Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Caney Creek Tidal

Assessment Unit: 1304_02

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Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
CAFO	concentrated animal feeding operation
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming unit
CGP	Construction General Permit
DAR	drainage-area ratio
ECHO	Enforcement and Compliance History Online
E. coli	*Escherichia coli*
EIH	Environmental Institue of Houston
EPA	(United States) Environmental Protection Agency
FDC	flow duration curve
FG	future growth
H-GAC	Houston-Galveston Area Council
I&I	inflow and infiltration
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	Multi-Sector General Permit
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic Database
SWMP	stormwater management program
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
TWRI	Texas Water Resources Institute
USCB	United States Census Bureau
USDA	United States Department of Agriculture

USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from wastewater treatment facilities
WWTF	wastewater treatment facility

Section 1. Introduction

1.1. Background

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of a water body included on a state's 303(d) list of impaired waters. The Texas Commission on Environmental Quality (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 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.

TCEQ first identified the bacteria impairment within Caney Creek Tidal assessment unit (AU) 1304_02, in the *2020 Texas Integrated Report of Surface Water Quality for the Clean Water Act Section 305(b) and 303(d)* (Texas Integrated Report; TCEQ, 2020). The impairment was identified again in the 2022 Texas Integrated Report (TCEQ 2022a), the latest United States Environmental Protection Agency (EPA)–approved edition. TCEQ first identified a bacteria impairment within the Caney Creek watershed to Caney Creek Tidal (1304_01) in the 2006 Texas Water Quality Inventory and 303(d) List (TCEQ, 2008).

This document will consider one bacteria impairment in one AU of Caney Creek Tidal. The impaired water body and its identifying AU number is shown below:

- Caney Creek Tidal – 1304_02

1.2. Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, TCEQ established the *Texas Surface Water Quality Standards* (TCEQ, 2018a). The Standards describe the limits for indicators that are monitored to assess the quality of available water for specific uses. TCEQ monitors and assesses water bodies based on these Standards and publishes the Texas Integrated Report list biennially.

The Standards are rules that do all of the following:

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

Standards are established to protect uses assigned to water bodies. The primary uses assigned to water bodies are:

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

Fecal indicator bacteria are used to assess the risk of illness during contact recreation (e.g., swimming) from ingestion of water. Fecal indicator bacteria are bacteria that are present in the intestinal tracts of humans and other warm-blooded animals. The presence of these bacteria in water indicates that associated pathogens from fecal wastes may be reaching water bodies, because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2018b). Enterococcus is a member of the fecal coliform bacteria group and is used in the state of Texas as the fecal indicator bacteria in tidal water bodies.

On Feb. 7, 2018, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2018a) and on May 19, 2020, EPA approved the categorical levels of recreational use and their associated criteria. Recreational use consists of several categories:

- **Primary contact recreation 1** – Activities that are presumed to involve a significant risk of ingestion of water (e.g., wading by children, swimming, water skiing, diving, tubing, surfing, handfishing, and the following whitewater activities: kayaking, canoeing, and rafting). It has a geometric mean criterion for Enterococci of 35 colony forming units (cfu) per 100 milliliters (mL) and an additional single sample criterion of 130 cfu per 100 mL.

- **Secondary contact recreation 1** – Activities that commonly occur but have limited body contact incidental to shoreline activity (e.g. fishing, canoeing, kayaking, rafting, and motor boating). These activities are presumed to pose a less significant risk of water ingestion than primary contact recreation 1. The geometric mean criterion for Enterococci is 175 cfu per 100 mL.

- **Noncontact recreation** – Activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic. The geometric mean criterion for Enterococci is 350 cfu per 100 mL.

AU 1304_02 falls within the portion of Caney Creek that is considered a tidal stream and has a primary contact recreation 1 use. The associated criterion for Enterococci is a geometric mean of 35 cfu per 100 mL.

1.3. Report Purpose and Organization

The Caney Creek Tidal TMDL project was initiated through a contract between TCEQ and the Houston-Galveston Area Council (H-GAC). This is the third TMDL for the Caney Creek watershed. The previous two TMDLs (Figure 1) were described in the *Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in the Caney Creek Watershed* (H-GAC, 2019).

The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired AU. This report contains:

- Information on historical data.
- Watershed properties and characteristics.
- Summary of historical bacteria data that confirm the Texas 303(d) listings of impairment due to presence of Enterococci.
- Development of a load duration curve (LDC).
- Application of the LDC approach for developing the pollutant load allocation.

Whenever it was feasible, the data development and computations for developing the LDC and pollutant load allocation were performed in a manner to remain consistent with the previously completed technical support document.

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

The Caney Creek watershed lies in southeast Texas. The 130-mile creek begins within the City of Wharton city limits and ends at the Intracoastal Waterway south of the town of Sargent (Figure 1). The 303 square mile watershed is located within portions of three Texas counties: Brazoria, Matagorda, and Wharton. The Caney Creek watershed comprises two classified segments, Caney Creek Tidal (1304) and Caney Creek Above Tidal (1305), and three unclassified water bodies, 1304A, 1305A, and 1305B (Figure 1).

The AU 1304_02 subwatershed is a small 2.57 square mile (1,643.79 acre) watershed within Caney Creek Tidal (Figure 1). The AU begins near the village of Cedar Lane and FM 521 and traverses approximately 7.51 miles southeastward to where the AU terminates and AU 1304_01 begins at Dead Slough. The subwatershed is rural, mostly made up of open pasture interspersed with scrub and shrub vegetation.

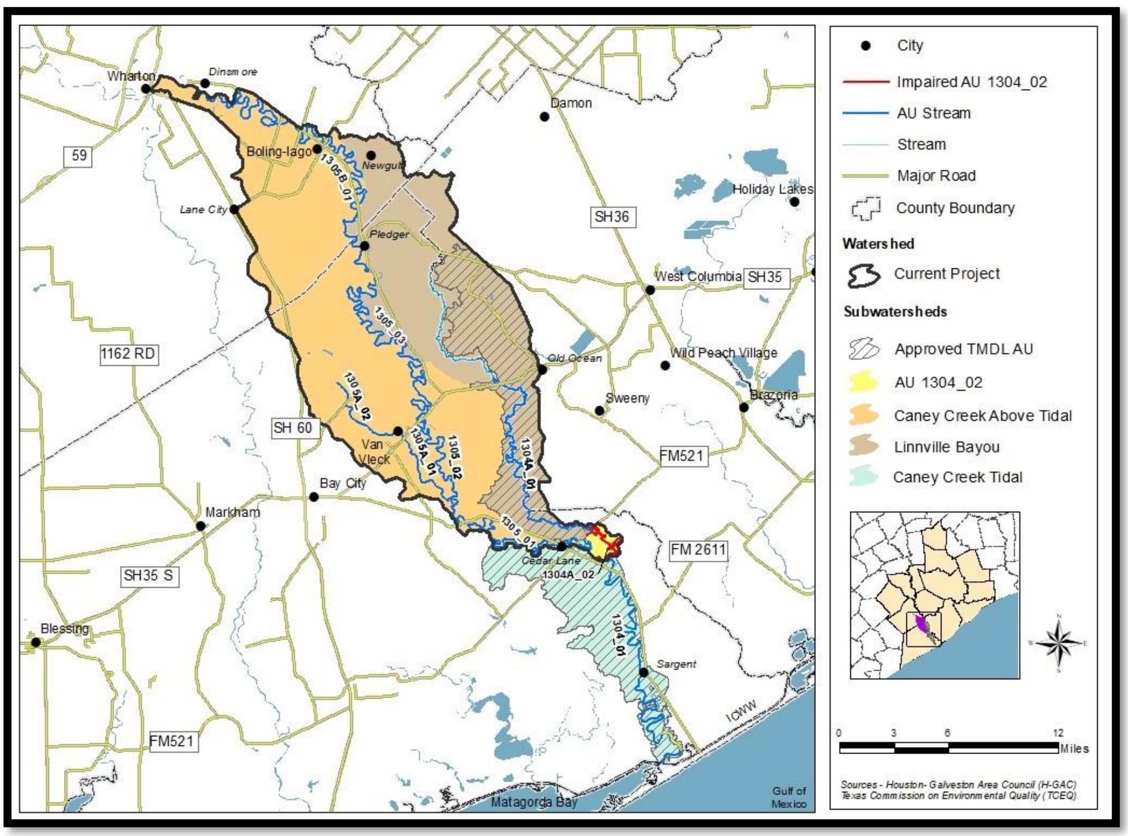

Figure 1. The Caney Creek watershed with two approved TMDLs

Collectively, the TMDL watershed for this report includes the AU 1304_02 subwatershed and its catchment area (Figure 2). The catchment area above AU 1304_02 includes the classified segment, Caney Creek Above Tidal, 1305 and the unclassified water bodies, Linnville Bayou, 1304A, Hardeman Slough, 1305A, and Caney Creek above Waterhole Creek, 1305B (Figure 2). Hardeman Slough and Caney Creek above Waterhole Creek will be considered part of Caney Creek Above Tidal for the remainder of this report.

The catchment area is approximately 261.61 square miles (167,432.78 acres). Like the AU 1304_02 subwatershed, the catchment area is mostly rural. Typical land cover within the catchment area includes open pasture, grasslands, and forest interspersed with small towns and villages. The cities, towns and villages found within the TMDL watershed include Wharton, Boling-Iago, Van Vleck, Lane City, Pledger, Cedar Lane, and Old Ocean.

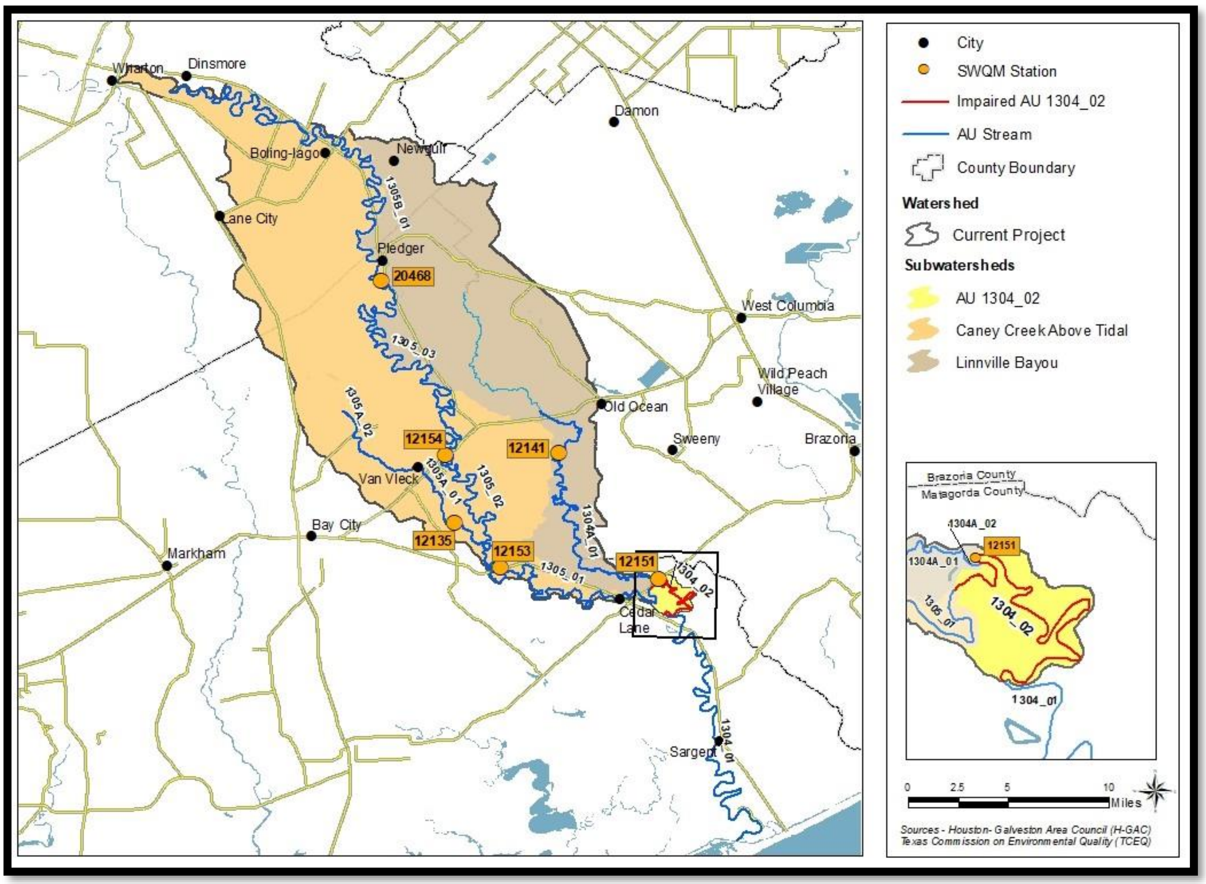

Figure 2. TMDL watershed with TCEQ surface water quality monitoring (SWQM) stations identified

The 2022 Texas Integrated Report (TCEQ, 2022a) provided the following water body and AU description:

- Segment 1304 (AU 1304_01 and 1304_02) – Caney Creek Tidal: From the confluence with the Intracoastal Waterway in Matagorda County to a point 1.9 kilometers (1.2 miles) upstream of the confluence of Linville Bayou in Matagorda County.
    - 1304_02 – From the confluence with Dead Slough to the upstream end of segment.

