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Five Draft Total Maximum Daily Loads for Indicator Bacteria in the Mustang, Persimmon, and New Bayous Watershed

Assessment Units 2432A_01, 2432A_02, 2432A_03, 2432D_01 and 2432E_01

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"Technical Support Document for Five Total Maximum Daily Loads for Indicator Bacteria in the Mustang, Persimmon and New Bayou Watersheds," TCEQ AS-502
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Abbreviations

AU	assessment unit
BMP	best management practice
CR	county road
cfs	cubic feet per second
cfu	colony forming units
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
FM	farm-to-market
FDC	flow duration curve
H3M	hexagonal grid of three-square miles each
H-GAC	Houston-Galveston Area Council
km	kilometer
LA	load allocation
LDC	load duration curve
MCM	minimum control measures
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
NPDES	National Pollutant Discharge Elimination System
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SH	state highway
SSURGO	Soil Survey Geographic Database
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
TSSWCB	Texas State Soil and Water Conservation Board
UA	urbanized area
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WWTF	wastewater treatment facility
WQBEL	water quality-based effluent limit
WQMP	Water Quality Management Plan

Executive Summary

This report describes total maximum daily loads (TMDLs) for the Mustang, Persimmon, and New Bayou watersheds where concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the primary contact recreation 1 use. The Texas Commission on Environmental Quality (TCEQ) has identified five bacteria impairments within the Mustang, Persimmon, and New Bayou watersheds in the 2022 Texas Integrated Report of Surface Water Quality for the Clean Water Act Section 305(b) and 303(d) (Texas Integrated Report, TCEQ, 2022a), the latest United States (U.S.) Environmental Protection Agency (EPA)-approved edition. TCEQ first identified concerns for bacteria within Persimmon and New Bayou in the 2010 Texas Integrated Report (TCEQ, 2010). The first identified impairments were to a portion of the Mustang Bayou and Persimmon Bayou watersheds in the 2018 Texas Integrated Report (TCEQ, 2018).

This document will consider five bacteria impairments to the Mustang, Persimmon, and New Bayou watersheds, which will be referred to as the TMDL Project watershed for the remainder of this document. The impaired water body and identifying assessment unit (AU) numbers are:

- Mustang Bayou 2432A_01, 2432A_02, and 2432A_03
- Persimmon Bayou 2432D_01
- New Bayou 2432E_01

The Mustang Bayou watershed covers 49.16 square miles. Mustang Bayou is approximately 42.7 miles long and flows southeast beginning in Fort Bend County and continues through Brazoria County, including portions of the cities and villages of Missouri City, Fresno, Pearland, Manvel, Alvin, and Hillcrest (Figure 1). The headwaters are located within the city limits of Missouri City, in southeast Fort Bend County (Snowden, 1989), while most of the stream is within the boundaries of Brazoria County. Mustang Bayou has been heavily modified and channelized in parts (USGS, 2007). The bayou terminates at its confluence with New Bayou, approximately 0.5 miles upstream of Farm-to-Market Road (FM) 2004.

The Persimmon Bayou watershed is 6.93 square miles. Persimmon Bayou branches off from Mustang Bayou near the intersection of FM 2004 and County Road (CR) 2917. The bayou flows southeastward for approximately 5.5 miles until it joins New Bayou, near its confluence with Chocolate Bay.

The New Bayou watershed is 14.51 square miles. New Bayou begins at Ditch C-1, a tributary to Chocolate Bayou, near CR 169 (Snowden, 1989) and flows southeastward 15.8 miles to its confluence with Chocolate Bay.

Escherichia coli (E. coli) and Enterococci are widely used as indicator bacteria to determine attainment of the contact recreation use in freshwater and saltwater, respectively. The criterion for determining attainment of the contact recreation use is expressed as the number of bacteria, typically given as colony forming units (cfu) in 100 milliliters (mL) of water. The primary contact recreation 1 use is not supported when the geometric mean of all samples during the assessment period exceeds the respective contact recreation criteria for indicator bacteria. For freshwater, the primary contact recreation 1 criterion is 126 cfu/100 mL of *E. coli*. For saltwater, the primary contact recreation 1 criterion is 35 cfu/100 mL of Enterococci.

E. coli and Enterococci data were collected at TCEQ surface water quality monitoring (SWQM) stations in each of the impaired AUs over a seven-year period from Dec. 1, 2013, through Nov. 30, 2020, except for AU 2432A_01 where data collection started in July 2013. These data were used in assessing attainment of the primary contact recreation 1 use and reported in the 2022 Texas Integrated Report. The assessed data indicate non-attainment of the contact recreation standard in AUs 2432A_01, 2432A_02, 2432A_03, 2432D_01, and 2432E_01.

Within the TMDL Project watershed, probable sources of bacteria include domestic and industrial wastewater treatment facilities (WWTFs), regulated stormwater runoff, sanitary sewer overflows (SSOs), illicit discharges, on-site sewage facilities (OSSFs), agricultural activities, and contributions from wildlife and domesticated animals.

A review of the TCEQ Central Registry was done in May 2022 and found 44 active permits in the TMDL Project watershed with a total of 3,694.47 acres of disturbed area for the timeframe. Of those, there are 17 permitted WWTFs, 13 active municipal separate storm sewer systems (MS4) Phase II permit authorizations, one active MS4 Phase I permit, one combined Phase I/II MS4 permit, and 12 active and permitted multi-sector general permit (MSGP) authorizations.

A load duration curve (LDC) analysis was done for the TMDL watershed to quantify allowable pollutant loads, as well as allocations for point and nonpoint sources of bacteria. Wasteload allocations (WLAs) were established for WWTFs discharging to the AUs. The WLA was calculated as the full permitted daily-average flow rate multiplied by the geometric mean criterion. Future growth (FG) of existing or new domestic point sources was determined for the watershed using population growth projections. For AUs that do not have existing WWTFs or where population is not expected to grow, the FG component was based upon population data and the addition of one new WWTF within each subwatershed, with the WLA based upon a hypothetical permitted discharge flow rate.

The TMDL calculations in this report will guide determination of the assimilative capacity of each water body under changing conditions, including FG. WWTFs will be evaluated case by case.

Introduction

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a TMDL for each pollutant that contributes to the impairment of a 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 report addresses impairments to the primary contact recreation 1 use due to elevated levels of indicator bacteria in 2432A, 2432D, and 2432E. This TMDL takes a watershed approach to addressing indicator 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. Information in this TMDL report was derived from the *Technical Support Document for Five Total Maximum Daily Loads for Indicator Bacteria in the Mustang, Persimmon and New Bayou Watersheds* (HGAC, 2024).[a]

Section 303(d) of the Clean Water Act and the implementing regulations of EPA in Title 40 of the Code of Federal Regulations (CFR), Chapter 1, 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 report has been prepared in accordance with those regulations and guidelines.

[a] https://www.tceq.texas.gov/waterquality/tmdl/nav/114-mustangbayou

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

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

Upon adoption of the TMDL report by the commission 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 impairment of the primary contact recreation 1 use within Persimmon and New Bayous in the 2010 Texas Integrated Report, and again in each subsequent edition through the EPA-approved 2022 Texas Integrated Report. The impairment of the primary contact recreation 1 use in Mustang Bayou was first identified in 2018 Texas Integrated Report, and then in each subsequent edition through the EPA-approved 2022 Texas Integrated Report. AUs 2432A_01, 2432A_02, 2432D_01 and 2432E_01 are listed in Subcategory 5a in the 2022 Texas Integrated Report, making them a high priority for TMDL development. AU 2432A_03 is listed in Subcategory 5c in the 2022 Integrated Report.

Recent surface water *E. coli* and Enterococci monitoring within the TMDL Project watershed has occurred at five TCEQ SWQM stations (Table 1). *E. coli* and Enterococci data, collected at these stations from Dec. 1, 2013 (July 17, 2013 for AU 2432A_01) through Nov. 30, 2020 were used to determine attainment of primary contact recreation use 1 as reported in the 2022 Texas Integrated Report. Data assessed indicate non-support of primary contact recreation 1 use in all five AUs because the geometric mean concentrations of available samples exceed the geometric mean criterion of 126 cfu/100 mL for *E. coli* and 35 cfu/100 mL for Enterococci, as summarized in Table 1.

Table 1. 2022 Texas Integrated Report Summary for the impaired AUs

Subwatershed	AU	Parameter	Station	No. of Samples	Data Date Range	Station Geometric Mean (cfu/100 mL)
Mustang Bayou	2432A_01	*E. coli*	11423	20	07/17/2013 to 11/30/2020	321.98
Mustang Bayou	2432A_02	*E. coli*	18554	26	12/01/2013 to 11/30/2020	1,143.74
Mustang Bayou	2432A_03	*E. coli*	21416	25	12/01/2013 to 11/30/2020	204.87
Persimmon Bayou	2432D_01	Enterococci	17913	27	12/01/2013 to 11/30/2020	87.46
New Bayou	2432E_01	Enterococci	17911	27	12/01/2013 to 11/30/2020	80.37

Watershed Overview

The TMDL Project watershed is 70.60 square miles and is located in southeast Texas, near the cities of Missouri City, Manvel, and Alvin, and the villages of Fresno and Hillcrest (Figure 1). The watershed consists of three bayous: Mustang Bayou, Persimmon Bayou, and New Bayou, which flow generally southeast from the headwaters in southeast Fort Bend County before heading more directly south near the City of Alvin in Brazoria County. From there, the water flows to Chocolate Bay (Segment 2432) and West Galveston Bay.

The Mustang Bayou watershed covers 49.16 square miles. Mustang Bayou is approximately 42.7 miles long and flows southeast beginning in Fort Bend County and continues through Brazoria County, including portions of the cities and villages of Missouri City, Fresno, Pearland, Manvel, Alvin, and Hillcrest (Figure 1). The headwaters are located within the city limits of Missouri City, in southeast Fort Bend County, while most of the stream is within the boundaries of Brazoria County. Mustang Bayou has been heavily modified and channelized in parts. The bayou terminates at its confluence with New Bayou, approximately 0.5 miles upstream of FM 2004.

The Persimmon Bayou watershed is 6.93 square miles. Persimmon Bayou branches off from Mustang Bayou near the intersection of FM 2004 and CR 2917. The bayou flows southeastward for approximately 5.5 miles until it joins New Bayou, near its confluence with Chocolate Bay.

The New Bayou watershed is 14.51 square miles. New Bayou begins at Ditch C-1, a tributary to Chocolate Bayou, near CR 169 and flows southeastward 15.8 miles to its confluence with Chocolate Bay.

The 2022 Texas Integrated Report provides the following AU descriptions for the water bodies considered in this document:

- Segment 2432A Mustang Bayou – From the New Bayou confluence upstream to an unnamed tributary 0.3 kilometers (km) (0.19 miles) upstream of State Highway (SH) 35 to an unnamed tributary downstream of Cartwright Road
    - AU 2432A_01 – From the New Bayou confluence upstream to CR 166
    - AU 2432A_02 – From CR 166 upstream to an unnamed tributary 0.3 km upstream of SH 35
    - AU 2432A_03 – From an unnamed tributary 0.3 km upstream of SH 35 upstream to an unnamed tributary downstream of Cartwright Road
- Segment 2432D Persimmon Bayou – From the New Bayou confluence upstream to the Mustang Bayou confluence
- 2432D_01 – From the New Bayou confluence upstream to the confluence with Mustang Bayou
  Segment 2432E New Bayou – From the Chocolate Bay confluence upstream 25.4 km (15.8 miles) to an unnamed tributary
    - 2432E_01 - From the Chocolate Bay confluence upstream 25.4 km (15.8 miles) to an unnamed tributary

