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

Assessment Unit: 1003A_01

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Abbreviations

AU	assessment unit
BMP	best management practice
CGP	construction general permit
cfs	cubic feet per second
cfu	colony forming units
CFR	Code of Federal Regulations
DAR	drainage-area ratio
DMU	Deer Management Unit
DSLP	days since last precipitation
E. coli	*Escherichia coli*
EPA	(United States) Environmental Protection Agency
FDA_{SWP}	fractional drainage area stormwater permit
FDC	flow duration curve
FG	future growth
I&I	inflow and infiltration
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
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
SSO	sanitary sewer overflow
SWMP	stormwater management program

SWQM	surface water quality monitoring
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
U.S.	United States
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
WUG	Water User Group
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 assessment unit (AU) 1003A_01 of Winters Bayou (1003A) in the U.S. Environmental Protection Agency (EPA)-approved *2022 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d) List* (Texas Integrated Report; TCEQ, 2022a).

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

- Winters Bayou AU 1003A_01

In this report, the impaired water body will be referred to as Winters Bayou AU 1003A_01 or AU 1003A_01.

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 freshwater in Texas is *Escherichia coli* (*E. coli*), a species of fecal coliform bacteria.

On Sept. 27, 2022, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2022b) and on April 26, 2023, 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 *E. coli* of 126 colony forming units (cfu) per 100 milliliters (mL) and an additional single sample criterion of 399 cfu per 100 mL.

- **Primary contact recreation 2** – Water recreation activities, such as wading by children, swimming, water skiing, diving, tubing, surfing, handfishing, and whitewater kayaking, canoeing, and rafting that involve a significant risk of ingestion of water but that occur less frequently than for primary contact recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean criterion for *E. coli* is 206 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 or 2 but more than secondary contact recreation 2. The geometric mean criterion for *E. coli* is 630 cfu per 100 mL.

- **Secondary contact recreation 2** – Activities with limited body contact incidental to shoreline activity (e.g., fishing, canoeing, kayaking, rafting, and motor boating) that are presumed to pose a less significant risk of water ingestion than secondary contact recreation 1. These activities occur less frequently than secondary contact recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean criterion for *E. coli* is 1,030 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 *E. coli* is 2,060 cfu per 100 mL.

Winters Bayou AU 1003A_01 is a freshwater stream and has a primary contact recreation 1 use. The associated criterion for *E. coli* is a geometric mean criterion of 126 cfu per 100 mL.

1.3. Report Purpose and Organization

The Winters Bayou AU 1003A_01 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 watershed; and 3) assist TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired AU. This report contains:

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

Whenever it was feasible, the data development and computations for developing the LDC and pollutant load allocation were performed in a manner to remain consistent with the previously completed *Addendum One: One Total Maximum Daily Load for Indicator Bacteria in Mound Creek* (TCEQ, 2018b), *Addendum Two: One Total Maximum Daily Load for Indicator Bacteria in White Oak Creek* (TCEQ, 2023c), and the original TMDL *Seven Total Maximum Daily Loads for Indicator Bacteria in Lake Houston, East Fork San Jacinto River, West Fork San Jacinto River, and Crystal Creek Watersheds* (TCEQ, 2016).

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

The Winters Bayou AU 1003A_01 watershed drains 170.7 square miles (109,265 acres) and is located within Walker and San Jacinto Counties (Figure 1). Winters Bayou is an unclassified, perennial freshwater stream that is a tributary of the East Fork San Jacinto River (Segment 1003) that eventually flows into Lake Houston.

The Winters Bayou watershed includes the contributing subwatersheds of Nebletts Creek (AU 1003B_01) and Boswell Creek (AU 1003C_01), along with that of AU 1003A_01, and is located within the greater Lake Houston watershed in the San Jacinto River Basin (Figure 2).

The 2022 Texas Integrated Report (TCEQ, 2022a) provides the following water body and AU description for Winters Bayou:

- Winters Bayou (Segment 1003A) – From the confluence with East Fork San Jacinto River to 0.17 miles upstream of Dorrell Road at the confluence of Phelps Creek.
    - AU 1003A_01 – Perennial stream from the confluence with East Fork San Jacinto River to 0.17 miles upstream of Dorrell Road at the confluence of Phelps creek

