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Six Total Maximum Daily Loads for Bacteria in Waters of the Upper Gulf Coast

Segments 2421, 2422, 2423, 2424, 2432, and 2439

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Six Total Maximum Daily Loads for Bacteria in Waters of the Upper Gulf Coast

Executive Summary

This document describes total maximum daily loads (TMDLs) for six segments in the Galveston Bay system along the Texas upper Gulf Coast near Houston and Galveston. Six segments have concentrations of bacteria that exceed the criteria used to evaluate the attainment of the designated oyster waters use, as identified in the state's *Texas Water Quality Inventory and 303(d) List.* Listings for oyster waters are based on information developed by the Texas Department of State Health Services (DSHS, formerly the Texas Department of Health) to classify oyster waters according to the potential risk to consumers of eating oysters harvested in a particular area. The six segments the DSHS has classified as restricted are:

- Upper Galveston Bay, Segment 2421 (assessment units 2421-1 & 2421-2)
- Trinity Bay, Segment 2422 (assessment unit 2422-1)
- East Bay, Segment 2423 (assessment unit 2423-1)
- West Bay, Segment 2424 (assessment unit 2424-2)
- Chocolate Bay, Segment 2432 (assessment unit 2432-1)
- Lower Galveston Bay Segment 2439 (assessment unit 2439-1)

The upper Gulf Coast area in and around Galveston Bay is 56 kilometers long and 31 kilometers wide at its extreme points. It has a total surface area of more than 1,300 square kilometers. Restricted Harvest Zones (RHZs) are areas where oyster harvesting is allowed, but not for direct marketing. The size range of oyster beds designated as RHZs varies from 27 percent of East Bay to 100 percent of Chocolate Bay.

The criteria for the oyster waters use are based on fecal coliform concentrations. If the minimum sample requirement is met (ten samples during the previous five years), then the oyster waters use is not supported when median fecal coliform concentrations in bay and gulf waters, exclusive of 1,000-foot buffer zones along shorelines:

- exceed 14 colonies per 100 mL; and/or
- the 90th percentile of all samples exceeds 43 colonies per 100 mL

The 1,000-foot buffer zone provides protection against runoff from the watershed and human use of the beaches. Within the 1,000-foot buffer, the contact recreation standard applies.

Many factors are considered in making use evaluations of oyster waters; water quality is only one factor. Meeting the criteria for bacteria in water does not necessarily result in removal of a restricted classification. The DSHS may or may not remove the RHZ classification because of other factors that must be considered.

For this project, calculations and reductions of bacteria loads were completed using a concentration-based approach. Concentration-based calculations compare water quality to both the median and the 90th percentile criteria. Initially, the median and 90th percentiles are calculated for each sampling location and compared to the water quality standards. Reductions in loading are based on the criterion that would require the largest reduction. At all sampling locations, the largest reduction would be achieved when applying the 90th percentile criterion.

Data show that samples collected within the RHZ for Upper Galveston Bay, Lower Galveston Bay, Chocolate Bay, and West Bay exceed the 90th percentile criterion. Within the six water bodies, the 90th percentile criterion was exceeded at 25 of the 41 locations routinely sampled within the RHZs; the median criterion was exceeded at only 2 of the 41 sample locations. The most probable sources of the impairment are marinas, boat traffic, failing septic systems, treatment facility discharges of untreated waste, migratory birds, wildlife refuges, storm water, and other unmanaged animals. The magnitude of exceedance of the bacteria criteria varies widely throughout all the bays. Analysis indicates that isolated zones of high bacteria concentrations occur in isolated areas near shorelines, rather than occurring chronically throughout the bays. Because the exceedances are confined to discrete areas, bay-wide reductions will be achieved by targeting each isolated zone.

Introduction

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of a listed water body. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas. The TMDL Program is a major component of Texas' overall process for managing surface water quality. The primary objective of the TMDL Program is to restore and maintain the beneficial uses—such as drinking water supply, recreation, support of aquatic life, oyster harvesting, and fishing—of impaired or threatened water bodies.

A TMDL expresses the total pollutant load a water body can receive and still meet water quality standards. The TMDL can be expressed as pollutant per unit time (load) or a pollutant concentration per unit time. In most cases, a TMDL establishes the allowable pollutant loading capacity and allocates a portion of that load to the various contributors in the watershed as wasteload (for permitted sources) and load (for non-permitted sources) allocations. TMDLs must also provide a margin of safety (implicit or explicit). A TMDL can be expressed in terms of mass per unit time, toxicity, density, concentration, or other appropriate measures. For these TMDLs, a concentration-based (number of organisms per unit volume) measure of indicator bacteria is used.

For most pollutants, TMDLs are expressed as a mass loading (e.g., pounds per day). For bacteria (e.g., fecal coliform), however, it is expressed as the number of organisms in a given volume of water (i.e., their concentration), not their mass or total number. The concentration is the significant value with respect to protection of the oyster waters use.

This concentration is the technically relevant criterion for assessing the impact of discharges, the quality of the affected receiving waters, and the public-health risk in a discharge and in the receiving waters. The Code of Federal Regulations, Title 40, Section 130.2(i) allows the state to establish a concentration-based TMDL for a pollutant that is not readily controllable on a mass basis. Flows in the Galveston Bay watershed (Figure 1) are highly variable and difficult to measure; consequently, a load-based analysis would add to uncertainty in the load allocations. Therefore, this TMDL establishes concentration-based TMDLs and load allocations, expressed in terms of bacteria concentrations.

This TMDL addresses impairments to the oyster waters use identified as RHZs by the DSHS, as illustrated in their "Classification of Shellfish Harvesting Areas of Galveston Bay" (Figures 2 and 3). The TMDL addresses elevated fecal coliform concentrations in the restricted areas of:

- Upper Galveston Bay, Segment 2421 (assessment units 2421-1 & 2421-2)
- Trinity Bay, Segment 2422 (assessment unit 2422-1)
- East Bay, Segment 2423 (assessment unit 2423-1)
- West Bay, Segment 2424 (assessment unit 2424-2)
- Chocolate Bay, Segment 2432 (assessment unit 2432-1)
- Lower Galveston Bay Segment 2439 (assessment unit 2439-1)

The goal of this TMDL is to reduce the bacteria concentrations in the areas identified as exceeding criteria associated with the oyster waters use. RHZs are defined as areas closed to the harvesting of shellfish for direct marketing. Before marketing for human consumption, shellfish harvested from an RHZ must be relayed to an approved harvest area and allowed to depurate for a prescribed amount of time. The DSHS is responsible for classifying oyster harvesting areas and for modifying the geographic extent of RHZs and providing maps of the coast showing classification areas. There are four classifications assigned to oyster waters, and each of the segments in the project area fall into one of the first three listed.

- **Prohibited Areas** are all areas not specifically designated as Restricted or Approved, and are closed for the harvesting of shellfish. Prohibited areas are most often found near outfalls, known contaminated areas, or any other area with high potential of containing unsafe levels of a pollutant. These areas are also called Prohibited Harvest Zones or PHZs.

- **Restricted Areas** are those where oyster harvesting is allowed, but not for direct marketing. These areas are also called Restricted Harvest Zones or RHZs.

- **Conditionally Approved Areas** are open to oyster harvesting during periods with limited rainfall; during significant storm events, Conditionally Approved areas can be temporarily closed.

- **Approved Areas** are open to oyster harvesting.

Classification of zones is constantly managed by DSHS. Classifications are subject to change based upon the DSHS's evaluation of the potential for risk to public health.

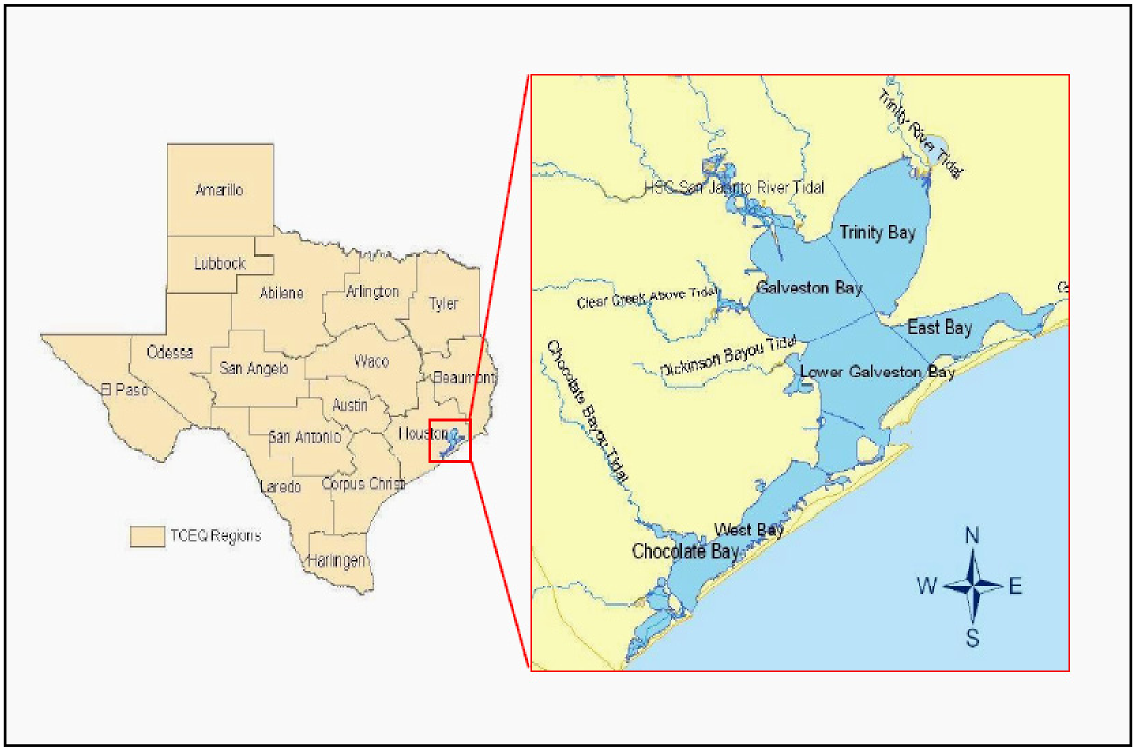

Figure 1. Geographic Location of Galveston Bay
(Zoun 2003)

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) in Title 40, Code of Federal Regulations, Part 130 (40 CFR 130) describe the statutory and regulatory requirements for acceptable TMDLs. The EPA provides further direction in its *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA 1991). This TMDL document has been prepared in accordance with those regulations and guidelines.

The TCEQ must consider certain elements in developing a TMDL; they are described in the following sections:

- **Problem Definition**
  Areas of the Galveston Bay system contain RHZs, areas closed to the harvest of oysters for direct marketing. Data shows that some sampling locations in these areas exceed the indicator bacteria criteria for oyster waters.

- **Endpoint Identification**
  The endpoint for this TMDL is to meet the 90th percentile criterion for indicator bacteria in oyster waters. The load reductions required to meet the 90th percentile criterion are in all cases greater than those required to meet the median criterion. Therefore, the percent reduction goals of these TMDLs are based upon attainment of the 90th percentile criterion. If the median criteria were defined as the endpoint, reductions would not be required. Achievement of the endpoint will only signify that water quality standards have been met; it may not cause a change in the RHZ classification, as those classifications are determined by DSHS and based on potential human health risk.

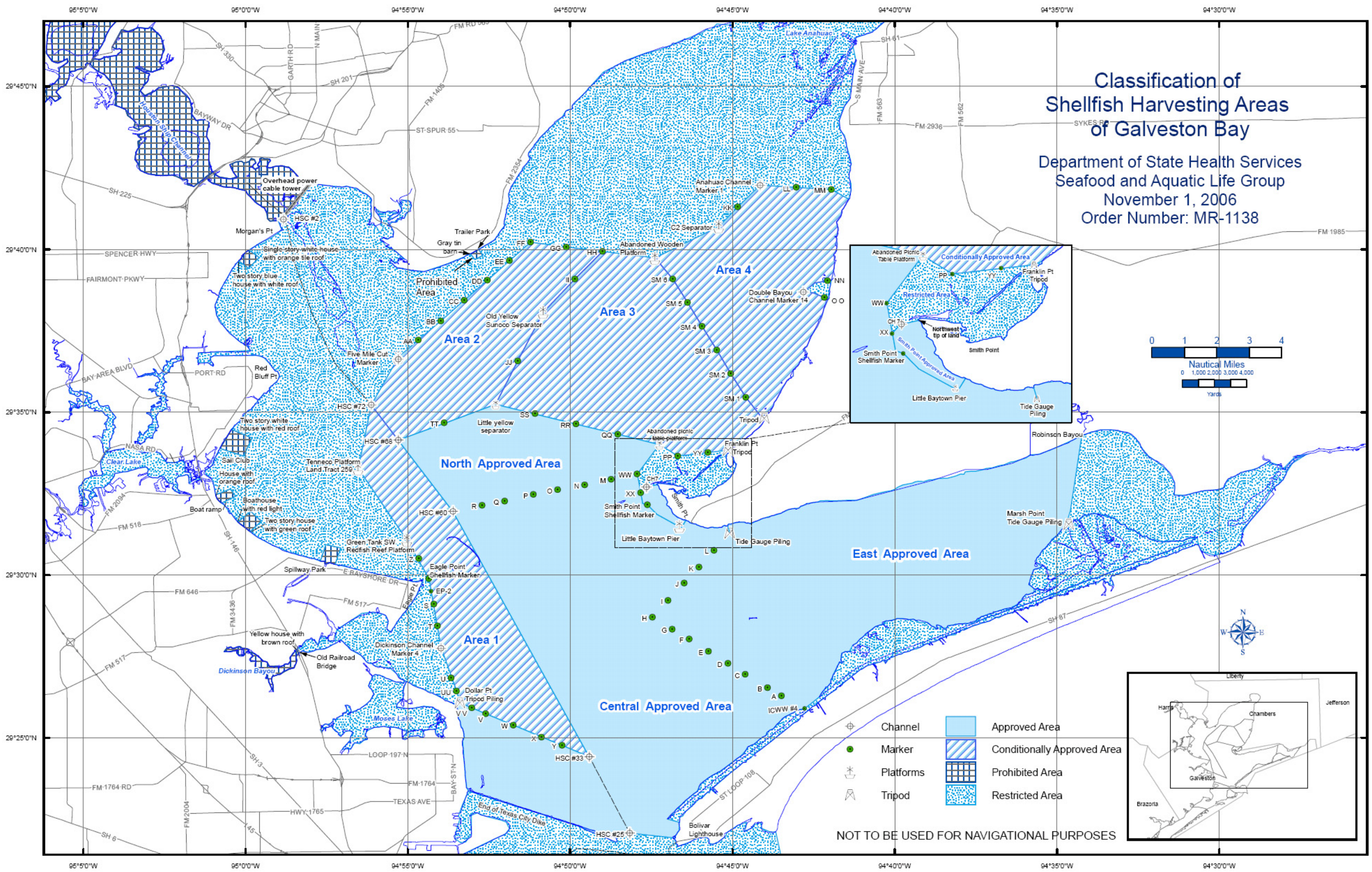

Figure 2. Classification of Shellfish Harvesting Areas of Galveston Bay

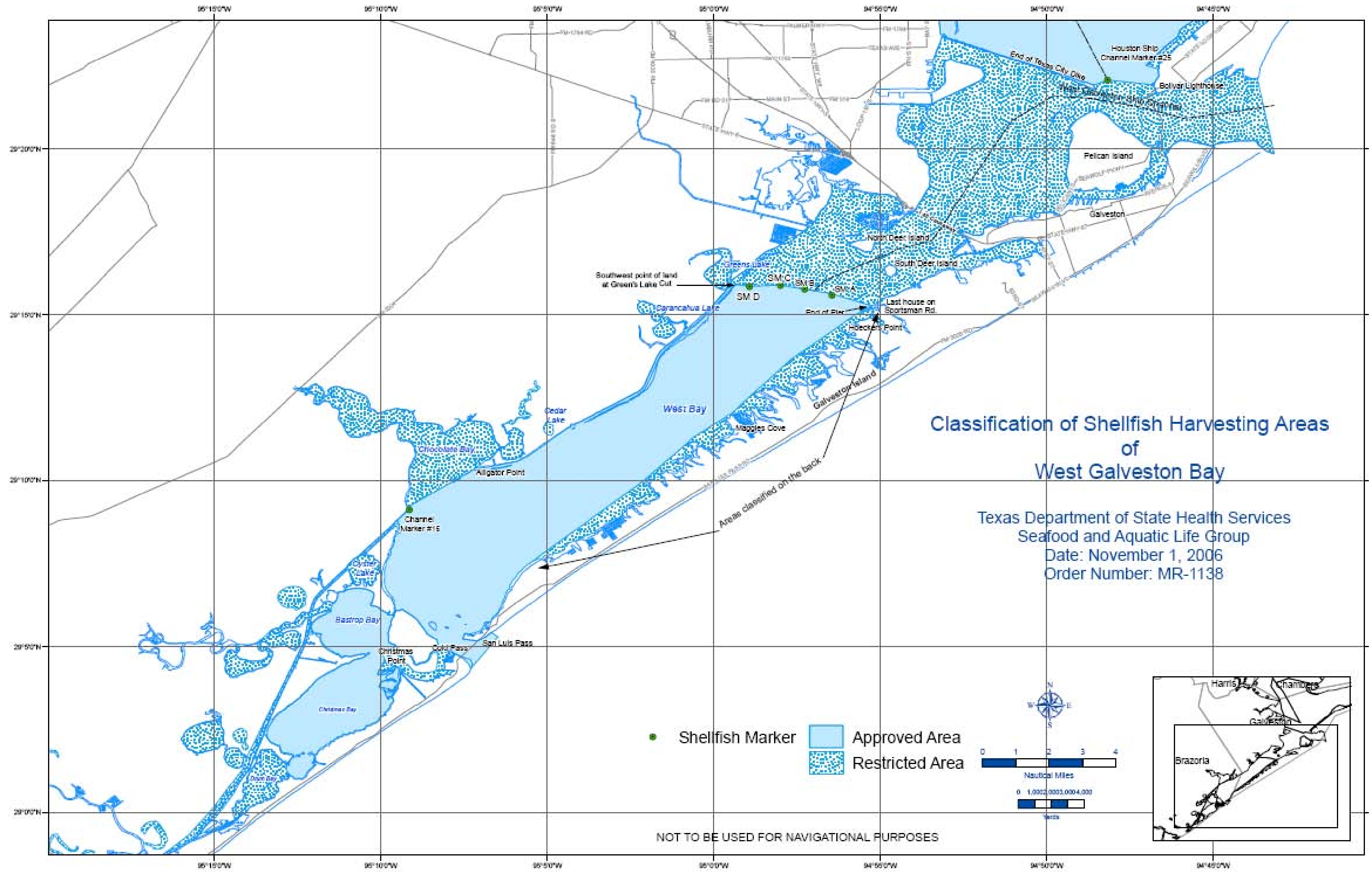

Figure 3. Classification of Shellfish Harvesting Areas of West Galveston Bay and Chocolate Bay

- **Source Analysis**
  Sources are identified and characterized by location, general magnitude, and general significance. The loads from the identified sources are not estimated because this is a concentration-based, rather than a load-based TMDL.

- **Linkage Analysis**
  An essential component of TMDL development is to establish a relationship (linkage) between pollutant loadings from various sources and the numeric targets chosen to measure the attainment of beneficial uses. For these TMDLs, the proposed load allocations protect the beneficial uses (the linkage is established) because the proposed concentration-based load allocations are the same or more stringent than the existing concentration-based numeric water quality objectives for the given water bodies. A causal relationship between the indicator bacteria loads entering the bay system and the measured concentrations is not established, nor necessary, because the concentration-based method is not load dependent. Achievement of the proposed concentration-based pollutant load allocations will ensure the protection of the water quality and beneficial uses of the Bay and its tributaries.

- **Margin of Safety**
  The TMDLs for the Upper Gulf Coast use an implicit MOS for the bacteria impairments. The implicit MOS used in these TMDLs is embodied in the assessment methods, as well as in the conservative measures used to develop criteria related to seafood consumption. Uncertainties that may arise from determining source loads and their effects on the indicator bacteria concentrations in the bay system are not a factor in a concentration-based analysis.

- **Pollutant Load Allocation**
  The load based TMDL equation ($TMDL = \Sigma WLA + \Sigma LA + MOS$) is not used for pollutant load allocations because the allocations are concentration-based limits for both permitted sources (waste load allocation) and non-permitted sources (load allocation).

- **Seasonal Variation**
  Seasonal variations must be considered to ensure that water quality standards for indicator bacteria will be met during all seasons of the year. The concentration-based approach used in these TMDLs applies throughout the entire year. This method has no dependency on flow or other seasonal factors so meeting the concentration-based goals at all times will result in achieving the water quality standards throughout the year.

- **Public Participation**
  The development of these TMDLs was coordinated with the Galveston Bay Estuary Program and other interest groups, and public meetings were conducted to coordinate with the public.

- **Implementation and Reasonable Assurance**
  Establishing and assessing the oyster waters use is the responsibility of the Texas Department of State Health Services. Many factors are considered in evaluating the oyster waters use, and water quality is only one factor. Meeting water quality standards for oyster waters use does not necessarily result in removal of the restricted harvest classification. The Texas Department of State Health Services may or may not modify the restricted classification because of other factors that must be considered to protect human health.

An Implementation Plan (I-plan) will be developed by the stakeholders and with the assistance of TCEQ to identify the programs and activities that will achieve the concentration limits identified in this TMDL. Starting in 2008, stakeholders will be organized to develop this plan focusing on all of the identified sources.

The commission adopted this document on August 20, 2008. Upon EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan.

Problem Definition

The TCEQ analyzed published maps from the DSHS to determine which oyster waters to list as impaired. Each of the project segments contains RHZs, which are closed to the harvest of oysters for direct marketing; these areas are targeted for reduction in the TMDLs included in this report. Table 1 shows the original listing date for each of the impairments and the area included in the RHZ.

Table 1. Characteristics of Impaired Segments of Galveston Bay

Segment Name	Segment Number	Year Listed	Area (square kilometers)	Percent Area in the RHZ
Upper Galveston Bay	2421	1996	299.1	47%
Trinity Bay	2422	2000	317.5	48%
East Bay	2423	1998	148.9	25%
West Bay	2424	1996	195.3	37%
Chocolate Bay	2432	1996	21.1	100%
Lower Galveston Bay	2439	1996	362.4	27%

The standards for water quality are defined in the *Texas Surface Water Quality Standards* (Chapter 307 of the Texas Administrative Code). The specific uses assigned to Chocolate Bay, East Bay, Lower Galveston Bay, Trinity Bay, Upper Galveston Bay, and West Bay are contact recreation, high aquatic life use, fish consumption use, and oyster waters use.

The designated use responsible for 303(d) listings in this project is oyster waters use. The criteria used for assessing attainment of the oyster waters use are expressed as the number of colony-forming units (cfu) of fecal coliform bacteria per hundred milliliters (100 mL) of water.

As described in the TCEQ's "2004 Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data" (TCEQ 2004), assessment of the oyster waters use was based on the TCEQ's evaluation of annually published maps from DSHS *Classification of Shellfish Harvesting Area Maps*, dated November 1, 2006.

Using the fecal coliform criteria (Table 2) in the Standards, if the minimum sample requirement of ten samples during the previous five years is met, the oyster waters use is not supported when:

- median fecal coliform concentration in bay and gulf waters, exclusive of 1,000 foot shoreline buffer zones, exceeds 14 colonies per 100 mL; AND/OR
- more than 10 percent of all samples exceed 43 colonies per 100 mL.

However, many factors are considered in evaluating the oyster waters use; water quality is only one. Attainment of the fecal coliform criteria does not necessarily result in removal of a restricted harvest designation. The DSHS may or may not choose to remove the restricted classification because of other factors that must be considered to protect human health (e.g. proximity to potential sources of contamination, inability to enforce harvesting regulations, or insufficient water quality data).

