Draft Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in Unnamed Tributaries of Dickinson Bayou Tidal and Gum Bayou

Assessment Units: 1103F_01 and 1103G_01

Unnamed Tributary of Dickinson Bayou at SWQM Station 20477

Unnamed Tributary of Gum Bayou at SWQM Station 20728

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Abbreviations

AU	assessment unit
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
DAR	drainage-area ratio
DMU	deer management unit
DSLP	days since last precipitation
EPA	Environmental Protection Agency (United States)
FDA_{SWP}	fractional drainage area stormwater permit
FG	future growth
gpcd	gallons per capita per day
gSSURGO	Gridded Soil Survey Geographic
H-GAC	Houston-Galveston Area Council
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
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 program
SWQM	surface water quality monitoring
TAZ	transportation analysis zones
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation

WLA_{SW}	wasteload allocation stormwater
WLA_{WWTF}	wasteload allocation wastewater treatment facilities
WWTF	wastewater treatment facility

Section 1. Introduction

1.1. Background

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

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units in 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 the 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 the Unnamed Tributary of Gum Bayou in the *2018 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report; TCEQ, 2018a), and the Unnamed Tributary of Dickinson Bayou Tidal in the 2020 Texas Integrated Report (2020a).

This document will consider two bacteria impairments in two assessment units (AUs) within the Dickinson Bayou watershed (Segments 1103 and 1104). The impaired AUs and their identifying numbers are shown below:

- Unnamed Tributary of Dickinson Bayou Tidal 1103F_01.
- Unnamed Tributary of Gum Bayou 1103G_01.

The phrase "TMDL watersheds" will be used in this report when referring to the direct drainage areas of the two impaired AUs addressed in this report.

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, 2018b). 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 indicates that associated pathogens from fecal wastes may be reaching water bodies because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2018c). Enterococci are members of the fecal coliform bacteria group and are used in the state of Texas as the fecal indicator bacteria in saltwater.

On February 7, 2018, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2018b) and on May 19, 2020, the United States Environmental Protection Agency (EPA) approved the categorical levels of recreational use and their associated criteria. Recreational use for tidal streams consists of the following 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 milliliter (mL) and an additional single sample criterion of 130 cfu per 100 mL.

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

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

The Unnamed Tributary of Dickinson Bayou Tidal and the Unnamed Tributary of Gum Bayou are saltwater streams and have a primary contact recreation 1 use. The associated standard for Enterococci is a geometric mean of 35 cfu per 100 mL.

1.3. Report Purpose and Organization

This TMDL project was initiated through a contract between TCEQ and the Texas Institute for Applied Environmental Research. 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 watersheds; and (3) assist TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDLs for the impaired AUs. This report contains:

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

Whenever feasible, project staff developed the data and computations for the load duration curves (LDCs) and pollutant load allocations to be consistent with the previously completed Addendum One, Three Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou[1] (TCEQ, 2016) and the original TMDL report, Eight Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou and Three Tidal Tributaries.[2] (TCEQ, 2012).

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[1] https://www.tceq.texas.gov/downloads/water-quality/tmdl/dickinson-bayou-recreational-80/80-dickinson-addendum-01-2016-july.pdf

[2] https://www.tceq.texas.gov/downloads/water-quality/tmdl/dickinson-bayou-recreational-80/80-dickinson-tmdl-adopted.pdf

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

The TMDL watersheds (AUs 1103F_01 and 1103G_01) are located within the Dickinson Bayou Tidal (Segment 1103) watershed in the southeastern portion of the "Greater Houston" metropolitan area and entirely within Galveston County (Figure 1). The AUs are tidally influenced by seawater from lower Galveston Bay. Dickinson Bayou Tidal (Segment 1103) begins approximately 2.5 miles downstream of Farm-to-Market 517 and flows 14.6 miles to the outlet into Dickinson Bay. For purposes of this report, the focus will be on the two unnamed tributary AUs 1103F_01 and 1103G_01.

The Unnamed Tributary of Dickinson Bayou Tidal (AU 1103F_01) is an unclassified, tidal stream approximately 1.71 miles in length that drains an area of 3.14 square miles (2,011 acres). The watershed is located within two city boundaries (Dickinson and Santa Fe).

The Unnamed Tributary of Gum Bayou (AU 1103G_01) is an unclassified, tidal stream approximately 3.29 miles in length that drains an area of 4.36 square miles (2,788 acres). The watershed is mostly urban and includes two cities (Dickinson and League City.

Both AUs were considered fully supporting when previous TMDLs were developed for AUs within the Dickinson Bayou watershed (Figure 2; TCEQ, 2012 and 2016).

The 2020 Texas Integrated Report (TCEQ 2020a) provides the following AU description for AU 1103G_01. AU 1103F_01 was revised at the time of this report (TCEQ, 2021a) and the new description shown here will be included in future Integrated Reports:

1103F (Unnamed Tributary of Dickinson Bayou Tidal AU 1103F_01) – From the Dickinson Bayou Tidal confluence to a point 2.75 kilometers (1.7 miles) upstream at Galveston County Drainage Ditch 9.

1103G (Unnamed Tributary of Gum Bayou AU 1103G_01) – From the confluence with Gum Bayou to a point 0.39 miles south of Farm-to-Market 646/Farm-to-Market 1266 intersection between League City and Dickinson.

Using a watershed-based approach, the entire watersheds of both the Unnamed Tributary of Dickinson Bayou Tidal and the Unnamed Tributary of Gum Bayou will be considered in this report. The watersheds of the original TMDLs, the first addendum, and the two TMDL watersheds of this current (second) addendum are presented in Figure 2.

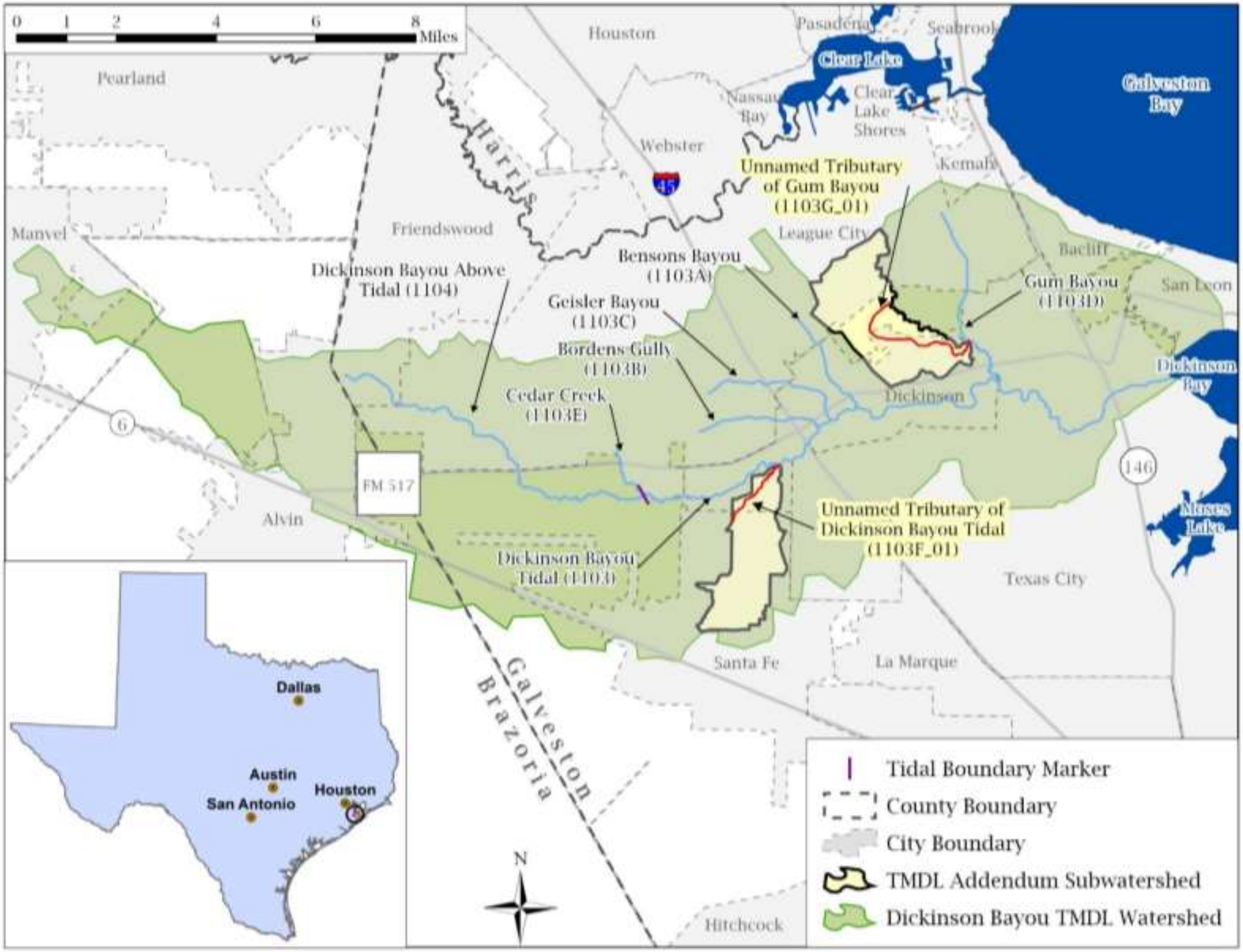

Figure 1. Overview map showing the TMDL watersheds in relation to the Dickinson Bayou watershed

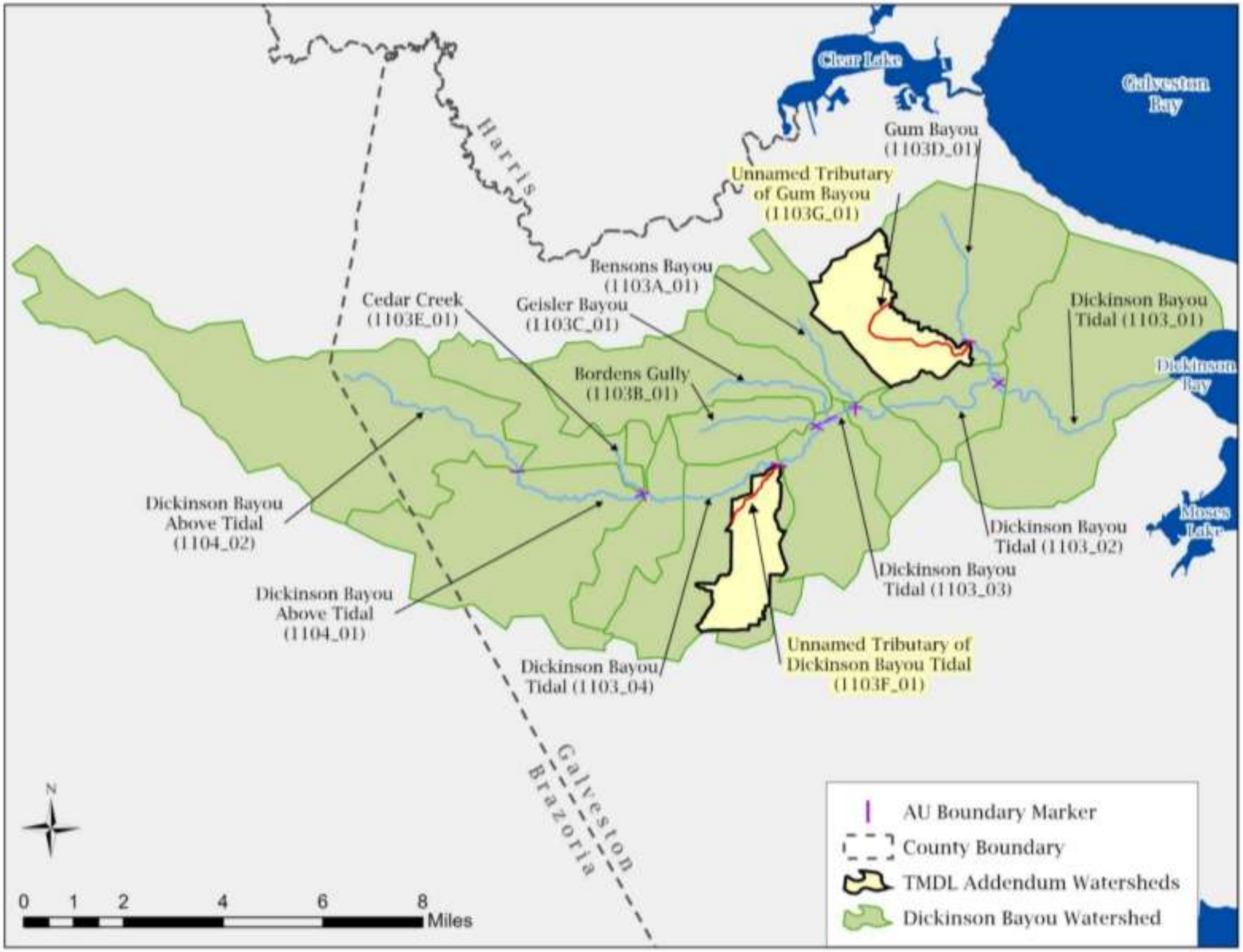

Figure 2. Map showing the watersheds of the eleven previously approved TMDLs and the two TMDL watersheds considered in this addendum

