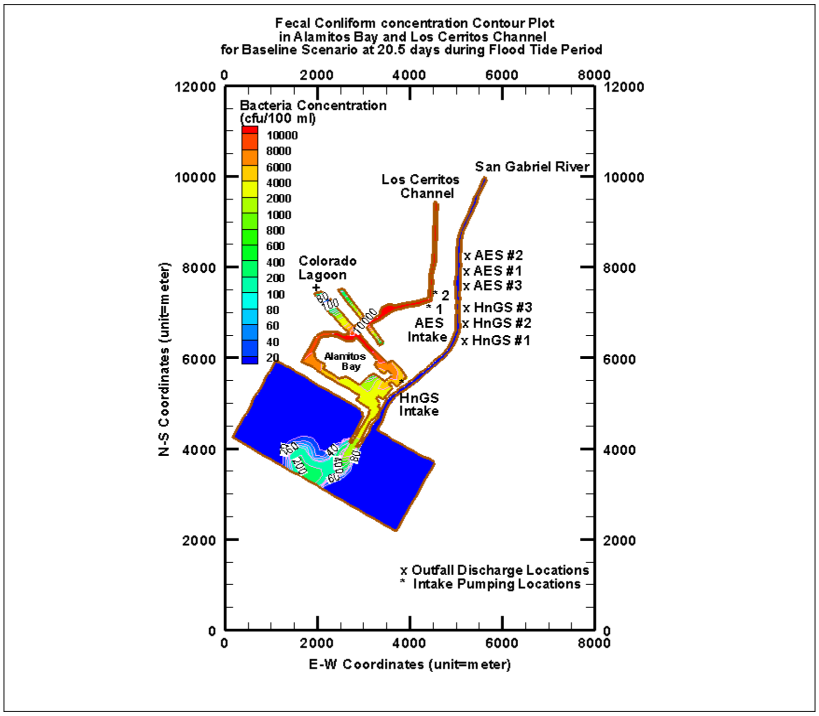

FIGURE 5.14 SPATIAL DISTRIBUTION OF FECAL COLIFORM CONCENTRATION AT DAY 20.5 SIMULATION DURING FLOOD TIDE FOR BASELINE SCENARIO

