Adopted January 24, 2018
Approved by EPA March 29, 2018

One Total Maximum Daily Load for Indicator Bacteria in Tres Palacios Creek Tidal

Segment 1501

Assessment Unit 1501_01

Water Quality Planning Division, Office of Water
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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The preparation of this report was financed in part through grants from the U.S. Environmental Protection Agency.

This TMDL report is based in large part on the report titled:
"Technical Support Document for Total Maximum Daily Load for Indicator Bacteria in Tres Palacios Creek Tidal"
prepared by the Texas Institute for Applied Environmental Research

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Abbreviations

AU	assessment unit
BMP	best management practice
CCN	Certificate of Convenience and Necessity
CFR	Code of Federal Regulations
cfs	cubic feet per second
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency (U.S.)
FDC	flow duration curve
GIS	Geographic Information System
I&I	inflow and infiltration
I-Plan	implementation plan
IRNR	Institute of Renewable Natural Resources
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
MUD	Municipal Utility District
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
ODEQ	Oregon Department of Environmental Quality
OSSF	on-site sewage facility
RMU	Resource Management Unit
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
USCB	United States Census Bureau

USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WQMP	Water Quality Management Plan
WUG	Water User Group
WWTF	wastewater treatment facility

One TMDL for Indicator Bacteria in Tres Palacios Creek Tidal

Executive Summary

This document describes a total maximum daily load (TMDL) for the tidal segment of Tres Palacios Creek where concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the contact recreation use. The Texas Commission on Environmental Quality (TCEQ) first identified the bacteria impairment in 2006 and then in each subsequent edition of the *Texas Integrated Report of Surface Water Quality for Clean Water Sections 305(b) and 303(d)* (Texas Integrated Report) through 2014. This document will consider bacteria impairments in one water body segment, consisting of one assessment unit (AU):

- Tres Palacios Creek Tidal (AU 1501_01)

The Tres Palacios Creek watershed is 268.5 square miles in area and is located along the Texas Gulf Coast midway between the cities of Victoria and Houston. The creek flows into Tres Palacios Bay, and then into Matagorda Bay. Segment 1501 is the portion of Tres Palacios Creek that is influenced by tidal action; meaning that the tidal segment receives freshwater inflows from the watershed and saline water from Tres Palacios Bay.

Three facilities within the Tres Palacios Creek watershed treat domestic wastewater. An additional facility is industrial, and has no human waste component. Three of the facilities discharge directly into Tres Palacios Creek Above Tidal (1502), and the other facility discharges into a tributary of Tres Palacios Creek Tidal (1501).

No municipal separate storm sewer system (MS4) permits are held in the Tres Palacios Creek watershed. However, a review of active stormwater general permits coverage in the Tres Palacios Creek watershed, as of April 15, 2015, found seven active construction sites and five active industrial multi-sector general permit (MSGP) facilities. Based on the current active permits, 0.83 percent of the Tres Palacios Creek watershed is regulated by stormwater permit. There are currently no petroleum bulk stations and terminal facilities in the watershed.

The discharges authorized by the stormwater general permits are considered intermittent and variable (subject to precipitation and runoff), and no flow limit is specified in the permits. Given the circumstances of the permits, these outfalls will be treated as part of the regulated stormwater discharge in the wasteload allocations (WLAs).

Escherichia coli (*E. coli*) are widely used as an indicator bacteria to assess attainment of the contact recreation use in freshwater bodies, while Enterococci are used as the indicator bacteria in salt waters. Enterococci are the relevant indicator for the Tres Palacios Creek Tidal segment. The criteria for assessing attainment of the contact recreation use are expressed as the number (or "counts") of Enterococci bacteria, typically given as the most probable number (MPN). The primary contact recreation use is not supported when the geometric mean of all Enterococci samples exceeds 35 MPN per 100 milliliters (mL).

Enterococci data collected at two monitoring stations over the seven-year period of December 1, 2005, through November 30, 2012, were used in assessing attainment of the primary contact recreation use as reported in the 2014 Texas Integrated Report (TCEQ, 2015a). The 2014 assessment data indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the geometric mean criterion at a measure of 67 MPN/100 mL.

A modified load duration curve (LDC) analysis was used to quantify allowable pollutant loads and specific TMDL allocations for point and nonpoint sources of indicator bacteria. The WLA for wastewater treatment facilities (WWTFs) was established as the full permitted discharge flow rate multiplied by the instream geometric criterion and also reduced to account for the required margin of safety (MOS). Future growth of existing or new domestic point sources was determined using population projections.

Within the Tres Palacios Creek watershed, the most probable sources of indicator bacteria are expected to be nonpoint sources. Nonpoint source loading enters the impaired segment through distributed, nonspecific locations, which may include urban runoff not covered by a permit, wildlife, various agricultural activities, agricultural animals, land application fields, failing on-site sewage facilities (OSSFs), unmanaged and feral animals, and domestic pets.

The TMDL calculations in this report will guide determination of the assimilative capacity of the water body under changing conditions, including future growth. Future wastewater discharge facilities will be evaluated case by case.

Introduction

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a 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.

The 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.

This TMDL addresses impairment of the primary contact recreation use due to exceedances of indicator bacteria in Tres Palacios Creek Tidal (Segment 1501). It takes a watershed approach to address the indicator bacteria impairment. While TMDL allocations were developed only for the impaired segment identified in this report, the entire project watershed (Figure 1) and all WWTFs that discharge within it are included within the scope of this TMDL.

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

The TCEQ must consider certain elements in developing a TMDL. They are described in the following sections of this report:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Analysis
- Margin of Safety
- Pollutant Load Allocation
- Seasonal Variation
- Public Participation
- Implementation and Reasonable Assurance

Upon adoption of the TMDL report by the TCEQ and subsequent EPA approval, this TMDL will become an update to the state's Water Quality Management Plan (WQMP).

Problem Definition

The TCEQ first identified the bacteria impairment within Tres Palacios Creek Tidal (Segment 1501) in 2006, and then in each subsequent edition of the Texas Integrated Report.

This document will consider the bacteria impairment in one segment, consisting of a single AU:

- Tres Palacios Creek Tidal (AU 1501_01).

Because the impaired segment is comprised of only one AU that encompasses the entire segment, the terms AU and segment may be used interchangeably throughout this report.

Ambient Indicator Bacteria Concentrations

Recent environmental bacteria monitoring in AU 1501_01 has occurred at two TCEQ monitoring stations within the watershed—12515 and 20636 (Table 1 and Figure 1). Enterococci data collected at these stations over the seven-year period from December 1, 2005, through November 30, 2012, were used in assessing attainment of the primary contact recreation use as reported in the 2014 Texas Integrated Report (TCEQ, 2015a). The 2014 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 Enterococci.

Table 1. 2014 Texas Integrated Report summary for the impaired AU.

Data date range: 12/2005 - 11/2012

Water Body	Segment Number	AU	Parameter	Stations	Number of Samples	Station Geometric Mean (MPN/100 mL)
Tres Palacios Creek Tidal	1501	1501_01	Enterococci	12515	46	49
				20636	18	149
				Both Stations	64	67

(The geometric mean criterion for primary contact recreation use is 35 MPN/100 mL for Enterococci.)

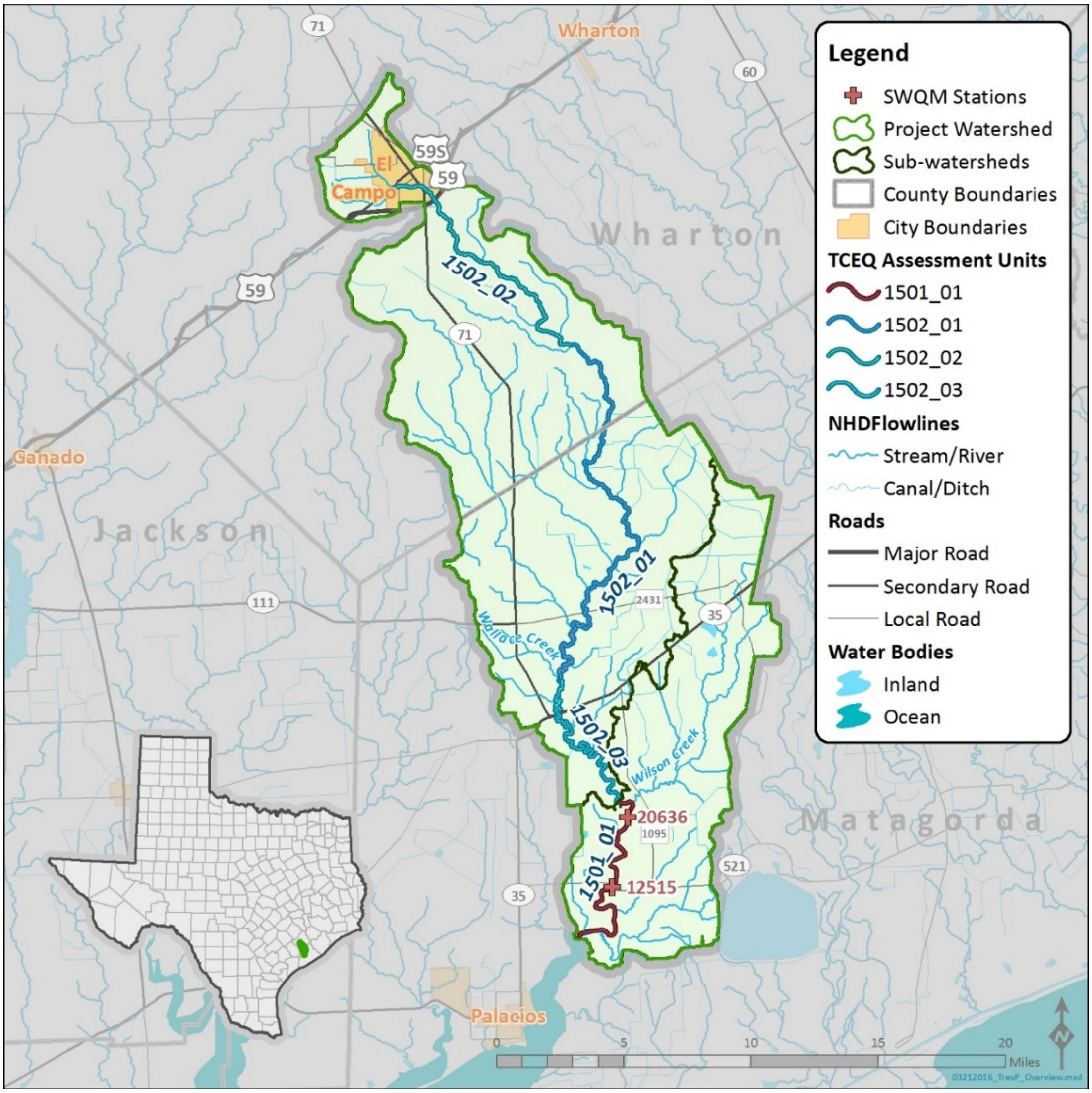

Figure 1. Overview map showing the total contributing drainage area for the TMDL watershed, including Segments 1501 and 1502, and TCEQ surface water quality monitoring stations.

Watershed Overview

Tres Palacios Creek, located along the Texas Gulf Coast midway between the cities of Victoria and Houston, is comprised of two segments. The upstream segment is designated as "Above Tidal (Segment 1502)" and the downstream segment is designated as simply "Tidal (Segment 1501)." The above tidal portion of the creek is a perennial freshwater stream, while the tidal portion is influenced by saline water from Tres Palacios Bay. At its mouth, Tres Palacios Creek drains 268.5 square miles (171,816 acres) in Wharton (64 percent of the watershed) and Matagorda (36 percent of the watershed) counties. This TMDL incorporates a watershed approach where the entire drainage area of segments

1501 and 1502 are considered, even though only Segment 1501 is impaired (Figure 1).

The 2014 Texas Integrated Report (TCEQ, 2015a) provides the following segment and AU descriptions for the water bodies considered in this document:

- Segment 1501: Tres Palacios Creek Tidal
  - From the confluence with Tres Palacios Bay in Matagorda County to a point 1.0 km (0.6 miles) upstream of the confluence of Wilson creek in Matagorda County
  - Segment Type: Tidal Stream
  - AU 1501_01 - From the confluence with Willow Dam Creek at Tres Palacios Bay/Turtle Bay upstream to a point 1.6 km (1.0 miles) upstream of the confluence of Wilson Creek in Matagorda County
- Segment 1502: Tres Palacios Creek Above Tidal
  - From a point 1.6 km (1.0 miles) upstream of the confluence of Wilson Creek in Matagorda County to State Route 525 (Old US 59) in Wharton County
  - Segment Type: Freshwater Stream
  - AU 1502_01 - Middle portion of segment from the confluence with Wallace Creek upstream to confluence with unnamed tributary with NHD RC 12100401013089 about 1.0 km SW of intersection of FM 418 and FM 422 NE of City of Danevang in Wharton County
  - AU 1502_02 - Upper portion of segment from the confluence with unnamed tributary about 1.0 km SW of intersection of 418 and 422 NE of City of Danevang in Wharton County upstream to US 59
  - AU 1502_03 - Lower portion of segment from a point 1.6 km (1.0 miles) upstream of the confluence of Wilson Creek upstream to confluence with Wallace Creek Matagorda County

Watershed Climate

The Tres Palacios Creek watershed is located in the eastern portion of the state of Texas, where the climate is classified as “Subtropical Humid” (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 to 2010, average annual precipitation over the Tres Palacios Creek watershed was 46 inches (PRISM Climate Group at Oregon State University, 2012) (Figure 2).