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

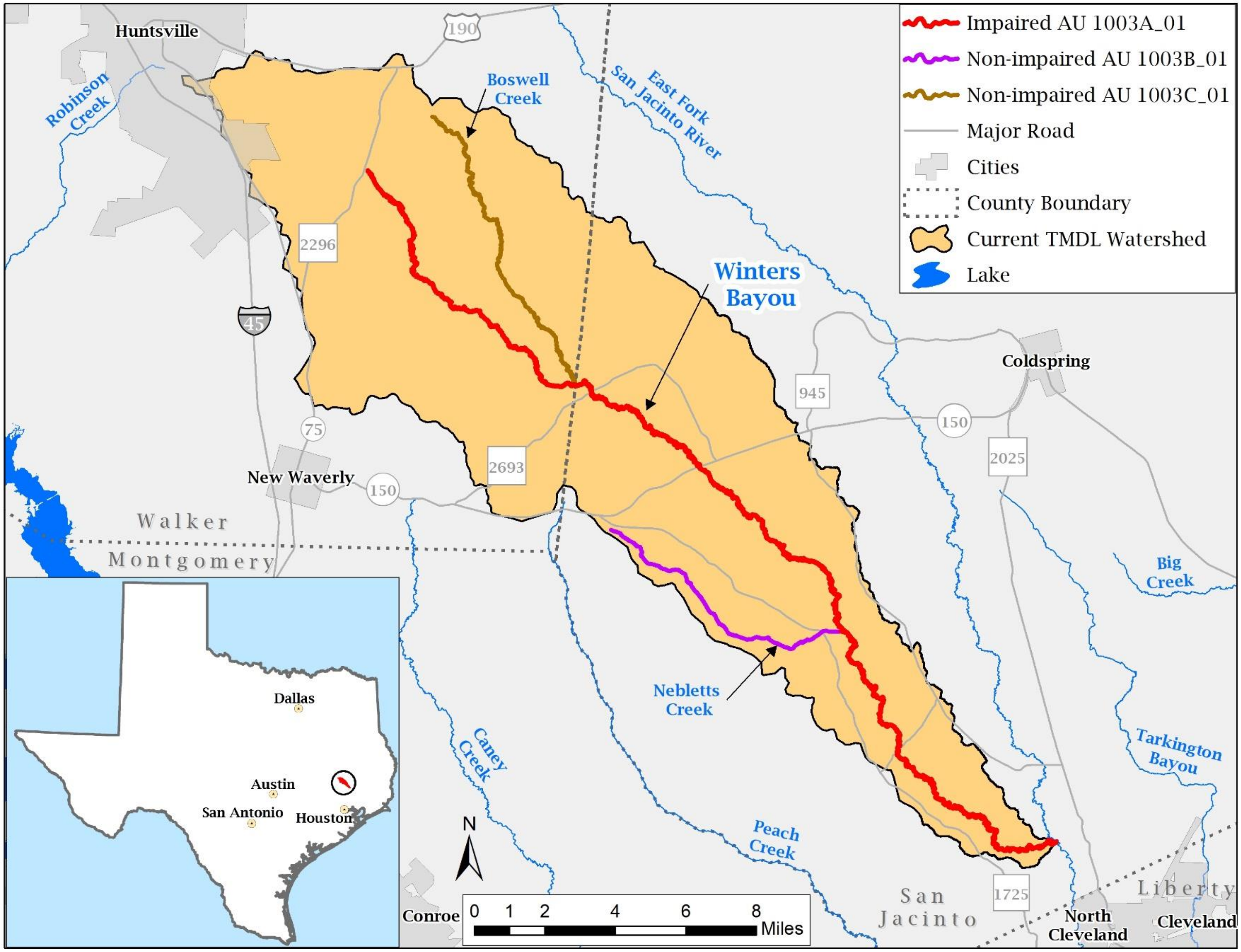

Figure 1. Map of the project watershed

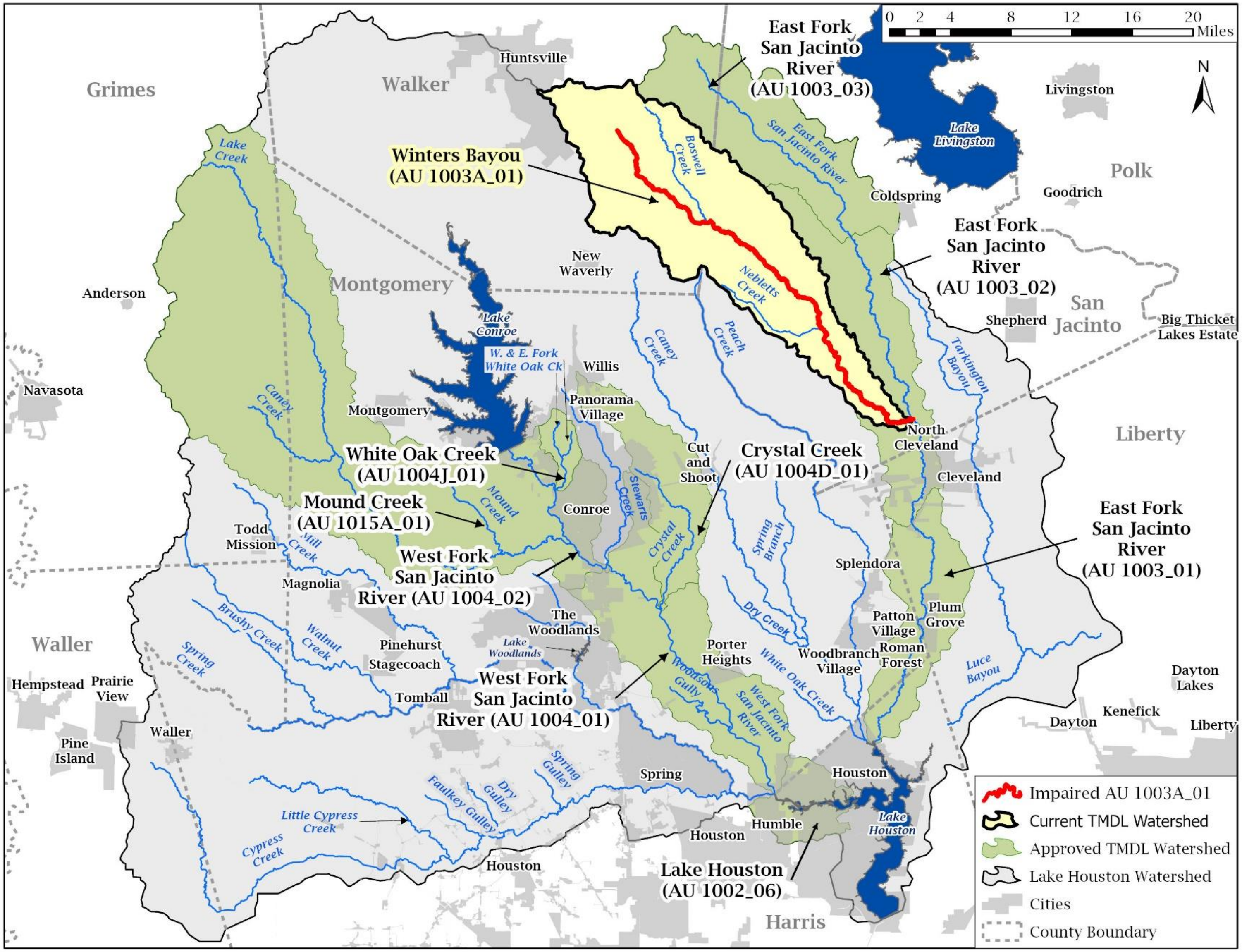

Figure 2. Map showing the previous TMDL watersheds and the AU 1003A_01 watershed considered in this addendum

2.2. Review of Routine Monitoring Data

2.2.1. Analysis of Bacteria Data

Water quality has been monitored within the Winters Bayou AU 1003A_01 watershed at five TCEQ surface water quality monitoring (SWQM) stations (Figure 3). *E. coli* data collected at the five SWQM stations on Winters Bayou 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). These data are summarized in Table 1. The 2022 assessment data for Winters Bayou indicates non-support of the primary contact recreation 1 use because *E. coli* geometric mean concentrations exceed the criterion of 126 cfu/100 mL.