The remainder of this document, unless otherwise stated, will focus on the impairment found in AU 1304_02 and its catchment area. For greater detail on the Caney Creek watershed and the other impairments, please review the previous technical support document (H-GAC, 2019).

2.2. Review of Routine Monitoring Data

2.2.1. Analysis of Bacteria Data

Assessment data from the 2022 Texas Integrated Report (TCEQ, 2022a) is shown in Table 1, and identifies AU 1304_02 as impaired and nonsupporting of the contact recreation standard.

TCEQ SWQM Station 12151 has been actively monitored on the AU (Figure 2) for Enterococci since 2013. The TCEQ uses seven years of data to determine the contact recreation status. The seven-year geometric mean for the most recent reporting period is presented in Table 1. The geometric mean above the 35 cfu/100 mL standard criterion for tidal waterbodies.

Table 1. 2022 Texas Integrated Report summary

Watershed	AU	Parameter	TCEQ SWQM Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
Caney Creek Tidal	1304_02	Enterococci	12151	26	12/1/2013 to 11/30/2020	45.86

Prior to the 2020 Integrated Report, AU 1304_02 was listed as having a concern for elevated levels of indicator bacteria due to a lack of data sufficient to categorize the waterbody. A historic review of the SWQM data for the station for the period beginning in 2004 through 2020 returned 36 samples collected (Table 2). The maximum value found was 6,400 cfu/ 100 mL. The overall geometric mean for the historic record is 53.59 cfu/ 100 mL.

Table 2. Enterococci results for TCEQ SWQM Station 12151 for 2004 – 2020

TCEQ SWQM Station	Number of Enterococci Samples	Maximum Value (cfu/100 mL)	Geometric Mean (cfu/100 mL)
12151	36	6,400	53.59

Figure 3 presents the historic record for TCEQ SWQM Station 12151 for the period of 2004–2020. Included with the data is the current water quality standard, 35 cfu/100 mL. Between August 2007 and November 2013, no Enterococci data were collected.

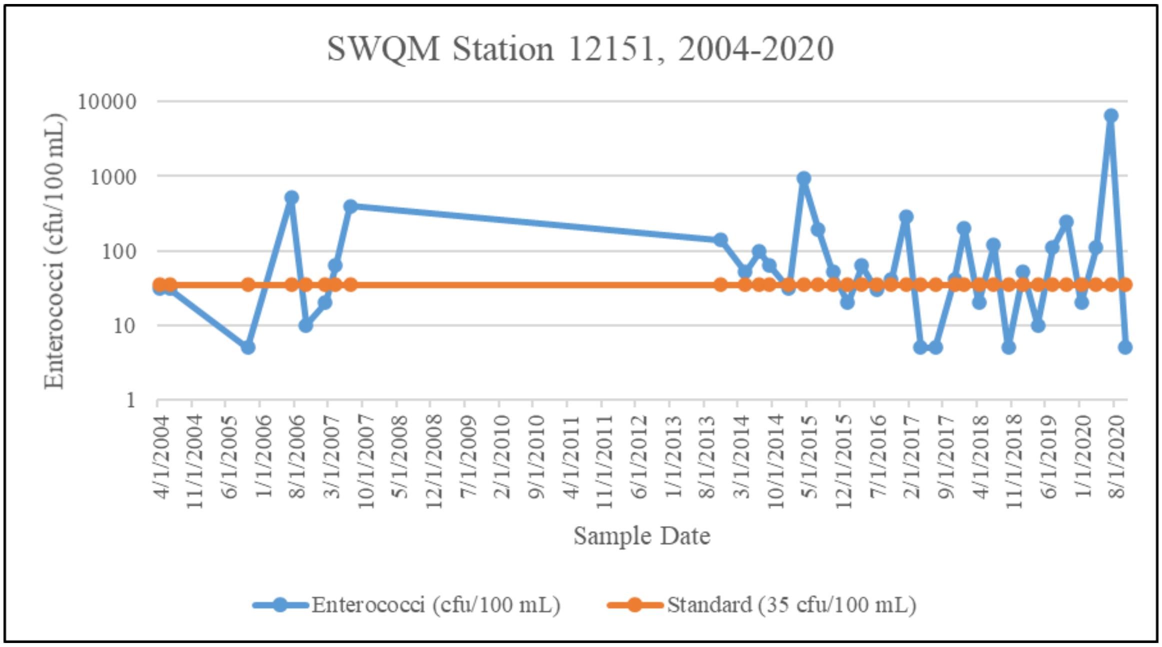

Figure 3. Enterococci measurements at TCEQ SWQM Station 12151

2.3. Climate and Hydrology

The National Oceanic and Atmospheric Administration (NOAA) has consistently operated a weather station in the City of Freeport near the TMDL watershed. From this station (GHCND:USC00413340), daily, monthly, and annual averages for weather parameters including temperature and precipitation have been assessed for the period from 2004 through 2020 (NOAA, 2022).

From this dataset, the estimate for mean annual precipitation in the region is 47.78 inches. This dataset includes measurements recorded during the statewide drought that peaked in 2011, when the measured annual rainfall was only 20.81 inches. The wettest year for this period was 2016, with 73.38 inches. Mean monthly precipitation ranged from a minimum of 2.27 inches in February to a maximum of 6.46 inches in September with a monthly average of 3.98 inches (Figure 4). The driest months typically occur in late winter or early spring. The wettest periods occur in summer and early fall, during hurricane season, where rainfall near or above 20 inches in a month is common.

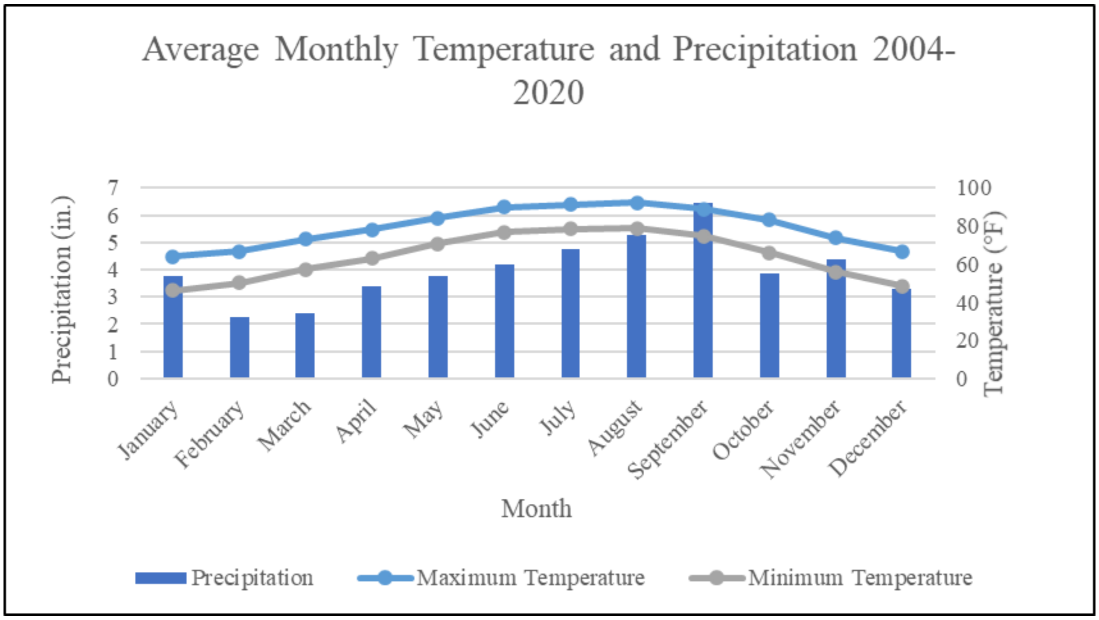

Figure 4. Average monthly temperature and precipitation (2004-2020) at NOAA Station GHCND:USC00413340

Temperatures in the TMDL watershed are consistent with that of a coastal subtropical region. Average annual minimum and maximum temperatures are 63.91 ˚F and 79.30 ˚F, respectively. Figure 4 includes maximum and minimum average monthly temperatures. As shown, December and January are the coolest months with the lowest monthly average minimum temperatures, 48.61 ˚F and 46.26 ˚F, respectively. July and August are the hottest months with the highest average maximum temperatures, 91.34 ˚F and 92.35 ˚F, respectively.

2.4. Population and Population Projections

As of 2020, the population of the TMDL watershed was approximately 9,274 (Table 3), based on H-GAC's Regional Forecast analysis of the United States Census Bureau (USCB) 2020 Decadal Census (H-GAC, 2022a). The area's population is anticipated to grow over the next fifty years by 21.78%, equal to 11,294. Much of the expected growth will likely take place in the Brazoria County portion of Linnville Bayou. The AU 1304_02 subwatershed has an estimated population of 74. Based on the rate of change in the AU watershed, the future population is estimated to be 85 in 2070.

To determine the change in population, data from the Texas Water Development Board's 2021 County Population Projection were reviewed (TWDB, 2019). Brazoria, Matagorda, and Wharton counties are, in 2070, anticipated to grow by 80%, 14%, and 24%, respectively. Those projected rates were then applied to the 2020 population based on the proportional area each county makes up within each watershed segment to determine the population in 2070. Projected 2070 populations were then added for each proportional area for the watershed segment and new population change rates were developed. The change rate was then used to develop the TMDL load calculation found in Section 4. Appendix A provides more detail on the steps to determine watershed populations in 2020 and projected population in 2070.

Table 3. 2020–2070 population projections

Subwatershed	2020	2070	% Change
1304_02	74	85	14.86%
Linnville Bayou	1,318	1,910	44.92%
Caney Creek Above Tidal	7,882	9,300	17.99%
Total	9,274	11,294	21.78%

2.5. Land Cover

As with many urban centers nationwide, areas surrounding the City of Houston have experienced an increase in development associated with urban sprawl, especially along transportation corridors. Due to its distance from Houston, the TMDL watershed has shown little evidence of this trend and is expected to see little development for the foreseeable future.

In 2018, H-GAC used LANDSAT imagery to categorize the Houston-Galveston region into 10 classes of land cover (H-GAC, 2018). The definitions for the ten land cover types are as follows:

1. **Developed - High Intensity** - Contains significant land area that is covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies < 20% of the landscape. Constructed materials account for 80% to 100% of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.

2. **Developed - Medium Intensity** - Contains area with mixture of constructed materials and vegetation or other cover. Constructed materials account for 50% to 79% of the total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.

3. **Developed - Low Intensity** - Contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. Constructed materials account for 21% to 49% of total area. This subclass commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.