Table 2. Summary of Oyster Waters Criteria and Assessment

	Water Quality Criteria (cfu/100mL)		Zone Classification
	Median	**90th Percentile**	
Fecal coliform	14	43	DSHS maps classifying Restricted Harvest Zones resulted in 303(d) the listing of 6 oyster waters segments

The determination of critical conditions requires that the median and the 90th percentile values of the ambient data be compared to the water quality criteria. If the median values dictate the higher reduction, this suggests that water sample counts are consistently high with limited variation around the mean. If the 90th percentile criterion requires a higher reduction, this suggests intermittent occurrences of high levels of fecal coliform due to variable hydrological conditions or unusually high spikes in fecal coliform concentrations under certain conditions, such as seasonal hurricanes or bird migrations. For this study, the 90th percentile criterion was found to be the most critical condition. Thus, the final reductions determined using the 90th percentile represent the most stringent conditions that are likely to result in attainment of the water quality standard. Upon examination of the data, neither of the two criteria is exceeded at some stations in the study area, which reduces the affected area within each of the listed segments.

The specific zones of the restricted use areas of the upper Gulf Coast are limited to localized areas, generally near shorelines. When examining all samples collected within a segment's

RHZ, none of the segments exceeded the median criterion of 14 cfu/100mL. However, a compilation of all samples collected in the RHZs of Lower Galveston Bay, Upper Galveston Bay, Chocolate Bay, and West Bay shows the 90th percentile criterion is exceeded. Additionally, Trinity Bay and East Bay, while meeting both criteria if assessed RHZ-wide assessment, require bacteria load reductions at some sampling stations.

Data show that the samples collected within the RHZ for Upper Galveston Bay, Lower Galveston Bay, Chocolate Bay, and West Bay exceed the 90th percentile criterion (Table 3). For this reason, implementation should focus on this subset of localized areas with elevated levels of fecal coliform.

Table 4 summarizes the bays' designated uses related to bacteria. For all areas within 1,000 feet of shore, only the contact recreation use and the aquatic life use apply. The oyster waters use is not a designated use within 1,000 feet of shore [30 TAC 307.7(b)(3)(B)(i)].

Watershed Overview

The Galveston Bay system is a complex ecosystem that provides natural resources, ecological services, recreational opportunities, transportation links, economic benefits, and aesthetic value. The Bay is home to a large number of living species. Fish and wildlife resources provide some of the Bay's greatest economic, recreational, and aesthetic assets. This system is also directly influenced by urban activities associated with the Houston Metropolitan area. The focus of the Galveston Bay Oyster waters project is the restricted harvest areas of six segments in the Upper Gulf Coast System—Upper Galveston Bay, Trinity Bay, East Bay, West Bay, Chocolate Bay, and Lower Galveston Bay.

Table 3. Bacteria Concentrations in Impaired Segments of Galveston Bay

Segment Number	Segment Name	Number of Samples in RHZ	RHZ Median (cfu/100 mL of Fecal Coliform)	RHZ 90th Percentile (cfu/100 mL of Fecal Coliform)	Exceedances at Sampling Locations within RHZ
2421	Upper Galveston Bay	947	8.0	130.0	Yes
2422	Trinity Bay	376	2.0	33.0	Yes
2423	East Bay	199	2.0	36.2	Yes
2424	West Bay	515	5.0	49.0	Yes
2432	Chocolate Bay	37	5.0	61.0	Yes
2439	Lower Galveston Bay	707	2.0	49.0	Yes

Table 4. Use Attainment of Segments of Galveston Bay
(TCEQ 2006)

Segment Number	Segment Name	Recreational Use	Oyster Use	Parameter
2421	Upper Galveston Bay	Fully Supporting	Dependent upon specific location	Bacteria
2422	Trinity Bay	Fully Supporting	Dependent upon specific location	Bacteria
2423	East Bay	Fully Supporting	Dependent upon specific location	Bacteria
2424	West Bay	Fully Supporting	Dependent upon specific location	Bacteria
2432	Chocolate Bay	Fully Supporting	Non-Supporting	Bacteria
2439	Lower Galveston Bay	Fully Supporting	Dependent upon specific location	Bacteria

In order to protect the oyster-consuming public from health risks, the Texas Department of State Health Services uses RHZs where conditions exist that pose a risk of shellfish contamination. The restricted harvesting areas are closed to direct marketing. Any shellfish harvested in these areas must be transported to approved harvesting areas and allowed to depurate to remove contaminants before marketing. Water quality standards are designated for water bodies to be suitable for oyster harvesting, and programs are implemented to attain the specified water quality criteria in water bodies subjected to oyster harvesting.

Oyster fisheries in Galveston Bay, with a history of over one hundred years, hold significant importance in the economy of the area. Oysters are harvested from both public reefs and private oyster leases in the bay (Figure 4), producing more oysters than any single water body in the United States, even more than the combined production of both Louisiana and Washington (Galveston Bay Estuary Program 2004). Between 1994 and 1998, the annual commercial harvest of oyster from Galveston Bay averaged close to four million pounds. For the same period, the annual value of oysters caught in Galveston Bay averaged more than $8 million (Lester 2002).

In addition to its commercial value, oysters also serve an important ecological role as filter feeders in the estuary. The volume of water filtered per hour is approximately 1500 times the volume of their body. A significant healthy oyster population is able to filter large volumes of bay water, and may, therefore, influence conditions such as water clarity and phytoplankton abundance (Lester et al. 2002). Oysters create reef habitats utilized by many other species and serve as an important indicator of the overall health of bay ecosystem.

The six segments of Galveston Bay have a total area of 519.1 square miles (1,344.5 square kilometers). Contiguous land use around Galveston Bay ranges from wetlands and undisturbed pasture to agricultural use to urban development (Figure 5).

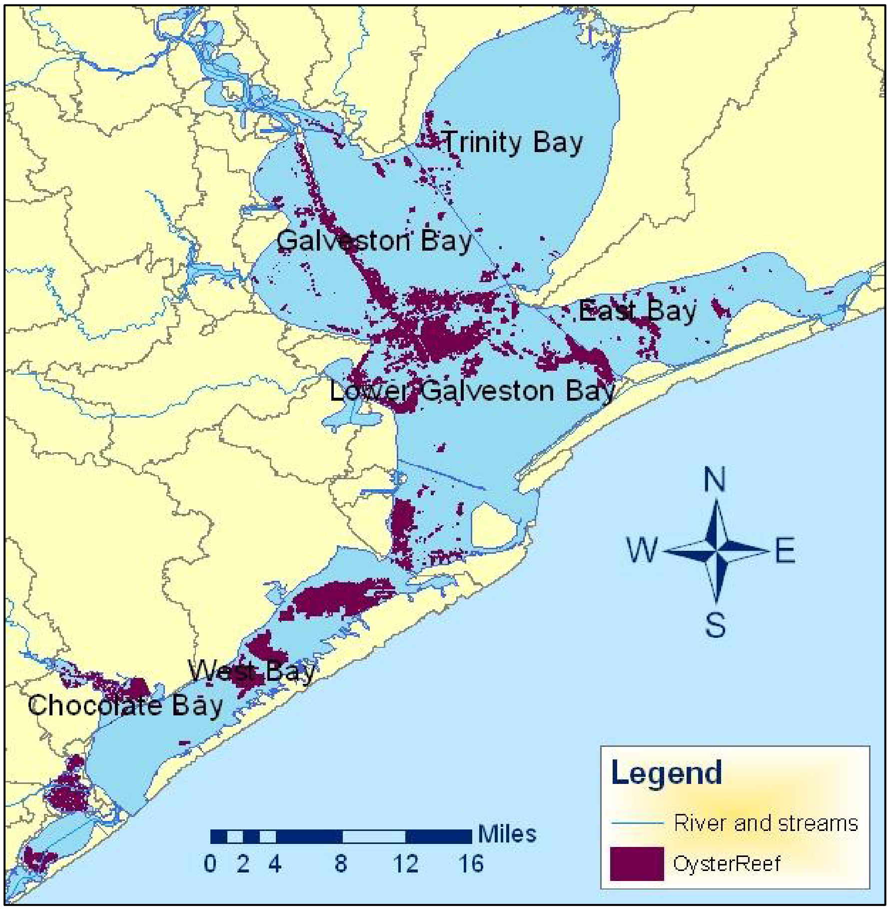

Figure 4. Location of Oyster Reefs in Galveston Bay

Upper Galveston Bay (Segment 2421) has a total area of 115.5 square miles (299.1 square kilometers). It is bordered by densely populated cities including Baytown, La Porte, Seabrook, Kemah, and League City on the west. Upper Galveston Bay receives the outflow of the San Jacinto River and much of the local drainage from areas of the City of Houston via the Houston Ship Channel. The port of Houston and the cities of Pasadena, Deer Park, and Baytown lie along the Houston Ship Channel and represent large population centers and heavily industrialized areas. The Houston Ship Channel then bisects Galveston Bay from north to south. The channel is responsible for bringing significant ship and barge traffic through the entire length of the bay system (TDH 2000).

Trinity Bay (Segment 2422) has a total area of 122.6 square miles (317.5 square kilometers). The Bay is bordered mostly by grazing land and small communities. Trinity Bay receives the outflow from the Trinity River. The Trinity River enters the Galveston Bay system in the eastern portion of Trinity Bay (TDH 2000).

East Bay (Segment 2423) has a total area of 57.5 square miles (148.9 square kilometers). East Bay lies landward of Bolivar Peninsula and receives inflow from Oyster Bayou and other runoff from Chambers County. East Bay is a shallow arm of Galveston Bay and is bordered on the north by sparsely populated Smith Point, livestock grazing land and the

Anahuac National Wildlife Refuge. Bolivar Peninsula, the southern shore of East Bay, is rich in wetland, marshes, and bird populations.

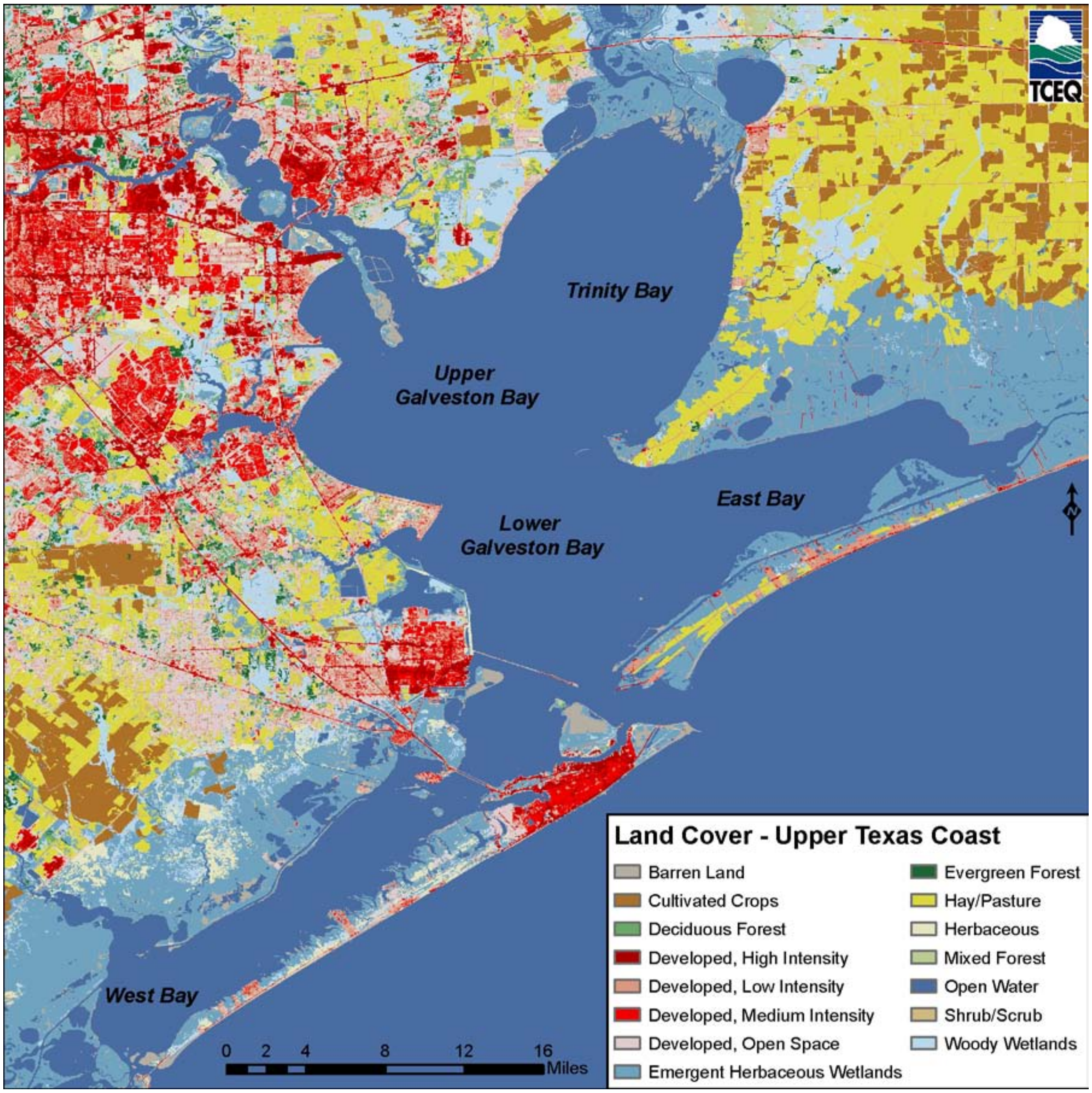

Figure 5. USGS Land Use Categories in the Project Watershed

West Bay (Segment 2424) and Chocolate Bay (Segment 2432) have total areas of 75.4 (195.3 square kilometers) and 8.1 (21.0 square kilometers) square miles respectively. The two segments include bodies of water southwest of the Galveston Causeway, South to Brazoria National Wildlife Refuge. West Bay is situated landward of Galveston Island, and receives runoff from Chocolate Bayou, Mustang Bayou and other local bayous. It is a shallow, lagoon-like arm of the Galveston bay system. The northern shore of West Bay is bisected by the Gulf Intracoastal Waterway.

Lower Galveston Bay (Segment 2439) has a total area of 140 square miles (362.4 square kilometers). It is bordered by Upper Galveston Bay in the north, Texas City and West Bay on the west and East Bay in the east. In the south, it is bordered by Galveston Island and Bolivar Peninsula, and it has an opening to the Gulf of Mexico.

There are three tidal inlets to the Galveston Bay system; two of these are of major importance with regard to water exchanged with the Gulf of Mexico. Bolivar Pass, located between Galveston Island and Bolivar Peninsula, accounts for the majority of the tidal exchange between the bay and the Gulf of Mexico (Figure 6). San Luis Pass, between the western end of Galveston Island and Follets Island, is a natural inlet that provides a lesser amount of bay's tidal exchange. Rollover Pass is a man-made cut through Bolivar Peninsula that provides minor tidal exchange between the Gulf of Mexico and the East Bay (Lester et al 2002).

Figure 6. Tidal Inlets to the Galveston Bay System

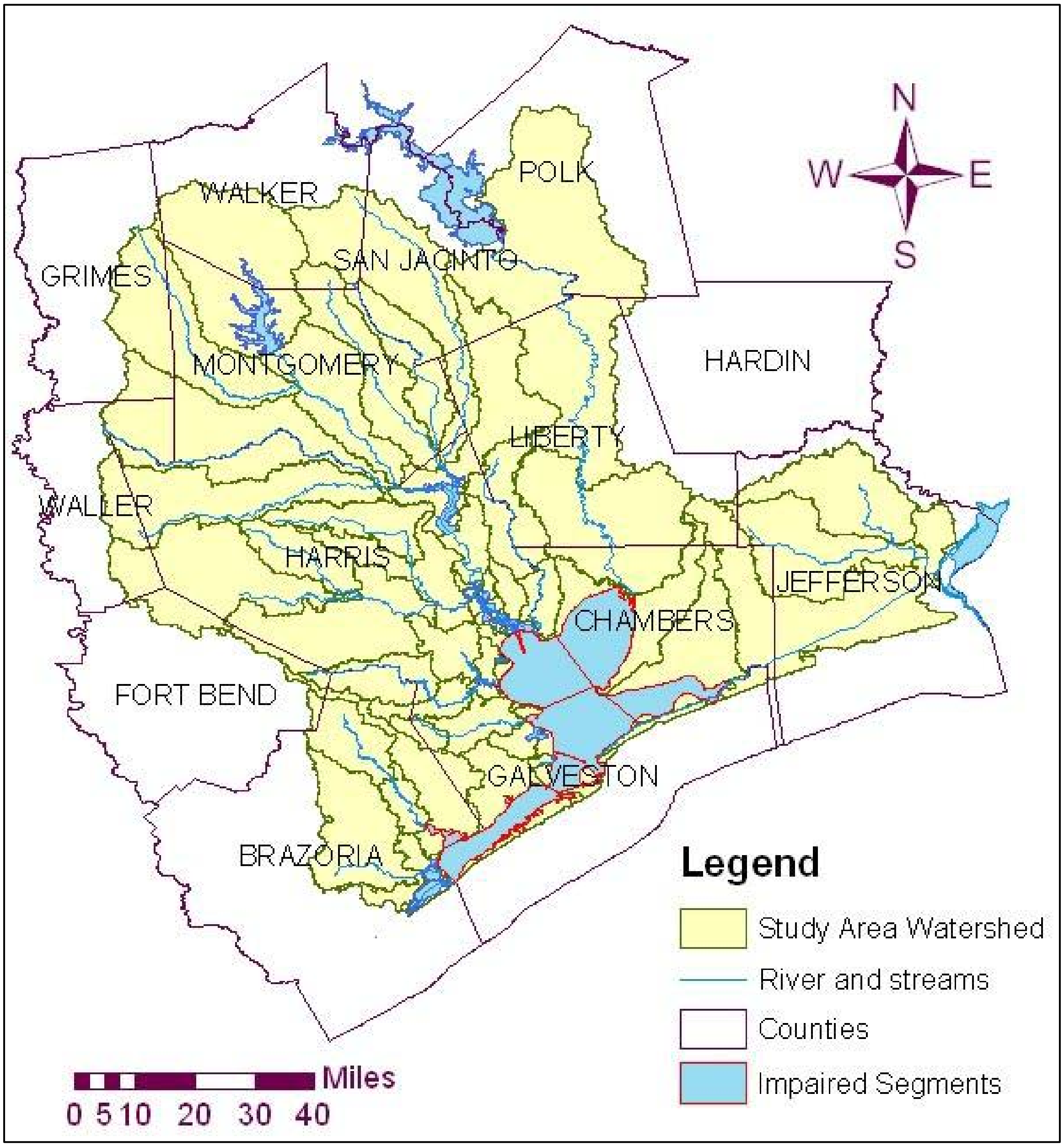

Figure 7. Counties Included in the Galveston Bay System Drainage Area

Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The TMDL determination and endpoint specification are coordinated, parallel activities. The endpoint for this TMDL is the concentrations of indicator bacteria that meet the oyster waters use. The water quality standards for oyster waters state that the median concentration of fecal coliform should not exceed 14 cfu/100mL, and single samples of fecal coliform shall not exceed 43 cfu/100mL more than 10 percent of the time. The concentration limits for waste load sources and for load sources are based on conditions that are designed to meet these standards. These limits include average concentrations that are protective of the oyster waters median criterion and single sample concentrations that are protective of the oyster waters single sample criterion.

The 90th percentile criterion was used to determine the percent reduction goals (Table 5). For all but two sampling locations, water quality results were below the median criteria. The reductions required to meet the 90th percentile criterion are in all cases greater than those required to meet the median criterion. Therefore, the load reductions based upon attainment of the 90th percentile criterion are also protective of the median criteria also.

Table 5. Endpoint Target Reductions at Sampling Stations in Project Segments

Segment, Station, and Sampling Results				**Exceedance Identified at Station**	**Reductions Needed to Meet Endpoint Concentrations**	
Segment 2421, Upper Galveston Bay					**REDUCTIONS**	
Station	Number of Samples[a]	Median[b]	90th Percentile[b]	Exceedance	Median Reduction	90th Percentile Reduction
13305	5	10.0	18.0	No		
14546	35	23.0[c]	130.0[d]	Yes	39%	67%
14556	67	11.0	73.6	Yes		42%
14560	107	5.0	110.0	Yes		61%
14562	105	5.0	97.6	Yes		56%
14570	116	5.0	79.0	Yes		46%
14571	107	13.0	174.0	Yes		75%
14572	107	10.0	110.0	Yes		61%
14580	58	79.0	920.0	Yes	82%	95%
14581	120	7.5	110.0	Yes		61%
14582	120	2.0	49.0	Yes		12%
Segment 2422, Trinity Bay					**REDUCTIONS**	
Station	Number of Samples	Median	90th Percentile	Exceedance	Median Reduction	90th Percentile Reduction
13314	62	2.0	23.0	No		
13315	66	2.0	15.0	No		
14548	62	6.0	49.0	Yes		12%
14549	60	5.0	51.1	Yes		16%

Segment, Station, and Sampling Results				Exceedance Identified at Station	Reductions Needed to Meet Endpoint Concentrations	
16838	64	2.0	16.1	No		
17092	62	2.0	22.4	No		
Segment 2423, East Bay						**REDUCTIONS**
Station	Number of Samples	Median	90th Percentile	Exceedance	Median Reduction	90th Percentile Reduction
14527	56	2.0	24.5	No		
14528	47	2.0	97.4	Yes		56%
14529	49	2.0	13.8	No		
14530	47	2.0	63.8	Yes		33%
Segment 2424, West Bay						**REDUCTIONS**
Station	Number of Samples	Median	90th Percentile	Exceedance	Median Reduction	90th Percentile Reduction
13321	37	13.0	33.0	No		
14607	37	2.0	3.2	No		
14608	37	11.0	49.0	Yes		12%
14618	36	2.0	17.0	No		
14620	37	11.0	49.0	Yes		12%
14621	37	5.0	33.0	No		
14622	36	13.5	94.5	Yes		54%
14623	37	11.0	73.6	Yes		42%
16839	37	8.0	99.4	Yes		57%
16840	37	2.0	9.2	No		
16841	37	2.0	19.4	No		
16842	37	5.0	73.6	Yes		42%
16844	37	5.0	33.0	No		
Segment 2439, Lower Galveston Bay						**REDUCTIONS**
Station	Number of Samples	Median	90th Percentile	Exceedance	Median Reduction	90th Percentile Reduction
14576	120	4.0	79.0	Yes		46%
14577	122	8.0	79.0	Yes		46%
14584	122	2.0	49.0	Yes		12%

Segment, Station, and Sampling Results				Exceedance Identified at Station	Reductions Needed to Meet Endpoint Concentrations	
14594	54	4.0	20.5	No		
14595	53	5.0	49.0	Yes		12%
14597	57	2.0	10.0	No		
Segment 2432 Chocolate Bay						REDUCTIONS
Station	Number of Samples	Median	90th Percentile	Exceedance	Median Reduction	90th Percentile Reduction
14610	37	5.0	61.0	Yes		30%

a. Samples used in assessing bacteria concentrations were collected during the years 2002 through 2007.

b. All concentrations are reported in cfu/100 mL.

c. Pink shading indicates concentrations exceed the median criterion.

d. Gray shading indicates concentrations exceed the 90th percentile criterion.

Point Sources

The point sources in the project watersheds are wastewater discharges from WWTFs and storm water discharges from MS4s.

Wastewater Treatment Facilities

Twenty-two domestic WWTFs discharge directly into or near the project-area segments (Table 6). Figures 8, 9, and 10 show the locations of permitted domestic wastewater treatment facilities that discharge to the Galveston Bay segments. At present, there are no permitted discharges of untreated human waste from the wastewater treatment facilities to the impaired segments.