2.2. Review of Routine Monitoring Data for TMDL Watershed

2.2.1. Analysis of Bacteria Data

Monitoring within the Unnamed Tributary of Dickinson Bayou Tidal watershed has occurred at TCEQ surface water quality monitoring (SWQM) Station 20477 and at SWQM Station 20728 for the Unnamed Tributary of Gum Bayou watershed (Figure 3). Enterococci data collected at SWQM stations 20477 and 20728 over the seven-year period from December 1, 2011 through November 30, 2018 were used in assessing attainment of the primary contact recreation 1 use as reported in the 2020 Texas Integrated Report (TCEQ, 2020a) and are summarized in Table 1. The 2020 assessment data for the TMDL watersheds indicate non-support of the primary contact recreation 1 use because geometric mean concentrations exceed the Enterococci geometric mean criterion of 35 cfu/100 mL

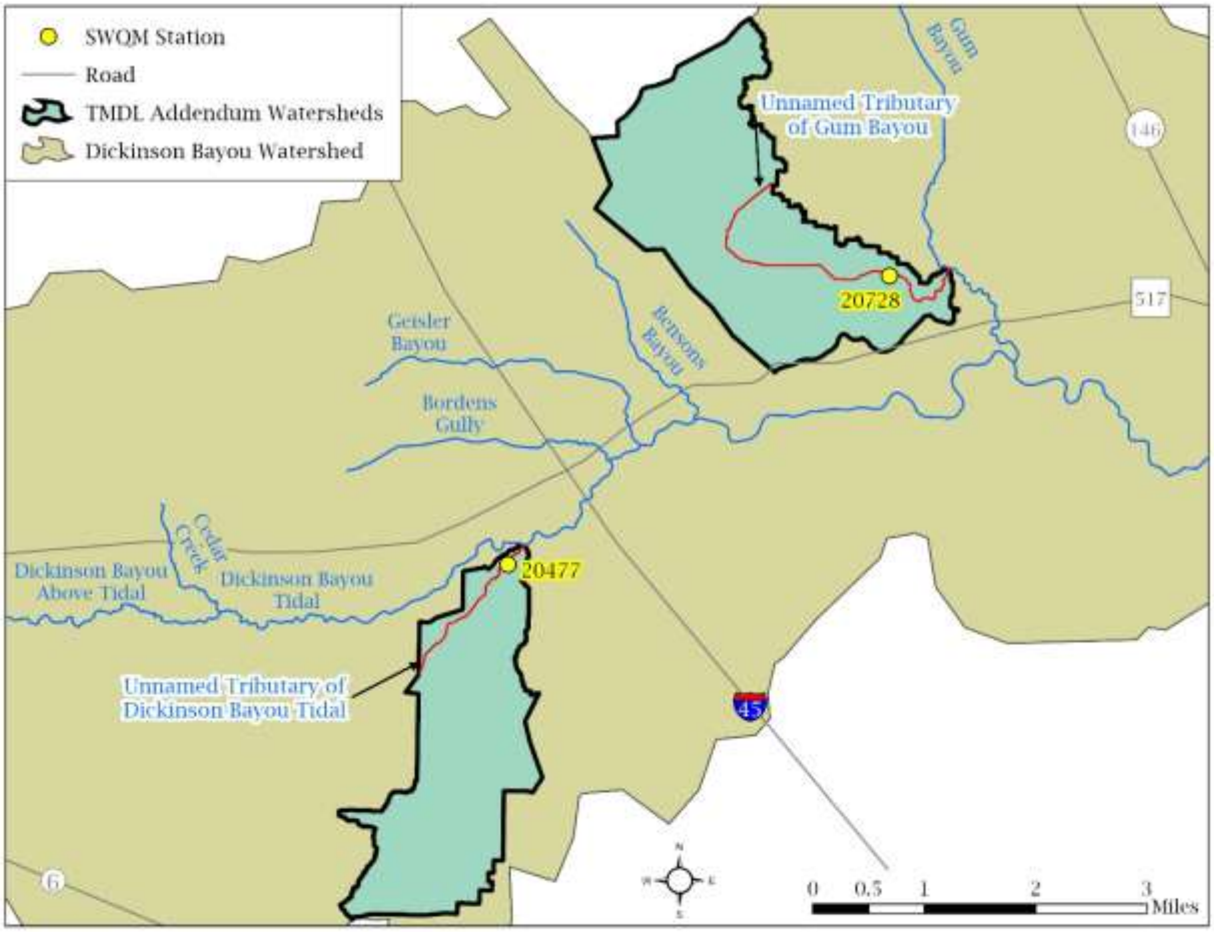

Figure 3. Current Addendum TMDL watersheds showing TCEQ SWQM stations 20477 and 20728

Table 1. 2020 Texas Integrated Report summary for the TMDL watersheds

Watershed	AU	Parameter	SWQM Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	Enterococci	20477	20	2011–2018	188
Unnamed Tributary of Gum Bayou	1103G_01	Enterococci	20728	28	2011–2018	522

2.3. Climate and Hydrology

The TMDL watersheds are 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 15-year period from January 2006 through December 2020 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, 2021). Data from this period indicates that the average high temperatures typically peak in August (92.5 ˚F). During winter, the average low temperature generally reaches a minimum of 43˚ F in January (Figure 4). Annual rainfall averages 60.7 inches. The wettest month was September (7.9 inches) while February (2.6 inches) was the driest month, with rainfall occurring throughout the year.

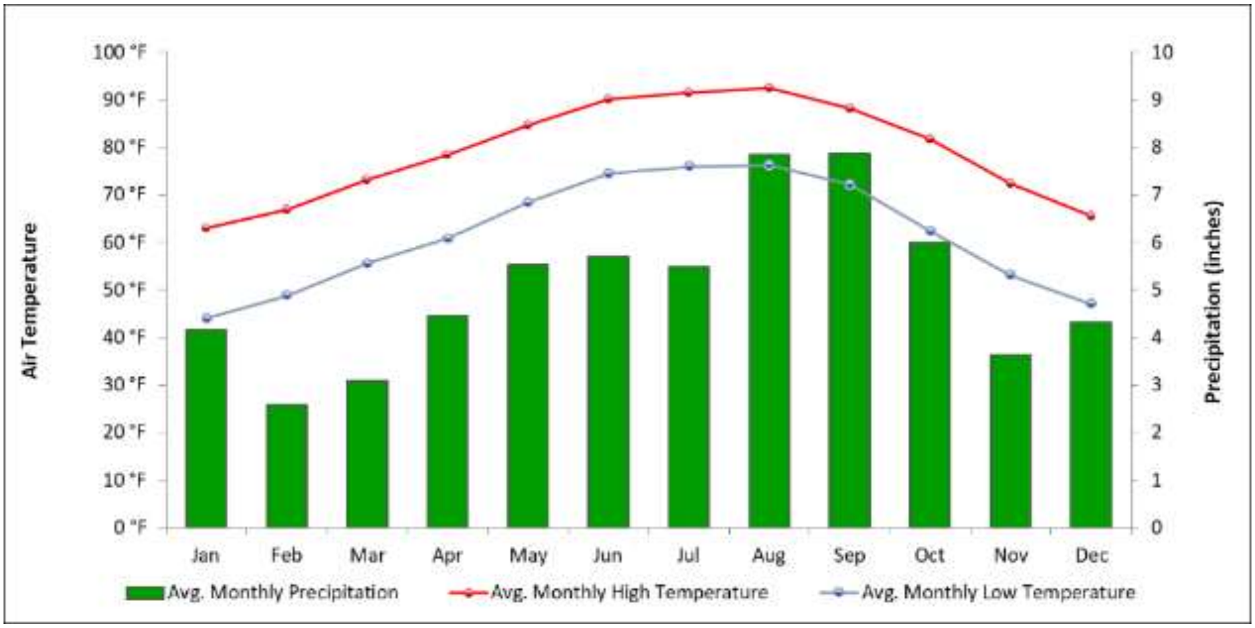

Figure 4. Average minimum and maximum air temperature and total precipitation by month from January 2006–December 2020 for Houston National Weather Service Office, League City, Texas

2.4. Population and Population Projections

Both TMDL watersheds lie entirely within Galveston County near the Texas Gulf Coast. As depicted in Figure 1, the Unnamed Tributary of Dickinson Bayou Tidal (AU 1103F_01) watershed is entirely within the city boundaries of Dickinson and Santa Fe. The low development intensity of the watershed is evident in that the current population is about zero to two people per acre (Figure 5). According to the 2010 United States Census Bureau (USCB) data (USCB, 2010) the watershed has an estimated population of 1,608 people.

The Unnamed Tributary of Gum Bayou (AU 1103G_01) watershed is at least partially within the city boundaries of Dickinson and League City. The watershed contains mostly urbanized area with a wide range of population density. (Figure 5). According to the 2010 USCB data (USCB, 2010), the watershed has an estimated population of 10,166 people.

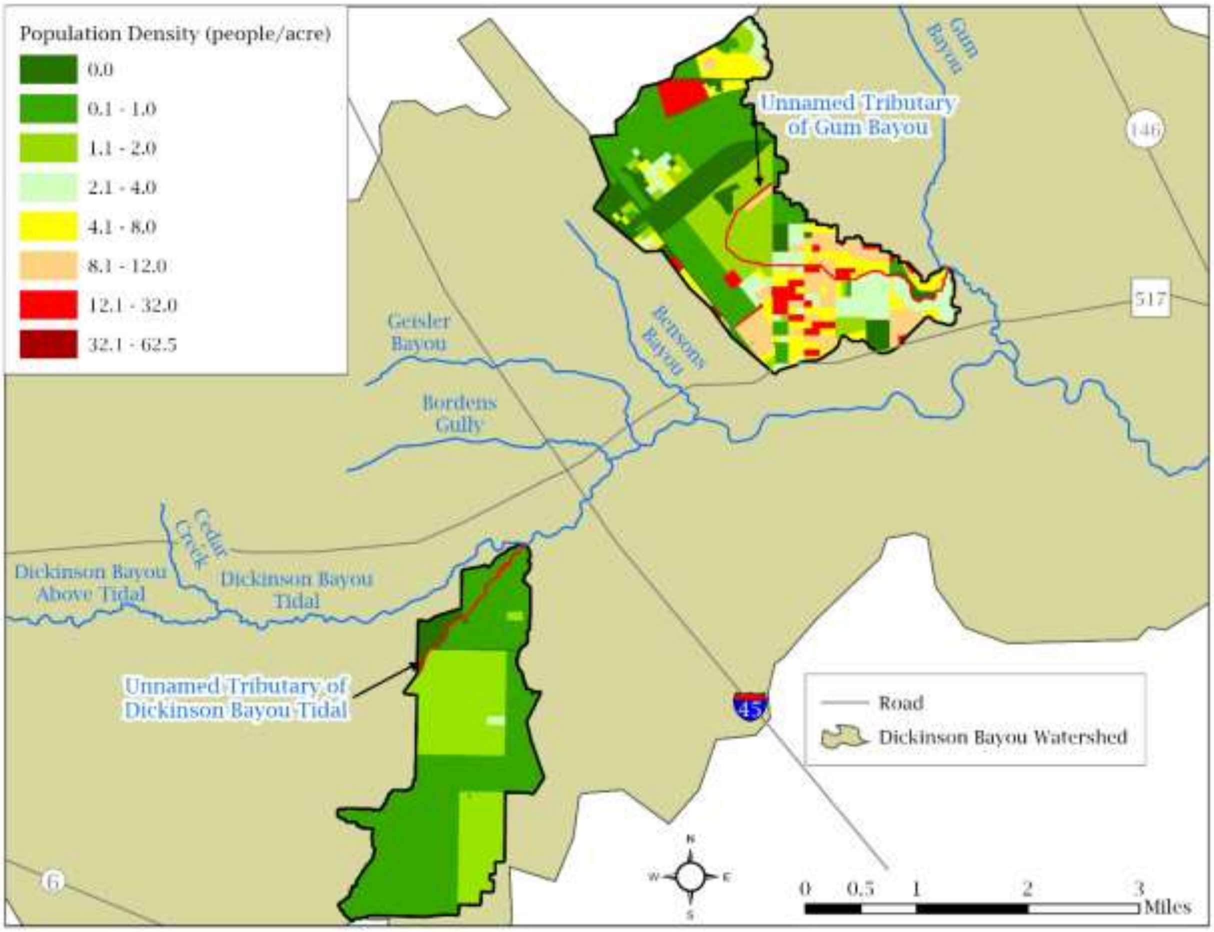

Figure 5. Population density

Population projections from 2010–2045 were developed using data from the Houston-Galveston Area Council (H-GAC) regional growth forecast (H-GAC, 2017). H-GAC updates their regional growth forecast annually, each release incorporates the latest available information on planned and announced developments, population and employment data, and feedback received from forecast users. The regional growth forecasts include population projections for transportation analysis zones (TAZ), planning areas used by H-GAC to provide analyses at a local scale. The projected 2010 through 2045 populations, shown in Table 2, were allocated based on the methodology described in Appendix A. According to the growth projections, a population increase of 94% is expected in the Unnamed Tributary of Dickinson Bayou watershed and of 69.8% in the Unnamed Tributary of Gum Bayou watershed by 2045.