4. **Developed - Open Space** - 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. Constructed surfaces account for less than 20% of total land cover.

5. **Cropland** - Contains areas intensely managed to produce annual crops. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

6. **Pasture/Grassland** - This is a composite class that contains both Pasture/Hay lands and Grassland/Herbaceous.

    a. ***Pasture/Hay*** - Contains 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 and not tilled. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

    b. ***Grassland/Herbaceous*** - Contains areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.

7. **Barren Land** - This class contains both barren lands and unconsolidated shore land areas.

    a. ***Barren Land*** - Contains areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10% of total cover.

    b. ***Unconsolidated Shore*** - Includes material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable.

8. **Forest/Shrubs** - This is a composite class that contains all three forest land types and shrub lands.

    a. ***Deciduous Forest*** - Contains areas dominated by trees generally greater than five meters tall and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.

b. ***Evergreen Forest*** - Contains areas dominated by trees generally greater than five meters tall and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.

c. ***Mixed Forest*** - Contains areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover. Both coniferous and broad-leaved evergreens are included in this category.

d. ***Scrub/Shrubs*** - Contains areas dominated by shrubs less than five meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes 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 and both palustrine and estuarine aquatic beds.

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

   b. ***Palustrine Aquatic Bed*** - Includes 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. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.

   c. ***Estuarine Aquatic Bed*** - Includes tidal wetlands and deep-water habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.

10. **Wetlands** - This is a composite class that contains all the palustrine and estuarine wetland land types.

   a. ***Palustrine Forested Wetlands*** - Includes tidal and nontidal wetlands dominated by woody vegetation greater than or equal to five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean derived salts is below 0.5%. Total vegetation coverage is greater than 20%.

b. ***Palustrine Scrub/Shrub Wetlands*** - Includes tidal and nontidal wetlands dominated by woody vegetation less than five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation coverage is greater than 20%. Species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions.

c. ***Palustrine Emergent Wetlands (Persistent)*** - Includes tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation cover is greater than 80%. Plants generally remain standing until the next growing season.

d. ***Estuarine Forested Wetlands*** - Includes tidal wetlands dominated by woody vegetation greater than or equal to five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.

e. ***Estuarine Scrub/Shrub Wetlands*** - Includes tidal wetlands dominated by woody vegetation less than five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.

f. ***Estuarine Emergent Wetlands*** - Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5% and that are present for most of the growing season in most years. Total vegetation cover is greater than 80%. Perennial plants usually dominate these wetlands.

The TMDL watershed remains largely undeveloped with most of the land cover being in agriculture production or a natural land cover type (Figure 5). Only 6.16% of the TMDL watershed is considered developed (Table 4). Most of the watershed was assessed as Pasture/Grassland at 39.04% with the next largest land cover types being that of Forest/Shrubs, Cropland, and Wetlands, at 18.91%, 18.36%, and 16.85%, respectively.

The AU 1304_02 subwatershed makes up only 0.97% of the TMDL watershed (Table 4). The land cover types represented in the AU subwatershed follow a similar pattern to that of the other subwatersheds (Figure 5). Here, the total of all developed land cover types is a small fraction of the land cover within the AU watershed at 2.22%. The largest land cover type is Pasture/Grassland at 51.70%. Forest/Shrubs, Wetlands, and Cropland make up the next largest land cover types at 14.94%, 13.82%, and 12.62%, respectively.

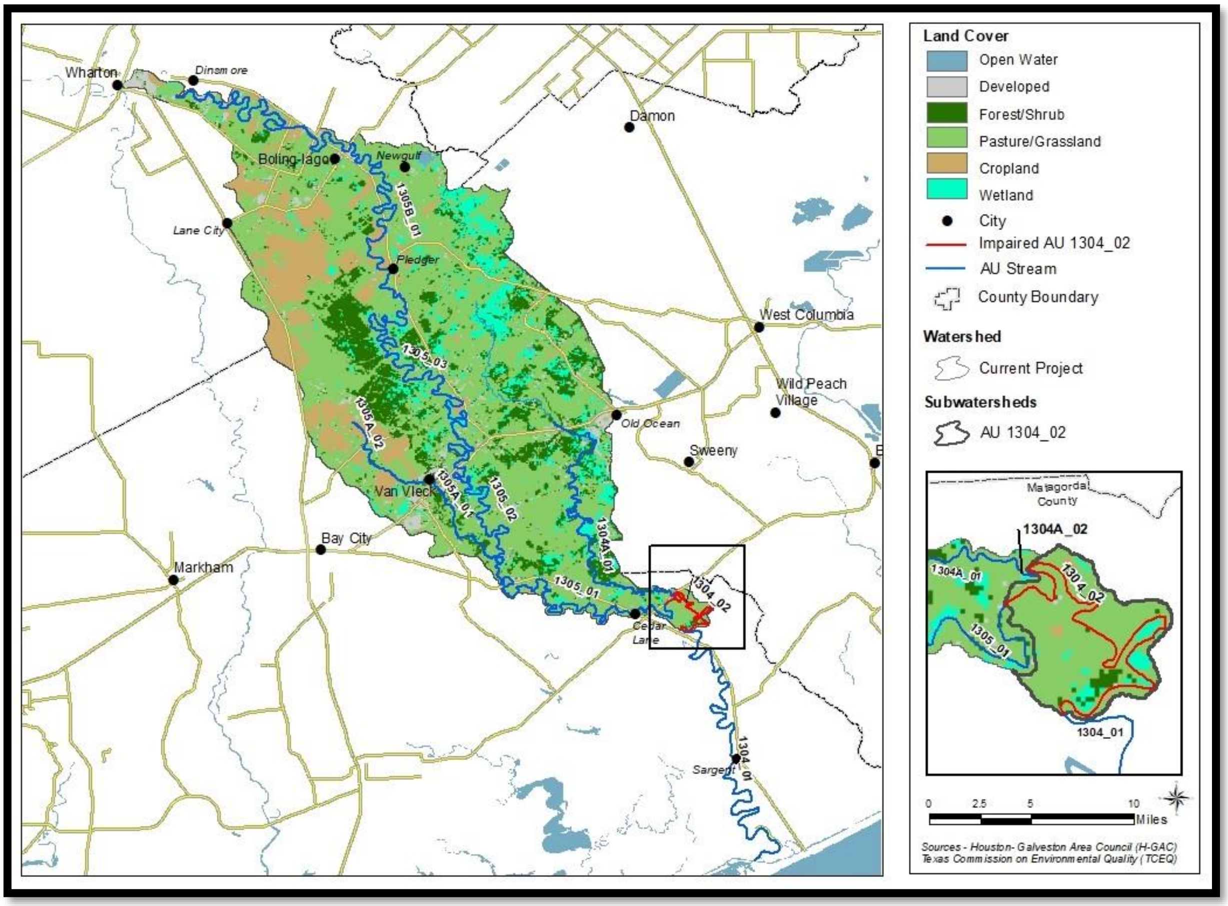

Figure 5. Land cover map showing classifications

For greater detail on land cover within the entire Caney Creek watershed, please review the previous technical support document (H-GAC, 2019).

Table 4. Land cover classification by area and percentage

Land Cover	Caney Creek Above Tidal		Linnville Bayou		AU 1304_02		Total	
Class Type	**Area (Acres)**	**% of Total Land Cover**	**Area (Acres)**	**% of Total Land Cover**	**Area (Acres)**	**% of Total Land Cover**	**Area (Acres)**	**% of Total Land Cover**
Open Water	140.61	0.14%	356.26	0.55%	64.66	3.93%	561.53	0.33%
Developed – High Intensity	401.68	0.39%	194.89	0.30%	0.00	0.00%	596.58	0.35%
Developed – Medium Intensity	269.19	0.26%	114.96	0.18%	0.00	0.00%	384.15	0.23%
Developed – Low Intensity	3,137.80	3.07%	1,621.94	2.49%	5.26	0.32%	4,765.00	2.82%
Developed – Open Space	2,795.61	2.73%	1,840.30	2.82%	31.28	1.90%	4,667.19	2.76%
Barren Land	241.83	0.24%	326.63	0.50%	12.46	0.76%	580.92	0.34%
Forest/Shrubs	16,189.69	15.83%	15,540.85	23.84%	245.60	14.94%	31,976.14	18.91%
Pasture/Grassland	41,257.05	40.35%	23,897.27	36.66%	849.92	51.70%	66,004.24	39.04%
Cropland	26,655.93	26.07%	4,186.10	6.42%	207.37	12.62%	31,049.40	18.36%
Wetlands	11,154.05	10.91%	17,110.12	26.25%	227.25	13.82%	28,491.42	16.85%
Total	102,243.45	100.00%	65,189.33	100.00%	1,643.79	100.00%	169,076.57	100.00%

2.6. Soils

Soils within the TMDL watershed are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (SSURGO) (USDA NRCS, 2015). The SSURGO data assigns different soils to one of seven possible runoff potential classifications or hydrologic groups. These classifications are based on the estimated rate of water infiltration when soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The four main groups are A, B, C, and D, with three dual classes (A/D, B/D, C/D). The SSURGO database defines the classifications below.

- **Group A** – Soils having high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
- **Group B** – Soils having a moderate infiltration rate when thoroughly wet. These consist of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- **Group C** – Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- **Group D** – Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high-water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.
- Soils with dual hydrologic groupings indicate that drained areas are assigned the first letter, and the second letter is assigned to undrained areas. Only soils that are in group D in their natural condition are assigned to dual classes.

Soil types found in the TMDL watershed include Groups B, C, D, and C/D. Groups B and D make up the largest percentage at 17% and 80%, respectively (Figure 6). Soil types within the AU 1304_02 subwatershed are made up entirely of Groups B and D at 55% and 45%, respectively. These moderate to slow infiltration rate alluvial clay, silt, and loam soils are consistent with the coastal areas of Texas.

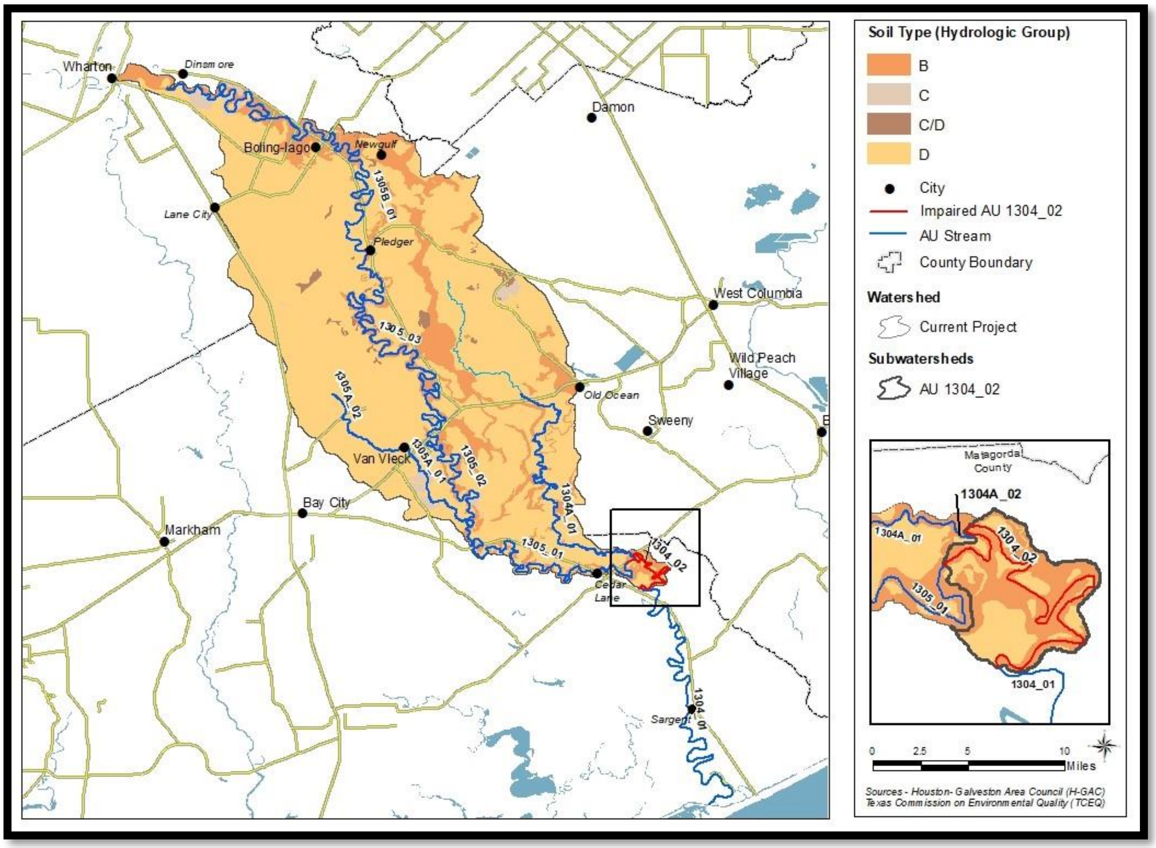

Figure 6. Hydrologic soil group categories

2.7. Potential Sources of Fecal Indicator Bacteria

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) program. Wastewater treatment facilities (WWTFs) and stormwater discharges from industrial sites, regulated construction activities, 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 permits.

