Technical Support Document for Total Maximum Daily Loads for Indicator Bacteria in the Watersheds of the Mission and Aransas Rivers

Segments: 2001 and 2003

Assessment Units: 2001_01 and 2003_01


View of the Mission River, just south of the US Hwy 77 bridge.

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Prepared for
Total Maximum Daily Load Program
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List of Acronyms and Abbreviations

AU	Assessment Unit
cfs	Cubic Feet per Second
cfu	Colony Forming Unit
DAR	Drainage-Area Ratio
DMR	Discharge Monitoring Report
DSLP	Days since last precipitation
ECHO	Enforcement & Compliance History Online
E. coli	*Escherichia coli*
FDC	Flow Duration Curve
FIB	Fecal Indicator Bacteria
FG	Future Growth
I&I	Inflow and infiltration
I-Plan	Implementation Plan
ICIS	Integrated Compliance Information System
LA	Load Allocation
LDC	Load Duration Curve
MGD	Million Gallons per Day
mL	Milliliter
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
MSGP	Multi-Sector General Permit
NEIWPCC	New England Interstate Water Pollution Control Commission
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
ODEQ	Oregon Department of Environmental Quality
OSSF	Onsite Sewage Facility
ppt	parts-per thousand
SNC	Significant Non-compliance
SSO	Sanitary Sewer Overflow
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TMDL	Total Maximum Daily Load
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
USCB	United States Census Bureau
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WUG	Water User Group
WWTF	Wastewater Treatment Facility

SECTION 1
INTRODUCTION

1.1 Background

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a Total Maximum Daily Load (TMDL) for each pollutant that contributes to the impairment of a listed water body. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. In addition to the TMDL an implementation plan (I-Plan) is developed, which is a description of the regulatory and voluntary management measures necessary to improve water quality and restore full use of the water body.

The TCEQ's TMDL Program is a major component of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

The Texas Commission on Environmental Quality (TCEQ) first identified the bacteria impairments within the Mission River Tidal and Aransas River Tidal segments in 2004, and then in each subsequent edition of the *Texas Water Quality Integrated Report for Clean Water Sections 305(b) and 303 (d) (*formerly called the *Texas Water Quality Inventory and 303(d) List)* through 2012.

This document will consider bacteria impairments in 2 water bodies (segments), each segment consisting of a single assessment unit (AU). The complete list of water bodies and their identifying AU number is shown below:

1) Mission River Tidal 2001_01;
2) Aransas River Tidal 2003_01;

Because the 2 impaired tributary segments are each comprised of only one AU that encompasses the entire segment, the AU descriptor (_01) is unnecessarily cumbersome. From this point forward, AU and segment may be used interchangeably. For example, Mission River Tidal may be referred to as AU 2001_01 or Segment 2001.

1.2 Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, water quality standards were established by the TCEQ. The water quality standards describe the limits for indicators which are monitored in an effort to assess the quality of available water for specific users. The TCEQ is charged with monitoring and assessing water bodies based on these water quality standards, and publishes the Texas Water Quality Integrated Report list biennially.

The *Texas Surface Water Quality Standards* (TCEQ, 2010b) are rules that:

- *designate the uses, or purposes, for which the state's water bodies should be suitable;*
- *establish numerical and narrative goals for water quality throughout the state; and*
- *provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality.*

Standards are established to protect designated uses assigned to water bodies of which the primary uses assigned in the *Texas Surface Water Quality Standards* to water bodies are:

- *aquatic life use*
- *contact recreation*
- *domestic water supply*
- *general use*

Fecal indicator bacteria (FIB) are used to assess the risk of illness during contact recreation (e.g., swimming) from ingestion of water. Both *E. coli* (*Escherichia coli*) and *Enterococcus* spp. are present in the intestinal tracts of humans and other warm blooded animal. The presence of these bacteria in water indicates that associated pathogens from the wastes that may be reaching water bodies as a result of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2006). *E. coli* is widely used as an indicator in freshwater, while Enterococci are more often used as an indicator in saline waters. Enterococci are the relevant indicator to the Mission River Tidal and Aransas River Tidal.

On June 30, 2010 the TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2010b) and on June 29, 2011 the U.S. Environmental Protection Agency (EPA) approved the categorical levels of recreational use and their associated criteria. For saltwater, recreational use consists of three categories:

- *Primary contact recreation is that with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion of 35 most probable number (MPN) per 100 mL for Enterococci and a single sample criterion of 104 MPN per 100 mL;*
- *Secondary contact recreation 1 covers activities with limited body contact and a less significant risk of ingestion of water (such as fishing), and has a geometric mean criterion of 175 per 100 mL for Enterococci;*
- *Noncontact recreation is that with no significant risk of ingestion of water, where contact recreation should not occur due to unsafe conditions. It has a geometric mean criterion of 350 per 100 mL for Enterococci.*

In the Mission and Aransas Rivers, the impaired segments (2001 and 2003) are approved for primary contact recreation and have the associated Enterococci geometric mean criterion of a 35 MPN per 100 mL and single sample of 104 MPN per 100 mL.

1.3 Report Purpose and Organization

The TMDL project for the watersheds of the Mission and Aransas Rivers was initiated through a contract between the TCEQ and the Texas Water Resources Institute (TWRI) with the Texas Institute for Applied Environmental Research (TIAER) as a subaward recipient to TWRI. The tasks of this project to be performed by TIAER were to (1) acquire existing (historical) data and information necessary to support assessment activities; (2) perform the appropriate activities necessary to allocate Enterococci loadings; and (3) assist the TCEQ and TWRI in preparing the TMDL.

Using historical bacteria and flow data, this portion of the project was to: (1) review the characteristics of the watershed and explore the potential sources of Enterococci bacteria for the impaired segments; (2) develop an appropriate tool for development of bacteria TMDLs for the impaired segments; and (3) submit the draft and final technical support document for the impaired segments. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDLs for the Mission and Aransas watersheds. This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas 303(d) listings of impairment due to presence of indicator bacteria (Enterococci),
- development of load duration curves, and
- application of the load duration curve approach for the pollutant load allocation process.

SECTION 2
HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Description of Study Area

The Mission and Aransas Rivers, located adjacent to each other along the Texas Gulf Coast, are both comprised of two segments – the upstream segment of each river, designated as "Above Tidal," and the downstream segment designated as simply "Tidal." The above tidal portions of both the Mission and Aransas Rivers are perennial freshwater streams, while the below tidal portions are influenced by seawater from Mission and Copano Bays. This study incorporates a watershed approach where the drainage area of the each river is considered (Figure 1).

The Mission River Above Tidal (Segment 2002) begins at the confluence of the Blanco and Medio Creeks in Refugio County and is approximately 11 miles in length. Mission River Tidal (Segment 2001) begins downstream of US 77 in Refugio County and flows approximately 16 miles into Mission Bay. Because of the contiguousness of these segments and the upstream position of Segment 2002 to the bacterially impaired Segment 2001, both water bodies are considered in this report. The TMDL development, however, will only be for Segment 2001. At its mouth, the Mission River drains an area of approximately 1,029 square miles in Bee (36% of the watershed), Refugio (31%), Goliad (30%), and Karnes (3%) counties (Figure 1).

Aransas River above Tidal (Segment 2004) begins at the confluence of Poesta and Aransas Creeks in Bee County and is approximately 35 miles in length. Aransas River Tidal (Segment 2003) begins upstream of US 77 on the Refugio/San Patricio County line, and flows approximately 28 miles into Copano Bay. At its mouth, the Aransas River drains an area of approximately 843 square miles in Bee (48% of the watershed), San Patricio (47%), Refugio (4%), Live Oak (0.6%) and Aransas (0.2%) counties (Figure 1). For the same reason as for the Mission River, both Segments 2003 and 2004 are described in this report, but the TMDL development is only for Segment 2003.

The 2012 Texas Water Quality Integrated Report (TCEQ, 2013a) provides the following segment and AU descriptions for the water bodies considered in this document:

- Segment 2001 (AU 2001_01) (Mission River Tidal) - From the confluence with Mission Bay in Refugio County to a point 7.4 kilometers (4.6 miles) downstream of US 77 in Refugio County
- Segment 2002 (AU 2002_01) (Mission River Above Tidal) - From a point 7.4 km (4.6 miles) downstream of US 77 in Refugio County to the confluence of Blanco Creek and Medio Creek in Refugio County
- Segment 2003 (AU 2003_01) (Aransas River Tidal) - From the confluence with Copano Bay in Aransas/Refugio County to a point 1.6 kilometers (1.0 mile) upstream of US 77 in Refugio/San Patricio County

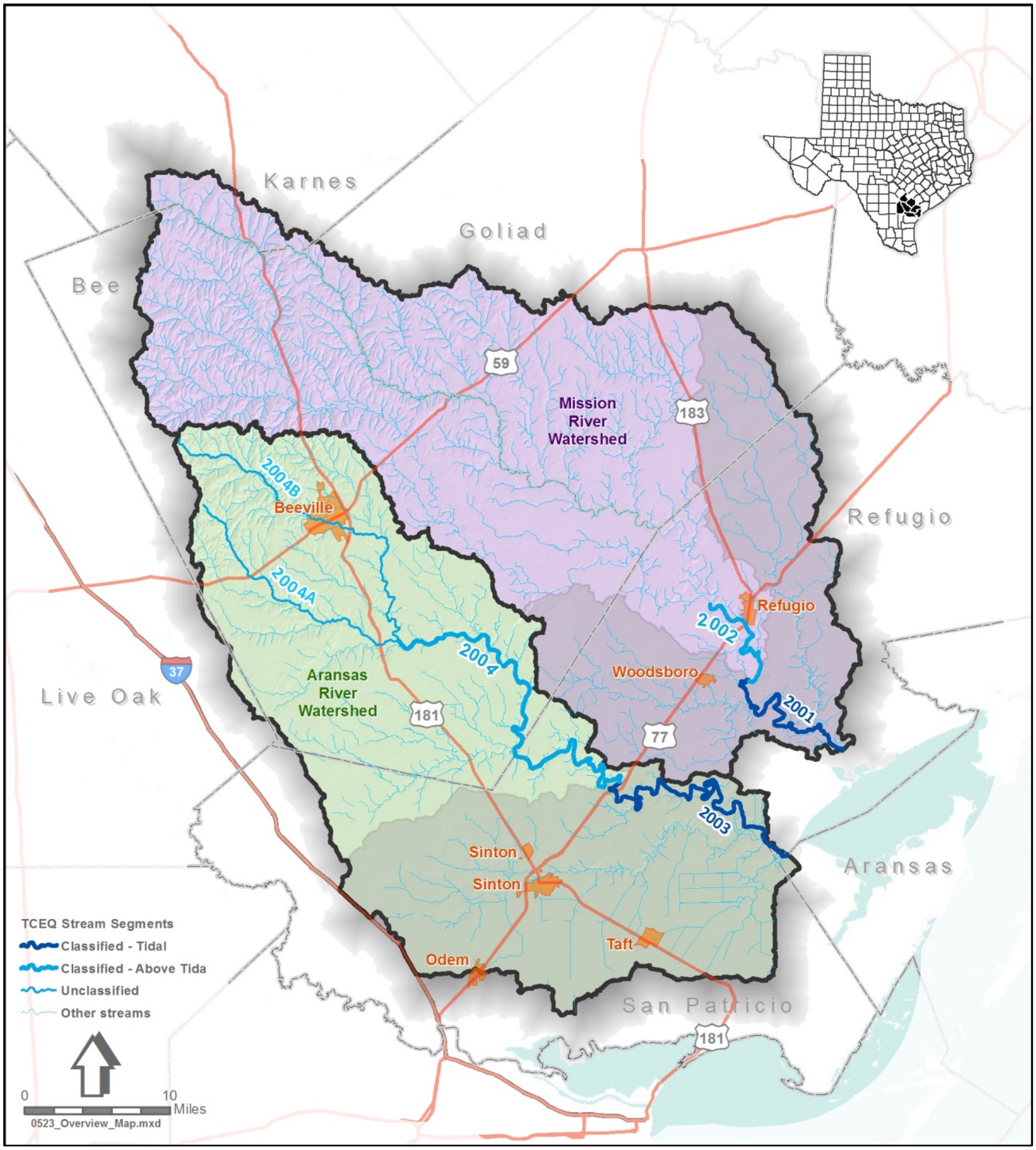

Figure 1. Overview map showing the total contributing drainage area for the study, including Segments 2001, 2002, 2003 and 2004.

Sources: Stream segments from TCEQ (2011)

- Segment 2004 (AU 2004_01 and 02)(Aransas River Above Tidal) - From a point 1.6 kilometers (1.0 mile) upstream of US 77 in Refugio/San Patricio County to the confluence of Poesta Creek and Aransas Creek in Bee County:
  - Segment 2004A (AU 2004A_01) (Aransas Creek [unclassified water body]) - From confluence with the Aransas River to the headwaters of the stream about 10 km upstream of US Highway 59.

- Segment 2004B (AU 2004B_01 and 02) (Poesta Creek [unclassified water body]) - From the confluence with the Aransas River to the headwaters of the stream about 7.5 km upstream of FM 673.

2.2 Watershed Climate and Hydrology

The watersheds of the Mission and Aransas Rivers (henceforth collectively referred to as the Mission and Aransas watersheds) are 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 Mission River watershed was 33.2 inches, slightly higher than the average annual total precipitation for the Aransas River watershed of 32.3 inches (Figure 2; PRISM, 2012).

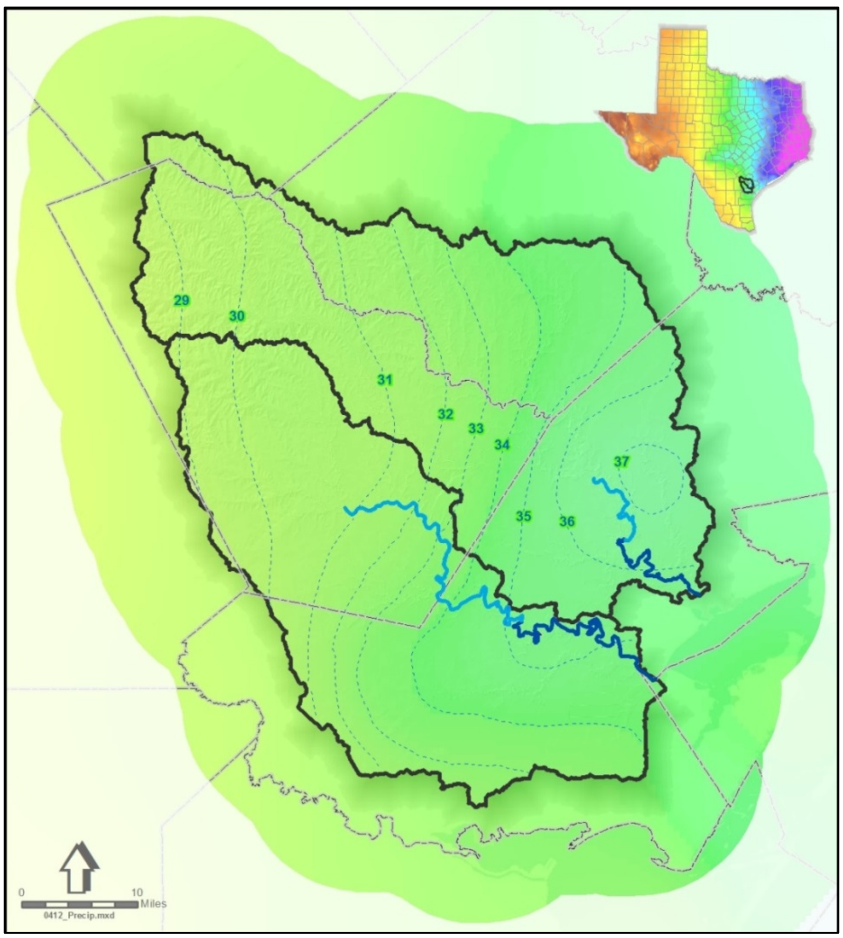

Figure 2. Annual average precipitation isohyeths (in inches) in the Mission and Aransas Rivers watersheds (1981-2010).

Source: PRISM Climate Group at Oregon State University (2012)

In Beeville, average high temperatures generally reach their peak of 95°F in August, and highs above 100°F have occurred from April through September. Fair skies generally accompany the highest temperatures of summer when nightly average lows drop to about 72°F. During winter, the average low temperature bottoms out at 43°F in January, although below freezing temperatures have occurred from September through April. The frost-free period in Beeville generally lasts for about 287 days, with the average last frost occurring February 23rd and the average first frost occurring in December 7th (Welsh, 2007).

Weather data obtained spanning a period from 1972 through 2012 indicate that annual average precipitation for the Beeville area is 32 inches (NOAA, 2012). The wettest month is normally September (3.8 in), and the driest month is normally February (1.6 inches), although some rainfall typically occurs year-round (Figure 3).