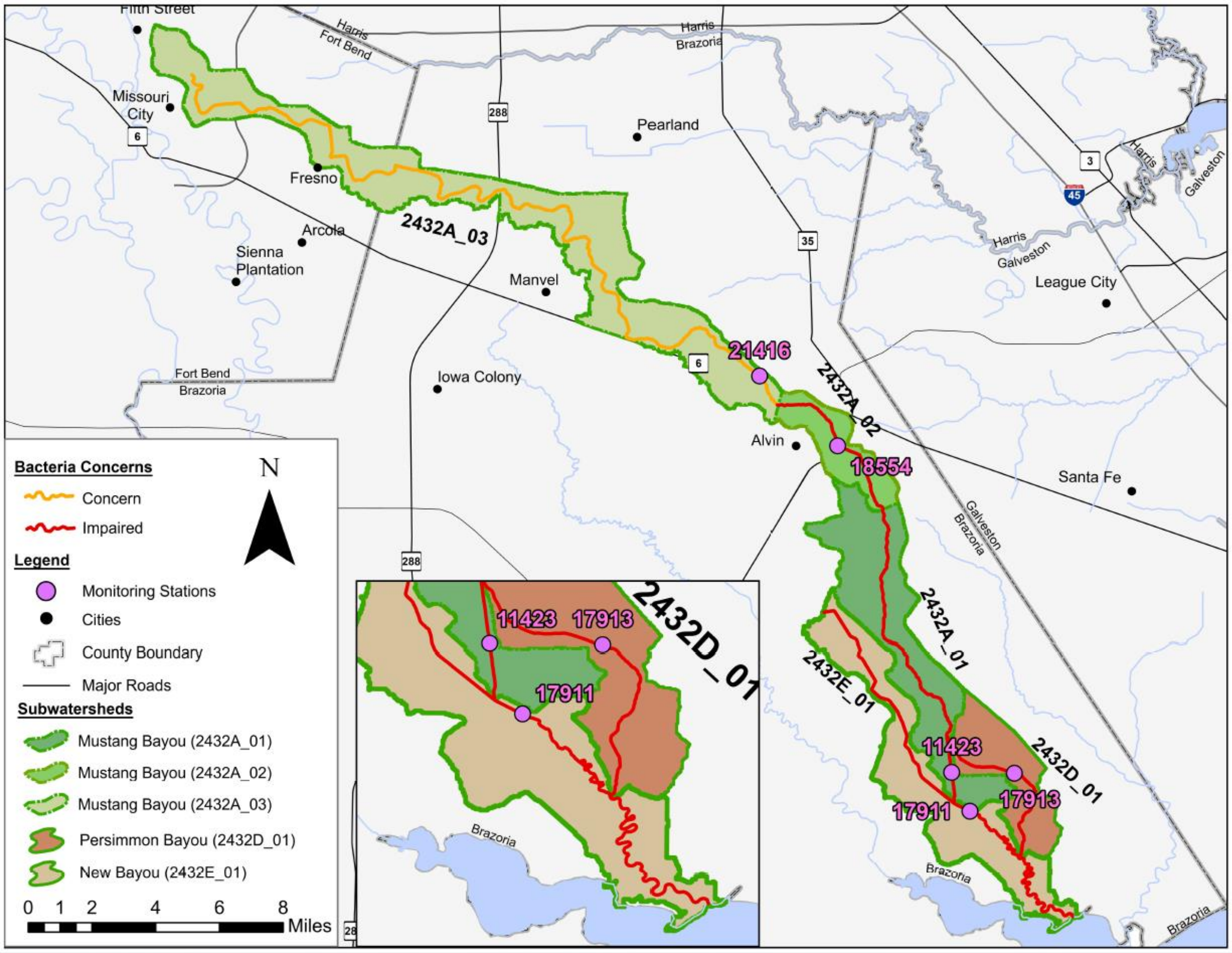


Figure 1. Map of the TMDL Project watershed

Climate and Hydrology

Precipitation and temperature data from 2004 through 2020 were retrieved from the National Climatic Data Center for Freeport (GHCND: USC00413340) (NOAA, 2022). Temperatures and precipitation in the TMDL Project watershed are consistent with subtropical coastal areas.

Average precipitation for the watershed is 47.78 inches per year (Table 2). 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 2). 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.

Table 2. Average annual rainfall recorded at Freeport, TX, 2004 – 2020

Station Number	Station Name	Latitude	Longitude	Average Annual Rainfall (inches)
GHCND: USC00413340	FREEPORT 2 NW TX US	28.9845	-95.3809	47.78

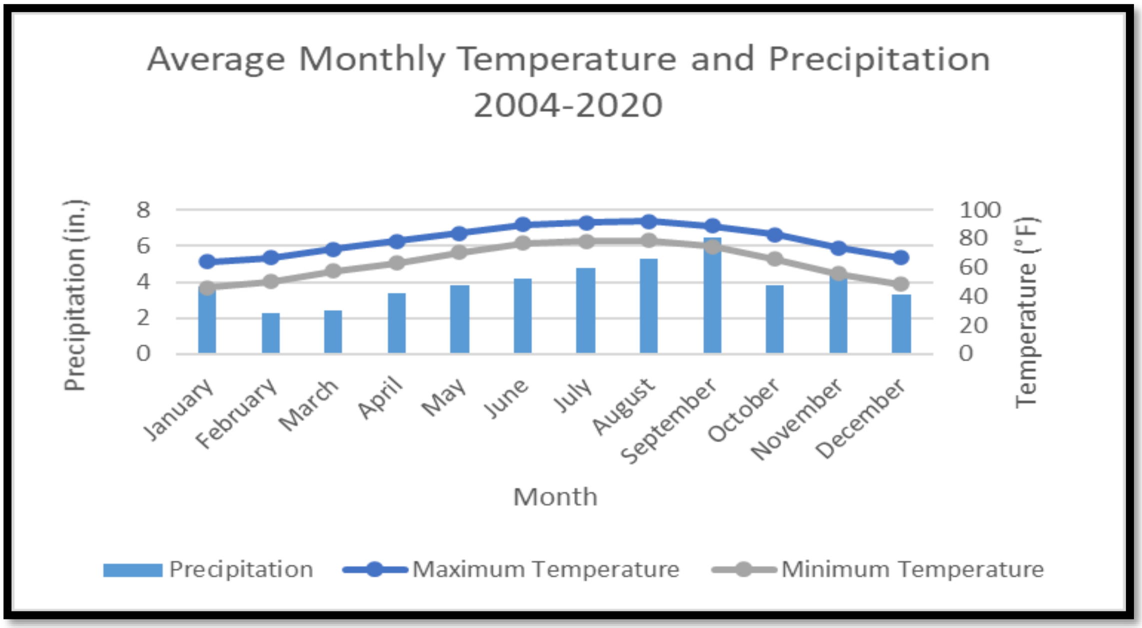


Figure 2. Average monthly temperature and precipitation from 2004 - 2020, Station GHCND:USC00413340

Temperatures in the region 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 2 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.

Population and Population Projections

Watershed population estimates were developed using the 2020 United States Census Bureau (USCB) census block geographic units and population data (USCB, 2020). Census blocks are the smallest geographic units used by USCB to tabulate population data. Using the methodology outlined in Appendix A, the TMDL Project watersheds' 2020 population is estimated at 40,392 people (Table 3).

Population projections in Table 3 were estimated from the Houston-Galveston Area Council's (H-GAC) 2021 Regional Growth Forecast Texas (H-GAC, 2021).

Table 3. Population estimates and projections

Subwatershed	AU	2020	2050	Population Change
		Population	Population	%
Mustang Bayou	2432A_01	2,441	4,240	73.69%
Mustang Bayou	2432A_02	10,168	13,878	36.49%
Mustang Bayou	2432A_03	27,774	84,977	205.96%
New Bayou	2432E_01	9	No growth	No growth
Persimmon Bayou	2432D_01	0	No growth	No growth
Total		**40,392**	**103,095**	**155.23%**

Land Cover

The land cover data for the TMDL Project watershed was obtained by H-GAC using LANDSAT imagery from 2018 to categorize the Houston-Galveston region into ten classes of land cover (H-GAC, 2021b) and is displayed in Figure 3. The definitions for the ten land cover types are:

1) **Developed High Intensity** – Contains significant land area that is covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies less than 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/Shrub** – 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/Shrub* – 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* – Include 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%.

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

   a. *Palustrine Forested Wetland* – Includes tidal and non-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 below 0.5%. Total vegetation coverage is greater than 20%.

   b. *Palustrine Scrub/Shrub Wetland* – Includes tidal and non-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 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 Wetland (Persistent)* – Includes tidal and non-tidal 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 Wetland* – 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 Wetland* – 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 Wetland* – 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.

A summary of the land cover data is provided in Table 4. As depicted in Table 4 and Figure 3, the largest single land cover type is Pasture/Grassland at 28.40% within the TMDL Project watershed. Cropland is the second largest land cover type at 20.33% (Table 5, Figure 3). Developed land cover would be the largest land cover type (33.78%, or 15,263.96 acres) if low, medium, and high-intensity categories were combined. This is consistent with the growth that is taking place in the upper portions of the TMDL Project watershed.

Looking at the subwatershed land cover types, agricultural lands still dominate the area, particularly in the Persimmon Bayou subwatershed, where Cropland (75.44%) and Pasture/Grassland (11.83%) predominate (Table 4, Figure 3). In the New Bayou subwatershed, agricultural lands dominate 56.31% of the land cover with 28.19% and 28.12% for Pasture/Grassland and Cropland, respectively. Wetlands also are a large land cover type for the Persimmon and New Bayou subwatersheds at 10.38% and 25.21%, respectively.

Developed land cover types are predominate in the Mustang Bayou subwatershed, with a total of 44.51% or 14,004.20 acres (Table 4, Figure 3). This contrasts with the Persimmon Bayou subwatershed, where Developed land cover accounts for 53.89 acres or 1.22%, which is a reflection of little to no population within this watershed. The New Bayou subwatershed's developed land cover is also lower than the Mustang Bayou subwatershed, but of its developed land cover types, 157.45 acres or 1.69%, is considered Developed, High Intensity. This proportion is similar to the Mustang Bayou subwatershed (1.65% for Developed, High Intensity). The reason for the large percentage of Developed, High Intensity land use in New Bayou is the heavy industry found along the bayou near the confluence with Chocolate Bay at FM 2004.

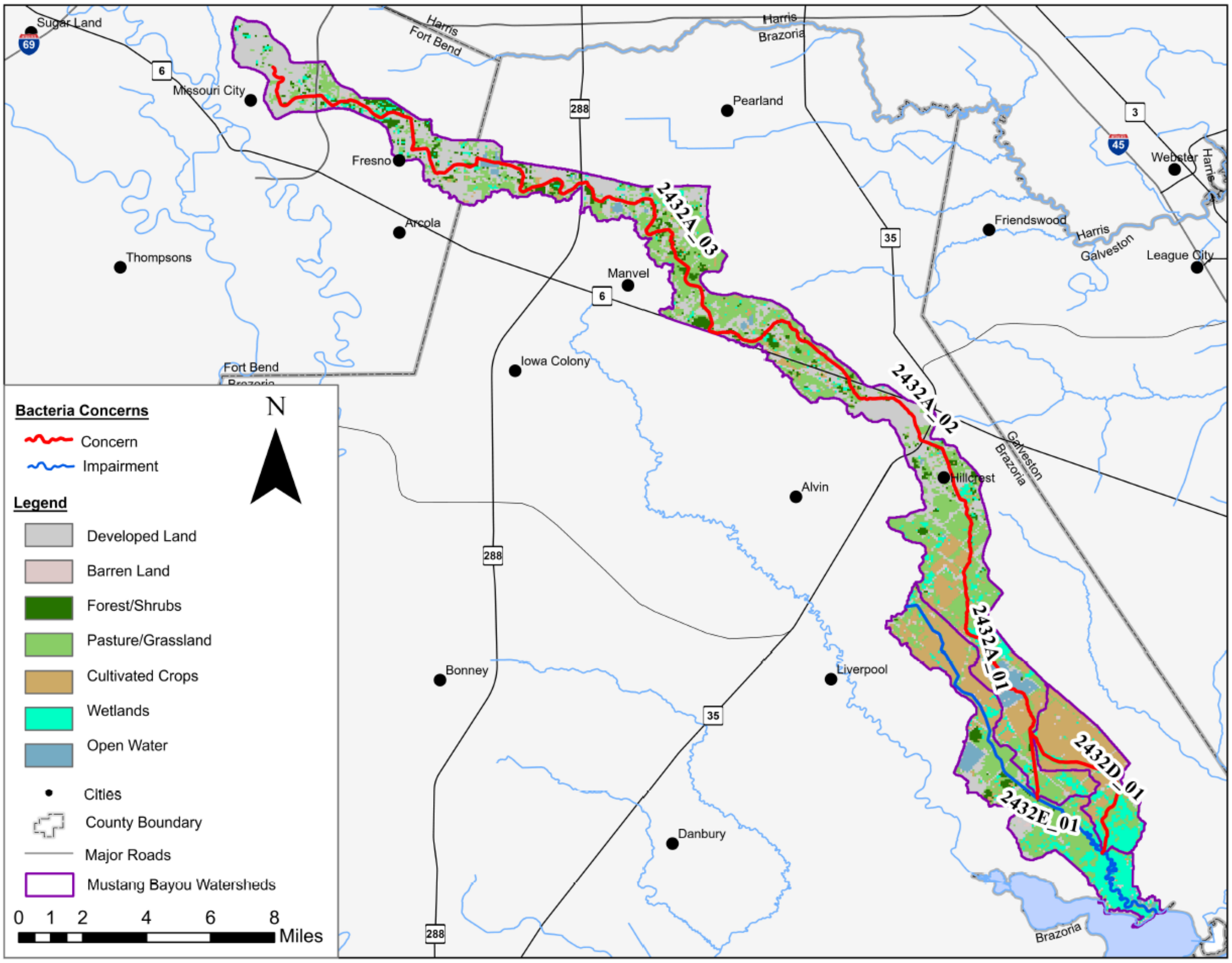


Figure 3. 2018 Land Cover map

Table 4. Land cover percentages

Land Cover	Mustang Bayou Subwatershed		Persimmon Bayou Subwatershed		New Bayou Subwatershed		Total	
Type	**Area (acres)**	**Percent**	**Area (acres)**	**Percent**	**Area (acres)**	**Percent**	**Area (acres)**	**Percent**
Developed, High Intensity	518.44	1.65%	0.67	0.02%	157.45	1.69%	676.55	1.50%
Developed, Medium Intensity	2,496.35	7.93%	0.89	0.02%	208.40	2.24%	2,705.64	5.99%
Developed, Low Intensity	3,654.56	11.62%	30.40	0.69%	298.70	3.22%	3,983.66	8.82%
Developed, Open Space	7,334.85	23.31%	21.94	0.49%	541.32	5.83%	7,898.11	17.48%
Forest/Shrub	1,536.64	4.88%	0.00	0.00%	1.79	0.02%	1,538.42	3.40%
Open Water	1,590.47	5.06%	50.08	1.13%	503.99	5.43%	2,144.54	4.75%
Barren Lands	95.82	0.30%	0.64	0.01%	4.66	0.05%	101.11	0.22%
Cropland	3,229.20	10.26%	3,345.86	75.44%	2,612.23	28.12%	9,187.29	20.33%
Pasture/Grassland	9,688.72	30.80%	524.46	11.83%	2,618.82	28.19%	12,832.01	28.40%
Wetlands	1,315.82	4.18%	460.18	10.38%	2,342.18	25.21%	4,118.17	9.11%
Total	**31,460.85**	**100.00%**	**4,435.11**	**100.00%**	**9,289.54**	**100.00%**	**45,185.50**	**100.00%**