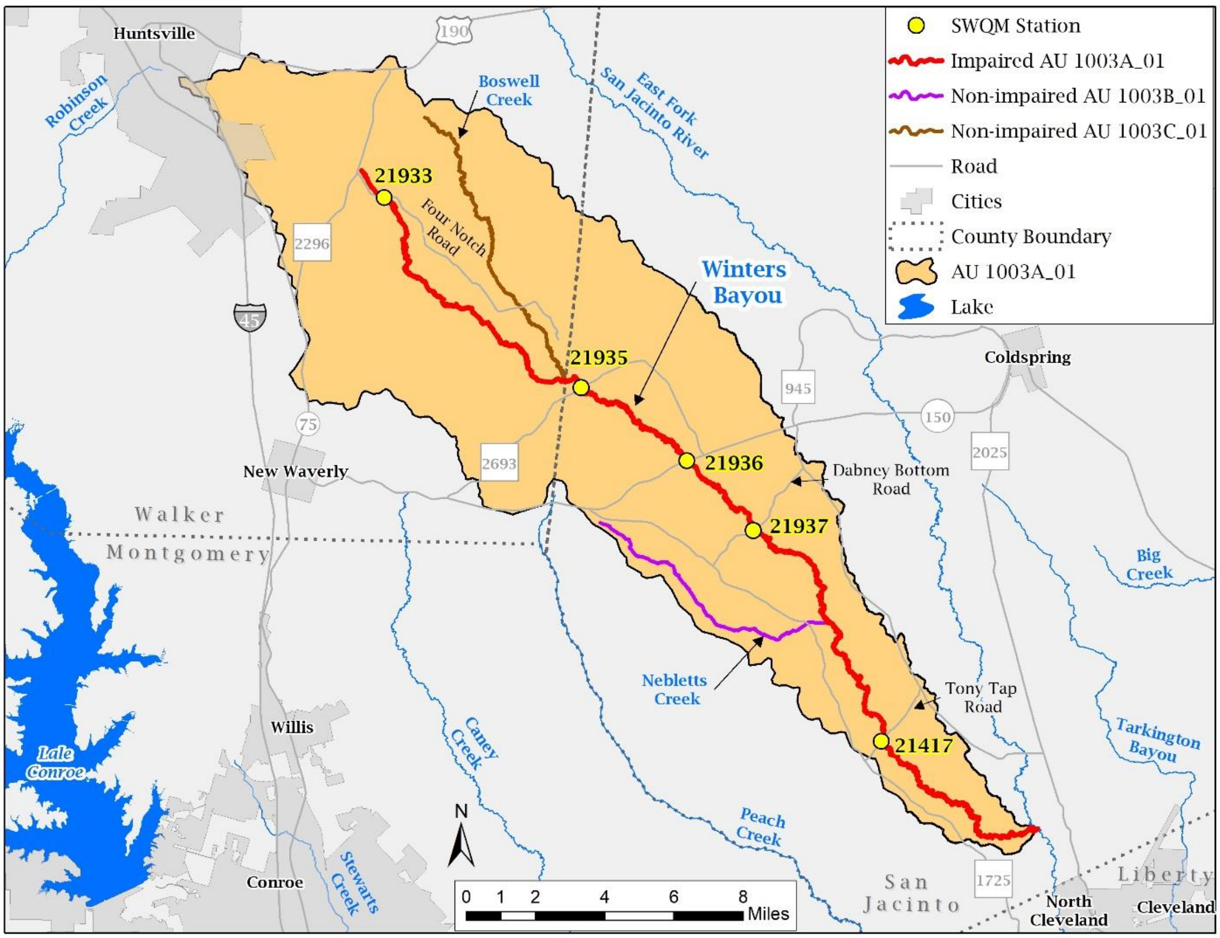

Figure 3. SWQM stations within the AU 1003A_01 watershed

Table 1. 2022 Texas Integrated Report summary for Winters Bayou AU 1003A_01

Integrated Report Year	Watershed	AU	Parameter	SWQM Stations	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
2022	Winters Bayou	1003A_01	*E. coli*	21417; 21933; 21935; 21936; 21937	63	Dec 1. 2013–Nov. 30, 2020	164.06

2.3. Climate and Hydrology

The Winters Bayou AU 1003A_01 watershed is within the Upper Coast and East Texas climatic divisions, which are categorized as subtropical humid (Larkin & Bomar, 1983). The Gulf of Mexico is the principal source of moisture that drives precipitation in the region. For the 10-year period from 2012–2022, weather data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information for the Conroe North Houston Regional Airport (NOAA, 2022). Data from this 10-year period indicate that the average high temperatures typically peak in August (94.6 ˚F). During winter, the average low temperature generally reaches a minimum of 38.2 ˚F in January (Figure 4). Annual rainfall averages 49.3 inches. The wettest month was May (7.4 inches), while February (2.5 inches) was the driest month, with rainfall occurring throughout the year.

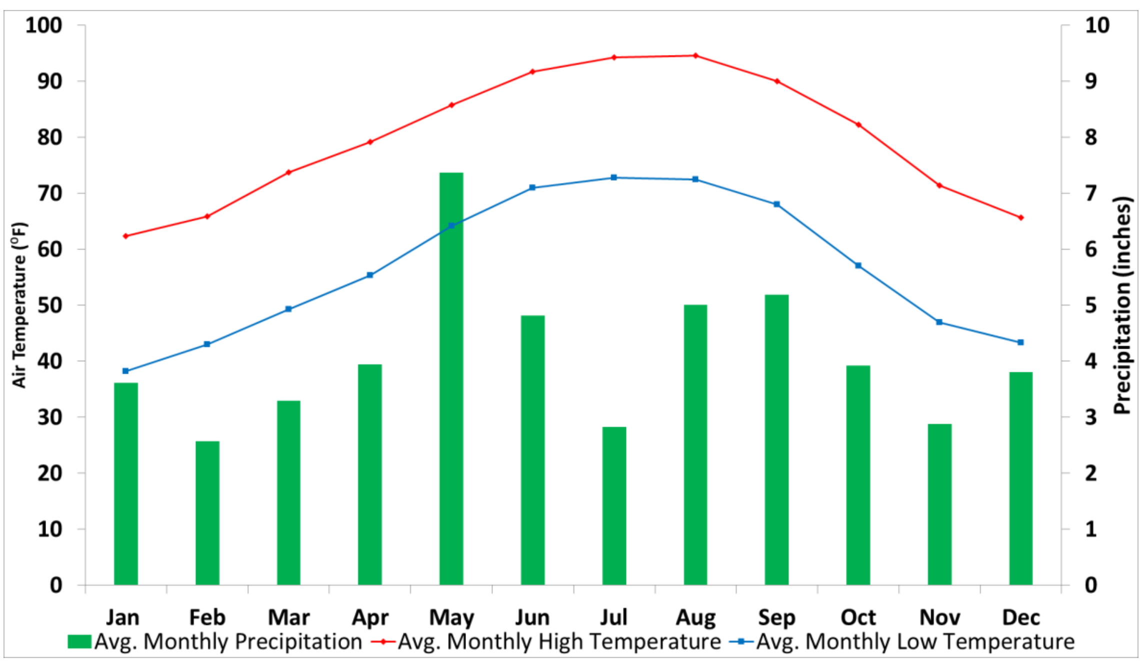

Figure 4. Average monthly temperature and precipitation (2012-2022) at Conroe North Houston Regional Airport weather station

2.4. Population and Population Projections

As depicted in Figure 1, the Winters Bayou AU 1003A_01 watershed is located within Walker and San Jacinto Counties and includes a portion of the City of Huntsville's municipal boundary.

The rural nature of the watershed is evident given that the predominant population densities throughout the watershed are less than one person per acre (Figure 5). According to the 2020 U.S. Census Bureau (USCB) data (USCB, 2021), the Winters Bayou watershed has an estimated population of 7,494.

Population projections in Table 2 were developed by utilizing Water User Group (WUG) data from the 2021 Texas Water Development Board (TWDB) Regional Water Plan (TWDB, 2021). The 2020 and projected 2070 populations were calculated based on proportion of the WUG area within the TMDL watershed. According to the growth projections, a population increase of 8% is expected for the Winters Bayou watershed by 2070. Additional information on this process can be found in the Appendix.