Table 6. Wastewater Treatment Facilities—Permit Numbers and Permitted Flow

Segment	Permittee	NPDES Permit	TCEQ Permit	Flow (MGD*)
2421	CITY OF LA PORTE	0022799	10206-001	7.56
2421	BACLIFF MUD	0021369	10627-001	1.24
2421	CITY OF SEABROOK	0022250	10671-001	2.5
2421	BAYVIEW MUD	0021822	10770-001	0.3
2421	SAN LEON MUD	0071978	11546-001	0.95
2421	GALVESTON COUNTY WCID 12	0078441	12039-001	0.75
2422	CITY OF ANAHUAC & TRINITY BAY CONSERV DIST	0033944	10396-001	0.6
2422	TRINITY BAY CONSERVATION DISTRICT	0054917	11537-001	0.1
2422	GULF UTILITY SERVICE INC	0042081	13643-001	0.1
2424	GALVESTON COUNTY MUD 12	0020311	10435-002	0.4

Segment	Permittee	NPDES Permit	TCEQ Permit	Flow (MGD*)
2424	CITY OF GALVESTON	0047309	10688-002	3.75
2424	CITY OF GALVESTON	0066125	10688-005	0.5
2424	GALVESTON COUNTY FWSD 6	0020079	10879-001	0.32
2424	CITY OF JAMAICA BEACH	0020061	11033-001	0.36
2424	GALVESTON COUNTY MUD 1	0126977	11477-001	0.624
2439	CITY OF GALVESTON	0047309	10688-001	10.0
2439	CITY OF GALVESTON	0063665	10688-004	0.5
2439	MARTIN OPERATING PARTNERSHIP LP	0057258	10931-001	0.0085
2439	TEXAS A&M UNIVERSITY AT GALVESTON	0063231	11085-001	0.3
2439	TEXAS DEPT OF TRANSPORTATION	0063207	11672-001	0.006
2439	AMBAR DRILLING FLUIDS LP LLLP	0104353	11679-001	0.0015
2439	HALLIBURTON ENERGY SERVICES INC	0119482	14113-001	0.0035

* MGD = Million Gallon per Day

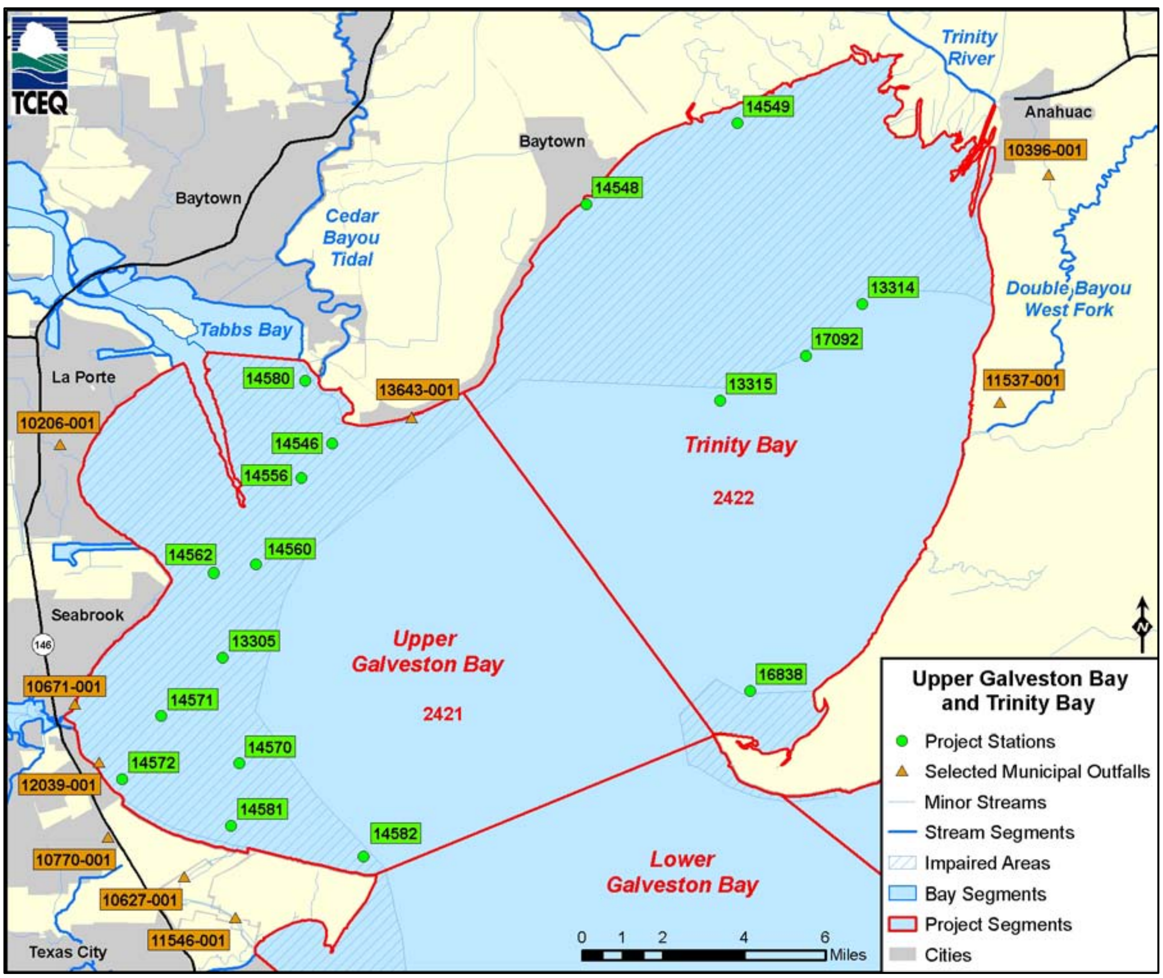

Figure 8. Upper Galveston and Trinity Bays—Wastewater Treatment Facilities and Sampling Stations

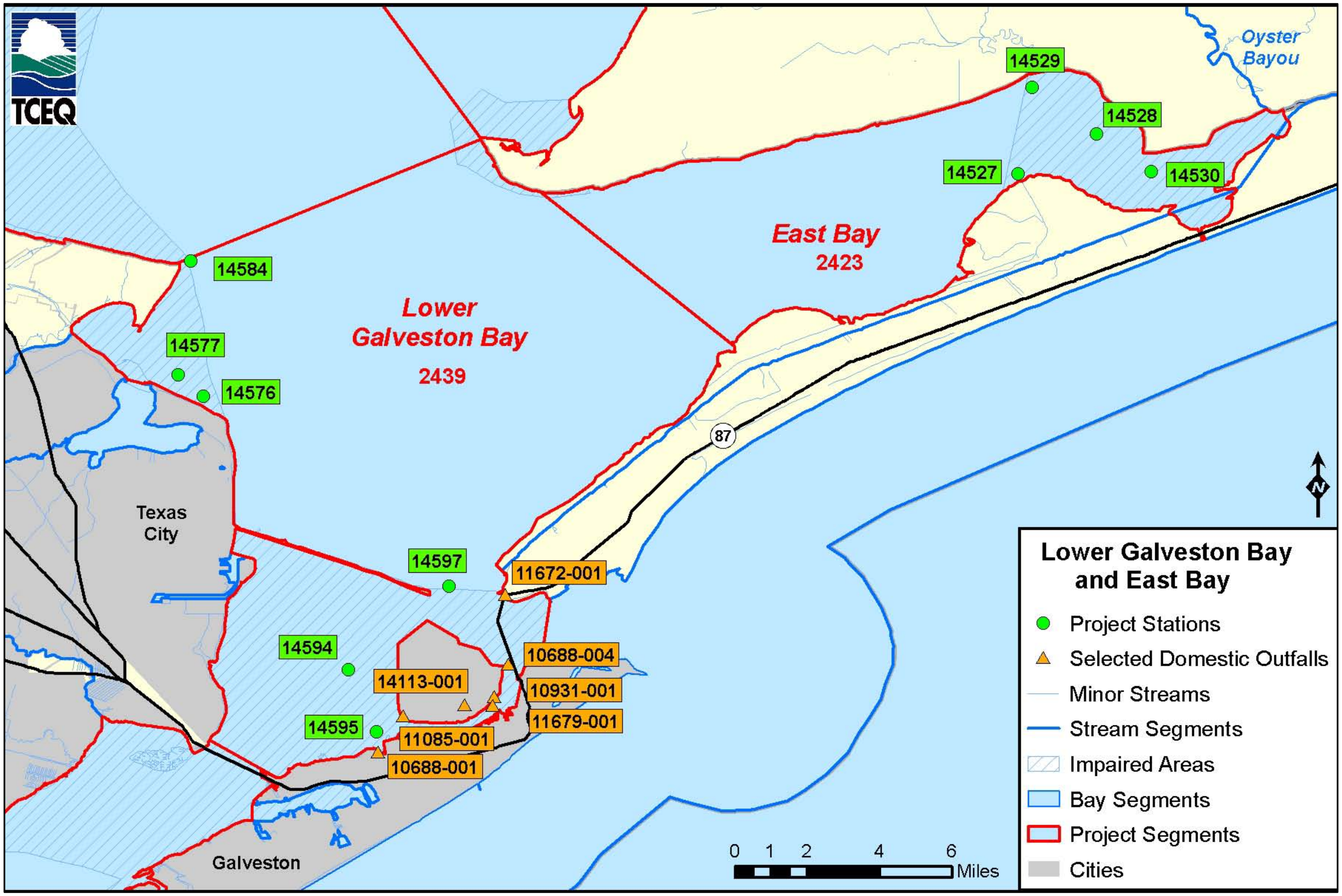

Figure 9. Lower Galveston and East Bays—Wastewater Treatment Facilities and Sampling Stations

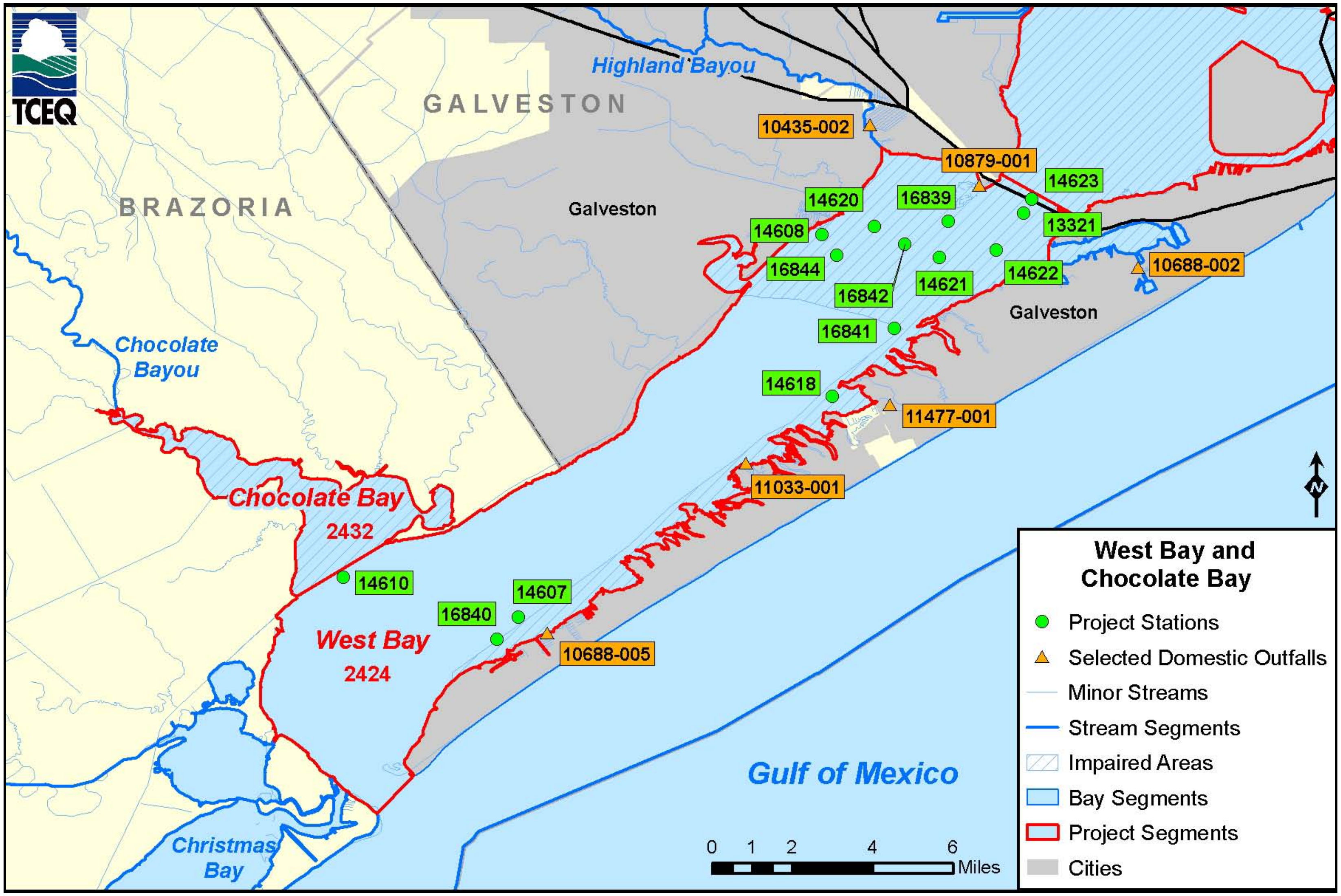

Figure 10. West and Chocolate Bays—Wastewater Treatment Facilities and Sampling Stations

Magnitude

Domestic waste dischargers are required to disinfect effluent prior to discharging. However, disinfection may be less effective during high flow and wet weather conditions due to exceeding the hydraulic capacity of the wastewater treatment facility. The 22 permitted discharges range from 0.0015 to 10.0 million gallons per day (MGD).

Significance

In each case, accidental malfunctions, including the breaching of ponds, a break in a sewage line, or land application at times when the soil is saturated, could result in a discharge of untreated or partially treated effluent to surface waters within the watershed. All facilities have the potential to adversely affect water quality and impair beneficial uses if an accidental discharge occurred. The impact of fecal coliform bacteria contributions from wastewater treatment facilities on oyster water use can be completely mitigated by the establishment of a Prohibited Harvest Zone (PHZ) surrounding outfalls. PHZs are established around all WWTFs and act as a safety perimeter designed to protect against any unauthorized discharges of raw sewage. DSHS uses a dilution equation to determine the volume necessary to supply a sufficient amount of water in the bay to dilute any raw sewage to an acceptable level of bacteria, compliant with state water quality criteria.

While these wastewater treatment facilities have the potential to contaminate waters due to isolated and unexpected incidents such as a system malfunction or breaching of the holding ponds, when properly operating they are not a significant source of indicator bacteria to the Bay. Jensen and Su (1992) concluded that wastewater treatment facilities along the bay shoreline were not a major contributor of fecal coliform bacteria to the bay as a whole. However, wastewater treatment facilities can be an important contributor of bacteria locally, which could reasonably assist in explaining the variance in fecal concentrations among sampling stations.

A large number of plants discharging near the project area have either self-reported incidents or problems identified during TCEQ site inspections. For example, the City of La Porte (permit–10206-001) reported inflow and infiltration problems of up to 19 MGD flowing through the 7.56 MGD plant during storms. The City of Anahuac and Trinity Bay Conservation District (permit–10396-001), with more than 20 self-reported violations, exceeded ammonia-nitrogen discharge limits and discharged low dissolved oxygen; the plant flow records show the WWTF is near capacity for daily permitted flow.

The compliance history for the 10.0 MGD plant in the City of Galveston (permit–10688-001) has reported 118 sanitary sewer overflows. City of Galveston (permit–10688-002) reported multiple sanitary sewer overflows. The chlorine contact basin at Galveston County Fresh Water Supply District (FWSD) 6 (permit–10879-001) contained sludge during a site visit by TCEQ inspectors.

Martin Operating Partnership LP (permit–10931-001) flow exceeded permitted flow for several months. City of Jamaica Beach (permit–11033-001) discharge water contained high levels of total soluble solids and ammonia-nitrogen. Texas A&M University-Galveston (permit–11085-001) inspections discovered faulty plant equipment. Galveston County Municipal Utility District (MUD) 1 (permit–11477-001) reported unauthorized discharges.

The San Leon MUD (permit–11546-001) permit file reports suggest inflow and infiltration problems. Galveston County Water Control and Improvements District (WCID) 12 (permit–12039-001) reported multiple sanitary sewer overflows along with inflow and infiltration problems. Gulf Utility Service Inc. (permit–13643-001) inspections during 2005 identified improper maintenance and self-reported unauthorized discharges during 2007. Inspection reports during 2005 and 2007 for Halliburton Energy Services (permit–14113-001) identified violation of discharge water quality and improper plant maintenance.

The following list of plants were generally in compliance with permit requirements based on TCEQ permit history files: Galveston County MUD 12 (permit – 10435-002); Bacliff MUD (permit – 10627-001); City of Seabrook (permit – 10671-001); City of Galveston (permits – 10688-004 and 10688-005); Bayview MUD (permit – 10770-001); Trinity Bay Conservation District (permit – 11537-001); and Texas Department of Transportation (permit – 11672-001).

Storm Water Runoff

Storm water in the project watershed originates from regulated discharges from phase I and phase II MS4s, and from non-regulated runoff. Runoff from shorelines and adjacent watersheds is a potential source of bacteria to the bay segments; it flows directly into the adjacent segment and subsequently to the project area's impaired waters.

Storm water originating from urbanized areas in adjacent watersheds must be regulated by a TPDES permit. Storm water is categorized as either a point source or nonpoint source, depending on the presence or absence of a storm water permit. Storm water must be considered a point source, identified in a TMDL as a waste load allocation, if it originates from a city, or urbanized area, in an adjacent watershed with a phase I MS4 or phase II MS4 storm water permit. MS4 permits are concentrated on the western segments, from Galveston (West Bay) north to the Houston area (Upper Galveston Bay). Storm water flowing to Chocolate Bay, Trinity Bay, and East Bay is not regulated.

Magnitude

Adjacent watershed precipitation averages from 41 to 57 inches (1,054-1,455mm) per year. Residential neighborhoods surrounding the project area are home to dog and cat waste, potential sources of bacteria contained in runoff. The populations of dogs and cats are estimated to be 0.58 dogs and 0.66 cats per household, from the American Veterinary Medicine Association (AVMA, 2002).

Houston's Phase I MS4 permit (NPDES Permit TXS001201) does discharge to the bay through the Houston Ship Channel. However, analysis of water quality data indicates that bacteria levels are lower where water flows past Hogg Island and into Tabbs Bay than at water quality stations in the bay. The conclusion drawn is that the Houston MS4 does not impact the oyster water impairment in Upper Galveston Bay.

Significance

Runoff containing animal waste and sediment can account for a significant amount of bacteria added to the impairment. One management practice implemented in Texas waters is a 1,000-foot buffer, measured from the shoreline at ordinary high tide, established for bay and gulf waters. Recreational criteria for indicator bacteria are applicable in buffer zones.

Monthly cumulative rainfall is relatively consistent over time. Ten of twelve months average in the 8-14 centimeters (3.0-5.5 inches) range of rainfall (Figure 11). Only February averages less than 8 centimeters of rainfall over the 30-year period. Coincidentally, February, with the lowest annual average rainfall, coincides with the peak concentrations of bacteria in the bays. Locally concentrated contributions could reasonably assist in explaining the variance in fecal concentrations among sampling stations.

Nonpoint Sources

Potential sources of nonpoint source pollution in the watershed include on-site sewage facilities, marinas, boat discharges during recreational activity, waterfowl, and non-regulated shoreline runoff (discussed with MS4 above).

On-Site Sewage Systems

Some areas around the Bays and tributaries are served by various types of OSSFs including holding tanks, seepage pits, septic tank, and leach-field systems. The location and distribution of land parcels with OSSFs near the bay are difficult to estimate. The 1990 Census collected data regarding the use of OSSFs (Figure 12).

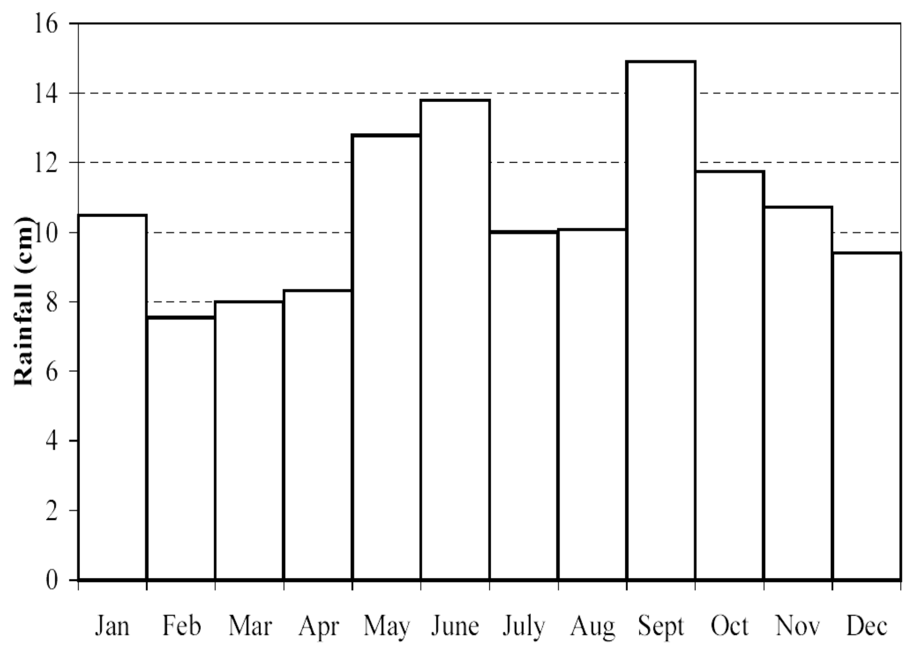

Figure 11. Average Monthly Rainfall Distribution for the Houston Area, 1971–2000
(Texas Weather Connection 2007)

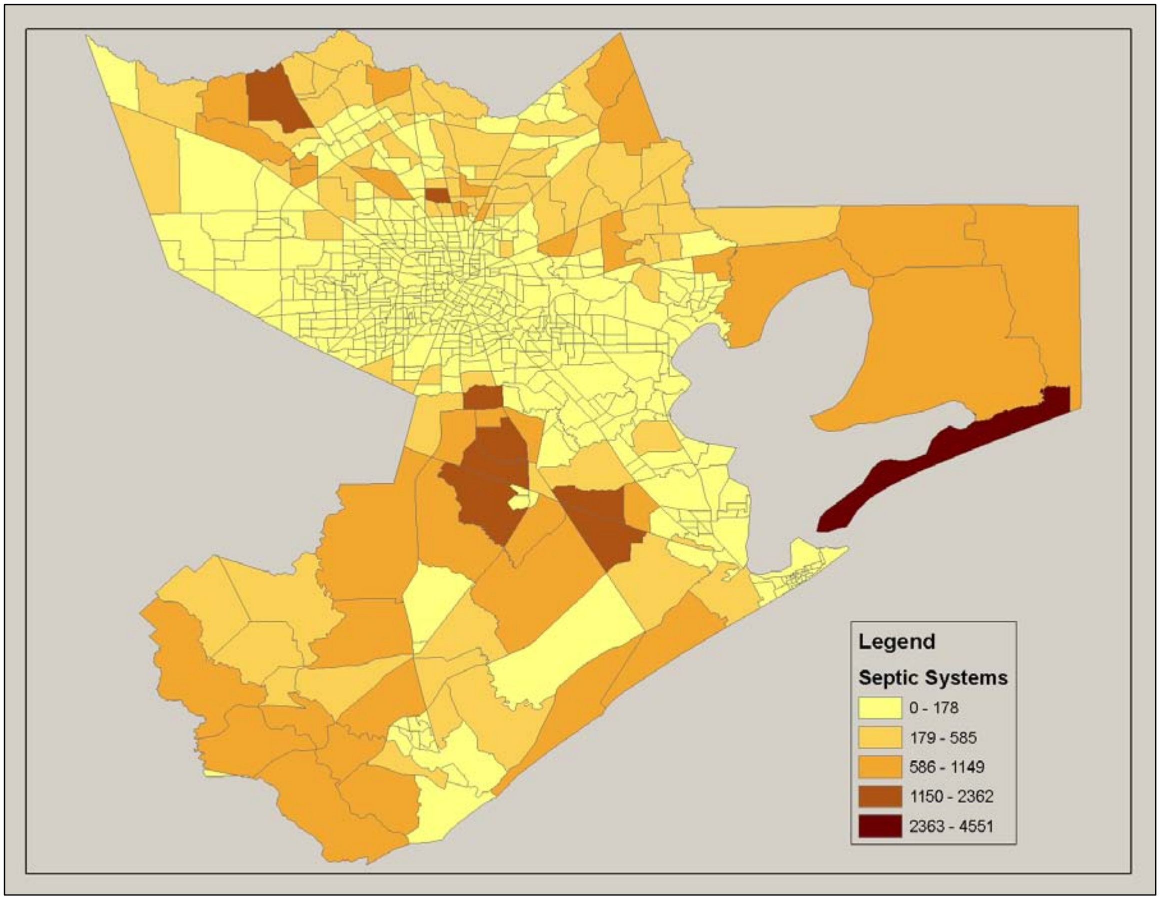

Figure 12. Number of Septic Systems by Area, Based on 1990 Census

Magnitude

The magnitude is difficult to assess because limited outdated data is available. Because of continued land development and the age of this data, the 1990 Census data may not be indicative of the current level of use of OSSFs.

