Draft Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Jarbo Bayou

Assessment Unit: 2425B_02

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Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming unit
CGP	construction general permit
DAR	drainage-area ratio
DSLP	days since last precipitation
EPA	(United States) Environmental Protection Agency
FG	future growth
gpcd	gallons per capita per day
gSSURGO	Gridded Soil Survey Geographic Database
H-GAC	Houston-Galveston Area Council
I&I	Inflow and infiltration
LA	load allocation
LDC	load duration curve
MCM	minimum control measures
MFDC	modified flow duration curve
MGD	million gallons per day
mL	milliliter
MLDC	modified load duration curve
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
ppt	parts per thousand
SSO	sanitary sewer overflow
SWMP	Stormwater Management Plan
SWQM	surface water quality monitoring
TAC	Texas Administrative Code
TAZ	transportation analysis zone
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute of Applied Environmental Research
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TXDOT	Texas Department of Transportation
UA	urbanized area

U.S.	United States
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from wastewater treatment facilities
WWTF	wastewater treatment facility

Section 1. Introduction

1.1. Background

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

A TMDL is like a budget — it determines the amount of a particular pollutant that a water body can receive and still meet applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time but may be expressed in other ways.

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

TCEQ first identified the bacteria impairment within Jarbo Bayou (assessment unit (AU) 2425B_02) in the U.S. Environmental Protection Agency (EPA)-approved 2022 edition of the *Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report, TCEQ, 2022a). TCEQ first identified a bacteria impairment within the Jarbo Bayou watershed at the downstream Jarbo Bayou AU (2425B_01) in the *2002 Texas Water Quality Inventory and 303(d) List* (TCEQ, 2002).

This document will consider one bacteria impairment in one AU of Jarbo Bayou. The impaired AU and its identifying number is:

- Jarbo Bayou AU 2425B_02

In this report, the impaired water body will be referred to as Jarbo Bayou AU 2425B_02 or AU 2425B_02.

1.2. Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, TCEQ established the *Texas Surface Water Quality Standards* (TCEQ, 2022b). The Standards describe the limits for indicators that are monitored to assess the quality of available water for specific uses. TCEQ monitors and assesses water bodies based on these Standards and publishes the Texas Integrated Report list biennially.

The Standards are rules that do all of the following:

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

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

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

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

On Feb. 7, 2018, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2022b) and on May 19, 2020, the EPA approved the categorical levels of recreational use and their associated criteria. Recreational use consists of several categories:

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

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

- **Noncontact recreation** – Activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic. The geometric mean criterion for Enterococci is 35 cfu per 100 mL.

Jarbo Bayou is a saltwater stream and has a primary contact recreation 1 use. The associated criterion for Enterococci is a geometric mean of 35 cfu per 100 mL.

1.3. Report Purpose and Organization

The Jarbo Bayou AU 2425B_02 TMDL project was initiated through a contract between TCEQ and TIAER. The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired AU. This report contains:

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

Whenever it was feasible, the data development and computations for developing the MLDC and pollutant load allocation were performed in a manner to remain consistent with the previously completed original TMDL report, *One Total Maximum Daily Load for Indicator Bacteria in Jarbo Bayou* (TCEQ, 2018b).

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

The TMDL watershed (AU 2425B_02) is located within the Jarbo Bayou (Segment 2425B) watershed in the southeastern portion of the "Greater Houston" metropolitan area and entirely within Galveston County (Figure 1). Influenced by seawater from Galveston Bay, Jarbo Bayou begins approximately 0.67 miles upstream of Farm-to-Market 518 and flows 1.61 miles to the outlet at Clear Lake, which feeds into Galveston Bay. Jarbo Bayou consists of two AUs (AU 2425B_01 and 2425B_02).

Jarbo Bayou AU 2425B_02 is an unclassified, tidal stream approximately 1.19 miles in length that drains an area of 1.91 square miles (1,221.92 acres). The watershed is mostly urban and located within two city boundaries, League City and Kemah. (Figure 1).

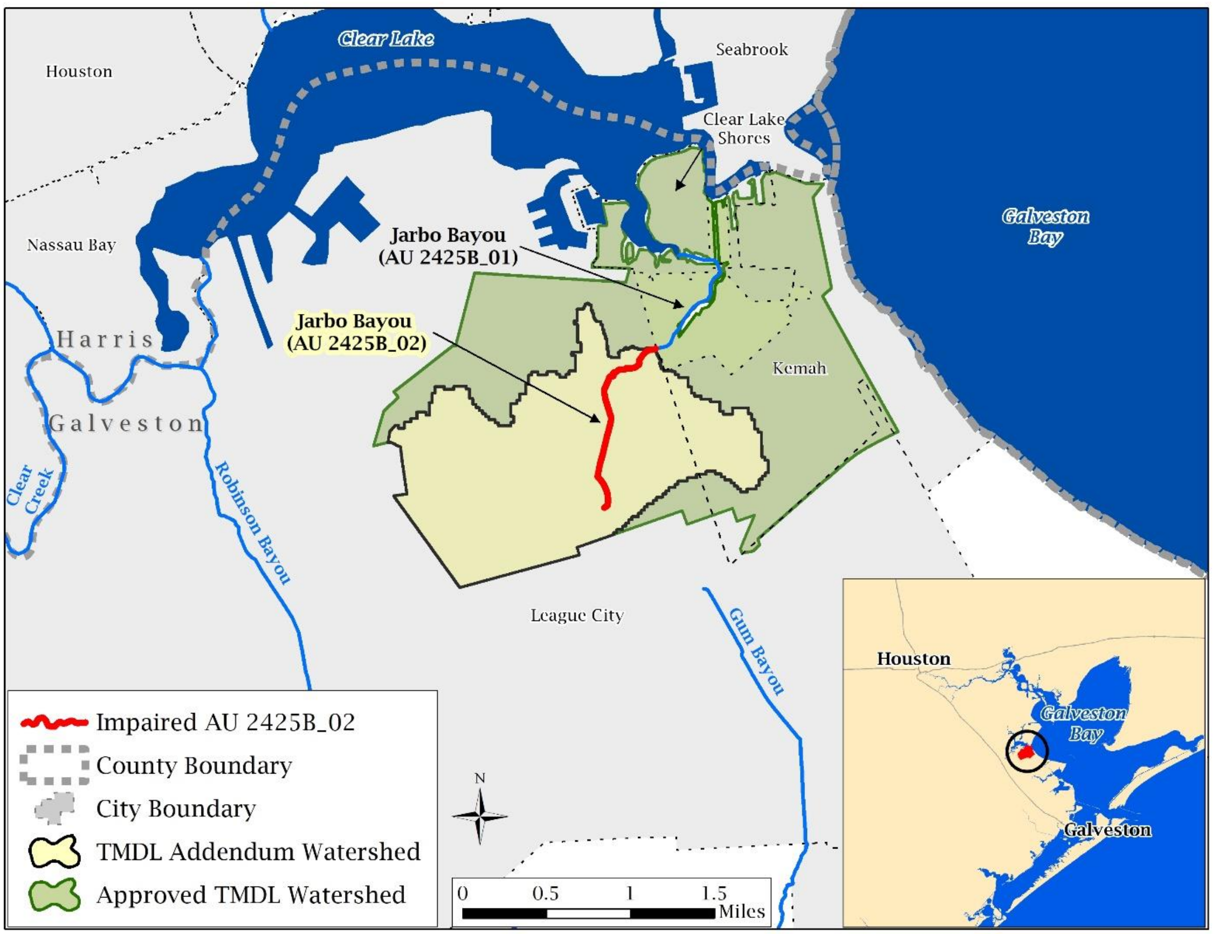

Figure 1. Map of the project watershed

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

- Jarbo Bayou (Segment 2425B) – From Clear Lake confluence with Clear Lake to 1.1 km (0.67 miles) upstream of FM 518 in Galveston County.
  - AU 2425B_01 – From the Clear Lake confluence upstream to Lawrence Road
  - AU2425B_02 – From Lawrence Road to the headwaters 1.1 km (0.67 miles) upstream of FM 518

This TMDL takes a watershed approach to addressing the bacteria impairment, thus the entire watershed of Jarbo Bayou AU 2425B_02 will be considered in this report.

2.2. Review of Routine Monitoring Data

2.2.1. Analysis of Bacteria Data

Monitoring within the Jarbo Bayou AU 2425B_02 watershed has occurred at TCEQ surface water quality monitoring (SWQM) Station 16485 (Figure 2). Enterococci data collected at SWQM Station 16485 over the seven-year period from Dec. 1, 2013 through Nov. 30, 2020 were used in assessing attainment of the primary contact recreation 1 use, as reported in the 2022 Texas Integrated Report (TCEQ, 2022a) and are summarized in Table 1. The 2022 assessment data for the TMDL watershed indicate nonsupport of the primary contact recreation 1 use because geometric mean concentrations exceed the Enterococci geometric mean criterion of 35 cfu/100 mL.