Except for WWTFs, which receive individual wasteload allocations (WLAs) (see the “WLA” 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.

2.7.1. Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watershed include WWTF outfalls, stormwater discharges from regulated construction sites, and municipal separate storm sewer systems (MS4s).

2.7.1.1. Domestic and Industrial Wastewater Treatment Facilities

There are currently no WWTFs located within the AU 1304_02 subwatershed. However, to determine the TMDL for this AU, the contributing subwatersheds are included.

There are five distinct WWTF permittees in the TMDL watershed above AU 1304_02 that maintain wastewater discharge permits for nine distinct wastewater outfalls—Table 5, Figure 7 (TCEQ, 2022b)—based on EPA's Enforcement and Compliance History Online (ECHO; EPA, 2022), TCEQ's Central Registry (TCEQ, 2022c), and TCEQ's Outfall Data Layer (TCEQ, 2022d), last reviewed on May 1, 2022. All permits were in either Segment 1304A or 1305.

The two listed permittees (Table 5) WQ0000721000 (Phillips 66 Co.) and WQ0005147000 (Chevron Phillips Chemical Co.), do not have bacteria limits in their permits. Both permitees are located at the Old Ocean chemical refining area in the Linnville Bayou subwatershed. As neither discharges an appreciable amount of fecal bacteria, their outfalls will be excluded from further analysis. Both facilities hold stormwater permits and will be discussed further under section 2.7.1.3.

The remaining three permittees (Table 5) are domestic WWTFs in the Caney Creek Above Tidal subwatershed, which hold bacteria limits in their permits. One facility is found near Boling in AU 1305B_01. The other two are located near Van Vleck in AU 1305A_01 (Figure 7). The maximum permitted discharge flows in million gallons per day (MGD) from each facility were recorded for use in development of the TMDL loading calculation. A review of ECHO did not show a permit violation for fecal indicator bacteria between June 2017 and May 2022 for any of the three facilities (EPA,2022).

Permit WQ0003891000 (Wharton County Generation, LLC) is in the northern part of the Linnville Bayou watershed but discharges outside of the TMDL watershed to Segment 1302 and is not included in Table 5.

Table 5. Permitted domestic and industrial WWTFs within the TMDL watershed

AU	TPDES/NPDES[a] Number	Facility Name	Permittee	Outfall Number	Bacteria Limits (cfu/100 mL)	Primary Discharge Type	Daily Average Flow – Permitted Discharge (MGD)	Daily Average Flow – Recent Discharge (MGD)[b]
1304A_01	WQ0000721000/ TX00007536	Sweeny Refinery and Petrochemical Complex	Phillips 66 Co.	2	No	Industrial	Continuous/Flow Variable	–
1304A_01	WQ0000721000/ TX00007536	Sweeny Refinery and Petrochemical Complex	Phillips 66 Co.	6	No	Industrial	Continuous/Flow Variable	–
1304A_01	WQ0000721000/ TX00007536	Sweeny Refinery and Petrochemical Complex	Phillips 66 Co.	10	No	Industrial	Continuous/Flow Variable	–
1304A_01	WQ0000721000/ TX00007536	Sweeny Refinery and Petrochemical Complex	Phillips 66 Co.	13	No	Industrial	0.216	0.083
1304A_01	WQ0005147000/ TX00135917	Chevron Phillips Chemical Sweeny Old Ocean Plant	Chevron Phillips Chemical Co. LP	1	No	Industrial	Intermittent/Flow Variable	–
1304A_01	WQ0005147000/ TX00135917	Chevron Phillips Chemical Sweeny Old Ocean Plant	Chevron Phillips Chemical Co. LP	3	No	Industrial	Intermittent/Flow Variable	–
1305A_01	WQ0010663001/ TX00024155	Van Vleck WWTF	Matagorda County WCID 6	1	126 Escherichia coli (E. coli)	Domestic	0.193	0.080
1305A_01	WQ0011768001/ TX00070297	Oak Hollow WWTF	Massey Jimmie Wayne	1	126 (E. coli)	Domestic	0.01	0.0001
1305B_01	WQ0010843001/ TX00033910	Boling WWTF	Boling MWD	1	126 (E. coli)	Domestic	0.133	0.066

[a] NPDES: National Pollutant Discharge Elimination System

[b] Reflects discharges available from June 2017 – May 2022 (EPA, 2022)

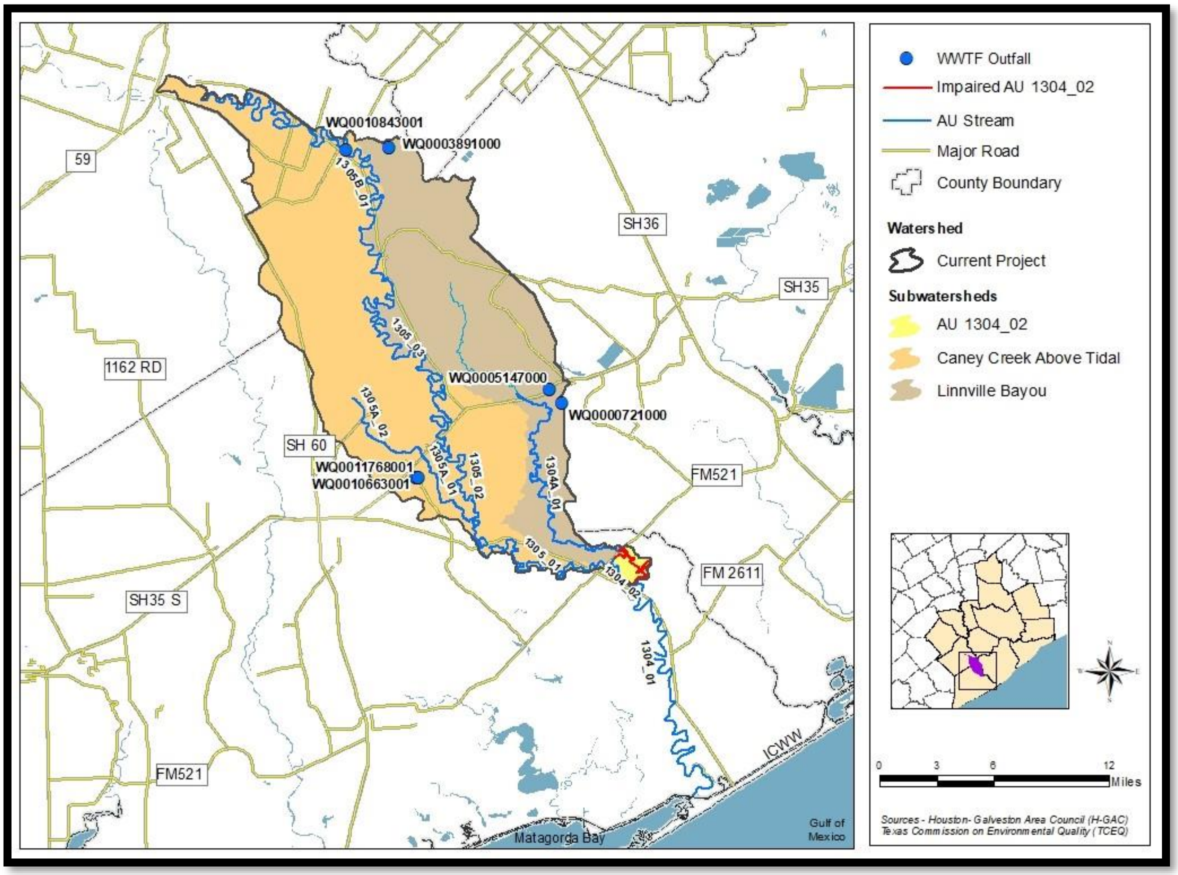

Figure 7. WWTFs in the TMDL watershed

2.7.1.2 TCEQ/TPDES General Wastewater Permits

Certain types of activities must be covered by one of several TCEQ/TPDES wastewater general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production
- TXG340000 – petroleum bulk stations and terminals
- TXG640000 – conventional water treatment plants
- TXG670000 – hydrostatic test water discharges
- 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)

Discharges related to the following general permit authorizations are not expected to affect the bacteria loading in the TMDL watershed and were excluded from this investigation:

- TXG640000 – conventional water treatment plants
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG870000 – pesticides (application only)
- WQG100000 – wastewater evaporation

A review of active general permit coverage via TCEQ's Central Registry (TCEQ, 2022c) for the TMDL watershed as of May 1, 2022, found no active general wastewater permits within the AU 1304_02 subwatershed. However, the TMDL must account for the contributions to watersheds upstream of the AU.

One concrete production facility was found in the Linnville Bayou subwatershed. The area under permit was estimated by reviewing county appraisal parcel data and/or importing the location information associated with the authorization into a geographic information system and measuring the disturbed area. The estimated area, 4.86 acres, will be used to calculate the TMDL.

One concentrated animal feeding operation (CAFO) was found in the Caney Creek Above Tidal subwatershed (Wharton County Foods LLC, a poultry facility). CAFOs are required to contain wastes on site and would not be considered a source of discharge to the water body. However, containment failures, particularly during heavy rainfall and flooding, do happen and can cause releases of fecal wastes to segment 1305.

No other general wastewater permits were found during the review.

2.7.1.3. 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, stormwater discharges associated with regulated industrial activities, and construction activities.
2. Stormwater runoff not subject to regulation.

TPDES MS4 Phase I and II rules require municipalities and certain other entities in urbanized areas to obtain permit coverage for their stormwater systems. A regulated MS4 is a publicly owned system of conveyances and includes ditches, curbs, gutters, and storm sewers that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized communities with populations of 100,000 or more based on the 1990 United States Census, while the Phase II General Permit regulates other MS4s within a USCB defined urbanized area.

The purpose of an MS4 permit is to reduce discharges of pollutants in stormwater to the "maximum extent practicable" by developing and implementing a stormwater management program (SWMP). The SWMP describes the stormwater control practices that the regulated entity will implement, consistent with permit requirements, to minimize the discharge of pollutants. MS4 permits require that SWMPs specify the best management practices to meet several minimum control measures (MCMs) that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving water bodies. Phase II MS4 MCMs include all of the following:

- Public education, outreach, and involvement.
- Illicit discharge detection and elimination.
- Construction site stormwater runoff control.
- Post-construction stormwater management in new development and redevelopment.
- Pollution prevention and good housekeeping for municipal operations.
- Industrial stormwater sources (only required for MS4s serving a population of 100,000 people or more in the urban area).
- Authorization for construction activities where the small MS4 is the site operator (*optional*).

Phase I MS4 individual permits have their own set of MCMs that are similar to the Phase II MCMs, but Phase I permits have additional requirements to perform water quality monitoring and implement a floatables program.

