UNIVERSITY OF CALIFORNIA
Santa Barbara

Assessment of an Artificial Breach of an Impounded Coastal Water Body: A Case Study of Goleta Slough, California

A Group Project submitted in partial satisfaction of the requirements for the degree of
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by

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Executive Summary

A study was performed to evaluate the impacts to ocean water quality subsequent to a breaching event at the Goleta Slough, Goleta, California. The field study results characterized how levels of bacterial indicator organisms, as specified in Assembly Bill 411, changed spatially and temporally along the coastline over a two-day sampling period subsequent to a breach of the Goleta Slough. Results indicated that significant exceedences of state ocean water quality standards for indicator organisms occurred throughout the study. Regional data collected through an informal statewide survey also indicated that water quality exceedences occurred at other breach sites at different temporal and spatial scales. We show that advisory zones should be established subsequent to breach events at the Goleta Slough. An analysis of the general permitting process associated with breach events highlighted the fragmented nature of coastal management between local, state, and federal agencies, resulting in jurisdictional overlap. The complexity of the process, as well as the sizeable bureaucratic procedures, can be very complicated and time-consuming to the applicants, and the report recommends streamlining the permitting process. Recommendations concerning artificial breaches include:

- After a breach at the Goleta Slough, a conservative advisory zone should be established 200 yards upcoast and 400 yards downcoast for a minimum of 48 hours. At the approximate 24-hour mark, samples should be collected at the –50 yard, mouth, and +50 yard locations.

- At the 48-hour mark, the results from the 24-hour sampling should be interpreted. If the results indicate ocean water quality violations, the beach advisory zone should remain in effect and a new round of samples should be taken. This process should repeat itself every 24 hours until bacteria levels subside below standards.

- Within the context of a stakeholder-based process, develop a list of simplified permitting guidelines for parties intent on performing breaching. This would ensure regulations are met while reducing overlaps between local, state and federal government, thereby streamlining the permitting process.

- To facilitate communication among regions, data and studies of artificial breach events should be presented and discussed at applicable conferences and meetings of professional associations. The collection of formal data should lead to comparisons among watersheds. This would provide an ideal opportunity to examine watershed-level factors that may influence bacterial loading, as well as a chance to investigate how long-term temporal changes within a basin and/or wetland affect coastal contamination.

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1.0 INTRODUCTION

1.1 IMPOUNDMENT AND BREACHING OF COASTAL WATER BODIES

California's 1,200-mile coastline offers a beautiful setting in which many choose to live. With so many living in close proximity to the coast, development is unusually pronounced. Oftentimes, this development requires the alteration and manipulation of many coastal water bodies. Such changes can include the narrowing and/or channelization of rivers and creeks, and the partial or complete filling of estuaries. This commonly results in aquatic systems that no longer function as they would in their natural condition. During storm events, excess water frequently causes these altered water bodies to flood; posing serious concerns to homeowners and city, county, and state agencies. Moreover, a related problem is the impoundment of such water bodies. During summer months when rainfall is at a minimum, many rivers, sloughs, and estuaries close off to the ocean as a result of lower flow conditions. Impoundment of such areas can lead to the development of eutrophic conditions, which can pose serious threats to wildlife. These effects, compounded with pollution from point and non-point sources, can cause the accumulation of undesirable pathogenic organisms and the formation of foul odors in the associated waters. Further, debris tends to accumulate in these impounded water bodies, which adds to the degradation of the water body. Agencies are faced with the task of managing these water bodies while balancing water quality, flood control, and aesthetic interests. In many circumstances, artificial breaches are performed to alleviate the likelihood of flooding and to stop the accumulation of fetid waters. While these breach events do mitigate the effects of impoundment, they are not without controversy.

Performing artificial breaches can be both beneficial and detrimental to the ecological health of an area. On the one hand, breaches are performed to increase the tidal flux into and out of a coastal water body, and thus reduce the likelihood for anoxic conditions to develop, which in turn can result in extensive fish kills and foul odors. On the other hand, the turbulent and abrasive nature of these breach events can cause the demise of fish and other aquatic species. Much of the controversy surrounding breaching events is linked to this latter possibility. The efficacy of a breach event rests in its ability to optimize overall ecological health with minimal damage to certain (potentially key) species living within and around the system.

The Endangered Species Act of 1973 and the understanding that artificial breaches can cause negative impacts to sensitive species of fish (such as the Tidewater Goby and the Steelhead Trout) have caused much of the friction present between government agencies that support breach events as a means of mitigation and those that oppose them. It is the assumption of many wildlife managers that breach events can negatively impact sensitive species due to the sudden physicochemical changes that result from a breach, such as differing salinities and temperatures, as well as the increase in suspended solids that is assumed to occur during such an event. Because governmental agencies are responsible for protecting endangered species, the process for acquiring a breaching permit has largely been concentrated on mitigating the upstream effects that occur after a breach event. Oftentimes, as was the case at Malibu Lagoon and Mission Creek, breaching permits are denied by conservation-oriented agencies due to the presence of endangered species. In contrast, many agencies dealing with flood control are urged to perform breach events by local home and business owners near impounded water bodies, all of whom are demanding that something be done to alleviate rising flood waters, eliminate odors, and to increase the aesthetic appearance of the associated waters.

California's coastal counties were surveyed to identify the locations and frequencies at which artificial breaches occur, as well as the reasons for which they are performed. The goal in identifying the number and frequency of such events was to understand the extent at which the issue affected the people of California. Several phone conversations were held with a variety of federal, state and local agencies to identify any breaches that were presently occurring on a regular basis. These agencies included the U.S. Army Corps of Engineers (USACOE), the California Coastal Commission, the State Regional Water Quality Control Board, the California Department of Fish and Game, and numerous coastal county agencies dealing with planning, environmental health and flood control. The survey illustrated the fact that artificial breaches do occur with some degree of frequency in many coastal counties throughout the State (Table 1.1). Managers of water quality and flood control are faced with several circumstances where mitigation efforts are needed to maintain suitable conditions for wildlife, property owners, and beachgoers.

Table 1.1. Breach events occurring in California.

County	Site Name	Reason for Breach
San Diego	Tijuana Estuary	Ecological Health
	Batiquitos Lagoon	Ecological Health
	San Luis Rey River	Ecological Health
	Buena Vista Lagoon	Flooding
	San Elijo Lagoon	Ecological Health
	San Dieguito River	Ecological Health
	Los Peñasquitos Lagoon	Ecological Health
	Loma Alta Creek	Undetermined
Orange	San Juan Creek	State Park Flooding
	Talbert Marsh	Ecological Health
	Aliso Creek	Public Health
Santa Barbara	Goleta Slough	Ecological Health
Monterey	Carmel River	Residential Flooding
	Salinas River	Farmland Flooding
Santa Cruz	Pajaro River	Residential Flooding
Sonoma County	Russian River	Residential Flooding
Del Norte	Lake Earl	Residential Flooding

Artificial breaches are performed for two main reasons statewide: to manage water quality for both wildlife and human health, and to manage waters that pose a threat to human development in the form of flooding. As mentioned earlier, the impoundment of coastal water bodies can lead to eutrophication and subsequently anoxic conditions, which may lead to fish kills and foul smelling water. In an effort to mitigate these effects, an artificial breach can be performed. Opening the impounded water body to tidal action helps to reverse the effects of impoundment by increasing the exchange of water with the ocean. This is witnessed in many locations including the San Elijo Lagoon in San Diego County and the Goleta Slough in Santa Barbara County, where both are regularly artificially breached.

Artificial breaches are also performed to prevent flooding hazards. In Sonoma County, the Russian River is occasionally breached to prevent flooding of surrounding residential areas. Another artificial breach is performed for the same reason in Del Norte County where Lake Earl is generally breached once a year to reduce water levels that would otherwise cause flooding to a nearby residential community. Artificial breaches occur for flood control in several locations throughout the State. See Appendix C for an expanded discussion of this informal regional survey.

As coastal development increases, the occurrence and need for artificial breaches is likely to increase. In many situations, artificial breaches are met with opposition by many federal, state, local, non-governmental organizations, and profit and non-profit groups for a host of reasons. A major problem that agencies performing breaches must now face is the presence of endangered species. Moreover, as public awareness of ocean water quality impacts and associated risks (due to recreational use) increases, public opposition to these impacts, such as a breach, continues to grow. Many artificial breaches that historically were completed without outside concern are now either occurring with less frequency or not at all due to regulatory controls. In the case of Mission Creek in Santa Barbara County, managers historically breached the impounded creek to mitigate the accumulation of foul smelling waters. However, when the presence of the endangered Tidewater Goby was discovered, the permit to perform the breach was revoked. Managers are finding it increasingly more difficult to get permits for artificial breaches where no permit was needed in the past.

In addition to heightened concern for artificial breaches and the need for permits, managers are also faced with the task of working under the current permitting process, one that is fragmented among federal, state, and local agencies. During the survey, identifying the locations where artificial breaches are occurring within the state was a complex endeavor; this was indicative of the fragmented distribution of authority in coastal management. In many cases, different statewide agencies would have to be contacted depending on the county under investigation. There appears to be no central agency that has jurisdiction over the artificial breaching process; this was the main factor behind the complexity of the investigation.

1.2 OCEAN WATER QUALITY

As alluded to in the previous section, a key controversy related to artificial breach events is the potential impacts to ocean water quality. In recent years, the impact on water quality due to bacterial contamination has become a highly publicized issue in California. Heightened public awareness and stakeholder actions are forcing scientists and policy makers to examine and find ways to minimize these impacts. During the mid 1990's, Heal the Bay, a non-profit environmental group, sponsored a study (the Santa Monica Bay Restoration Project) to investigate the concerns of beachgoers about the possible health risks of swimming in the Santa Monica Bay. The Director of the Santa Monica Bay Restoration Project (SMBRP), Catherine Tyrrell, reported that "for years, swimmers and surfers complained about eye, ear, skin, and stomach problems, which they believe stem from their contact with the bay" (SMBRP, 2000a). This investigation showed a correlation among public health risks and flowing storm drains. Specifically, it was shown that a higher incidence of illnesses were reported by swimmers and surfers that came into contact with waters in increasing proximity to stormwater outflows. In addition to showing this correlation, the study not only brought about an increase in public awareness, but also served as a major cueing event that resulted in the development of AB 411 and its regulations to monitor the quality of recreational waters and beaches (AB 411, statutes of 1997).

With the increase in beach postings and closings, beachgoers have become more aware of ocean bacterial contamination and are seeking resolutions, so that waters may be safe again for recreational use. In response to public outcry, the Natural Resources Defense Council and Heal the Bay went to court and won a lawsuit that forced the Los Angeles Regional Water Quality Control Board to set enforceable runoff limits for contaminants, including regulations for coliform bacteria, due in 2001 (Cone, 2000). The monitoring of breach events, using indicator organism thresholds set by AB 411, reveals that abundances of indicator organisms (coliform and enterococcus bacteria) increase subsequent to an artificial breach event (Sears, 2000). In response to these concerns and findings, local agencies applying for breaching permits must now consider both the upstream (i.e. endangered species) and downstream impacts (i.e. water quality) on the managed waters.

1.3 GOLETA BEACH WATER QUALITY PROJECT

Given the potential water quality impacts that may stem from an artificial breach, research exploring the nature and characteristics of these impacts is warranted. Decreased water quality along the beaches represents a serious health concern for a coastal community. Due to the current prevalence of this specific practice in California, and given its potential to increase in the future, understanding these impacts is an important endeavor. Under the current regulatory framework, Goleta Slough offered an ideal opportunity to explore this phenomenon. Located in the County of Santa Barbara near the University of California, Santa Barbara campus, Goleta Slough is a coastal wetland that regularly impounds during the low- to no-flow conditions of the summer months. In contrast to the Malibu Lagoon and Mission Creek examples mentioned earlier, no endangered fish species are known to be present in the Slough waters, and a permit to breach is already in place. Because of these site characteristics, it was deemed that the Goleta Slough was the best study area available to evaluate the potential negative impacts to ocean water quality subsequent to breaching events of coastal lagoons. The goal of the project was to develop any relationship(s) among flow from the Slough, concentrations of bacteria, sediments, and nutrients in the discharge, and distance along the beach at which bacteria are at levels of concern.

2.0 BACKGROUND

2.1 ASSEMBLY BILL 411

California Assembly Bill 411 (AB 411), as mandated in 1999, sets exposure limits to the levels of indicator organisms found in recreational waters. The term indicator organisms refer to organisms that can be used to indicate the presence or absence of any particular factor, e.g. fecal coliforms can be used as an indicator species for the presence of disease causing organisms in water (Manitoba Conservation, 2001). The bill calls for the weekly monitoring of ocean water quality at beaches that are located near storm drains that flow during the summer months and/or at beaches that are visited by more than 50,000 people annually (DHS, 2000a). This monitoring program begins on April 1st and ends on October 31st of every year. Bathing advisories and/or beach closures are required when single grab samples exceed the following standards (DHS, 2000a):

Table 2.1. Single-Limit Bacteria Standards for Ocean Water Quality

Total Coliforms	E. coli	Enterococcus
10,000 MPN/100 ml; or 1000 MPN/100 ml, if the ratio of fecal/total coliform is greater than 0.1	400 MPN/100 ml	104 MPN/100 ml

MPN= Most Probable Number: a way of quantifying the number of colonies present at the time of sampling, based on dilution.

2.2 REASONS FOR THE USE OF INDICATOR ORGANISMS

Assembly Bill 411 is based on the assumption that bacterial indicator organisms like total coliforms, fecal coliform (*Escherichia coli*), and enterococci are good surrogates for a wide range of pathogens: viruses, bacteria, protozoan, and helminthes (e.g., Joyce, 1999). Indicator organisms are used because direct pathogen monitoring is not a feasible method of monitoring; the great number of waterborne pathogens to test for would require the use of several different protocols and consequently result in high costs (Schaub, 1999). Because these usually harmless bacteria are naturally found in the gastrointestinal systems of warm blooded animals, it is assumed that elevated counts of these organisms in bathing waters demonstrates the presence of animal and/or human waste products and presumably the presence of pathogens. While elevated levels do not automatically translate to the presence of harmful pathogens, they currently offer the most efficient means for assessing recreational ocean water quality.

Total and Fecal Coliforms

The Santa Monica Bay Study proved to be an important tool in developing the content of Assembly Bill 411 (SMBRP, 1996). The single grab threshold of 10,000 total coliforms per 100 ml was used after the study correlated exposures to total coliforms levels greater than 10,000 MPN/100 ml and a 200% increased risk in skin rash. Further, the ratio of total to fecal coliform was added after it was correlated in the study with an increase in illness cases. More precisely, the number of swimmers near storm drains was correlated with the number of reported illnesses. It was determined that as the ratio of total/fecal coliforms decreased below 10, the number of cases increased, thereby showing that the fecal coliforms represented a larger proportion of the total coliforms, and that correlated with a significantly increased health risk. Investigators from the Santa Monica Bay Study also compared the risk of illness among swimmers at different total/fecal ratios and levels of total coliform bacteria. While a ratio of 10 in conjunction with total coliforms levels of 5,000 MPN/100 ml were related to risks of 107-657 per 10,000 swimmers for eight different effects (fever, eye, and ear discomfort, skin rash, nausea, diarrhea, stomach pain, and runny nose), a total coliform count of 1,000 MPN/100 ml and a total-fecal ratio of 10 was related to risks of 117-281 per 10,000 swimmers for three different effects (chills, nausea, and diarrhea), giving rise to the current conservative thresholds of 1,000 total coliform bacteria per 100 ml, if the ratio of fecal/total coliform exceeds 0.1 (DHS, 1999). The study used the ratio of total-fecal coliform while the AB 411 uses the ratio of fecal-total coliforms (see table 2.1).

The threshold limits for fecal coliforms used in AB 411 were derived from studies performed during the 1940's and 1950's by the US Public Health Services and were subsequently used by the US EPA in 1986. The most significant study, the Ohio River Study (US EPA, 1986) showed that the rate of gastrointestinal illness was significantly higher when the geometric mean total coliform density was 2,300 MPN per 100 milliliters compared to when it was 43 MPN per 100 ml. However, there was no difference in illness rate when coliform densities compared were 732 MPN versus 32 MPN per 100 ml. As a result, a threshold of 1,000 per 100 ml was established (US EPA, 1986) and was later correlated with the ratio of fecal-total coliforms by the Santa Monica Bay study of 1996. Because fecal coliforms are a subgroup of total coliforms, they were found to represent about 18% of the total coliforms present in the Ohio River study (2,300 MPN/100 ml). As a result, the EPA calculated the proportion of fecal coliforms to total coliforms that would result in an increase of reported illnesses, giving rise to the single threshold limit of 400 MPN/100 ml (see table 2.1).

Enterococcus

Epidemiological studies performed by Cabelli (1983) in New York, Louisiana, and Massachusetts, showed that enterococci were the best indicator organism to predict human health risk associated with recreational waters. Effectively, Cabelli found that the mean enterococcus density had correlation coefficients of 0.75-0.96 for highly credible gastrointestinal symptoms (vomiting, diarrhea, or stomach ache or nausea with fever), compared to correlation coefficients of 0.12-0.46 for total coliform bacteria and -0.01-0.51 for fecal coliforms. He also found similar results for total gastrointestinal symptoms. Using Cabelli's report, the US EPA in 1986 estimated that a fecal coliform level of 200 MPN per 100 ml and an enterococcus level of 35 MPN per 100 ml would result in 19 cases of total illnesses per 1,000 people exposed, and that the level of risk associated with an average of 35 enterococci per 100 ml and a single exposure of 104 enterococcus bacteria per 100 ml were equivalent (DHS, 1999). This single threshold measure was later validated by the Santa Monica Bay Study (1996) when investigators found a 323 percent increase in diarrhea containing blood and a 44 percent increase in vomiting and fever associated with exceeding the enterococci limit value of 104 MPN/ 100 ml (DHS, 1999).

2.3 Effectiveness of Indicator Organisms

As previously explained, indicator organisms' threshold limits in AB 411 were extrapolated from studies performed since the 1940's. Controversy has arisen since researchers have not been able to show any correlation between the presence of these otherwise harmless indicator organisms and human pathogens (SMBRP, 2000b). While a body of evidence seems to show that enterococcus concentrations are a good indicator of gastroenteritis symptoms as shown earlier (DHS, 1999; Nuzzi et al., 1997; SMBRP, 2000a), gastrointestinal symptoms have not been correlated with the presence of fecal or total coliforms (Nuzzi et al., 1997). However, looking at types of non-gastrointestinal illnesses, the Santa Monica Bay Restoration Project has found a statistical relationship between the occurrence of certain ear ailments and nasal congestion due to the presence of *E. coli*. Another relationship has also been shown between total coliforms and the occurrence of skin rashes (SMBRP, 2000a). This suggests that the presence of certain indicator organisms might be able to predict the possible occurrence of specific diseases.

Another important issue is that while a correlation between indicator organisms and gastroenteritis symptoms exists, it is strongly suspected that enteric viruses cause most of the gastroenteritis illnesses reported from bathers. However, to date, no relationship has been established between indicator organisms, which are bacteria, and pathogenic viruses in overlying marine waters (SMBRP, 2000b; Noble et al., 1999). Noble et al. mentioned that this poor relationship could indicate the substantial presence of non-human sources of bacterial contamination. More specifically, large amounts of marine animals and waterfowl present at the entrance of creeks and lagoons do contribute a significant amount of fecal bacterial contamination seen at the entrance of freshwater outlets (Noble et al., 1999 and 2000). Furthermore, viruses may have a greater survival rate in ocean water than bacteria, suggesting that bacteria might not be detected at a significant level even though potential pathogenic viruses might be present at potentially dangerous levels (SMBRP, 2000b). Because of the definite lack of knowledge on both viral and bacterial pathogens occurring in marine water, more research needs to be undertaken to determine the relevance of these indicator organisms in predicting human illnesses.

While these findings undermine the current content of AB 411, they also show the incremental nature of most regulations and guidelines. Effectively, policy is an ongoing process, and "no policy decision or solution is final because changing conditions, new information, and shifting opinions will require policy reevaluation and revision" (Kraft et al., 1999). Consequently, it is expected that as more data becomes available, a new consensus will form which will result in the use of better indicators and/or thresholds to assess public health risk. Meanwhile, the current indicators' greatest advantage is that beach compliance, using the current ocean water testing methods, is determined within 24 hours of sampling as sampling techniques and analysis procedures are straightforward and simple (SMBRP, 2000b). As a result, public actions can be initiated within a relatively short period of time to ensure prompt protection of the beachgoers. It is true that the AB 411 indicator organisms may not be the best to assess the water quality of beaches; nonetheless, they are indicators of fecal pollutions and should not be discarded, as no better indicator organism has been found yet. As a result of these scientific remarks and uncertainty, the relevance of the findings presented earlier could decrease over time. However, our conclusions were reached using the more protective indicator organisms and their thresholds as described in AB 411; consequently, this study adds to the current body of research already in existence on breaching impounded water bodies and ocean water quality.

2.4 AQUATIC DISPERSION AND ATTENUATION OF PATHOGENS

Besides considering the efficacy of current indicators, it is also import to consider how indicators may be distributed in the surf zone. Limited studies have explored how pathogens are mixed and distributed along the immediate coastline after discharge from a freshwater outlet or storm drain system. The Santa Monica Bay study indirectly examined the importance of this issue in its epidemiological study (SMBRP, 1996). To estimate the risk due to recreation in areas exposed to storm drain discharge, bacterial and epidemiological data were collected and compared at four locations: one in front of a storm drain, two locations 100 yards north and south of the storm drain outlet, and another 400 yards downcoast from the point of discharge. Results demonstrated that significant increases in illnesses and episodes of bacterial loading were largely found in front of the storm drain (SMBRP, 1996). Understanding how these abundances and risks change along the shoreline over time is important as it influences how local agencies will post and identify potentially contaminated waters after storms and artificial breach events. These agencies can benefit from conservative spatial and temporal standards that describe indicator organism levels change with loading from specific creeks and artificial discharges.

Several factors play into the dispersion and attenuation of pathogen abundances in ocean waters. Initially, one needs to consider the mixing processes associated with discharge from a coastal waterbody. There is a significant amount of mixing that occurs during each change of tide. The amount of flushing that occurs at a given outlet is the tidal prism, and it is a function of the outlet cross-section, the aquatic area of the wetland, and the difference between sea level and the water levels within the wetland (Dean and Dalrymple, unpub.). A freshwater discharge should normally lead to the formation of a jet-like plume, although low-flow conditions will rapidly lose momentum and be mixed within the surf zone. Processes that contribute to this mixing include wave breaking; wave swashing; wave interaction with shallow bottom topography; wind-induced circulation; and nearshore eddies around the outlet (URS, 1999).

After discharge into the surf zone, other processes play into the attenuation of bacterial abundances. The mixed water becomes entrained in the longshore current; this advection is overlapped by eddy diffusion processes in the horizontal plane (Riddle and Lewis, 2000). Vertical mixing will be dependent upon the presence of stratification due to strong differences in thermal and/or salinity differences throughout the water column (Riddle and Lewis, 2000), though much of freshwater may have been thoroughly mixed at the discharge point due to surf zone mixing. This diffusion will occur much more rapidly along the direction of mean flow rather than across the flow; these velocity shears will result in an elliptical pattern of dispersion (Riddle and Lewis, 2000). Other nearshore circulatory features such as rip currents (Dean and Dalrymple, unpub.) may also significantly influence how pathogens are attenuated. Finally, it is important to consider die-off rates due to the biological nature of the contaminants in question. One factor that is greatly focused on is the resistance of indicator organisms to salinity; survival of coliform bacteria diminishes at higher salinities (Coelho *et al.*, 1999). Understanding this relationship can be complicated by the fact that many bacteria will accumulate and/or release potassium and glutamate (Gauthier *et al.*, 1991), as well as glycine betaine (Cosquer *et al.*, 1999), to manage osmotic stresses. Other factors that will play into the survival rate include solar radiation, temperature, pH, predation, competition for nutrients, lysis, and algal toxins (Solic and Krstulovic, 1992).

Field and laboratory experiments offer the best means of understanding these specific factors that can affect the attenuation of indicator abundances. However, research focusing on the physical dispersal mechanisms at a given location has often involved the use of tracers. For research at the coastal interface, the best tracers are those whose properties remain constant within the ocean; they are considered to be conservative and non-labile in the ocean. Salinity is considered a conservative tracer because the total mass of salt in the water does not change over the spatial and temporal scales considered. The use of dye has been popular to achieve this end (Riddle and Lewis, 2000), and has been used to simulate bacterial dispersal in coastal waters. Other tracers of this type include chemicals and water quality properties that demonstrate strong correlations with indicator abundances in the ocean. One can also use nutrients as tracers such as nitrate, as long as the source contains concentrations several magnitudes or more than the receiving water body (Petty, per comm., 2000). If differences due to mixing are small, then the observed changes of a proposed tracer will be difficult to interpret. Properties that change independent of mixing actions are non-conservative, and not necessarily ideal candidates for tracers.

3.0 RESEARCH HYPOTHESES AND OBJECTIVES

3.1 Research Hypothesis

Assessing impacts to ocean water quality is often a difficult task to accomplish during low-flow/ no-flow conditions because the source inputs are often difficult to detect as compared to storm events. Breaches are controlled and planned events that lend themselves to study the dispersion patterns of bacteria in the ocean after a breach. Using the Goleta Slough site, the following questions can be examined:

- Ocean water quality will be negatively impacted subsequent to an artificial breach of the Goleta Slough. Measuring the concentrations of indicator organisms and comparing against background levels in the ocean can characterize this negative impact.

- The temporal pattern of indicator organism concentrations will be such that the initial concentration immediately following breaching will be high, followed by attenuation, then elevated again due to the influx of creek water containing suspended and sediment borne indicator organisms.

- The longshore spatial pattern of indicator organism concentrations away from the Slough mouth will be such that the levels safe for human contact will be attained at some distance less than 400 yards.

- The lateral dispersion of bacteria away from the Slough mouth correlates with the Slough discharge velocity/volume subsequent to a breaching event.

3.2 Research Objectives

Based on the previous hypothesis, the research objectives can be divided into scientific objectives and social objectives.

The Scientific objectives are to:

- Utilize the current water quality monitoring procedures (i.e. IDEXX methods for quantification of MPN) to document bacterial levels in the upper surf zone relative to the distance from the Slough mouth to evaluate the impacts on recreational ocean water quality subsequent to artificial breaching of the Goleta Slough.

- Document the physical properties associated with bacterial levels in the upper surf zone, including discharge of the slough water into the ocean, tidal movement and height, winds, and the longshore currents.

- Investigate whether a correlation exists among bacterial abundance, total suspended solids, and nitrate concentrations subsequent to the breach.

- Develop a conceptual model of dispersion subsequent to the breaching event at the Slough mouth.

The Societal objectives are to:

- Extrapolate the Goleta Slough results to a larger scale: provide recommendations for best management practices for monitoring water quality after regional coastal breaching events.

- Determine where breaching events occur in California and their regulatory framework.

- Report the information to the public and provide further discussion and awareness of water quality issues.

3.3 MANAGEMENT DELIVERABLES FOR THE COUNTY OF SANTA BARBARA

This research was performed to answer questions asked by the County of Santa Barbara. Management deliverables include:

- Inform the County of Santa Barbara of the adequate beach closure distance and time frame around the mouth of the Slough after a breach event based on bacterial observations.

- Inform the County of Santa Barbara of the indicator organisms loading during the breach event of September 2000 to assess the ocean water quality of Goleta beach at that time. This could help determine if the beach needs to be closed during a breach event at the Slough.

4.0 GOLETA BEACH FIELD STUDY

The goal of this field study was to evaluate the potential water quality impacts subsequent to a breach event of the Goleta Slough. More specifically, the objective was to develop the relationships between the flow from the Slough mouth, abundances of indicator organisms, concentrations of nutrients and sediments, and discharge; and characterize the distance along the beach at which bacteria are at levels of concern. Last, a simplified conceptual model that links bacteria, nutrients, and physical measurements was developed to describe the breaching event.

4.1 SITE SELECTION

Goleta Slough, located approximately eight miles west of downtown Santa Barbara, consists of a severely fragmented wetland and network of creeks (Figure 4.1). The Goleta Slough is almost entirely surrounded by urban development and is managed by several different owners. This includes a municipal airport to the north, public utilities and light industrial operations to the east, a public beach between the ocean and the slough, the campus of UC Santa Barbara to the south and west, and residential and light industrial operations to the north and west. The study focused on the region of the Slough mouth that empties into the ocean and the adjacent public beach.

Figure 4.1. Aerial View of the Goleta Slough and Tributaries. Photo Courtesy of Karl Treiberg, Santa Barbara County Flood Control.

The Goleta Slough was not the first choice for the study. Originally, the study sought to characterize water quality impacts subsequent to a series of breach events at Mission Creek, located in downtown Santa Barbara. However, the filing of a lawsuit by the Environmental Defense Council (EDC) of Santa Barbara put an end to all breachings at Mission Creek due to the lack of necessary permits. Although many agencies including the Army Corps of Engineers and the California Department of Fish and Game (CDFG) were supportive of the proposed study, none could legally authorize the breaching of the Mission Creek due to the presence of the Tidewater Goby, a protected species under the Endangered Species Act of 1973. Therefore, a search for a site that did not have any associated permitting constraints was conducted; this search led to the Goleta Slough.

The Santa Barbara County Flood Control manages the Goleta Slough. The agency is responsible for maintaining an open tidal inlet between the Goleta Slough mouth and the ocean. When the Slough impounds, the permit established by the CDFG requires that County Flood Control breach the Slough within one week of impoundment. County Flood Control breaches the Slough at the lowest tide of the week to maximize the elevation gradient between the Slough and the ocean. This creates a maximum pressure gradient and scouring effect upon the release of the discharge that reduces the likelihood of an early impoundment. Typically, the Slough impounds one to two times per year, depending on the amount of rainfall received during the winter months. During El Niño years, such as the winter of 1998, there was enough creek flow and groundwater inputs to keep the Goleta Slough open for the entire year.

4.2 EXISTING DATA

The Santa Barbara County Water District conducted a small study in 1999 at the Goleta Slough/Goleta Beach site subsequent to an artificial breach event (Sears, 2000). Multiple ocean water and slough water samples were taken 24 to 48 hours after the October breach event and Most Probable Number (MPN) concentrations were measured for total coliforms, *Escherichia coli*, and enterococcus. The ocean samples were taken 25 yards west (or upcoast) of the slough mouth. Researchers found that the tidal cycle appeared correlated with bacteria levels. As the tide subsided, waters with higher bacterial content from the upstream zone of the Slough began to flow out and bacteria levels increased in both the ocean and slough samples. This was observed for all indicator organisms on the first day of sampling. On the second day there seemed to be a greater delay before bacterial content increased, suggesting that the tidal cycle influenced bacterial densities within the Slough itself (Sears, 2000). The study revealed the highest levels of total coliforms were 1400 MPN/100ml, indicating a low potential health risk to swimmers. However, there were several exceedences associated with single grab limits for *E. coli* and enterococcus.

There were several limitations in the design of the experiment. No samples were taken directly in front of the slough mouth where the largest concentration of bacteria would likely be found as the greatest mixing of sediments and resuspension of bacteria would also be expected occur at that location. No ocean samples were taken east of the slough mouth, which is the predominate direction of the nearshore surf zone currents. One would expect to find the greatest bacterial abundances directly in front of the source, and that the MPN numbers decrease as a function of the distance of the nearshore current (eastward direction). In the conclusion of the report, several recommendations were made to increase the validity of the study. These included (Sears, 2000):

- More days could be added to clarify the time dependency of attenuation of bacteria levels.

- Flow measurements should be taken at the mouth to obtain accurate discharge rates.

More samples should be collected on a larger spatial scale, including more replicate samples to quantify the variability between samples.

Other studies have shown the highest bacteria levels in the nearshore surfzone occur directly in front of the source (i.e. creek mouth or storm drain), and bacteria levels increase as the tides decrease (Grant and Sanders, 2000; Gersberg *et al.*, 1995). It has been suggested that the timing and magnitude of bacterial pulses flowing out of a creek are controlled by the tidal range (Grant and Sanders, 2000). Bacteria levels in the nearshore environment are highest at the end of the ebb tide or at the very beginning of the high tide because water is still flowing from the source and the change in tide direction causes the largest mixing and scouring of sediments (Grant and Sanders, 2000; Armstrong, 2000). Due to logistical constraints, sampling for this field experiment could not occur at frequent rates that would have allowed examination of bacteria levels along different points in the tidal cycle. Therefore, replicate samples were collected each sampling event just after the end of the low tide to ensure the probability of capturing the highest levels of bacteria in the surfzone.

Preliminary sampling experiments at the site were also performed during the spring in an effort to determine the number of replicates samples needed for analysis. The results showed the variability within each indicator organism is very high in the ocean samples (Appendix B). Four replicates for each sample location was chosen because this number represented the maximum number of samples that could be processed with the time and budget constraints of the research. Further, a scientist from SCCWRP confirmed that the number of replicates (four) was adequate to determine if significant differences existed between the sample sites and control sites (Schiff, pers. comm.,2000).

The historical weekly sampling data from Santa Barbara County Department of EHS for Goleta Beach were used to determine background levels and variability of indicator organisms during the dry low flow season. This data set served as a control group to compare against the levels of indicator organisms measured in the ocean water immediately following the breach event.

4.3 PARAMETER AND MEASUREMENT SELECTION

In order to effectively characterize water quality impacts and the extent of the Slough water plume in the ocean, a suite of parameter measurements were necessary. The most important consideration was that of indicator organisms. Abundances of several species of microbes are used as indicator organisms for water quality. Assembly Bill 411 identifies which indicators shall be used for monitoring: total coliforms, fecal coliforms (*E. coli*) and enterococcus. Although the EPA recognizes that the enterococcus bacteria are the most conservative indicator for marine waters, it recommends using all three indicators for monitoring purposes (USEPA, 2000). The need for this parameter was obvious because it is the only standard used to characterize recreational ocean water quality.

Several other parameters were selected for their potential use as tracers of the slough water ejected into the surfzone. Nitrate concentration was a clear candidate because of the order-of-magnitude or more difference between the slough water concentrations and typical coastal seawater concentrations (Petty, pers. comm., 2000). Given that a mechanical breach involves the substantial movement of sediments, it was believed that total suspended solids offered the same benefits as a tracer. Bacteria are capable of growth in the benthic environment (Chan *et al.*, 1979), thereby making marine sediments an excellent reservoir for bacteria; such an environment can offer limited protection from predation (Roper and Marshall, 1979) as well as harmful UV radiation (Bitton *et al.*, 1972). Numerous studies have shown that bacteria may survive for longer periods of time in marine and estuarine sediments than they could free-floating in the saline environment (Gerba and McLeod, 1976; Roper and Marshall, 1979). It was expected that TSS concentrations would be significantly higher than background conditions; it was hypothesized that a positive correlation would exist between TSS and abundance of indicator organisms.

Other parameters selected had to do with the fact that Goleta Slough is breached to preserve the chemical and physical quality of the inland waters. Salinity, dissolved oxygen (DO), and temperature within the Slough may dramatically change, thereby affecting the ecological health of the wetland system. In particular, salinity has been used to characterize the mixing of freshwater and seawater sources, and can be used to detect the presence of slough water in the ocean. Although the water found within the Slough is somewhat saline, it was a possibility that significant changes in the salinity post-breach could occur; a fluctuation in this parameter should initially correlate with the flow coming out of the Slough since there has been limited saline input due to the impoundment. Also, pre-breach observations of the water in the Slough indicated that the DO level was depressed and temperature was elevated. Given the possibility that all three of these parameters may cause observable differences in the coastal recreational waters, they were included with in the experiment design.

To assist with the characterization of the event, it was also necessary to collect flow and current data, as well as swell and wind data. All these factors contribute to the advection and diffusion of water from the Slough. As a result, this data may also explain results obtained through the measurement of other parameters. One particular parameter, nearshore flow, was observed through multiple means to ensure redundancy in the experiment. There were various options available that all offered certain advantages relative to each other. Dye has been used to replicate the dispersion of bacteria in the near-surface currents (Ackerman, per. comm. 2000); the visual observation of buoyant objects (such as oranges) offered an uncomplicated means for grossly estimating the direction and speed of longshore flow; and the use of global positioning system (GPS) technology offered a more precise track of currents along the coastline. However, given the concern over the uncertainty of the field worthiness of these novel techniques, it was decided to include all three in the general experimental design.

4.4 EXPERIMENTAL DESIGN

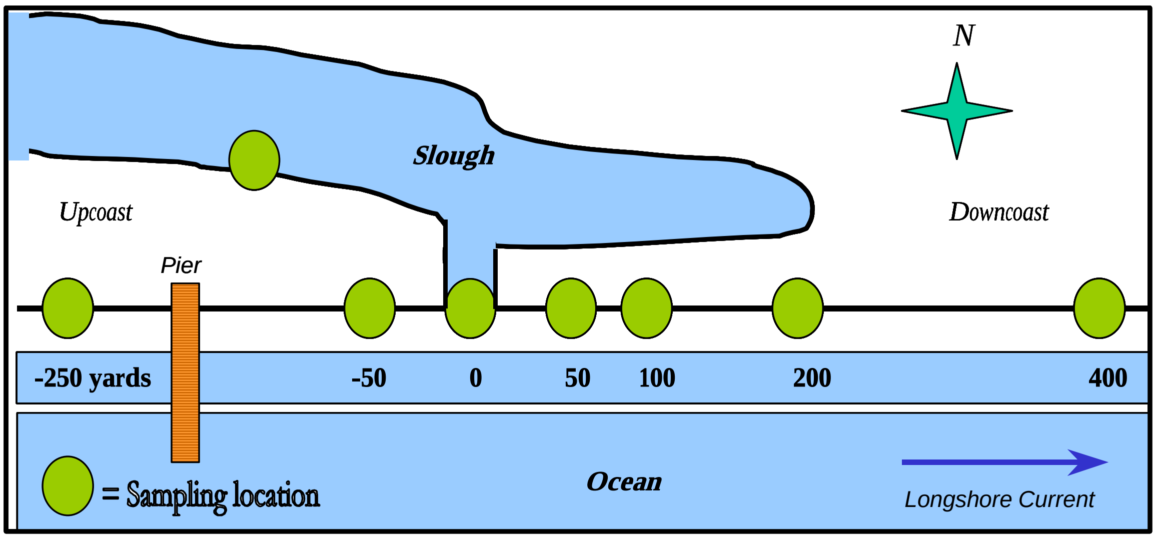


Figure 4.2. Schematic of Sampling Stations at Goleta Beach/Slough.

Seven sampling stations were selected along the shoreline at Goleta Beach in relation to the slough's mouth; a sampling station was also located 100 yards back into the slough (Figure 4.2). The collection of field data consisted of 5 sampling periods within a 72-hour time frame. The first sampling event occurred approximately 24 hours prior to breaching the impoundment to serve as a control. Samples for this initial event came from three stations: 250 yards upshore, the slough location, and the probable location of the actual outlet formed by the breach (the "0" station). Further sampling periods occurred after the breach at roughly 3 hours, 12 hours, 24 hours, and 48 hours. Samples were collected from all the stations during these events. At each station, bacteria, TSS, and nitrate/nitrite were taken simultaneously in ankle- to knee-depth seawater, 4 replicates for each parameter. Salinity, temperature, and DO were also assessed at each station during sampling episodes using a YSI-85 DO meter. Longshore flow velocities were assessed during each sampling period through visual observation of oranges and fluorescein dye released into the surf zone. A makeshift buoy was also constructed to hold a Garmin GPS 12CX receiver; the buoy was released just beyond the surf zone and activated to track and log its drift downshore. For the 4 sampling periods that occurred post-breach, flow was assessed by mechanically estimating the cross-section of the newly formed channel; actual velocity was determined through the use of a General Oceanics mechanical flow meter. Variations in channel width over time were accounted for by taking duplicate measurements at channel locations representing minimum and maximum widths. Specific details regarding sampling procedures may be found in Appendix A.