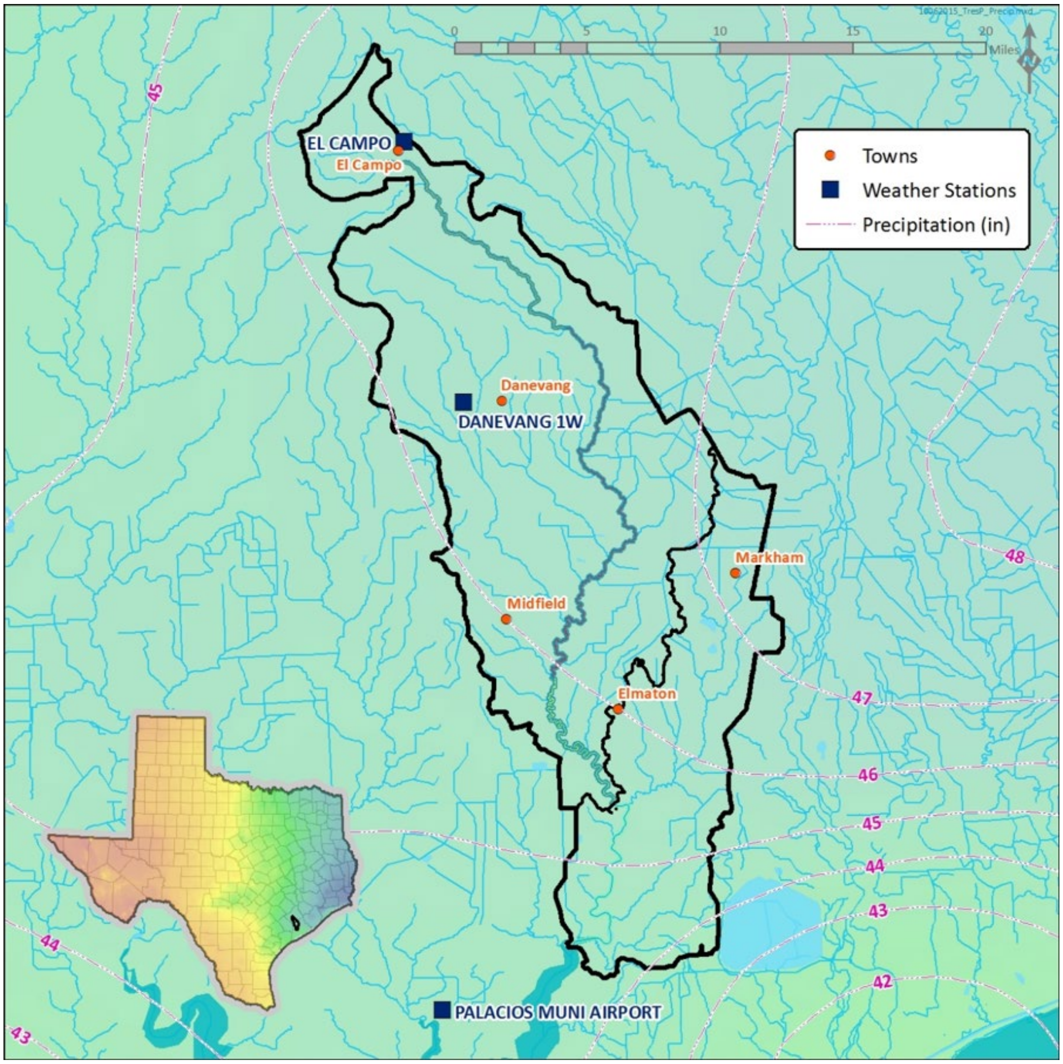

Figure 2. Annual average precipitation isohyets (in inches) in the Tres Palacios Creek watershed (1981-2010).

Towns within the watershed, as well as the area National Climatic Data Center weather stations, are shown.

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

At the Danevang 1W weather station, located near the center of the watershed, the average high temperatures generally reach their peak of 93.5˚F in August, and highs above 100˚F can occur in June, July, and August. Fair skies generally accompany the highest temperatures of summer when nightly average lows drop to about 72˚F [National Oceanic and Atmospheric Administration (NOAA), 2015b]. During winter, the average low temperature bottoms out at 41.5˚F in January (NOAA, 2015b). The frost-free period in the region generally lasts for about 292 days, with the average last frost occurring February 23, and the average first frost occurring on December 12 (Southern Regional Climate Center, 1994). In Danevang, the wettest month is normally September (5.1 inches), and the driest month is normally April (2.4 inches), although rainfall typically occurs year-round (NOAA, 2015b) (Figure 3).

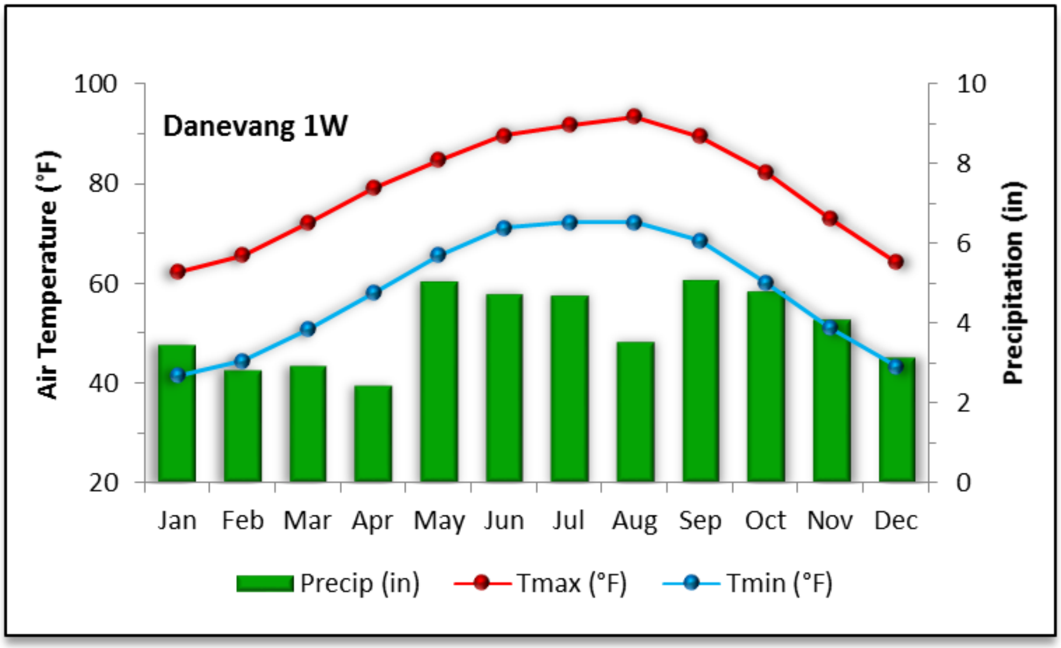

Figure 3. Average minimum and maximum air temperatures and average total precipitation by month over 1981-2010 for the Danevang area.

Source: NOAA (2015b)

Watershed Population and Population Projections

According to the 2010 Census, there were an estimated 14,663 people in the Tres Palacios Creek watershed, indicating an average population density of approximately 55 people per square mile (or 1 person per 11.7 acres). Of those, an estimated 9,547 people (65 percent) are located within the city of El Campo, indicating that the watershed population is mostly urban, even though only 2 percent of the area of that watershed is within the city limits of El Campo (Figure 4 and Table 2).

Calculations based on population projections developed by the Office of the State Demographer and the Texas Water Development Board [(TWDB), 2014] indicate that between 2010 and 2050, the populations of Matagorda and Wharton counties are expected to increase by 18.7 percent and 23.1 percent, respectively. Estimates for the Tres Palacios Creek watershed, refined by the Water User Group (WUG), range from 17.3 percent to 22.5 percent (Table 3).

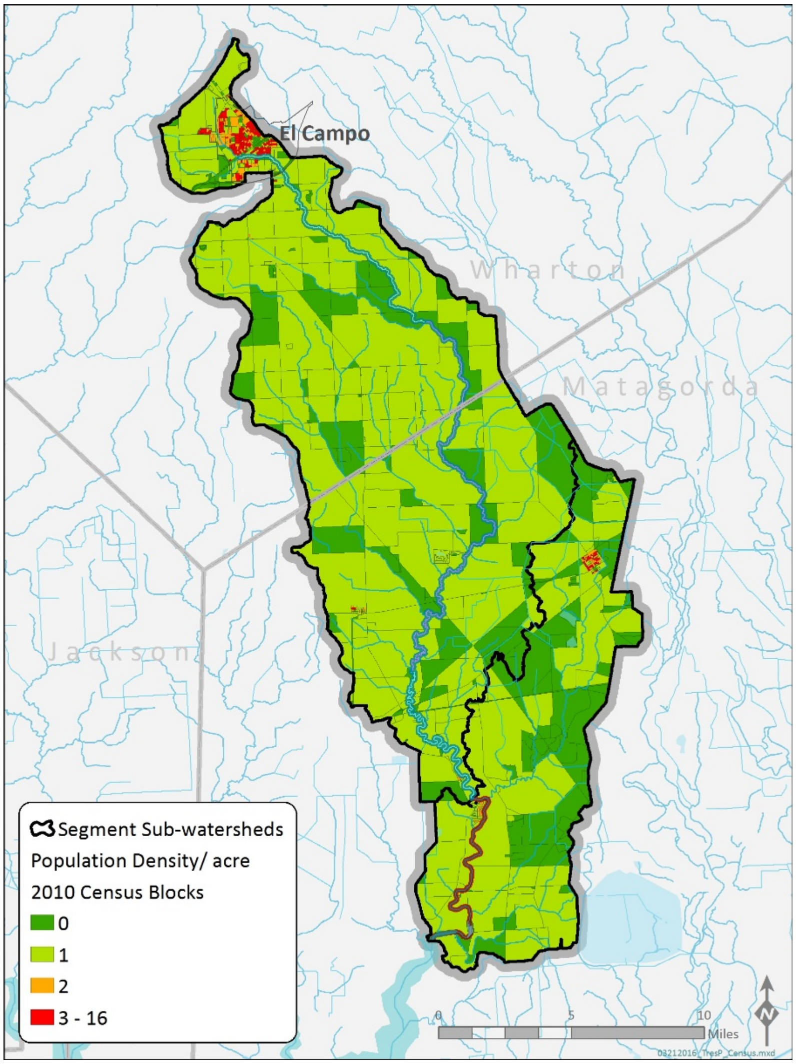

Figure 4. 2010 total population by census block.

Sources: StratMap city boundaries [Texas Natural Resources Information System (TNRIS), 2012], Census Blocks [United States Census Bureau (USCB), 2010]

Table 2. 2010 population for the Tres Palacios Creek watershed.

Source: Calculated from United States Census Bureau Census Blocks (USCB, 2010)

Segment	2010 Census Population
Tidal (1501)	1,788
Above Tidal (1502)	12,875
Total	14,663

Table 3. 2010 population and 2010-2050 population projections for Water User Groups in the Tres Palacios Creek watershed.

Source: TWDB (2014)

WUG	2010 U.S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Percent Increase (2010 - 2050)
El Campo (in Wharton County)	9,544	10,470	10,959	11,350	11,688	22.46%
Wharton County - Other	2,189	2,250	2,418	2,552	2,669	21.93%
Matagorda County - Other	2,930	3,090	3,252	3,357	3,437	17.30%
Total	14,663	15,810	16,629	17,259	17,794	21.33%

Water Rights Review

Surface water rights in Texas are overseen by the TCEQ. A search of the TCEQ water rights database files (TCEQ, 2014b) revealed that within the Tres Palacios Creek watershed, there are an estimated 16 surface water rights, with counterparts in the water rights Geographic Information System (GIS) coverage (TCEQ, 2014a), authorizing the diversion of 25,450 acre-feet annually. A review of water rights water use data files (TCEQ, 2014b) indicates that 10 of the 16 water users diverted an average of approximately 10,647 acre-feet annually (with the remainder reporting zero flows) from 1990-2013 (Figure 5). Of this, 9,834 acre-feet were diverted downstream of the U.S. Geological Survey (USGS) gauge, indicating that 813 acre-feet were diverted upstream of the USGS streamflow gauge. The diversion locations relative to the USGS streamflow gauge location were considered in the development of the pollutant load allocation, which is discussed in the Linkage Analysis section.

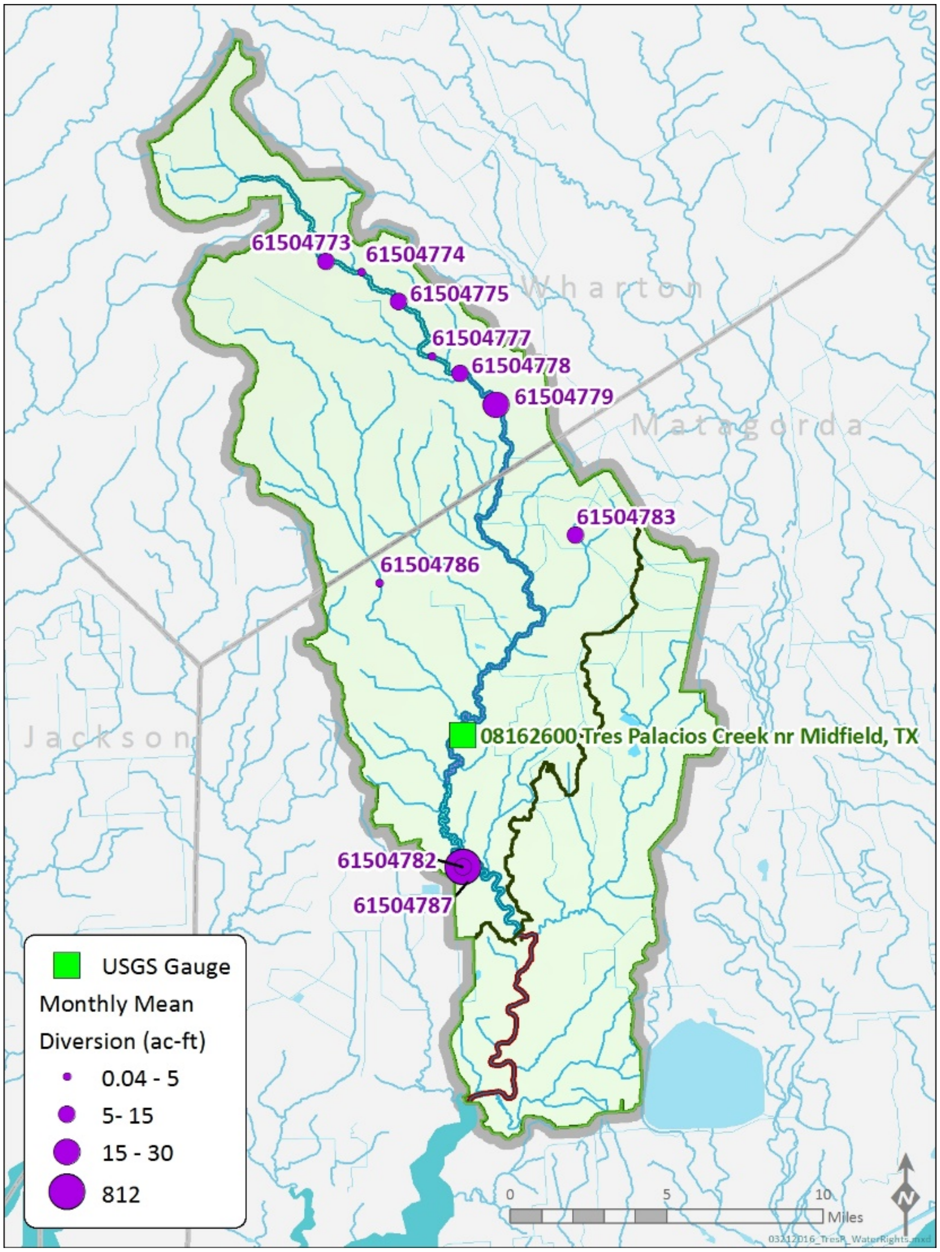

Figure 5. Monthly average diversion amounts over the period 1990-2013 for surface water rights within the Tres Palacios Creek watershed, shown in relation to the U.S. Geological Survey stream gauge station.

