Basin Approach to Address Bacterial Impairments in Basins 15, 16, and 17

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Basin Approach to Address Bacterial Impairments in Basins 15, 16, and 17

Year One Report

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List of Acronyms

CFU	Colony-Forming Unit of Bacteria
CWA	Clean Water Act
ECHO	EPA – Environmental Compliance History Online
EPA	Environmental Protection Agency
FDC	Flow Duration Curves
GIS	Geographic Information System
GPS	Global Positioning System
ICIS	Integrated Compliance Information System
LDC	Load Duration Curve
MGD	Million Gallons per Day
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NHD	National Hydrology Dataset
NLCD	National Land Cover Database
NPS	Nonpoint Source
NRCS	USDA – Natural Resources Conservation Service
OSSF	Onsite Sewage Facility
RUAA	Recreational Use Attainability Analysis
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
TWRI	Texas A&M AgriLife Research, Texas Water Resources Institute
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WWTF	Wastewater Treatment Facility

Introduction

In the *2012 Texas Integrated Report and 303(d) List*, approximately 48% of the 568 impaired water bodies were caused by high bacteria levels. Once a water body has been listed, the Clean Water Act requires action to be undertaken to restore water quality in that water body. Several options exist to achieve this, which include additional monitoring, a standards assessment, development of a total maximum daily load (TMDL) or development of another watershed based plan such as a watershed protection plan. Traditionally, impairments have been addressed one at a time. In order to more efficiently address similar impairments within the same basin, more efficiently distribute resources, and with the hopes of preventing future listings within the same watershed, a new basin wide approach is being implemented in the Texas River Basins 15 (Colorado – Lavaca), 16 (Lavaca), and 17 (Lavaca Guadalupe). These watersheds, collectively referred to as the Matagorda Bay watershed have five water body assessment units impaired for elevated levels of fecal indicator bacteria: Carancahua Bay, Arenosa Creek, Tres Palacios Creek and two segments of the Lavaca River.

This report discusses the current and historical state of the study area and focuses on describing the physical, hydrological, climatic, and demographic conditions as well as potential sources of pollution. Information presented will be used in future water quality analysis and will assist in determining how to address bacteria impairments in the watershed. Information is compiled on a watershed level, summarizing all three basins, as well as within each basin where appropriate.

Description of Study Area

The Matagorda Bay watershed is located adjacent to each other along the Texas Gulf Coast in the upper portion of the coastal bend region. This area is sometimes referred to as the golden crescent and consists of all or part of Calhoun, Colorado, DeWitt, Fayette, Gonzales, Jackson, Lavaca, Matagorda, Victoria, and Wharton counties. The watersheds are largely rural with grassland, cropland, and forests dominating the landscape. The Matagorda Bay system consists of nine named bays including Carancahua, Chocolate, Espiritu Santo, Keller, Lavaca, Matagorda, San Antonio, Tres Palacios, and Turtle Bays. This bay system and the water bodies feeding it support a diverse and rich ecosystem that supports a robust commercial fishery, abundant wildlife and over 300 species of birds. The cities of Port Lavaca and Palacios are leaders nationally in shrimp and blue crab processing respectively. Tourism is a major economic driver locally, as are industries such as aluminum, chemical and petroleum processing.

In the watersheds feeding into the bay, agriculture is very important and well established. Land along the Colorado River has historically been utilized for extensive rice production; however, recent water shortages in the Colorado River basin have prevented extensive irrigation of rice crops. Other crops such as cotton, soybeans, sorghum, and turfgrass are also produced in this area. Cattle production has been critical to the area's economy with well over a million head being produced annually. Oil and gas exploration has rapidly increased recently with the discovery and production of Eagle Ford Shale resources, especially in Colorado, DeWitt, Fayette, Gonzales, and Lavaca counties.

Three river basins comprise the Matagorda Bay watershed: the Colorado-Lavaca, the Lavaca, and the Lavaca-Guadalupe basins and are labeled as Basins 15, 16, and 17 respectively by the state of Texas. Within these basins, major water bodies include Tres Palacios Creek, the Lavaca and Navidad Rivers and Lake Texana. A number of smaller water bodies also exist in the area and contribute stream flow into the bay system. Figure 1 illustrates the location of these basins and the overall project area.

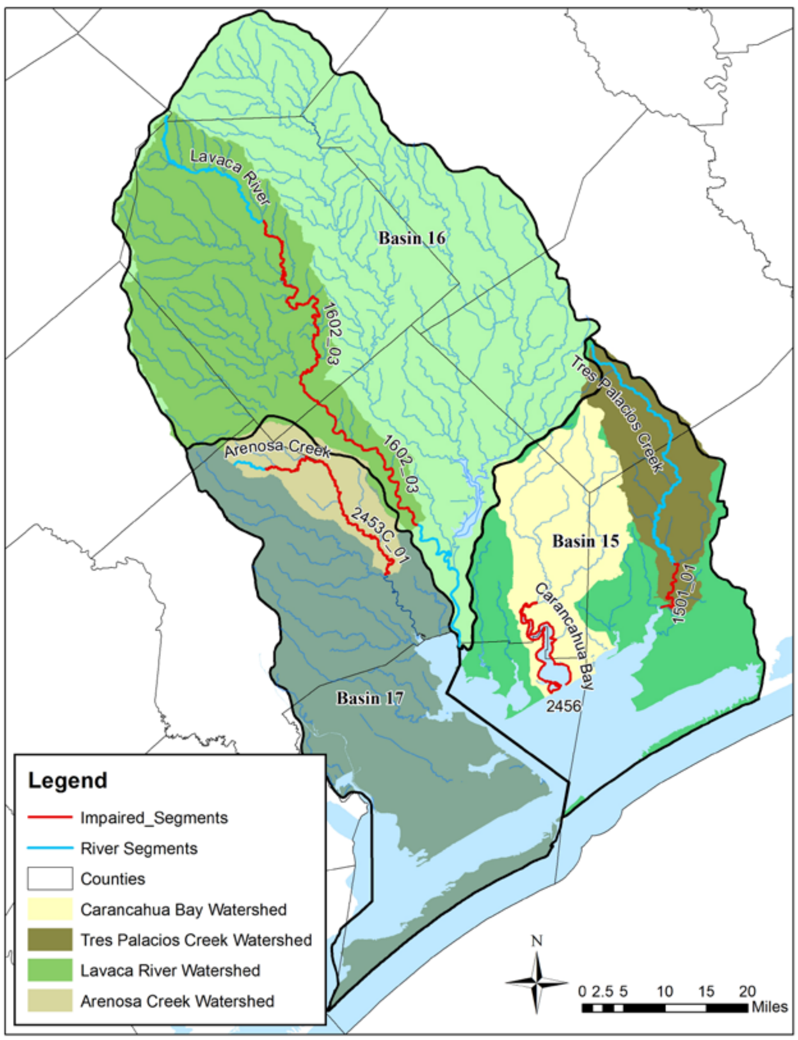

Figure 1. Map showing the Matagorda Bay watershed, major subbasin, impaired water bodies, and their watersheds

In Basin 15, the Tres Palacios Creek Tidal (Segment 1501) begins 1 km upstream of the confluence of Wilson Creek in Matagorda County and flows approximately 9 miles into Tres Palacios Bay. Tres Palacios Creek Above Tidal (Segment 1502) extends from the confluence of Wilson Creek in Matagorda County up to the upstream portion of the creek in Wharton County. At its mouth, the Tres Palacios Creek drains an area of approximately 956 square miles in Calhoun, Jackson, Matagorda, and Wharton counties. The impaired segment and its watershed drain approximately 258 square miles. Of this area, 61% is in Matagorda County and 39% is in Wharton County.

In Basin 16, the Lavaca River is the primary water conveyance to the coast. The river rises in Gonzales County and flows in a southerly direction into and through Lavaca and Jackson Counties before flowing into Lavaca Bay. Water body segments in the basin include the Tidal portion of the Lavaca River, which extends from Lavaca Bay up to the river's confluence with the Navidad River in Jackson County. The Lavaca River Above Tidal (Segment 1602_02) begins at the confluence of Campbell Branch and ends approximately 44 miles later, at the confluence with Beard Branch in Lavaca County while Segment 1602_03 begins at the confluence of Beard Branch and ends approximately 23 miles later, just south of Edna in Jackson County. At its mouth, the Lavaca River drains an area of approximately 2,316 square miles in Calhoun, Colorado, DeWitt, Fayette, Gonzales, Jackson, Lavaca, Victoria, and Wharton counties. The watershed of both impaired segments drains approximately 829 miles in DeWitt (16% of the watershed), Fayette (0.2%), Gonzales (1%), Jackson (11%), Lavaca (71%), and Victoria (0.4%) counties. The basin also contains other water bodies, which are not impaired due to elevated bacteria levels. These include the Navidad River, Lake Texana, East Mustang Creek, West Mustang Creek, Sandy Creek, and Dry Creek.

Within Basin 17, Arenosa Creek (Segment 2453C) is the other impaired water body in the Matagorda Bay watershed and begins at J-2 Ranch Road and ends at the confluence of Garcitas Creek in Victoria County and is approximately 33 miles in length. At its mouth, Arenosa Creek drains approximately 1,045 square miles in Calhoun, DeWitt, Jackson, Lavaca, and Victoria counties. The impaired segment and its watershed drain approximately 161 square miles in DeWitt (0.1% of the watershed), Jackson (45%), Lavaca (3%), and Victoria (52%) counties (Figure 1).

The 2012 Texas Water Quality Integrated Report (TCEQ, 2012) provides the following segment and AU descriptions for the impaired water bodies considered in this document:

- Segment 1501 (AU 1501_01) (Tres Palacios Creek Tidal) - From the confluence with Tres Palacios Bay in Matagorda County to a point 1.0 km (0.6 miles) upstream of the confluence of Wilson creek in Matagorda County

- Segment 1602 (AU 1602_02 and 03) (Lavaca River Above Tidal) – From a point 8.6 km (5.3 miles) downstream of US 59 in Jackson County to a point 5.5 km (3.4 miles) upstream of SH 95 in Lavaca County
- Segment 2453C (AU 2453C_01) (Arenosa Creek) – From Garcitas Creek confluence upstream to J-2 Ranch Road

Watershed Climate and Hydrology

The Matagorda Bay watershed is in the approximate boundary area between climate regions (Larkin & Bomar, 1983). The region's subtropical climate is caused by the "predominant onshore flow of tropical maritime air from the Gulf of Mexico," while the increasing moisture content (from west to east) reflects variations in "intermittent seasonal intrusions of continental air" (Larkin & Bomar, 1983). For the period from 1981 – 2010, average annual precipitation in the Basin 15, 16 and 17 watershed was between 38 to 44 inches. (Figure 2; PRISM, 2012).

At the Victoria Regional Airport, average high temperatures generally peaked in August with an average temperature of 85°F and a typical high of 94.5°F; highs above 100°F are not uncommon and have occurred from April through September. Fair skies generally accompany the highest temperatures of summer when nightly average lows drop to about 75°F. During winter, the average low temperatures typically reach 45°F in January; although below freezing temperatures have occurred from September through April. The wettest month is normally May (4.59 in), and the driest month is normally February (2.24 inches), although some rainfall typically occurs year-round (Figure 2).

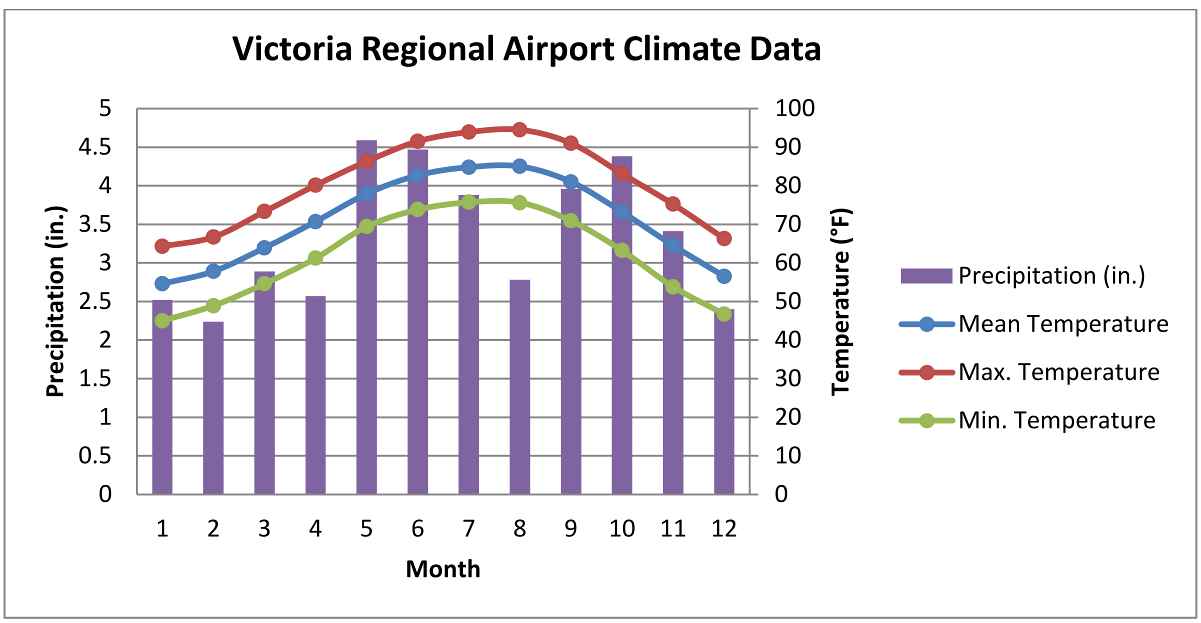

Figure 2. Annual average precipitation (in inches) for Basins 15, 16 and 17 (1981-2010). Source: NOAA (2014)