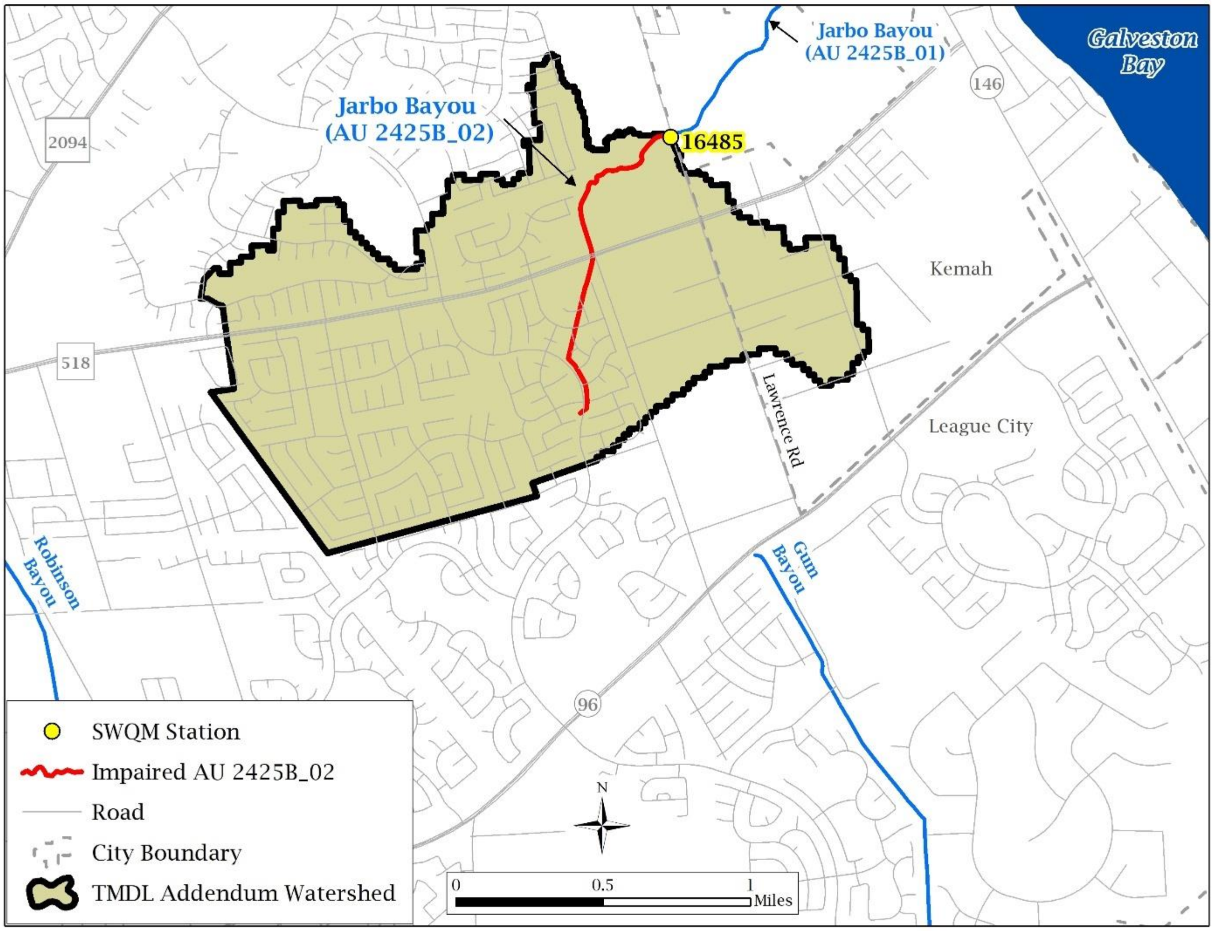

Figure 2. Active TCEQ SWQM station

Table 1. 2022 Texas Integrated Report summary for the Jarbo Bayou AU 2425B_02 watershed

Watershed	AU	Parameter	SWQM Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
Jarbo Bayou	2425B_02	Enterococci	16485	22	12/01/2013 – 11/30/2020	126.96

2.3. Climate and Hydrology

The TMDL watershed is within the Upper Coast climatic division, categorized as subtropical humid (Larkin & Bomar, 1983). The Gulf of Mexico is the principal source of moisture that drives precipitation in the region. Weather data were obtained for the 10-year period from January 2013 through December 2022 from the National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information for the Houston National Weather Service Office located in League City (NOAA, 2023). Data from this period indicate that the average high temperatures typically peak in August (92.2 ˚F). During winter, the average low temperature generally reaches a minimum of 44.4 ˚F in January (Figure 3). Annual rainfall averages 64.2 inches. The wettest month was August (9.9 inches) while February (2.3 inches) was the driest month, with rainfall occurring throughout the year.

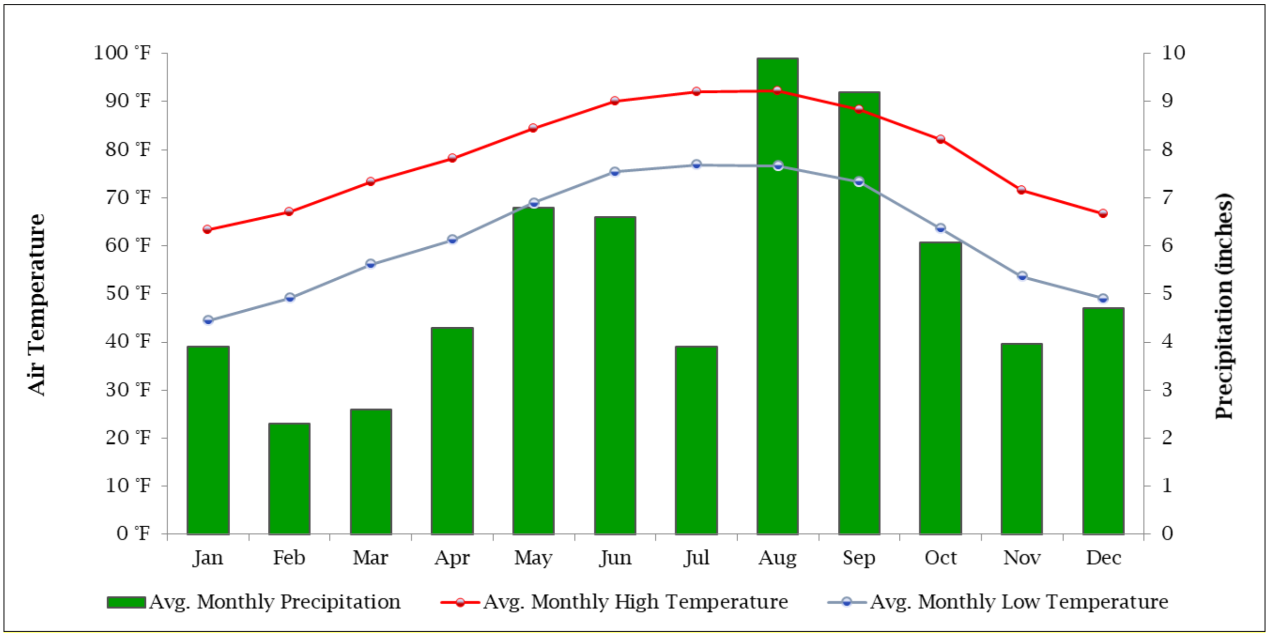

Figure 3. Average minimum and maximum air temperature and total precipitation by month from January 2013-December 2022 for Houston National Weather Service Office, League City, Texas

2.4. Population and Population Projections

As depicted in Figure 1, the TMDL watershed is entirely within Galveston County and includes portions of two city boundaries (League City and Kemah).

The Jarbo Bayou AU 2425B_02 watershed is mostly urban, with the predominant population density in the watershed being eight to fourteen people per acre (Figure 4). According to the 2020 U.S. Census Bureau (USCB) data (USCB, 2022), the Jarbo Bayou AU 2425B_02 watershed has an estimated population of 8,137.

Population projections in Table 2 are estimated from the Houston-Galveston Area Council (H-GAC) Regional Growth Forecast data (H-GAC, 2018). H-GAC updates their Regional Growth Forecast annually, and each release incorporates the latest available information on planned and announced developments, population and employment data, and feedback from forecast users. The forecasts include population projections for transportation analysis zones (TAZ), which are planning areas used by H-GAC to provide analyses at a local scale. According to the population projections, the population is expected to increase by 4.6% in the Jarbo Bayou AU 2425B_02 watershed by 2045. Additional information on the process used to calculate the population projection for the Jarbo Bayou AU 2425B_02 watershed can be found in Appendix A.

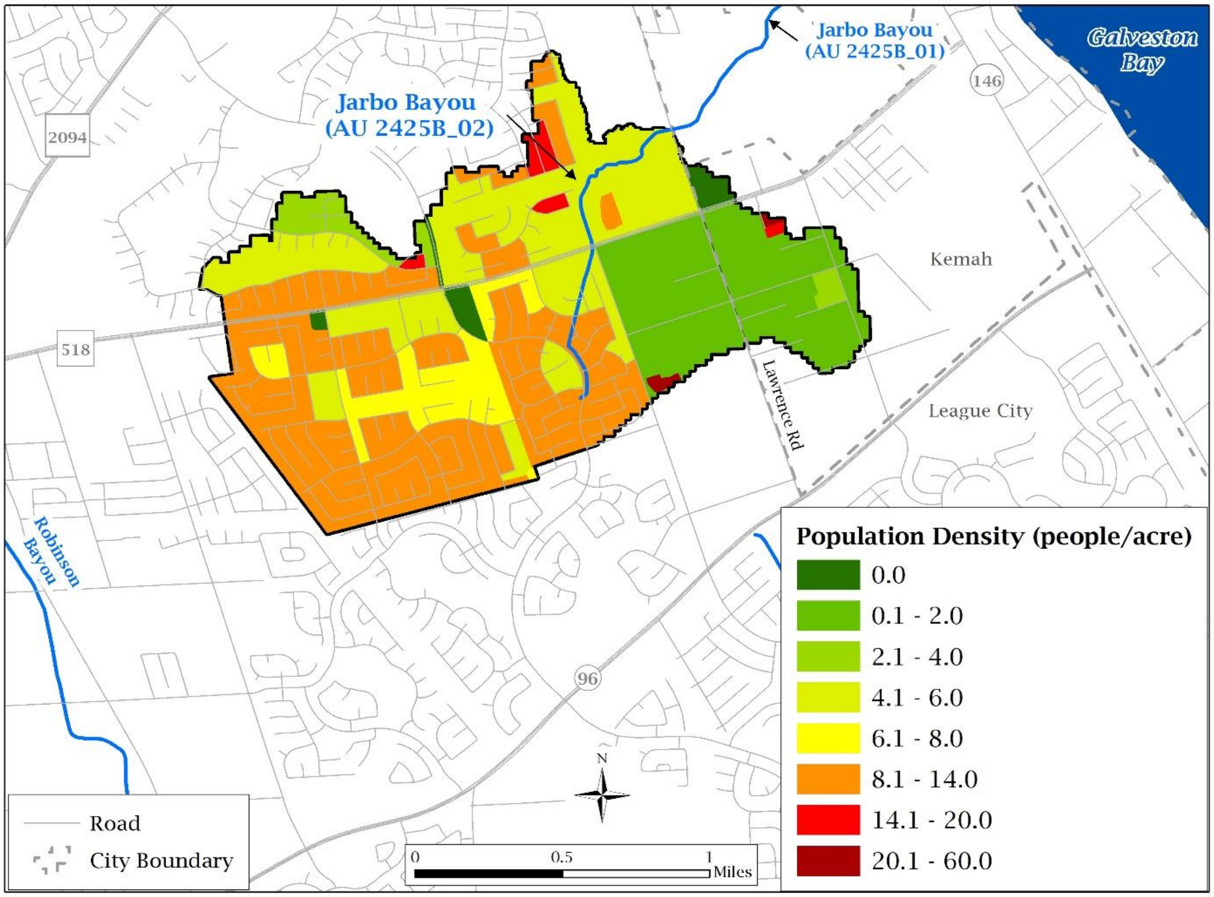

Figure 4. **Population density based on the 2020 U.S. Census blocks**

Table 2. **2020 – 2045 population and population projections for Jarbo Bayou**

Watershed	AU	2020 U. S. Census	2045 Population Projection	Projected Population Increase (2020-2045)	Percentage Change
Jarbo Bayou	2425B_02	8,137	8,508	371	4.56%

2.5. Land Cover

The land cover data presented in this report were obtained from the United States Geological Survey (USGS) 2019 National Land Cover Database (NLCD) (USGS, 2021). The land cover is represented by the following categories and definitions:

- **Developed, High Intensity** – Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

- **Developed, Low Intensity** – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% of total cover. These areas most commonly include single-family housing units.
- **Developed, Medium Intensity** – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
- **Developed, Open Space** – Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Deciduous Forest** – 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.
- **Evergreen Forest** – 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.
- **Mixed Forest** – 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.
- **Grassland/Herbaceous** – 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.
- **Pasture/Hay** – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
- **Emergent Herbaceous Wetlands** – Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Woody Wetlands** – Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

The land cover data for the Jarbo Bayou AU 2425B_02 watershed are provided in Figure 5. For the AU 2425B_02 watershed, the Developed land cover classifications (Medium Intensity 58.13%, Low Intensity 19.18%, Open Space 10.28%, and High

Intensity 9.74%) are the dominant land covers comprising 97.33% of the total land cover. Table 3 summarizes the land cover data for the TMDL watershed.