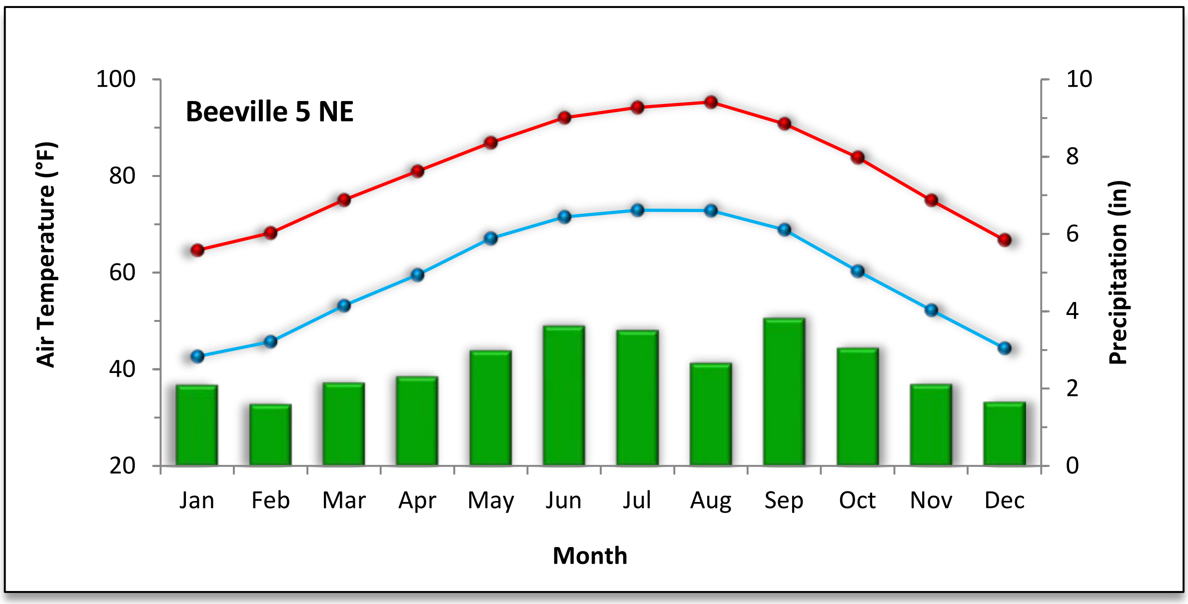

Figure 3. Average minimum and maximum air temperature and total precipitation by month over Dec 1972 –Nov 2012 for Beeville area.

Source: NOAA (2012)

2.3 Watershed Population and Population Projections

According to the 2010 Census (USCB, 2012), population throughout the Mission River watershed is generally rural and dispersed outside of the cities of Refugio (population 2,890) and Woodsboro (1,512). The total population of the Mission watershed was approximately 8,882, indicating a population density of about 9 people/ mi^2. The largest municipalities within the more populous Aransas River watershed are the cities of Beeville (population 12,863), Sinton (5,665), Taft (3,048), and Odem (2,389). The total population of the Aransas watershed was approximately 45,689, indicating a population density of about 54 people/ mi^2, more than six times that of the Mission River watershed (Figure 4).

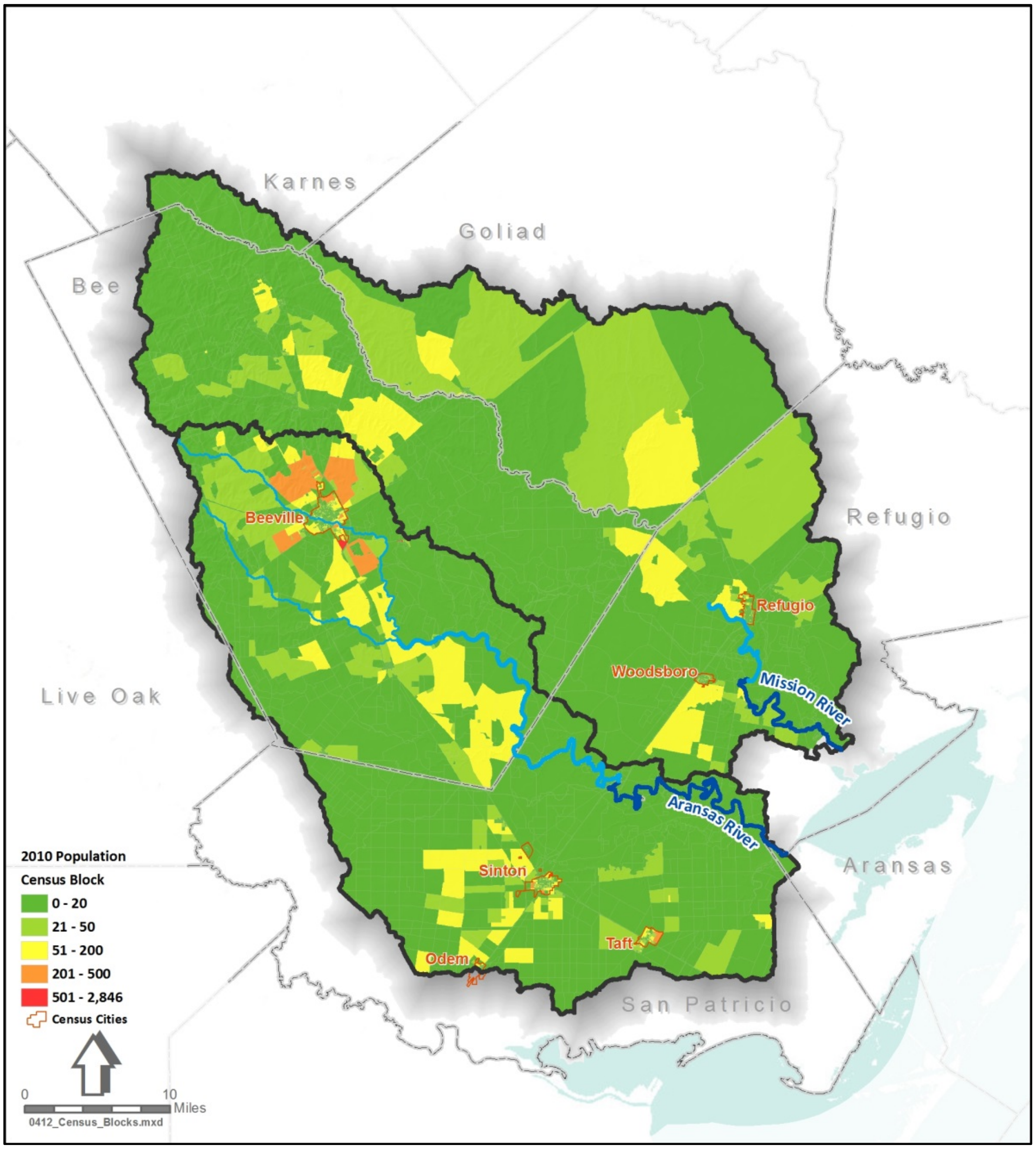

Figure 4. 2010 Population by Census Block.

Sources: Census information obtained from TNRIS (2012b) & 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 seven counties that are included within the Mission and Aransas watersheds (Aransas, Bee, Goliad, Karnes, Live Oak, Refugio and San Patricio) are expected to increase by an average of 14.5% between 2010 and 2050. For the cities within the watershed, including Beeville, Odem, Refugio, Sinton, Taft and Woodsboro, the populations are projected to increase by an average of 13.5% between 2010 and 2050 (Table 1). The cities of Odem, Sinton and Taft, all located within the Aransas River Tidal watershed, are expected to have the most significant growth (Table 1).

Table 1. 2010 Population and 2020 – 2050 Population Projections for cities in the Mission River and Aransas River watersheds.

Source: TWDB (2013)

City	Watershed	2010 U.S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Percent Increase (2010 - 2050)
Refugio	Mission	2,890	3,009	3,104	3,126	3,179	10.00%
Woodsboro	Mission	1,512	1,575	1,624	1,636	1,663	10.00%
Beeville	Aransas	12,863	13,516	14,082	14,327	14,351	11.60%
Odem	Aransas	2,389	2,535	2,659	2,730	2,782	16.50%
Sinton	Aransas	5,665	6,011	6,305	6,473	6,596	16.40%
Taft	Aransas	3,048	3,235	3,392	3,483	3,549	16.40%

2.4 Review of Mission and Aransas Watershed Routine Monitoring Data

2.4.1 Data Acquisition

Ambient Enterococci data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) on 11 December 2012. The data represented all the historical routine ambient Enterococci and other water quality data collected in the project area, and included Enterococci data collected from October 1999 through March 2012. General assessment criteria methodologies established by TCEQ were used in data evaluations.

2.4.2 Analysis of Bacteria Data

Recent environmental monitoring within the Mission and Aransas Tidal Segments has occurred at three TCEQ monitoring stations (Figure 5). Enterococci data collected at these stations over the seven-year period of 1 December 2003 through 30 November 2010 were used in assessing attainment of the primary contact recreation use as reported in the *2012 Texas Integrated Report* (TCEQ, 2013b)and as summarized in Table 2. The 2012 assessment data indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the geometric mean criterion of 35 MPN/100 mL for Mission River Tidal (2001) and Aransas River Tidal (2003).

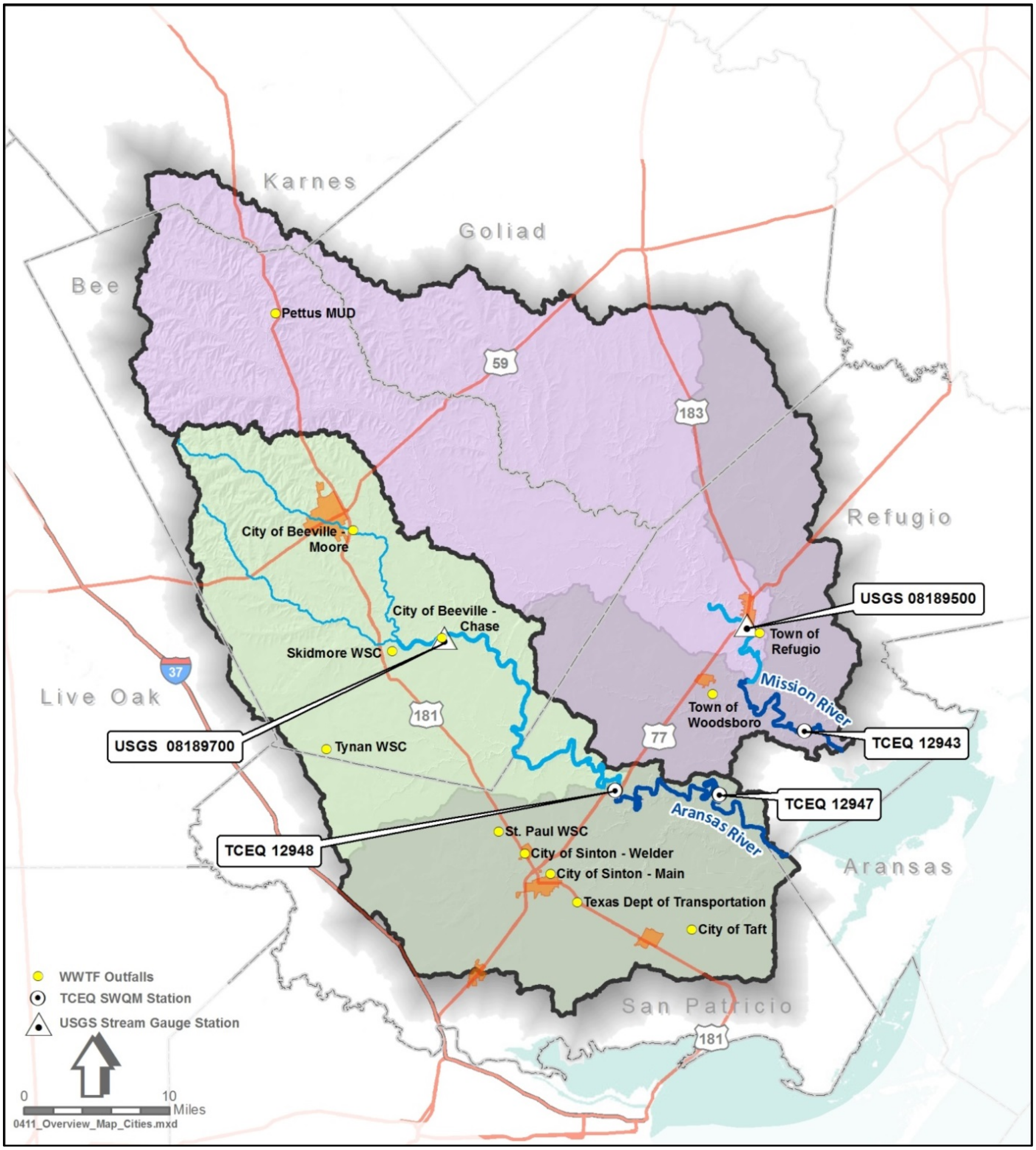

Figure 5. Mission and Aransas watersheds showing wastewater treatment facilities (WWTFs), TCEQ surface water quality monitoring stations, and USGS stream gage stations.

Source: Permitted outfalls from TCEQ (2012a); TCEQ stations from TCEQ (2012b); USGS stream gage stations from USGS (2013)

Table 2. 2012 Integrated Report Summary for the Mission River Tidal and Aransas River Tidal.

Source: TCEQ (2013b)

Water Body	Segment Number	Assessment Unit (AU)	Parameter	Station	No. of Samples	Data Date Range	Station Geometric Mean (MPN/100 mL)
Mission River Tidal	2001	2001_01	Enterococcus Geomean	12943	28	2003-2010	66.70
Aransas River Tidal	2003	2003_01	Enterococcus Geeomean	12948/ 12947	46	2003-2010	60.40

2.5 Land Use

The land use/land cover data for the watersheds of the Aransas and Mission Rivers was obtained from the 2006 National Land Cover Database (U.S. Geological Survey), and is displayed in Figure 6. The land use/land cover is represented by the following categories and definitions:

- **Scrub/Grassland** – Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. *Grassland*: 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.

- **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.

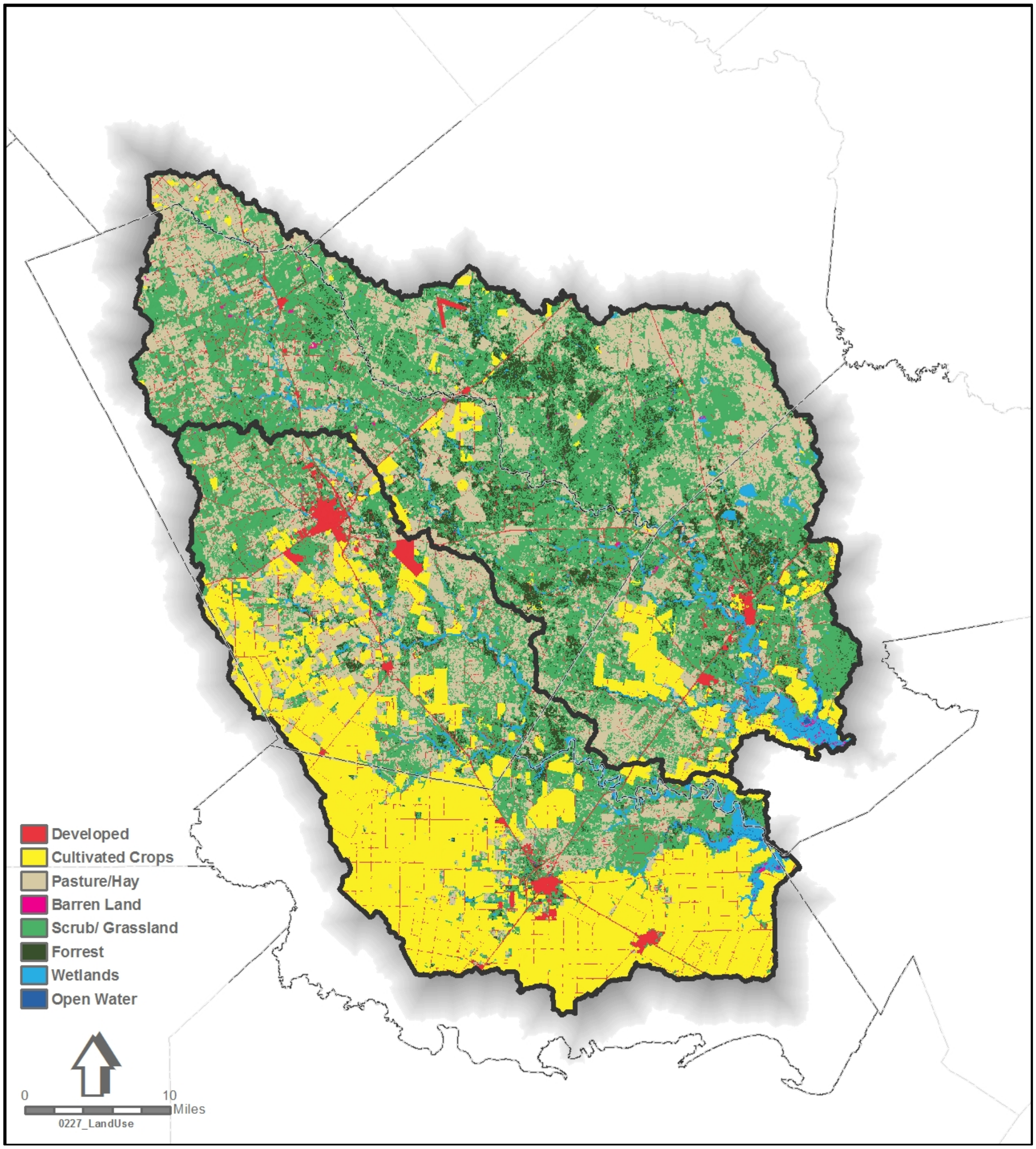

Figure 6. 2006 land use/land cover within the watersheds of the Mission and Aransas Rivers.

Source: USGS (2011)

- **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 3, the watershed area encompassing Segments 2001 and 2002 (Mission River Watershed) is 658,581 acres. Dominant land uses in the Mission River watershed include Scrub/Grassland (47.3%) and Pasture (31.5%). The watershed area encompassing Segments 2003 and 2004 (Aransas River Watershed) is 539,714 acres, and is dominated by Cultivated Crops (44.7%) and Scrub/Grassland (24.3%). Both watersheds are mostly rural, with only about 5% of the combined area classified as Developed.