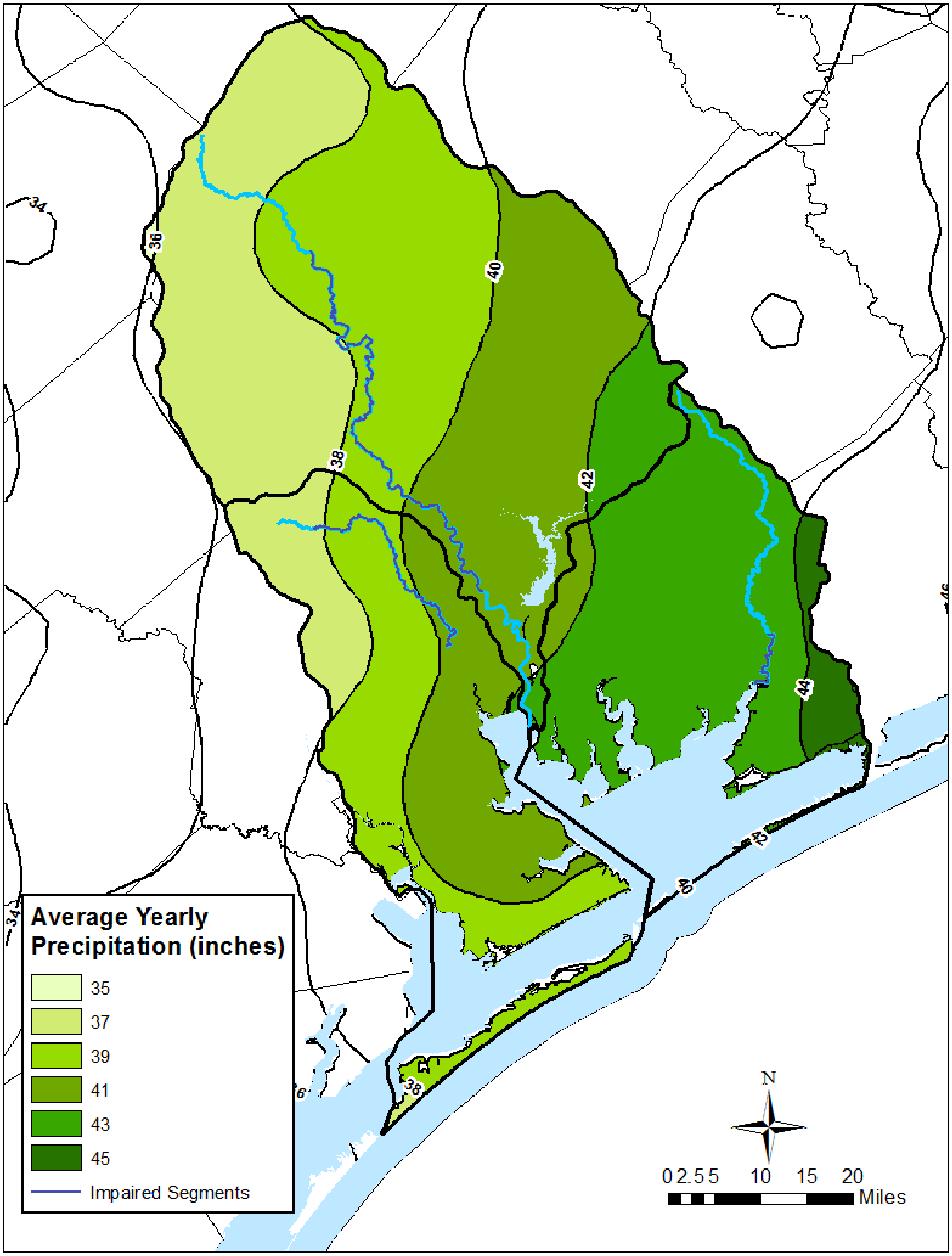

Figure 3. Annual average precipitation (in inches) Basins 15, 16 and 17 (1981-2010).
Source: PRISM (2012)

Watershed Population and Population Projections

According to the 2010 Census (USCB, 2012), the population throughout the Matagorda Bay watershed are generally rural with dispersed cities. In Basin 15 the two major cities are El Campo and Palacios with a total basin population of 58,682. This produces a population density of approximately 61.40 people/mi^2. Basin 16 has the largest population at 137,816 and a population density of 59.51 people/mi^2. The municipalities for Basin 16 are Flatonia, Schulenburg, Shiner, Hallettsville, Yoakum, and Edna. Finally Basin 17 has two major municipalities Port Lavaca and a portion of Victoria. The general population 0f the Basin is 108,328 with a population density of 155 people/mi^2.The population density of the Basins is visually demonstrated below by census block (Figure 4).

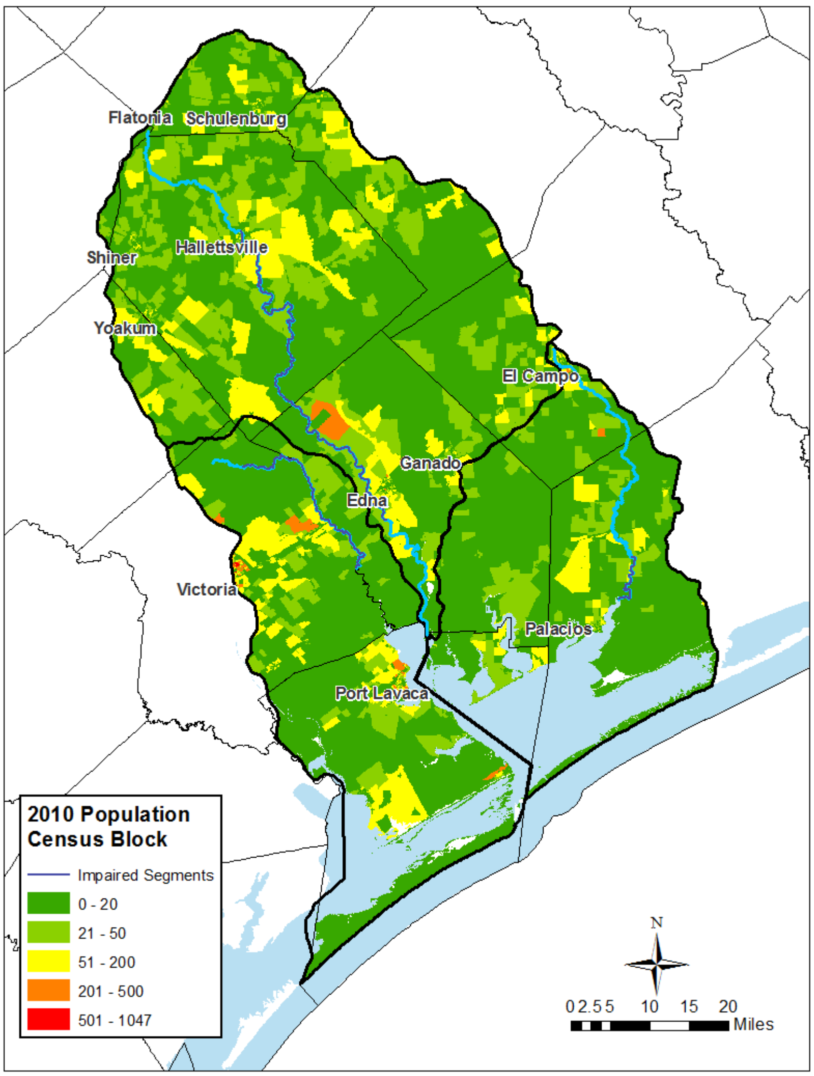

Figure 4. 2010 Population by Census Block. Source: Census information obtained from USCB (2010)

Population projections developed by the Office of the State Demographer and the Texas Water Development Board (TWDB, 2013) indicate that the populations of the ten counties that are included within Basins 15, 16 and17 watersheds (Calhoun, Colorado, Dewitt, Fayette, Gonzales, Jackson, Lavaca, Matagorda, Victoria, Wharton) are expected to increase between 2010 and 2050 with the exception of Lavaca and Fayette counties. The cities of Palacios, El Campo, Flatonia, Schulenburg, Shiner, Hallettsville, Yoakum, Edna, Victoria, and Port Lavaca, all located within the Matagorda Bay watershed, are expected to have the most significant growth. Current population and projected populations for each Basin were determined by taking the population for each county within the watershed and then multiplied by the percentage of the county in the basin thus producing the data in Tables 1 through 3.

Table 1. 2010 Population and 2020 – 2050 Population Projections for counties in the Basin 15 watershed. Source: TWDB (2013)

County	2010 U.S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Percent Increase (2010 - 2050)
Calhoun	2,427	2,575	2,708	2,801	2,878	19%
Jackson	4,723	4,984	5,256	5,459	5,661	20%
Matagorda	36,702	39,042	41,079	42,654	44,251	21%
Wharton	14,830	15,697	16,673	17,513	18,310	23%

Table 2. 2010 Population and 2020 – 2050 Population Projections for counties in the Basin 16 watershed. Source: TWDB (2013)

County	2010 U.S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Percent Increase (2010 - 2050)
Calhoun	35	37	39	40	41	19%
Colorado	20,874	21,448	22,075	22,596	23,460	12%
Dewitt	18,991	19,458	19,994	20,327	20,792	9%
Fayette	24,554	24,333	24,453	24,206	24,210	-1%
Gonzales	19,807	21,413	23,226	25,005	27,079	37%
Jackson	7,276	7,678	8,097	8,410	8,721	20%
Lavaca	19,115	18,862	18,981	18,886	18,804	-2%
Victoria	714	773	826	870	913	28%
Wharton	26,450	27,999	29,739	31,236	32,659	23%

Table 3. 2010 Population and 2020 – 2050 Population Projections for counties in the Basin 17 watershed. Source: TWDB (2013)

County	2010 U.S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Percent Increase (2010 - 2050)
Calhoun	18,919	20,071	21,110	21,834	22,433	19%
Dewitt	1,106	1,133	1,165	1,184	1,211	9%
Jackson	2,075	2,190	2,309	2,399	2,487	20%
Lavaca	148	146	147	146	145	-2%
Victoria	86,079	93,259	99,664	104,896	110,100	28%

Routine Water Quality Monitoring Data Review

The TCEQ, in order to uphold sections 303(d) and 304(a) of the Clean Water Act, conducts periodic monitoring of surface water quality throughout Texas and identifies water bodies that do not meet the water quality standards. These water quality standards are listed for each segment and can be found in the Texas Surface Water Quality Standards (TSWQS) portion of the Texas Administrative Code, Title 30, Chapter 307 (TCEQ 2012). For water body assessments, the TCEQ uses data from the most recent seven year period and requires a minimum of 10 data points (except bacteria which requires 20 data points) to be collected within the assessed period. Recent monitoring within the Matagorda Bay watershed has occurred at six TCEQ monitoring stations listed in Table 4 (Figure 5) on intermittent time scales. Data summaries for each of these sites are included in Tables 5A through 5H. .

Data included in Texas' 2012 water quality assessment indicates that several water body segments within the Matagorda Bay watershed do not support one or more of their designated uses. Segment 1501, represented by stations 12515 and 20636 and Segment 1602, represented by stations 12524, 12525 and 12527 both have bacterial impairments that do not support contact recreation uses and dissolved oxygen impairments that impair their aquatic life uses. Segment 2453C, represented by station 13295, has a bacterial impairment for contact use.

Analysis of Bacteria Data

All segments in the Matagorda Bay watershed project area are designated for primary contact recreation uses and must maintain fecal indicator bacteria levels at or below the designated level. In tidal waters, enterococci is the preferred fecal indicator bacteria. To be supportive of contact recreation uses, the geometric mean of recorded enterococci levels must be at or below 35 cfu/100 mL. Segments 1501 and 2456 must adhere to this standard and are currently listed as impaired due to their exceedance of this standard. In non-tidal segments, *E. coli* is used as the fecal indicator bacteria and the geometric mean of recorded numbers must be at or below 126 cfu/100mL. Segment 1602 and 2453C currently exceed this criterion and are listed as impaired for bacteria. This standard is in place as a measure that is protective of human health. When fecal indicator bacterial levels above this standard exist, the expected number of gastrointestinal illnesses contracted by swimmers increases.

Analysis of Dissolved Oxygen (DO) Data

DO is a measurement of the amount of dissolved oxygen available in the water and is essential for determining a water body's ability to support aquatic life. Because DO is temperature dependent, the critical period for DO measurement is July 1st to September 20th as that is generally the season with highest temperatures, lowest stream flow and historically the timeframe for lowest DO measurements. For all three segments, the dissolved oxygen criterion is 5.0 mg/L as a 24-hour average for aquatic life purposes. Depending on the designated aquatic life use category, minimum DO levels in the Matagorda Bay watershed should not be less than 3.0 mg/L in perennial streams, 4.0 mg/L in tidal streams more than 25 percent of the time with high and exceptional aquatic life use designations respectively. According to the 2012 Texas Integrated Report, segments 1501 and 1602 are considered impaired due to depressed DO levels. All other water bodies either meet their designated standards or were not assessed.

Data Acquisition

Ambient water quality data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) on 24 October 2013. To acquire this large data set, TCEQ's Data Management and Assessment team extracted and sent all field, conventional and bacteriological data from TCEQ's surface water quality monitoring stations within the Matagorda Bay watershed area. This included all data that was utilized in the 2012 Texas Integrated Report.

Lavaca River at FM 616 downstream of Navidad River Confluence

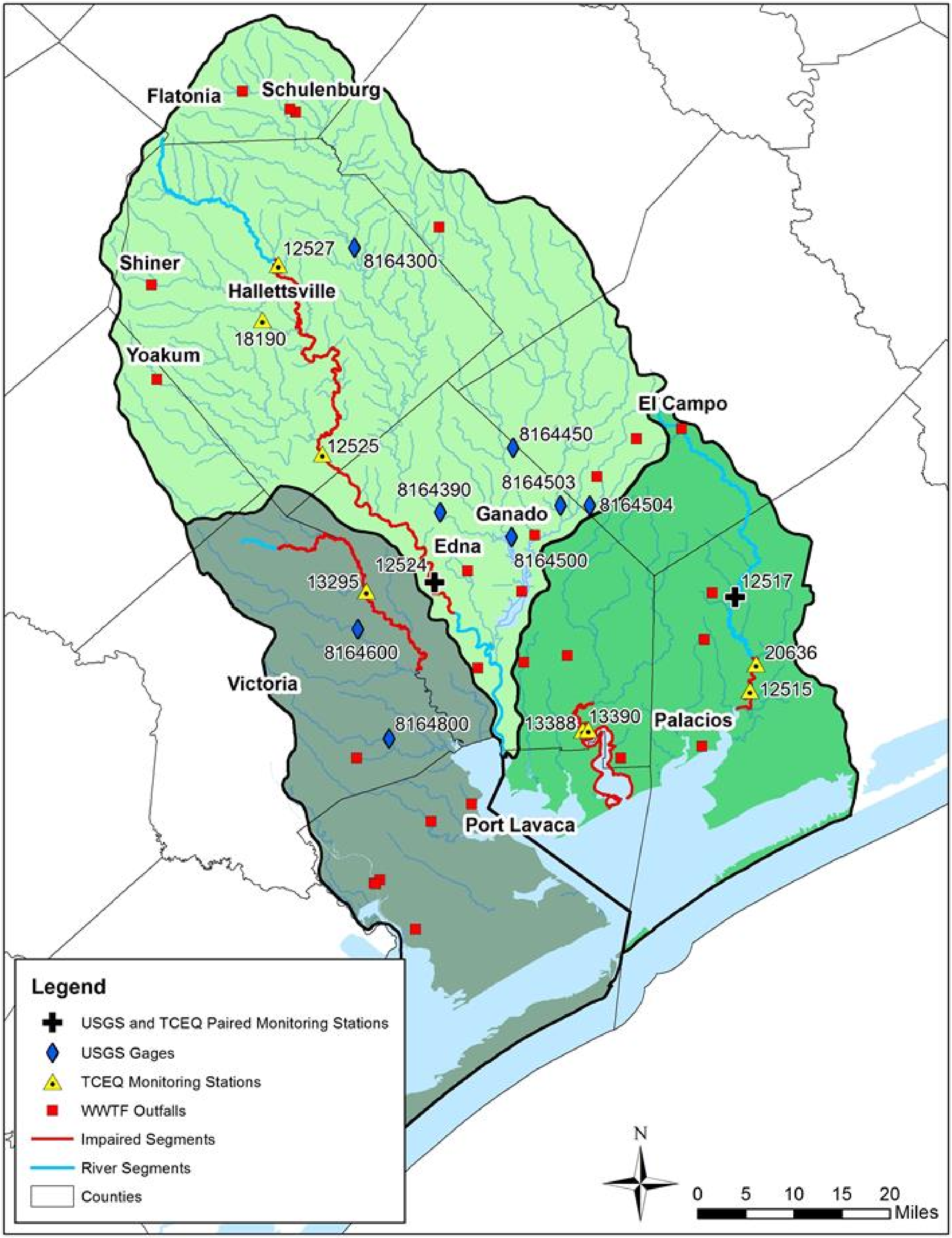

Figure 5. Wastewater treatment facilities (WWTFs), TCEQ surface water quality monitoring stations, and USGS stream gage stations across the watershed. Source: Permitted outfalls from TCEQ (2012a); TCEQ stations from TCEQ (2012b); USGS stream gage stations from USGS (2013)

