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Two Total Maximum Daily Loads for Indicator Bacteria in the Caney Creek Watershed

Assessment Units 1304_01 and 1304A_01

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

Distributed by the
Total Maximum Daily Load Team
Texas Commission on Environmental Quality
MC-203
P.O. Box 13087
Austin, Texas 78711-3087
Email: tmdl@tceq.texas.gov

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This total maximum daily load report is based in large part on the report titled:
"Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in the Caney Creek Watershed"
prepared by the Houston-Galveston Area Council.

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Abbreviations

AA	authorized agent
AU	assessment unit
BMP	best management practice
CAFO	concentrated animal feeding operation
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
DAR	drainage area ratio
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
FDC	flow duration curve
FG	future growth
H-GAC	Houston-Galveston Area Council
ICWW	Intracoastal Waterway
I/I	inflow and infiltration
I-Plan	implementation plan
LA	load allocation
LDC	load duration curve
LR	load regression
mL	milliliter
MGD	million gallons per day
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
MUD	municipal utility district
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SWMP	Stormwater Management Program
SWQM	surface water quality monitoring
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSD	technical support document
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WQBEL	water quality-based effluent limit

WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility

Two Total Maximum Daily Loads for Indicator Bacteria in the Caney Creek Watershed

Executive Summary

This document describes total maximum daily loads (TMDLs) for two water bodies in the Caney Creek watershed where concentrations of indicator bacteria exceed the criterion used to determine attainment of the primary contact recreation 1 use. The Texas Commission on Environmental Quality (TCEQ) first identified the impairment to Caney Creek Tidal (Segment 1304), in the *2006 Texas Water Quality Inventory and 303(d) List* (Inventory and 303(d) List; since 2010 called the *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)*, or Texas Integrated Report). The impairment to Linnville Bayou (1304A), an unclassified stream discharging to Caney Creek, was first identified in the 2010 Texas Integrated Report. This document will consider bacteria impairments in the two water bodies, 1304 and 1304A, which include the following impaired assessment units (AUs):

- Caney Creek Tidal (AU 1304_01)
- Linnville Bayou (AU 1304A_01)

The Caney Creek watershed lies in southeast Texas, covering parts of three counties: Brazoria, Matagorda, and Wharton. Caney Creek is 130 miles in length. It originates within the City of Wharton and travels southeast through Wharton County before entering eastern Matagorda County. The creek meanders across the Texas coastal plain before terminating at the Gulf Coast Intracoastal Waterway (ICWW) south of the town of Sargent.

Fecal indicator bacteria are used to determine attainment of contact recreation standards in the state of Texas. *Escherichia coli* (*E. coli*) and Enterococci are used as indicator bacteria in freshwater and saltwater, respectively. The criterion for determining attainment of contact recreation standards is the number or counts of bacteria, often given as the number of colony forming units (cfu) found in 100 milliliters (mL) of water. The primary contact recreation 1 use is not supported when the geometric mean of all samples for the assessment period exceeds the contact recreation criterion for *E. coli* in freshwater or Enterococci in saltwater. The primary contact recreation 1 geometric mean criterion for *E. coli* is 126 cfu/100 mL. The primary contact recreation 1 geometric mean criterion for Enterococci is 35 cfu/100 mL.

Fecal bacteria data were collected at TCEQ surface water quality monitoring (SWQM) stations located in each of the impaired AUs in the Caney Creek watershed over a seven-year period from December 1, 2011, through November

30, 2018. These data were used in assessing attainment of the primary contact recreation 1 use and reported in the 2020 Texas Integrated Report (TCEQ, 2020). The assessed data indicate non-attainment of the contact recreation standard in both AUs 1304_01 and 1304A_01.

Within the Caney Creek watershed, probable sources of bacteria are nonpoint, as the majority of the watershed is undeveloped. Nonpoint sources enter the impaired water bodies through mostly non-distinct distribution of runoff, including urban runoff in areas without a stormwater permit, unregulated agricultural practices, on-site sewage facilities (OSSFs), wildlife and feral animal populations, and domestic pets.

Dischargers regulated through permits under the Texas Pollutant Discharge Elimination System (TPDES) program, often labeled as point sources, are also potential sources of indicator bacteria in the Caney Creek watershed. However, extensive population growth in developed areas is not expected over the next 20 years. This suggests that there will not be a significant increase in point source contributions over time.

There are currently three permitted domestic wastewater treatment facilities (WWTFs) in the Caney Creek watershed that have effluent limits for bacteria. A review of the TCEQ Central Registry found one active concentrated animal feeding operation (CAFO) in the watershed. No other active general wastewater permits were found.

A review of the TCEQ Central Registry for active stormwater permits found that there were no active municipal separate storm sewer system (MS4) permits in the Caney Creek watershed. Four active construction permit authorizations and six industrial multi-sector general permit (MSGP) authorizations were found.

A load duration curve (LDC) analysis was performed to quantify allowable pollutant loads and TMDL allocations for point and nonpoint sources of bacteria. A modified LDC analysis was performed in Segment 1304 to account for tidal influences on daily flow. The wasteload allocation (WLA) for WWTFs was established as the full permitted daily average flow rate multiplied by the instream geometric mean criterion. Future growth (FG) of existing or new domestic point sources was determined using population growth projections.

The TMDL calculations in this report will guide determination of the assimilative capacity of each water body under changing conditions, including FG. Wastewater discharge facilities will be evaluated on a case-by-case basis.

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 water body included on a state's 303(d) list of impaired waters. 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 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 program's primary objective is to restore and maintain water quality uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

This TMDL document addresses impairments to the primary contact recreation 1 use due to elevated levels of indicator bacteria in Segment 1304 and an associated unclassified water body, 1304A. These TMDLs take a watershed approach to addressing bacteria impairments. While TMDL allocations were developed only for the impaired AUs 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 document. Information in this TMDL document was derived from the *Technical Support Document for Total Maximum Daily Loads for Indicator Bacteria in the Caney Creek Watershed*[1] (H-GAC, 2019).

Section 303(d) of the Clean Water Act and the implementing regulations of the United States 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. 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.

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

[1] www.tceq.texas.gov/assets/public/waterquality/tmdl/115caneycreek/115-caneycreek-tsd-2020april.pdf

- Margin of Safety
- Pollutant Load Allocation
- Seasonal Variation
- Public Participation
- Implementation and Reasonable Assurance

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

Problem Definition

TCEQ first identified the bacteria impairment to Caney Creek Tidal (Segment 1304) in the *2006 Texas Water Quality Inventory and 303(d) List* and then in each subsequent edition through 2020. TCEQ first identified the bacteria impairment to Linnville Bayou (1304A) in the 2010 Texas Integrated Report and then in each subsequent edition through 2020.

This document will consider the bacteria impairment in two water bodies of the Caney Creek watershed, for the following AUs:

- Caney Creek Tidal (AU 1304_01)
- Linnville Bayou (AU 1304A_01)

The 2020 Texas Integrated Report (TCEQ, 2020; the latest EPA-approved edition) found the geometric mean for Enterococci within AU 1304_01 to exceed the criterion of 35 cfu/100 mL. The same assessment cycle found the geometric mean for *E. coli* within AU 1304A_01 to exceed the criterion of 126 cfu/100 mL (Table 1).

Table 1. 2020 Texas Integrated Report summary for the impaired AUs

Name	AU	Parameter	Data Date Range	Number of Samples	Geometric Mean
Caney Creek Tidal	1304_01	Enterococci	12/1/2011 - 11/30/2018	29	55.81
Linnville Bayou	1304A_01	*E. coli*	12/1/2011 - 11/30/2018	23	141.72

The 2020 Texas Integrated Report also included a new bacteria impairment for AU 1304_02. This AU will be addressed through a future update to the state's WQMP.

Watershed Overview

The Caney Creek watershed lies in southeast Texas. The 303-square-mile study area includes parts of three Texas counties: Brazoria, Matagorda, and Wharton. Caney Creek initially begins as an intermittent stream within the city limits of Wharton, traveling generally southeast through Wharton County to the Matagorda County line. By the time it reaches the county line, Caney Creek has become a perennial stream that meanders southeast through eastern Matagorda County before terminating south of the town of Sargent at the ICWW. Water from Caney Creek then flows southwest in the ICWW to a point where the ICWW connects to East Matagorda Bay.

The Caney Creek watershed includes two classified segments, Caney Creek Tidal (1304) and Caney Creek Above Tidal (1305), and three unclassified water bodies, Linnville Bayou (1304A), Hardeman Slough (1305A), and Caney Creek Above Water Hole Creek (1305B) (Figure 1). Caney Creek Tidal begins near the town of Cedar Lane and Farm-to-Market (FM) 457 and traverses 36 miles southeast to the confluence with the ICWW (H-GAC, 2016). The tidal segment has a watershed area of 44 square miles. The tidal segment is broken into two AUs: 1304_01 and 1304_02. Three small towns are found along the tidal segment: Sargent, Hawkinsville, and Cedar Lane.

Linnville Bayou (1304A) is a freshwater tributary to Caney Creek Tidal and has a watershed area of 100 square miles. Linnville Bayou begins in southeastern Wharton County near the town of Newgulf as an intermittent stream and travels downstream for approximately 20.3 miles, much of it as the border between Matagorda and Brazoria counties, before terminating into Caney Creek Tidal (AU 1304_02) in Matagorda County. Linnville Bayou has three AUs: 1304A_01, 1304A_02, and 1304A_03. AU 1304A_02 is located at the downstream end of the water body, and AU 1304A_03 is located at the upstream end. Both of the unimpaired AUs are under a mile in length and are not labeled on the maps in this document because of the scale at which they are presented.

For this document, the TMDL watershed (the full Caney Creek watershed) is divided into three subwatersheds. The Caney Creek Tidal and Linnville Bayou subwatersheds include the TMDL water bodies. The Caney Creek Above Tidal subwatershed covers the remaining upstream portion of the TMDL watershed.