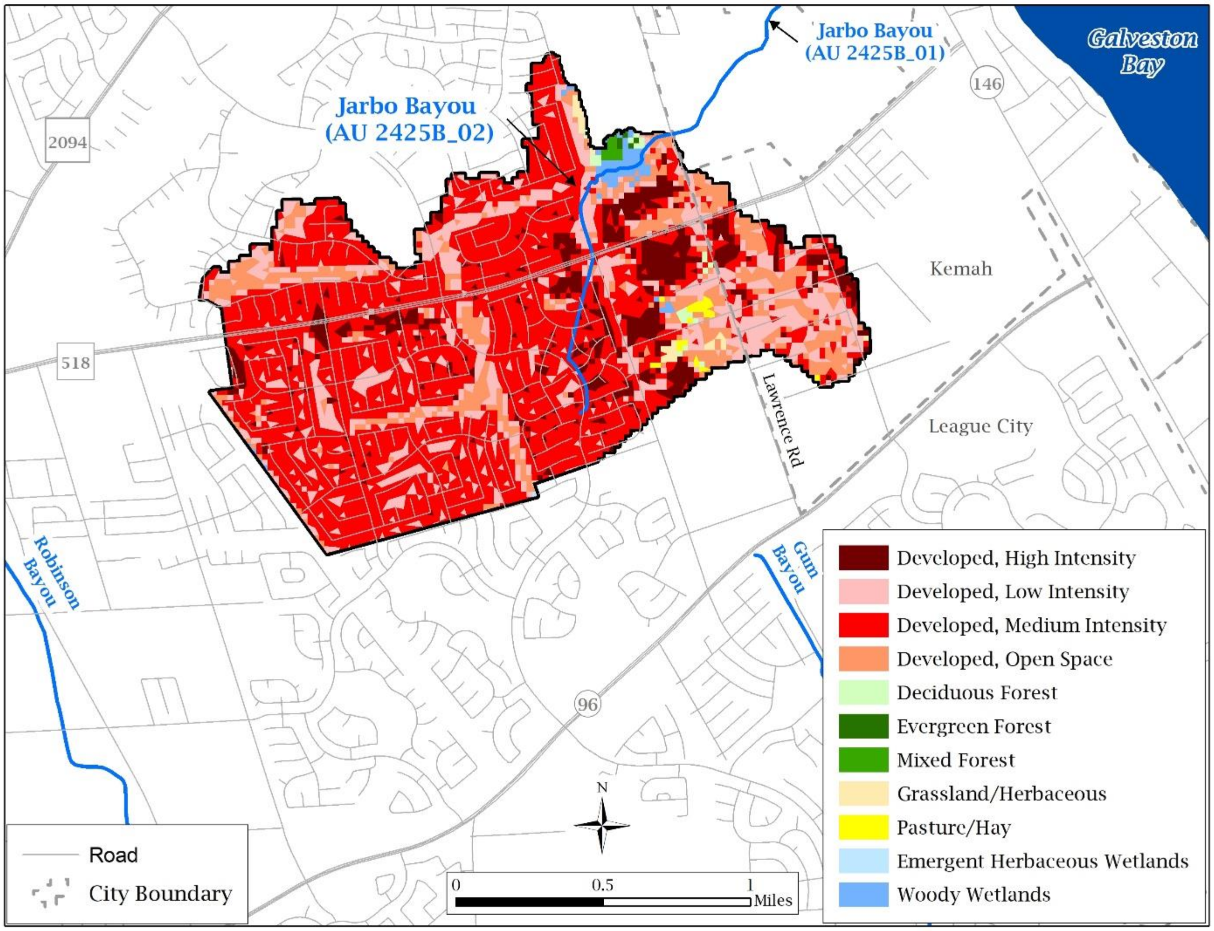

Figure 5. Land cover map showing classifications

Table 3. Land cover classification by area and percentage

Classification	Area (Acres)	Percentage of Total
Developed, High Intensity	119.00	9.74%
Developed, Low Intensity	234.32	19.18%
Developed, Medium Intensity	710.31	58.13%
Developed, Open Space	125.60	10.28%
Deciduous Forest	5.03	0.41%
Evergreen Forest	1.08	0.09%
Mixed Forest	2.71	0.22%
Grassland/Herbaceous	6.12	0.50%
Pasture/Hay	4.90	0.40%
Emergent Herbaceous Wetlands	0.16	0.01%
Woody Wetlands	12.69	1.04%
Total	1,221.92	100%

2.6. Soils

Soils within the Jarbo Bayou AU 2425B_02 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 (NRCS) Gridded Soil Survey Geographic database (gSSURGO) (NRCS, 2022). The gSSURGO data assign 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 gSSURGO database defines the classifications below.

- Group A – Soils having high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

- Group B – Soils having a moderate infiltration rate when thoroughly wet. These consist of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

- Group C – Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

- Group D – Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

- Soils with dual hydrologic groupings indicate that drained areas are assigned the first letter, and the second letter is assigned to undrained areas. Only soils that are in group D in their natural condition are assigned to dual classes.

As indicated in Figure 6, soils for the TMDL watershed are comprised of hydrologic Groups D and C/D, indicating high runoff potential and restricted water infiltration rates. Group C/D is the dominant soil group, which is present in 55% of the watershed, followed by Group D soils at 45%.

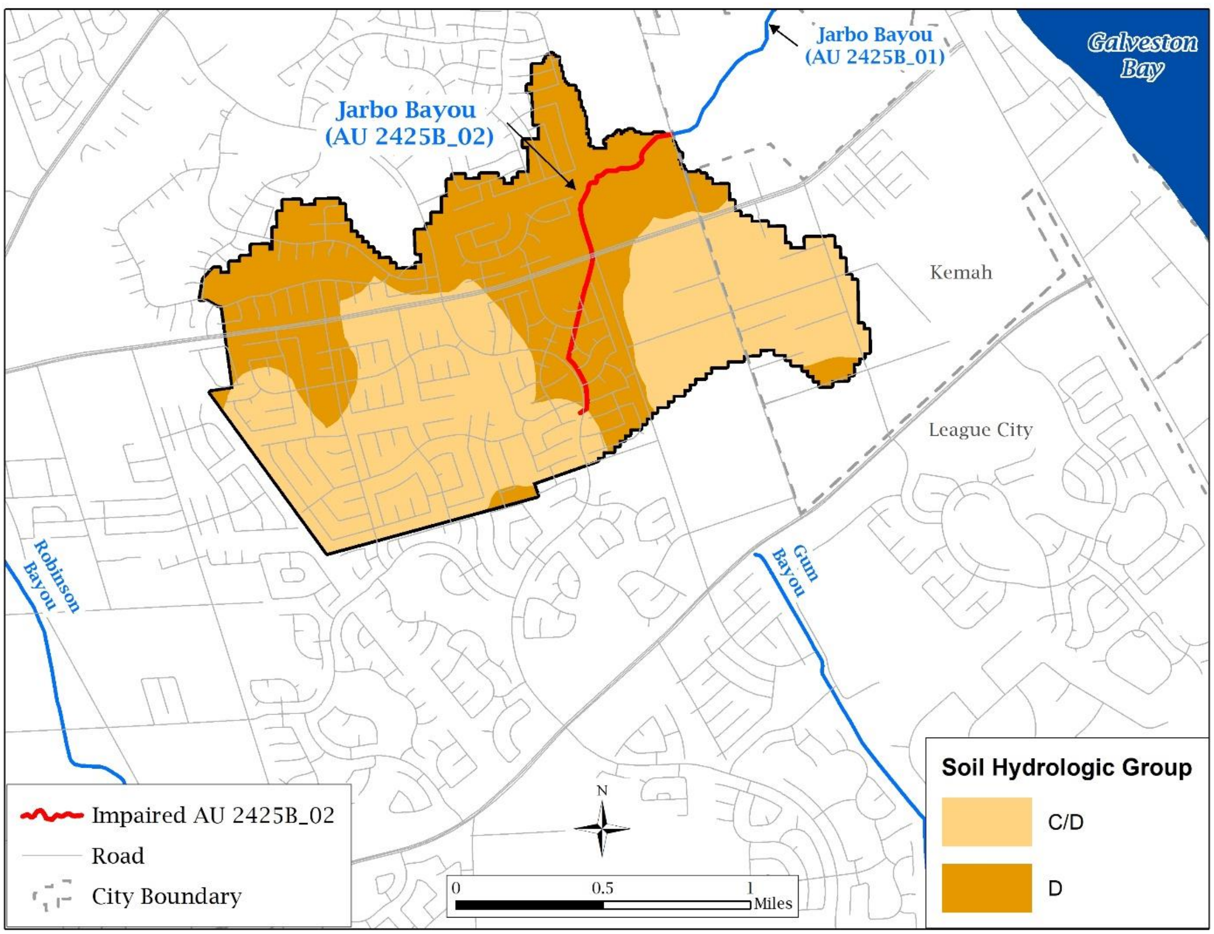

Figure 6. Soil hydrologic groups

2.7. Potential Sources of Fecal Indicator Bacteria

Pollutants may come from several sources, both regulated and unregulated. Regulated pollutants, referred to as "point sources," come from a single definable point, such as a pipe, and are controlled by permit under the Texas Pollutant Discharge Elimination System (TPDES) program. Wastewater treatment facilities (WWTFs) and stormwater discharges from industrial sites, regulated construction activities, and the separate storm sewer systems of cities are considered point sources of pollution.

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

Except for WWTFs, which receive individual wasteload allocations (WLAs—see the "WLA" section), the regulated and unregulated sources in this section are presented to give a general account of the various sources of bacteria expected in the watershed. These are not meant to be used for allocating bacteria loads or interpreted as precise inventories and loadings.

2.7.1. Regulated Sources

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

2.7.1.1. Domestic and Industrial Wastewater Treatment Facilities

There are no permitted WWTFs in the TMDL watershed.