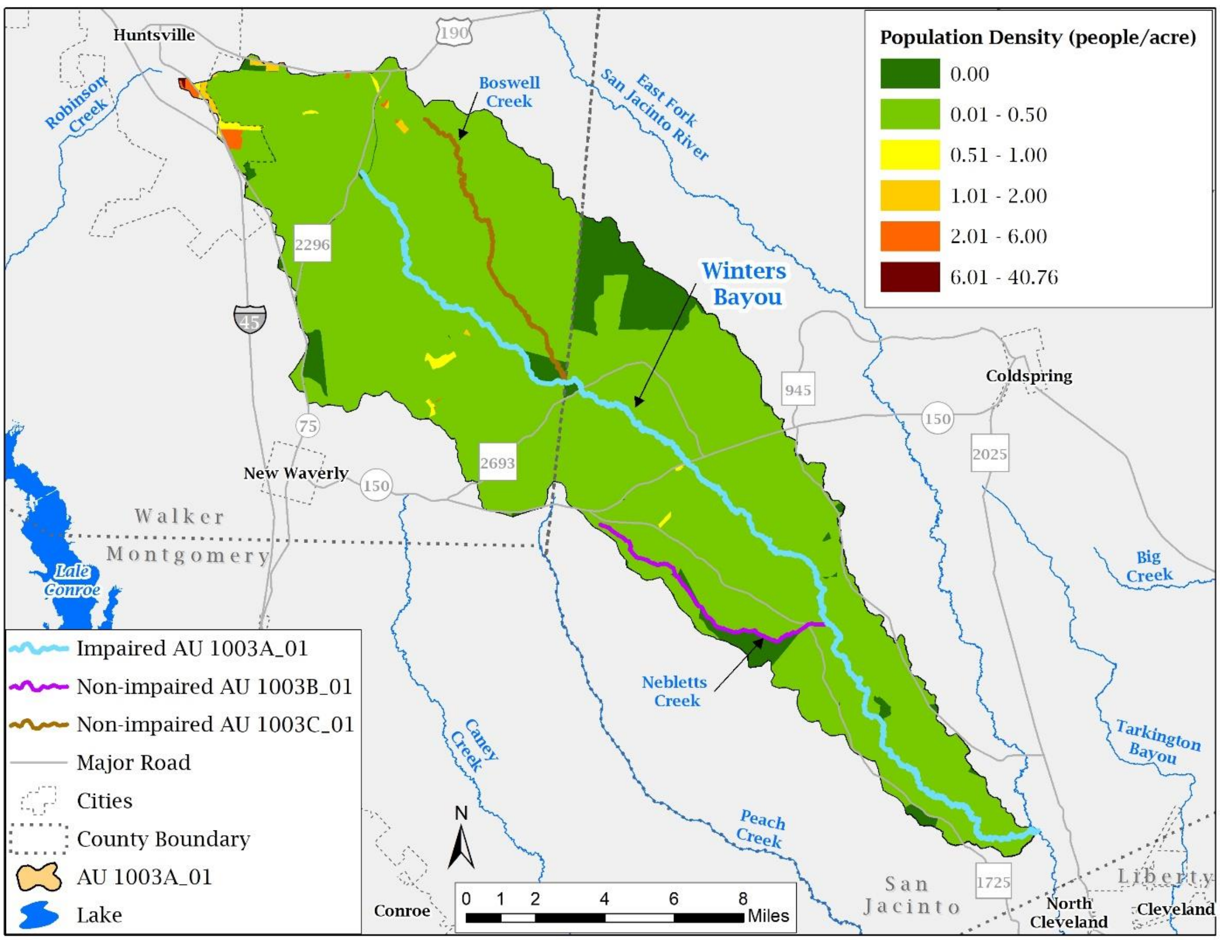

Figure 5. Population density estimate based on 2020 U.S. Census block data in the AU 1003A_01 watershed

Table 2. 2020 population and population projections for the Winters Bayou AU 1003A_01 watershed

Watershed	2020 U. S. Census	2070 Population Projection	Projected Population Increase (2020–2070)	Percent Change (%)
Winters Bayou	7,494	8,127	633	8%

2.5. Land Cover

The land cover data presented in this report were obtained from the U.S. Geological Survey (USGS) 2019 National Land Cover Database (NLCD) (USGS, 2021). 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 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.
- **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.
- **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 are provided for the Winters Bayou AU 1003A_01 watershed in Figure 6. Evergreen forest (50.43%) and pasture/hay (18.54%) are the dominant land covers within the TMDL watershed. Table 3 summarizes the land cover data for the TMDL watershed.

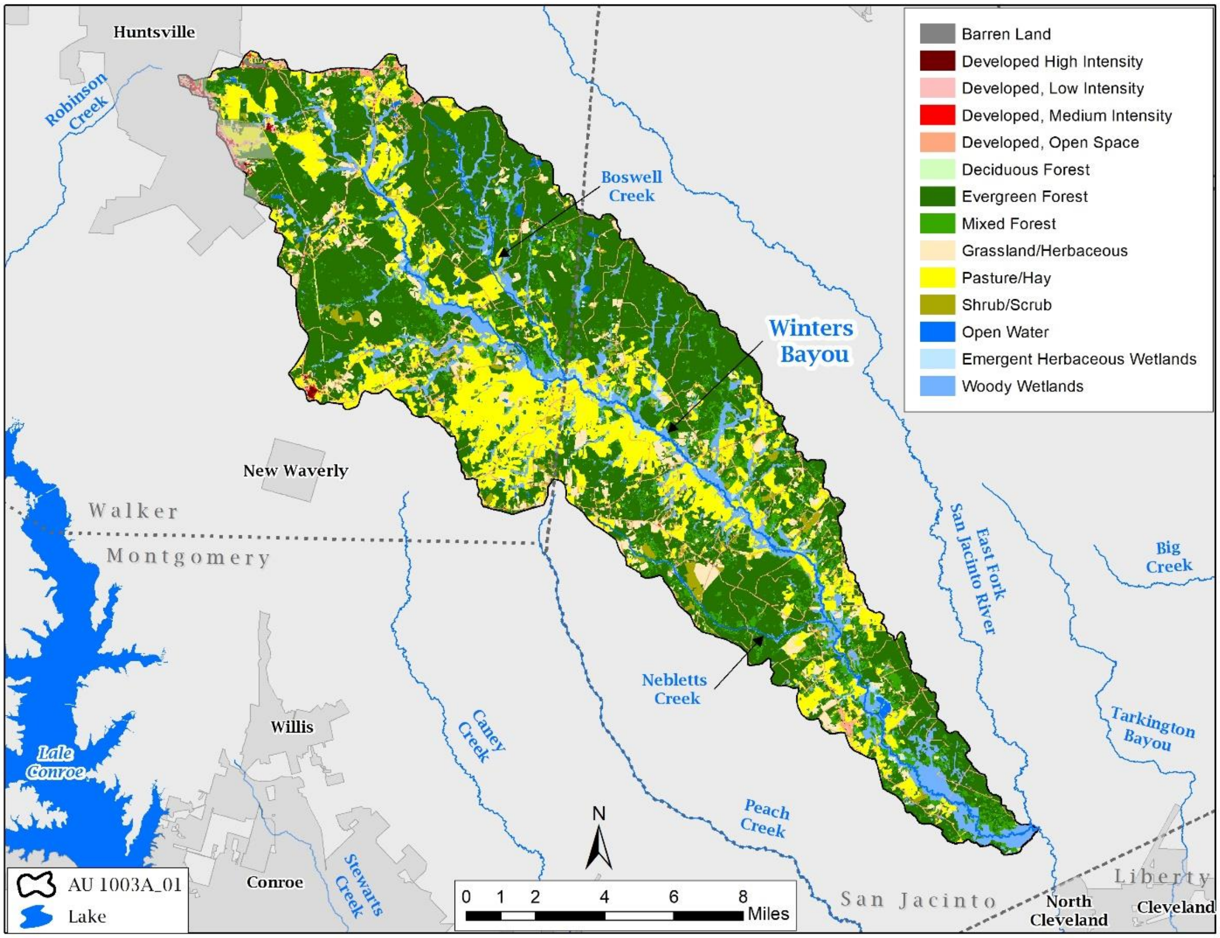

Figure 6. Land cover map of land use classifications

Table 3. Land cover classification percentages

Classification	Area (Acres)	Percentage of Total (%)
Barren Land	101.12	0.09%
Developed, High Intensity	114.74	0.11%
Developed, Low Intensity	1,294.11	1.18%
Developed, Medium Intensity	332.90	0.30%
Developed, Open Space	3,933.44	3.60%
Deciduous Forest	76.23	0.07%
Evergreen Forest	55,102.45	50.43%
Mixed Forest	7,966.98	7.29%
Grassland/Herbaceous	5,134.01	4.70%
Pasture/Hay	20,258.85	18.54%
Shrub/Scrub	2,596.26	2.38%

Classification	Area (Acres)	Percentage of Total (%)
Open Water	765.18	0.70%
Emergent Herbaceous Wetlands	556.51	0.51%
Woody Wetlands	11,032.23	10.10%
Total	**109,265.01**	**100%**

2.6. Soils

Soils within the Winters Bayou AU 1003A_01 watershed, categorized by their septic tank absorption field ratings (the method used in previous addenda in the Lake Houston watershed), are shown in Figure 7. These data were obtained through the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Gridded Soil Survey Geographic database (NRCS, 2022).

Soil properties and features such as saturated hydraulic conductivity, flooding, depth to bedrock, depth to cemented pan, ponding, rocks, fractured bedrock, subsidence, and excessive slope can affect septic tank effluent absorption, construction, maintenance, and public health (NRCS, 2022). The dominant soil condition within a septic drainage field can be used to identify soils that may prove problematic regarding septic system installation/performance and potentially lead to system failures such as effluent surfacing or downslope seepage.