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Table 3. Land/Use Land Cover within the Mission and Aransas watersheds.

Source: USGS (2011)

2006 NLCD	Mission Tidal (2001_01)		Mission Above Tidal (2002_01)		Mission River Grand Total	
Classification	**Acres**	**% of Total**	**Acres**	**% of Total**	**Acres**	**% of Grand Total**
Barren land	560	0.3%	1,152	0.3%	1,713	0.3%
Cultivated Crops	26,955	13.3%	11,532	2.5%	38,487	5.8%
Developed	7,476	3.7%	18,207	4.0%	25,683	3.9%
Forest	10,143	5.0%	38,424	8.4%	48,567	7.4%
Open Water	633	0.3%	210	0.0%	843	0.1%
Pasture	62,182	30.7%	145,204	31.8%	207,386	31.5%
Scrub/ Grassland	81,994	40.5%	229,593	50.3%	311,586	47.3%
Wetlands	12,593	6.2%	11,723	2.6%	24,316	3.7%
Total	202,535	acres	456,046	acres	658,581	acres

2006 NLCD	Aransas Tidal (2003_01)		Aransas Above Tidal (2004_01)		Aransas River Grand Total	
Classification	**Acres**	**% of Total**	**Acres**	**% of Total**	**Acres**	**% of Grand Total**
Barren land	398	0.2%	265	0.1%	663	0.1%
Cultivated Crops	152,145	66.3%	89,111	28.7%	241,256	44.7%
Developed	13,024	5.7%	19,605	6.3%	32,629	6.0%
Forest	2,486	1.1%	11,974	3.9%	14,460	2.7%
Open Water	1,196	0.5%	26	0.0%	1,222	0.2%
Pasture	17,105	7.5%	83,805	27.0%	100,910	18.7%
Scrub/ Grassland	33,808	14.7%	97,542	31.5%	131,350	24.3%
Wetlands	9,406	4.1%	7,818	2.5%	17,224	3.2%
Total	229,567	acres	310,147	acres	539,714	acres

2.6 Potential Sources of Fecal Indicator Bacteria

Potential sources of indicator bacteria pollution 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 are wastewater treatment facility (WWTF) discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities.

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.

With the exception of WWTFs, which receive individual waste load allocations or WLAs (see report Section 4.7.3, Waste Load Allocation), the regulated and unregulated sources in this section are presented to give a general account of the potential sources of bacteria in the watershed.

2.6.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES programs. WWTF outfalls and stormwater discharges from industries and construction represent the permitted sources in the watershed of the Mission and Aransas Rivers.

2.6.1.1 Domestic Wastewater Treatment Facility Discharges

Twelve facilities in the Mission and Aransas watersheds treat domestic wastewater; three are in the Mission River watershed and nine are within the more populated Aransas River watershed (Table 4; Figure 5). None of the WWTFs in the watersheds discharge directly into either the impaired Mission or Aransas River Tidal segments (Segments 2001 and 2003). The only WWTF that discharges directly into a mainstem river is the Chase Field WWTF operated by the City of Beeville, which discharges into the Aransas River Above Tidal (Segment 2004). All other WWTFs discharge into tributaries of the rivers. For information regarding bacteria permit limits see Section 2.6.1.6, “Review of Information on Permitted Sources.”

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Table 4. Permitted domestic wastewater treatment facilities in the Aransas River and Mission River watersheds.

Source: Individual TPDES Permits

TPDES Permit No.	Facility	AU	Receiving Waters	Final Permitted Discharge[a] (MGD)	Recent Discharge[b] (MGD)
WQ0010124004	City of Beeville - Chase Field WWTF	2004	Aransas River Above Tidal	2.5	0.4155
WQ0010124002	City of Beeville - Moore Street WWTF	2004	Poesta Creek to Aransas River Above Tidal	3.0	0.0707
WQ0010055001	City of Sinton-Main WWTF	2003	Chiltipin Creek to Aransas River Tidal	0.80	0.3901
WQ0013641001	City of Sinton - Rod and Bessie Welder WWTF	2003	San Patricio County Drainage District ditch to Unamed Tributary to Chiltipin Creek to Aransas River Tidal	0.015	0.0078
WQ0010705001	City of Taft WWTF	2003	Taft Drainage Ditch to Mud Flats to Copano Bay	0.90	0.3967
WQ0010748001	Pettus MUD WWTF	2002	Medio Creek to Mission Creek Above Tidal	0.105	0.0388
WQ0014112001	Skidmore WSC WWTF	2004	Unnamed Tributary to Aranasas River Above Tidal	0.131	0.0457
WQ0014119001	St. Paul WSC WWTF	2003	Unnamed Tributary to Chiltipin Creek to Aransas River Tidal	0.05	0.0261
WQ0013412001	Texas Department of Transportation - Sinton Engineering Building WWTF	2003	Oliver Drainage Ditch to Unnamed Tributary to Chiltipin Creek to Aransas River Tidal	0.00038	0.0005
WQ0010255001	Town of Refugio WWTF	2002	Dry Creek to Mission River Above Tidal	0.576	0.2790
WQ0010156001	Town of Woodsboro WWTF	2001	Ditch to Willow Creek to Sous Creek to Mission River Tidal	0.25	0.0967
WQ0014123001	Tynan WSC WWTF	2004	Papalote Creek to Aransas River Above Tidal	0.045	0.0338

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

2.6.1.2 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.

The TCEQ Region 14 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. The reports of SSO events that occurred within the watersheds of the Mission and Aransas Rivers between August 2009 and January 2013 are shown in Table 5. Ten separate incidences were reported for four different facilities. The reported data indicate that the SSOs occurred year-round, and that the durations lasted from 1 minute to almost 44 hours, and overflow volumes ranged from less than 1 gallon to 28,200 gallons.

Table 5. SSO incidences reported in the watersheds of the Mission and Aransas Rivers watersheds from Aug. 2009 – Jan. 2013.

Source: TCEQ Region 14

Facility Name	Discharge Date(s)	Duration (hr-min)	Volume (Gallons)	Cause	Segment
Pettus MUD WWTF	intermittent from at least 01/5/2011 thru 03/07/2011	unknown	unknown	clogged rags/grease	2002
	5/16/2012	unknown	unknown	power outage	2002
Town of Refugio WWTF	6/29/2009; 07/02/2009 and 07/08/2009	unknown	unknown	concrete obstruction in the main line	2002
	4/16/2012	0-1	less than 1	I&I	2002
	8/23/2009	unknown	unknown	unknown	2002
City of Sinton Main WWTF	9/11/2009	43-45	28200	I&I	2003
City of Taft WWTF	9/16/2009	0-20	5000 -8000	Line Break	2003
	11/20/2009	8-45	unknown	I&I	2003
	4/10/2010	unknown	500	Line Break	2003
	9/21/2010	unknown	unknown	I&I	2003

2.6.1.3 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 the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) 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.

2.6.1.4 TPDES General Wastewater Permits

In addition to the individual wastewater discharge permits listed in Table 4, discharges of processed wastewater from certain types of facilities are required to be covered by one of several TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production facilities
- TXG340000 – petroleum bulk stations and terminals
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG920000 – concentrated animal feeding operations
- WQG20000 – livestock manure compost operations (irrigation only)

A review of active general permit coverage (TCEQ, 2008) in the Mission River watershed as of 26 March 2013 found no operations or facilities of the type described above. A review of active general permit coverage (TCEQ, 2008) in the Aransas River watershed as of 26 March 2013 found one concrete production facility covered by the general permit. This facility is located in Segment 2002, above the impaired AU watershed. No other active general wastewater permit facilities or operations were found. There were no facilities covered under the general permits for aquaculture production, petroleum bulk stations and terminals, hydrostatic test water discharges, water contaminated by petroleum fuel or petroleum substances, concentrated animal feeding operations or livestock manure compost operations. No attempt was made to allocate bacteria loads to wastewater discharges from these general permit sites because (1) there are a relatively small number of facilities, (2) flows are intermittent and variable, and (3) the flows are not anticipated to contain high bacteria loadings.

2.6.1.5 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
- TXG340000 – petroleum bulk stations and terminals

Three of these permits (MS4, MSGP, and construction) pertain solely to stormwater discharges. The other two – concrete production facilities and petroleum bulk stations and terminals – also authorize the discharge of process wastewater as discussed above under TPDES General Wastewater Permits.

A review of active stormwater general permits coverage (TCEQ, 2008) in the Mission River watershed, as of 26 March 2013, found 4 active industrial (MSGP) facilities and 3 active construction sites. A review of active stormwater general permits coverage in the Aransas River watershed, as of 26 March 2013, found 7 active industrial (MSGP) facilities, 8 active construction sites, and 1 active concrete production facility. There are currently no Phase II MS4s or petroleum bulk stations and terminals facilities in either watershed. See Section 4.7.3 for more detailed information.

2.6.1.6 Review of Compliance Information on Permitted Sources

A review of the EPA Enforcement & Compliance History Online (ECHO) database (USEPA, 2013b), conducted 17 April 2013, revealed non-compliance issues regarding *E. coli* permit limits for 4 WWTFs in the Mission and Aransas watersheds (See Table 6). For the period from July 2009 through December 2012, the following 4 facilities reported exceedances in bacteria concentration discharge limits:

Table 6. Bacteria monitoring requirements and compliance status for WWTFs in the watersheds of the Mission and Aransas Rivers.

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. 2009 – Dec. 2012 timeframe. "% Monthly Exceedances" were calculated based on reported monthly records.

TPDES Permit No.	Facility	Bacteria Monitoring Requirement	Min. Self-Monitoring Requirement Frequency	Daily Average (Geometric Mean) Limitation	Single Grab (or Daily Max) Limitation	% Monthly Exceedances Daily Average	% Monthly Exceedances Single Grab
WQ0010124004*	City of Beeville - Chase Field WWTF	*E. coli*	Two/month	126	394	n/a	n/a
WQ0010124002	City of Beeville - Moore Street WWTF	*E. coli*	One/week	126	394	9%	16%
WQ0010055001	City of Sinton- Main WWTF	n/a	n/a	n/a	n/a	n/a	n/a
WQ0013641001	City of Sinton - Rod and Bessie Welder WWTF	*E. coli*	Five/week	126	394	6%	56%
WQ0010705001	City of Taft WWTF	Enterococci	Two/month	35	89	0%	0%
WQ0010748001	Pettus MUD WWTF	*E. coli*	One/month	126	394	0%	0%
WQ0014112001	Skidmore WSC WWTF	n/a	n/a	n/a	n/a	n/a	n/a
WQ0014119001	St. Paul WSC WWTF	*E. coli*	One/quarter	126	394	0%	0%
WQ0013412001	TxDOT- Sinton Engineering Building WWTF	*E. coli*	One/week	126	394	3%	6%
WQ0010255001	Town of Refugio WWTF	*E. coli*	Twice/month	126	394	0%	0%
WQ0010156001	Town of Woodsboro WWTF	*E. coli*	One/month	126	394	0%	6%
WQ0014123001	Tynan WSC WWTF	*E. coli*	One/quarter	126	394	0%	0%

* No compliance data was available through ECHO for Chase Field WWTF.

- City of Beeville - Moore Street WWTF,
- City of Sinton - Rod and Bessie Welder WWTF,
- TxDOT- Sinton Engineering Building WWTF and
- Town of Woodsboro WWTF.

None of the bacteria effluent violations were reported as Significant Non-compliance (SNC) effluent violations, but unresolved SNC violations for bacteria were indicated for the following three facilities:

- City of Sinton - Rod and Bessie Welder WWTF,
- TxDOT- Sinton Engineering Building WWTF and
- Town of Woodsboro WWTF.

Two of the 12 permits do not require monitoring bacteria concentrations in effluent; those are the City of Sinton- Main WWTF and the Skidmore WSC WWTF. For the City of Beeville - Chase Field WWTF, *E. coli* monitoring is a permit requirement, but no *E. coli* data were available through ECHO when that database was searched.

Bacteria data were collected under a special study by the Nueces River Authority (NRA) (Nueces River Authority, 2011). The NRA sampled 14 stream sites and 12 WWTFs over a period from October 2007 to January 2011 (Rocky Freund, NRA, personal communication, 16 Sept 2013). A summary of bacteria sampling data collected at the 10 WWTF outfalls that were located within the Mission River and Aransas River watersheds is presented in the following Table 7 (The City of Odem (outfall) and the City of Bayside are both outside of the subject watersheds, and therefore were not included in the table below.) The data indicate that most WWTFs were providing disinfected effluent with indicator bacteria levels below state instream indicator bacteria criteria, though the data indicte that two facilities (City of Sinton- Main and St. Paul WSC) exceeded the criteria for one or both indicator bacteria more than 50% of the time.

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Table 7. Summary of Enterococci and *E. coli* WWTF effluent data collected by NRA from October 2007 to January 2011.

Source: (Nueces River Authority, 2011).

TPDES Permit No.	Facility	Enterococci			*E. coli*		
		N	Percent Exceeding Geometric Mean Criterion (35 MPN/ 100 mL)	Geo-metric Mean (MPN/ 100 mL)	N	Percent Exceeding Geometric Mean Criterion (126 MPN/ 100 mL)	Geo-metric Mean (MPN / 100 mL)
WQ0010124004	City of Beeville - Chase Field WWTF	28	18%	8	28	0%	6
WQ0010124002	City of Beeville - Moore Street WWTF	27	0%	4	27	0%	5
WQ0010055001	City of Sinton- Main WWTF	31	61%	163	34	15%	65
WQ0010705001	City of Taft WWTF	32	6%	2	35	9%	2
WQ0010748001	Pettus MUD WWTF	27	22%	7	27	22%	6
WQ0014112001	Skidmore WSC WWTF	27	7%	2	28	0%	2
WQ0014119001	St. Paul WSC WWTF	31	68%	439	34	74%	419
WQ0010255001	Town of Refugio WWTF	31	23%	8	34	15%	6
WQ0010156001	Town of Woodsboro WWTF	28	0%	2	31	0%	2
WQ0014123001	Tynan WSC WWTF	24	29%	29	24	21%	31

2.6.2 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.

2.6.2.1 Wildlife and Unmanaged Animal Contributions

Enterococci bacteria are common inhabitants of the intestines of all warm blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife. Wildlife are naturally attracted to riparian corridors of streams and rivers. 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. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. An estimate of deer and feral hog populations for the watersheds of the Mission and Aransas Rivers were made by Borel & Karthikeyan (2013) and are reported in Table 8.

Table 8. Estimated distributed deer and feral hog populations. Populations in animal units of 1,000 lbs live weight.

Source: Adapted from Table 5 in Borel & Karthikeyan (2013)

Watershed	Deer	Feral Hogs
Aransas Above Tidal	2,462	1,089
Aransas Tidal	2,075	781
Mission Above Tidal	3,731	1,636
Mission Tidal	1,681	692
Total Watershed	**9,949**	**4,198**

2.6.2.2 On-Site Sewage Facilities

Failing onsite sewage facilities (OSSFs) were estimated by Borel & Karthikeyan (2013) for the portions of the counties within the watersheds of the Mission and Aransas Rivers. Table 9 shows the total number of OSSFs, by fractional part of the county, distributed by soil limitation class. More detail on the soil limitation class and failure rates is provided in Borel & Karthikeyan (2013).

Table 9. Number of OSSFs by County and soil condition for the combined watersheds of the Mission and Aransas Rivers.

Source: Adapted from Borel & Karthikeyan (2013), Table 3.

Soil Condition	Total OSSFs by County							Total OSSFs by Soil Condition	Total Failing OSSFs
	Karnes	Refugio	Goliad	Bee	Live Oak	Aransas	San Patricio		
Very Limited	83	721	346	3,920	1	1	2,979	8,051	1,208
Somewhat Limited	65	0	63	1,850	0	0	9	1,987	199
Not Limited	0	0	0	0	0	0	0	-	-
Not Rated	1	0	0	8	0	0	0	9	1
Totals by County	149	721	409	5,778	1	1	2,988	10,047	**1,408**

2.6.2.3 Non-Permitted Agricultural Activities and Domesticated Animals

As a component of the TDML development process, Borel & Karthikeyan (2013) estimated the number of animal units present in the Mission and Aransas watersheds for a number of wildlife and livestock species, including deer, feral hogs, goats, horses, sheep and cattle. An animal unit is a standard unit for assessing animal fecal bacteria production and is representative of 1,000 lbs of live weight. The numbers, distributed to watersheds that match the boundaries presented in Figure 1 of this report, are presented in Table 10.

Table 10. Estimated distributed domesticated animal populations. Populations in animal units of 1,000 lbs live weight.

Source: Adapted from Tables 5 and 6 in Borel & Karthikeyan (2013)

Watershed	Goats	Horses	Sheep	Total Cattle
Aransas Above Tidal	198	812	34	15,022
Aransas Tidal	34	401	31	3,658
Mission Above Tidal	281	1,071	41	29,090
Mission Tidal	51	488	4	11,736
Total Watershed	**564**	**2,772**	**110**	**59,506**

Activities, such as livestock grazing close to water bodies and farmers' use of manure as fertilizer, can contribute fecal indicator bacteria such as Enterococci to nearby water bodies. Pets can also be sources of Enterococci, because storm runoff carries the animal wastes into streams (USEPA, 2013a). The estimated number of domestic dogs in the Mission and Aransas watersheds was estimated by Borel & Karthikeyan (2013), and is shown in Table 11.

Table 11. Estimated distributed dog population.