2.7.1.2 TCEQ/TPDES General Wastewater Permits

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

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production
- TXG340000 – petroleum bulk stations and terminals
- TXG640000 – conventional water treatment plants
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG870000 – pesticides (application only)
- TXG920000 – concentrated animal feeding operations
- WQG100000 – wastewater evaporation
- WQG200000 – livestock manure compost operations (irrigation only)

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

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

A review of active general permits (TCEQ, 2023a) in the Jarbo Bayou AU 2425B_02 watershed, as of May 2023, found no active general permit authorizations.

2.7.1.3. TPDES-Regulated Stormwater

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

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

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

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

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

- Authorization for construction activities where the small MS4 is the site operator (*optional*).

Phase I MS4 individual permits have their own set of MCMs that are similar to the Phase II MCMs, but Phase I permits have additional requirements to perform water quality monitoring and implement a floatables program. The Phase I MCMs include 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 authorized under one of the following general permits:

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

There is currently one combined Phase I/II permit authorization within the Jarbo Bayou AU 2452B_02 watershed (Table 4 and Figure 7).

A review of active stormwater general permit coverage (TCEQ, 2023a) as of May 8, 2023, found two active Phase II MS4 permit authorizations and four CGP authorizations located within the TMDL watershed. The areas covered by the CGP authorizations are not discussed further, since MS4 permits cover 100% of the TMDL watershed.

Table 4. TPDES MS4 permits

Regulated Entity	Authorization Type	TPDES Permit No./ NPDES[a] ID	Location
Texas Department of Transportation	Combined Phase I and II MS4	WQ0005011000/ TXS002101	TXDOT[b] rights-of way located within Phase I MS4s and Phase II UAs[c]
City of League City	Phase II MS4	TXR040249	Area within the City of League City that is located within the Houston UA
City of Kemah	Phase II MS4	TXR040096	Area within the City of Kemah corporate limits that is located within the UA of Galveston County

[a] NPDES: National Pollutant Discharge Elimination System

[b] TXDOT: Texas Department of Transportation

[c] UA: urbanized area

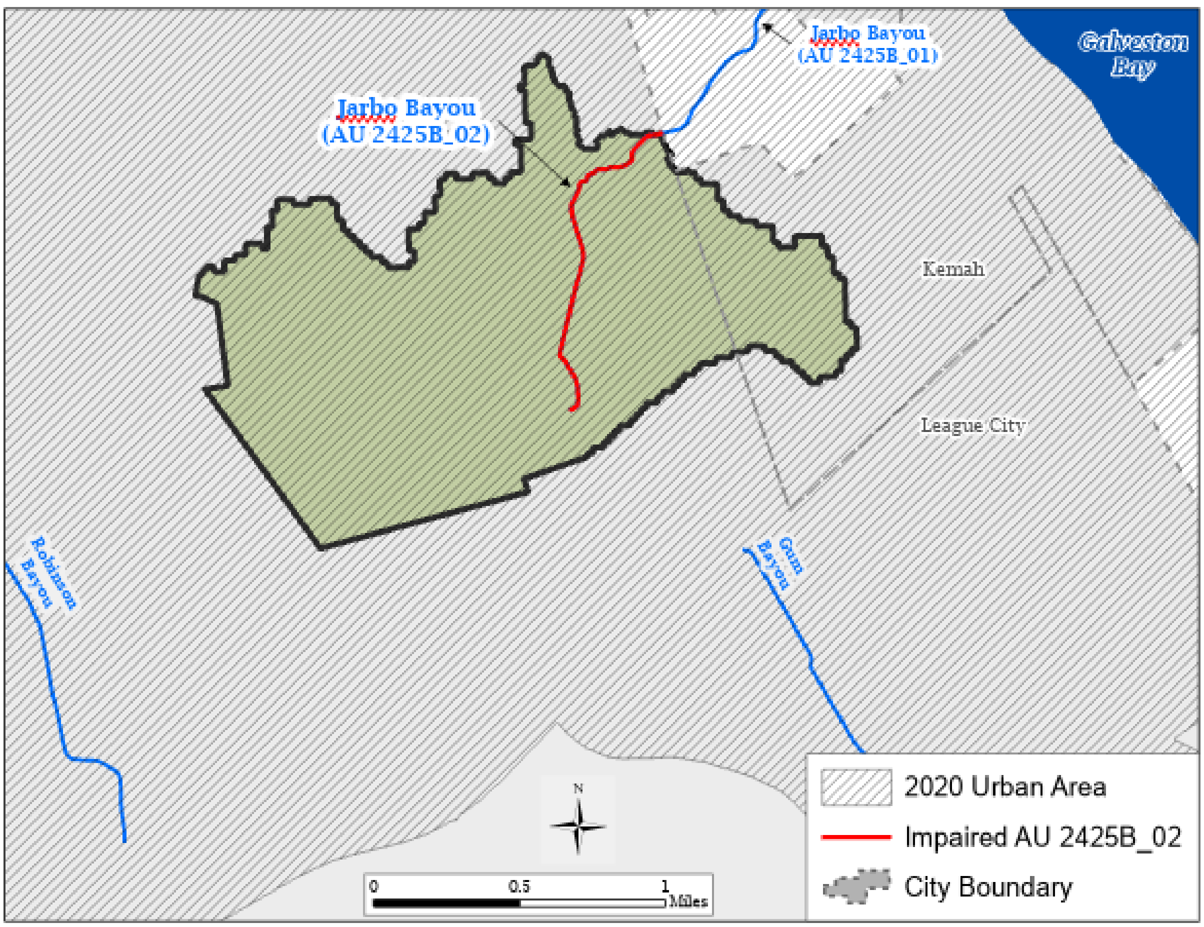

Figure 7. Regulated stormwater area based on MS4 permits, as defined by the 2020 Urban Area (USCB, 2022)

2.7.1.4. Sanitary Sewer Overflows

SSOs are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. These overflows in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and infiltration (I&I) are typical causes of overflows under conditions of high flow in the WWTF system. Blockages in the line may worsen the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

Information about reported SSO incidents that occurred during a seven-year period of 2016 to 2022 in Galveston County was obtained from TCEQ headquarters in Austin (TCEQ, 2023b). According to that information, there were three reported SSO incidents within the TMDL watershed. Table 5 summarizes the SSO data.

Table 5. Summary of reported SSO events (from 2016 through 2022) in Jarbo Bayou AU 2425B_02 watershed (in gallons)

AU	Estimated Incidents	Total Volume	Minimum Volume	Maximum Volume
2425B_02	3	5,002	1	5,000

2.7.1.5. Dry Weather Discharges/Illicit Discharges

Pollutant loads can enter water bodies from MS4 outfalls that carry authorized sources as well as illicit discharges under both dry- and wet-weather conditions. The term "illicit discharge" is defined in TPDES General Permit TXR040000 for Phase II MS4s as "Any discharge to a municipal separate storm sewer system that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities."

Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges included in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct Illicit Discharges:

- Sanitary wastewater piping that is directly connected from a home to the storm sewer.
- Materials that have been dumped illegally into a storm drain catch basin.
- A shop floor drain that is connected to the storm sewer.
- A cross-connection between the sanitary sewer and storm sewer systems.

Indirect Illicit Discharges:

- An old and damaged sanitary sewer line that is leaking fluids into a cracked storm sewer line.
- A failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.7.2. Unregulated Sources

Unregulated sources of bacteria are generally nonpoint. Nonpoint source loading enters the impaired water body through distributed, nonspecific locations, which may include urban runoff not covered by a permit. Potential sources, detailed below, include wildlife, feral hogs, agricultural animals, failing on-site sewage facilities (OSSFs), and domestic pets.

2.7.2.1. Wildlife and Unmanaged Animals

Fecal bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife and feral hogs. Wildlife and feral hogs are naturally attracted to riparian corridors of water bodies. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Wildlife and feral hogs also leave feces on land, where they may be washed into nearby water bodies by rainfall runoff.

The Enterococci contribution from feral hogs and wildlife in the Jarbo Bayou AU 2425B_02 watershed cannot be determined based on existing information. However, due to the watershed's urbanized nature (see Table 3), it is anticipated that the contribution would be minimal.

2.7.2.2. Unregulated Agricultural Activities and Domesticated Animals

Due to the highly urbanized nature of the TMDL study area, livestock are not a major source of bacteria loading.

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 6 summarizes the estimated number of dogs and cats in the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household according to data from the American Veterinary Medical Association 2017–2018 U.S. Pet Statistics (AVMA, 2018). The number of households in the watershed was estimated using 2010 Census data (USCB, 2010). The actual contribution and significance of bacteria loads from pets reaching the water bodies is unknown.

Table 6. Estimated households and pet populations

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
2425B_02	2,877	1,767	1,315

2.7.2.3. On-Site Sewage Facilities

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

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters if the systems are not properly operating. Properly designed and operated, however, OSSFs contribute virtually no fecal bacteria to surface waters. For example, Weiskel et al. (1996) reported that less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drain field of a septic system. Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The Jarbo Bayou AU 2425B_02 watershed is located within the Region IV area, which has a reported failure rate of about 12%, providing insights into expected failure rates for the area.

Estimates of the number of OSSFs in the Jarbo Bayou AU 2425B_02 watershed were determined using data supplied by H-GAC. Data from this source indicate that there are approximately 10 OSSFs located within the Jarbo Bayou AU 2425B_02 watershed (Figure 8).