Soils are rated based on the limiting factors (or conditions) affecting proper effluent drainage and filtering capacity. Soil conditions for septic tank drainage fields are expressed by the following rating terms and definitions (NRCS, 2022):

- Not Limited – Indicates that the soil has features that are very favorable for the specific use. Good performance and very low maintenance can be expected.
- Somewhat Limited – Indicates that the soil has one or more features that are moderately favorable for the specified use. The limitations can be overcome or minimized with special planning, design, and installation procedures. Fair performance and moderate maintenance can be expected.
- Very Limited – Indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.
- Not Rated – Indicates insufficient data exists for soil limitation interpretation.

Most of the soils within the Winters Bayou AU 1003A_01 watershed are categorized as “Very Limited” based on the dominant soil condition for septic drainage field installation and operation.

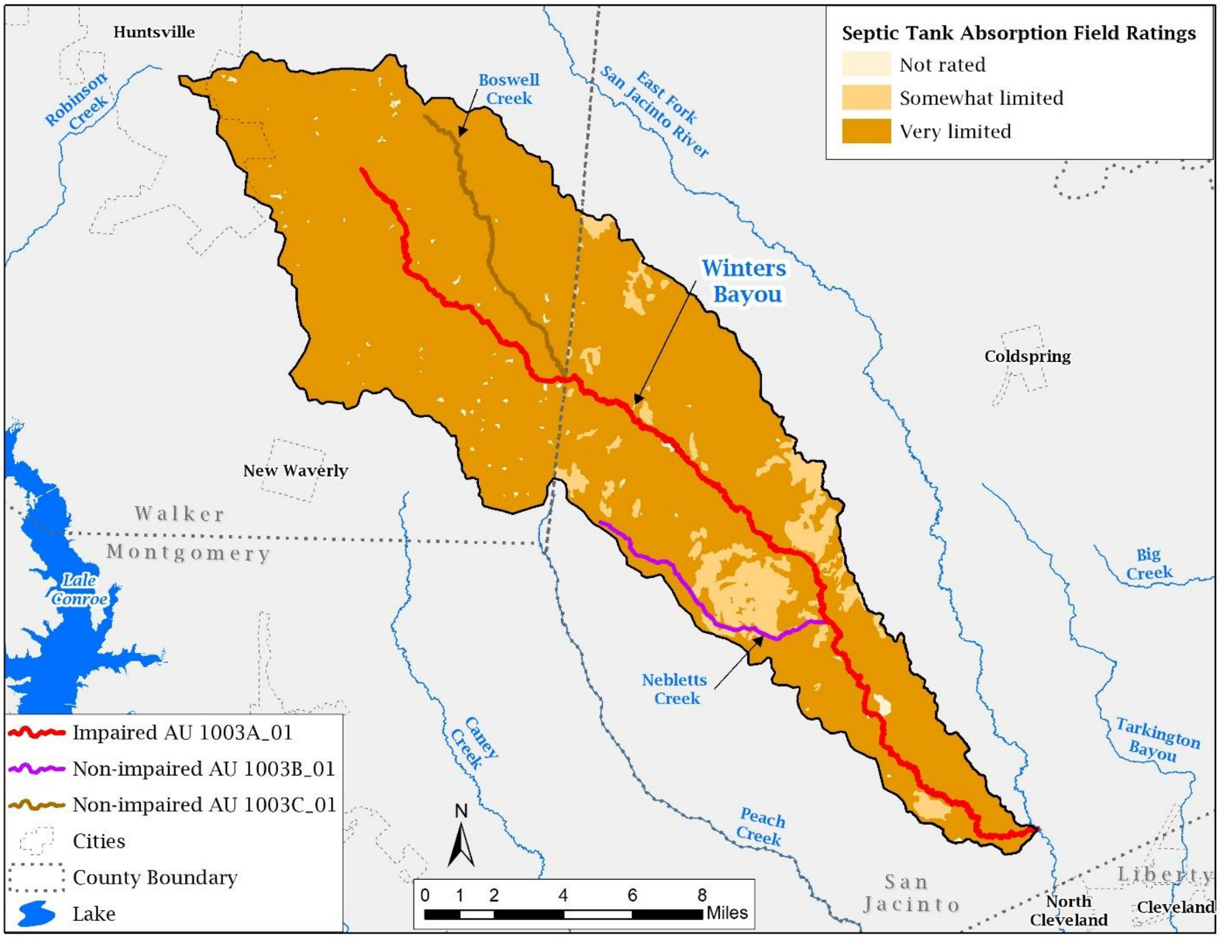

Figure 7. Septic tank absorption field limitation ratings

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 permit.

Except for WWTFs, which receive individual wasteload allocations (WLAs—see report Section 4.7.3., Wasteload Allocations), 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 Winters Bayou watershed include one WWTF outfall and stormwater discharges from regulated industrial activities.

2.7.1.1. Domestic and Industrial Wastewater Treatment Facilities

As of Mar. 25, 2022, there was one domestic WWTF and one industrial WWTF with TPDES permits within the Winters Bayou AU 1003A_01 watershed (Table 4 and Figure 8). Recent discharge data are presented in Table 4 from discharge monitoring report data (EPA, 2023).

Table 4. Permitted domestic and industrial WWTFs

AU	TPDES/NPDES[a] Number	Facility Name	Permittee	Outfall Number	Bacteria Limits (cfu/100 mL)	Primary Discharge Type	Daily Average Flow – Permitted Discharge (MGD)[b]	Daily Average Flow – Recent Discharge (MGD)[c]
1003A_01	WQ0014996001/ TX0028169	Universal Forest Products New Waverly WWTF	Universal Forest Products Texas LLC	001	63	Treated domestic wastewater	0.02	0.004
1003A_01	WQ0004249000/ TX0123421	Steely Lumber Plant	Steely Lumber Co., Inc.	001	NA	Wet decking wastewater, utility wastewater, and stormwater	Report	0.043