Discharges of stormwater from a Phase II MS4 area, regulated industrial facility, construction area, or other facility involved in certain activities must be authorized under the following TCEQ/TPDES general permits:

- TXR040000 – Phase II MS4 General Permit for MS4s located in urbanized areas (discussed above)
- TXR050000 – Multi-Sector General Permit (MSGP) for industrial facilities
- TXR150000 – Construction General Permit (CGP) for construction activities disturbing more than one acre or are part of a common plan of development disturbing more than one acre

A review of active stormwater coverage via TCEQ's Central Registry (TCEQ, 2022c) for the TMDL watershed was made on May 1, 2022. No active MS4 permits were discovered for the TMDL watershed based on this review.

The TCEQ Central Registry was also reviewed May 1, 2022 for MSGP authorizations found within the TMDL watershed (TCEQ, 2022c). No active MSGP authorizations were found within the AU 1304_02 subwatershed, but four active MSGP authorizations were found within the catchment area upstream of the AU. To determine the MSGP authorization area under permit, county parcel data was reviewed for the permittee. Based on that review, there was a total of 2,079.23 acres under MSGP authorizations within the catchment area of the TMDL watershed, 1,327.68 acres in Linnville Bayou subwatershed and 751.55 acres in Caney Creek Above Tidal subwatershed. The acres under the MSGP authorizations were used to calculate the TMDL.

CGP authorizations were reviewed covering a five-year period via the TCEQ Central Registry on May 1, 2022 (TCEQ, 2022c). There were no authorizations found for the AU 1304_02 subwatershed. Seven CGP authorizations were found in the catchment area of the TMDL watershed for the period of 2017-2021. Five authorizations were found in Linnville Bayou subwatershed and two in Caney Creek Above Tidal subwatershed.

CGP authorizations are required when one acre or more of land is disturbed during construction. Construction activities found in the TMDL watershed change over time and the permit data found via the TCEQ Central Registry is only considered accurate for the date the data was accessed. Within the TCEQ Central Registry, CGP authorizations record disturbed areas as “Area Disturbed” acreages in the permit field. The acres recorded, due to the variable nature of these permits, 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.

The annual average of the total disturbed area is 678.12 acres, 81.12 acres within the Linnville Bayou subwatershed and 597 acres within the Caney Creek Above Tidal subwatershed. These acreages were used to calculate the TMDL.

2.7.1.4. 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 worsen the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

No WWTFs or collections systems are located within the AU 1304_02 subwatershed. For the three WWTFs found upstream of the AU, no SSOs were reported between 2016 and 2021 (TCEQ, 2022e).

2.7.1.5. Dry Weather Discharges/Illicit Discharges

Pollutant loads can enter water bodies 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 TXR040000 for Phase II MS4s as “Any discharge to a municipal separate storm sewer system that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities.” Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) 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.
- 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.
- A failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.7.2. 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. Potential sources, detailed below, include wildlife, feral hogs, various agricultural activities, agricultural animals, urban runoff not covered by a permit, failing on-site sewage facilities (OSSFs), and domestic pets.

2.7.2.1. Wildlife and Unmanaged Animals

Fecal 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 and feral hogs. Wildlife and feral hogs are naturally attracted to riparian corridors of water bodies. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Wildlife and feral hogs also leave feces on land, where they may be washed into nearby water bodies by rainfall runoff.

Most avian and mammalian wildlife, including invasive species, are difficult to estimate, as long-term monitoring data or literature values indicating historical baselines are lacking. However, the White-Tailed Deer Program of the Texas Parks and Wildlife Department (TPWD) estimates deer populations for their Deer Management Units. In the ecoregion surrounding Caney Creek for Deer Management Unit 10, TPWD deer population estimates recorded from 2008 through 2019 average one deer for every 25.27 acres (TPWD, 2020). By applying this factor to the acreage in the TMDL watershed, the white-tailed deer population is estimated to be 6,691 (Table 6).

Table 6. Estimated deer population

Subwatershed	Acres	Deer Population
1304_02	1,643.79	65
Linnville Bayou	65,189.33	2,580
Caney Creek Above Tidal	102,243.45	4,046
Total	169,076.57	6,691

Feral hogs are a non-native, invasive species, which likely impact the watershed with fecal waste contamination. Like deer, factors for estimating feral hog populations based on land area are available. These factors vary depending on land cover types and range between 8.9 and 16.4 hogs per square mile (Timmons et al., 2012). Feral hog population estimates may be weighted more heavily in riparian areas where animals are protected from the stresses associated with development and have more direct access to water resources. Considering these factors, feral hog populations were estimated to be 8.9 per square mile in Developed – Low Intensity, Barren Lands, and Cropland ("Low Quality"); 16.4 per square mile in Developed – Open Space, Pasture/Grassland, Forest/Shrubs and Wetlands ("High Quality"); and no hogs in other developed areas or open water. Using these assumptions, the total feral hog population of the TMDL watershed is estimated to be 3,867 (Table 7).

Table 7. Estimated feral hog population

Subwatershed	Low Quality (acres)	Feral Hogs	High Quality (acres)	Feral Hogs	Total
1304_02	225.08	3	1,354.05	35	38
Linnville Bayou	6,134.68	85	58,388.53	1,496	1,582
Caney Creek Above Tidal	30,035.56	418	71,396.40	1,830	2,247
Total	36,395.32	506	131,138.99	3,360	3,867

2.7.2.2. Unregulated Agricultural Activities and Domesticated Animals

Several agricultural activities that do not require permits can be potential sources of fecal bacteria loading. In Table 8, estimates of livestock in the TMDL watershed are shown. Livestock numbers from the 2017 Census of Agriculture are provided at the county level for Brazoria, Matagorda, and Wharton counties, collected by the USDA (USDA, 2019). The county livestock numbers were reviewed by Texas State Soil and Water Conservation Board (TSSWCB) staff and were distributed equally across livestock and farm operations in pasture and grassland land cover types within the county. To determine the number of livestock within each subwatershed, the number of livestock to acre was calculated for each county and then that stocking rate was applied to the subwatershed based on the proportion of the county found within the subwatershed. Livestock numbers are not used to develop the TMDL loading allocation.

Table 8. Estimated livestock populations

Subwatershed	Cattle and Calves	Hogs and Pigs	Horses	Sheep and Goats
1304_02	190	1	3	3
Linnville Bayou	6,177	173	235	251
Caney Creek Above Tidal	9,244	47	181	171
Total	15,611	221	419	425

Fecal matter from dogs and cats is transported to water bodies by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 9 summarizes the estimated number of dogs and cats in the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household according to data from the American Veterinary Medical Association (AVMA) 2017-2018 United States Pet Statistics (AVMA, 2018). The number of households in the watershed was estimated using USCB 2020 census data, with the average household size of 2.71. The actual contribution and significance of bacteria loads from pets reaching the water bodies of the watershed is unknown.

Table 9. Estimated pet population

Subwatershed	Estimated Households	Estimated Dog Population	Estimated Cat Population
1304_02	27	17	12
Linnville Bayou	487	299	223
Caney Creek Above Tidal	2,910	1,787	1,330
Total	3,424	2,103	1,565

2.7.2.3. 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) and 2) aerobic systems that have an aerated holding tank and often an above ground sprinkler system for distributing the liquid. In simplest terms, household waste flows into the septic tank or aerated tank, where solids settle out. The liquid portion of the water flows to the distribution system, which may consist of buried perforated pipes or 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 contribute virtually no fecal bacteria to surface waters. For example, Weiskel et al. (1996) reported that less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system. Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The TMDL watershed is located within the Region IV area, which has a reported failure rate of about 12%, providing insights into expected failure rates for the area.

Some OSSFs in the watershed are operated under permit; however, some units are unregistered or not consistently reported. For the purposes of this report, all OSSFs will be treated as unregulated sources of fecal waste due to the nature of their permits, lack of reported data, and diffuse nature.

Within the TMDL watershed, 599 permitted OSSFs have been documented (Table 10; H-GAC, 2022b). Nonregistered OSSF locations were estimated using H-GAC's geographic information database of potential OSSF locations (H-GAC, 2022c) in the Houston-Galveston area using known OSSF locations, 911 addresses, and WWTF service boundaries. For the TMDL watershed there is an estimated additional 1,642 nonregistered OSSF units. Figure 8 presents the permitted and nonregistered OSSF locations within the TMDL watershed.

Table 10. Estimated OSSFs

Subwatershed	Permitted	Nonregistered	Total
1304_02	2	4	6
Linnville Bayou	140	442	582
Caney Creek Above Tidal	457	1,196	1,653
Total	599	1,642	2,241

OSSFs can be a source of fecal waste when not sited or functioning properly, especially when they are in close proximity to waterways. Many factors including soil type, design, age, and maintenance can influence the likelihood of an OSSF failure. By applying the estimated 12% failure rate to the 2,241 OSSFs estimated within the TMDL watershed, 269 OSSFs are projected to be failing.

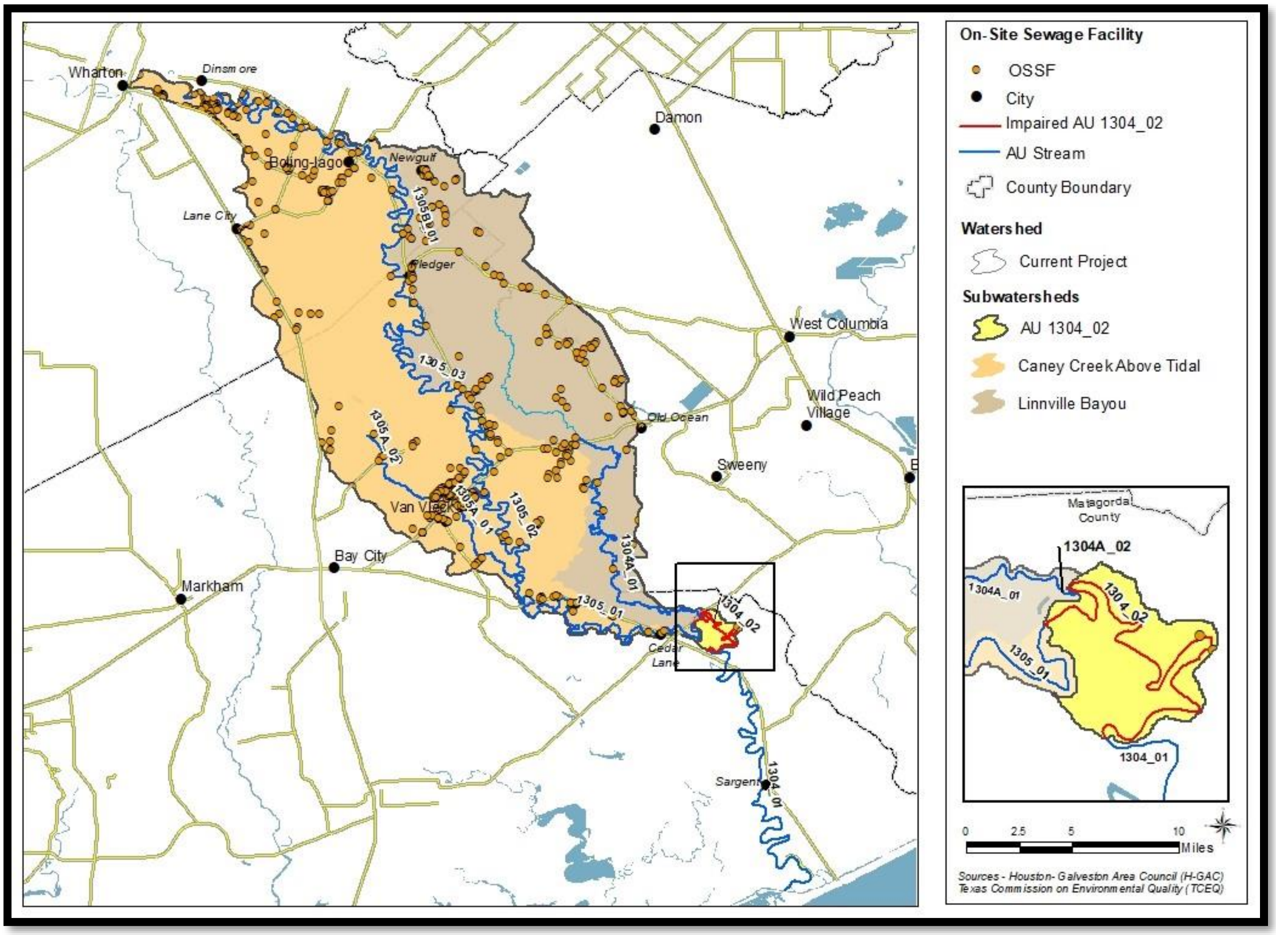

Figure 8. Permitted OSSFs

2.7.2.4. 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 (such as warm temperature). Fecal organisms from improperly treated effluent can survive and replicate during their transport in pipe networks, and they can survive and replicate in organic-rich materials such as improperly treated compost and sewage sludge (or biosolids). While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less well understood. Both replication and die-off are instream processes and are not considered in the bacteria source loading estimates in the TMDL watershed.