Table 4. TCEQ sampling station IDs and names

TCEQ Station ID	TCEQ Station Name
12515	Tres Palacios Creek at FM 521
12517	Tres Palacios Creek at FM 457
12524	Lavaca River US 59 Southwest of Edna
12525	Lavaca River at SH 111
12527	Lavaca River at US 77 in Hallettsville
13295	Arenosa Creek at CR 103 North of Inez
13388	Carancahua Bay at SH 35
13390	Carancahua Bay near SH 35 Boat Ramp
18190	Rocky Creek at Lavaca CR 387
20636	Tres Palacios Creek 1.02 km downstream of its confluence with Wilson Creek

Tres Palacios Creek at the FM 521 Boat Ramp

Table 5A. Historic water quality data collected at the TCEQ Monitoring Site 12515 on Tres Palacios Creek at FM 521 from Aug. 1973 to Mar. 2014 (Segment 1501_01)

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard (*Screening Criteria*)	Impaired/ Concern ☨☨
Water Temp (°C)	411	7.34	33.2	23.71		35.00 maximum	
Dissolved Oxygen (mg/L)	372	0.56	16.3	6.89		5.0/4.0 (grab avg/min)[χ]	Impaired
pH (standard units)	373	6.5	9.9	7.82		6.5 - 9.0 range	
Ammonia Nitrogen (mg/L)	250	0.01	2	0.12		*0.46 (>20% exceedance)*[y]	
Nitrate Nitrogen (mg/L)	184	0.5	100	15.57		*1.10 (>20% exceedance)*[y]	
Total Phosphorus (mg/L)	51	0	3.4	0.68		*0.66 (>20% exceedance)*[y]	
Orthophosphorus (mg/L)	48	0.03	1.13	0.35		*0.46 (>20% exceedance)*[y]	
Enterococci (cfu/100mL)	160	1	24,000		105.68	35.00 geometric mean	Impaired
Chlorophyll-a (μg/L)	184	0.5	100	15.57		*21.00 (>20% exceedance)*[y]	Concern

Source: TCEQ (2013b)

☨☨ the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Table 5B. Historic water quality data collected at the TCEQ Monitoring Site 20636 located 1.02 km downstream of the Tres Palacios Creek (Segment 1501_01) confluence with Wilson Creek from Sept. 2009 to July 2012

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard (*Screening Criteria*)	Impaired/ Concern ††
Water Temp (°C)	18	9.70	31.40	22.70		35.00 maximum	
Dissolved Oxygen (mg/L)	18	3.00	10.90	6.18		5.0/4.0 (grab avg/min)[χ]	Impaired
pH (standard units)	18	6.60	8.40	7.76		6.5 - 9.0 range	
Ammonia Nitrogen (mg/L)	18	0.02	0.90	0.15		*0.46 (>20% exceedance)*[y]	
Nitrate Nitrogen (mg/L)	18	0.02	2.33	0.73		*1.10 (>20% exceedance)*[y]	
Total Phosphorus (mg/L)	17	0.08	0.59	0.30		*0.66 (>20% exceedance)*[y]	
Orthophosphorus (mg/L)	9	0.04	0.43	0.19		*0.46 (>20% exceedance)*[y]	
Enterococci (cfu/100mL)	18.00	10	1.3×10^{6}		148.92	35.00 geometric mean	Impaired
Chlorophyll-a (µg/L)	18	1.00	38.00	10.67		*21.00 (>20% exceedance)*[y]	Concern

Source: TCEQ (2013b)

†† the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Table 5C. Historic water quality data collected at the TCEQ Monitoring Site 12524 on the Lavaca River at US 59 from Sept. 1968 to Nov. 2013 (Segment 1602_03)

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard (*Screening Criteria)*	Impaired/ Concern ☨☨
Water Temp (°C)	341	6	31.8	22.14		32.80 maximum	
Dissolved Oxygen (mg/L)	328	3	13.6	8.13		5.0/3.0 (grab avg/min)[χ]	
pH (standard units)	284	6.51	9	7.96		6.5 - 9.0 range	
Total Dissolved Solids (mg/L)	10	154	1,140	469.30		700.00 (annual average)	
Ammonia Nitrogen (mg/L)	140	0.01	8.2	0.14		*0.33 (>20% exceedance)*[y]	
Nitrate Nitrogen (mg/L)	67	0.01	2.6	0.27		*1.95 (>20% exceedance)*[y]	
Total Phosphorus (mg/L)	24	0	0.98	0.43		*0.69 (>20% exceedance)*[y]	
Sulfate (mg/L)	185	0.5	74.5	18.48		100.00 (annual average)	
Chloride (mg/L)	32	20	800	95.76		200.00 (annual average)	
E. coli (cfu/100mL)	51	4	3,300		230.21	126 geometric mean	Impaired
Chlorophyll-a (µg/L)	24	4	14	7.67		*14.1 (>20% exceedance)*[y]	

Source: TCEQ (2013b)

☨☨ the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Table 5D. Historic water quality data collected at the TCEQ Monitoring Site 12525 on the Lavaca River at SH 111 from Feb. 1972 to Nov. 2013 (Segment 1602_03)

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard (*Screening Criteria*)	Impaired/ Concern ϯϯ
Water Temp (°C)	175	5	31.9	21.83		32.80 maximum	
Dissolved Oxygen (mg/L)	176	5	12.7	8.83		5.0/3.0 (grab avg/min)[χ]	
pH (standard units)	174	7.1	8.7	8.00		6.5 - 9.0 range	
Ammonia Nitrogen (mg/L)	63	0.01	0.23	0.07		*0.33 (>20% exceedance)*[y]	
Nitrate Nitrogen (mg/L)	42	0.02	1.27	0.23		*1.95 (>20% exceedance)*[y]	
Total Phosphorus (mg/L)	7	0.48	1.04	0.69		*0.69 (>20% exceedance)*[y]	
Orthophosphorus (mg/L)	2	0.17	0.28	0.23		*0.37 (>20% exceedance)*[y]	
Sulfate (mg/L)	61	2.3	832	50.32		100.00 (annual average)	
Chloride (mg/L)	18	13	83	57.67		200.00 (annual average)	
E. coli (cfu/100mL)	15	1	48		5.76	126 geometric mean	Impaired
Chlorophyll-a (µg/L)	13	1	20	7.58		*14.1 (>20% exceedance)*[y]	

Source: TCEQ (2013b)

ϯϯ the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

* this is a 'carry forward' impairment meaning that it is an impairment that is based on historic data due to currently insufficient data records

Table 5E. Historic water quality data collected at the TCEQ Monitoring Site 12527 on the Lavaca River at US 77 from Nov. 1973 to Sept. 2013 (Segment 1602_02)

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard (*Screening Criteria)*	Impaired/ Concern ☨☨
Water Temp (°C)	75	7.6	36.6	22.26		32.80 maximum	
Dissolved Oxygen (mg/L)	74	5	17.8	10.197		5.0/3.0 (grab avg/min)[χ]	
pH (standard units)	73	7.2	8.5	7.911		6.5 - 9.0 range	
Ammonia Nitrogen (mg/L)	64	0.01	0.68	0.1208		*0.33 (>20% exceedance)*[y]	
Nitrate Nitrogen (mg/L)	55	0.02	11.2	0.7683		*1.95 (>20% exceedance)*[y]	
Total Phosphorus (mg/L)	23	0.03	1.8	0.4352		*0.69 (>20% exceedance)*[y]	
Orthophosphorus (mg/L)	23	0.03	1.01	0.1948		*0.37 (>20% exceedance)*[y]	
Chloride (mg/L)	1	1030	1030	1030		200.00 (annual average)	
Sulfate (mg/L)	64	0	63.3	31.422		100.00 (annual average)	
E. coli (cfu/100mL)	36	3	2600		114.994	126 geometric mean	Impaired
Chlorophyll-a (µg/L)	25	4	25.1	7.596		*14.1 (>20% exceedance)*[y]	

Source: TCEQ (2013b)

☨☨ the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Table 5F. Historic water quality data collected at the TCEQ Monitoring Site 13295 on Arenosa Creek (Segment 2453C_01) at CR 103 off US 59 from Sept. 1988 to Aug. 2003

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard (*Screening Criteria)*	Impaired/ Concern ☨☨
Dissolved Oxygen (mg/L)	120	1.03	13.48	5.48		3.0/2.0 (grab avg/min)[χ]	
Ammonia Nitrogen (mg/L)	17	0.02	2.39	0.22		*0.33 (>20% exceedance)*[y]	
Nitrate Nitrogen (mg/L)	2	0.01	0.35	0.18		*1.95 (>20% exceedance)*[y]	
Total Phosphorus (mg/L)	34	0.04	1.11	0.25		*0.69 (>20% exceedance)*[y]	
E. coli (cfu/100mL)	32	6	4,838		197.60	126 geometric mean	Impaired
Chlorophyll-a (µg/L)	34	1	68	9.95		*14.1 (>20% exceedance)*[y]	

Source: TCEQ (2013b)

☨☨ the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Table 5G. Historic water quality data collected at the TCEQ Monitoring Site 13388 on Carancahua Bay at SH 35 between Port Lavaca and Palacios from Sept. 1973 to Dec. 2013 (Segment 2456_02)

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern ††
Water Temp (°C)	194	8.5	34	23.97		35.00 maximum	
Dissolved Oxygen (mg/L)	196	5	15.3	8.34		5.00/4.00 (grab avg/min)[χ]	
pH (standard units)	193	6.42	9.5	8.23		6.5 - 9.0 range	
Ammonia Nitrogen (mg/L)	143	0	0.67	0.08		*0.10 (>20% exceedance)*[y]	
Nitrate Nitrogen (mg/L)	75	0.01	2.6	0.28		*0.17 (>20% exceedance)*[y]	
Total Phosphorus (mg/L)	46	0	1.16	0.52		*0.21 (>20% exceedance)*[y]	Concern
Orthophosphorus (mg/L)	46	0.03	0.77	0.21		*0.19 (>20% exceedance)*[y]	
Enterococci (cfu/100mL)	37	10	10,111		105.28	35.00 cfu/100mL	Impaired
Chlorophyll-a (µg/L)	107	1	77.4	14.73		*11.60 (>20% exceedance)*[y]	Concern

Source: TCEQ (2013b)

†† the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Table 5H. Historic water quality data collected at the TCEQ Monitoring Site 13390 on Carancahua Bay off SH 35 at boat ramp, 2 mi. west of 2456.0100 from Nov. 1999 to Aug. 2001 (Segment 2456_02)

Parameter	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard	Impaired/ Concern ☨☨
Water Temp (°C)	4	20.10	29.40	26.23		35.00 maximum	
Dissolved Oxygen (mg/L)	3	5.30	7.10	6.37		5.00/4.00 (grab avg/min)[χ]	
pH (standard units)	4	7.60	8.20	7.85		6.5 - 9.0 range	
Enterococci (cfu/100mL)	3	20	220		56.04	35.00 cfu/100mL	Impaired

Source: TCEQ (2013b)

☨☨ the listed impairment/concern is according to the 2012 303(d) List

[χ] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Load Duration Curve Analysis

Load Duration Curves (LDCs) were used to evaluate the relationship between recorded instream *E. coli* levels and stream flow rates in the non-tidal portions of the basin. LDCs utilize paired stream flow records and pollutant data when available (e.g. *E. coli* and stream flow were both available on the same date and time). LDCs are commonly used simple analytical tools (Babbar-Sebens and Karthikeyan 2009) that are supported by USEPA as an effective method for estimating needed pollutant loading reductions to achieve water quality standards (Morrison and Bonta 2008).

LDCs are constructed by first developing a flow duration curve (FDC). FDCs relate measured stream flow to the percent of time a specific flow value is met or exceeded within the evaluated time period. Available stream flow data are sorted from largest flow value to smallest and plotted versus percent of days that a specific flow level is expected to occur. Flow categories are developed to partition data and commonly include high flows, moist conditions, mid-range flows, dry conditions, and low flows. Category breaks can be adjusted to fit natural breaks in the recorded flow record.

The FDC is then multiplied by the water quality standard and the appropriate unit conversion to establish the maximum allowable pollutant load, or the TMDL line. The monitored loading is approximated by plotting paired pollutant concentration (*E. coli* in this case) data with monitored recorded stream flow levels. Once plotted, the majority of *E. coli* data should be below the TMDL line to support the applicable water quality standard; however, this is often not the case. The distribution of monitored data allows the type of pollution responsible for the excessive *E. coli* loadings to be identified. If exceedances are to the left side of the graph and in the high flow or moist condition categories, then nonpoint source pollution or sediment re-suspension driven by rain events are the primary cause of pollutant loading. Alternatively, exceedances in the dry condition and low flow categories implicate point source pollution, direct deposition, or streambed disturbance as the primary problems. LDCs do not enable specific sources of pollution to be identified nor do they allow the timing of the pollution event to be determined.

LDCs also enable the amount of pollutant load reduction needed to achieve the water quality goal to be estimated. A regression line plotted through these data points produces a graphical representation of the overall *E. coli* load carried by the stream. Using the average difference between the TMDL line and the estimated *E. coli* load within flow categories illustrates either the amount of pollutant load reduction needed to meet the applied water quality standard or the amount of assimilative capacity that remains within the stream to be estimated.

Within the basins, TCEQ monitoring stations 12517, 12524, 12525, 12527, and 18190 had sufficient *E. coli* concentration data paired with measured stream flow to develop load duration curves. LDCs for each of these sites are presented in Figures 6 – 11 and estimated loadings and load reductions are presented in Tables 6 - 11. These figures illustrate measured *E. coli* loads at each station in relation to flow conditions at the time and establish a baseline understanding of the pollutant loading mechanisms at work at each site. It should be noted that TCEQ assessments are usually not conducted on an individual sampling site. Instead, data are aggregated within assessment units and may include data from one or more sampling locations. LDCs cannot be developed in this same manner due to changes in flow regimes from site to site. Therefore, LDCs are developed only for individual sampling sites.

LDCs were not conducted through this project in tidal waters and bays due to insufficient or non-existent stream flow data. LDCs can be developed for these waters, but a more complicated modified approach must be employed to quantify flow in these systems. Plans are in place to develop these modified LDCs on tidal portions of Tres Palacios Creek in the future.

Loading Assessments

Station 12517 on Tres Palacios Creek at FM 456 had the most extensive data record available for developing LDCs; however, it is not located within an impaired portion of the creek. In total, 103 *E. coli* data points existed that also had stream flow rates associated with them. Additionally, USGS gage 08162600 is also located at this site. Daily mean flow values were acquired from the past 15 years and used to develop the LDC. The inclusion of this USGS data produces an extremely accurate record of flow and estimation of the TMDL for this site. The LDC revealed that the bulk of *E. coli* loadings occurring above the allowable level occurred during high flows and moist conditions suggesting that nonpoint source pollution and/or sediment resuspension within the channel are the primary pollutant sources. Under mid-range, dry and low flow conditions, *E. coli* loads are typically within allowable levels suggesting that point sources and direct depositions to the water body are not overly problematic. That said, exceedances do exist within all flow categories.