[a] NPDES = National Pollutant Discharge Elimination System

[b] MGD = million gallons per day

[c] Reflects discharges available from December 2017 – October 2022

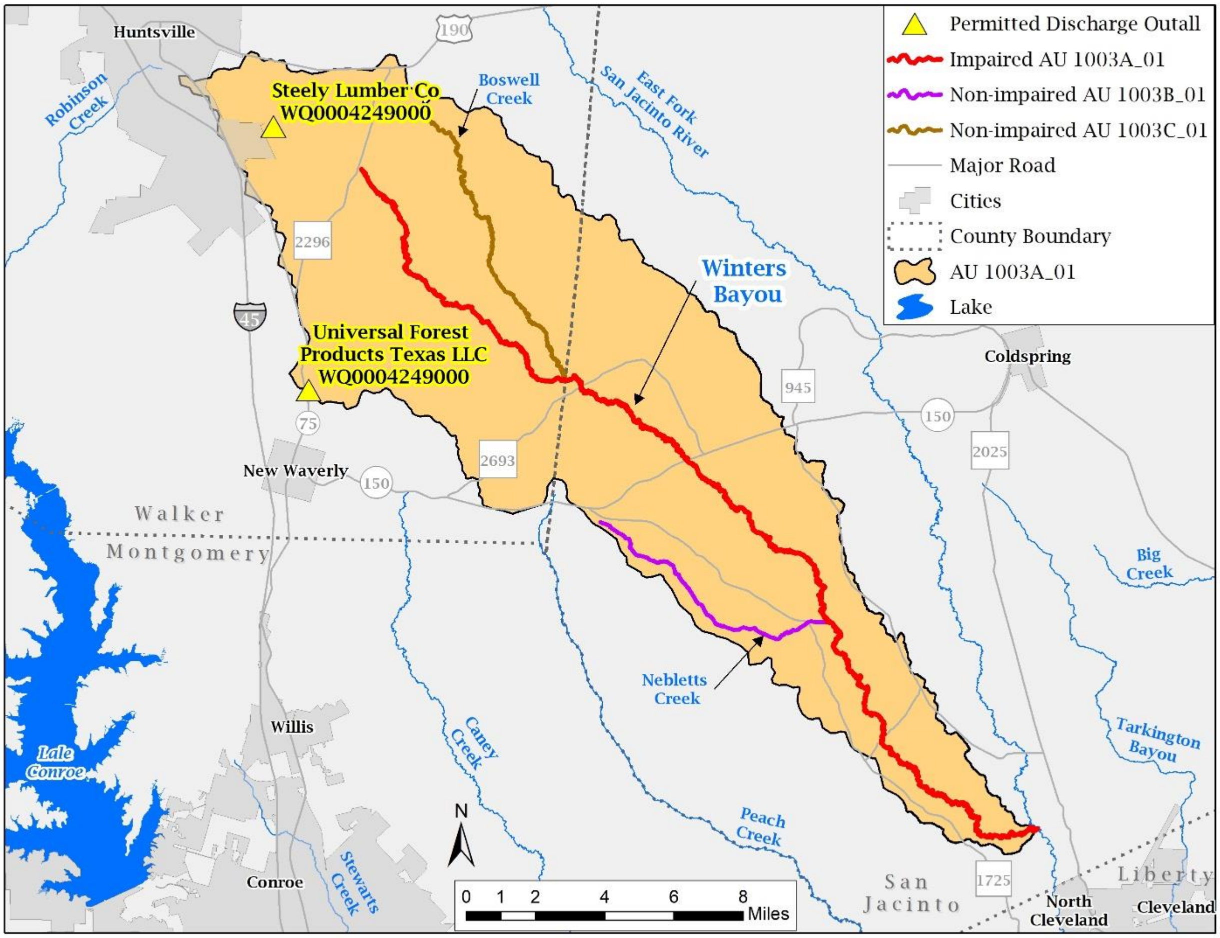

Figure 8. WWTFs in the TMDL watershed

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 facilities
- 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 Winters Bayou AU 1003A_01 watershed as of Jan. 12, 2023, found one active permit for a concrete production facility. No other active general wastewater permit authorizations were found.

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 municipal separate storm sewer system (MS4) entities, stormwater discharges associated with regulated industrial facilities, and construction activities.
2. Stormwater runoff not subject to regulation.

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

The purpose of an MS4 permit is to reduce discharges of pollutants in stormwater to the "maximum extent practicable" by developing and implementing a stormwater management program (SWMP). The SWMP describes the stormwater control practices that the regulated entity will implement, consistent with permit requirements, to minimize the discharge of pollutants. MS4 permits require that SWMPs specify the best management practices (BMPs) to meet several minimum control measures (MCMs) that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving water bodies. Phase II MS4 MCMs must 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 — but only required for MS4s serving a population of 100,000 people or more in the urban area.
- Authorization for construction activities where the small MS4 is the site operator (*optional*).

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

Discharges of stormwater from a Phase II MS4 area, regulated industrial facility, construction area, or other facility involved in certain activities must be authorized under the following 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 are currently no Phase I or Phase II MS4s in the Winters Bayou AU 1003A_01 watershed. A review of other active stormwater general permit coverage (TCEQ, 2023a) in the Winters Bayou watershed as of March 1, 2023, found one active concrete production facility. See for more detailed information.

2.7.1.4. Sanitary Sewer Overflows

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

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

Table 5. Summary of reported SSO events (from 2016 – 2022) in Winters Bayou AU 1003A_01 (in gallons)

AU	Estimated Incidents	Total Volume	Minimum Volume	Maximum Volume
1003A_01	5	2,610	60	2,000

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 No. TXR040000 for Phase II MS4s as "Any discharge to a municipal separate storm sewer system that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities."

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

Direct Illicit Discharges:

- Sanitary wastewater piping that is directly connected from a home to the storm sewer.
- Materials that have been dumped illegally into a storm drain catch basin.
- A shop floor drain that is connected to the storm sewer.
- A cross-connection between the municipal 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 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 streams by rainfall runoff.

For feral hogs, a study by Timmons et al. (2012) estimated a range of feral hog densities within suitable habitat in Texas (8.9 to 16.4 hogs per square mile). The average hog density (12.65 hogs per square mile) was multiplied by the hog-habitat area (159.64 square miles) in the Winters Bayou AU 1003A_01 watershed. Habitat deemed suitable for hogs followed as closely as possible to the land cover selections of the study and include from the 2019 NLCD land cover: Forest, Wetlands, Pasture/Hay, Shrub/Scrub, and Grassland/Herbaceous. Using this methodology, there are an estimated 2,019 feral hogs in the Winters Bayou AU 1003A_01 watershed.

For deer, the Texas Parks and Wildlife Department (TPWD) published data showing deer population-density estimates by Deer Management Unit (DMU) and Ecoregion in the state (TPWD, 2023). The Winters Bayou AU 1003A_01 watershed is located within DMU 14 therefore density data from DMU 14 was used to estimate deer populations for the Winters Bayou watershed. For the 2022 TPWD survey year, the estimated deer population density for DMU 14 was 25.61 deer per 1,000 acres and applies to all habitat types within the DMU area. Applying this value to the project watershed returns an estimated 2,798 deer within the Winters Bayou AU 1003A_01 watershed.

The *E. coli* contribution from feral hogs and wildlife could not be determined based on existing information.

2.7.2.2. Unregulated Agricultural Activities and Domesticated Animals

Several agricultural activities that do not require permits can be potential sources of fecal bacteria loading. The number of livestock within the TMDL watershed was estimated from county-level data obtained from the 2017 Census of Agriculture (USDA NASS, 2019). The county-level data for San Jacinto and Walker counties were refined to better reflect actual numbers within the Winters Bayou AU 1003A_01 watershed. The refinement was performed by dividing the total area of suitable grazing land in the watershed by the total area of suitable grazing land in San Jacinto and Walker counties. This ratio was then applied to the county-level livestock data (Table 6). The livestock numbers in Table 6 are provided to demonstrate that livestock are a potential source of bacteria in the TMDL watershed. These livestock numbers are not used to develop an allocation of allowable bacteria loading to livestock.

Table 6. Estimated livestock populations

Watershed	Cattle and Calves	Hogs and Pigs	Sheep and Lambs	Poultry	Goats	Horses	Mules and Burros
Winters Bayou	5,307	58	149	6,578	252	384	74

Fecal matter from dogs and cats are transported to water bodies by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 7 summarizes the estimated number of dogs and cats within the Winters Bayou AU 1003A_01 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). Due to the absence of the 2020 Census household data, the number of households in the TMDL watershed were estimated using 2010 Census household and population data (USCB, 2010) to obtain the ratio of people to households. This ratio was applied to the 2020 Winters Bayou population data (USCB, 2021) to estimate the number of households in the Winters Bayou AU 1003A_01 watershed. The actual contribution and significance of bacteria loads from pets reaching the water bodies is unknown.

Table 7. Estimated households and pet populations

Watershed	Estimated Households	Estimated Dog Population	Estimated Cat Population
Winters Bayou	2,931	1,800	1,339

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. Winters Bayou is located within east-central Texas Region V, which has a reported failure rate of 19%, providing insight into expected failure rates for the area.

Estimates of the number of OSSFs in the Winters Bayou AU 1003A_01 watershed were determined using data supplied by San Jacinto County 911 Addressing for San Jacinto County and the Houston-Galveston Area Council supplied data for Walker County. Data from these sources indicate that there are approximately 2,633 OSSFs located within the Winters Bayou AU 1003A_01 watershed (Figure 9).