Source: Adapted from Table 4 in Borel & Karthikeyan (2013).

Watershed	Distributed Dog Population
Aransas Above Tidal	4,254
Aransas Tidal	2,940
Mission Above Tidal	2,444
Mission Tidal	427

2.6.2.4 Bacteria Survival and Die-off

Bacteria are living organisms that survive and die in the environment. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (e.g., warm temperature). Fecal organisms from improperly treated effluent can survive and replicate during their transport in pipe networks, and they can survive and replicate in organic rich materials such as compost and sludge. While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less well understood. Both processes (replication and die-off) are in-stream processes and are not considered in the bacteria source loading estimates of each water body in the TMDL watersheds.

SECTION 3
BACTERIA TOOL DEVELOPMENT

This section describes the rationale of the bacteria tool selection for TMDL development and details the procedures and results of load duration curve development.

3.1 Model Selection

The TMDL allocation process for bacteria involves assigning bacteria, e.g., Enterococci, loads to their sources such that the total loads do not violate the pertinent numeric criterion protecting contact recreation use. To perform the allocation process, a tool must be developed to assist in allocating bacteria loads. Selection of the appropriate bacteria tool for impaired AUs in the TMDL watersheds considered availability of data and other information necessary for supportable application of the selected tool and guidance in the Texas bacteria task force report (TWRI, 2007). In general, two basic tools are commonly used for bacteria TMDLs—mechanistic computer models and an empirical approach referred to as the load duration curve (LDC).

Mechanistic computer models provide analytical abstractions of a real or prototype system. Mechanistic models, also referred to as process models, are based on theoretical principles that provide a representation of governing physical processes that determine the response of certain variables, such as stream flows and bacterial concentrations, to precipitation. Under circumstances where the governing physical processes are acceptably quantifiable, the mechanistic model provides an understanding of the important biological, chemical, and physical processes of the prototype system and reasonable predictive capabilities to evaluate alternative allocations of pollutant load sources.

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). An adaptation of the LDC method to tidal waters has been successfully developed and applied by the State of Oregon (ODEQ, 2006). In addition to estimating stream loads, the load duration curve method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs, that constrain the use of more powerful mechanistic models. Further, the bacteria task force appointed by the TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) supports application of the load duration curve method within their three-tiered approach to TMDL development (TWRI, 2007). The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion, and can give indications of broad sources of the bacteria, i.e., point source and nonpoint source.

3.1.1 Situational Limitations of Mechanistic Modeling

The present surface water bacteria standards do not restrict what streamflow conditions the primary contact recreation criteria should meet; therefore, the allocation process must consider all streamflow conditions ranging from low flows to high flows. Additionally, the water bodies for TMDL development are tidally influenced, which adds yet another level of complexity to the processes that need to be considered. The TMDL allocation tool, therefore, must be capable of characterizing tidal influences, streamflow and bacteria loads at desired locations under the wide variety of environmental conditions experienced in the TMDL watersheds. If a mechanistic modeling tool is applied, it must be capable of simulating response of bacterial loadings to streamflow and tidal conditions during base flow as well as during times of response to rainfall runoff and those intermediate conditions between well-defined base flow and strong rainfall-runoff response. The type of mechanistic tool with capabilities to simulate all these complexities is often referred to as a combined watershed loading and hydrologic/water quality model. These models simulate the hydrologic response of the watershed's land uses and land covers to rainfall, route runoff water through the conveyance channels of the watershed, add in point source contributions, and may include other hydrologic processes such as interaction of surface waters with shallow ground water.

While admittedly the streamflow and tidal processes requiring simulation are complex, these processes are generally better understood and more readily simulated than the bacterial processes. Nonetheless, mechanistic bacteria modeling has progressed significantly over the last several decades beginning in the late 1960s to early 1970s as increasing computer resources made such endeavors possible. Regrettably for the application of mechanistic bacteria models, while the numerical equations to represent many pertinent processes exist and are incorporated in readily available models, these processes are appreciably more watershed specific than hydrologic processes. As one simple example, failing on-site treatment systems, such as septic systems, rarely makes measurable differences to streamflow, but can dramatically impact fecal bacteria concentrations present in the same streamflow. In the vast majority of circumstances, and the Mission and Aransas watersheds are no exception, only very limited watershed-specific information is available to define many of the physical and biological processes that affect bacteria concentrations and loadings. Consequentially, the operator of the mechanistic model must specify, in many circumstances, numerous input parameters governing bacteria processes for which actual numeric values may not be known within a reasonable range of certainty.

3.1.2 Mission and Aransas Rivers Data Resources

Streamflow, salinity, and Enterococci data availability were used to provide guidance in the allocation tool selection process. (Salinity data provided a measure of the degree of mixing of seawater and freshwater in the tidal segments.) As already mentioned, the necessary information and data are largely unavailable for watersheds of the Mission and Aransas Rivers to allow adequate definition of many of the physical and biological processes influencing in-stream bacteria concentrations for mechanistic model application, and these limitations became an important consideration in the allocation tool selection process.

Hydrologic data in the form of daily streamflow records were available for the mainstem portions of the Mission and Aransas Rivers. Streamflow records for the mainstem portions of the Mission and Aransas Rivers are collected and made readily available by the U.S. Geological Survey (USGS), which operates one streamflow gage on the Mission River and one gage on the Aransas River (Table 12; Figure 5). USGS streamflow gage 08189500 is located along the mainstem of the Mission River within Segment 2002, and USGS streamflow gage 08189700 is located along the mainstem of the Aransas River within Segment 2004. Both gages serve as the primary sources for streamflow records used in this document.

Table 12. Basic information on USGS streamflow gages in project area

Gage No.	Site Description	Assessment Unit (AU)	Drainage Area (sq. mi.)	Daily Streamflow Record (beginning & end date)
08189500	Mission River at Refugio, TX	2002_01	690	Jul. 1939 – present
08189700	Aransas River near Skidmore, TX	2004_01	247	Mar. 1964 – present

Self-reported data in the form of monthly discharge reports (DMRs) were available for at least the most recent 5 year (Nov. 2007- Oct. 2012) timeframe for all but one of the WWTFs in the Mission and Aransas watersheds. The exception was Tynan WSC WWTF, where records were available for only the period of Feb. 2009- Oct. 2012. For each WWTF, DMR data were downloaded as available from at least one of two EPA compliance databases – Enforcement and Compliance History Online (ECHO) or the Integrated Compliance Information System (ICIS).

Ambient Enterococci and salinity data were available through the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) for one station in Segment 2001 and for two stations in Segment 2003 (Table 13).

Table 13. Summary of historical data set of Enterococci concentrations.

Water Body	Assessment Unit (AU)	Station	Station Location	No. of Enterococcus Samples	No. of Salinity Samples	Data Date Range
Mission River	2001_01	12943	Mission River at FM 2678	51	51	1999 - 2012
Aransas River	2003_01	12947	Aransas River Tidal at FM 629	31	31	2004 - 2012
		12948	Aransas River Tidal at US 77	51	17	1999 - 2011

3.1.3 Allocation Tool Selection

Based on good availability of historical daily streamflow records, discharge information for large municipal WWTFs, ambient Enterococci, and salinity data as well as deficiencies in data to describe bacterial landscape and in-stream processes, the decision was made to use the load duration curve method with modifications to include tidal influences as opposed to a mechanistic watershed loading and hydrologic/water quality model. A modification of the LDC method (modified LDC method) developed by State of Oregon Department of Environmental Quality for bacteria TMDLs of tidal streams of the Umpqua River Basin (ODEQ, 2006) was adapted to the Mission River Tidal (Segment 2001) and Aransas River Tidal (Segment 2003).

The modified LDC method is based on the assumption that combining of river water with seawater increases the loading capacity in the tidal river because seawater typically contains lower concentrations of indicator bacteria, such as Enterococci, than river water. The assumption of decreasing concentrations of Enterococci with distance from the tidal segments of the Mission and Aransas River into Copano Bay are borne out in the historical data. More details on the modified LDC method and the spatial trends of Enterococci are provided in Appendix A.

3.2 Methodology for Flow Duration & Load Duration Curve Development

To develop the modified flow duration curves (FDCs) and modified load duration curves (LDCs), the previously discussed data resources were used in the following series of sequential steps.

- **Step 1:** Determine the hydrologic period of record to be used in developing the flow duration curves.
- **Step 2:** Determine desired stream locations for which flow and load duration curves will be developed. (The stream locations will be at the three monitoring stations along the impaired AUs of the mainstem Mission and Aransas Rivers.)

- **Step 3:** Develop daily streamflow records at desired stream locations using the daily gaged streamflow records, drainage area ratios, municipal WWTF DMR data for actual discharges, full permitted flows and future growth flows.
- **Step 4:** Develop regressions of salinity to streamflow at the desired stream locations.
- **Step 5:** Develop modified FDCs at desired stream locations, segmented into discrete flow regimes.
- **Step 6:** Develop the allowable bacteria LDCs at the same stream locations based on the relevant criteria and the data from the FDCs.
- **Step 7:** Superpose historical bacteria data, if such data exist at the location, on the allowable bacteria LDCs.

Additional information explaining the LDC method may be found in Cleland (2003) and NDEP (2003). Information on the modified LDC method is found in OCED (2006),

3.2.1 Step 1: Determine Hydrologic Period

Daily hydrologic (streamflow) records were available for two USGS gage locations, one in each watershed. For the gage located at the Mission River at Refugio, the period of record is 73 years and for the gage located at the Aransas River near Skidmore, the period of record of 48 years (Table 12, Figure 5). Both periods of record are more than adequate to capture a reasonable variation in meteorological patterns of high and low rainfall periods.

Optimally, the period of record to develop flow duration curves should include as much data as possible in order to capture extremes of high and low streamflows and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of recent conditions experienced within the watershed and when the Enterococci data were collected. Therefore, a 15-year record of daily streamflow from 1 January 1998 through 31 December 2012 was selected to develop the streamflow duration curves at each station, and this period includes the collection dates of all available Enterococci data at the time this work effort was undertaken. A 15-year period is of sufficient duration to contain a reasonable variation from dry months and years to wet months and years and at the same time is short enough in duration to contain a hydrology that is responding to recent and current conditions in the watershed.

3.2.2 Step 2: Determine Desired Stream Locations

The SWQM stations that were located within the impaired reaches and for which adequate Enterococci data were available determined the stream locations for which modified FDCs and LDCs were developed. Of the three stations that were located within the impaired reaches, all had a sufficient number of Enterococci records (Table 12).

3.2.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station locations were determined, the next step was to develop the 15-year daily streamflow record for each monitoring station. The daily streamflow records were developed from extant USGS records for both the Mission and Aransas Rivers (Table 12).

The method to develop the necessary streamflow record for each FDC/LDC location (SWQM stations location) involved a drainage-area ratio (DAR) approach. With this basic approach, each USGS gage daily streamflow value within the 15-year period was multiplied by a factor to estimate the flow at a desired SWQM station location. The factor was determined by dividing the drainage area above the desired monitoring station location by the drainage area above the USGS gage. Further, all WWTFs were evaluated at their full permitted discharge (Table 4).

In order to account for WWTF flow and to properly apply the DAR, first the average DMR reported discharge for all WWTFs upstream of the USGS gage location were subtracted from the streamflow record of the gage providing an adjusted streamflow record with point source discharge influences removed. For both of the Aransas River SWQM station locations, the upstream WWTFs included the City of Beeville (Chase Field and Moore Street WWTFs) and the Skidmore WSC; for the Mission River station, only the Pettus MUD WWTF average DMR reported discharges were subtracted. The DAR for the desired FDC/LDC location was then multiplied by this adjusted streamflow record giving the estimated daily flow record.

Next, the full-permitted flows along with the future growth flows (calculated in Section 4.7.4) for all within-watershed WWTF contributions to streamflow were added into to the DAR-adjusted USGS flows for each FDC/LDC location, regardless of their particular hydrologic connection to the TMDL locations. For example, in the Aransas watershed, the full permitted WWTF flows for all nine of the WWTFs included within the watershed (AU 2003_01 and AU 2004_01) were included in the FDC computation for Station 12947.

The DARs for locations within the watersheds of the Mission and Aransas Rivers are presented in Table 14. The drainage areas were calculated using the ArcSwat 2009.10.1 tool in ArcMap 10.

Table 14. DARs for locations within the watersheds of the Mission and Aransas Rivers based on the drainage area of upstream USGS gages.

Assessment Unit	Location	Location	Location Drainage Area (acres)	Drainage Area Ratio (DAR)
2001	USGS 08189500	Mission River at Refugio, TX	439,615	1.000
	TCEQ 12943	Mission River at FM 2678	549,471	1.250
2003	USGS 08189700	Aransas River near Skidmore, TX	155,603	1.000
	TCEQ 12947	Aransas River Tidal at FM 629	336,487	2.162
	TCEQ 12948	Aransas River Tidal at US 77	310,425	1.995

3.2.4 Step 4: Salinity to Streamflow Regressions

As part of the development of the modified LDC method, it was necessary to develop a relationship of daily streamflow and measured salinity where the resulting regression became instrumental in determining the daily volume of saltwater present for each daily freshwater flow in the 15-year period of record. Due to the location of the three monitoring stations within the tidally-influenced portions of the Mission and Aransas Rivers (Station 12943 in Segment 2001 and Stations 12947 and 12948 in Segment 2003; Figure 5), it was necessary to develop individual regressions for each of these stations.

Salinity to flow regressions were developed for the two downstream monitoring stations located within the impaired portions of the Mission and Aransas Rivers (Figures 7 and 8). The resultant equations were used to calculate the volume of seawater that would flow through the station cross-section over the period of a day. For Station 12948 (Aransas River Tidal most upstream station), the salinity to flow regression was developed, although the concentrations indicated that virtually no seawater is present at that station as all salinity values were 1.3 ppt or less (Figure 9). Since the salinity concentrations at Station 12948 indicated that freshwater background levels were never exceeded by much, the assumption was that the modified LDC method was unnecessary at this location and the LDC method was applied without the modification.

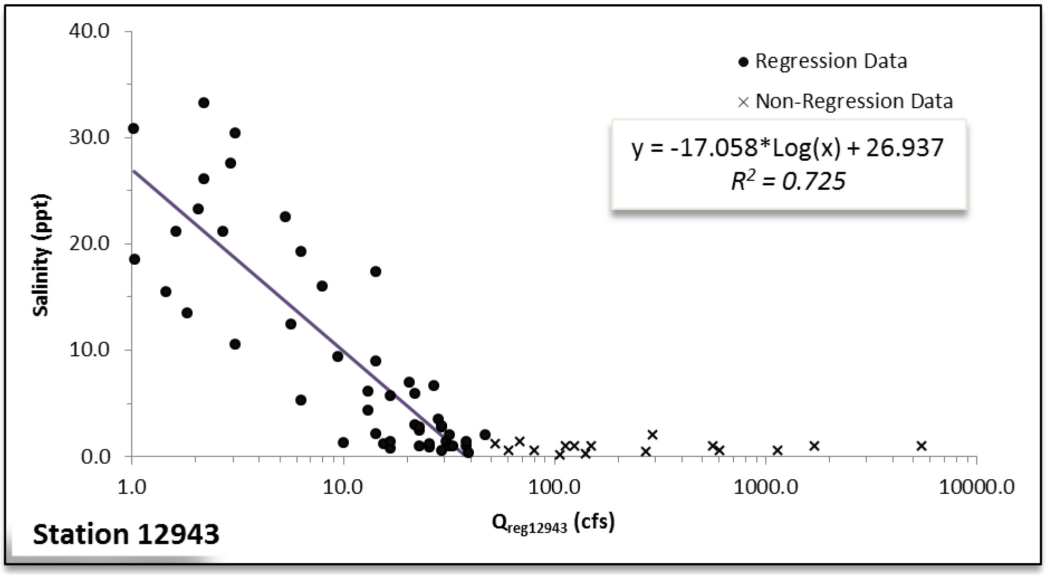

Figure 7. Salinity to flow regression for Station 12943, Mission River Tidal.

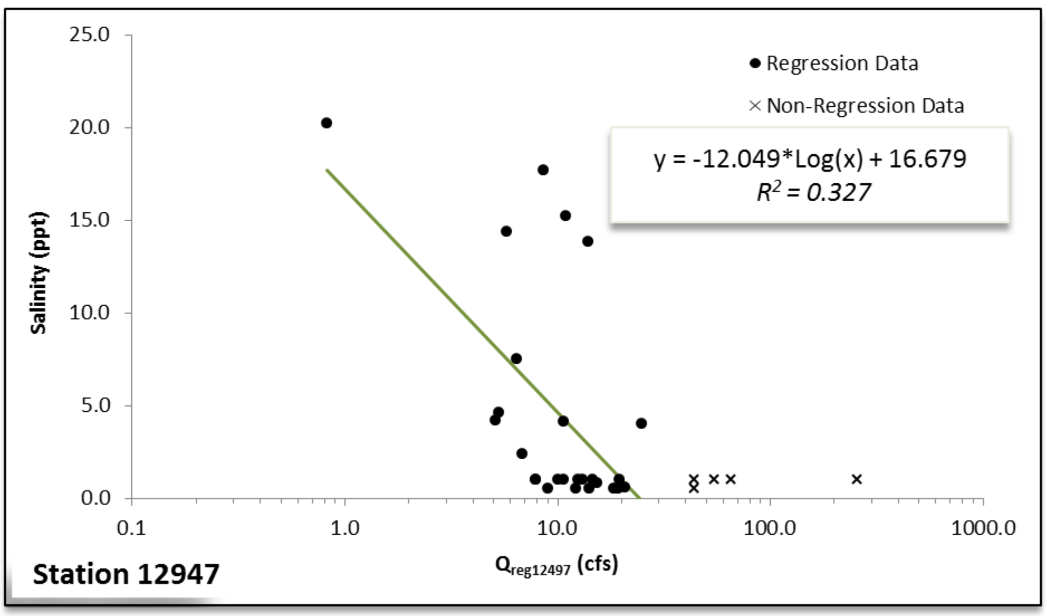

Figure 8. Salinity to flow regression for Station 12947, downstream Aransas River Tidal.