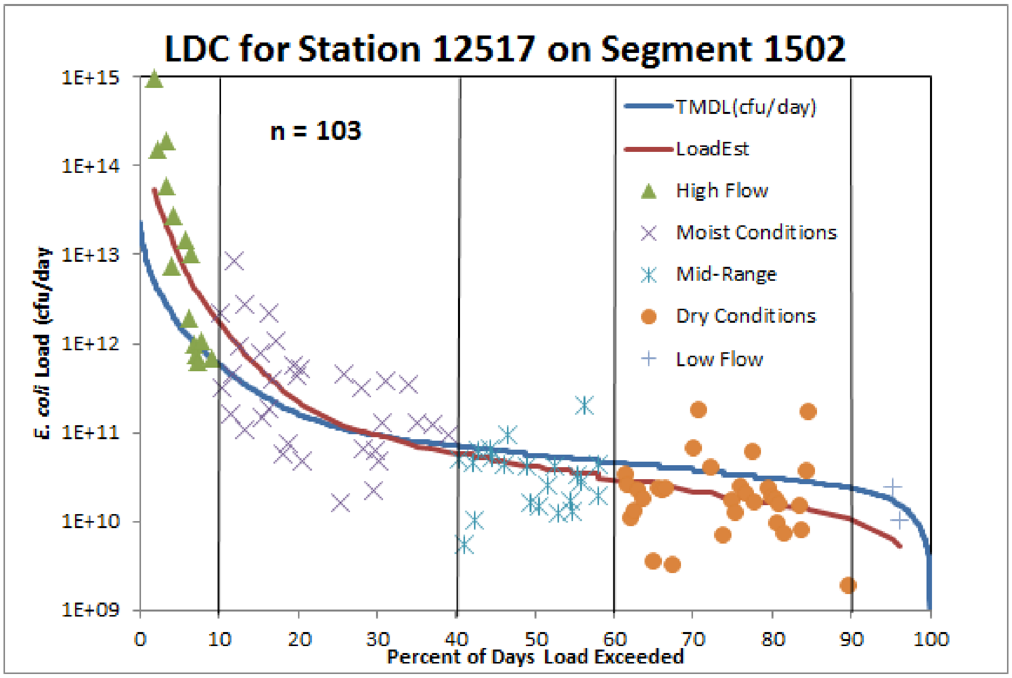

Figure 6. LDC for Station 12517 using all available *E. coli* data (1999 – 2013)

Table 6. Percent based load reductions needed to achieve water quality standards, daily and annual *E. coli* loadings at Station 12517.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	80.69	1.03E+14	3.76E+16
Moist Conditions	10-40%	27.30	7.27E+11	2.65E+14
Mid-Range	40-60%	NA	4.25E+10	1.55E+13
Dry Conditions	60-90%	NA	3.00E+10	1.09E+13
Low Flow	90-100%	NA	1.75E+10	6.39E+12

Station 12524 on the Lavaca River at US 59 had a total of 48 *E. coli* data points with associated stream flow data. USGS gage 08164000 is also located at this site and produced a total of 5,714 daily mean flow values were acquired and used to develop the LDC thus yielding an accurate flow record and approximation of the TMDL for this site. The LDC revealed that the *E. coli* loadings were approximately evenly distributed above the allowable level during all flow conditions. This suggests that nonpoint source pollution and/or sediment resuspension within the channel as well as point sources and direct depositions to the water body are all contributors to the overall pollutant load at this site.

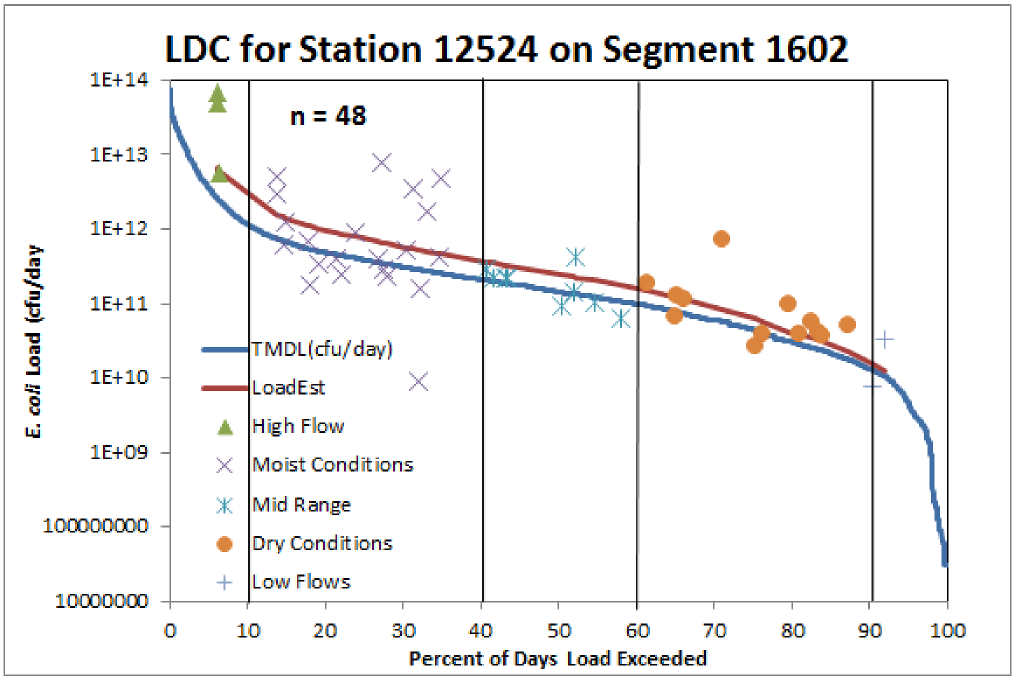

Figure 7. LDC for Station 12524 using all available *E. coli* data (2001 – 2013)

Table 7. Percent based load reductions needed to achieve water quality standards, daily and annual *E. coli* loadings at Station 12524.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	60.01	4.13E+13	1.51E+16
Moist Conditions	10-40%	48.69	1.57E+12	5.73E+14
Mid Range	40-60%	41.45	1.98E+11	7.24E+13
Dry Conditions	60-90%	29.61	1.22E+11	4.46E+13
Low Flows	90-100%	16.57	2.00E+10	7.31E+12

Station 12525 on the Lavaca River at SH 111 had 21 *E. coli* data points with associated stream flow data available. An additional 42 stream flow readings were also available and used to improve the FDC. Under high, moist and mid-range flow conditions, the LDC illustrated that the bulk of *E. coli* loadings were distributed above the allowable level suggesting that nonpoint source pollution and/or sediment resuspension within the channel are the primary pollutant sources under these conditions. Under dry and low flow conditions, measured loads are more evenly spread around the allowable load, which suggests point sources and direct *E. coli* deposition are not extremely problematic.

However, the available data set is quite limited thus decreasing confidence in these results.

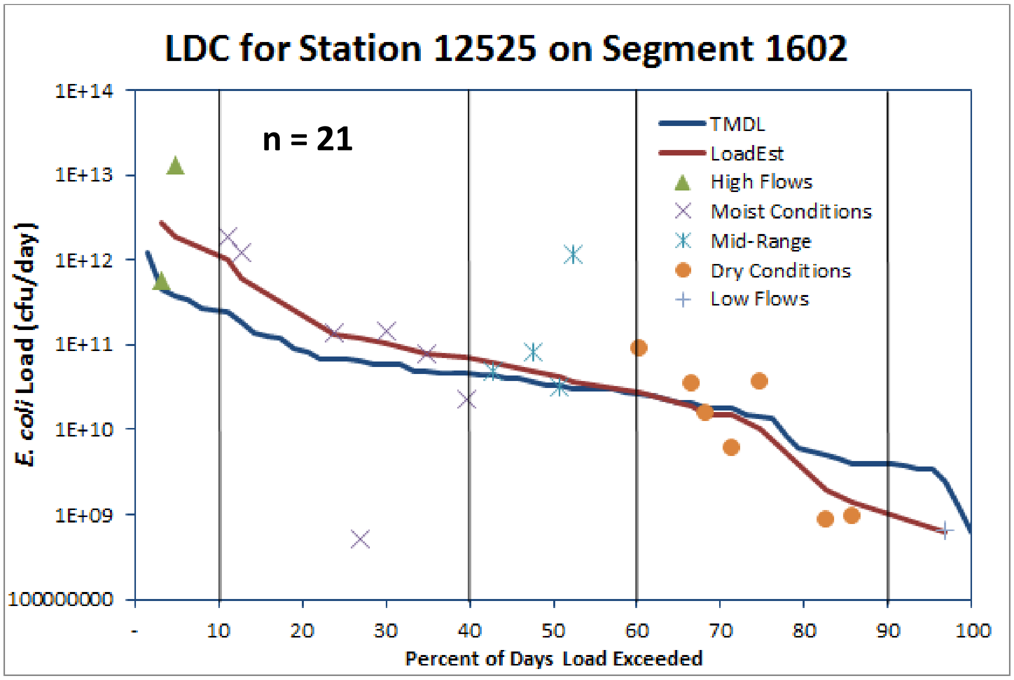

Figure 8. LDC for Station 12525 using all available *E. coli* data (2008 – 2013)

Table 8. Percent based load reductions needed to achieve water quality standards, daily and annual *E. coli* loadings at Station 12525.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	82.01	2.31E+12	8.42E+14
Moist Conditions	10-40%	50.11	3.03E+11	1.10E+14
Mid-Range	40-60%	22.33	4.73E+10	1.73E+13
Dry Conditions	60-90%	NA	1.28E+10	4.68E+12
Low Flows	90-100%	NA	6.34E+08	2.31E+11

Station 12527 on the Lavaca River at US 77 had 34 *E. coli* data points with associated stream flow data available. An additional 49 stream flow readings were also available and were used to enhance the FDC. Under high, moist and mid-range flow conditions, the LDC illustrated that *E. coli* loadings were distributed almost evenly around the allowable level. The load regression calculated for these flow categories is lower than the allowable load suggesting no needed *E. coli* reduction to meet applicable standards; however, the plotted data indicate that the actual load may be closer to the TMDL line plotted below. Therefore, nonpoint source pollution and/or sediment resuspension within the channel can be considered somewhat problematic under these flow conditions. During dry conditions, measured *E. coli* loads are largely within allowable levels except for loads measured under low flows are the opposite. This suggests that point sources and/or direct *E. coli* deposition could be problematic at this site. The quantity of data available at this site is quite limited though, especially under higher flow conditions, thus decreasing confidence in these results.

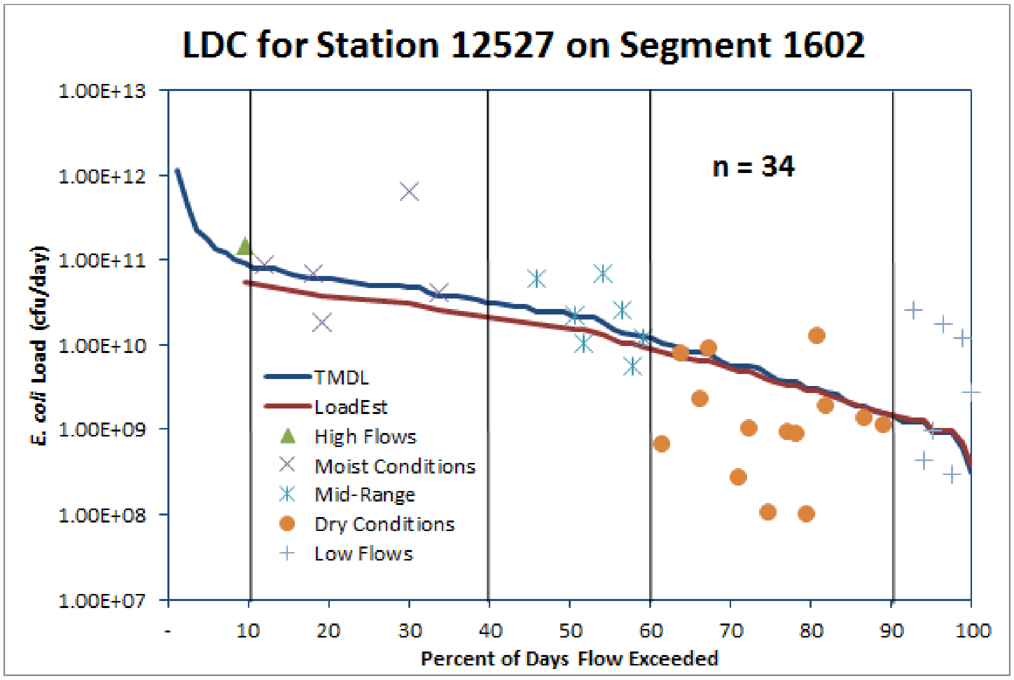

Figure 9. LDC for Station 12527 using all available *E. coli* data (2004 – 2013)

Table 9. Percent based load reductions needed to achieve water quality standards, daily and annual *E. coli* loadings at Station 12527.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	NA	5.43E+10	1.98E+13
Moist Conditions	10-40%	NA	3.60E+10	1.32E+13
Mid-Range	40-60%	NA	1.30E+10	4.75E+12
Dry Conditions	60-90%	NA	4.28E+09	1.56E+12
Low Flows	90-100%	7.68	9.38E+08	3.43E+11

Station 18190 on Rocky Creek at Lavaca County Road 387 had 25 *E. coli* data points with associated stream flow data available. This station is not within an impaired stream segment and is a tributary of the Lavaca River. Only one additional stream flow reading was available and only marginally improved the FDC. Under all flow conditions, measured *E. coli* loadings were distributed above the allowable level. This suggests that nonpoint source pollution and/or sediment re-suspension within the channel, along with point sources and direct deposition are the primary pollutant sources impacting this site. The limited amount of data available does decrease the utility of these results though.