Laboratory Procedures

Bacteria samples were analyzed for total coliforms, fecal coliforms, and enterococci using water quality protocols developed by IDEXX (Colilert-18 and Enterolert). TSS was evaluated using methods based on the protocol laid out for TSS measurements in *Standard Methods for the Examination of Water and Wastewater, 20th Edition*. A 1-liter vacuum filtration system was used for the procedure; Gelman A/E 47 mm glass fiber filters were used to screen the samples. A laboratory certified for flow injection analysis analyzed all the nitrate/nitrite samples. Average nearshore velocities were calculated using the visual observations of the fluorescein dye and oranges; data from GPS observations were downloaded into a compatible cartography program (MapSource) and analyzed for longshore flow information. Conversions of data regarding the flow out of the slough yielded information on the volume of water being discharged for each sampling period. Specific details regarding laboratory procedures may also be found in Appendix A.

Statistical and Conceptual Analyses

Outside of examining bacterial observations for numerical violations of recreational water quality standards, statistical tests were performed to evaluate temporal and spatial patterns of bacteria, and regression relationships between the bacteria and other parameters measured. All statistical analyses were conducted using S-Plus Software (S-Plus 2000, 2000). Statistical tests were used to determine whether or not bacterial background conditions varied significantly at the different sampling locations during the different sampling periods as well as to identify significant differences between locations for each sampling period. One-way analysis of variance (ANOVA) tests were utilized. One-way ANOVA procedures test whether the group means differ significantly from one another, taking into account the variability associated with the replicates (Zar, 1996). In order to evaluate the control site, ANOVA tests were used to determine whether post-breach bacteria levels at the control site differed from the background conditions for each sampling period. ANOVA analyzes the variance among the values and divides it in a ratio between the variance among the different sampling locations and the variance that exists between the replicates of each location (Motulsky, 1995). This ratio is quantified into an F-statistic that is compared to a critical F-statistic derived from probability tables. If the F test statistic is larger than the critical value, the alternative hypothesis is accepted that one or more of the groups differ from one another (Motulsky, 1995). One-way ANOVA is based on the assumptions that the samples are collected randomly and the observations within each sample were obtained independently (i.e. replicates taken independently of one another for each location) (Motulsky, 1995). The obvious question then is which of the groups differ from one another.

Multiple comparison tests are used to compare each group against one another for significant differences between the mean, taking into account the variability among the groups. Multiple comparison tests are only performed after the ANOVA analysis indicates there are significant differences among the groups and the test identifies which groups differ from one another. Potential relationships between each indicator organism and various field parameters (nitrate, TSS, salinity, and DO) were evaluated through linear regression analysis. Finally, linear regressions of distance and changes in three parameters (nitrate, bacteria, and salinity) relative to their background levels were used to construct estimates of plume length along the shoreline. Using field data and assumptions based on visual observations, a conceptual mass balance exercise was done to further characterize and estimate plume dimensions after the breach.

Limitations to design

There are several limitations to this experimental design. Most importantly, this data comes solely from a single breach event; evaluation of multiple breach events would have allowed for greater validation of the findings, as well as opportunities to explore the potential influences of other parameters such as the timing of the actual breach event in relation to the tidal cycle. An opportunity to look at multiple breach events under different seasons and conditions would have provided stronger basis for analysis, interpretation, and extrapolation to other breaches. The spatial and temporal scale of sampling events was limited by financial and logistical factors. It would have been preferable to have a finer scale that could detect further variability and patterns not seen under the experimental sampling regime. An increase in the amount of sampling stations along the shoreline may have provided a better understanding of how indicator organisms disperse and attenuate along the shoreline; this would have strengthen statistical analyses. A finer temporal scale would have allowed better characterization of the changes in water quality subsequent to the breach. It would have also provided a chance to explore the variability of the indicator abundances and other parameters due to tidal changes. Overall, a finer scale in time and space, as well as the sampling of multiple breach events, could have potentially allowed for the development of a simple regression model that would characterize bacterial abundances subsequent to a breach. Finally, laboratory procedures could have been verified by sending a select few split samples to independent and certified laboratories. Once again, lack of adequate resources and restrictions on time prevented such a quality control procedure.

5.0 GOLETA BEACH FIELD STUDY AND REGIONAL BREACH DATA

5.1 PHYSICAL DISPERSION PARAMETERS AND PRE-BREACH CONDITIONS

Physical Dispersion Parameters

The physical parameters affecting bacteria dispersal that were observed and collected during the field experiment included tides, wind speed and direction, estimated slough discharge, deep-water swell, nearshore wave conditions, and ocean water temperature and salinity. The approach for addressing these parameters was to characterize the typical values for these parameters at the Goleta Beach site (except for the estimated slough discharge volume), present the method by which the data was obtained, present the data collected for this experiment, and provide observations and assessment of the data.

Tide Heights

Tide heights for the Santa Barbara region for the time period covering the Goleta Slough breach fieldwork were estimated subsequent to the fieldwork using a tide predictor (University of South Carolina Tide/Current Predictor, 2001). The tide heights during the breach event (See Figure 5.1) are displayed as a function of the elapsed time from breaching. The tide range was significant on the day of the breach and the days immediately following the breach. This relatively extreme range was considered to be crucial by Santa Barbara Flood Control to maximize the scouring effect of the initial discharge during the breach (Treiberg, per. comm., 2001).

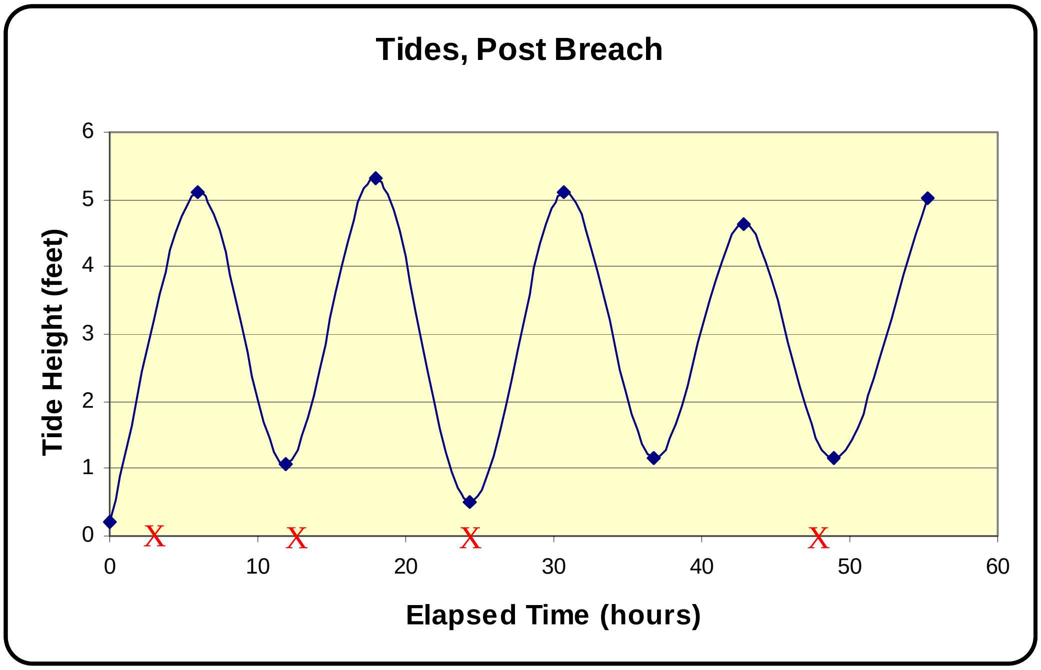


Figure 5.1. Santa Barbara tide heights during breach event. X denotes beginning sampling time for each sampling period.

Ocean water quality sampling was conducted at times corresponding to the low tides only. To capture the bacteria signal variability in the tidal cycle, it would have been necessary to look at the multiple stations at various times in the tidal cycle, rather than just during the low tide. Sampling was not conducted at various times in the tidal cycle, however, because introducing this parameter into the field experiment and analysis was not possible due to constraints on personnel and budget. Given limited resources, low tide sampling should have captured something like the maximum export rates (Hubbard, 2001). Tidal distortion occurs in the Goleta Slough characterized by flood tides coming in relatively fast, and the ebb tides draining slowly (Hubbard, 2001). The consequences of this asymmetry include increased bedload transport with higher velocity and shorter duration flood tides (Hubbard, 2001). This can build flood tide deltas in the slough, increasing sedimentation, decreasing the inlet depth, and causing increasingly distorted tides (Hubbard, 2001). Bacteria transport may be affected by these dynamics.

Wind Speed and Direction

The prevailing winds for coastal California are from the northwest and blow generally parallel to the coastline. However, due to the local coastline's orientation (Point Arguello and Point Conception protect Santa Barbara from the prevailing northwesterly), the winds are light and variable from the southerly quadrant most of the time (Gable, 1981). Measurements at the Santa Barbara Airport (in close proximity to the site) indicate southwest winds prevailing October through March and south winds prevailing the rest of the year. Generally, strong winds are infrequent with an average wind speed of 5.2 knots most of the year (Gable, 1981). The typical wind pattern is a sea breeze in the afternoon and evening hours and a land breeze during the morning and night. This typical sea breeze and average wind speed were evident during the breach event.

The wind speeds and directions during the breach event were documented subsequent to the fieldwork. The data were obtained from archived climatological data from a NOAA station located at the Santa Barbara Airport (National Climatic Data Center, 2001). See Figure 5.2 for wind speeds during the breach event.

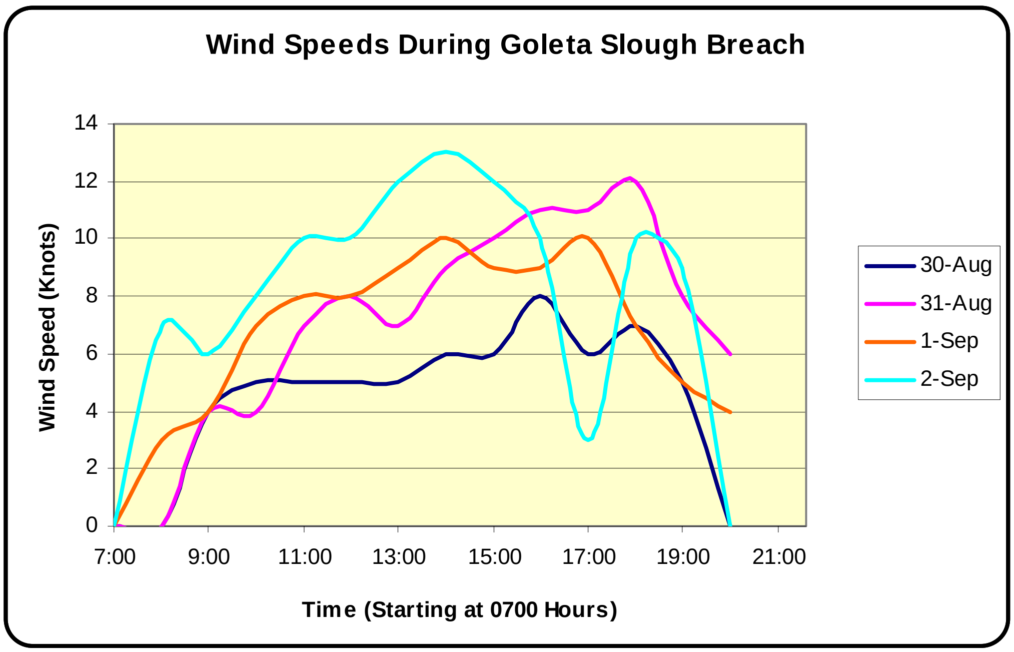


Figure 5.2. Wind speeds during the breach event. Speeds during the late evening are not shown due to their low values (< 1 knot).

The wind speeds during the breach event follow a recognizable pattern: calm in the morning, gradually increasing throughout the day to a peak wind speed of 8 to 13 knots between 1400 hours and 1800 hours, and quickly decreasing after 1800 hours. The wind directions corresponding to the wind speeds in Figure 5.2 were predominantly out of the west-southwest.

Deep Water Swell and Near Shore Wave Conditions

The term deep-water swell describes swells arriving from outside the Channel Islands with wave periods of 8 seconds or longer. It does not consider any local generation of seas. The deep-water swell is obtained from a swell model based on wave refraction-diffraction simulations performed on the San Diego Supercomputer Center in 1990 (Scripps Institute of Oceanography, 2001) (Scripps Institute of Oceanography, 2001. Nearshore wave conditions are a combination of deep-water swell and locally generated seas (wind swell). These latter swells were ignored since wind speed itself was already taken into account for this experiment.

The deep-water swell heights, periods, and directions at a number of times corresponding to the sampling times for the period covering the sampling effort were obtained from the Coastal Data Information Program (CDIP) swell model archives (Scripps Institute of Oceanography, 2001). To create the image in the swell model archives, a buoy moored in 549 meters of water collects deep-water wave data, about 19 kilometers west of Pt. Arguello. The buoy data is processed to produce an estimate of the deep-water directional spectrum (see Appendix B). Table 5.1 contains the North and South Pacific Deep Water Swell Heights and Periods and the time at which they were collected.

Table 5.1. North and South Pacific Deep Water Swell Height and Period.

		Deep Water Swell					
		North Pacific			South Pacific		
Date	Time	Hs (ft)	Tp(s)	Dp (°)	Hs (ft)	Tp(s)	Dp (°)
30 Aug	0736	1.6	9	315	1.7	14	175
31 Aug	0836	1.2	9	315	1.6	12	170
31 Aug	1906	0.7	8	305	2.0	11	195
1 Sep	0706	1.5	8	310	1.7	9	205
2 Sep	0806	1.2	8	310	2.2	17	205

The predominant swell direction for this time of year is from the south, and south Pacific swell energy was evident in the record, albeit small. During the period of the fieldwork, a trivial amount of swell energy was coming out of the North Pacific. The archived deep-water swell information indicates that the deep-water swell conditions during the fieldwork were markedly benign, particularly on the day of the breach. It should be noted that the Goleta Beach site is unique: the deep-water swell conditions would be much more of a factor for most locations in California. The Goleta Beach site is protected from northerly deep water swell due to its south facing orientation and wave shadowing by Point Conception, and the site is protected from southerly deep water swell due to the Channel Islands; most other sites in California (outside the Santa Barbara area) would be more exposed to north Pacific swell energy in the winter and/or south Pacific swell energy in the summer. The nearshore waves during the fieldwork were small and did not vary significantly from day to day. Small waves, approximately 1 foot, were present during the sampling events.

Longshore Current

As the name suggests, longshore currents are currents that flow along the shore. These currents are generated by waves breaking while approaching the coast obliquely. Typical values for the longshore currents are about 1 m/s on natural beaches (Office of Naval Research, 2001). Significant temporal and spatial variability is characteristic of longshore currents, however, and considerable averaging must be done to obtain a mean value representative of a beach as a whole (Inman et. al., 1986). The currents are generally strongest within the surf zone and diminish offshore from the surf zone near the shoreline (URS Greiner, 1999). The intensity of the longshore current depends on the height and direction of the incoming waves; the current strength increases with increasing wave heights and the obliqueness of the wave approach angle relative to the shoreline (URS Greiner, 1999).

Wave-driven longshore currents are confined to the surf zone (Inman et. al., 1986). Surf-zone longshore currents advect a tracer much faster than any cross-shore or outside the surf zone processes. Currents outside the surf zone are not wave-driven and can be in a direction opposite to the surf currents (Inman et. al., 1986), which is the case here. Considering cases in which measurable longshore currents existed both in the surf zone and at a pier end, Shepard and Saylor (1953) found these currents to oppose each other about 1/3 of the time. The prevailing current well outside the surf zone for the Santa Barbara Channel is westward, while waves drive nearshore flow eastward.

As one means of characterizing the longshore flow during the experiment, a hand-held global positioning system (GPS) mounted in a float that could track the longshore current outside the surf zone. A field calibration exercise determined that the GPS made position measurements with an accuracy of +/- 5 m. The GPS unit was placed inside a 9 inch wide, 13 inch long, 4-½ inch deep plastic Tupperware container, so that it was centered and unable to slide (or influence the balance of the float). A bottom sail was created using two sheets of stiff plastic; the sheets of plastic were assembled so that they formed an "X". The "X" was mounted to the bottom of the Tupperware, extending approximately 10 inches below the Tupperware. Eight pounds of ballast were affixed to the base of the "X" sail, so that the drifter buoy would not overturn, and the sail area presented by the Tupperware was minimized.

The GPS unit was set to auto record a waypoint every 30 seconds to capture the current speed and direction along the buoy's track. The drifter buoy was placed in the ocean from the Goleta Pier at approximately 40 yards offshore. Two deployments of the drifter buoy were made, one on the morning of August 30 and one on the afternoon of Aug 31. In both cases, the drifter buoy traveled in a predominantly eastward (downcoast) direction at an average speed of 0.3 fps (9 cm/s); this represents the longshore current outside the surfzone, but it is not indicative of the prevailing westward current in the deeper waters of the Santa Barbara Channel. At this rate, water exiting the slough would reach 400 yards downcoast in approximately an hour, assuming no other significant physical forcing is occurring. The deep-water swell and near-shore wave conditions indicate that the wave climate was relatively benign during the breaching event; therefore, a significant longshore current in the surf zone would not be expected.

Pre-breach Conditions

In order to accurately assess typical indicator organism abundances at Goleta Beach, weekly ocean water quality monitoring results from Santa Barbara County EHS's database were obtained. Each week, the EHS department tests a single grab sample at Goleta Beach for all three indicator organisms. The data provide an ideal opportunity to examine the range and weekly variability among the different indicators. Figure 5.3 shows the weekly sampling results from the summer months leading up to the breach event at Goleta Beach (Goleta Beach Weekly Water Quality Database, 2000).

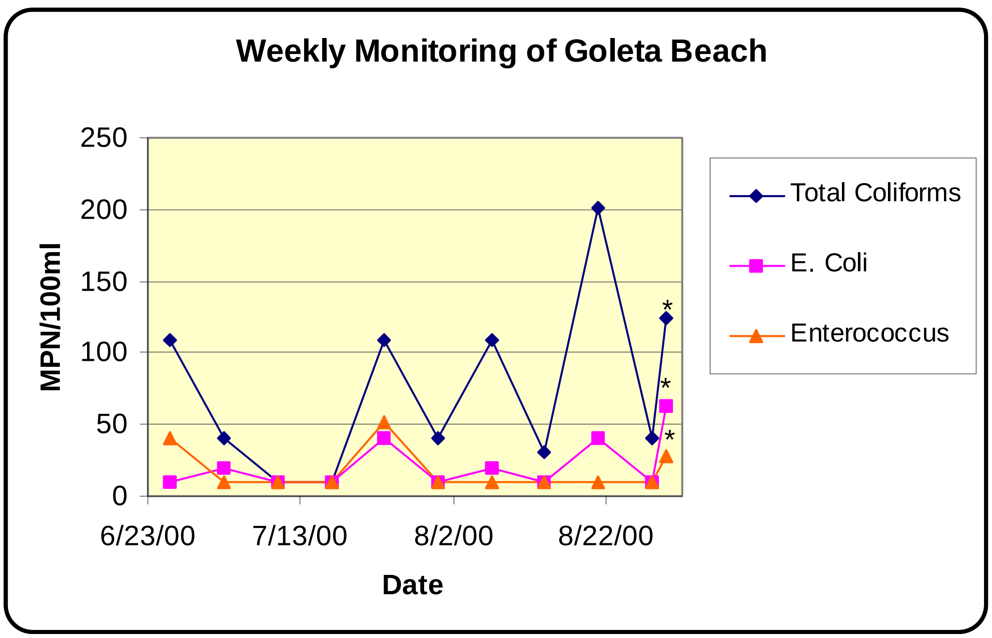


Figure 5.3. Weekly Bacteria Samples from County EHS at Goleta Beach
*(Day Zero) Samples taken 24 hours prior to breach event

The data demonstrate the weekly bacteria levels were well below the water quality standards, as specified in Assembly Bill 411, and the samples taken the day before the breach (Day Zero) fall well within the range of the typical conditions.

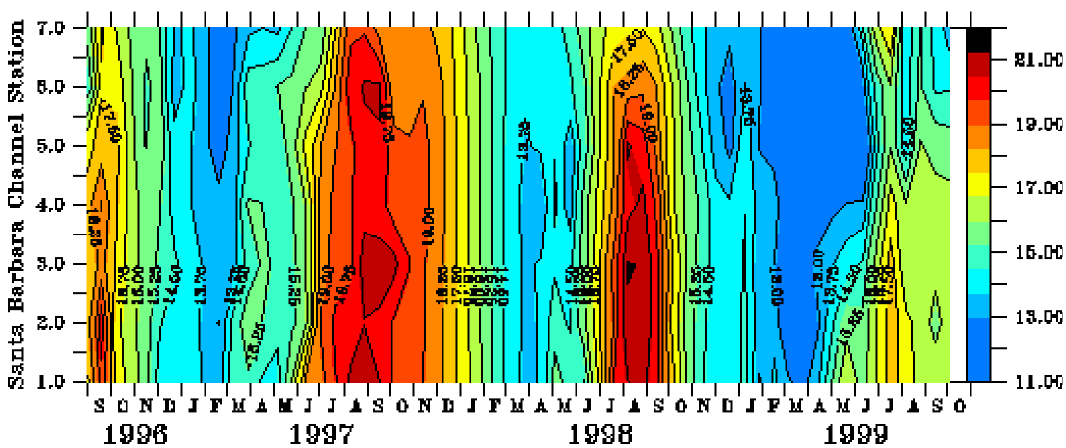
Background conditions were also established for other parameters including nitrate concentrations, salinity, and temperature. Measurements were periodically taken during the month of August to ensure proper standard operating procedures were developed and practiced prior to the breach event. Measurements were also taken along with the bacteria samples during the Day Zero sampling on August 30, 2000. Table 5.2 summarizes the average values associated with each parameter directly prior to the breach of the Goleta Slough.

Table 5.2. Average Background Levels for Selected Variables

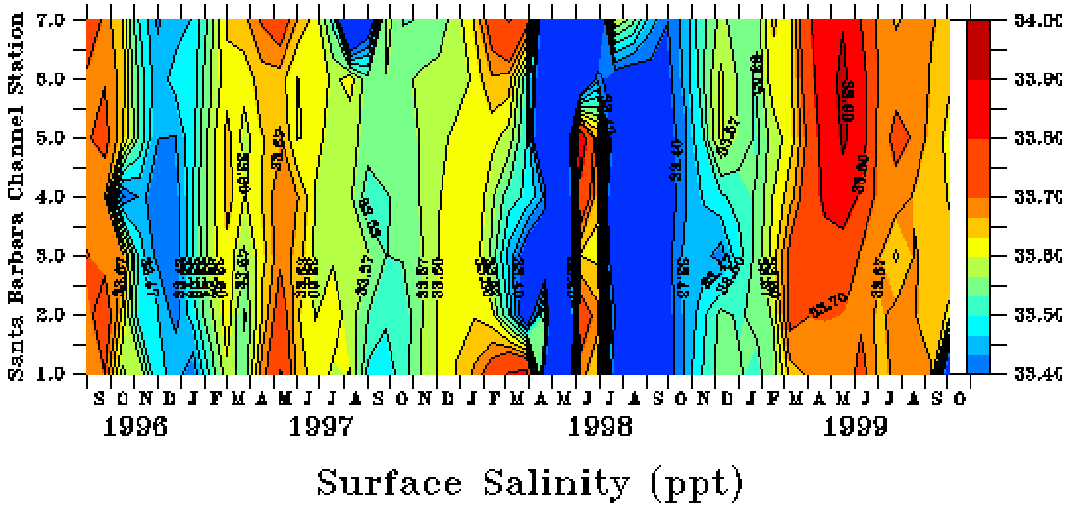
Total Coliforms	*E. coli*	Enterococcus	Nitrate	Salinity	Temperature
50 MPN/100 ml, n=15	20 MPN/100 ml, n=15	10 MPN/100 ml, n=15	0.3 micromolar/L, n=8	33.7, n=8	19.8, n=8

n= number of observations used to quantify background levels

These values were compared to a much larger database from the Plumes and Blooms Project (ICESS, UCSB, 2001) which tracks a variety of parameters offshore including temperature, salinity, and nitrate concentrations. All comparisons between Goleta Beach pre-breach measurements and the Plumes and Blooms offshore measurements were made to the station located closest to Goleta Beach (Station 1). Figure 5.4 below displays the historical data from three of the parameters measured.



Surface Temperature (°C)



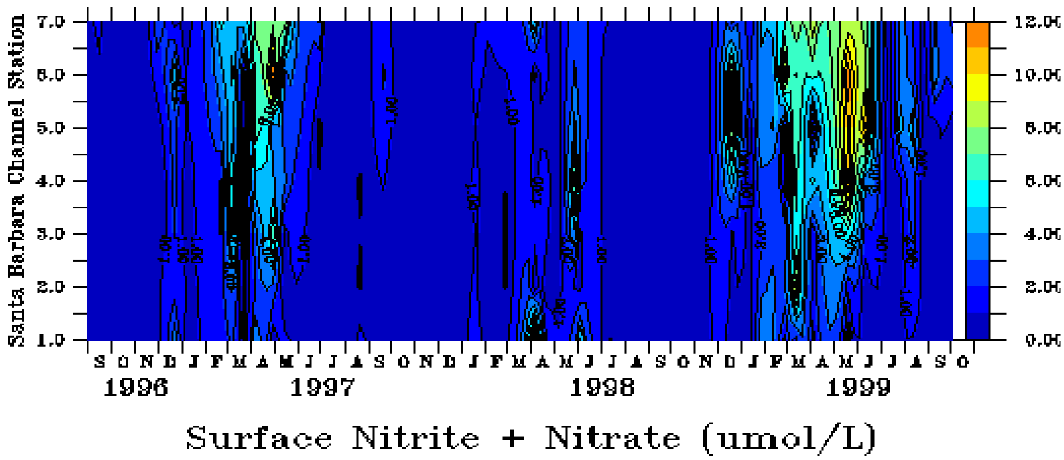


Figure 5.4. Surface temperature, salinity, and nitrate contour maps for local marine waters (Plumes and Blooms, **http://www.icess.ucsb.edu/**, 2001).

According to Figure 5.4, typical sea surface temperatures fluctuate seasonally and vary significantly from year to year. Typical temperatures for August and September range from 19 to 21°C (1999 was cooler than average) and temperatures taken at the Day Zero sampling fell within this range. According to the Plumes and Blooms project data, typical salinity profiles for August/September range from 33.4 to 33.7 ‰, and this is consistent with the salinity measurements taken prior to the breach. According to the contour profiles for nitrite + nitrate (umol/L), typical concentrations for August/September are less than one umol/L, and pre-breach measurements fell well below one umol/L. Ocean water temperature and salinity are examined again in Section 5.3 when the post breach data is discussed.

5.2 Estimated Slough Discharge Volume

An effort was made to obtain the most accurate discharge volume from the Slough mouth attainable with the Project's budget to examine the conclusions in the URS Greiner study (URS Greiner Woodward-Clyde, 1999) that described a relationship between discharge and bacteria levels. A General Oceanics Inc. mechanical flow meter was employed to measure the discharge velocity at the Slough mouth; the flow meter is a small and lightweight general-purpose impeller instrument. A significant measurement goal was to obtain an accurate measurement of the width and the bottom profile to facilitate an accurate cross sectional area measurement. This measurement, combined with an average flow rate for a particular cross sectional area, enabled the calculation of the discharge volume.

A station along the mouth channel was selected for the purpose of measuring the discharge velocity and the cross sectional area, so that the discharge volume could be calculated. To take these measurements, a location with well-defined channel borders and a uniform channel bottom was sought, so that the best effort at an accurate cross-sectional area measurement was facilitated. The flow rate is typically not uniform across the channel; ideally, a channel location was selected where the flow also appeared to be most uniform. Consequently, a number of flow rate readings across the channel and a number of depth readings were recorded in an attempt to characterize the flowrate and the cross sectional area, respectively.

The flowmeter impeller measures 'counts' or rotations. The impeller is immersed for a known time (i.e. 60 seconds), and then a 'counts/second' reading is obtained and converted to a 'distance/second'. This distance/second measurement is averaged for the cross-section at the station and multiplied by the best measurement of the cross-sectional area to obtain the discharge volume. Figure 5.5 depicts the estimated Slough discharge data from the breach with a second-order polynomial trend line fit to the data points.

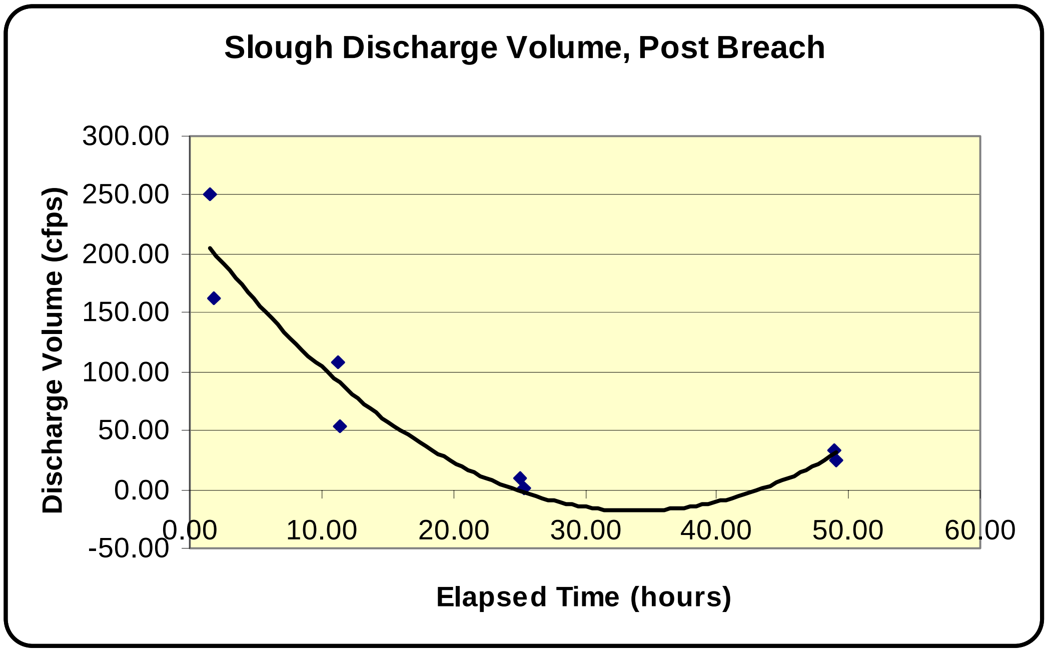


Figure 5.5. Estimated discharge volume versus elapsed time from the breach.

The discharge volume out of the Slough was initially high and significantly decreased at each measurement until the morning of September 1 (elapsed time of approximately 24 hours). The morning of September 2 (approximate 48 elapsed hours) had an increase in the flowrate from the previous morning. Since flowrate data is at discrete times widely spaced in time, the function of how the flowrate changes (decreases) with respect to time, particularly later in the elapsed time, cannot be construed. Later in the elapsed time, a flowrate reversal (water flowing into the Slough) may actually occur due to the reduction of the head inside the slough and an incoming tide. As a result, confidence in the flowrate function over time at later elapsed times is significantly diminished. Therefore, when a conceptual model of mass balance was attempted (Section 5.4), the two data points that were collected at a sampling time were averaged, and a linear decrease in flowrate was assumed for the data collected on the first day.

5.3 Patterns of Discharge

The discharge of the Slough water subsequent to the breach affected the adjacent ocean water quality at Goleta Beach in numerous ways, and the following sections will describe the patterns of discharge upon each of the following parameters: total coliforms, E. coli, enterococcus, nitrate, salinity, and temperature.

Total Coliforms

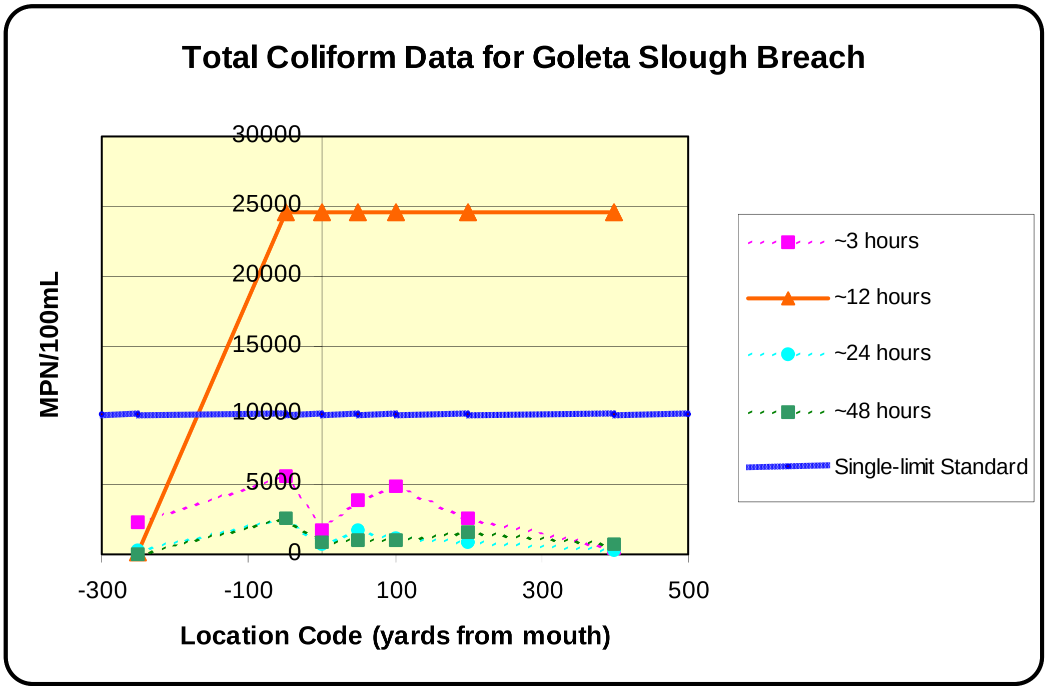


Figure 5.6. Total Coliform Data for Goleta Slough Breach
Note: All hours reported post-breach

The total coliform results are displayed in Figure 5.6 above. The flattened peak for total coliforms observed 12 hours after the breach was due to insufficient dilutions of the samples during the laboratory analysis. This problem was most evident during this specific sampling period and for all the total coliforms samples taken from the slough during the study (Appendix B). Exceedences of single-limit grab samples (10,000 MPN/100 ml) only occurred at the 12-hour sampling period. All the sampling locations, except for the –250 location, recorded maximum MPNs during this sampling period; slough abundances remained elevated for the duration of the field study.

Escherichia coli

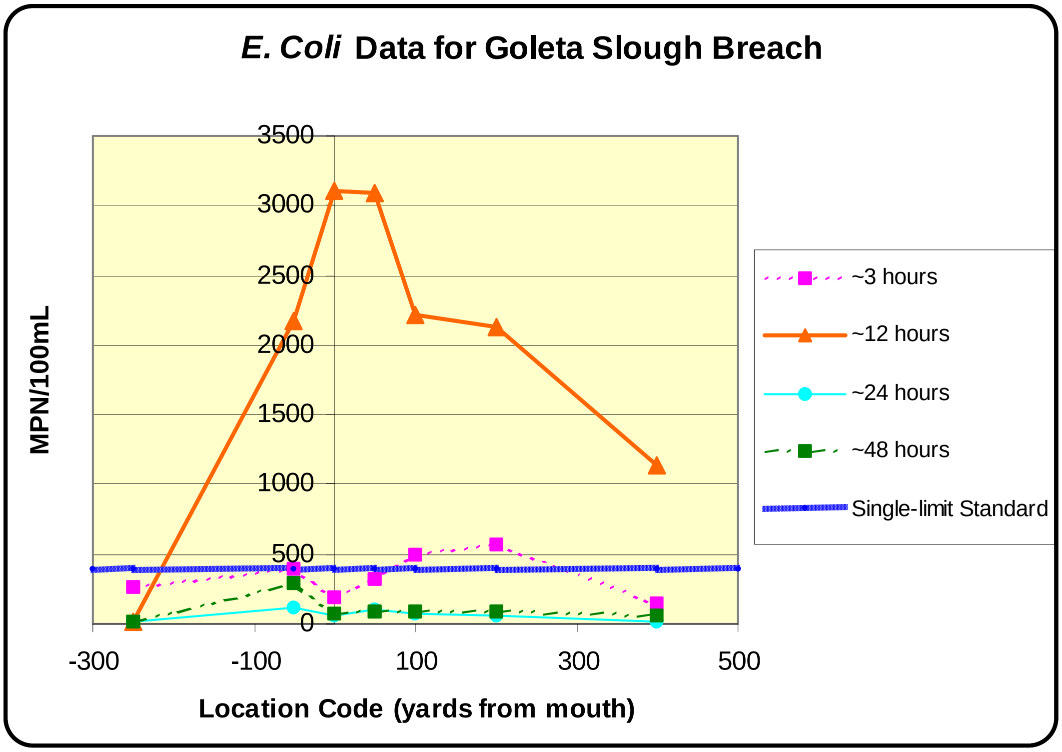


Figure 5.7. *E. coli* Data for Goleta Slough Breach
Note: All hours reported post-breach

E. coli exceeded the single-limit standard (400 MPN/100 ml) three hours post-breach at the following locations: -50, +50, +100, and +200. At the 12-hour sampling period, all the sampling locations except the control location (-250) observed *E. coli* abundances well above the standard limit. At the 48-hour sampling period, an exceedence occurred at the –50 sampling location. MPN densities in the slough remained a magnitude or more above the single limit standards for the duration of the study (Appendix B).

Enterococcus

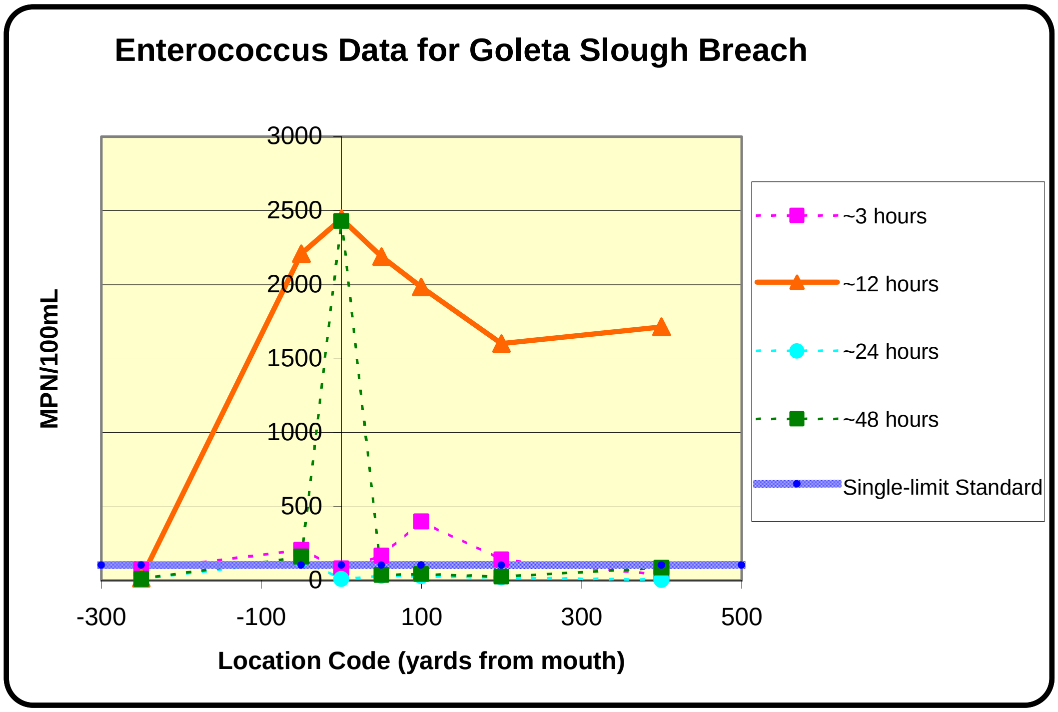


Figure 5.8. Enteroccocus Data for Goleta Slough Breach.
Note: All hours reported post-breach

Enterococcus exceeded the single limit standard (104 MPN/100 ml) at all sampling locations except for +400 location three hours after the breach. Twelve hours after the breach, all the sampling locations except the control location (-250) observed enteroccocus abundances a magnitude or larger above the standard limit. By 24 hours post-breach, the -50 sampling location was the only one to record an exceedence of the standards. At the 48-hour sampling period, the -50 and 0 (mouth) sampling locations were in violation of water quality standards. MPN densities in the slough remained extremely high for the duration of the experiment, often an order of magnitude or more above the single limit standards.