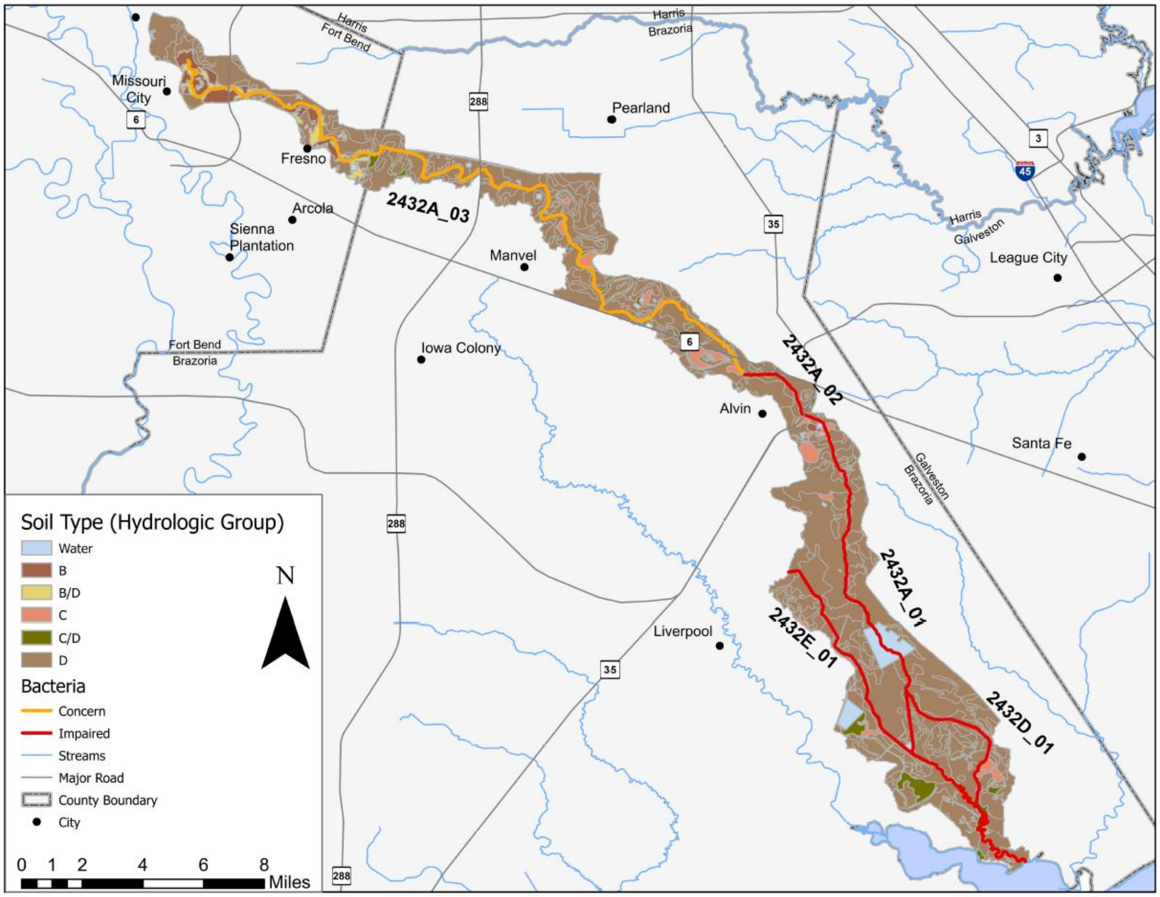
Soils

Soils within the TMDL Project watershed are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service Soil Survey Geographic database (SSURGO) (NRCS, 2018). 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 following classifications.

- **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.

The predominant soil group within the TMDL Project watershed is Group D at 89.16% (Figure 4). The second largest soil group is that of Groups C and C/D at 5.36% each. All three soil groups are typical of Texas coastal areas which are made up of very slow to slow-draining alluvial clays and fine textured clay loams.

Figure 4. Hydrologic soils groups



Water Rights Review

Surface water rights in Texas are administered and overseen by TCEQ. A search of TCEQ's Texas Water Rights Viewer (TCEQ, 2022b) indicated there are three water rights in the TMDL Project watershed. The withdrawals were found to be minimal and infrequent. It was determined that they had little effect on flow and these diversions were not used to naturalize the flow.

Due to a lack of streamflow data in the TMDL Project watershed, Chocolate Bayou Above Tidal was used as a surrogate to develop flow data, this process is discussed in more detail in the "Load Duration Curve Analysis" section and the *Technical Support Document for Five Total Maximum Daily Loads for Indicator Bacteria in the Mustang, Persimmon and New Bayou Watersheds* (HGAC, 2024). There were three water rights diversions within the catchment area above the United States Geological Survey (USGS) station in Chocolate Bayou Above Tidal.

Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for the TMDLs in this report is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 cfu/100mL, which is protective of the primary contact recreation 1 use in freshwater, and below the mean criterion of 35 cfu/100mL, which is protective of the primary contact recreation 1 use in saltwater (TCEQ, 2022c).

Source Analysis

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

Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watersheds include WWTF outfalls, stormwater discharges from industries, stormwater discharges from construction, and MS4s.

Domestic and Industrial Wastewater Treatment Facilities

As of May 2022, there are 17 distinct wastewater permits, including 20 outfalls, in the TMDL Project watershed (Table 5, Figure 5, TCEQ, 2022d). Three permits are industrial, two in the New Bayou subwatershed, and one in the Mustang Bayou subwatershed. The two industrial WWTFs in the New Bayou subwatershed are not permitted to discharge fecal indicator bacteria through their effluent outfalls. However, the permit holders also maintain a stormwater permit, and both facilities will be reviewed under regulated stormwater in the "TPDES Regulated Stormwater" section below.

The remaining 14 wastewater permittees are permitted to discharge treated effluent via their outfalls and were reviewed further. Table 5 includes the maximum permitted discharge. Permit WQ0014322001, Brazoria County Municipal Utility District (MUD) 25, discharges outside of the Mustang Bayou subwatershed, so their discharge is not relevant to determining the TMDL. However, a portion of their collection system is within the watershed and could potentially contribute to SSOs in the watershed.

Table 5. Permitted domestic and industrial WWTFs

AU	EPA ID	TPDES Number	Facility Name	Permittee Name	Facility Type	Outfall Number	Daily Average Flow – Permitted Discharge (MGD[a])
2432A_01	TX0024554	WQ0010005001	City of Alvin WWTF	City of Alvin	Domestic	1	5
2432A_01	TX0117234	WQ0014039001	South Meadows East WWTF	AQUA Texas, Inc.	Domestic	1	0.0924
2432A_02	TX0056057	WQ0010420001	City of Hillcrest Village WWTF	City of Hillcrest Village	Domestic	1	0.15
2432A_03	TX0142093	WQ0016073001	Nantucket RV Park WWTF	Alvin Mustang LLC	Domestic	1	0.02
2432A_03	TX0142239	WQ0016089001	Magnolia RV Resort	Green Raindrops INC	Domestic	1	0.0099
2432A_03	TX0094790	WQ0013600001	Astro WWTF	AQUA Texas, Inc.	Domestic	1	0.0225
2432A_03	TX0118001	WQ0013735001	Willow Manor Mobile Home Park	Rancho La Fuente Partners LLC	Domestic	1	0.075
2432A_03	TX0112461	WQ0004306000	NALCO Fresno Facility	NALCO Production, LLC	Industrial	1	0.015
2432A_03	TX0112461	WQ0004306000	NALCO Fresno Facility	NALCO Production, LLC	Industrial	2	0.020
2432A_03	TX0124737	WQ0014322001	Brazoria County MUD 25 WWTF	Brazoria County MUD 25	Domestic	1	–
2432A_03	TX0122823	WQ0014188001	Oak Crest WWTF	Manvel Utilities LP	Domestic	1	0.099
2432A_03	TX0128163	WQ0014641001	Mustang Creek Development WWTF	Brazoria County MUD 39	Domestic	1	0.5
2432A_03	TX0129178	WQ0014756001	Sedona Lake WWTF	Sedona Lakes MUD 1	Domestic	1	0.6
2432A_03	TX0134333	WQ0015077001	Tuscany Lakes WWTF	AUC Group LP	Domestic	1	0.8

AU	EPA ID	TPDES Number	Facility Name	Permittee Name	Facility Type	Outfall Number	Daily Average Flow – Permitted Discharge (MGD[a])
2432A_03	TX0138126	WQ0015636001	Chimney Rock WWTF	Hanover Estates LTD	Domestic	1	0.7
2432A_03	TX0138894	WQ0015747001	Lake Olympia Parkway WWTF	KB Home Lone Star, INC	Domestic	1	0.25
2432E_01	TX0003875	WQ0000001000	Ascend Chocolate Bayou Plant	Ascend Performance Materials Texas, Inc.	Industrial	4	Intermittent/Flow Variable
2432E_01	TX0003875	WQ0000001000	Ascend Chocolate Bayou Plant	Ascend Performance Materials Texas, Inc.	Industrial	5	Intermittent/Flow Variable
2432E_01	TX0003875	WQ0000001000	Ascend Chocolate Bayou Plant	Ascend Performance Materials Texas, Inc.	Industrial	6	Intermittent/Flow Variable
2432E_01	TX0003875	WQ0000001000	Ascend Chocolate Bayou Plant	Ascend Performance Materials Texas, Inc.	Industrial	7	Intermittent/Flow Variable
2432E_01	TX0004821	WQ0001333000	INEOS USA Chocolate Bayou Plant	INEOS USA, LLC	Industrial	5	Intermittent/Flow Variable

[a] million gallons per day

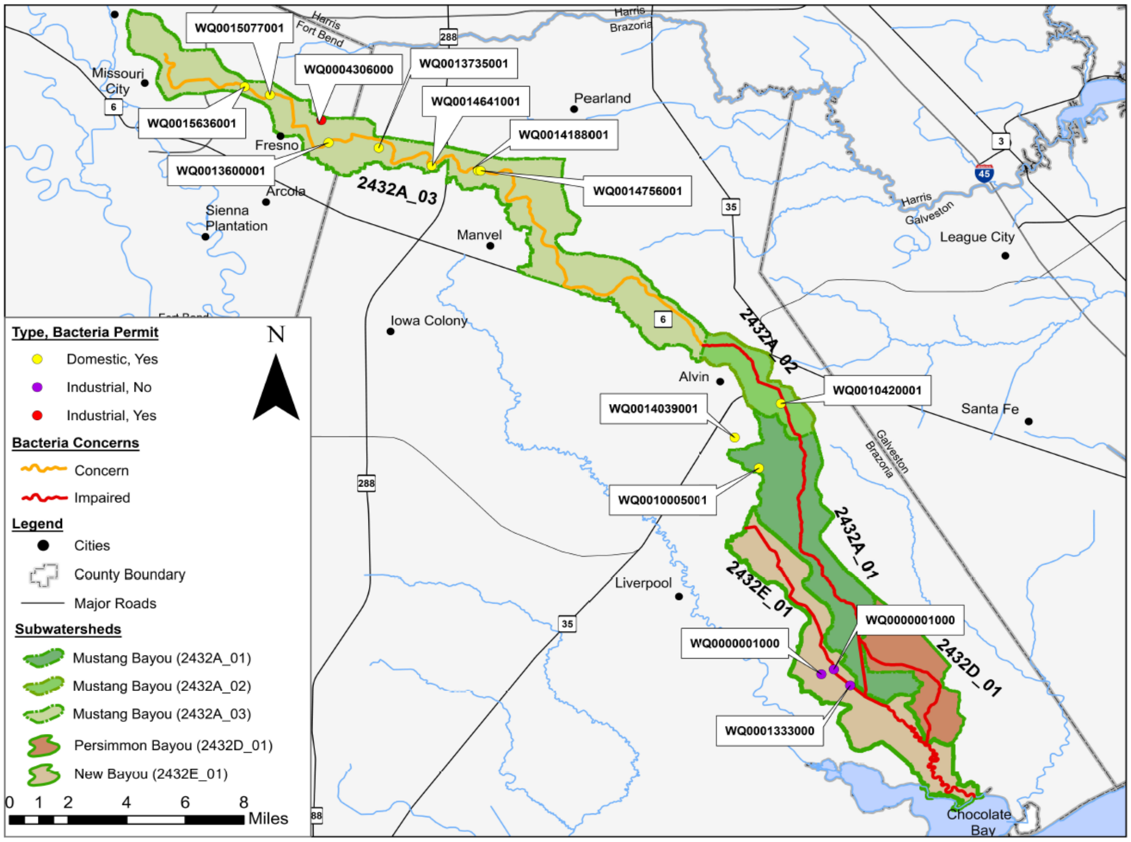


Figure 5. WWTFs in the TMDL Project watershed

TCEQ/TPDES Water Quality General Permits

Certain types of activities must be covered by one of several TCEQ/TPDES 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)
The following general permit authorizations are not considered to affect the

bacteria loading in the TMDL Project 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 permits (TCEQ, 2022d) in the TMDL Project watershed as of May 2022 found two concrete production facilities within the Mustang Bayou subwatershed (AU 2432A_03). These concrete production facilities do not have bacteria reporting requirements or limits in their permits and are assumed to contain inconsequential amounts of bacteria in their effluent. Therefore, it was unnecessary to allocate bacteria loads to these facilities. The concrete production facilities (Table 6) are authorized to discharge stormwater, so they will be considered in the stormwater allocation analysis.