Water right diversion points are labeled by TCEQ water rights ID number.

Source: Water Rights Database and Related Files (TCEQ, 2014a)

Land Use

The land use/land cover data for the Tres Palacios Creek watershed were obtained from the USGS 2011 National Land Cover Database (NLCD) and are displayed in Figure 6.

The land use/land cover is represented by the following categories and definitions (USGS, 2014):

- **Open Water** - areas of open water, generally with less than 25 percent cover of vegetation or soil.
- **Developed, Open Space** - areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Developed, Low Intensity** - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20 to 49 percent of total cover. These areas commonly include single-family housing units.
- **Developed, Medium Intensity** - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover. These areas commonly include single-family housing units.
- **Developed High Intensity** - highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.
- **Barren Land (Rock/Sand/Clay)** - 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 percent of total cover.
- **Deciduous Forest** - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
- **Evergreen Forest** - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Forest** - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
- **Shrub/Scrub** - areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
- **Grassland/Herbaceous** - areas dominated by graminoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

- **Pasture/Hay** - 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.
- **Woody Wetlands** - areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Emergent Herbaceous Wetlands** - areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

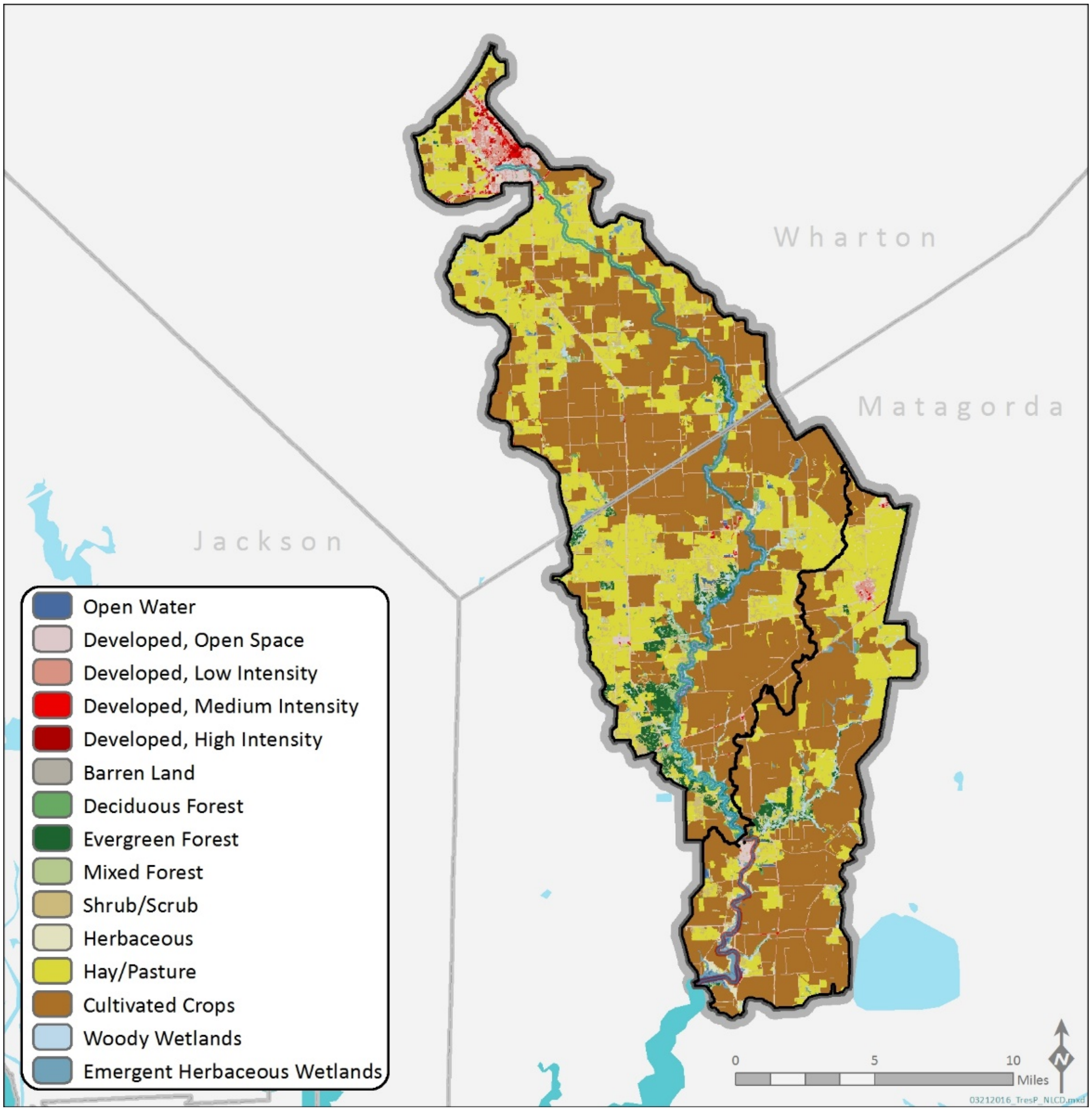

Figure 6. 2011 National Land Cover Database land use/land cover within the Tres Palacios Creek watershed.

Source: USGS (2014)

As displayed in Table 4, the dominant land use in the watershed area encompassing both the Tidal and Above Tidal segments of Tres Palacios Creek is cultivated crops (52.5 percent) followed by hay/pasture (29.3 percent). The watershed is predominantly rural, as only approximately 6 percent of the area is classified as developed (open space, low intensity, medium intensity, and high intensity).

Table 4. Land use/land cover within the Tres Palacios Creek watershed.

Source: USGS (2014)

2011 NLCD	Tres Palacios Creek Tidal (1501)		Tres Palacios Creek Above Tidal (1502)		Tres Palacios Creek Watershed Total	
Classification	Area (mi^2)	% of Total	Area (mi^2)	% of Total	Area (mi^2)	% of Total
Open Water	1.0	1.2%	0.5	0.3%	1.5	0.6%
Developed, Open Space	2.7	3.5%	9.0	4.8%	11.8	4.4%
Developed, Low Intensity	0.8	1.0%	2.2	1.2%	3.0	1.1%
Developed, Medium Intensity	0.1	0.1%	1.0	0.5%	1.1	0.4%
Developed, High Intensity	0.0	0.0%	0.4	0.2%	0.4	0.1%
Barren Land	0.1	0.1%	0.1	0.1%	0.2	0.1%
Deciduous Forest	0.6	0.8%	2.2	1.2%	2.8	1.0%
Evergreen Forest	1.1	1.4%	4.8	2.5%	5.8	2.2%
Mixed Forest	0.5	0.7%	1.8	0.9%	2.3	0.8%
Shrub/Scrub	1.8	2.3%	8.3	4.4%	10.1	3.8%
Herbaceous	1.4	1.7%	1.7	0.9%	3.0	1.1%
Hay/Pasture	18.8	23.9%	59.8	31.5%	78.6	29.3%
Cultivated Crops	47.0	59.8%	93.8	49.4%	140.9	52.5%
Woody Wetlands	1.2	1.5%	3.4	1.8%	4.6	1.7%
Emergent Herbaceous Wetlands	1.5	1.9%	0.9	0.5%	2.4	0.9%
Total	78.6	100%	189.9	100%	268.5	100%

Analysis of the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Cropland Data Layer for 2014 indicates that the agricultural crops that cover the most area in the watershed include cotton (11.1 percent of the watershed), corn (9.6 percent), and sorghum (6.0 percent). The agricultural land cover data for the Tres Palacios Creek watershed are shown in Figure 7.

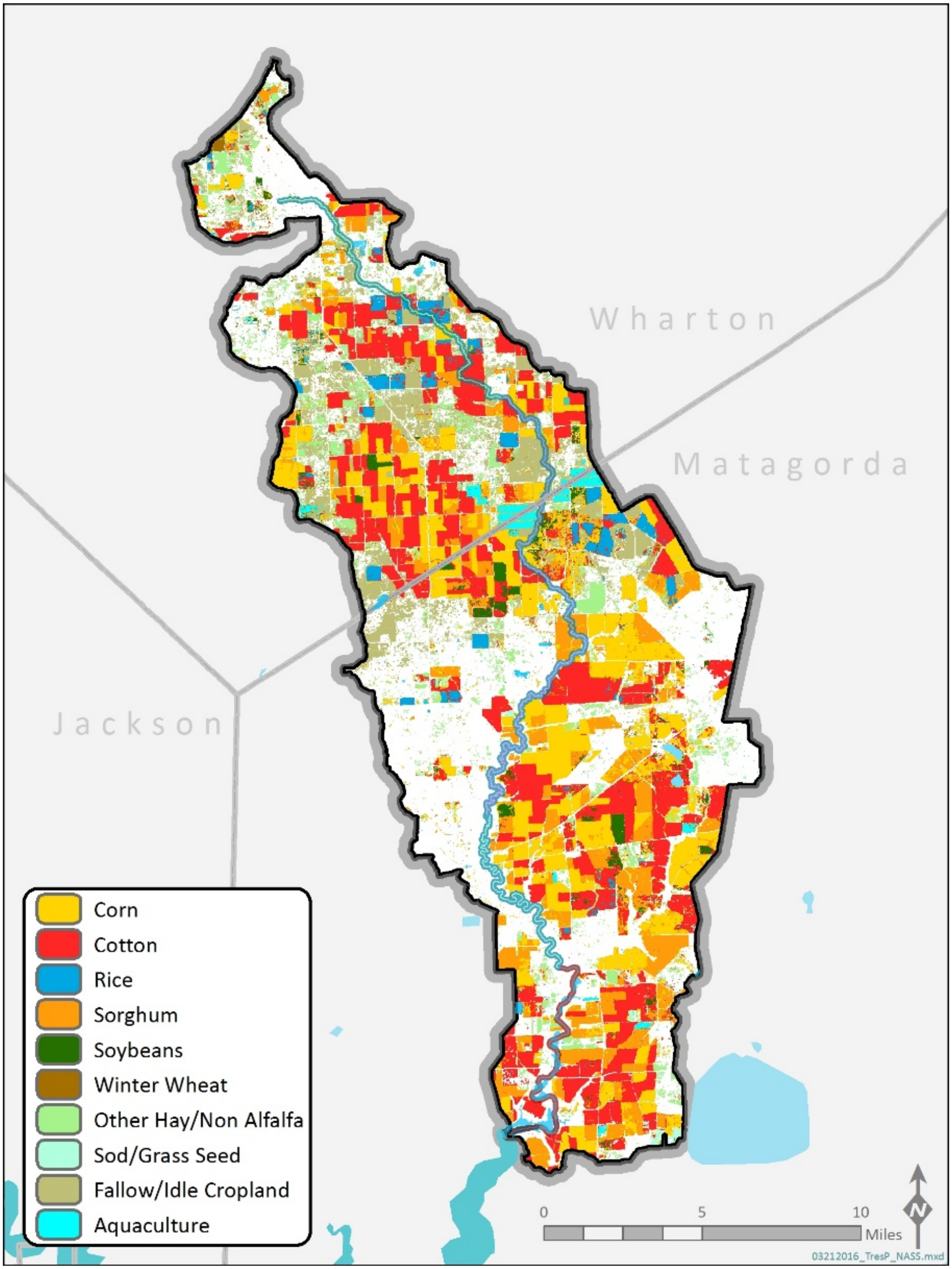

Figure 7. 2014 agricultural land cover within the Tres Palacios watershed.

Source: USDA NASS (2014a)

Soils

Soils within the Tres Palacios Creek watershed, categorized by their Hydrologic Soil Group, are shown in Figure 8. These data were obtained through the USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (NRCS, 2013a). Within the Tres Palacios Creek watershed, approximately 98 percent of the soils are classified in Hydrologic Soil Group D, and therefore have the following characteristics: a high runoff potential when thoroughly wet, restricted water movement though the soil, and a high shrink-swell potential (NRCS, 2007). The soils along portions of the Tres Palacios Creek Tidal Segment 1501 are classified within Hydrologic Soil Group C, so these soils have a moderately high runoff potential when thoroughly wet (NRCS, 2007).