Significance

While both human and animal waste are associated with a variety of bacterial and protozoa pathogens, human waste can also contain viral pathogens, which are of great concern to human health. One study (Cogger and Carlile, 1984) found that OSSFs in year-round saturated soil on average could only treat (reduce) the concentration of fecal coliform to the most probable number (MPN*) of 170 MPN/100mL. The study also found that even the OSSFs that were only seasonally saturated on average could only reduce the concentration of fecal coliform down to 56 MPN/100mL in the groundwater. The greatest amount of lateral transport occurred when continuous saturation was accompanied by a steep groundwater gradient.

Jensen and Su (1992) concluded that septic systems along the bay shoreline were not a major contributor of fecal coliform bacteria to the bay as a whole. However, septic systems

* MPN is the most probable number of colonies of bacteria in the samples. It is a method that relies on dilutions to approximate the number of bacteria in a sample.

may be an important contributor of bacteria locally. Locally concentrated contributions could reasonably assist in explaining the variance in fecal concentrations among sampling stations.

Marinas

There are 37 marinas in the Galveston Bay area (Sea Grant College Program, 2006). This includes recreation boats and live-aboard boats. These marinas have a total capacity of 10,174 boats with 8,209 wet slips and 1,956 dry boat storage slips. Most marinas are located in Clear Lake. Locations are available in Table 7.

Magnitude

These facilities are distributed throughout the Galveston Bay segments and have the potential to affect numerous areas of the oyster waters in the Galveston Bay segments. Of the 37 marinas, only 12 are reported to have permanent pump out facilities (Table 7) able to remove waste from boats and transfer to an appropriate waste treatment facility. The marinas with pump out facilities have the capacity to serve approximately 6,600 boats.

Significance

Improper handling of human waste at any of these marinas can result in unauthorized discharge. This can cause elevated bacteria concentrations both within the marina area and in oyster water areas by transport of bacteria by currents or boating activity. Although the exact magnitude of this source is unknown, the nature of the bacteria source identifies this as an important target for reduction. Locally concentrated marina contributions could reasonably assist in explaining the variance in fecal concentrations among sampling stations. The impact of fecal coliform bacteria contributions from marinas on oyster water use are completely mitigated by the establishment of PHZs surrounding each of the marinas. PHZs are a safety perimeter designed to protect against any unauthorized discharges of raw sewage. DSHS uses a dilution equation to determine the radius required to supply a sufficient volume of water in the bay that would dilute any raw sewage to an acceptable level of bacteria, compliant with state water quality criteria.

Boat Discharges

The marinas in the Galveston Bay segments have a capacity of 10,174 boats (Sea Grant College Program, 2006). In addition, there are a large number of private boat piers and boat ramps adding to the number of boaters. The Port of Houston is also a significant source of ship traffic. More than 200 million tons of cargo moved through the Port of Houston in 2006 with a total of 7,550 vessel calls.

Magnitude

The very large number of ships and boats represents a large potential source of human waste and bacteria. All of the Galveston Bay segments are No Discharge Zones, meaning discharge of human waste is prohibited.

Table 7. Marinas in the Galveston Bay Area

Marina Name and Location						Slips and Ramps			
Clear Lake						**Wet Slips**	**Dry Slips**	**Ramp**	**Pump Out**
Anchorage Apts. & Marina	451 Constellation	League City	TX	77573	(281) 334-2527	53	0	0	
Bal Harbor Marina	123 Lakeside Lane	Houston	TX	77058	(281) 333-5168	141	0	0	
Blue Dolphin Yachting Center, Inc.	P.O. Box 123	Seabrook	TX	77586	(281) 474-4450	238	0	0	
Clear Lake Marine Center, Inc.	P.O. Box 716	Seabrook	TX	77586	(281) 326-4426	161	0	0	
El Lago Marina	P.O. Box 722	El Lago	TX	77586	(832) 228-0884	60	30	0	Yes
Endeavour Marina	3101 NASA Parkway	Seabrook	TX	77586	(832) 864-4000	14	350	0	
Kemah Boardwalk Marina	555 Bradford St	Kemah	TX	77565	(281) 334-2284	420	0	0	
Lakeside Yachting Center, Inc.	2511-B Nasa Rd. 1, Ste. 101	Seabrook	TX	77586	(281) 326-5547	75	0	0	
Lakewood Yacht Club (Private)	2425 Nasa Parkway	Seabrook	TX	77586	(281) 474-2511	375	180	1	Yes
Landing (The)	4445 Nasa Rd. 1	El Lago	TX	77586	(281) 326-2714	76	0	1	
Legend Point	1300 Marina Bay Dr.	Clear Lake Shores	TX	77565	(281) 334-3811	252	0	0	Yes
Marina Bay Harbor Yacht Club	P.O. Box 478	Kemah	TX	77565	(281) 535-2222	0	280	0	
Marina Del Sol	1203 Twin Oaks Blvd	Kemah	TX	77565	(281) 334-3909	331	225	0	Yes
Nassau Bay Hilton Marina	3000 Nasa Rd. 1	Houston	TX	77058	(281) 333-9300	83	0	0	
Nassau Bay Homes Assoc., Inc.	1120 Nasa Pkwy, Ste. 109	Nassau Bay	TX	77058	(281) 333-2570	44	45	1	
Nassau Bay Yacht Club	18250 Nassau Bay Dr.	Nassau Bay	TX	77058	(281) 333-5809	45	60	2	
Portofino Harbour	One Portofino Plaza	Clear Lake Shores	TX	77565	(281) 334-6007	212	0	0	Yes
Seabrook Marina Inc.	1900 Shipyard Dr.	Seabrook	TX	77586	(281) 474-2586	700	70	0	Yes
South Shore Harbour	2551 South Shore Blvd., Ste B	League City	TX	77573	(281) 334-0515	896	0	0	Yes
Waterford Harbor Marina	800 Mariners Drive	Kemah	TX	77565	(281) 334-4400	649	0	0	Yes
Watergate Yachting Center	1500 Marina Bay Dr.	Clear Lake Shores	TX	77565	(281) 334-1511	1,150	0	0	Yes
Wharf at Clear Lake (WSMA)	P.O. Box 1208	League City	TX	77574		320	0	0	

Marina Name and Location						Slips and Ramps			
Galveston Bay						**Wet Slips**	**Dry Slips**	**Ramp**	**Pump Out**
Eagle Point Fishing Camp, Inc.	Route 1 Box 1718	San Leon	TX	77539	(281) 339-1131	62	51	3	
Galveston Yacht Club, Inc.	715 North Holiday Dr.	Galveston	TX	77550	(409) 762-9689	500	145	2	Yes
Houston Yacht Club	3260 Miramar Drive	La Porte	TX	77571	(281) 471-1255	350	370	2	Yes
San Leon Marina	100 6th St.	San Leon	TX	77539	(281) 339-1515	81	22	1	
Waterman's Harbor, Inc.	16426 Clearcrest	Houston	TX	77059	(281) 339-1416	52	0	0	
Harborwalk Marina	P.O. Box 2328	League City	TX	77574	(409) 935-3737	156	0	2	Yes
Payco, Inc.	501 Blume Dr.	Galveston	TX	77554	(409) 744-7428	130	32	1	
Pirates Beach Bait & Tackle	14302 Steward Rd	Galveston	TX	77554	(409) 737-3635	25	0	2	
Teakwood Marina	615 Tiki Dr.	Galveston	TX	77554		58	0	1	
Marina Landing Resort	7302 Heards Lane	Galveston	TX	77551	(409) 744-3625	133	25	0	
West Bay Marina	6019 Sea Isle	Galveston	TX	77554	(409) 737-3636	54	80	2	
Inter-Coastal Waterway									
Bolivar Yacht Basin	P.O Box 30	Port Bolivar	TX	77650	(409) 684-6700	175	0	1	
Trinity Bay									
Baytown Marina	2405 Kilgore Rd.	Baytown	TX	77520	(281) 427-1997	50	51	2	

Significance

Unauthorized discharge by boats and ships can cause elevated bacteria concentrations in oyster-harvesting areas. The No Discharge Zone designation is unlikely to completely eliminate or minimize the source unless further efforts of education and enforcement occur. Although the exact magnitude of this source is unknown, the nature of the bacteria source identifies this as an important target for reduction.

Wildlife Refuges Runoff and Direct Deposition

A variety of terrestrial animals, such as deer, birds, rodents, and unmanaged animals that inhabit the open space lands adjacent to the Bay and its tributaries may contribute indicator bacteria to these water bodies.

Magnitude

No accurate information as to the magnitude and geographic dispersion of this waste is available at this time. The Brazoria National Wildlife Refuge, Moody National Wildlife Refuge, and Anahuac National Wildlife Refuge, along with multiple parks and wild areas border the impaired segments.

Significance

Runoff containing animal feces and sediment along shorelines can cause elevated bacteria concentrations in oyster-harvesting areas. The implementation of shoreline erosion-control projects has been used in East Bay to limit sediment loss. Complete control of runoff along shorelines in natural areas does not prevent animals from adding to the bacteria load by direct deposition. Locally concentrated contributions from wildlife refuges could reasonably assist in explaining the variance in fecal concentrations among sampling stations.

Water Birds

The Texas coast is an important migratory route and habitat for a large number of water birds. During the spring and summer months, water birds are concentrated around breeding islands and during the winter months, large amounts of waterfowl inhabit the shallows of the Galveston bay segments.

Figure 13 shows common locations for bird colonies in the Galveston Bay system. During winter migrations, large numbers of birds travel to the bays. During the winter season, larger numbers of birds are present throughout the bay system, beyond the locations represented by Figure 13.

Magnitude

Various populations of water birds are present in the Bay throughout the year. The distribution and dispersal of water birds is very complex depending on season, conditions in the bays, and other factors. Population numbers also vary widely depending on the same factors.

Two important variables in estimating fecal coliform loads from bird sources are average number of birds at a particular location and amount of excretion per bird. There can be substantial numbers of birds around breeding islands in the late spring and early summer.

These same birds spread out in the winter, and rafts of ducks, White Pelicans, and Double-crested Cormorants join them in the open water, potentially increasing bacteria during the winter.

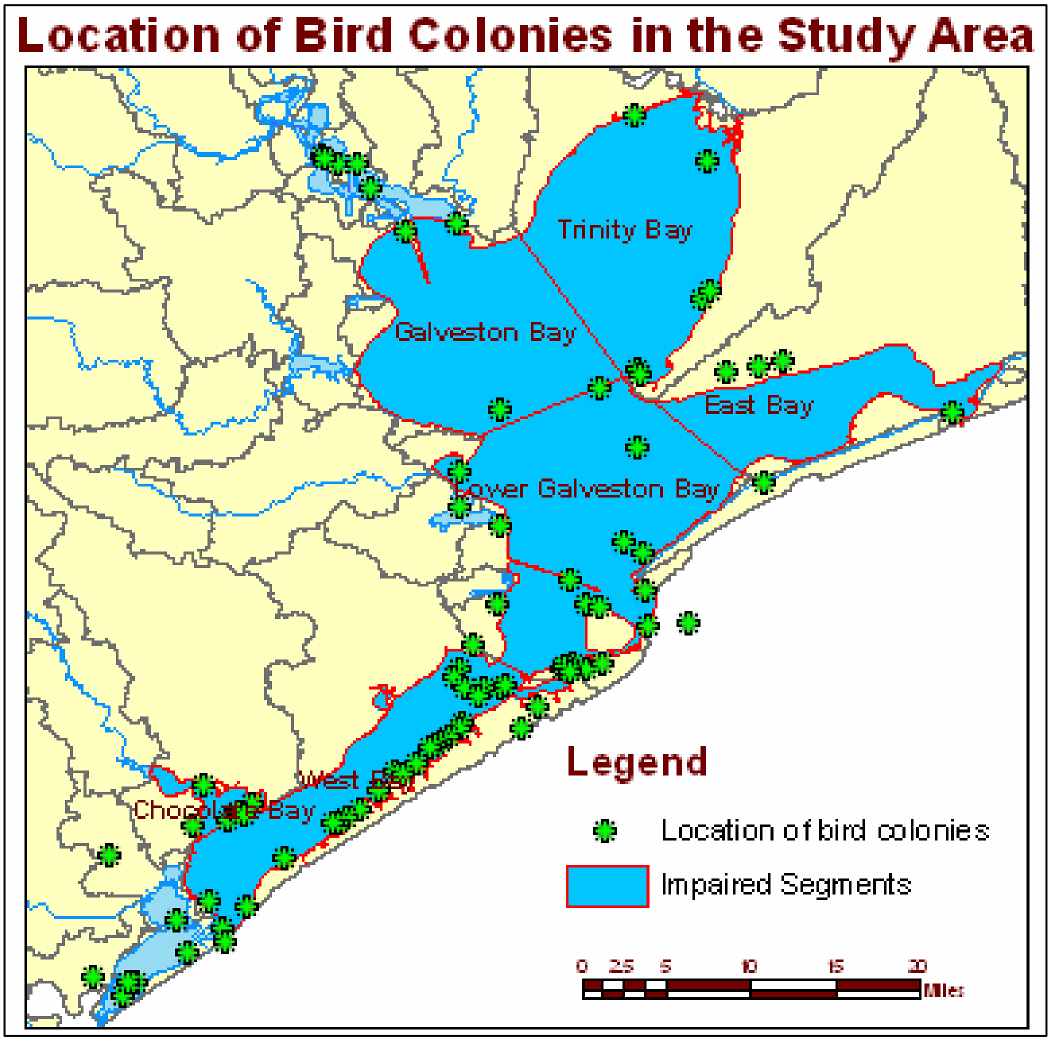

Figure 13. Location of Colonies of Breeding Pairs of Birds

(Zoun 2003)

Migratory waterfowl are more numerous in the Bay during the winter months. Census data from the 2007 Annual Audubon Christmas Bird Counts for Galveston and the Bolivar Peninsula, a one-day census of birds within a set 15-mile diameter circle provides a snapshot of birds present during one day of the year (Tables 8–10). Populations vary from year to year and these numbers are only estimates taken on one day of the year. However, this census data does provide a list of 80 bird species present. Over half of the species (41 species listed in bold) identified were migratory birds moving into the bay during winter. Depending upon weather patterns, migratory bird populations would be expected to continue increasing after the Christmas bird count is completed until February or later.

Significance

Because of the great variety of water birds, complex distribution and dispersal patterns, and fluctuating populations, it is very difficult to assess the impact of birds on water quality in the RHZs in the Galveston Bay segments. It may be expected that bacteria levels would rise during winter months when the number of migratory birds from the north increases. During months when migratory populations are at their peak, a seasonal spike is noticeable in the bacteria concentrations for multiple stations. The bird population and bacteria concentration peaks coincide with the months that produce the least amount of precipitation; for this reason, migratory birds may be significant contributors to the bacteria load in the impaired segments. Locally concentrated contributions from birds could reasonably assist in explaining the variance in fecal concentrations among sampling stations.

Table 8. Birds Likely to be Found in Marshes or Grassy Areas near the Bay

Note: could occasionally feed or roost in bay water.

Name	Number near Galveston	Number near Bolivar
Black-crowned Night-Heron	133	7
Canada Goose		136
Cattle Egret	7	5
Common Moorhen	4	71
Greater White-fronted Goose		313
Green Heron	1	4
Hooded Merganser	2	10
Killdeer	184	170
Long-billed Curlew	47	4
Pied-billed Grebe	114	34
Ross's Goose		26
Snow Goose	1	23,917
Sora	3	4
White Ibis	138	741
White-faced Ibis	21	425
Wilson's Snipe	18	26
Yellow-crowned Night-Heron	36	8

Species shown in bold are migratory birds moving into the bay in winter.

Table 9. Birds Likely to be Found Wading near the Edge of the Bay

Name	Number near Galveston	Number near Bolivar
American Avocet	8,040	25
American Oystercatcher	38	2
Belted Kingfisher	34	36
Black-bellied Plover	276	89
Black-necked Stilt	58	61
Clapper Rail	7	7
Dowitcher sp.	530	316
Dunlin	1,239	230
Great Blue Heron (Blue form)	90	73
Great Egret	165	594
Greater Yellowlegs	21	35
Least Sandpiper	42	30
Lesser Yellowlegs	21	90
Little Blue Heron	19	23
Long-billed Dowitcher	2	112
Marbled Godwit	47	10
Peep sp.	1,195	
Piping Plover	109	4
Red Knot	16	
Reddish Egret	5	7
Roseate Spoonbill	122	74
Ruddy Turnstone	110	
Sanderling	265	58
Semipalmated Plover	58	67
Short-billed Dowitcher	104	24
Snowy Egret	306	304
Snowy Plover	20	4
Spotted Sandpiper	14	1
Tricolored Heron	20	32
Western Sandpiper	995	6
Willet	341	47

Species shown in bold are migratory birds moving into the bay in winter.

Table 10. Birds Likely to be Found in Open Water or Flying over the Bay

Name	Number near Galveston	Number near Bolivar
American Coot	1,691	229
American Green-winged Teal	345	5,265
American White Pelican	951	422
American Wigeon	35	
Black Skimmer	918	200
Blue-winged Teal	168	122
Bonaparte's Gull	16	38
Brown Pelican	370	77
Bufflehead	47	2
Canvasback	22	
Caspian Tern	15	6
Common Goldeneye	8	8
Common Loon	26	1
Double-crested Cormorant	415	366
Eared Grebe	21	1
Forster's Tern	3,199	185
Gadwall	111	2,412
Herring Gull	156	19
Laughing Gull	4,135	162
Lesser Scaup	261	6
Mallard	6	63
Mottled Duck	112	174
Neotropic Cormorant	379	217
Northern Pintail	75	698
Northern Shoveler	469	666
Osprey	16	5
Red-breasted Merganser	122	99
Redhead	15	
Ring-billed Gull	627	89
Ring-necked Duck	65	
Royal Tern	445	21
Ruddy Duck	354	20

Species shown in bold are migratory birds moving into the bay in winter.

Linkage Analysis

Establishing the relationship between water quality in the Galveston Bay waters and the source of loadings is an important component in developing a TMDL. It allows for the evaluation of management options that will achieve the desired endpoint. The concentration-based method used for these TMDLs does not identify source loads that require a specific reduction. In place of the load limits, concentration limits are determined for the sources that have the potential of contributing indicator bacteria to the RHZs.

By establishing and enforcing these concentration limits through control measures, the indicator bacteria load is expected to be reduced from existing levels and, as a result, the indicator bacteria concentrations in the RHZs are reduced. The concentration limits provide clear targets for managing the indicator bacteria loads and a clear path toward the endpoint water-quality goals. Achievement of the endpoint may not necessarily result in a reclassification of the RHZ by DSHS. Classifications of DSHS regulated oyster harvesting zones are based on potential risk factors beyond attainment of water quality standards. Oyster beds are managed by DSHS continuously throughout the year; DSHS opens and closes areas depending upon current conditions influencing each section within the oyster waters.

In addition, the proposed load allocations (concentration limits) protect the beneficial uses because:

- The proposed concentration-based load allocations are the same or more stringent than the existing concentration-based numeric water quality objectives for the given water bodies; and
- The numeric water-quality objectives, contained in the TMDL, are protective of beneficial uses.

Therefore, achievement of the proposed pollutant load allocations will ensure the protection of the water quality and beneficial uses of the Bay and its tributaries.

Margin of Safety

The margin of safety (MOS) should account for uncertainty in the analysis used to develop the TMDL and thus provide a higher level of assurance that the goal of the TMDL will be met. The margin of safety may be incorporated into the analysis using two methods:

- implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- explicitly assigning a loading amount for the MOS.

The TMDLs for the Upper Gulf Coast use an implicit MOS for the bacteria impairments. The implicit MOS used in these TMDLs is embodied in the assessment methods, as well as in the conservative measures used to develop criteria related to seafood consumption.

In an effort to be conservative in development of the TMDLs for fecal coliform, the load reductions were calculated using the 90^{th} percentile criterion as the target. In all cases, attainment of the 90^{th} percentile criterion required a higher load reduction than attainment of the median criterion.

An additional measure of safety is provided by the DSHS programs. DSHS monitors water quality throughout each segment. Temporarily elevated bacteria levels in any portion of the oyster waters can lead to an immediate halt to oyster harvesting in affected areas. DSHS's monitoring program strengthens the protection of human health by creating a dynamic boundary around any oyster waters identified as impaired. The monitoring program accounts for uncertainty in predicting water quality in this complex ecosystem.

Pollutant Load Allocation

U.S. EPA protocol (EPA, 2001) for developing bacteria TMDLs defines the total maximum daily load as the allowable loadings for specific pollutants that a water body can receive without exceeding water quality standards. TMDLs are the sum of individual wasteload allocations for point sources and load allocations for nonpoint sources for a given water body. The sum of these components must not result in the exceedance of water quality standards for that water body. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. To express load-based allocations the TMDL equation is used:

$$TMDL = \Sigma WLA + \Sigma LA + MOS \quad \text{(Equation 1)}$$

Where:

WLA = wasteload allocation (permitted or point source contributions)
LA = load allocation (non-permitted or nonpoint source contributions)
MOS = margin of safety

For most pollutants, TMDLs are expressed on a mass-loading basis (e.g., pounds per day). For indicator bacteria (i.e., fecal coliform), however, it is the number of organisms in a given volume of water (i.e., their concentration), and not their mass or total number, that is significant with respect to public health risk and protection of beneficial uses. The concentration of fecal coliform organisms in a discharge and in the receiving waters is the technically relevant criterion for assessing the impact of discharges, the quality of the affected receiving waters, and the public-health risk. The EPA protocol on the development of pathogen TMDLs recommends establishing a TMDL in this manner (concentration-based) for a pollutant that is not readily controllable on a mass basis. Therefore, this TMDL plan establishes concentration-based TMDLs and pollutant load allocations, expressed in terms of fecal coliform concentrations. Using a concentration-based method, the TMDL term in Equation 1 becomes the target water-quality concentration and the WLA and LA terms are the concentration limits placed on the sources belonging to each type of source.

Total Maximum Daily Load

For a concentration-based TMDL, the Total Maximum Daily Load is the target water-quality concentration. Table 11 lists the TMDL for the Upper Gulf Coast segments: Upper Galveston Bay, Trinity Bay, East Bay, West Bay, Chocolate Bay, and Lower Galveston Bay. These TMDLs will be applicable year-round. Because shellfish harvesting is the most sensitive beneficial use of the Upper Gulf Coast project watershed, shellfish harvesting criteria are used as the TMDL for the Bays' oyster waters, expressed as the concentration of fecal coliform organisms. This proposed TMDL requires that the water quality of the RHZ in each bay be maintained to ensure a median of 14 cfu/100 mL of fecal coliform with no more than 10 percent of the samples in the Bay exceeding 43 cfu/100 mL.

Table 11. Total Maximum Daily Loads of Indicator Bacteria for Galveston Bay System Segments

Water Body	TMDL Indicator Parameter
Upper Galveston Bay Trinity Bay East Bay West Bay Chocolate Bay Lower Galveston Bay	Fecal coliform 90th Percentile < 43 cfu/100 mL

Load Allocations

Concentration limits on identified sources replace the flow or volume based load allocations. In place of the WLA, concentration limits are established for all of the permitted sources that were identified. Likewise, for the LA, concentration limits are established for all of the non-permitted sources that were identified.