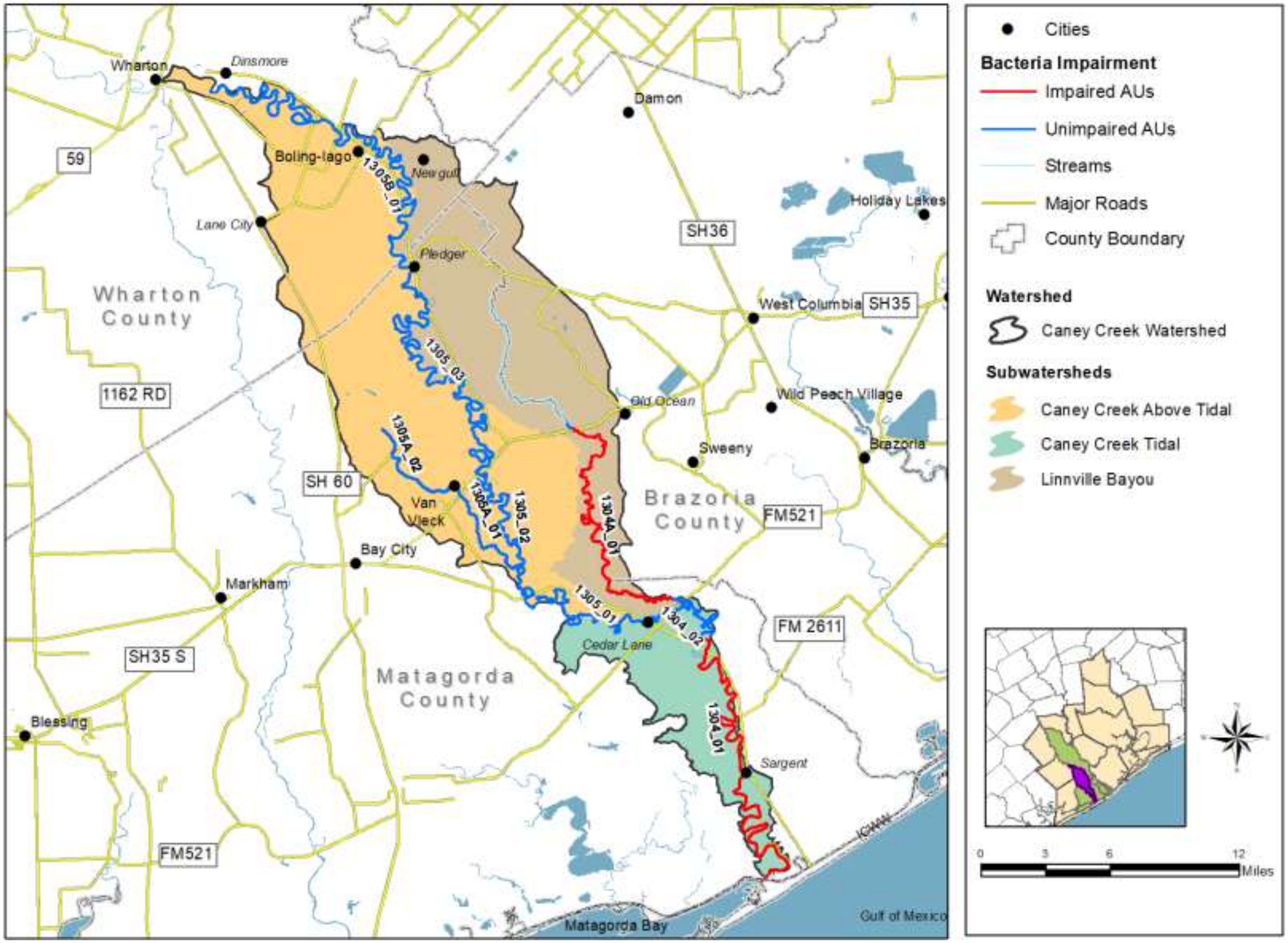

Figure 1. Caney Creek TMDL watershed

The 2020 Texas Integrated Report (TCEQ, 2020) provides the following AU descriptions for the impaired water bodies considered in this document:

- Segment 1304 – Caney Creek Tidal: From the confluence with the ICWW in Matagorda County to a point 1.9 kilometers (1.2 miles) upstream of the confluence of Linnville Bayou in Matagorda County.
    - 1304_01 – From the downstream end of segment to the confluence with Dead Slough.
- 1304A – Linnville Bayou: From the confluence with Caney Creek in Matagorda County upstream to a point 0.7 kilometers above State Highway 35 in Brazoria/Matagorda counties.
    - 1304A_01 – Intermittent stream with perennial pools from a point 1.1 kilometers above the confluence with Caney Creek in Matagorda County upstream to a point 0.1 kilometers above State Highway 35 in Brazoria/Matagorda counties.

Watershed Climate and Hydrology

Precipitation and temperature data for the period of 1972 through 2017 (Figure 2) were retrieved from the National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center for Freeport Station USC00413340 (NOAA, 2018), located approximately 20 miles east of the TMDL water bodies. Average monthly precipitation for this period ranged from slightly under three to slightly over seven inches, with an annual average of about 47 inches. Rainfall occurs throughout the year, with February and March having the least amount of rainfall, while September typically has the greatest rainfall. Average monthly air temperature ranges from slightly above 50ºF in the winter to slightly below 90ºF in the summer months.

The watershed elevation ranges from just under 100 feet above sea level at Old Caney Road in Wharton County near the City of Wharton to sea level at the ICWW. The source water for Caney Creek is mostly from rainfall runoff. The creek and its tributaries are generally sluggish due to the gentle 0.04% sloping relief (Snowden, 1989) found on the coastal plain. Typical soil types in the region include fine, poorly draining alluvial clays, clay-based silts, and loams, with dispersed areas of sandy substrate resulting from subtropical climate and fluvial geologic characteristics (Figure 3; USDA, 2012a).

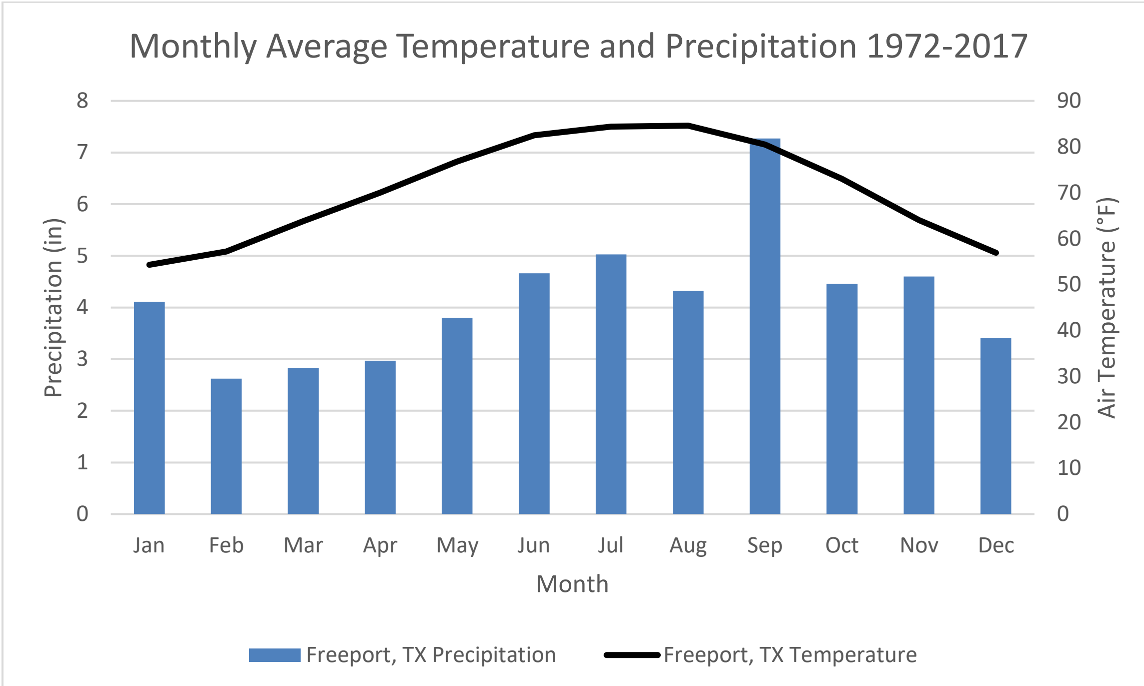

Figure 2. Precipitation and temperature recorded in Freeport, Texas near the Caney Creek TMDL watershed

Watershed Population and Population Projections

In 2016, the Caney Creek Tidal subwatershed had a population of 438, the Linnville Bayou subwatershed had a population of 912, and the Caney Creek Above Tidal subwatershed had a population of 7,597 (Table 2; H-GAC, 2017a). To determine projected changes in population, data from the Texas Water Development Board's (TWDB) 2070 county population projections were reviewed (TWDB, 2018).

Brazoria, Matagorda, and Wharton counties are anticipated to grow by approximately 80%, 14%, and 24%, respectively. Those projected rates were then applied to the estimated 2016 watershed population based on the proportional area each county makes up within each subwatershed to determine the proportional area population in 2070. Projected 2070 populations were then added for each proportional area to determine the estimated watershed population in 2070 (Table 2). The Caney Creek watershed population is anticipated to grow by about 21% by 2070.

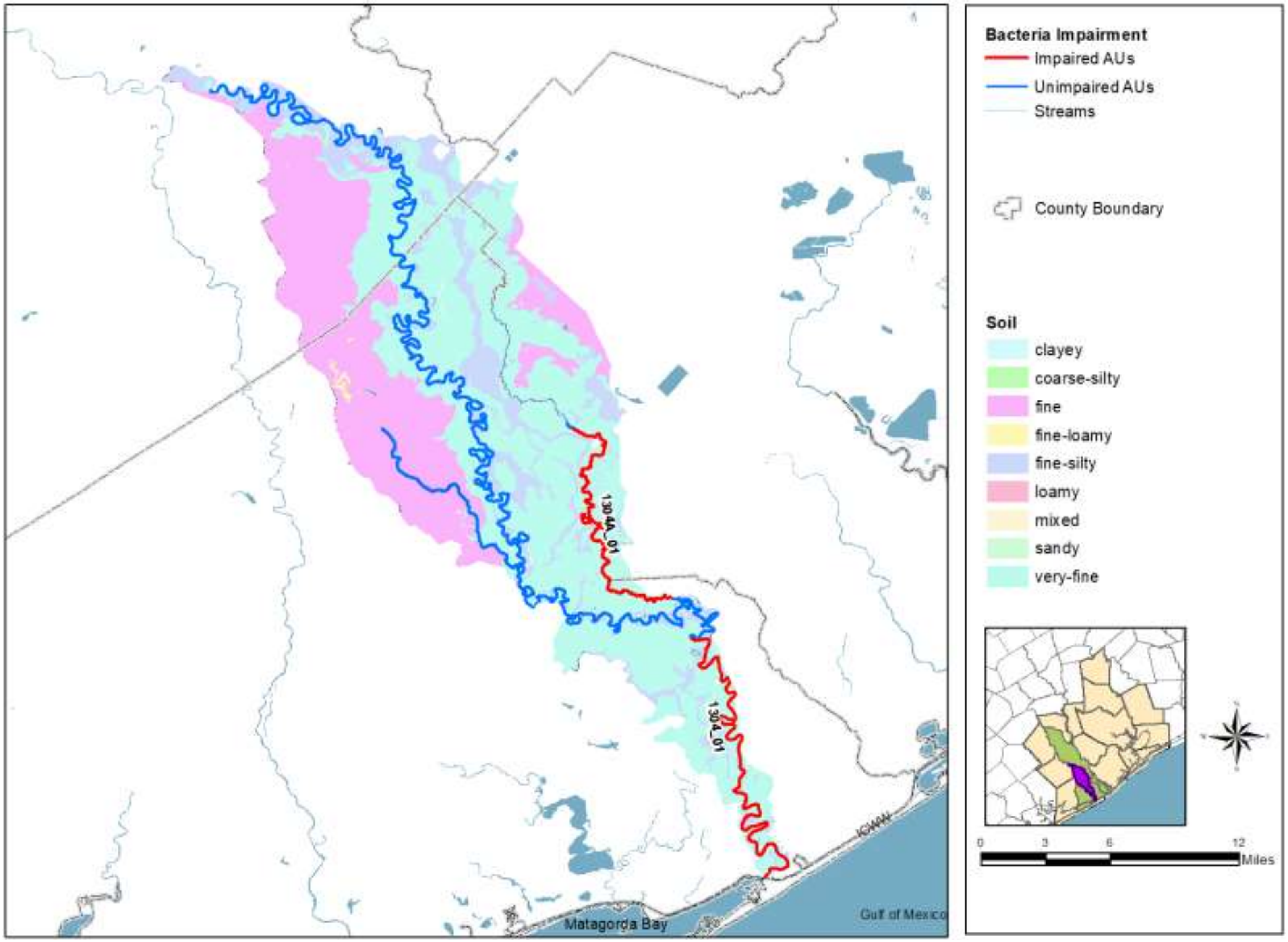

Figure 3. Soil types within the Caney Creek TMDL watershed

Table 2. 2016 population and 2070 population projections for the Caney Creek TMDL watershed

Subwatershed	2016	2070	% Change
Caney Creek Tidal	438	501	14.38%
Linnville Bayou	912	1,321	44.85%
Caney Creek Above Tidal	7,597	8,964	17.99%
Total	**8,947**	**10,786**	**20.55%**

The procedure used to determine the values shown in Table 2 is detailed in Appendix A.