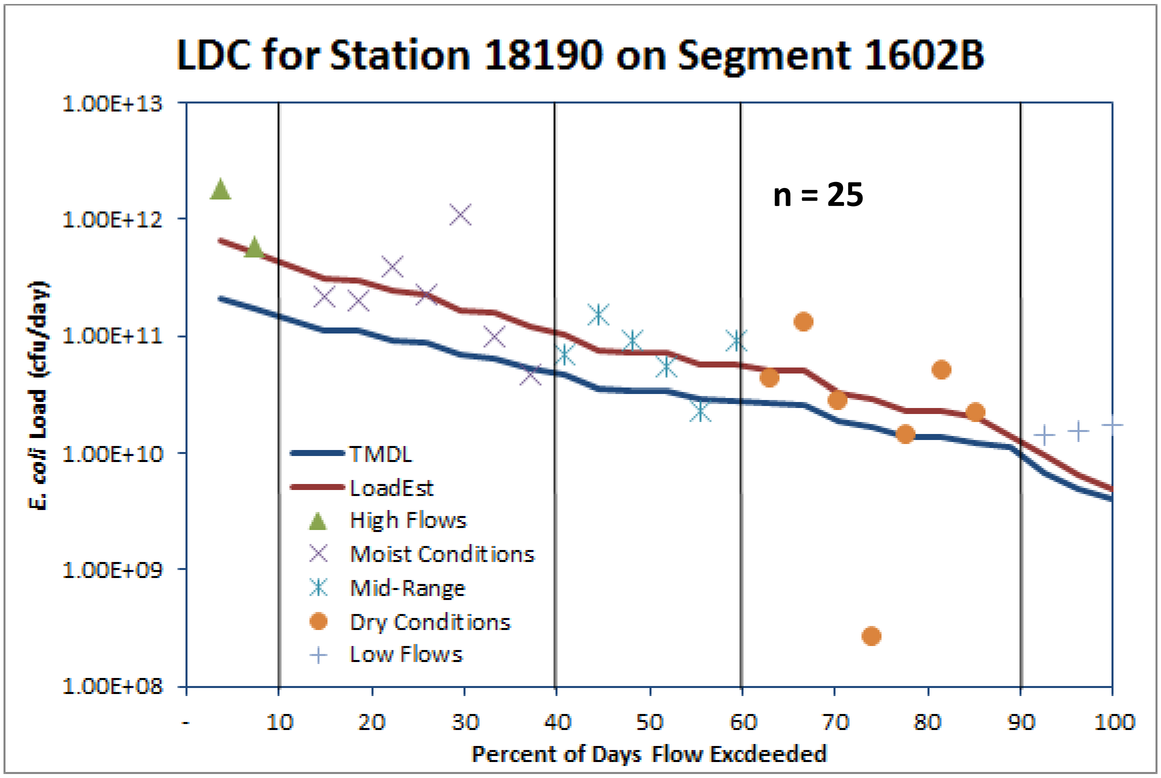

Figure 10. LDC for Station 18190 using all available *E. coli* data (2004 – 2011)

Table 10. Percent based load reductions needed to achieve water quality standards, daily and annual *E. coli* loadings at Station 18190.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	68.09	5.90E+11	2.15E+14
Moist Conditions	10-40%	60.85	2.18E+11	7.95E+13
Mid-Range	40-60%	51.77	7.19E+10	2.62E+13
Dry Conditions	60-90%	43.19	3.26E+10	1.19E+13
Low Flows	90-100%	23.81	6.98E+09	2.55E+12

Station 13295 on Arenosa Creek north of Inez had 27 *E. coli* data points with associated stream flow data available. Only one additional stream flow reading was available while six additional data records exist for *E. coli* with measured flow recorded as 0.00 cfs. They could not be used to estimate a load, but were accounted for in the LDC in the 'no flows' category. High, moist and mid-range flow conditions, measured *E. coli* loadings were distributed above the allowable level suggesting that nonpoint source pollution and/or sediment resuspension within the channel are the primary pollutant sources impacting this site. The limited amount of data available does decrease the utility of these results as does the age of the data.

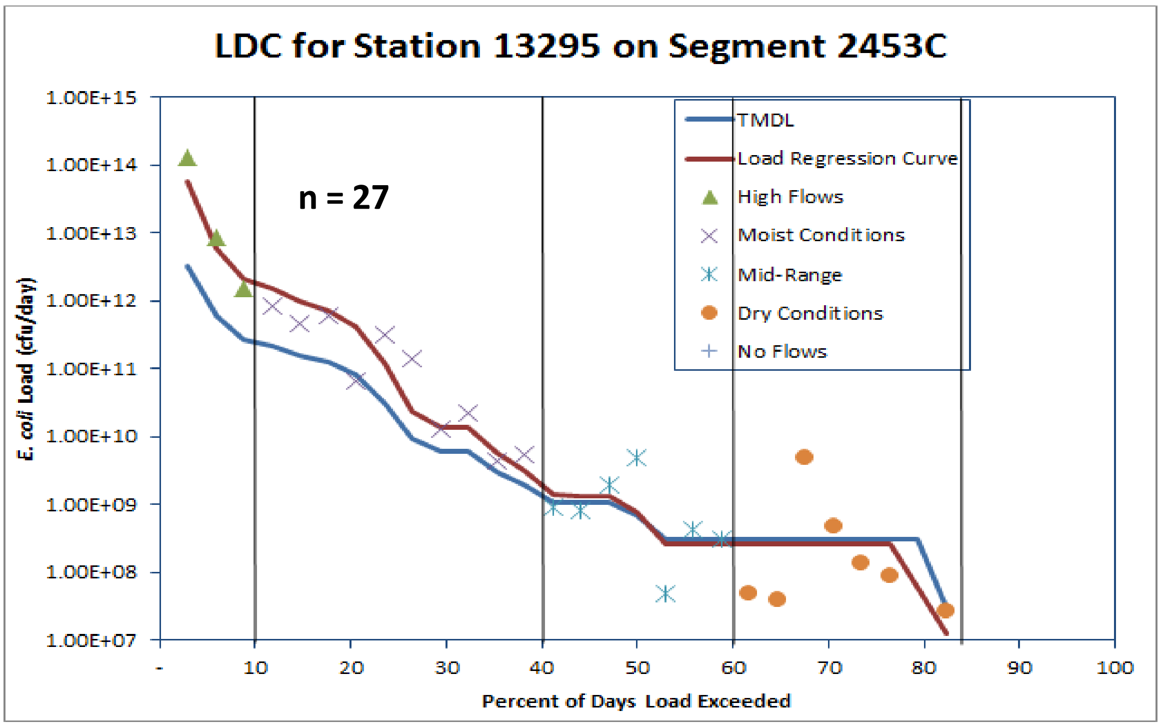

Figure 11. LDC for Station 13295 using all available *E. coli* data (2000 – 2003)

Table 11. Percent based load reductions needed to achieve water quality standards, daily and annual *E. coli* loadings at Station 13295.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	90.20	2.13E+13	6.82E+15
Moist Conditions	10-40%	66.09	3.81E+11	1.96E+14
Mid-Range	40-60%	5.03	8.10E+08	1.50E+13
Dry Conditions	60-84%	NA	2.33E+08	7.10E+12
No Flows	84-100%	N/A	N/A	N/A

Land Use

The land use/land cover data for the watersheds of the Matagorda Bay watershed was obtained from the 2011 National Land Cover Database (U.S. Geological Survey), and is displayed in Figure 12. This data set is based on Landsat imagery collected at 30-meter resolution and provides spatial representation of land surface characteristics such as vegetative cover or impervious cover. The watershed was subdivided into eight different land use/land cover categories described below:

- **Shrub/Scrub** – Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation.
- **Herbaceous** - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
- **Hay/Pasture** - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
- **Cultivated Crops** - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
- **Developed** - Includes areas of constructed materials (residential/commercial), impervious surfaces, parks, and golf courses. Impervious surfaces account for 20 to 100 percent of total cover.
- **Forest** - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Includes deciduous and evergreen species.
- **Wetlands** - Areas where forest, shrubland vegetation and/or perennial herbaceous vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Barren Land (Rock/Sand/Clay)** - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

- **Open Water** - All areas of open water, generally with less than 25% cover of vegetation or soil.

As displayed in Table 12, and in Figure 12, the Matagorda Bay watershed and each of the impaired subbasins within watershed are largely rural in nature. Dominant land uses in the watershed include hay/pastures (35.4%), cultivated crops (20.2%), forests (13.6%), and wetlands (9.7%). The distribution of these land covers is not even across the watershed. Cropland and wetlands are more prevalent in the coastal portions of the watershed while hay/pastures and forests are more common in its middle and upper extents. Development across the watershed is largely limited to population centers and areas immediately surrounding them. However, the recent eruption of oil and gas production throughout the Eagle Ford Shale area has certainly increased the amount of barren and developed area in the watershed. Quantifying this area could not be done with this land use/land cover layer but can be completed with recent aerial imagery. Table 11 also illustrates land use/land cover acreages and percentages within each of the impaired watershed subbasins.

Pastures and riparian forested areas are common throughout the watershed

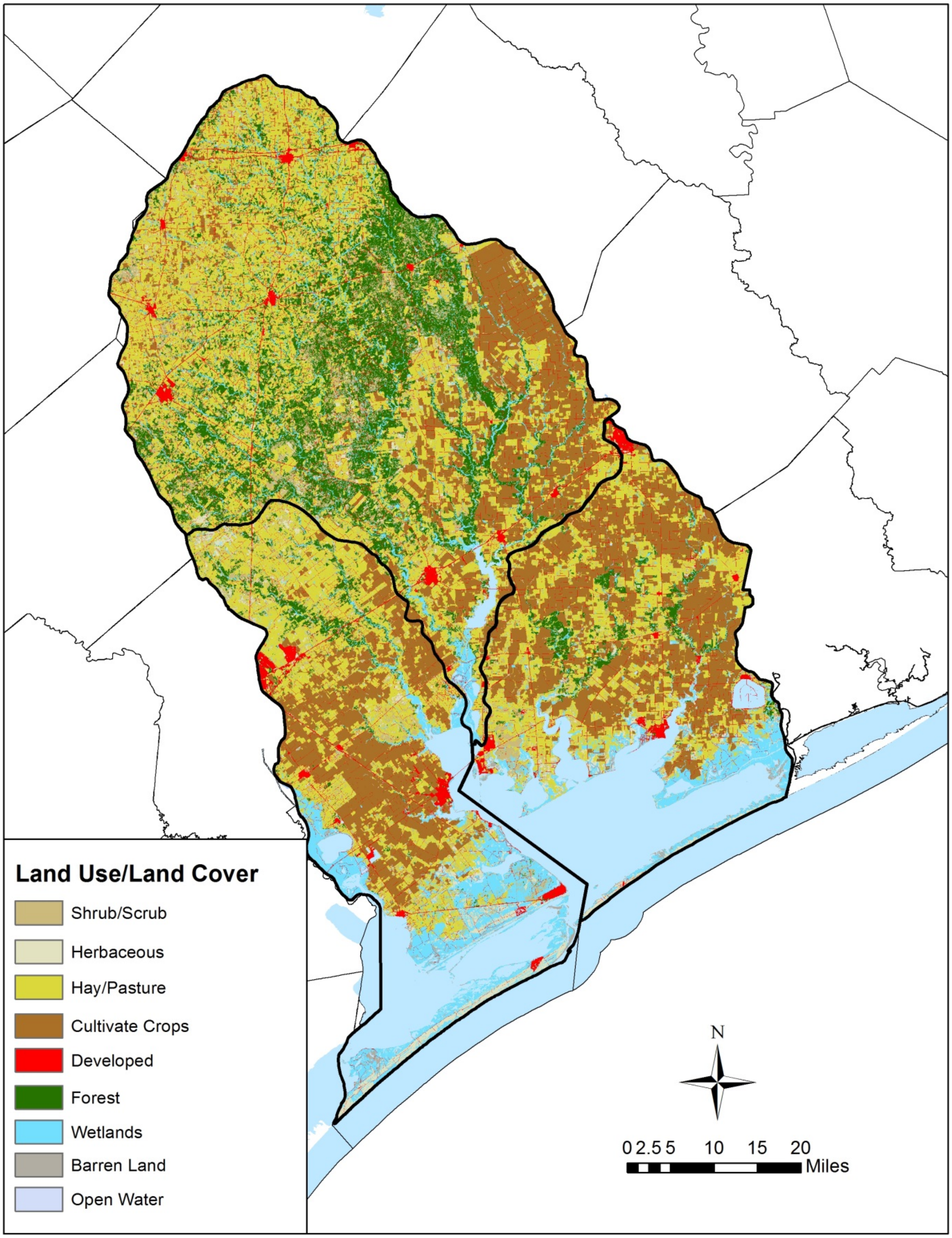

Figure 12. 2011 land use/land cover within Basins 15, 16 and 17
Source: USGS (2011) and NLCD (2011)

Table 12. LandUse / Land Cover within Basins 15, 16, and 17.
Source: USGS (2011) and NLCD (2011)

2011 NLCD	**Basin 15**		**Tres Palacios Creek Impaired Subbasin**	
Land Use Classification	**Area (ac)**	**% in Watershed**	**Area (ac)**	**% in Watershed**
Barren Land	8,117	1.33%	109	0.07%
Cultivated Crops	209,275	34.22%	80,145	48.61%
Forest	28,792	4.71%	6,849	4.15%
Developed	33,238	5.43%	10,153	6.16%
Wetlands	65,998	10.79%	4,257	2.58%
Hay/Pasture	189,614	30.99%	55,227	33.49%
Shrub/Scrub	39,259	6.42%	5,918	3.59%
Herbaceous	24,209	3.96%	1,615	0.98%
Open Water	13,138	2.15%	617	0.37%
Total	**611,640**	**acres**	**164,890**	**acres**

2011 NLCD	**Basin 15**		**Carancachua Bay Impaired Subbasin**	
Land Use Classification	**Area (ac)**	**% in Watershed**	**Area (ac)**	**% in Watershed**
Barren Land	8,117	1.33%	3,415	1.49%
Cultivated Crops	209,275	34.22%	44,407	19.40%
Forest	28,792	4.71%	33,462	14.62%
Developed	33,238	5.43%	12,806	5.60%
Wetlands	65,998	10.79%	22,467	9.82%
Hay/Pasture	189,614	30.99%	68,877	30.09%
Shrub/Scrub	39,259	6.42%	28,386	12.40%
Herbaceous	24,209	3.96%	12,978	5.67%
Open Water	13,138	2.15%	2,069	0.90%
Total	**611,640**	**acres**	**228,867**	**acres**

2011 NLCD	**Basin 16**		**Lavaca Creek Impaired Subbasin**	
Land Use Classification	**Area (ac)**	**% in Watershed**	**Area (ac)**	**% in Watershed**
Barren Land	2,536	0.17%	500	0.09%
Cultivated Crops	210,636	14.21%	28,876	5.45%
Forest	316,640	21.36%	112,806	21.30%
Developed	73,668	4.97%	26,620	5.03%
Wetlands	78,871	5.32%	21,740	4.11%
Hay/Pasture	580,321	39.15%	251,740	47.54%
Shrub/Scrub	167,798	11.32%	69,717	13.17%
Herbaceous	36,339	2.46%	16,657	3.15%
Open Water	15,436	1.04%	827	0.16%
Total	**1,482,245**	**acres**	**529,483**	**acres**

2011 NLCD	Basin 17		Arenosa Creek Impaired Subbasin	
Land Use Classification	**Area (ac)**	**% in Watershed**	**Area (ac)**	**% in Watershed**
Barren Land	9,390	1.41%	12	0.02%
Cultivated Crops	137,732	20.61%	20,108	19.53%
Forest	30,086	4.5%	8,496	8.25%
Developed	38,266	5.73%	3,116	3.03%
Wetlands	122,709	18.36%	3,614	3.51%
Hay/Pasture	208,213	31.16%	53,571	52.02%
Shrub/Scrub/Herbaceous	56,763	8.50%	9,383	9.11%
Herbaceous	47,009	7.04%	4,624	4.49%
Open Water	18,059	2.70%	63	0.06%
Total	**668,227**	**acres**	**102,987**	**acres**

Potential Sources of Fecal Indicator Bacteria

Potential sources of indicator bacteria can be divided into two primary categories: *regulated* and *unregulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and National Pollutant Discharge Elimination System (NPDES) programs. Examples of regulated sources include wastewater treatment facility (WWTF) discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities and other regulated entities. Unregulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff. Nonpoint sources are not regulated by permit.

Regulated Sources

In the study area, permitted sources consist of domestic WWTFs, general wastewater permits, and general stormwater permits. Sanitary sewer overflows and illicit or dry weather discharges are also included in this group.