Unlike the load-based TMDL method, the concentration-based load allocations do not add up to equal the TMDL because the concentrations of individual pollution sources are not additive. Rather, in order to achieve the concentration-based target, it is simply necessary to ensure that each concentration limit is met.

In setting the concentration limits, it is necessary to understand the regulatory framework. In oyster waters, there is buffer zone extending 1,000 feet from the shoreline where oyster waters use does not apply. This buffer zone provides protection of the contact recreation use. Application of the oyster waters use within the 1,000-foot buffer would be wholly unreasonable due to the proximity to shorelines. Within the 1,000-foot buffer and the adjacent watershed, the contact recreation standard for indicator bacteria is permissible.

Table 12 presents concentration-based limits (load allocations) for indicator bacteria in the source categories associated with the Upper Gulf Coast project. These load allocations will apply year-round to the each source category of pollution in the watershed (e.g., urban runoff, OSSFs, WWTFs, boat discharges). Compliance with these load allocations will ensure protection of the water quality and beneficial uses of the Bay.

Waste Load Allocations

All permitted sources discharge either to the PHZ, 1,000-foot buffer zone, or to the adjacent watershed. This includes WWTF discharges and storm water runoff from areas covered by a Phase I or Phase II MS4 permit. Contact recreation standards for indicator bacteria apply to these sources. While fecal coliform are the indicator used to evaluate oyster waters, bacteria used to evaluate contact recreation may be either *E. coli* for discharges to freshwater bodies or Enterococcus for saline water bodies.

The TCEQ intends to implement any individual WLAs through the permitting process. However, there may be a more economical or technically feasible means of achieving the goal of improved water quality and circumstances may warrant changes in individual WLAs after this TMDL is adopted. Therefore, these individual WLAs are non-binding until implemented via a separate TPDES permitting action, which may involve preparation of a "Water Quality Management Plan Update." Regardless, all permitting actions will demonstrate compliance with the TMDL. Any future changes to effluent limitations will be addressed through the permitting process and, when necessary, by updating the WQMP.

Load Allocations

Sources that are not required to have a discharge permit can discharge either to the 1,000-foot buffer zone and the adjacent watershed, or to the open bay. Contact recreation standards for indicator bacteria apply to sources that enter the bay system at the shoreline. The indicator bacteria may be either *E. coli* for discharges to freshwater bodies or Enterococcus for saline water bodies. Discharges of untreated human waste into the State's waters from any source are not allowed. Non-regulated sources can significantly affect compliance with oyster waters standards.

Discharging entities will not be held responsible for uncontrollable coliform discharges originating from wildlife. The discharge of untreated human waste is prohibited. All sources of untreated human waste have an allocation of zero. Nonpoint source runoff containing fecal coliform bacteria originating from animals and wildlife, at levels that do not result in exceedances of water objectives, does not constitute wastewater with characteristics of concern to beneficial uses. Therefore, animal and wildlife-associated discharges, in compliance with the conditions of this TMDL, do not constitute a violation of applicable discharge prohibitions.

The TCEQ maintains an overall water quality management plan (WQMP) that directs the efforts to address water quality problems and restore water quality uses throughout Texas. The WQMP is continually updated with new, more specifically focused WQMPs, or "water quality management plan elements" as identified in federal regulations (40 Code of Federal Regulations (CFR130.6(c)). Consistent with federal requirements, each TMDL is a plan element of a WQMP and commission adoption of a TMDL is state certification of the WQMP update.

Table 12. Concentration-Based Pollutant Wasteload and Load Allocations for Upper Gulf Coast Segments

Pollutant Waste Load Allocations[a]		
	Fecal coliform densities for Discharges to the RHZ	**For Discharges to Adjacent Watersheds and the 1,000 foot Buffer Zone**[b]
Mechanical WWTFs[c]	Discharges directly to the RHZ are not possible[d]	Fecal Coliform 200 per 100 mL OR *E. coli* 126 per 100 mL OR Enterococcus 35 per 100 mL
Wetland WWTFs	Discharges directly to the RHZ are not possible[d]	Wetland systems are measured based on detention time. Human waste must be detained for at least 21 days in sun light before reaching the bay system, unless individual permit requires additional time.
MS4s[c]	Discharges directly to the RHZ are not possible[e]	Numerical concentrations requirements are unreasonable for storm water runoff. This TMDL will require MS4s to follow implementation of bacteria reduction efforts and best management practices.
Pollutant Load Allocations[a]		
OSSFs	Discharges directly to the RHZ are not possible[e]	0 per 100 mL
Recreational Boat and Ship Discharges	0 per 100 mL	0 per 100 mL
Marina	Discharges directly to the RHZ are not possible[d]	0 per 100 mL
Non-Regulated Municipal Runoff	Discharges directly to the RHZ are not possible[e]	Numerical concentrations requirements are unreasonable for storm water runoff. Incentive based options will be developed for municipalities with non-regulated runoff. Bacteria reductions will be achieved through the implementation of the resulting I-plan.
Direct Deposition into Segment[f]	The reduction of wildlife or changing natural background conditions is not the intended goal of a TMDL.	

a. Allocations are applicable year-round. WLAs apply to any sources (existing or future) subject to regulation by a TPDES permit.

b. All concentrations limits within the 1,000-foot buffer zone will be based on the geometric means of the applicable indicator bacteria.

c. Regulated entities may use indicator bacteria other than fecal coliform, as listed in individual TPDES permits. Indicator bacteria concentrations for each permit must be consistent with the applicable water quality standard for the receiving water. Dischargers releasing effluent into a segment buffer zone shall meet those water quality standards.

d. Discharges to RHZ are not possible for WWTFs and Marinas because TDSHS implements safety perimeters known as Prohibited Harvest Zones around this source to protect against any unauthorized discharges of raw sewage.

e. Discharges to RHZ are not possible because TCEQ implements a 1000-foot buffer zone around this source designated as contact recreation.

f. The listed segments contain wildlife and unmanaged animals and are therefore potential sources.

The three-tiered antidegradation policy in the Standards prohibits an increase in loading that would cause or contribute to degradation of an existing use. The Antidegradation Policy applies to both point and nonpoint source pollutant discharges. In general, antidegradation procedures establish a process for reviewing individual proposed actions to determine if the activity will degrade water quality. The TMDLs in this document will result in protection of existing beneficial uses, and conform to Texas's antidegradation policy. The classification of RHZs, PHZs, and conditionally approved areas are managed by the DSHS in a manner that protects oyster water uses and sufficiently separates waters designated with the oyster water use from the 1000-foot buffer zone designated as contact recreation.

Allowance for Future Growth

Compliance with these TMDLs is based on keeping the bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. Future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause bacteria to exceed the limits. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for increased loadings. The concentration limits and tables in this TMDL will guide determination of the assimilative capacity of the stream under changing conditions, including future growth.

Seasonal Variation

Seasonal variations involve changes in surface runoff, stream flow, and water quality because of hydrologic and climatologic patterns. Variations due to changes in the hydrologic cycle as well as temporal variability in fecal coliform sources, such as migrating duck and goose populations, and recreational boating are accounted for by the use of the long-term data record to estimate the current load.

An investigation of the historical data from each station revealed that there is a consistent winter peak in bacteria concentrations. Peaks occur most often during the first three months of the year and do not persist. These cyclical peaks may be related to the winter movements of migratory birds. The peaks occur during the driest season in terms of monthly precipitation, reducing the likelihood of runoff being responsible for the seasonal peaks.

It is commonly expected that the highest bacteria levels occur in the season with the most frequent rainfall, because runoff washes fecal matter built up on land into waterways, as well as contributing to sewer overflows and WWTF bypasses. However, in the summer when rainfall levels peak, surface waters tend to comply with bacteria criteria. Though problems such as runoff, leaking septic systems, and excessive inflow and infiltration from WWTFs are not necessarily the major contribution to the Upper Gulf Coast loads, problems associated with rainfall events still must be addressed because no discharge of untreated human waste is allowed by the TMDL.

Public Participation

The TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and

involved. The project team also recognized that communication and comments from the stakeholders in the watershed would strengthen the project and its implementation.
Notices of meetings were posted on the TMDL program's web calendar. Two weeks prior to scheduled meetings, media releases were distributed. To ensure that the public was informed of past meetings and pertinent material, a project web page was established to provide project updates, meeting times and locations, meeting summaries, and presentations, at <www.http://www.tceq.state.tx.us/implementation/water/tmdl/74-upper coast oyster.html>.

Public meetings were held on the following dates: February 27, 2008 in Hankamer, TX; February 28, 2008 in Clear Lake, TX; February 29, 2008 in Galveston, TX. Public meetings covered the TMDL process, historical tests results on bacteria levels found in the RHZs, evaluated the affected waters, discussions on strategies to restore water quality, and educated the public on water quality issues.

Implementation and Reasonable Assurances

The TMDL development process involves the preparation of two documents:

1) **a TMDL**, which determines the maximum amount of pollutant a water body can receive in a single day and still meet applicable water quality standards, and
2) **an implementation plan (I-Plan)**, which is a detailed description and schedule of the regulatory and voluntary management measures necessary to achieve the pollutant reductions identified in the TMDL.

During TMDL development, the TCEQ determines the acceptable pollutant load for impaired water bodies and apportions the load among broad categories of pollutant sources in the watershed. This information is summarized in a TMDL report such as this document.

During TMDL implementation, the TCEQ develops the management strategies needed to restore water quality to an impaired water body. This information is summarized in an implementation plan that references, but is separate from, the TMDL document. The I-Plan details load reduction and other mitigation measures planned to restore water quality in an impaired water body.

Implementation measures, which can include the use of better treatment technology, replacement, or elimination of faulty equipment, and the installation of best management practices (BMPs), are developed and installed in an adaptive process. Texas intends for the required reductions to be implemented in an adaptive process that first addresses those sources with the largest impact on water quality, with anthropogenic sources being the initial primary focus. No untreated human sources may be directly discharged into the bay waters. Human sources must be treated and disinfected prior to discharge.

Reducing human fecal loading from failing septic systems should be a primary implementation focus due to health implications and associated risk of illness. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems. Reducing the loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Reducing human fecal loading from recreational boaters and marinas is being addressed through an educational program. Efforts to identify when fecal discharges have been released from boats into the bay are an option for implementation.

Additionally, because storm water contributions are not completely known, storm water sampling results will be used to determine implementation strategies for storm water. Sampling efforts will be based on sampling requirements found in Phase I and Phase II MS4 permits in watersheds adjacent to the bays. Phase II MS4 permits are part of a newly implemented program outside of Phase I MS4 areas to control storm water pollution in less populated urban areas. Information collected as part of MS4 sampling efforts will provide insight into the potential requirements and BMPs applicable to reduce contributions of indicator bacteria.

In some waters for which TMDLs have been developed, water quality data indicates that even after removal of all of the sources of bacteria (other than wildlife), the segment will not attain standards during some seasons at some times. *However, neither TCEQ nor EPA is proposing the elimination of wildlife to allow for the attainment of water quality standards*. This is an impractical and undesirable action. The reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. The pollutant reductions for the interim goal are applied only to controllable, anthropogenic sources identified in the TMDL, setting aside any control strategies for wildlife.

Implementation planning and efforts for TMDL affected watersheds upstream of this TMDL project will contribute to on-going efforts to improving and restoring water quality in the bays. Approximately 80 percent of the upstream area of this TMDL is impaired. Potential contributions from these upstream watersheds are already being addressed as part of a regional TMDL implementation effort. Separating the implementation efforts based on TMDL projects will allow this TMDL I-plan to focus on problems in the immediate vicinity of the bays, while providing assurance that upstream contributions will be controlled through a separate I-plan.

Furthermore, a number of projects have been implemented to reduce bacteria sources since the initial 303(d) listing. Recently completed, on-going, and pending projects will provide additional assurance that watershed implementation efforts will be effective in reducing sources of indicator bacteria, include the following projects:

- **Bay Day** (Galveston Bay Foundation). An annual one-day celebration presented by Galveston Bay Foundation and other contributors. It is a signature education event providing information about Galveston Bay to many area residents. Programs and activities during this event provide an increased awareness of issues related to NPS pollution.
- **Galveston Bay Watershed Academic Partnership** (UH–Clear Lake). Creation of school campuses in the Lower Galveston Bay Watershed that are continual partners in the current and future advocacy of Galveston Bay. Includes NPS education and materials that are delivered to students and parents.

- ***Galveston Bay: Discover a Treasure in Your Own Backyard*** (GBEP). This newspaper insert provided an easy to read overview of the Galveston Bay, including NPS, seafood safety, and public health information. Distributed to approximately 680,000 subscribers of four different newspapers in the Houston–Galveston area.
- **Boater Waste Campaign** (Galveston Bay Foundation). The purpose of the campaign is to decrease the incidence of illegal discharge of boater sewage waste to the Galveston Bay Estuary, particularly Clear Lake through targeted outreach and education to boaters.
- **Envirocast®** (Houston–Galveston Area Council). A broad based communication and public outreach for environmental quality, Envirocast utilizes a network of local content providers and works with KHOU - TV Channel 11 to develop short environmental news stories. The stories will be broadcast either immediately before or after weathercasts and include information pertaining to NPS pollution.
- **Environmental Kiosks for the City of Pearland** (City of Pearland). The Centennial Greenbelt will connect to an environmental education building and ten interpretative kiosks. Each kiosk will serve as a community outreach vehicle containing environmental, historical, and educational information about the habitat, wildlife, and natural resources of the Texas Gulf Coast.
- **Charting the Course to 2015 Galveston Bay and A Day on Galveston Bay** (UT-Austin). Seven open houses for the general public were held where stakeholders could interact with experts. One-page summaries on various issues including NPS, public health, and seafood safety were available at the open houses. “A Day on Galveston Bay” is a 15-minute video about Galveston Bay.

The TCEQ is committed to developing I-Plans for all TMDLs adopted by the commission and to ensuring the plans are implemented. I-Plans are critical to ensure water quality standards are restored and maintained. They are not subject to EPA approval. With successful completion of implementation plans, Texas will be well on the way to restoring impaired waters and enhancing the value of this important resource for both oyster harvest and other uses. However, restoration of water quality standards does not ensure that DSHS will lift the RHZ status. DSHS will continue to enforce boundaries as it sees fit in order to protect human health, independent of the TMDL and I-Plan. The DSHS classification program is in accordance with national seafood safety regulations. The classification program is extremely stringent in order to protect against the potential human health risk that is necessary when consuming raw shellfish.

The TCEQ works with stakeholders to develop the strategies summarized in the I-Plan. I-Plans may use an adaptive management approach that achieves initial loading allocations from a subset of the source categories. Adaptive management allows for development or refinement of methods to achieve the environmental goal of the plan. Periodic and repeated evaluations of the effectiveness of implementation methods assure that progress is occurring, and may show that the original distribution of loading among sources should be modified to increase efficiency. This adaptive approach provides reasonable assurance that the necessary regulatory and voluntary activities to achieve the pollutant reductions will be implemented.

A TMDL I-Plan specifically identifies required or voluntary implementation actions that will be taken to achieve the pollutant loading goals of the TMDL. Regulatory actions identified in the I-Plan could include:

- adjustment of an effluent limitation in a wastewater permit.
- a schedule for the elimination of a certain pollutant source.
- identification of any nonpoint source discharge that would be regulated as a point source.
- a limitation or prohibition for authorizing a point source under a general permit.
- a required modification to an SWMP and PPP.

Strategies to optimize compliance and oversight are identified in an I-Plan when necessary. Such strategies may include additional monitoring and reporting of effluent discharge quality to evaluate and verify loading trends, adjustment of an inspection frequency or a response protocol to public complaints, and escalation of an enforcement remedy to require corrective action of a regulated entity contributing to an impairment.

The TMDL document and its underlying assumptions, model scenarios, and assessment results are not and should not be interpreted as required effluent limitations, pollutant load reductions that will be applied to specific permits, or any other regulatory action necessary to achieve attainment of the water quality standard. The I-Plan developed by stakeholders, and approved by the state, will direct implementation efforts to certain sources contributing to the impaired water.

In determining which sources need to accomplish what reductions, the I-Plan may consider factors such as:

- cost and/or feasibility
- current availability or likelihood of funding
- existing or planned pollutant reduction initiatives such as watershed-based protection plans
- whether a source is subject to an existing regulation
- the willingness and commitment of a regulated or unregulated source
- a host of additional factors

Ultimately, the I-Plan will identify the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the Implementation Plan that is adopted may not approximate the predicted loadings identified category by category in the TMDL and its underlying assessment, but with certain exceptions, the Implementation Plan must nonetheless meet the overall loading goal established by the commission-adopted and EPA-approved TMDL.

An exception would include an I-Plan that identifies a phased implementation that takes advantage of an adaptive management approach. It is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction was required by the TMDL, high uncertainty with the TMDL analysis exists, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

Instead, activities contained in the first phase of implementation may be the full scope of the initial I-Plan and include strategies to make substantial progress towards source reduction and elimination, refine the TMDL analysis, conduct site-specific analyses of the appropriateness of an existing use, and monitor in stream water quality to gauge the results of the first phase. Ultimately, the accomplishments of the first phase would lead to development of a phase two or final Implementation Plan or revision of TMDL. This adaptive management approach is consistent with established guidance from EPA (see memorandum from EPA relating to clarifications on TMDL revisions, August 2, 2006).

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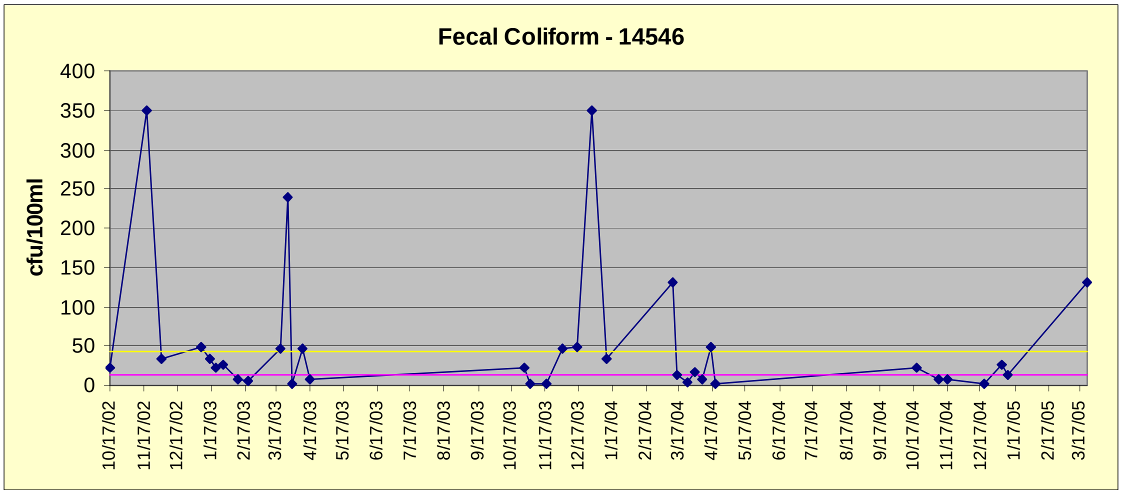
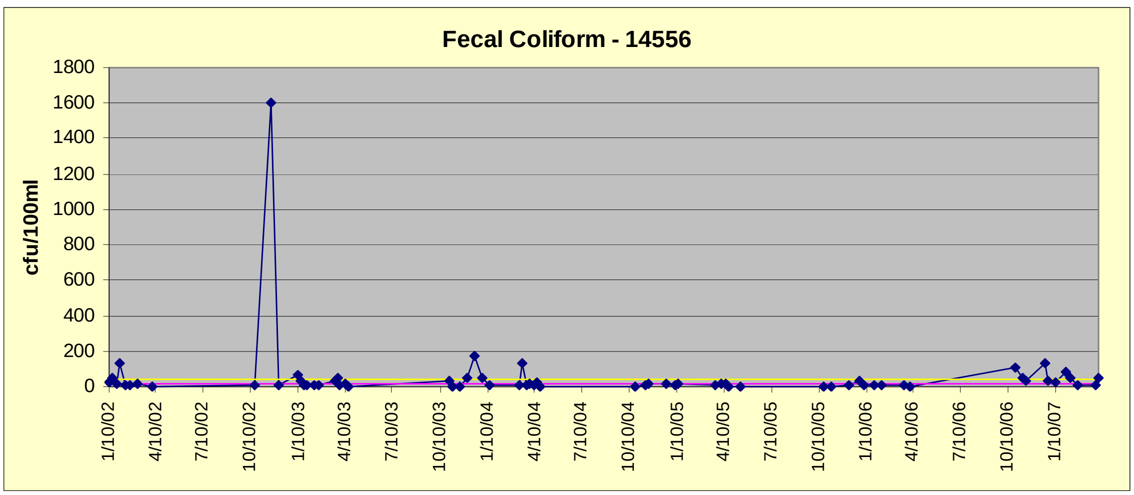
Appendix A.
Daily Loads for WWTFs based on Concentration Allocations

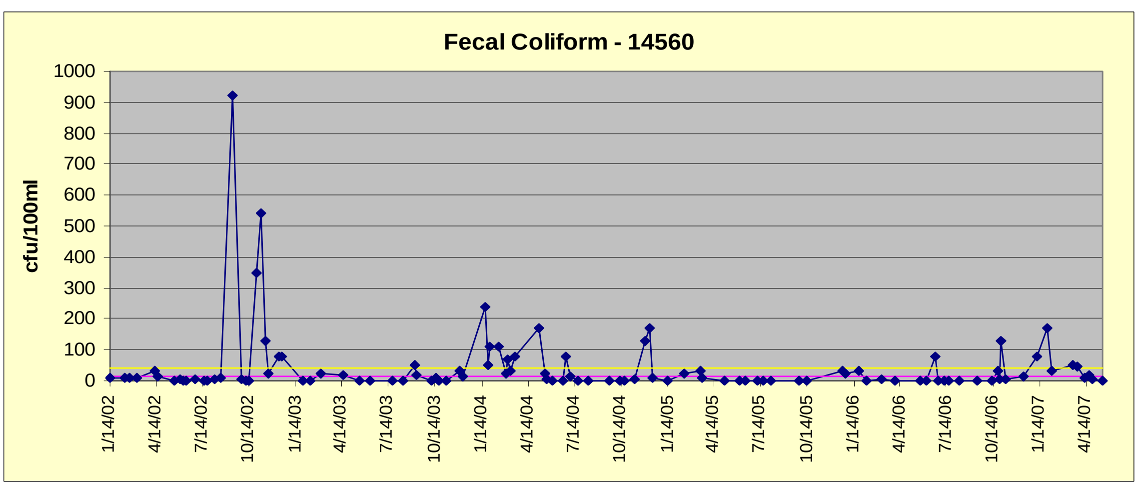
Segment	Permittee	NPDES Permit	TCEQ Permit	Daily Load - Fecal Coliform Organisms	Daily Load - *E. coli* Organisms	Daily Load - Enterococcus Organisms
2421	CITY OF LA PORTE	22799	10206-001	57,235,426,114	36,058,318,452	10,016,199,570
2421	BACLIFF MUD	21369	10627-001	9,387,821,214	5,914,327,365	1,642,868,713
2421	CITY OF SEABROOK	22250	10671-001	18,927,058,900	11,924,047,107	3,312,235,308
2421	BAYVIEW MUD	21822	10770-001	2,271,247,068	143,0885,653	397,468,237
2421	SAN LEON MUD	71978	11546-001	7,192,282,382	4,531,137,901	1,258,649,417
2421	GALVESTON COUNTY WCID 12	78441	12039-001	5,678,117,670	3,577,214,132	993,670,592
2422	CITY OF ANAHUAC & TRINITY BAY CONSERV DIST	33944	10396-001	4,542,494,136	2,861,771,306	794,936,474
2422	TRINITY BAY CONSERVATION DISTRICT	54917	11537-001	757,082,356	476,961,884	132,489,412
2422	GULF UTILITY SERVICE INC	42081	13643-001	757,082,356	476,961,884	132,489,412
2424	GALVESTON COUNTY MUD 12	20311	10435-002	3,028,329,424	1,907,847,537	529,957,649
2424	CITY OF GALVESTON	47309	10688-002	28,390,588,350	1,788,607,0661	4,968,352,961
2424	CITY OF GALVESTON	66125	10688-005	3,785,411,780	2,384,809,421	662,447,062
2424	GALVESTON COUNTY FWSD 6	20079	10879-001	2,422,663,539	1,526,278,030	423,966,119
2424	CITY OF JAMAICA BEACH	20061	11033-001	2,725,496,482	1,717,062,783	476,961,884
2424	GALVESTON COUNTY MUD 1	126977	11477-001	4,724,193,901	2,976,242,158	826,733,933
2439	CITY OF GALVESTON	47309	10688-001	75,708,235,600	47,696,188,428	13,248,941,230
2439	CITY OF GALVESTON	63665	10688-004	3,785,411,780	2,384,809,421	662,447,062
2439	MARTIN OPERATING PARTNERSHIP LP	57258	10931-001	64,352,000	40,541,760	11,261,600
2439	TEXAS A&M UNIVERSITY AT GALVESTON	63231	11085-001	2,271,247,068	1,430,885,653	397,468,237
2439	TEXAS DEPT OF TRANSPORTATION	63207	11672-001	45,424,941	28,617,713	7,949,365
2439	AMBAR DRILLING FLUIDS LP LLLP	104353	11679-001	11,356,235	7,154,428	1,987,341
2439	HALLIBURTON ENERGY SERVICES INC	119482	14113-001	26,497,882	16,693,666	4,637,129