Land Cover

The Caney Creek watershed consists primarily of coastal prairies and marshes, broken up by ribbons of riparian woodlands. Native vegetation consists of tallgrass prairies, live oak woodlands, and a variety of halophilic (salt-tolerant) plants with extensive wetland habitats providing food and shelter for numerous bird species and aquatic organisms.

The Houston-Galveston Area Council (H-GAC) acquired land satellite imagery (LandSat 8) taken in 2015, which it analyzed in 2017 for ten land cover classes following protocols adapted from NOAA's Coastal Change Analysis Program (H-GAC, 2017b). The ten land cover classes are summarized as follows. See the technical support document (TSD) for Caney Creek (H-GAC, 2019) for full descriptions of all land cover classes and subclasses.

1) High Intensity Development – Contains significant land area that is covered by concrete, asphalt, and other constructed materials. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
2) Medium Intensity Development – Contains area with a mixture of constructed materials and vegetation or other cover. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
3) Low Intensity Development – Contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. This subclass commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
4) Open Space Development – Contains areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. These areas are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass

productivity, and can be recognized through vegetative indices based on spectral characteristics.

5) Cultivated Crops – Contains areas intensely managed to produce annual crops. This class also includes all land being actively tilled.
6) Pasture/Grasslands – This is a composite class that contains both Pasture/Hay lands (planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled) and Grassland/Herbaceous (areas are not subject to intensive management such as tilling but can be utilized for grazing).
7) Barren Lands – This class contains both Barren Land (areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material) and Unconsolidated Shore (material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water) areas.
8) Forest/Shrubs – This is a composite class that contains Deciduous Forest (dominated by tree species that shed foliage simultaneously in response to seasonal change), Evergreen Forest (dominated by tree species that maintain their leaves all year), Mixed Forest (neither deciduous nor evergreen species are completely dominant), and Scrub/Shrub (tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions).
9) Open Water – This is a composite class that contains Open Water, Palustrine Aquatic Bed (tidal and non-tidal wetlands) and deep-water habitats in which salinity due to ocean-derived salts is below 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water), and Estuarine Aquatic Bed (similar to Palustrine Wetlands except salinity due to ocean-derived salts is equal to or greater than 0.5%) areas.
10) Wetlands – This is a composite class that contains all the palustrine (Palustrine Forested Wetland, Palustrine Scrub/Shrub Wetland, and Palustrine Emergent Wetland) and estuarine (Estuarine Forested Wetland, Estuarine Scrub/Shrub Wetland, and Estuarine Emergent Wetland) wetland land types.

The Caney Creek watershed covers 193,653 acres: 28,200, 64,041 and 101,412 acres in the Caney Creek Tidal, Linnville Bayou, and Caney Creek Above Tidal subwatersheds, respectively (Table 3, Figure 4). The four developed land cover classes (High Intensity, Medium Intensity, Low Intensity, and Open Space Development) were combined into a single class for Table 3 and Figure 4 to simplify the presentation, as each development class makes up a relatively small fraction of the land cover within the Caney Creek watershed.

Pasture/Grassland makes up the single largest land classification at 35%, 37%, and 40% within the Caney Creek Tidal, Linnville Bayou, and Caney Creek Above Tidal subwatersheds, respectively (Table 3). In the Caney Creek Tidal and Linnville Bayou subwatersheds, Wetlands and Forest/Shrubs classes make up the next two major classes at or slightly above 25% of the land cover for each class. For the Caney Creek Above Tidal subwatershed, Cultivated Crop (26%) and Wetland (18%) make up the next two land cover types. Developed land within the three subwatersheds makes up slightly less than 5% to slightly over 6% of the land cover types.

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.

There are two endpoints for the TMDLs in this report based on numeric criteria in the Texas Surface Water Quality Standards for primary contact recreation (TAC, 2019):

1) Maintain the concentration of Enterococci in Segment 1304 below the geometric mean criterion for saltwater of 35 cfu/100 mL.
2) Maintain the concentration of *E. coli* in 1304A below the geometric mean criterion for freshwater of 126 cfu/100 mL.

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 TPDES program. WWTFs and stormwater discharges from industries, construction, and the separate storm sewer systems of cities 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.

Except for 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.

Table 3. Land cover classes within the Caney Creek TMDL watershed

Land Cover Class Type	Segment 1304 Area (Acres)	% Total	1304A Area (Acres)	% Total	Segment 1305 Area (Acres)	% Total	Total, Area (Acres)	% Total
Developed	1,343.60	4.76%	3,551.19	5.55%	6,513.98	6.42%	11,408.77	5.89%
Cultivated Crops	817.43	2.90%	4,169.14	6.51%	26,481.25	26.11%	31,467.82	16.25%
Pasture/Grasslands	9,904.68	35.12%	23,429.63	36.59%	40,842.56	40.27%	74,176.87	38.30%
Barren Lands	31.36	0.11%	275.53	0.43%	240.21	0.24%	547.10	0.28%
Forest/Shrubs	7,631.67	27.06%	15,963.73	24.93%	9,369.39	9.24%	32,964.79	17.02%
Open Water	570.03	2.02%	356.27	0.56%	111.87	0.11%	1,038.17	0.54%
Wetland	7,901.17	28.02%	16,295.97	25.45%	17,852.63	17.60%	42,049.77	21.71%
Total	**28,199.94**	**100.00%**	**64,041.46**	**100.00%**	**101,411.89**	**100.00%**	**193,653.29**	**100.00%**

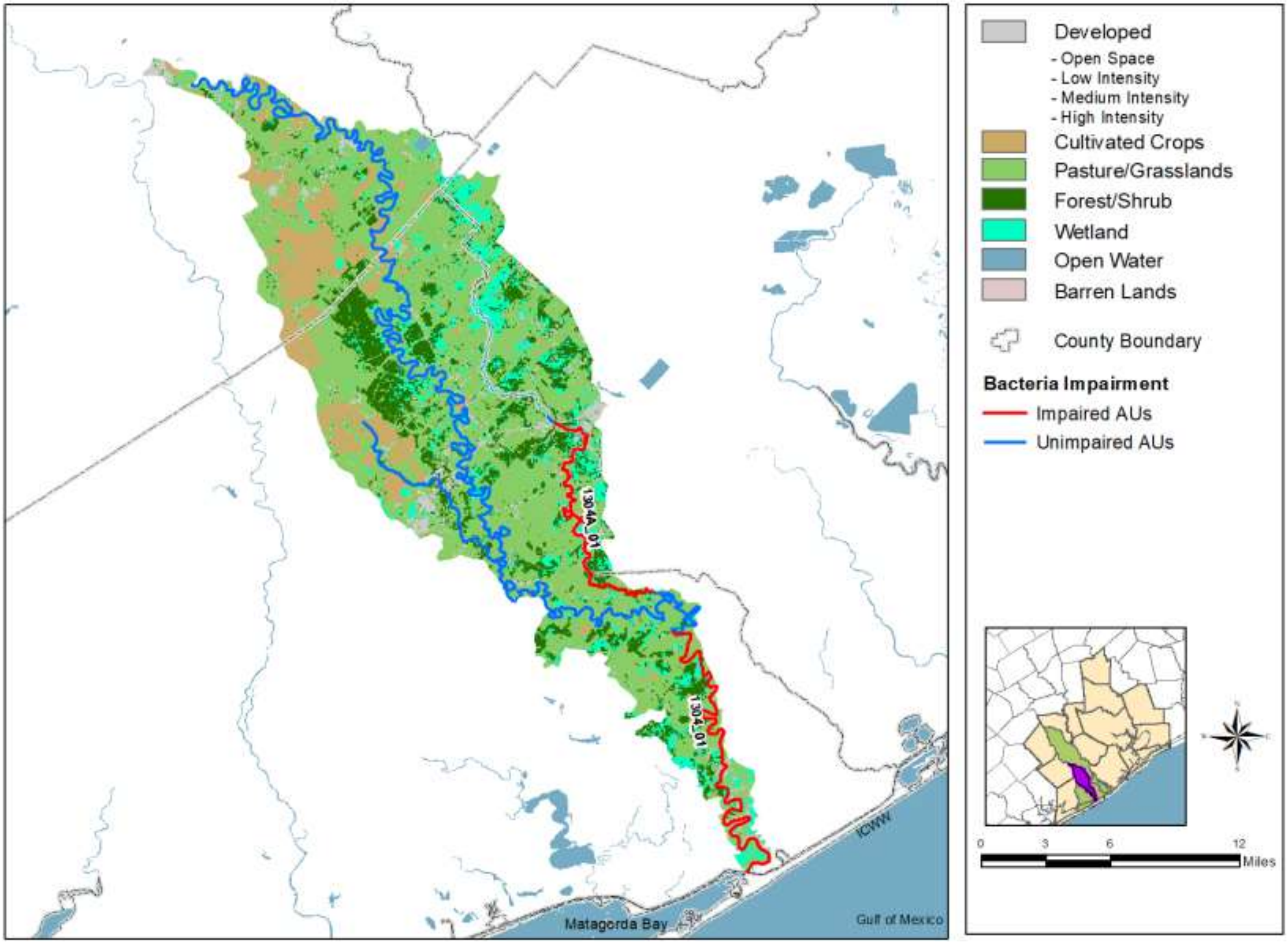

Figure 3. Land cover in the Caney Creek TMDL watershed

Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watershed include WWTF outfalls and stormwater discharges from industries and construction activities.

Domestic and Industrial WWTFs

There are five permittees—two industrial and three domestic—with wastewater discharge permits for nine outfalls that discharge within the Caney Creek watershed (Table 4, Figure 5), based on TCEQ's Central Registry (TCEQ, 2018) and TCEQ's Outfall Data Layer. These permits discharge only to AUs 1304A_01, 1305A_01, and 1305B_01.

The two industrial permittees in the Linnville Bayou subwatershed do not have bacteria limits in their permits. As neither contains a domestic component for outfalls that discharge within the Caney Creek watershed, the two facilities (including their six outfalls within the Caney Creek watershed) were excluded from further analysis. Both industrial permittees also have one or more outfalls that discharge outside the Caney Creek watershed, including one outfall with a domestic component.