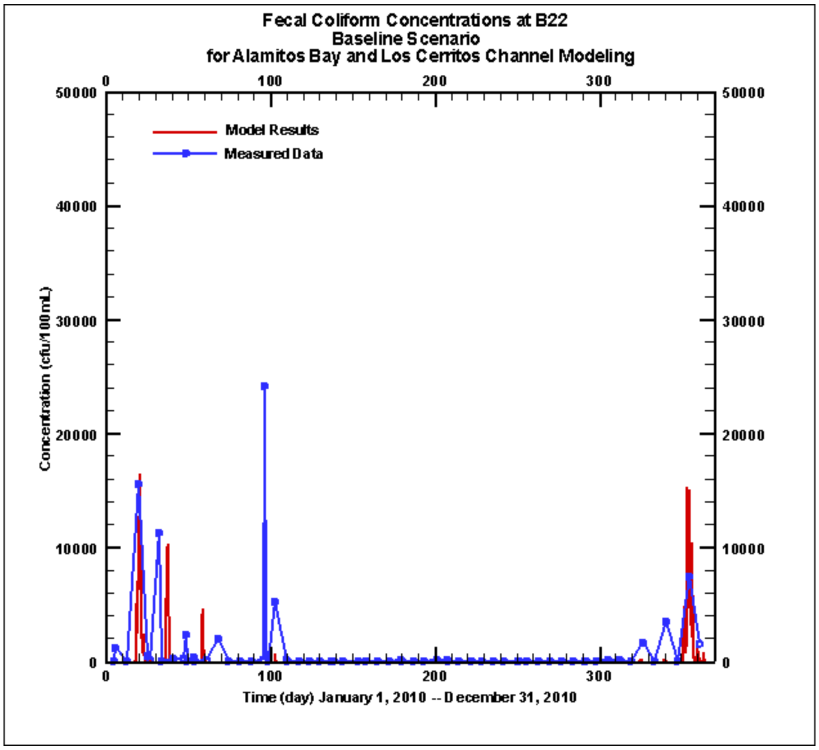

FIGURE 5.15 MODEL RESULTS OF FECAL COLIFORM CONCENTRATION AT B-22 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

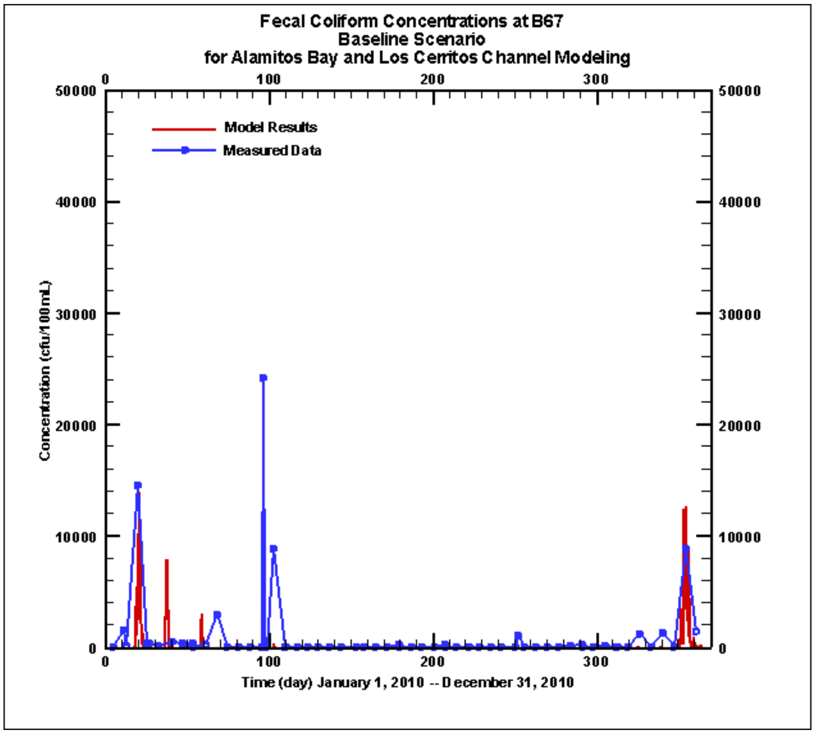

FIGURE 5.16 MODEL RESULTS OF FECAL COLIFORM CONCENTRATION AT B-67 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

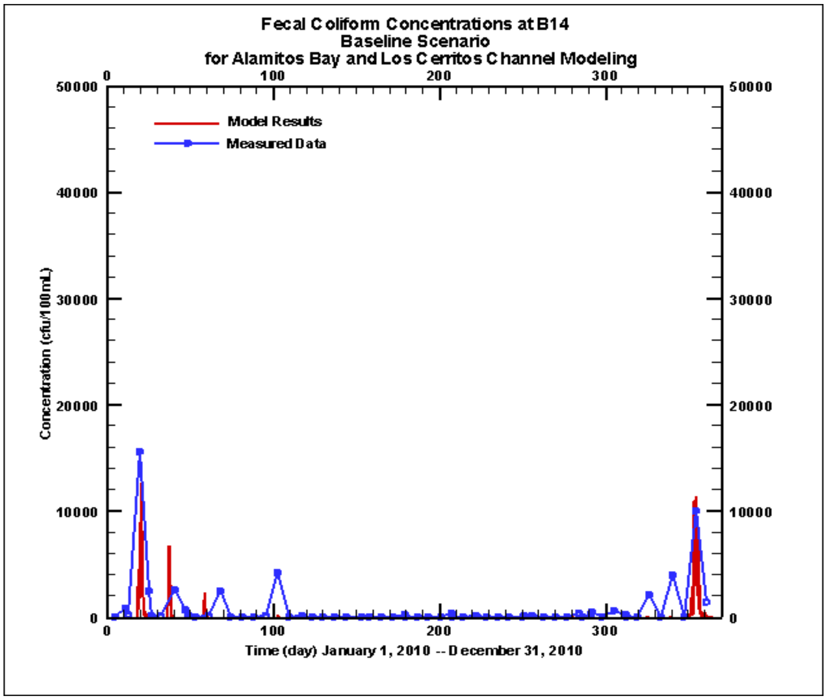

FIGURE 5.17 MODEL RESULTS OF FECAL COLIFORM CONCENTRATION AT B-14 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

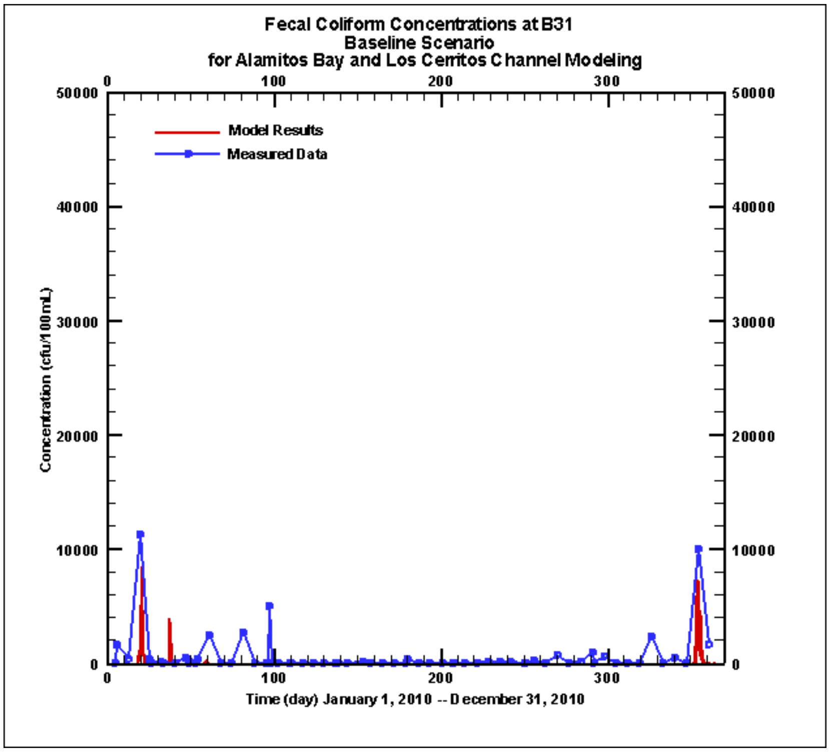