Section 3. Bacteria Tool Development

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

3.1. Tool Selection

The LDC method allows for the estimation of existing and allowable loads by using the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment.

Texas and other states have successfully used the LDC method to develop TMDLs which have been accepted by the regulatory community due to the method's simplicity and ability to address information limitations commonly found with bacteria TMDLs. The LDC has become recommended as part of a three-tiered approach by the appointed bacteria task force driven by TCEQ and the TSSWCB (TWRI, 2007). More recently, Texas began using modified LDCs for TMDLs in tidal waters with the Mission and Aransas Bay TMDL (Hauck *et al*., 2013) and Tres Palacios Creek Tidal TMDL (Hauck *et al*., 2017).

3.2. Data Resources

To complete LDCs, daily streamflow and fecal indicator bacteria data are required. With the exception of daily streamflow, Caney Creek data resource availability was sufficient to perform LDC analysis in AU 1304_02. Streamflow will be discussed further below to address this data limitation.

All the required ambient water quality data (Enterococci) were adequately available through the Surface Water Quality Monitoring Information System (SWQMIS) for the period of Jan. 1, 2004, to Dec. 31, 2020, though as noted previously, during the period between August 2007 and November 2013, data was limited at TCEQ SWQM Station 12151. SWQMIS is a database that serves as the repository for TCEQ surface water quality data for the state of Texas. All data used for these analyses were collected under a TCEQ-approved Quality Assurance Project Plan. Qualified data (data added to SWQMIS with "qualifier" codes that identify quality, sampling, or other problems that may render the data unsuitable) were excluded from the download. All data for TCEQ SWQM Station 12151 were combined into a working data set for LDC development.

Daily stream flow records are an essential component of LDC development. Lack of available daily stream flow data for the period of Jan. 1, 2004, to Dec. 31, 2020, in the Caney Creek mainstem was an issue. However, a daily stream flow gage was installed at TCEQ SWQM Station 12153 (Figure 9) by the Environmental Institute of Houston (EIH) in Segment 1305_01. Flow data was retrieved generated for the period between Feb. 14, 2017, and Nov. 20, 2019, through EIH.

To augment the daily flow observed at TCEQ SWQM Station 12153 to cover the period 2004–2020, daily flow records from a nearby waterbody were acquired. To be usable, the identified stream should be of a similar watershed size, volume, and land cover makeup (agriculture, industry, etc.) and located close to Caney Creek to mitigate for weather differences. These comparisons led to the selection of United States Geological Survey (USGS) gage 08162600 on Tres Palacios Creek Above Tidal (Figure 9), Segment 1502. The size of the catchment areas between the USGS station and TCEQ SWQM Station 12153 are relatively similar (Table 11). At of the time of this report, USGS streamflow gage 08162600 is still active.

Table 11. Catchment area comparison between Caney Creek at TCEQ SWQM Station 12153 and Tres Palacios at USGS Gage 08162600

Catchment	Area (Square Miles)
USGS Gage Station 08162600	154.6
TCEQ SWQM Station 12153	153.04

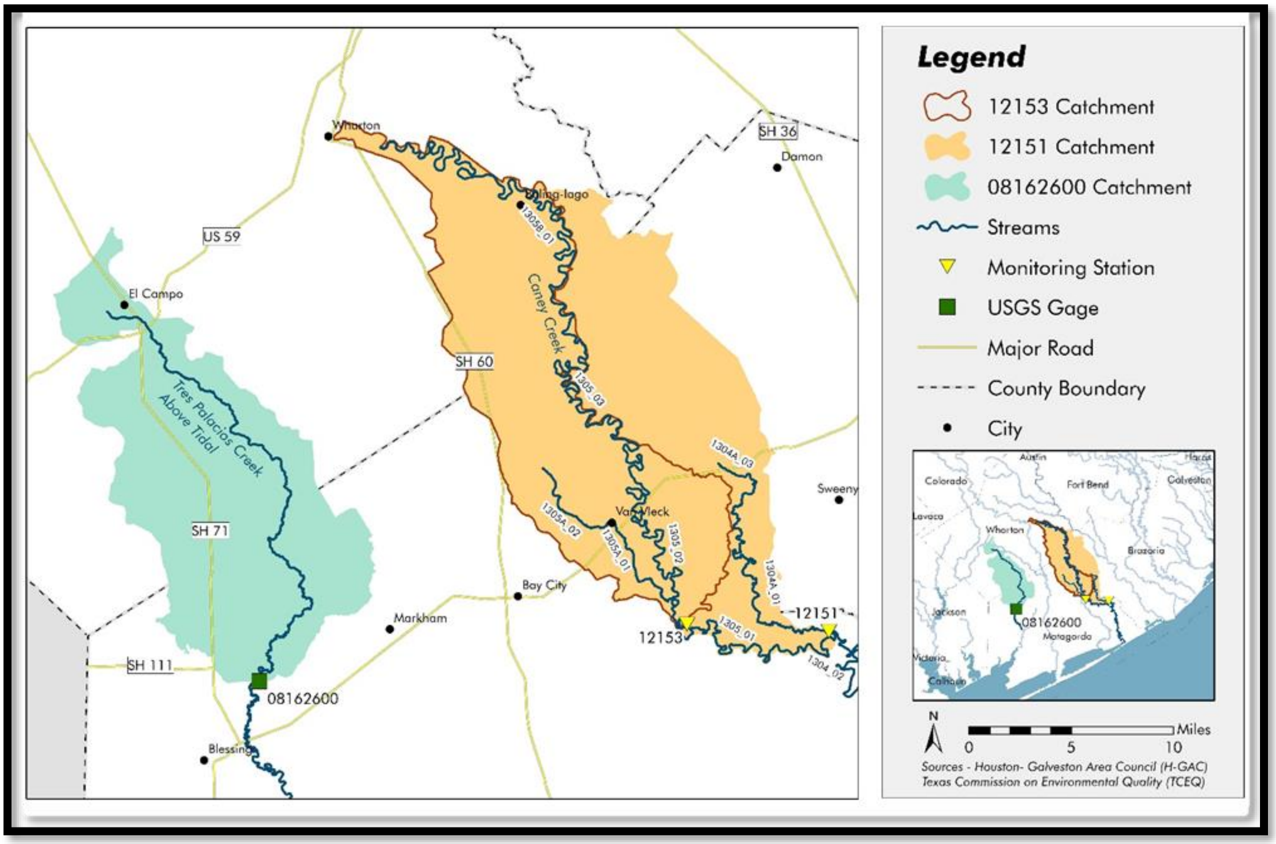

Figure 9. Catchment area comparison between the Tres Palacios Creek Above Tidal and the TMDL watershed

3.3. Method for Developing Flow Duration and Load Duration Curves

To develop the flow duration curve (FDC) and LDC, the previously discussed data resources were used in the following sequential steps.

- Step 1: Determine the hydrologic period of record to be used in developing the FDC.
- Step 2: Determine the stream location for which FDC and LDC development is desired.
- Step 3: Develop daily streamflow record at desired location.
- Step 4: Develop FDC at the desired stream location, segmented into discrete flow regimes.
- Step 5: Develop allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- Step 6: Superimpose historical bacteria data on the allowable bacteria LDC.

More information explaining the LDC method may be found in Cleland (2003) and EPA (2007).

3.3.1. Step 1: Determine Hydrologic Period

A period of 17 years between January 2004 and December 2020 is a sufficient timeframe to cover both drought and flood years as referenced in Section 2.3.

3.3.2. Step 2: Determine Desired Stream Location

Data from TCEQ SWQM Station 12151 will be used to develop the TMDL for AU 1304_02. TCEQ SWQM Station 12151 is located within the impaired AU and though sparsely monitored prior to 2013, TCEQ SWQM Station 12151 has been actively monitored for Enterococci since that time. Because there are no established USGS gages in the TMDL watershed covering the entire timeframe, USGS gage 08162600 on the Tres Palacios Creek Above Tidal near Midfield, Texas was used to augment flow for the EIH gage at TCEQ SWQM Station 12153 in Caney Creek Above Tidal.

3.3.3. Step 3: Develop Daily Streamflow Record at Desired Location

The USGS gage records were "naturalized" by correcting the additions of WWTF discharge and withdrawals of upstream water rights diversions. As used herein, naturalized flow is referring to the flow without the additions of permitted discharges and withdrawals from water rights, i.e., the flow that would occur in response to precipitation, evapotranspiration, near surface geology, soils, land cover of the watershed, and other factors. The naturalized daily streamflow records were developed from extant USGS records.

Only one outfall permitted to discharge to the Tres Palacios Creek Above Tidal was found above USGS flow gage 08162600. The estimated daily discharge monitoring report reported by the City of El Campo for the time period of 2015 to 2019 from the WWTF outfall (Table 12) was subtracted from the daily gage streamflow records. This resulted in an adjusted streamflow record with the point source discharge influence removed.

Table 12. Tres Palacios Creek Above Tidal permitted discharges

TPDES Number	NPDES Number	Permittee	Average Daily Flow (MGD)
WQ0010844001	TX0021474	City of El Campo	1.135

Next, water right consumptions (i.e., the balance between diverted amount and returned flow amount) were calculated for the period of 2009 to 2020 using the Texas Water Rights Viewer (TCEQ, 2022f). The calculated daily average consumption values from all water rights were added back into the adjusted streamflow records, resulting in an adjusted streamflow record with upstream water rights diversion influences removed.

The EIH-generated flow curve at TCEQ SWQM Station 12153 was converted into daily values by correlating the monthly measured flow at the station with the 15-minute height recordings. The next step was to find a relationship between daily flow patterns of the two streams, at TCEQ SWQM Station 12153 in Caney Creek and Tres Palacios Creek Above Tidal, by constructing a linear regression model. For the regression model, only flow records between Feb. 14, 2017, and Nov. 20, 2019, for both watersheds, were considered. The linear regression estimation was performed using Statistical Analysis Software. Based on the estimated regression relationship, the daily flow values for TCEQ SWQM Station 12153 in Caney Creek for the period of Jan. 1, 2004, through Dec. 31, 2020, were derived.

The daily freshwater flow values at TCEQ SWQM Station 12151 were calculated based on the adjusted flow values of USGS gage 08162600 and the drainage-area ratio (DAR) method. To compute the DAR, the drainage area or catchment above TCEQ SWQM Station 12153 was compared with the catchment area contributing to TCEQ SWQM Station 12151 (Table 13, Figure 9). This DAR, 1.71, is then applied to the derived daily streamflow measurements for TCEQ SWQM Station 12153 to determine the estimated daily flow at TCEQ SWQM Station 12151.