Summary of Water Quality Violations

The graphs for each indicator organism reveal the distinctive patterns observed throughout the duration of the study. Table 5.3 summarizes the number of water quality violations for each organism and the sampling period and location for when they occurred.

Table 5.3. Summary of Water Quality Violations For Each Sampling Event.

Station (yards)→ Indicators↓	-250	-50	0 (mouth)	+50	+100	+200	+400	Total No. of Violations
Total Coliforms		12	12	12	12	12	12	**6**
E. coli		3,12,24	12	3,12	3,12	3,12	12	**11**
Enterococcus	3	3,12,24,48	3,12,48	3,12	3,12	3,12	12	**15**
Total No. of Violations	**1**	**8**	**5**	**5**	**5**	**5**	**3**	

Note: Numbers reported as hours post-breach.

Enterococcus violated the water quality standards more than the other two indicators (Table 5.3). This finding is consistent with and supports other studies that have documented that enterococcus is the most conservative organism for ocean water quality monitoring (Gersberg et al., 1995).

Nitrate Concentrations

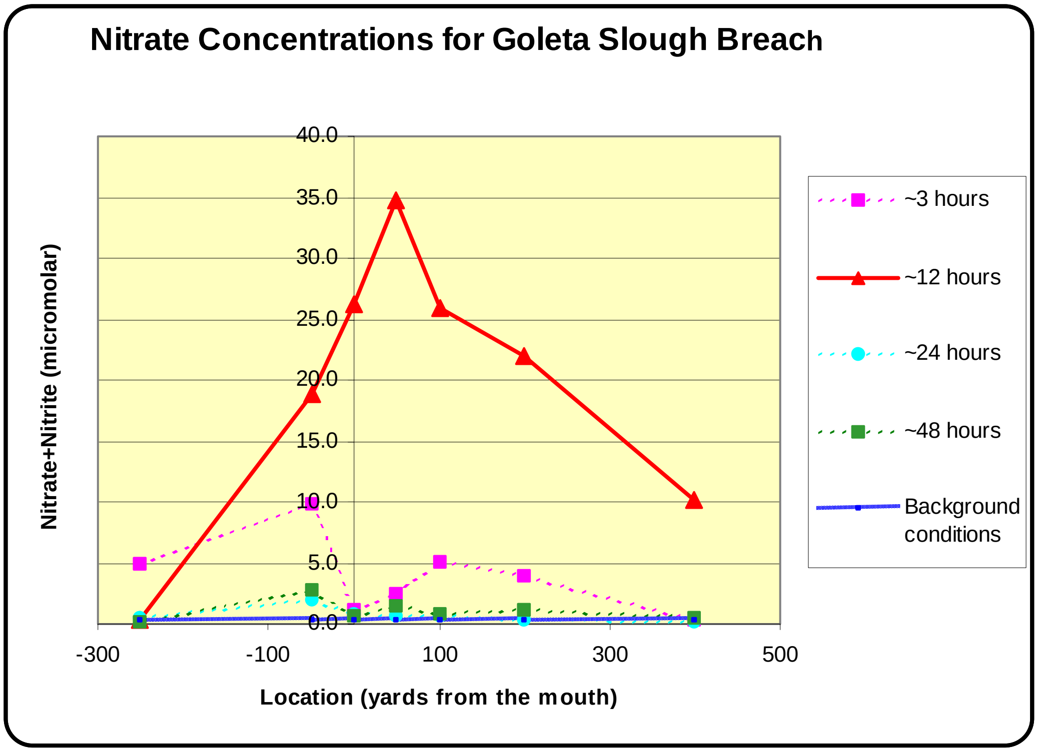


Figure 5.9. Nitrate Data for Goleta Slough Breach.
Note: All hours reported post-breach; background conditions too low to observe on graph

The nitrate concentrations revealed similar patterns to the *E. coli* abundances at the ocean water sampling locations. The highest observed nitrate concentrations occurred at the 12-hour sampling event and decreased to background levels for the remaining sampling periods. Nitrate levels in the slough remained an order of magnitude or greater compared to background levels in the slough for the duration of the field study.

Ocean Water Temperature

Typical surface ocean water temperatures for the Goleta nearshore region for August and September range from 19 to 21°C (ICESS, UCSB, 2001). Figure 5.10 contains the ocean water temperatures at sampling locations subsequent to the breach.

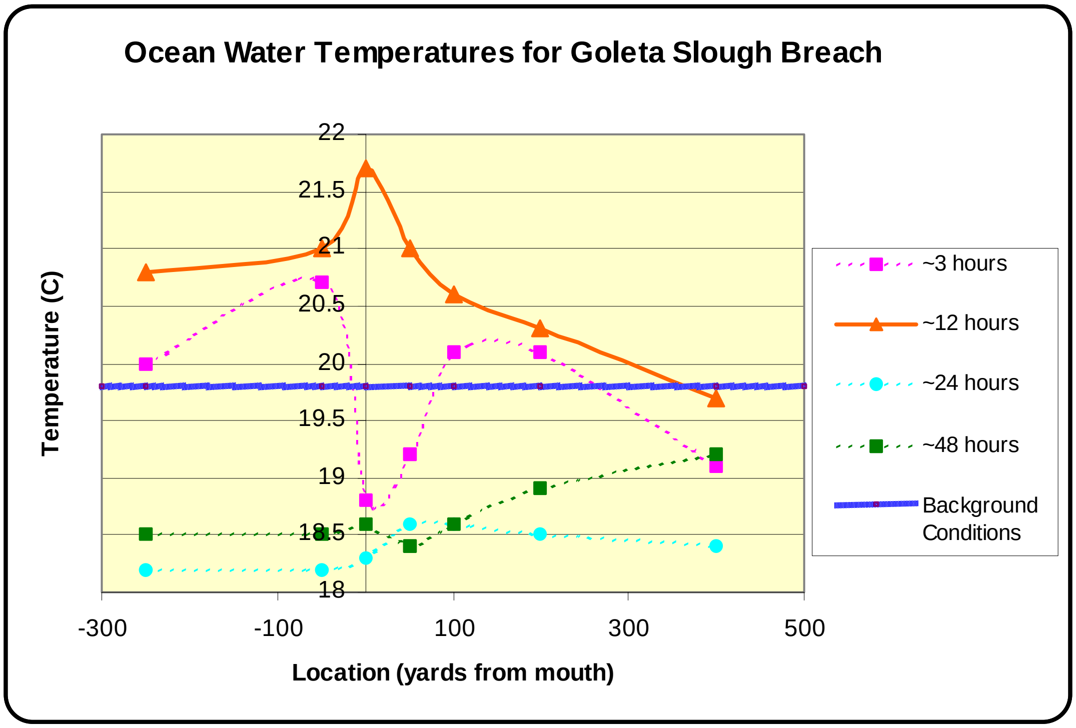


Figure 5.10. Ocean Water Temperatures for Goleta Slough Breach.

Prior to the breach, the Slough water was warm compared to the ocean water temperature. Ocean water temperature fluctuations due to the breach were evident at 3-hour and the 12-hour sampling periods. The 3-hour sampling period shows the ocean water temperature at the mouth apparently unaffected by the warmer water being discharged from the Slough. A possible explanation is that the mouth sampling location was adjacent to the mouth rather than in the inlet, and the discharge flow was still high at the 3-hour sampling period, so the mouth temperature measurement reflects mostly ocean water since the high flow was taking the Slough water out to deeper waters where it slowed and dissipated, thereby influencing the ocean water 50 to 100 yards on either side of the mouth before influencing the water adjacent to the mouth. The 24-hour and 48-hour sampling periods displayed a more constant alongshore temperature profile, with the temperature range being between 18 and 19 °C. This indicates that warmer Slough water had mixed with the ocean water and cooled, no longer influencing the ocean water temperature. The ocean water temperature at all times subsequent to the breach was warmer than the seasonal average.

Ocean Water Salinity

The typical surface ocean water salinity for the Goleta nearshore region for August and September range from 33.4 to 33.7 ‰ (ICESS, UCSB, 2001). Figure 5.11 depicts the ocean salinity at the sampling locations for each of the sampling times, while Figure 5.12 shows the salinity in the Slough versus elapsed time from the time of the breach.

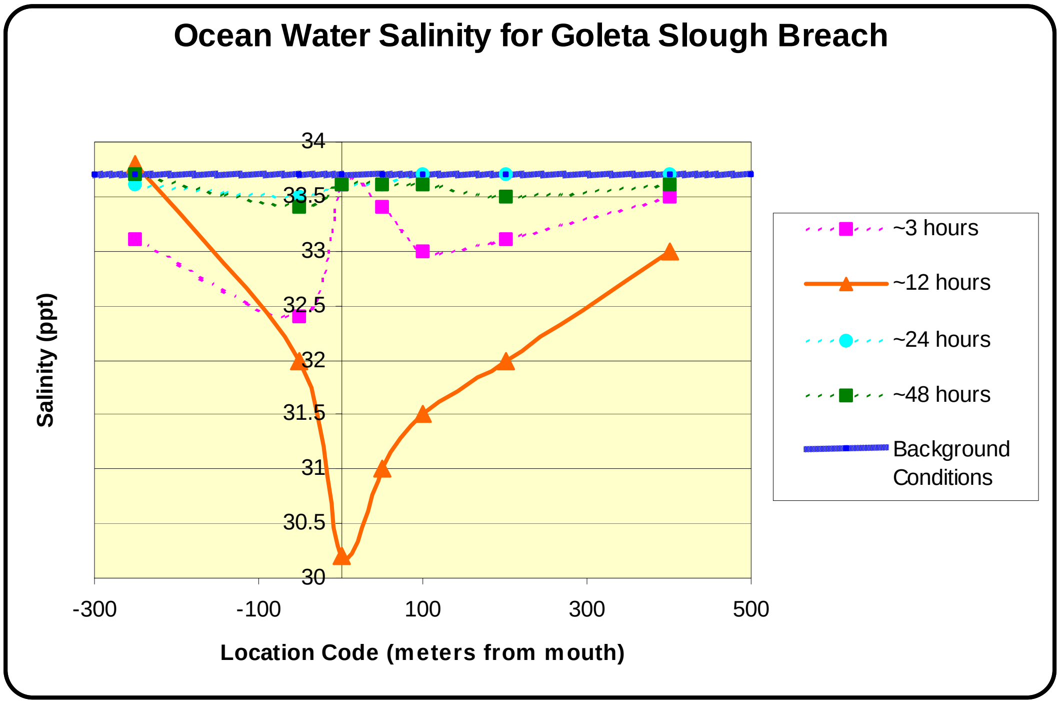


Figure 5.11. Ocean Salinities for the Goleta Slough Breach

At the 3-hour sampling period, the ocean water salinity is lowered at –50 yards and 100 yards; the impact of the fresh water plume appears more pronounced upcoast for this sampling period. At the 12-hour sampling period, the ocean water salinity was significantly impacted by the freshwater that had been discharged out of the slough: the ocean water salinity was significantly lowered, to almost 30 ‰, in front of the Slough mouth, and lowered across all the sampling stations, getting closer to background levels the further the measurement was from the Slough mouth. At the 24- and 48-hour sampling periods, the ocean water salinity had returned to a uniform alongshore profile, with measurements close to the mean surface ocean water salinity value for the region for this time of year.

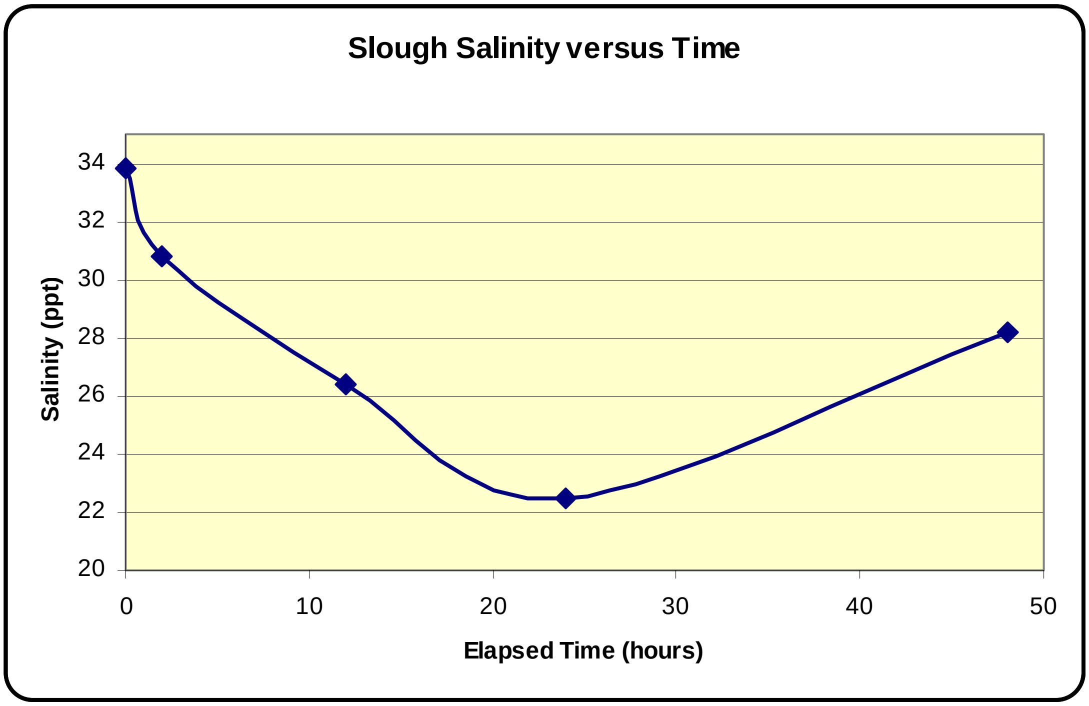


Figure 5.12. Slough Salinity versus Elapsed Breach Time

The Slough salinity (measured inside the Slough close to the mouth) initially matched the ocean water salinity and decreased during the first 24-hours after the breach. This trend is indicative of fresh water from the upper reaches of the Slough being drawn down, decreasing the salinity value of the water exiting the slough. Slough salinity values for the 24- and 48-hour sampling periods show the slough salinity on an increasing trend, attributable to tidal influence (flushing). This pattern is consistent with the flowrate data.

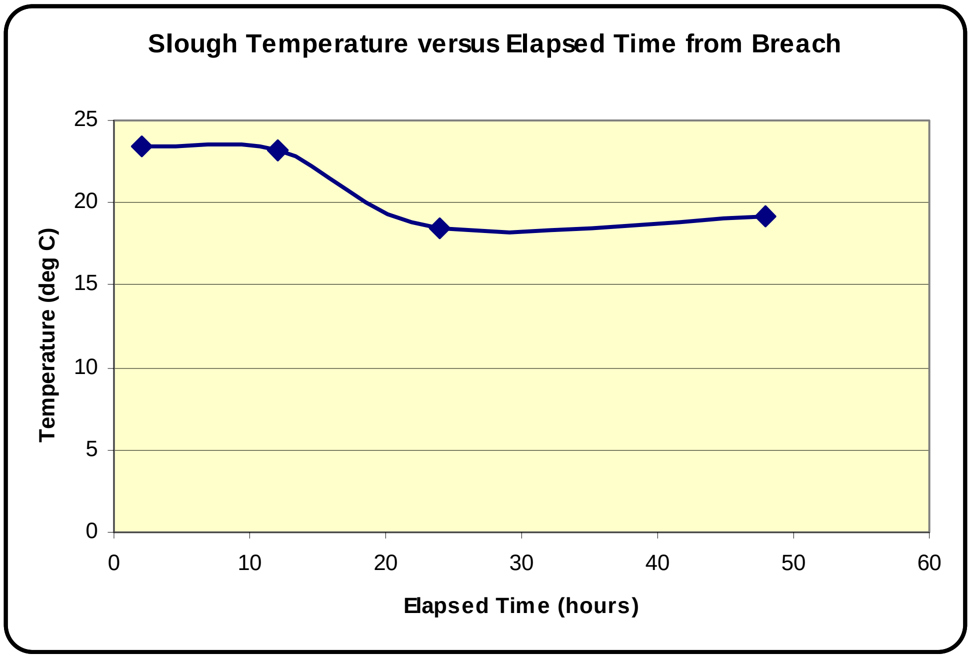


Figure 5.13. Slough Water Temperature versus Elapsed Breach Time

At the time of the breach, the slough water temperature was elevated above the ocean water temperature at approximately 23ºC. The slough water temperature began to decline within 12 hours as a result of tidal flushing and ocean water mixing with the slough water. Using the seawater equation of state, temperature and salinity values for the slough and the ocean suggests that less dense water was exiting the slough and potentially forming a freshwater lens over the more dense ocean water. As tidal flushing occurred over greater elapsed times from the breach, the slough water temperature dropped and eventually matched the ocean water temperature. Concurrently, the slough salinity began to increase.

5.4 Statistical Analysis of Bacterial Data

The following statistical tests will describe the statistically significant differences between sample periods and sample locations for each indicator organism, as well as identify significant linear regression relationships among the particular variables.

Control Site

A control site was chosen 250 yards upshore of the Goleta Slough mouth. Background levels were established by sampling 24 hours before the breach event, and these bacteria abundances were compared to the weekly monitoring data for Goleta Beach to confirm the indicator organism levels fell within range (Figure 5.3). All bacteria abundances fell clearly within the range of normal conditions for the time period. The function of the control site served to primarily establish whether the observed levels of bacteria in the ocean after the breach event were significantly different than the background levels prior to the breach, indicating slough bacteria signals in the ocean.

To determine whether there was a significant difference between background conditions and the subsequent sampling periods at the control site, an analysis of variance (ANOVA) was performed on the indicator organism observations for each sampling event. There was a significant effect between at least one of the sampling periods and the background conditions (refer to the S-Plus software output in Figure 5.14). To determine which sampling events differed from the control, a multi-comparison test was performed for each indicator organism (S-Plus 2000, 2000). The test revealed which sampling period(s) was significantly different from the control. The sample outputs in Figures 5.14 and 5.15 are examples from the analysis on *E. coli*.

```
 *** Analysis of Variance Model ***

Short Output:
Call:
   aov(formula = E.Coli ~ Time, data = SDF6, na.action =
na.exclude)

Terms:
                    Time Residuals
 Sum of Squares 185506.5   15902.5
Deg. of Freedom        4        15

Residual standard error: 32.5602
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value         Pr(F)
     Time  4  185506.5 46376.62 43.74465 4.250658e-008
Residuals 15   15902.5  1060.17
Critical point:  3.0879
```

Figure 5.14. ANOVA Output for Control Site for *E. coli*

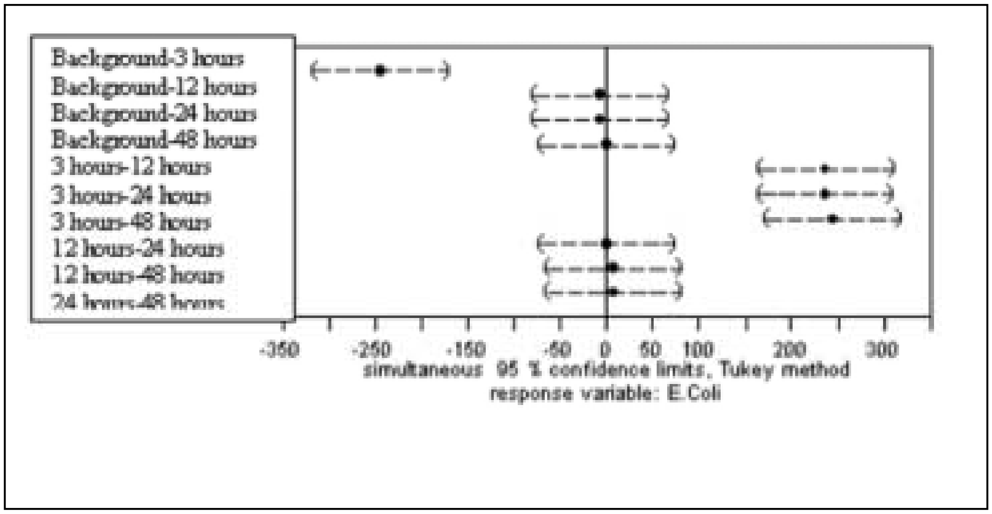


Figure 5.15. Comparison of *E. coli* Levels for Each Time Code at Control.

The ANOVA output table in Figure 5.14 reveals a significant F-Value compared to the critical value (43.74 > 3.09), indicating at least one of the sample periods varied from the control. Figure 5.15 shows that 3-hour sampling period was the only sampling event that significantly differed compared to the background conditions. The same pattern was observed for total coliforms and enterococcus. Aside from the raised bacteria levels during the first sampling period, the location served as an effective control site for comparing background bacteria levels against elevated levels following the breach.

Comparison of Background Levels versus Post-Breach Levels

In order to evaluate how the different stations compared to background levels over discrete time intervals, ANOVA analysis and multi-comparison methods were used to identify those sites that had significant increases in bacteria levels compared to the background levels. The results of the ANOVA analysis are summarized in Table 5.4.

Table 5.4. Background Conditions versus Post-breach Conditions

Location	~3 hours	~12 hours	~24 hours	~48 hours
-250	X			
-50	X	X	X*	X
0	X	X		X$^{\tau}$
+50	X	X		
+100	X	X		
+200	X	X		
+400		X		

X= significant difference compared to background levels

Note: X = all three indicator organisms; X*= T. coliform only; X$^{\tau}$= Enterococcus only

The results from Table 5.4 clearly demonstrate the majority of statistically significant differences between the background levels and the observed bacteria levels occurred during the first two sampling periods (i.e. less than ~24 hours post-breach). This information is consistent with the previously displayed graphs that show the majority of bacteria abundances in the ocean subside to background conditions within 24 hours. Table 5.4 does not provide any information on the magnitude of the differences between the observed levels versus background conditions, nor does it identify when these elevated levels violate water quality standards.

Analysis of Significant Differences Between Sampling Locations

A series of multi-comparison methods were performed to assess the bacterial abundances at each sampling location that significantly varied from one another for each discrete sampling period. The purpose of this analysis is to identify the minimum number of sampling locations necessary to capture the spatial patterns of the three different indicators organisms based on the data generated from the study. This analysis also identifies the locations that did not differ from one another, thereby indicating excess sampling efforts.

The number of times a location's bacteria observations are deemed statistically significant from the sampling location on either side can be tallied up from each table and Table 5.5 shows the results for all three indicator organisms.

Table 5.5. Significant Differences between Sampling Locations

Total Coliforms

Sampling Time	Location Code						
	-250	-50	0	+50	+100	+200	+400
~ 3 hours	X	X	X		X		X
~ 12 hours	X	X			X		X
~ 24 hours	X	X	X	X			
~ 48 hours	X	X		X			

E.Coli

Sampling Time	Location Code						
	-250	-50	0	+50	+100	+200	+400
~ 3 hours		X	X			X	
~ 12 hours	X	X		X			X
~ 24 hours	X	X	X	X			
~ 48 hours	X	X	X	X			

Enterococcus

Sampling Time	Location Code						
	-250	-50	0	+50	+100	+200	+400
~ 3 hours		X			X	X	
~ 12 hours	X	X		X			X
~ 24 hours	X	X	X	X			
~ 48 hours		X	X	X			

X= significant location

Note: If there are no significant differences between downcoast locations, the default selection is +50 for the most conservative approach.

Table 5.6 combines the number of times a location's bacteria levels varied significantly from the location on either side of the specified location with the number of water quality violations that occurred. The results show that the majority of significant responses between the different sampling locations occur around the mouth, indicating locations on either side of the mouth should be targeted for monitoring. The largest number of water quality violations occurred at the -50 sampling location, further strengthening the need to monitor this specific location.

Table 5.6. Total Number of Times Location Classified as Significant.

Location Code	-250	-50	0	+50	+100	+200	+400
# of Significant Responses	9	12	7	8	3	2	4
# Violations	**1**	**8**	**5**	**5**	**5**	**5**	**3**

The study site is south-facing and is sheltered by Campus Point (UCSB) to the west and the Channel Islands to the south, which minimizes the effects of deep-water swells and wave-induced longshore currents. Therefore, it is not unusual that a relatively equal number of bacteria exceedences were observed both upcoast and downcoast of the mouth. At other beaches where the wave climate and the corresponding longshore currents are more pronounced, one might expect to find a bacterial signal in either a predominant upcoast or a predominant downcoast direction, dependent on the direction and magnitude of the longshore current.

Based off the analyses from Tables 5.5 and 5.6, a streamlined monitoring protocol can be designed for future monitoring efforts. The objective is to provide the most effective and efficient sample design that public health officials can use to safely monitor ocean water quality. The design also includes a recommendation for the number of sampling days necessary to ensure ocean water quality standards have been met.

Table 5.7 displays the recommended sampling design for the Santa Barbara County EHS Department for post-breach monitoring activities at the Goleta Slough. Although the analysis of the data showed significant pulses of the indicator organisms within the 12-hour sampling period, the downcoast locations beyond the +50 location were removed from the proposed sample design because the majority of time, bacterial abundances did not significantly vary beyond the 50-yard distance.

Table 5.7. Minimum Proposed Post-breach Monitoring Activities.

Location Code (→) and Time (↓)	-250	-50	0	+50	+100	+200	+400
2-3 hours		X	X	X			
12 hours		X	X	X			
24 hours		X	X	X			
48 hours		X	X	X			
72 hours		X*	X*	X*			

* 72-hour sampling is unnecessary if 48-hour results are below standards.

In general, the +50 location was a fair indicator of conditions downcoast. Monitoring the sampling locations +100, +200, and +400 at the 12-hour sampling period indicates this observed pattern is characteristic of all breach events at the Slough. Although this may be true, it is possible that the patterns of bacterial dispersion will change with each breach event. Further monitoring of Goleta Slough breach events would be extremely useful for verifying the existence of bacteria pulses, and if so, the temporal and spatial patterns associated with them.

The control site showed up as a significant location for the majority of the study, but it was removed from the sample design because it is not necessary for the County EHS to sample locations that have a low probability of exceeding the water quality standards. It is more useful for public officials to allocate their sampling efforts to locations closer to the source that are more likely to contain higher bacteria abundances. Although the majority of water quality violations occurred within the first 24 hours, exceedences were observed through the 48-hour experiment. Since violations were still observed at this time, further sampling events (the next one following at 72 hours) should occur to verify indicator abundances fall below AB 411 standards. If needed, monitoring should occur every 24 hours following the low tide in the tidal cycle until exceedences subside.

Regression Relationships Among Variables

Linear regression analyses were performed between each indicator organism and the other field data collected during the experiment. The independent variables consisted of nitrate concentrations, TSS, salinity, dissolved oxygen (DO), and temperature and the dependent variables consisted of two of the three indicator organisms. The purpose of the analysis is to develop a conceptual understanding of the interactions among the variables observed in relation to the spatial abundances of the bacteria.

Total coliforms were removed from the analysis because of the insufficient dilutions during the laboratory analysis. Table 5.8 demonstrates the strong and weak relationships among the different combinations of bacteria and the other variables. Nitrate, salinity and temperature were all significantly correlated with the *E. coli* and enterococcus and serve as useful variables for estimating influence of the Slough water in the ocean; little correlation was shown for TSS and DO.

Table 5.8. Linear Regression Relationships Among Specified Parameters

Indicator Organism	Nitrate	TSS	Salinity	Dissolved Oxygen	Temperature
E. coli	0.87, ≈0	0.002, 0.59	0.92, ≈0	0.001, 0.86	0.57, 5.8e-6
Enterococcus	0.57, ≈0	0.007, 0.34	0.61, 3.1e-007	0.12, 0.73	0.32, .002

*Relationships calculated with a 95% Confidence Interval, reported by R-values, p-values respectively

Regression techniques were also used to estimate the extent of the slough water plume in the ocean, primarily in the downcoast direction. Using linear regression techniques, the independent variables consisting of nitrates, *E. coli*, salinity, and temperature were independently regressed against the dependent sampling locations (0, +50, +100, +200, +400) downcoast from the mouth. TSS was not considered for this analysis because of the lack of correlation observed with the bacteria data. The data from the 12-hour sample period was used for this analysis because this was the only period that documented significant lateral migration of bacteria in either direction of the Slough mouth.

Background conditions for each variable, established in Section 5.1, Table 5.2, were put into each regression equation to estimate the distance at which the independent variables returned to normal levels (Table 5.9).

Table 5.9. Regression Equations for Estimating Plume Length

Independent Variable	Dependent Variable = Distance Regression Equation	R-value, p-value	Estimated Extent of Plume Downcoast (yds)*
Nitrates	Distance = 509.3 – 13.9*(nitrate)	0.88, 4.95e-08	505
E. coli	Distance = 484.5 – 0.14*(*E. coli*)	0.67, 8.8e-05	482
Salinity	Distance = -5287.5 + 170.5*(salinity)	0.63, 0.10	458
Temperature	Distance = 4232.5 –197.6021*(temp)	0.87, 0.01	319

*Estimated length that observed variable returns to background levels
Significance reported by R-values, p-values, respectively

Using the regression equations identified in Table 5.9, estimates of the plume length can be calculated by inputting the corresponding background values found in Table 5.2. For example, the average seawater nitrate concentration for pre-breach conditions was 0.3 micromolar/L. Inputting this value into the nitrate distance equation results in the estimated distance of 505 yards from the mouth of the Slough. This represents the distance at which the influence of the plume of Slough water is no longer detectable, specific to nitrates. Using the same method, distances at which E. coli exceeded the single grab standards can be estimated. The standard for E. coli is 400 MPN/100ml, so the estimated distances at which violations occur extended to 429 yards. According to Table 5.9, the salinity relationship is non-significant and should not be used to estimate the extent of the plume for this analysis. Enterococcus was not used in this analysis because the pattern of attenuation in the downcoast direction was non-linear and did not satisfy the assumptions for a linear regression model. Enterococcus levels actually increased from the (+200) to (+400) locations. All but the temperature equation estimate the extent of the plume to exceed the arbitrary 400-yard boundary established in previous bacteria/illness studies. This does not imply that water quality standards are violated the entire extent of the plume but there is the potential for violations beyond the 400-yard boundary, as indicated by the E. coli estimates.

5.5 Conceptual Model of Mass Balance

A mass balance approach is used to scale the physical extent of the plume and confirm that the plume is consistent within an order of magnitude with the estimated volume of discharged Slough water. Visual observations of the plume length and width are used with the volume discharge estimate to characterize the depth of the discharged freshwater plume created from breaching the Slough. Several assumptions are made in order to perform the calculations, including:

- The assumed plume length is based on visual observations that indicated the plume is at least 400 yards downcoast and 200 yards upcoast. Note: the plume length downcoast is reaffirmed with statistical evidence (Table 5.9) that indicated the plume signal in the range of 400 to 500 yards. A total length of 700 yards is used in the calculation, representing a plume that reaches 500 yards downcoast and 200 yards upcoast.

- The plume width based on visual observations is approximately the width of the pier.

- The flowrate varies in a linear manner between the discrete times when the flowrate was measured.

Slough Water Volume

Before characterizing the size of the plume created by the discharge, an estimate of the volume of available water in the slough is calculated. This information serves as a check that the calculated plume volume is not larger than the available volume of water in the slough and facilitates calculating what fraction of slough water gets into the ocean on what time scales. Plans (1":200' scale) of the Goleta Slough were obtained from Santa Barbara County Flood Control Office and were used to trace out the surface area of the tributaries. The County Flood Control office also provided depth surveys of Goleta Slough's tributaries that were prepared for a channel dredging project conducted by the Flood Control office. The depth surveys are available for Atascadero, San Jose, and San Pedro Creeks. These depth surveys are referenced to obtain channel depths for the tributaries. When selecting a channel depth at a survey station, a high tide condition in the Slough is assumed. The slough mouth had been closed for approximately 10 days prior to the breach, and, during this time, the highest tides spill into the slough, but no water escapes due to the sand berm (Treiberg, 2001). This results in a water surface elevation consistent with the highest tide that occurs during the time the mouth is closed (evaporation negates inflow from creeks) (Treiberg, 2001). The high tide condition assumption is a high tide of 6.8 ft; this equates to a mean sea level (MSL) of 4 feet from which the channel depth is referenced. The MSL-tide relationship is as follows: 0 ft MSL equals a tide of 2.8 ft which is considered mean tide (Treiberg, 2001). Mean lower low water (MLLW) equals a tide of 0 ft or 2.8 ft below MSL, and mean higher high water (MHHW) equals a tide of 5.6 ft or 2.8 ft above MSL (Treiberg, 2001). An average depth of 5 feet is assumed for Tecolotito and Carneros Creeks since depth survey data is not available for these creeks. The results follow:

Table 5.10. Slough Volume Estimates

Creek	Average Depth (ft)	Surface Area* (sq ft)	Volume (cu ft)
Atascadero	6	448,000	2,688,000
	8	252,000	2,016,000
	5	108,000	540,000
San Jose	7	130,000	910,000
	4	32,800	131,200
San Pedro	7	46,400	324,800
	3.8	82,000	311,600
Tecolotito	5	568,400	2,842,000
Carneros	5	102,800	514,000
Total			**10,278,000**

* The conversion of sq. in. measured with the planimeter to sq. ft. of creek surface area was based on the scale of the plan: 1 in = 200 ft, so 1 sq in = 40,000 sq ft.

The slough water volume estimate is 10,278,000 cubic feet. This volume estimate is considered a conservative (over-) estimate due to conservative depth averaging and is considered only accurate to an order-of-magnitude due to the depth averaging and difficulties/inaccuracies associated with using the planimeter when calculating surface area.

Plume Volume as a Function of Time After the Breach

Once the estimated volume of slough water is calculated, the next step is to utilize the flowrate data to estimate the volume of slough water discharged. The flowrate data is interpreted as follows. While the flowrate is known at discrete time points, the function of how the flowrate changes (decreases) with respect to time, particularly later in the elapsed time, cannot be construed. Later in the elapsed time, a flowrate reversal (water flowing into the Slough) may actually occur with an incoming tide and the reduction of the head inside the slough. Therefore, data from the three-hour and the twenty-four hour sampling points are utilized for the calculation of slough water volume discharged, and the assumption is that the flowrate varies in a linear manner between these discrete times. See Figure 5.16.

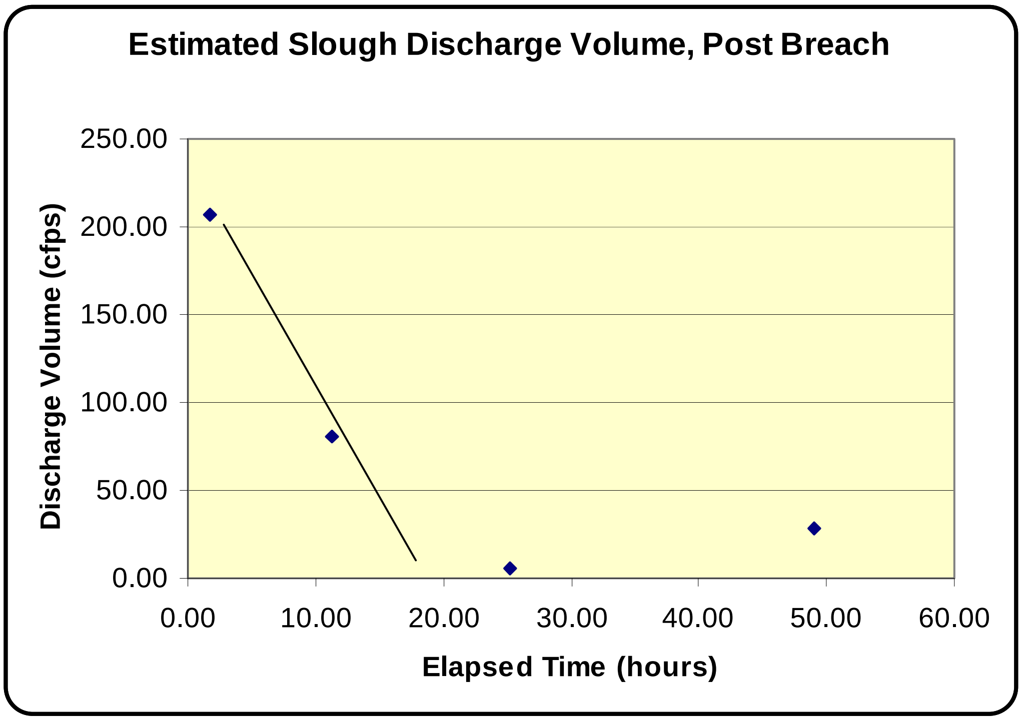


Figure 5.16. Estimated Discharge Volume Rate versus Elapsed Breach Time

Table 5.11. Sampling Times versus Location.

Location	Time Code 1	Time Code 2
-250	8:20 am	5:55 pm
-50	8:25 am	5:50 pm
50	8:58 am	6:30 pm
100	9:03 am	6:35 pm
200	9:08 am	6:45 pm
400	9:16 am	6:51 pm

Note: Breach time is 6 am

Steps for Estimating Plume

The twenty-four hour sampling time for the 400-yard location is selected as a time point for which a plume length and width is estimated based on visual observations. The average flow rate between the breach time and the selected time was calculated; to perform this calculation, a linear decrease in flow rate was assumed between the measured values (see Figure 5.16).

The average flow rate was multiplied by the elapsed time (12 hours, 51 minutes) to determine the volume of water that had exited the Slough in that time period. This value was justified against the available volume in the Slough (10,278,000 cubic feet); obviously the volume of water that has flowed out of the Slough cannot exceed the available volume of water in the Slough. One can conduct a parametric study by varying the length, width, and/or depth of the plume; the parametric study can be accomplished by selecting two of these parameters and multiplying the inverse of their product by the discharge volume to determine the third parameter.

For example, use the elapsed time at which the 400-yard sample was collected during the twelve-hour sampling period:

> Elapsed time = 12 hours 51 minutes = 46,260 s
> Average flow rate over this time = 143 cfps
> Volume = 143 cfps x 46,260 s = 6,615,180 cu ft
>
> Assume plume length = 700 yards (based on visual observations; 200 yards upcoast and 500 yards downcoast)
> Assume plume width = 100 yards (based on visual observations)
>
> ➔Resultant depth = (245,006 cu yds)/(700 yds x 100 yds) = 3.5 yds = 11 ft

This result indicates a fresh water plume that is 11 feet deep, 700 yards long, 100 yards wide and corresponds to approximately six-tenths of the slough water being released in the first thirteen hours after the breach. If the surface area of the plume is assumed to be somewhat smaller, then resultant plume depth would be deeper; the calculated plume depth parameter would still not be unreasonable if one assumes the average water depth along the width of the plume (sloping downhill from onshore to offshore) is on the order of 30 feet. This result characterizes the potential physical boundaries of the plume only. The physical boundaries are reasonable and hence the assumptions are reasonable. In other words, an average flowrate of 143 cubic feet per second of water discharging from the slough over the first thirteen hours after the breach does not violate the volume of available fresh water in the slough, the visual observations of the plume length and width in the ocean, or the physical boundaries (the sea surface and the seafloor) constraining the freshwater plume in the ocean.