FIGURE 5.18 MODEL RESULTS OF FECAL COLIFORM CONCENTRATION AT B-31 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

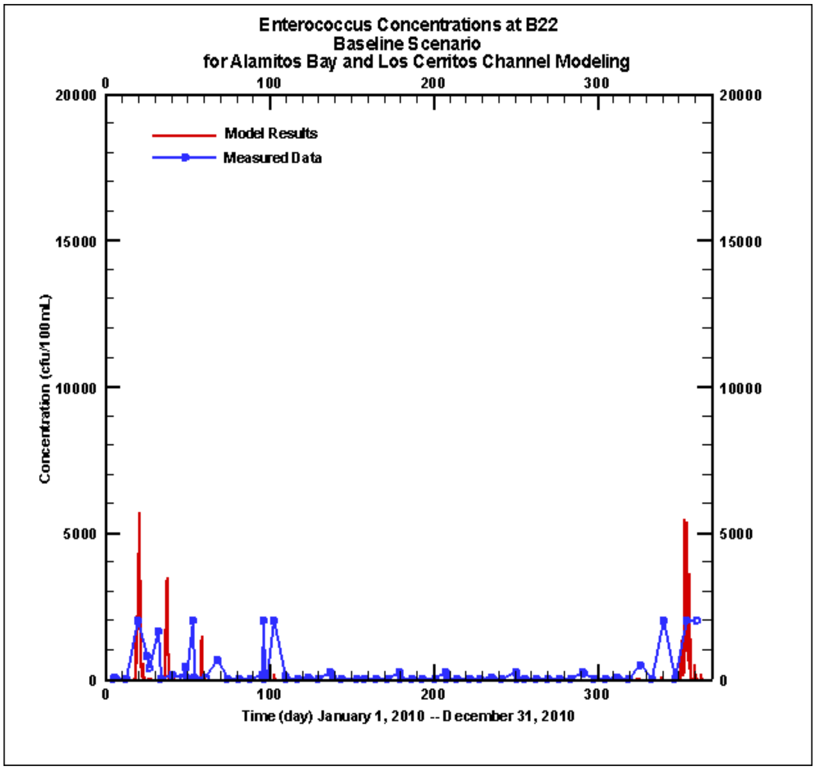

FIGURE 5.19 MODEL RESULTS OF ENTEROCOCCI CONCENTRATION AT B-22 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

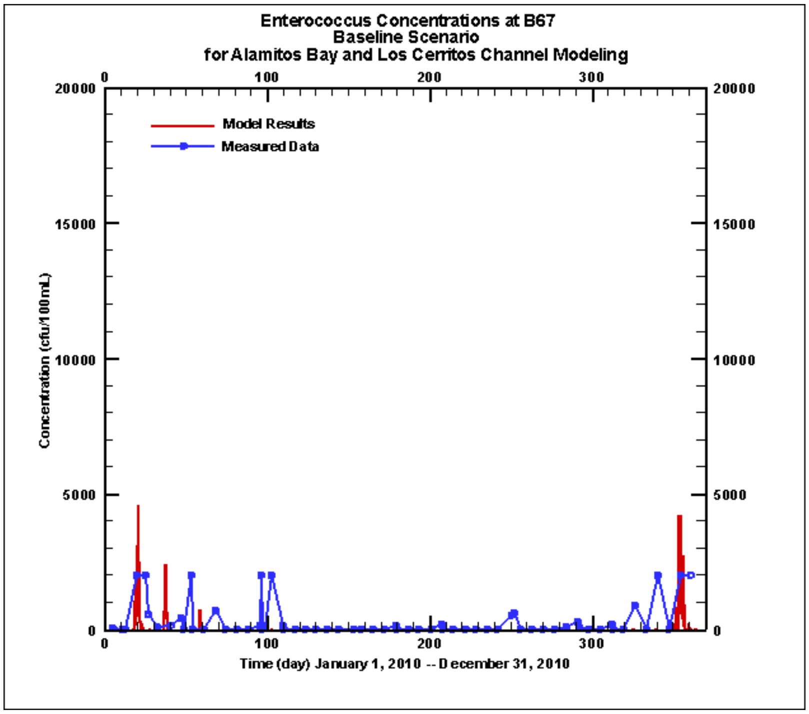

FIGURE 5.20 MODEL RESULTS OF ENTEROCOCCI CONCENTRATION AT B-67 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

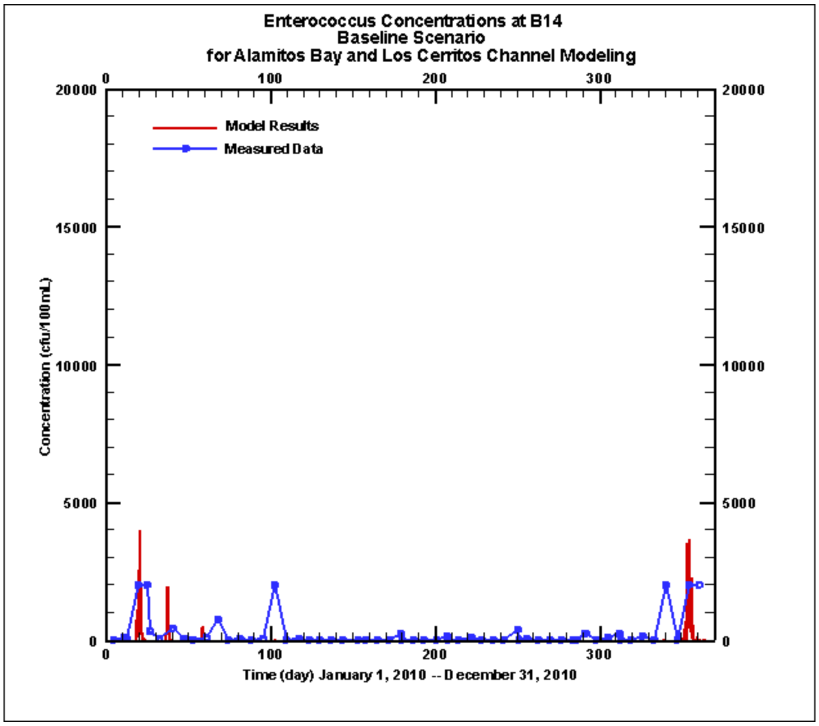