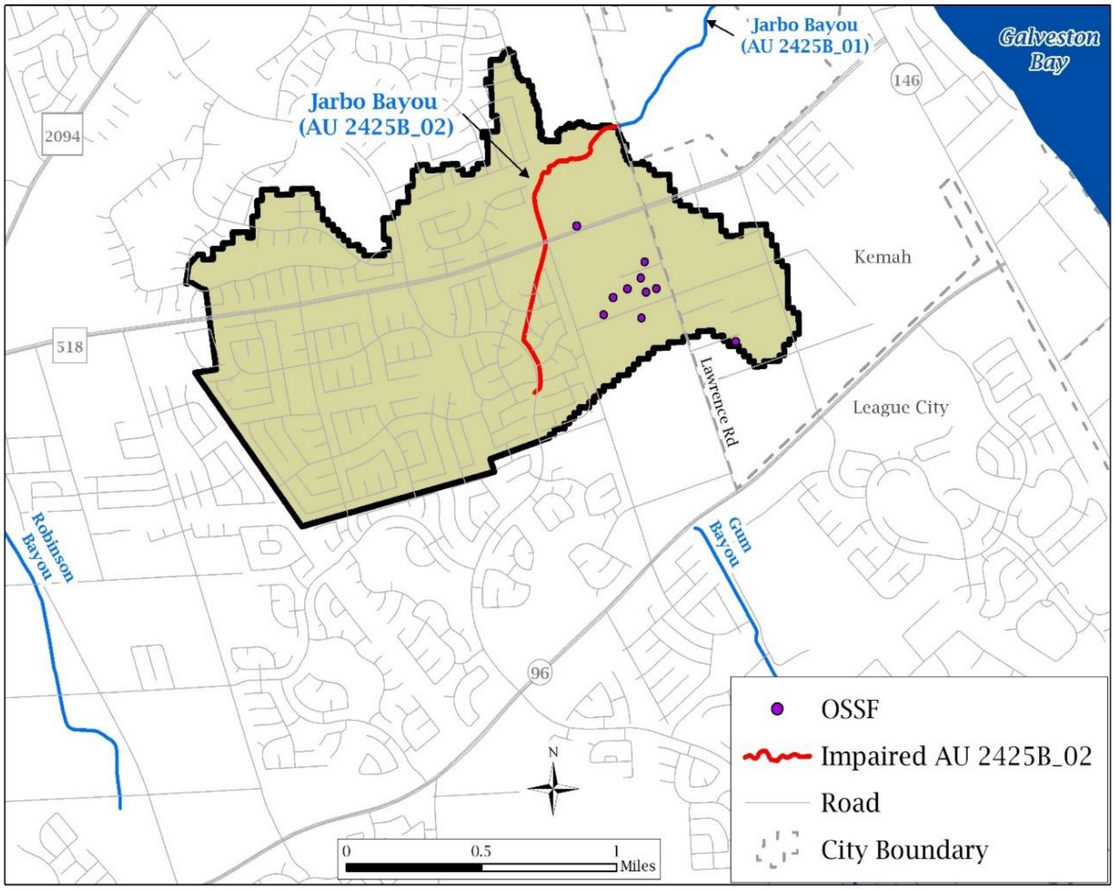

Figure 8. Estimated OSSFs in the TMDL watershed

2.7.2.4. Bacteria Survival and Die-off

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

Section 3. Bacteria Tool Development

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

3.1. Tool Selection

The pollutant load allocations were developed for the TMDL watershed using the LDC method. This method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). An adaptation of the LDC method to tidal waters has been successfully developed and applied by the State of Oregon (ODEQ, 2006); this approach, which will later be described in detail, is known as the modified load duration curve (MLDC) method. In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment.

The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs that constrain the use of more powerful mechanistic models. Further, the bacteria task force appointed by TCEQ and the Texas State Soil and Water Conservation Board supports application of the LDC method within their three-tiered approach to TMDL development (Jones et al., 2009). The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion and can give indications of broad sources of the bacteria.

3.2. Data Resources

To develop the MLDC method for the Jarbo Bayou AU 2425B_02 watershed, various data resources are required. The three main sources are hydrologic data in the form of daily streamflow records, historical indicator bacteria data (Enterococci), and salinity data.

Streamflow, salinity, and Enterococci data availability were used to provide guidance in the allocation tool selection process. Salinity data provided a measure of the degree of mixing of seawater and freshwater in the tidal TMDL waterbody.

Hydrologic data in the form of daily streamflow records were unavailable for the TMDL watersheds; however, streamflow records were available for the nearby Vince Bayou watershed. Streamflow records for Vince Bayou are collected and made available by USGS Survey (USGS, 2023), which operates the streamflow gage (Table 7, Figure 9). USGS Streamflow Gage 08075730 is located along the mainstem of Vince Bayou and is close enough to the TMDL watershed that the same precipitation events would likely affect each watershed.

The streamflow records for Vince Bayou were modified using a drainage-area ratio (DAR) approach. This approach is explained in more detail in Section 3.3.3. The modified streamflow records from Vince Bayou are the primary source for streamflow records in this document.

Table 7. USGS streamflow gage information for Vince Bayou

Gage Number	Site Description	Drainage Area (acres)	Daily Streamflow Record (beginning and end date)
08075730	Vince Bayou at Pasadena, TX	5,286	Oct. 1971 - present

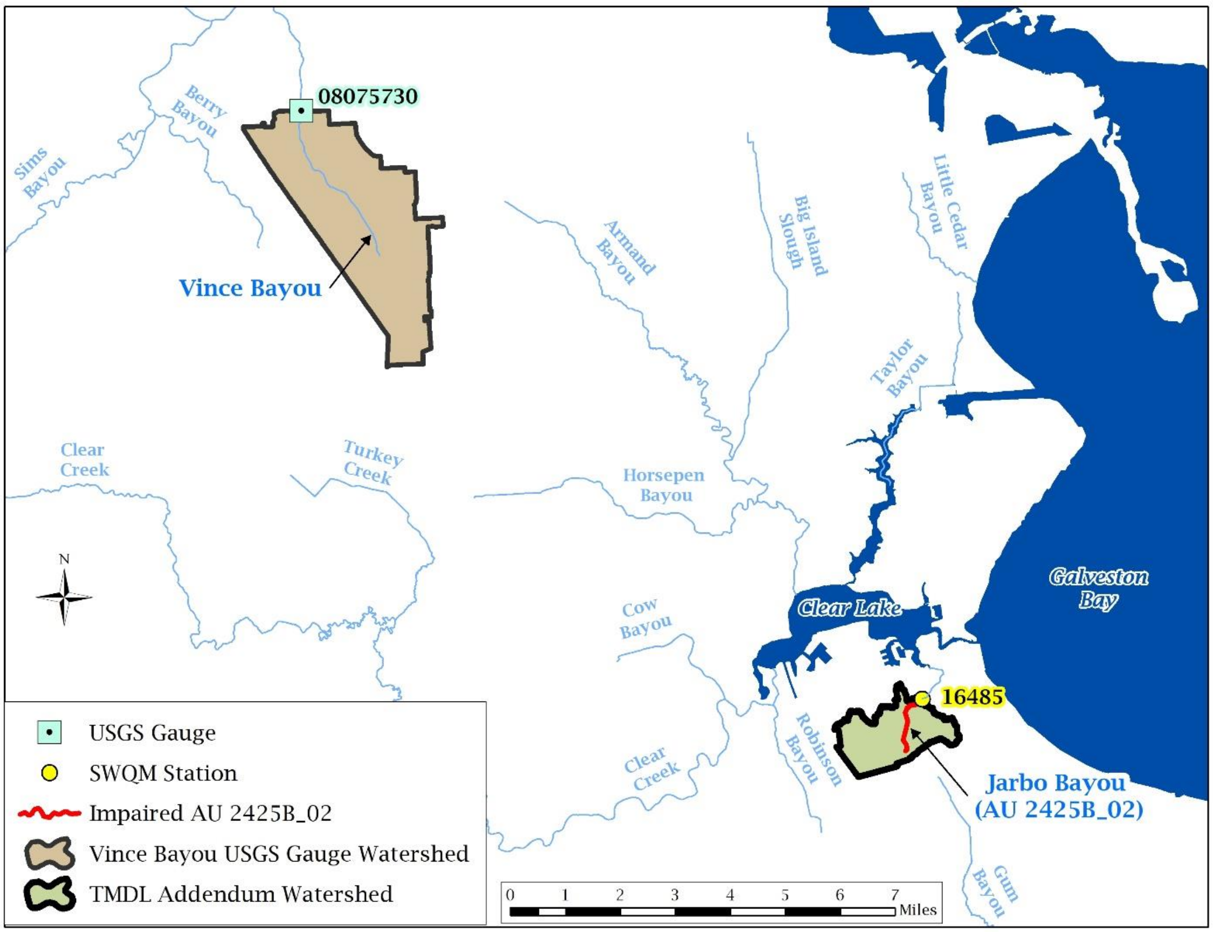

Figure 9. TMDL watershed and the watershed of USGS Gage 08075730

Paired ambient Enterococci and salinity data were available for the TMDL watershed through the TCEQ Surface Water Quality Monitoring Information System (TCEQ, 2023c) (Table 8).

Table 8. Summary of historical bacteria and salinity data sets

Water Body	AU	SWQM Station	SWQM Station Location	No. of Enterococci Samples	No. of Salinity Samples	Date Range
Jarbo Bayou	2425B_02	16485	Jarbo Bayou at Lawrence Road	26	26	Oct. 2014 – Feb. 2022

3.3. Method for Developing Modified Flow Duration and Load Duration Curve

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

- Step 1: Determine the hydrologic period of record to be used in developing the MFDC.
- Step 2: Determine the stream location for which MFDC and MLDC development is desired.
- Step 3: Develop daily streamflow record at desired location.
  - Step 3.1: Develop regression of salinity to streamflow for stream location.
  - Step 3.2: Incorporate daily tidal volumes into streamflow record.
- Step 4: Develop MFDC at the desired stream location, segmented into discrete flow regimes.
- Step 5: Develop allowable bacteria MLDC at the same stream location based on the relevant criteria and the data from the MFDC.
- Step 6: Superimpose historical bacteria data on the allowable bacteria MLDC.

More information explaining the LDC method may be found in Cleland (2003) and EPA (2007). More information explaining the MLDC method may be found in Chapter 2 and Appendix 1 of the Umpqua Basin Total Maximum Daily Loads and supporting documents (ODEQ, 2006).

3.3.1. Step 1: Determine Hydrologic Period

A daily hydrologic (streamflow) record spanning 50 years was available for USGS Gage 08075730 located on nearby Vince Bayou (Table 7, Figure 9). Optimally, the period of record to develop MFDCs should include as much data as possible in order to capture extremes of high and low streamflow and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of recent conditions within the watershed and when the Enterococci data were collected. Therefore, a 10-year record of daily streamflow from Jan. 1, 2013 through Dec. 31, 2022 was selected to develop the MFDC at SWQM Station 16485. This period includes the collection dates of all Enterococci data available at the time this study was undertaken. A 10-year period is long enough to contain a reasonable variation between dry months and years to wet months and years. At the same time, it is short enough to contain a hydrology that is responding to current conditions in the watershed.

3.3.2. Step 2: Determine Desired Stream Location

SWQM Station 16485 is the only location within the TMDL watershed where an adequate number of Enterococci data have been collected. The 26 Enterococci sampling results were adequate to develop pollutant load allocations and exceed the minimum of 24 samples suggested in Jones et al. (2009).

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

Once the hydrologic period of record and station location were determined, the next step was to develop the 10-year daily streamflow record for the monitoring station. The daily streamflow records were developed from historical USGS records.

The method to develop the necessary streamflow record for the MFDC/MLDC at SWQM Station 16485 involved a DAR approach. The DAR approach involves multiplying a USGS gaging station daily streamflow value by a factor to estimate the flow at a desired SWQM station location. The factor is determined by dividing the drainage area upstream of the desired monitoring station by the drainage area upstream of the USGS gage (Table 9).

Because an assumption of the DAR approach is similarity of hydrologic response based on commonality of landscape features such as geology, soils, and land cover, point-source derived flows from within the USGS-gage watershed should first be removed from the flow record prior to application of the ratio. There were no WWTFs within the USGS-gage watershed at the time of this study, so no correction was necessary to compensate for WWTF flows.

In addition to WWTF discharges, surface water diversions associated with water rights permits can affect stream hydrology when applying the DAR approach. A spatial query of water rights features (diversions, withdrawals, return flows) revealed that the TMDL watershed and the Vince Bayou watershed above USGS Gage 08075730 did not contain any active water rights permits (TCEQ, 2023d). Therefore, diversions associated with water rights permits were not considered in the development of the streamflow record.