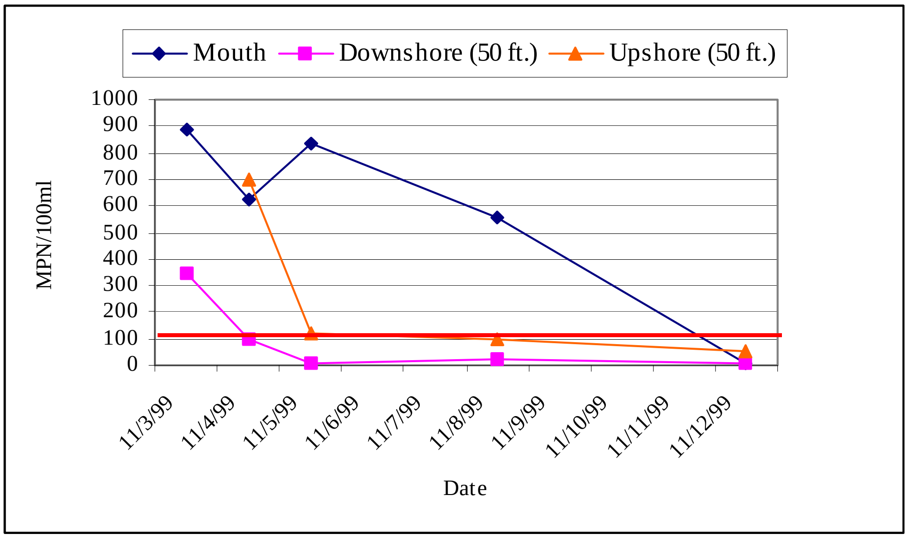
A method of estimating the plume has been developed, and it can be utilized to conduct a scaling analysis when data on other impounded coastal water bodies is available. Developing an understanding of how the experience at Goleta Slough scales to other locations would be useful. The following questions can be explored: If an impounded coastal water body is ten times larger than the Goleta Slough, what are the implications? How large is the plume? How does the larger release of impounded water affect the temporal and spatial scales of the ocean water quality impacts?

5.6 REGIONAL BREACH DATA

The informal survey of California coastal counties indicated that limited data exists regarding changes in water quality subsequent to an artificial breach. Very few field experiments on breach events have collected bacteria data on a spatial and temporal scale as fine as the one used in this experiment. With the exception of one published long-term study at San Elijo Lagoon in San Diego County (Gersberg et al., 1995), most data associated with breach events must be gleaned from ocean water quality monitoring records. These records do not represent formal scientific experiments, but can provide clues and facts for comparison to the Goleta Slough field experiment. For example, in the Gersberg et. al. study of the breach in San Diego, samples were taken every four days for a period of six weeks from one sample location; his results suggested indicator violations post-breach. While this study could marginally provide an opportunity for comparing water quality exceedences to the Goleta Slough study, it does not allow for any rigorous comparisons because of the differences in the spatial and temporal sampling designs. A relatively better example is the data related to a late 1999 breach at Buena Vista Lagoon in San Diego. First, of the three indicator organisms, enterococcus had the most number of single-sample violations of state standards during the 5 post-breach sampling periods that took place over a span of ten days; the other indicators did not register as many violations of their respective standards (Appendix C). This supports the conclusion offered in Gersberg et al. (1995) that enterococcus is a more conservative indicator than total coliform and fecal coliform, and is consistent with the present findings. Second, there were sampling stations approximately 50 feet both upcoast and downcoast of the Lagoon's mouth for the duration of the monitoring period (Figure 5.17). At both these stations, enterococcus abundances fell off relatively rapidly compared to those found at the mouth (CSDDEH database).

This anecdotal evidence indicates a certain lack of consistency among indicator organisms in terms addressing the need for advisories, evidenced in other studies too. It also shows that indicator organism standard violations at the breach outflow do not necessarily translate into violations in the waters adjacent to the mouth; this could have significant implications for how beaches are posted for advisories. When compared to the findings presented in the Goleta Beach study, the survey findings suggest that the bacterial loading and dispersal in coastal waters may be influenced by site-specific characteristics. Data from another breach at San Elijo Lagoon indicated no violations of state water quality standards (CSDDEH database). The mid-1999 breach had extremely low levels that differ significantly from that observed in the Gersberg et al. (1995) study.[1] A greater understanding of water quality and breach events could be developed by examining the dynamic processes within the lagoons or sloughs that lead to differences in ocean water quality at receiving beaches. For example, impounded water bodies that are not well mixed may contain stratified layers that harbor higher levels of bacteria in the freshwater lenses compared to a well mixed brackish water body, and these differences may lead to a larger input source of bacteria into the adjacent shoreline following a breach.

Figure 5.17. Enterococcus Data for Buena Vista Lagoon Breach, San Diego



Actual values obtained from sampling are denoted with symbols shown in the legend. Data comes froms the CSDDEH database. Red line represents the single-limit standards for enterococcus.

[1] Densities for total coliform and fecal coliform were at or below 80 MPN/100 ml for two subsequent sampling days following this 1999 breach. The 1994 breach of San Elijo examined in Gersberg et al. (1995) shows data for a sample taken at the mouth within 24 hours of the breach. Compared to the 1999 breach, total coliform was two orders of magnitude higher, and fecal coliforms was one order of magnitude higher.

6.0 GOLETA BEACH FIELD STUDY AND REGIONAL DISCUSSION

6.1 INDICATOR ORGANISM AND TRACER DISCUSSION

Indicator Organisms

The field study clearly demonstrated the artificial breaching of the Goleta Slough negatively affects adjacent ocean water quality. Exceedences of the individual indicator organism standards occurred as early as 3 hours post-breach, and pulses of bacteria above the standards were observed up to the last sampling period 48 hours after the breach event. For each indicator organism, exceedences varied from several times over the limit to an order of magnitude or more. The highest levels of bacteria were observed during the 12-hour sampling event and within 24 hours, the bacteria levels had attenuated near to background conditions. Water quality exceedences were captured during 24- and 48-hour sample periods, but these exceedences were localized around the mouth of the Slough. In general, all three indicators faded to background levels in the ocean after the first 24 hours even though levels in the Slough increased significantly during this time period. The Slough water bacteria levels continued to remain high for the duration of the study. Although data were not collected at various locations throughout the Slough, this trend suggests that bacteria laden water is being drawn down from the upper reaches of the Slough and/or the turbulence created from the discharging Slough water is resuspending bacteria in the water column. The fact that the three indicators faded to background levels in the ocean indicates the extent of the Slough water plume in the ocean was reduced as the discharge rate out of the Slough diminished and as the changing tidal cycle reduced the ability of the Slough water to exit during the coinciding low tide. This in turn diminished the exodus of bacteria from the Slough and bacteria abundances in the ocean decreased significantly within 24 hours.

Nitrates and Total Suspended Solids

Nitrate concentrations served as an excellent signal documenting the extent and magnitude of the Slough water in the ocean and followed closely the distribution patterns of the bacteria. Nitrate concentrations in the Slough were two orders of magnitude greater than typical ocean concentrations during the first 24 hours post-breach and consequently, the highest nitrate concentrations observed in the ocean occurred during the 12-hour sample period. Nitrate levels correlated well with *E. coli* abundances and served as a useful signal for estimating the plume length. Within 24 hours, all nitrate levels had returned to background conditions even though levels continued to remain very high in the Slough. Similar to the bacteria, this was due to reduced flow from the Slough. TSS measurements performed poorly as an indicator for bacteria and there was no evidence that enhanced TSS levels correlated with high levels of bacteria. Whether this was due to a lack of a true relationship, a flaw in the sampling and analysis design, or a combination of these two, was undetermined.

Temperature and Salinity

The temperature and salinity gradient between the slough water and the ocean water was significant, resulting in a buoyant jet discharge from the slough. A jet is the discharge of fluid from a slot into a large body of the same or similar fluid; a plume is a flow that looks like a jet, but is caused by a potential energy source that provides the fluid with positive or negative buoyancy relative to its surroundings. Many discharges into the environment are classed as buoyant jets, which are derived from sources of both momentum and buoyancy. A buoyant jet has jet-like characteristics depending on its initial volume and momentum fluxes, and plume-like characteristics depending on its initial buoyancy flux (Fischer, et. al., 1979). Far enough from the source, the plume-like characteristics begin to dominate; that is, a buoyant jet will turn into a plume if given enough free distance (Fischer, et al., 1979). Indeed, this was the case for the Slough. The Slough discharge had high initial volume and momentum fluxes and also a buoyancy flux that was based on the density difference between the Slough and the ocean. Both temperature and salinity served as useful tracers for detecting the Slough signal in the ocean. Salinity proved to be a better tracer of bacterial abundances released from the Slough into the ocean, while temperature was a better tracer for detecting the extent of the Slough water in the ocean. Both tracers should be used to supplement bacterial observations in this type of study, and to facilitate the detection of the spatial and temporal patterns of Slough plumes in the ocean.

6.2 PHYSICAL PARAMETER DISCUSSION

The oceanographic conditions during the breach could be described as benign. By virtue of the fact that effects of the Slough water were seen on both sides of the mouth, the swell, waves, longshore current, and wind did not play a significant role in the rapid advection of the plume upcoast or downcoast. Over time and as the plume grew, the longshore current measured outside the surfzone would have contributed to the downcoast advection of the plume. Nearshore breaking waves and wind-induced vertical circulation enhance vertical mixing in nearshore waters (URS Greiner, 1999); these parameters were not significant, however, and would not have been a significant forcing function to overcome the density stratification inhibiting vertical mixing. Table 6.1 attempts to summarize these observations.

Table 6.1. Qualitative Assessment of Physical Parameters at Goleta Beach

Physical Parameter	Deviation from Normal/Long Term Mean OR (Size of Parameter)	Extent of Effect on Plume Advection and Dispersal	Extent of Effect on Plume Mixing	Comments
Tidal Range	(large)	notable	notable	
Wind Speed	normal	small	small	
Wind Direction	normal	small	small	
Slough Discharge	(large)	significant	significant	Important within first 12 hours
Longshore Current	(small)	notable	notable	Significant at 12-hour sample
Temperature and Salinity Gradient	(significant)	small	large	Particularly important within first 12 hours
Deep Water Swell	normal	small	small	
Nearshore Waves	normal	small	small	

6.3 SYNTHESIS OF OBSERVATIONS AND INTER-RELATIONSHIPS AMONG VARIABLES

The development of a conceptual model seeks to link the observed bacteriological and physical data so that the basic processes that occurred during the field study can be understood and conceptualized in a broad perspective. The preceding analysis of the bacteria, nitrate, salinity, temperature, and flow characteristics during the breach event all show consistent patterns. The following discussion provides a summary timeline of these changes that occurred during the entire experiment, as well as how they relate to one another. This provides insight into the processes driving these changes.

- Pre-Breach conditions, including Day 0: Slough impounds, and a pressure head builds as water from watershed continues to fill Slough; bacteria and nutrient levels increase within the stagnant water. Salinity of Slough water near the mouth is similar to ocean.

- Day 1 morning: Slough is breached at lowest tide of the week to insure maximum water level height difference between the Slough and the ocean. Initial discharge is very high; observed bacteria levels in Slough rise dramatically from background conditions. Salinity levels decrease in Slough, indicating more freshwater filling from the upper reaches of the watershed. Visual plume is evident in the ocean, extending 250 yards upcoast and 400 yards downcoast and about 100 yards seaward. Significant differences are observed in upcoast and downcoast bacteria levels when compared to background levels, although few exceed water quality standards. Physical oceanographic conditions are benign. Slight evidence of nitrate enhancement and decrease of salinity recognized at spatial locations upcoast and downcoast.

- Day 1 afternoon: Discharge of Slough water is decreasing but still relatively strong. Slough salinity continues to drop and bacteria levels remain high in the Slough waters. Highest abundances of bacteria during the experiment are observed in ocean at all stations, minus the control. The link of these elevated abundances to discharge is largely supported by changes in two observed tracers. First, salinity reached its lowest levels at the mouth of the slough during this time, indicating the presence of a strong "pulse" of freshwater from the upper reaches of the watershed where water was unaffected by saltwater intrusions prior to the impoundment of the Slough. Second, nitrate levels peaked at the mouth: since nitrate levels in the wetland are orders-of-magnitude higher than those found in the ocean, this nutrient is strongly present in the discharge coming from the Slough.

- Day 2, morning: Slough discharge is reduced. Bacteria and nitrate levels remain high in Slough. Slough temperature is beginning to drop, and salinity is beginning to rise, indicating the influence of ocean water from tidal mixing and flushing. As a result, the temperature and salinity gradient between slough water and ocean water has been minimized. Bacteria and nitrate levels in ocean attenuated to near background conditions, except for one indicator organism exceedence near the mouth.

- Day 3, morning: Slough discharge is minimal. Bacteria and nitrate levels in Slough begin to subside. Slough temperature and salinity is returning to background conditions. Bacteria and nitrate levels in the ocean remain at background levels, aside from two bacteria standard exceedences at the mouth. No salinity or temperature effects are detected in the ocean due to adequate tidal mixing.

Similar patterns and processes should occur for subsequent Goleta Slough breach events and other regional events. Although the breach characteristics will be similar among different events, the scales and magnitudes of physical and biological processes will likely change. For example, the initial discharge of estuarine water, the influx of bacteria into the ocean, and the subsequent forcing due to the physical oceanographic conditions will be replicated from event to event. However, the size and rate of the flow, the levels of bacteria, and the magnitude of the physical oceanographic conditions and their influence on the mixing will change for each event. Influence on mixing implies that different temporal and spatial scales of bacteria movement will be observed.

6.4 LIMITATIONS OF FIELD STUDY

With any field study, there are limitations inherent within the experimental design and these limitations put constraints on the analysis, conclusions, and confidence of the results. The research performed at Goleta Beach is limited by two major problems, which are subdivided into internal and external categories.

- **External: Only One Breach Event** – This is the most significant drawback to the study. The data gathered from the study is useful for showing the potential impacts to water quality but it is difficult to make any conclusive statements regarding how the results compare to other events. Several monitorings of breach events are necessary under different physical conditions in order to effectively characterize the dispersion of bacteria subsequent to a breach and measure impacts to ocean water quality. Key physical factors that may vary between breach events most notably include swell characteristics and wind speed.

- **Internal: The Experimental Design** – The experimental design only captured discrete "snapshots" of the Slough and ocean conditions, and all the sampling occurred during the low tides. These discrete sampling events occurred over periods of 12 to 24 hours, making it difficult to interpolate how the conditions changed during that time. Greater temporal and intra-tidal samplings are needed to increase the understanding of how the conditions change with the tidal cycle and how the discharge volumes are affected by the tidal cycle. More stations along the shoreline may help verify the plume lengths estimated through the calculations made in Section 5.5. Furthermore, since violations occurred at all stations during at least one point in the experiment, sampling stations beyond those employed in the experiment may show the "boundaries" of *unsafe* contamination due to an artificial breach.

6.5 REGIONAL BREACH PROTOCOL DISCUSSION

There are other potential factors not considered in this experiment that may influence the characteristics of post-breach contamination. The survey of California counties revealed that there are different standards regarding the appropriate time to perform breach activities. Much like the Santa Barbara County Flood Control Agency maintenance activities at Goleta Slough, managers at Los Peñasquitos Lagoon in San Diego desire constant tidal exchange. They have adopted similar breaching practices that utilize an extreme low tide to maximize the flow and scouring of outlet channel, thereby maximizing the time before the next impoundment. Dr. Michael Wells (per. comm., 2001) indicated that the development of this practice has dramatically improved tidal exchange over the last 16 years. In 1984, Los Peñasquitos Lagoon was closed approximately 80% of the year. The evolution of breaching protocol is directly responsible for the Lagoon only being closed for a couple of months *total* over the last couple of years (Wells, 2001).

As a point of contrast, Monterey County Water Resources Agency has detailed protocols outlining when breach events should occur at the mouth of the Salinas River. Mobilization to perform a breach event is outlined in manner that relies on defined conditions (readings on flood monitoring stations and size of diversionary flows) that act to minimize the impacts to various interests in the region. While breaches are performed to prevent the flooding of farmlands and nesting habitats, the Agency strives to minimize the number of breaches that must occur because it recognizes the need to prevent any adverse impacts to other life in the surrounding wetlands. Contrary to the practice at Goleta Slough and Los Peñasquitos Lagoon, the Salinas River is preferably breached subsequent to a high tide peak. It is argued that the long tide recession time allows the outflow sufficient time to widen and deepen the inlet cut, so that it remains open during the next high tide (MCWRA, 1992). The survey indicated that the Salinas River is usually breached no more than once a year. Understanding how different breach protocols may potentially influence water quality raises an interesting scientific question, as well as point towards the need to consider the role of various stakeholder interests in the design of artificial breach events.

7.0 PERMITTING PROCESS

7.1 FEDERAL, STATE, AND LOCAL REQUIREMENTS

To breach a slough or creek such as the Goleta Slough, a series of permits are required at the federal, state, and local levels. The permitting process described below is specific to sites in Santa Barbara and California in general; however, variations can exist, most notably at the state and local levels. The intent of such a process is to account for and consider the wide range of interests that may be invested at a given site. In California, the natural order of the process requires the local lead agency of the project (Santa Barbara County Flood Control Department in the case of the Goleta Slough) to contact a myriad of agencies in order to obtain the proper permits and perform a breach. Important agencies to contact are the US Army Corp of Engineers, the California Coastal Commission, the Regional Water Quality Control Board, the State Land Commission, the California Department of Fish and Game, and the City and County Department in charge of a Local Coastal Program (See Figure 7.1 for an overview of the agencies interactions). While the specifics of the process may vary with the site and project characteristics, the permits for most breaching events will fall within the guidelines outlined below.

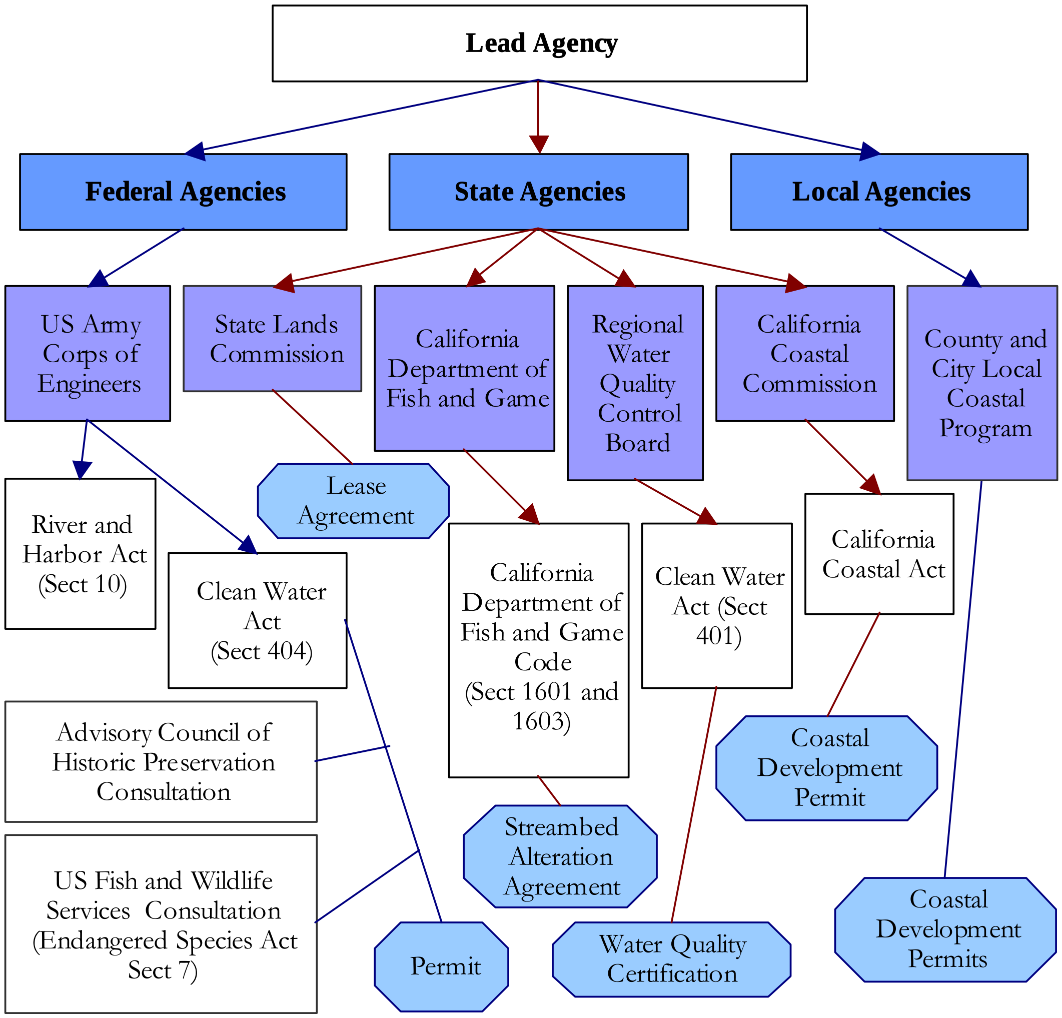


Figure 7.1. Permitting Flowchart for Breaches in California.

Federal Process

Federal agencies are important players in the overall permitting process. Effectively, if any of the federal agencies refuse to issue a permit to breach an impounded body of water, none of the state and local agencies will approve the project. Table 7.1 contains a summary of the federal permit process.

Table 7.1. Federal Agencies Role in Permitting Process

Federal Agencies	Regulations	Objective	Permit
United States Fish and Wildlife Service *National Marine Fisheries Service*	**Endangered Species Act** Section 7 (federal nexus)	"No take"	Part of 404 CWA permit
US Army Corps of Engineers	**Clean Water Act (CWA)** (Section 404)	Minimize the impact of dredged materials on US waters	Yes
	Rivers and Harbors Act (Section 10)	To authorize the extraction/ dredging or deposition of material in waters	
	National Environmental Policy Act (NEPA)	Assess project environmental impact	No
Advisory Council of Historic Preservation	**National Historic Preservation Act** (Section 106)	Avoid damaging cultural resources	Part of 404 CWA permit

One key agency to consider in the permit process is the United States Army Corps of Engineers (USACOE). This agency has jurisdiction (Figure 7.2) over "waters of the United States" which is defined under "33 Code of Federal Regulations 328.3 as (1) all navigable waters and their tributaries; (2) all interstate waters and their tributaries; (3) all other waters, the use, degradation, or destruction of which could affect interstate commerce; (4) all water impoundments; (5) territorial seas; and (6) wetland adjacent to waters identified above" (California Wetlands Information System, 1997).

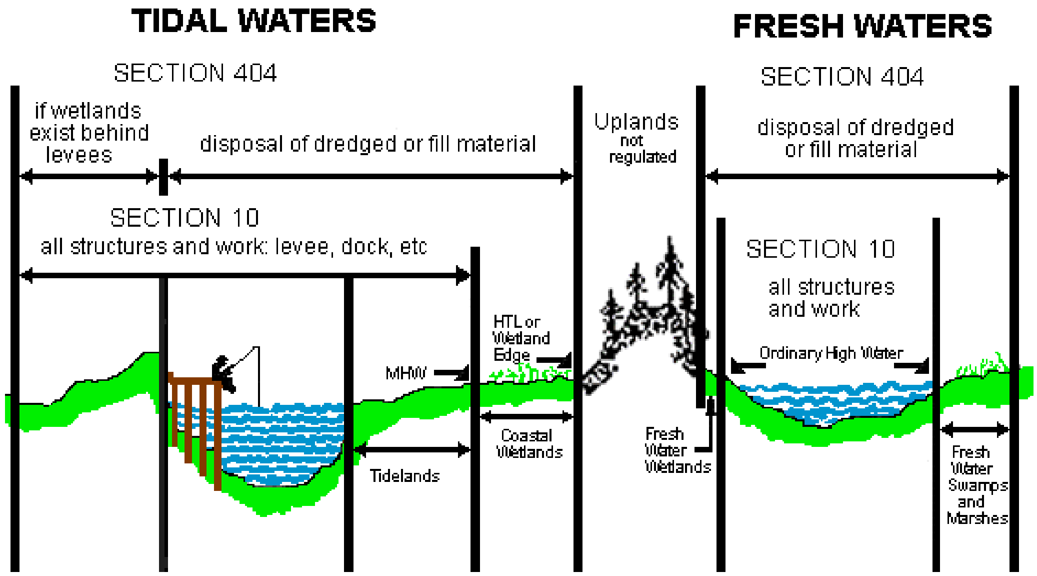


Figure 7.2: Corps Regulatory Jurisdiction (USACOE, 2001)

The USACOE must consider a couple of acts during the permit process for a coastal breach. The Clean Water Act (CWA) of 1972 is responsible for protecting the waters of the United States. Section 404 regulates the discharge of dredge or fill materials in coastal waters, inland waters, and wetlands. USACOE must evaluate the impacts of dredging, excavation, and depositing of fill and dredged materials onto waters of the US, avoid or minimize impacts on wetlands, restore or create wetlands when unavoidable impacts occur, and consult with USFWFS under Section 7 of the Endangered Species Act (California Wetlands Information System, 1998d). In breaching events, the placement of the material that is to be breached, and the method used to breach, will determine if a permit is required. For example, if the sand bar is removed with a bulldozer and/or the sand is disposed on the beach, then a permit is required since the moved material is considered "fill" (Mace, 2001). Because most breaching events occur within USACOE's jurisdiction, and large amounts of sand are usually removed by mechanical means, most breaching projects will require a permit.

The Corps is also responsible for the enforcement of Section 10 of the River and Harbor Act of 1899. This regulation prohibits unnecessary and artificial alterations to the "navigable waters" (EIR, p 3-4). Because the breach of a sand berm usually requires some work below the high tide line, the breaching activity will fall within regulations outlined within Section 10 of the River and Harbor Act.

The Corps must also ensure compliance with the National Environmental Policy Act (NEPA) of 1970. Under NEPA, the USACOE determines whether or not a project falls under one of the categorical exclusions outlined in the act. If it does, no environmental assessment (EA) is needed and the NEPA compliance process stops there. However, if it does not, an EA must be prepared by the Corps to determine a project's impacts on the environment. If no effect on the environment is found, then the EA provides the documentation to support a finding of no significant impact. However, if environmental effects do exist, the EA helps determine the scope and content of the environmental impact statement (EIS). In an EIS, the different alternatives to the project must be exposed, and the intended action and proposed mitigation actions must be evaluated. Government agencies and the public are then asked to comment on the project. Last, the USACOE issues a final EIS addressing the different comments received, and proposes a decision and the reasons for it (Bass et al., 1993).

Another agency that must be consulted is the United States Fish and Wildlife Service (USFWS). USFWS is the principal federal agency for conserving, protecting, and enhancing fish, wildlife, plants, and their habitats. Among its numerous duties, the agency takes the lead role in the enforcing the Endangered Species Act (ESA), a federal regulation responsible for protecting threatened and endangered species and their habitat. Both Sections 7 and 10 of the ESA prohibit the "take" of any endangered or threatened species, but to whom the sections apply is different. While Section 10 applies to both private and public individual entities that have no federal agency involvement, Section 7 "applies to the management of federal lands as well as to any other federal actions that may affect listed species such as federal approval of private activities through the issuance of federal permits, licenses, or other actions" (US Fish and Wildlife Service, 2000). It can be can concluded that Section 7 of the Endangered Species Act is appropriate when breaching events are considered because of the United States Army Corps of Engineers' requirement to consult with USFWS prior to issuing a permit allowing dredging and excavation activities to take place in a wetland, as will be discussed below.

Section 7 of the ESA also requires federal agencies to conduct a biological assessment of possible endangered species presence and engage in informal consultation with the USFWS as well as the National Marine and Fisheries Service (EIR, 3-5). The US Fish and Wildlife Service states that if no adverse effects to the species are found, the process stops there. However, if adverse effects exist to an endangered species, consultation with the USFWS becomes formal, and the USFWS prepares a "biological opinion". The biological opinion is a determination of the impacts of a federal action on listed species and their habitat. If the USFWS finds that jeopardy to a protected species exists, the biological opinion will include reasonable and prudent alternatives for the proposed federal action that will not result in such jeopardy, or otherwise state why there are no alternatives. If the USFWS finds that no jeopardy to the species exists, the biological opinion may include reasonable and prudent conservation measures considered to be minor modifications to the proposed federal action and issue an incidental take statement. In light of the biological opinion, the federal agency has to adopt a final decision and inform the USFWS of it. At this point, the federal agency can choose to accept the recommendation of the USFWS, cancel the project, modify the project, or request an exemption to Section 7 (US Fish and Wildlife Services, 2000).

Finally, one must consider the potential role of the Advisory Council of Historic Preservation (ACHP). The National Historic Preservation Act of 1966 authorizes the ACHP and state historic preservation agencies to review and comment in writing on proposed CWA Section 404 permits, or other federal permits that may affect properties listed or eligible for listing on the National Register of Historic Places (California Wetlands Information System, 1996c). The National Register can include sites, districts, buildings, structures, and objects considered significant for their historic, architectural, engineering, archeological, or cultural value (EIR, 3-4). However, no separate permits are required as it is usually part of the 404 permit procedures (Treiberg, 2001).

State (California) Process

The involvement of state governmental agencies in the permitting process for breaching an impounded body of water is summarized in Table 7.2. In California, several agencies are involved in the process. Further, some overlap exists among the state and the federal agencies. For example, this is particularly true between the California Department of Fish and Game (CDFG) and the US Fish and Wildlife Services (USFWS), whose goals are to minimize the adverse effects of the project to fish and wildlife.

Table 7.2. State Agencies Role in Permitting Process

State Agencies	Regulation	Objectives	Permit
California Coastal Commission	**California Coastal Act** (1976)	Coastal Development Permit	Yes
California Department of Fish and Game	**California Fish and Game Code** (Section 1601 and 1603)	Minimize adverse effect to fish and wildlife	Yes Streambed Alteration Agreement
SWRCB and the Regional Water Quality Control Boards	**Clean Water Act** (Section 401 and 402)/ **Porter Cologne Act**	Water quality Certification	Yes
State Lands Commission	None specific; requires **California Environmental Quality Act** (CEQA) compliance	Lease agreement for disposal of dredged materials below the mean high tide	Yes Lease
State Historic Preservation Agency	**National Historic Preservation Act** (Section 106)	Avoid damaging cultural resources	Part of 404 CWA permit

The California Coastal Commission (CCC) has jurisdiction within the "coastal zone" which extends three miles seaward and generally about 1,000 yards inland. However, "in particularly important and generally undeveloped areas where there can be considerable impact on the coastline from inland development, the coastal zone extends to a maximum of 5 miles inland from mean high tide line. In developed urban areas, the coastal zone extends substantially less than 1,000 yards inland" (California Wetlands Information System, 1996a and 1998a). The CCC was formed on the impetus provided by the Coastal Zone Management Act of 1972. This federal regulation is implemented by the USACOE who delegates its power to states that develop and implement their own coastal zone management program. The State of California did develop and implement its own program through the California Coastal Act of 1976, and the promulgation of this act led to the formation of the CCC (California Wetlands Information System, 1996a and 1998a). As a result of this transfer of power, the CCC, and not the USACOE, manages the coastal development permit process. Nevertheless, states that do not have this program in place must go through the USACOE to get the coastal development permit (EIR, p. 3-4 to 3-7). The CCC is responsible for ensuring that a project like an artificial breach falls within goals outlined for the management of coastal resources.

As mentioned earlier, the California Department of Fish and Game (CDFG) has the same basic mission than the US Fish and Wildlife Services. CDFG is "responsible for conserving, protecting, and managing California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public" (Department of Fish and Game, 1999). Section 1601 of the California Fish and Game Code requires state and local governments, as well as public utilities, to notify CDFG prior to any maintenance dredging in waterways. Prior to the scheduled maintenance, a representative of the department will assess the adverse effects of the dredging on wildlife habitat and wetland acreage. Recommendations are made through a 1601 Lake and Streambed Alteration Agreement between the acting entity and CDFG (EIR, p. 3-6). However, under Section 1603, any person other than the one mentioned in Section 1601 must notify the department if the project will result in "substantial" diversion, obstruction, or change to a lake, river, and stream. Further, the project must be compliant with the California Environmental Quality Act (CEQA) (California Department of Fish and Game Code, 1994).

A third state agency that must be considered is the State Water Resources Control Board (SWRCB). Under the Porter-Cologne Water Quality Control Act, the SWRCB has the ultimate authority over State water rights and water quality policy. Porter-Cologne also establishes nine Regional Water Quality Control Boards (RWQCBs) to oversee water quality on a day-to-day basis at the local/regional levels (California Wetlands Information System, 1998b). As a result, RWQCBs enforce the Sections 401 and 402 of the CWA (EIR, p. 3-7). Under Section 401, prior to conducting a breach, the permit applicant must ensure that the discharge will be within the state water quality standards. This entails a detailed review of the nature of the discharge and its impact on the receiving waters. The board may give a water quality certification, a waiver (equivalent of a certification), a waste discharge requirement (a state discharge permit), or deny the project (California Wetlands Information System, 1998c). Furthermore, Section 402 of the CWA requires the issuance of a National Pollutant Discharge Elimination System (NPDES) permit for non-point source discharge into waters of the United States. Phase I, implemented in 1990, requires municipalities with population above 100,000 to get that permit. Phase II, signed in 1999, regulates all small and urbanized municipalities with a population under 100,000 (EPA, 2000). Impacts on the permitting process are likely; however, details are not known yet as development of the guidelines are underway.

Finally, the State Lands Commission holds a place in the permit process. According to Public Resources Code § 6000 et seq., the Commission has jurisdiction and control over state-owned lands. "These lands include: a three mile-wide section of tidal and submerged land adjacent to the coast and offshore islands, including bays, estuaries, and lagoons; the waters and underlying beds of more than 120 rivers, lakes, streams, and sloughs; and 585,000 acres of school lands granted to the state by the federal government to support public education" (California Wetland Information System, undated). The State Lands Commission ensures that the breach project complies with CEQA, and oversees the disposal of dredge materials below the mean high tide by issuing a lease agreement to the lead agency.

The State Historic Preservation Agency also plays a role in the state process but the same guidelines discussed for the ACHP apply for this agency.

Local process

The involvement of local governments in the permitting process will vary greatly with site, project characteristics, and local regulations. Table 7.3 summarizes the basic local government that would be involved in a breach event.

Table 7.3. Local Agencies Role in Permitting Process.

Local Agency	Regulations	Objectives	Permit
City	Local Coastal program	Coastal Development Permit	Yes
County	**Local Coastal program**	Coastal Development Permit	Yes
Lead agency	**California Environmental Quality Act (CEQA)**	Least environmental project review	No

Generally, a lead agency must be considered. The informal state survey revealed that in counties with traditionally heavy beach use (largely in southern California), county agencies were the lead agencies of breach projects, while the State Regional Water Quality Control Boards were typically the lead agencies for counties with lower recreational use of the ocean.

In California, the California Environmental Quality Act (CEQA) has similar guidelines as NEPA (EIR, 3-6). CEQA can lead to a categorical exemption, and an initial study determines if a negative declaration or an environmental impact report (EIR) is appropriate. However, it is the lead agency that is responsible for preparing the documentation (Bass et al., 1993). The California Coastal Act also delegates local governments with much of the authority entailed by the Federal Coastal Zone Management Program. As a result, many cities and counties have Local Coastal Programs (LCPs) that have been reviewed and certified by the CCC (California Wetlands Information System, 1996b). In such a case, the project needs to be authorized by the county and/or city department in charge of coastal management, and two permits usually need to be issued before a breach event is undertaken. Other local requirements might be necessary before the project can be undertaken; these will vary with local governments and geographic location.

7.2 Specific Example: Goleta Slough

The County of Santa Barbara Department Flood Control acts as the lead agency and is responsible for writing the environmental impact report (EIR) and acquiring the necessary permits prior to undertaking the breaching project. The permitting requirements for the Goleta Slough closely follow the guidelines outlined above. Effectively, a USACOE permit under both section 404 of the Clean Water Act and Section 10 of the River and Harbor Act were required because the project falls within their jurisdiction, and a bulldozer was used to open the mouth resulting in the presence of fill materials. This federal involvement of the USACOE implies that consultation with the USFWS was necessary in order to get the 404 permit. Because no endangered species are known to exist in the Slough, the permitting process was straightforward. Furthermore, all of the state and local requirements were also met, and coastal development permits from the city and county of Santa Barbara, water quality certification from the Regional Water Quality Control Board, a streambed alteration from the California Department of Fish and Game, and a lease agreement from the State Lands Commission were given before the project was undertaken (Treiberg, 2001). Interestingly, the law does not require the County of Santa Barbara Environmental Health Services (EHS) to be involved in any step of the permitting process, and the County of Santa Barbara Flood Control has full liability. However, EHS does test the ocean water on the day of the breach to measure the water quality and ensure public health. This cooperation between the County EHS and Flood Control allows for the full protection of the public and the usage of adequate postings as required by the AB 411 mandate. In this region, it has been estimated that under the current regulatory structure, it takes approximate one to two years for all necessary agencies to fully evaluate an application for establishing an artificial breach program at a specific outfall (Cope, per. comm., 2000).

7.3 Regional Breach Events

The permitting process and local regulatory structure may vary from one breach site to another. While a comprehensive investigation of all breach sites could not be performed, the informal state survey conducted during this project hinted at a range of differences. For example, oversight of breach events at Los Peñasquitos Lagoon in San Diego County is handled by Los Peñasquitos Lagoon Foundation, a management group consisting of a wide range of watershed stakeholders. Money for this activity comes from the City of San Diego; although California Department of Parks and Recreation oversee and own a large portion of this wetland, it is the Foundation that constructs management strategies. The Foundation then contracts out the actual work to a private company (Wells, 2001). This is very different than the Goleta Slough, which is handled by the County of Santa Barbara Flood Control Department, indicating that the funding comes from the County. Nonetheless, the informal survey shows that the lead agency of a breach project will depend on the site geographic location and the agency that has the most information on that site. In Southern California, local agencies generally manage breach activities, while sites in Northern California are more likely to be handled by state authorities such as the Regional Water Quality Control Board or California Coastal Commission. Together, these pieces of information hint that the government bodies involved and responsible (and the resources available to them) for overseeing breach events are not consistent throughout California.

The survey also hints that no matter the agency or organization carrying out the breach event, a suite of permits similar to those held by Santa Barbara County Flood Control usually is required. Russ Yoshimaru (2001) indicated that the Monterey County Water Resources Agency (MCWRA) is currently undergoing the *formal* process to get such permissions despite the fact that breaches have been conducted for years at the mouths of the Carmel and Salinas Rivers. The agency is working through USACOE and recognizes the need to acquire approvals from numerous agencies including NMFS, USFWS, CDFG, CCC, California State Parks and Recreation, and Monterey County Planning and Building Inspection Department. The evaluation of wetland habitat and critical species is expected to be a major factor during this process, though it has yet to be determined whether or not a full EIR will be necessary. While eager to work with all the agencies, the MCWRA admits that the conditional recommendations that may arise from the process places the nature and occurrence of breaches in uncertainty.

It is also worth noting that a California Superior Court case was recently tried regarding the role of CEQA in the regulatory process surrounding artificial breaches. In late September 2000, an unincorporated private association brought suit against the City of Del Mar to prevent it from conducting an artificial breach of the impounded mouth of the San Dieguito River (*Citizens United to Save the Beach, et al. v. California State Lands Commission, et al.*). Concerned about coastal erosion and pollution resulting from the breach, the group sought an injunction to prevent the breach, a move which city officials and many environmental organizations (such as the Audubon Society and the Surfrider Foundation) saw as necessary to relieve the stagnant aquatic conditions that were adversely affecting wildlife within the watershed (Smith, 2001). The plaintiffs argued that the City did not comply with CEQA, and needed to do a full EIS before conducting the breach. The City responded by pointing out that it had a blanket CWA 404 permit and permission from the California Coastal Commission to conduct periodic breaches as necessary. Although the judge issued a temporary injunction, he rescinded it a week later by claiming that this particular breach did not have to be evaluated under the full CEQA process (Smith, 2001).

