Support for Total Maximum Daily Loads (TMDL) for Indicator Bacteria in Oso Bay
Monitoring Report
Fiscal Year 2013 (Year-one) and Fiscal Year 2014 (Year-two)

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1.0 INTRODUCTION

1.1 Background

Disease causing microorganisms, or pathogens, can adversely affect estuarine systems and densities considered unsafe often result in adverse effects on human health through the transmittal of microbial pathogens during recreational use or the ingestion of edible tissue (Nicolau and Nuñez 2004). Once an organism absorbs a contaminant, the concentration in animal tissue can increase significantly through subsequent contamination (i.e. bioaccumulation). This same bioaccumulation pattern also happens when humans eat contaminated tissue, especially oysters and other shellfish since they are often consumed raw, thereby effecting human health.

Typically, high pathogen concentrations in the water column may result from such possible sources as polluted stormwater runoff, wastewater overflows, boating wastes, and malfunctioning septic systems that carry microorganisms from fecal material into the environment. Besides humans, it may also indicate contamination by fecal matter originating from other warm-blooded animals.

The state of Texas requires that bay and gulf waters have suitable conditions for recreational use and for the production and harvesting of edible species of clams, oysters, or mussels. The Department of State Health Services (DSHS) has authority to administer the National Shellfish Sanitation Program for Texas. This authority allows DSHS to designate, monitor, and classify shellfish harvesting areas along the Texas coast according to the potential risk to consumers of eating oysters harvested in a particular area; and develop listings based on data collected. The basis for restrictions is determined on the estimated risk of bacterial contamination rather than on actual measurements of bacteria in oysters or oyster waters. The utilization of Texas coastal waters for harvesting shellfish, or the oyster waters use, is the most commonly impaired use among Texas coastal waters.

Oso Bay (Segment 2485OW_01) has been identified by DSHS as an oyster harvesting area and is classified as restricted. Although oyster beds do not exist in Oso Bay, the bay flows into Corpus Christi Bay, and is considered a part of the Corpus Christi Bay harvesting area. Based on data collected, in 2006 the oyster waters in Oso Bay were listed on the 303(d) List of Impaired Waters for bacteria and placed in Category 5a, meaning a TMDL is underway, scheduled, or will be scheduled.

In response, TCEQ initiated a contract with the Center for Coastal Studies at Texas A&M University-Corpus Christi to provide monitoring and the collection of additional indicator bacteria data to assess water quality in Oso Bay. Data collected will determine whether the bacteria concentrations actually do exceed the oyster harvesting criteria. If bacteria concentrations exceed the standards, TCEQ will develop a Total Maximum Daily Load (TMDL) for the bay, and stakeholders in the watershed will be asked to develop an Implementation Plan for the TMDL that identifies measures to reduce pollution.

1.2 Water Quality Standards

The DSHS Environmental and Consumer Safety Section, Seafood and Aquatic Life Group, assesses the oyster waters use for Texas waters. DSHS is responsible for designating, monitoring and classifying all shellfish beds into harvesting categories: approved, conditionally approved, restricted, or prohibited. These classifications are published as maps on their website. The maps, along with DSHS water quality data and sanitary surveys, serve as the basis for the TCEQ's assessment of the oyster water use. Restricted Harvest Zones (RHZs) are areas where oyster harvesting is allowed, but not for direct marketing (https://www.dshs.state.tx.us/seafood/classification.shtm).

The criteria for waters listed as "Oyster Waters" utilize fecal coliform concentrations as a standard and are based on risk assessments established by the DSHS. To protect the safety of seafood consumption, median fecal coliform concentrations in bay and gulf waters should not exceed 14 colony forming units (CFU)/100 ml, and the 90th percentile (not more than 10 percent of all samples) exceeding 43 CFU/100 ml. In addition, the criterion imposes a 1,000-foot buffer zone, measured from the shoreline at ordinary high tide, where those fecal coliform criteria do not apply. This buffer provides a protection zone against influences from watershed runoff and beach use by people. While no oyster beds actually exist in Oso Bay, the waters of Oso Bay empty into Corpus Christi Bay and therefore are considered a part of the Corpus Christi Bay harvesting area.

1.3 Project Objectives

Specific project objectives involved the collection of bacteriological (fecal coliform), field parameters, and avian data at five (5) locations in Oso Bay over a two-year period to support evaluation of water quality as it pertains to the oyster water classification. The project also incorporated up to five rain event sampling scenarios during the course of each year.

Data collected is intended for TMDL development for Indicator Bacteria in Oso Bay should it be determined that impairment exists. Birds may be a significant source of bacteria loading to the bay so observations (in the form of photos taken at the site to show the surrounding area) were conducted along with each sampling event. These photos are for general assessments only. There was no correlation between bird counts and sampling results so the information was not entered into any regulatory databases.

To ensure that data generated for the purposes described herein are scientifically valid and legally defensible, this project was conducted under a TCEQ approved Quality Assurance Project Plan (QAPP). This ensures that data submitted to the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database have been collected and analyzed in a way that guarantees its reliability.

2.0 STUDY AREA DESCRIPTION

2.1 Corpus Christi

According to data obtained from the City of Corpus Christi Department of Developmental Services, the total area within the city limits is 1060.6 km^2 (409.5 mi^2). Land represents 409.7 km^2 (158.2 mi^2) with water and right-of-way easements contributing 526.3 km^2 (230.2 mi^2) and 54.6 km^2 (21.1 mi^2), respectively. The population was 305,215 in 2010 as recorded by the 2010 US Census making it the eighth-largest city in Texas. The population of the Corpus Christi Metropolitan Statistical Area, which consists of Nueces, Aransas, and San Patricio Counties, was 428,185. Corpus Christi is the only major metropolitan area within the Oso Creek/Oso Bay watershed boundaries. The only other large community within the watershed is Robstown. Economic activities in and around Oso Bay include oil and gas refining and production, agriculture, manufacturing, and tourism.

2.2 Oso Bay

Oso Bay (Segment 2485) is an enclosed, shallow water, secondary bay located on the southern shore of Corpus Christi. Situated in the northern-most portion of the Nueces-Rio Grande Coastal Basin, the watershed is entirely contained within Nueces County. Ecologically, TCEQ presently classifies Oso Bay as possessing "exceptional aquatic habitat" with an aquatic life use Dissolved Oxygen (DO) criteria of 5.0 mg l^{-1}. Oso Bay provides productive nursery habitats for commercially important species, such as White and Brown shrimp (*Litopenaeus setiferus* and *Farfantepenaeus aztecus*), Blue Crabs (*Callinectes sapidus*), and assorted finfish species (Hildebrand and King 1979; TNRCC 1996).

Oso Bay receives freshwater inflows from Oso Creek. Bowman and Jennings (1992) characterized Oso Creek as a small, effluent-dominated, low gradient stream, which enters the upper reaches of Oso Bay and creates a small estuarine area. Oso Creek originates in Nueces County near the city of Robstown, about 32 km west and north of Oso Bay. The combined drainage area for the bay and creek encompasses approximately 600 km^2 (Bowman and Jennings 1992). Sediments within Oso Creek are typically comprised of soft organic muds, silts, and clays. Water depth varies from 0.20 to 0.75 m within the main creek channel; with pools having a depth up to 1.5 m. Vegetation is primarily sedges, grasses, shrubs, and some trees along the banks. Farther downstream, banks become barren and dry during drought conditions, but vegetation can be present after rains.