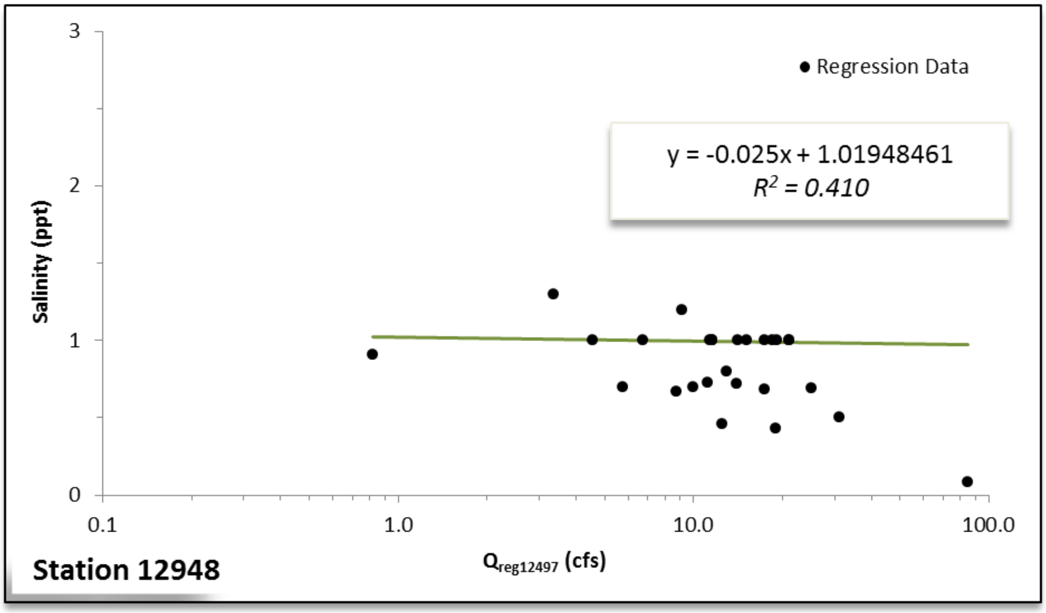

Figure 9. Salinity to flow regression for Station 12948, Aransas River Tidal.

3.2.5 Step 5: Development of Modified Flow Duration Curves (FDC)

The regression equations from Step 4 were used in Step 5 to provide information to allow computation of a total daily flow volume including freshwater and seawater. The process requires manipulation of the following mass balance equation for salinity at a tidally influenced station:

$$(V_r + V_s) * S_t = V_r * S_r + V_s * S_s \qquad \text{(Eq. 1)}$$

Where

- V_r = volume of daily freshwater (river) flow
- V_s = volume of daily seawater flow
- S_t = salinity in river (part per thousand or ppt)
- S_r = background salinity of upstream river water (ppt); assumed = 0 ppt
- S_s = salinity of seawater (assumed to be 35 ppt)

Through algebraic manipulation this mass balance equation can be solved for the daily volume of seawater required to be mixed with freshwater (again, freshwater having an assumed salinity = 0) giving the equation found in the ODEQ (2006) technical information:

$$V_s = V_r / (S_s/S_t - 1);$$
$$\text{for } S_t > \text{ than background salinity, otherwise } V_s = 0 \qquad \text{(Eq. 2)}$$

where S_t was computed for each day of the 15-year streamflow record using the station-specific regression equations of Step 4 and the daily streamflow (V_r) as input to the equation. The calculation of S_t allowed V_s to be computed from Eq. 2.

The modified daily flow volume (V_t) that includes the daily freshwater flow (V_r) and the daily volume of seawater flow (V_s) is computed as:

$$V_t = V_r + V_s \quad \text{(Eq. 3)}$$

Each FDC was generated by

1) Ranking the daily flows (V_t) from highest to lowest
2) Calculating the percent of days each flow was exceeded (exceedance value): (rank ÷ (number of data points + 1) * 100)
3) Plotting each flow value (y-axis) against its exceedance value (x-axis).

Exceedance values along the x-axis represent the percent of days that flow was at or above the associated flow value on the y-axis. Exceedance values near 100% occur during low flow or drought conditions while values approaching 0% occur during periods of high flow or flood conditions. This graphical procedure provides information on basic hydrological characteristics in the stream based upon flows observed within specific reaches.

For the Mission River Tidal, one FDC was created for Station 12943 (Figure 10); for the Aransas River Tidal, FDCs were created for Stations 12947 and 12948 (Figures 11 and 12). For Station 12943 on Mission River Tidal and Station 12947 on Aransas River Tidal, the amount of estimated seawater is also provided on the FDCs graphs. As expected from the equations, the amount of seawater present increases as both the freshwater flow decreases and the percent of days the flow is exceeded increases. Note that the x-axis direction of increase on the seawater plot is reversed from that on the FDC.

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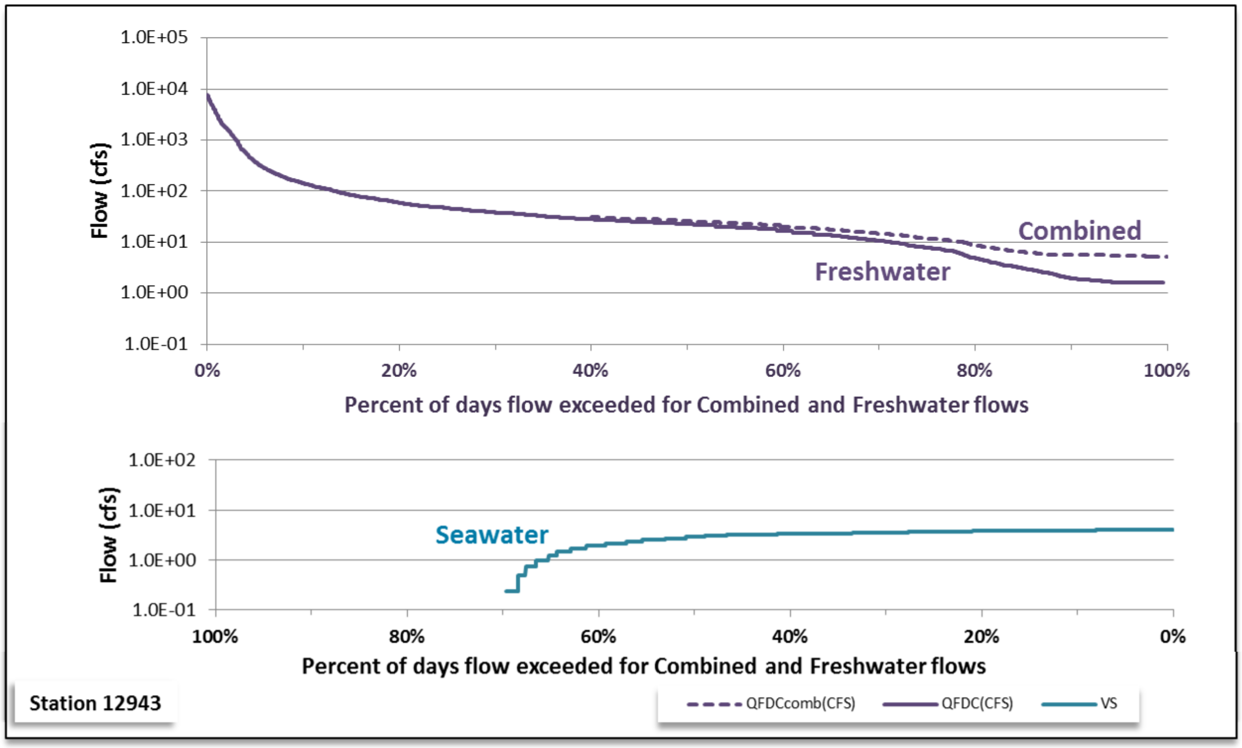

Figure 10. Flow duration curves for Station 12943, Mission River Tidal.

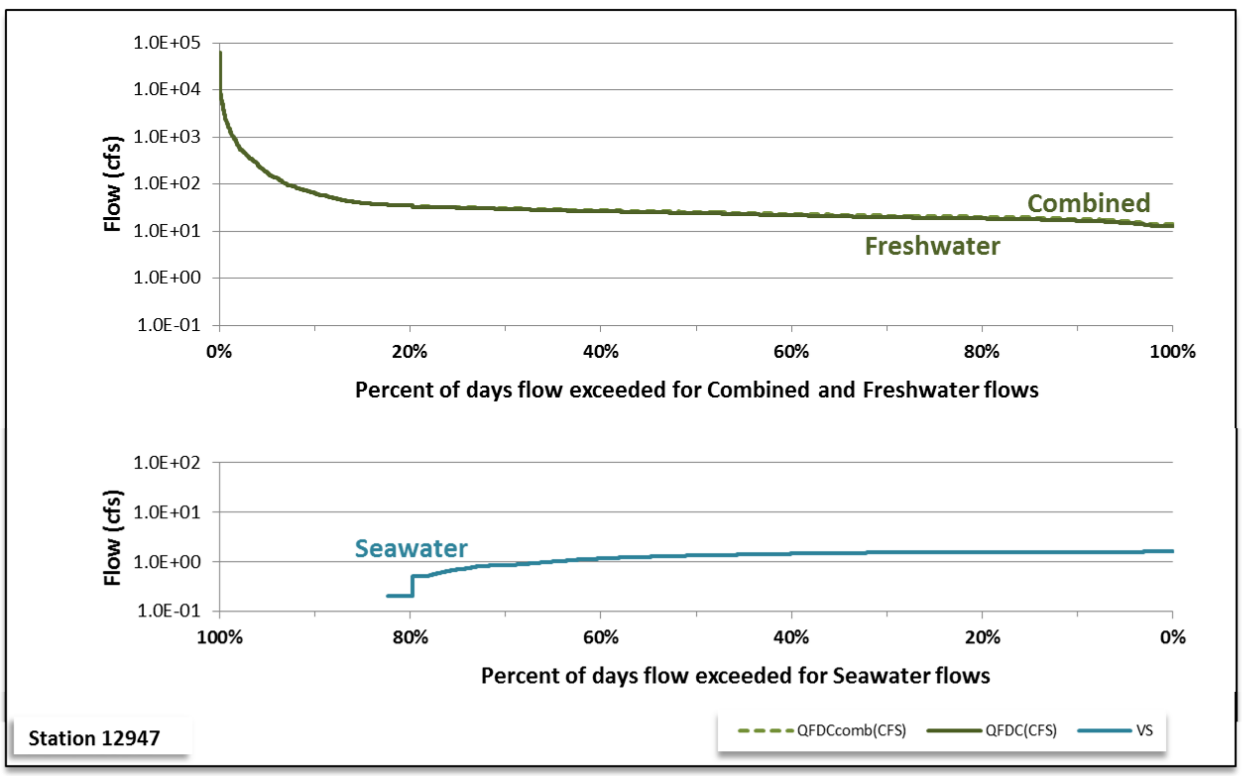

Figure 11. Flow duration curves for Station 12947, Aransas River Tidal.

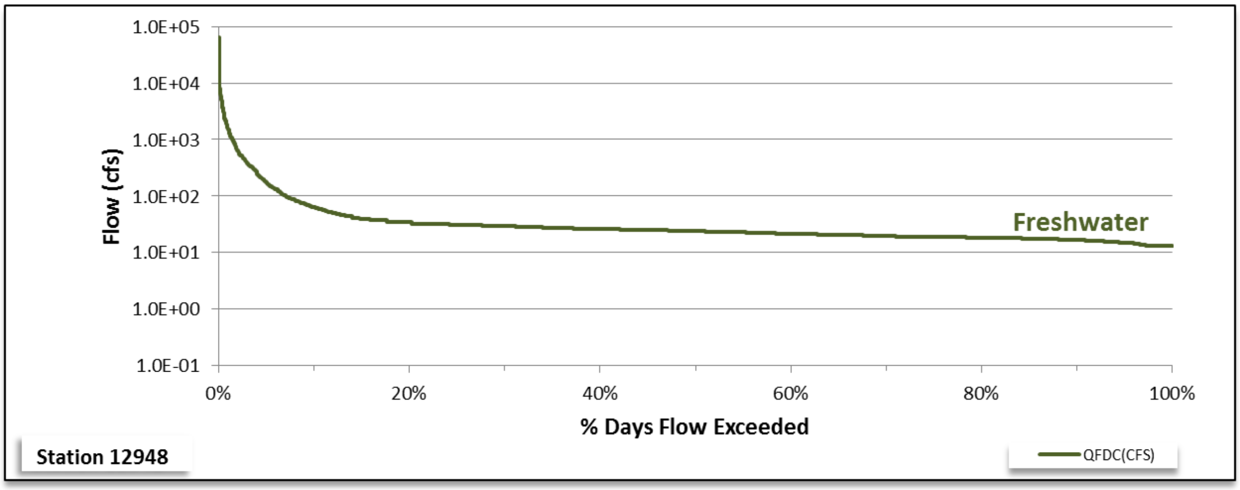

Figure 12. Flow duration curves for Station 12948, Aransas River Tidal.

3.2.6 Step 6: Development of Modified LDCs

In Step 6, the modified FDC is combined with the pertinent numeric water quality criterion established to protect the contact recreation use. The pertinent criterion is the geometric mean concentration of Enterococci not to exceed 35 MPN per 100 ml. A modified LDC was developed by multiplying each streamflow value (cfs) from Step 5 by the Enterococci criterion (35 MPN/ 100 ml) and by the conversion factor (283.168 100 mL/ft^3 * 86,400 seconds/day) to express the loadings as MPN per day. Separate modified LDCs were created for the three TCEQ SWQM stations located within the impaired segments. For the Mission watershed, one modified LDC was created for Station 12943 (Figure 13); for the Aransas watershed, modified LDCs were created for Station 12947 (downstream) and Station 12948 (upstream) (Figures 14 and 15).

The appearance shape of the modified LDC is identical to that of the modified FDC, because the data in the FDCs have all been multiplied by the same conversion factor. Notice that the label on the y-axis has changed from Flow (cfs) to Enterococcus (MPN/ day), and the label on the x-axis has changed from "percent of days flow exceeded" to "percent of days load exceeded."

A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves. This approach can assist in determining streamflow conditions under which exceedances are occurring. A commonly used set of regimes that is provided in Cleland (2003) is based on the following five intervals along the x-axis of the FDCs and LDCs: (1) 0-10% (high flows); (2) 10-40% (moist conditions); (3) 40-60% (mid-range flows); (4) 60-90% (dry conditions); and (5) 90-100% (low flows).

For the Mission River Tidal and Aransas River Tidal, a three-interval division was selected:

- High flow regime: 0-10% range, related to flood conditions and non-point source loading
- Mid-range flow regime: 10-60% range, related to point and non-point source loading
- Low flow regime: 60-100% range, related to dry conditions and point source loading

The selection of the flow regime intervals was based on general observations of all the monitoring station modified LDCs. Both the 10 and 60 percentile divisions are convenient, as data collected during wet weather occurs more frequently below them, and non-wet weather data occurs more frequently above them (wet and non-wet weather events are defined in the next section). Additionally, for the high flow regime, the 0-10% range generally represents the steepest portion of the LDC.

3.2.7 Step 7: Historical Enterococci measurements

In Step 7, for the three monitoring station locations, each historical Enterococci measurement was aligned with the streamflow on the day of measurement. The historical Enterococci measurements were then multiplied by the streamflow value and the conversion factor, as performed in Step 6, to calculate a loading associated with each measured Enterococci concentration.

The points were then plotted on the LDC, and were symbolized according to whether the sampling event was considered to be a wet or non-wet weather event, based on antecedent rainfall. A sample was determined to be influenced by a wet weather event based on the reported “days since last precipitation” (DSLP) (TCEQ water quality parameter code 72053). Wet weather events were determined by DSLP of 0-3. Points above a curve represent exceedances of the bacteria criteria and associated allowable loadings. Geometric mean loadings for the data points within each flow regime were calculated and displayed on each figure to aid in interpretation. The Enterococci concentrations and associated streamflows at each of the stations are provided in Appendix B.

For all three LDCs (Figures 13, 14 and 15), the wet weather data points occurred, as expected, predominately under the higher flow regimes and consistently exceeded the geometric mean criterion. Wet weather data points in the lowest flow regime typically represent Enterococci data collected after a small rainfall runoff event when conditions up to the event were very dry.

LDCs developed for the two downstream stations within the Mission and Aransas Rivers (Figures 13 and 14) indicate geometric mean Enterococci loadings exceeded allowable loadings within the highest flow regime, and the proportion of exceedences (based on the number of sampling events per flow regime) decreased with flow. Enterococci loading exceedances were generally not restricted to wet weather events but also occurred during conditions not influenced by rainfall runoff. Actual interpretation of these curves in the context of the TMDL allocation process is reserved for the next report section.