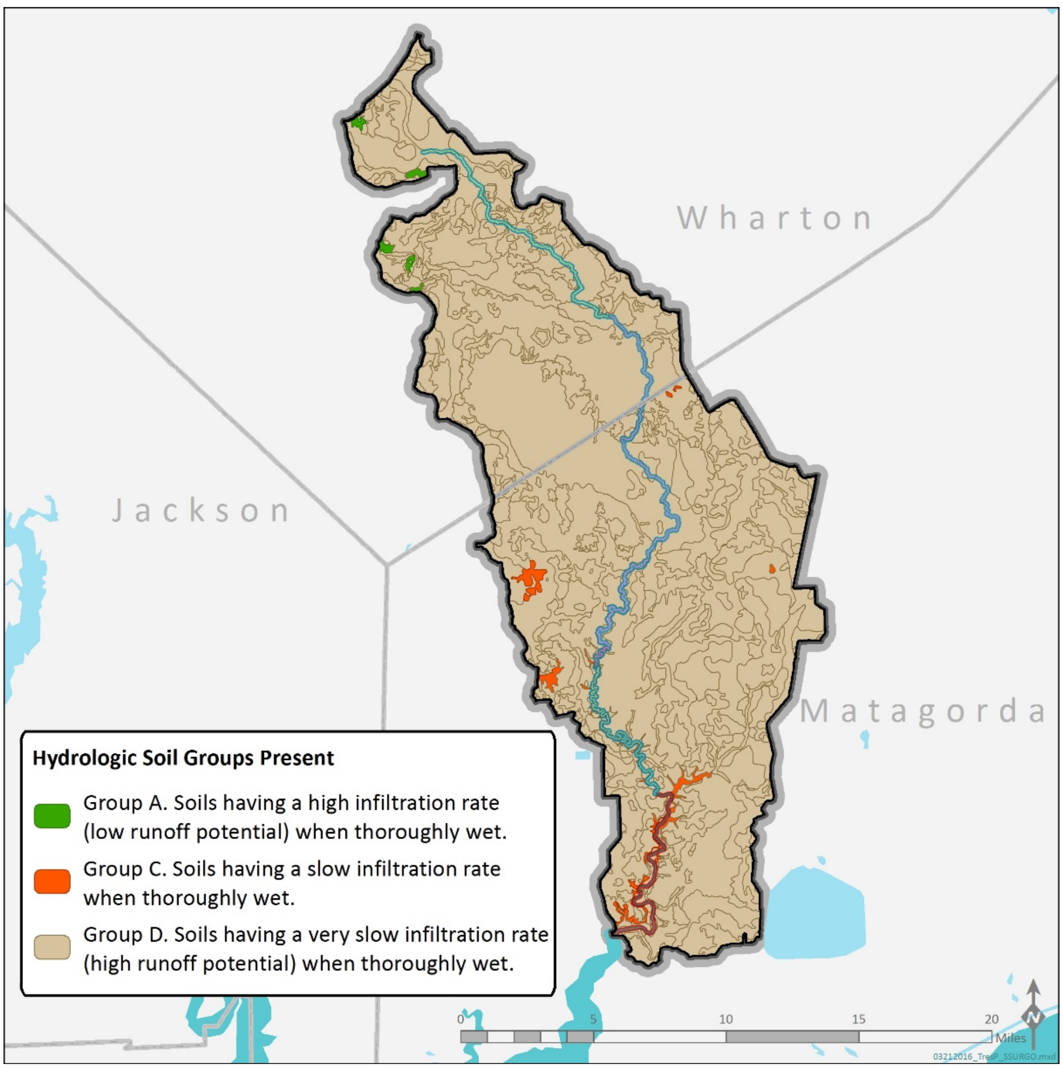

Figure 8. Tres Palacios Creek watershed soil map; soils categorized by Hydrologic Soil Group.

Source: NRCS (2013a); NRCS (2013b); NRCS (2014)

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 endpoint for the TMDL in this report is to maintain concentrations of Enterococci below the geometric mean criterion of 35 MPN/100 mL, which is the criterion in the 2010 Texas Surface Water Quality Standards (TCEQ, 2010) for primary contact recreation in saline water bodies.

Source Analysis

Pollutants may come from several sources, both regulated and unregulated. Regulated pollutants, referred to as "point sources," come from a single definable point, such as a pipe, and are regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES). WWTFs and stormwater discharges from industries, construction, and MS4s are considered point sources of pollution.

Unregulated sources are typically nonpoint source in origin, meaning the pollutants originate from multiple locations and rainfall runoff washes them into surface waters. Nonpoint sources are not regulated by permit.

With the exception of WWTFs, which receive individual WLAs (see the Wasteload Allocation section), the regulated and unregulated sources in this section are presented to give a general account of the different sources of bacteria expected in the watershed. These are not meant to be used for allocating bacteria loads or interpreted as precise inventories and loadings.

Regulated Sources

Regulated sources are controlled by permit under the TPDES and the National Pollutant Discharge Elimination System (NPDES) programs. The regulated sources in the TMDL watershed include domestic and industrial WWTFs and stormwater discharges from industry and construction.

Domestic and Industrial Wastewater Treatment Facilities

As of September 1, 2015, there were four facilities with TPDES/NPDES permits that operated within the watershed (Figure 9 and Table 5); three of the WWTFs are located in the Above Tidal portion of Tres Palacios Creek (Segment 1502) and one is located in the Tidal portion of Tres Palacios Creek (Segment 1501). Three facilities within the watershed treat exclusively domestic wastewater and one facility (Apex Matagorda Energy) treats wastes associated with a compressed air energy storage facility with no human waste component. Three of the facilities discharge directly into Tres Palacios Creek Above Tidal (1502), and the other facility discharges into a tributary of Tres Palacios Creek (1501). No WWTFs discharge directly into the impaired AU (1501_01).

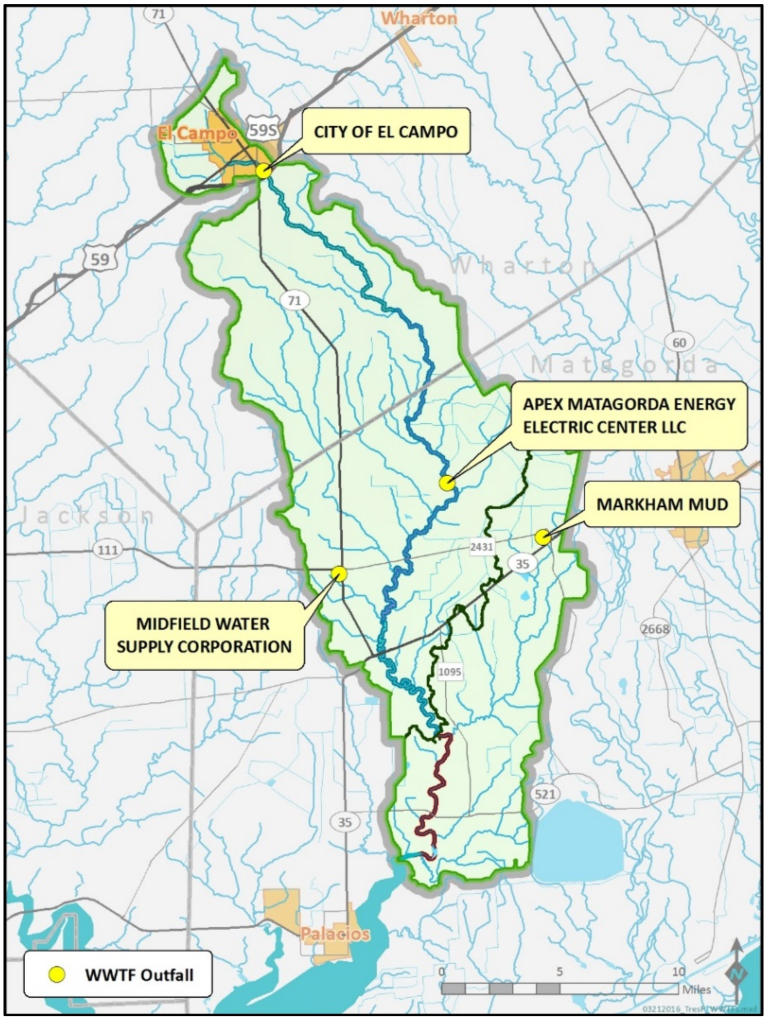

Figure 9. Tres Palacios Creek watershed showing wastewater treatment facilities.

Source: Permitted outfalls (TCEQ, 2012)

TPDES General Wastewater Permits

In addition to the individual wastewater discharge permits listed in Table 5, 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, or
- WQG20000 – livestock manure compost operations (irrigation only).

Table 5. Permitted wastewater treatment facilities in the Tres Palacios Creek watershed.

Source: Individual TPDES Permits

TPDES Permit No.	NPDES Permit No.	Facility	AU	Receiving Waters	Permitted Discharge[a] (MGD)	Recent Discharge (MGD)
WQ0005009000	TX0134317	Apex Matagorda Energy Center	1502_01	Tres Palacios Creek Above Tidal	0.223 (daily avg)	0.0[b]
WQ0010844001	TX0021474	City of El Campo WWTF	1502_02	Tres Palacios Creek Above Tidal	2.628 (annual avg)	1.015[c]
WQ0013091001	TX0098205	Midfield WWTF	1502_03	an unnamed tributary; thence to Wallace Creek; thence to Tres Palacios Creek Above Tidal	0.03 (daily avg)	0.016[c]
WQ0015075001	TX0134309	Markham MUD WWTF	1501_01	an unnamed ditch; thence to Wilson Creek; thence to Tres Palacios Creek Tidal	0.3 (daily avg)	0.045[d]

[a] Significant figures reflect million gallons per day (MGD) presented in TPDES permits

[b] No reported discharge; facility not built

[c] Average measured discharge from November 2009 through June 2014, as available

[d] Average measured discharge from November 2009 through October 2012

MUD – Municipal Utility District

A review of active general permit coverage (TCEQ, 2015e) in the Tres Palacios Creek watershed as of April 8, 2015, found two bass aquaculture facilities covered by the general permit. These facilities are located in Segment 1502, above the impaired segment watershed. The two aquaculture facilities do not have bacteria reporting or limits in their permit. Both facilities were assumed to contain inconsequential amounts of indicator bacteria in their effluent; therefore, it was unnecessary to allocate bacteria load to these aquaculture facilities. No other facilities or operations with active general wastewater permits were found.

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 12 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. A search of the database, based on the three domestic facilities in Segments 1501 and 1502, revealed that no SSOs have been reported since record-keeping began on September 1, 2001 (TCEQ, 2015b). It is possible that SSOs are being under-reported in the Tres Palacios watershed, since some overflows would have been anticipated over the period covered in the dataset.

TPDES-Regulated Stormwater

When evaluating stormwater for a TMDL allocation, a distinction must be made between stormwater originating from an area under a TPDES or NPDES-regulated discharge permit and stormwater originating from areas not under a TPDES or NPDES-regulated discharge permit. Stormwater discharges fall into two categories:

1) stormwater subject to regulation, which is any stormwater originating from TPDES-regulated MS4s, industrial facilities, and regulated construction activities; or
2) stormwater runoff not subject to regulation.

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 MS4 general permit for urbanized areas,
- TXR050000 – stormwater MSGP for industrial facilities,
- TXR150000 – stormwater from construction activities disturbing more than one acre,
- TXG110000 – concrete production facilities, or
- 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.

A review of active stormwater general permits coverage (TCEQ, 2015e) in the Tres Palacios Creek watershed, as of April 15, 2015, found seven active construction sites and five active industrial (MSGP) facilities. There are currently no other active stormwater permits in the watershed. Based on the current active permits, 0.83 percent of the Tres Palacios Creek watershed is regulated by stormwater permit.

Illicit Discharges

Pollutant loads can enter streams from MS4 outfalls that carry authorized sources as well as illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TXR040000 for Phase II MS4s 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* (New England Interstate Water Pollution Control Commission, 2003) include:

Direct illicit discharges:

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials 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 sanitary sewer and storm sewer systems.

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.

Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint sources. Nonpoint source loading enters the impaired segment through distributed, nonspecific locations, which may include urban runoff not covered by a permit, wildlife, various agricultural activities, agricultural animals, land application fields, OSSFs, unmanaged and feral animals, and domestic pets.

On-Site Sewage Facilities

Private residential OSSFs, commonly referred to as septic systems, consist of various designs based on physical conditions of the local soils. Typical designs consist of 1) one or more septic tanks and a drainage or distribution field (anaerobic system) or 2) aerobic systems that have an aerated holding tank and often an above-ground sprinkler system for distributing the effluent. In simplest terms, household waste flows into the septic tank or aerated tank, where solids settle out and a portion of the treatment process occurs. The liquid portion then flows or is pumped to the distribution system, which may consist of buried perforated pipes or, for example, an above-ground sprinkler system.

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters if the systems are not properly operating. Properly designed and operated, however, OSSFs would be expected to contribute virtually no fecal bacteria to surface waters. For example, it has been reported that less than 0.01 percent of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system (Weikel et al., 1996). Reed, Stowe, and Yanke, LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. Tres Palacios Creek is located within the east-central Texas area, which has a reported failure rate of about 12 percent. Twelve percent is used in this report as the expected failure rate for the area.

Estimates of the number of OSSFs in the Tres Palacios Creek watershed were based on 2010 Census block data. For the area of the Tres Palacios Creek watershed, OSSFs were estimated to be households that were outside of either a Certificate of Convenience and Necessity (CCN) sewer area or a city boundary. The total estimate is shown in Table 6, and the OSSF density is shown in Figure 10.

Table 6. On-site sewage facilites estimate for the Tres Palacios Creek watershed.