Generally characterized as a soft sediment estuarine area, temperature and wind exert a strong influence on Oso Bay. The entire bay (18 km^2) is subject to tidal exchange, and significant portions of the bay bottom are alternately exposed and submerged, depending on wind velocity and direction. Typically, average depth in Oso Bay is <1.0 m. The majority of all tidal exchange occurs through a pass located on the east side of Ward Island; with minimal exchange occurring through the small pass located to the west. A small wind-tidal flat, covering approximately 28 hectares, lies west of Ward Island. This flat, known as the Blind Oso, submerges under high tide events combined with strong southerly winds or tropical storms. During such conditions, water is exchanged between the Blind Oso and Corpus Christi Bay through the small pass (Bowman and Jennings 1992).

Clays and sands dominate Oso Bay sediments, with areas high in organic material found near the City of Corpus Christi Oso Wastewater Treatment Plant (OWWTP) (Oppenheimer 1972; White *et al*. 1983; Armstrong 1987). Bowman and Jennings (1992) stated that rough shell hash constituted a major bottom component present near the mouth of the bay as it empties into Corpus Christi Bay, but was not present elsewhere. Seagrass beds, mostly comprised of *Halodule beaudettei*, cover numerous

areas of the bay bottom. Emergent vegetation, and a well-defined wetland area, is located adjacent to the OWWTP outfall in the area known as the Blind Oso.

The soils surrounding Oso Bay and Creek are composed of three types, Victoria Association, Orelia-Banquete Association, and Galveston-Mustang-Tidal Flats Association (USDA 1992) (Figure 2.1). The Victoria Association soil is dark, calcareous, crumbly, and called blackland. These soils crack when dry and swell when wet; however, they take in water slowly. The Orelia-Banquete Association soils are deep, dark-colored, crusty soils that contain a hardpan. The surface soil and subsoil of Orelia soils are less crumbly than Victoria soils are, and because the subsoil is dense, the Orelia-Banquete soils take in water even slower than the Victoria soils. Most areas surrounding Oso Creek/Bay with Orelia soils are cultivated.

The Galveston-Mustang-Tidal Flats Association exists along coastal strips of the mainland. These soils are deep, hummocky, light-colored, loose sands, and normally less than a foot thick. Runoff on these soils is very slow because practically all rain enters and moves through these soils. Therefore, surface and storm water runoff primarily to the west of Oso Creek/Bay, which is dominated by cultivated, pastured, and urban land, is fast, while runoff to the east of the creek and bay is slow (USDA 1992) (Figure 2.1).

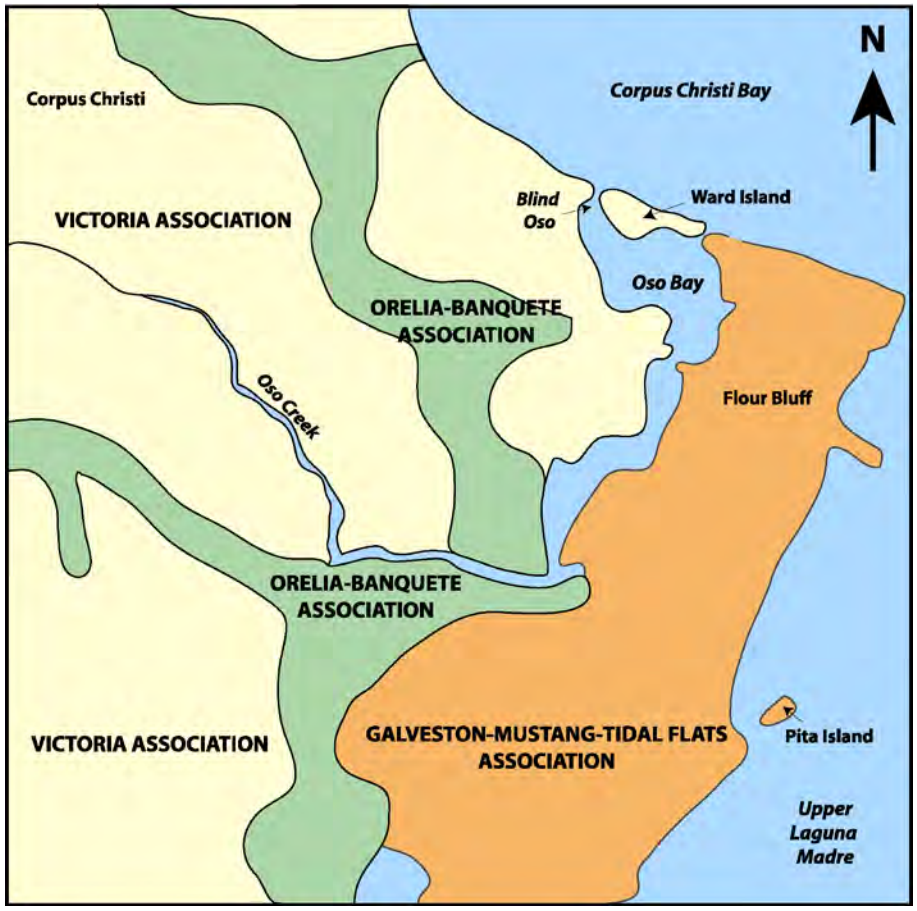

Figure 2.1. Soil types surrounding Oso Creek and Oso Bay. Map adapted from USDA 1992.

2.3 Climate

Corpus Christi is located between a humid subtropical region to the northeast and a semiarid region to the west and southwest of the city. Summers are hot and humid, with June through August high temperatures exceeding 32.2 °C (90.0 °F) 83.0% of the time with an average morning humidity of 93.0% (National Climatic Data Center 2012). Moderate winters, where the average high in January is 18.3 °C (65.0 °F) and the low is 7.2 °C (45.0 °F), may occasionally produce a freeze following the passage of strong northerly high-pressure fronts (Jones 1975; Chabreck 1990). December through February low temperatures are below freezing only 11% of the time (National Climatic Data Center 2012).

Mean annual precipitation recorded at the Corpus Christi International Airport is approximately 76.9 cm yr^{-1} (30.3 in yr^{-1}) (NOAA 2013). This is offset by evaporation rates ranging from 90 to 115 cm yr^{-1} (35.4 to 45.3 in yr^{-1}) but may reach as high as 150 cm yr^{-1} (TWC 1991). Peak rainfall months are from May to September with the winter months being the driest season. Southeasterly prevailing winds serve as a primary source of atmospheric moisture. The hurricane season runs from June to November (peak months are August and September), with tropical storms and hurricanes occasionally resulting in substantial rainfall during late summer and early fall (Armstrong 1987).

3.0 METHODS

3.1 Sampling Process Design and Frequency

The sample design is based on the program requirements of the Total Maximum Daily Load Program to provide data and information to characterize water quality conditions to identify the presence or absence of impairments of designated water body uses, and to support water quality modeling, site-specific water quality standard revisions, TMDL load allocations, and other TMDL data and information needs. The environmental data were collected and evaluated with a high degree of confidence that the data are scientifically valid, of known quality, and legally defensible.