Table 2. Population projections

Water Body	AU	2010 USCB Population	2045 Population Projection	Projected Population Increase (2010–2045)	Percentage Increase
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	1,608	3,120	1,512	94.0%
Unnamed Tributary of Gum Bayou	1103G_01	10,166	17,266	7,100	69.8%

2.5. Land Cover

The land cover data presented in this report are from the 2016 National Land Cover Database (NLCD; MRLC, 2019). The land cover is represented by the following categories and definitions:

- **Barren Land** – Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

- **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 some constructed materials, but mostly vegetation in the form of lawn grasses. These areas most commonly include single-family housing units. Constructed surfaces account for 20% to 49% of total cover.

- **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.
- **Shrub/Scrub** – Areas dominated by shrubs less than five meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
- **Cultivated Crops** – Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
- **Open Water** – Areas of open water, generally with less than 25% cover of vegetation or soil.
- **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 is provided for the TMDL watersheds in Figure 6. For the Unnamed Tributary of Dickinson Bayou Tidal (AU 1103F_01) watershed, the predominant land cover is Developed, Open Space comprising 45.41% of the total land cover, followed by Pasture/Hay (11.88%) and Developed, Low Intensity (10.77%). For the Unnamed Tributary of Gum Bayou (AU 1103G_01) watershed, the Developed categories (Low Intensity 30.53%, Open Space 26.76%, Medium Intensity 16.63%, and High Intensity 5.27%) are the dominant land covers comprising 79.19% of the total. Table 3 provides a summary of land cover data for the TMDL watersheds.

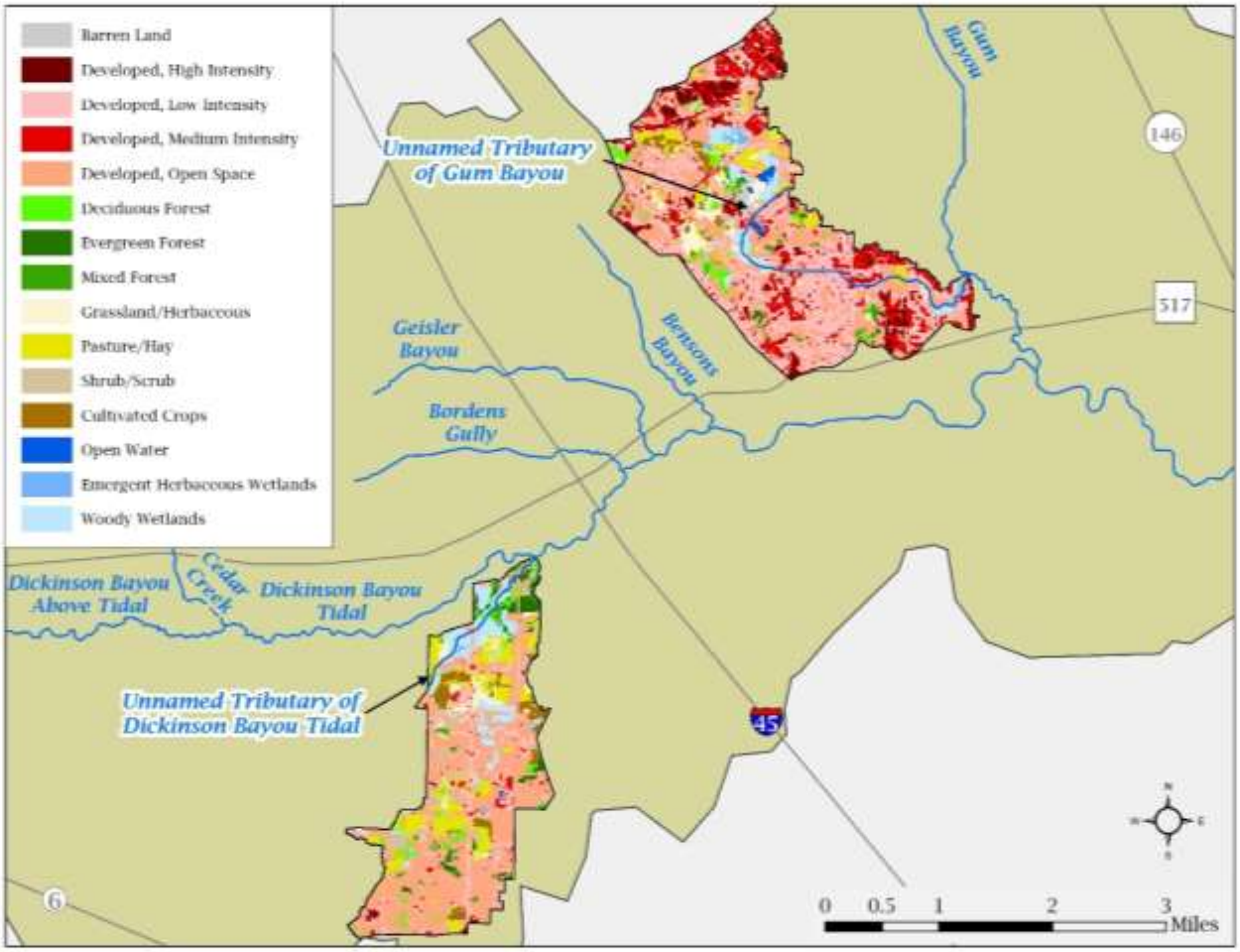

Figure 6. Land cover map

Table 3. Land cover percentages

2016 NLCD Classification	1103F_01 Area (Acres)	1103F_01 % of Total	1103G_01 Area (Acres)	1103G_01 % of Total
Barren Land	0.45	0.02%	18.23	0.65%
Developed, High Intensity	6.47	0.32%	146.81	5.27%
Developed, Low Intensity	216.61	10.77%	850.94	30.53%
Developed, Medium Intensity	40.26	2.00%	463.65	16.63%
Developed, Open Space	913.25	45.41%	745.97	26.76%
Deciduous Forest	53.73	2.67%	57.05	2.05%
Evergreen Forest	61.31	3.05%	10.55	0.38%
Mixed Forest	41.06	2.04%	32.11	1.15%
Grassland/Herbaceous	65.11	3.24%	122.32	4.39%
Pasture/Hay	238.89	11.88%	122.45	4.39%
Shrub/Scrub	103.79	5.16%	29.77	1.07%
Cultivated Crops	82.04	4.08%	41.78	1.50%
Open Water	1.88	0.09%	15.33	0.55%
Emergent Herbaceous Wetlands	6.35	0.32%	21.46	0.77%
Woody Wetlands	180.09	8.95%	109.17	3.92%
Total	**2,011.29**	**100%**	**2,787.59**	**100 %**

2.6. Soils

Soils within the TMDL watersheds are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Gridded Soil Survey Geographic database (gSSURGO) (USDA NRCS, 2019). The gSSURGO 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 gSSURGO database defines the classifications as follows.

- **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 7, soils for the TMDL watersheds are comprised of hydrologic Groups D and C/D, indicating high runoff potential and restricted water infiltration rates. In the Unnamed Tributary of Dickinson Bayou Tidal watershed, the soils are primarily Group C/D, which are present in 70% of the watershed, followed by Group D soils at 30%. The Unnamed Tributary of Gum Bayou watershed has Group D soils in 57% of its area and Group C/D in 43%.

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 watersheds. These are not meant to be used for allocating bacteria loads or interpreted as precise inventories and loadings.

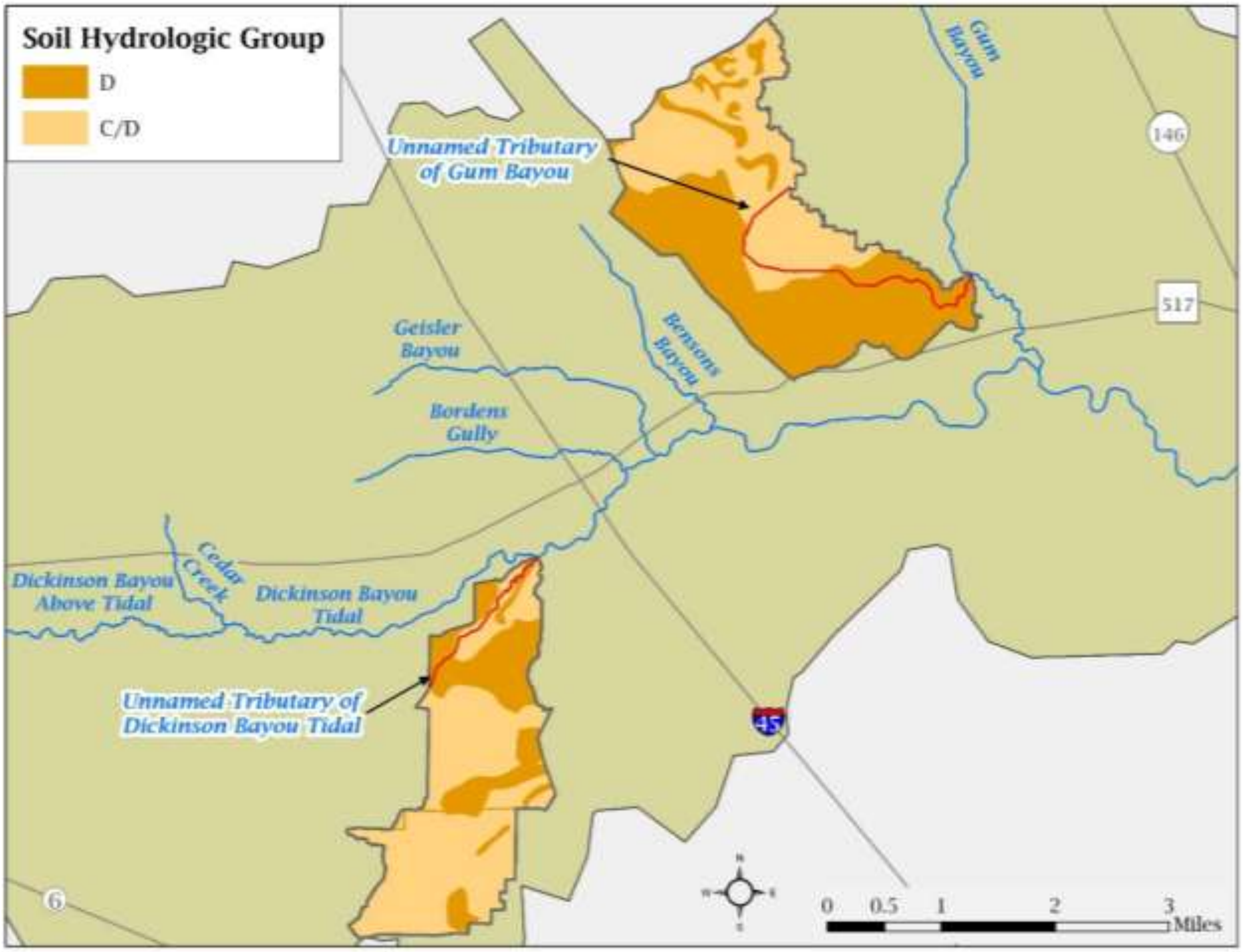

Figure 7. Soil hydrologic groups

2.7.1. Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watersheds include stormwater discharges from industrial and 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 watersheds.