The remaining three permittees are domestic WWTFs that have bacteria limits in their permits. One facility is near the town of Boling and discharges to AU 1305B_01. The other two are located near the town of Van Vleck and discharge to AU 1305A_01.

Two additional permits are included in Figure 5 but are not listed in Table 4, as they both discharge outside of the Caney Creek watershed. Permit WQ0003891000 (Wharton County Generation, LLC) is in the northern portion of the Linnville Bayou subwatershed, but discharges to Segment 1302. Part of the service area for permit WQ0014177001 [Caney Creek Municipal Utility District (MUD)] is within the Caney Creek Tidal subwatershed, but it discharges to Segment 2441 via the ICWW. These two permits were excluded from further analysis.

TCEQ/TPDES Water Quality General Permits

Certain types of activities are required to be covered by one of several TCEQ/TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production
- TXG340000 – petroleum bulk stations and terminals
- TXG670000 – hydrostatic test water discharges

Table 4. Permitted domestic and industrial WWTFs discharging in the Caney Creek watershed

AU	TPDES Number	NPDES[a] Number	Permittee	Outfall Number	Bacteria Limits (cfu/100 mL)	Primary Discharge Type	Daily Average Flow – Permitted Discharge (MGD[b])
1304A_01	WQ0000721000	TX0007536	Phillips 66 Co.	002	None	Industrial – Stormwater	Intermittent and flow-variable
1304A_01	WQ0000721000	TX0007536	Phillips 66 Co.	006	None	Industrial – Stormwater, Utility Wastewater	Intermittent and flow-variable
1304A_01	WQ0000721000	TX0007536	Phillips 66 Co.	010	None	Industrial – Stormwater, Utility Wastewater	Intermittent and flow-variable
1304A_01	WQ0000721000	TX0007536	Phillips 66 Co.	013	None	Industrial – Stormwater, Utility Wastewater	0.1
1304A_01	WQ0005147000	TX0135917	Chevron Phillips Chemical Co. LP	001	None	Industrial – Washdown, Utility Wastewater	Intermittent and flow-variable
1304A_01	WQ0005147000	TX0135917	Chevron Phillips Chemical Co. LP	003	None	Industrial – Stormwater, Utility Wastewater	Intermittent and flow-variable
1305A_01	WQ0010663001	TX0024155	Matagorda County WCID 6	001	126 (*E. coli*)	Domestic – Sanitary Waste	0.193
1305A_01	WQ0011768001	TX0070297	Jimmie Wayne Massey	001	126 (*E. coli*)	Domestic – Sanitary Waste	0.01
1305B_01	WQ0010843001	TX0033910	Boling Municipal Water District	001	126 (*E. coli*)	Domestic – Sanitary Waste	0.133

[a]NPDES: National Pollutant Discharge Elimination System

[b]MGD: million gallons per day

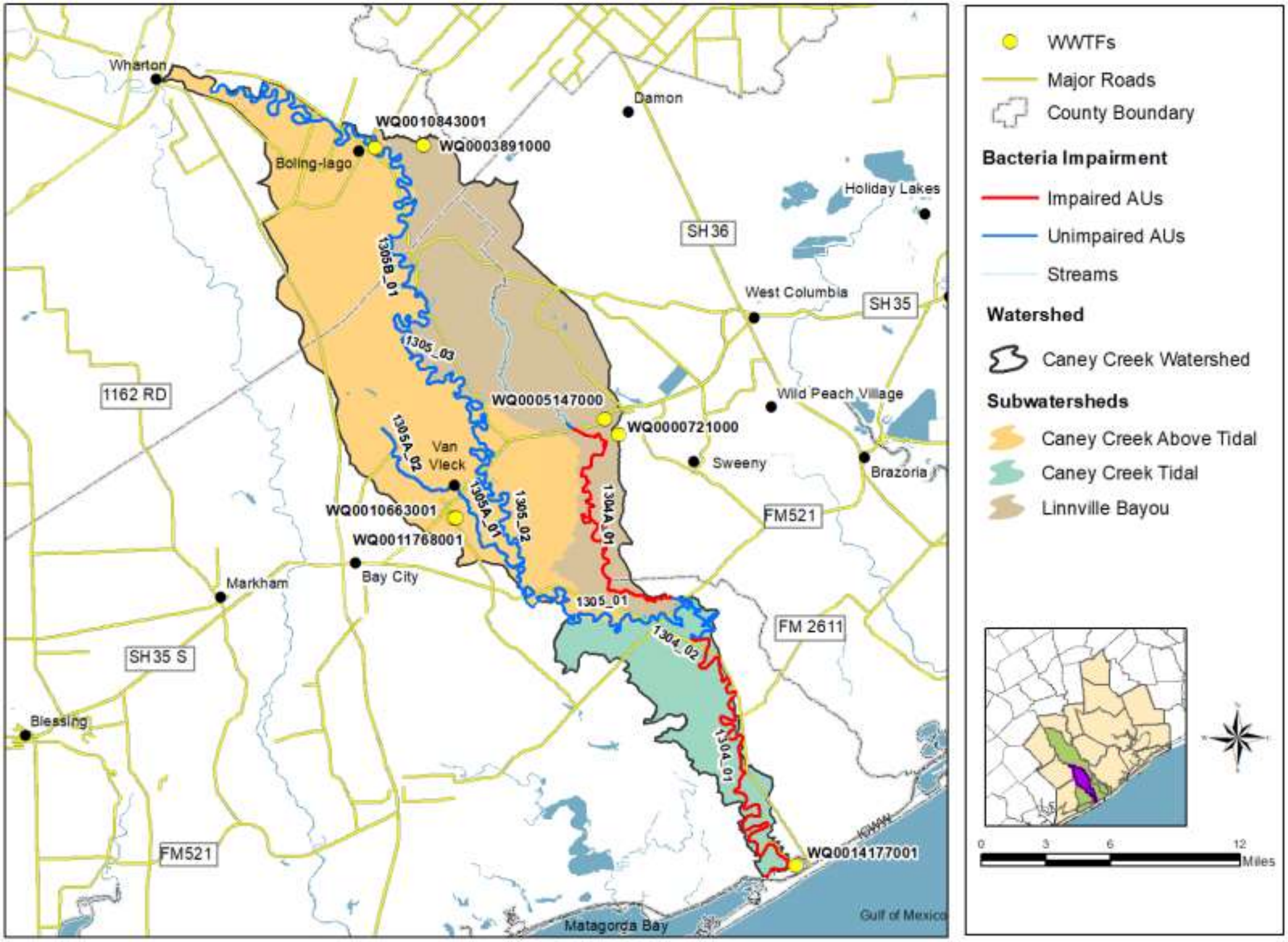

Figure 4. Location of WWTFs in the Caney Creek TMDL watershed

- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG870000 – pesticides (application only)
- TXG920000 – concentrated animal feeding operations
- WQG100000 – wastewater evaporation
- WQG200000 – livestock manure compost operations (irrigation only)

A review of active general permit coverage (TCEQ, 2018) in the Caney Creek watershed found one poultry CAFO in the Caney Creek Above Tidal subwatershed. This CAFO is required to contain the volume of wastewater generated during the 25-year, 24-hour-design storm event. The CAFO is authorized to discharge wastewater in excess of the design storm event, provided that it complies with certain conditions in the TXG920000 general permit. Additionally, containment failures during heavy rainfall and flooding conditions could happen, which could release fecal wastes to Segment 1305. No other active water quality general 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. These overflows 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 overflows 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.

A review of SSOs reported to TCEQ Region 12 by permit holders in the Caney Creek watershed found only one SSO reported for the period of 2012 through 2018. Caney Creek MUD reported one SSO on May 27, 2012, due to a blockage in the collection system. The SSO released an estimated 3,000 gallons of untreated sewage into the Caney Creek Tidal subwatershed.

TPDES Regulated Stormwater

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

1) Stormwater subject to regulation, which is any stormwater originating from TPDES-regulated MS4 entities, industrial facilities, and construction activities.
2) Stormwater runoff not subject to regulation.

TCEQ Central Registry (2018) was reviewed on June 8, 2018, for stormwater permits. No permits were found that pertain to Phase II MS4s for the Caney Creek watershed.

There were four active construction authorizations—two in the Linnville Bayou subwatershed and two in the Caney Creek Above Tidal subwatershed. Construction permits (TXR150000) are required when one acre or more of land is disturbed during construction activity. Due to the variable nature of these permits, the acres recorded serve only as a representative estimate, after summing up all disturbed areas of the watershed area under a stormwater construction permit at any given time. For the period of 2004 through 2018 the average number of permits was 4.3, with an annual average of 684 acres of disturbed area. However, for use in development of the TMDL, the more recent (2018) construction disturbed areas (1,194 acres for the Caney Creek Above Tidal subwatershed and 345 acres for the Linnville Bayou subwatershed) were used, as they were considered more representative of current conditions.

The MSGP authorizes the discharge of stormwater associated with industrial activity and those authorizations are more permanent in nature than authorizations for construction activities. MSGP authorizations (TXR050000) were reviewed in TCEQ's Central Registry in 2018, with six active permits discharging within the Caney Creek watershed. Three discharge to AU 1304A_01 and three discharge to AU 1305A_01. Acreages were estimated by reviewing county appraisal district parcel data and/or importing the location information associated with the authorization into GIS and measuring the facility area. There were 1,935 acres in the Linnville Bayou subwatershed and 678 acres in the Caney Creek Above Tidal subwatershed under an MSGP in 2018. Once calculated, the area for each MSGP was used in the development of the TMDL allocations.

Unregulated Sources

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

Unregulated Agricultural Activities and Domesticated Animals

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

Agriculture makes up between 38 and 66% of the land cover in the Caney Creek watershed. Livestock estimates for Brazoria, Matagorda, and Wharton counties were compiled by the United States Department of Agriculture (USDA) Census of Agriculture (USDA, 2012b). A stocking rate for each county was developed by analyzing county land cover data with Pasture/Grassland use for the county. Livestock estimates for the Caney Creek watershed (Table 5) were developed using a proportional stocking rate for the county and multiplying it by the area for each subwatershed's Pasture/Grassland use found within each county. The county-level estimated livestock populations were reviewed by Texas State Soil and Water Conservation Board (TSSWCB) staff. These livestock numbers, however, were not used to develop an allocation of allowable bacteria loading to livestock.

Table 5. Estimated livestock numbers for the Caney Creek watershed

Subwatershed	Pasture/ Grassland Area (Acres)	Cattle and Calves	Hogs and Pigs	Sheep and Lambs	Equine	Poultry
Caney Creek Tidal	9,904.68	2,194	2	13	47	52
Linnville Bayou	23,429.63	5,804	127	63	215	244
Caney Creek Above Tidal	40,842.56	9,069	13	56	224	144 [a]

[a] Estimate does not include poultry associated with the CAFO

Fecal bacteria from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Estimated rates of dog and cat ownership per household have been developed and can be applied to generate an estimate of the number of dogs and cats found in the Caney Creek watershed. Pet population estimates (Table 6) were calculated using the estimated number of dogs (0.614) and cats (0.457) per household (AVMA, 2018) and the estimate of the number of households in each subwatershed (USCB, 2012). The actual contribution and significance of bacteria loads from pets reaching the water bodies of the watershed is unknown.