As part of the TMDL stakeholder involvement process, the CCS coordinates closely with the TCEQ and other TMDL participants to ensure an adequate water monitoring strategy to supply informational needs for modeling, assessment, load allocation, and decision-making. Therefore, as Oso Bay Oyster Waters are listed on the Texas 303(d) List of Impaired Waters for bacteria, these sites were selected based on providing monitoring data of sufficient quantity and quality. Data collected will provide an adequate representation of water quality from the upper to lower reaches of Oso Bay and utilize existing stations were SWQMIS data has been collected to support the evaluation of water quality in Oso Bay oyster waters pertaining to fecal coliform concentrations

Over the course of the two-year study, 56 sampling events took place, which primarily involved the weekly collection of field, avian, and fecal coliform data at five established TCEQ monitoring stations in Oso Bay (Figure 3.1). In Year-one data collection occurred from April 2013 through July 2013 for 24 total sampling events. Twelve events were non-rainfall events and four were rainfall-dependent collection events that occurred at all five stations within 12, 24, and 48 hours following rainfall for a total of 12 rainfall events.

In Year-two, data collection resulted in 32 total sampling events. There were two events conducted in November 2013 and 30 sampling events that occurred from January 2014 through June 2014 for a total of 32 sampling events. Of these 23 were non-rainfall events and there were three additional rainfall-dependent collection events occurring at all five stations within 12, 24, and 48 hours following rainfall for a total of nine rainfall events.

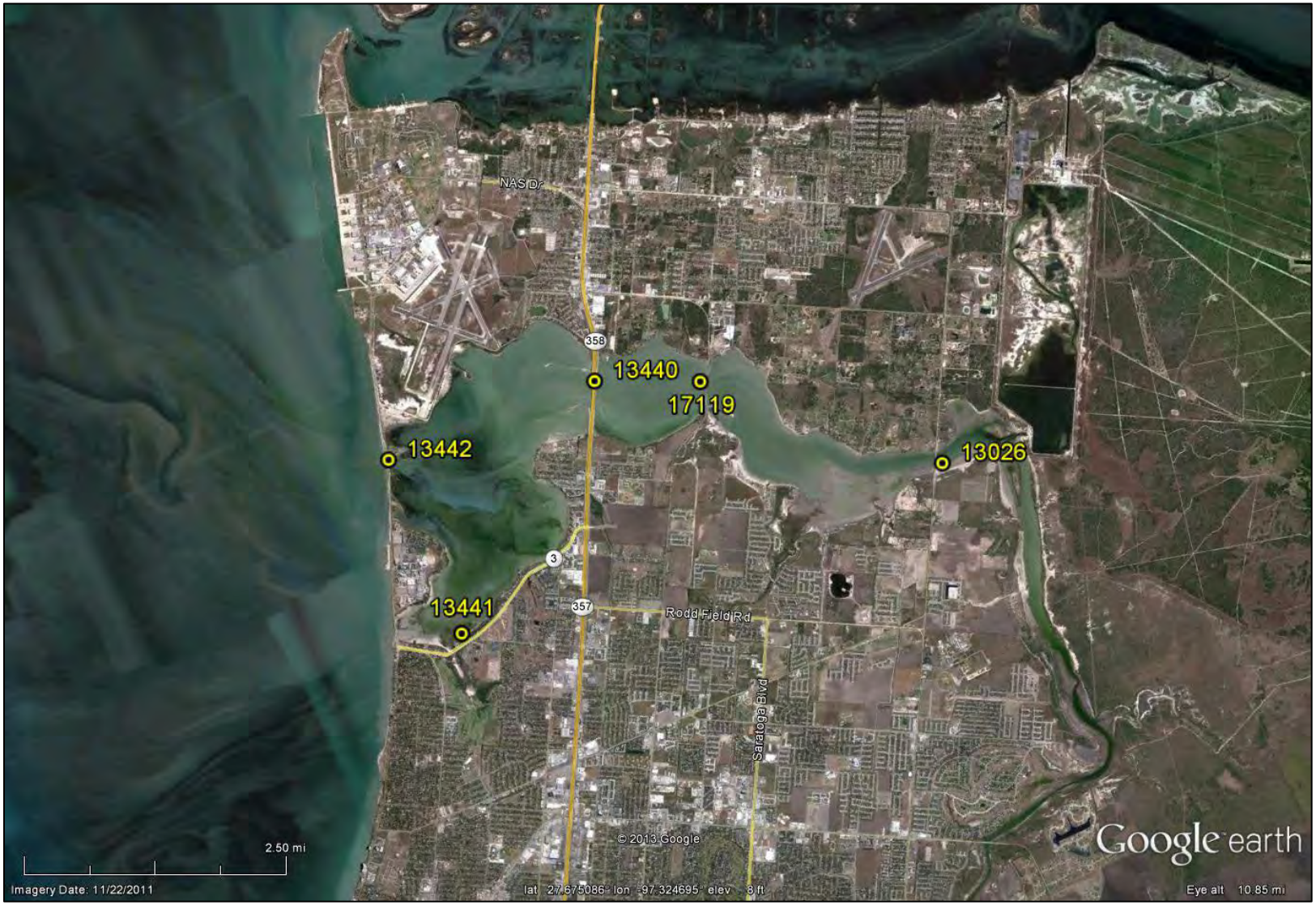

Figure 3.1. Map of current Center for Coastal Studies Oso Bay TMDL sampling locations.

3.2 Station Descriptions

Station 13026

Located where the Yorktown Road Bridge crosses Oso Bay (see Figure 3.1), this station is approximately 1000 m downstream of the Topaz Energy Group-Barney Davis Energy Center (formally the Central Power & Light Barney M. Davis Power Plant) cooling ponds outfall (Figure 3.2 and Figure 3.3). Clearing of vegetation for the construction of the adjacent bridge resulted in the shoreline being bare or covered in riprap to control erosion. Location of the outfall exerts a substantial influence on the substrate characteristics of the location. A scoured channel exists, with an approximate depth of 2.5 m, in the middle of the bay. This area is composed of a hard clay substrate but nearer the shore, the substrate transitions to a finer clay and silt composition mixed with patches of sand. Patches of the seagrass, *Halodule beaudettei* exists near the cooling pond discharge. The sampling area is adjacent and upstream (south side) of the bridge and water depth in the sample area ranges from 0.20 to 1.3 m. A large amount of tidal flat area exists and due to easy access to the water, anglers often use the bridge and surrounding area heavily, often driving vehicles around the protective barriers and across the tidal flats. This often results in a large amount of debris deposited on the shoreline or along the roadway near the bridge (Figure 3.4). Birds are observed in a limited number utilizing the flats.

Figure 3.2. Station 13026 – Oso Bay at Yorktown Road.

Figure 3.3. Cooling pond outfalls at the Topaz Energy Group-Barney Davis Energy Center.

Figure 3.4. Abandoned tires at Station 13026.

Station 17119

Located where the abandoned Holly Road railroad tracks cross Oso Bay (see Figure 3.1), this station is located in the upper mid-bay reaches of the bay. Access to the station (Figure 3.5) is via the access road off Flour Bluff Drive, which ends at the old railway bridge. This station is used as a year-round illegal dumping ground for trash with the occasional animal carcass also deposited (Figure 3.6). The sampling site is from the railway bridge on the upstream (south) side. Bottom sediments at this station are primarily a soft clay/sand composition. Scour channels do exist under the bridge, as water velocity can be strong around the bridge supports during tidal exchange and storm events (Figure 3.7). Water depth within the sampling area typically ranged from 0.30 to 0.80 m. Anglers often use the bridge and will walk out on the bridge from either shoreline to fish. As this location has limited public exposure, it is often used for various illegal activities. Birds are observed in a limited number feeding on the adjacent mud flats or resting on the bridge itself.

Figure 3.5. Station 17119 – Approach to station at the abandoned Holly Road Railroad tracks over Oso Bay.

Figure 3.6. Trash deposited along access road to Station 17119.