FIGURE 5.21 MODEL RESULTS OF ENTEROCOCCI CONCENTRATION AT B-14 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

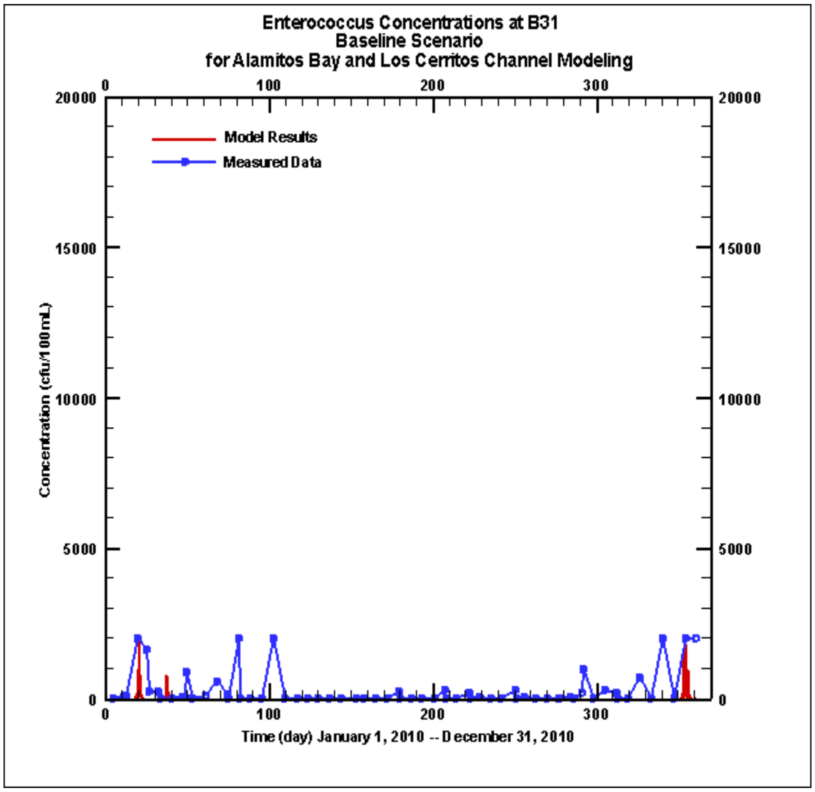

FIGURE 5.22 MODEL RESULTS OF ENTEROCOCCI CONCENTRATION AT B-31 FOR BASELINE SCENARIO FOR ALAMITOS BAY BACTERIA MODEL

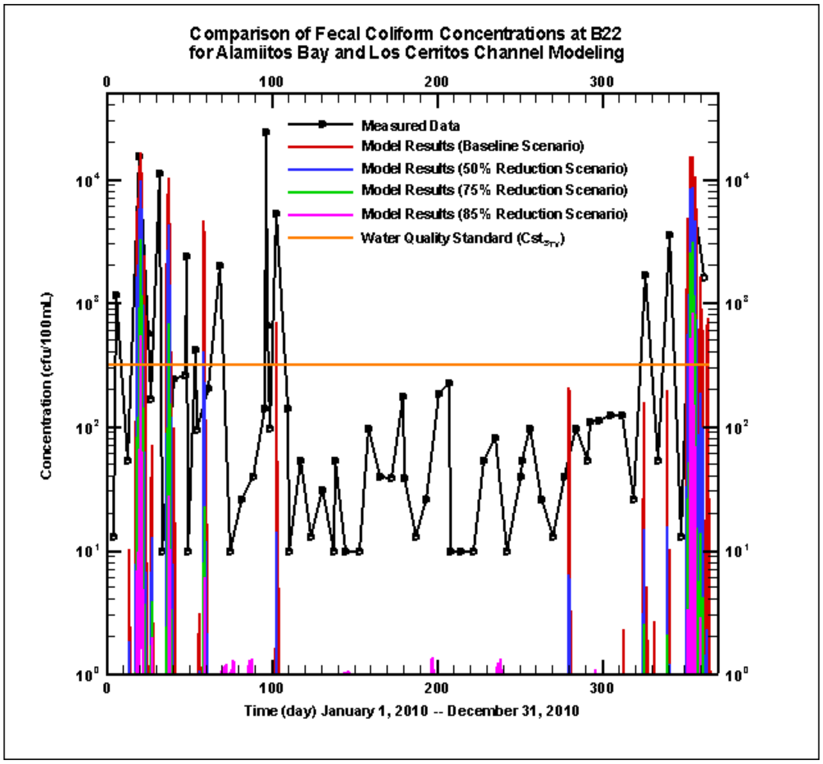

FIGURE 5.23 COMPARISON OF FECAL COLIFORM CONCENTRATIONS AT B-22 FOR DIFFERENT LOAD REDUCTION SCENARIOS

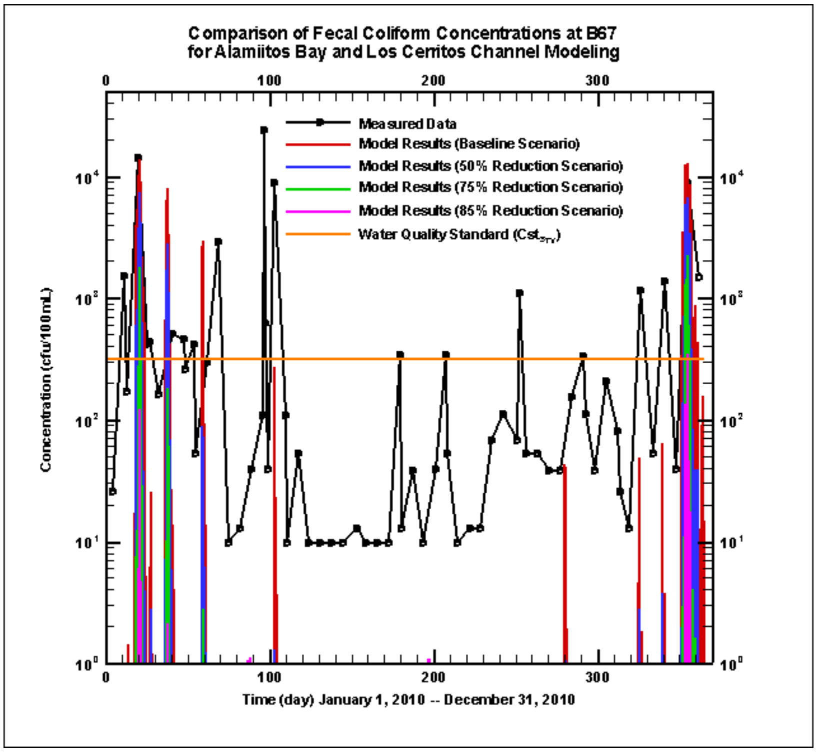

FIGURE 5.24 COMPARISON OF FECAL COLIFORM CONCENTRATIONS AT B-67 FOR DIFFERENT LOAD REDUCTION SCENARIOS