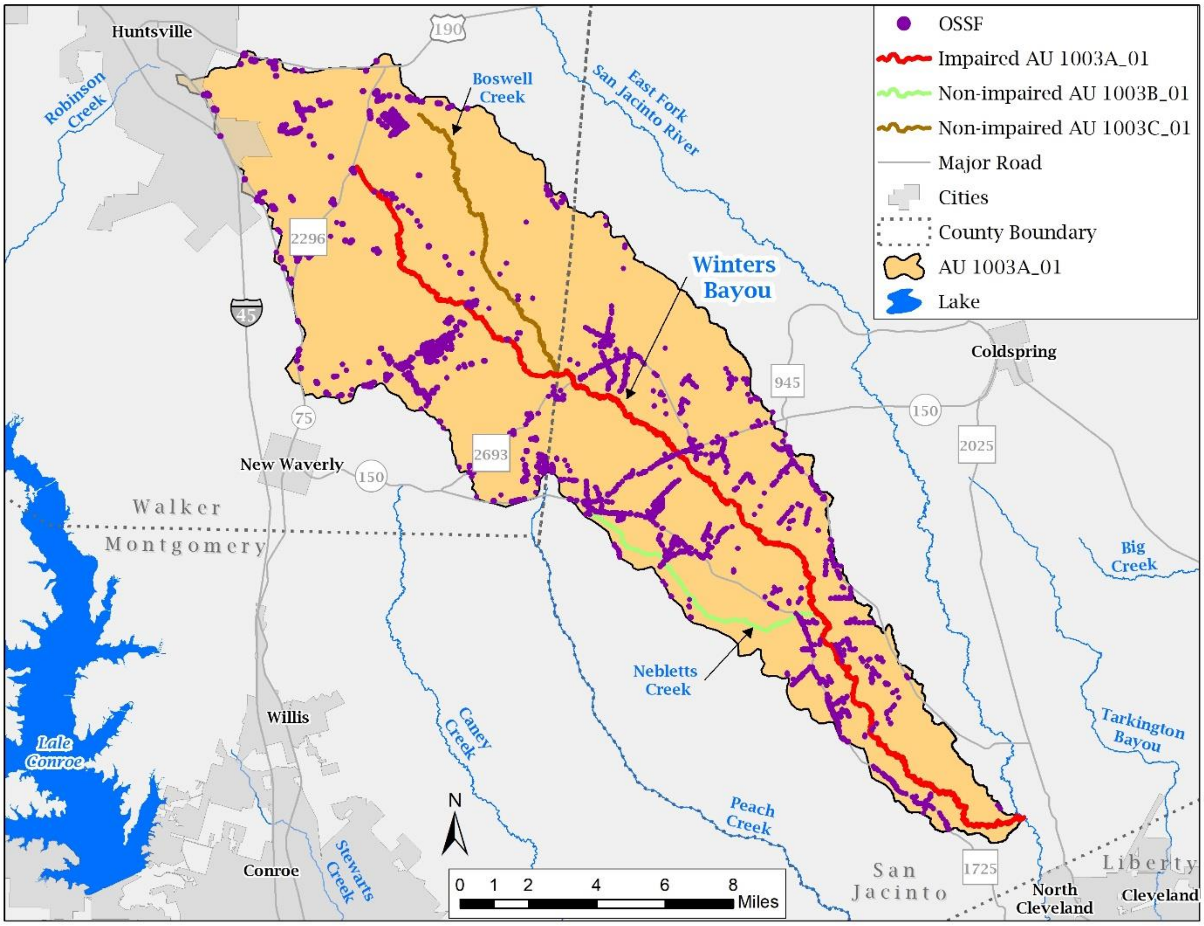

Figure 9. Estimated OSSFs in the Winters Bayou AU 1003A_01 watershed

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

Section 3. Bacteria Tool Development

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

3.1. Tool Selection

For consistency between the Winters Bayou AU 1003A_01 TMDL and the previously completed TMDLs, the pollutant load allocation activities for Winters Bayou AU 1003A_01 used the LDC method. The LDC method has been previously used on TCEQ-adopted and EPA-approved TMDLs for the TMDL *Addendum One: One Total Maximum Daily Load for Indicator Bacteria in Mound Creek* (TCEQ, 2018b), *Addendum Two: One Total Maximum Daily Load for Indicator Bacteria in White Oak Creek* (TCEQ, 2023c), and the original TMDL *Seven Total Maximum Daily Loads for Indicator Bacteria in Lake Houston, East Fork San Jacinto River, West Fork San Jacinto River, and Crystal Creek Watersheds* (TCEQ, 2016).

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

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

Successful application of the LDC method requires two basic types of data: continuous daily streamflow data and historical bacteria data for the relevant indicator bacteria, which in this case is *E. coli*.

Hydrologic data in the form of daily streamflow records were unavailable for the Winters Bayou AU 1003A_01 watershed; however, streamflow records were available for the nearby Peach Creek watershed. Streamflow records for Peach Creek are collected and made readily available by the USGS; (USGS, 2022), which operates the streamflow gage (Figure 10, Table 8). USGS Streamflow Gage 08071000 is located on the mainstem of Peach Creek and is in close enough proximity to Winters Bayou that the same precipitation events would likely impact each watershed. The determination was made to modify the streamflow records for USGS Streamflow Gage 08071000 by using a drainage-area ratio (DAR) approach. This approach is explained in more detail in Section 3.3.3. The modified streamflow records from 08071000 serve as the primary source for streamflow records in this document.