Appendix B.
Temporal Trends in Bacteria Samples

Upper Galveston Stations



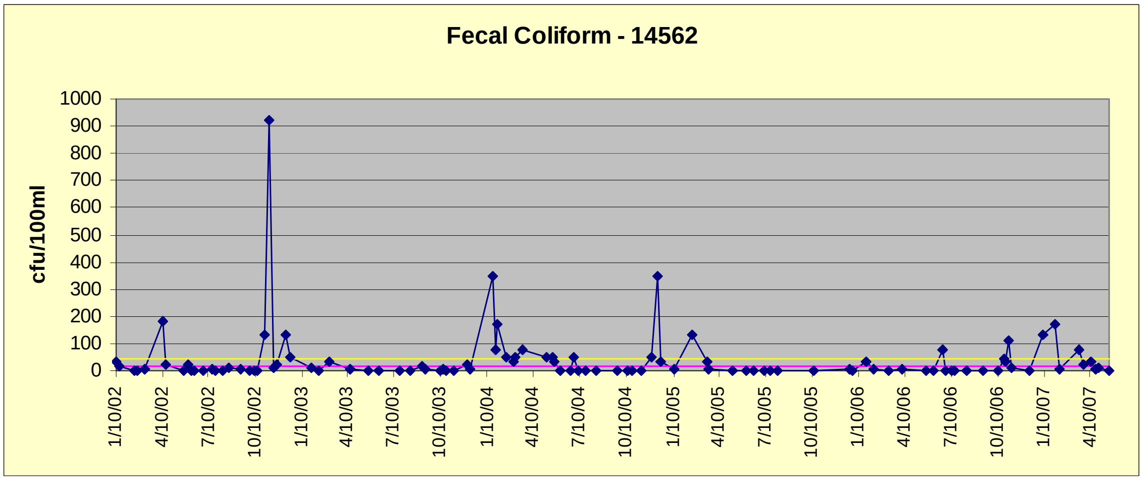


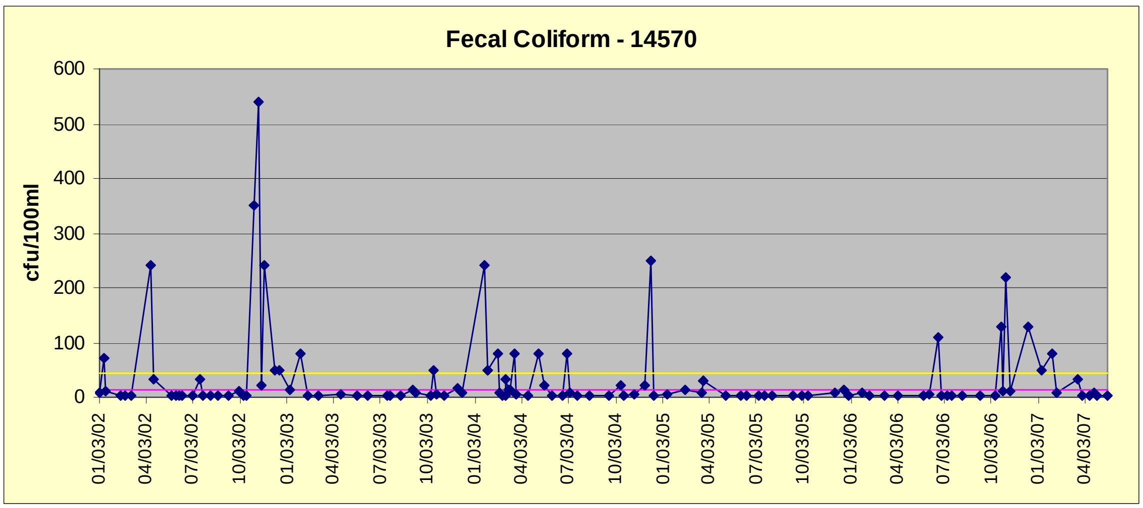


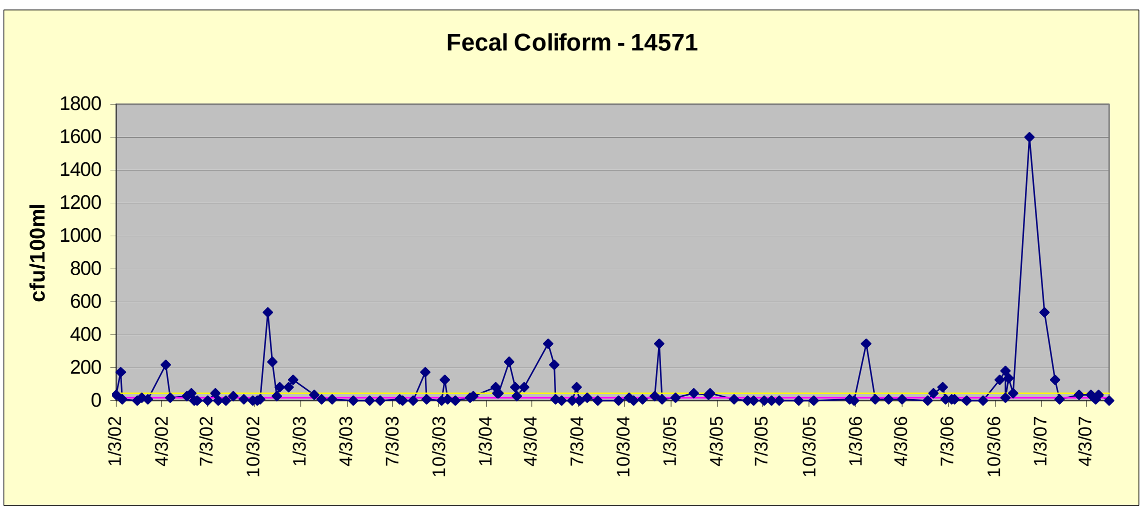
Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.



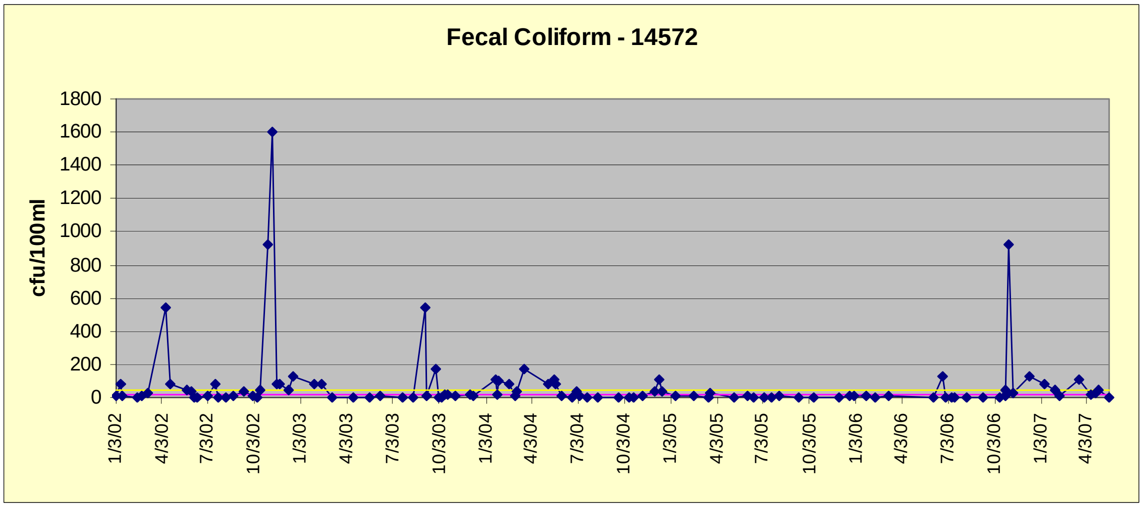


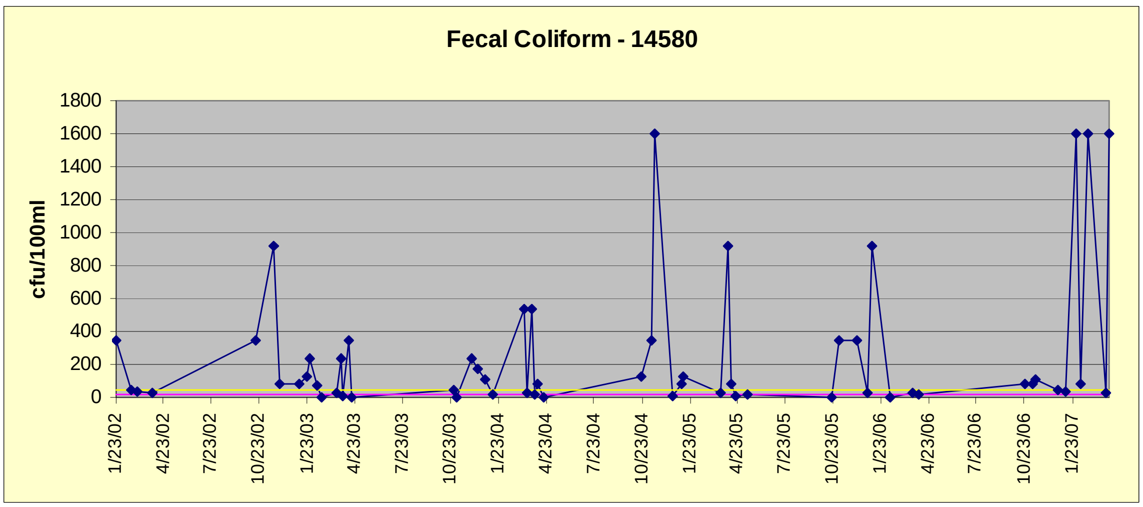


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

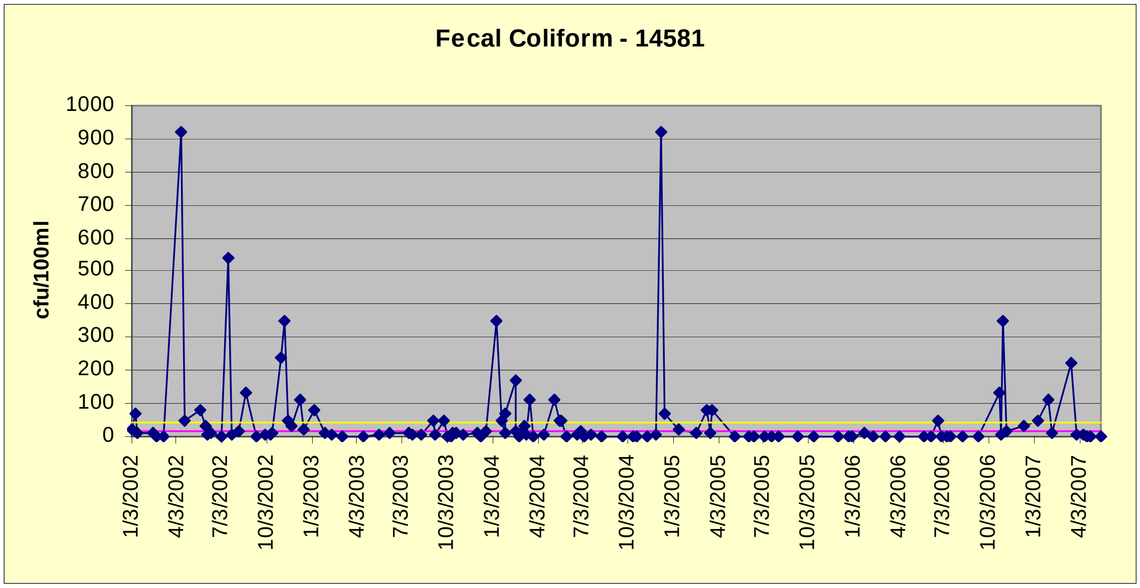


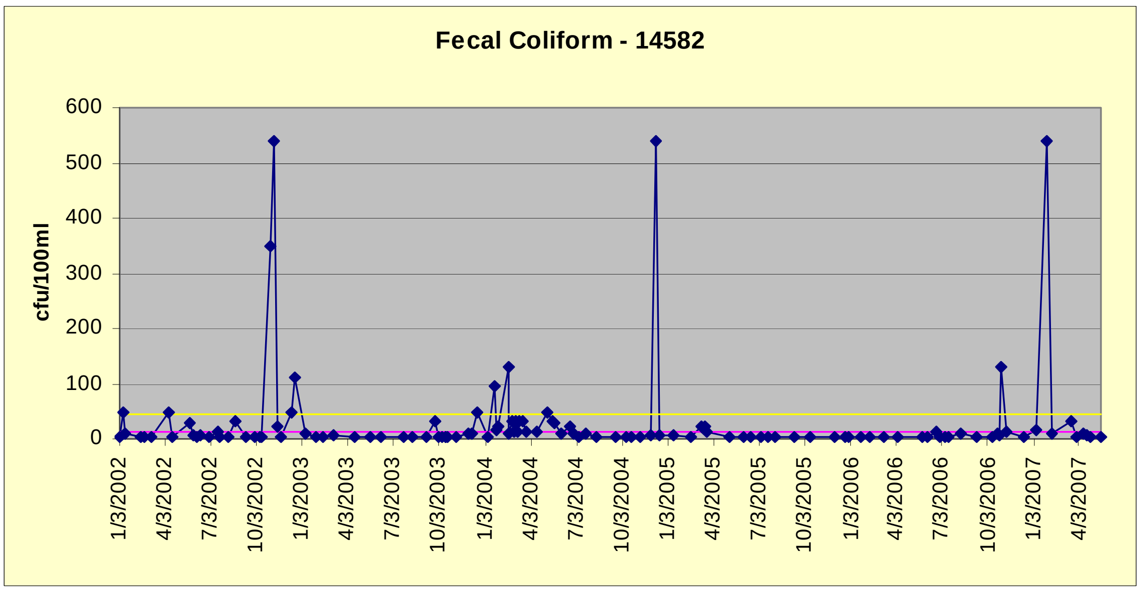


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.



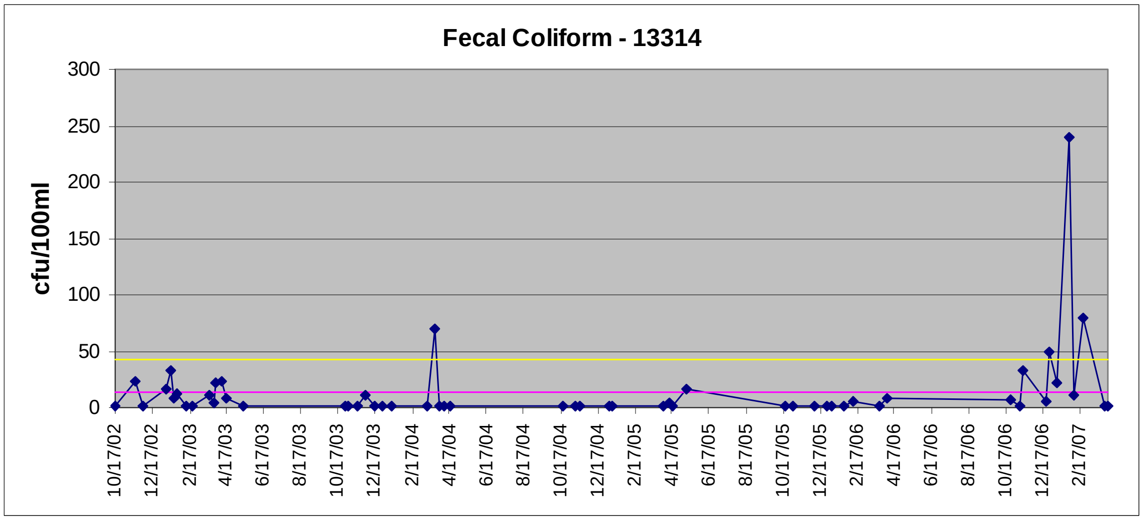


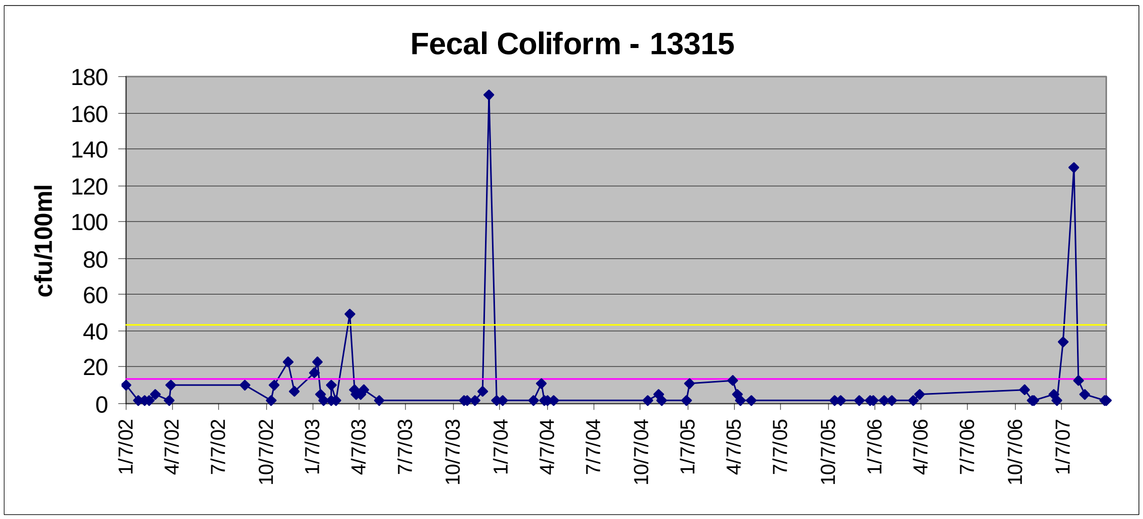
Yellow Line = 90th percentile criterion (43 cfu/100mL)

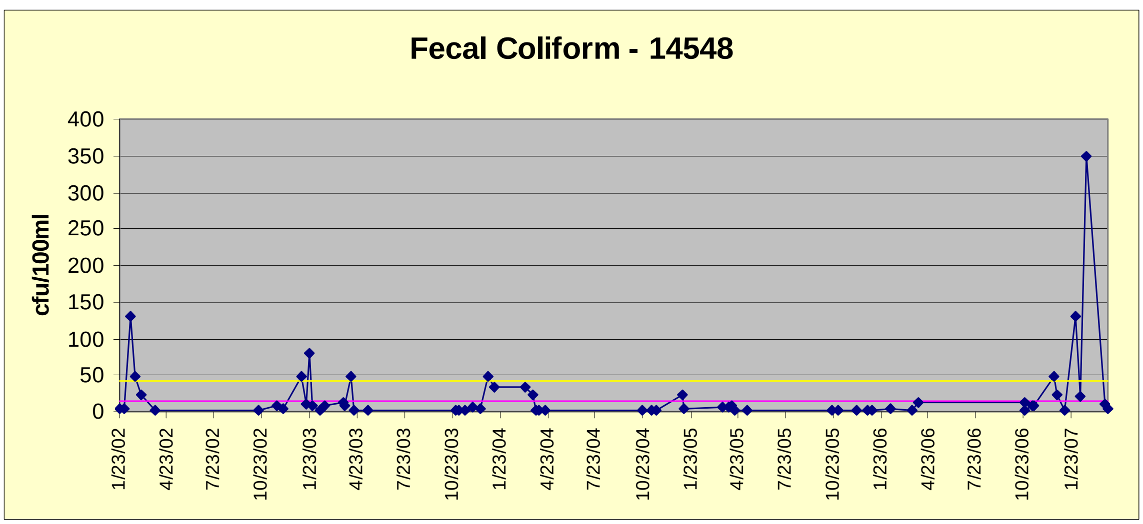
Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

Trinity Bay Stations



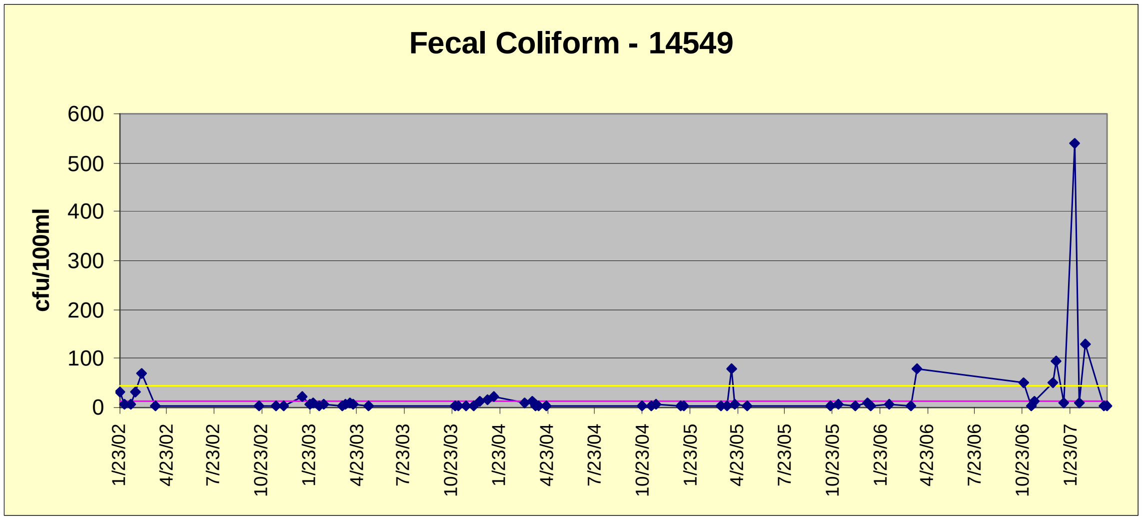


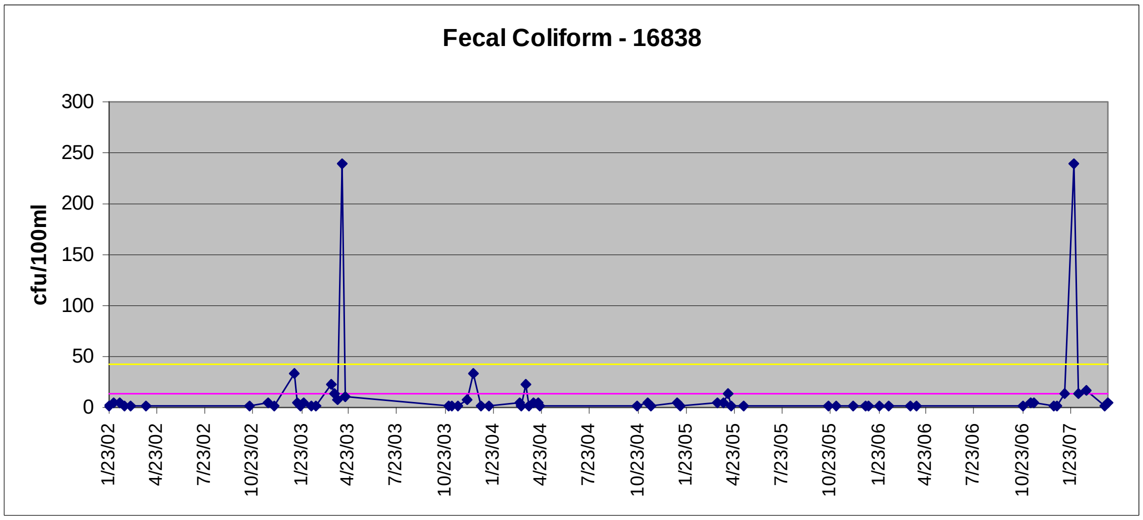


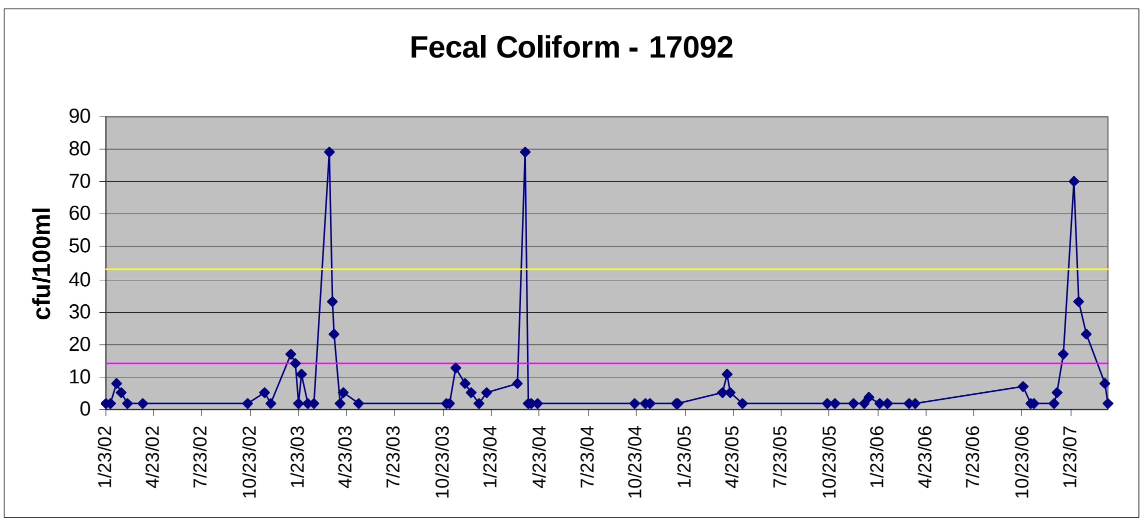
Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.