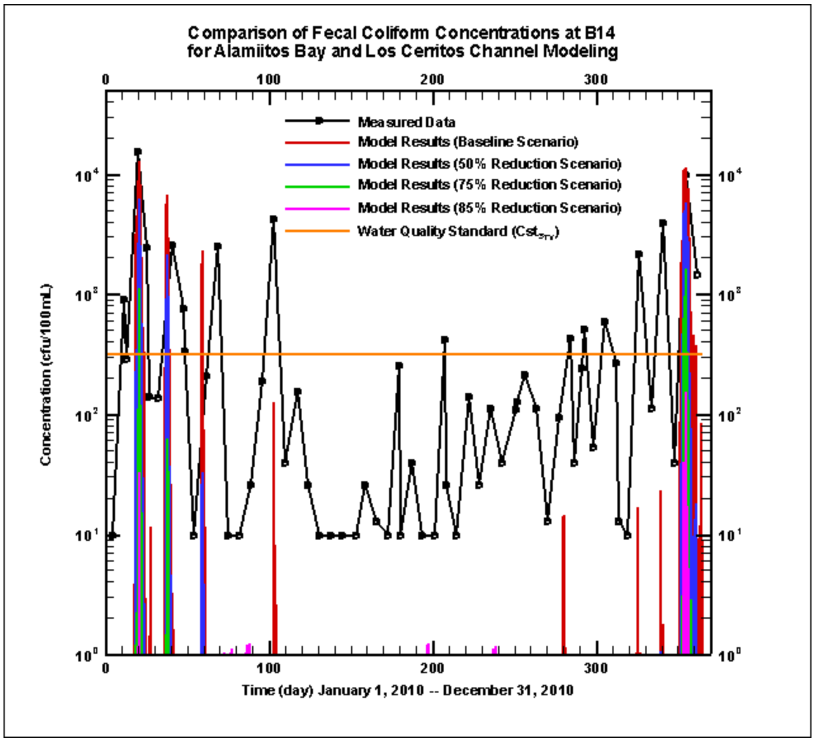

FIGURE 5.25 COMPARISON OF FECAL COLIFORM CONCENTRATIONS AT B-14 FOR DIFFERENT LOAD REDUCTION SCENARIOS

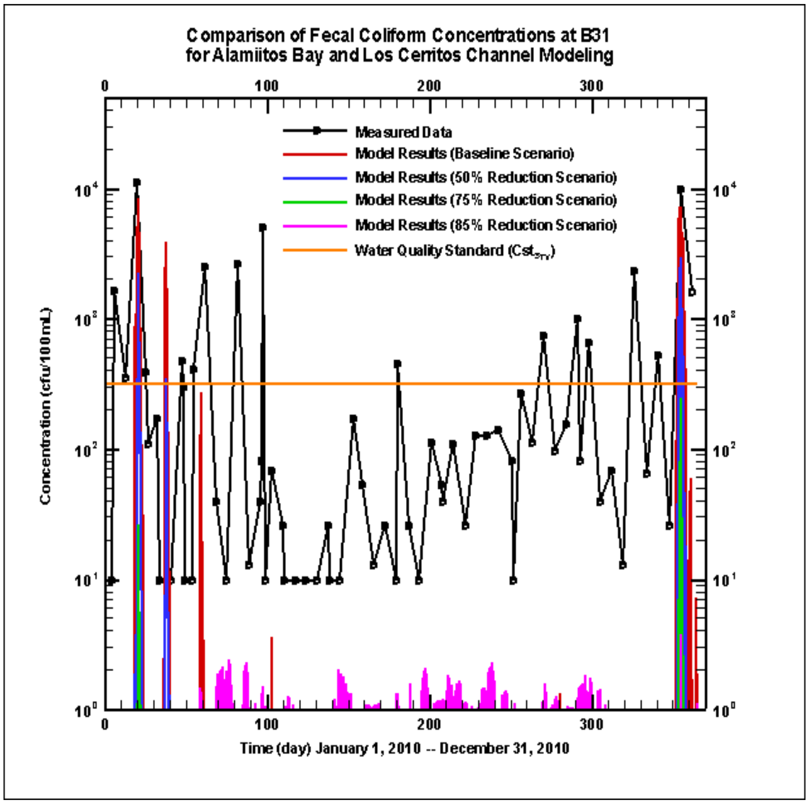

FIGURE 5.26 COMPARISON OF FECAL COLIFORM CONCENTRATIONS AT B-31 FOR DIFFERENT LOAD REDUCTION SCENARIOS

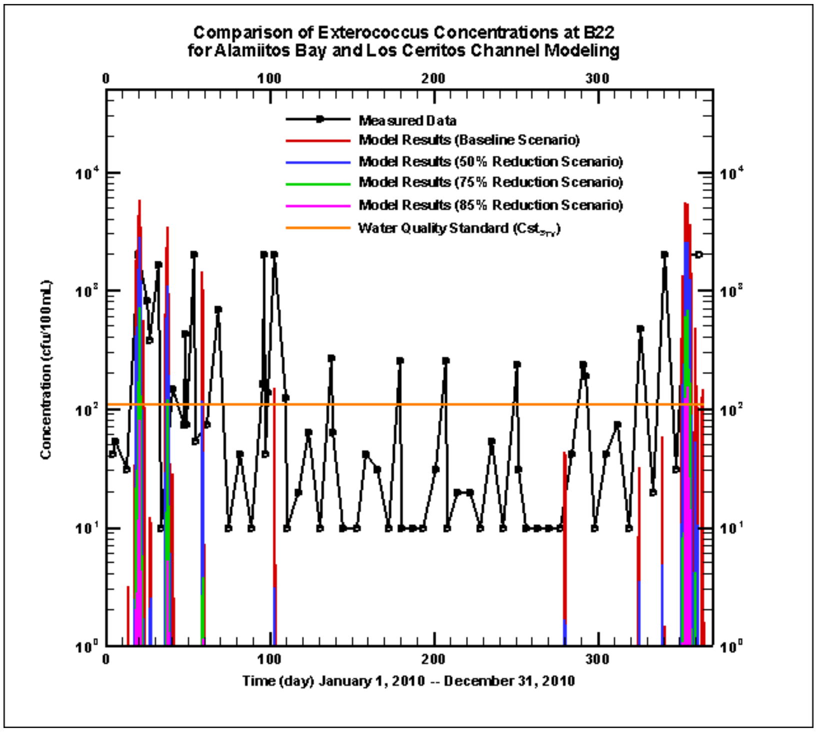

FIGURE 5.27 COMPARISON OF ENTEROCOCCI CONCENTRATIONS AT B-22 FOR DIFFERENT LOAD REDUCTION SCENARIOS

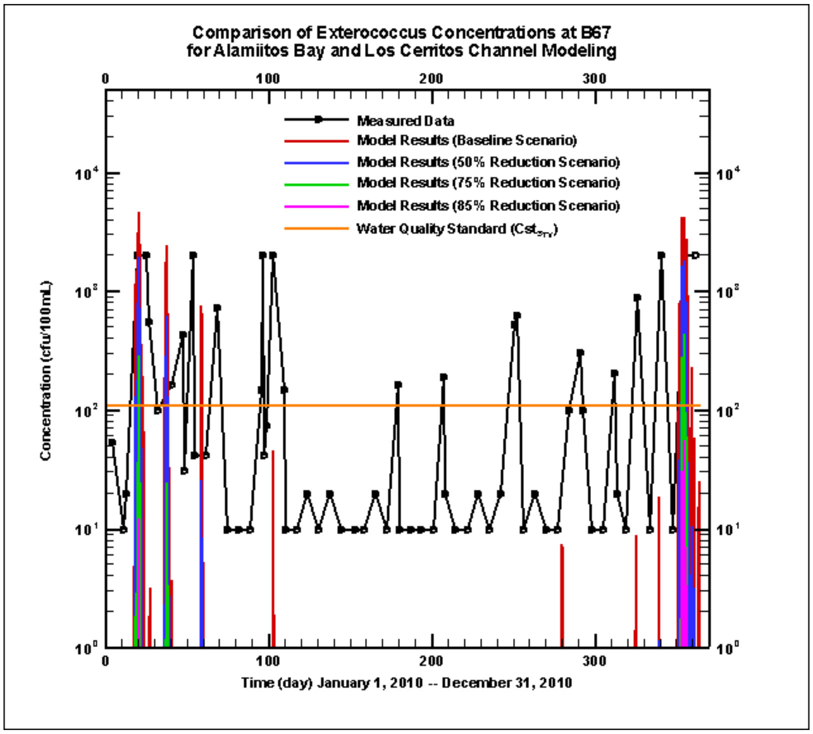

FIGURE 5.28 COMPARISON OF ENTEROCOCCI CONCENTRATIONS AT B-67 FOR DIFFERENT LOAD REDUCTION SCENARIOS