Figure 3.7. Access road submerged at Station 17119 during a storm at high tide.

Station 13440

Located where State Highway 358 (South Padre Island Drive) crosses Oso Bay (see Figure 3.1), this station is located at mid-bay (Figure 3.8). As with Station 13026, the clearing of vegetation during the construction of the adjacent bridge resulted in the shoreline being bare or covered in riprap to control erosion (Figure 3.9). The sampling area is adjacent to and on the southern side of the bridge. Bottom sediments are primarily a soft clay/sand composition. Water depth within the sampling area ranged from 0.30 to 0.80 m with some areas greater than 1.0 m. Small patches of seagrass composed of *Halodule beaudettei* exist on the northern portion of the location. Prevailing southeasterly winds provide for constant mixing of the water within this area of Oso Bay. Easy access to the water also makes this an attractive spot for anglers and despite trashcans provided by the City of Corpus Christi, there is still a considerable amount of trash and debris deposited on the shoreline in the immediate area (Figure 3.10). Bird use at this station is limited.

Figure 3.8. Station 13440 - Oso Bay at State Highway 358 (South Padre Island Drive).

Figure 3.9. Station 13440 – Concrete blocks along shoreline.

Figure 3.10. Station 13440 – Trash deposited among concrete riprap.

Station 13441

Located west of Ward Island and the Texas A&M University-Corpus Christi campus (see Figure 3.1) this unique station is located at the Hans Suter Wildlife Refuge, which is adjacent to the OWWTP (Figure 3.11). Treated wastewater released from the OWWTP creates a freshwater wetland with such plant species as cattail. Transcending to the bay and adjacent areas, low, mid, and high marsh vegetation (i.e. *Borrichia frutescens*, *Avicennia germinans*) is along the banks (Figure 3.12). This station is located where the discharge channel enters Oso Bay; approximately 200 m from the OWWTP discharge pipe. Sampling takes place approximately 50 m from the end of the discharge channel adjacent to the viewing platform used by visitors to the refuge. Birds are observed feeding and resting at this location in high numbers year round.

While considered a low energy environment, there is potential for considerable mixing from the prevailing southeasterly winds when water levels are high (Figure 3.13). While the permit defines the mixing zone as being within a 50-foot radius from the outflow pipe, typically the low water levels at this location result in a visible dominant plume of freshwater that flows out and mixes with the higher saline waters of Oso Bay. Due to low water levels resulting in extended periods of emergent tidal flats (see Figure 3.11), it is often necessary to walk extended distances to obtain enough water for representative samples. Bottom substrate is hard clay overlaid with silt and/or a layer of black pluffy organic material.

Figure 3.11. Station 13441 - Oso Bay at Hans Suter Park below OWWTP outfall.

Figure 3.12. Station 13441 – Upper reach of discharge channel with freshwater wetland vegetation.

Figure 3.13. Station 13441 – High tide and strong winds covering tidal flats.

Station 13442

This station is located east of Ward Island, where Oso Bay connects with Corpus Christi Bay (Segment 2484) and flows under Ocean Drive (see Figure 3.1). This area experiences significant wash and scour effects due to high rates of tidal exchange (Figure 3.14). Under usual conditions, all water exchange with Oso Bay and Corpus Christi Bay occurs through this area. The sampling area is adjacent to and south of the bridge. The bottom sediment at this station includes broken shell and sand atop clay substrate. Water depth within the sampling area ranged from 0.30 to 0.50 m with areas greater than 1.5 m located in the channel under the bridge. Seagrass beds composed of *Halodule beaudettei* exist on the southern portion of the sampling area. As with Station 13026 and 13440 the clearing of vegetation during the construction of the adjacent bridge resulted in the shoreline being bare or covered in riprap to control erosion (Figure 3.15). Easy access to the water also makes this an attractive spot for anglers and as seen at other stations this often results in debris deposited on the shoreline in the immediate area. Bird use is moderate at this location along shoreline and mudflats.

Figure 3.14. Station 13442 - Oso Bay at Ocean Drive.

Figure 3.15. Station 13442 – Riprap along mostly bare shoreline.

Figure 3.16. Station 13442 – Kayakers and anglers along shoreline.

3.3 Parameters Sampled

Table 3.1. Parameters collected for the Oso Bay TMDL project and submitted to TCEQ.

Routine Field Parameters	Units	Parameter Codes*
Depth of Bottom of Water Body at Site	Meters	82903
Depth of Measurement	Meters	13850
Temperature, Water (Grab)	°C	00010
Dissolved Oxygen (Grab)	mg/L	00300
Dissolved Oxygen (Grab)	% Saturation	00301
Salinity (Grab)	ppt (psu)	00480
Specific Conductance (Grab)	µS/cm	00094
pH (Grab)	s.u.	00400
Turbidity	NTU	82078
Days Since Last Significant Precipitation	Days	72053
Routine Field Observations		
Air Temperature	°C	00020
Present Weather	Visual Assessment	89966
Wind Intensity	MPH	89965
Wind Direction	Compass Direction	89010
Tide Stage	Meters	89972
Water Surface	Visual Assessment	89968
Microbiological		
Fecal Coliform, Membr Filter, M-FC Broth	CFU/100 ml	31616
Enterococci, Enterolert, Water, IDEXX	MPN/100 ml	31701

3.4 Sampling Methods

The CCS followed sampling procedures as documented in the TCEQ-approved QAPP for this project (*Support for Total Maximum Daily Loads (TMDL) for Indicator Bacteria in Oso Bay, Revision 1, April 8, 2013)*. All data underwent quality assurance review, and complied with TCEQ Data Management protocols.

A two-person field crew conducted sampling by walking out from the shore to the desired sampling depth of 0.3 m. At each sampling site, field crews collected water quality and field parameters following the methods and protocols described in the TCEQ *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment and Tissue* (TCEQ RG-415), and the QAPP. Water quality and field parameters included those specified in Table 3.1 above with additional or modified procedures for field sampling clarified in detail below.

3.4.1. Field Parameter Measurements

The first activities conducted upon arriving onsite were routine field observations such as ambient weather and water conditions, (see Table 3.1 Routine Field Observations) avian surveys, and then water sampling and water column measurements followed.

3.4.2. Avian Survey Measurements

Avian abundance, behavior, habitat use, and species composition was recorded at each sampling location along with photo documentation. Avian observation data will only be used to assist the TMDL team in assessing the general environment of the bay, and simple observations (photos) will provide the necessary information. There was no attempt to correlate the number of observed birds with the bacteria results of the sampling.

3.4.3. Hydrographic Profile

Water column measurements were conducted at each station to measure routine water quality parameters (see Table 3.1 Routine Field Parameters) using a YSI multiparameter water quality instrument with a cable connection to a hand held display.

3.4.4. Microbiological Samples - Water

Before actual sample collection, the sampling site identification number was written on the bottle label and on the field log sheet. In order to reduce possible contamination, before collecting samples from a station, all field personnel washed hands and arms with alcohol wipes or a disinfectant lotion to reduce exposure to potentially harmful bacteria or other microorganisms. After drying washed areas, all field personnel performing sample collection wore latex gloves to further reduce the risk of possible contamination.

Personnel removed the protective seal from the sterile collection bottles just before obtaining each sample and protected them from contamination by not touching the inside of the bottle itself or the inside of the lid. While collecting the surface water sample, personnel avoided disturbing the bottom sediment at the sampling station and positioned the bottle upstream of any water current to avoid sample contamination. The bottle mouth was positioned into the current, away from the hand of the person sampling, and pushed downward into the water to avoid introducing surface scum. Sampling depth was 0.3 m below the water surface at all locations where such a depth was feasible.