Table 6. General permit authorizations for concrete production facilities

AU	Permit Number	Site Name	City	County	Estimated Area (acres)
2432A_03	TXG112003	R & S Concrete, L.L.C.	Fresno	Fort Bend	4.48
2432A_03	TXG112023	Gulf Coast Concrete and Shell, Inc.	Manvel	Brazoria	28.71

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 are typical causes of overflows under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the inflow and infiltration problem. Other causes, such as a collapsed sewer line, may occur under any condition.

Table 7 presents the number of SSOs reported and the estimated volume of untreated or partially treated effluent released into the TMDL Project watershed between 2012 and 2021. A total of 62 SSOs were reported and over 3 million gallons were estimated to be released during that timeframe (TCEQ, 2022e). The largest single cause of SSOs is attributed to blockages due to grease and non-grease, e.g., roots, wipes, etc.

Table 7 summarizes the number of SSO incidents that have been reported by regulated entities in the TMDL Project watershed.

Table 7. Summary of reported SSO events from 2012 through 2021

Year	Number of SSOs Reported	Estimated Volume (Gallons)
2012	2	1,050
2013	4	15,155
2014	5	1,480
2015	5	1,590
2016	2	950
2017	7	502,069
2018	12	2,513,461
2019	13	189,600
2020	10	47,400
2021	2	11,000
Total	**62**	**3,283,755**

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 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 sanitary wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized MS4s with populations of 100,000 or more based on the 1990 United States Census, whereas the Phase II General Permit regulates other MS4s within an urban area with a population of at least 50,000 people.

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. The MS4 permits require that SWMPs specify the best management practices (BMPs) 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*)[b].

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. The Phase I MCMs include all of these activities:

- MS4 maintenance activities.
- Post-construction stormwater control measures.
- Detection and elimination of illicit discharges.
- Pollution prevention and good housekeeping for municipal operations.
- Limiting pollutants in industrial and high-risk stormwater runoff.
- Limiting pollutants in stormwater runoff from construction sites.
- Public education, outreach, involvement, and participation.
- Monitoring, evaluating, and reporting.

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

- TXR040000 – Phase II MS4 General Permit for MS4s located in an urban area with a population of at least 50,000 people
- TXR050000 – Multi-Sector General Permit (MSGP) for industrial facilities

[b] MCM only applies to Phase II MS4s which serve a population of 100,000 or more

- 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

TCEQ's Central Registry, as of May 2022 (TCEQ, 2022d) included two concrete production facilities (Table 6), 13 active MS4 Phase II permit authorizations, one active MS4 Phase I permit, one combined Phase I/II MS4 permit (Table 8), and 12 active MSGP authorizations (Table 9, Figure 6).

To eliminate the possibility of overcounting the stormwater permit area, only the area of MSGPs located outside of the urbanized area (UA) defined by the USCB's 2010 census (USCB, 2010) were included. Six of the twelve permits were found within the UA and were excluded from TMDL calculations. The remaining six MSGP authorizations were outside the UA within AUs 2432A_03 and 2432E_01 (Table 9).

Table 8. MS4 permit authorizations

AU	Entity	Authorization Type	TPDES Permit No./ NPDES[a] ID	Location
All	Texas Department of Transportation	Combined Phase I and Phase II MS4	WQ0005011000/ TXS002101	Brazoria County and Fort Bend County
2432A_02	City of Alvin	Phase II MS4 General Permit TXR040000	TXR040138/Not Applicable	Area within the City of Alvin limits that is located within the Houston UA
2432A_02	Brazoria County Reclamation District	Phase II MS4 General Permit TXR040000	TXR040148/Not Applicable	Area within Brazoria CRD 3 limits that is located within the Houston UA
2432A_03	Brazoria Drainage District 4	Phase II MS4 General Permit TXR040000	TXR040144/Not Applicable	Area within the City of Pearland limits that is located within the Houston UA
2432A_03	City of Pearland	Phase II MS4 General Permit TXR040000	TXR040208/Not Applicable	Area within the City of Pearland city limits that is located within the Houston UA
2432A_03	City of Houston	Phase I MS4 Permit	TXS001201/ WQ0004685000	This permit covers all portions of the Houston-Harris County Municipal Separate Storm Sewer
2432A_03	Blue Ridge West MUD	Phase II MS4 General Permit TXR040000	TXR040219/Not Applicable	This MS4 is located in the area of Blue Ridge West MUD within the City of Missouri City limits that is located within the Houston UA in Fort Bend County, Texas.
2432A_03	City of Stafford	Phase II MS4 General Permit TXR040000	TXR040252/Not Applicable	Area within the City of Stafford limits that is located within the Houston UA
2432A_03	Fort Bend County MUD 26	Phase II MS4 General Permit TXR040000	TXR040295/Not Applicable	Area of Fort Bend County MUD 26 is located within the City of Missouri City limits within the Houston UA
2432A_03	Meadowcreek MUD	Phase II MS4 General Permit TXR040000	TXR040296/Not Applicable	Area of Meadowcreek MUD is located within the City of Missouri City limits within the Houston UA

AU	Entity	Authorization Type	TPDES Permit No./ NPDES[a] ID	Location
2432A_03	City of Missouri City	Phase II MS4 General Permit TXR040000	TXR040298/Not Applicable	The MS4 is located in the area within the City of Missouri City limits that's located within the Houston UA in Fort Bend and Harris Counties, Texas
2432A_03	Quail Valley UD	Phase II MS4 General Permit TXR040000	TXR040359/Not Applicable	Area within the boundaries of Qual Valley Utility District within the City of Missouri City limits that is located within the Houston UA
2432A_03	Thunderbird UD	Phase II MS4 General Permit TXR040000	TXR040360/Not Applicable	Area within legal district boundaries of Thunderbird Utility District located within the City of Houston UA
2432A_03	Palmer Plantation MUD 02	Phase II MS4 General Permit TXR040000	TXR040362/Not Applicable	Area within the boundaries of Palmer Plantation MUD 2 that is located within the City of Missouri City limits within the Houston UA
2432A_03	Fort Bend County DD	Phase II MS4 General Permit TXR040000	TXR040383/Not Applicable	Area within Fort Bend County that is located within the Houston UA

[a] National Pollutant Discharge Elimination System

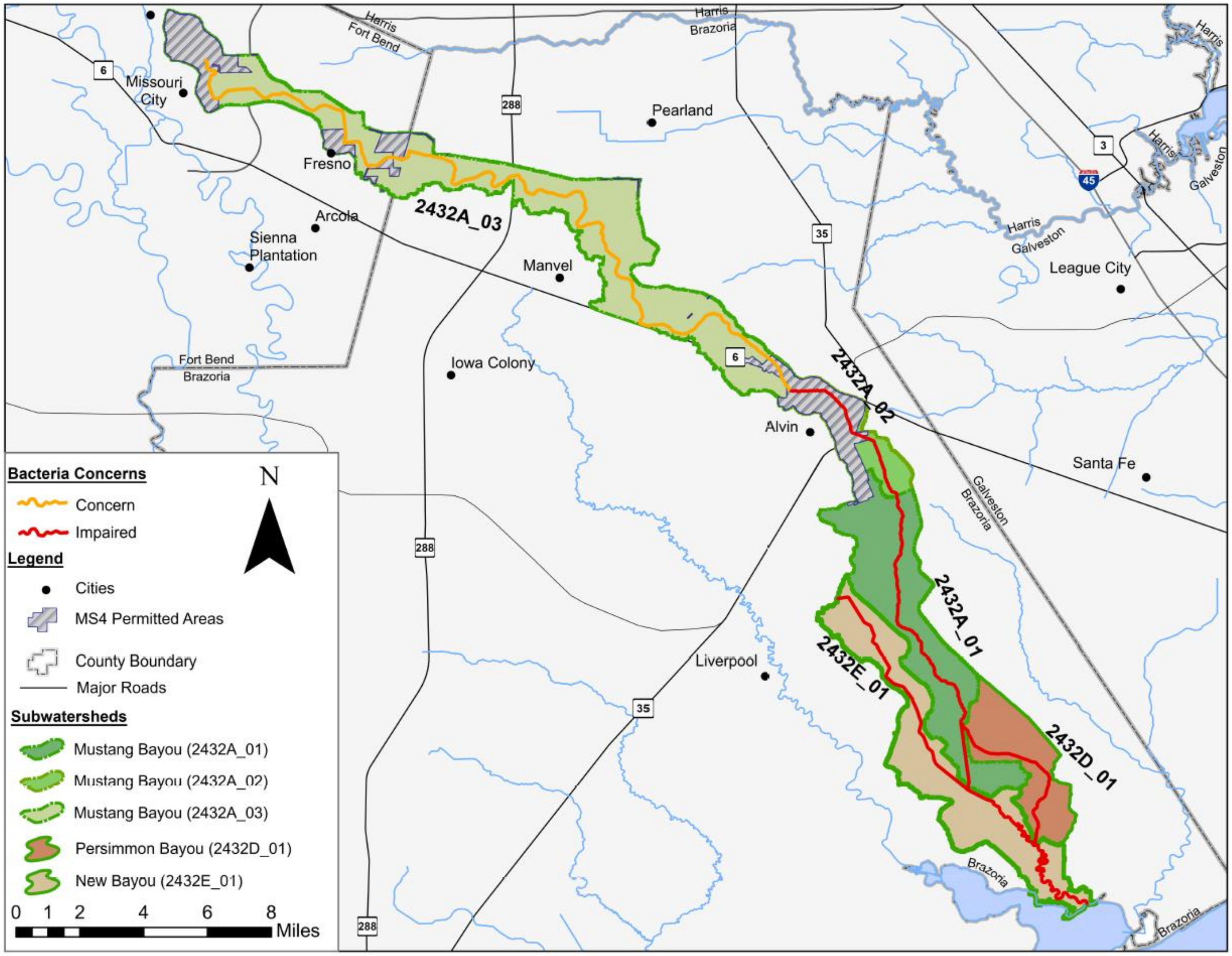


Figure 6. Regulated stormwater area based on MS4s

Table 9. Industrial stormwater authorizations

AU	MSGP Permit Number/TPDES	Permittee	County	City	Area (acres)	Area Outside UA (acres)
2432A_02	TXR05FM40/Not Applicable	Riviana Foods Inc.	Brazoria	Alvin	14.62	0.00
2432A_03	TXR05AV89/Not Applicable	Sprint Sand and Clay, LLC	Brazoria	Manvel	1.42	0.00
2432A_03	TXR05DH42/Not Applicable	J D B Services, Inc.	Brazoria	Alvin	201.38	201.38
2432A_03	TXR05DM55/Not Applicable	Sprint Sand and Clay, LLC	Fort Bend	Fresno	73.63	6.36
2432A_03	TXR05EE18/Not Applicable	East Palm Holdings, LLC	Brazoria	Fresno	16.24	0.00
2432A_03	TXR05EP17/ WQ0004306000	Nalco Production LLC	Fort Bend	Fresno	29.01	0.00
2432A_03	TXR05EQ25/Not Applicable	Tierra De Los Lagos, LLC	Fort Bend	Fresno	35.27	35.27
2432A_03	TXR05FF33/Not Applicable	Sand Land, Inc.	Brazoria	Alvin	38.63	38.33
2432A_03	TXR05FM92/Not Applicable	Cherry Crushed Concrete, Inc.	Fort Bend	Fresno	7.71	0.00
2432A_03	TXR05S302/Not Applicable	Blue Ridge Landfill TX, LP	Fort Bend	Fresno	183.87	0.00
2432D_01	TXR05BQ25/ WQ0000001000	Ascend Performance Materials Texas Inc.	Brazoria	Alvin	1,286.21	1,286.21
2432D_01	TXR05DG63/ WQ0001333000	INEOS USA LLC	Brazoria	Alvin	426.23	426.23
				Total	**2,314.22**	**1,993.78**

In May 2022, a review of TCEQ Central Registry was performed for 2016 through 2021 for active permits (TCEQ 2022d). The results were reviewed and filtered to remove duplicates, i.e., authorizations referring to the same area in the same year, and for locations outside of the TMDL Project watershed. Once the initial review was completed, there were a total of 174 authorizations that were active during the timeframe. The authorizations were then compared to the UA to further remove any within the UA to prevent duplication. To determine an estimated area potentially under a MS4 Phase II permit within the TMDL Project watershed, a review of the USCB's 2010 census defined UA was also done in May 2022 (USCB, 2010). This yielded a total of 45 authorizations in the TMDL Project watershed with a total 3,694.47 acres of disturbed area (Table 10).