Table 6. Estimated households and pet population in the Caney Creek watershed

Subwatershed	Estimated Households	Estimated Dog Population	Estimated Cat Population
Caney Creek Tidal	185	114	85
Linnville Bayou	357	219	163
Caney Creek Above Tidal	3,003	1,844	1,372
Total	**3,545**	**2,177**	**1,620**

Wildlife and Unmanaged Animals

Fecal bacteria inhabit the intestines of all warm-blooded animals, including wildlife such as mammals and birds. To develop 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 water bodies. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff.

While wildlife inhabit all parts of the Caney Creek watershed, areas that remain undeveloped are key reservoirs for wildlife. Development accounts for less than 6% of the Caney Creek watershed, leaving large areas available for wildlife use.

For deer, the Texas Parks and Wildlife Department published data showing deer population density estimates by deer management unit (DMU; TPWD, 2019). The Caney Creek watershed is located within DMU 10, which has an average deer density of 39.57 deer/1,000 acres across all habitats. Applying this value to the entire area of the Caney Creek watershed returns an estimated 7,663 deer. This number was then proportionally distributed to account for deer preference toward certain land cover types (forest/shrub, grassland/pasture, and barren land) to give estimates by subwatershed: 1,990 in the Caney Creek Tidal subwatershed, 2,679 in the Linnville Bayou subwatershed, and 2,994 in the Caney Creek Above Tidal subwatershed.

Feral hogs, a nonnative, invasive species, are able to adapt to a variety of habitats and have high reproductive rates. Feral hogs have been identified as a significant potential contributor of fecal bacteria due to their tendency to wallow in mud and spend time in shallow water.

Feral hog density rates suggest that there are roughly 1.33 to 2.45 hogs per square mile in areas with suitable habitat (Texas A&M AgriLife Extension Service, 2012). Both rates were applied to suitable habitat (all land cover types except for high intensity and medium intensity developed land) in each subwatershed to develop estimates for feral hogs: Caney Creek Tidal—44.04 square miles of suitable habitat and 59-108 feral hogs; Linnville Bayou—99.66 square miles of suitable habitat and 133-244 feral hogs, and Caney Creek Above Tidal—157.41 square miles of suitable habitat and 209-386 feral hogs.

Onsite Sewage Facilities

Away from municipal centers where centralized public wastewater treatment is common, rural and low-density suburban residences and stand-alone commercial and industrial businesses are more likely to use owner operated OSSFs, often referred to as septic systems. When functioning properly and sited correctly, much like WWTFs, OSSFs contribute little bacteria.

The number of permitted and registered OSSFs in this watershed has been compiled by H-GAC in coordination with authorized agents (AAs) in H-GAC's service region, which includes the Caney Creek watershed. AAs are local authorities who have accepted responsibility from TCEQ to permit OSSFs and enforce laws and rules governing OSSFs on behalf of the state.

There are 568 permitted OSSFs in the Caney Creek watershed (Table 7, Figure 6). In addition to permitted systems, there are additional systems that are unregistered, including abandoned OSSFs. These systems are difficult to identify and enumerate. Reed, Stowe and Yanke (2001) estimated a 12% failure rate for OSSFs in Texas. That rate, derived from survey responses received from the AAs, falls in line with EPA's guidance on failure rates nationally of 10 to 20% (H-GAC, 2005). Applying the 12% failure rate to 568 registered systems, an estimated 68 of these systems could be failing in the Caney Creek watershed.

Table 7. Permitted OSSFs in the Caney Creek watershed

Subwatershed	Permitted OSSFs	Estimated Number of Failing OSSFs
Caney Creek Tidal	193	23
Linnville Bayou	65	8
Caney Creek Above Tidal	310	37
Total	**568**	**68**

Bacteria Survival and Die-off

Potential sources for fecal bacteria have been examined in previous sections. It is well understood that fecal bacteria in the water column in natural systems die off, decreasing concentrations due to the presence of sunlight, predators, and competition for available nutrients. Recent research has also made clear that fecal bacteria can survive outside of warm-blooded hosts in the organic films found on pipes and upper sediment layers of streambeds (Brinkmeyer et. al, 2014). Less clear is the understanding of fecal bacteria regrowth and any potential relationship with pathogenic bacteria. As these are considered instream processes, they were not used in the development of bacteria source loading estimates.

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.

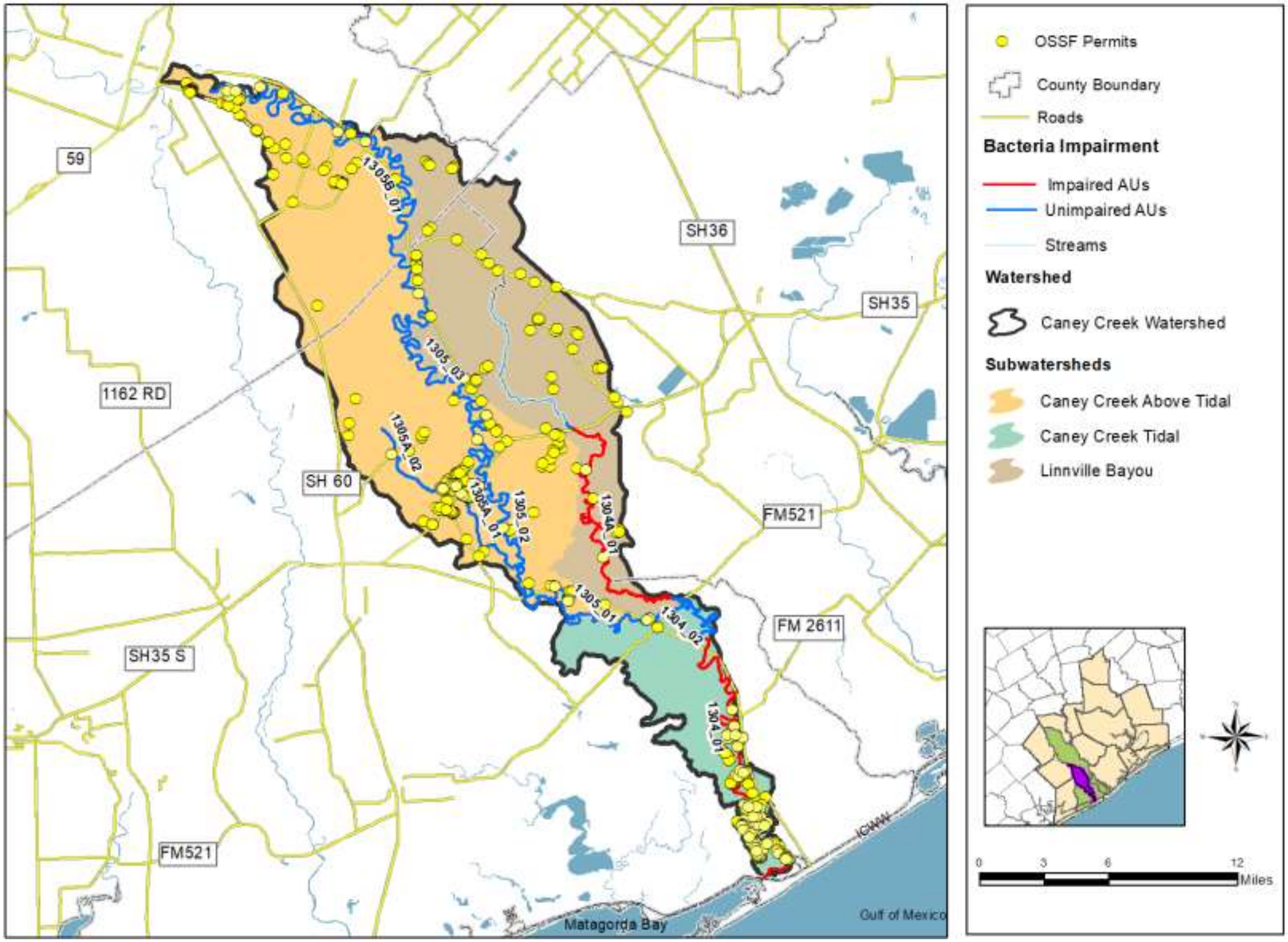

Figure 5. Permitted OSSFs found in the Caney Creek TMDL watershed

One common technique is to use LDCs in developing the TMDL load allocation. LDC use requires linking sources of loading with instream water quality as measured by ambient monitoring. Regulatory agencies have supported the use of LDCs in development of TMDL load allocations, and the method has been used successfully in the state of Texas. They are also easy to present to watershed stakeholders.

A review of the LDC method and partition of the graph into flow regimes allows for gross analysis of sources. During low flows and dry conditions, contributions of bacteria can typically be attributed to point sources and direct fecal deposition to the water body. The ambient bacteria concentration at these flows will fluctuate as the magnitude from contributing sources changes.

During storm events, runoff over land picks up deposited sources—nonpoint sources—and begins to contribute to the loading of the stream. With storms of sufficient size, the runoff contribution greatly outpaces the input from point sources. These events are captured on the LDC in the high flow regime, which captures elevated levels of both regulated sources and unregulated sources. Typically, the bacteria concentration rises as runoff first reaches the water body. This “first flush” of bacteria is generally attenuated over time as the bacteria have been washed off the land and runoff decreases following the rain event.

One assumption of the LDC method is the link between bacteria sources and the concentration found in the stream. LDCs assume a one-to-one relationship between instream loadings and loadings originating from point sources and the landscape’s regulated and unregulated sources (e.g., WWTFs, areas of the watershed under stormwater regulation, and the remaining allocation apportioned to unregulated sources).

The median loading of the high flow regime (0-10% exceedance) is used for the TMDL calculations. The median loading of the high flow regime (represented by the 5% exceedance flow) represents a reasonable yet high value for the allowable pollutant load allocation.

In watersheds where there are tidal exchanges along the Texas coast, the flow is adjusted to address tidal influences. The LDC developed through this approach is called a modified LDC (Hauck et. al, 2013). The 5% exceedance value is important for the modified LDC, as saltwater intrusion is considered absent from the streamflow in that portion of the modified LDC. The modified LDC will then function more like the standard LDC and eliminates the need to address the complex dynamics of tidal flows.

Load Duration Curve Analysis

LDCs and modified LDCs are graphs of the frequency distribution of loads of pollutants in a stream. In the case of these TMDLs, the loads shown are of *E. coli* bacteria for freshwater or Enterococci in tidal waters in cfu/day. LDCs are derived from flow duration curves (FDCs). For detailed discussion of FDCs, LDCs, modified LDCs, and the derivation of TMDL allocations, please review the TSD for Caney Creek (H-GAC, 2019). The LDCs that were developed represent the maximum acceptable load in the stream that will result in achievement of the TMDL water quality target. The basic steps to generate LDCs involve:

- Preparing FDCs. The United States Geological Survey's (USGS's) LoadEst program was used to generate flow records that have incorporated the full permitted flow for WWTFs at the monitoring stations chosen for analysis (Runkel et.al., 2004).
- Identifying the critical flow range from the FDCs to define the TMDL. The high flow regime (0-10 percentile range) was chosen, as it provides the greatest flexibility with higher allocations.
- Addressing tidal exchange effects on flow in coastal waters to produce modified FDCs for use in modified LDCs.
- Converting the FDCs to LDCs.
- Estimating existing indicator bacteria loading in the receiving water using ambient water quality data collected at the stations selected for analysis.
- Interpreting LDCs to understand the relative contributions of regulated and unregulated sources.