Domestic Wastewater Treatment Facility Discharges

Eighteen facilities in the study area treat domestic wastewater; eight in Basin 15, six in Basin 16, and four in Basin 17 (Tables 13A through 13C; Figure 13). The City of El Campo WWTF discharges directly into the Tres Palacios (Segments 1501) and is the only facility that directly discharges into an impaired segment. There are three facilities that discharge directly into main river channels: the City of El Campo WWTF, Lake Texana Plant 1, and Lynns Bayou WWTF; the exact segments each discharges to can be seen in Tables 12A through 12C below. All other WWTFs discharge into tributaries of the rivers. Permitted sizes of WWTFs range from 7,500 gallons per day up to 2,628,000 gallons per day; several have reported recent daily discharges exceeding permitted discharge limits.

Table 13A. Permitted domestic wastewater treatment facilities in the Basin 15 watersheds.
Source: Individual TPDES Permits

TPDES Permit No.	Facility	Receiving Waters	Final Permitted Discharge (MGD)[a]	Recent Discharge (MGD)[b]
WQ0010217001	BLESSING WWTF	unnamed drainage ditch, to Cashs Creek to Tres Palacios Bay (2452)	0.075	0.103
WQ0010593001	PALACIOS WWTF	drainage ditch to Prices Slough, to Tres Palacios Bay/Turtle Bay (2452)	0.8	0.599
WQ0010844001	CITY OF EL CAMPO WWTF 1	Tres Palacios Creek Above Tidal in segment 1502	2.628	1.400
WQ0010911001	LOLITA WWTF	Cox Creek to Cox Creek Lay to Cox Bay (2454)	0.062	0.001
WQ0012743001	PLACEDO WWTF	unnamed ditch to Ninemile Creek, to Placedo Creek to Lavaca Bay/Chocolate Bay (2453)	0.072	0.001
WQ0012880001	BOCA CHICA SEC 3 PLT	unnamed drainage ditch, to small lake, to marsh, to Carancahua Bay (2456)	0.024	0.004
WQ0013091001	MIDFIELD WWTF	unnamed tributary, to Wallace Creek, to Tres Palacios Creek Above Tidal (1502)	0.03	0.025
WQ0013479001	LA WARD WWTF	unnamed ditch, unnamed tributary, West Carancahua Creek, Carancahua Creek, Carancahua Bay (2456)	0.013	0.012885417

[a] Significant figures reflect MGDs presented in TPDES permits
[b] Average measured discharge from Nov. 2007 through Oct. 2012, as available.

Table 13B. Permitted domestic wastewater treatment facilities in the Basin 16 watersheds.
Source: Individual TPDES Permits

TPDES Permit No.	Facility	Receiving Waters	Final Permitted Discharge (MGD) [a]	Recent Discharge (MGD) [b]
WQ0004697000	PRASEKS HILLJE SMOKEHOUSE	unnamed drainage ditch, to East Mustang Creek, Lake Texana (1604)	0.01	0.40
WQ0010010001	CITY OF GANADO WWTF	directly to Lake Texana in Segment No. 1604 of the Lavaca River Basin	0.35	0.27
WQ0010013001	CITY OF HALLETTSVILLE WWTF	directly to Lavaca River Above Tidal in Segment No. 1602 of the Lavaca River Basin	0.80	0.44
WQ0010115001	KALLUS STREET WWTF	unnamed tributary, to West Navidad River, to the Navidad River Above Lake Texana in Segment No. 1605	0.46	0.40
WQ0010115002	BABYLON LANE STP	Unnamed tributary to West Navidad River, to Navidad River Above Lake Texana (1605)	0.25	0.29
WQ0010164001	CITY OF EDNA WWTF	Post Oak Branch, to Dry Creek, to Navidad River Tidal (1603)	1.80	0.75
WQ0010196001	JACKSON COUNTY WCID 2 WWTF	Drainage ditch to an unnamed tributary, to Menefee Bayou to Lavaca River Tidal in Segment No. 1601	0.05	0.02
WQ0010280001	SHINER WWTF	Rocky Creek, to Lavaca River Above Tidal in Segment No. 1602	0.85	0.46
WQ0010463001	CITY OF YOAKUM WWTF	To Big Brushy Creek, to Clarks Creek, to Lavaca River Above Tidal Segment No. 1602	0.95	0.82
WQ0010849001	WHARTON COUNTY WCID 1 WWTF	unnamed tributary to East Mustang Creek to lake Texana (1604)	0.15	0.10
WQ0012084001	LAKE TEXANA PLANT 1	Lake Texana (1604)	0.05	0.01
WQ0013452001	SHERIDAN WWTF	To a ditch, to unnamed tributary of Middle Sandy Creek, to Middle Sandy Creek to Sandy Creek to Lake Texana in Segment No. 1604	0.05	8.71
WQ0014940001	WESTSIDE COMMUNITY DEVELOPMENT WWTF	unnamed tributary to Rocky Creek, to West Navidad River, to Navidad River Above Lake Texana (1605)	0.01	*

[a] Significant figures reflect MGDs presented in TPDES permits
[b] Average measured discharge from Nov. 2007 through Oct. 2012, as available.
* no discharge information was found for Westside Community Development WWTF

Table 13C. Permitted domestic wastewater treatment facilities in the Basin 17 watersheds.
Source: Individual TPDES Permits

TPDES Permit No.	Facility	Receiving Waters	Final Permitted Discharge (MGD) [a]	Recent Discharge (MGD) [b]
WQ0002586000	76 SEADRIFT COKE	directly to Victoria Barge Canal Tidal (1701)	0.202	0.142
WQ0010251001	LYNNS BAYOU WWTF	Lynn Bayou, to Lavaca Bay/Chocolate Bay (2453)	2.00	1.360
WQ0013954001	CRESTVIEW SUBDIVISION	to a swale, to Chocolate Bayou Non-Tidal, to Chocolate Bayou Tidal, to Lavaca Bay/Chocolate Bay (2453)	0.03	0.012
WQ0014815001	CALHOUN COUNTY MUD 1 HARBOR MIST	To unnamed drainage ditch, to Victoria Barge Canal Tidal (1701)	0.15	*

[a] Significant figures reflect MGDs presented in TPDES permits
[b] Average measured discharge from Nov. 2007 through Oct. 2012, as available.
* no discharge information was found for Calhoun County MUD 1 Harbor Mist

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. SSOs in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and infiltration (I&I) are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition. Information concerning known events occurring in Basins 15, 16 and 17 are included in Table 14.

Table 14. Reported SSO incidences reported in Basins 15, 16 and 17 between Aug. 2009 – Jan. 2013. Source: TCEQ (2014)

Facility Name	Discharge Date(s)	Duration (hr-min)	Volume (Gallons)	Cause	Segment
City of Edna WWTF	11/13/2013	5 hr	2000	failure in a sewer line thru the creek	1602
	11/13/2013	20 min	200	blockage/rag inflow	1604

Dry Weather Discharges/Illicit Discharges

Bacteria loads from regulated stormwater can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term “illicit discharge” is defined in TPDES General Permit No. TXR040000 for Phase II Municipal Separate Storm Sewer Systems as “any discharge to a municipal separate storm sewer that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities.” Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments* (Brown et al. 2004) includes:

Examples of direct illicit discharges:

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials (e.g., used motor oil) that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- a cross-connection between the municipal sewer and storm sewer systems.

Examples of indirect illicit discharges:

- an old and damaged sanitary sewer line that is leaking fluids into a cracked storm sewer line; and
- a failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

No records of dry weather or illicit discharges to the water bodies exist; however, it is likely that some form of these exists given the broad range of items that they encompass. If documentation of these items do exist, it is possible that cities or county health officials may have this information.

TPDES General Wastewater Permits

In addition to the individual wastewater discharge permits listed in Table 14A through 14C, discharges of processed wastewater from certain types of facilities are required to be covered by one of several TPDES general permits. Within the counties that contain the project area, current permits include:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production facilities
- TXG670000 – hydrostatic test water discharges
- TXG920000 – concentrated animal feeding operations

A review of active general permit coverage (TCEQ, 2008) in the Matagorda Bay watershed as of 25 April, 2014 found 45 such operations or facilities of the type described above in the counties that are included in the project area and 5 discharging into segments covered by project area. By county, the breakdowns of facilities in each county are as follows: Calhoun (6), Colorado (1), Dewitt (1), Fayette (5), Gonzales (9), Jackson (5), Lavaca (2), Matagorda (6), Victoria (4), and Wharton (6). These permits are divided between 20 concrete production facilities, 13 aquaculture production facilities, 1 hydrostatic testing water discharge, and 11 concentrated animal feeding operations. Not all of the listed facilities occur within the Matagorda Bay watershed area though. Of these, only 7 concrete production facilities and 13 aquaculture facilities are currently operating. The rest lie outside the watershed.

Concrete production facilities pose no significant risk of bacteria contribution to area water bodies. Aquaculture facilities are also thought to pose little risk of fecal indicator bacteria loading; however, evidence suggests that fish may harbor or may even produce fecal indicator bacteria such as *E. coli* or others. Birds may also congregate around such facilities thus increasing the potential bacteria loading; however, this represents an indirect source that is not easily quantified nor is directly attributable to the facility itself. As a result, bacteria contributions from aquaculture facilities are possible. Three

(3) of the currently operating aquaculture facilities are located in the drainage of Tres Palacios Creek above the impaired portion of the stream.

Collectively, the bacteria loads from wastewater discharged under these general permit sites is considered due to the nature of the discharge.

Stormwater General Permits

Discharges of stormwater from a Phase II urbanized area, industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

- TXR040000 – stormwater Phase II Municipal Separate Storm Sewer System (MS4) general permit for urbanized areas
- TXR050000 – stormwater multi-sector general permit (MSGP) for industrial facilities
- TXR150000 – stormwater from construction activities disturbing more than one acre
- TXG110000 – concrete production facilities

Three of these permits (MS4, MSGP, and construction) pertain solely to stormwater discharges. Concrete production facility permits also authorize the discharge of process wastewater as discussed under TPDES General Wastewater Permits.

A review of active stormwater general permits coverage as of 25 April 2014, found 42 Phase II municipal separate storm sewer systems (MS4), 131 active industrial (MSGP) facilities, 97 active construction sites, and 20 concrete production facilities. Of these facilities, 43 discharge into the segments covered by this project. By county, the breakdowns of facilities in each county are as follows: Calhoun (19), Colorado (34), Dewitt (17), Fayette (33), Gonzales (30), Jackson (9), Lavaca (14), Matagorda (34), Victoria (74), and Wharton (26).

Review of Compliance Information on Permitted Sources

A review of the EPA Enforcement & Compliance History Online (ECHO) and Integrated Compliance Information System (ICIS) databases (USEPA, 2013b), conducted March 7, 2014, revealed non-compliance issues regarding *E. coli* permit limits for 6 WWTFs in the Basins 15, 16, 17 watersheds (See Table 14A through Table 14C).For the period from July 2009 through December 2013, the following 6 facilities reported exceedances in bacteria concentration discharge limits:

- City of Blessings WWTF,
- City of Placedo WWTF,
- Boca Chica Section 3 Plant,
- La Ward WWTF,

- City of Edna WWTF,
- Lynn Bayou WWTF.

None of the bacteria effluent violations were reported as Significant Non-compliance (SNC) effluent violations. SNC status is displayed in the ECHO database and is the result of a number of violations recorded. These violations can include late or missing reports, discharges above limitations, among others. Facility inspections may also result in SNC status in the ECHO database. Unresolved SNC violations for bacteria were indicated for the following three facilities:

- City of Placedo WWTF
- City of El Campo WWTF
- Lynn Bayou WWTF

Sunilandings WWTF, Westside Community Development WWTF, Lake Texana Plant 1, Wharton County WCID 1 WWTF, Calhoun County MUD – 1 Harbor Mist have permit requirements for bacteria releases, but are currently not providing self-reporting on the ECHO or ICIS databases.

Stormwater conveyance channel in El Campo

Table 15A. Bacteria monitoring requirements and compliance status for WWTFs in Basin 15 watershed.

					Permit Limitations		Reported Sample Values	
TPDES Permit No.	**EPA ID**	**Facility**	**Permit Monitoring Requirement**	**Min. Self-Monitoring Requirement - Frequency**	**Discharge Limitation: Daily Average**	**Discharge Limitation: Daily Maximum per Sample**	**Recorded Daily Average**	**Number of Times Grab Sample Exceeded Daily Max Grab Sample Limitation**
WQ0010217001	TX0091260	BLESSING WWTF	*E. coli*	1/week	126 (mg/l) Daily avg	89 (mg/l) single grab	461.51	3
			Enterococci	1/week	35 (mg/l) Daily Avg	89 (mg/l) single grab	169.56	59
WQ0010593001	TX0023051	PALACIOS WWTF	Enterococci	1/week	35 (mg/l) Daily Avg	89 (mg/l) single grab	3.67	0
WQ0010844001	TX0021474	CITY OF EL CAMPO WWTF 1	*E. coli*	1/week	126 (mg/l) Daily avg	394 (mg/l) Daily Max	7.70	2
WQ0010911001	TX0064998	LOLITA WWTF	*E. coli*	1/quarter	126 (mg/l) Daily avg	394 (mg/l) Daily Max	2.59	0
WQ0012743001	TX0093360	PLACEDO WWTF	*E. coli*	1/week	126 (mg/l) Daily avg	394 (mg/l) Daily Max	16.11	17
WQ0012880001	TX0098248	TRI-COUNTY POINT PROSPERTY OWNERS ASSN. WWTF	*E. coli*	1/week	126 (mg/l) Daily avg	394 (mg/l) Daily Max	4.95	4
WQ0013091001	TX0098205	MIDFIELD WWTF	No Bacteria	- -	- -	- -	- -	- -
WQ0013479001	TX0105104	LA WARD WWTF	*E. coli*	1/week	126 (mg/l) Daily avg	394 (mg/l) Daily Max	13.46	12

* No compliance data was available through ECHO or ICIS for Sunilandings WWTF. Compliance status based on the period of record available through the EPA's Enforcement & Compliance History Online (ECHO) database. Periods of record vary, but all fall within the Jul. 2010 – Dec. 2013 timeframe.

Table 15B. Bacteria monitoring requirements and compliance status for WWTFs in Basin 16 watershed.

TPDES Permit No.	EPA ID	Facility	Permit Monitoring Requirement	Min. Self-Monitoring Requirement - Frequency	Permit Limitations: Discharge Limitation: Daily Average	Permit Limitations: Discharge Limitation: Daily Maximum per Sample	Reported Sample Values: Recorded Daily Average	Reported Sample Values: Number of Times Grab Sample Exceeded Daily Max Grab Sample Limitation
WQ0004697000	TX0126349	PRASEKS HILLJE SMOKEHOUSE	*E.coli*	1/month	Daily 394	Grab 394	2.94	1
WQ0010010001	TX0026026	CITY OF GANADO WWTF	No Bacteria	--	--	--	--	--
WQ0010013001	TX0025232	CITY OF HALLETTSVIL LE WWTF	No Bacteria	--	--	--	--	--
WQ0010115001	TX0024414	KALLUS STREET WWTF	No Bacteria	--	--	--	--	--
WQ0010115002	TX0024422	BABYLON LANE STP	*E.coli*	1/month	Daily 126	Grab 394	1	0
WQ0010164001	TX0024252	CITY OF EDNA WWTF	*E.coli*	1/Day	Daily 126	Max 394	72.13	31
WQ0010196001	TX0027669	JACKSON COUNTY WCID 2 WWTP	No Bacteria	--	--	--	--	--
WQ0010280001	TX0026042	SHINER WWTF	No Bacteria	--	--	--	--	--
WQ0010463001	TX0026034	CITY OF YOAKUM WWTF	No Bacteria	--	--	--	--	--
WQ0010849001	TX0027456	WHARTON COUNTY WCID 1 WWTF	*E.coli*	1/month	Daily 126	Grab 399	1.15	0
WQ0012084001	TX0079006	LAKE TEXANA PLANT 1	*E.coli*	1/quarter	Daily126	Grab 399	1	0

WQ0013452001	TX0103781	SHERIDAN WWTF	No Bacteria	--	--	--	--	--
WQ0014940001	TX0131989	WESTSIDE COMMUNITY DEVELOPMENT WWTF	*E.coli*	1/quarter	daily 126	Grab 394	--	--

* No compliance data was available through ECHO or ICIS for Wharton County WCID 1 WWTF, Lake Texana Plant 1, Westside Community Development WWTF.
Compliance status based on the period of record available through the EPA's Enforcement & Compliance History Online (ECHO) database. Periods of record vary, but all fall within the Jul. 2010 – Dec. 2013 timeframe.