Source: Census Blocks USCB, 2010

Segment	Estimated OSSFs
Tidal (1501)	510
Above Tidal (1502)	1,288
Total	1,798

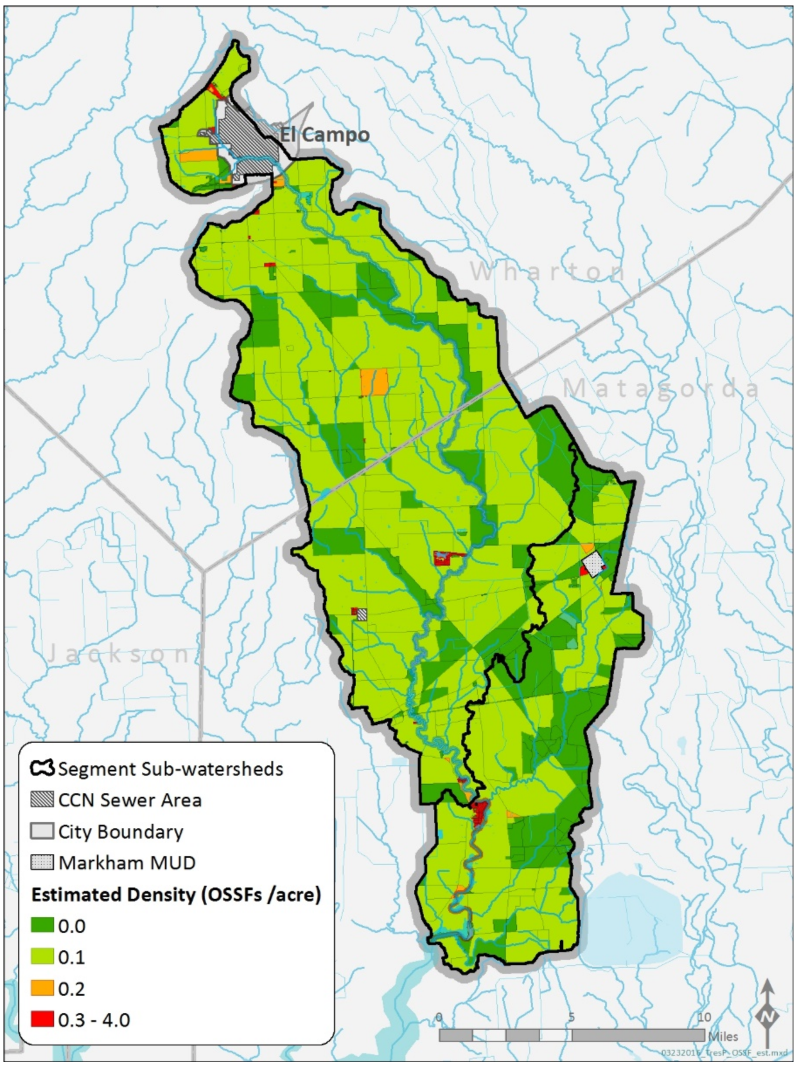

Figure 10. On-site sewage facilities densities within the Tres Palacios Creek watershed.

Sources: StratMap City boundary [Texas Natural Resources Information System (TNRIS), 2012], CCN Sewer Areas (Public Utility Commission of Texas, 2014), Census Blocks (USCB, 2010), Water District Spatial Data (TCEQ, 2015d)

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 the 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 they may be washed into nearby streams by rainfall runoff.

Unfortunately, quantitative estimates of wildlife are rare, inexact, and often limited to discrete taxa groups or geographical areas of interest so that even county-wide approximations of wildlife numbers are difficult or impossible to acquire. However, population estimates for feral hogs and deer, as well as many species of birds, are available for the Tres Palacios Creek watershed.

For feral hogs, the Institute of Renewable Natural Resources (IRNR, 2013) estimated a range of feral hog densities within Texas (1.33 to 2.45 hogs/square mile). The average hog density (1.89 hogs/square mile) was multiplied by the hog-habitat area (250.4 square miles) in the Tres Palacios Creek watershed. Habitat deemed suitable for hogs followed as closely as possible to the land use selections of the IRNR study and include from the 2011 NLCD: hay/pasture, cultivated crops, shrub/scrub, herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands, and emergent herbaceous wetlands. Using this methodology, there are an estimated 473 feral hogs in the Tres Palacios Creek watershed.

For deer, the Texas Parks and Wildlife Department (TPWD) published data showing deer population-density estimates by Resource Management Unit (RMU) and Ecoregion in the state (TPWD, 2012). The Tres Palacios Creek watershed incorporates areas of RMU 12, for which the average deer density over the period 2005-2011 was calculated to be 35.9 deer/square mile. Applying this value to the area of the watershed that is suitable deer habitat (31.0 square miles of woodland, shrubland, and near riparian forest) returns an estimated 1,113 deer within the Tres Palacios Creek watershed.

For birds, the Cornell Lab of Ornithology and the National Audubon Society maintain an online database (eBird, 2015) that provides bird abundance and distribution information at a variety of spatial scales. A query of Wharton and Matagorda counties reveals that there have been 352 species of birds observed within the last 5 years. Querying “Abundance” data by county for the last full year (2014) and summing the number of individual birds by month indicates that there were 543,098 birds observed in Matagorda County and 133,688 observed in Wharton County in 2014.

Unregulated Agricultural Activities and Domesticated Animals

A number of agricultural activities that do not require permits can be potential sources of fecal bacteria loading. Livestock are present throughout the rural portions of the project watershed.

The number of livestock that are found within the Tres Palacios Creek watershed was estimated from county level data obtained from the 2012 Census of Agriculture (USDA NASS, 2014b). The county level data were refined to better reflect actual numbers within the impaired AU watershed. The refinement was performed by determining the total area of each county as well as the subject watershed that was designated as either "herbaceous/grassland" or "hay/pasture" in the 2011 NLCD (USGS, 2014). A ratio was then developed by dividing the selected land use area of the watershed area within a county by the total area of the county. This ratio was then applied to the county level data. Table 7 summarizes the estimated number of livestock in the watershed. These estimated livestock populations were reviewed by the Texas State Soil and Water Conservation Board (TSSWCB).

Table 7. Estimated distributed domesticated animal populations within the Tres Palacios Creek watershed, based on proportional area.

Source: USDA NASS (2014b).

Segment	Cattle and Calves	Goats	Hogs and Pigs	Horses and Ponies	Mules, Burros, and Donkeys	Poultry	Sheep and Lambs
Tidal (1501)	2,829	46	2	61	7	7	16
Above Tidal (1502)	10,100	142	18	266	37	35	65
Total	12,929	188	20	327	44	42	81

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and is a potential source of bacteria loading. Table 8 summarizes the estimated number of dogs and cats for the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household (American Veterinary Medical Association, 2012). The actual contribution and significance of fecal coliform loads from pets reaching the water bodies of the watershed are unknown.

Table 8. Estimated households and pet populations for the Tres Palacios Creek watershed.

Segment	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
Tidal (1501)	888	519	567
Above Tidal (1502)	5,108	2,983	3,259

Segment	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
Total	5,996	3,502	3,826

Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (e.g., warm temperature). Fecal organisms can survive and replicate from improperly-treated effluent during their transport in pipe networks and 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 replication is less understood. Both processes (replication and die-off) are instream processes and are not considered in the bacteria source loading estimates for the TMDL watershed.

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. This 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 regulated and unregulated stormwater sources are greatest during runoff events. Rainfall runoff 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 reduced as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

Modified Load Duration Curve Analysis

A modified LDC method was used to examine the relationship between instream water quality and the source of indicator bacteria loads. LDCs are graphs of the frequency distribution of loads of pollutants in a stream. In the case of this TMDL, the loads shown are of Enterococci bacteria in MPN/day. LDCs are derived from flow duration curves (FDCs), which are graphs of the frequency distribution of flow in a stream. The LDC shown in Figure 11 represents the maximum acceptable load in the stream that will result in achievement of the TMDL water quality target.

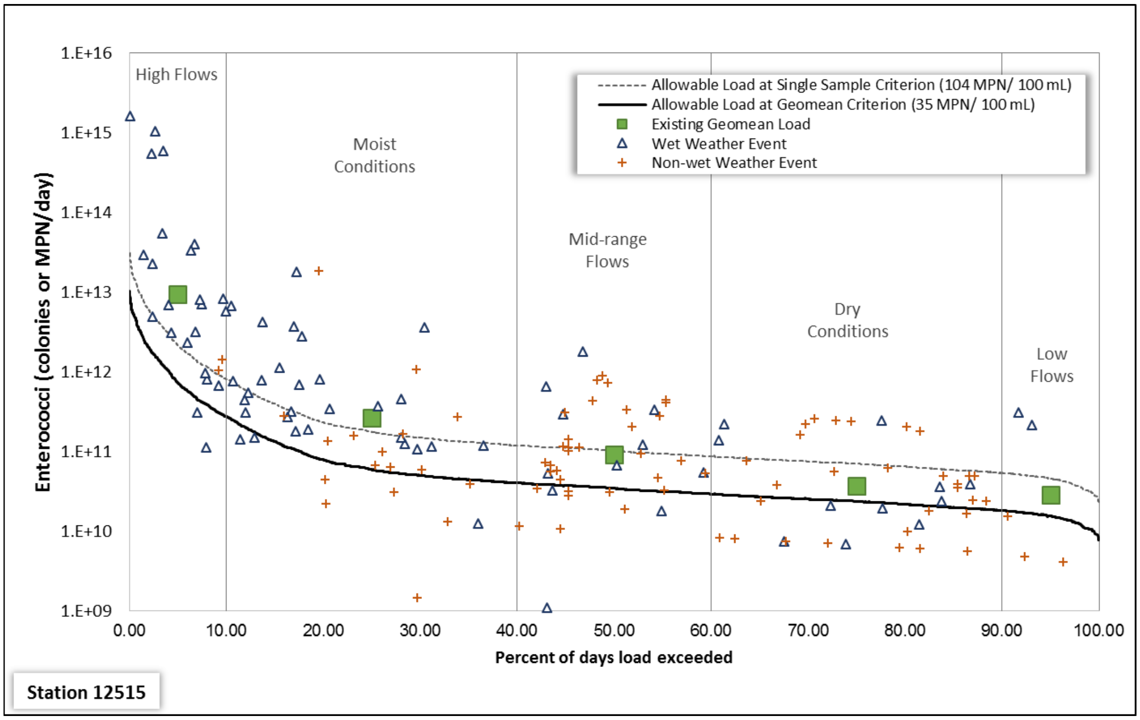

Figure 11. Load duration curve at Station 12515 on Tres Palacios Creek Tidal (Segment 1501) for the period of January 1, 1999 through December 31, 2013.

LDCs are a simple statistical method that provide a basic description of the water quality problem. The strength of this tool is that it is easily developed and explained to stakeholders, and uses available water quality and flow data. The LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed.

The weaknesses of the LDC method include the limited information it provides regarding the magnitude or specific origin of the various sources. Only limited information is gathered regarding point and nonpoint sources in the watershed. The general difficulty in analyzing and characterizing Enterococci in the environment is also a weakness of this method.

The State of Oregon Department of Environmental Quality (ODEQ) developed a modified LDC method for tidal streams of the Umpqua River Basin (ODEQ, 2006). This method was applied to Tres Palacios Creek Tidal.

The modified LDC method is based on the assumption that combining 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. Historical data are showing a decrease in Enterococci concentrations with increasing distance from where the tidal segment of Tres Palacios Creek reaches Tres Palacios Bay.

The modified LDC method allows for the estimation of existing TMDL loads by utilizing the cumulative frequency distribution of streamflow with diluting seawater and measured pollutant concentration data (ODEQ, 2006). In addition to estimating instream loads, this method 1) allows for the determination of the hydrologic conditions under which impairments are typically occurring, 2) can give indications of the broad origins of the bacteria (i.e., point source and stormwater), and 3) provides a means to allocate allowable loadings.

Data requirements for the modified LDC method are minimal, consisting of continuous daily streamflow records, and historical bacteria and salinity data. A 15-year period of record from January 1, 1999, through December 31, 2013, was selected for LDC development, and this period included all available Enterococci data at the time of the study. 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.

For this report, an LDC was constructed for the most downstream monitoring station within the Tres Palacios Creek Tidal segment—Station 12515. The most downstream Surface Water Quality Monitoring (SWQM) station was selected because this location encompasses more of the drainage area of the watershed and is representative of conditions in more of the watershed than stations located further upstream.

On numerous creeks and rivers in Texas, USGS streamflow gauging stations have been in operation for a sufficient period to provide long-term streamflow records. USGS streamflow gauge 08162600 (Tres Palacios Creek near Midfield, TX) was used for LDC development.

The required daily streamflow record for the LDC was estimated based on application of a drainage area ratio computed as the drainage area above the LDC location divided by the drainage area of the USGS gauge. Prior to application of the drainage area ratio, the USGS gauge record was corrected by removing (subtracting) upstream WWTF discharges based on Discharge Monitoring Report information, and by adding upstream water rights diversions based on TCEQ water rights water use records. After multiplication of the corrected streamflow record by the drainage area ratio, a final adjustment occurred for the purposes of pollutant load computations. The hydrologic records were adjusted to reflect full permitted flows from all upstream WWTFs and future growth flows that account for the probability that additional flows from WWTF discharges may occur as a result of population increases.

Another part of the development of the modified LDC method is to determine a relationship of daily streamflow and measured salinities. The resulting regression is used to determine the daily volume of saltwater present for each daily freshwater flow in the 15-year period of record.

Information on the modified LDC method is provided in Appendix A and additional details are provided in the *Technical Support Document for Total Maximum Daily Load for Indicator Bacteria in Tres Palacios Creek Tidal* (Painter and Hauck, 2015).

The FDC was generated by:

1) ordering the daily streamflow data from highest to lowest values and assigning a rank to each data point (one for the highest flow, two for the second highest flow, and so on);
2) computing the percent of days each flow was exceeded by dividing each rank by the total number of data points plus one; and
3) plotting the corresponding flow data against exceedance percentages.

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 percent occur during low flow or drought conditions while values approaching 0 percent occur during periods of high flow or flood conditions.

Bacteria LDCs were developed by multiplying each streamflow value along the FDCs by the Enterococci geometric mean criterion (35 MPN/100 mL) and by the conversion factor to convert to loading in colonies per day. This effectively displays the LDC as the curve of maximum allowable loading:

TMDL (MPN/day) = Criterion * flow, cubic feet per second (cfs) * conversion factor

Where:

Criterion = 35 MPN/100 mL (Enterococci)

Conversion factor (to MPN/day) = 283.168 100 mL/ft^3 * 86,400 seconds/day (s/d)

The resulting curve plots each bacteria load value (y-axis) against its exceedance value (x-axis). Exceedance values along the x-axis represent the percent of days that the bacteria load was at or above the allowable load on the y-axis.