Data Resources

Availability of bacteria data for the impaired water bodies in the Caney Creek watershed was sufficient to develop the LDCs and modified LDCs. However, to complete LDCs, streamflow measurements are required, and in the case of tidally influenced waters, salinity is required. There was no source of continuous streamflow data, as there is no historical or current USGS streamflow gauge located within the Caney Creek watershed.

To address the lack of in situ continuous streamflow data, records were obtained from a nearby USGS streamflow gauge (08162600) found in Tres Palacios Creek Above Tidal (Segment 1502) near Midfield, Texas, for the period of 2004 through 2018. This segment was selected due to its location and comparative similarity of land cover characteristics and weather patterns.

There is a recently established Environmental Institute of Houston gauge station on Caney Creek Above Tidal at TCEQ SWQM station 12153 in AU 1305_01 (Figure 7) that was used to further refine daily flow estimates for this project. The gauge measures the stream height in 15 minutes intervals. A flow rating curve was developed correlating monthly measured flow with the 15-minute height measurements to develop stream flow. The stream flow records at this gauge station were available for the period of February 14, 2017, through December 31, 2018.

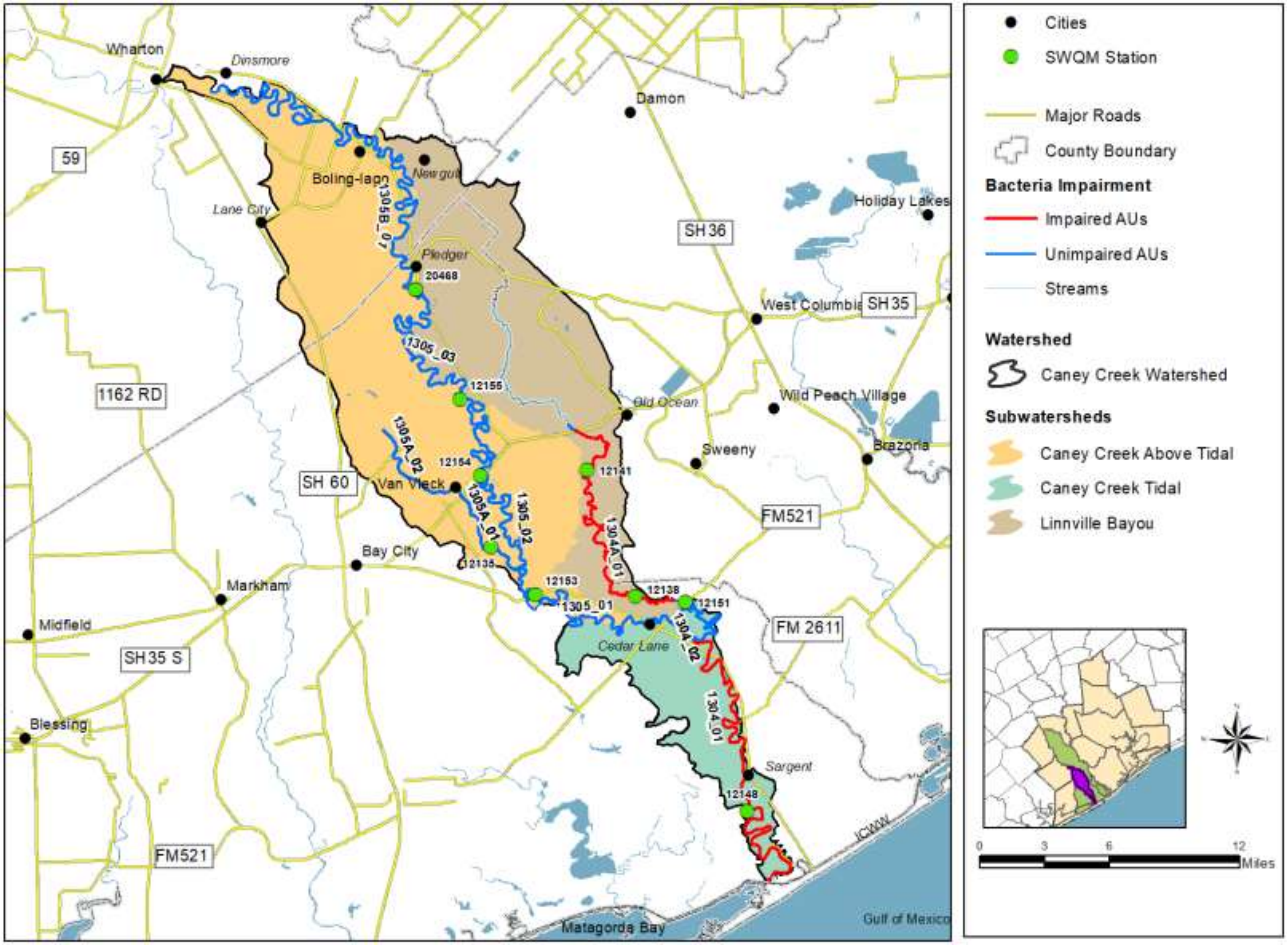

Figure 6. TCEQ SWQM station locations in the Caney Creek TMDL watershed

To find a relationship between daily flow patterns of the two streams (Caney Creek Above Tidal and Tres Palacios Creek Above Tidal), a linear regression model was built between two flow records. For the regression model, only the flow records from February 14, 2017, through December 31, 2018, from both the watersheds were considered. The linear regression estimation was performed using SAS statistical software. Based on the estimated regression relationship, the daily flow values for TCEQ SWQM station 12153 in Caney Creek for the period of January 1, 2004, through December 31, 2018, were derived. To apply the daily flow at station 12153 to the other stream stations, the drainage area ratio (DAR) was used. To compute the DAR, the area above station 12153 was compared with the watershed contributing to each monitoring station. Water quality data used (*E. coli,* Enterococci, and salinity) for analyses in this report from 2004 through 2018 were extracted from TCEQ's Surface Water Quality Monitoring Information System on February 18, 2019.

Load Duration Curve Results

The components of each of the LDCs in this document include the FDC, geometric mean and single grab standard curves, observed data, and the load regression (LR) curve.

Using the flow regimes of 0-10% (high flows), 10-40% (moist conditions), 40-60% (mid-range conditions), 60-90% (dry conditions), and 90-100% (low flows), the LDCs can be viewed as periods when the bacteria load meets the standard (i.e., the LR curve is below the geometric mean) and periods when it exceeds the standard (i.e., the LR curve is above the geometric mean). Geometric mean load values using the bacteria data were generated for each flow regime.

Additionally, individual observed data points can be contrasted with the single sample standard curve. This can be useful in conveying whether dry weather conditions or wet weather conditions present the biggest challenge in meeting the standard (e.g., dry weather inputs from WWTFs or wet weather sources such as stormwater).

An LDC was developed for the TCEQ SWQM station 12141 in AU 1304A_01 (Figure 8). Station 12141 was selected for LDC development, as it is the only station in AU 1304A_01 at which bacteria data have been routinely collected. The LR curve begins above the standard-geometric mean curve during high flow conditions. The LR curve modestly begins to approach the standard-geometric mean curve throughout the flow record but never meets the standard-geometric mean curve. This suggests that fecal bacteria sources typically associated with wet weather and dry weather should be addressed during TMDL implementation.

Modified Load Duration Curve Results

The difference between the modified LDC and the traditional LDC is the application of salinity in the development of the FDC to account for tidal flux in Segment 1304. In addition, the fecal bacteria indicator is Enterococci, which is used to indicate the potential for pathogens in tidal waters.

To develop the modified LDC for AU 1304_01, ambient SWQM data from TCEQ, including Enterococci and salinity measurements, from 2004 through 2018 were acquired. Due to the tidal nature of the stream, there were no daily flow records to estimate the daily loads of bacteria. As a surrogate, USGS daily flow measurements at USGS station 08162600 from the Tres Palacios Creek Above Tidal watershed (as presented in the Data Resources section) from 2004 through 2018 and correlated with flow data from a height level gauge at TCEQ SWQM station 12153 were used. Daily flow records were generated and related to the salinity of the stream.

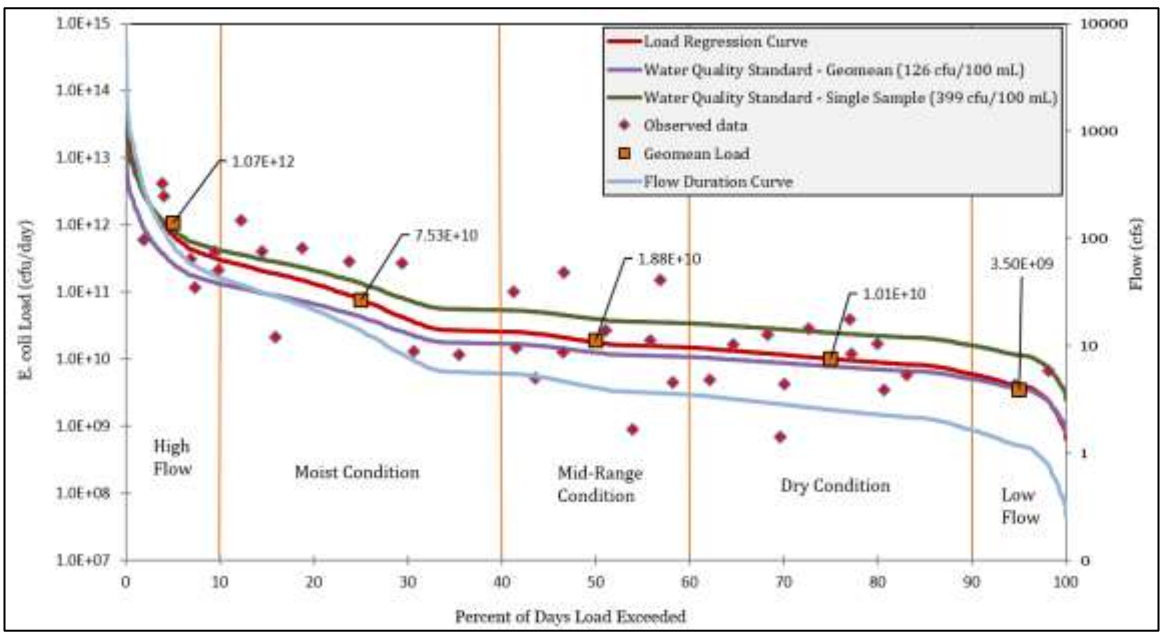

Figure 7. **LDC for TCEQ SWQM station 12141, AU 1304A_01, Linnville Bayou subwatershed**

The modified LDC for TCEQ SWQM station 12148, the only station in AU 1304_01 at which bacteria data have been routinely collected, is presented in Figure 9. A review of the LDC finds the LR curve is well above the standard curve during high flow events. The LR curve approaches the standard curve during the later stages of the moist condition regime. The LR curve then follows along the standard curve before crossing it during the middle part of the mid-range conditions. This pattern would suggest nonpoint sources during wet weather events are driving the impairment in this AU.