One authorization was for pipeline construction across the three subwatersheds. Without additional information other than what is found within the TCEQ database, the estimated disturbed area was split evenly within the three applicable subwatersheds. For four of the AU subwatersheds, there was either one or two authorizations for the timeframe reviewed. Rather than taking an average across six years, the total disturbed area was retained for the TMDL. Construction within the AU 2432A_03 subwatershed, was more active with 40 authorizations. For this subwatershed, a yearly average was calculated (Table 10).

Table 10. Construction stormwater authorization review

Subwatershed	Filtered Authorizations (2016–2021)	Disturbed Area (acres)	Yearly Average Disturbed Area* (acres)
2432A_01	1	16.11	16.11
2432A_02	1	15.00	15.00
2432A_03*	40	3,629.14	604.86
2432D_01	1	16.11	16.11
2432E_01	2	18.11	18.11
TMDL Project Watershed Total	**45**	**3,694.47**	**670.19**

*Yearly average calculated for 2432A_03.

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.

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

A number of agricultural activities that do not require permits can be potential sources of fecal bacteria loading. Activities, such as livestock grazing close to water bodies and the use of manure as fertilizer, can contribute *E. coli* and Enterococci to nearby water bodies. Livestock are present throughout the more rural portions of the TMDL project watershed.

Estimates of livestock in the TMDL Project watershed are shown in Table 11. These estimates were calculated by applying a ratio of watershed land area compared to county land area times the livestock numbers from the 2022 Census of Agriculture for Brazoria and Fort Bend counties performed by the USDA (USDA, 2024). This calculation assumes equal distribution of livestock and farm operations throughout the two counties. Texas State Soil and Water Conservation Board (TSSWCB) staff reviewed the watershed estimated livestock numbers. These livestock numbers, however, were not used to develop an allocation of allowable bacteria loading to livestock.

Table 11. Estimated livestock populations

Area Name	Pasture/ Grassland Area (Acres)	Cattle and Calves	Hogs and Pigs	Sheep and Goats	Equine	Poultry
Brazoria County	262,076	59,766	2,600	3,607	3,608	202,164
Fort Bend County	197,123	33,343	36	970	1,660	6,232
2432A_01	3,134.63	715	31	43	43	2,418
2432A_02	801.64	183	8	11	11	618
2432A_03	5,752.45	1,232	44	67	72	3,433
2432D_01	524.46	120	5	7	7	405
2432E_01	2,618.82	597	26	36	36	2020
Total TMDL Project Watershed	**12,832.01**	**2,847**	**114**	**164**	**169**	**8,894**

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 12 summarizes the estimated number of dogs and cats in the TMDL Project watershed. Due to the very small number of households in the New Bayou subwatershed and the complete lack of households in the Persimmon Bayou subwatershed, an analysis on the estimated number of cats and dogs was only performed for the Mustang Bayou subwatershed. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household (AVMA, 2018). The actual contribution and significance of bacteria loads from pets reaching the water bodies of the watershed is unknown.

Table 12. Estimated households and pet populations

Mustang Bayou Subwatershed	Estimated Households	Dogs	Cats
2432A_01	904	555	413
2432A_02	3,766	2,312	1,721
2432A_03	10,287	6,316	4,701
Total	**14,957**	**9,183**	**6,835**

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. Wildlife are naturally attracted to 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 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, 2019) estimates deer populations for their Resource Management Units. In the ecoregion surrounding the TMDL Project watershed, TPWD deer population estimates recorded from 2008 through 2020 average 0.03957 deer for every acre, regardless of land cover type. By applying this factor to the acreage in the TMDL Project watershed, the white-tailed deer population can be estimated at 1,788 (Table 13).

Table 13. Estimated deer population

Subwatershed	Area (acres)	Estimated Deer Population
2432A_01	9,288.85	368
2432A_02	4,255.91	168
2432A_03	17,916.10	709
2432D_01	4,435.11	175
2432E_01	9,289.54	368
Total	**45,185.50**	**1,788**

Feral hogs are a non-native, invasive species, which likely impact the TMDL Project watershed with fecal waste deposition. 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 available food and water resources. The 8.9 hogs per square mile is applied to Barren, Cropland, and Developed Low Intensity land cover types. The 16.4 hogs per square mile is applied to Open Space Development, Forest/Shrub, Pasture/Grassland, and Wetland land cover types. Feral hogs were estimated to have a total population of 861 within the TMDL Project watershed (Table 14).

Table 14. Estimated feral hog population

Subwatershed	Low Quality Habitat (acres)	Feral Hogs – Low Quality Habitat	High Quality Habitat (acres)	Feral Hogs – High Quality Habitat	Total Estimated Feral Hogs
2432A_01	3,511.16	49	4,697.93	120	169
2432A_02	915.56	13	2,670.16	68	81
2432A_03	2,552.85	36	12,507.93	321	356
2432D_01	3,376.89	47	1,006.58	26	73
2432E_01	2,915.59	41	5,504.11	141	182
Total	**13,272.06**	**186**	**26,386.71**	**676**	**861**

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. However, properly designed and operated OSSFs contribute virtually no fecal bacteria to surface waters. For example, 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 (Weiskel et al., 1996). Reed, Stowe, and Yanke LLC (2001) provide estimated failure rates of OSSFs for different regions of Texas. The TMDL Project watershed is located within the Region IV area, which has a reported failure rate of about 12%, providing insight into expected failure rates for the area.

H-GAC, in coordination with authorized agents in H-GAC's service region, compiled the number of permitted and registered OSSFs in the TMDL Project watershed (H-GAC, 2022a). Brazoria and Fort Bend counties are local authorized agents who have accepted responsibility from TCEQ to permit OSSFs and enforce laws and rules governing OSSFs on behalf of the State. There are 1,666 registered OSSFs in the TMDL Project watershed (Table 15, Figure 7).

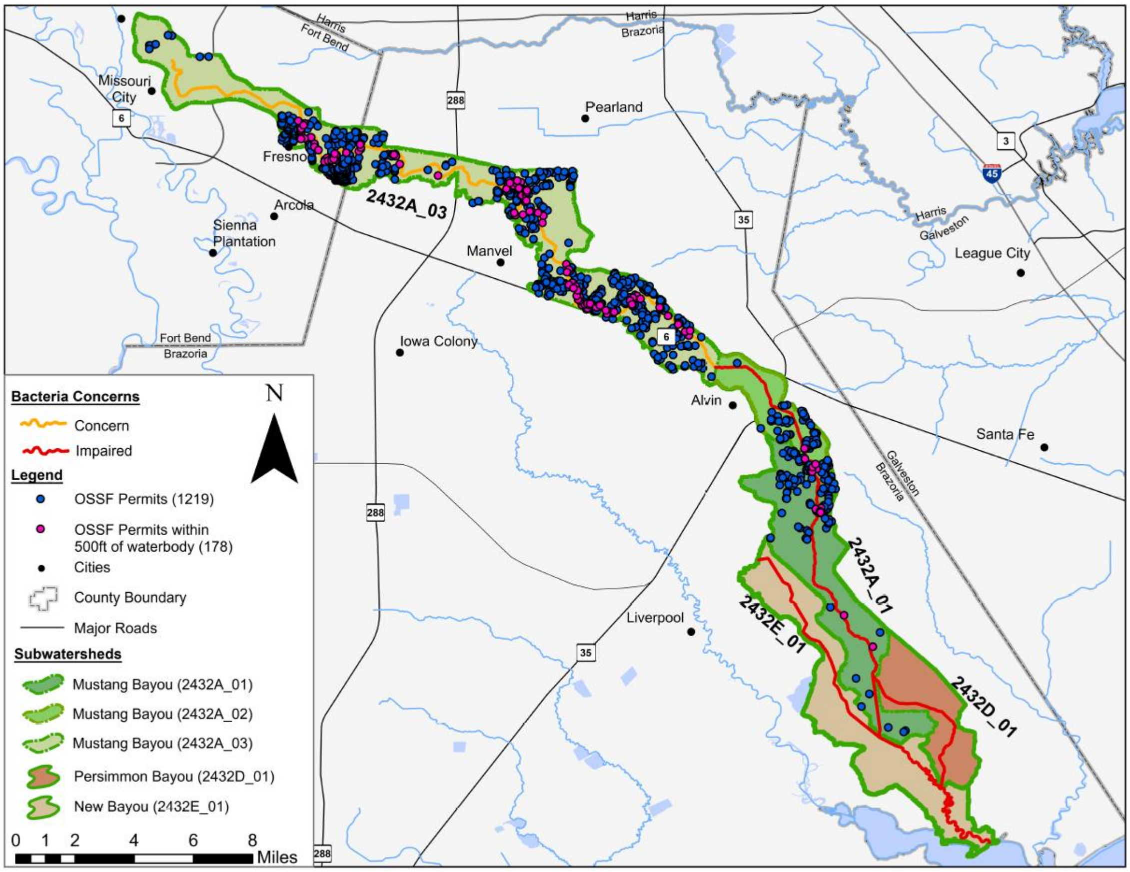
In addition to permitted systems, there are OSSFs that are not registered. Non-registered OSSF locations were estimated using H-GAC's geographic information database of potential OSSF locations (H-GAC, 2022b) in the Houston-Galveston area using known OSSF locations, 911 addresses, and WWTF service boundaries. Using H-GAC's estimate of non-registered OSSFs, there are likely another 1,413 non-registered OSSFs within the TMDL Project watershed (Table 15, Figure 7).

Table 15. Estimated OSSFs

AU	Registered	Non-registered	Total
2432A_01	186	98	284
2432A_01	214	246	460
2432A_03	1,236	1,069	2,305
2432D_01	9	_	9
2432E_01	21	_	21
Total	**1,666**	**1,413**	**3,079**

OSSFs can be an appreciable source of fecal waste when not sited or functioning properly, especially when they are close 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 3,079 OSSFs estimated within the TMDL Project watershed (Table 15), 369 OSSFs are projected to be failing.

Figure 7. Estimated Distribution of OSSFs in the TMDL Project watershed



Bacteria Survival and Die-off

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

Linkage Analysis

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

Generally, if high bacteria concentrations are measured in a water body at low to median flows in the absence of runoff events, the main contributing sources are likely to be point sources and direct deposition. During ambient flows, these inputs to the system will increase pollutant concentrations depending on the magnitude and concentration of the sources. As flows increase in magnitude, the impact of point sources 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 fecal bacteria from the land surface into the receiving water body. Generally, this loading follows a pattern of higher concentrations in the water body as the first flush of storm runoff enters the receiving water body. Over time, the concentrations decline because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

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 also inherently assumed when using LDCs to define the TMDL pollutant load allocation.

Load Duration Analysis

LDCs are graphs of the frequency distribution of loads of pollutants in a water body. LDC analyses are used to examine the relationship between instream water quality and broad sources of bacteria loads which are the basis of the TMDL allocations (Cleland, 2003). In the case of these TMDLs, the loads shown are of *E. coli* bacteria in cfu/day for AUs 2432A_01, 2432A_02 and 2432A_03, and Enterococci in cfu/day for AUs 2432D_01 and 2432E_01.

It should be noted that modified LDCs are typically performed on tidal water bodies to account for tidal fluctuations in the waterbody's flow. A regression analysis between flow and salinity was completed for the tidal AUs (2432D_01 and 2432E_01), and only a weak correlation was found. While tidal inflows do impact these tidal water bodies, they are minimal when measured at the AUs' SWQM stations, and most salinity data points are less than two parts per thousand. This makes it acceptable to complete traditional LDCs instead of modified LDCs on the tidal AUs.

LDCs are derived from flow duration curves (FDCs). LDCs shown in the following figures represent the maximum acceptable load in the water bodies that will result in achievement of the TMDL water quality target(s). The basic steps to generate LDCs involve all of the following:

- Generating a daily flow record – the mean daily streamflow record incorporating full permitted discharges and FG was developed for a TCEQ SWQM station within each AU using the drainage area ratio methodology and the mean daily streamflow reported at USGS Gage 08078000 on Chocolate Bayou Above Tidal.
- Developing the FDC – the mean daily streamflow is plotted against the exceedance probability of the mean daily streamflow for each day.
- Converting the FDC to an LDC – the mean daily streamflow for each day is multiplied by the primary contact recreation 1 use geometric mean criterion and a conversion factor to produce a graph of the frequency distribution of allowable loads.
- Overlaying the LDC with available indicator bacteria loading measurements to understand under what flow conditions indicator bacteria loading exceeds the primary contact recreation 1 use geometric mean criterion.