For the LDC developed for Station 12515, historical bacteria data obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database were superimposed on the allowable bacteria LDC. Each historical

Enterococci measurement was associated with the flow on the day of measurement and converted to a bacteria load. The associated flow for each bacteria loading was compared to the FDC data to determine its value for "percent days flow exceeded," which becomes the "percent of days load exceeded" value for purposes of plotting the Enterococci loading. Each load was then plotted on the LDC at its percent exceedance. This process was repeated for each Enterococci measurement. Points above the LDC represent exceedances of the bacteria criterion and their associated allowable loadings.

As a further refinement, the historical Enterococci points on the LDCs 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 precipitation records from the Danevang 1W weather station (Figure 2; NOAA, 2015a). A wet weather event was defined as a sample collected on a day in which the sum of total daily precipitation on that day and the two preceding days exceeded 10 millimeters (0.39 inches).

The flow exceedance frequency can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of FDCs and LDCs. The hydrologic classification scheme utilized for the TMDL watershed is as follows: 0-10 percent (high flows); 10-40 percent (moist conditions); 40-60 percent (mid-range flows); 60-90 percent (dry conditions); and 90-100 percent (low flows). Additional information explaining the LDC method and the modified LDC method may be found in Cleland (2003), Nevada Division of Environmental Protection (2003), and ODEQ (2006). The median loading of the high flow regime (0-10 percent exceedance) is used for the TMDL calculations. The median loading of the high flow regime is represented by the 5 percent exceedance and is used for the TMDL calculations because it represents a reasonable yet high value for the allowable pollutant load allocation.

An important observation is that under the high flow regime used for the TMDL calculations, there was no seawater volume computed as being present at the location where the LDC was developed. Saltwater has been effectively pushed out of the creek by the freshwater inflows present under the high flow regime. With an absence of seawater at these high flows, the modified LDC results are effectively simplified to those of the LDC method without any adjustments to accommodate tidal influences.

Load Duration Curve Results

For developing the TMDL allocation, an LDC was constructed for the most downstream monitoring station within the Tres Palacios Creek Tidal segment (Figure 11), which is also the station with the majority of the bacteria data. Geometric mean loadings for the data points within each flow regime have also been distinguished on the figure to aid interpretation. The LDC provides a means of identifying the streamflow conditions under which exceedances in

Enterococci concentrations have occurred. The LDC depicts the allowable loadings at the station under the geometric mean criterion (35 MPN/100 mL) and shows that existing loadings often exceed the criterion. For purposes of the pollutant load computations, the hydrologic records for the FDC and subsequent allowable loads from the LDC are adjusted to reflect future capacity estimates that account for the probability that additional flows from WWTF discharges may occur as a result of future population increases in the TMDL watershed.

Based on this LDC (Figure 11), with the addition of historical Enterococci data, the following broad linkage statements can be made. For the Tres Palacios Creek watershed, the historical Enterococci data indicate that elevated bacteria loadings occur under all flow conditions, but become most elevated under the highest flows. Regulated stormwater is considered only a minor contributor, as it comprises a very small portion of the watershed (0.83 percent). Most likely, unregulated 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 being located at a distance from Station 12515. 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 also 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.

Margin of Safety

The MOS is used to account for uncertainty in the analysis used to develop the TMDL and thus provide a higher level of assurance that the goal of the TMDL will be met. According to EPA guidance (EPA, 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 MOS 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 an MOS.

The TMDL covered by this report incorporates 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 an MOS is that the assimilative capacity or allowable pollutant loading of each water body is slightly reduced.

Pollutant Load Allocation

The 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

Where:

TMDL = total maximum daily load

WLA = wasteload allocation, the amount of pollutant allowed by permitted or regulated dischargers

LA = load allocation, the amount of pollutant allowed by unregulated sources

FG = loadings associated with future growth from potential permitted facilities

MOS = margin of safety load

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.

The TMDL component for the impaired AU covered in this report is derived using the median flow within the high flow regime (or 5 percent flow) of the LDC developed for the downstream SWQM station (12515) in the Tres Palacios Creek Tidal segment. The following sections will present an explanation of the TMDL component, followed by the results of the calculation for that component.

AU-Level TMDL Computations

The bacteria TMDL for the Tres Palacios Creek Tidal segment was developed as a pollutant load allocation based on information from the LDC for the most downstream SWQM station (Figure 11). As discussed in more detail in Appendix A, 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 percent exceedance (the median value of the high-flow regime) is the TMDL:

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

Where:

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

At 5 percent load duration exceedance, the TMDL values are provided in Table 9.

Table 9. Summary of allowable loading calculations for the impaired AU 1501_01 within Tres Palacios Creek.

5% Exceedance Flow (CFS)	5% Exceedance Load (Billion MPN/day)	Indicator Bacteria	TMDL (Billion MPN/day)
847.722	725.905	Enterococci	725.905

Margin of Safety

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

MOS = 0.05 * TMDL

Where:

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

Since the MOS is based solely on the TMDL term, the calculation is straightforward (Table 10).

Table 10. Margin of safety calculations for downstream station within the Tres Palacios Creek watershed.

Indicator Bacteria	TMDL (Billion MPN/ day)	MOS (Billion MPN/ day)
Enterococci	725.905	36.295

Wasteload Allocation

The WLA consists of two parts—the waste load that is allocated to TPDES-regulated WWTFs (WLA_{WWTF}) and the waste load that is allocated to regulated stormwater dischargers (WLA_{SW}).

$$WLA = WLA_{WWTF} + WLA_{SW}$$

Wastewater Treatment Facilities

TPDES-permitted WWTFs 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 saltwater Enterococci criterion (35 MPN/100mL) is used as the WWTF target. The WLA_{WWTF} term is also calculated for the freshwater *E. coli* primary contact 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:

$$WLA_{WWTF} = \text{Criterion} * \text{Flow} * \text{Conversion Factor} * (1 - \text{FMOS})$$

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) = 1.547 cfs/MGD *283.168 100 mL/ft3 * 86,400 s/d

FMOS = fraction of loading assigned to margin of safety (5 percent 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 WWTF and summed for the watershed. Table 11 presents the WLAs for each individual WWTF located within the TMDL watershed. The WLA_{WWTF} for the Tidal AU (1501_01) 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 11 that will be used in subsequent computations. Note that Apex Matagorda Energy Center (TPDES permit number WQ0005009000) is not assigned a bacteria permit limit within this TMDL because there is no human waste component associated with its discharge; this facility is not included in Table 11.

Table 11. Wasteload allocations for TPDES-permitted facilities in Tres Palacios Creek watershed.

AU	TPDES Permit No.	NPDES Permit No.	Facility	Full Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/ day)	Enterococci WLA_{WWTF} (Billion MPN/ day)
1502_02	WQ0010844001	TX0021474	City of El Campo WWTF	2.628	11.908	3.307
1502_03	WQ0013091001	TX0098205	Midfield WWTF	0.03	0.136	0.038
1501_01	WQ0015075001	TX0134309	Markham MUD WWTF	0.3	1.359	0.378
Tres Palacios Creek Watershed Total					13.403	3.723

Stormwater

Stormwater discharges from MS4, industrial, and construction areas are considered regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated 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 the Tres Palacios Creek 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}.

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

$$\Sigma WLA_{SW} = (TMDL - \Sigma WLA_{WWTF} - FG - MOS) * FDA_{SWP}$$

Where:

ΣWLA_{SW} = sum of all permitted or regulated stormwater loads

TMDL = total maximum daily load

ΣWLA_{WWTF} = sum of all WWTF loads

FG = future growth loads from potential permitted facilities

MOS = margin of safety load

FDA_{SWP} = fractional proportion of drainage area under jurisdiction of stormwater permits

To calculate the WLA_{SW} component of the TMDL, the FDA_{SWP} must be determined. The FDA_{SWP} was calculated based on the combined area under regulated stormwater permits. As described in the Source Analysis section, a search for all five categories of stormwater general permits was performed. The search results are summarized in Table 12.

No MS4 permits are held in the Tres Palacios Creek watershed. For the MSGPs, 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. The total acreage for the most recent full month (April 2015) was used. No concrete production facilities or petroleum bulk stations were located within the Tres Palacios Creek watershed.

Table 12. Stormwater general permit areas and calculation of the FDA_{SWP} term for the Tres Palacios Creek watershed.

MS4 General Permit (acres)	MSGP (acres)	Construction Activities (acres)	Concrete Production Facilities (acres)	Petroleum Bulk Stations (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
0	839	586	0	0	1,425	171,815	0.829%

In order to calculate WLA_{SW}, the future growth term must be known. The calculation for the future growth term is presented in a later section, but the results will be included here for continuity. Table 13 provides the information needed to compute WLA_{SW}.

Table 13. Regulated stormwater calculations for the Tres Palacios Creek watershed.

Load units expressed as billion MPN/day Enterococci

TMDL	WLA_{WWTF}	FG	MOS	FDA_{SWP}	WLA_{SW}
725.905	3.723	0.812	36.295	0.829%	5.679

Once the WLA_{SW} and WLA_{WWTF} terms are known, the WLA term can be calculated as the sum of the two parts, as shown in Table 14.

Table 14. Wasteload allocation calculations for the Tres Palacios Creek watershed.

Load units expressed as billion MPN/day Enterococci

WLA_{WWTF}	WLA_{SW}	WLA
3.723	5.679	9.402

An iterative, adaptive management approach will be used to address stormwater discharges. This approach encourages the implementation of structural or non-structural controls, implementation of mechanisms to evaluate the performance of the controls, and finally, allowance to make adjustments [e.g., more stringent controls or specific best management practices (BMPs)] as necessary to protect water quality.

Implementation of WLAs

The TMDLs in this document will result in protection of existing beneficial uses and conform to Texas's antidegradation policy. The three-tiered antidegradation policy in the Standards prohibits an increase in loading that would cause or contribute to degradation of an existing use. The antidegradation policy applies to point source pollutant discharges. In general, antidegradation procedures establish a process for reviewing individual proposed actions to determine if the activity will degrade water quality.

The TCEQ intends to implement the individual WLAs through the permitting process as monitoring requirements and/or effluent limitations, as required by the amendment of 30 Texas Administrative Code Chapter 319, which became effective November 26, 2009. WWTFs discharging to the TMDL segments will be assigned an effluent limit based on the TMDL. Monitoring requirements are based on permitted flow rates and are listed in 30 Texas Administrative Code Section 319.9.

The permit requirements will be implemented during the routine permit renewal process. However, there may be a more economical or technically feasible means of achieving the goal of improved water quality and circumstances may warrant changes in individual WLAs after this TMDL is adopted. Therefore, the individual WLAs, as well as the WLAs for stormwater, are non-binding until implemented via a separate TPDES permitting action, which may involve preparation of an update to the state's WQMP. Regardless, all permitting actions will demonstrate compliance with the TMDL.

The executive director or commission may establish interim effluent limits and/or monitoring-only requirements at a permit amendment or permit renewal. These interim limits will allow a permittee time to modify effluent quality in order to attain the final effluent limits necessary to meet the TCEQ and EPA approved TMDL allocations. The duration of any interim effluent limits may not be any longer than three years from the date of permit re-issuance. New permits will not contain interim effluent limits because compliance schedules are not allowed for a new permit.

Where a TMDL has been approved, domestic WWTF TPDES permits will require conditions consistent with the requirements and assumptions of the WLAs. For NPDES/TPDES-regulated municipal, construction stormwater discharges, and industrial stormwater discharges, water quality-based effluent limits that implement the WLA for stormwater may be expressed as BMPs or other similar requirements, rather than as numeric effluent limits.

The November 26, 2014 memorandum from EPA relating to establishing WLAs for stormwater sources states:

> "Incorporating greater specificity and clarity echoes the approach first advanced by EPA in the 1996 Interim Permitting Policy, which anticipated that where necessary to address water quality concerns, permits would be modified in subsequent terms to include "more specific conditions or limitations [which] may include an integrated suite of BMPs, performance objectives, narrative standards, monitoring triggers, numeric WQBELs, action levels, etc."

Using this iterative adaptive BMP approach to the maximum extent practicable is appropriate to address the stormwater component of this TMDL.

Updates to WLAs

This TMDL is, by definition, the total of the sum of the WLAs, the sum of the LAs, and the MOS. Changes to individual WLAs may be necessary in the future in order to accommodate growth or other changing conditions. These changes to individual WLAs do not ordinarily require a revision of the TMDL document; instead, changes will be made through updates to the TCEQ's WQMP. Any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

Load Allocation

The LA is the load from unregulated sources, and is calculated as:

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS$$

Where:

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

The calculation results are shown in Table 15.

Table 15. Load allocation calculation for the Tres Palacios Creek watershed.

Load units expressed as billion MPN/day Enterococci

TMDL	WLA_{WWTF}	WLA_{SW}	FG	MOS	LA
725.905	3.723	5.679	0.812	36.295	679.396

Allowance for Future Growth

The future growth component of the TMDL equation addresses the requirement to account for future loadings that may occur due to population growth, changes in community infrastructure, and development. Specifically, this TMDL component takes into account the probability that new flows from WWTF discharges may occur in the future.

The allowance for future growth will result in protection of existing beneficial uses and conform to Texas's antidegradation policy.

The future growth component of impaired AU 1501_01 was based on the percent population increase information by WUG between 2010 and 2050 (provided previously in Table 3) and the existing full permitted discharge for each WWTF within a WUG. While the future growth allowance is computed using information from existing WWTF permits, it is not the intent to restrict any future assignments of this allocation solely to expansions at these facilities. Rather, the future growth allocation is purposed for any new facilities that may occur and expansions of existing facilities.

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

Where:

Criterion = 35 MPN/100 mL Enterococci or 126 MPN/100 mL for *E. coli*

$\%POP_{2010\text{-}2050}$ = estimated percent 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 percent or 0.05)

The calculation results for the impaired AU watershed are shown in Table 16.

Table 16. Future growth calculations for the Tres Palacios Creek watershed.