Upon removing the bottle from the water, the sample was inspected for any debris, contaminants, or excessive sediment/sand. If sampling personnel felt the sample might have been contaminated, a new bottle was used to take a new sample. Upon taking a successful sample, the lid was tightly closed and the bottle labeled with the time the sample was collected. Samples were immediately placed on ice at < 6 °C for transport to the laboratory. Care was taken to ensure sample bottles were not immersed in melt water during storage or transit to the laboratory. After collecting samples from a station, personnel washed hands and arms with alcohol wipes or a disinfectant lotion and dried affected areas to reduce exposure to potentially harmful bacteria or other microorganisms.

4.0 INTERIM DATA RESULTS

This report represents data collection efforts for the first and second years of the Oso Bay Bacteria Indicator Monitoring Project. All data are submitted to TCEQ and can be accessed through the TCEQ SWQMIS database.

4.1 Field Data

Water Temperature

During Year-one, water temperature in Oso Bay was consistent with water temperatures for the period (April 2013 through July 2013) sampling occurred. Water temperature ranged from 15.68 °C at Station 13026 to 32.38 °C at Station 13440. Water temperature increased from April 2013 through the summer months with mean temperatures relatively consistent for four of the stations sampled at approximately 26.49 °C. However, Station 13441 at Hans Suter Park had the highest mean water temperature of 27.55 °C possibly due to the shallow nature of this station and proximity of the OWWTP discharge channel.

As opposed to the previous year, in Year-two sampling also occurred during the winter months (November 2013 and January 2014 through June 2014) and was reflected in water temperature values recorded. Water temperature ranged from 5.91 °C to 32.07 °C at Station 17119. As seen previously, Station 13441 at Hans Suter Park had the highest mean water temperature of 23.26 °C recorded.

Dissolved Oxygen

In Year-one, dissolved oxygen (DO) ranged from 3.64 mg/L to 12.14 mg/L at Station 13441 at Hans Suter Park. Mean DO was greatest at Station 13441 at 8.12 mg/L and of the 120 DO readings recorded in Year-one; only five (once each at Station 13026, 17719, 13440 in June 2013 and once each at 17119 and 13441 in July 2013), fell below the 5.00 mg/L exceptional aquatic life criteria established for Oso Bay.

In Year-two, DO ranged from 5.37 mg/L at Station 13441 to 15.70 mg/L at Station 13442 and was highest at Station 13026 with 9.01 mg/L. Of the 160 DO readings recorded in Year-two no concentrations fell below the 5.00 mg/L exceptional aquatic life criteria established for Oso Bay.

Salinity

In Year-one, salinity ranged from 0.04 PSU at Station 13441 at Hans Suter Park to 62.37 PSU at Station 13440. Extremely high salinity values (>50.00 PSU) began at the end of May 2013 and continued through the summer with some moderation following the two rain events in July 2013. Mean salinity was highest at mid-bay Station 17719 with 47.43 PSU and Station 13440 with 46.94 PSU. Both stations are located furthest from freshwater inputs from Oso Creek or from the OWWTP at Station 13441.

In Year-two, salinity ranged from 0.03 PSU at Station 13441 at Hans Suter Park to 51.93 PSU at Station 17119. Extremely high salinity values (>50.00 PSU) occurred only in June 2014. Mean salinity was highest at Station 13440 with 37.77 PSU.

pH

Year-one pH concentrations ranged from 7.26 at Station 13441 at Hans Suter Park to 8.68 at Station 17119. Mean pH of all stations combined was 8.00 over the course of the four-month sampling period. Year-two pH concentrations ranged from 6.89 to 8.77 at Station 13441 at Hans Suter Park. Mean pH of all stations combined was 8.01 over the course of the sampling period.

Turbidity

Turbidity measures the amount of suspended particles in the water that may come from such sources as natural sediment erosion (clay, silt, and sand particles), organic decay, plankton, and other microscopic organisms.

In Year-one, turbidity ranged from 0.40 NTU at Station 13441 to 795.1 NTU at Station 13440. Mean turbidity for all stations combined was 69.51 NTU over the course of the four-month sampling period. Higher turbidity values observed occurred during rain events when flow in Oso Bay was greatest.

In Year-two, turbidity ranged from 0.50 NTU at Station 13441 to 1231.80 NTU at Station 13440. Mean turbidity for all stations combined was 112.66 NTU over the course of the Year-two sampling period.

4.2 Fecal coliform concentrations

Year-one

Analysis of Year-one data results from 120 bacteria samples (60 non-rainfall in Table 4.1 and 60 rainfall in Table 4.2) collected from 4/15/2013 through 7/24/2013 were used to characterize the Oyster Waters in Oso Bay. During Non-rainfall sampling events, out of 60 samples collected for all Oso Bay stations (5 Stations with 12 samples per station), the median criteria of 14 CFU/100 ml was exceeded at one station and the 90th percentile was exceeded at two stations. The magnitude of these exceedances resulted in both the median and 90th percentile being exceeded for Oso Bay as a whole (Table 4.1).

During Rainfall sampling events, out of 60 samples collected for all Oso Bay stations (5 Stations with 12 samples per station), the median criteria was exceeded at four stations and the 90th percentile was exceeded at all five stations, respectively, with both the median and 90th percentile exceeded for Oso Bay as a whole (Table 4.2).

Regardless of rainfall, when all sampling events were combined the median criteria was exceeded at three stations and the 90th percentile was exceeded at all five stations, with both the median and 90th percentile exceeded for Oso Bay as a whole (Table 4.3).

Fecal coliform values ranged from <2 CFU/100 ml at all stations to >1700 CFU/100 ml at Station 13026. Highest concentrations typically occurred after rainfall events at all locations, except Station 13441 at Hans Suter Park (Figures 4.1 through 4.5). Station 13441 had only one concentration that was <43 CFU/100 ml during the four months of sampling.

Year-two

Analysis of Year-two data results from 160 bacteria samples (115 non-rainfall in Table 4.1 and 45 rainfall in Table 4.2) collected from the two events in November 2013 and the 30 events that occurred from 1/15/2014 through 6/19/2014 produced more exceedances of the criteria than seen in Year-one.

During Non-rainfall sampling events, out of 115 samples collected for all Oso Bay stations (5 Stations with 23 samples per station), the median criteria of 14 CFU/100 ml was exceeded at three stations and the 90th percentile was exceeded at four stations with both the median and 90th percentile being exceeded for Oso Bay as a whole (Table 4.1).

During Rainfall sampling events, out of 45 samples collected for all Oso Bay stations (5 Stations with 9 samples per station), both the median criteria and the 90th percentile was exceeded at all five stations and for Oso Bay as a whole (Table 4.2).

Regardless of rainfall, when all sampling events were combined the median criteria was exceeded at three stations and the 90th percentile was exceeded at all five stations, with both the median and 90th percentile exceeded for Oso Bay as a whole (Table 4.3).

Fecal coliform values ranged from <2 CFU/100 ml at all stations to >2000 CFU/100 ml at Stations 13026, 13440, and 13441 after rainfall events. As seen in Year-one, highest bacteria concentrations typically, but not consistently, occurred after rainfall events at all locations except Station 13441 at Hans Suter Park (Figures 4.1 through 4.5). All samples taken at Station 13441 exceeded the 90th percentile of >43 CFU/100 ml during sampling.