The fact that this conflict was brought before a court exemplifies some of the uncertainty surrounding the regulatory process of breaches. It is true that a full EIS was not necessary in this particular instance; however, this might not apply in all circumstances throughout California. Furthermore, the activity surrounding this short court case also informally raised the question of the importance of police powers in these matters. When the temporary injunction was issued, local newspapers reported that the city council unanimously declared the San Dieguito Lagoon a public nuisance. "Where the public health, safety and welfare is at stake, and after the council has made the proper finding to declare a public nuisance, it may exercise its police powers to open the lagoon" (S.D. Union-Tribune, 2000). Since the City conducted the breach with the support of the Court, the validity of using such powers in these circumstances remains untested. Nevertheless, the question of whether an impounded water body can truly be declared a nuisance may be a critical point to explore in understanding the regulatory structure surrounding artificial breaches.

7.4 ANALYSIS OF PERMITTING PROCESS

Because of the large number of agencies involved in the permitting process, overlapping responsibilities between these different agencies are unavoidable. For example, the USFWS and CDFG have the same mission of protecting, conserving, and enhancing wildlife, plants, fish and their habitats. Two different processes, however, with overlapping agency oversight from these two agencies must be followed before a breach project can start: consultation with the USFWS to get a Section 404 permit from the Corps, and establishment of a streambed alteration agreement with CDFG. The permitting of dredged soils disposal serves as another example of overlapping agency oversight between the Corps and the State Lands Commission. Dredge materials are regulated at the federal level by the USACOE. However, an additional lease agreement must be allowed by the State Lands Commission for the disposal of the dredged materials within their jurisdiction. In many cases, both the Corps and the State Land Commission have overlapping jurisdiction of the same land.

The process can also be very confusing for any agency or organizations trying to get these myriad of permits. For example, the California Coastal Commission is mandated under the California Coastal Act to plan for and regulate land and water uses in the coastal zone consistent with the policies of the Coastal Act. The lead agency needs to acquire a Coastal Development permit before performing a breach. However, because the state delegated part of its authority down to the local governments, many cities and/or counties have their own local coastal programs, and permits through those local programs instead of the state need to be pursued before the project can start.

As described, the current permitting process is complex and confusing, and the lead agency efforts are very often replicated more than once for different agencies at different levels of government because of the delegation of power from the top-down. The permitting process required to conduct an artificial breach of a coastal estuary is one of the many issues falling under the complex category of coastal zone management (Beatley, 1994). Effectively, Beatley mentioned that no single agency has control over coastal management, and currently, no single or unified national coastal zone plan or strategy exists which guides or coordinates federal actions or programs. He concluded that this fragmented system has resulted in situations where programs and policies of different federal agencies work at cross-purposes in some cases (Beatley et al., 1994). To date, proposals to consolidate authority have been made, but improvements in this regard have not yet been implemented. Consequently, this characteristic of the federal coastal management authority impacts the state and local processes by favoring the replication of efforts and is somewhat imitated by the lower levels of government.

Another way to understand the involvement of so many agencies is to realize that they have different perspectives on any given action taken in the coastal zone. With the different controversies accompanying breach events, it is easy for agencies to stake an interest in a given activity or management decision. For example, when considering a minor dredge project, the USFWS sees a need to consider potential impacts on sensitive species, whereas the CDFG wants to know how the action will modify the streambed habitat, while the RWQCB wants to know how that action will affect water quality, and so on and so on. An applicant seeking permission to dredge or breach will encounter these overlaps throughout the process, and would typically find such a process burdensome compared to other non-coastal activities. Furthermore, with so many different interests involved, a relatively fast evaluation process is difficult to develop. Regulatory processes where evaluations of one agency are embedded into the specific process of another (consider the USACOE and USFWS) may contribute to a slower evaluation. Especially in an environment where redundancy exists among several levels of government, isolating similar considerations from each other (such as those of the USFWS and the CDFG) may hinder the design of an efficient regulatory process.

Obviously, coastal policies are clearly the result of political processes in which different factions and interest groups compete for attention and resources. Coastal policy is carried out by a unique blend of government and non-governmental organizations, profit and non-profit groups, and development and environmental advocates. Different coastal stakeholder groups have different perspectives on coastal management, and coastal management decisions are often the result of the interplay of these different groups. The permitting process for conducting a breach is inefficient in that entities and specific evaluation processes are impractically involved in the process; many responsibilities overlap between the local, state, and federal agencies, resulting in a redundant and lengthy permit process.

8.0 RECOMMENDATIONS

8.1 RECOMMENDATIONS FOR FUTURE BREACH EXPERIMENTS

There are limitations to the breach event data and the conclusions that may be derived from a single breach event; multiple monitoring data sets are needed to improve the certainty of findings. Further research would ideally include a repeat experiment at the Goleta Slough, using a similar sample design to see if there are similar bacterial loads into the ocean and similar process patterns. The repeat experiment, however, should be conducted with the following experimental design improvements:

- Concentrate sampling efforts within the first twenty-four hours rather than the later sampling times used in this experiment; ocean water quality impacts are significant and change rapidly during the initial twenty-four hours.

- Quantify the changes in the Slough with more monitoring, specifically with a finer temporal scale for key tracers (e.g. nitrate, salinity, and bacterial readings every 4 hours). This should also include more sampling locations within the Slough, reaching into the upper reaches of the watershed. For example, a profile of the salinity changes along a transect of sampling locations from downstream to upstream would increase the understanding of tidal influences mixing with fresh water drawn from the upper reaches of the watershed.

- The increased temporal sampling scale should capture the effects of the tidal cycle on bacteria levels. From a scientific perspective, the optimal sampling design would include a full spatial sampling (all locations) following each low and high tide for a 24-hour cycle, recognizing that this is difficult to accomplish due to the logistics of processing the samples and reading the results.

- Increase the number of discharge measurements, trying to capture how flow rate decays over time and understand the presence and extent of flow reversal during high tides.

- Take visual measurements of plume evolution from different vantage points. From these observations, a distance and width of the overall plume can be characterized.

8.2 Recommendations for Santa Barbara County Environmental Health Services and Flood Control Departments

The study demonstrated the potential for water quality exceedences up to 48 hours after a breach event. The following recommendation describes a monitoring plan that assesses impacts to ocean water quality for the purpose of protecting human health. This monitoring plan is conditional upon the physical characteristics that were present during the breaching experiment. For example, if swell conditions and/or wind conditions were severe during the post-breach time frame, the advection and dispersion characteristics of bacteria would most likely be significantly different. The recommendations intend to optimize the number of samples needed to adequately characterize the ocean water quality conditions subsequent to a breach at the Slough. The recommendations are as follows:

- The County should initially follow the conservative recommendation of beach advisory at 200 yards upcoast and 400 yards downcoast for a minimum of 48 hours and collect samples at the approximate 24-hour mark at the –50 yard, mouth, and +50 yard locations.

- At the 48-hour mark, the results from the 24-hour sampling should be interpreted. If the results indicate ocean water quality violations, the beach advisory zone should remain in effect and a new round of samples should be taken. This process should be repeated every 24 hours until bacteria levels subside below standards.

A downcoast 400-yard spatial boundary was selected due to previous studies, and is consistent with most County Agency policies throughout Southern California for beach advisory zones. The study did not necessarily place into question the use of this arbitrary boundary, although our results showed that exceedences may occur beyond that boundary. It is difficult to make a decisive decision on this point since the analyses hinted that the true boundary of harmful contamination fell *near* the 400-yard; whether this was within or beyond the arbitrary boundary remains questionable.

8.3 Permit Process Recommendations

As discussed earlier, the permitting process has been characterized as lengthy and redundant. Furthermore, many applicants define the process as confusing because of the large quantity of information that must be supplied to the various agencies due to overlapping political boundaries and jurisdictions. Consequently, two approaches have emerged as a means for alleviating permitting problems. One approach is to streamline the permitting process through unique permits. The other involves incorporating concepts such as watershed management approaches that solve problems through stakeholder committees. An ideal solution may involve combining these two approaches.

Streamlining the permitting process into an easy-to-implement procedure is one of the preferred alternatives. Developing an easy application process could actually encourage conservation practices that protect water quality and wetland areas (WQPP, 1997). Many agencies and environmental groups are trying to develop streamlined procedures where overlaps exist between the three levels of government (federal, state, and local); however, specific information on how such a process would be done is lacking. For example, the Water Quality Protection Program for Monterey Bay National Marine Sanctuary emphasizes the idea of a regulatory coordination program by "streamlining permits over broad geographic areas, restructuring the permit process and improving communication among the parties" involved (WQPP, 1997). The Florida Department of Environmental Protection has developed a consolidated application process called a "Joint Coastal Permit" for coastal construction permits, environmental resource permits, wetland resource (fill and dredge) permits, and sovereign submerged lands authorizations. One application is filled and sent to the Florida Department of Environmental Protection, Office of Beaches and Coastal Systems, which is then forwarded to the Army Corps of Engineers for their review when a fill and dredge permit is required for a project (FDEP, 2001). In the state of Washington, The Project Review and Environmental Analysis Advisory Committee (PREAAC) proposes to delegate authority for stormwater, wetlands, and other critical areas to local governments which often already have considerable environmental authority, suggesting the possibility for watershed-based management (PREAAC, 2001). Further analysis of these experimental programs may suggest potential means of streamlining the complexity currently found in the permitting process for artificial breaches in California. In an unrelated case, Florida's Broward County Department of Natural Resource Protection sought means for improving compliance with the complicated regulatory structure surrounding the marina industry. Their solution, largely supported by local marina operators, was to create a list of best management practices (BMPs) that represented a series of guidelines that would ensure compliance with county regulations (Espejo et al., 1998). Similarly, a list of streamlined guidelines that would ensure compliance with all regulations could possibly be developed for artificial breaches in California. The development of such a list would have to be carried out within a stakeholder process to ensure that all agencies would support the measures outlined within the BMPs.

This stakeholder process easily falls under approaches that involve regional organization. For example, a watershed-based management approach might entail a committee made up of representatives from county and city governments, environmental and business interests, and homeowners and citizen's organizations. State and federal environmental regulators would participate in the decision-making process via a technical advisory committee. While this type of process could replace a permit-based regulatory structure, a combination of this strategy with streamlined guidelines would ensure a process that takes into account regional considerations as well as those of organizations intent on conducting an artificial breach. Management of coastal resources at the regional level would facilitate the transcending of political boundaries, and the associated artificial and arbitrary regulatory and administrative jurisdictions.

8.4 REGIONAL INFORMATION-SHARING RECOMMENDATIONS

An enhanced understanding of the relationship between artificial breaching events and ocean water quality may also be gained through examination of regional practices. In particular, managers and stakeholders of breaching locales would benefit in two significant ways:

- The collection and sharing of formal data on artificial breach activities should eventually lead to comparisons among watersheds. Thus offering an ideal opportunity to examine watershed-level factors that may influence bacterial loading associated with such activities, as well as a chance to investigate how long-term temporal changes within a basin and/or wetland affects coastal contamination.

- To facilitate communication among regions, data and studies of artificial breach events should be presented and discussed at applicable conferences and meetings of professional associations. Given the pervasiveness of this practice throughout California, and given that it represents a unique type of dry-flow event, artificial breaches may be given special attention as a unique topic for discussion at such gatherings.

8.5 GENERAL RESEARCH RECOMMENDATIONS

There are also actions that are not only important to understanding the effects of artificial breaching on ocean water quality, but will improve understanding across a range of issues associated with ocean water quality. It is most important that research continues in a search for improved tools and techniques for coastal managers:

- Given that the established indictors do not rest upon the best endeavors that science can offer, research needs to improve epidemiological understanding of these organisms, as well as develop efficient and cost-effective means for evaluating samples for the presence of pathogens.

- Research of novel modeling approaches that incorporate key elements of coastal and watershed processes will offer many benefits to managers in the future

Currently, the US EPA recognizes the deficiencies of the current suite of indicators and would like to ultimately improve testing methods to better differentiate between human and animal wastes, to develop better indicators for waterborne non-gastrointestinal type diseases, and design real-time monitoring techniques to prevent beachgoers' exposure to the greatest extent possible (Schaub, 1999). Schaub (1999) suggests that better differentiation between human and animal wastes will probably be achieved through DNA fingerprinting, phage typing, or polymerase chain reaction. Nonetheless, the extent to which animals' pathogens are threats to public health needs to be determined. Potential indicators of non-enteric diseases could be *pseudomonas* spp, *staphylococcus* spp, or fungi. However, it is difficult to imagine that a unique indicator organism will represent all non-gastrointestinal type diseases (ear, upper respiratory tract, and skin infections) and their sources. Real-time monitoring and beach closure action could be achieved through "dipstick" or other rapid, easy to use, and inexpensive technologies. Good candidates could be caffeine, fecal sterols, detergents, Ig A, and immunological tests for antigens such as ELISA (Schaub, 1999). With time, more research will be undertaken on these subjects, and results will lead to better monitoring and public protection practices.

Models should also be explored as useful tools for understanding bacterial contamination at beaches. Simple rainfall based alert curves are used by a few local agencies throughout the U.S. These are based on a probabilistic analysis and frequency exceedence analysis of indicator organism concentrations at fixed stations near the beach and rainfall events at one or more locations in the upstream watershed (USEPA, 1999). Other models used are based on fate and transport processes in receiving waters to predict pathogen concentrations and subsequently water quality around wastewater treatment outfalls (such as CORMIX and PLUMES). Another interesting model is the Hydrological Simulation Program - FORTRAN (HSPF), developed by EPA. This program is able to model pollutant load and water quality at any point in a complex watershed by taking into account storm events, continuous flow, and fate and transport processes such as hydrolysis, oxidation, photolysis, biodegradation, volatilization, and sorption in one-dimensional stream basin. HSPF has been integrated into USEPA's BASINS program as the Non-point Source Model (NPSM). BASINS can perform watershed and water quality-based studies (bacteria monitoring station summary) using point as well as non-point source data. Models like BASINS should offer a chance to look at integrated processes and how they are altered over time and space (US EPA, 1999). Furthermore, with sufficient data and proper validation, such an approach may allow for predictions of changes in ocean water quality at an actual marine discharge point, as is currently done in limited U.S. coastal locations. A properly constructed and validated model would allow for immediate actions and advisories, as opposed to waiting for the 18- to 24-hour period necessary for processing ocean water samples.

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APPENDIX A – FIELD AND LABORATORY METHODS

Bacteria sample collection

Background:

1. There were five separate sampling events to monitor the breaching of Goleta Slough.
2. The first event established baseline conditions for the subsequent observations and consisted of only three stations: the slough, the mouth, and 250 yards upshore. It was carried out approximately 24 hours before the breach.
3. The next event captured the short-term impacts of the breach; sampling events occurred within the first couple hours after the daytime low tide.
4. The following three events were conducted at 12 hours, 24 hours, and 48 hours after the breach.
5. 4 replicate samples were taken at each of the 8 sampling locations for these events.

Pre-event:

1. Placed 6 blue packs in a freezer.
2. Labeled 36 thiosulfate IDEXX sampling bottles.
   - 2.1. For 32 of the bottles, used a Sharpie Permanent Pen to write an identification number on the bottle.
     - 2.1.1. Wrote the day number, metered location (GS for the Slough), and replicate number in a column. For example: for the sample taken on August 18, 50 meters upshore, second replicate, one wrote: 18, -50 underneath, and 02 underneath that.
     - 2.1.2. Filled out (wrote and prepared) a bottle for each sampling point.
   - 2.2. Collected 4 other blank bottles; stored a Sharpie Pen with them.
3. Located and collected the following items: paper towels, a large ice chest, 12 locator flags, and a measuring wheel.
4. About 1.5 hours before the event, placed the blue packs and sampling bottles into the ice chest; packaged other material together in preparation for transportation to the beach.

Collection:

1. Immediately placed the flags along the beach just outside of splash zone.
   - 1.1. From the center of the Slough mouth, walked upshore with the measuring wheel. Placed a flag at 50 yards and 250 yards.
   - 1.2. From the center of the Slough mouth, walked downshore with the measuring wheel. Placed flags at all these locations: 0, 50, 100, 200, and 400 yards.
   - 1.3. Placed an eighth flag at the head of the lagoon mouth.
2. At the same time, placed the sampling bottles with their corresponding location flag. Made sure that they were in a dry area unaffected by water.
3. At the appointed sampling time, took water samples at the designated locations.
   - 3.1. Removed any plastic wrapping on two of the bottles.

3.2. Walked perpendicular to shoreline, from the flags, into the ocean to ankle- to knee-depth.
3.3. Took off the caps, making sure that one did not touch the inside of the caps or bottles.
3.4. Pulled a water sample.
3.4.1. Sample was best taken just after the wave had come in.
3.4.2. Minimized the amount of sediment in the bottles; overfilling required new sampling bottles.
3.4.3. Made sure the bottles were filled to the 100 ml line on the bottle.
3.4.4. Made sure the labeling corresponded to the sampling point; made sure the writing had not washed off. Replaced it if necessary.
3.5. Repeated 3 as necessary.
4. Once the samples were collected at one location, placed them in the ice chest immediately to prevent die-off from heat or photolysis.
5. Once all the samples were collected, immediately delivered them to the laboratory for analysis.

Bacteria laboratory analysis

Background:
1. Once the samples were received, they needed to be processed within 6 hours.
2. If they were not processed immediately, they were placed in the fridge to prevent degradation of samples.
3. Those conducting the laboratory work studied the appropriate dilution diagram to make sure that they understood the process.
4. Controls would be done only if time permitted.

Pre-event:
1. Before the sampling event, all materials required to process the samples were labeled. They were not left by the window since sunlight would degrade the different media.
1.1. The Butterfield's phosphate buffer and quanti-tray sheets were labeled with a sharpie pen and organized on the working bench so that processing of the water samples would be rapid once received.
1.1.1. Identification of any Butterfield's phosphate buffer solution was as follows: the type of media, the day, the location, replicate number, and dilution in a column. For example: August 1st an Enterolert sample was pulled from the ocean 25 m upstream from the mouth, the sample was the second repeat, and this was the 1/100 dilution: Ent, 1, -25, 2, 1/100 in column.
1.1.2. Quanti-tray sheets were labeled with a sharpie pen as follow:
1.1.2.1. On the front right top, the media used was written (col or ent).
1.1.2.2. On the back, a line separated the sheet in the middle.

1.1.2.2.1. On top, someone wrote the identification information as described above in 1.1.1.

1.1.2.2.2. On the bottom, a grid was made to separate TC large wells from TC small wells and FC large wells from FC small wells. The grid for Enterolert was smaller as the laboratory personnel were only separating the positive large wells from the positive small wells.

1.1.3. The number of Colilert and Enterolert media was distributed on the working bench next to each Butterfield bottle, ready to be mixed.

1.1.4. Because one had 2 different media, one had 2 different columns. Because there were 8 sampling sites and 4 repeats at each site, one had 32 rows. The number of subcolumns depended on the number of dilutions.

1.2. Took the bag of 10-ml pipettes and placed it on the bench with the pipet-aid.

1.3. Took a bag of sterile transfer pipettes and placed it on the bench.

1.4. Controls:

1.4.1. 3 Butterfield's phosphate buffers of 90 ml were labeled as follows: Col - *E. coli*, Col- *P aeruginosa*, and Col – *K pneumoniae.*

1.4.2. 3 Butterfield's phosphate buffers of 90 ml were labeled as follows: ent-*E faecalis*, Ent-*S epidermitis*, and Ent-*E cleacae.*

2. Kept a few Butterfield buffers and Colilert/Enterolert media around so that it could have been used in case a mistake is made.

Processing:

1. Took each media and poured them in their respective Butterfield's phosphate buffers.
2. Made sure that the lids were tightly closed and shook them well.
3. Because of the large number of samples to process, no one had more than 2 sets of bottles (4 bottles total) out on the bench in front of their Butterfield's phosphate buffers / media solution to prevent mistakes.
4. Shook the water samples to resuspend anything that might have settled.
5. To achieve a 1/10 dilution, 10 ml of the sampled water was placed into a 90 ml Butterfield's phosphate buffer solution. Closed and shook well.
6. Poured each dilution into the correct quantitray sheet and sealed using the sealer. Made sure there were some liquids in all the wells. If one or more were empty, the tray was discarded, and the dilution was done again.
7. Incubated the quantitray sheets inverted.
   7.1. Colilert was incubated for 18 hours at 35 + or - .5 °C
   7.2. Enterolert was incubated for 24 hours at 41 + or - .5 °C.
8. Controls were to be prepared as follow:
   8.1. Placed the adequate media in the adequate Butterfield's phosphate buffers. Closed and shook.
   8.2. Took the control microorganisms out of the fridge; they were ready for use and in a liquid broth.

8.3. Turned on the flame.
8.4. Took one of the tubes, opened it and flamed the opening very rapidly to preserve aseptic conditions.
8.5. Using a transfer pipette, transferred **one** drop of each cultures in the appropriate buffer + media solutions.
8.6. Closed and shook.
8.7. Placed the used pipette in a biohazard bag.
8.8. Incubated with the quanti-trays. Did not invert (it would have leaked).
8.9. The samples containing Enterolert were incubated for 24 hours at 41°C.
8.10. The samples containing Colilert were incubated for 18 hours at 35°C.

9. Reading the results:
9.1. It was important to look at the result at the correct time since the bacteria present would have continued to break down the chemical present, thereby altering the results.
9.1.1. Total coliforms were present if any of the wells were yellow. With a sharpie pen, the wells that were yellow were marked. On the back of the sheet, the number of large yellow wells and the number of small yellow wells was written down. In the IDEXX table, or using an appropriate computer program, the number of TC /100 ml was determined. If the sheet was a 1/10 dilution, the number given by the grid was multiplied by 10, to get the number of TC in the original sample. If the sheet was a 1/100 dilution, the number was multiplied by 100 instead.
9.1.2. Fecal coliforms were present if any of the wells fluoresced under UV light. It was important to check that the fluorescent wells were also yellow. If it fluoresced but was not yellow in color (the well was not checked), than there was no fecal coliform in that well. It singled the presence of another group of bacteria. Again, the number of large wells and small wells that fluoresced and were yellow were recorded on the back of the sheet. Looked on the IDEXX table or the computer program to determine the number of bacteria/ 100 ml, as previously described.
9.1.3. Enteroccocci were present if any of the wells were fluorescent under UV light. Here all the wells were yellow and did not apply to results. On the back of the quantitray, the number of large and small wells that were fluorescent was noted. Looked on the IDEXX table or the computer program to determine the number of bacteria /100 ml, as previously described.
9.1.4. Took the controls out of the incubators and made sure that color and fluorescence were as follow:
9.1.4.1. Colilert:
9.1.4.1.1. *E. coli* should have been yellow and fluorescing under UV light (+TC and + EC) .

9.1.4.1.2. *Pseudomonas aeruginosa* should have been yellow only (-TC and - EC).
9.1.4.1.3. *Klebsiella pneumoniae* should not have been yellow or fluoresced (+TC and –EC).

9.1.4.2. Enterolert:

9.1.4.2.1. *Enterococcus faecalis* should have fluoresced under UV light (+ control).
9.1.4.2.2. *Staphilococcus epidermitis* should not have fluoresced under UV light (- control).
9.1.4.2.3. *Enterococcus cleacae* should not have fluoresced under UV light (- control).

9.2. Using the appropriate spreadsheet, recorded the results. There were separate spreadsheets for Colilert and Enterolert.

Nitrate samples

Background:

1. TSS samples were taken in a manner consistent with the temporal and spatial scales that bacterial sampling was conducted on.
2. The collection of these samples coincided with bacterial sampling.
3. Laboratory processing of the samples was conducted by a certified laboratory (Marine Science Institute Analytical Lab, UCSB) using flow injection analysis.
4. On the advice of the analytical laboratory, its own sampling bottles were used to ensure the greatest accuracy and precision during analysis.

Pre-event:

1. About 12 hours before the event, labeled 28 20-ml plastic sampling bottles (only 12 for the first day [pre-breach]) using the identification system employed in the bacteria section.
2. Collected 8 other blank bottles and stored a Sharpie Pen with them.
3. About 1.5 hours before the event, placed the blue packs and sampling bottles into the ice chest; packaged other material together for transportation down to the beach.

Collection:

1. At the same time of bacterial sampling, placed the sampling bottles with their corresponding location flag. Made sure that they were in a dry area unaffected by water.
2. At the appropriate sampling time, took water samples at the designated, flagged locations.
   2.1. Walked perpendicular to shoreline, from the flags, into the ocean to ankle- to knee depth.
   2.2. Took off the caps, making sure that one did not touch the inside of the caps or bottles.
   2.3. Pulled two water samples.

2.3.1. Samples were best taken just after the wave had come in.
2.3.2. Minimized the amount of sediment in the bottles; overfilling would have required a new sampling bottle.
2.3.3. Made sure the bottle was ¾ filled and NO MORE.
2.3.4. Made sure the labeling corresponded to the sampling point; made sure the writing had not washed off. Replaced if necessary.

2.4. Repeated section 2.3.

3. Once the samples were collected at one location, placed them in the ice chest immediately to prevent sample degradation.
4. Once all the samples were collected, immediately delivered them to the laboratory for analysis. If storage had to occur, the samples were placed in the freezer.

Total suspended solids sample collection

Background:

1. TSS samples were taken in a manner consistent with the temporal and spatial scales that bacterial sampling was conducted on.
2. The collection of these samples coincided with bacterial sampling.

Pre-event:

1. Using a Sharpie pen, labeled four replicate 500 ml bottles for each sampling point within a collection event; used the labeling system previously described.
2. Collected and stored 8 blank bottles, in case any problems occurred in the field.
3. Placed the sampling bottles into an ice chest for transportation to the study site.

Collection of Samples:

1. Placed the sampling bottles with their corresponding location flag. Made sure they were in an area unaffected by water.
2. At the appointed sampling time, took water samples at the designated locations.
   2.1. Walked perpendicular to the shoreline, from the flags, into the ocean at ankle- to knee-depth.
   2.2. Took off the cap, making sure that one did not touch the inside of the cap or bottle.
   2.3. Took a water sample.
      2.3.1. The sample was best taken just after a wave had come in.
      2.3.2. Completely filled the bottle.
      2.3.3. Made sure the labeling corresponded to the sampling point; made sure the writing had not washed off. Replaced if necessary.
3. Once all the samples were collected, they were immediately delivered to the laboratory and stored in a refrigerator until analysis could be performed.

Total suspended solids sample analysis

Background:

1. Necessary lab space for analysis was pre-arranged before sampling events.
2. During laboratory work, forceps were used whenever moving glass-fiber filter disks.
3. It was assumed that these measurements would only show a signal if the additional sediment coming out of a breach was strong enough to overcome the wave-induced variability of normal TSS levels.

Analysis Preparation:

1. All glass-fiber disks were prepared prior to processing samples.
    1.1. Labeled aluminum weigh boats for each sample using the labels on the sampling bottles.
    1.2. Removed one filter disk and placed in a filtering apparatus.
    1.3. Washed filter with three 20-ml volumes of de-ionized water.
    1.4. Removed the filter from the filtering apparatus and placed in a labeled aluminum weigh boat.
    1.5. Placed the filter and its weigh boat in the oven and dried for 45 minutes at 103-105° C.
    1.6. Removed the filter and weigh boat and placed into a muffle furnace; ignited for 10 minutes at 550° C to remove any DOC from the washing process.
    1.7. Re-wrote the label on the weigh boat as necessary.
    1.8. Immediately weighed the filter and weigh boat; placed in a dessicator for drying and cooling.
2. Repeated Step 1 as necessary.

Sample Processing:

1. Placed a filter in the filtering apparatus.
2. Slowly poured the corresponding sample into the center of the filtering apparatus; swirled the sample as it poured out.
3. Removed the filter and returned it to its weigh boat; washed the filtering apparatus with de-ionized water.
4. Placed the sample in the oven and dried for 45 minutes at 103-105° C.
5. Weighed the sample; took this measurement and subtracted the pre-weight to determine TSS (TSS = [Sample weight - pre-weight]/500 mL).
6. Took the sample and ignited it in the muffle furnace for 15 minutes at 550° C to ash any organic material.
7. Weighed the ashed filter and subtracted from pre-ashed weight to determine the amount of suspended organic solids (suspended organic solids = [pre-ashed filter weight - ashed filter weight]/500 mL).
8. Determined whether the samples should be disposed of or stored for further measurement.

Salinity, temperature, and dissolved oxygen measurements

Background:

1. These tests coincided with or were done immediately following bacteria and nitrate sampling.
2. All three of these values were measured with a YSI-85 meter; it was important to review the manual of the meter used in these tests before going into the field.

Pre-Event:

1. Before each day in the field, one should have collected 1 gallon of sterilized water, a large and thoroughly washed 10-gallon bucket, and a logbook with a pen.
2. These items should be bundled together for transportation down to the study site.

Collection:

1. Following bacteria and nitrate sampling, collected measurements.
   - 1.1. Filled the bucket with ocean water at the same depth of other parameters sampled.
   - 1.2. Placed the probe in the bucket and got a reading.
     - 1.2.1. Recorded in the logbook, taking note of the day number and flag location.
     - 1.2.2. Cycled through all the necessary parameters until necessary data were recorded.
   - 1.3. Poured the ocean water out; put some sterile water in the bucket and swirled to sterilize; poured it out.
   - 1.4. Poured a little of the sterile water over the probe.
2. Repeated at all the flag locations.
3. Stored the equipment.

Breach flow measurements

Background:

1. A station along the mouth channel was selected for the purpose of measuring the discharge velocity and the cross sectional area, so that the volume could be calculated.
2. A location was selected where the channel borders were well defined, so that an accurate width could be measured.
3. Initially, Group members expected the County to cut a fairly uniform channel. However, as the days progress, the channel could start to deform. Should this happen, the Group member performing this task repeated the measurement along differing portions of the channel. The following protocol represents a single measurement.
4. In addition to the results from the flow meter, multiple flow rate *estimates* were made. This was accomplished by marking a known distance along the mouth of the Slough and timing the passage of a floating object along this distance.

Should problems arise with the flow meter data measurements, this data would serve as backup data.

Pre-event:

1. Prior to the event, collected 6 wooden meter sticks, a logbook (with pen), a rolling measuring tape, two weights (for holding the tape measure down, if needed), a flowmeter, and an attaching rod.
2. Bundled this material together for transportation to the study site.

Collection:

1. Identified a well-defined portion of the channel.
2. Weighing down one end of the tape measure on one side of the channel, the tape was stretched across the channel, and its width was measured.
3. Established five equidistant stations along the width of the channel; marked each area with a well-buried meter stick. If the flow was too strong, made temporary marks on the tape.
4. At each station, measurements were made:
   - 4.1. Set the flowmeter to zero.
   - 4.2. Made sure meter did not break the surface or touch the bottom during measurement.
   - 4.3. Watched for debris from upstream that could interfere with the meter (i.e., kelp).
   - 4.4. Placed the meter in the water for twenty seconds; recorded counts.
   - 4.5. Measured the depth at the station and recorded.
5. Repeated Step 4 at the other four stations.
6. Repeated Steps 1 – 5. If the channel width varied greatly from place to place, locations were selected that represented minimum and maximum widths.
7. Disassembled the flow meter, and cleaned it according to instructions provided in the instruction manual.

Data Conversion:

1. Converted the measurement into a volume flow rate.
   - 1.1. Using the conversion provided by the manufacturer of the flow meter, converted "counts/second" into "meters/second" for each of the five stations in the measurement.
   - 1.2. Found the average of the numbers calculated in 1.1.
   - 1.3. Found the average depth of the five stations.
   - 1.4. Multiplied the numbers in 1.2 and 1.3, and then multiplied by the width specific to this flow measurement. This provided a "volume/time" value.
2. Repeated conversions for the other flow measurements taken during the sampling episode.

Longshore flow measurement, dye & orange drop

Background:

1. The selection of fluorescein dye or oranges were mixed in order to provide an estimation of longshore flow.
2. When using dye, it would have been preferable to establish a protocol that would allow for the use of a fluorometer. Nevertheless, visual observation of the dye provided estimates similar to other tests.
3. Flow measurements followed the collection of other field data.

Pre-event:

1. Prior to a sampling event, one gathered 8 oranges, fluorescein dye, two ½ liter plastic mixing containers, a 10-ml pipette, a vacuum bulb, a measuring wheel, 5 flag markers, a stopwatch, and a clipboard.
2. Bundled this material together for transportation down to the study site.

Collection using dye:

1. Using the flags and the measuring wheel, marked 20-meter intervals downcoast from the mouth of the slough.
2. Measured out 50 to 100 ml of fluorescein and placed it in one of the mixing containers.
3. Collected some seawater with the other mixing container and diluted the fluorescein partitioned out. Mixed well. Recorded the amount of dye used and carried the diluted dye to the mouth.
4. After a wave washed in, poured the diluted solution into the water and started the stopwatch. Rinsed the container to make sure all the dye was released.
5. Visually followed the front edge of the plume and recorded the elapsed time once it traveled the distance denoted by each flag. Ceased recording times when the plume edge became too difficult to follow.
6. Collected flags once the measurement ceased. Calculated velocity for each observed marker and averaged the numbers.

Collection using oranges off of Goleta Pier:

1. Walked 30 meters out from the wave swash zone on Goleta Pier.
2. Measured the width of the pier at that location.
3. Dropped 2 oranges off the upshore side of the pier; began timing with the stopwatch.
   - 3.1. Watched for the appearance of the oranges on the downshore side of the pier; recorded the times at which they were visually sited.
   - 3.2. If the oranges did not follow the expected pattern of longshore flow, one qualitatively recorded what happened.
   - 3.3. Calculated the velocity for each orange using the width of the pier as distance traveled, and averaged the values together.
4. Repeated Step 3 as necessary.

Longshore measurement, GPS buoy

Background:

1. Longshore flow data collected using the buoy was considered supplemental to that collected through the use of dye and oranges. Nevertheless, one kept in mind that the buoy was deployed beyond the wave zone; significant differences could appear as a result.
2. It was important to read the manual associated with the GPS unit in order to understand its operation.
3. This data was collected in concurrent with other flow data.

Buoy construction and preparation:

1. As soon as possible, a buoy was constructed to hold the GPS unit. Used some standard carpenter tools.
   - 1.1. Acquired a large plastic Tupperware container. It was large enough to hold the GPS unit inside and buoyant enough to stay afloat.
   - 1.2. Using waterproof, silicon-based glue and (cut) pieces of wood, constructed a frame inside the container that held the GPS unit in the middle of the container.
   - 1.3. Placed an X-shaped "water sail" underneath the container to stabilize the boat AND capture the water currents.
     - 1.3.1. The sail could have been constructed of firm plastic or wood, cut and glued into the shape of an "X". Plastic was used for this buoy.
     - 1.3.2. The plastic was buoyant, and had to be weighted to prevent the buoy from tipping over. This required experimentation with the GPS unit placed inside its frame.
     - 1.3.3. The sail was fastened with waterproof epoxy.
   - 1.4. Ensured that the buoy remained afloat in the oceanic environment through careful experimentation.
2. Before each sampling event, charged the GPS and made sure there were spare fresh batteries.
3. Collected a reel of fishing line, a wetsuit, and stable floatation device (ex: longboard or kayak).
4. Bundled this equipment together for transportation down to the study site.

Collection:

1. Locked the GPS into the buoy and sealed it up.
2. Deployed the buoy through one of two methods:
   - 2.1. Swam out with the buoy 15-20 yards past the wave swell. Steadied the buoy, and activated the automatic GPS log function so that it recorded a point every minute. Closed up the case.
   - 2.2. Activated the log function, closed up the buoy, and used the fishing line to slowly lower it off the pier beyond the wave swell.
3. Followed the buoy for up to an hour, or until it entered substantial wave influence. Switched off the GPS unit, closed up the case, and swam back to shore.

4. Repeated the measurement as deemed necessary. When repeating this measurement, selected locations that could be physically distinguished from one another.
5. Immediately went to a computer workstation to download the data into an electronic format.

Collection of background data (wind, tide height, wave height and swell, etc.)

1. Collection of this specific data was conducted on the day following a sampling event.
2. Deep-water swell heights, periods, and directions for times corresponding to sampling periods were obtained from the CDIP swell model archives (http://cdip.ucsd.edu/cgi-bin/csh_model_request). The data used came from a buoy approximately 19 kilometers west of Point Arguello.
3. For tide heights, a tide predictor was used to determine heights that corresponded with sampling times: http://tbone.boil.sc.edu/tide/tideshow.cgi?site=Santa+Barbara%2C+California.
4. Wind speeds and directions during the sampling events were obtained from archived data collected from a NOAA station at the Santa Barbara Airport: http://ols.ncdc.noaa.gov/cgi-bin/nndc/buyOL-002.cgi.

APPENDIX B – RAW DATA AND DATA PLOTS

Preliminary Results of Sampling Event (06/08/2000)

In the Slough near the parking lot, control 1 was taken on the south side of the creek. Control 2 was taken on the north side of the creek. At the same locations then control 1 and 2 were collected, S1 and 2 samples were taken after stirring the sediment to resuspend them. An additional sample (S3) was collected on the north shore as the water was naturally turbid. Stirring the sediments definitely increased the bacterial content of all indicators (they are significantly higher but they stay within the same magnitude). At this time, a 1/10 dilution is enough to capture the bacterial density.

In the ocean by the Slough mouth, 5 samples were simultaneously taken on the first wave. On the next wave, four samples were simultaneously taken. Three samples were then taken on the fourth wave and 2 samples were taken on the sixth wave. Data are shown on table 2 of this appendix. To look at the variability of the MPN numbers in the ocean, we took the average and standard deviation of the 14 samples for each indicator (table 1). Looking at the overall data of the ocean, we can see that the variability in the numbers is great.

Table 1: Average and Standard deviation calculated for the 14-ocean water samples collected.

	Enterococcus	Total coliforms	E coli
Average	25.78571429	303.7142857	213.0714
Standard deviation	23.56718243	45.31501461	66.17397

Table 2: Recording spreadsheet for MPN Numbers

	Enterolert	Colilert	
	Enterococcus	Total Coliform	E coli
Sample Slough	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)
Sctl 1	146	3784	414
Sctl 2	110	2359	1430
S 1	199	5172	2046
S 2	148	5794	2613
S 3	84	3282	1354
Sample Goleta beach	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)
V1-1	20	377	209
V1-2	63	309	145
V1-3	74	355	155
V1-4	31	305	96
V1-5	41	292	203
Sample Goleta beach	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)
V2-1	41	309	246
V2-2	30	262	216
V2-3	31	336	299
V2-4	20	288	201
Sample Goleta beach	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)
V3-1	10	243	187
V3-2	0	327	279
V3-3	0	235	145
Sample Goleta beach	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)	.1 dilution (MPN /100ml)
V4-1	0	250	327
V4-2	0	364	275

Description of Data and Plots

The following table contains the bacteria data for the Goleta Beach Water Quality Project field experiment.

The first set of plots (8 plots) is the bacteria data plotted with the three indicator organism MPN results for each sampling location.

The next set of plots (12 plots) are plots of a specific indicator organism MPN at a sampling time plotted as a function of sampling locations with error bars at each data point. The error bars represent plus and minus the standard deviation for that data point, calculated from the four replicates taken at each location for one sampling time.

The third set of plots (24 plots) is the bacteria data plotted with one indicator organism MPN result for each sampling location. This view provides the viewer with a more accurate MPN scale with which to view the results.

The next plot (before the table) is nitrate level in the slough versus time.

The following table is wind speed and direction data from the Santa Barbara Airport.

The final set of plots are the deep-water swell heights, periods, and directions at a number of times corresponding to the sampling times for the time period covering the water sampling were obtained from the Coastal Data Information Program (CDIP) swell model archives (Scripps Institute of Oceanography, 2001).