WUG	Full Permitted Flow by WWTF (MGD)	% Increase (2000-2050)	Future Growth (MGD)[a]	FG (*E. coli* Billion MPN/ day)	FG (Enterococci Billion MPN/ day)
El Campo (in Wharton County)	2.628	22.46%	0.590	2.673	0.7425
Matagorda County - Other	0.03	17.30%	0.005	0.0227	0.0063
Matagorda County - Other	0.3	17.30%	0.05	0.227	0.063
Tres Palacios Creek Total			0.645	2.923	0.812

[a] Significant digits based on full permitted flow

[b] FG = Criterion * [%POP2010-2050*WWTFFP] * Conversion Factor *(1-FMOS)

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

Summary of TMDL Calculations

Table 17 summarizes the TMDL calculations for Tres Palacios Creek Tidal (1501_01). The TMDL was calculated based on the median flow in the 0-10 percentile range (5 percent exceedance, high flow regime) for flow exceedance from the LDC developed for the most downstream SWQM station in the watershed (12515). Allocations are based on the current geometric mean criterion for Enterococci of 35 MPN/100 mL for each component of the TMDL.

The final TMDL allocations (Table 18) 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 B provides guidance for recalculating the allocations in Table 18. Figure B-1 was developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant LAs change in relation to a number of proposed water quality criteria for Enterococci. The equations provided, along with Figure B-1, allow calculation of a new TMDL and pollutant LA based on any potential new water quality criterion for Enterococci.

Table 17. TMDL allocation summary for the Tres Palacios Creek watershed.

Load units expressed as billion MPN/day Enterococci

AU	Stream Name	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	Future Growth[f]
1501_01	Tres Palacios Creek Tidal	725.905	36.295	3.723	5.679	679.396	0.812

[a] TMDL = Median flow (highest flow regime) * 35 MPN/100 mL * Conversion Factor; where the Conversion Factor = 283.168 100 mL/ft³ * 86,400 s/d; Median (5 percent exceedance) Flow from Table 9

[b] MOS = 0.05 * TMDL (Table 10)

[c] WLA_{WWTF} = 35 MPN/day * Flows (MGD) * Conversion Factor * (1 – FMOS); where Flow is the full permitted flow from regulated discharging facilities; Conversion Factor = 1.547 cfs/MGD * 283.168 100 mL/ft^3; FMOS = 5 percent or 0.05 (Table 11)

[d] WLA_{SW} = (TMDL - ΣWLA_{WWTF} - ΣFG - MOS) * FDA_{SWP} (Table 13)

[e] LA = TMDL - ΣWLA_{WWTF} - ΣWLA_{SW} - ΣFG - MOS (Table 15)

[f] Future Growth = 35 MPN/100 mL * [%POP2010-2050 * $WWTF_{FP}$] * Conversion Factor * (1 – FMOS); Conversion Factor = 1.547 cfs/MGD * 283.168 100 mL/ft^3; $WWTF_{FP}$ is full permitted flows and %POP2010-2050 is from Table 16

Table 18. Final TMDL allocations for the impaired Tres Palacios Creek AU 1501_01 watershed.

Load units expressed as billion MPN/day Enterococci

AU	TMDL	WLA_{WWTF} [a]	WLA_{SW}	LA	MOS
1501_01	725.905	4.535	5.679	679.396	36.295

[a] WLA_{WWTF} includes the future growth component

Seasonal Variation

Seasonal variations (or seasonality) occurs when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations [40 CFR 30.7(c)(1)] require that TMDLs account for seasonal variation in watershed conditions and pollutant loading.

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 no significant difference in indicator bacteria between cool and warm weather seasons for Tres Palacios Creek Tidal (Station 12515, Segment 1501).

Public Participation

The TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. Communication and comments from the stakeholders in the watershed strengthen TMDL projects and their implementation.

The TCEQ and the Texas Water Resources Institute (TWRI) are jointly providing coordination of public participation for development of both the TMDL and implementation plan (I-Plan). A series of public meetings have been held since 2015 to keep the public aware of the TMDL and to engage public participation in the development of the I-Plan.

The first public meetings to discuss watershed-based plans were held in Palacios on July 30, 2015 and October 8, 2015, and stakeholder meetings have continued to be held every couple of months in 2016. Stakeholders provided input on the documents associated with the TMDL and the I-Plan. Notices of meetings were posted on the project webpages for both TWRI and TCEQ and on the TCEQ's TMDL program's online calendar. At least two weeks prior to scheduled meetings, the TWRI issued direct mailings, media releases through Texas A&M AgriLife and local AgriLife Extension Offices, and formally invited stakeholders to attend. To ensure that absent or new stakeholders could get information about past meetings and pertinent material, the TWRI project webpage provides meeting summaries, presentations, ground rules, and documents produced for review at <http://matagordabasin.tamu.edu/>

Implementation and Reasonable Assurance

The issuance of TPDES permits consistent with TMDLs provides reasonable assurance that wasteload allocations in this TMDL report will be achieved. Per federal requirements, each TMDL is included in an update to the Texas WQMP as a plan element.

The WQMP coordinates and directs the state's efforts to manage water quality and maintain or restore designated uses throughout Texas. The WQMP is continually updated with new, more specifically focused plan elements, as identified in federal regulations [40 CFR Sec. 130.6(c)]. Commission adoption of a TMDL is the state's certification of the associated WQMP update.

Because the TMDL does not reflect or direct specific implementation by any single pollutant discharger, the TCEQ certifies additional elements to the WQMP after the I-Plan is approved by the commission. Based on the TMDL and I-Plan, the TCEQ will propose and certify WQMP updates to establish required water-quality-based effluent limitations necessary for specific TPDES wastewater discharge permits.

Currently, there are no Phase II MS4 permit authorizations or Phase I MS4 individual permits held in the TMDL watershed. However, future population growth within the urbanized areas located in the watershed may require some entities to obtain authorizations under the Phase II MS4 general permit. Where numeric effluent limitations are infeasible for MS4 entities, the TCEQ often establishes best management practices, which are a substitute for effluent limitations, as allowed by federal rules. When such practices are established in Phase II MS4 permit authorizations or Phase 1 MS4 individual permits, the TCEQ will not identify specific implementation requirements applicable to a specific TPDES stormwater permit or permit authorization through an effluent limitation update. Rather, the TCEQ will revise its Phase II MS4 general permit during the renewal process or amend or revise a permittee's Phase I MS4 individual permit as needed, to require a revised Stormwater Management Program or to require the implementation of other specific revisions in accordance with an approved I-Plan.

Strategies for achieving pollutant loads in TMDLs from both point and nonpoint sources are reasonably assured by the state's use of an I-Plan. The TCEQ is committed to supporting implementation of all TMDLs adopted by the commission.

I-Plans for Texas TMDLs use an adaptive management approach that allows for refinement or addition of methods to achieve environmental goals. This adaptive approach reasonably assures that the necessary regulatory and voluntary activities to achieve pollutant reductions will be implemented. Periodic, repeated evaluations of the effectiveness of implementation methods ascertain whether progress is occurring, and may show that the original distribution of loading among sources should be modified to increase efficiency. I-Plans will be adapted as necessary to reflect needs identified in evaluations of progress.

Key Elements of an I-Plan

An I-Plan includes a detailed description and schedule of the regulatory and voluntary management measures to implement the WLAs and LAs of particular TMDLs within a reasonable time. I-Plans also identify the organizations responsible for carrying out management measures, and a plan for periodic evaluation of progress.

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

The TCEQ works with stakeholders and interested governmental agencies to develop and support I-Plans and track their progress. Work on the I-Plan begins during development of TMDLs. Because this TMDL addresses agricultural sources of pollution, the TCEQ will also work in close partnership with the TSSWCB when developing the I-Plan. The TSSWCB is the lead agency in Texas responsible for planning, implementing, and managing programs and practices for preventing and abating agricultural and silvicultural nonpoint sources of water pollution. The cooperation required to develop an I-Plan will become a cornerstone for the shared responsibility necessary to carry it out.

Ultimately, the I-Plan will identify the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the I-Plan that is approved may not approximate the predicted loadings identified category-by-category in the TMDL and its underlying assessment. The

I-Plan is adaptive for this very reason; it allows for continuous update and improvement.

In most cases, it is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction is required by the TMDL, there is high uncertainty with the TMDL analysis, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

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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 LA. 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:

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

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 (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:

$$V_s = V_r / (S_s/S_t - 1); \qquad \text{(Equation A-2)}$$

for S_t > background salinity; otherwise $V_s = 0$

For the Umpqua Basin tidal streams (e.g., Figure A-1), as well as the present application to the Tres Palacios Creek Tidal (Figure A-4 in this 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 S_t regressions developed were then used to compute V_s. As S_t approaches 0.0, V_s likewise approaches a value of 0.0 in Equation A-2, meaning the only flow present is the river flow (Q or V_r).

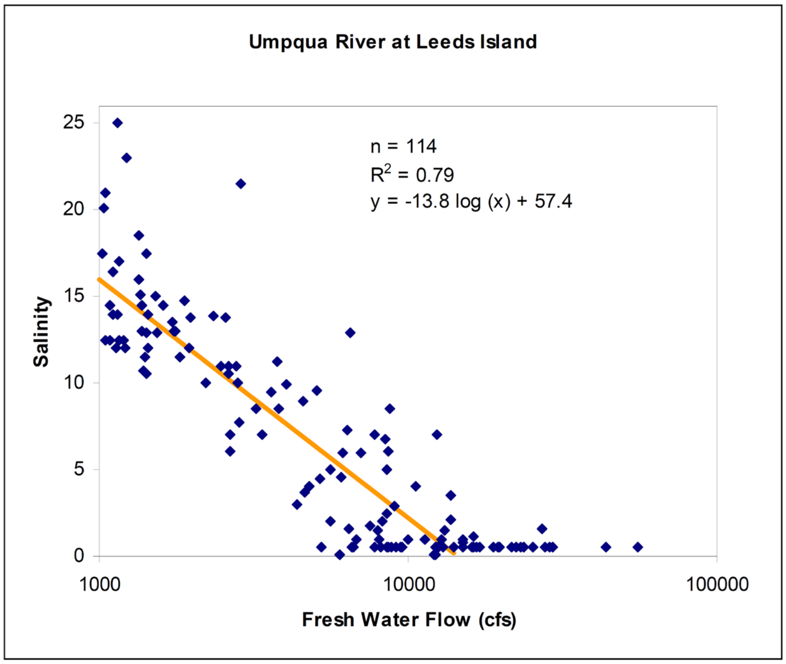

Figure A-1. Example salinity to flow regression from Umpqua Basin tidal streams (ODEQ, 2006).

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 the FDC for Tres Palacios Creek. These FDCs and the plotted flow exceedance values where salinities approach background levels should be viewed from the perspective of the TCEQ's approach for bacteria TMDLs. Within the TCEQ TMDL approach for 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 percent for the Tres Palacios Creek Tidal segment. All the flows in the highest flow regime are greater than the amount of streamflow shown by the regression analysis 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 levels. As salinity approaches background levels, V_s in Equation A-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 Tres Palacios Creek 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. These results are confirmed in the observed salinity data; at these elevated streamflows, seawater is effectively pushed completely out into Tres Palacios Bay. But the other implication, in hindsight, is that for this tidal river, 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):

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

Resulting in:

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

The modified LDC method, as captured in Equation A-4, is based on the assumption that combining 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.

To confirm the assumption that the tidal water or seawater has low concentrations of Enterococci, historical data were obtained from TCEQ SWQMIS for stations in Tres Palacios Creek, Tres Palacios Bay, and Matagorda Bay from near the Gulf of Mexico to Tres Palacios Creek Above Tidal (Figure A-2). As shown in Figure A-3, the geometric means of historical Enterococci data at these stations do indicate a decreasing trend in Enterococci concentrations with distance toward the Gulf of Mexico.

Additional information on the application of this modified LDC approach includes:

- The salinity to streamflow regression for Station 12515, which is the most downstream SWQM station on Segment 1501 and one with sufficient bacteria and salinity data for application of this approach (Figure A-4); and
- The flow duration curve showing freshwater and seawater components for Station 12515 prior to the addition of full permitted WWTFs and future growth flows, as needed for development in the Pollutant Load Allocation section (Figure A-5). As expected from the modified daily flow volume equation, 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.

Further details on the application of the modified LDC approach are provided in *Technical Support Document for Total Maximum Daily Load for Indicator Bacteria in Tres Palacios Creek Tidal* (Painter and Hauck, 2015).

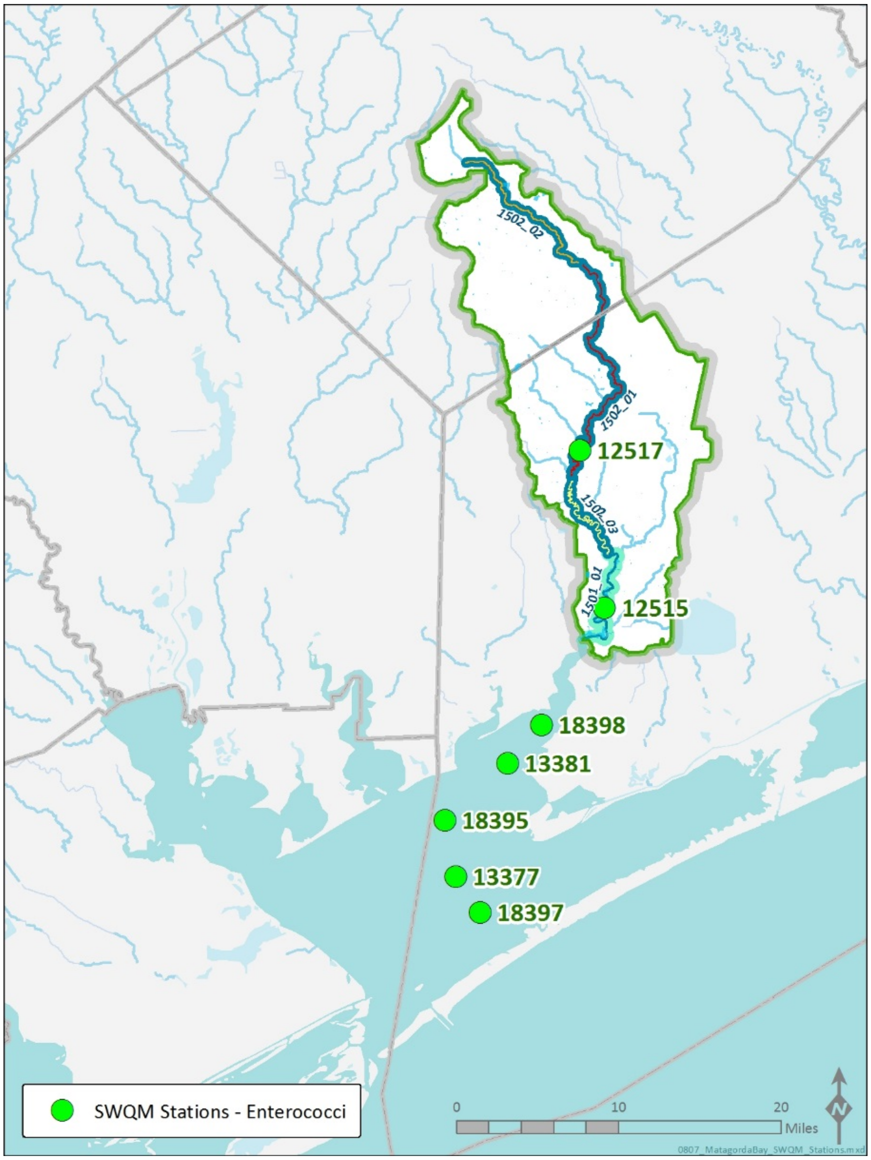

Figure A-2. Surface water quality monitoring stations with Enterococci data in Tres Palacios Creek, Tres Palacios Bay, and Matagorda Bay.