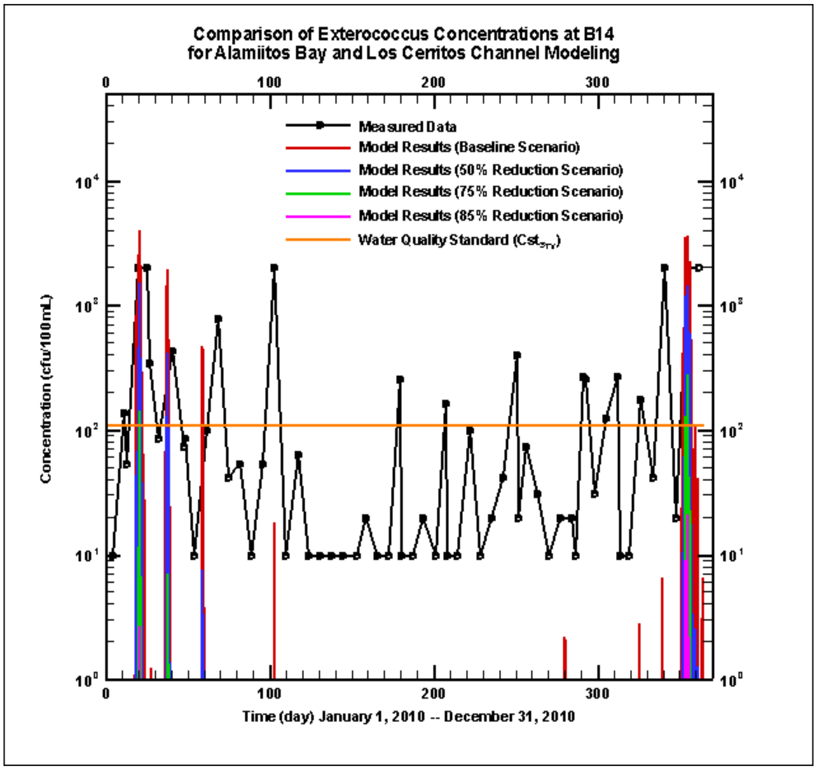

FIGURE 5.29 COMPARISON OF ENTEROCOCCI CONCENTRATIONS AT B-14 FOR DIFFERENT LOAD REDUCTION SCENARIOS

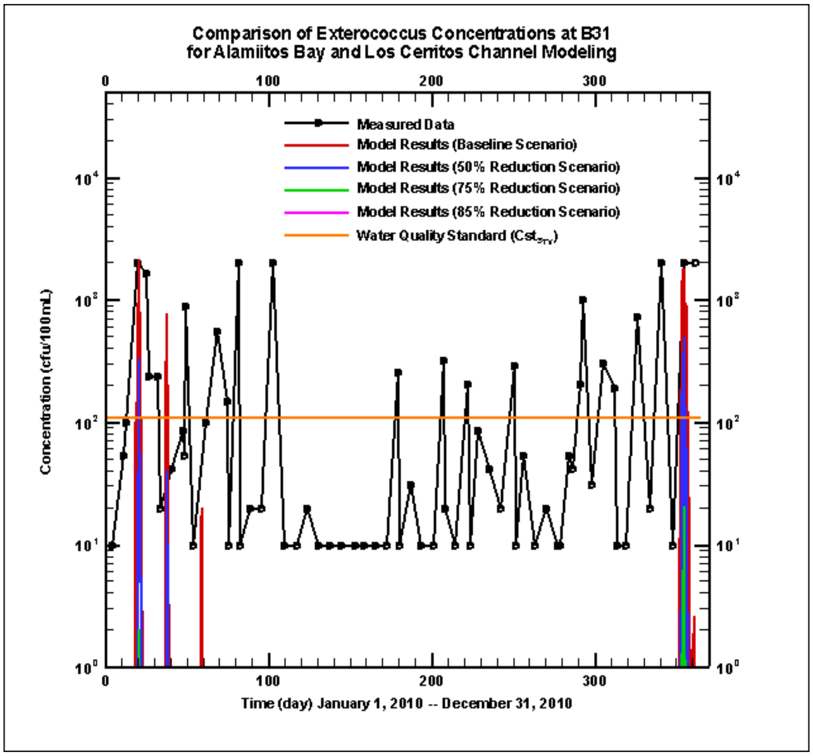

FIGURE 5.30 COMPARISON OF ENTEROCOCCI CONCENTRATIONS AT B-31 FOR DIFFERENT LOAD REDUCTION SCENARIOS

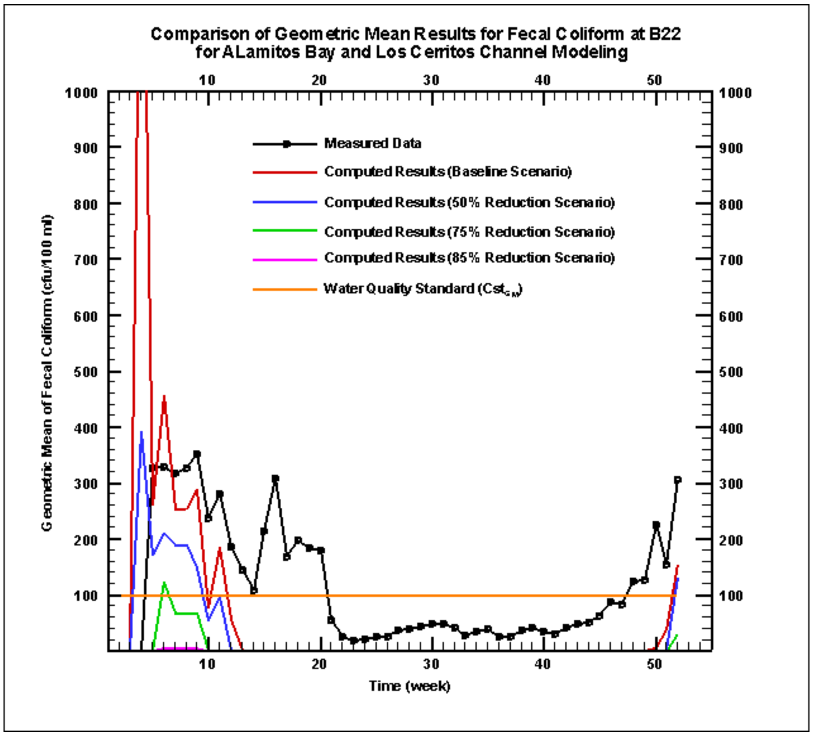

FIGURE 5.31 COMPARISON OF GEOMETRIC MEAN RESULTS FOR FECAL COLIFORM AT B-22 FOR DIFFERENT LOAD REDUCTION SCENARIOS

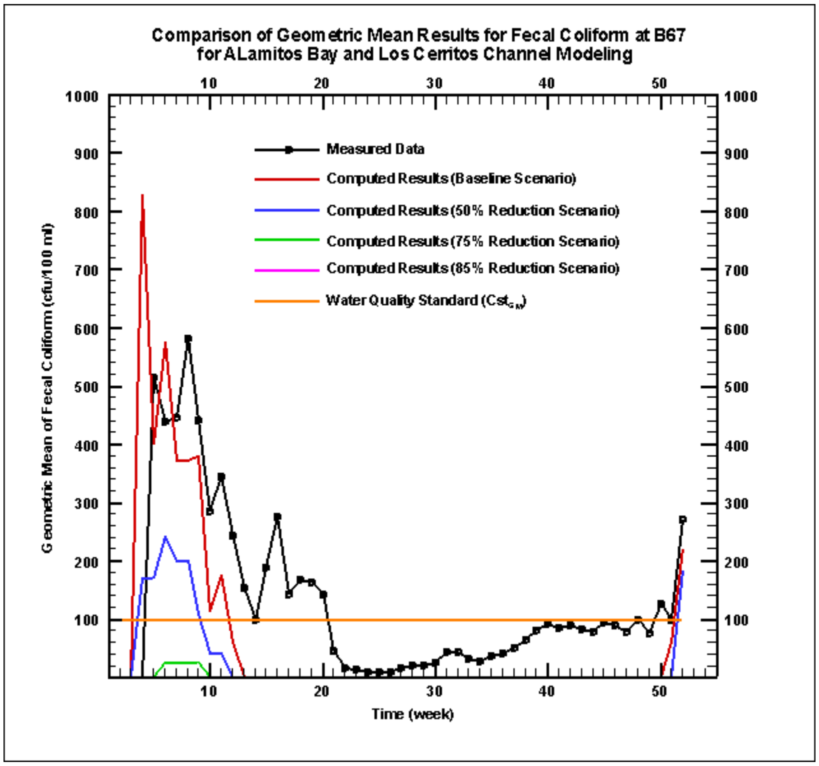