Table 13. DAR for TCEQ SWQM Stations in the TMDL watershed

TCEQ SWQM Station	Area (Square Miles)	DAR
12153	153.04	1
12151	261.35	1.71

Following application of the DAR, the full permitted flows from WWTFs located within the TMDL watershed (Table 5) were added to the streamflow record along with future growth (FG) flows (calculated in Section 4.7.4) that account for the probability that additional flows from WWTF discharges may occur as a result of population increases. Additionally, water rights diversions in the catchment area below TCEQ SWQM Station 12153 were removed prior to proceeding to the next step.

As AU 1304_02 is considered a tidal waterbody, constructing a modified LDC was considered (ODEQ, 2006). At this point in developing the daily flow, salinity values would be evaluated. After a review of salinity for TCEQ SWQM Station 12151, the values were found to be too low for tidal inflows to negatively influence LDC development, therefore, calculating a modified LDC was not necessary.

3.3.4. Steps 4 through 6: Flow Duration and Load Duration Curves

FDCs and LDCs are graphs that visualize the percentage of time during which a value of flow or load is equaled or exceeded. To develop a FDC for a location, all of the following steps were taken in the order shown:

- Order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (one for the highest flow, two for the second highest flow, and so on).

- Compute the percentage of days each flow was exceeded by dividing each rank by the total number of data points plus one.
- Plot the corresponding flow data against exceedance percentages.

Further, when developing an LDC:

- Multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for Enterococci (geometric mean of 35 cfu/100 mL) and by a conversion factor (2.44658×10^9), which gives you a loading unit of cfu/day.
- Plot the exceedance percentages, which are identical to the value for the streamflow data points, against the geometric mean criterion for Enterococci.

The resulting curve represents the maximum daily allowable loadings for the geometric mean criterion. The next step was to plot the measured Enterococci data on the developed LDC using the following steps:

- Compute the daily loads for each sample by multiplying the measured Enterococci concentrations on a particular day by the corresponding streamflow on that day and the conversion factor (2.44658×10^9).
- Plot on the LDC for each station the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads (Enterococci concentrations times daily streamflow) display the frequency and magnitude at which measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above a maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below a curve show compliance.

3.4. Flow Duration Curve for the TMDL Watershed

In Figure 10, the FDC for TCEQ SWQM Station 12151 is shown. The curve is separated into five flow regimes including high flows (0–10%), moist conditions (10–40%), mid-range flows (40–60%), dry conditions (60-90%), and low flows (90-100%). For reference, the Enterococci geometric mean criterion curve (load at 35 cfu/100 mL) and the Enterococci single sample criterion curve (load at 130 cfu/100 mL) are also included on the FDC.

3.5. Load Duration Curve for the TMDL Watershed

In Figure 11, the LDC for TCEQ SWQM Station 12151 is shown. The figure includes the FDC, the Enterococci geometric mean criterion curve (load at 35 cfu/100 mL), the Enterococci single sample criterion curve (load at 130 cfu/100 mL), the existing load curve, the existing geometric mean load by flow regime (single points), and individual bacteria samples.

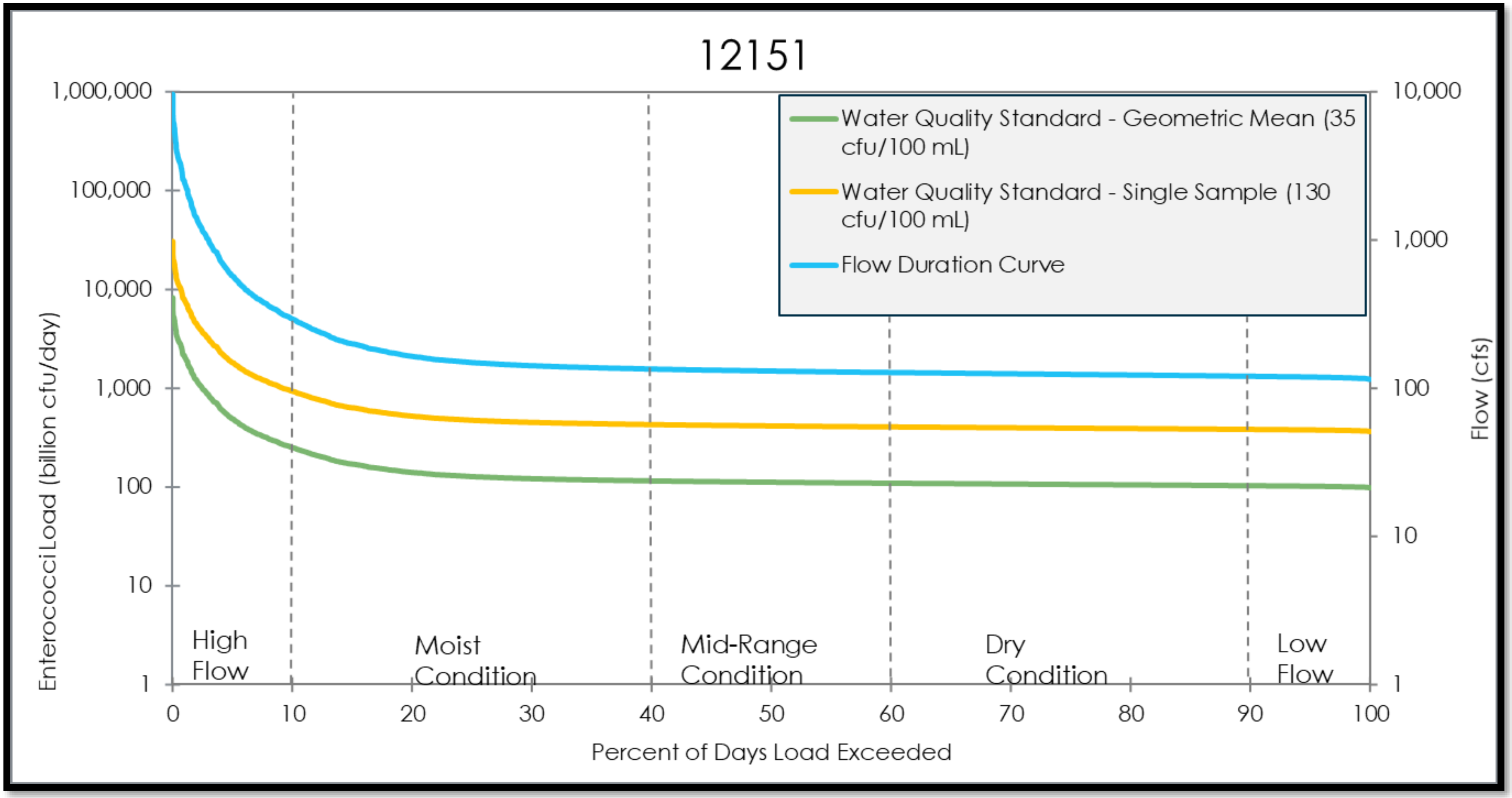

Figure 10. FDC for TCEQ SWQM Station 12151

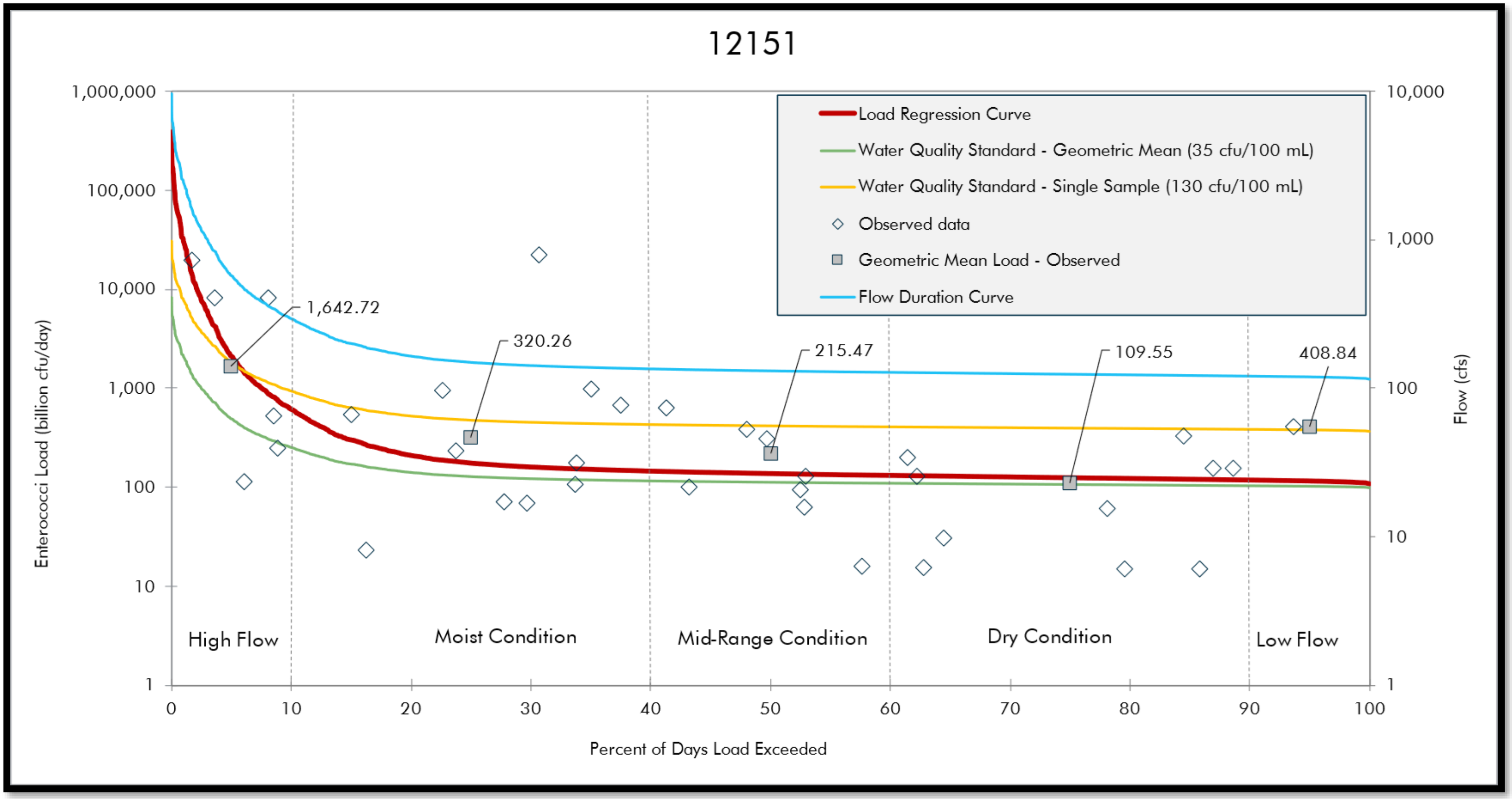

Figure 11. LDC for TCEQ SWQM Station 12151

Section 4. TMDL Allocation Analysis

4.1. Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work needed and as a criterion against which to evaluate future conditions. Please note that some calculations completed in this section have been rounded and may not lead to the exact final amounts listed in the text, tables, or figures.

The endpoint for the TMDL is to maintain the concentration of Enterococci below the geometric mean criterion of 35 cfu/100 mL, which is protective of the primary contact recreation 1 use in tidal water bodies.

4.2. Seasonal Variation

Seasonal variations occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. TMDLs must account for seasonal variation in watershed conditions and pollutant loading, as required by federal regulations [Title 40, Code of Federal Regulations (CFR), Chapter 1, Part 130, Section 130.7(c)(1)—or 40 CFR 130.7(c)(1)].

Differences in Enterococci concentrations were evaluated by performing a Wilcoxon Rank Sum test. Enterococci concentrations during warmer months (May through September) were compared against those during the cooler months (November through March). April and October are considered transitional periods between warm and cool seasons and therefore were excluded from the analysis. This analysis of Enterococci data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Caney Creek Tidal.