Year-one and Year-two combined

Combining data for both years for 280 bacteria samples (175 non-rainfall in Table 4.1 and 105 Rainfall in Table 4.2) taken for the 56 sampling events conducted essentially confirmed the results of Year-one and Year-two.

During Non-rainfall sampling events, out of 175 samples collected for all Oso Bay stations (5 Stations with 35 samples per station), the median criteria of 14 CFU/100 ml was exceeded at three stations and the 90th percentile was exceeded at four stations with both the median and 90th percentile being exceeded for Oso Bay as a whole (Table 4.1).

During Rainfall sampling events, out of 105 samples collected for all Oso Bay stations (5 Stations with 21 samples per station), both the median criteria and the 90th percentile was exceeded at all five stations and for Oso Bay as a whole (Table 4.2).

Regardless of rainfall, when all sampling events were combined the median criteria was exceeded at three stations and the 90th percentile was exceeded at all five stations, with both the median and 90th percentile exceeded for Oso Bay as a whole (Table 4.3). The largest source(s) of bacteria are likely carried in with stormwater, as exceedances were typically greater during rainfall events (see Table 4.2 and Figures 4.1 through 4.5). However, the 98.2% exceedance rate observed at Station 13441 at Hans Suter Park, adjacent to the OWWTP, indicates that additional investigation is needed to understand the source of the high bacteria concentrations being observed at this location (Figure 4.1)

Table 4.1. Median (14 CFU/100 ml) and 90th percentile (<10% of samples exceed 43 CFU/100 ml) concentration values (CFU/100 ml) calculated at individual sampling stations and all stations combined for Oso Bay for **Non-Rainfall** sampling events for individual and combined sampling years.

Year	Station	Number of Samples	Median	90th Percentile
Year 1	13026	12	8.3	186.4
	17719	12	2.2	33.5
	13440	12	2.2	39.8
	13441	12	199.0	410.0
	13442	12	11.2	41.1
	Oso Bay	60	15.0	243.0
Year 2	13026	23	3.5	21.9
	17719	23	4.7	43.4
	13440	23	30.6	210.4
	13441	23	300.0	728.0
	13442	23	36.5	438.4
	Oso Bay	115	27.1	424.0
Year 1 and Year 2	13026	35	3.5	87.2
	17719	35	2.4	33.6
	13440	35	23.5	200.8
	13441	35	290.0	600.0
	13442	35	30.6	191.6
	Oso Bay	175	20.0	322.2

Table 4.2. Median (14 CFU/100 ml) and 90th percentile (<10% of samples exceed 43 CFU/100 ml) concentration values (CFU/100 ml) calculated at individual sampling stations and all stations combined for Oso Bay for **Rainfall** sampling events for individual and combined sampling years.

Year	Station	Number of Samples	Median	90th Percentile
Year 1	13026	12	32.2	375.0
	17719	12	20.6	530.3
	13440	12	104.0	410.2
	13441	12	464.5	870.7
	13442	12	10.0	72.0
	Oso Bay	60	41.0	588.0
Year 2	13026	9	94.0	680.0
	17719	9	38.8	670.8
	13440	9	420.0	1456.0
	13441	9	290.0	1712.0
	13442	9	41.2	426.0
	Oso Bay	45	171.0	1288.0
Year 1 and Year 2	13026	21	42.0	380.0
	17719	21	35.3	591.0
	13440	21	160.0	1240.0
	13441	21	410.0	1260.0
	13442	21	22.4	212.0
	Oso Bay	105	92.0	947.2

Table 4.3. Median (14 CFU/100 ml) and 90th percentile (<10% of samples exceed 43 CFU/100 ml) concentration values (CFU/100 ml) calculated at individual sampling stations and all stations combined for Oso Bay for **Non-Rainfall and Rainfall** sampling events for individual and combined sampling years.

Year	Station	Number of Samples	Median	90th Percentile
Year 1	13026	24	**14.7**	**365.0**
	17719	24	4.1	**197.3**
	13440	24	**14.9**	**334.0**
	13441	24	**320.0**	**709.0**
	13442	24	10.0	**51.6**
	Oso Bay	120	**22.0**	**437.0**
Year 2	13026	32	4.7	**213.0**
	17719	32	8.8	**117.6**
	13440	32	**45.8**	**555.0**
	13441	32	**300.0**	**1039.0**
	13442	32	**38.9**	**447.0**
	Oso Bay	160	**40.0**	**552.9**
Year 1 and Year 2	13026	56	5.3	**290.0**
	17719	56	7.1	**178.0**
	13440	56	**28.9**	**417.0**
	13441	56	**305.0**	**821.5**
	13442	56	**23.5**	**202.0**
	Oso Bay	280	**31.8**	**521.0**

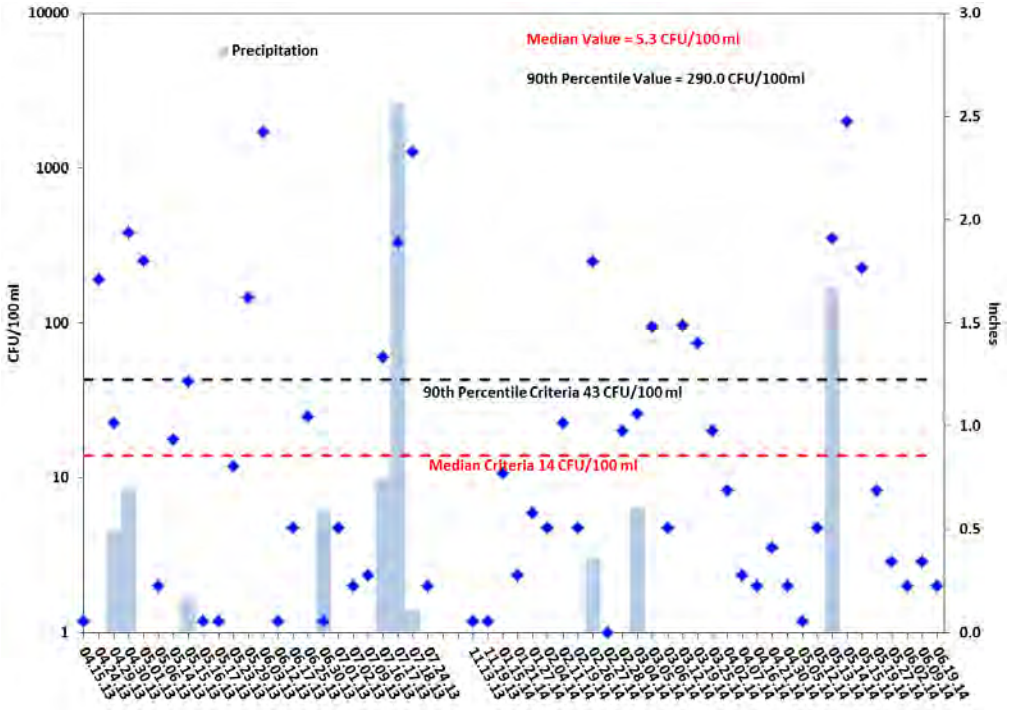

Figure 4.1. All fecal coliform concentrations at Station 13026 with precipitation amounts, median and 90th percentile criteria, and actual calculated median and 90th percentile values.