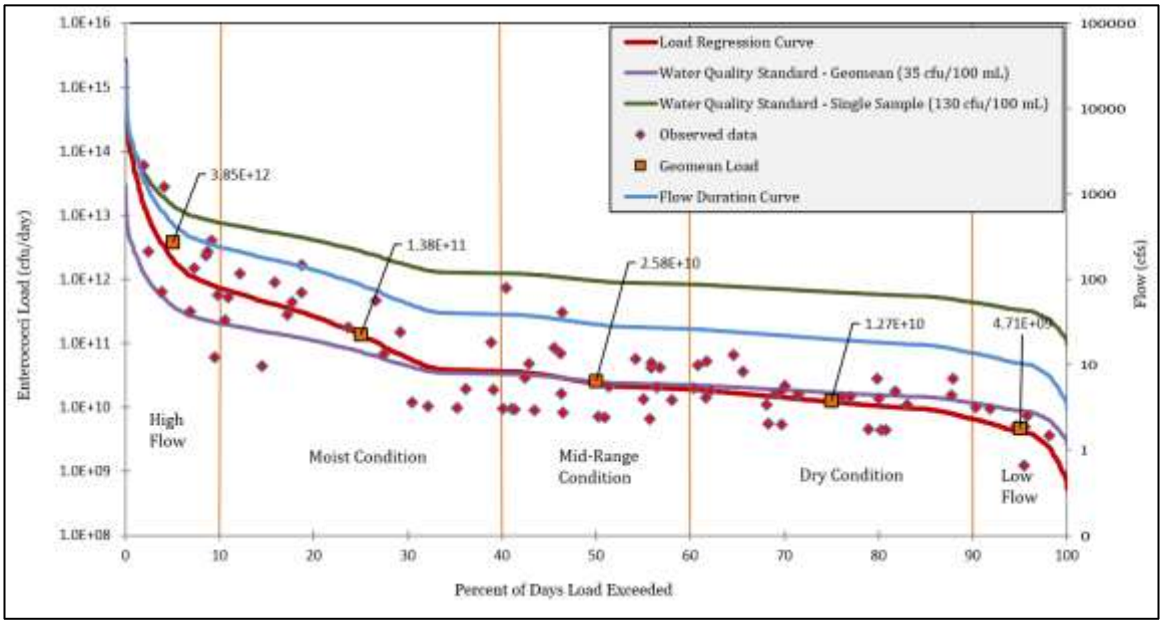

Figure 8. **LDC for TCEQ SWQM station 12148, AU 1304_01, Caney Creek Tidal subwatershed**

Margin of Safety

The margin of safety (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 goals 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.
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 TMDLs in this report incorporate an explicit MOS of 5% of the total TMDL allocation.

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:

WLA = wasteload allocations, the amount of pollutant allowed by regulated dischargers

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

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

As stated in 40 CFR 130.2(i), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. Bacteria in TMDLs are expressed as cfu/day, representing the maximum one-day load the stream can assimilate while still attaining the standards for contact recreation.

AU-Level TMDL Computations

To develop the TMDL loading allocation for both AUs, the median flow in the 0-10 percentile range (5% exceedance, high flow regime) was used. This value is taken from the LDC created for the furthest downstream monitoring station with sufficient bacteria data representing the segment. The standard curve for the applicable bacteria criterion was created by multiplying the flow value developed from the FDC with the geometric mean criterion for freshwater (126 cfu/100 mL of *E. coli*) and saltwater (35 cfu/100 mL of Enterococci) and the conversion factor. This effectively creates a daily maximum loading value in cfu/day.

An additional step must be taken to account for upstream loading from Caney Creek Above Tidal (Segment 1305) and Linnville Bayou (Segment 1304A) on Caney Creek Tidal (Segment 1304). LDCs were developed for 1305_02 and 1305A_01, as these AUs had sufficient data to perform TMDL loading allocations. The TMDLs developed, along with the TMDL loading completed for the impaired AU (1304A_01), were then used to develop a TMDL loading allocation for 1304_02. The AU 1304_02 value was then used to develop the TMDL loading allocation for impaired AU 1304_01.

Each computation includes a discussion accounting for the tributary contribution when needed. The loadings for stations without impairments were first developed using the freshwater geometric mean criterion (126 cfu/100 mL) and were then converted using the same calculation but substituting in the saltwater geometric mean criterion (35 cfu/100 mL). This allowed the tributary loading to be applied to downstream tidal AUs.

By selecting the 5% exceedance value as the allowable load, the TMDL is set by the equation:

TMDL (cfu/day) = criterion * flow [in cubic feet per second (cfs)] * conversion factor

Where:

Criterion = either 35 cfu/100 mL or 126 cfu/100 mL

Conversion factor (to billion cfu/day) = 0.0244657152

Using the 5% load duration exceedance, the TMDL values are provided in Table 8.

Table 8. TMDL calculations at the 5% exceedance flow

AU	Bacteria Indicator	Criterion (cfu/100 mL)	5% Exceedance Flow (cfs)	TMDL (Billion cfu/day)
1304_01	Enterococci	35	452.76	387.70
1304A_01	*E. coli*	126	87.15	268.66

Margin of Safety Formula

The TMDLs in this report incorporate an explicit MOS of 5%.

The MOS is therefore expressed by the equation:

MOS = 0.05 * TMDL

Where:

MOS = margin of safety load

TMDL = total maximum daily load

An additional step must be made to address the contribution of Segments 1305 and 1304A on the downstream Segment 1304. Load allocation from upstream AUs (LA_{TRIB}) was calculated, but the freshwater criterion was replaced with the saltwater criterion. The sum of the LA_{TRIB} from the upstream segments was subtracted from 1304_01's allocation prior to multiplying by 0.05. For the two TMDL AUs, the MOS values are presented in Table 9.

Table 9. MOS calculation based on TMDL calculated at 5% exceedance flow

AU	Bacteria Indicator	TMDL[a] (Billion cfu/day)	LA_{TRIB}[b] (Billion cfu/day)	MOS (Billion cfu/day)
1304_01	Enterococci	387.70	341.37	2.32
1304A_01	*E. coli*	268.66	_	13.43

[a]TMDL from Table 8

[b]LA_{TRIB} for 1304_01 is LA taken from upstream AUs/segments

Wasteload Allocation

The WLA is the sum of loads from regulated sources. Developing the WLA requires calculating two pieces of information: the wasteload that is allocated to TPDES-permitted WWTFs (WLA_{WWTF}) and the wasteload that is allocated to regulate stormwater dischargers (WLA_{SW}). The equation is:

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

Wastewater Treatment Facilities

Calculating the WLA_{WWTF} requires developing a daily wasteload allocation for TPDES-permitted facilities. The full permitted daily average flow of each WWTF is multiplied by the instream geometric criterion for the segment and the conversion factor. This calculation is expressed by:

$$WLA_{WWTF} = \text{criterion} * \text{flow} * \text{conversion factor}$$

Where:

Criterion = 35 cfu/100 mL for Enterococci; 126 cfu/100 mL for *E. coli*

Flow = full permitted flow (MGD)

Conversion factor (to billion cfu/day) = 0.037854118

Using this equation, each WWTF's allowable loading was calculated using the permittee's full permitted flow. The individual results were summed for each AU. The criterion was applied based on the indicator bacteria designated for the segment. To account for the contribution of upstream WWTFs, the WLA_{TRIB} sums up loadings from the Caney Creek Above Tidal subwatershed, using 35 cfu/100 mL as the criterion.

Table 10 presents the load allocations for each WWTF and sums the load allocations, providing a total WLA_{WWTF} and WLA_{TRIB} in the segments.

Table 10. Wasteload allocations for TPDES-permitted facilities in the Caney Creek watershed

AU	TPDES Number	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Daily Average Flow (MGD)	WLA_{WWTF} (Billion *E. coli* cfu/day)	WLA_{TRIB} (Billion Enterococci cfu/day)
1305B_01	WQ0010843001	Boling Municipal Water District	126 (*E. coli*)	0.133	0.634	0.176
1305A_01	WQ0010663001	Matagorda County WCID 6	126 (*E. coli*)	0.193	0.921	0.256
1305A_01	WQ0011768001	Jimmie Wayne Massey	126 (*E. coli*)	0.010	0.048	0.013
			Total	**0.336**	**1.603**	**0.445**

Regulated 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_{SW} 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 each subwatershed that is under the jurisdiction of stormwater permits was used to estimate the amount of the overall runoff load to be allocated as the regulated stormwater contribution in the WLA_{SW} component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint source runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

The equation for the WLA_{SW} is the sum of all loads from regulated stormwater sources and is calculated:

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

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

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

The FDA_{SWP} must be calculated to arrive at the fractional proportion of the drainage area under jurisdiction of stormwater permits. FDA_{SWP} is calculated by first totaling the area of each stormwater permit. The stormwater sources and area estimates were discussed in the "TPDES-Regulated Stormwater" section. Those area estimates were determined for each category and summed up to determine the total area under stormwater jurisdiction in each AU (Table 11).

To arrive at the proportion, the area under stormwater jurisdiction was then divided by the total subwatershed area. The FDA_{SWP} for AU 1304_01 accounts for the upstream area contribution by adding the total area of regulated stormwater for the AU and upstream segments and then dividing by the watershed area for the AU and upstream segments.

Table 11. Regulated stormwater FDA_{SWP} for the Caney Creek watershed

AU	Drainage Area[a] (acres)	Multisector General Permit (acres)	Construction Activities (acres)	Total Area of Permits[a] (acres)	FDA_{SWP}
1304_01	193,653.29	0	0	4,152	2.14%
1304A_01	64,041.46	1,935	345	2,280	3.56%

[a]Drainage area and total area of permits are calculated as the sum of those areas within the AU and any contributing areas upstream of the AU

To complete the WLA_{SW}, a value for FG is needed. The calculation for the FG term is presented later in the document, but the results will be included here for continuity. All the needed information to calculate the WLA_{SW} is presented in Table 12. LA_{TRIB} is used here to account for the nonpoint source contribution of AU 1304_02.

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 13.

In urbanized areas currently regulated by an MS4 permit, development and/or re-development of land in urbanized areas must implement the control measures/programs outlined in an approved stormwater management program (SWMP). Although additional flow may occur from development or re-development, loading of the pollutant of concern should be controlled and/or reduced through the implementation of best management practices (BMPs) as specified in both the TPDES permit and the SWMP.