2.7.1.2. TPDES GeneralPermits

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

- TXG110000 – concrete production facilities.
- TXG130000 – aquaculture production.
- TXG340000 – petroleum bulk stations and terminals.
- 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).

A review of active general-permit authorizations in the TMDL watersheds (TCEQ, 2021b) on April 5, 2021 indicated two authorizations under the pesticide application general permit—one county-wide and one statewide. The pesticide general-permit authorizations do not have bacteria reporting requirements or limits and are assumed to contain inconsequential amounts of indicator bacteria; therefore, it was unnecessary to allocate bacteria loads to them. No other active authorizations were found for the TMDL watersheds.

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 the following categories:

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

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

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

- Public education, outreach, and involvement.
- Illicit discharge detection and elimination.

- Construction site stormwater runoff control.
- Post-construction stormwater management in new development and redevelopment.
- Pollution prevention and good housekeeping for municipal operations.
- Industrial stormwater sources.

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 small MS4s located in UAs.
- TXR050000 – Multi-sector general permit (MSGP) for industrial facilities.
- TXR150000 – Construction general permit for construction activities that disturb more than one acre or are part of a common plan of development disturbing more than one acre.

One combined Phase I/II permit authorization and five Phase II MS4 permit authorizations cover 88.46% of the Unnamed Tributary of Dickinson Bayou Tidal watershed and 84.83% of the Unnamed Tributary of Gum Bayou watershed (Table 4 and Figure 8).

A review of active stormwater general permit coverage (TCEQ, 2021b) as of April 5, 2021, found one active MSGP authorization in the Unnamed Tributary of Dickinson Bayou Tidal watershed. The review also found one MSGP authorization and one construction general permit authorization within the Unnamed Tributary of Gum Bayou watershed. The authorizations listed above were found in locations regulated by the Phase I and Phase II MS4 permits. Loadings for the areas authorized under the MSGP and construction general permit were not specifically determined since these areas are already accounted for in the combined area of regulated stormwater.

Table 4. MS4 permits

AUs	Entity	TPDES Permit	NPDES[a] Permit	Permit Type
1103F_01, 1103G_01	Texas Department of Transportation	WQ0005011000	TXS002101	Combined Phase I/II
1103F_01, 1103G_01	Galveston County	--------------	TXR040364	Phase II
1103F_01, 1103G_01	City of Dickinson	--------------	TXR040686	Phase II
1103F_01	City of Santa Fe	--------------	TXR040193	Phase II
1103F_01	Galveston County Drainage District 1	--------------	TXR040620	Phase II
1103G_01	City of League City	--------------	TXR040249	Phase II

[a] National Pollutant Discharge Elimination System

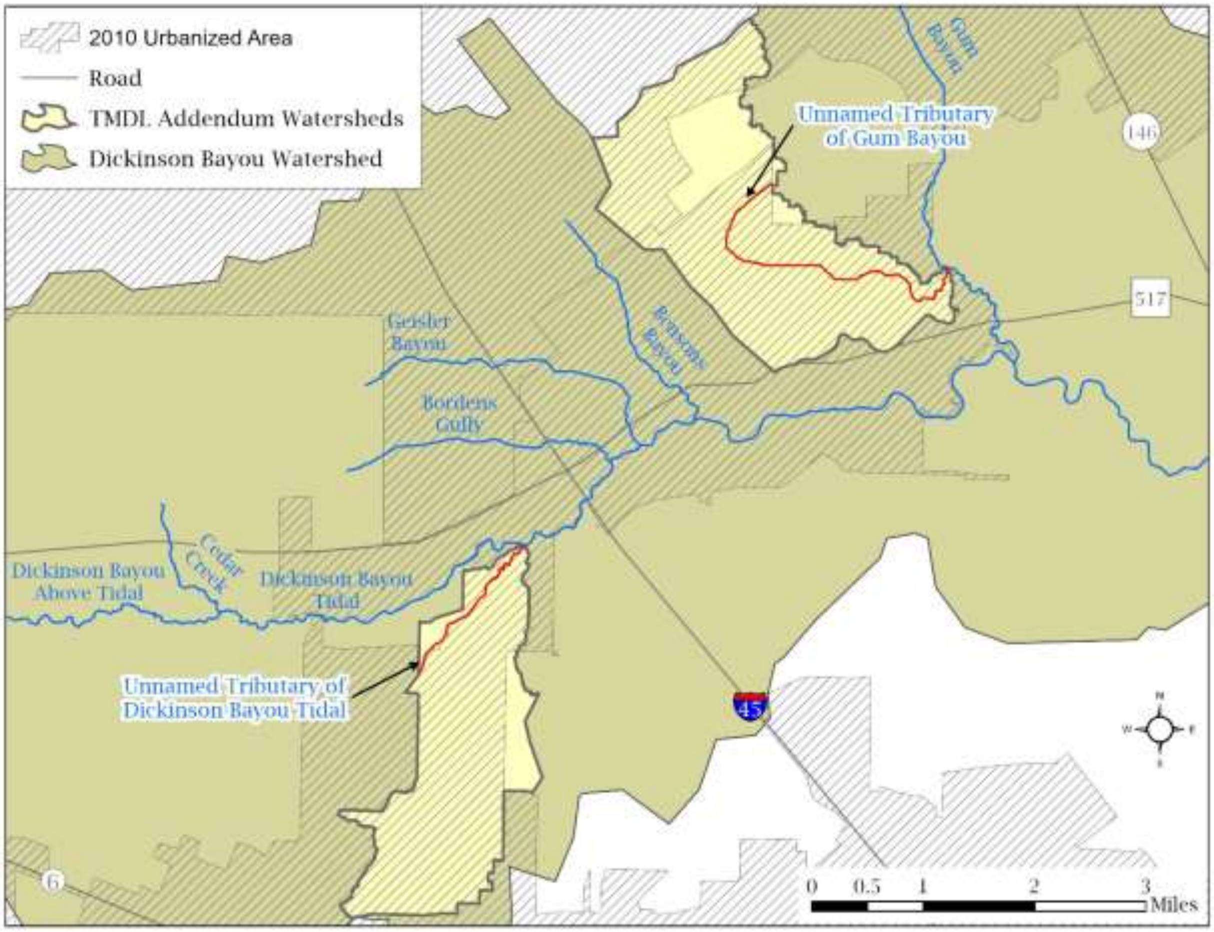

Figure 8. **Regulated stormwater areas based on MS4 permits, as defined by the 2010 Urbanized Area (USCB, 2010)**

2.7.1.4. Sanitary Sewer Overflows

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

A summary of SSO incidents during a five-year period from 2016–2020 in Galveston County was obtained from TCEQ headquarters in Austin (TCEQ, 2021c). According to that summary, there were no reported SSO incidents within the TMDL watersheds.

2.7.1.5. Dry Weather Discharges/Illicit Discharges

Pollutant loads can enter the 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 either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct Illicit Discharges:

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

Indirect Illicit Discharges:

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

2.7.2. Unregulated Sources

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

2.7.2.1. Wildlife and Unmanaged Animal Contributions

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 unmanaged animals. Wildlife and feral hogs are naturally attracted to the riparian corridors of water bodies. With direct access to the stream channel, the direct deposition of wildlife and feral hog wastes 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.

Unfortunately, quantitative estimates of wildlife are rare, inexact, and often limited to discrete taxa groups or geographical areas of interest so that even county-wide approximations of wildlife numbers are difficult or impossible to acquire. Bird diversity is high in Galveston County where the TMDL watersheds are located (eBird, 2021), but population sizes for individual species are not known. However, population estimates for feral hogs and deer are readily available.

For feral hogs, AgriLife Extension (2012) estimates a range of feral hog densities within suitable habitat in Texas from 8.9 to 16.4 hogs per square mile. The average hog density (12.65 hogs/square mile) was multiplied by the hog-habitat area of 1.17 square miles in the Unnamed Tributary of Dickinson Bayou watershed and 0.79 square miles in the Unnamed Tributary of Gum Bayou watershed. Habitat deemed suitable for hogs includes the following classifications from the 2016 NLCD land cover: Deciduous Forest, Evergreen Forest, Mixed Forest, Emergent Herbaceous Wetlands, Woody Wetlands, Pasture/Hay, Shrub/Scrub, and Grassland/Herbaceous. Using this calculation, the estimated feral hog population is 15 in the Unnamed Tributary of Dickinson Bayou watershed and 10 in the Unnamed Tributary of Gum Bayou watershed.

For deer, the Texas Parks and Wildlife Department (TPWD) has published data showing deer population-density estimates by deer management unit (DMU) and Ecoregion in the state (TPWD, 2021). The TMDL watersheds are located entirely within the DMU Urban Houston, for which there is no deer density data. However, because the TMDL watersheds are close to DMU 10, density data from this DMU was used to estimate deer populations for the TMDL watersheds. For the 2020 TPWD survey year, the estimated deer population density for DMU 10 was 21.52 deer per 1,000 acres and applies to all habitat types within the DMU. Applying this value to the entire area of the TMDL watersheds returns an estimated 43 deer within the Unnamed Tributary of Dickinson Bayou Tidal watershed and 60 deer in the Unnamed Tributary of Gum Bayou watershed. The Enterococci contribution from feral hogs and wildlife could not be determined based on existing information.

2.7.2.2. Unregulated Agricultural Activities and Domesticated Animals

A number of agricultural activities that do not require permits can be potential sources of fecal bacteria loading. The number of livestock within the TMDL watersheds was estimated from county-level data obtained from the 2017 Census of Agriculture (USDA NASS, 2019). The county-level data for Galveston County was then refined to better reflect actual numbers within the TMDL watersheds. Using 2016 NLDC, the county numbers were refined by determining the total area of the suitable livestock land cover categories of “Grassland/Herbaceous”, “Hay/Pasture”, and “Shrub/Scrub” within the TMDL watersheds and Galveston County. A ratio was then computed by dividing the livestock total land use area of each TMDL watershed by the livestock total land use area of the county. The county-level agricultural census data were then multiplied by the ratio to determine the estimated livestock populations (Table 5). These numbers were not used to develop a loading allocation for livestock.

Table 5. Estimated livestock populations

AU	Cattle and Calves	Hogs and Pigs	Sheep and Lambs	Goats	Horses and Ponies	Mules, Burros, and Donkeys
1103F_01	106	7	3	6	11	4
1103G_01	71	4	2	4	7	2

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

Table 6. Estimated households and pet populations in the TMDL watersheds

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
1103F_01	607	373	277
1103G_01	3,597	2,209	1,644

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 TMDL watersheds are within the east-central Texas Region IV, 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 TMDL watersheds were determined using data supplied by H-GAC (H-GAC, 2020) and from the TCEQ Coastal On-Site Sewage Inventory Database (TCEQ, 2018d). Both datasets were combined and then refined by removing duplicate data from analysis. The combined data indicate that there are 233 OSSFs located within the watershed of the Unnamed Tributary of Dickinson Bayou Tidal watershed and 229 OSSFs within the Unnamed Tributary of Gum Bayou watershed (Figure 9).