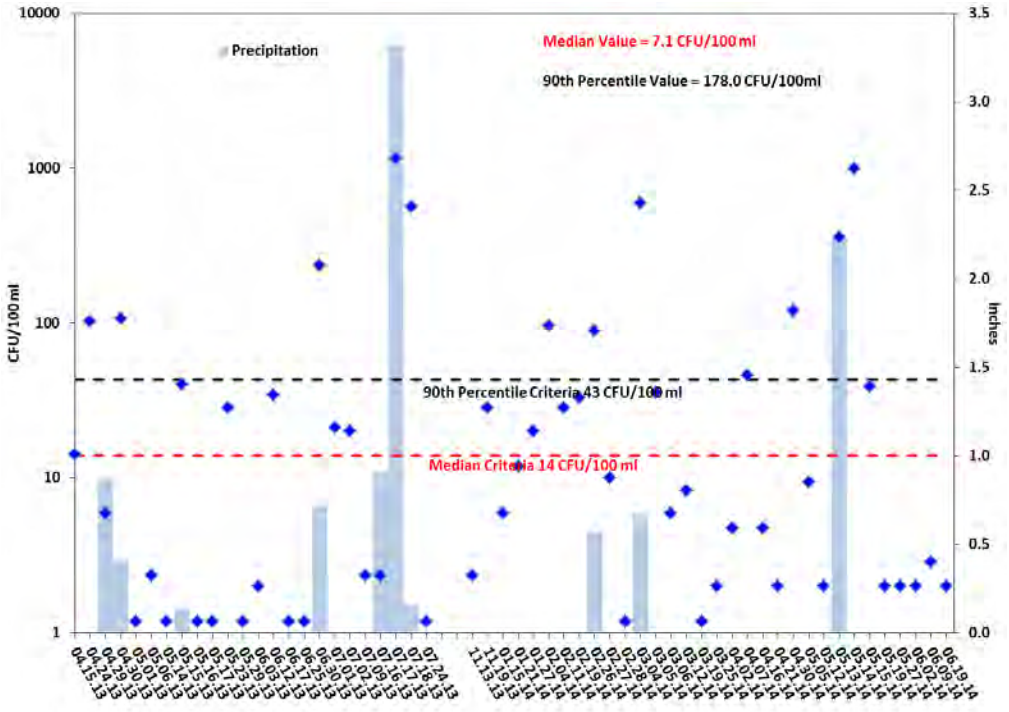

Figure 4.2. All fecal coliform concentrations at Station 17719 with precipitation amounts, median and 90th percentile criteria, and actual calculated median and 90th percentile values.

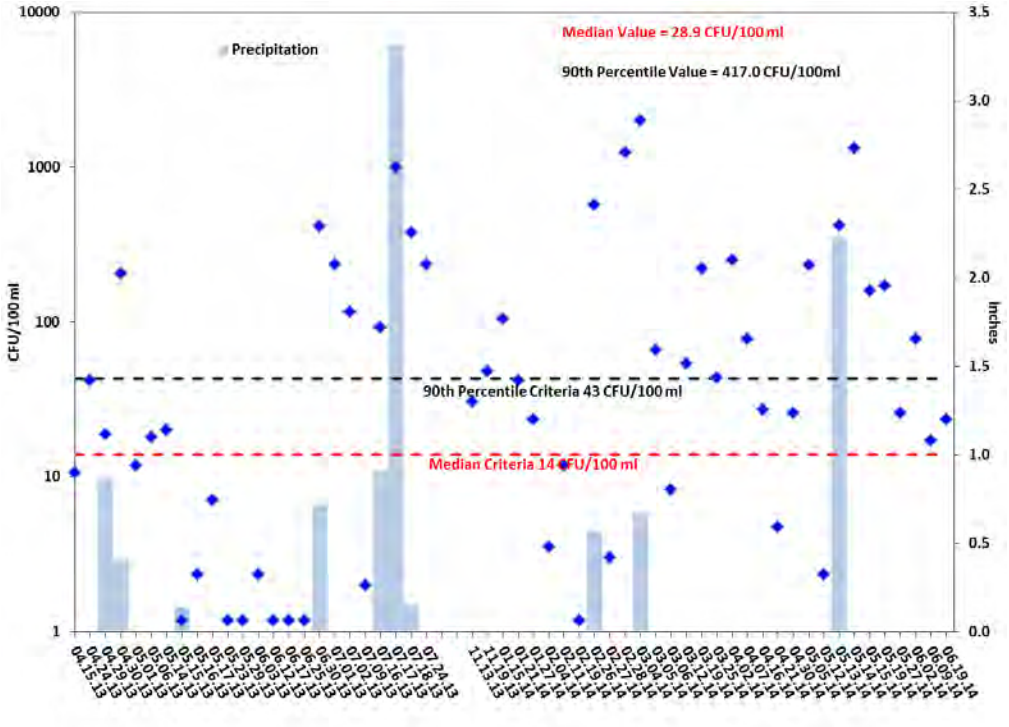

Figure 4.3. All fecal coliform concentrations at Station 13440 with precipitation amounts, median and 90th percentile criteria, and actual calculated median and 90th percentile values.

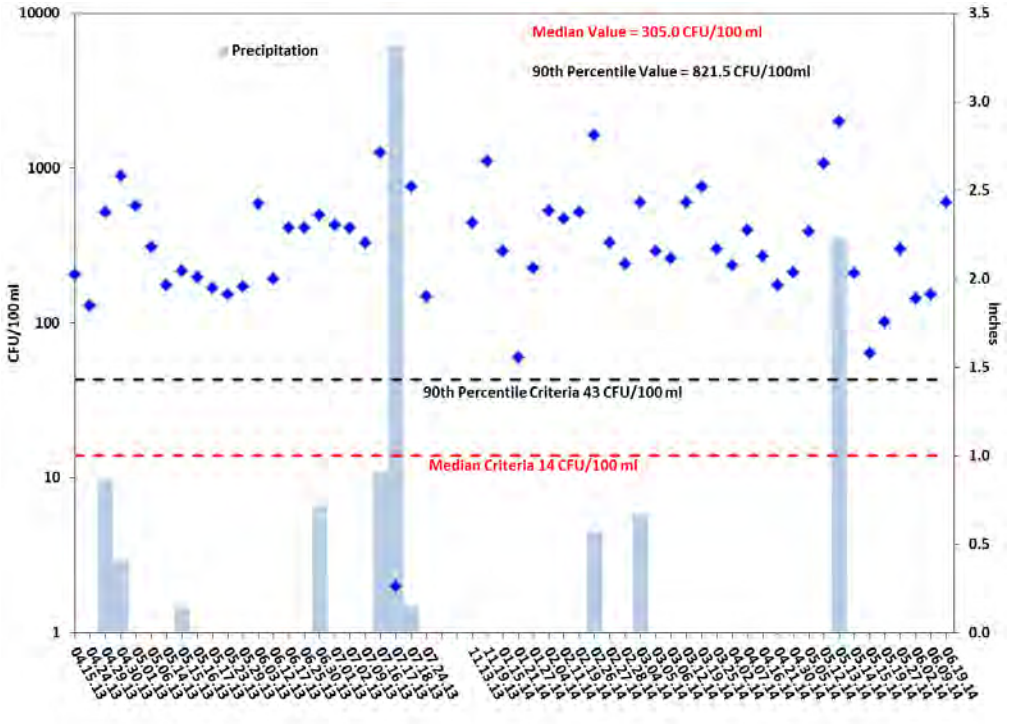

Figure 4.4. All fecal coliform concentrations at Station 13441 with precipitation amounts, median and 90th percentile criteria, and actual calculated median and 90th percentile values.