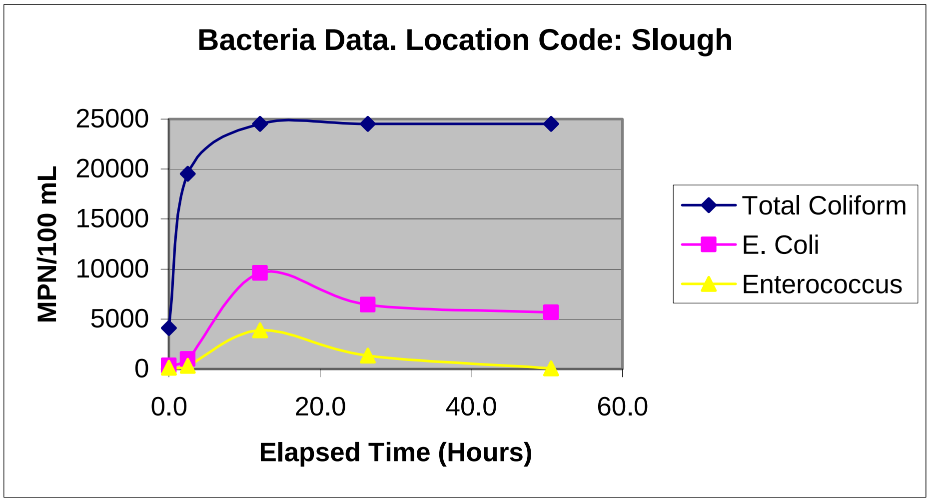
Goleta Beach Water Quality Project Bacteria Data from Field Experiment

Day Code	Location (yds from slgh mouth)	Indicator Organisms		
		Total Coliform	E. Coli	Enterococcus
		MPN	MPN	MPN
0	-250	20	20	0
0	-250	41	31	0
0	-250	31	0	0
0	-250	20	0	20
0	0	120	52	41
0	0	218	98	31
0	0	86	52	20
0	0	75	52	20
0	slough	4352	243	145
0	slough	4611	414	98
0	slough	3130	408	146
0	slough	4352	295	98
1	-250	2143	187	20
1	-250	2613	243	63
1	-250	2359	243	134
1	-250	2247	355	84
1	-50	5794	265	160
1	-50	5475	620	241
1	-50	6131	422	183
1	-50	4884	288	246
1	0	2064	120	187
1	0	2247	350	20
1	0	1670	146	41
1	0	1153	171	86
1	slough	24196	1086	216
1	slough	19863	794	313
1	slough	19863	910	410
1	slough	14136	1223	313
1	50	4884	315	253
1	50	3654	318	109
1	50	4884	441	187
1	50	2098	216	122
1	100	5475	761	384

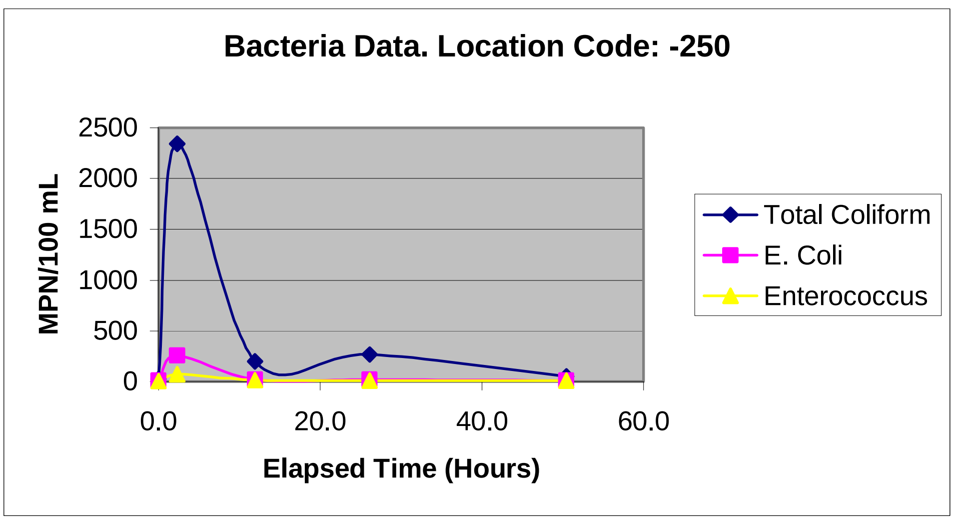
1	100	4884	422	450
1	100	5172	452	441
1	100	4106	322	327
1	200	2143	464	74
1	200	1274	530	96
1	200	4352	882	241
1	200	2613	410	161
1	400	480	185	52
1	400	373	145	30
1	400	408	183	41
1	400	282	98	30
2	-250	158	20	10
2	-250	110	20	20
2	-250	238	20	10
2	-250	295	20	31
2	-50	24510	1785	1860
2	-50	24510	1935	2755
2	-50	24510	2755	2613
2	-50	24510	2224	1607
2	0	24510	3873	3873
2	0	24510	4106	2247
2	0	24510	1935	1872
2	0	24510	2513	1789
2	slough	24510	9804	3130
2	slough	24510	9208	3076
2	slough	24510	11199	4884
2	slough	24510	8164	4352
2	50	24510	3654	2359
2	50	24510	2143	1860
2	50	24510	2909	2489
2	50	24510	3654	2046
2	100	24510	2603	1872
2	100	24510	2014	1354
2	100	24510	2382	1956
2	100	24510	1860	2755
2	200	24510	2014	2247
2	200	24510	2382	2014
2	200	24510	2382	1210
2	200	24510	1725	932
2	400	24510	805	1430
2	400	24510	1396	2282
2	400	24510	1012	1500

2	400	24510	1317	1650
3	-250	345	20	0
3	-250	288	31	0
3	-250	183	20	20
3	-250	246	10	20
3	-50	3873	173	249
3	-50	4611	121	265
3	-50	860	63	31
3	-50	1178	84	10
3	0	663	41	0
3	0	794	85	20
3	0	833	20	20
3	0	776	63	0
3	slough	24510	7270	2481
3	slough	24510	6867	1162
3	slough	24510	6488	1126
3	slough	24510	5172	629
3	50	1918	96	20
3	50	2014	97	31
3	50	1500	110	31
3	50	1723	86	41
3	100	1014	75	52
3	100	1050	52	20
3	100	1529	75	41
3	100	1054	63	0
3	200	1153	51	31
3	200	960	85	20
3	200	644	41	10
3	200	816	52	20
3	400	175	0	0
3	400	266	41	20
3	400	285	10	0
3	400	279	10	0
4	-250	98	10	10
4	-250	31	10	20
4	-250	41	20	0
4	-250	41	10	10
4	-50	2382	341	110
4	-50	1725	63	211
4	-50	3609	426	193
4	-50	2481	331	134
4	0	749	30	2247

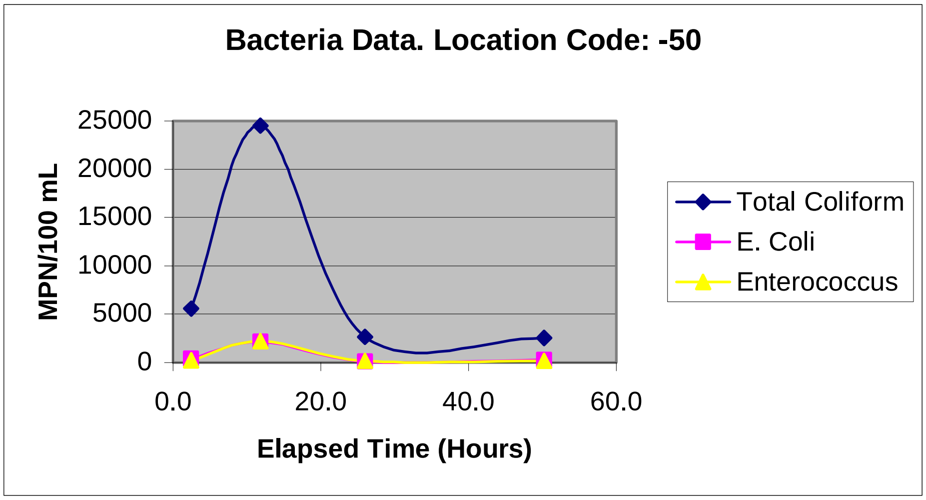
4	0	1046	158	1860
4	0	733	52	3654
4	0	657	63	1956
4	slough	24510	5172	30
4	slough	24510	6488	52
4	slough	24510	5172	85
4	slough	24510	5794	52
4	50	1017	98	74
4	50	1178	75	10
4	50	1137	97	10
4	50	933	75	52
4	100	1036	86	20
4	100	1354	122	74
4	100	754	84	62
4	100	771	41	20
4	200	1616	122	20
4	200	1782	63	20
4	200	1178	41	52
4	200	1515	98	10
4	400	591	41	98
4	400	862	31	75
4	400	708	97	63
4	400	714	51	110

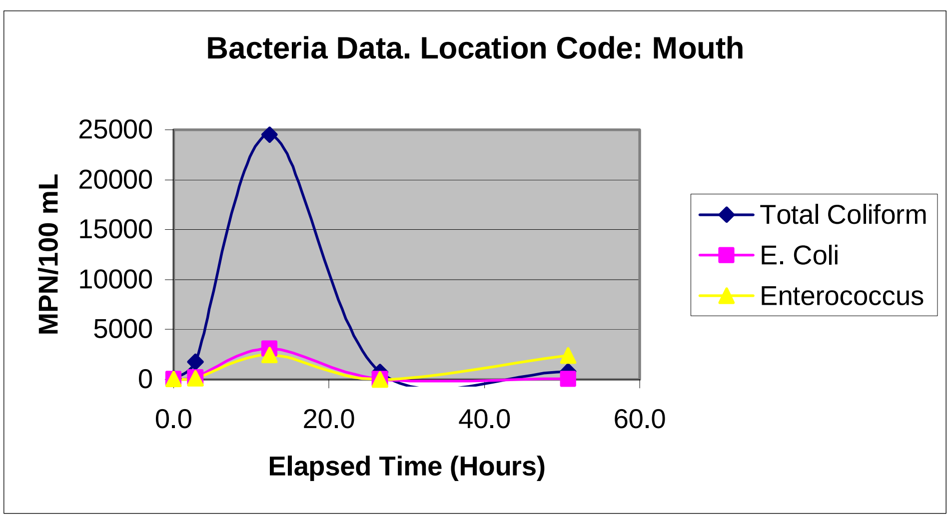


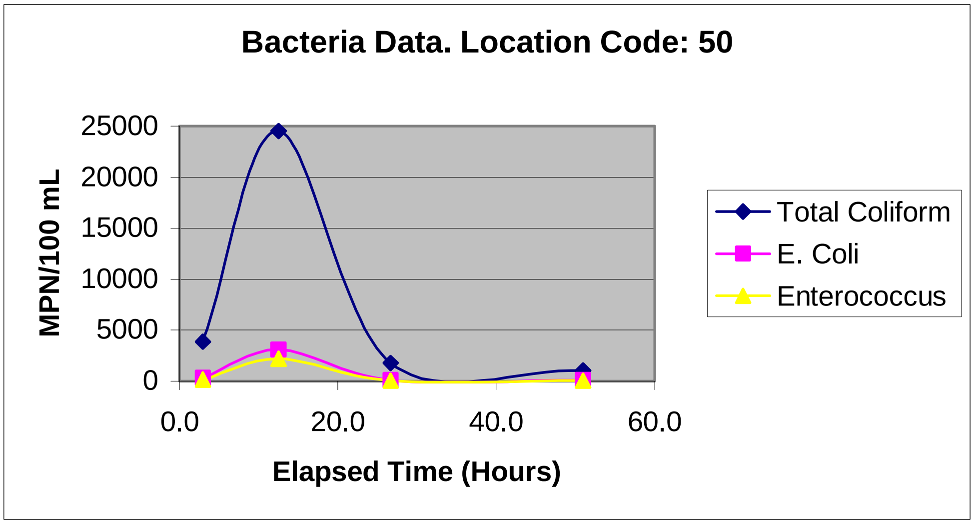
Bacteria Data. Location Code: Slough
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus

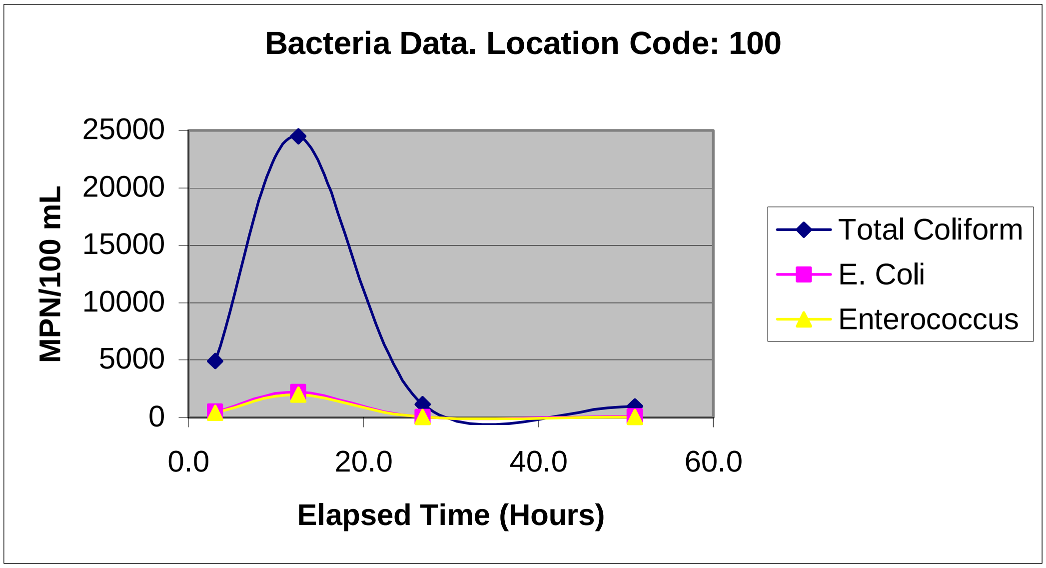


Bacteria Data. Location Code: -250
MPN/100 mL
2500
2000
1500
1000
500
0
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus

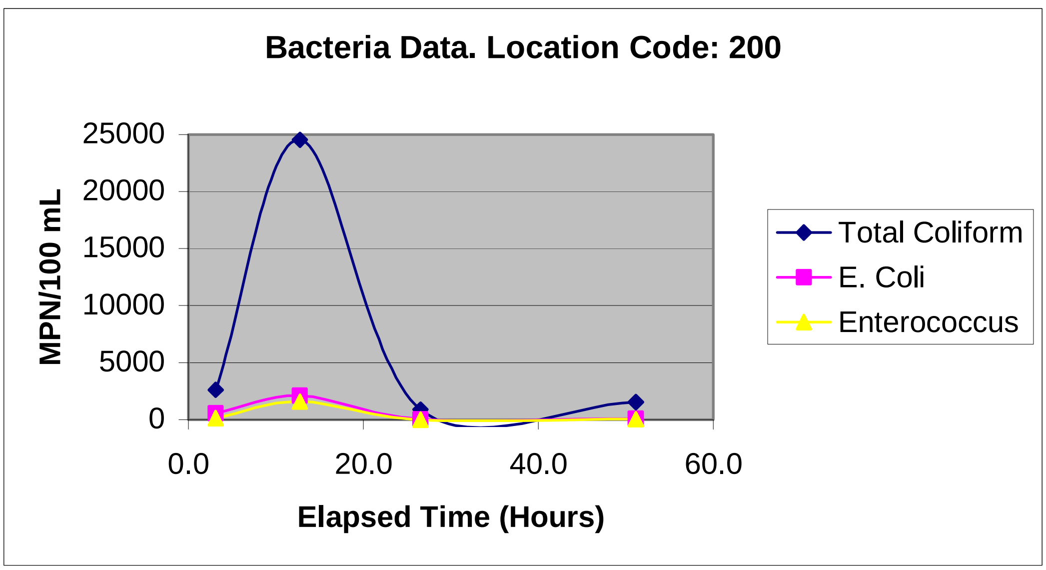

Bacteria Data. Location Code: -50
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus


Bacteria Data. Location Code: Mouth
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus

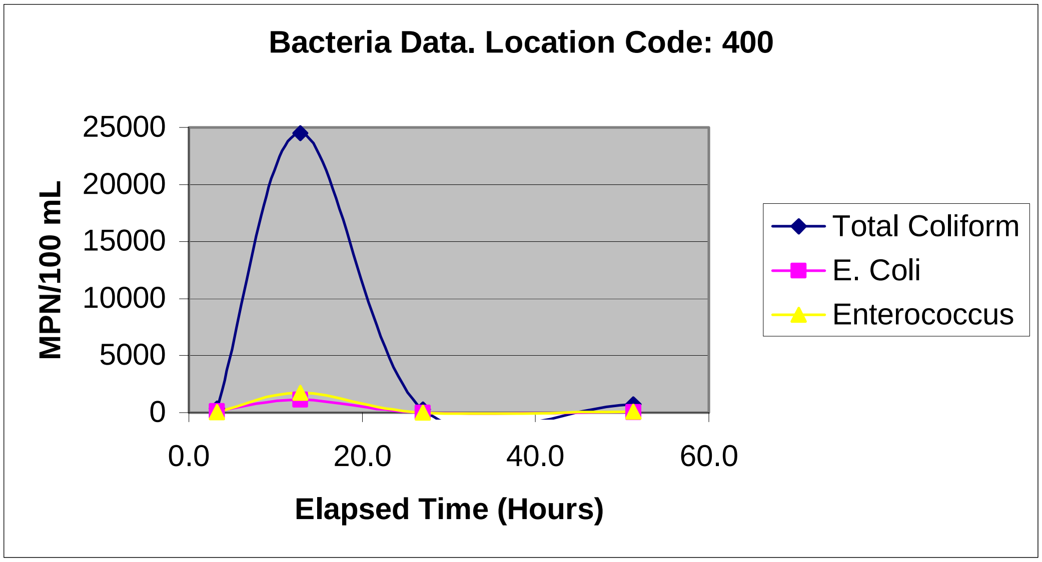

Bacteria Data. Location Code: 50
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus



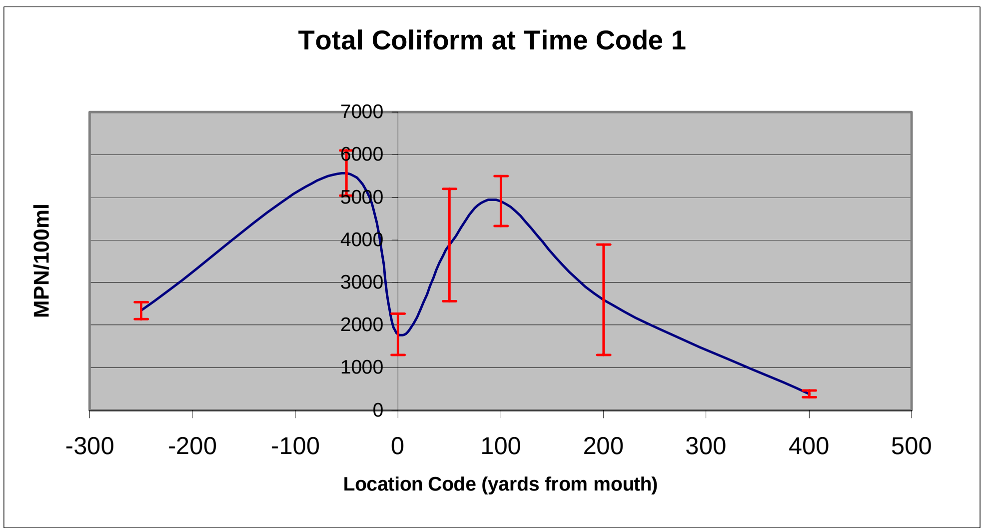
Bacteria Data. Location Code: 100
25000
20000
15000
10000
5000
0
MPN/100 mL
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus



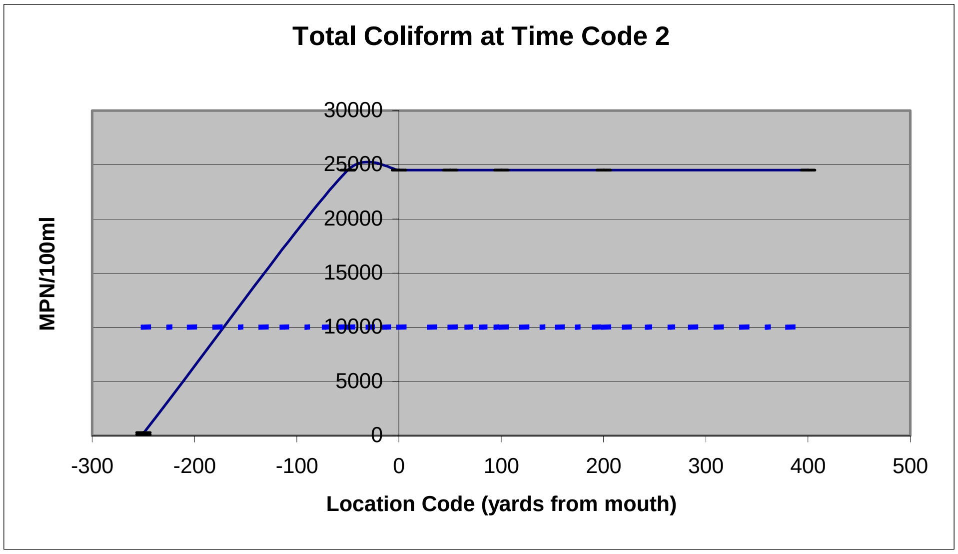
Bacteria Data. Location Code: 200
25000
20000
15000
10000
5000
0
MPN/100 mL
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus

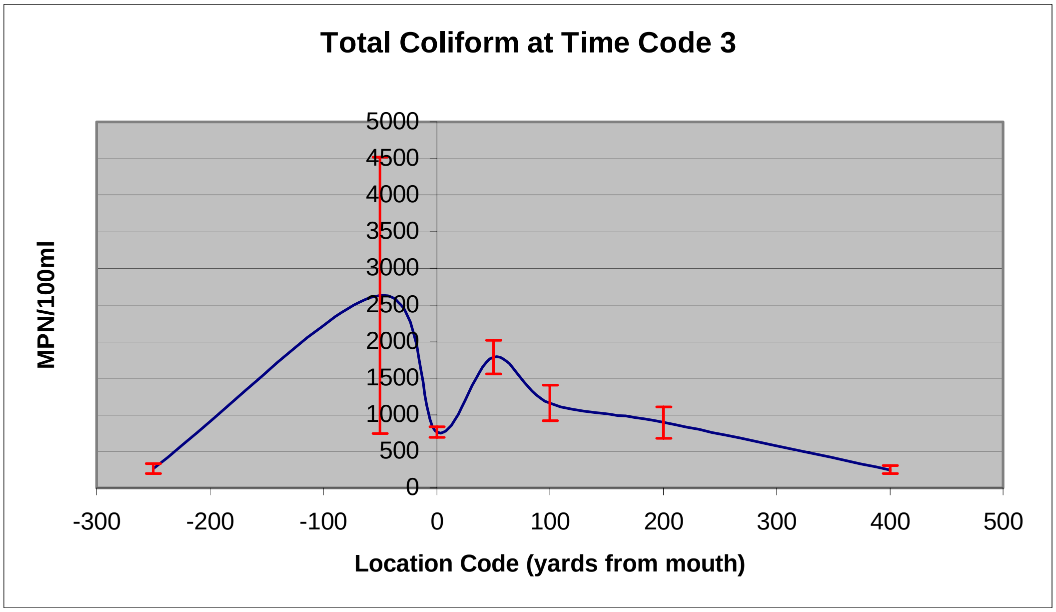


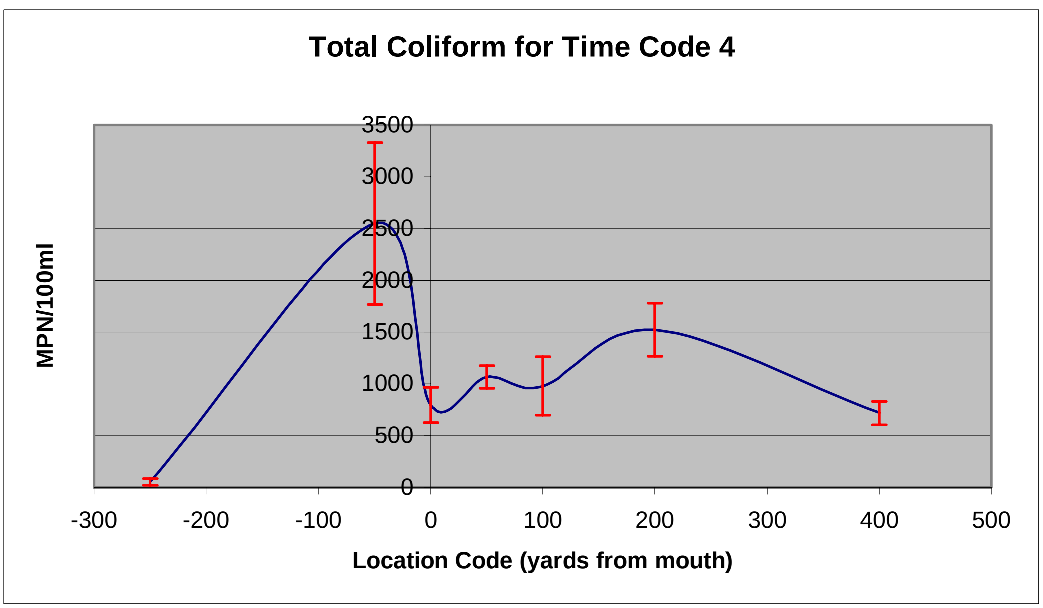
Bacteria Data. Location Code: 400
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
20.0
40.0
60.0
Elapsed Time (Hours)
Total Coliform
E. Coli
Enterococcus

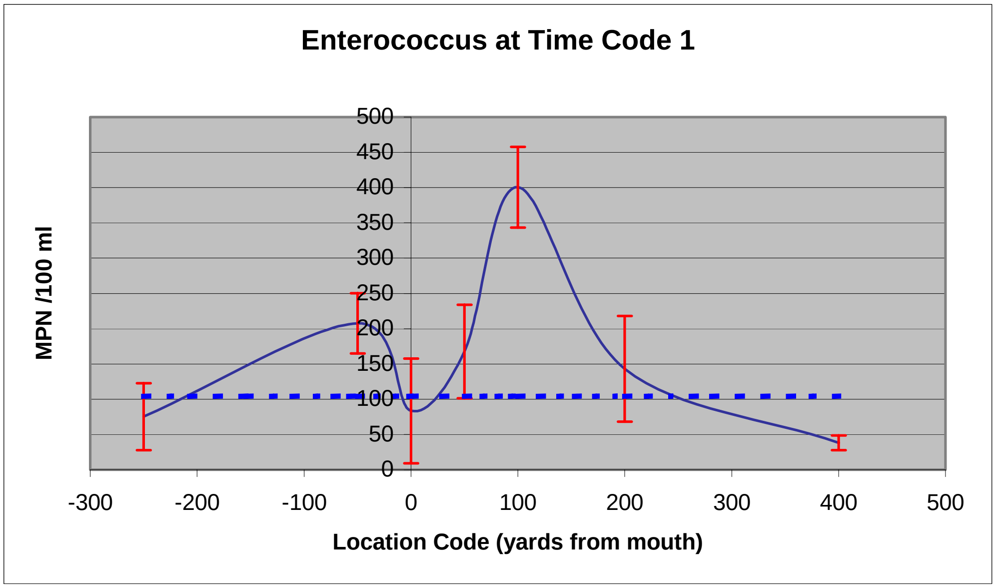


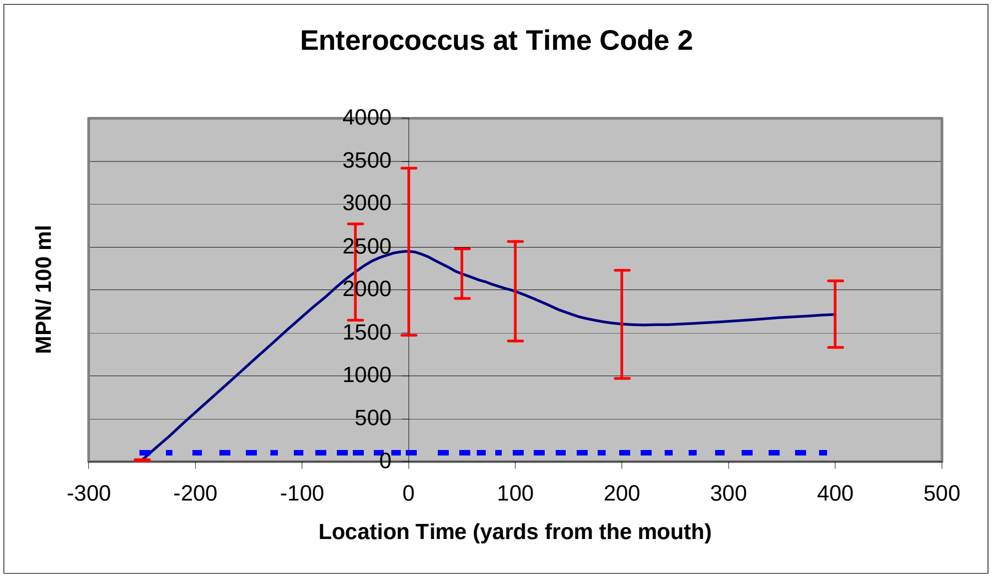
Total Coliform at Time Code 1
MPN/100ml
7000
6000
5000
4000
3000
2000
1000
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)

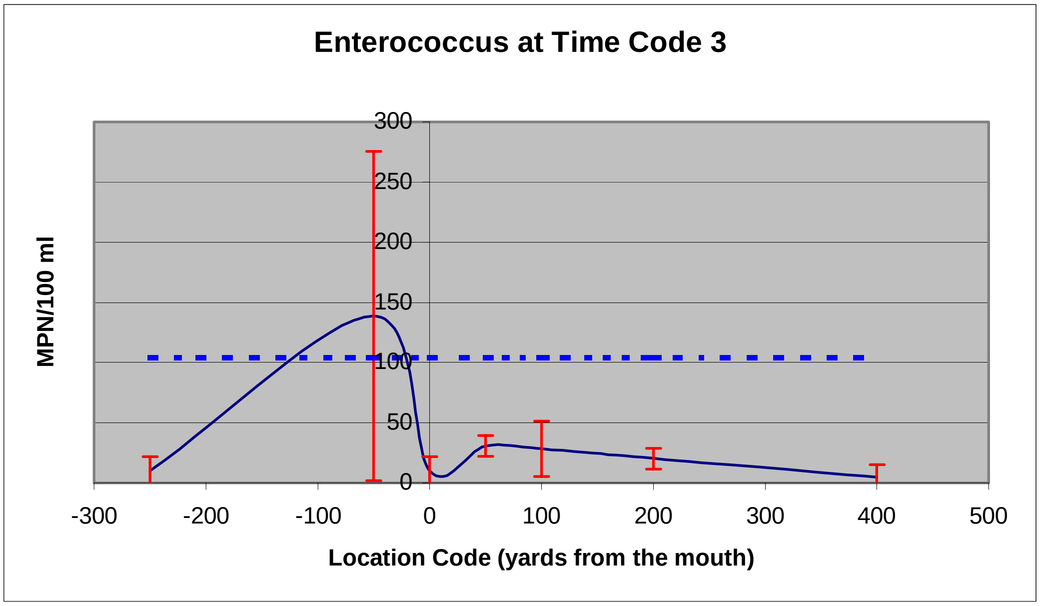

Total Coliform at Time Code 2
MPN/100ml
30000
25000
20000
15000
10000
5000
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)


Total Coliform at Time Code 3
MPN/100ml
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)

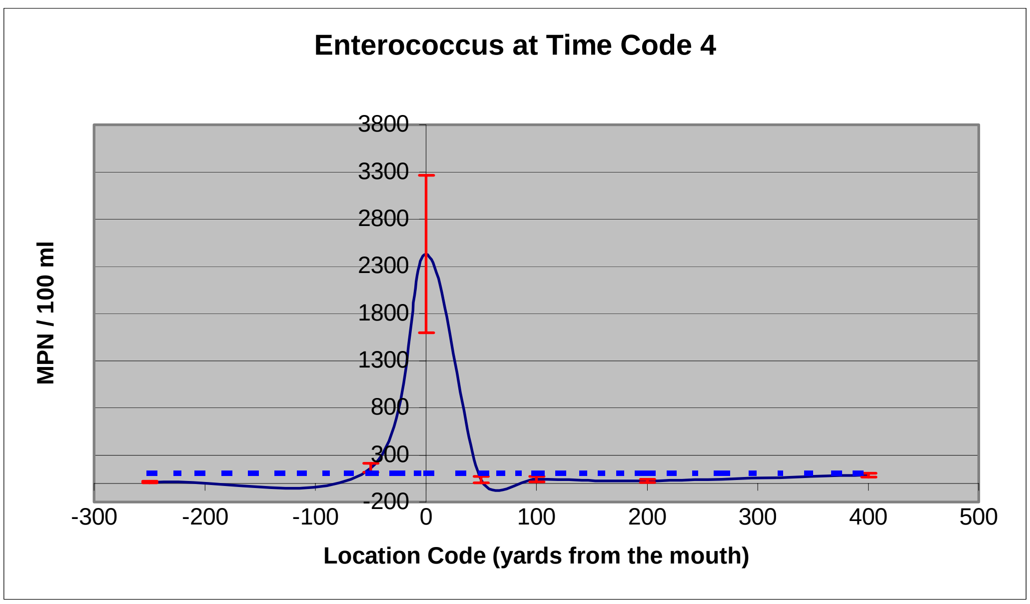

Total Coliform for Time Code 4
MPN/100ml
3500
3000
2500
2000
1500
1000
500
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)


Enterococcus at Time Code 1
MPN /100 ml
500
450
400
350
300
250
200
150
100
50
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)

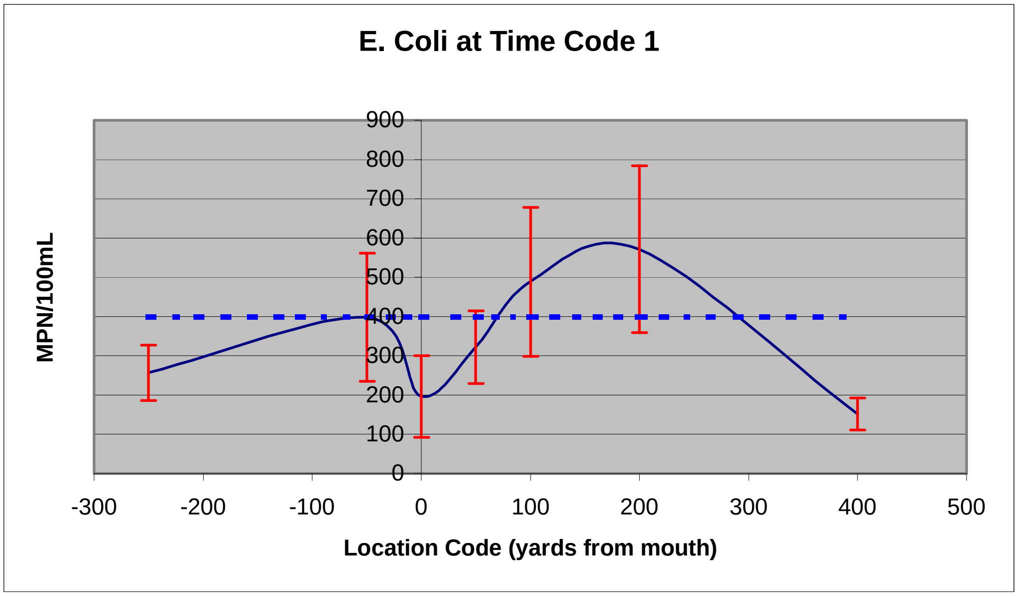

Enterococcus at Time Code 2
MPN/ 100 ml
4000
3500
3000
2500
2000
1500
1000
500
0
-300
-200
-100
0
100
200
300
400
500
Location Time (yards from the mouth)



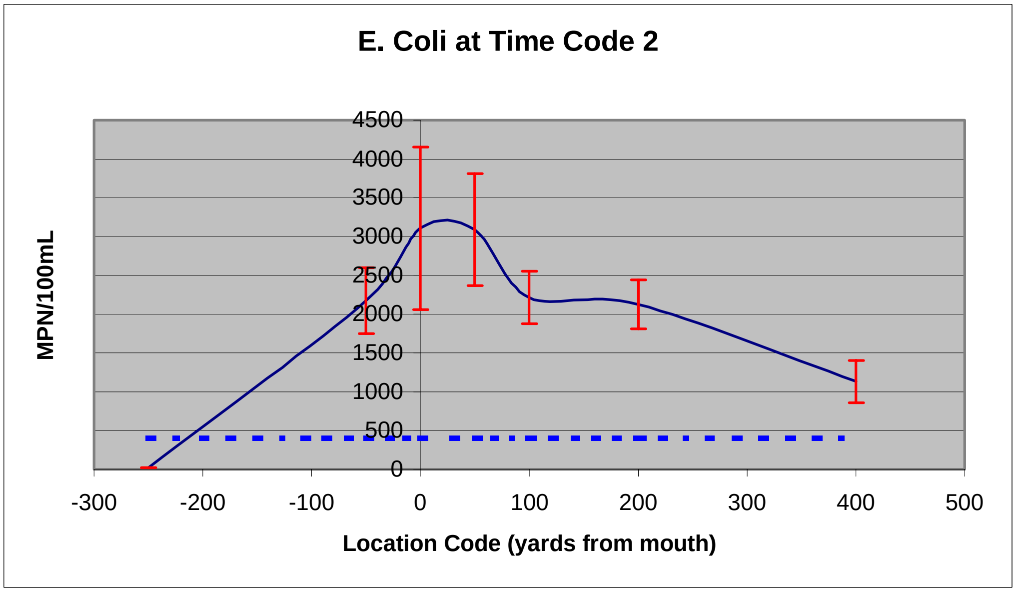
Enterococcus at Time Code 3
MPN/100 ml
300
250
200
150
100
50
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from the mouth)



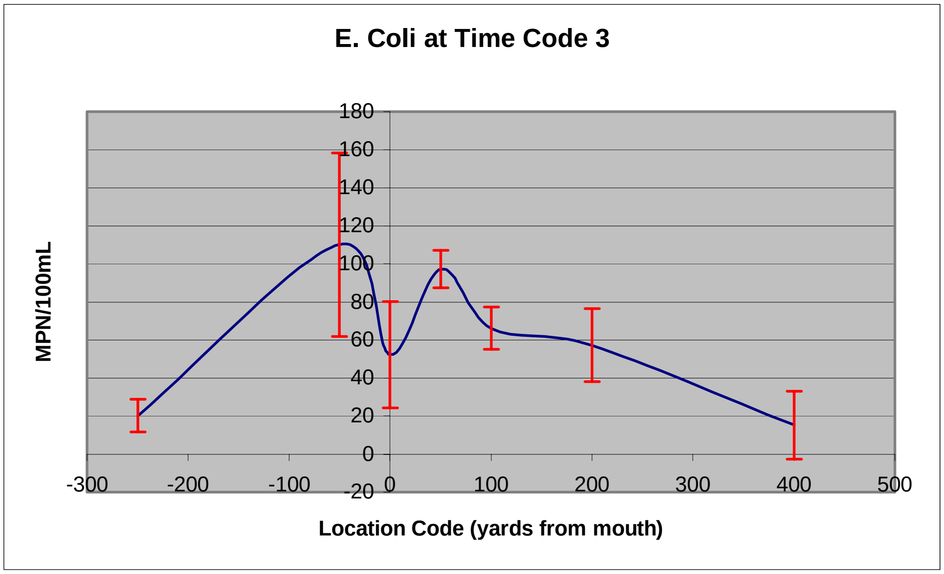
Enterococcus at Time Code 4
MPN / 100 ml
3800
3300
2800
2300
1800
1300
800
300
-200
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from the mouth)