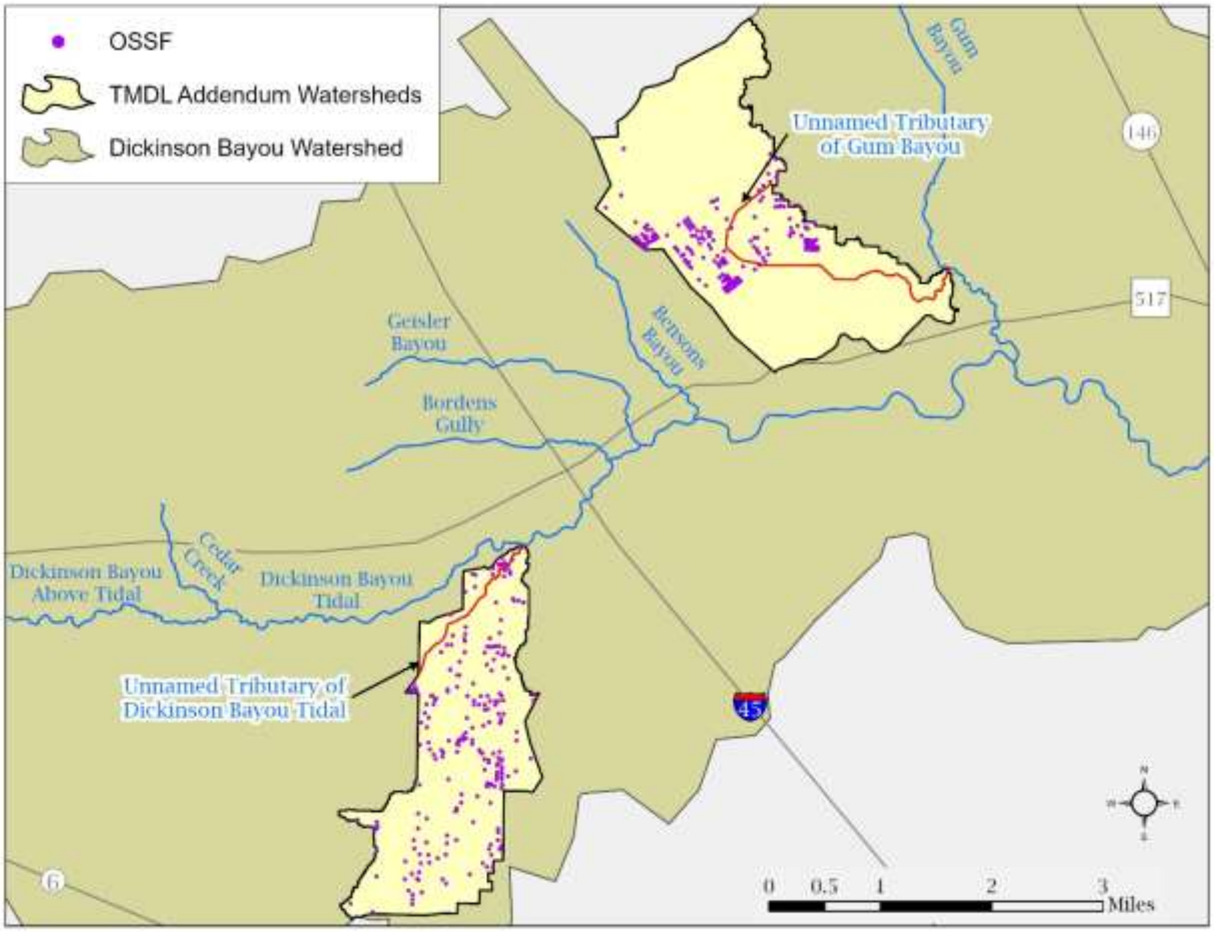

Figure 9. **Estimated locations of OSSFs in the TMDL watersheds**

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 watersheds.

Section 3. Bacteria Tool Development

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

3.1. Tool Selection

The pollutant load allocations were developed for the TMDL watersheds 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, i.e., point source and nonpoint source.

3.2. Data Resources

To develop the MLDC method for the Unnamed Tributary of Dickinson Bayou Tidal and Unnamed Tributary of Gum Bayou, 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 waterbodies.

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 readily available by the United States Geological Survey (USGS; USGS, 2020), which operates the streamflow gauge (Table 7, Figure 10). USGS Streamflow Gauge 08075730 is located along the mainstem of Vince Bayou and is close enough to the TMDL watersheds 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. Basic information about the Vince Bayou USGS streamflow gauge

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

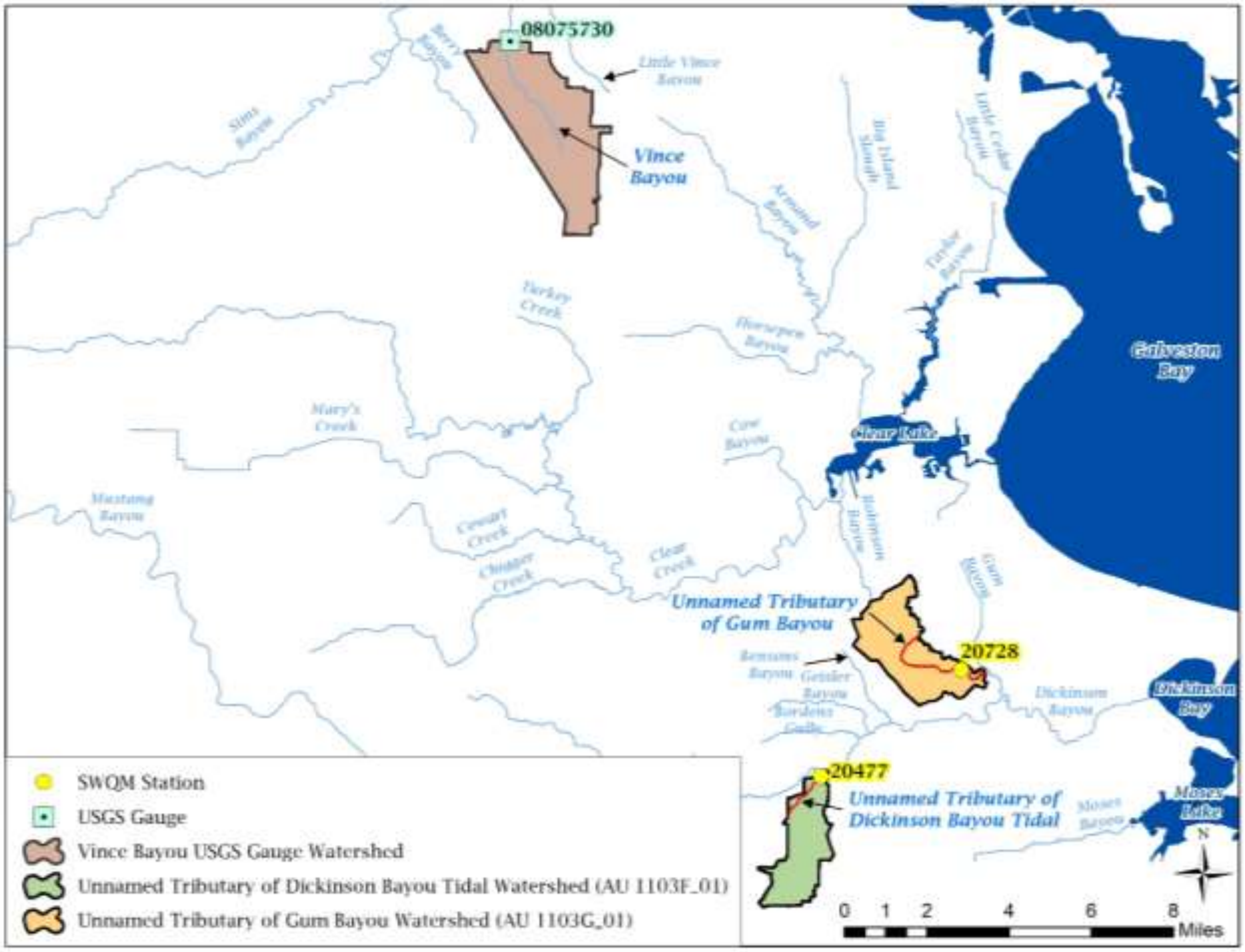

Figure 10. TMDL watersheds and the watershed of USGS Station 08075730

Paired ambient Enterococci and salinity data were available for the TMDL watersheds through the TCEQ Surface Water Quality Monitoring Information System (TCEQ, 2020c) (Table 8).

Table 8. Summary of historical bacterial and salinity data sets

Water Body	AU	SWQM Station	SWQM Station Location	No. of Enterococci Samples	No. of Salinity Samples	Date Range
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	20477	Unnamed Tributary of Dickinson Bayou Tidal at Ave. L	33	36	Jul. 2008 – Jan. 2020
Unnamed Tributary of Gum Bayou	1103G_01	20728	Unnamed Tributary of Gum Bayou at Owens Drive	33	21	Oct. 2009 – Apr. 2019

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

To develop the modified flow duration curves (MFDCs) and MLDCs, the previously discussed data resources were used in the following series of 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 DAR parameter estimates.
- Step 4: Develop daily streamflow record at desired stream location.
- Step 5: Develop regression of salinity to streamflow for stream location.
- Step 6: Incorporate daily tidal volumes into streamflow record.
- Step 7: Develop MFDC at the desired stream location, segmented into discrete flow regimes.
- Step 8: Develop the allowable bacteria MLDC at the same stream location based on the relevant criteria and the data from the MFDC.
- Step 9: Superimpose historical bacteria data on the allowable bacteria MLDC.

Additional 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 nearly 50 years was available for USGS gauge 08075730 located on nearby Vince Bayou (Table 7, Figure 10). 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 13.6-year record of daily streamflow from June 15, 2006 through January 14, 2020 was selected to develop the MFDCs at the SWQM stations within both TMDL watersheds. This period includes the collection dates of all Enterococci data available at the time this study was undertaken. A 13.6-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 both recent and current conditions in the watershed. A 13.6-year hydrologic period was also used in the previously completed Addendum One: Three Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou[3] (TCEQ, 2016), which maintains consistency of the current TMDLs with the previous three.

3.3.2. Step 2: Determine Desired Stream Locations

SWQM Station 20477, which is located within the Unnamed Tributary of Dickinson Bayou Tidal and SWQM Station 20728, located within Unnamed Tributary of Gum Bayou, were the only locations within the TMDL watersheds where an adequate number of Enterococci data have been collected. The 33 Enterococci sampling results that were available for both stations 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 Drainage-Area Ratio Parameter Estimates

Once the hydrologic period of record and station location were determined, the next step was to develop the 13.6-year daily streamflow record for the monitoring stations. The daily streamflow records were developed from extant USGS records.

The method to develop the necessary streamflow record for the MFDC/MLDC locations (SWQM station location) involved a DAR approach. The DAR approach involves multiplying a USGS gauging 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 gauge (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-gauge watershed should first be removed from the flow record prior to application of the ratio. There were no WWTFs within the USGS-gauge watershed at the time of this study, so no correction was necessary to compensate for WWTF flows.

3.3.4. Step 4: Develop Daily Streamflow Records at Desired Locations

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 watersheds and the Vince Bayou watershed above USGS Gauge 08075730 did not contain any active water rights permits (TCEQ, 2020b and 2021d). Therefore,

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[3] https://www.tceq.texas.gov/downloads/water-quality/tmdl/dickinson-bayou-recreational-80/80-dickinson-tmdl-adopted.pdf

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-gauge watershed, each daily flow record was multiplied by the appropriate DAR.

Table 9. DAR for the TMDL watersheds based on the drainage area of the Vince Bayou USGS gauge

Water Body	Gauge/Station	Drainage Area (acres)	DAR
Vince Bayou	USGS Gauge 08075730	5,286	1.0
Unnamed Tributary of Dickinson Bayou Tidal (AU 1103F_01)	SWQM Station 20477	1,970	0.373
Unnamed Tributary of Gum Bayou (AU 1103G_01)	SWQM Station 20728	2,552	0.483

3.3.5. Step 5: Develop Salinity to Streamflow Regression

As part of the development of the MLDC method, it was necessary to develop a relationship between estimated actual daily streamflow and measured salinity for the selected tidally influenced locations (SWQM stations 20477 and 20728). The resulting regressions were instrumental in determining the daily volume of seawater present for each daily freshwater flow in the 13.6-year period of record. Salinity to streamflow regressions were developed for SWQM Station 20477 located within the Unnamed Tributary of Dickinson Bayou Tidal (AU 1103F_01) and SWQM Station 20728 located with the Unnamed Tributary of Gum Bayou (AU 1103G_01). The equations derived from the regression analyses were used to calculate the volume of seawater that would flow through the cross-section of each station over the period of a day (Figures 11 and 12). Salinity is presented in parts per thousand (ppt).