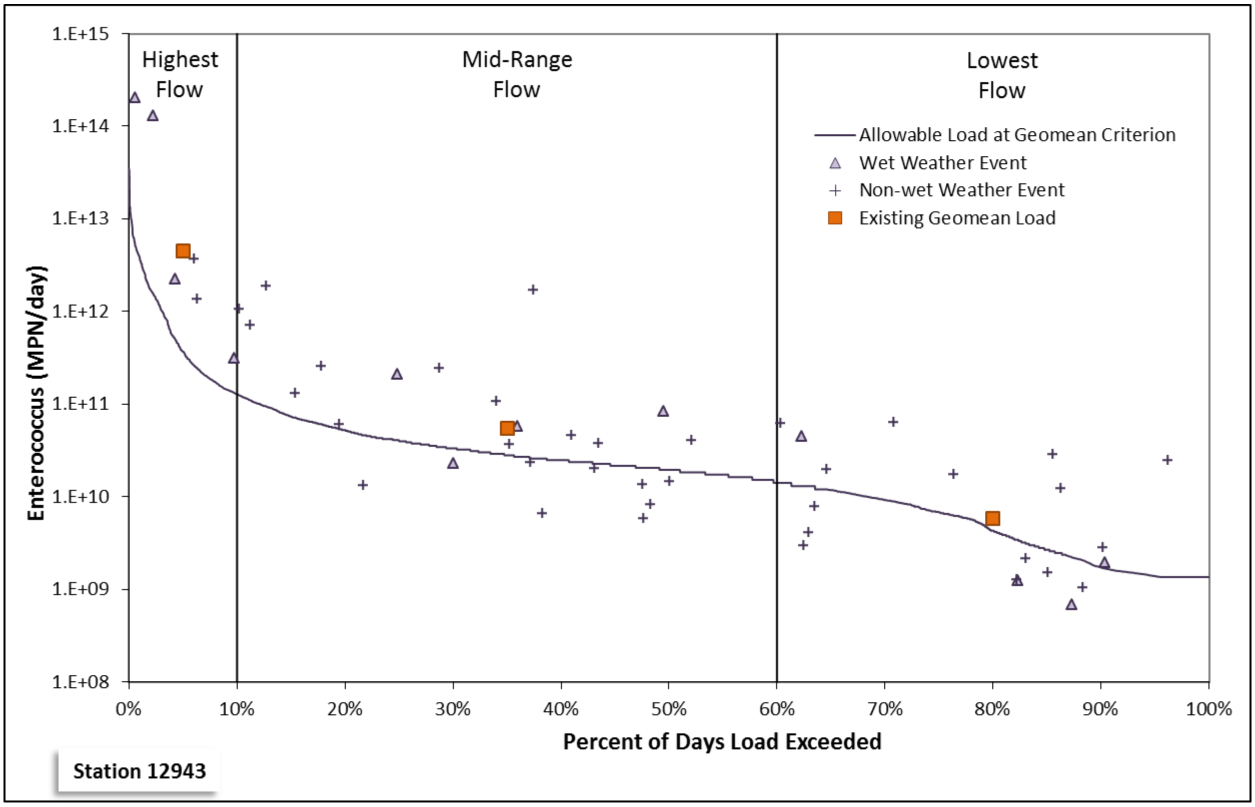

Figure 13. Load duration curve for Station 12943, Mission River Tidal.

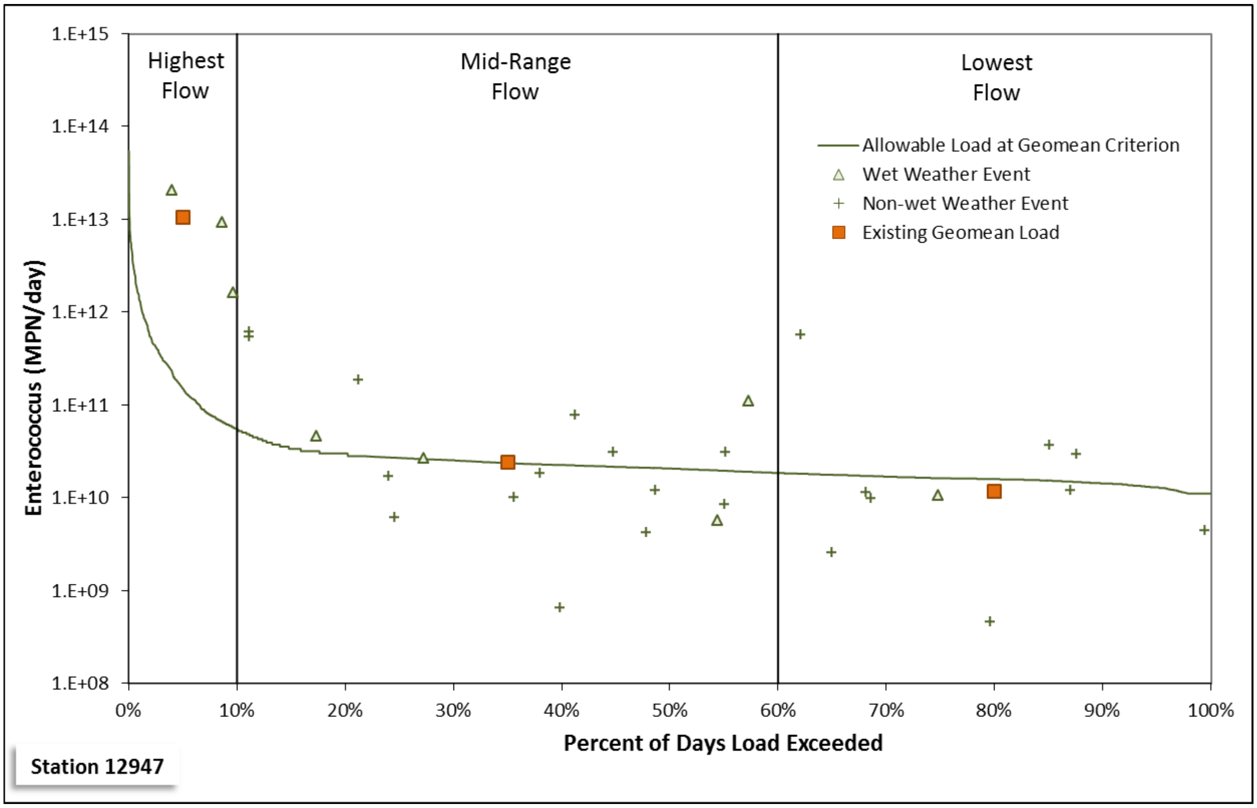

Figure 14. Load duration curve for Station 12947, Aransas River Tidal.

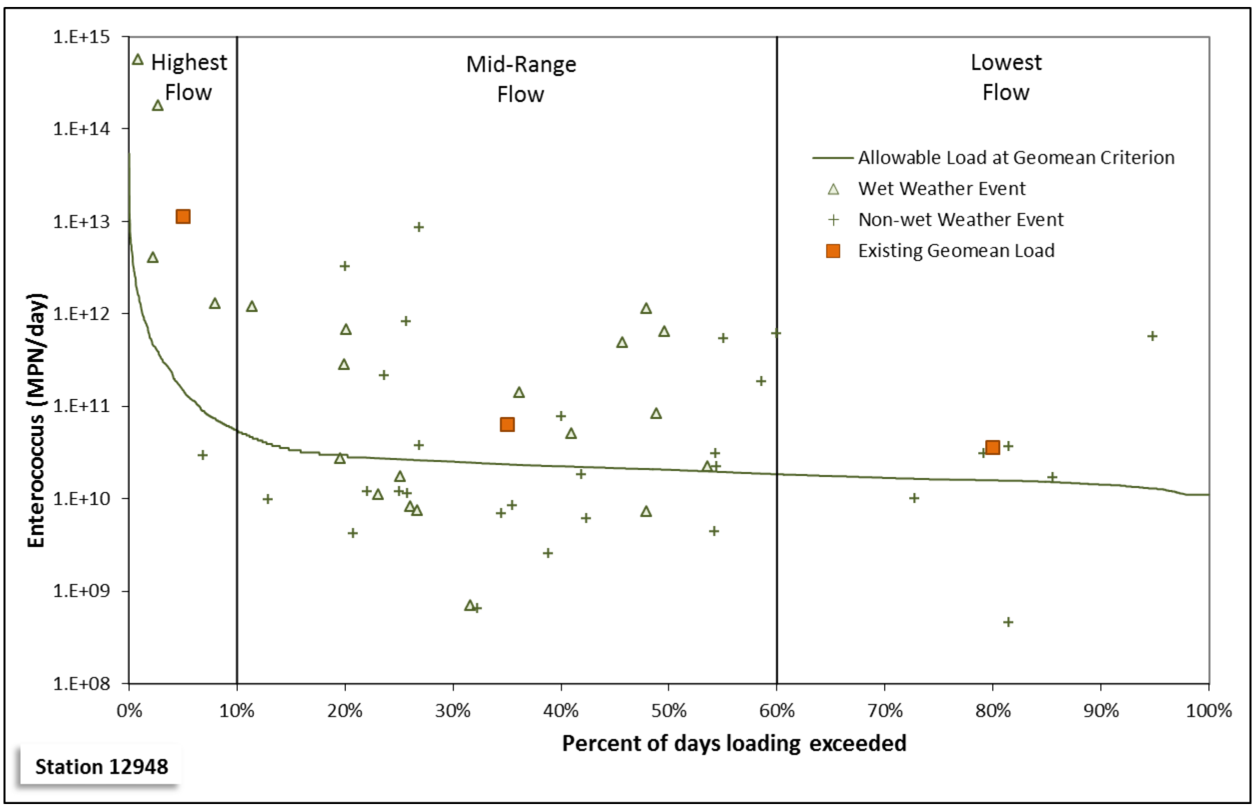

Figure 15. Load duration curve for Station 12948, Aransas River Tidal.

SECTION 4
TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocation for the two TMDL watersheds. The tool used for developing each TMDL allocation was the modified LDC method previously described in Section 3 – Bacteria Tool Development, which accounts for tidal influences. Endpoint identification, margin of safety, load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The modified LDC method provided a flow-based approach to determine necessary reductions in bacteria loadings and allowable loadings within the two TMDL watersheds. As developed previously in this report, the modified LDC method uses frequency distributions to assess a bacteria criterion over the historical range of flows, providing a means to determine maximum allowable loadings and the load reduction necessary to achieve support of the primary contact recreation use.

For the purposes of this TMDL study, the TMDL watersheds are considered to be the entire Mission River watershed (AU 2001_01 and 2002_01) and the entire Aransas River watershed (AU 2003_01 and 2004_01) as shown in the overview map (Figure 1). Although the modified LDCs were computed for all three of the SWQM stations that are located in the impaired segments, TMDLs are only calculated for the two most downstream SQWM stations (12943 in the Mission River and 12947 in the Aransas River; Figure 5). The most downstream SWQM stations were selected because these locations encompass more of the drainage area of each watershed and are representative of conditions in more of each watershed than stations located further upstream.

4.1 Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions. The water bodies within these two TMDL watersheds have a use of primary contact recreation, which is measured against a numeric criterion for the indicator bacteria Enterococci due to the fact that they are tidally influenced. Indicator bacteria are not generally pathogenic and are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. The Enterococci criterion to protect contact recreation in saltwater systems consists of a geometric mean concentration not to exceed 35 MPN/100 mL (TCEQ, 2010b).

The endpoint for these TMDLs is to maintain concentrations of Enterococci below the geometric mean criterion of 35 MPN/100 mL. This endpoint was applied to both watersheds addressed by this TMDL. This endpoint is identical to the geometric mean criterion in the 2010 Surface Water Quality Standard (TCEQ, 2010a) for primary contact recreation in saline water bodies.

4.2 Seasonality

Seasonal variations or seasonality occur(s) when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing Enterococci concentrations obtained from routine monitoring collected in the warmer months (May - September) against those collected during the cooler months (November - March). The months of April and October were considered transitional between the warm and cool seasons and were excluded from the seasonal analysis. Differences in Enterococci concentrations obtained in warmer versus cooler months were then evaluated by performing a Wilcoxon Rank Sum test on the original dataset. The nonparametric Wilcoxon Rank Sum test was selected because even with logarithmic transformation the bacteria data were non-normally distributed. This analysis of Enterococci data indicated that there was a significant difference ($\alpha=0.05$, $p=0.0090$) in indicator bacteria between cool and warm weather seasons only for the upstream station of the Aransas River Tidal (Station 12948, Segment 2003), where cool season concentrations were determined to be less than the warm season concentrations. Seasonality was not detected at the Aransas River Tidal downstream station (12947, Segment 2003), nor at the Mission River Tidal station (12943, Segment 2001).

4.3 Linkage Analysis

Establishing the relationship between instream water quality and the source of loadings is an important component in developing a TMDL. It allows for the evaluation of management options that will achieve the desired endpoint. The relationship may be established through a variety of techniques.

Generally, if high bacteria concentrations are measured in a water body at low to median flow in the absence of runoff events, the main contributing sources are likely to be point sources and direct fecal material deposition into the water body. During ambient flows, these inputs to the system will increase pollutant concentrations depending on the magnitude and concentration of the sources. As flows increase in magnitude, the impact of point sources and direct deposition is typically diluted, and would therefore be a smaller part of the overall concentrations.

Bacteria load contributions from permitted and non-permitted stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, has the capacity to carry indicator bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of lower concentrations in the water body just before the rain event, followed by a rapid increase in bacteria concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

Load duration curves were used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a 1 to 1 relationship between instream loadings and loadings originating from point sources and the landscape as regulated and non-regulated sources. Further this 1 to 1 relationship was also inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7). That is the allocation of pollutant loads was based on apportioning the loadings based on flows assigned to WWTFs, a fractional proportioning of the remaining flow based on the area of the watershed under stormwater regulation, and assigning the remaining portion to non-regulated stormwater.

4.4 Modified Load Duration Curve Analysis

A modified LDC method was used to examine the relationship between instream water quality, the broad sources of indicator bacteria loads, and are the basis of the TMDL allocations. The strength of this TMDL is the use of the modified LDC method to determine the TMDL allocations. Modified LDCs are a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders, and uses available water quality and flow data. The modified LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The EPA supports the use of the basic LDC approach to characterize pollutant sources including the modifications to include tidal influences. In addition, many other states are using this basic method to develop TMDLs, though the modified LDC method is more limited in its application. As discussed in more detail in Section 4.7 (Pollutant Load Allocation), the TMDL loads were based on the median flow within the high flow regime (or 5% flow), where exceedances of the primary contact recreation criteria are most pronounced. Under the high flow regime, there was no seawater volume computed as being present at any of the stream locations where LDCs were developed. With an absence of seawater at these high flows, the modified LDC results effectively simplified to those of the LDC method without adjustments to accommodate tidal influences (see Figures 10 and 11).

The modified LDC method allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003) with adjustments to include tidal influences (ODEQ, 2006). In addition to estimating stream loads, this method allows for the determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (*i.e.*, point source and stormwater) and provides a means to allocate allowable loadings.

Based on the LDCs to be used in the pollutant load allocation process with historical Enterococci data added to the graphs (SWQM Station 12943, Figure 13 and SWQM Station 12947, Figure 14) and Section 2.6 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. For both the Mission River and Aransas River watersheds, the historical Enterococci data indicate that elevated bacteria loadings occur under all flow conditions, but become most elevated under the highest flows and are often below the single sample criterion under the lowest flows. Regulated stormwater comprises only a very small portion of the watershed (0.06% for Mission River watershed and 0.04% for Aransas River watershed) and must be considered only a minor contributor and most likely non-regulated stormwater comprises the majority of high flow related loadings. The elevated Enterococci loadings under the lower flow conditions cannot be reasonably attributed exclusively to WWTFs due to outfalls typically being located at distance from the SWQM stations and a relatively good compliance record for most WWTFs. Therefore, other sources of bacteria loadings under lower flows and in the absence of overland flow contributions (i.e., without stormwater contribution) are most likely contributing bacteria directly to the water as could occur through direct deposition of fecal material from wildlife, feral hogs and livestock. The actual contribution of bacteria loadings attributable to these direct sources of fecal material deposition cannot be determined using LDCs.

4.5 Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis performed to develop the TMDL and thus provides a higher level of assurance that the goal of the TMDL will be met. According to EPA guidance (USEPA, 1991), the MOS can be incorporated into the TMDL using two methods:

1) Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
2) Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The margin of safety is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning a margin of safety.

The TMDLs covered by this report incorporate an explicit MOS by setting a target for indicator bacteria loads that is 5 percent lower than the geometric mean criterion. For primary contact recreation, this equates to a geometric mean target for Enterococci of 33.3 MPN/100 mL. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each water body is slightly reduced.

4.6 Load Reduction Analysis

While the TMDLs for the two TMDL watersheds were developed using LDCs and associated load allocations, additional insight may, in certain situations, be gained through a load reduction analysis. A single percent load reduction required to meet the allowable loading for each of the three flow regimes was determined using the historical Enterococci data obtained from stations within the impaired reaches.

For each station and flow regime, the percent reduction required to achieve the geometric mean criterion was determined by calculating the difference in the existing (or measured) geometric mean concentration and the 35 MPN/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 15).

Table 15. Percent reduction calculations for stations within the water bodies of the TMDL watersheds.