Table 15C. Bacteria monitoring requirements and compliance status for WWTFs in Basin 17 watershed.

					Permit Limitations		Reported Sample Values	
TPDES Permit No.	**EPA ID**	**Facility**	**Permit Monitoring Requirement**	**Min. Self-Monitoring Requirement - Frequency**	**Discharge Limitation: Daily Average**	**Discharge Limitation: Daily Maximum per Sample**	**Recorded Daily Average**	**Number of Times Grab Sample Exceeded Daily Max Grab Sample Limitation**
WQ0002586000	TX0090948	76 SEADRIFT COKE	Enterococci	1/week	Daily Avg. 35	Grab 89	3.58	2
WQ0010251001	TX0047562	LYNN BAYOU WWTF	Enterococci	Daily	Daily Avg. 35	Max 89	5.61	5
WQ0013954001	TX0118923	CRESTVIEW SUBDIVISION	*E.coli*	1/week	Daily 126	Grab 399	1	0
WQ0014815001	TX0129682	CALHOUN COUNTY MUD 1 HARBOR MIST	*E.coli*	1/month	Daily 126	Grab 394	--	--

* No compliance data was available through ECHO or ICIS for Calhoun County MUD 1 Harbor Mist.
Compliance status based on the period of record available through the EPA's Enforcement & Compliance History Online (ECHO) database. Periods of record vary, but all fall within the Jul. 2010 – Dec. 2013 timeframe.

Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint and can emanate from wildlife, feral hogs, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing onsite sewage facilities (OSSFs), and domestic pets.

Non-Permitted Agricultural Activities and Domesticated Animals

Non-permitted agricultural activities such as livestock grazing or the presence of other domesticated animals such as cats and dogs also contribute to the overall bacteria loading in a watershed. Similar to other sources of bacteria, the number of a specific animal and its distribution across the watershed are important factors to consider when assessing the overall pollutant loading potential of a specific animal. Numbers for these animals must also be estimated from existing information such as the National Agricultural Statistics Service's 2012 Census of Agriculture. This report contains information by county and includes data on the number of farms or ranches per county, average farm size, total number livestock produced, and the volume of crops produced. Using this county-level information, estimates at the watershed level can be made.

Further, the number of animals within the watershed can be estimated by determining the portion of each county within the watershed and then simply multiplying the total number of animals (or animal units) by the percentage of the county in the watershed. Using this approach, the number of animal units for cattle, chickens, goats, horses, and sheep were calculated for each county, river basin and the entire project area were calculated and are presented in Table 16.

Pets can also be sources of fecal indicator bacteria to local waterways when storm runoff carries animal wastes into streams (USEPA, 2013a). The formula for determining pet dog populations is included below, where 0.584 is the estimated dogs per household as determined by AVMA (2013) and the national average persons per household is 2.6 as determined in the 2012 census:

$$\text{Number of Dogs} = 0.584*(\text{Human Population} \div 2.6)$$

The estimated number of domestic dogs in the watersheds was estimated, as shown in Table 17 by county, basin and for the project area.

Table 16. Estimated domesticated animal populations.
Source: USDA NASS 2012 Census of Agriculture

County or Area	Cattle	Chickens	Goats	Horses	Sheep
Calhoun	14,729	1,690	749	317	404
Colorado	19,088	13,477	159	473	133
DeWitt	13,670	11,007	160	169	133
Fayette	14,392	211,528	287	358	223
Gonzales	1,713	310,341	18	25	12
Jackson	41,429	820	672	969	37
Lavaca	89,236	463,218	1,050	1,107	791
Matagorda	30,619	725	495	656	175
Victoria	34,105	1,007	299	785	242
Wharton	21,562	---	274	637	149
Watershed Total	**280,543**	**1,013,813**	**4,163**	**5,496**	**2,299**
Basin 15	62,644	2,191	1,347	1,434	526
Basin 16	167,847	1,005,335	1,962	2,937	1,276
Basin 17	50,052	6,288	854	1,126	497

Table 17. Estimated dog population.
Source: Adapted from AVMA (2013).

County	Human Population	Number of Households	Estimated Dog Population
Calhoun	21,381	8,223	4,803
Colorado	20,874	8,028	4,689
DeWitt	20,097	7,730	4,514
Fayette	24,554	9,444	5,515
Gonzales	19,807	7,618	4,449
Jackson	14,075	5,413	3,161
Lavaca	19,263	7,409	4,327
Matagorda	36,702	14,116	8,244
Victoria	86,793	33,382	19,495
Wharton	41,280	15,877	9,272
Watershed Total	**304,826**	**792,548**	**462,848**
Basin 15	58,682	152,572	89,102
Basin 16	137,816	358,322	209,260
Basin 17	108,328	281,653	164,485

Wildlife and Unmanaged Animal Contributions

Fecal indicator bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. These animals represent a potentially significant source of bacteria in a watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers due to the presence of water, food, and shelter. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Similarly, fecal bacteria from wildlife deposited onto land surfaces nearby are likely to be washed into nearby streams by rainfall runoff. As a result, estimating potential contributions of fecal loading from these sources is important. However, population estimates from many wildlife species do not exist making this task quite difficult.

White-tailed deer populations are one such source that reasonable numbers or density estimates are not available to base these estimates upon. While exact numbers for deer populations in the Matagorda Bay watershed does not exist, estimates from the nearby Copano Bay watershed can be extrapolated to estimate the population in the study area. In Copano Bay, it was estimated that overall deer density across the watershed was 15.6 acres per deer. Using this density, and applying it to all land uses/land covers except open water, wetlands and urban areas, the number of individuals were estimated and are presented in Table 18 below.

Similar information was also available for feral hog density in the Copano Bay watershed. In work conducted near Corpus Christi at the Welder Wildlife Refuge, feral hogs were determined to exist at a density of 33.3 acres per hog and use all land uses except open water and urban areas. Applying this density to all other land uses/land covers, both the number of individuals and animal units were estimated and are presented in Table 18 below.

Table 18. Estimated deer and feral hog populations.

Basin	# of Deer	# of Feral Hogs
15	32,126	16,975
16	82,303	41,733
17	33,205	18,312
Watershed Total	**147,634**	**77,020**

On-Site Sewage Facilities

OSSFs are also a potential source of bacteria in a watershed that can influence instream water quality. Functional status of the system, its age, location, soils the system is constructed in and the density of systems in a given area can all influence the likelihood of pollutants from an OSSF entering waterways. As a result, knowing the number and location of OSSFs in a watershed is important for assessing potential water quality impacts.

Data providing the locations of OSSFs in Basins 15, 16, and 17 are not available. This is a common problem encountered across Texas and other parts of the U.S. However, other sources of available information enable reasonable approximations of OSSF numbers and distribution to be developed. Using 1990 and 2010 Census data, 911 address points, and recent aerial imagery, Gregory et al. (2013) published a method to approximate OSSF density and distribution in a rural Texas watershed. Census data provides information on the number of housing units within a defined area, 911 address data provides a specific point on a map for any location having a defined address, and aerial imagery can be used to aid in determining the location and type of a structure. In each of these cases, assumptions are made about the presence or absence of an OSSF; thus, the method contains inherent uncertainties that cannot be eliminated without on-site inspections. Despite these uncertainties, this method produces a reasonable approximation as multiple data sets are compared to yield the same outcome. Using this approach as a general guideline, needed data were gathered for the area.

Addresses are regularly maintained by Councils of Government throughout the state of Texas or in some cases by the counties themselves. With the exception of Calhoun County, 911 data was obtained for the entire project area. Data are available as a GIS shapefile, which projects specific points onto a digital map. Data collected were processed using ESRI's ArcGIS 10.2 to reduce the data gathered to the basin area only. In addition to residences, addresses are often given to any point with an electrical service connection such as businesses, churches, radio towers, barns, irrigation well motors, abandoned houses, and habitable structure among others (Gregory et al., 2013). As a result, 911 addresses potentially overestimate the number of OSSFs in a given area.

Aerial imagery collected via satellite is also used in this assessment. The world imagery base map (0.3 meter resolution) provided through ESRI was used to visualize where the 911 addresses were located and identify other potential OSSFs not included in 911 address data. By comparing the 911 points to the imagery, those points obviously associated with a non-inhabited structure can be excluded and those not associated with a point can be added. In Calhoun County, imagery was used in lieu of 911 address points to determine potential OSSFs. Identical considerations were utilized when selecting potential OSSF presence.

The process of creating a dataset of all potential OSSFs in the watersheds involved zooming into a 911 data point to verify on the imagery if the point had potential to be a habitable structure with an active OSSF. Assumptions needed to be made to determine if the structure was inhabited on abandoned. Although subjective, the determinations were made based on how the structure looked and the surrounding area. Noting the condition of the driveway, presence of cars, the shape of the structure, type of road leading to the structure, presence and type of outbuildings and the presence of exceedingly green areas in or near the structure were all assessed.

Data from the 2010 U.S. Census was also utilized. The number of housing units within Census blocks is provided along with a GIS shapefile of the Census block boundaries. Census block boundaries do not follow watershed boundaries and thus extend beyond the watershed area and over-estimate the number of housing units within the area. Approximations of the actual number of housing units within the basin can be made though by reducing the number of housing units in Census blocks along the basin's fringe by the respective percent of area that is contained within the basin.

Cities and some communities within the basin have wastewater treatment facilities (WWTF) that serve a number of the basin's residents. Information on the number of houses served and maps respective service areas for each WWTF are not readily available. Several available sources of information can be used to determine the presence and extent of WWTFs and were utilized in this area. TCEQ maintains digital maps of WWTF outfalls, which indicate the presence of a sewer system in the area. Certificates of convenience and necessity (CCN) are also associated with some of these WWTFs and illustrate the area served by the WWTF. This data does not exist for all WWTFs though. In these cases, city limits were used to approximate WWTF service areas. Some smaller communities in the basin with WWTFs did not have defined city limit boundaries. In these situations, the likely service area was evaluated based on city structure. The gridded layout of these areas was assumed to include the sewage collection system going to the WWTF. All homes falling within these described areas were assumed to be serviced by the WWTFs and not considered to have an OSSF.

Table 18 illustrates results of this assessment and notes the predicted number of OSSFs within the project area. Figure 13 depicts the estimated distribution of OSSFs across the Matagorda Bay watershed developed using the approach described. This map only illustrates the current state of understanding as OSSF locations have not been verified through and on-site inspection.

Overall, the estimated number of OSSFs in the watershed using the above described approach is 19,678. Table 18 illustrates the number of OSSFs by county and in aggregate within the basin area. This number differs from the estimated number of housing units with OSSFs as determined from the 2010 Census block data by 1,768 but is in reasonable agreement as this is only an 8.6 percent difference. This evidence suggests that the actual number of OSSFs in the basin area is near this estimated range.

The total number of OSSFs in an area is not necessarily problematic. Instead, the proximity of OSSFs to waterways is one factor often noted as a potential cause of water quality issues in nearby streams. Using the GIS developed for the watershed, these factors were assessed in an effort to identify potential problem areas within the basin. Of all the systems in the basin area, 134 are anticipated to be located within 100 yards of perennial streams and 314 are within 50 yards of intermittent streams. This is a relatively small proportion of the total number of OSSFs; however, several potential problem areas relative to existing water quality impairments do appear in the upper portion of the Lavaca River and Tres Palacios Creek's impaired segments have a number of OSSFs within close proximity to the water body.

Table 19. Number of OSSFs by County and soil condition within Basins 15, 16, and 17.

Soil Condition	Total OSSFs by County										Total OSSFs by Soil Condition
	Calhoun	Colorado	DeWitt	Fayette	Gonzales	Jackson	Lavaca	Matagorda	Victoria	Wharton	
Very Limited	2,324	178	134	523	21	849	1,413	737	999	1,498	8,676
Somewhat Limited	22	315	232	487	23	0	1,587	0	0	0	2,666
Not Limited	237	527	281	584	6	1,854	2,353	804	1,247	425	8,318
Not Rated	4	1	0	0	0	10	2	0	0	1	18
Totals by County	2,587	1,021	647	1,594	50	2,713	5,355	1,541	2,246	1,924	19,678
Total 2010 Census Block Housing Units	3,257	1,576	539	1,726	41	2,874	5,231	2,190	2,140	1,872	21,446

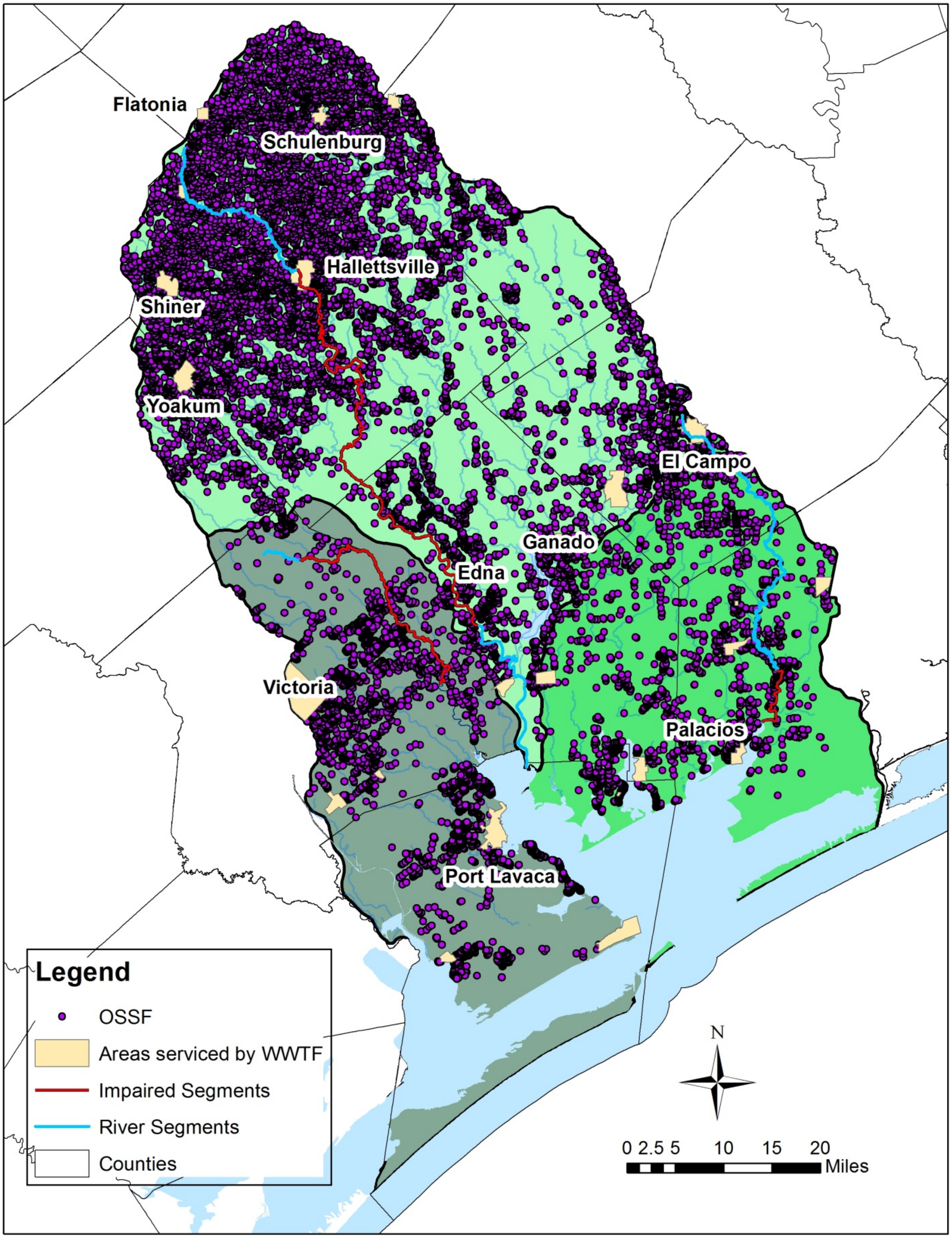

Figure 13. All OSSFs and serviced areas by a WWTF in Basins 15, 16, and 17.