3.3.6. Step 6: Incorporate Daily Tidal Volumes into Streamflow Record

The regression equations developed in Step 5 were 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)

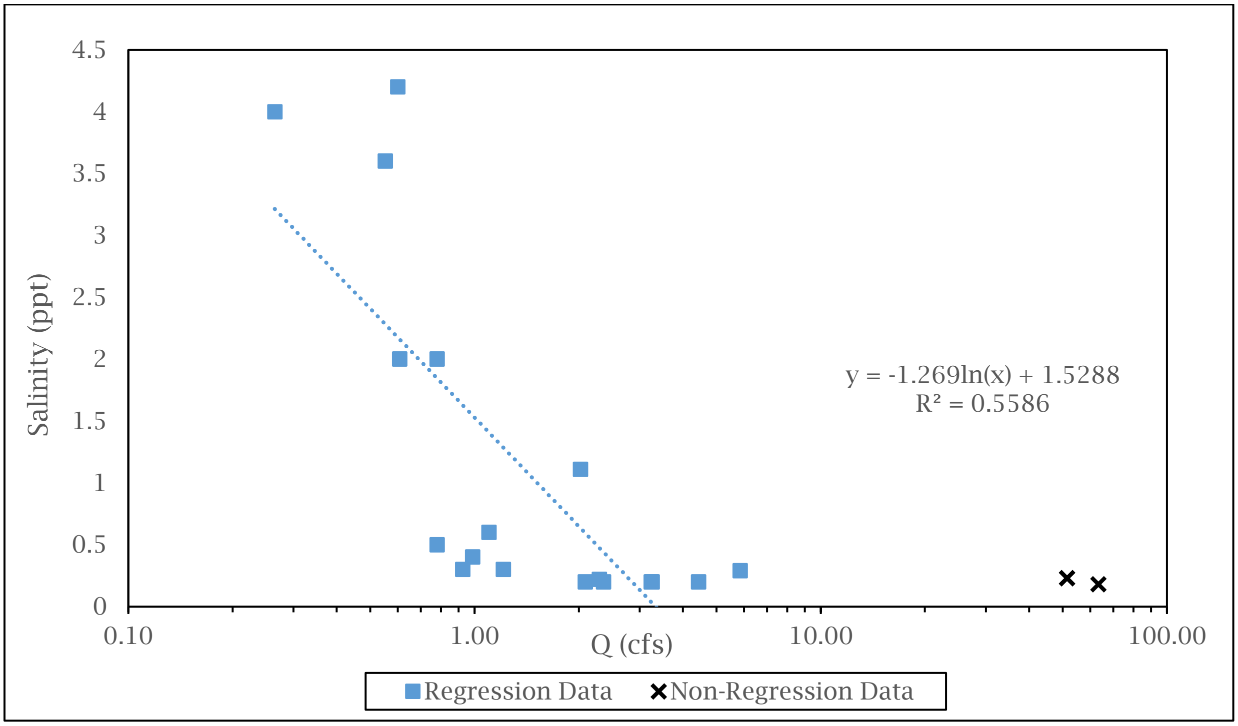

Figure 11. Salinity to streamflow regression at SWQM Station 20477 on AU 1103F_01

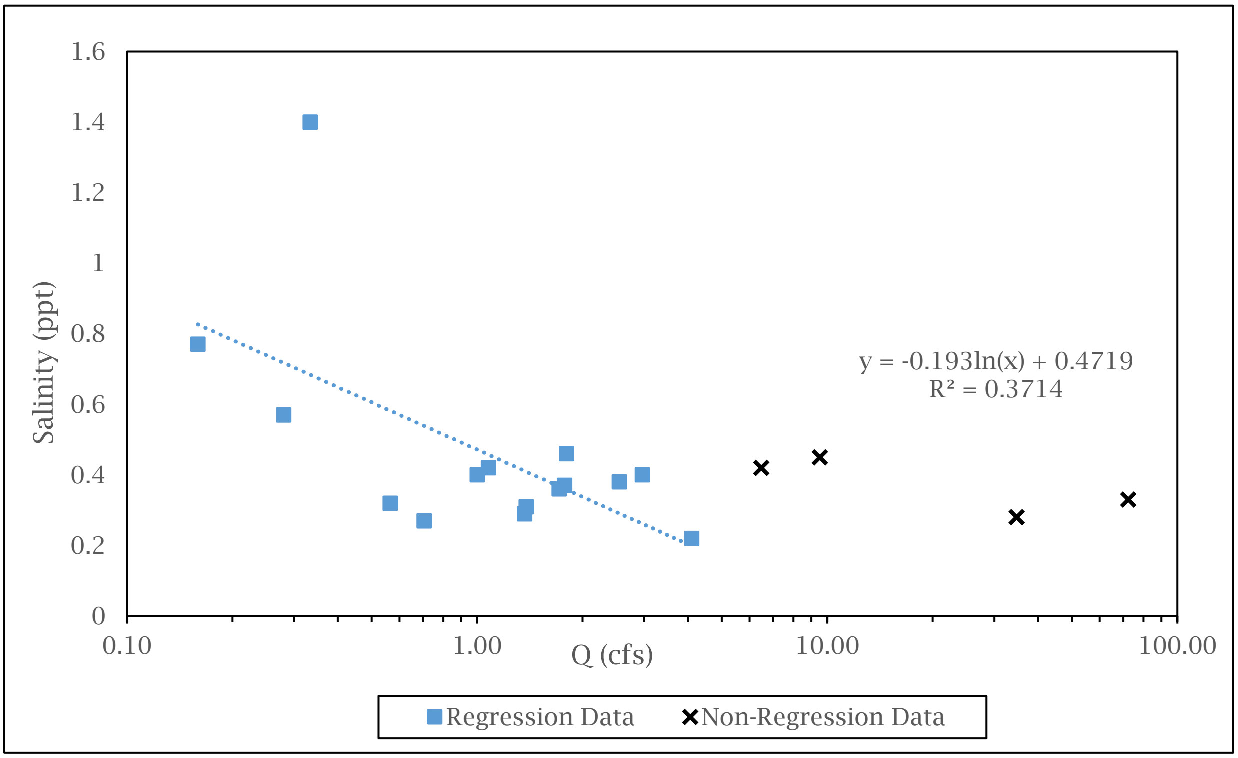

Figure 12. Salinity to streamflow regression at SWQM Station 20728 on AU 1103G_01

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:

$$V_s = V_r / (S_s/S_t - 1)\text{; for } S_t \text{ greater than background salinity, otherwise } V_s = 0 \qquad \text{(Equation 2)}$$

Where S_t was computed for each day of the 13.6-year streamflow record using the station-specific regression equations of Step 5 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:

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

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

3.3.7. Step 7: Develop Modified Flow Duration Curves

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, all of the following steps were taken in the order shown:

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

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.

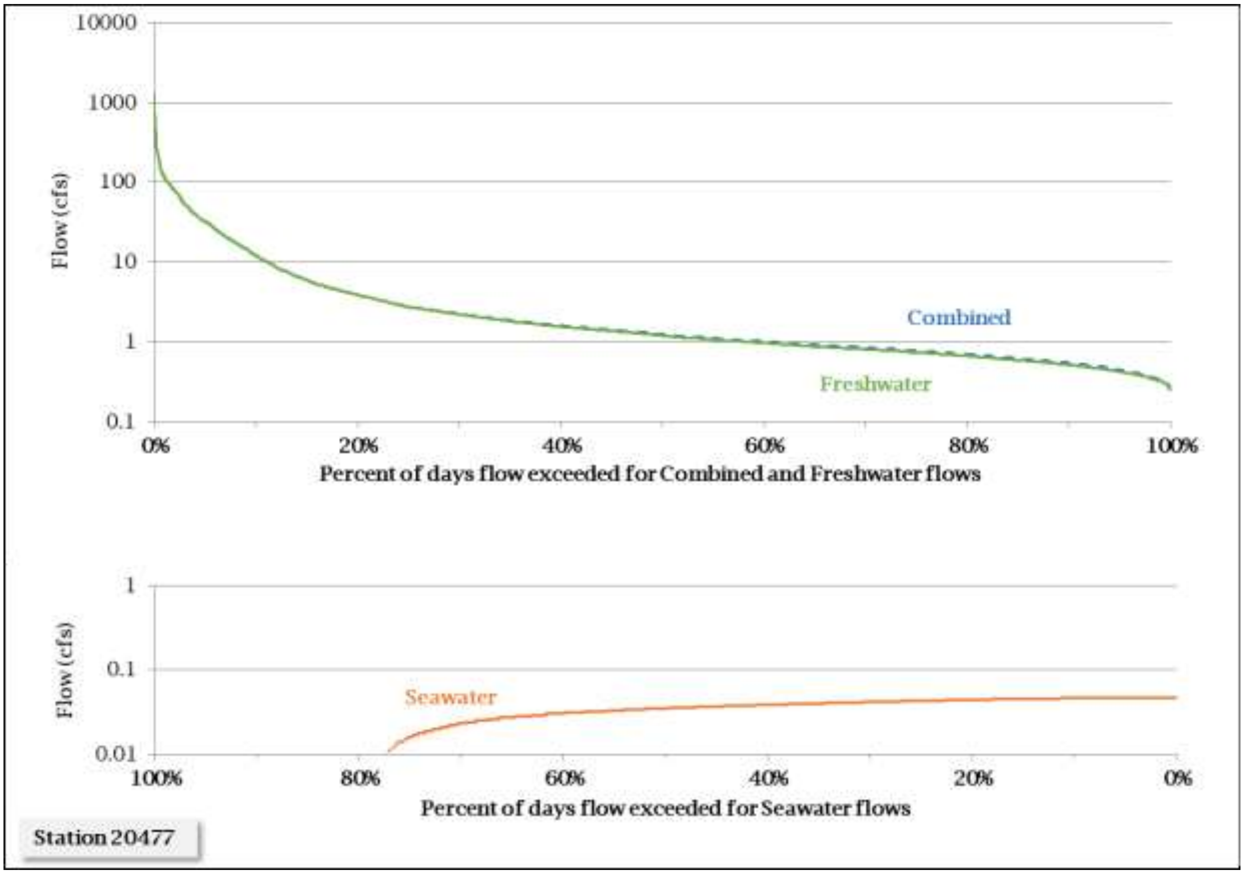

Figure 13. **Intermediate MFDC for Unnamed Tributary of Dickinson Bayou Tidal at SWQM Station 20477**

At SWQM Station 20477 within the Unnamed Tributary of Dickinson Bayou Tidal (AU 1103F_01) and SWQM Station 20728 within the Unnamed Tributary of Gum Bayou (AU 1103G_01), the amount of estimated seawater is presented in the intermediate MFDCs (Figures 13 and 14) using the flows from Steps 4 and 6. 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 both stations. 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.

The final MFDCs for SWQM stations 20477 and 20728 are presented in Figures 15 and 16. The Unnamed Tributary of Dickinson Bayou Tidal (AU 1103F_01) combined flows calculated at SWQM Station 20477 ranged from a high of 1,275.894 cubic feet per second (cfs), to a low of 0.253 cfs. The Unnamed Tributary of Gum Bayou (AU 1103G_01) combined flows calculated at SWQM Station 20728 ranged from a high of 1,652.959 cfs, to a low 1.119 cfs.

A point of importance to the pollutant load allocation process is shown in Figures 13 and 14 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.

3.3.8. Steps 8 through 9: Develop Modified Load Duration Curves

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, all of the following steps were taken in the order shown:

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

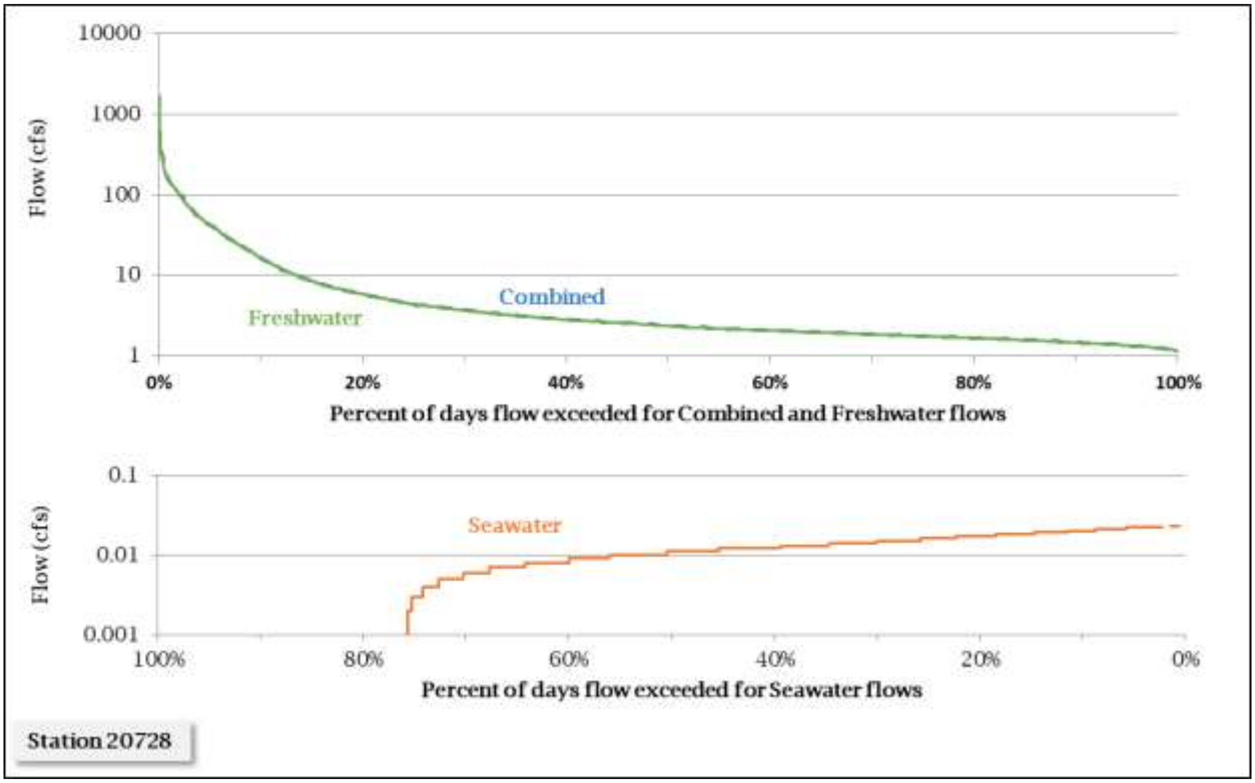

Figure 14. Intermediate MFDC for Unnamed Tributary of Gum Bayou at SWQM Station 20728