Watershed (Station)	AU	High Flows (0-10%)		Mid-Range Flows (10-60%)		Low Flows (60-100%)	
		Geometric Mean (MPN/100 mL)	Required Percent Reduction	Geometric Mean (MPN/100 mL)	Required Percent Reduction	Geometric Mean (MPN/100 mL)	Required Percent Reduction
Mission (12943)	2001_01	429	91.8%	68	48.7%	48	27.1%
Aransas (12947)	2003_01	2,451	98.6%	35	1.0%	26	0.0%

4.7. Pollutant Load Allocation

A TMDL represents the maximum amount of a pollutant that the stream can receive in a single day without exceeding water quality standards. The pollutant load allocations for the selected scenarios were calculated using the following equation:

$$TMDL = WLA + LA + FG + MOS \quad \text{(Eq. 4)}$$

Where:

TMDL = total maximum daily load

WLA = waste load allocation, the amount of pollutant allowed by existing regulated or permitted dischargers

LA = load allocation, the amount of pollutant allowed by non-regulated or non-permitted sources
FG = loadings associated with future growth from potential permitted facilities
MOS = margin of safety

As stated in 40 CFR, §130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For Enterococci, TMDLs are expressed as MPN/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

The TMDL component for the two impaired AUs covered in this report are derived using the median flow within the high flow regime (or 5% flow) of the LDC developed for the downstream SWQM station in each AU (12943 in the Mission River and 12947 in the Aransas River). For the remainder of this report, each section will present an explanation of the TMDL component first, followed by the results of the calculation for that component.

4.7.1 AU-Level TMDL Computations

The bacteria TMDLs for the Mission and Aransas Tidal Rivers were developed as a pollutant load allocation based on information from the most downstream LDCs (Figures 13 and 14). As discussed in more detail in Section 3, bacteria LDCs using modifications to include tidal influences were developed by multiplying each flow value along the flow duration curves by the Enterococci criterion (35 MPN/100 mL) and by the conversion factor used to represent maximum loading in MPN/day. Effectively, the "Allowable Load" displayed in the modified LDC at 5% exceedance (the median value of the high-flow regime) is the TMDL:

TMDL (MPN/day) = Criterion * Flow (cfs) * Conversion factor (Eq. 5)

Where:

Criterion = 35 MPN/100 mL (Enterococci)
Conversion factor (to MPN/day) = 283.168 100 mL/ft^3 * 86,400 sec/day

At 5% load duration exceedance, the TMDL values are provided in Table 16.

Table 16. Summary of allowable loading calculations for AUs within the TMDL watersheds

Watershed	AU	5% Exceedance Flow (cfs)	5% Exceedance Load (MPN/ day)	TMDL (Billion MPN/ day)
Mission	2001_01	432.72	3.7054E+11	370.543
Aransas	2003_01	175.55	1.5032E+11	150.321

4.7.2 Margin of Safety (MOS)

The margin of safety is only applied to the allowable loading for a watershed. Therefore the margin of safety is expressed mathematically as the following:

$$MOS = 0.05 * TMDL \qquad \text{(Eq. 6)}$$

Where:

MOS = margin of safety load
TMDL = total maximum allowable load

Since the MOS is based solely on the TMDL term, the calculation is straightforward (Table 17)

Table 17. MOS calculations for downstream stations within the Mission and Aransas Rivers.

Watershed	AU	TMDL (Billion MPN/ day)	MOS (Billion MPN/ day)
Mission	2001_01	370.543	18.527
Aransas	2003_01	150.321	7.516

4.7.3 Waste Load Allocation (WLA)

The Waste Load Allocation (WLA) consists of two parts – the waste load that is allocated to TPDES-regulated wastewater treatment facilities (WLA_{WWTF}) and the waste load that is allocated to regulated stormwater dischargers (WLA_{SW}).

$$WLA = WLA_{WWTF} + WLA_{SW} \qquad \text{(Eq. 7)}$$

TPDES-permitted wastewater treatment facilities are allocated a daily waste load (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion and also reduced to account for the required MOS. The saline water Enterococci criterion (35 MPN/100mL) is used as the WWTF target. The WLA_{WWTF} term is also calculated for the freshwater *E. coli* primary contract recreation geometric mean criterion of 126 MPN/100 mL, since WWTF bacteria permit limits are often expressed in terms of *E. coli*. . This is expressed in the following equation:

$$WLA_{WWTF} = Criterion * Flow * Conversion\ Factor * (1 - F_{MOS}) \qquad \text{(Eq. 8)}$$

Where:

Criterion= 35 MPN/100 mL for Enterococci; 126 MPN/100 mL for *E. coli*
Flow = full permitted flow (MGD)
Conversion Factor (to MPN/day)= 1.54723 cfs/MGD *283.168 100 mL/ft^3 * 86,400 s/d
F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

Thus the daily allowable loading of Enterococci and *E. coli* assigned to WLA_{WWTF} was determined based on the full permitted flow of each WWTFs using Eq. 8 and summed individually for the watersheds of the Mission and Aransas Rivers. Table 18 presents the waste load allocations for each individual WWTF located within each of the two TMDL watersheds. The WLA_{WWTF} for each AU includes the sum of the WWTF allocations for all upstream AUs. Since the pollutant load allocation is developed in terms of Enterococci as the indicator bacteria, it is the Enterococci loadings from Table 18 that will be used in subsequent computations.

Table 18. Waste load allocations for TPDES-permitted facilities

AU	TPDES Permit No.	Facility	Full Permitted Discharge (MGD)	Enterococci WLA_{WWTF} (Billion MPN/ day)	*E. coli* WLA_{WWTF} (Billion MPN/ day)
2001_01	WQ0010156001	Town of Woodsboro WWTF	0.25	0.315	1.133
2002_01	WQ0010748001	Pettus MUD WWTF	0.105	0.132	0.476
2002_01	WQ0010255001	Town of Refugio WWTF	0.576	0.725	2.610
		Mission River Tidal Total	0.931	1.172	4.218
2003_01	WQ0010055001	City of Sinton- Main WWTF	0.80	1.007	3.625
2003_01	WQ0013641001	City of Sinton - Rod and Bessie Welder WWTF	0.015	0.019	0.068
2003_01	WQ0010705001	City of Taft WWTF	0.90	1.133	4.078
2003_01	WQ0014119001	St. Paul WSC WWTF	0.05	0.063	0.227
2003_01	WQ0013412001	Texas Department of Transportation - Sinton Engineering Building WWTF	0.00038	0.0005	0.0017
2004_01	WQ0010124004	City of Beeville - Chase Field WWTF	2.5	3.147	11.328
2004_01	WQ0010124002	City of Beeville - Moore Street WWTF	3.0	3.776	13.593
2004_01	WQ0014112001	Skidmore WSC WWTF	0.131	0.165	0.594
2004_01	WQ0014123001	Tynan WSC WWTF	0.045	0.057	0.204
		Aransas River Tidal Total	7.441	9.366	33.718

Stormwater discharges from MS4, industrial, and construction areas are also considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading. The percentage of the land area included in each watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the

TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

WLA_{SW} is the sum of loads from regulated stormwater sources and is calculated as follows:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \quad \text{(Eq. 9)}$$

Where:

WLA_{SW} = sum of all regulated stormwater loads
TMDL = total maximum daily load
WLA_{WWTF} = sum of all WWTF loads
FG = sum of future growth loads from potential permitted facilities
MOS = margin of safety load
FDA_{SWP} = fractional proportion of drainage area under jurisdiction of stormwater permits

In order to calculate the WLA_{SW} component of the TMDL, the fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined in order to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits. As described in Sections 2.6.1.5, a search for all five categories of stormwater general permits was performed. The search results are displayed in Table 19.

No MS4 permits are held in the watersheds of the Mission and Aransas Rivers. For the Multi-sector and Concrete Production general permits, only the acreages associated with active permits were tallied. These acreages were calculated by importing the location information associated with the authorizations into GIS, and measuring the estimated disturbed area based on the most recently available aerial imagery. For the Construction Activities general permits, the authorization contains an "Area Disturbed" field. Due to the variable and temporary nature of construction projects, it was preferable to average the acreages (on a monthly basis) associated with active permits over the entire available period of record (approximately 5 years). The results of this temporal averaging were used as representative of the average area under Construction Activities stormwater permits.

Table 19. Stormwater General Permit areas and calculation of the FDA_{SWP} term for the Mission and Aransas Rivers.

Water-shed	AU	MS4 General Permit (acres)	Multi-sector General Permit (acres)	Construction Activities (acres)	Concrete Production Facilities (acres)	Petroleum Bulk Stations (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
Mission	2001_01	0	343	57	0	0	400	658,817	0.0606%
Aransas	2003_01	0	49	149	5	0	203	539,806	0.0375%

In order to calculate WLA_{SW} (Eq. 9), the Future Growth (FG) term must be known. The calculation for the FG term is presented in the next section, but the results will be included here for continuity. Table 20 provides the information needed to compute WLA_{SW}.

Table 20. Regulated stormwater calculations for Mission River Tidal and Aransas River Tidal.

All loads expressed as billion MPN/day Enterococci

Watershed	AU	TMDL	WLA_{WWTF}	FG	MOS	FDA_{SWP}	WLA_{SW}
Mission	2001_01	370.543	1.172	0.119	18.527	0.0606%	0.213
Aransas	2003_01	150.321	9.366	0.715	7.516	0.0375%	0.050

Once the WLA_{SW} and WLA_{WWTF} terms are known, the WLA term can be calculated based on Eq. 7, as shown in Table 21.

Table 21. Waste load allocation calculations for the Mission River Tidal and Aransas River Tidal.

All loads expressed as billion MPN/day Enterococci

Watershed	AU	WLA_{WWTF}	WLA_{SW}	WLA
Mission	2001_01	1.172	0.213	1.384
Aransas	2003_01	9.366	0.050	9.416

4.7.4 Future Growth (FG)

The Future Growth (FG) component of the TMDL equation addresses the requirement of TMDLs to account for future loadings that may occur as a result of population growth, changes in community infrastructure, and development. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

Currently 12 facilities that treat domestic water are located within the watersheds of the Mission and Aransas River; 3 in the Mission watershed and 9 in the Aransas watershed (Table 22). To account for the FG component of the impaired segments (2001 or 2003), the loading from all WWTFs are included in the FG computation, which is based on the WLA_{WWTF} formula (Eq. 8). The FG equation contains an additional term to account for projected population growth within the WWTF service areas between 2010 and 2050, based on data obtained from the TWDB 2017 State Water Plan Projections Data website (TWDB, 2013)

$$FG = Criterion * [\%POP_{2010\text{-}2050} * WWTF_{FP}] * Conversion\ Factor * (1 - F_{MOS}) \qquad \text{(Eq. 10)}$$

Where:

Criterion = 35 MPN/100 mL (Enterococci)

$\%POP_{2010\text{-}2050}$ = estimated % increase in population between 2010 and 2050

$WWTF_{FP}$ = full permitted discharge (MGD)

Conversion Factor = 1.547 cfs/MGD *283.168 100 mL/ft^3 * 86,400 s/d

F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

The calculation results are shown in Table 22.

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Table 22. Future growth calculations for the Mission River Tidal and Aransas River Tidal.

Entries are sorted alphabetically by County and Water User Group.

Water -shed	County	Water User Group (WUG)	% Population Increase (2010 - 2050)*	Facility	AU	Full Permitted Flow (MGD)*	Future Growth (MGD)	FG (Enterococci Billion MPN/ 100 mL)
Mission	Bee	County - Other	11.6%	Pettus MUD WWTF	2002_01	0.105	0.012	0.015
Mission	Refugio	Refugio	10.0%	Town of Refugio WWTF	2002_01	0.576	0.058	0.072
Mission	Refugio	Woodsboro	10.0%	Town of Woodsboro WWTF	2001_01	0.25	0.025	0.031
Mission Total						0.931	0.095	0.119
Aransas	Bee	Beeville	11.6%	City of Beevillle - Moore Street WWTF	2004_01	3.0	0.35	0.230
Aransas	Bee	County - Other	11.6%	City of Beevillle - Chase Field WWTF	2004_01	2.5	0.29	0.191
Aransas	Bee	County - Other	11.6%	Skidmore WSC WWTF	2004_01	0.131	0.015	0.010
Aransas	Bee	County - Other	11.6%	Tynan WSC WWTF	2004_01	0.045	0.005	0.007
Aransas	San Patricio	County - Other	16.4%	St. Paul WSC WWTF	2003_01	0.05	0.008	0.010
Aransas	San Patricio	County - Other	16.4%	Texas Dept of Trans-portation - Sinton Engineering Building WWTF	2003_01	0.00038	0.0001	0.00008
Aransas	San Patricio	Sinton	16.4%	City of Sinton-Main WWTF	2003_01	0.80	0.131	0.165
Aransas	San Patricio	Sinton	16.4%	City of Sinton-Rod and Bessie Welder WWTF	2003_01	0.015	0.0025	0.0031
Aransas	San Patricio	Taft	16.4%	City of Taft WWTF	2003_01	0.90	0.148	0.098
Aransas Total						7.441	0.947	0.715

*Significant figures reflect MGD figures presented in TPDES permits

4.7.5 Load Allocation (LA)

The load allocation (LA) is the loads from unregulated sources, and is calculated as:

$$LA = TMDL - WLA - FG - MOS \quad \text{(Eq. 11)}$$

Where:

LA = allowable loads from unregulated sources within the AU
TMDL = total maximum daily load
WLA = sum of all WWTF loads and all regulated stormwater loads
FG = sum of future growth loads from potential permitted facilities
MOS = margin of safety load

The calculation results are shown in Table 23.

Table 23. Load allocation calculations for the Mission River Tidal and Aransas River Tidal.

Units expressed as billion MPN/ day Enterococci

Watershed	AU	TMDL	WLA	FG	MOS	LA
Mission	2001_01	370.5426	1.3845	0.1192	18.5271	350.5118
Aransas	2003_01	150.3207	9.4159	0.7150	7.5160	132.6738

4.8 Summary of TMDL Calculations

Table 24 summarizes the TMDL calculations for the Mission River Tidal and Aransas River Tidal. Each of the TMDLs was calculated based on the median flow in the 0-10 percentile range (5% exceedance, high flow regime) for flow exceedance from the LDC developed for the downstream SWQM station within each watershed. Allocations are based on the current geometric mean criterion for Enterococci of 35 MPN/100 mL for each component of the TMDL.

Table 24. TMDL allocation summary for the Mission River Tidal and Aransas River Tidal watersheds.

Units expressed as billion MPN/ day Enterococci

AU	Stream Name	TMDL	MOS	WLA_{WWTF}	WLA_{SW}	LA	Future Growth
2001_01	Mission River Tidal	370.534	18.527	1.172	0.213	350.512	0.119
2001_03	Aransas River Tidal	150.321	7.516	9.366	0.050	132.674	0.715

The final TMDL allocations (Table 25) needed to comply with the requirements of 40 CFR 130.7 include the future growth component within the WLA_{WWTF}.
In the event that the criterion changes due to future revisions in the state's surface water quality standards, Appendix C provides guidance for recalculating the allocations in Table 25. Figures C-1 and C-2 of Appendix C were developed to demonstrate how

assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for Enterococci. The equations provided, along with Figures C-1 and C-2, allow calculation of new TMDLs and pollutant load allocations based on any potential new water quality criterion for Enterococci.

Table 25. Final TMDL allocations for the Mission River Tidal and Aransas River Tidal.

Units expressed as billion MPN/ day Enterococci

AU	TMDL	WLA_{WWTF}*	WLA_{SW}	LA	MOS
2001_01	370.543	1.291	0.213	350.512	18.527
2001_03	150.321	10.081	0.050	132.674	7.516

* WLA_{WWTF} includes the future potential allocation to wastewater treatment facilities

Section 5
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Appendix A
Modified Load Duration Curve

Traditionally the LDC approach has been restricted in TMDL development to freshwater, non-tidally influenced streams and rivers. The reason for excluding application of LDCs in TMDL development for tidally influenced stream and river systems is the presence of seawater in these river systems, i.e., an additional flow that has a loading. An assumption behind the LDC approach is that the loadings of bacteria are derived exclusively from the sources of the streamflows. These sources and their associated loadings may be varied, but it is inherently assumed that they may be computationally determined based on the streamflow at the selected exceedance frequency on the LDC used for the load allocation. But in a tidal system there is other water (i.e., seawater) that is a source with an associated loading that must be considered.

If the LDC approach is to be adapted to tidally influenced streams and rivers, some means of addressing the additional water and loadings from the seawater that mixes with freshwater in tidal rivers is needed. Oregon's Umpqua Basin Bacteria TMDL provides a modification of the LDC approach that accounts for the seawater component (ODEQ, 2006).

Their approach is based on determining the volume of seawater that must be mixed with the volume of freshwater going down the river to arrive at the "observed" salinity using a simple mass balance approach as provided in the following:

$$(V_r + V_s)*S_t = V_r*S_r + V_s*S_s \qquad \text{(Eq. A-1)}$$

Where

V_r = volume daily river flow (m^3) = Q (cfs)*86,400 (sec/day); where Q = river flow (cfs)
V_s = volume of seawater
S_t = salinity in river (parts per thousand or ppt)
S_r = background salinity of river water (ppt); assumed to be close to 0 ppt
S_s = salinity of seawater (35 ppt)

As noted in the computation of V_r, the volumes are actually time-associated using a day as the temporal measure, thus providing the proper association for the daily pollutant load computation. Through algebraic manipulation this mass balance equation can be solved for the daily volume of seawater required to be mixed with freshwater (again, freshwater having an assumed salinity = 0) giving the equation found in the ODEQ (2006) technical information:

$V_s = V_r / (S_s/S_t - 1)$;
for $S_t >$ than background salinity; otherwise $V_s = 0$ (Eq. A-2)

For the Umpqua Basin tidal streams (e.g., Figure A-1), as well as the present application to the Mission River Tidal and the Aransas River Tidal (Figures 7 and 8 in report), regressions were developed of S_t to Q using measured salinity data (S_t) with freshwater flows (Q). These regressions all had some streamflow above which $S_t = 0$. The daily Q and regression developed S_t were then used to compute V_s. As S_t approaches 0.0, V_s likewise approaches a value of 0.0 in Eq. B-2, meaning the only flow present is the river flow (Q or V_r).