Load Duration Curve Results

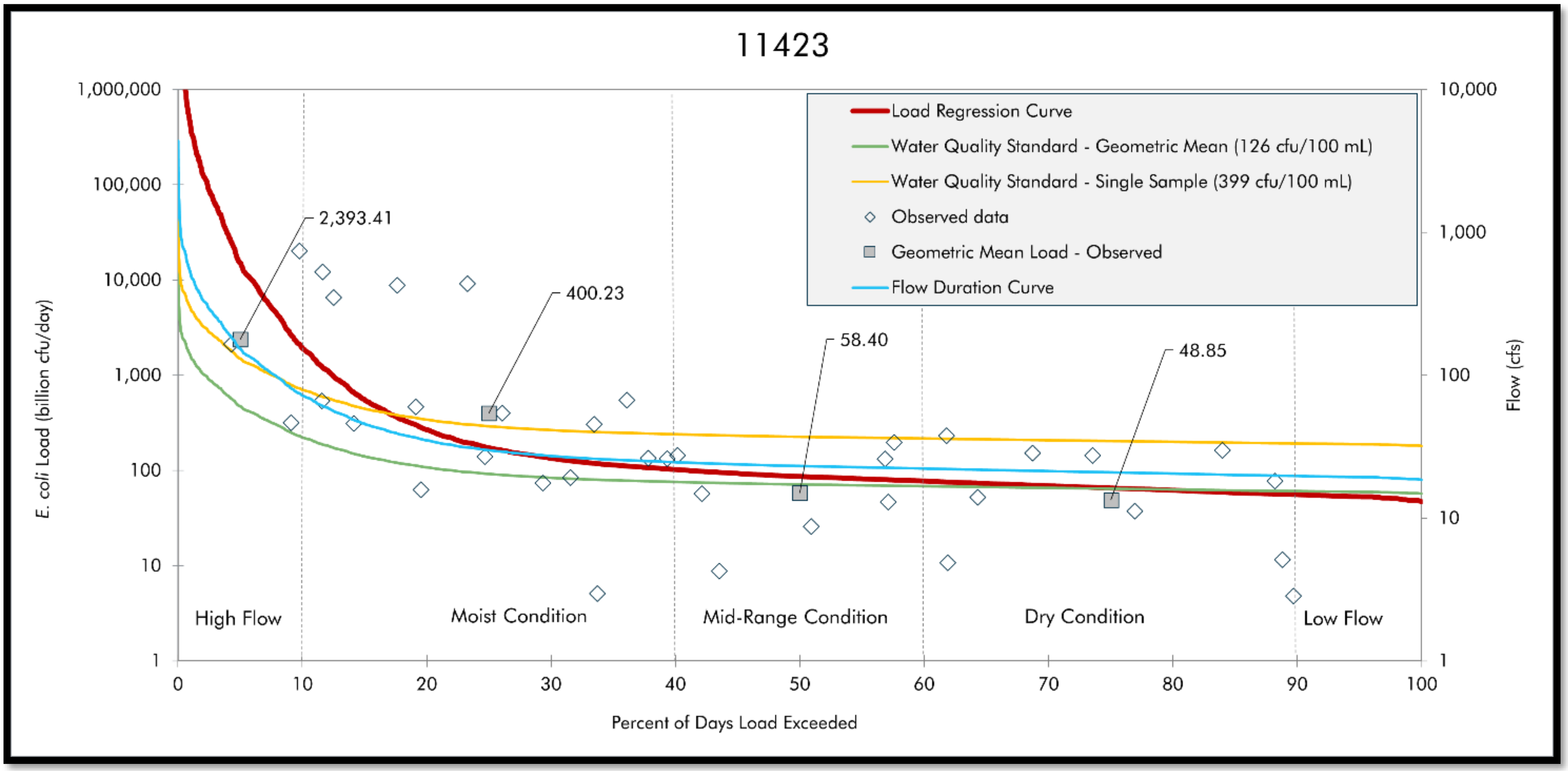


Figure 8. LDC for SWQM Station 11423 in Mustang Bayou, AU 2432A_01

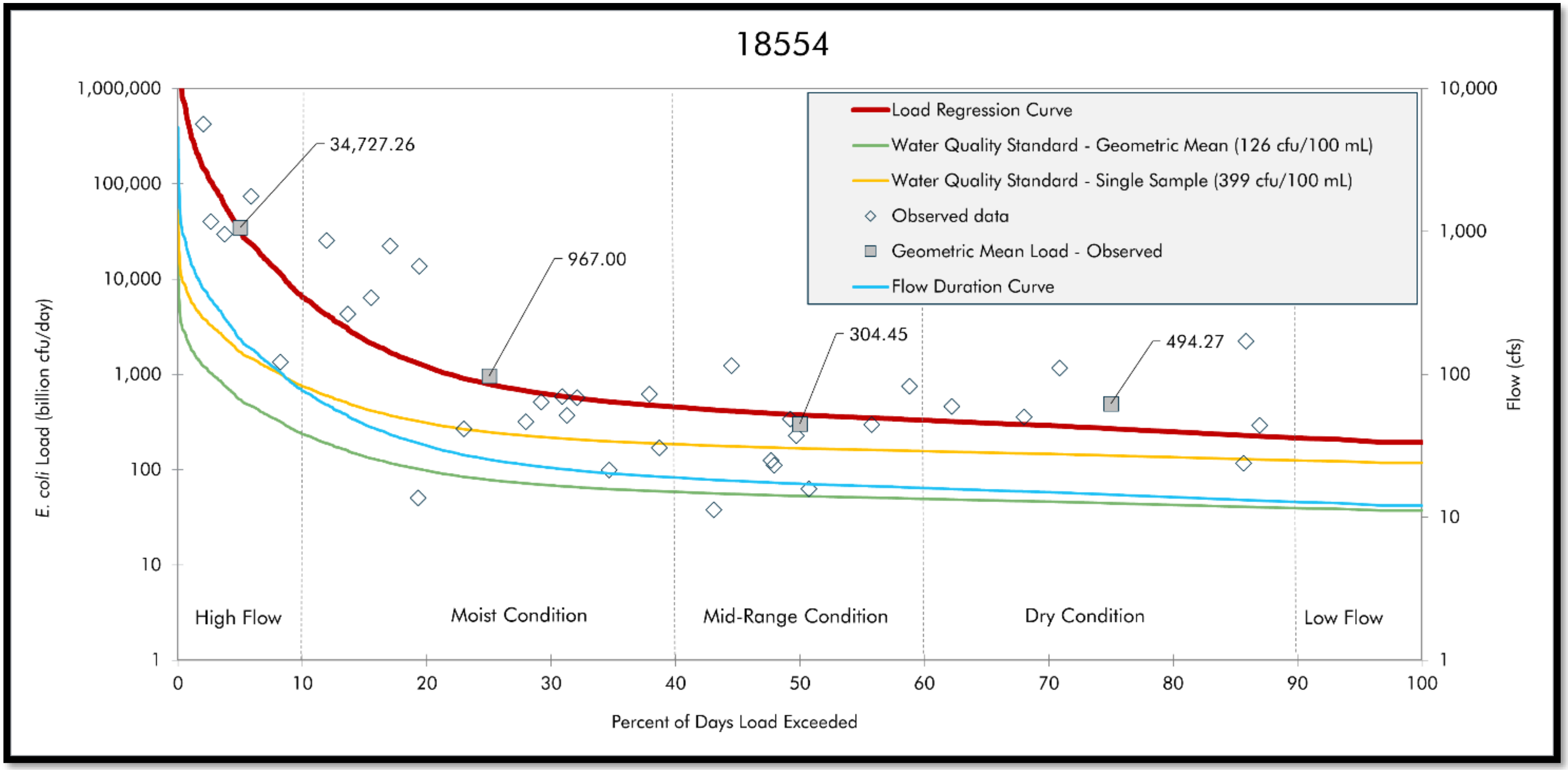


Figure 9. LDC for SWQM Station 18554 in Mustang Bayou, AU 2432A_02

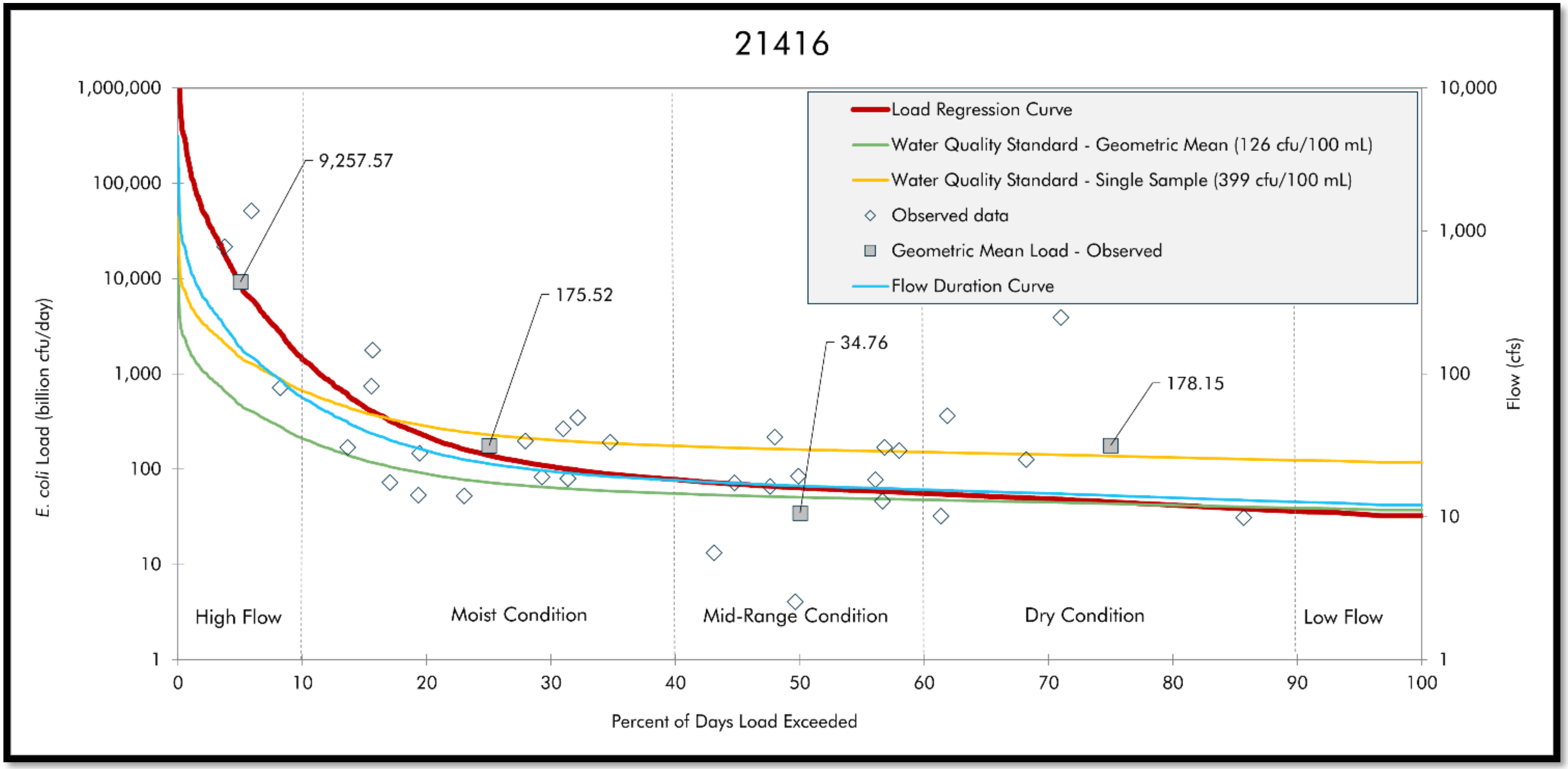


Figure 10. LDC for SWQM Station 21416 in Mustang Bayou, AU 2432A_03

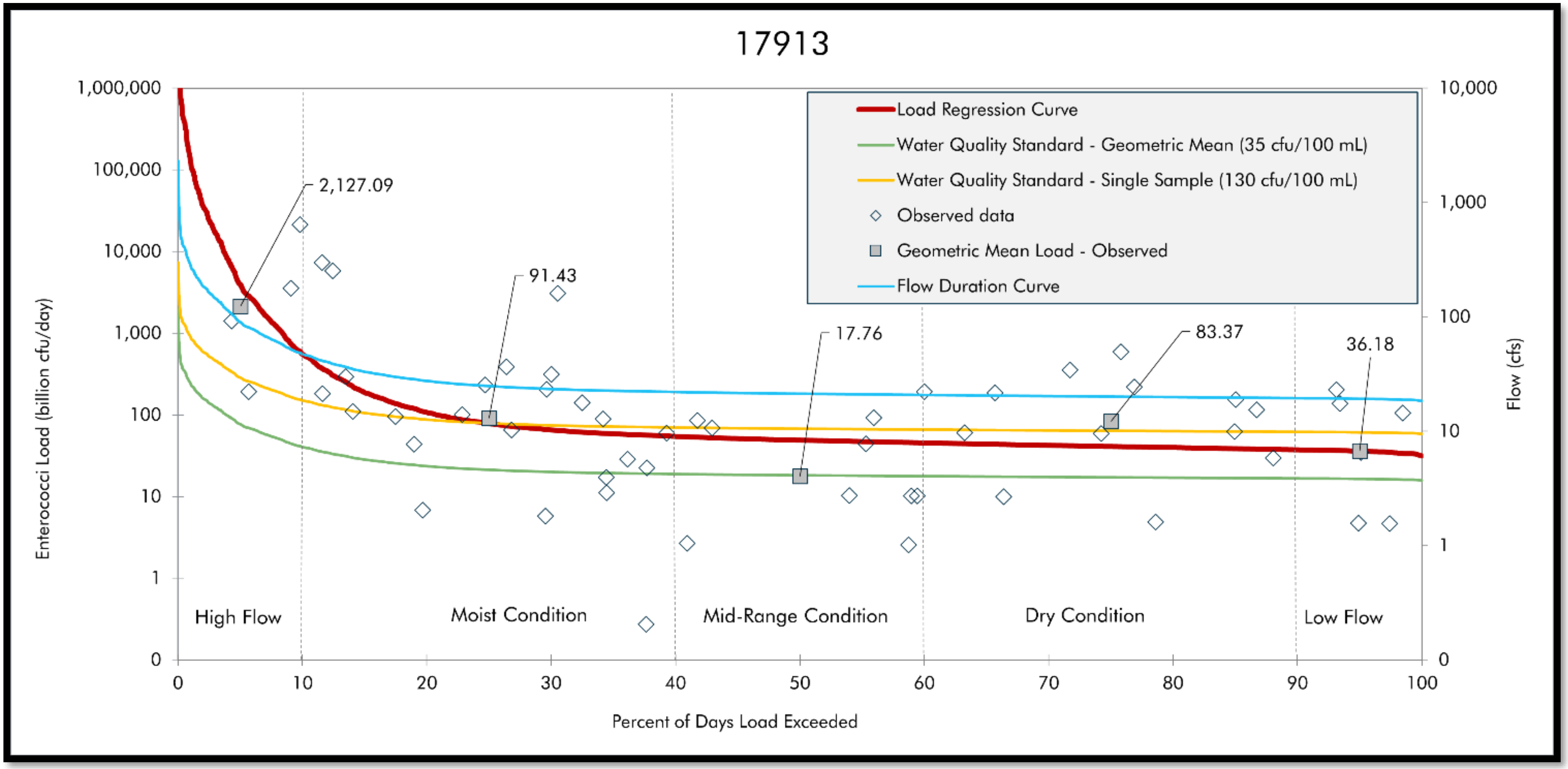


Figure 11. LDC for SWQM Station 17913 in Persimmon Bayou, AU 2432D_01

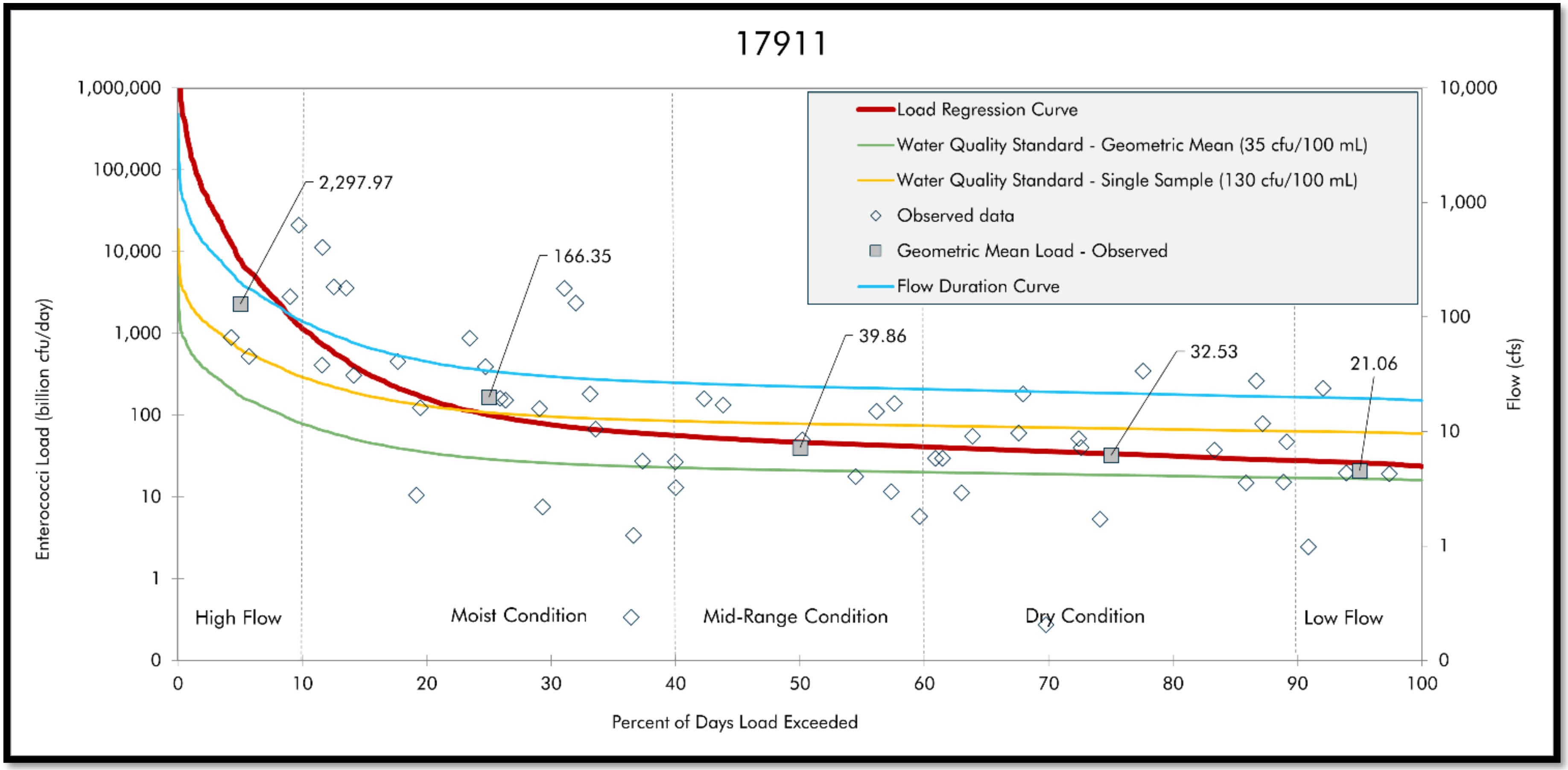


Figure 12. LDC for SWQM Station 17911 in New Bayou, AU 2432E_01

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 goal of the TMDL will be met. It also accounts 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.

According to EPA guidance (EPA, 1991), the MOS can be incorporated into 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.

These TMDLs 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

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

The TMDL components for the impaired AUs are derived using the median flow within the high-flow regime (or 5% flow) of the LDCs developed for each of the TMDL subwatersheds. For the remainder of this report, each section will present an explanation of the TMDL component first, followed by the results of the calculation for that component. Also, please note that some calculations completed in the remainder of this report have been rounded and may not lead to the exact final amounts listed in the text, tables, or figures.

Assessment Unit-Level TMDL Calculations

The TMDLs for the impaired AUs were developed as pollutant load allocations based on information from the LDCs for the SWQM stations located within each subwatershed. The bacteria LDCs were developed by multiplying each streamflow value along the FDCs by the primary contact recreation 1 use geometric mean criterion for *E. coli* and Enterococci (126 cfu/100 mL or 35 cfu/100 mL, respectively) and the conversion factor to convert loading into cfu per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

TMDL (billion cfu/day) = Criterion * Flow * Conversion Factor

Where:

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

Flow = 5% exceedance flow from FDC in cubic feet per second (cfs)

Conversion Factor (to billion cfu/day) = 28,316.8 mL/cubic foot (ft^3) * 86,400 seconds/day (s/d) ÷ 1,000,000,000

Table 16 shows the TMDL values at the 5% load duration exceedance.

Table 16. Summary of allowable loadings

AU	Indicator Bacteria	Criterion (cfu/ 100 mL)	5% Exceedance Flow (cfs)	TMDL (Billion cfu/day)
2432A_01	*E. coli*	126	153.725	473.886
2432A_02	*E. coli*	126	176.731	544.804
2432A_03	*E. coli*	126	153.811	474.149
2432D_01	Enterococci	35	89.775	76.874
2432E_01	Enterococci	35	201.955	172.934

Margin of Safety Formula

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

MOS = 0.05 * TMDL

Where:

TMDL = total maximum daily load

The MOS calculations for each AU are shown in Table 17.

Table 17. MOS calculations

AU	Indicator Bacteria	Criterion (cfu/100 mL)	TMDL	MOS
2432A_01	*E. coli*	126	473.886	23.694
2432A_02	*E. coli*	126	544.804	27.240
2432A_03	*E. coli*	126	474.149	23.707
2432D_01	Enterococci	35	76.874	3.844
2432E_01	Enterococci	35	172.934	8.647

All loads are expressed in billion cfu/day.

Wasteload Allocation

The WLA is the sum of loads from regulated sources. 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}).

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