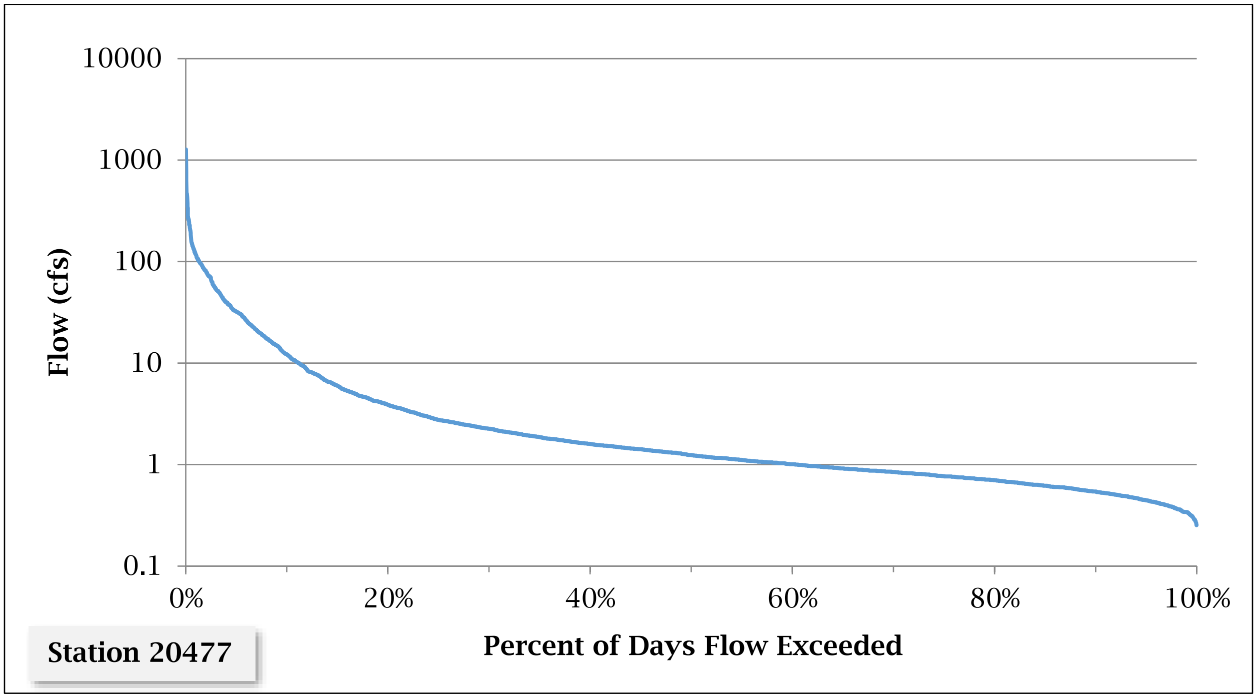

Figure 15. MFDC for Unnamed Tributary of Dickinson Bayou Tidal at SWQM Station 20477

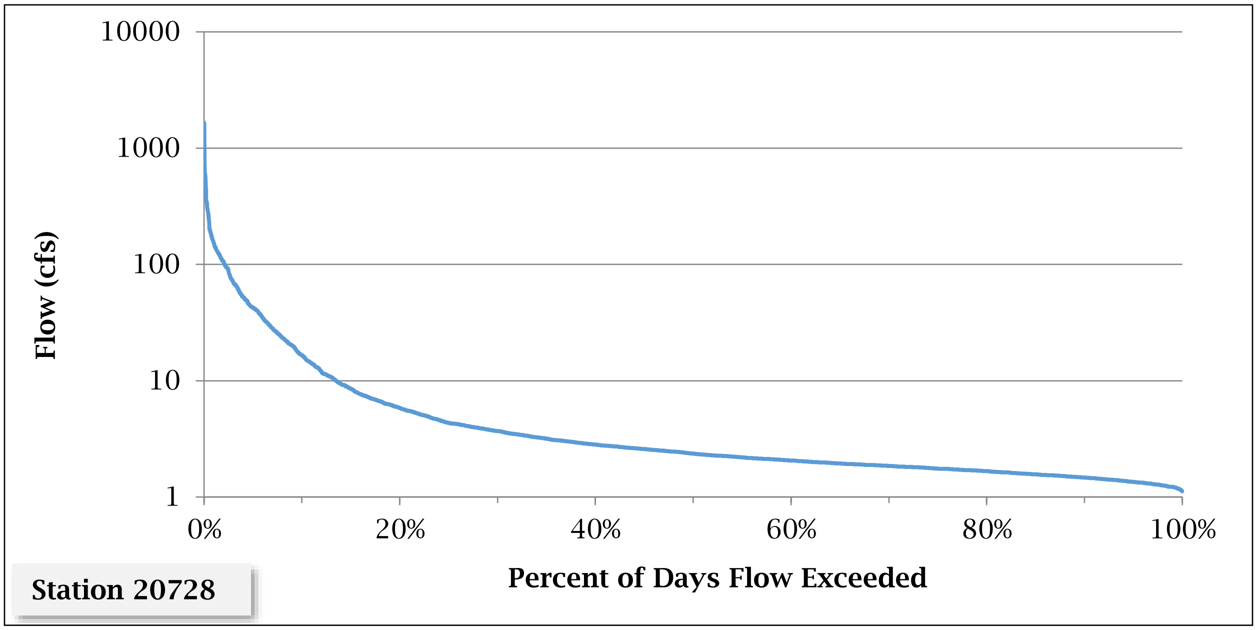

Figure 16. MFDC for Unnamed Tributary of Gum Bayou at SWQM Station 20728

The shape of each MLDC is identical to that of the FDC for the same station because the data in the FDCs have all been multiplied by the same conversion factor. The label on the y-axis simply changes from "Flow (cfs)" to "Enterococci (cfu/ day)", and the label on the x-axis changes from "% Days Flow Exceeded" to "% Days Load Exceeded."

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 stations within the TMDL watersheds, streamflow distribution was divided into three flow regimes: Highest Flow, Mid-range Flow, and Lowest Flow, which maintains consistency with the previously completed TMDLs (Table 10) (TCEQ, 2012 and 2016). 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 MLDCs with these three flow regimes for SWQM stations 20477 and 20728 are provided in Figures 17 and 18 and were constructed for developing the load allocations for the TMDL watersheds. Geometric-mean loadings for the data points within each flow regime have also been distinguished on the figure to aid interpretation. The MLDCs for the SWQM stations provide a means of identifying the streamflow conditions under which Enterococci concentrations exceeded the geometric mean criterion. The MLDCs depict the allowable loading at each SWQM station under the geometric mean criterion (35 cfu/100 mL) and shows that existing loadings often exceed the criterion. In addition, the MLDCs present the allowable loading at stations under the single sample criterion (130 cfu/100 mL).

On the graphs, 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 both SWQM stations 20477 and 20728. 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 20477 (Unnamed Tributary of Dickinson Bayou Tidal AU 1103F_01) in Figure 17 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 20728 indicated exceedances of the geometric mean criterion have commonly occurred in all flow regimes (Figure 18). Results from wet-weather events indicate a frequent exceedance of both sample criterion at SWQM Station 20728.

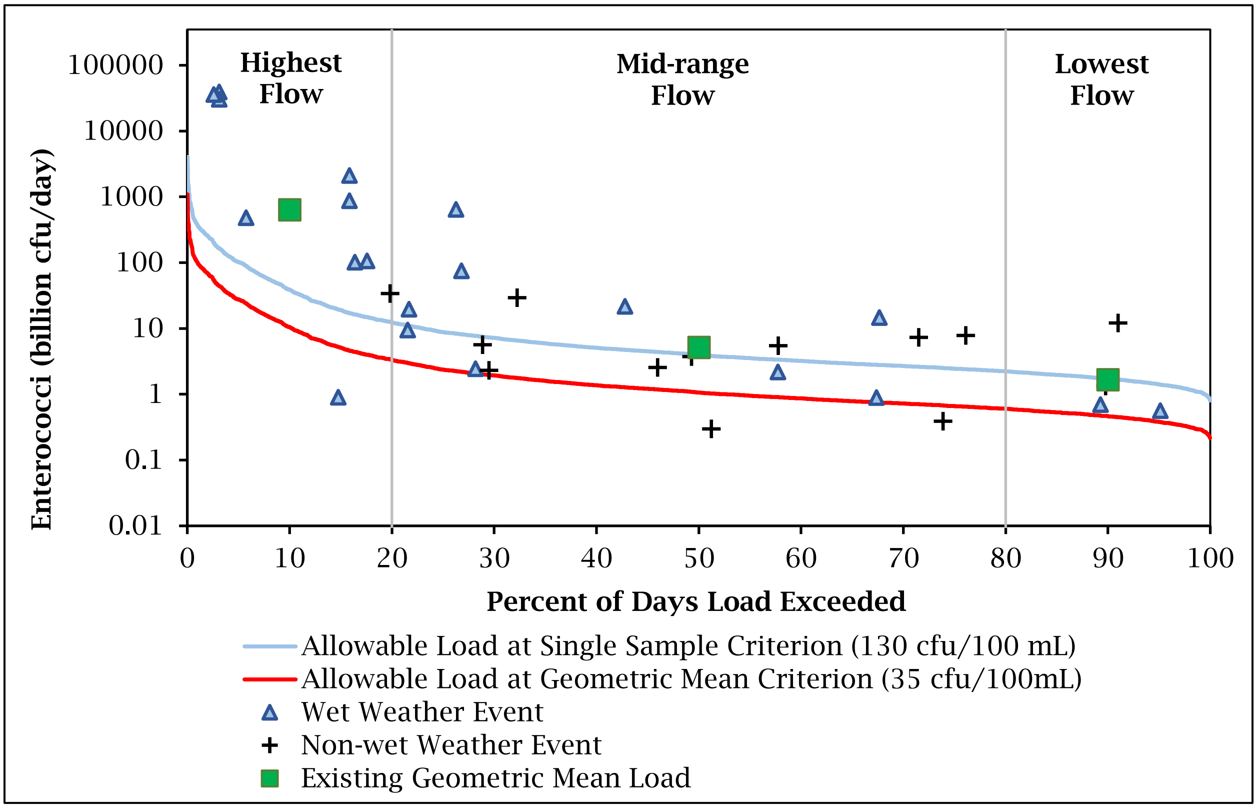

Figure 17. **MLDC for Unnamed Tributary of Dickinson Bayou Tidal AU 1103F_01 at SWQM Station 20477**