After confirming that there were no point-source derived flows within the TMDL watersheds and the USGS-gage watershed, each daily flow record was multiplied by the appropriate DAR.

Table 9. DAR for the TMDL watershed based on the drainage area of the Vince Bayou USGS gage

Water Body	Gage/Station	Drainage Area (acres)	DAR
Vince Bayou	USGS Gage 08075730	5,286	1.0
Jarbo Bayou (AU 2425B_02)	SWQM Station 16485	1221.92	0.231

3.3.3.1. Step 3.1 Develop Salinity to Streamflow Regression

As part of the development of the MLDC method, it was necessary to develop a relationship between daily streamflow and measured salinity for the selected tidally influenced location (SWQM Station 16485). The resulting regression was instrumental in determining the daily volume of seawater present for each daily freshwater flow in the 10-year period of record. Salinity to streamflow regression was developed for SWQM Station 16485 located within the TMDL watershed. The equation derived from the regression analysis was used to calculate the volume of seawater that would flow through the cross-section of the station over the period of a day (Figure 10). Salinity is presented in parts per thousand (ppt).

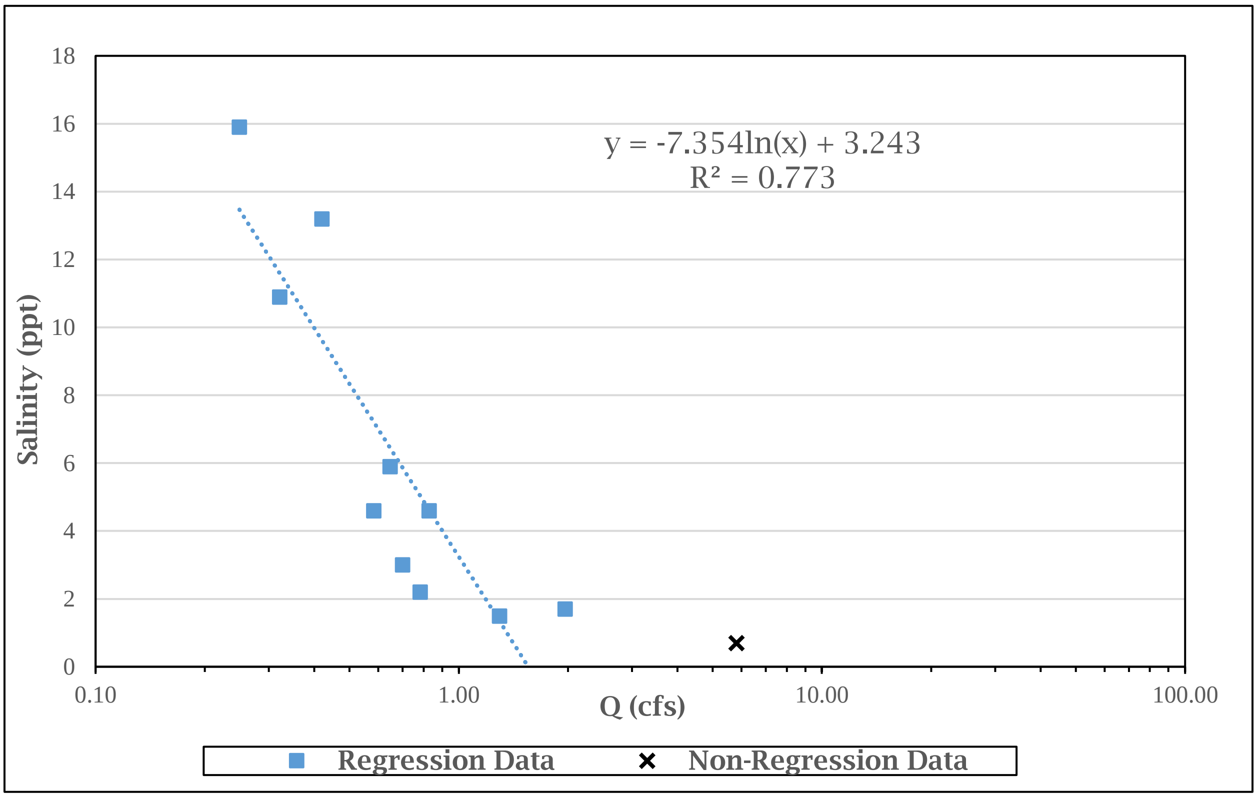

Figure 10. Salinity to streamflow regression at SWQM Station 16485

3.3.3.2. Step 3.2: Incorporate Daily Tidal Volumes into Streamflow Record

The regression equation developed in Step 3.1 was used to allow computation of a total daily flow volume that includes freshwater and seawater. The process requires manipulation of the following mass balance equation for salinity at the tidally influenced stations:

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

V_r = volume of daily freshwater (river) flow

V_s = volume of daily seawater flow

S_t = salinity in river (ppt)

S_r = background salinity of upstream river water (ppt); assumed = 0 ppt

S_s = salinity of seawater (assumed to be 35 ppt)

Through algebraic manipulation this mass balance equation can be solved for the daily volume of seawater required to be mixed with freshwater giving the equation found in the ODEQ TMDL (2006) technical information:

$V_s = V_r / (S_s/S_t - 1)$; (Equation 2)

for S_t greater than background salinity, otherwise $V_s = 0$

Where S_t was computed for each day of the streamflow record using the station specific regression equations of Step 4 and the estimated actual daily streamflow (V_r), from Step 4, as input to the equation. The calculation of S_t allowed V_s to be computed from Equation 2.

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

$V_t = V_r + V_s$ (Equation 3)

Lastly, future growth (FG) flows for the TMDL watershed were added to the streamflow record. The calculation of FG flows is described in Section 4.7.4.

3.3.4. Step 4: Develop Modified Flow Duration Curve

An MFDC is a graph that visualizes the percentage of time during which a value of flow is equaled or exceeded. To develop an MFDC for a location, the following steps were taken:

1. Order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (one for the highest flow, two for the second highest flow, and so on).
2. Compute the percentage of days each flow was exceeded by dividing each rank by the total number of data points plus one.
3. Plot the corresponding flow data against exceedance percentages.

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

At SWQM Station 16485 within the Jarbo Bayou AU 2425B_02 watershed, the amount of estimated seawater is presented in the intermediate MFDC (Figure 11) using the flows from Steps 3 and 3.2. As expected from the modified daily flow volume equation, the amount of seawater present increases as both the freshwater flow decreases and the percentage of days the flow is exceeded increases for SWQM Station 16485. Note that the x-axis direction of increase on the seawater plot is reversed from that on the MFDC, because the seawater flow increases as freshwater flow decreases.

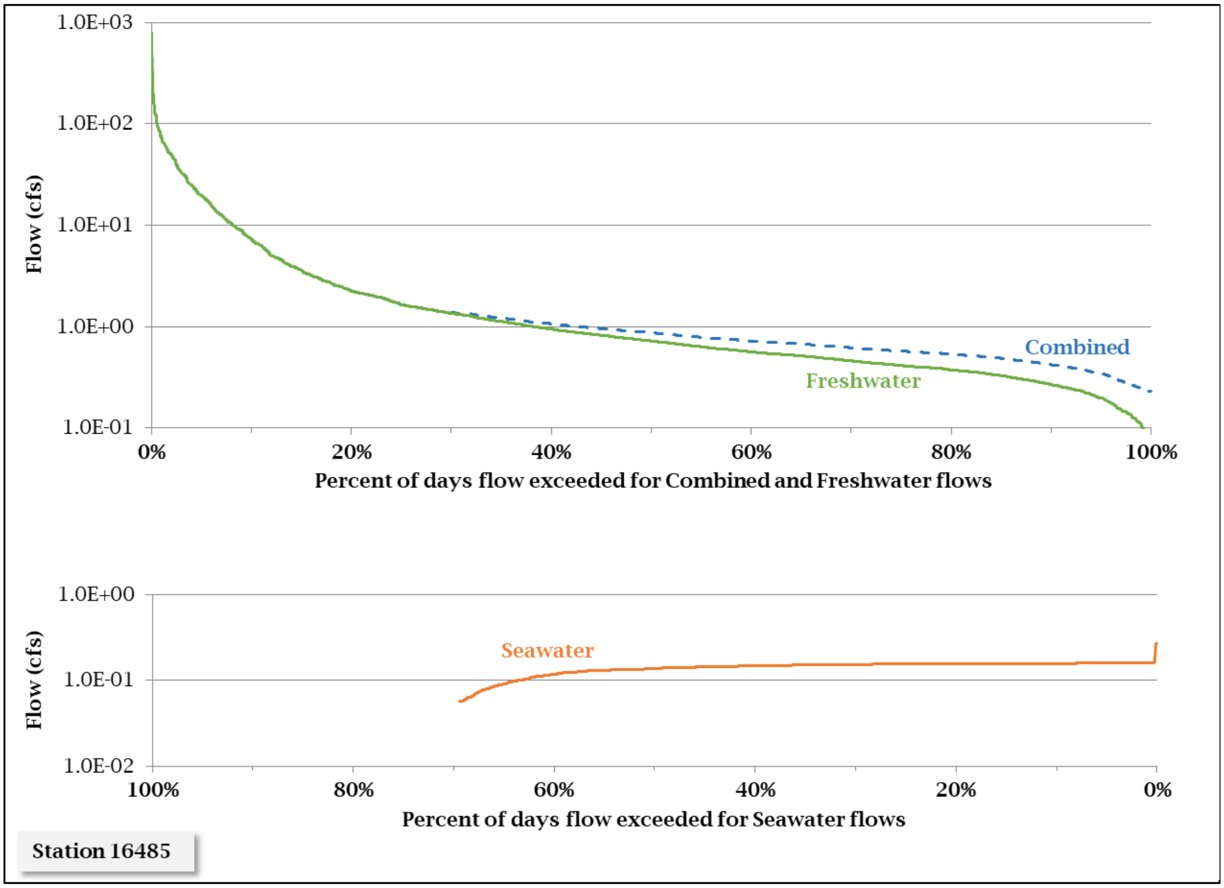

Figure 11. Intermediate MFDC for Jarbo Bayou AU 2425B_02 at SWQM Station 16485

The final MFDC for SWQM Station 16485 is presented in Figure 12. The Jarbo Bayou (AU 2425B_02) combined flows calculated at SWQM Station 16485 ranged from a high of 790.077 cubic feet per second (cfs), to a low of 0.229 cfs.