FIGURE 5.32 COMPARISON OF GEOMETRIC MEAN RESULTS FOR FECAL COLIFORM AT B-67 FOR DIFFERENT LOAD REDUCTION SCENARIOS

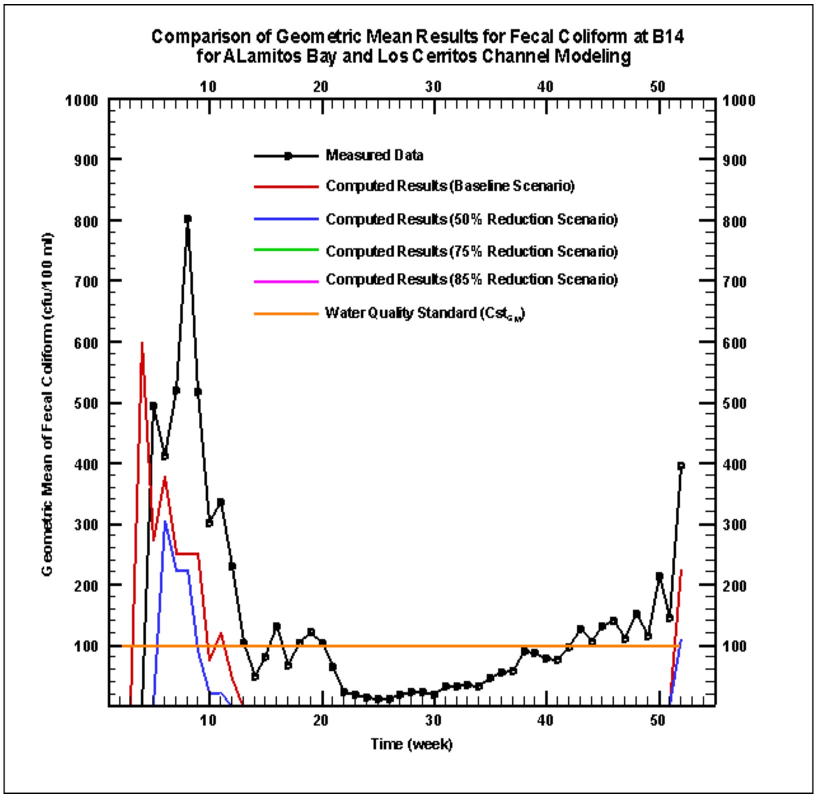

FIGURE 5.33 COMPARISON OF GEOMETRIC MEAN RESULTS FOR FECAL COLIFORM AT B-14 FOR DIFFERENT LOAD REDUCTION SCENARIOS

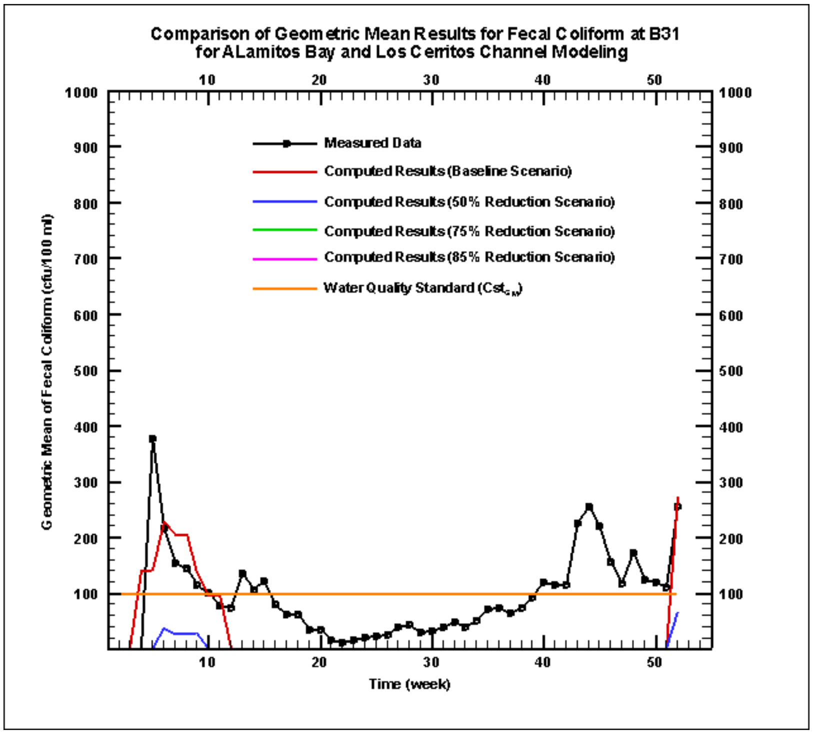

FIGURE 5.34 COMPARISON OF GEOMETRIC MEAN RESULTS FOR FECAL COLIFORM AT B-31 FOR DIFFERENT LOAD REDUCTION SCENARIOS

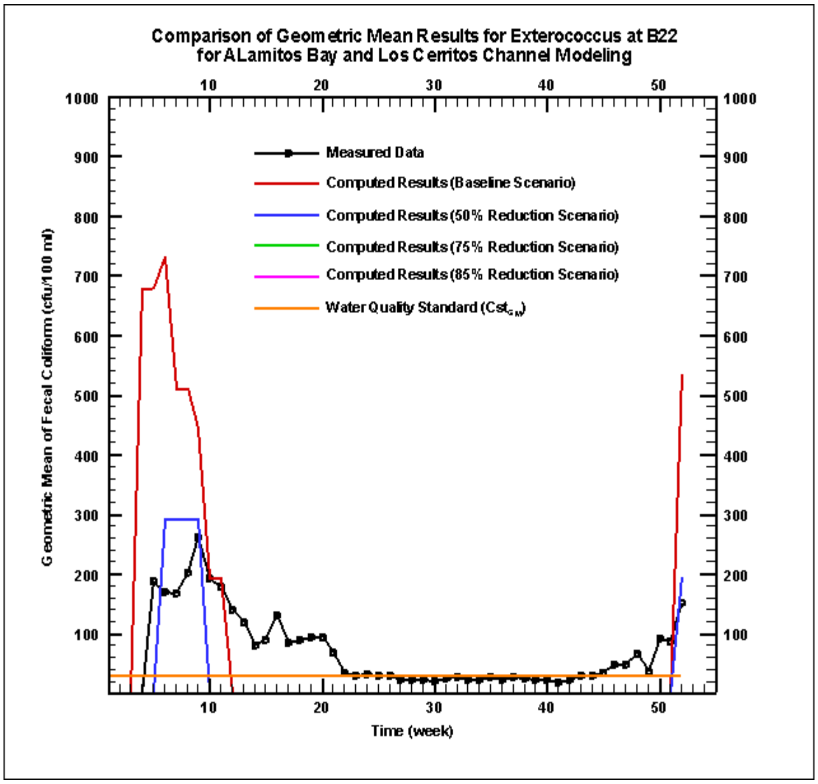