4.3. Linkage Analysis

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

Generally, if high bacteria concentrations are measured in a water body at low to median flows in the absence of runoff events, the main contributing sources are likely to be point sources and direct deposition (such as direct fecal 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 size, the impact of point sources like 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, depending upon the severity of the storm, can carry bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of higher concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

LDCs were used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a direct relationship between pollutant load sources (regulated and unregulated) and instream loads. Further, this one-to-one relationship was inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7). That allocation was based on the flows associated with the watershed areas under stormwater regulation, and the remaining portion was assigned to the unregulated stormwater.

4.4. Load Duration Curve Analysis

LDC analyses were used to examine the relationship between instream water quality and the broad sources of indicator bacteria loads, and they are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. An LDC is a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders and uses available water quality and flow data. The LDC method does not require any assumptions about loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The EPA supports the use of this approach to characterize pollutant sources. In addition, many other states are using this method to develop TMDLs.

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

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

At TCEQ SWQM Station 12151, the load regression curve modeled from observed data exceeds the curve representing the geometric mean maximum in all flow conditions (Figure 11). However, the large reductions needed in higher flow conditions relative to lower flow conditions can indicate the influence of nonpoint sources as major contributors to bacteria exceedance at this site. While reduction strategies targeting improvement of nonpoint source pollutants may have greater impacts at this site, improvements to both point and nonpoint source loading will positively affect the watershed.

4.5. Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis performed to develop the TMDL and thus provides a higher level of assurance that the goal of the TMDL will be met. According to EPA guidance (EPA, 1991), the MOS can be incorporated in the TMDL using either of the following 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 TMDL in this report incorporates an explicit MOS of 5%.

4.6. Load Reduction Analysis

According to analyses of the geometric means of observed bacteria data compared to water quality standards for primary contact recreation 1 activities, bacteria concentrations in the TMDL AU are above the water quality criterion at all levels of flow. The highest reductions required are found with the high flow and moist flow regimes. This indicates that nonpoint source load pressures are of particular concern in this watershed and should be central to the development of future water quality improvement strategies. However, point sources should also be considered as targets for improvement, as LDC results indicated potential point source influence on bacteria loads in dry and low flow conditions.

Based on these results, potential reduction targets for Enterococci loads at each flow condition are detailed in Table 14.

Table 14. Load reduction calculations for TCEQ SWQM Station 12151

Flow Condition	Exceedance Range	Geometric Mean (cfu/100 mL)	Required Percent Reduction
High Flow	(0-10%)	124.39	71.86%
Moist	(10-40%)	86.79	59.67%
Mid-Range	(40-60%)	66.75	47.57%
Dry	(60-90%)	36.30	3.58%
Low Flow	(90-100%)	140.00	75.00%

4.7. Pollutant Load Allocations

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

$$TMDL = WLA + LA + FG + MOS \qquad \text{(Equation 1)}$$

Where:

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

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

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

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

4.7.1. Assessment Unit-Level TMDL Calculations

The bacteria TMDL for the water body was developed as a pollutant load allocation based on information from the LDC for the TCEQ SWQM station located within the watershed (Figure 11). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the FDC by the Enterococci criterion (35 cfu/ 100 mL) and by the conversion factor used to represent maximum loading in cfu/day. Effectively, the "Allowable Load" displayed in the LDC at 5% exceedance (the median value of the high flow regime) is the TMDL.

TMDL (cfu/day) = criterion * flow (cfs) * conversion factor (Equation 2)

Where:

Criterion = 35 cfu/100 mL (Enterococci)

Conversion Factor (to billion cfu/day) = 28,316.846 mL/cubic feet (ft^3) * 86,400 seconds/day (s/d) ÷ 1,000,000,000

The allowable loading of Enterococci that the impaired water body can receive on a daily basis was determined using Equation 2 based on the median value within the high flow regime of the FDC (or 5% flow exceedance value) for the TCEQ SWQM station (Table 15).

Table 15. Summary of allowable loading calculation

Water Body Name	AU	Criterion (cfu/100 mL)	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
Caney Creek Tidal	1304_02	35	413.279	3.539E+11	353.891

4.7.2. Margin of Safety Allocation

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 (Equation 3)

Using the TMDL value for the AU provided in Table 15, the MOS may be readily computed by proper substitution into Equation 3 (Table 16).

Table 16. MOS calculation

Load units expressed as billion cfu/day Enterococci

Water Body Name	AU	TMDL[a]	MOS
Caney Creek Tidal	1304_02	353.891	17.695

[a] TMDL from Table 15

4.7.3. Wasteload Allocations

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

$WLA = WLA_{WWTF} + WLA_{SW}$ (Equation 4)

4.7.3.1. Wastewater

TPDES-permitted WWTFs are allocated a daily wasteload calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion. The water quality criterion (35 cfu/100 mL for Enterococci) is used as the WWTF target to provide instream and downstream load capacity. Thus, WLA_{WWTF} is expressed in the following equation:

WLA_{WWTF} = Target * Flow * Conversion Factor (Equation 5)

Where:

Target= 35 cfu/100 mL for Enterococci

Flow = full permitted flow (MGD)

Conversion Factor (to billion cfu/day) = 3,785,411,800 mL/million gallons ÷ 1,000,000,000

Using this equation, each WWTF's allowable loading was calculated using the permittee's full permitted flow. All WWTFs in the TMDL watershed occur in the above tidal reaches. To account for the contribution of WWTFs upstream in above tidal portions of the watershed, loadings for use in calculating TMDLs in the impaired tidal AU 1304_02 replaced 126 cfu/ 100 mL, the freshwater criterion, with 35 cfu/ 100 mL, the tidal criterion. Table 17 presents the WLA for each WWTF and the resulting total allocation for the AU within the TMDL watershed.

Table 17. WLAs for TPDES-permitted facilities

Load units expressed as billion cfu/day Enterococci

Watershed (AU)	TPDES Permit No.	Permittee	Full Permitted Flow[a] (MGD)	Enterococci WLA_{WWTF}
1305A_01	WQ0010663001	Matagorda County WCID 6	0.193	0.256
1305A_01	WQ0011768001	Massey Jimmie Wayne	0.01	0.013
1305B_01	WQ0010843001	Boling MWD	0.133	0.176
		Total	0.336	0.445

[a] Full Permitted Flow from Table 5.

4.7.3.2. 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. A simplified approach for estimating the WLA for these areas was used in the development of this TMDL 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 that is under the jurisdiction of stormwater permits in the TMDL watershed was 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:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \quad \text{(Equation 6)}$$

Where:

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 fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}; Table 18) must be determined to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits, as described in section 2.7.1.2.

Table 18. Basis of regulated stormwater area and computation of FDA_{SWP} term

AU	Total Area (acres)	Concrete Production Facility (acres)	MSGP Area (acres)	CGP Area (acres)	Total Area of Permits (acres)	FDA_{swp}
1304_02	169,076.57	4.86	2,079.23	678.12	2,762.21	1.634%

The daily allowable loading of Enterococci assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. To calculate the WLA_{SW} (Equation 6), the FG term must be known. The calculation for that term is presented in the next section, but the results will be included here for continuity. Table 19 provides the information needed to compute WLA_{SW}.

Table 19. Regulated stormwater WLA calculation

Load units expressed as billion cfu/day Enterococci

Water Body Name	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	FG[d]	FDA_{swp}[e]	WLA_{SW}[f]
Caney Creek Tidal	1304_02	353.891	17.695	0.445	0.146	1.634%	5.483

[a] TMDL from Table 15

[b] MOS from Table 16

[c] WLA_{WWTF} from Table 17

[d] FG from Table 20

[e] FDA_{SWP} from Table 18

[f] $WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$ (Equation 6)

4.7.4. 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 component was based on population projections and current permitted wastewater dischargers for the entire TMDL watershed. Recent population and projected population growth between 2020 and 2070 for the TMDL watershed are provided in Table 20. The projected population percentage increase within the watershed was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. The permitted flows were increased by the expected population growth per segment watershed between 2020 and 2070 to determine the estimated future flows. In consideration of a possible 44.92% growth in population within the Linnville Bayou watershed where there is currently no existing WWTF, a hypothetical future WWTF was included. This hypothetical WWTF was given a 0.05 MGD permitted flow.

Thus, the FG is calculated as follows:

$$FG = Criterion * (WWTF_{FP} * POP_{2020\text{-}2070}) * Conversion\ Factor \qquad \text{(Equation 7)}$$

Where:

Criterion = 35 cfu/100 mL

$POP_{2020\text{-}2070}$ = estimated percent increase in population between 2020 and 2070

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

Conversion factor = 3,785,411,800 mL/million gallons ÷ 1,000,000,000

The calculation results for the TMDL watershed are shown in Table 20.

Table 20. FG calculation

Water Body Name	Watershed	Full Permitted Flow (MGD)	% Population Increase (2020–2070)	FG[a] (MGD)	FG[b] (Enterococci Billion cfu/day)
Caney Creek Tidal	1304_02	0.336	17.99%	0.110	0.146

[a]FG includes the addition of a hypothetical future WWTF in the Linnville Bayou watershed, 0.05 MGD

[b]$FG = Criterion * WWTF_{FP} * POP_{2020-2070} * Conversion\ Factor$ (Equation 7)

4.7.5. Load Allocation

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

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \qquad \text{(Equation 8)}$$

Where:

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 results are shown in Table 21.

Table 21. LA calculation

Load units expressed as billion cfu/day Enterococci

Water Body Name	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	FG[e]	LA[f]
Caney Creek Tidal	1304_02	353.891	17.695	0.445	5.483	0.146	330.122

[a] TMDL from Table 15

[b] MOS from Table 16

[c] WLA_{WWTF} from Table 17

[d] WLA_{SW} from Table 19**Error! Reference source not found.**

[e] FG from Table 20

[f] $LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS$ (Equation 8)

4.8. Summary of TMDL Calculations

Table 22 summarizes the TMDL calculation for the TMDL watershed. The TMDL was calculated based on the median flow in the 0-10 percentile range (5% exceedance, high flow regime) for flow exceedance from the LDC developed for TCEQ SWQM Station 12151. Allocations are based on the current geometric mean criterion for Enterococci of 35 cfu/100 mL for each component of the TMDL.

Table 22. TMDL allocation summary

Load units expressed as billion cfu/day Enterococci

AU	TMDL[a]	MOS[b]	WLA_{WTTF}[c]	WLA_{SW}[d]	LA[e]	FG[g]
1304_02	353.891	17.695	0.445	5.483	330.122	0.146

[a] TMDL from Table 15

[b] MOS from Table 16

[c] WLA_{WWTF} from Table 17

[d] WLA_{SW} from Table 19

[e] LA from Table 21

[f] FG from Table 20

The final TMDL allocation (Table 23) needed to comply with the requirements of 40 CFR 130.7 includes the FG component within the $WLA_{WWTF.}$

Table 23. Final TMDL allocation

Load units expressed as billion cfu/day Enterococci

AU	TMDL	MOS	WLA_{WWTF}	WLA_{sw}	LA
1304_02	353.891	17.695	0.591	5.483	330.122

[a] WLA_{WWTF} includes the FG component

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Appendix A. Method Used to Determine Population Projections

The following steps detail the method used to estimate the 2020 and projected 2070 populations in the TMDL watershed.

1. The H-GAC regional forecast team obtained 2020 USCB data at the block level.
2. The H-GAC regional forecast team used census block data to develop population estimates for a hexagonal grid of three-square miles each (H3M) for the H-GAC region.
3. H-GAC staff estimated the 2020 watershed population using the H3M data for the portion of the H3M located within the watershed assuming equal distribution.
4. Obtained county population change rates for Brazoria, Matagorda, and Wharton counties for the year 2070 from the Texas Water Development Board (TWDB, 2019). Rate is determined based on the growth projected between the 2016 county population (TWDB) and the TWDB's 2070 estimated county population.
5. Developed population projections for each county's proportion of the segment by applying the county 2070 population change rate to the H-GAC calculated county segment 2020 population, which was based on the proportion each county makes up within the TMDL watershed.
6. The 2070 total project segment populations were calculated by adding the county proportional area populations together for each segment.
7. New segment population change rates were then calculated between the 2020 population and the projected 2070 population for each segment.