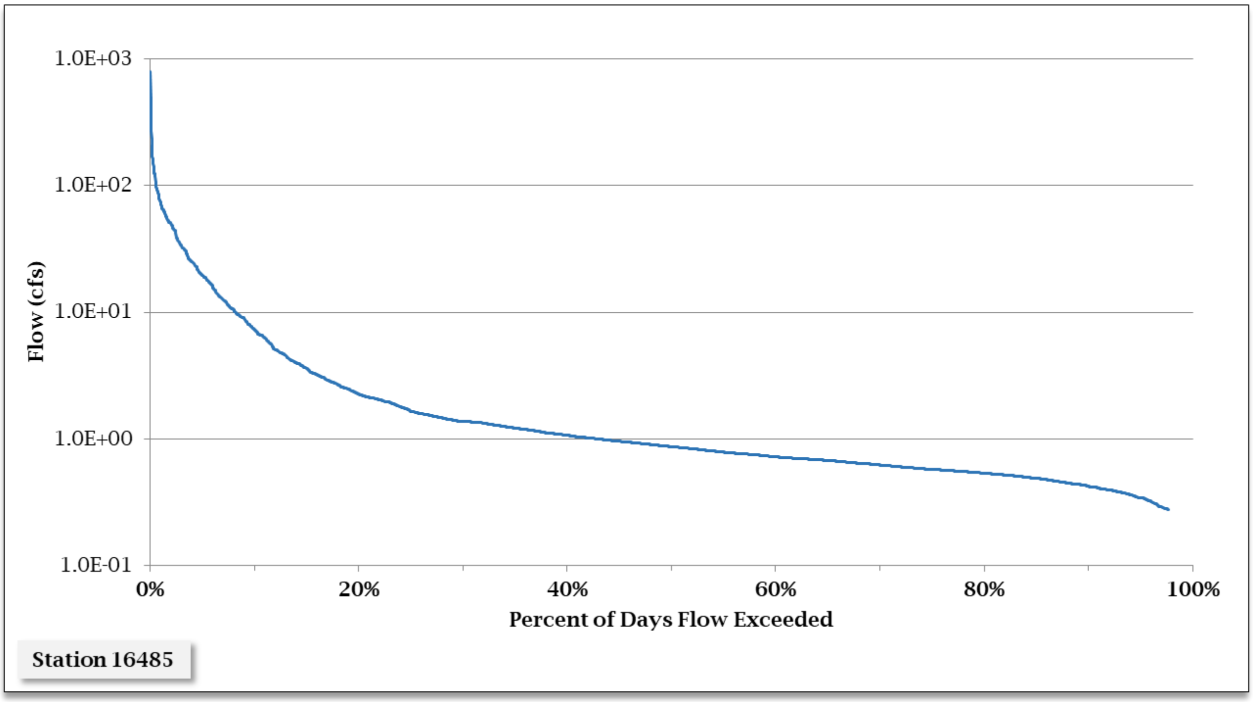

Figure 12. MFDC for Jarbo Bayou AU 2425B_02 at SWQM Station 16485

A point of importance to the pollutant load allocation process is shown in Figure 11 regarding the fact that daily seawater volume is only computed as a nonzero value for less than 80% of the time (i.e., for flows exceeded more than 20% of the time). The significance of the above observation is related to what happens within the MLDC method when salinities are at background. As salinity approaches background, V_s in Equation 2 approaches a value of zero, and in fact would be defined as zero when salinities are at background levels, resulting in the MLDC flow volume ($V_r + V_S$) defaulting to the freshwater flow of the tidal stream, i.e., no seawater modification occurring to that portion of the MLDC.

3.3.5. Steps 5 through 6: Develop Modified Load Duration Curve

An MLDC is a graph indicating the percentage of time during which a value of load is equaled or exceeded. To develop an MLDC for a location, the following steps were taken:

1. Multiply the streamflow in cfs by the appropriate water quality criterion for Enterococci (geometric mean of 35 cfu/100 mL or 130 cfu/mL) and by a conversion factor (2.44658×10^9), which gives you a loading unit of cfu/day.
2. Plot the exceedance percentages, which are identical to the value for the streamflow data points, against the geometric mean criterion for Enterococci.

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

A useful refinement of the MLDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves. This approach can assist in determining streamflow conditions under which exceedances are occurring.

For SWQM Station 16485, streamflow distribution was divided into three flow regimes: Highest Flow, Mid-range Flow, and Lowest Flow (Table 10). The Highest Flow regime corresponds to large storm-induced runoff events. The Mid-range Flow regime typically represents periods of medium base flows but can also represent small runoff events and periods of flow recession following large storm events. The Lowest Flow regime represents relatively dry conditions resulting from extended periods of little or no rainfall.

Table 10. Flow regime classifications

Flow Regime Classification	Flow Exceedance Percentile
Highest Flow	0 – 20%
Mid-Range Flow	20 – 80%
Lowest Flow	80 – 100%

The MLDC with these three flow regimes for SWQM Station 16485 is provided in Figure 13 and was made for developing the load allocations for the TMDL watershed. Geometric-mean loadings for the data points within each flow regime have also been distinguished on the figure to aid interpretation. The MLDC for the SWQM station provides a means of identifying the streamflow conditions under which Enterococci concentrations exceeded the geometric mean criterion. The MLDC depicts the allowable loading at the SWQM station under the geometric mean criterion (35 cfu/100 mL) and shows that existing loadings often exceed the criterion. In addition, the MLDC presents the allowable loading at SWQM Station 16485 under the single sample criterion (130 cfu/ 100 mL).

On the graph, the measured Enterococci data are presented as associated with a “wet-weather event” or a “non-wet-weather event.” A sample was determined to be influenced by a wet-weather event based on the reported number of days since last precipitation (DSLP) noted on field data sheets associated with each sampling event. DSLP (TCEQ water quality parameter code 72053) is a field parameter that may be noted during a sampling event to illuminate the general climatic and hydrologic conditions. A sample taken with a DSLP of less than or equal to three days was defined as a wet-weather event at SWQM Station 16485. Note that a wet-weather event can be indicated even under low-flow conditions from only a small runoff event that occurs during a period of very low base flow in the stream.

The Enterococci data plotted on the MLDC for SWQM Station 16485 in Figure 13 show exceedances of the geometric mean criterion have commonly occurred regardless of streamflow conditions. Results from sampling indicate a frequent exceedance of the geometric mean criterion. Likewise, Enterococci data plotted on the MLDC for SWQM Station 16485 indicated exceedances of the geometric mean criterion have commonly occurred in all flow regimes (Figure 13). Results from wet-weather events indicate a frequent exceedance of both sample criterion at SWQM Station 16485.

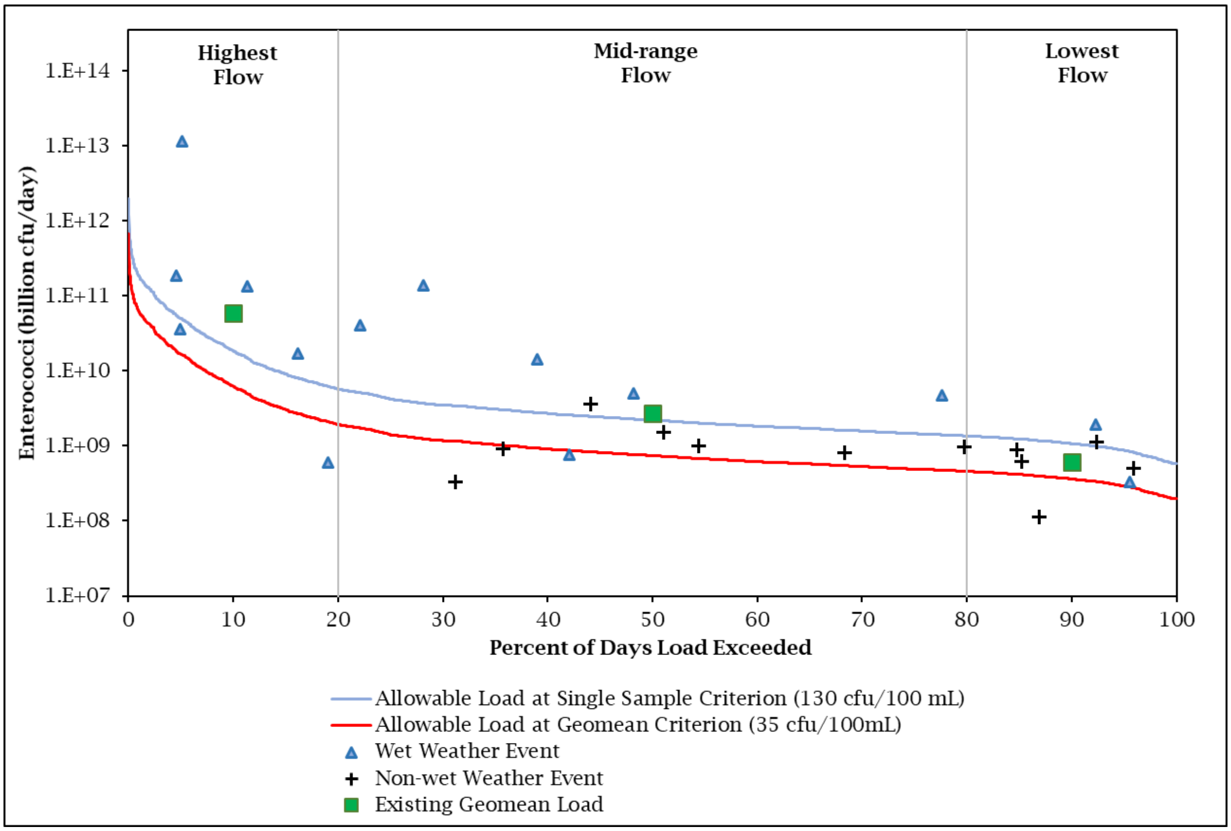

Figure 13. MLDC for Jarbo Bayou AU 2425B_02 at SWQM Station 16485

Section 4. TMDL Allocation Analysis

4.1. Endpoint Identification

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

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

4.2. Seasonal Variation

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

Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing available Enterococci concentrations obtained from routine monitoring at one SWQM monitoring station (16485). Differences in Enterococci concentrations were evaluated by performing a Wilcoxon Rank Sum test. Enterococci concentrations during warmer months (May through September) were compared against those during the cooler months (November through March). April and October are considered transitional periods between warm and cool seasons and therefore were excluded from the analysis. This analysis of Enterococci data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Jarbo Bayou AU 2425B_02 (p=0.7106).

4.3. Linkage Analysis

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

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

Bacteria load contributions from regulated and unregulated stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, can carry bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of higher concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline as runoff washes fecal bacteria from the land surface and the volume of runoff decreases following the rain event.

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

4.4. Load Duration Curve Analysis

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

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

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

Based on the MLDC used in the pollutant load allocation process with historical Enterococci data added to the graphs (Figure 13) and Section 2.7, the following broad linkage statements can be made. For the TMDL watershed, the historical Enterococci data indicate that elevated bacteria loadings occur under all three flow regimes. There is some moderation of the elevated loadings under Mid-range and Lowest-flow conditions for the TMDL watershed. On Figure 13, the geometric means of the measured data shown for each flow regime generally support the observation of decreasing concentration with decreasing flow.