Wastewater Treatment Facilities

Determination of the WLA_{WWTF} requires development of a daily WLA for each TPDES-permitted facility. The full permitted daily average flow of each WWTF is multiplied by the instream geometric criterion for the water body and the conversion factor. This calculation is expressed by:

WLA_{WWTF} (billion cfu/day) = Criterion * Flow * Conversion Factor

Where:

Criterion = 126 cfu/100 mL for *E. coli* OR 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. The individual results were summed for each AU. The criterion was applied based on the indicator bacteria designated for the segment.

Table 18 shows the load allocations for each WWTF and sums the load allocations, providing a total WLA_{WWTF} for the AUs.

Table 18. Wasteload allocations for TPDES-permitted facilities

AU	TPDES Number	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Flow (MGD)	WLA_{WWTF} [a] (billion cfu/day)
2432A_03	WQ0016073001	Alvin Mustang, LLC	126	0.02	0.10
2432A_03	WQ0016089001	Green Raindrops, Inc	126	0.01	0.05
2432A_03	WQ0015747001	KB Home Lone Star, Inc.	126	0.25	1.20
2432A_03	WQ0015636001	Hanover Estates, Ltd.	126	0.70	3.34
2432A_03	WQ0015077001	AUC Group LP	126	0.80	3.82
2432A_03	WQ0004306000	Nalco Company, LLC (outfall 1)	126	0.02	0.07
2432A_03	WQ0004306000	Nalco Company, LLC (outfall 2)	126	0.02	0.10
2432A_03	WQ0013600001	Aqua Texas, Inc.	126	0.02	0.11
2432A_03	WQ0013735001	Rancho La Fuente Partners, LLC	126	0.08	0.36
2432A_03	WQ0014641001	Brazoria County Municipal Utility District 40	126	1.20	5.72
2432A_03	WQ0014188001	Brazoria County Municipal Utility District No. 40	126	0.10	0.47
2432A_03	WQ0014756001	Sedona Lakes Municipal Utility District 1	126	0.60	2.86
			2432A_03 Total	**3.82**	**18.18**
2432A_02	WQ0010420001	City of Hillcrest Village	126	0.15	0.72

AU	TPDES Number	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Flow (MGD)	WLA_{WWTF} [a] (billion cfu/day)
			2432A_02 Total	**0.15**	**0.72**
			Cumulative Total	**3.97**	**18.90**
2432A_01	WQ0014039001	Aqua Texas, Inc.	126	0.09	0.44
2432A_01	WQ0010005001	City of Alvin	126	5.00	23.85
			2432A_01 Total	**5.09**	**24.29**
			2432D_01 Total	**0.00**	**0.00**
			Cumulative Total	**9.06**	**43.19**
2432E_01	WQ0000001000	Ascend Performance Materials Texas, Inc.	Not Applicable	Intermittent/ Flow Variable	Not Applicable
2432E_01	WQ0001333000	INEOS USA, LLC	Not Applicable	Intermittent/ Flow Variable	Not Applicable
			2432E_01 Total	**0.00**	**0.00**
			TMDL Project Watershed Total	**9.06**	**43.19**

[a] WLA_{WWTF} used in Table 20 is the sum of each AUs WLA_{WWTF} (Table 18) and the contribution from watersheds upstream. AUs 2432A_01 and 2432D_01 split evenly the contributions from AUs 2432A_01, 2432A_02, and 2432A_03 above the channel division with the flow assumed to be 50%. AUs 2432D_01 and 2432E_01 substituted the tidal criterion.

Regulated Stormwater

Stormwater discharges from MS4s, industrial facilities, concrete production and construction activities 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 watershed that is under the jurisdiction of stormwater permits (i.e., defined as the area designated as urbanized area in the 2010 United States Census) was used to estimate the amount of the overall runoff load that should be allocated as the regulated stormwater contribution in the WLA_{SW} component of the TMDL (Figure 6). The load allocation (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}.