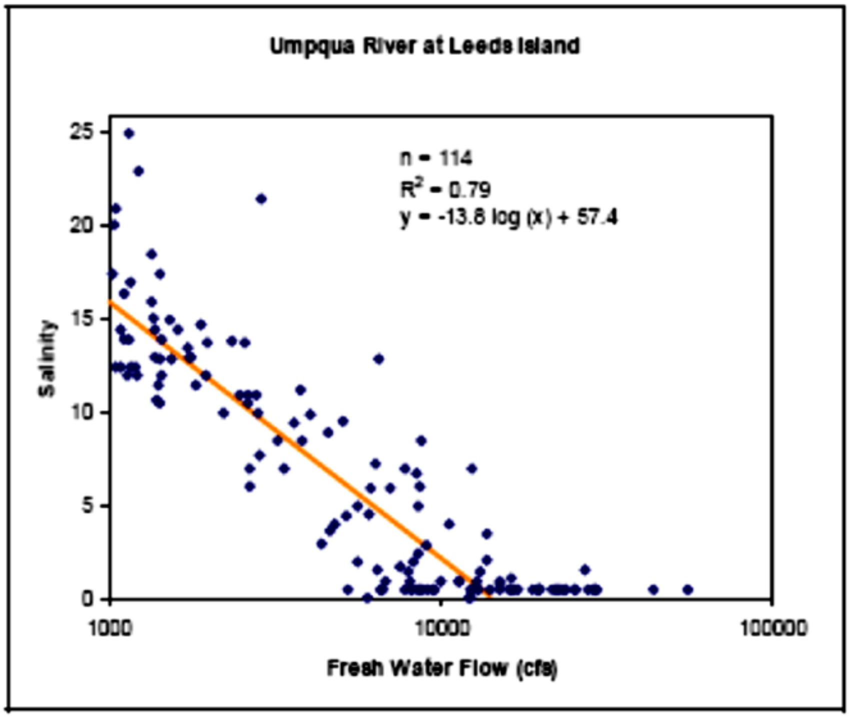

Figure A-1 Example salinity to flow regression from Umpqua Basin Tidal streams (ODEQ, 2006)

It is also relevant to discuss the response of measured salinities at assessment stations to streamflow and the streamflows above which salinities approach background levels (again, assumed to be 0.0) within the context of FDCs for Mission and Aransas River. These FDCs and the plotted flow exceedance values where salinities approach background should be viewed from the perspective of TCEQ's approach for bacteria TMDLs. Within the TCEQ TMDL approach with indicator bacteria, the highest flow regime is selected for developing the pollutant load allocation. This flow regime is defined as the range of 0-10% for the Mission River Tidal and Aransas River Tidal. All the flows in the highest flow regime are greater than the amount of streamflow indicated by the regression analysis as needed to result in an absence of seawater.

The significance of the above observation is related to what happens within the Modified LDC approach when salinities are at background. As salinity approaches background, V_s in Eq. B-2 approaches a value of zero, and in fact would be defined as zero when salinities are at background levels, resulting in the Modified LDC flow volume ($V_s + V_r$) defaulting to the flow of the river, i.e., no modification occurring to that portion of the LDC. Therefore regarding the pollutant load allocation process for the Mission River Tidal and Aransas River Tidal, the modified LDC method provides identical allowable loadings in the highest flow regime to those that would be computed using the standard LDC method that does not include tidal influences. The identical results of the modified and standard LDC method for the highest flow regime is the physical reality indicated in the observed salinity data that at these elevated streamflows seawater is effectively pushed completely out into Copano Bay. But the other implication, in hindsight, is that for these two tidal rivers, the same Pollutant Load Allocation results would be determined with the LDC method with or without tidal influences being considered due to development of the TMDL for the higher streamflows.

Continuing with the theoretical development of the Modified LDC for the Umpqua TMDLs, a total daily volume (V_t) is comprised of V_r computed from Q and the volume of seawater (V_s):

$$V_t = V_r + V_s \qquad \text{(Eq. A-3)}$$

Resulting in

$$\text{TMDL (MPN/day)} = \text{Criterion} * V_t * \text{Conversion factor} \qquad \text{(Eq. A-4)}$$

APPENDIX B
BACTERIA DATA USED IN DEVELOPING LOAD DURATION CURVES

Table B-1 Measured Enterococcus concentration and estimated streamflow at Station 12943, Mission River, Segment 2001.

Sample Date	Enterococcus (MPN/100 mL)	Estimated Daily Flow on Sampling Date (cfs)
25-Oct-99	98	7.26
19-Jan-00	23	14.01
17-Apr-00	31	26.51
11-Jul-00	18	2.39
9-Oct-00	13	3.89
15-Jan-01	700	109.00
10-Apr-01	68	27.76
18-Jun-01	32	30.26
8-Oct-01	84	152.75
14-Jan-02	150	70.26
9-Apr-02	150	22.76
8-Jul-02	200	276.49
15-Oct-02	250	40.26
21-Jan-03	39	62.76
22-Apr-03	74	31.51
18-Aug-03	152	16.51
5-Nov-03	130	34.01
21-Jan-04	65	82.75
31-Mar-04	2300	30.26
7-Jul-04	300	144.00
20-Oct-04	58	26.51
25-Jan-05	23	24.01
7-Apr-05	10	54.01
15-Aug-05	26	22.76
25-Oct-05	120	15.26
10-Jan-06	77	21.51
10-Apr-06	8	15.26
17-Jul-06	10	24.01
3-Oct-06	46	32.76
23-Jan-07	70	32.76
20-Mar-07	230	127.75

Continued in next column...

Sample Date	Enterococcus (MPN/100 mL)	Estimated Daily Flow on Sampling Date (cfs)
19-Jun-07	24	39.01
28-Nov-07	14	24.01
11-Feb-08	11	15.26
16-Apr-08	250	10.39
30-Jul-08	180	2.76
6-Oct-08	11	2.56
20-Jan-09	24	3.64
24-Mar-09	13	4.01
3-Aug-09	630	1.59
12-Oct-09	180	47.76
12-Jan-10	9	30.26
20-Apr-10	160	572.71
6-Jul-10	500	297.74
22-Sep-10	1500	5563.53
18-Jan-11	3100	1726.36
22-Mar-11	58	14.01
12-Jul-11	58	1.97
20-Sep-11	41	1.96
4-Jan-12	20	3.14
27-Mar-12	390	3.01

Table B-2 Measured Enterococcus concentration and estimated streamflow at Station 12947, Aransas River Downstream, Segment 2003.

Sample Date	Enterococcus (MPN/100 mL)	Estimated Daily Flow on Sampling Date (cfs)
20-Oct-04	15	27.42
25-Jan-05	22	31.74
7-Apr-05	230	32.82
15-Aug-05	1100	21.15
25-Oct-05	23	18.98
10-Jan-06	23	20.06
10-Apr-06	70	17.25
17-Jul-06	8	31.53
3-Oct-06	20	24.39
23-Jan-07	200	22.23
20-Mar-07	440	56.61
19-Jun-07	36	30.44
28-Nov-07	1	26.34
11-Feb-08	7	24.61
16-Apr-08	15	22.88
30-Jul-08	20	20.06
6-Oct-08	55	22.88
20-Jan-09	1	18.55
24-Mar-09	83	17.90
3-Aug-09	14	12.98
12-Oct-09	51	37.15
12-Jan-10	50	25.25
20-Apr-10	990	67.42
6-Jul-10	390	56.61
22-Sep-10	3100	270.70
18-Jan-11	4800	78.24
22-Mar-11	28	26.77
12-Jul-11	28	17.47
20-Sep-11	10	23.09
4-Jan-12	5	20.71
27-Mar-12	120	26.12

Table B-3 Measured Enterococcus concentration and estimated streamflow at Station 12948, Aransas River Upstream, Segment 2003.

Sample Date	Enterococcus (MPN/100 mL)	Estimated Daily Flow on Sampling Date (cfs)
25-Oct-99	47	19.20
19-Jan-00	16	17.69
17-Apr-00	6100	21.79
11-Jul-00	590	15.09
14-Jan-02	1082	30.88
9-Apr-02	1082	24.17
8-Jul-02	3400	104.18
15-Oct-02	60	25.69
21-Jan-03	29	32.61
22-Apr-03	210	27.20
18-Aug-03	44	21.58
5-Nov-03	240	28.50
21-Jan-04	190	32.82
31-Mar-04	7	27.42
7-Jul-04	220	45.80
2-Oct-07	32	34.99
3-Oct-07	14	32.17
4-Oct-07	11	30.88
19-Feb-08	12	24.61
20-Feb-08	140	24.39
21-Feb-08	1900	24.61
15-Jul-08	57	18.55
16-Jul-08	63	18.33
17-Jul-08	160	18.33
19-Aug-08	310	534.52
20-Aug-08	12000	1903.36
21-Aug-08	16000	458.83
30-Sep-08	46	23.09
1-Oct-08	80	23.09
2-Oct-08	310	22.88
9-Mar-10	10	30.66
23-Mar-10	1	28.93
13-Apr-10	15	25.90
27-Apr-10	140	31.31
11-May-10	600	26.55
25-May-10	800	25.04
8-Jun-10	610	86.89
13-Jul-10	330	34.99
20-Jul-10	220	26.34
27-Jul-10	80	26.12
17-Aug-10	39	23.31
24-Aug-10	18	23.09
14-Sep-10	160	27.85
28-Sep-10	910	54.45
6-Oct-10	87	34.99
27-Oct-10	280	31.96
10-Nov-10	22	31.09
17-Nov-10	23	31.31
1-Dec-10	33	30.66
8-Dec-10	25	30.66
12-Jan-11	790	34.99

continued in next column...

APPENDIX C
EQUATIONS FOR CALCULATING TMDL ALLOCATIONS FOR CHANGED CONTACT RECREATION STANDARD

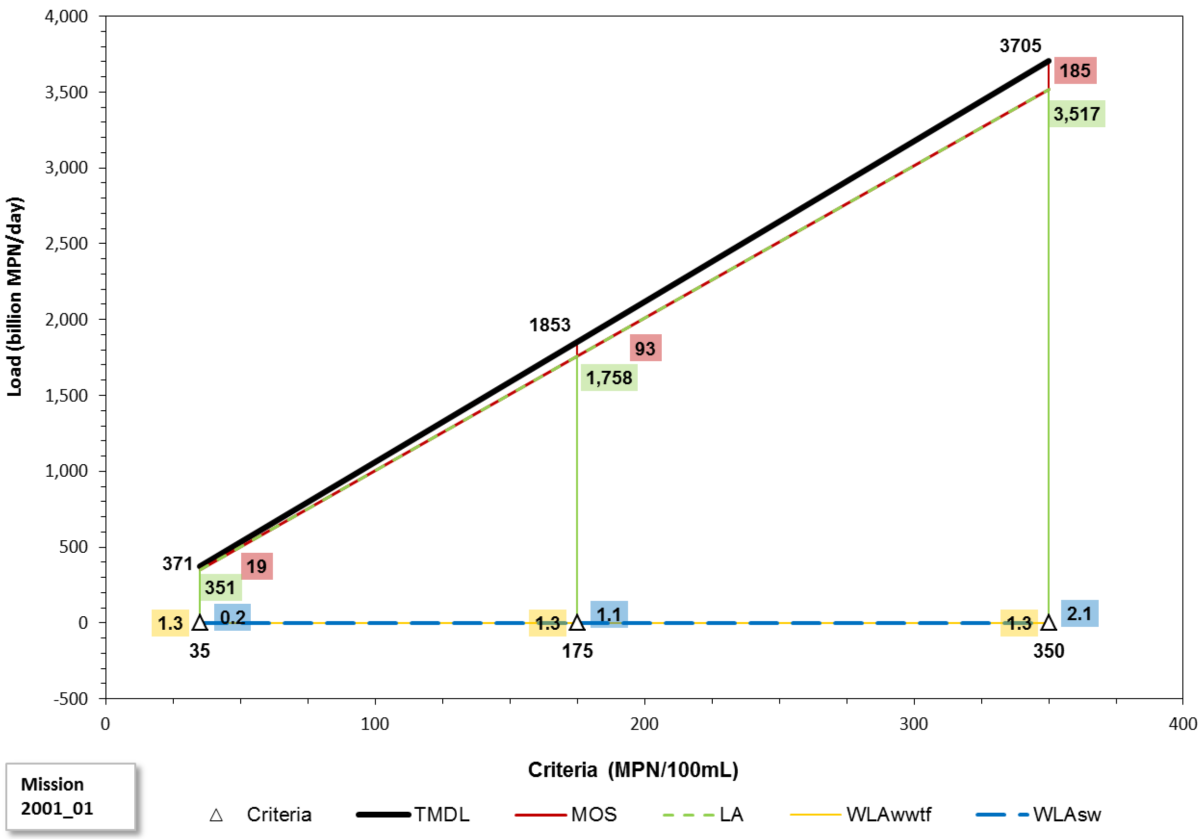

Figure C-1. Allocation loads for the Mission River (2001_01) as a function of water quality criteria

Equations for calculating new TMDL and allocations (in billion MPN/day)

TMDL	=10.5869 * Std
MOS	=0.5293 * Std
LA	= 10.0515 * Std - 1.2902
WLA_{WWTF}	= 1.2910
WLA_{sw}	=0.0061 * Std - 0.0008

Where:

Std =	Revised Contact Recreation Standard
MOS =	Margin of Safety
LA =	Total load allocation (non-permitted source contributions)
WLA_{WWTF} =	Waste load allocation (permitted WWTF load + future growth) [Note: WWTF load held at Primary Contact (35 MPN/ 100 mL) criteria]
WLA_{SW} =	Waste load allocation (permitted stormwater)

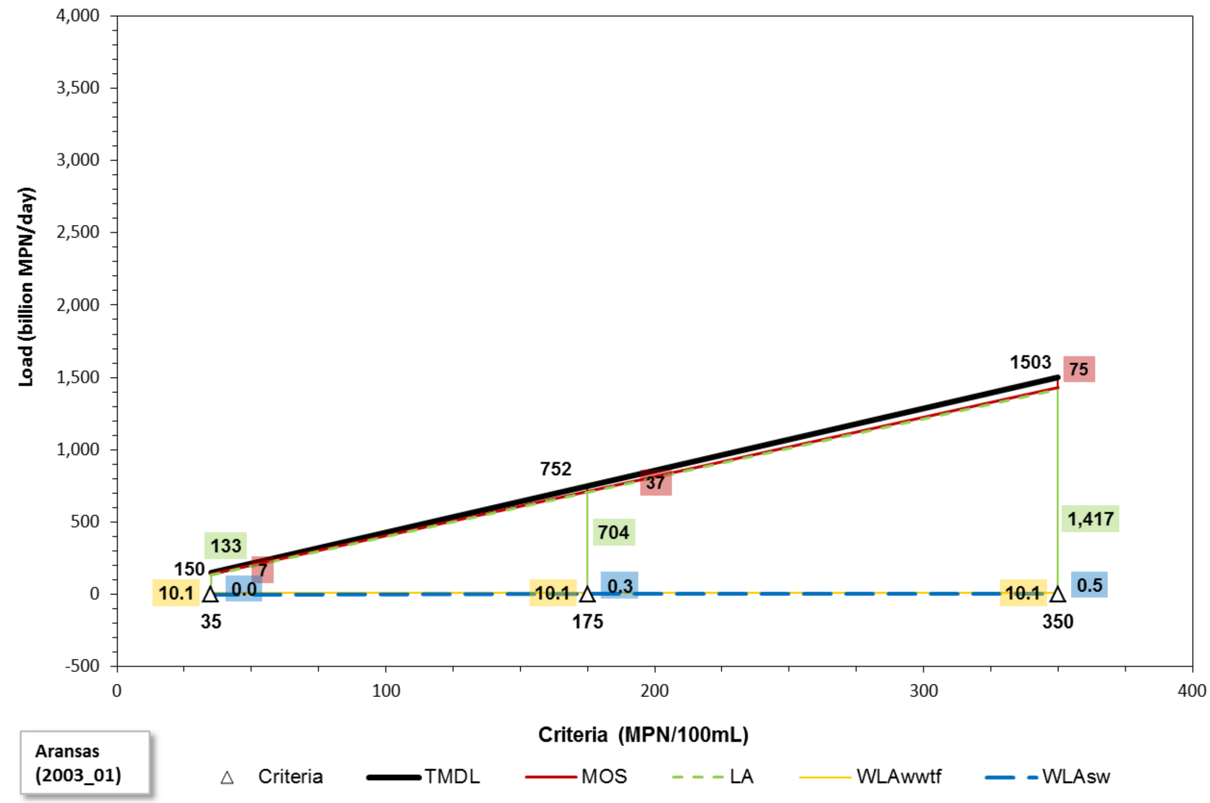

Figure C-2. Allocation loads for the Aransas River (2003_01) as a function of water quality criteria

Equations for calculating new TMDL and allocations (in billion MPN/day)

TMDL	= 4.2949 * Std
MOS	= 0.2147 * Std
LA	=4.0786* Std - 10.0773
WLA_{WWTF}	= 10.0810
WLA_{sw}	=0.0015 * Std - 0.0038

Where:

Std =	Revised Contact Recreation Standard
MOS =	Margin of Safety
LA =	Total load allocation (non-permitted source contributions)
WLA_{WWTF} =	Waste load allocation (permitted WWTF load + future growth) [Note: WWTF load held at Primary Contact (35 MPN/ 100 mL) criteria]
WLA_{SW} =	Waste load allocation (permitted stormwater)