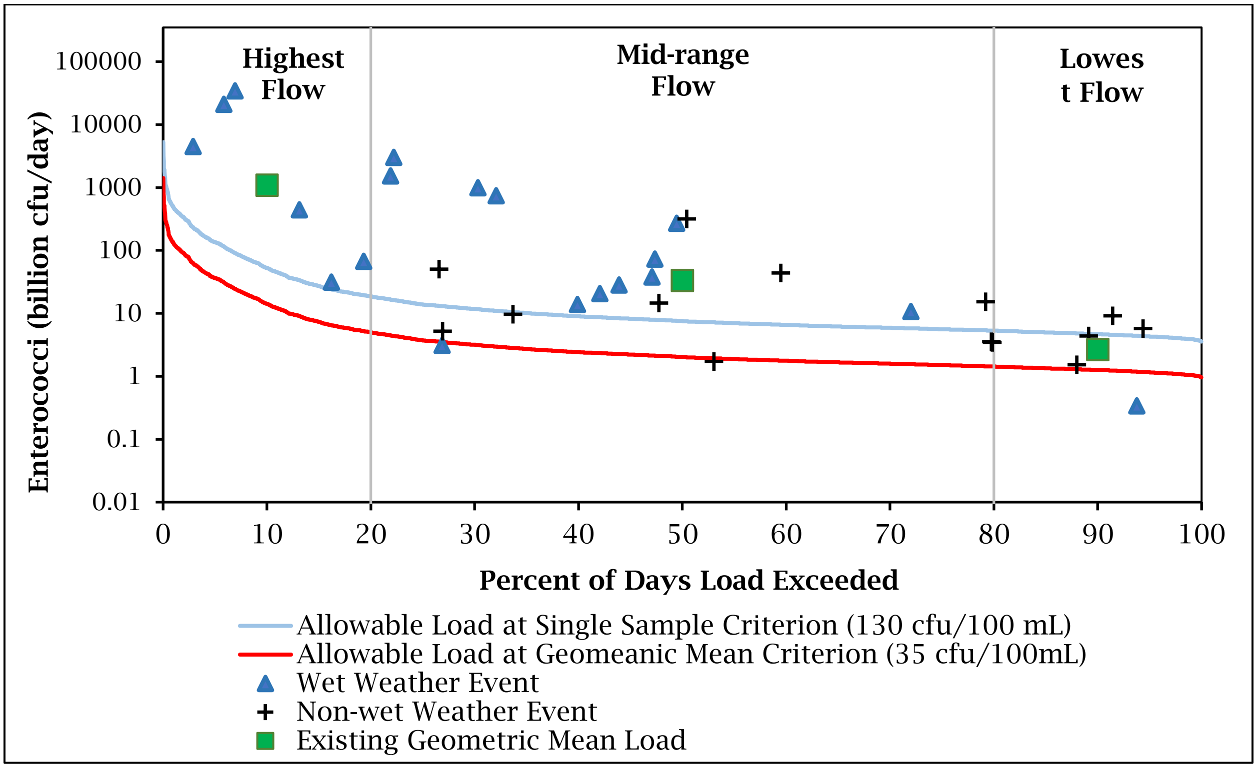

Figure 18. MLDC for Unnamed Tributary of Gum Bayou AU 1103G_01 at SWQM Station 20728

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 to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for this 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) of 40 CFR 130.7(c)(1))].

Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing Enterococci concentrations obtained from 13 years (2008–2020) of routine monitoring. Differences in Enterococci concentrations were evaluated by performing a Wilcoxon Rank Sum test. Enterococci concentrations during warmer months (May-September) were compared against those during the cooler (November-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 significant difference ($\alpha=0.05$) in indicator bacteria between cool and warm weather seasons for the Unnamed Tributary of Dickinson Bayou Tidal AU 1103F_01 ($p=0.0026$) with higher Enterococci concentrations during the cool season. For the Unnamed Tributary of Gum Bayou AU 1103G_01 ($p=0.0716$), there was no indication of significant difference of indicator bacteria between cool and warm weather seasons. Seasonal variation is addressed in these TMDLs by incorporating many years of flow and bacteria data spanning all seasons for development of the LDCs.

4.3. Linkage Analysis

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

Generally, if high bacteria concentrations are measured in a water body at low to median flow 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 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 bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of higher concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

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

4.4. Load Duration Curve Analysis

An MLDC method was 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. 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 *E. coli* 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 hydrologic 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 MLDCs used in the pollutant load allocation process with historical Enterococci data added to the graphs (Figures 17 and 18) and Section 2.7 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. For the TMDL watersheds, 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 both TMDL watersheds. On Figures 17 and 18, 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 load allocations this report incorporate an explicit MOS of 5%.

4.6. Load Reduction Analysis

While the TMDLs for the impaired AU watersheds were developed using LDCs 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 stations within the impaired water bodies.

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
1103F_01	Highest Flow	2,136	98.4%
	Mid-range Flow	170	79.4%
	Lowest Flow	126	72.2%
1103G_01	Highest Flow	2,694	98.7%
	Mid-range Flow	577	93.9%
	Lowest Flow	74	52.7%

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:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{FG} + \text{MOS} \qquad \text{(Equation 5)}$$

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

TMDL (cfu/day) = Criterion * Flow (cfs) * Conversion Factor (Equation 6)

Where:

Criterion = 35 cfu/100 mL (Enterococci)
Conversion Factor (to billion cfu/day) = 28,316.846 mL/cubic foot * 86,400 seconds/day ÷ 1,000,000,000

The allowable loading of Enterococci that the impaired water bodies can receive daily was determined using Equation 6 based on the median value within the Highest-Flow regime of the FDC (or 10% flow exceedance value) for the SWQM stations (Table 12).

Table 12. Summary of allowable loading calculation

Water Body	AU	10% Exceedance Flow (cfs)	10% Exceedance Load (Billion cfu/day)	TMDL (Billion cfu/day)
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	12.170	10.421	10.421
Unnamed Tributary of Gum Bayou	1103G_01	16.555	14.176	14.176

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:

MOS = 0.05 * TMDL (Equation 7)

Using the values of TMDL for each AU provided in Table 12, the MOS may be readily computed by proper substitution into Equation 7 (Table 13).

Table 13. MOS calculations

Load units expressed as billion cfu/day Enterococci

Water Body	AU	TMDL[a]	MOS
Unnamed Tributary Dickinson Bayou Tidal	1103F_01	10.421	0.521
Unnamed Tributary Gum Bayou	1103G_01	14.176	0.709

[a] TMDL from Table 12.

4.7.3. Waste Load Allocations

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

$WLA = WLA_{WWTF} + WLA_{SW}$ (Equation 8)

4.7.3.1. Wastewater

TPDES-permitted WWTFs are allocated a daily wasteload calculated as their full permitted discharge flow rate multiplied by one-half the instream geometric criterion. One-half of the water quality criterion (17.5 cfu/100mL) is used as the WWTF target to provide instream and downstream load capacity, and to be consistent with previously developed TMDLs. Thus, WLA_{WWTF} is expressed in the following equation:

$$WLA_{WWTF} = Target * Flow * Conversion\ Factor \qquad \text{(Equation 9)}$$

Where:

Target= 17.5 cfu/100 mL
Flow = full permitted flow million gallons per day (MGD)
Conversion Factor (to billion cfu/day) = 3,785,411,800 mL/million gallons ÷ 1,000,000,000

Since there are no WWTFs in the TMDL watersheds, the WLA_{WWTF} component 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 permitted 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 included in the TMDL watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

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

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \qquad \text{(Equation 10)}$$

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 in order 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 TMDL watersheds are covered at 88.46% (AU 1103F_01) and 84.83% (AU 1103G_01) by MS4 permits. These values were used to compute an area of regulated stormwater contribution (Table 14).

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

Watershed	AU	Total Area (acres)	Area Under MS4 (acres)	FDA_{SWP}
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	2,011	1,779	0.8846
Unnamed Tributary of Gum Bayou	1103G_01	2,788	2,365	0.8483

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 10), the FG term must be known. The calculation for that term is presented in the next section, but the results will be included here for continuity. Table 15 provides the information needed to compute WLA_{SW}.

Table 15. Regulated stormwater calculations for TMDL water bodies

Load units expressed as billion cfu/day Enterococci

Water Body	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[C]	FG[d]	FDA_{SWP}[e]	WLA_{SW}[f]
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	10.421	0.521	0	0.100	0.8846	8.669
Unnamed Tributary of Gum Bayou	1103G_01	14.176	0.709	0	0.470	0.8483	11.025

[a] TMDL from Table 12

[b] MOS from Table 13

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

[d] FG from Table 16

[e] FDA_{SWP} from Table 14

[f] $WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$ (Equation 10)

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's antidegradation policy.

For these two TMDLs, 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) according to Rule 217.32 of the Texas Administration Code. 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 2010 and 2045 within the Unnamed Tributary of Dickinson Bayou watershed and the Unnamed Tributary of Gum Bayou is 1,512 and 7,100, respectively. Multiplying the projected population growth of both water bodies by the higher daily wastewater flow capacity, yields a value of 0.151 MGD for the Unnamed Tributary of Dickinson Bayou and 0.710 MGD for the Unnamed Tributary of Gum Bayou. This value would be considered the full permitted discharge of a potential future WWTF.

Thus, the FG is calculated as follows:

$$FG = WWTF_{FP} * \text{Conversion factor} * \text{Target} \qquad \text{(Equation 11)}$$

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 = 17.5 cfu/100 mL

The calculation results for the impaired TMDL watersheds are shown in Table 16.

Table 16. FG calculations

Water Body	AU	Estimated Additional Service Population	Daily Wastewater (gpcd)	FG (MGD)	FG (Enterococci Billion cfu/day)[a]
Unnamed Tributary Dickinson Bayou Tidal	1103F_01	1,512	100	0.151	0.100
Unnamed Tributary Gum Bayou	1103G_01	7,100	100	0.710	0.470

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

4.7.5. Load Allocations

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

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \qquad \text{(Equation 12)}$$

Where:

TMDL = total maximum daily load
WLA_{WWTF} = sum of all WWTF loads
WLA_{SW} = sum of all regulated stormwater loads
FG = sum of future growth loads from potential regulated facilities
MOS = margin of safety load

The calculation results are shown in Table 17.

Table 17. LA calculation for the TMDL water bodies

Load units expressed as billion cfu/day Enterococci

Water Body	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	FG[e]	LA[f]
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	10.421	0.521	0	8.669	0.100	1.131
Unnamed Tributary of Gum Bayou	1103G_01	14.176	0.709	0	11.025	0.470	1.972

[a] TMDL from Table 12

[b] MOS from Table 13

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

[d] WLA_{SW} from Table 15

[e] FG from Table 16

[f] $LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS$ (Equation 12)

4.8. Summary of TMDL Calculations

Table 18 summarizes the TMDL calculation for the TMDL watersheds. 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 MLDCs developed for SWQM stations 20477 (AU 1103F_01) and 20728 (AU 1103G_01). Allocations are based on the geometric mean criterion for Enterococci of 35 cfu/100 mL for each component of the TMDL.

Table 18. TMDL allocation summary

Load units expressed as billion cfu/day Enterococci

Water Body	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	10.421	0.521	0	8.669	1.131	0.100
Unnamed Tributary of Gum Bayou	1103G_01	14.176	0.709	0	11.025	1.972	0.470

[a] TMDL = from Table 12

[b] MOS = from Table 13

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

[d] WLA_{SW} = from Table 15

[e] LA = from Table 17

[f] FG = from Table 16

The final TMDL allocations (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 allocations

Load units expressed as billion cfu/day Enterococci

Water Body	AU	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
Unnamed Tributary of Dickinson Bayou Tidal	1103F_01	10.421	0.521	0.100	8.669	1.131
Unnamed Tributary of Gum Bayou	1103G_01	14.176	0.709	0.470	11.025	1.972

[a] WLA_{WWTF} includes the FG component

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Appendix A. Method Used to Determine Population Projections

The following steps detail the method used to estimate the 2010 and projected 2045 populations in the Unnamed Tributary of Dickinson Bayou Tidal AU 1103F_01 watershed and Unnamed Tributary of Gum Bayou AU 1103G_01 watershed.

1. Obtained 2010 USCB data at the block level.
2. Developed 2010 watershed populations using the block level data for the portion of the census blocks located within the watershed.
3. For the census blocks that were partially located in the watershed, estimated population by multiplying the block population to the proportion of its area in the watershed.
4. Obtained the 2018 H-GAC regional growth forecast data and associated TAZs to be used for population projections (H-GAC, 2017).
5. Joined population data for each TAZ with the TAZ polygons in a geographic information system and located the TAZs within the TMDL watersheds.
6. For the TAZs that were partially located in the watersheds, estimated population projections by multiplying the TAZ population to the proportion of its area in the watershed.
7. Subtracted the 2010 watershed populations from the 2045 population projections to determine the projected population increases. Subsequently, divided the projected population increases by the 2010 watershed populations to determine the percent population increases for the TMDL watersheds.