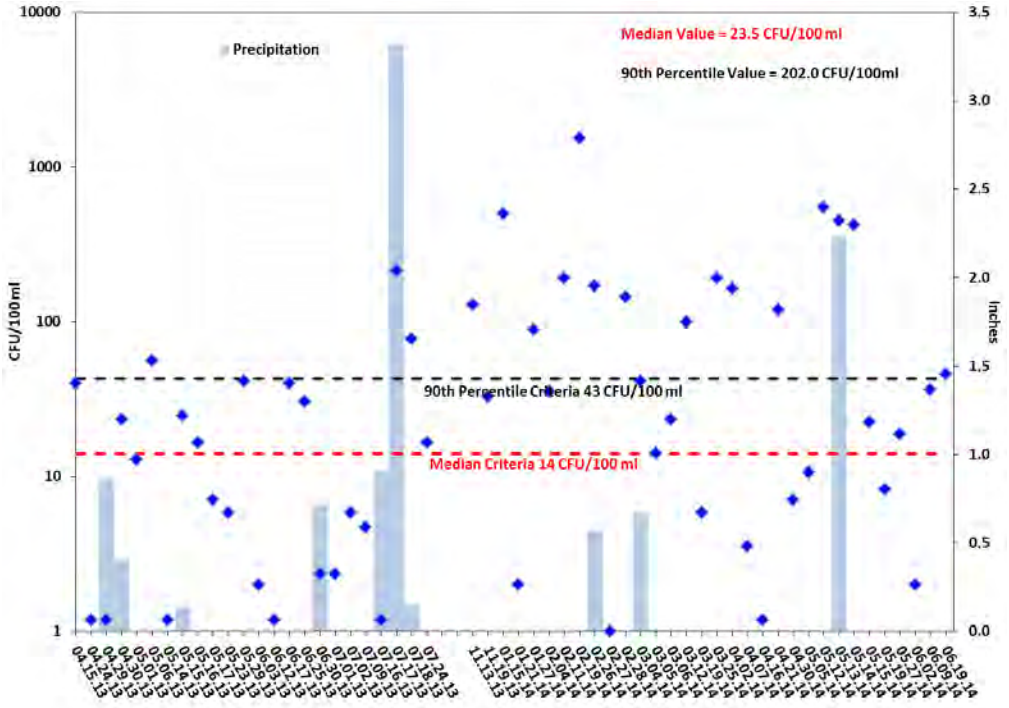

Figure 4.5. All fecal coliform concentrations at Station 13442 with precipitation amounts, median and 90th percentile criteria, and actual calculated median and 90th percentile values.

4.3 Avian Use by Location

As previously stated, bird use at a particular location may be a significant source of bacteria loading to the bay. Oso Bay and the surrounding region are on the Central Flyway of bird migration in North America and the region is renowned as a destination for birders from all over the world. In particular is the location Station 13441 at Hans Suter Park, which sustains a yearlong bird population that increases during migratory periods. With this influence in mind, sampling incorporated the notation of avian abundance, behavior, habitat use, and species composition at each sampling location through written and photo documentation. These observations, as stated, are to assist the TMDL team in assessing the general environment of the bay, and simple photo observations provide the necessary information. There was no attempt to correlate the number of observed birds with the results of the sampling.

Observations of avian activity during the 56 individual sampling events demonstrated the high use of Station 13441 in the Hans Suter Park area as a resting and feeding location for birds, especially during Year-two. As opposed to Year-one, higher numbers of birds observed in Year-two relate directly to sampling events that occurred during the winter months when wintering populations of birds populate this area. Station 13442 at Ocean Drive, while having approximate 50% less bird observations then Station 13441 in both years, was still a preferred habitat for bird species and regularly used for resting and feeding (Figure 4.6). Figures 4.7 through 4.11 provide pictures of bird use at each location.

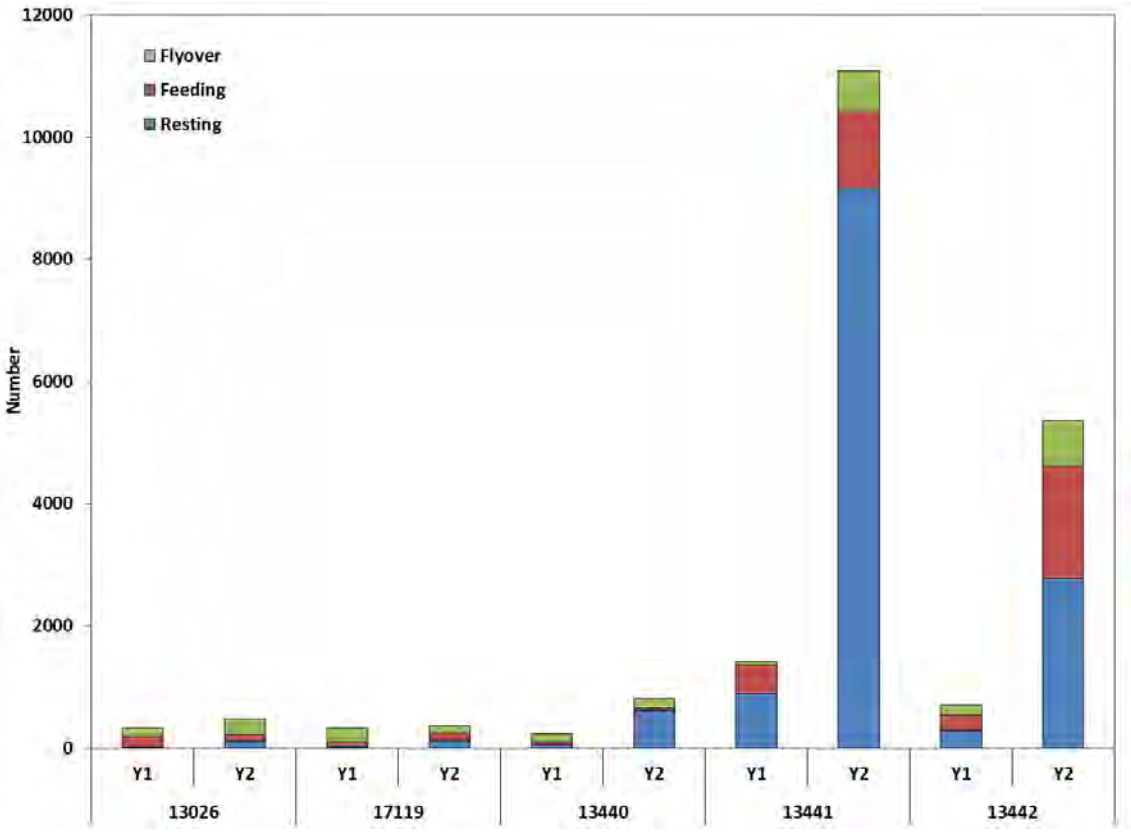

Figure 4.6. Total numbers of birds at each sampling location by activity observed for Year-one and Year-two.

Figure 4.7. Station 13026 at Yorktown Road – Sandpipers feeding along shoreline.

Figure 4.8. Station 17119 at Holly Road Railroad Tracks– Snowy Egret and Rosette Spoonbill feeding along access road.

Figure 4.9. Station 13440 at South Padre Island Drive – Tri-colored Heron feeding along shoreline.

Figure 4.10. Station 13441 at Hans Suter Park – American White Pelicans, Brown Pelican, Black-necked Stilts, and various duck species resting and feeding on tidal flats.

Figure 4.11. Station 13442 at Ocean Drive – Various shorebirds feeding on mudflats.

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