Source: TCEQ (2015c)

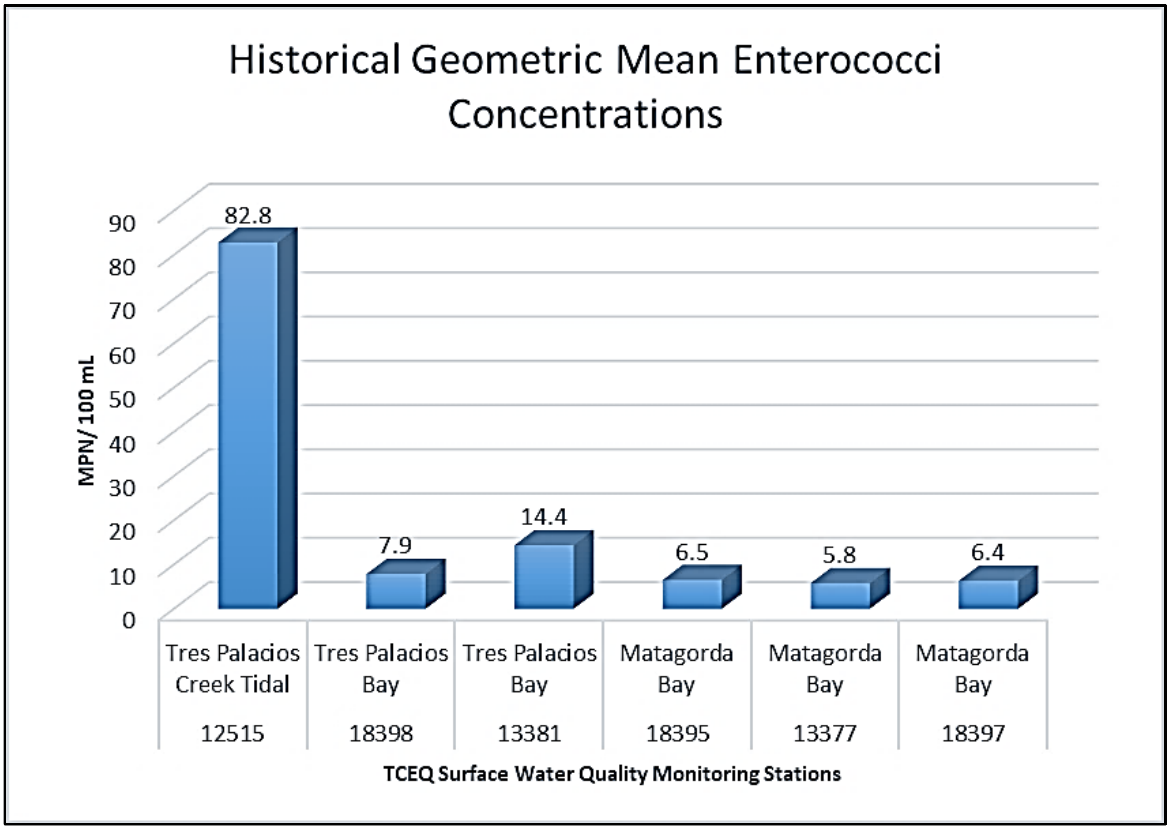

Figure A-3. Geometric mean Enterococci concentrations at SWQM stations with historical data in Tres Palacios Creek, Tres Palacios Bay, and Matagorda Bay.

Source: TCEQ (2015c)

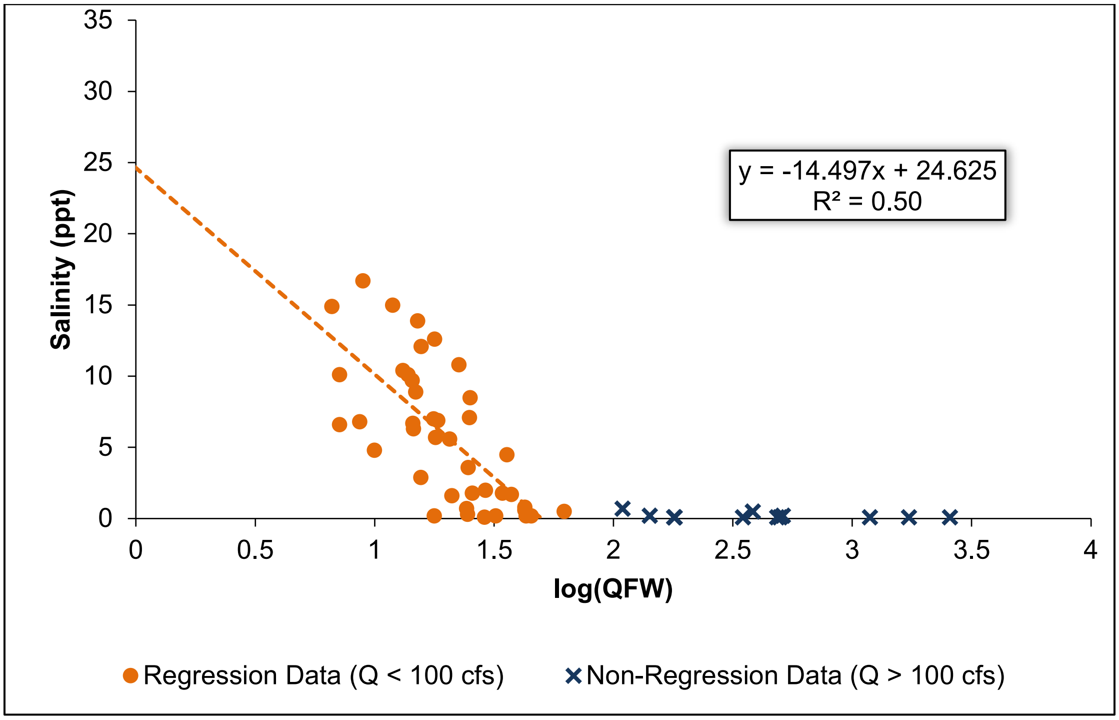

Figure A-4. Salinity to streamflow regression for Station 12515 (Segment 1501).

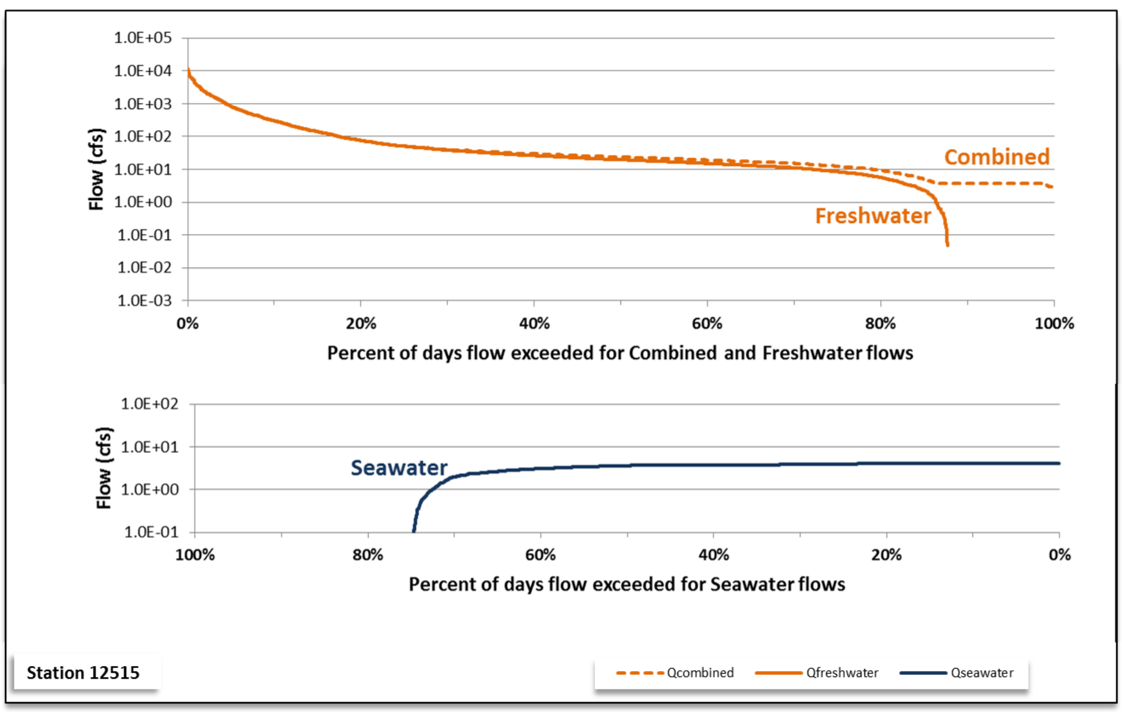

Figure A-5. Flow duration curves for the tidal location (Station 12515) showing the freshwater and seawater components, prior to final streamflow record modifications.

Appendix B. Equations for Calculating TMDL Allocations for Changed Contact Recreation Standard

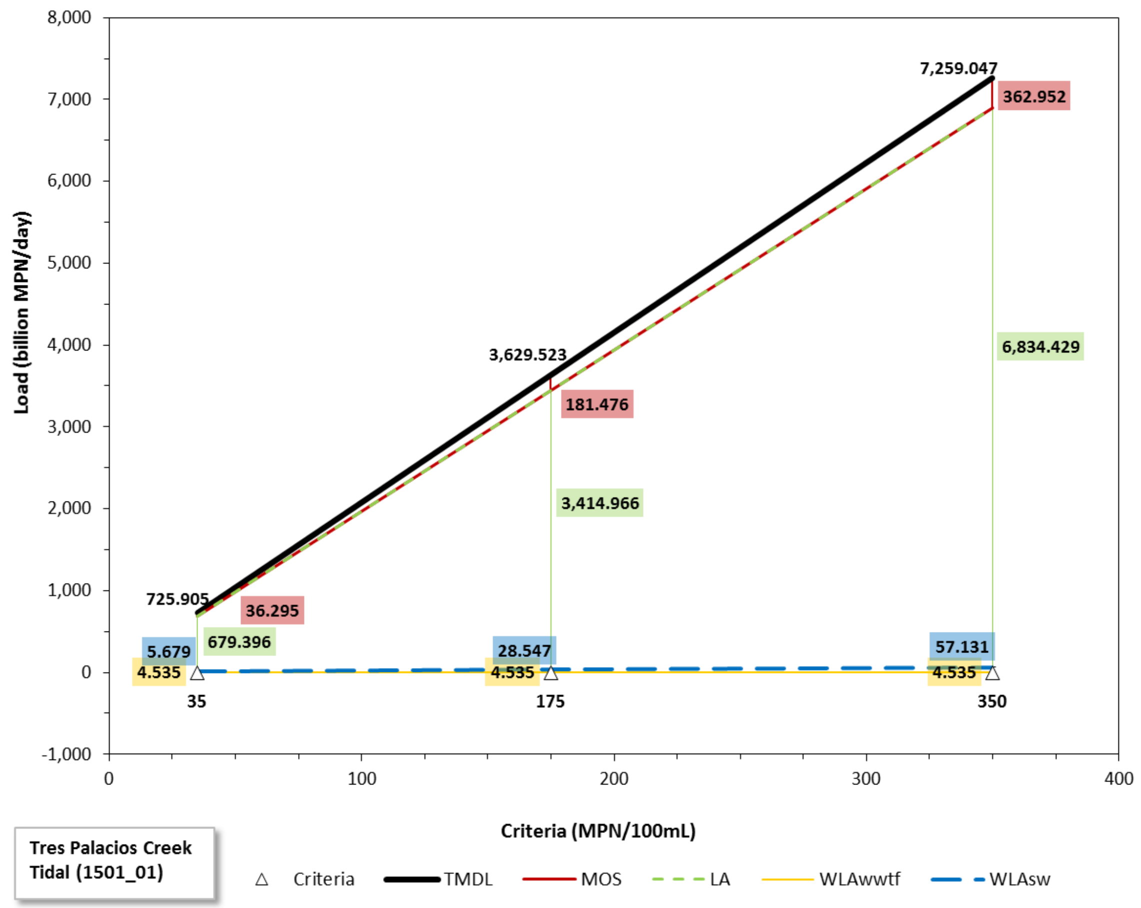

Figure B-1. Allocation loads for Tres Palacios Creek Tidal (1501_01) as a function of water quality criteria.

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

TMDL =20.7401339 * Std

MOS =1.0370067 * Std

LA =19.5397883 * Std -4.4969080

WLA_{WWTF} =4.5345000

WLA_{SW} =0.1633389 * Std -0.0375914

Where:

Std = revised contact recreation standard

MOS = margin of safety

LA = total load allocation (unregulated source contributions)

WLA_{WWTF} = wasteload allocation (permitted WWTF load + future growth)
[Note: WWTF load held at primary contact criterion (35 MPN/ 100 mL)]

WLA_{SW} = wasteload allocation (permitted stormwater)