FIGURE 5.35 COMPARISON OF GEOMETRIC MEAN RESULTS FOR ENTEROCOCCI AT B-22 FOR DIFFERENT LOAD REDUCTION SCENARIOS

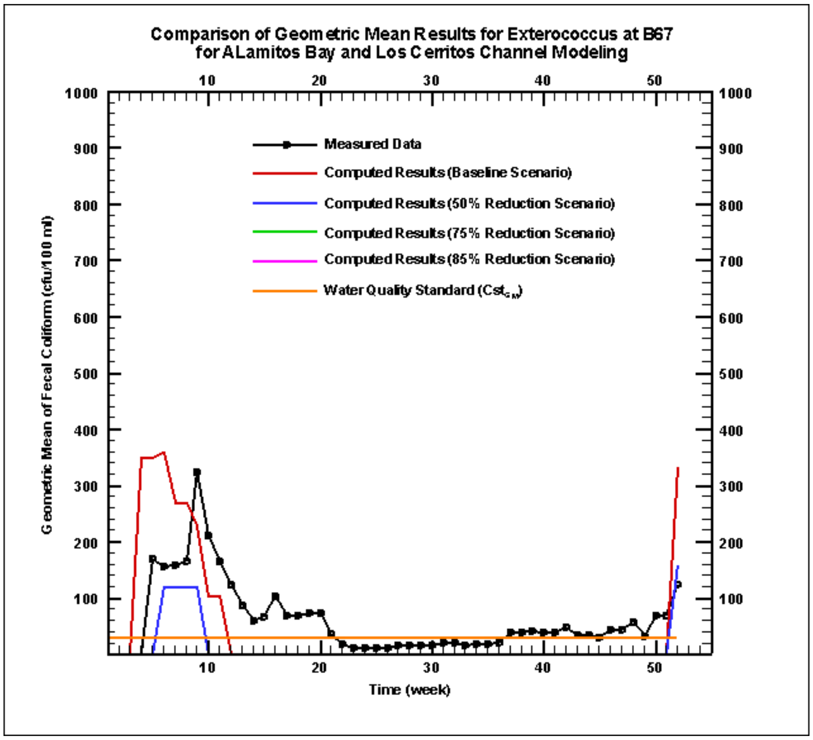

FIGURE 5.36 COMPARISON OF GEOMETRIC MEAN RESULTS FOR ENTEROCOCCI AT B-67 FOR DIFFERENT LOAD REDUCTION SCENARIOS

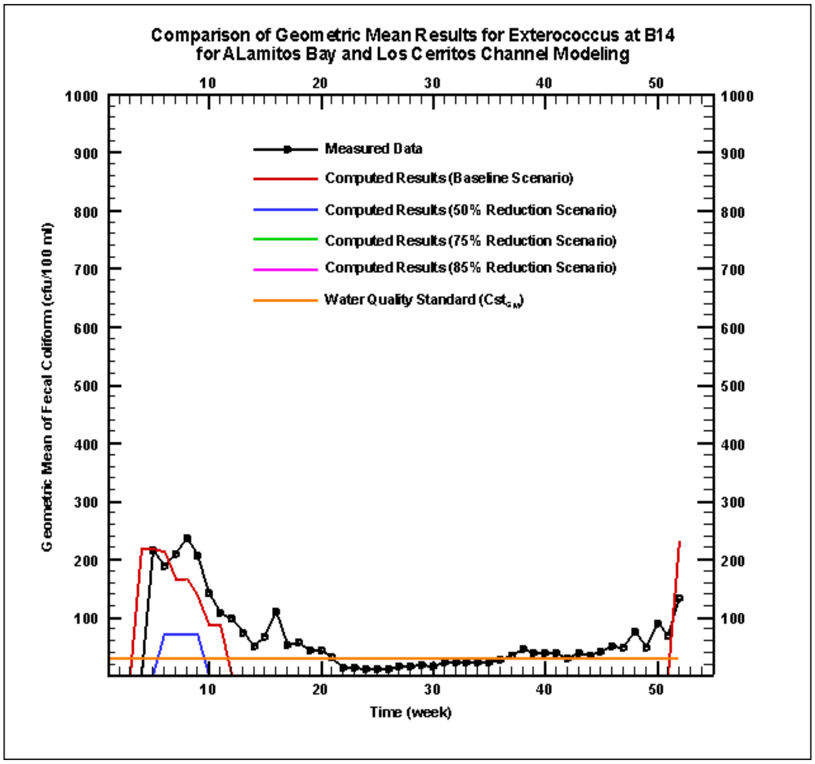

FIGURE 5.37 COMPARISON OF GEOMETRIC MEAN RESULTS FOR ENTEROCOCCI AT B-14 FOR DIFFERENT LOAD REDUCTION SCENARIOS

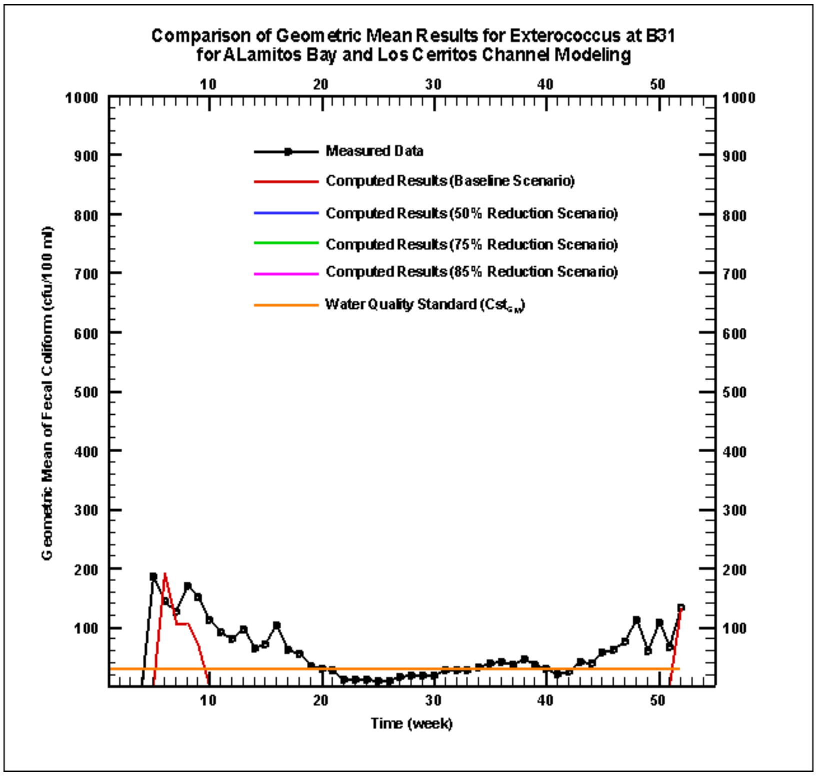

FIGURE 5.38 COMPARISON OF GEOMETRIC MEAN RESULTS FOR ENTEROCOCCI AT B-31FOR DIFFERENT LOAD REDUCTION SCENARIOS