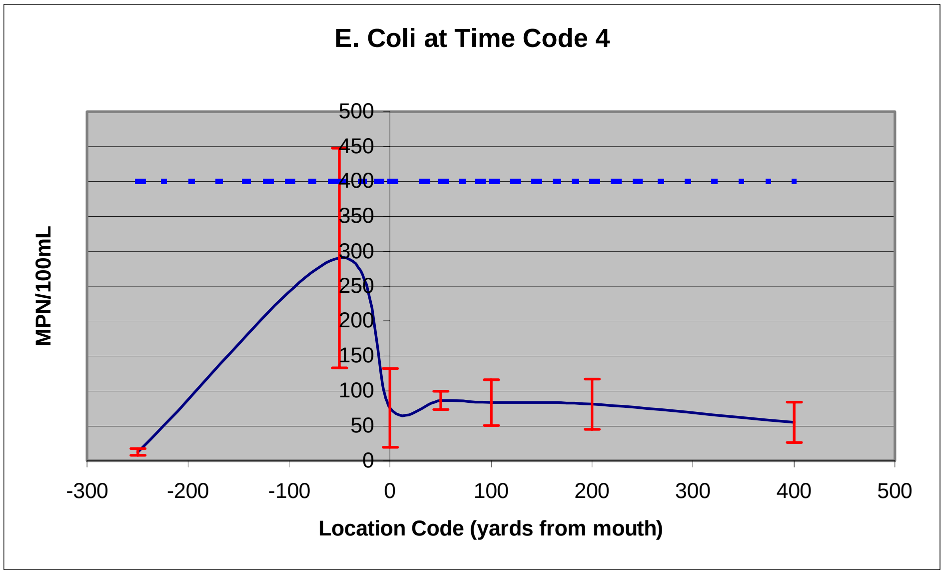


E. Coli at Time Code 1
MPN/100mL
900
800
700
600
500
400
300
200
100
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)

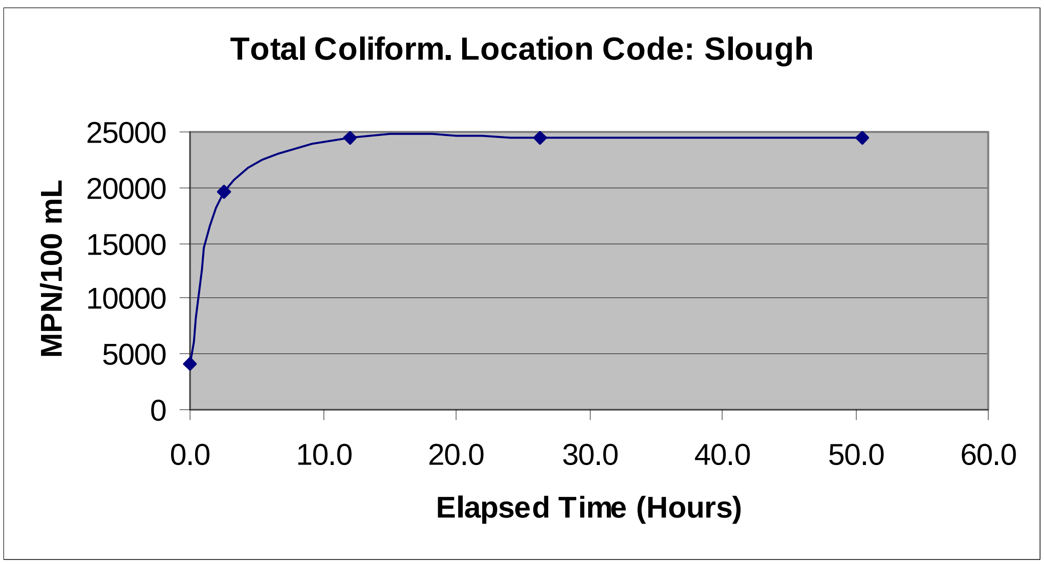


E. Coli at Time Code 2
MPN/100mL
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)

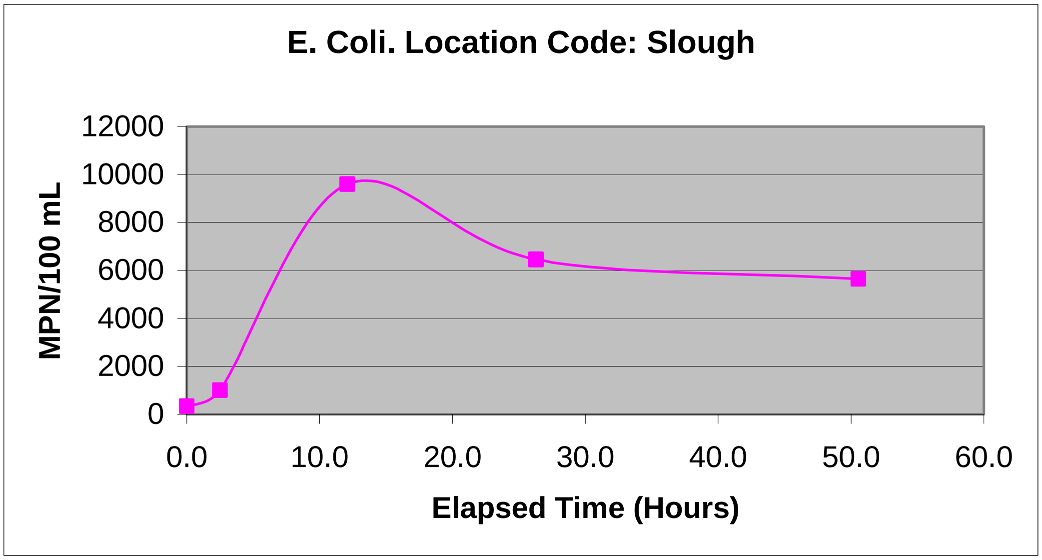

E. Coli at Time Code 3
MPN/100mL
180
160
140
120
100
80
60
40
20
0
-20
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)



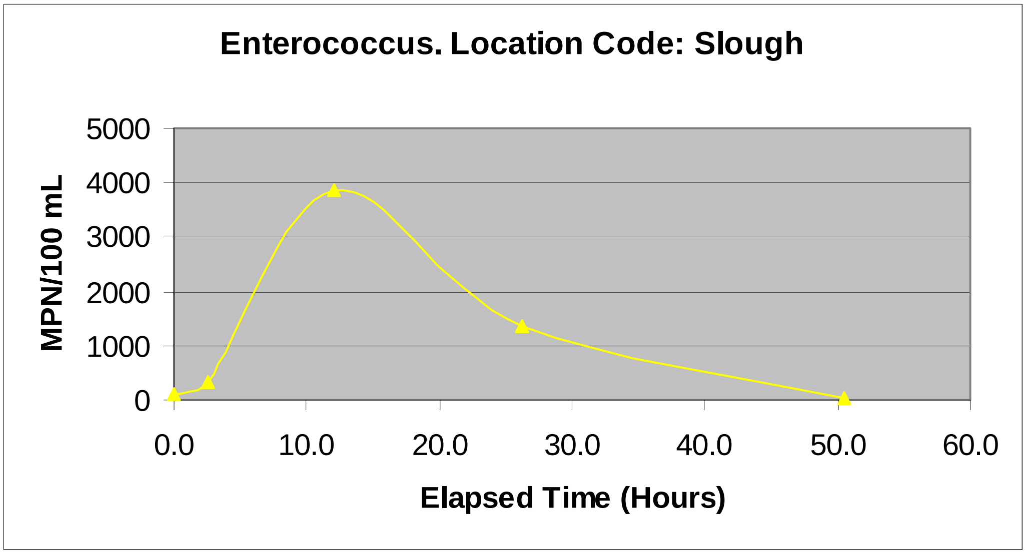
E. Coli at Time Code 4
MPN/100mL
500
450
400
350
300
250
200
150
100
50
0
-300
-200
-100
0
100
200
300
400
500
Location Code (yards from mouth)



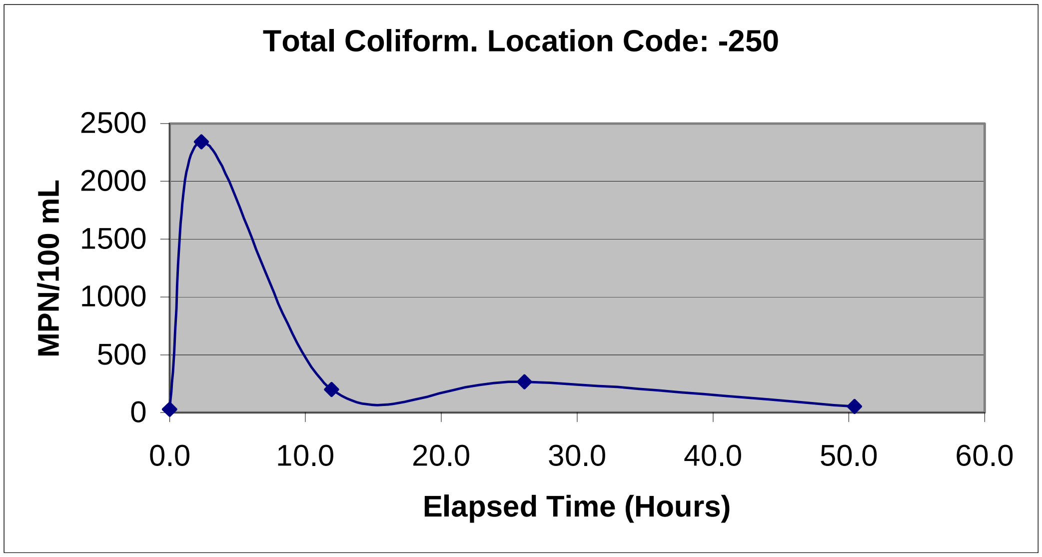
Total Coliform. Location Code: Slough
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

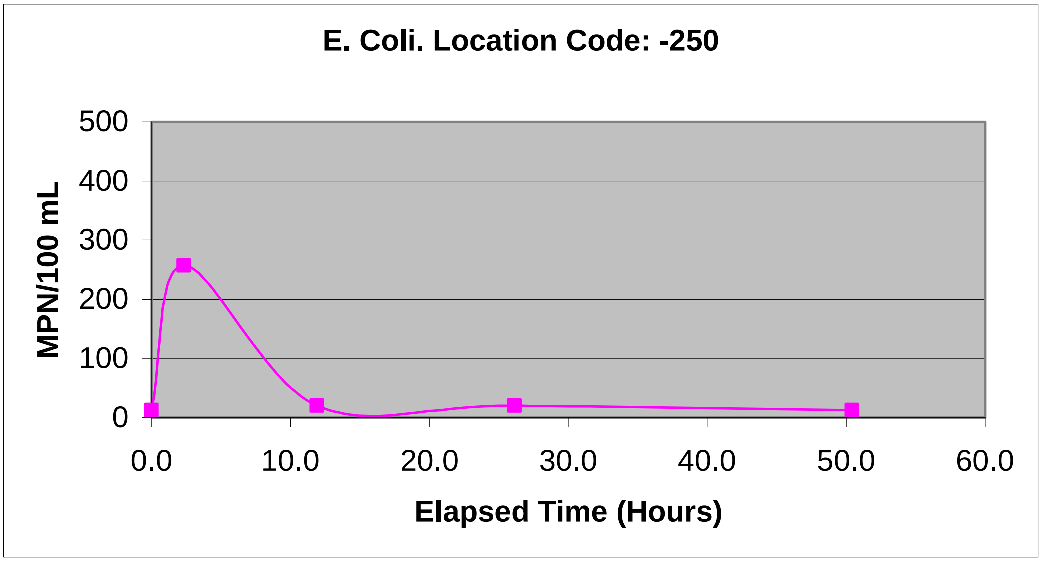


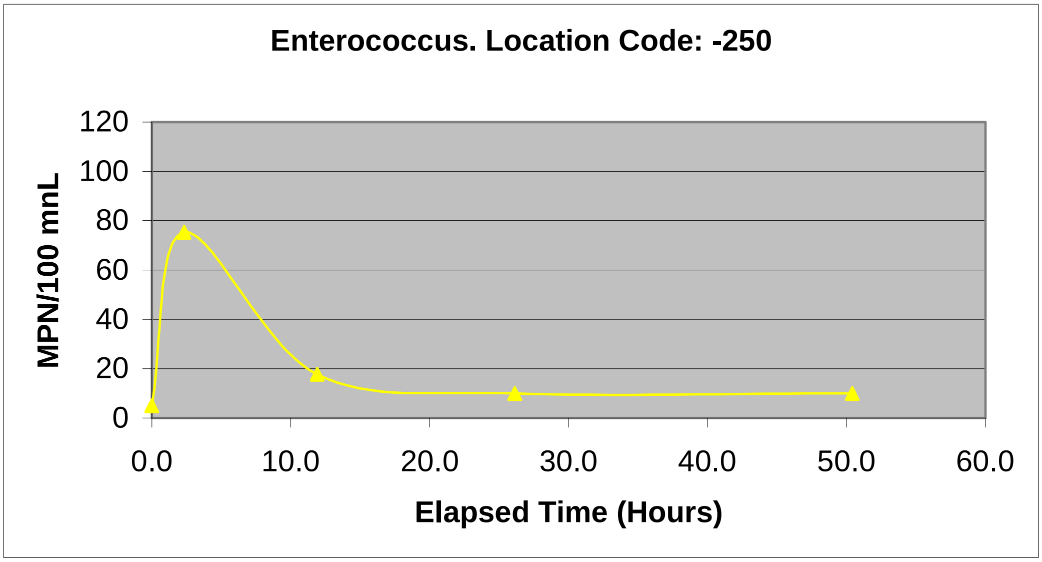
E. Coli. Location Code: Slough
MPN/100 mL
12000
10000
8000
6000
4000
2000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

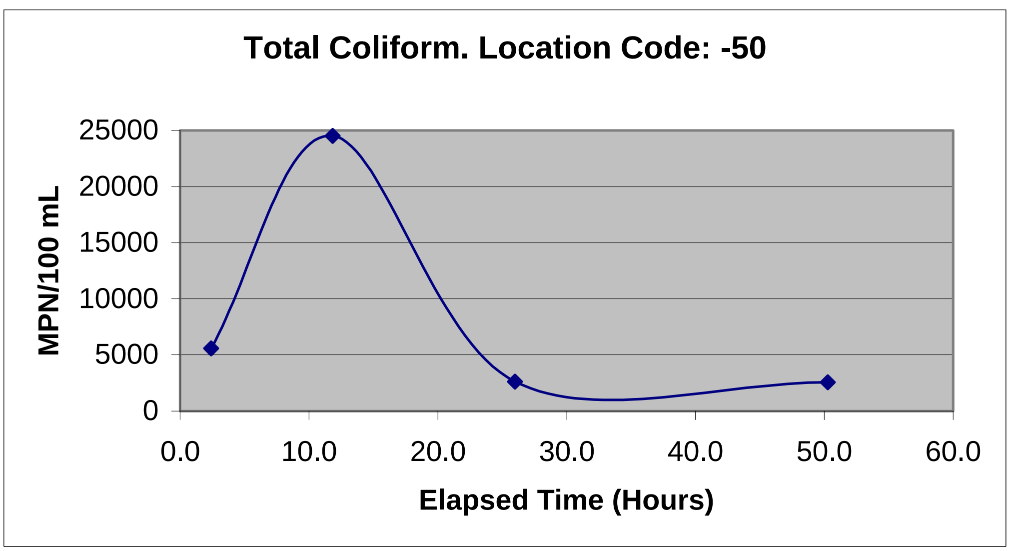


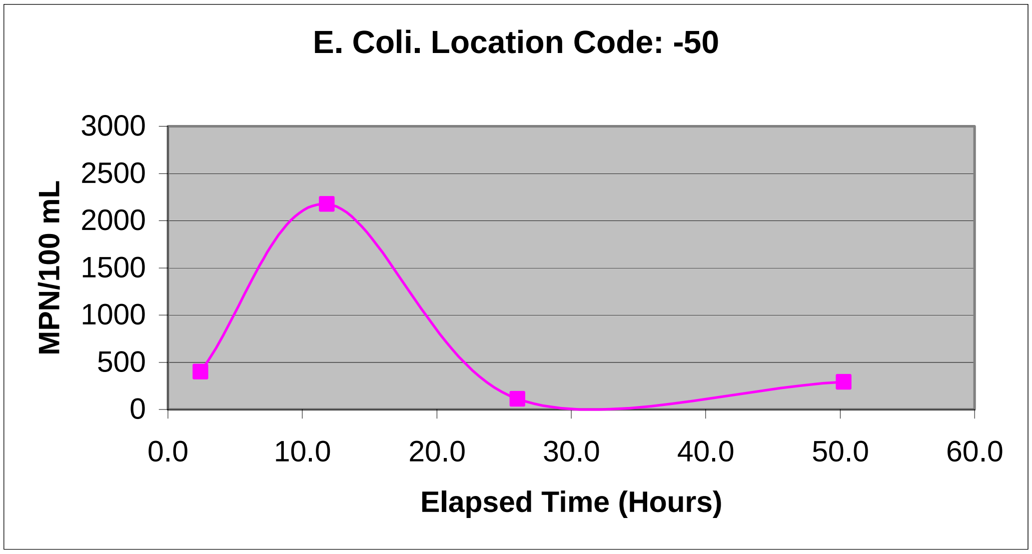
Enterococcus. Location Code: Slough
MPN/100 mL
5000
4000
3000
2000
1000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

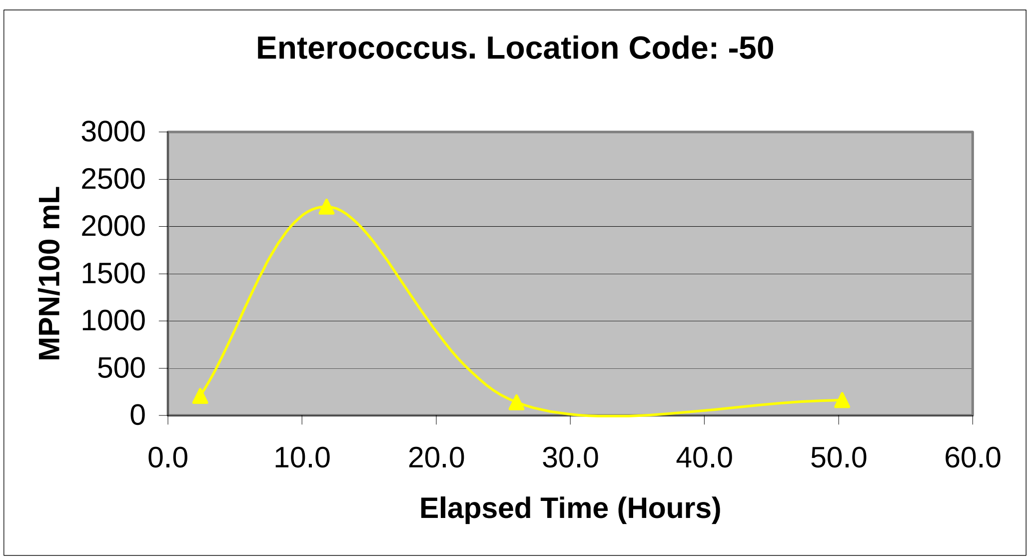

Total Coliform. Location Code: -250
MPN/100 mL
2500
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

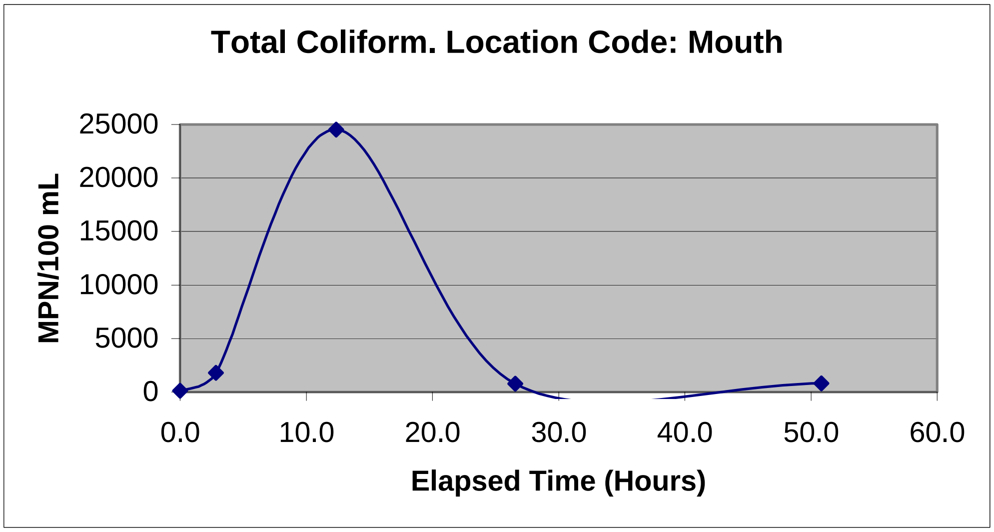

E. Coli. Location Code: -250
MPN/100 mL
500
400
300
200
100
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

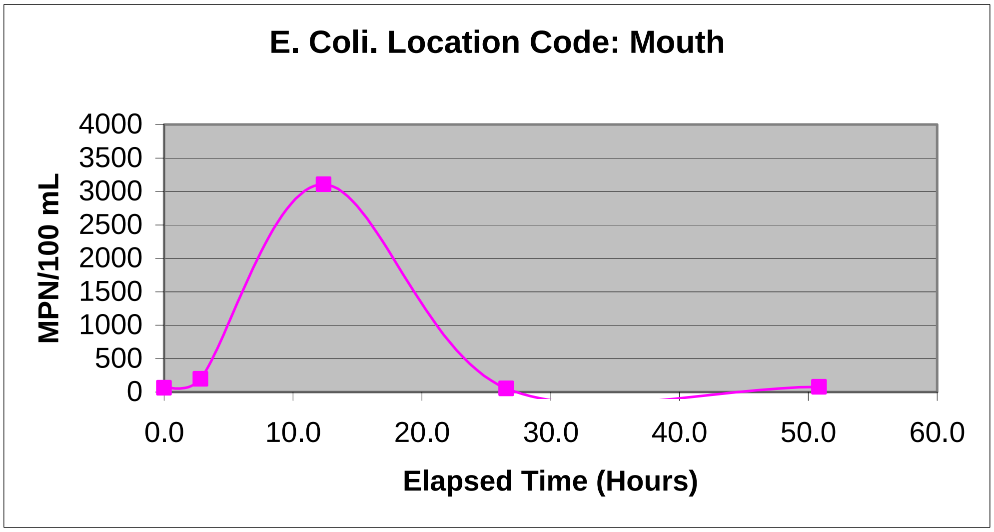

Enterococcus. Location Code: -250
MPN/100 mnL
120
100
80
60
40
20
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

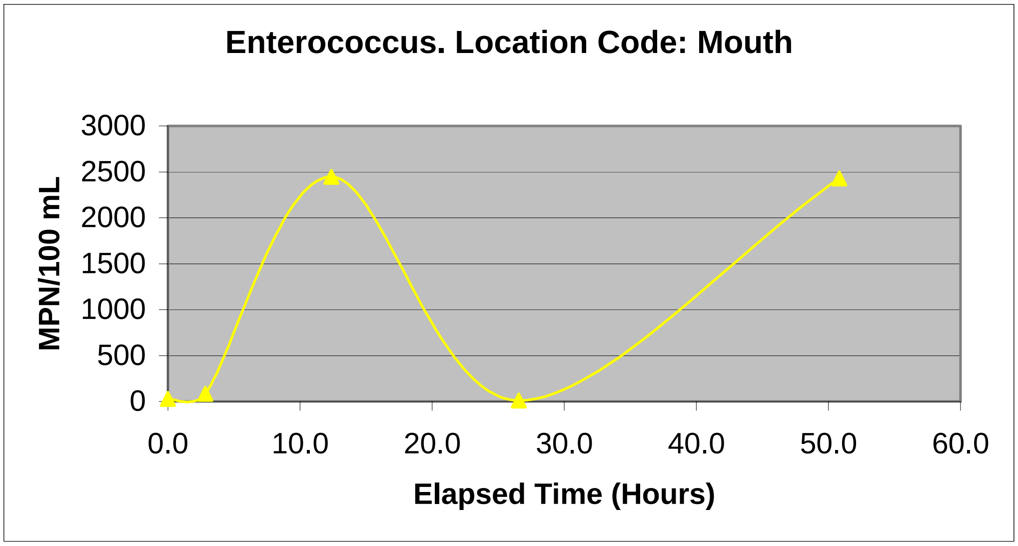

Total Coliform. Location Code: -50
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

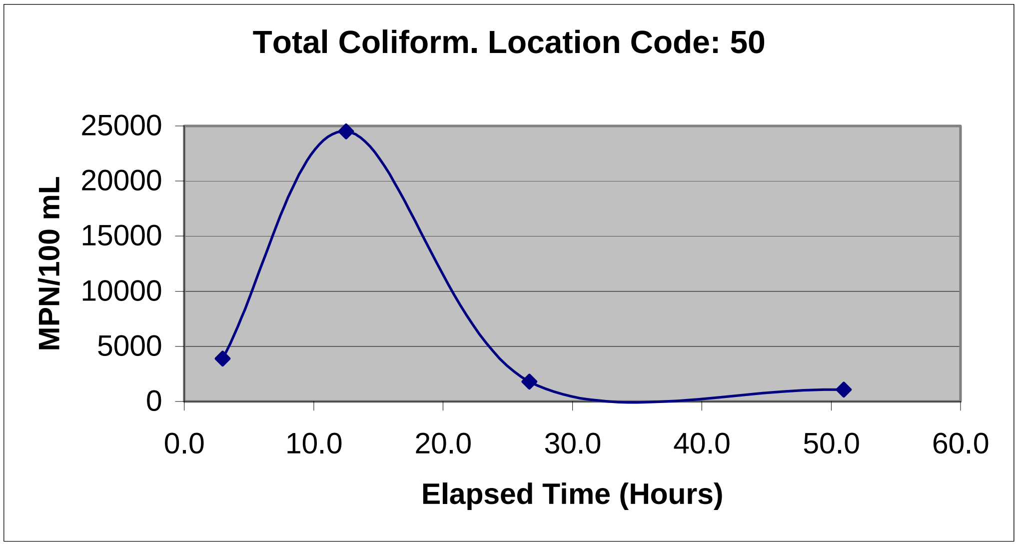

E. Coli. Location Code: -50
MPN/100 mL
3000
2500
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

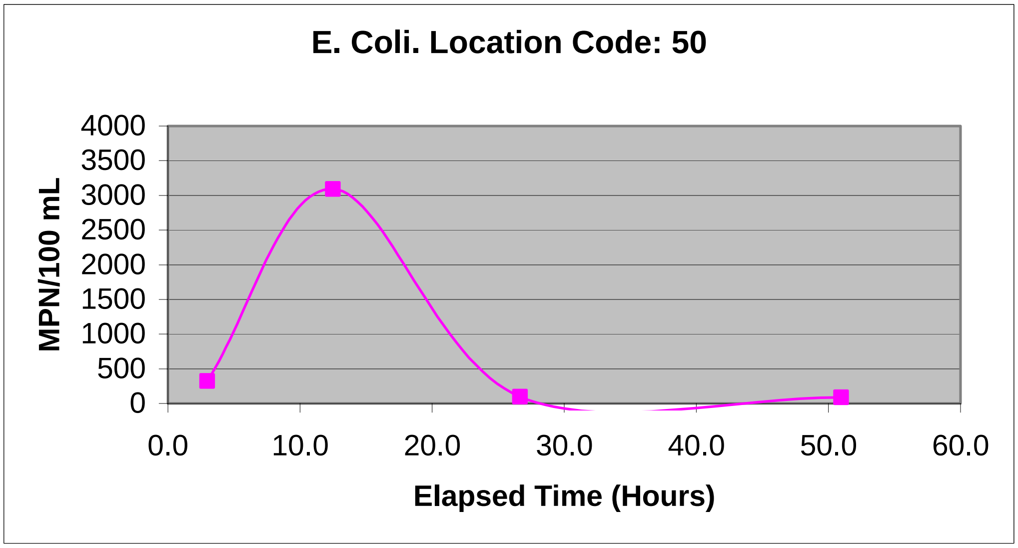

Enterococcus. Location Code: -50
MPN/100 mL
3000
2500
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

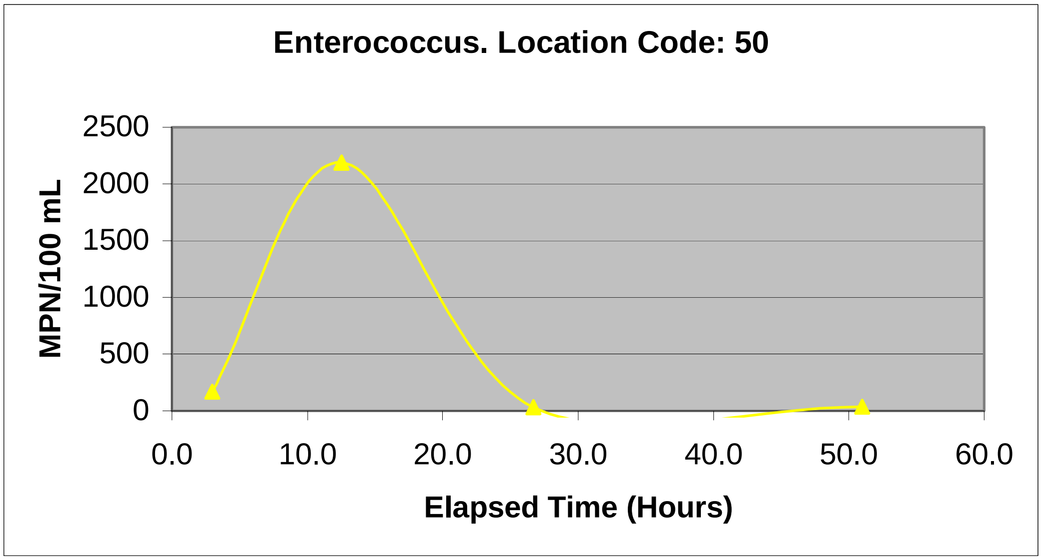

Total Coliform. Location Code: Mouth
25000
20000
15000
10000
5000
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

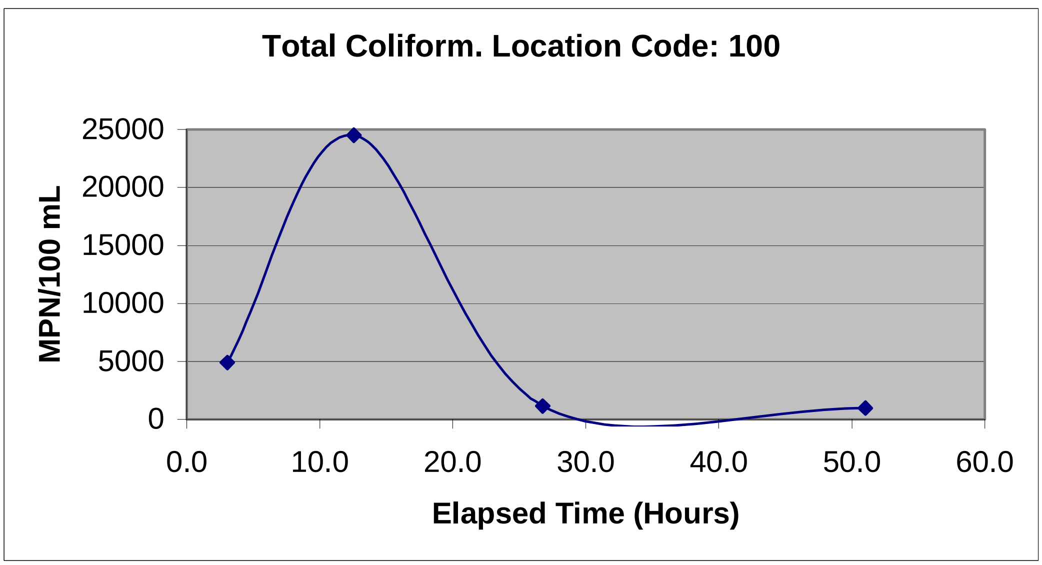

E. Coli. Location Code: Mouth
4000
3500
3000
2500
2000
1500
1000
500
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

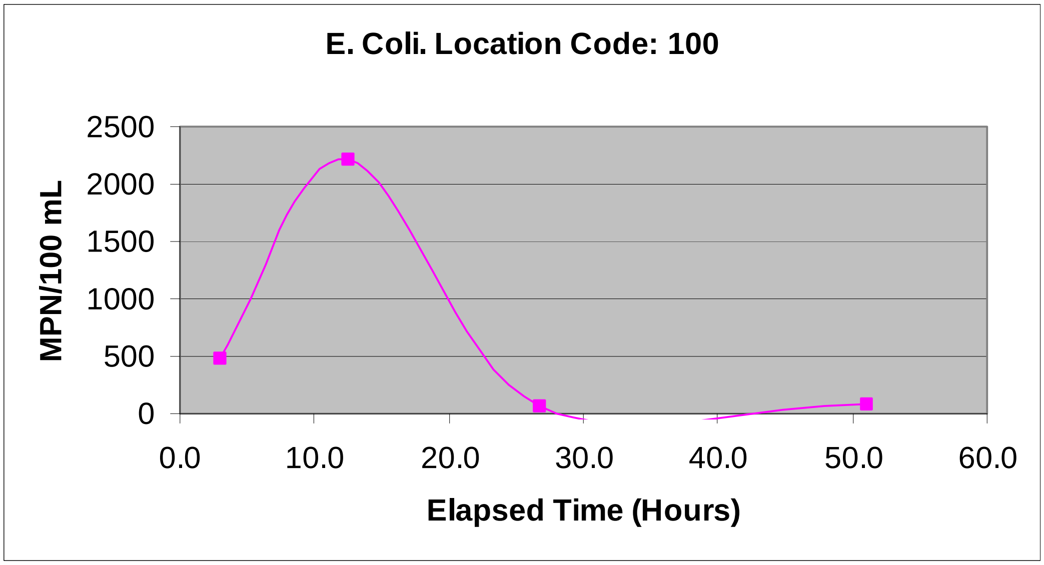

Enterococcus. Location Code: Mouth
MPN/100 mL
3000
2500
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

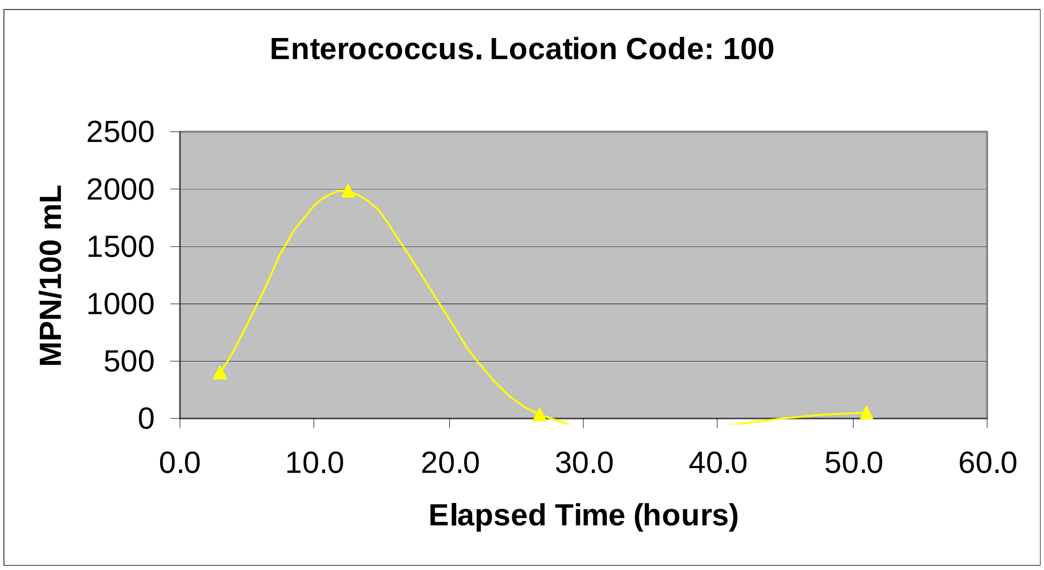

Total Coliform. Location Code: 50
25000
20000
15000
10000
5000
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

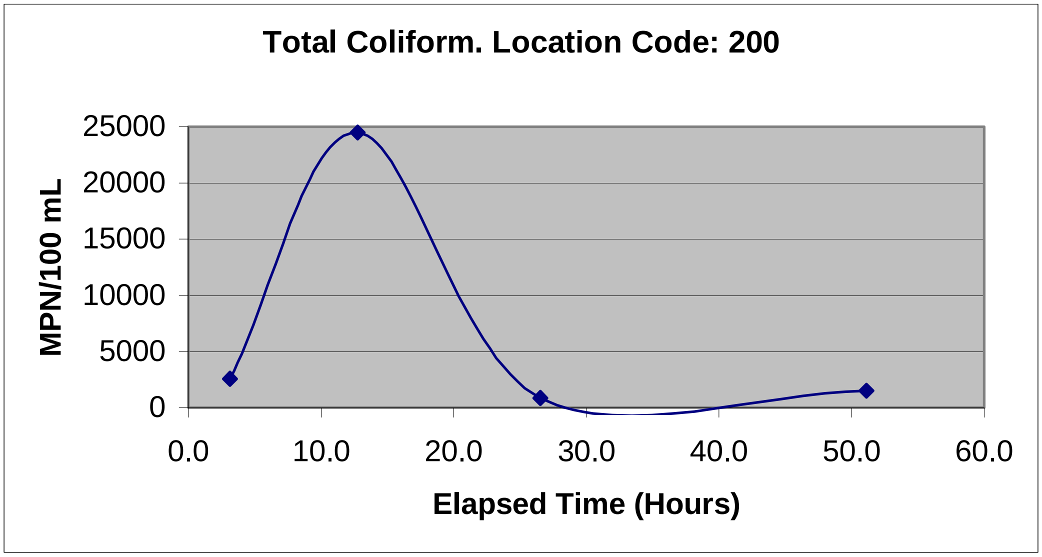

E. Coli. Location Code: 50
4000
3500
3000
2500
2000
1500
1000
500
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

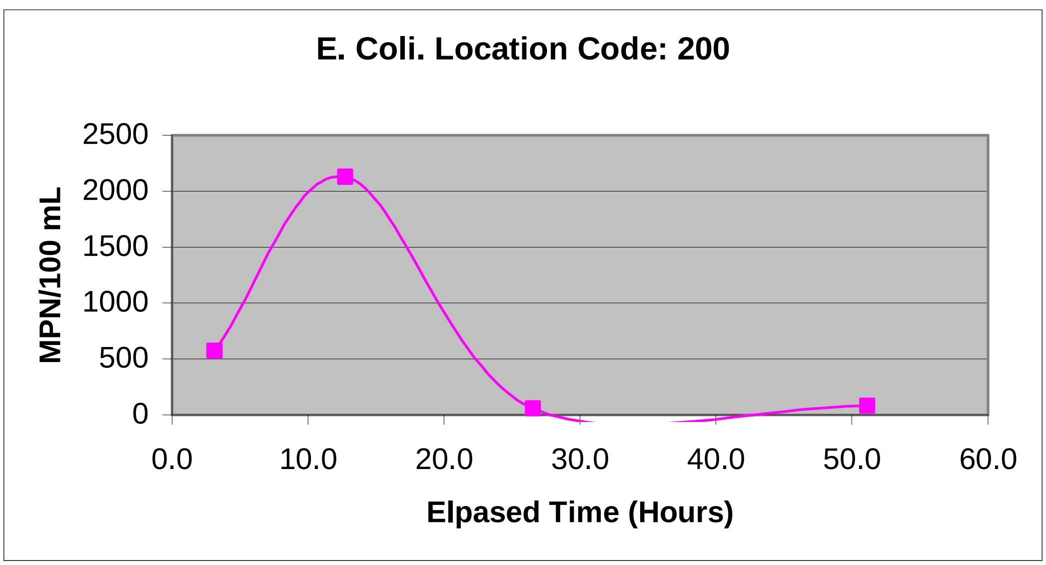

Enterococcus. Location Code: 50
MPN/100 mL
2500
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