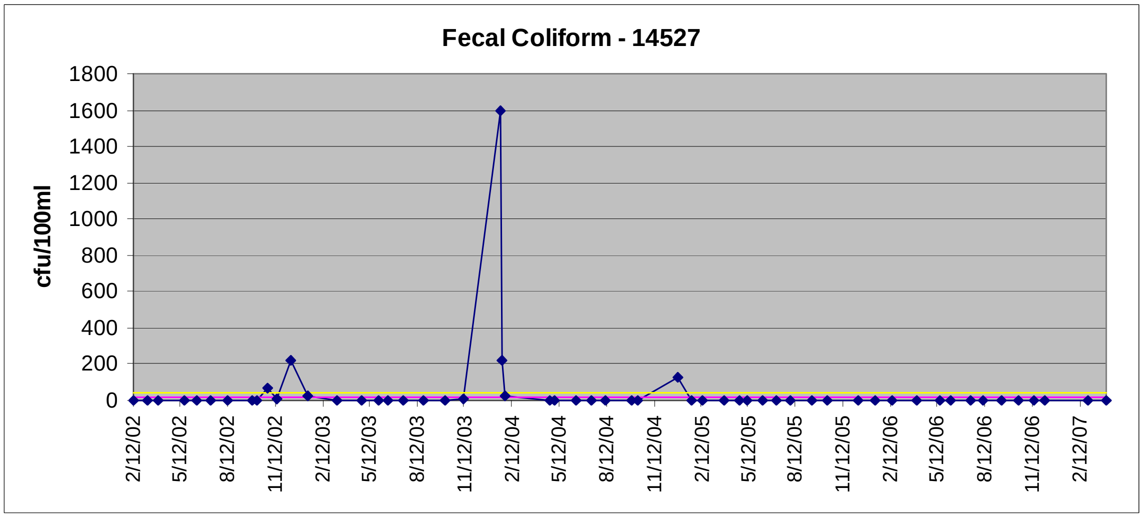


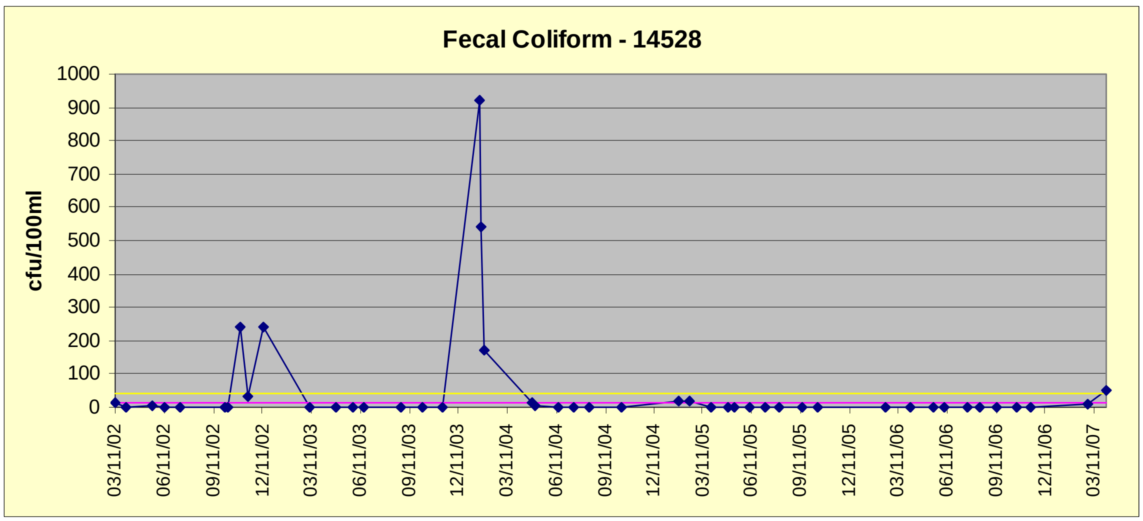
Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

East Bay Stations

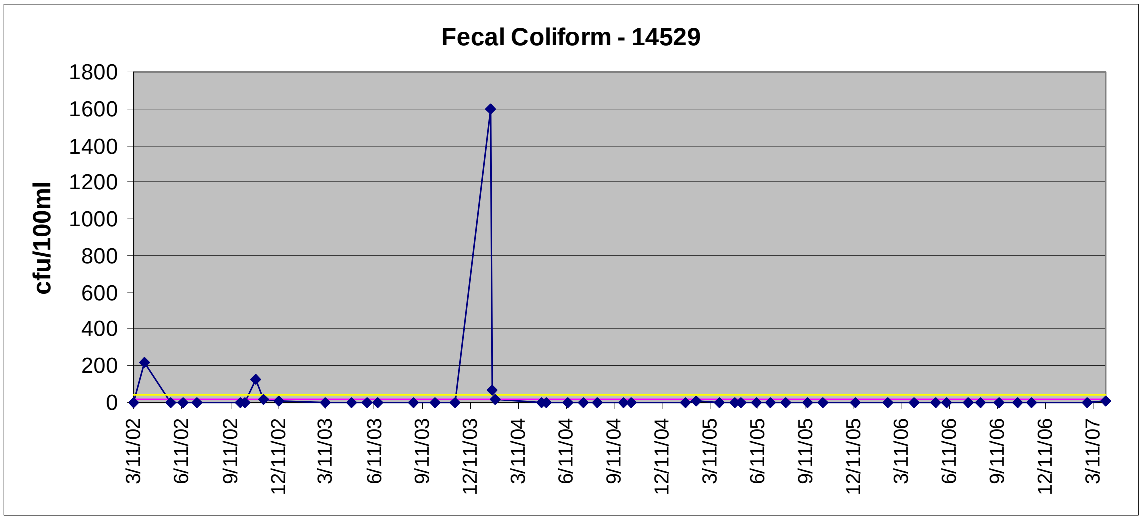


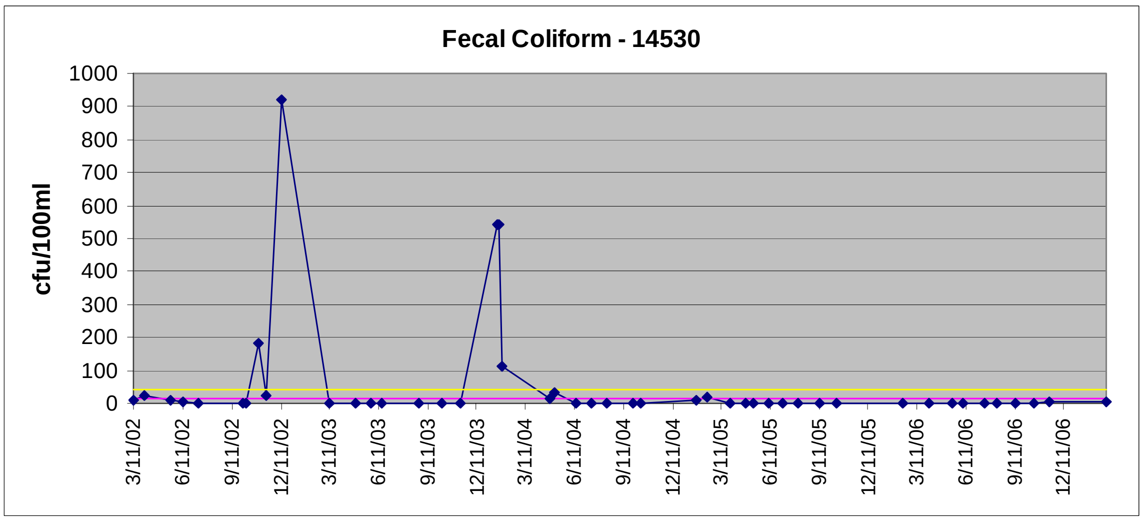


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.



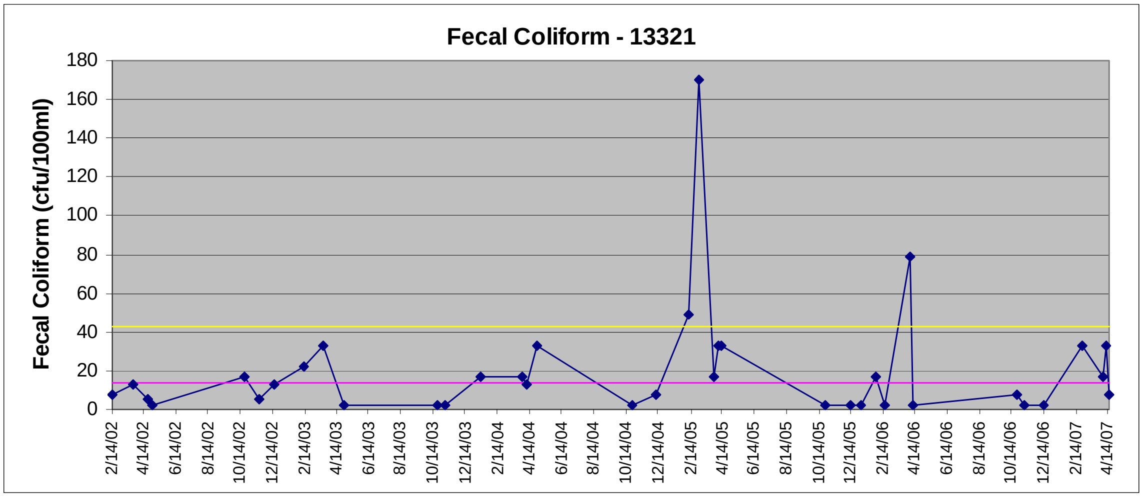


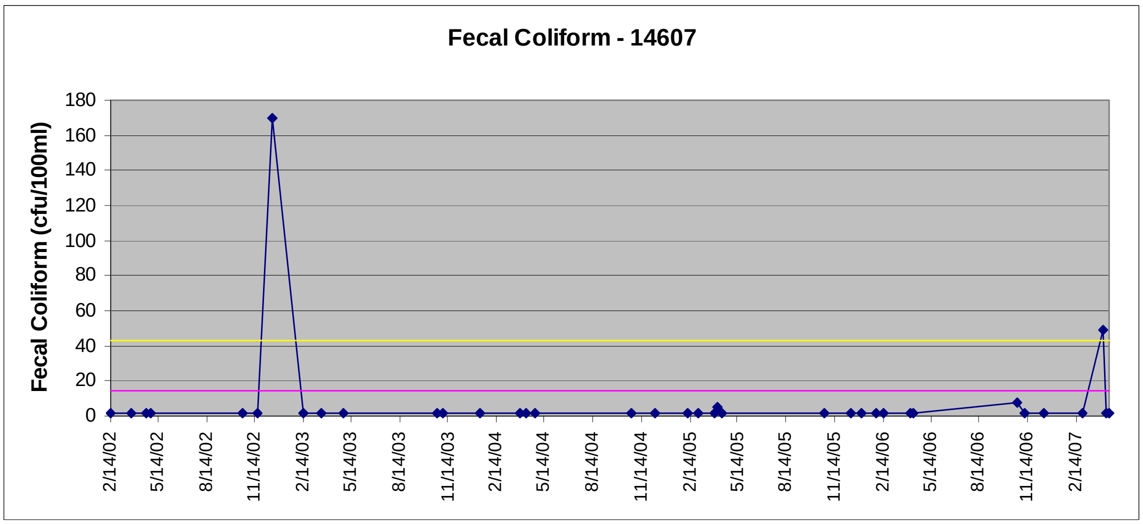
Yellow Line = 90th percentile criterion (43 cfu/100mL)

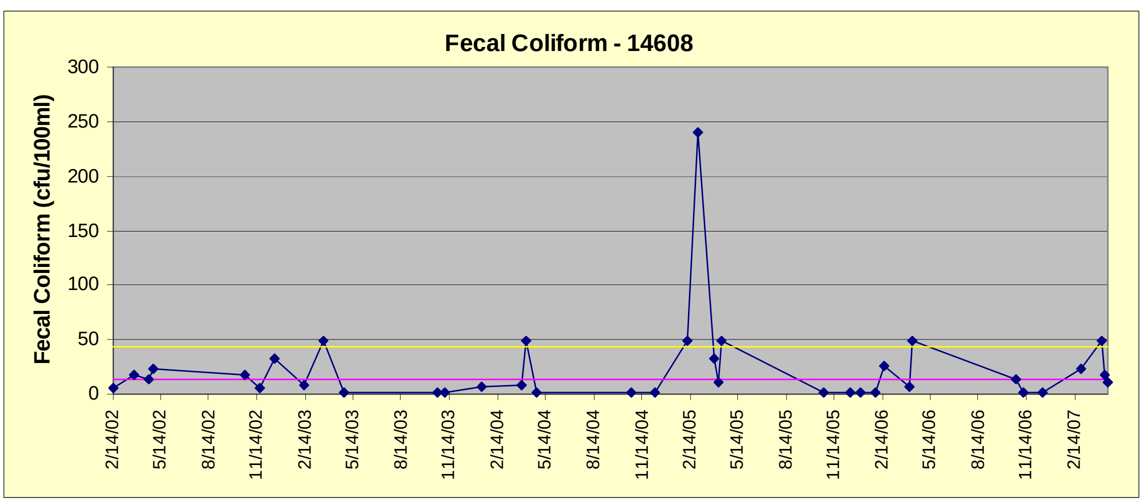
Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

West Bay Stations



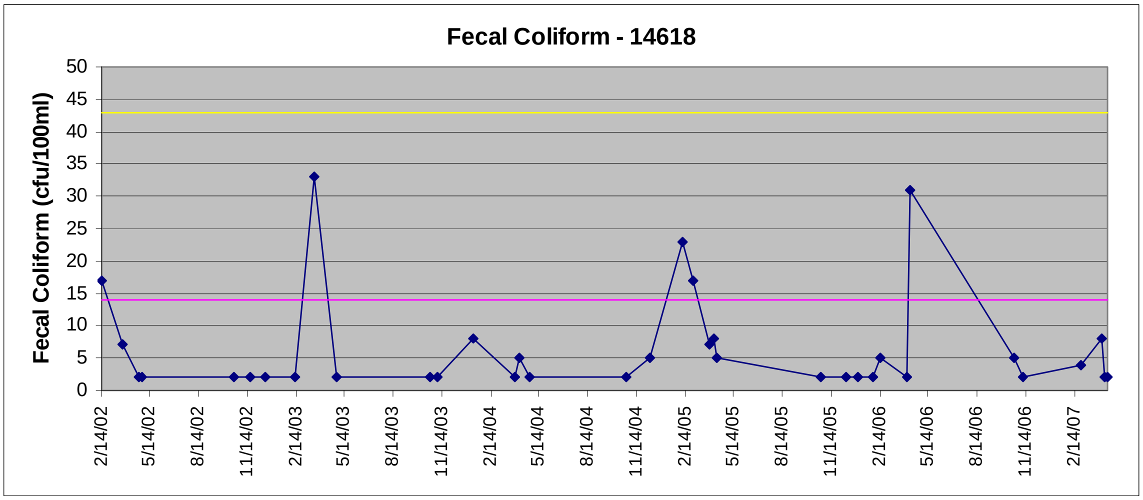


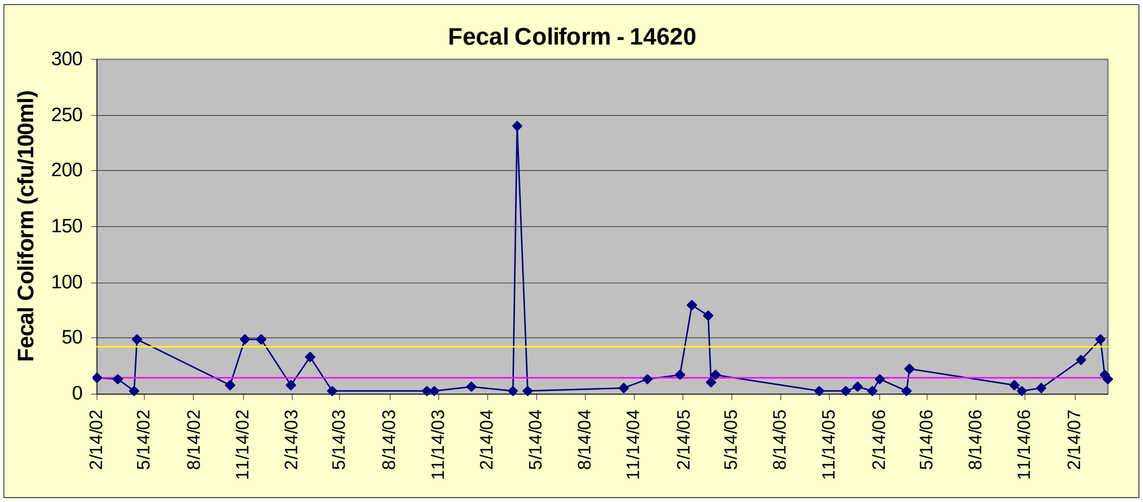


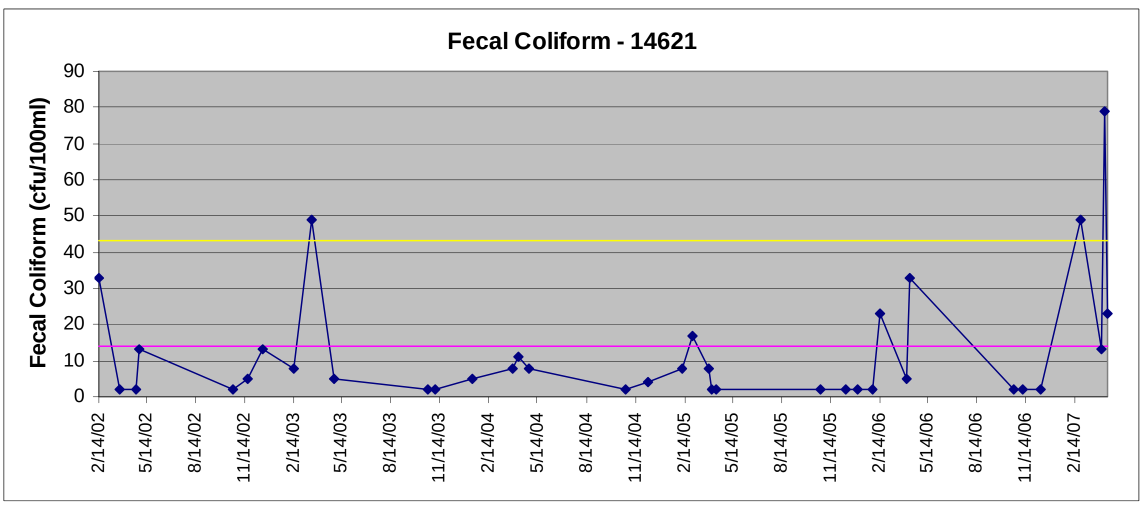
Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.



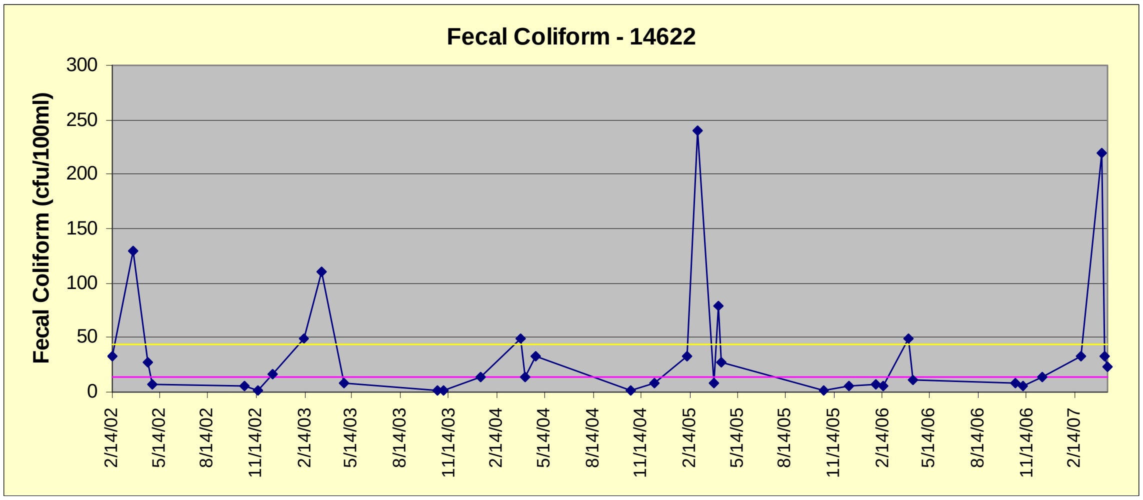


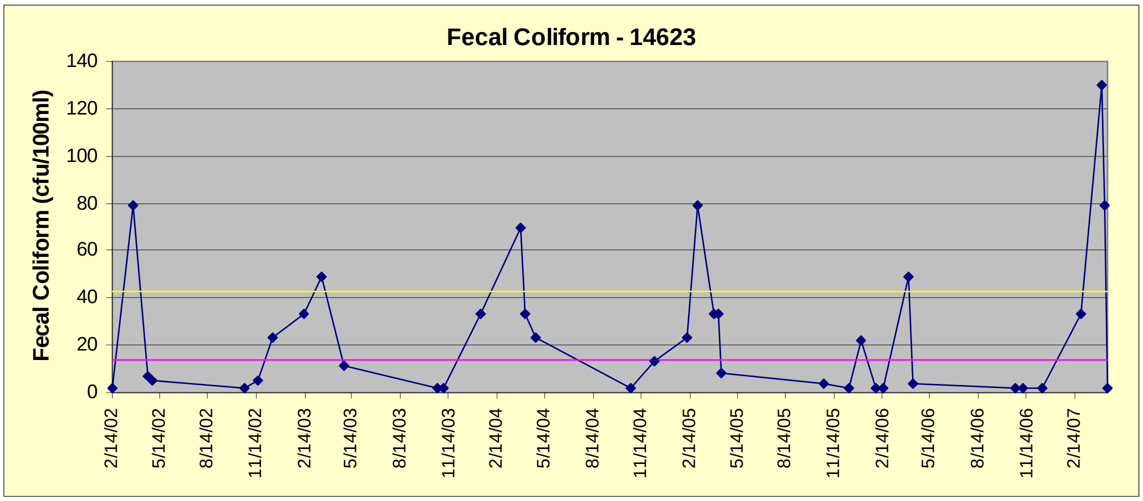


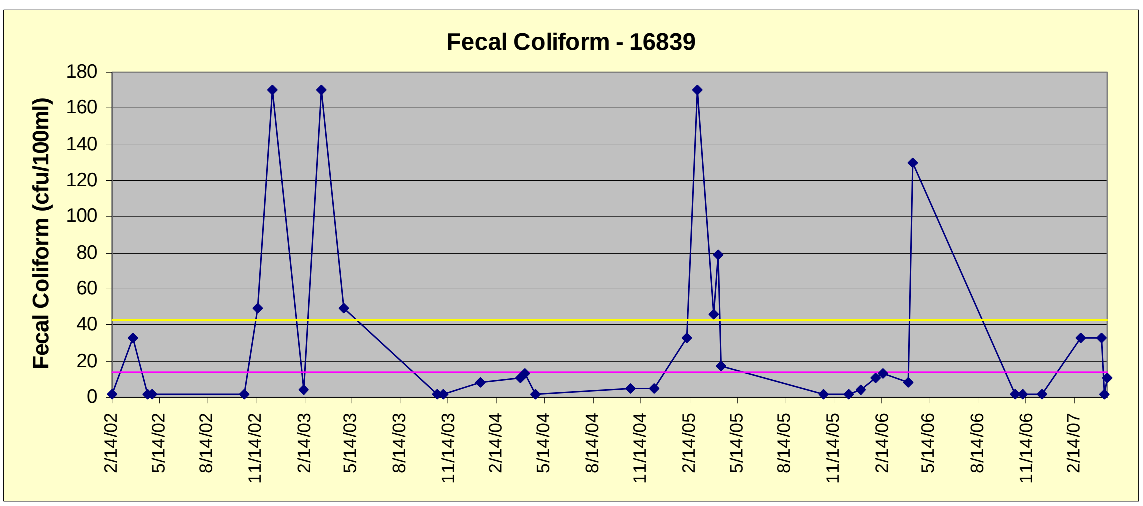
Yellow Line = 90^{th} percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90^{th} percentile criterion.