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

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

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 FDA_{SWP} must be calculated to arrive at the fractional proportion of the drainage area under jurisdiction of stormwater permits. FDA_{SWP} was calculated by first totaling the area of each stormwater permit and authorization. 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 watershed. To arrive at the proportion, the area under stormwater jurisdiction was then divided by the total watershed area. The estimated areas in Table 19 are cumulative, each AU accounts for the upstream area contribution by adding the total area of regulated stormwater for the AU and that of the upstream AU and then dividing by the watershed area.

Table 19. Regulated stormwater FDA_{SWP} calculations

AU	MS4 Area	MSGP Area	CGP Area	Construction Activities	Total Area of Permits	Watershed Area	FDA_{SWP} [a]
2432A_01	364.956	0.000	0.000	16.110	381.066	9,288.848	0.382
2432A_02	3,213.342	0.000	0.000	15.000	3,228.342	4,255.907	0.524
2432A_03	7,481.414	281.340	33.190	604.860	8,400.804	17,916.097	0.469
2432D_01	0.000	0.000	0.000	16.110	16.110	4,435.109	0.298
2432E_01	0.000	1,712.440	0.000	18.110	1,730.550	9,289.543	0.309

All areas are expressed in acres.

[a] To calculate FDA_{SWP}, Total Area of Permits and Watershed Areas are summed prior to division, e.g., AU 2432A_02 FDA_{SWP} (0.524) is the sum of permit area 2432A_02+ 2432A_03 divided by the sum of watershed area of 2432A_02 + 2432A_03. AU 2432A_01 values are divided by 2 when calculating values for 2432D and 2432E due to the split in flow.

A value for FG is necessary to complete the WLA_{SW}. The calculation for FG is presented in the later section "Allowance for Future Growth," but the results will be included here for continuity. The WLA_{SW} calculations are presented in Table 20.

Table 20. Regulated stormwater load calculations

AU	TMDL	MOS	WLA_{WWTF}	Adjusted FG	FDA_{SWP}	WLA_{SW}	Indicator Bacteria
2432A_01	473.886	23.694	21.592	30.938	0.382	151.808	*E. coli*
2432A_02	544.804	27.240	18.894	37.702	0.524	242.776	*E. coli*
2432A_03	474.149	23.707	18.179	37.441	0.469	185.131	*E. coli*
2432D_01	76.874	3.844	5.998	8.614	0.298	17.397	Enterococci
2432E_01	172.934	8.647	5.998	8.614	0.309	46.277	Enterococci

All loads are expressed in billion cfu/day. With the WLA_{SW} and WLA_{WWTF} terms, the total WLA term can be determined by adding the two parts (Table 21).

Table 21. WLA calculations

AU	WLA_{WWTF}	WLA_{SW}	WLA
2432A_01	21.592	151.808	173.400
2432A_02	18.894	242.776	261.670
2432A_03	18.179	185.131	203.310
2432D_01	5.998	17.397	23.395
2432E_01	5.998	46.277	52.275

In areas currently regulated by an MS4 permit, development, re-development, or both, of land must include the implementation of the control measures/programs outlined in an MS4's approved SWMP. Although additional flow may occur from development or redevelopment, loading of the pollutant of concern should be controlled or reduced through the implementation of BMPs as specified in both the TPDES permit and the approved SWMP.

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

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, effluent limitations, or both as required by the amendment of Title 30, Texas Administrative Code (TAC) Chapter 319, which became effective Nov. 26, 2009. WWTFs discharging to TMDL water bodies will be assigned an effluent limit based on the TMDL. Monitoring requirements are based on permitted flow rates and are listed in 30 TAC Section 319.9.

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 these TMDLs are 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 comply with the TMDLs.

The executive director or commission may establish interim effluent limits, monitoring-only requirements, or both during amendment or renewal of a permit. These interim limits will allow a permittee time to modify effluent quality 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. Compliance schedules are not allowed for new permits.

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, construction stormwater, 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 Nov. 26, 2014 memorandum from EPA (EPA, 2014) 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.'

Verify 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 LA, and the MOS for each impaired AU. Changes to individual WLAs may be necessary in the future to accommodate growth or other changing conditions. These changes to individual WLAs do not ordinarily require a revision of the TMDL report; 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:

$$LA = TMDL - WLA - FG - MOS$$

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

Table 22 summarizes the LA.

Table 22. LA calculations

AU	Indicator Bacteria	TMDL	WLA_{WWTF}	WLA_{SW}	FG	MOS	LA
2432A_01	*E. coli*	473.886	21.592	151.808	30.938	23.694	245.854
2432A_02	*E. coli*	544.804	18.894	241.776	37.702	27.240	219.192
2432A_03	*E. coli*	474.149	18.179	185.131	37.441	23.707	209.691
2432D_01	Enterococci	76.874	5.998	17.397	8.614	3.844	41.022
2432E_01	Enterococci	172.934	5.998	46.277	8.614	8.647	103.399

All loads are expressed in billion cfu/day.

Allowance for 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 considers 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 for TMDL watersheds is typically based on population projections (Table 3) and current permitted wastewater discharges for the entire TMDL Project watershed. As there are no WWTFs present in AUs 2432D_01 or 2432E_01, and the population within these subwatersheds is not expected to grow, a different method was used. Potential future 0.015 MGD WWTFs were sited within both subwatersheds to account for unforeseen population growth or planned developments in the future. The size of 0.015 MGD was based on a wastewater permit for an RV park sited in the Chocolate Bayou Tidal watershed.

Table 23 provides the FG for each AU in the TMDL Project watershed. An adjusted FG term is provided to demonstrate the adjustment needed to account for upstream WWTFs on downstream AUs. WWTFs FG calculated using the freshwater criterion were recalculated for the saltwater criterion for the tidal AUs. Additionally, based on the geospatial view of the Persimmon Bayou confluence with Mustang Bayou, the flow would appear to split almost evenly. Without the ability to measure this accurately, an assumption was made to simply set the upstream flow contribution to AU 2432A_01 and AU 2432D_01 at 50%.

$$\text{FG (billion cfu/day)} = \text{Criterion} * (\%\text{POP}_{2020\text{-}2070} * \text{WWTF}_{\text{FP}}) * \text{Conversion Factor}$$

Where:

Criterion = 126 cfu/100 mL (*E. coli*) or 35 cfu/100 mL (Enterococci)

$\%\text{POP}_{2020\text{-}2070}$ = estimated percentage increase in population between 2020 and 2050

WWTF_{FP} = full permitted discharge (MGD)

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

Table 23. FG calculations

Subwatershed	Indicator Bacteria	% Population Change (2020-2050)	Full Permitted Discharge (MGD)	FG Flow (MGD)	FG [a]	Indicator Bacteria
2432A_01	*E. coli*	99.53%	5.092	5.068	30.938[b]	*E. coli*
2432A_02	*E. coli*	36.49%	0.150	0.055	37.702	*E. coli*
2432A_03	*E. coli*	205.96%	3.811	7.850	37.441	*E. coli*
2432D_01	Enterococci	0.0%	-	0.015	8.614[c]	Enterococci
2432E_01	Enterococci	0.0%	-	0.015	8.614[c]	Enterococci

All loads are expressed in billion cfu/day.

[a] FG accounts for the contribution of future growth upstream of the AU.

[b] Calculated as the FG 2432A_01 plus FG of 2432A_02 divided by 2.

[c] Calculated as the FG plus the FG of 2432A_01 when calculated using the tidal criterion, 35 cfu/100 mL of Enterococci

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. FGs of existing or new point sources are not limited by these TMDLs if 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 LDCs and tables in this TMDL report will guide determination of the assimilative capacity of the water body under changing conditions, including FG.

Summary of TMDL Calculations

The TMDLs in freshwater were calculated using the median flow (5% exceedance) in the high flow range for flow exceedance from the LDCs developed for SWQM stations 11423, 18554, and 21416 based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDLs.

The TMDLs in tidal waters were calculated using the median flow (5% exceedance) in the high flow range for flow exceedance from the LDCs developed for SWQM stations 17913 and 17911 based on the current geometric mean criterion for Enterococci of 35 cfu/100 mL for each component of the TMDLs.

The TMDL allocation summary for the TMDL Project watershed is summarized in Table 24.

Table 24. TMDL allocation summary

AU	Indicator Bacteria	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
2432A_01	*E. coli*	473.886	21.592	151.808	245.854	30.938	23.694
2432A_02	*E. coli*	544.804	18.894	241.776	219.192	37.702	27.240
2432A_03	*E. coli*	474.149	18.179	185.131	209.691	37.441	23.707
2432D_01	Enterococci	76.874	5.998	17.397	41.022	8.614	3.844
2432E_01	Enterococci	172.934	5.998	46.277	103.399	8.614	8.647

All loads are expressed in billion cfu/day.

The final TMDL allocations (Table 25) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 25. Final TMDL allocation

AU	Indicator Bacteria	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
2432A_01	*E. coli*	473.886	52.530	151.808	245.854	23.694
2432A_02	*E. coli*	544.804	56.597	241.776	219.192	27.240
2432A_03	*E. coli*	474.149	55.620	185.131	209.691	23.707
2432D_01	Enterococci	76.874	14.612	17.397	41.022	3.844
2432E_01	Enterococci	172.934	14.612	46.277	103.399	8.647

All loads are expressed in billion cfu/day.

Seasonal Variation

Federal regulations require that TMDLs account for seasonal variation in watershed conditions and pollutant loading [40 CFR 130.7(c)(1)].

Analysis of the seasonal differences in fecal indicator bacteria concentrations were assessed by comparing *E. coli*/Enterococci concentrations obtained from eight years (2013 through 2020) of routine monitoring data collected in the warmer months (May through September) against those collected during the cooler months (November through March). The months of April and October were considered transitional between warm and cool seasons and were excluded from the seasonal analysis.

Differences in *E. coli*/Enterococci concentrations obtained in warmer versus cooler months were then evaluated by performing a Wilcoxon Rank Sum test (also known as the "Mann-Whitney" test). This analysis of fecal bacteria data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for the TMDL Project watershed (p=0.271). Seasonal variation was also addressed by using all available flow and fecal indicator 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 to generate and maintain stakeholder interest since 2020. Direct e-mail, letters, and phone calls were made with identified stakeholders to provide information and encourage participation in future meetings. Press releases and general e-mails were created by H-GAC to cast a broad net using listservs and news outlets. Project webpages and informational brochures were developed to provide information, meeting notifications, and project updates. Stakeholders that could potentially be impacted by the TMDL and future implementation plan (I-Plan) were contacted, and one-on-one meetings were held with some to foster interest, build support, and generate trust.

TCEQ and H-GAC held a series of ten meetings between 2020 and 2024 to make the public, local governments, businesses, non-profits, agriculture producers, and others, aware of the TMDLs, initiate I-Plan development, and develop management measures to include in the I-Plan. Notices of meetings were posted on the 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[c] provides meeting summaries, presentations, ground rules, and documents produced for review.

The stakeholder group is committed to additional meetings in 2024 and 2025 to complete development of the Chocolate Bay I-Plan and the selection of management measures to reduce sources of fecal bacteria.

Implementation and Reasonable Assurance

The issuance of TPDES permits consistent with TMDLs provides reasonable assurance that WLAs 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 130.6(c)]. Commission adoption of a TMDL is the state's certification of the associated WQMP update.

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

[c] www.h-gac.com/watershed-based-plans/san-jacinto-brazos-coastal-basin-tmdl-and-implementation-plan

For MS4 entities, where numeric effluent limitations are infeasible, the permits require that the MS4 develop and implement BMPs under each MCM, which are a substitute for effluent limitations, as allowed by federal rules. How a regulated MS4 meets each MCM is not prescribed in detail in the MS4 permits but is included in the permittee's SWMP. During the permit renewal process, TCEQ revises its MS4 permits as needed to require the implementation of other specific revisions in accordance with an approved TMDL and 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 TSSWCB when developing the I-Plan. 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 identifies the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the approved I-Plan may not approximate the predicted loadings identified category by category in the TMDL and its underlying assessment. The I-Plan is adaptive for this very reason; it allows for continuous update and improvement.

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

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Appendix A.
Population and Population Projections

The following steps detail the method used to estimate the 2020 and projected 2050 populations in the TMDL Project watershed:

1. Obtained 2020 American Community Survey data from the USCB at the block level.
2. Used U.S. Census block data to develop population estimates for a hexagonal grid of three-square miles each (H3M) for the H-GAC region.
3. Determined the 2020 population for H3Ms that do not lie entirely in the watershed by multiplying the H3M population by the portion of the H3M located within the watershed assuming equal distribution.
4. Obtained population projections for the year 2050 from the H-GAC regional forecast based on H3M data.
5. Determined the 2050 population projections for H3Ms that do not lie entirely in the watershed by multiplying the H3M population by the portion of the H3M located within the watershed assuming equal distribution.
6. Subtracted the 2020 watershed population from the 2050 population projection to determine the projected population increase. Subsequently, the projected population increase was divided by the 2020 watershed population to determine the percent population increase for the TMDL Project watershed.