4.5. Margin of Safety

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

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

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

The TMDL in this report incorporates an explicit MOS of 5%.

4.6. Load Reduction Analysis

While the TMDL for the impaired AU watershed was developed using an MLDC and associated load allocations, additional insight may, in certain situations, be gained through a load reduction analysis. A single percentage load reduction required to meet the allowable loading for each of the three flow regimes was determined using the historical Enterococci data obtained from the SWQM station within the impaired water body.

For each flow regime, the percentage reduction required to achieve the geometric mean criterion was determined by calculating the difference in the existing (or measured) geometric mean concentration and the 35 cfu/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 11).

Table 11. Percentage reduction calculations

AU	Flow Regime	Geometric Mean (cfu/100 mL)	Required Percentage Reduction
2425B_02	Highest Flow	331	89.4%
	Mid-range Flow	130	73.1%
	Lowest Flow	59	40.7%

4.7. Pollutant Load Allocations

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

TMDL = WLA + LA + FG + MOS (Equation 4)

Where:

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

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

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

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

4.7.1. Assessment Unit-Level TMDL Calculations

The bacteria TMDL for the water body was developed as a pollutant load allocation based on information from the MLDC for the SWQM station located within the watershed (Figure 9). As discussed in more detail in Section 3, the bacteria MLDC was developed by multiplying each flow value along the MFDC by the Enterococci criterion (35 cfu/100 mL) and by the conversion factor used to represent maximum loading in cfu/day. Effectively, the “Allowable Load” displayed in the MLDC at 10% exceedance (the median value of the Highest flow regime) is the TMDL.

TMDL (cfu/day) = Criterion * Flow (cfs) * Conversion Factor (Equation 5)

Where:

Criterion = 35 cfu/100 mL (Enterococci)

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

The allowable loading of Enterococci that the impaired water body can receive on a daily basis was determined using Equation 5 based on the median value within the Highest-Flow regime of the MFDC (or 10% flow exceedance value) for the SWQM station (Table 12).

Table 12. Summary of allowable loading calculation

Water Body Name	AU	10% Exceedance Flow (cfs)	10% Exceedance Load (Billion cfu/Day)	TMDL (Billion cfu/Day)
Jarbo Bayou	2425B_02	7.287	6.240	6.240

4.7.2. Margin of Safety Allocation

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

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

Using the value of TMDL for the AU provided in Table 12, the MOS may be readily computed by proper substitution in Equation 6 (Table 13).

Table 13. MOS calculations

Load units expressed as billion cfu/day Enterococci

Water Body Name	AU	TMDL[a]	MOS
Jarbo Bayou	2425B_02	6.240	0.312

[a] TMDL from Table 12.

4.7.3. Wasteload Allocations

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

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

4.7.3.1. Wastewater

TPDES-permitted WWTFs are allocated a daily wasteload calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion. The water quality criterion (23 cfu/100 mL) is used as the WWTF target to provide instream and downstream load capacity, and to be consistent with the previously developed TMDL. Thus, WLA_{WWTF} is expressed in the following equation:

$$WLA_{WWTF} = Target * Flow * Conversion\ Factor \qquad \text{(Equation 8)}$$

Where:

Target= 23 cfu/100 mL

Flow = full permitted flow (in million gallons per day, or MGD)

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

Due to the absence of any permitted dischargers in the Jarbo Bayou AU 2425B_02 watershed, the WLA_{WWTF} is zero.

4.7.3.2. Regulated Stormwater

Stormwater discharges from MS4, industrial, and construction areas are considered regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated stormwater discharges. A simplified approach for estimating the WLA for these areas was used in the development of this TMDL due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading.

The percentage of the land area that is under the jurisdiction of stormwater permits in the TMDL watershed was used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

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

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \qquad \text{(Equation 9)}$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

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

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits. As described in Section 2.7.1.3, the Jarbo Bayou AU 2425B_02 watershed is 100% covered by MS4 Phase I and II permits. However, even in highly urbanized areas such as this one, there remain small areas of potential direct deposition of bacteria loadings from unregulated sources such as wildlife. To account for these small unregulated areas, the stream length based on the TCEQ definition of AU 2425B_02 and average channel width as calculated based on recent aerial imagery was used to compute an area of unregulated stormwater contribution (Table 14).

Table 14. Basis of unregulated stormwater area and computation of FDA_{SWP} term

Watershed	AU	Total Area (acres)	Stream Length (feet)	Estimated Average Channel Width (feet)	Estimated Stream Area (acres)	Fraction Unregulated Area	FDA_{SWP}
Jarbo Bayou	2425B_02	1,221.9	6,283	24	3.5	0.003	0.997

The daily allowable loading of Enterococci assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. To calculate the WLA_{SW} (Equation 9), the FG term must be known. The calculation for that term is presented in the next section, but the results are included here for continuity. Table 15 provides the information needed to compute WLA_{SW}.

Table 15. Regulated stormwater WLA calculations

Load units expressed as billion cfu/day Enterococci

Water Body Name	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	FG[d]	FDA_{SWP}[e]	WLA_{SW}[f]
Jarbo Bayou	2425B_02	6.240	0.312	0	0.032	0.997	5.878

[a] TMDL from Table 12

[b] MOS from Table 13

[c] WLA_{WWTF} = 0 due to an absence of any WWTFs in the TMDL watershed

[d] FG from Table 16

[e] FDA_{SWP} from Table 14

[f] $WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$ (Equation 9)

4.7.4. Future Growth

The FG component of the TMDL equation addresses the requirement to account for future loadings that may occur due to population growth, changes in community infrastructure, and development. Specifically, this TMDL component 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.

For this TMDL, the conventional FG calculation is hampered by the absence of WWTFs. By using TCEQ design guidance for domestic WWTFs, and assuming the potential for a residential development of a density sufficient to require centralized sewer collection, an alternative method was implemented.

A new WWTF must accommodate daily wastewater flow of 75–100 gallons per capita per day (gpcd) as required under Title 30, Texas Administrative Code, Chapter 217, Subchapter B, Section 217.32 (30 TAC 217.32) (TCEQ, 2015). Conservatively using the higher daily wastewater flow capacity (100 gpcd), and multiplying it by a potential population change, would result in a conservative FG permitted flow. Based on the information in Table 2, the projected population change between 2020 and 2045 within the TMDL watershed is 371. Multiplying the projected population growth of TMDL watershed by the higher daily wastewater flow capacity, yields a value of 0.037 MGD for the Jarbo Bayou AU 2425B_02 watershed. This value would be considered the full permitted discharge of a potential future WWTF.

Thus, the FG is calculated as follows:

$$FG = WWTF_{FP} * \text{Conversion factor} * \text{Target} \qquad \text{(Equation 10)}$$

Where:

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

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

Target = 23 cfu/100 mL

The Target of 23 cfu/100mL in Equation 10 remains consistent with the previous TMDL. The calculation results for the TMDL watershed are shown in Table 16.

Table 16. FG calculation

Water Body Name	AU	Estimated Additional Service Population	Daily Wastewater (gpcd)	FG (MGD)	FG (Enterococci Billion cfu/Day)[a]
Jarbo Bayou	2425B_02	371	100	0.037	0.032

[a] FG = $WWTF_{FP}$ * conversion Factor * target (Equation 10)

4.7.5. Load Allocations

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

$$LA = TMDL - WLA - FG - MOS \qquad \text{(Equation 11)}$$

Where:

TMDL = total maximum daily load

WLA = sum of all WLA_{WWTF} and WLA_{SW} loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The calculation results are shown in Table 17.

Table 17. LA calculation

Load units expressed as billion cfu/day Enterococci

Water Body Name	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	FG[e]	LA[f]
Jarbo Bayou	2425B_02	6.240	0.312	0	5.878	0.032	0.018

[a] TMDL from Table 12

[b] MOS from Table 13

[c] WLA_{WWTF} = 0 due to an absence of any WWTFs in the TMDL watershed

[d] WLA_{SW} from Table 15

[e] FG from Table 16

[f] LA = TMDL – WLA_{WWTF} – WLA_{SW} – FG – MOS (Equation 11)

4.8. Summary of TMDL Calculations

Table 18 summarizes the TMDL calculation for the TMDL watershed. The TMDL was calculated based on the median flow in the 0–20 percentile range (10% exceedance, Highest flow regime) for flow exceedance from the MLDC developed for SWQM Station 16485. Allocations are based on the current geometric mean criterion for Enterococci of 35 cfu/100 mL for each component of the TMDL, except for the WLA_{WWTF} component which will use a criterion of 23 cfu/100 mL to remain consistent with the previous TMDL for any future WWTFs. The TMDL allocation summary for Jarbo Bayou AU 2425B_02 TMDL watershed is summarized in Table 18.

Table 18. TMDL allocation summary

Load units expressed as billion cfu/day Enterococci

AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
2425B_02	6.240	0.312	0	5.878	0.018	0.032

[a] TMDL from Table 12

[b] MOS from Table 13

[c] WLA_{WWTF} = 0 due to an absence of any WWTFs in the TMDL watershed

[d] WLA_{SW} from Table 15

[e] LA from Table 17

[f] FG from Table 16

The final TMDL allocation (Table 19) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the $WLA_{WWTF.}$

Table 19. Final TMDL allocation

Load units expressed as billion cfu/day Enterococci

AU	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
2425B_02	6.240	0.312	0.032	5.878	0.018

[a] WLA_{WWTF} includes the FG component

Section 5. References

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Appendix A. Estimation of the 2020 Census Population and 2045 Population Projections

The following steps detail the method that was used to estimate the 2020 and projected 2045 populations in the Jarbo Bayou AU 2425B_02 TMDL watershed.

1) Obtained 2020 USCB data at the block level.
2) Developed the 2020 watershed population using the USCB block level data for the portions of census blocks within the watershed.
3) For the census blocks that were partially located in the watershed, estimated population was calculated by multiplying the block population to the proportion of its area in the watershed. The results of blocks located wholly and/or partially within the watershed were added together to obtain the 2020 population for the TMDL watershed.
4) Obtained the 2018 H-GAC Regional Growth Forecast (tabular data) and associated TAZs (spatial data) to be used for population projections (H-GAC, 2018).
5) Joined population data for each TAZ in a geographic information system and located the relevant TAZs within the watershed.
6) For the TAZs that were partially located in the watershed, estimated population projections by multiplying the TAZ population to the proportion of its area in the watershed. Summed the results of TAZs located wholly and/or partially within the watershed to obtain the 2045 population projections.
7) Subtracted the 2020 watershed population (Step 4) from the 2045 population projection (Step 7) to determine the projected population increase. Subsequently, divided the projected population increase by the 2020 watershed population to determine the percentage population increase for the TMDL watershed.