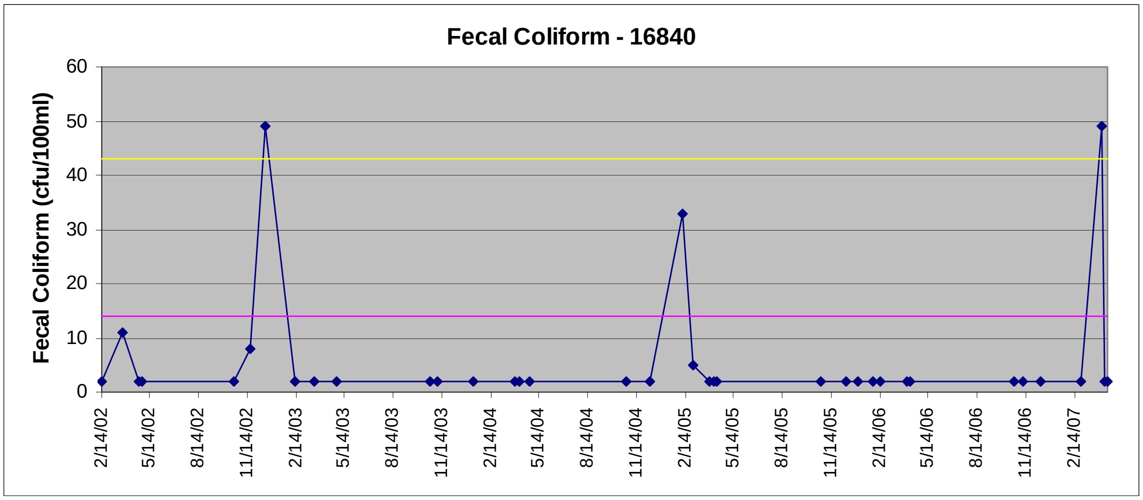


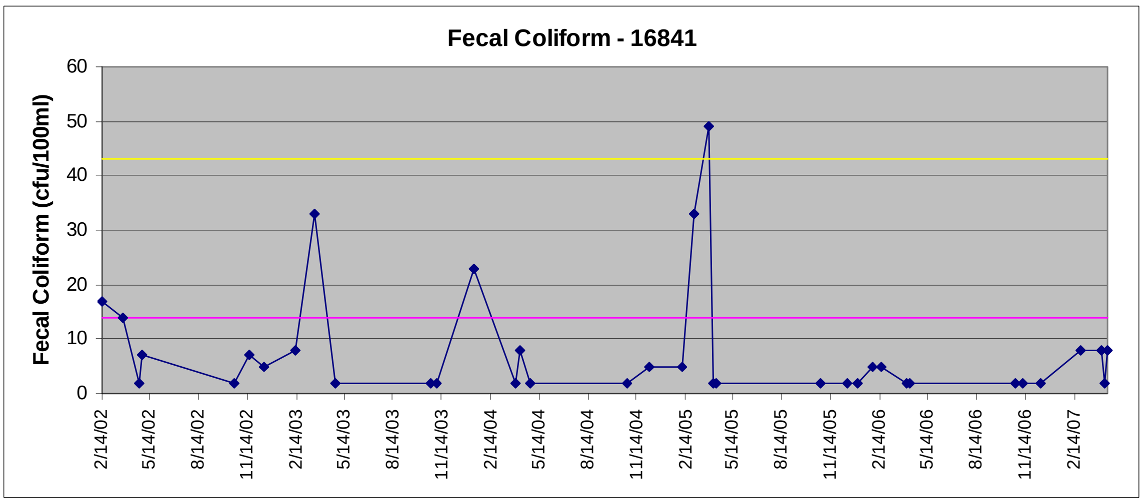


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

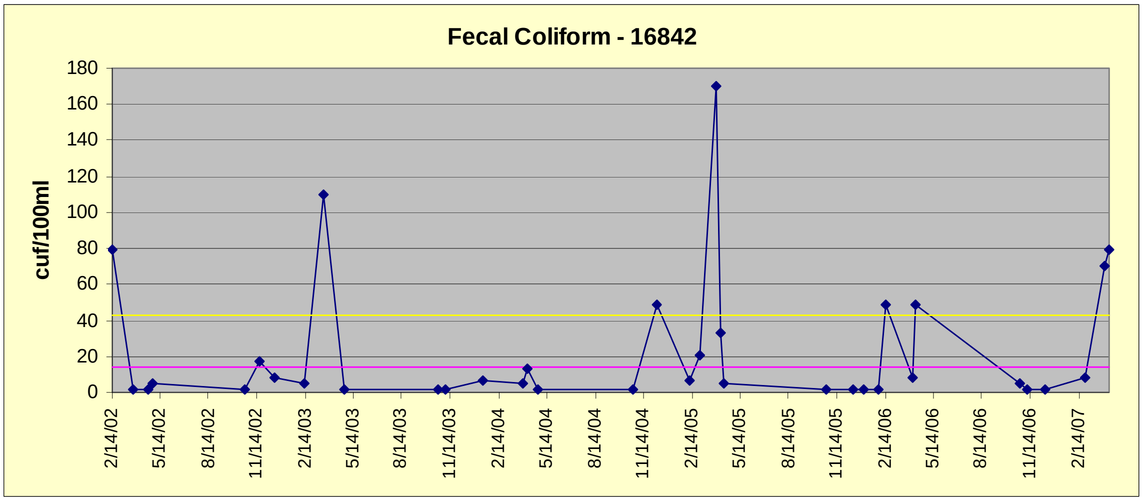


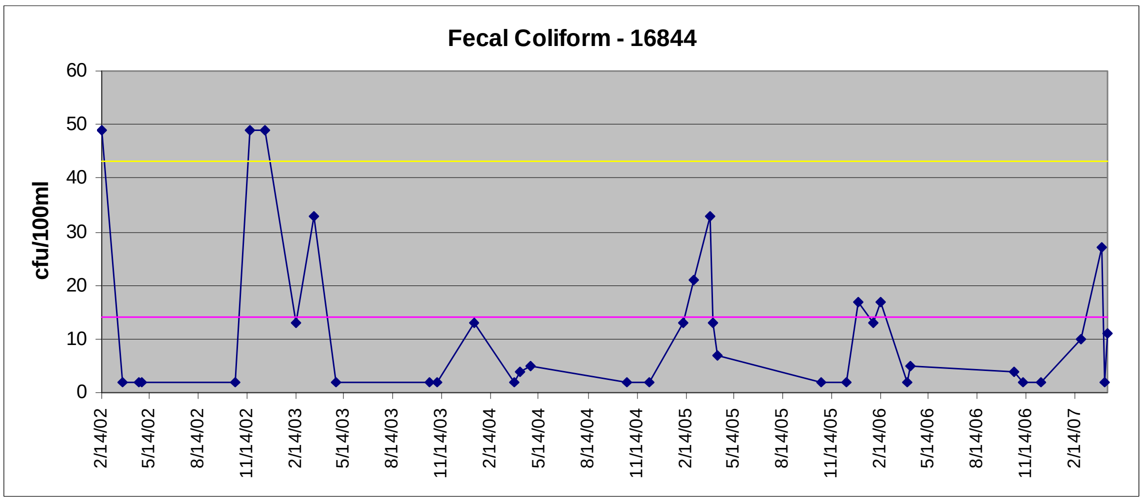


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.



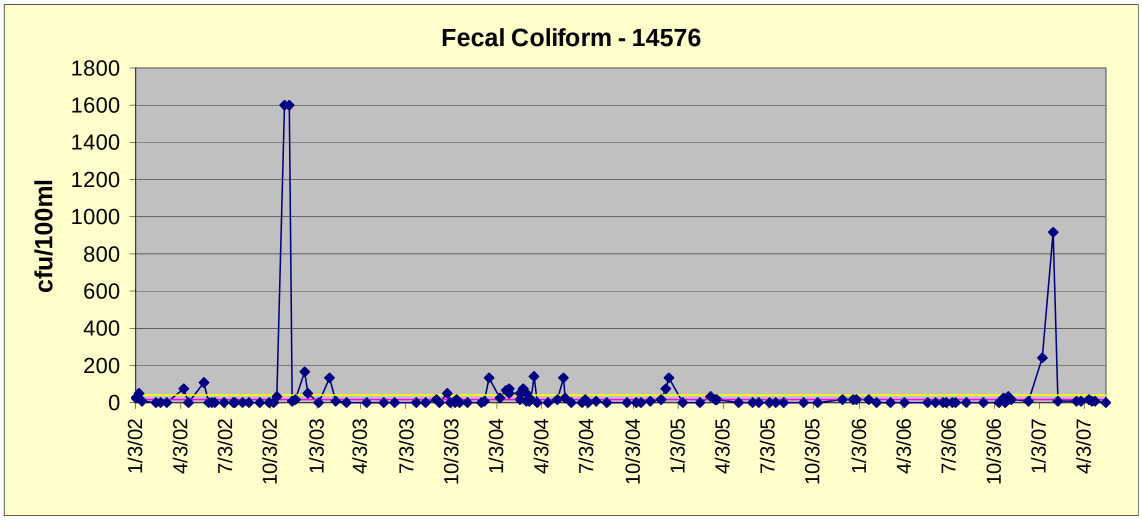


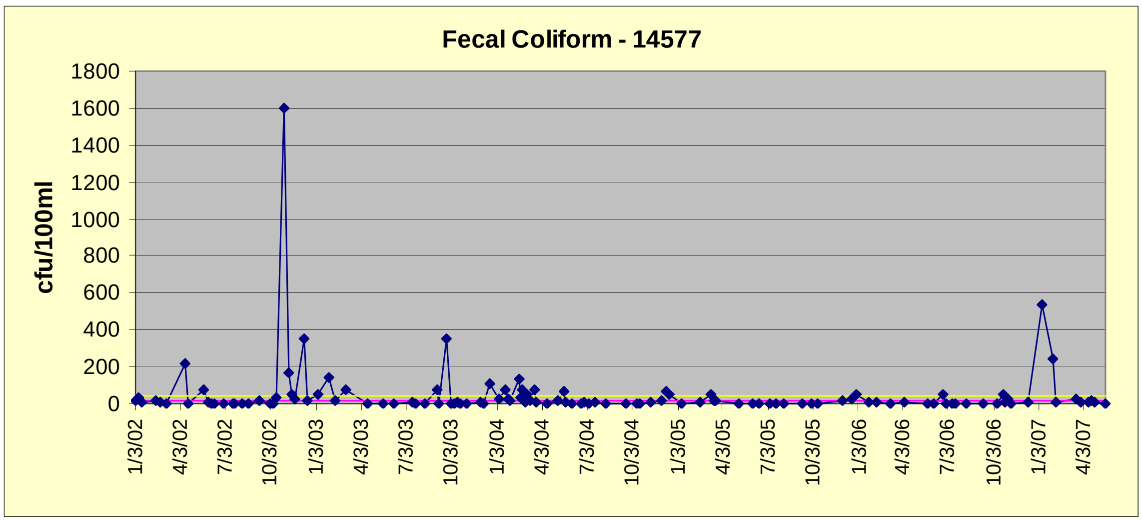
Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

Lower Galveston Bay

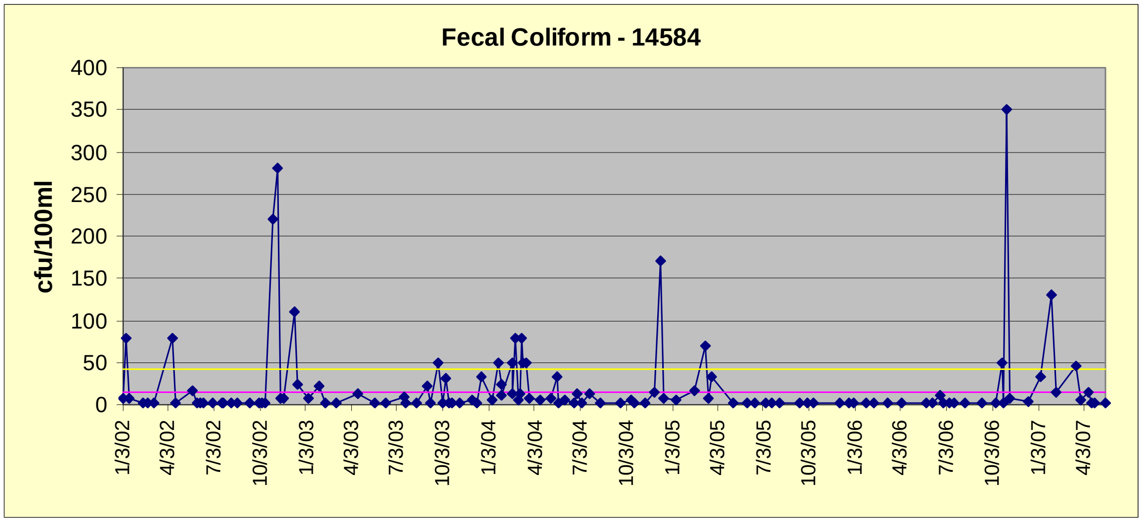


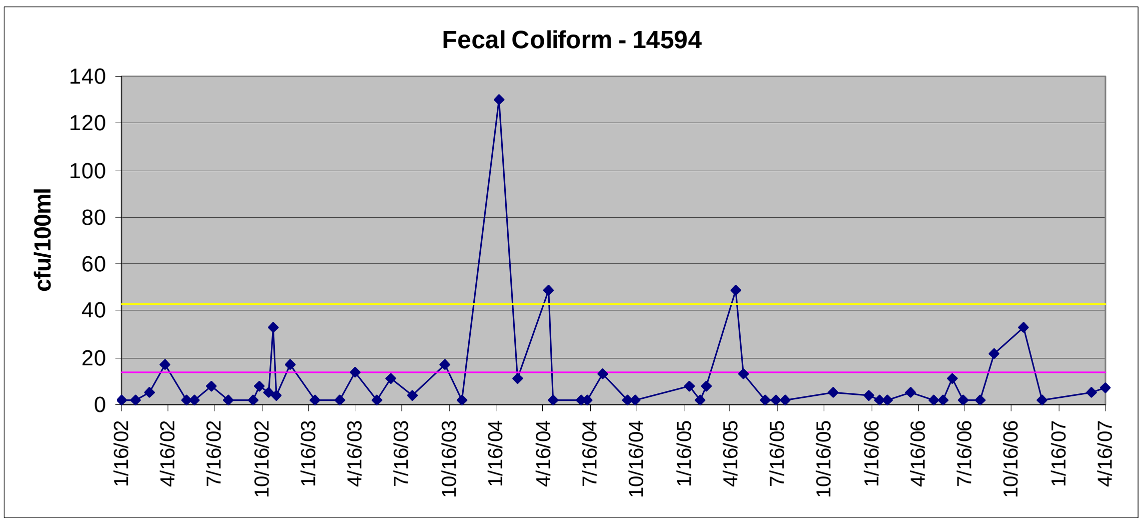


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

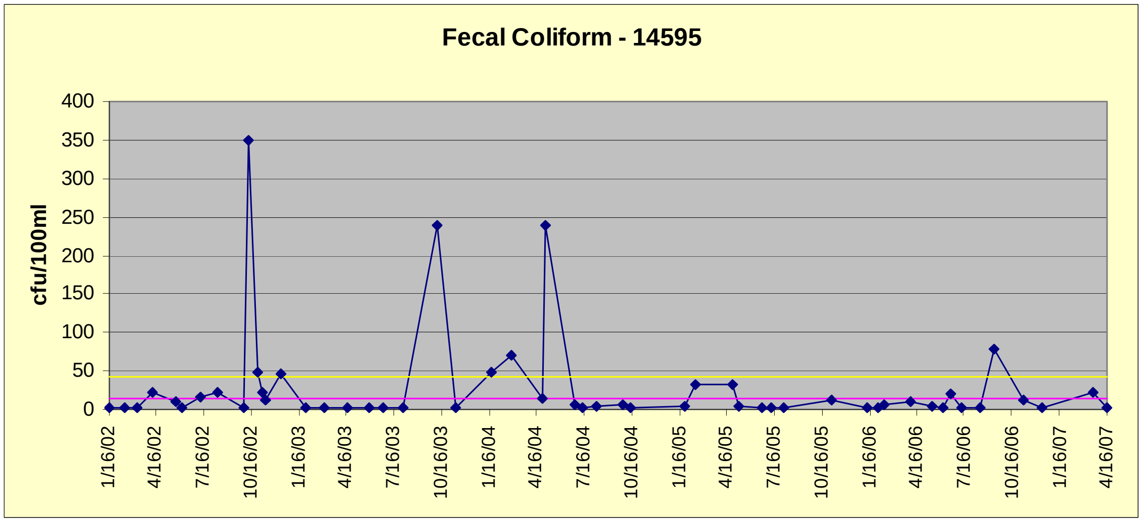


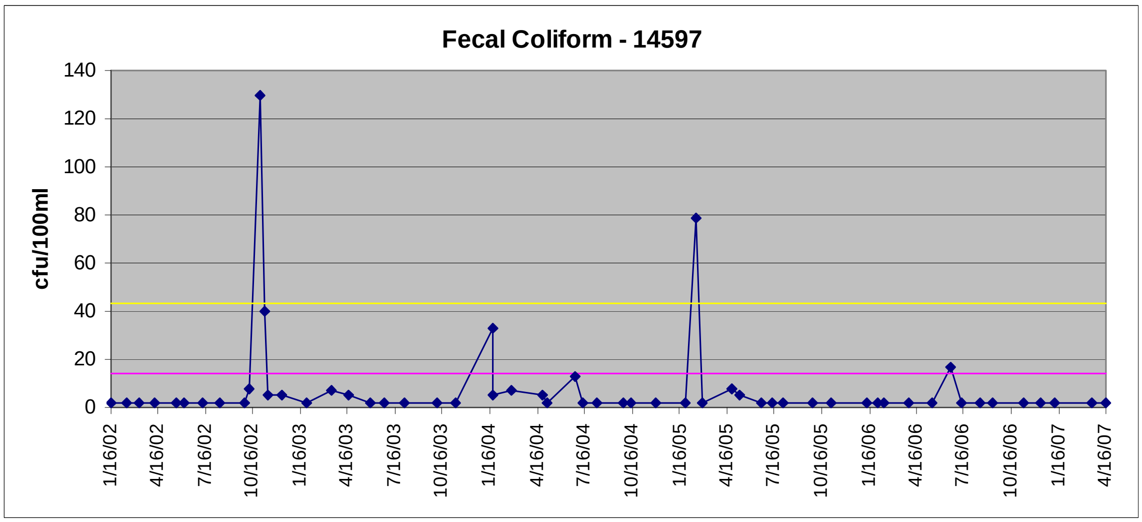


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.



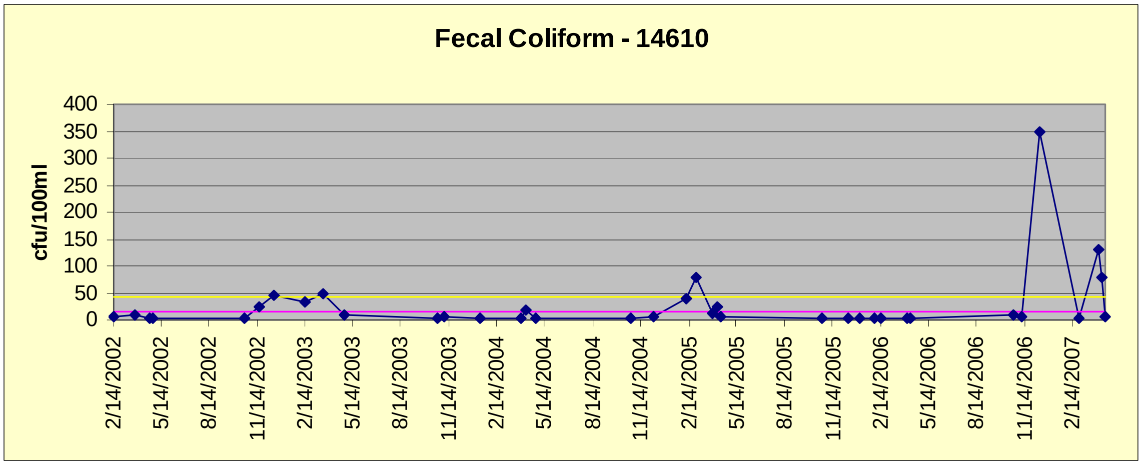


Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

Chocolate Bay Stations



Yellow Line = 90th percentile criterion (43 cfu/100mL)

Red Line = median criterion (14 cfu/100mL)

Yellow shaded border = concentrations at station exceeded 90th percentile criterion.

Amendment
Median Fecal Coliform Capacity of Restricted Harvest Zone Assessment Units

Based on the Oyster Waters criterion of 14 CFU/100mL, the median concentration, the capacity of the restricted oyster water assessment units are listed below.

	RHZ Assessment Unit	Area (Sq.Mi.)	Average Depth (Ft.)	Volume (CU. Ft)	Median RHZ Capacity colony forming units
Upper Galveston Bay	2421_01	16.8	9.5	4,449,392,640	1.76E+13
Upper Galveston Bay	2421_02	48.2	9.5	12,765,519,360	5.06E+13
Trinity Bay	2422_01	64.4	7.5	13,465,267,200	5.34E+13
East bay	2423_01	52.1	3.5	5,083,626,240	2.02E+13
Chocolate Bay	2432_01	7.6	3.5	741,565,440	2.94E+12
West Bay	2424_02	17.1	5	2,383,603,200	9.45E+12
Lower Galveston Bay	2439_01	38.4	3.5	3,746,856,960	1.49E+13