Density of OSSFs in an area can also factor in to the potential for failure and may increase the influence of these OSSFs on nearby water quality. As OSSF density increases, the soil's ability to absorb and attenuate potential pollutants expelled from the system as designed diminishes as the volume of effluent received increases. After a point, the soil can no longer treat OSSF effluent effectively and can contribute to downstream water quality issues. Within the Matagorda Bay watershed, several areas of the watershed have areas with high densities of OSSFs relative to the remainder of the watershed. Figures 14 and 15 illustrate these areas of high density for all OSSFs in the watershed and for OSSFs within 100 yards of perennial streams respectively. Collectively across the watershed, OSSF densities are highest around Carancahua Bay, north of Port Lavaca along the bay, north of El Campo, northwest of Inez and along the middle portion of Tres Palacios Creek. For OSSFs that are located within 100 yards of perennial streams, the highest densities occur southwest of Port Lavaca and along the middle portion of Tres Palacios Creek.

Soils can also impact OSSF function and their potential to contribute to localized water pollution issues. NRCS' Soil Survey Geographic (SSURGO) soils database contains national soil data including a suitability rating for serving as an OSSF leach-field. Soils are classified as not-limiting, somewhat limiting, very limiting or are not rated. These classifications provide cursory information on the soils suitability to effectively treat OSSF effluent it receives. Within the basin area, 44.1% of OSSFs are situated in 'very-limited' soils, 42.3% are in 'not-limited' soils, and the remaining 13.6 percent are in 'somewhat-limited' soils (Table 16). While the soil's suitability to effectively treat OSSF effluent is a factor in overall system function, it does not mean that systems in 'very-limited' soils are problematic. A properly designed and maintained system can function well and effectively treat wastewater in almost any setting.

Age, improper design, lack of owner education, and poor system maintenance are also noted as factors influencing the potential for OSSF failure; however, no information regarding these factors was available and thus they were not considered in this analysis. Physical OSSF inspections and owner interviews are needed to glean this type of information.

If a houses this close to a water body has a failing OSSF, it can easily impact instream water quality

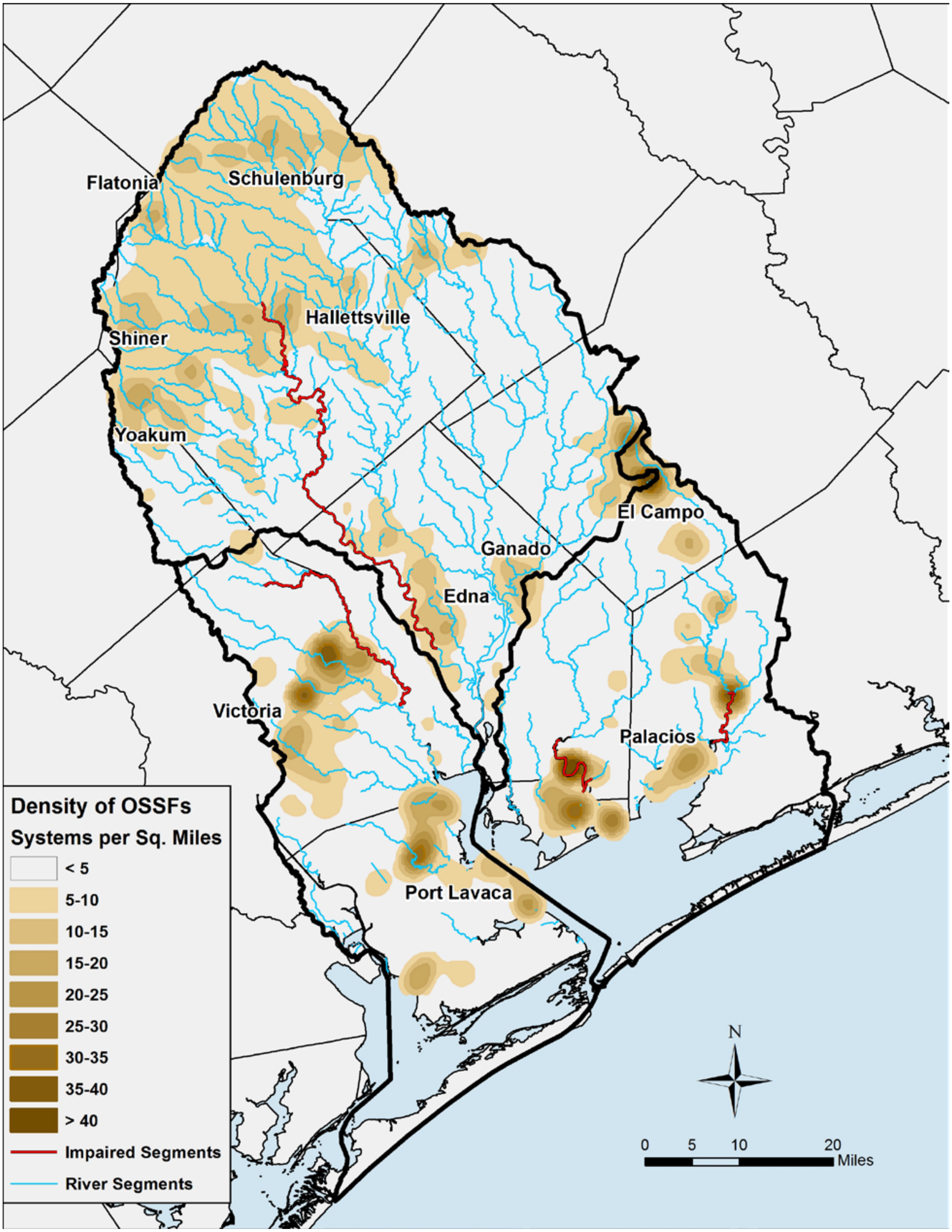

Figure 14. Density of OSSFs located in Basins 15, 16, and 17.

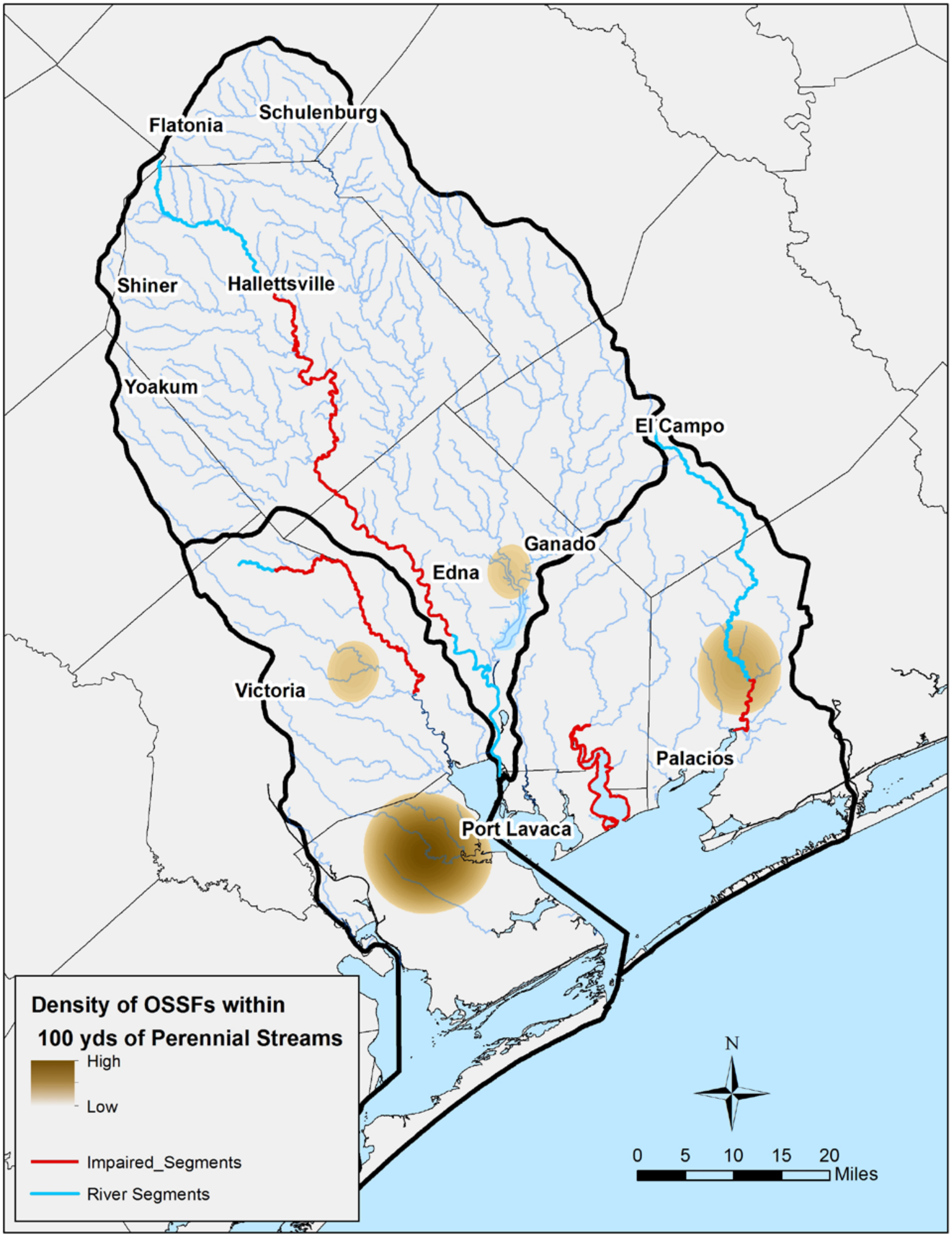

Figure 15. Density of OSSFs within 100 yards of a perennial stream.

Potential for Water Quality Recovery

Using the information presented in this report, the potential for water quality restoration was assessed using EPA's Recovery Potential Screening (RPS) Tool. This tool was developed as a technical aid that compares water bodies or watersheds and identifying differences in how well they may respond to restoration activities. RPS is a flexible framework that can be adapted to fit any watershed or water body and aid in scheduling restoration activities. Within the tool, ecological, stressors and social indicators are considered and weigh into the overall restoration potential assessment (EPA 2014).

The RPS tool has only been applied in Texas one other time and its utility for predicting restoration potential continues to be evaluated. The Matagorda Bay watershed was selected as second test area for this tool. Originally, the goal of its application was to assess the restoration potential of impaired water bodies only. During the data gathering process, it became clear that applying this tool to the entire watershed was more appropriate. Thus the tool was applied to all water bodies and recovery potential rankings and scores were developed and subsequently plotted and mapped. This enabled results for all water bodies to be quickly compared. A report on the tool and its application was developed and illustrates the results (Gregory et al. 2014).

Lavaca River south of Edna

References

AVMA (American Veterinary Medical Association), 2013. U.S. Pet Ownership & Demographics Sourcebook. American Veterinary Medical Association. ISBN 978-1-882691-29-6

Babbar-Sebens, M. and R. Karthikeyan, 2009. Consideration of sample size for estimating contaminant load reductions using load duration curves. *Journal of hydrology* 372:118-123.

Borel, K., & Karthikeyan, R. 2013. Support for the Aransas River and Mission River Watersheds Bacteria Assessment Using the Spatially Explicit Load Enrichment Calculation Tool. Texas A&M University, Biological and Agricultural Engineering.

Brown, E., Caraco, D., Pitt, R. 2004. Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments. http://www.epa.gov/npdes/pubs/idde_manualwithappendices.pdf.

Gregory, L.F., Blumenthal, B., Wagner, K., Borel, K., Karthikeyan, R. 2013. Estimating On-site Sewage Facility Density and Distribution Using Geo-Spatial Analyses. *Journal of Natural and Environmental Sciences.* 4(1): 14-21.

Gregory, L.F., Brown, M., Skow, K., Engling, A., Wagner, K.L., Berthold, T.A. 2014. *Applying United States Environmental Protection Agency Recovery Potential Screeinging Tool to the Impairments in the Matagorda Bay Watershed*. Texas Water Resources Institute, Technical Report 460.

Larkin, T. J. and G. W. Bomar, 1983. Climatic Atlas of Texas. *Texas Department of Water Resources*, www.twdb.state.tx.us/publications/reports/limited_printing/doc/LP192.pdf, DOI.

Morrison, M. and J. Bonta, 2008. Development of Duration-Curve Based Methods for Quantifying Variability and Change in Watershed Hydrology and Water Quality, N. R. M. R. Laboratory (N. R. M. R. Laboratory)N. R. M. R. Laboratorys).

NOAA (National Oceanic and Atmospheric Administration) National Climatic Data Center, 2014. Climate Data Online (CDO). Retrieved Apr. 11, 2014. http://www.ncdc.noaa.gov/cdo-web/

PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Group at Oregon State University. 2012. *PRISM Products Matrix*. Retrieved Apr 11, 2014. www.prism.oregonstate.edu/

TCEQ. 2012 Texas Water Quality Inventory Water Bodies Evaluated. *2012 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d),* www.tceq.texas.gov/assets/public/waterquality/swqm/assess/12twqi/2012_wbevaluated.pdf

TWDB. 2013. Draft Population and Municipal Water Demand Projections. *2016 Regional and 2017 State Water Plan Projections Data*, www.twdb.state.tx.us/waterplanning/data/projections/2017/demandproj.asp

USCB. 2012. Annual Estimates of the Resident Population for Incorporated Places: April 1, 2010 to July 1, 2011. www.census.gov/popest/data/cities/totals/2011/SUB-EST2011-3.html

USDA NASS. 2012. Census of Agriculture- County Summary Highlights. http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/st48_2_001_001.pdf