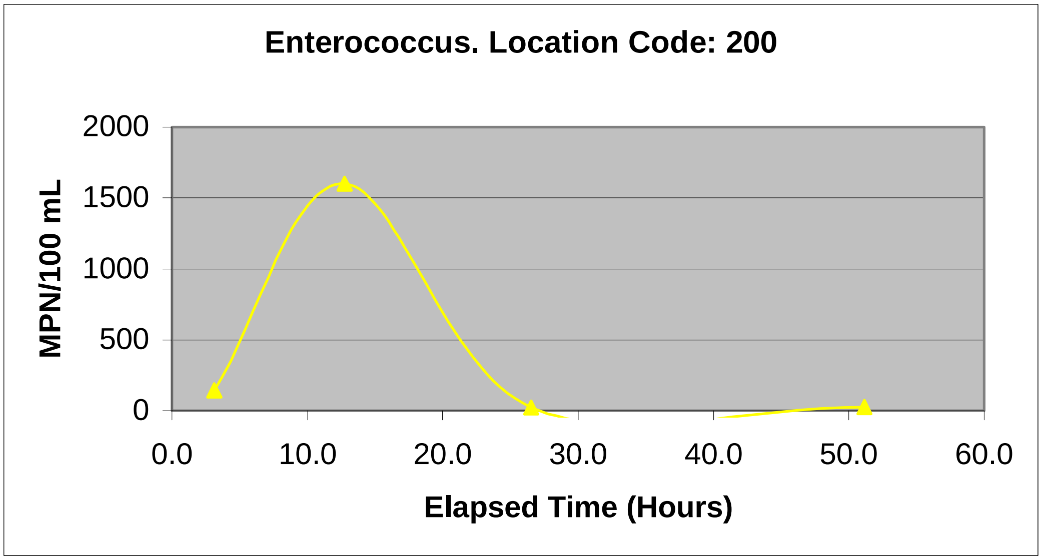

Total Coliform. Location Code: 100
MPN/100 mL
25000
20000
15000
10000
5000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

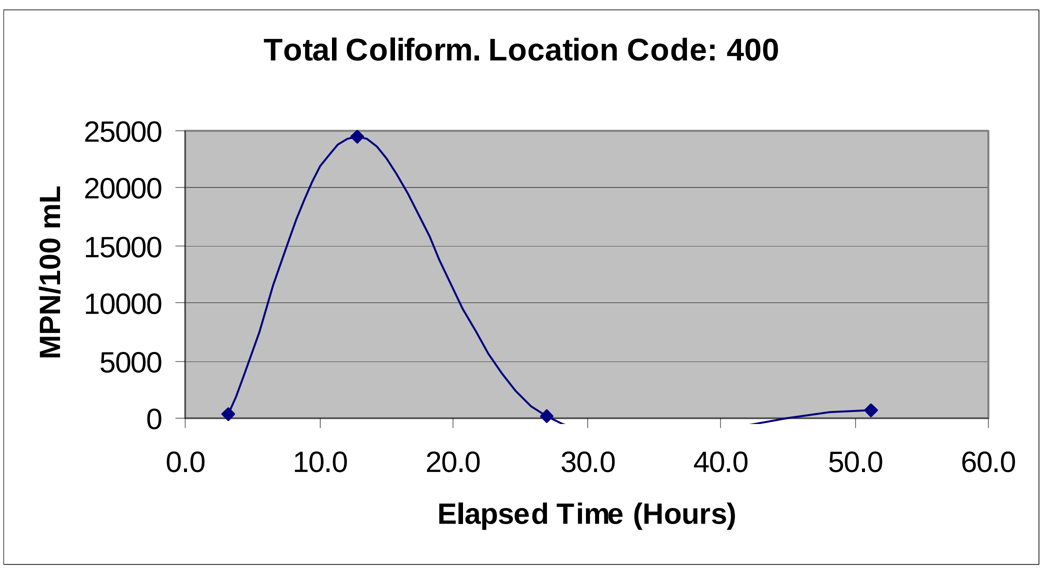

E. Coli. Location Code: 100
MPN/100 mL
2500
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

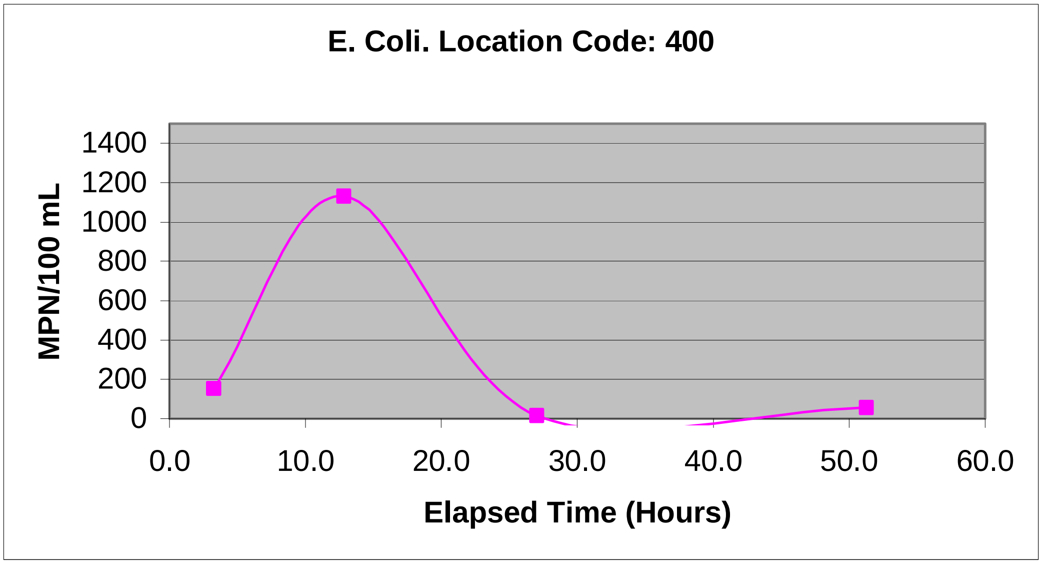

Enterococcus. Location Code: 100
MPN/100 mL
2500
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (hours)

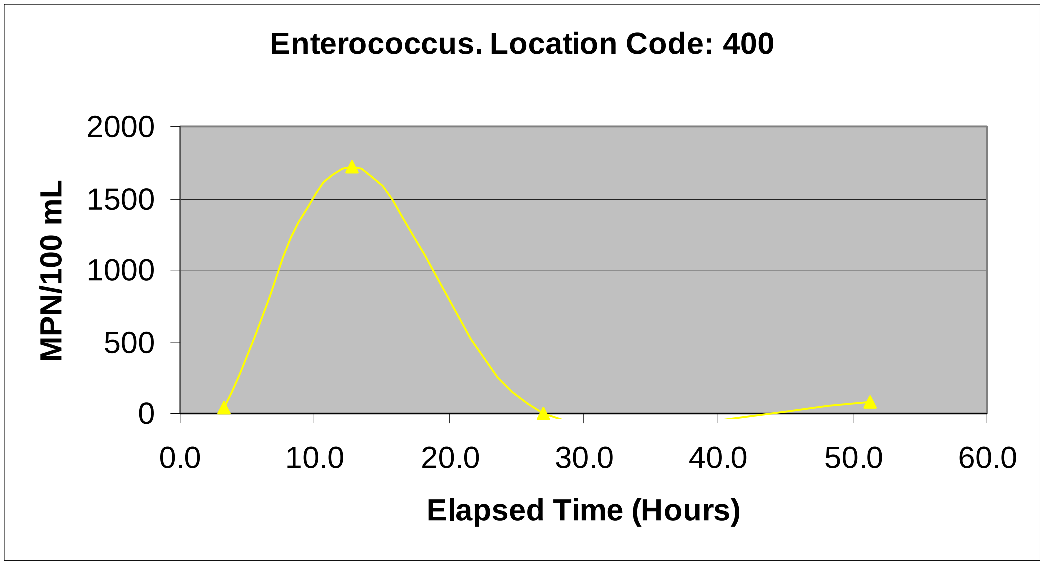

Total Coliform. Location Code: 200
25000
20000
15000
10000
5000
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

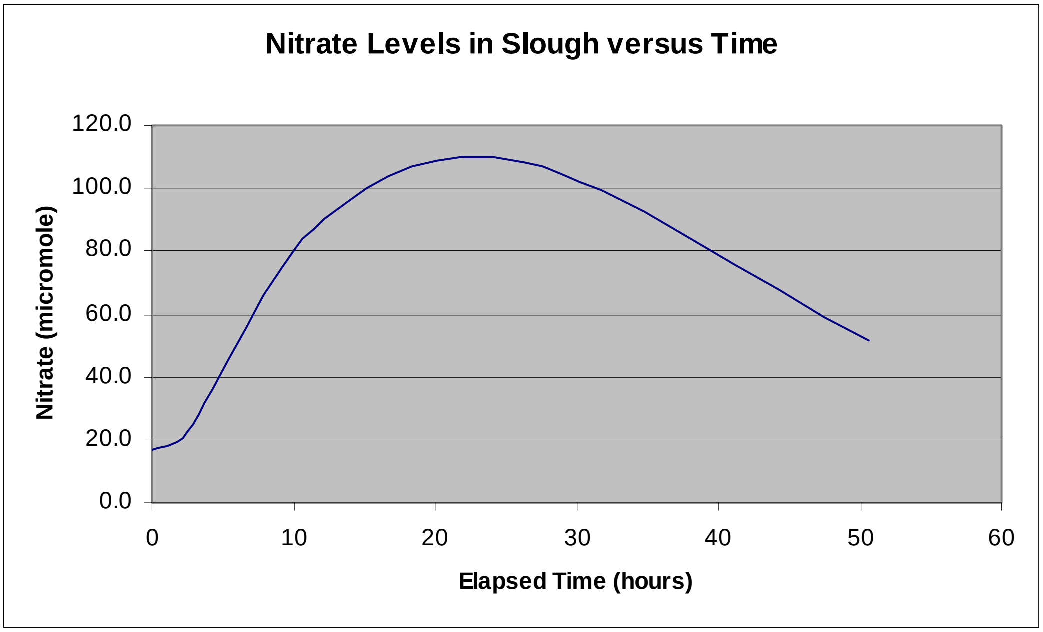

E. Coli. Location Code: 200
2500
2000
1500
1000
500
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elpased Time (Hours)


Enterococcus. Location Code: 200
2000
1500
1000
500
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)


Total Coliform. Location Code: 400
25000
20000
15000
10000
5000
0
MPN/100 mL
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

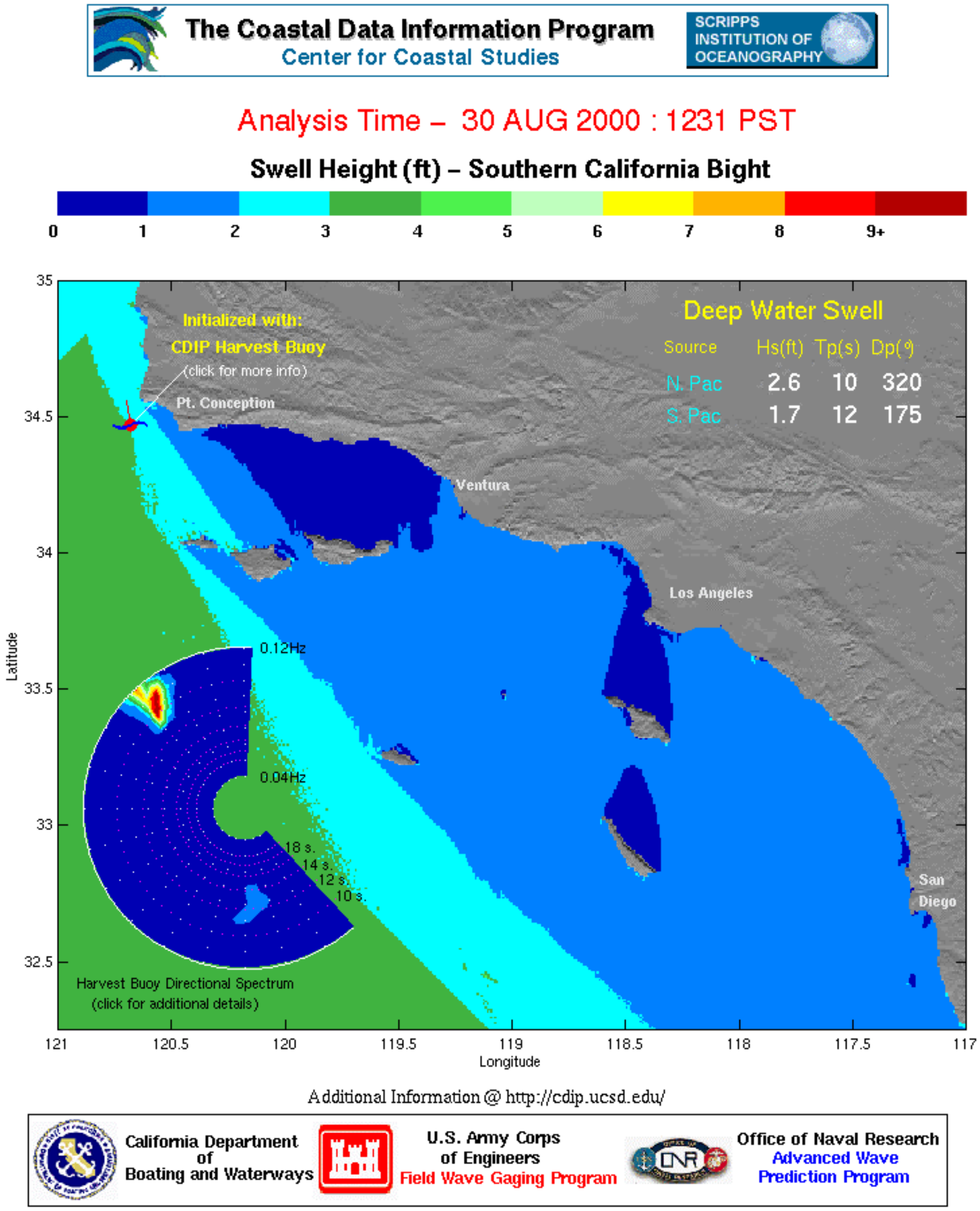

E. Coli. Location Code: 400
MPN/100 mL
1400
1200
1000
800
600
400
200
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)

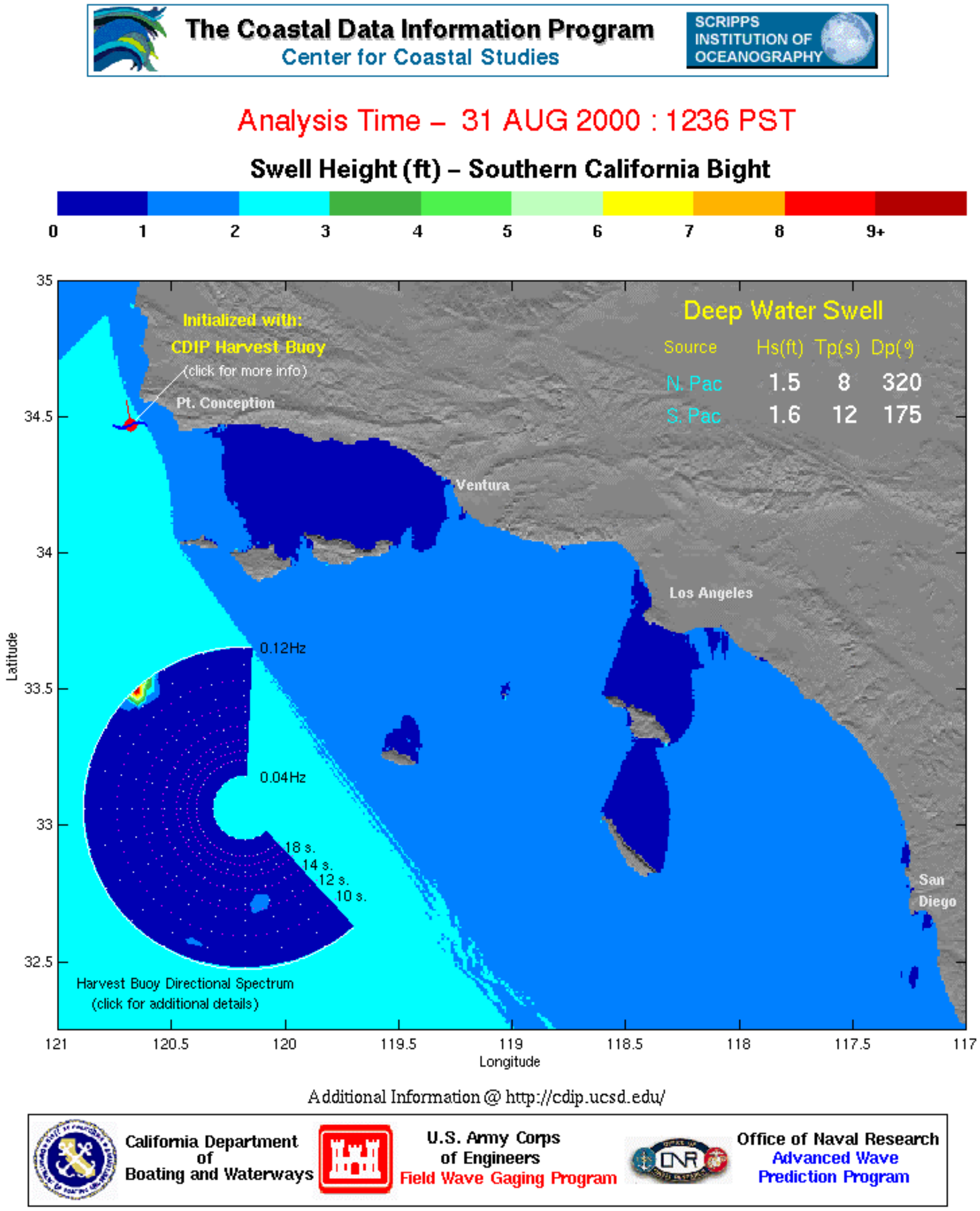

Enterococcus. Location Code: 400
MPN/100 mL
2000
1500
1000
500
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Elapsed Time (Hours)



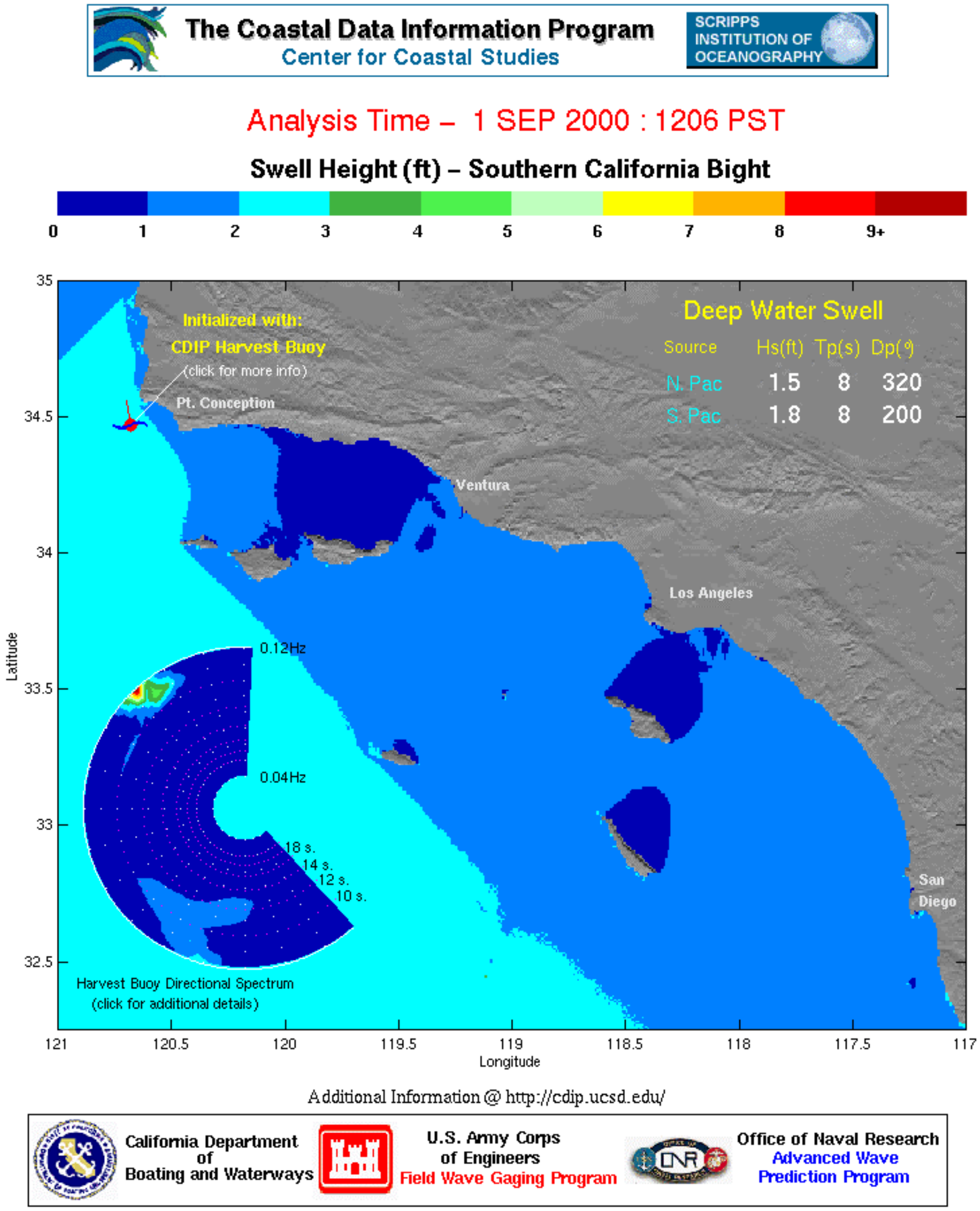
Date	*Time*	*Wind Speed (knots)*	*Wind Direction (degrees)*	*Date*	*Time*	*Wind Speed (knots)*	*Wind Direction (degrees)*
30-Aug	653	0	0	1-Sep	653	0	0
30-Aug	753	0	0	1-Sep	753	3	120
30-Aug	853	4	130	1-Sep	853	4	150
30-Aug	953	5	200	1-Sep	953	7	210
30-Aug	1053	5	210	1-Sep	1053	8	220
30-Aug	1153	5	190	1-Sep	1153	8	210
30-Aug	1253	5	210	1-Sep	1253	9	210
30-Aug	1353	6	240	1-Sep	1353	10	230
30-Aug	1453	6	230	1-Sep	1453	9	240
30-Aug	1553	8	250	1-Sep	1553	9	230
30-Aug	1653	6	250	1-Sep	1653	10	240
30-Aug	1753	7	260	1-Sep	1753	7	250

30-Aug	1853	5	250	1-Sep	1853	5	260
30-Aug	1953	0	0	1-Sep	1953	4	250
31-Aug	653	0	0	2-Sep	653	0	0
31-Aug	753	0	0	2-Sep	753	7	220
31-Aug	853	4	vrb	2-Sep	853	6	210
31-Aug	953	4	140	2-Sep	953	8	210
31-Aug	1053	7	210	2-Sep	1053	10	230
31-Aug	1153	8	200	2-Sep	1153	10	260
31-Aug	1253	7	200	2-Sep	1253	12	240
31-Aug	1353	9	230	2-Sep	1353	13	240
31-Aug	1453	10	240	2-Sep	1453	12	240
31-Aug	1553	11	260	2-Sep	1553	10	240
31-Aug	1653	11	250	2-Sep	1653	3	vrb
31-Aug	1753	12	260	2-Sep	1753	10	90
31-Aug	1853	8	250	2-Sep	1853	9	140
31-Aug	1953	6	280	2-Sep	1953	0	0

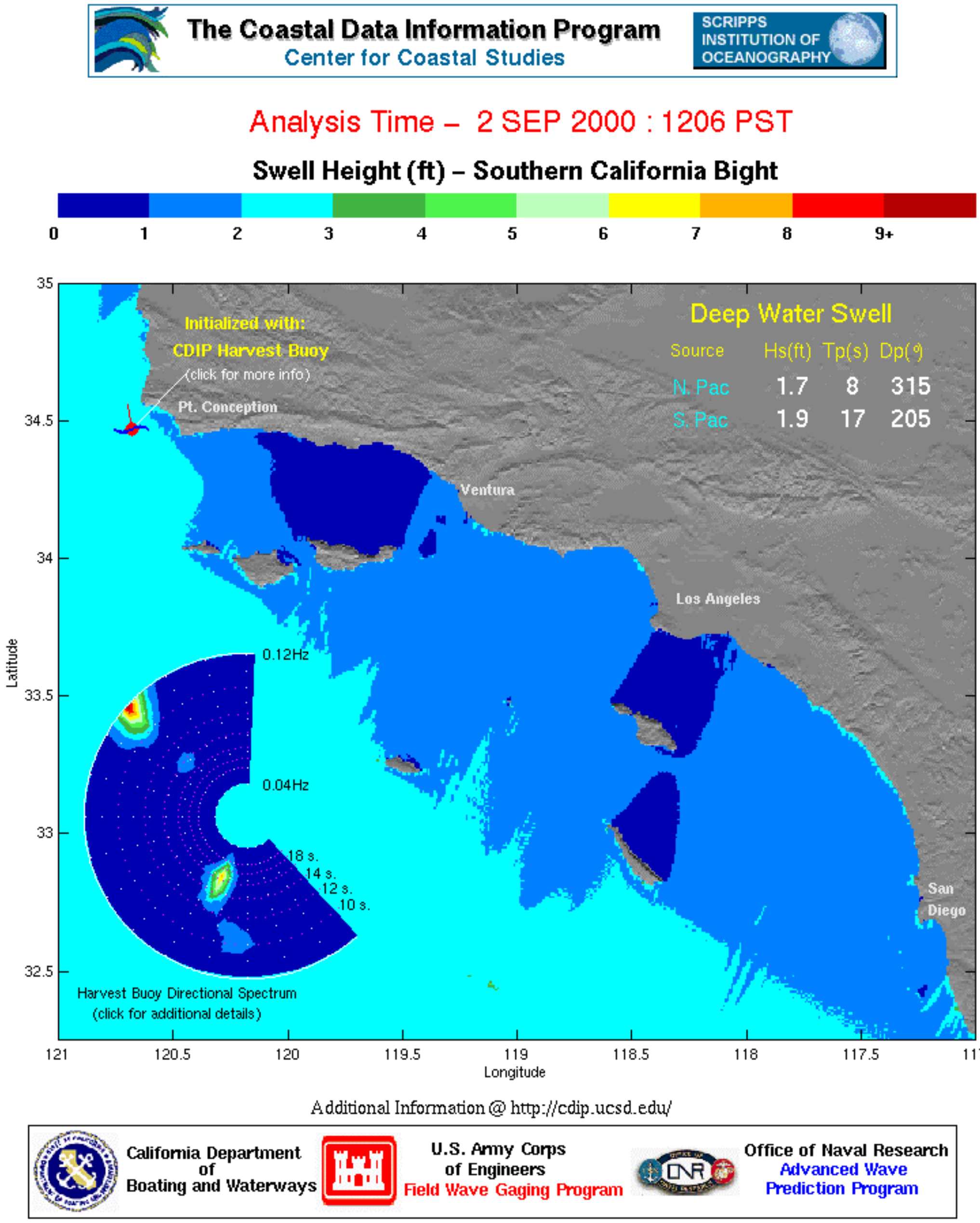

The Coastal Data Information Program
Center for Coastal Studies
SCRIPPS INSTITUTION OF OCEANOGRAPHY
Analysis Time – 30 AUG 2000 : 1231 PST
Swell Height (ft) – Southern California Bight
0 1 2 3 4 5 6 7 8 9+
Initialized with:
CDIP Harvest Buoy
(click for more info)
Pt. Conception
Deep Water Swell
Source Hs(ft) Tp(s) Dp(°)
N. Pac 2.6 10 320
S. Pac 1.7 12 175
Ventura
Los Angeles
San Diego
0.12Hz
0.04Hz
18 s.
14 s.
12 s.
10 s.
Harvest Buoy Directional Spectrum
(click for additional details)
Latitude
Longitude
35
34.5
34
33.5
33
32.5
121
120.5
120
119.5
119
118.5
118
117.5
117
Additional Information @ http://cdip.ucsd.edu/
California Department of Boating and Waterways
U.S. Army Corps of Engineers
Field Wave Gaging Program
Office of Naval Research
Advanced Wave Prediction Program



The Coastal Data Information Program
Center for Coastal Studies
SCRIPPS INSTITUTION OF OCEANOGRAPHY
Analysis Time – 31 AUG 2000 : 1236 PST
Swell Height (ft) – Southern California Bight
0 1 2 3 4 5 6 7 8 9+
Initialized with:
CDIP Harvest Buoy
(click for more info)
Pt. Conception
Deep Water Swell
Source Hs(ft) Tp(s) Dp(°)
N. Pac 1.5 8 320
S. Pac 1.6 12 175
Ventura
Los Angeles
San Diego
0.12Hz
0.04Hz
18 s.
14 s.
12 s.
10 s.
Harvest Buoy Directional Spectrum
(click for additional details)
Latitude
35
34.5
34
33.5
33
32.5
121
120.5
120
119.5
119
118.5
118
117.5
117
Longitude
Additional Information @ http://cdip.ucsd.edu/
California Department of Boating and Waterways
U.S. Army Corps of Engineers
Field Wave Gaging Program
Office of Naval Research
Advanced Wave Prediction Program



The Coastal Data Information Program
Center for Coastal Studies
SCRIPPS INSTITUTION OF OCEANOGRAPHY
Analysis Time – 1 SEP 2000 : 1206 PST
Swell Height (ft) – Southern California Bight
0
1
2
3
4
5
6
7
8
9+
Initialized with:
CDIP Harvest Buoy
(click for more info)
Pt. Conception
Deep Water Swell
Source Hs(ft) Tp(s) Dp(°)
N. Pac 1.5 8 320
S. Pac 1.8 8 200
Ventura
Los Angeles
San Diego
0.12Hz
0.04Hz
18 s.
14 s.
12 s.
10 s.
Harvest Buoy Directional Spectrum
(click for additional details)
Latitude
Longitude
35
34.5
34
33.5
33
32.5
121
120.5
120
119.5
119
118.5
118
117.5
117
Additional Information @ http://cdip.ucsd.edu/
California Department of Boating and Waterways
U.S. Army Corps of Engineers
Field Wave Gaging Program
Office of Naval Research
Advanced Wave Prediction Program



The Coastal Data Information Program
Center for Coastal Studies
SCRIPPS INSTITUTION OF OCEANOGRAPHY
Analysis Time – 2 SEP 2000 : 1206 PST
Swell Height (ft) – Southern California Bight
0 1 2 3 4 5 6 7 8 9+
Initialized with:
CDIP Harvest Buoy
(click for more info)
Pt. Conception
Deep Water Swell
Source Hs(ft) Tp(s) Dp(°)
N. Pac 1.7 8 315
S. Pac 1.9 17 205
Ventura
Los Angeles
San Diego
0.12Hz
0.04Hz
18 s.
14 s.
12 s.
10 s.
Harvest Buoy Directional Spectrum
(click for additional details)
Latitude
Longitude
35
34.5
34
33.5
33
32.5
121
120.5
120
119.5
119
118.5
118
117.5
117
Additional Information @ http://cdip.ucsd.edu/
California Department of Boating and Waterways
U.S. Army Corps of Engineers
Field Wave Gaging Program
Office of Naval Research
Advanced Wave Prediction Program

APPENDIX C – REGIONAL BREACH DATA

An informal survey was conducted to determine how many California locations use mechanical breaching in the management of coastal waterbodies. It was conducted between December 2000 and March 2001. The search for potential contacts was broken down to a county-by-county basis. Through exhaustive research on the internet, a list of government agencies and respective employees who could potentially have knowledge of such activities was created. Some of this research was also guided by numerous news articles and bulletins that indicated the existence of breaching activity for given locations. Contact was made at all levels of government, from local to federal agencies. In many cases, effort was made to contact several agencies that would have knowledge within a given county. All people contacted were given a distinct description of what a "breach event" entailed, a description that described what occurs at Goleta Slough.

It is important to emphasize that there are no formal mandates that standardize the agencies responsible for overseeing breach activities along the California coastline. Coastal management is characterized by numerous agencies with overlapping responsibilities, and it is therefore extremely difficult to determine the appropriate people to contact. As a result, it should be stressed that the number of breach locations identified does not necessarily represent the exact number; it is only an informal listing that does not represent those that may be found in a comprehensive investigation. Given time limitations, every agency in every county could not be contacted for comment.

Selected Monitoring Data From Recent Breaches in San Diego County

The following is indicator data from a database of monitoring samples largely collected after four artificial breaches of impounded coastal water bodies in San Diego County, California (CSDDEH database). The information was accessed and collected during January 2001 by Clay Clifton at the County Department of Environmental Health, San Diego. It is important to stress that this is monitoring data, not samples collected under the context of a formal experimental design. Consequently, there are limitations to the value of this information in understanding breach events. One key aspect of information that is not available is the specific differences in time between when the breach occurred and when the associated samples were collected; only calendar dates are provided for each sample. It is also uncertain as to the means used to determine distances along the shoreline, if any formal method was used at all. The distances listed with the data may be visual estimations. Nevertheless, considering these limitations, the data offers hints as to how water quality can change at other artificially breached sites; it also offers a limited qualitative opportunity to compare other breach events to the one formally sampled in this paper.

All four breaches presented occurred during 1999. Samples were evaluated using multi-tube fermentation, and miscellaneous information describing the breach event was added along with the indicator data. All units are included with the variable name with the exception of "direction". The letters "M", "L", and "R" were used to signify the mouth, downcoast, and upcoast, respectively. All values for the variable "distance" are relative to the mouth; negative values for samples taken at the mouth denote samples taken up the watershed, away from the shoreline.

1st breach event: Los Peñasquitos Lagoon

A complaint of strong odors on 11/29/99 led to a request for a breach at Los Peñasquitos Lagoon. The breach was conducted on 12/1/99, and sampling began afterwards. An advisory was posted, but a rupture in a sewer main at El Camino Real and Carmel Valley Road occurred early the next day, leading to an estimated discharge of 133,800 gallons. An unknown amount of this made its way into the surrounding creeks, and public officials feared that the lagoon was significantly contaminated. This led to closures at the beach where the Lagoon flowed out later that day. Together, advisories and closures remained posted from 12/1/99 to 12/8/99.

Total coliform

Date	Distance (ft)	Direction	MPN/ 100ml
12/1	-100	M	300
12/3	-100	M	9000
12/6	-50	M	130
12/7	-100	M	40
12/1	0	M	500
12/3	0	M	16000
12/6	0	M	<20
12/7	0	M	<20
12/1	50	L	110
12/3	50	L	3000
12/6	50	L	80
12/7	50	L	<20
12/1	50	R	230
12/3	50	R	2400
12/6	50	R	20
12/7	50	R	<20

Fecal coliforms

Date	Distance (ft)	Direction	MPN/ 100ml
12/1	-100	M	130
12/3	-100	M	3000
12/6	-50	M	130
12/7	-100	M	40
12/1	0	M	500
12/3	0	M	9000
12/6	0	M	<20
12/7	0	M	<20
12/1	50	L	80
12/3	50	L	1300
12/6	50	L	20
12/7	50	L	0
12/1	50	R	230
12/3	50	R	1300
12/6	50	R	<20
12/7	50	R	<20

Enterococcus

Date	Distance (ft)	Direction	MPN/ 100ml
12/1	-100	M	10
12/3	-100	M	453
12/6	-50	M	53
12/7	-100	M	10
12/1	0	M	87
12/3	0	M	478
12/6	0	M	20
12/7	0	M	<10
12/1	50	L	64
12/3	50	L	124
12/6	50	L	20
12/7	50	L	<10
12/1	50	R	75
12/3	50	R	64
12/6	50	R	<10
12/7	50	R	<10

2nd breach event: Buena Vista Lagoon

Sand had accumulated in front of the weir at the outlet of the Buena Vista Lagoon. The City of Oceanside Public Works excavated sand to lower the lagoon level. The advisory was posted from 11/3/99 to 11/13/99.

Total coliform

Date	Distance (ft)	Direction	MPN/ 100ml
11/3	0	M	500
11/4	0	M	170
11/5	0	M	1300
11/8	0	M	140
11/12	0	M	<20
11/3	50	L	500
11/4	50	L	40
11/5	50	L	<20
11/8	50	L	20
11/12	50	L	<20
11/4	50	R	230
11/5	50	R	230
11/8	50	R	20
11/12	50	R	20

Fecal coliform

Date	Distance (ft)	Direction	MPN/ 100ml
11/3	0	M	70
11/4	0	M	110
11/5	0	M	500
11/8	0	M	40
11/12	0	M	<20
11/3	50	L	300
11/4	50	L	20
11/5	50	L	<20
11/8	50	L	20
11/12	50	L	<20
11/4	50	R	130
11/5	50	R	230
11/8	50	R	20
11/12	50	R	20

Enterococcus

Date	Distance (ft)	Direction	MPN/ 100ml
11/3	0	M	885
11/4	0	M	624
11/5	0	M	831
11/8	0	M	560
11/12	0	M	10
11/3	50	L	344
11/4	50	L	99
11/5	50	L	<10
11/8	50	L	20
11/12	50	L	<10
11/4	50	R	697
11/5	50	R	124
11/8	50	R	99
11/12	50	R	53

3rd breach event: San Elijo Lagoon

Excavation of the outlet was ordered to restore tidal flushing to the surrounding wetlands. The advisory was posted from 7/29/99 to 7/30/99.

Total coliform

Date	Distance (ft)	Direction	MPN/ 100ml
7/29	0	M	40
7/30	0	M	80
7/29	50	L	<20
7/30	50	L	<20
7/29	50	R	<20
7/30	50	R	40

Fecal coliform

Date	Distance (ft)	Direction	MPN/ 100ml
7/29	0	M	20
7/30	0	M	<20
7/29	50	L	<20
7/30	50	L	<20
7/29	50	R	<20
7/30	50	R	40

Enterococcus

Date	Distance (ft)	Direction	MPN/ 100ml
7/29	0	M	64
7/30	0	M	20
7/29	50	L	31
7/30	50	L	<10
7/29	50	R	20
7/30	50	R	20

4th breach event: San Luis Rey River

A natural sand berm west of Pacific Street was excavated to restore tidal flushing to the river. Prior to the breach there had only been limited tidal exchange over the last several months. The work was carried out by the City of Oceanside Public Works. The advisory was posted from 10/27/99 to 11/3/99.

Total coliform

Date	Distance (ft)	Direction	MPN/ 100ml
10/26	-200	M	900
10/29	-200	M	800
10/27	0	M	5000
10/29	0	M	140
11/1	0	M	220
10/27	50	L	210
10/27	100	L	170
10/29	50	L	40
11/1	50	L	<20

Fecal Coliform

Date	Distance (ft)	Direction	MPN/ 100ml
10/26	-200	M	900
10/29	-200	M	500
10/27	0	M	2400
10/29	0	M	90
11/1	0	M	170
10/27	50	L	210
10/27	100	L	170
10/29	50	L	40
11/1	50	L	<20

Enterococcus

Date	Distance (ft)	Direction	MPN/ 100ml
10/26	-200	M	6
10/29	-200	M	31
10/27	0	M	453
10/29	0	M	<10
11/1	0	M	64
10/27	50	L	75
10/27	100	L	75
10/29	50	L	<10
11/1	50	L	20