Table 12. Regulated stormwater WLA calculations

AU	Bacteria Indicator	TMDL[a] (Billion cfu/day)	WLA_{WWTF}[b] (Billion cfu/day)	FG[c] (Billion cfu/day)	LA_{TRIB}[d] (Billion cfu/day)	MOS[e] (Billion cfu/day)	FDA_{SWP}[f]	WLA_{SW} (Billion cfu/day)
1304_01	Enterococci	387.70	0.45	0.15*	341.37	2.32	2.14%	0.93
1304A_01	*E. coli*	268.66	0.00	0.24	_	13.43	3.56%	9.08

[a]TMDL from Table 8

[b]WLA_{WWTF} from Table 10

[c]FG from Table 15 (*FG is the sum of FG and FG_{trib})

[d]LA_{TRIB} is LA taken from upstream AUs/segments

[e]MOS from Table 9

[f]FDA_{SWP} from Table 11

Table 13. WLA calculations

AU	Bacteria Indicator	WLA_{WWTF}[a] (Billion cfu/day)	WLA_{SW}[b] (Billion cfu/day)	WLA (Billion cfu/day)
1304_01	Enterococci	0.45	0.93	1.38
1304A_01	*E. coli*	0.00	9.08	9.08

[a]WLA_{WWTF} from Table 10 (WLA_{WWTF} in 1304 is the value WLA_{TRIB} from Table 10)

[b]WLA_{SW} from Table 12

Implementation of Wasteload Allocations

The TMDLs in this document will result in protection of existing uses and conform to Texas' antidegradation policy. The three-tiered antidegradation policy in the Texas Surface Water Quality 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.

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

The permit requirements are 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 in 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 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 TPDES-regulated municipal discharges, construction stormwater discharges, and industrial stormwater discharges, water quality-based effluent limits (WQBELs) 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 these TMDLs.

Updates to Wasteload Allocations

These TMDLs are, by definition, the total of the sum of the WLA (including FG), the sum of the load allocation (LA), 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 state'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 sum of loads from unregulated sources, and is calculated as:

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

Where:

LA = allowable loads from unregulated sources within the segments

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The calculation for LA is presented in Table 14.

Table 14. LA calculations

AU	Indicator Bacteria	TMDL[a] (Billion cfu/day)	WLA[b] (Billion cfu/day)	FG[c] (Billion cfu/day)	MOS[d] (Billion cfu/day)	LA (Billion cfu/day)
1304_01	Enterococci	387.70	1.38	0.15	2.32	383.85
1304A_01	*E. coli*	268.66	9.08	0.24	13.43	245.91

[a]TMDL from Table 8

[b]WLA from Table 13

[c]FG from Table 15, where 1304_01 is the total WLA_{TRIB}, including the sum of FG in Segment 1305 and 1304A

[d]MOS from Table 9

Future Growth

The FG 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 assimilative capacity of water bodies increases as the amount of flow increases.

The allowance for FG will result in protection of existing uses and conform to Texas' antidegradation policy.

The FG for these TMDLs is calculated as follows.

$$FG = Criterion * [\%POP_{2016\text{-}2070} * WWTF_{FP}] * Conversion\ Factor$$

Where:

Criterion = 35 cfu/100 mL for Enterococci; 126 cfu/100 mL for *E. coli*

$\%POP_{2016\text{-}2070}$ = estimated percent increase (or decrease) in population between 2016-2070

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

Conversion factor (to billion cfu/day) = 0.037854118

Population growth was presented previously and is used to project changes in population. For the three WWTFs found in the two AUs 1305A_01 and 1305B_01 (Table 10), the full permitted flow was used in the development of FG.

Projecting FG for AU 1304A_01 is hindered by the absence of WWTFs. Linnville Bayou is projected to grow from a population of 912 in 2016 to that of 1,321 by 2070, a population increase of 409 (TWDB, 2018 and H-GAC, 2017a). To account for this 44.85% increase in population and the potential for future development that may require centralized wastewater treatment, an alternative approach was taken.

New municipal WWTFs are required by 30 TAC Section 217.32 to accommodate daily wastewater flow of 75 to 100 gallons per capita per day (TAC, 2008). Using the daily wastewater upper figure (100) and multiplying it by the estimated population change would produce a conservative future permitted flow and FG value. Conservatively rounding the population increase up to 500 individuals and multiplying by the higher daily wastewater flow capacity results in a potential future WWTF with a permitted capacity of 0.05 MGD. Applying this new potential permitted flow with the projected FG in permitted flows from WWTFs in AUs 1305A_01 and 1305B_01, FG can be calculated and is presented in Table 15.

FG_{TRIB} was calculated as the sum of FG in AUs 1304A_01, 1305A_01 and 1305B_01 with the tidal criterion, 35 cfu/100 mL, substituted for the freshwater criterion. Absent in situ WWTFs, FG in AU 1304_01 becomes the FG_{TRIB}.

Compliance with these TMDLs is based on keeping the bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. FG 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 water bodies 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 water body under changing conditions, including FG.

Table 15. FG calculations

AU	TPDES Permit Number	Permittee	% Population Change (2016-2070)	Full Permitted Flow (MGD)	FG in Flow (MGD)	FG in WLA_{WWTF} (Billion *E. coli* cfu/day)	FG in WLA_{TRIB} (Billion Enterococci cfu/day)
1304A_01[a]	–	–	44.85%	–	0.05	0.239	0.066
1305B_01	WQ0010843001	Boling Municipal Water District	17.99%	0.133	0.024	0.114	0.032
1305A_01	WQ0010663001	Matagorda County WCID 6	17.99%	0.193	0.035	0.166	0.046
1305A_01	WQ0011768001	Jimmie Wayne Massey	17.99%	0.01	0.002	0.009	0.002
			Total	**0.336**	**0.111**	**0.528**	**0.146**[b]

[a]Hypothetical future WWTF in 1304A_01, with a projected future full permitted flow of 0.05 MGD

[b]WLA_{TRIB}, including the sum of FG in Segment 1305 and 1304A, will represent FG in 1304

Summary of TMDL Calculations

Table 16 summarizes the TMDL calculations for AUs 1304_01 and 1304A_01. The calculations were based on development of LDCs for each subwatershed, using the median flow (5% exceedance) in 0-10 percentile (high flow) range for the selected TCEQ SWQM station in each segment. Allocations are based on current geometric mean criteria set for Segment 1304 and Segment 1304A, at 35 cfu/100 mL Enterococci and 126 cfu/100 mL *E. coli* respectively.

Table 16. TMDL allocations for AUs 1304_01 and 1304A_01

AU	Indicator Bacteria	TMDL (Billion cfu/day)	MOS (Billion cfu/day)	WLA_{WWTF} (Billion cfu/day)	WLA_{SW} (Billion cfu/day)	LA (Billion cfu/day)	FG (Billion cfu/day)
1304_01	Enterococci	387.70	2.32	0.45	0.93	383.85	0.15
1304A_01	*E. coli*	268.66	13.43	0.00	9.08	245.91	0.24

The final step is to comply with 40 CFR 130.7, which includes combining the FG component with the WLA_{WWTF}. Table 17 presents the final TMDL with FG as part of the WLA_{WWTF}.

Table 17. Final TMDL allocations for AUs 1304_01 and 1304A_01

AU	Indicator Bacteria	TMDL (Billion cfu/day)	MOS (Billion cfu/day)	WLA_{WWTF} (Billion cfu/day)	WLA_{SW} (Billion cfu/day)	LA (Billion cfu/day)
1304_01	Enterococci	387.70	2.32	0.60	0.93	383.85
1304A_01	*E. coli*	268.66	13.43	0.24	9.08	245.91

Seasonal Variation

Federal regulations [40 CFR 130.7(c)(1)] require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. To evaluate potential seasonal differences, ambient monitoring data for Caney Creek were grouped into a cool season (November through March) and a warm season (May through September). Data collected in April and October were excluded, assuming those months are transitions between the two seasons. There was no discernable difference observed comparing seasons using a variety of statistical analyses (e.g., Wilcoxon rank analysis, ANOVA/Kruskal-Wallis). Seasonal variation was also addressed by using all available flow and bacteria records (covering all seasons) from the period of record used in LDC development for this project.

Public Participation

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.

A variety of stakeholder engagement methods were employed, beginning in 2016, to generate and maintain stakeholder interest. Direct email, letters, and phone calls were made to identified stakeholders to provide information and encourage participation in future meetings. Press releases and general emails were created by H-GAC using listservs and news outlets. Project webpages and brochures were developed to provide information, meeting notifications, and project updates. Stakeholders that could potentially be impacted by the TMDLs and their implementation plan (I-Plan) were contacted, and one-on-one meetings were held with some to foster interest, build support, and generate trust.

TCEQ held a series of meetings with stakeholders to get their advice on elements of the project and to keep them informed of progress. Notices of meetings were posted on TCEQ and H-GAC project webpages and on the TMDL program's online calendar. To ensure that absent or new stakeholders could get information about past meetings and pertinent material, the H-GAC project webpage[2] provides meeting summaries, presentations, ground rules, and documents produced for review.

Four public meetings were held on November 28, 2016, August 1, 2017, December 7, 2017, and November 1, 2018. The first public meeting was used to:

- Introduce TCEQ's basin approach to improving water quality.
- Review the status of water quality impairments in Basin 13.

[2] www.h-gac.com/community/water/tmdl/brazos-colorado-coastal-basin-tmdl-and-implementation-plan.aspx

- Discuss potential watershed management tools to improve water quality.
- Highlight water bodies to employ watershed management tools.

The second public meeting presented a characterization analysis of Caney Creek and review of supplemental monitoring of Caney Creek. The third meeting focused specifically on reviewing Caney Creek data and analysis as the foundation of the Caney Creek TSD and initiated the discussion on developing a Caney Creek Coordination Committee to explore development of a bacteria reduction plan. The fourth public meeting sought stakeholders for the Caney Creek Coordination Committee.

Outreach shifted to the Caney Creek Coordination Committee, which first met February 21, 2019. Additional meetings were held on July 11 and December 10, 2019. In these meetings, committee members discussed elements of the Caney Creek Bacteria I-Plan and were asked to consider potential bacteria reduction management measures. The Caney Creek TMDL watershed stakeholders are committed to additional meetings to complete the I-Plan to reduce sources of fecal bacteria.

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 TMDLs do not reflect or direct specific implementation by any single pollutant discharger, TCEQ certifies additional elements to the WQMP after the I-Plan is approved by the commission. Based on the TMDLs and I-Plan, 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 watershed may require some entities to obtain authorizations under the Phase II MS4 general permit. Where numeric effluent limitations are infeasible for MS4 entities, TCEQ normally establishes BMPs, which are a substitute for effluent limitations, as allowed by federal rules. When such practices are established in Phase II MS4 permit authorizations, TCEQ will not identify specific implementation requirements applicable to a specific TPDES stormwater permit or permit authorization through an effluent limitation update. Rather, TCEQ will revise its Phase II MS4 general permit during the renewal process as needed, to require a revised SWMP 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. 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.

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 these TMDLs address agricultural sources of pollution, 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 TMDLs and their 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. Method Used to Determine Population Projections in the Caney Creek Watershed

The following steps detail the method used to estimate the 2016 and projected 2070 populations in the subwatersheds within the Caney Creek watershed.

1) H-GAC's 2017 Regional Growth Forecast reports population projections each year. The forecast uses the US Census Bureau's American Community Survey (USCB, 2018) to arrive at population estimates via group census blocks.
2) The 2016 subwatershed populations were developed proportionally using the fractional area of the group census blocks within the subwatersheds.
3) H-GAC obtained TWDB's 2018 Regional Water Plan data for Wharton, Brazoria, and Matagorda counties. The plan projected county populations to the year 2070.
4) The county population figures were apportioned to each watershed based on the proportion of the county within the watershed.
5) The watershed population growth rate was calculated as the difference between the 2016 population estimate and the 2070 estimate.