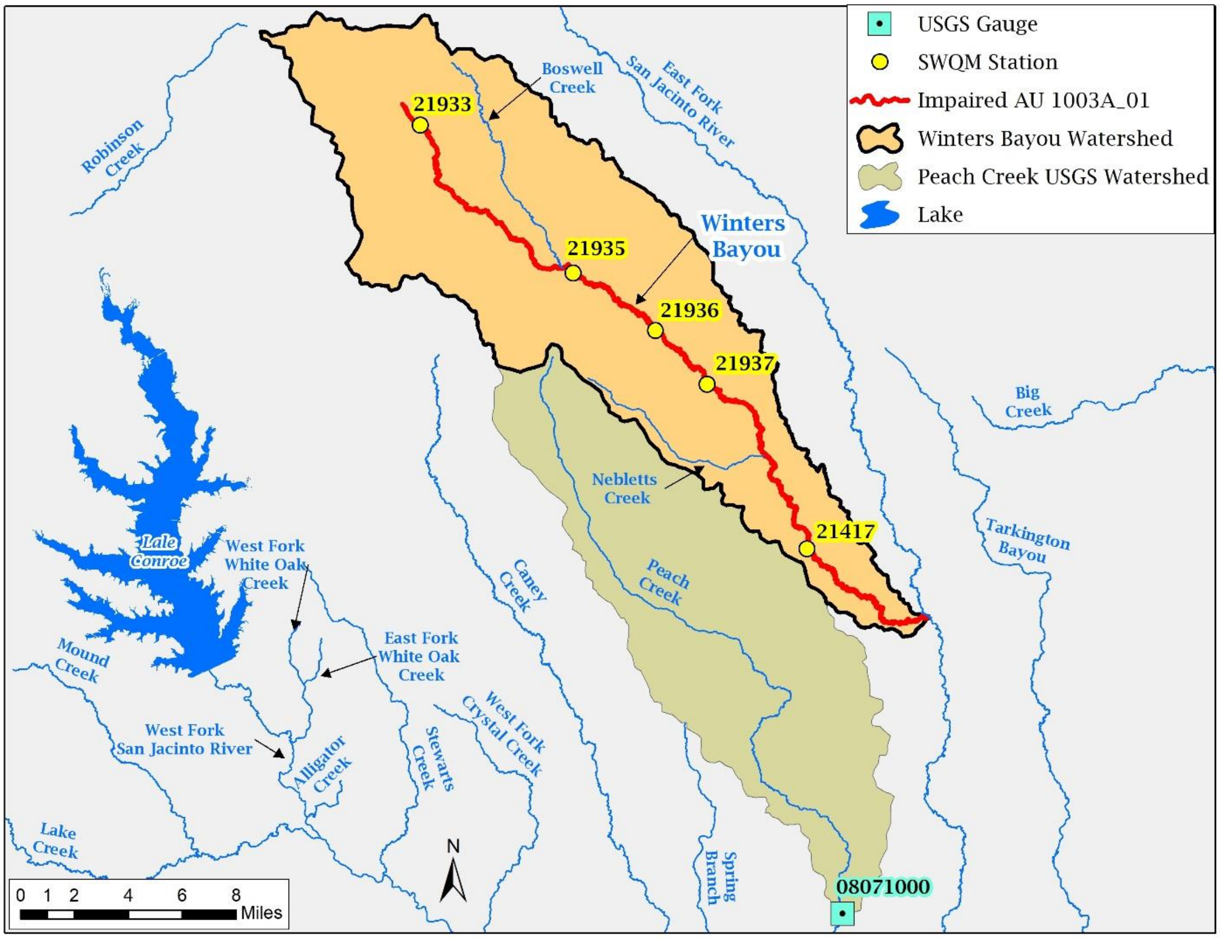

Figure 10. TMDL watershed showing USGS Gage 08071000 and SWQM stations

Table 8. Peach Creek USGS streamflow gage information

Gage No.	Site Description	Drainage Area (acres)	Daily Streamflow Record (beginning & end date)
08071000	Peach Creek at Splendora, TX	74,880	Apr. 1999 – present

Ambient *E. coli* data were available through the TCEQ Surface Water Quality Monitoring Information System for five SWQM stations located along Winters Bayou (Table 9).

Table 9. Summary of historical data set of *E. coli* concentrations collected at sampling stations along Winters Bayou

Stations	Station Location	No. of *E. coli* Samples	Data Date Range
21417	Winters Bayou at Tony Tap Road near Cleveland, TX	35	Dec. 2013 – Apr. 2022
21933	Winters Bayou at FM 2929	21	Dec. 2016 – Apr. 2022
21935	Winters Bayou at FM 2693	20	Dec. 2016 – Apr. 2022
21936	Winters Bayou SH 150	21	Dec. 2016 – Apr. 2022
21937	Winters Bayou at Dabney Bottom Road	21	Dec. 2016 – Apr. 2022

3.3. Methodology for Flow Duration and Load Duration Curve Development

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

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

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

3.3.1. Step 1: Determine Hydrologic Period

A 22-year daily hydrologic (streamflow) record was available for USGS gage 08071000 located on Peach Creek (Table 8, Figure 10). The period of record to develop FDCs should include as much data as possible to capture streamflow and hydrologic variability from high to low precipitation years, be representative of recent conditions, and overlap with the *E. coli* data period of record. Therefore, a 10-year record of daily streamflow, from November 2012 through October 2022, was selected to develop the

FDC at the sampling station location. This period is within the range of the collection dates of available *E. coli* data. A 10-year period is of sufficient duration to contain a reasonable variation from dry months and years to wet months and years and, at the same time, is short enough in duration to contain a hydrology that is responding to recent and current conditions in the watershed.

A 10-year hydrologic period was also used in the previously completed TMDL *Addendum One: One Total Maximum Daily Load for Indicator Bacteria in Mound Creek* (TCEQ, 2018b), *Addendum Two: One Total Maximum Daily Load for Indicator Bacteria in White Oak Creek* (TCEQ, 2023c), and the original TMDL *Seven Total Maximum Daily Loads for Indicator Bacteria in Lake Houston, East Fork San Jacinto River, West Fork San Jacinto River, and Crystal Creek Watersheds* (TCEQ, 2016) which maintains consistency of the Winters Bayou AU 1003A_01 TMDL with the completed TMDLs.

3.3.2. Step 2: Determine Desired Stream Location

When using the LDC method, the optimal location for developing the pollutant load allocation is a currently monitored SWQM station located near the outlet of the watershed. SWQM Station 21417 (Figure 10) was selected as the location for developing the pollutant load allocation due to being located near the watershed outlet and is currently monitored. The 35 *E. coli* sampling results for SWQM Station 21417 collected over a period from December 2013 to April 2022 and during the 10-year hydrologic period were determined to be adequate to develop pollutant load allocations and exceed the minimum of 24 samples suggested in Jones et al. (2009). Within this document, the FDCs and LDCs for the remaining four SWQM station locations are included to provide additional information.

3.3.3. Step 3: Develop Daily Streamflow Records 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 TCEQ SWQM Station 21417 in the Winters Bayou AU 1003A_01 watershed. The daily streamflow records were developed from historical USGS records.

The method to develop the necessary streamflow record for the FDC/LDC location (SWQM station location) 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 appropriate monitoring station by the drainage area upstream of the USGS gage (Table 10).

Because an assumption of the DAR approach is that there is a similarity of hydrologic response based on the 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. This complication was addressed by determining the average discharge for each of the WWTFs located above the Peach Creek USGS gage. The average discharge for each

WWTF was computed by averaging the data obtained from the EPA Enforcement and Compliance History Online database (EPA, 2023). The WWTF discharge averages were summed and then subtracted from the Peach Creek USGS daily record.

In addition to the WWTF discharges, surface water diversions associated with water rights permits have the potential of impacting stream hydrology when applying the DAR approach. A spatial query of water rights features (diversions, withdrawals, return flows) revealed that the TMDL watershed contained three active water rights permits in the TMDL watershed and no active water rights permits in the Peach Creek watershed upstream of the USGS Gage 08071000 (TCEQ, 2022c). A review of the water use in the Texas Water Rights Viewer (TCEQ, 2022c) indicates that there were no recent water diversions in the TMDL watershed. Due to the absence of recently reported diversions in the TMDL watershed, it is assumed that water diversions associated with the water rights permit in the TMDL watershed will not have a significant impact on stream hydrology and were not considered in the development of the streamflow record.

After removing the average daily WWTF discharge values from the daily streamflow gage record, each daily flow record was multiplied by the DAR. Following application of the DAR, the full permitted flows from WWTFs located within the TMDL watershed (Table 4) were then added to the streamflow record along with future growth (FG) flows (calculated in Section 4.7.4) that account for the probability that additional flows from WWTF discharges may occur as a result of population increases.

Table 10. DAR for locations within the TMDL watershed based on the drainage area of the Peach Creek USGS gage

Water Body	Gage/Station	Drainage Area (acres)	DAR
Peach Creek	USGS Gage 08071000	74,880	1.0
Winters Bayou	SWQM Station 21417	102,815	1.373
Winters Bayou	SWQM Station 21937	82,525	1.102
Winters Bayou	SWQM Station 21936	72,229	0.965
Winters Bayou	SWQM Station 21935	54,572	0.729
Winters Bayou	SWQM Station 21933	13,099	0.175

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

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

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

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

Further, when developing an LDC:

- Multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL) and by a conversion factor (2.44658×10^9), which gives a loading in units of cfu/day.
- Plot the exceedance percentages, which are identical to the value for the streamflow data points, against geometric mean criterion of *E. coli*.

The resulting curve represents the maximum allowable daily loadings for the geometric mean criterion. The next step was to plot the sampled *E. coli* data on the developed LDC using the following two steps:

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

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

3.4. Flow Duration Curve

FDCs were developed for five monitoring stations located within the TMDL watershed (Figure 11). For this report, the FDC was developed by applying the DAR method using the Peach Creek USGS gage 10-year period of record described in the previous sections. Flow exceedances less than 30% typically represent streamflow influenced by storm runoff while higher flow exceedances represent receding hydrographs after a runoff event and base flow.

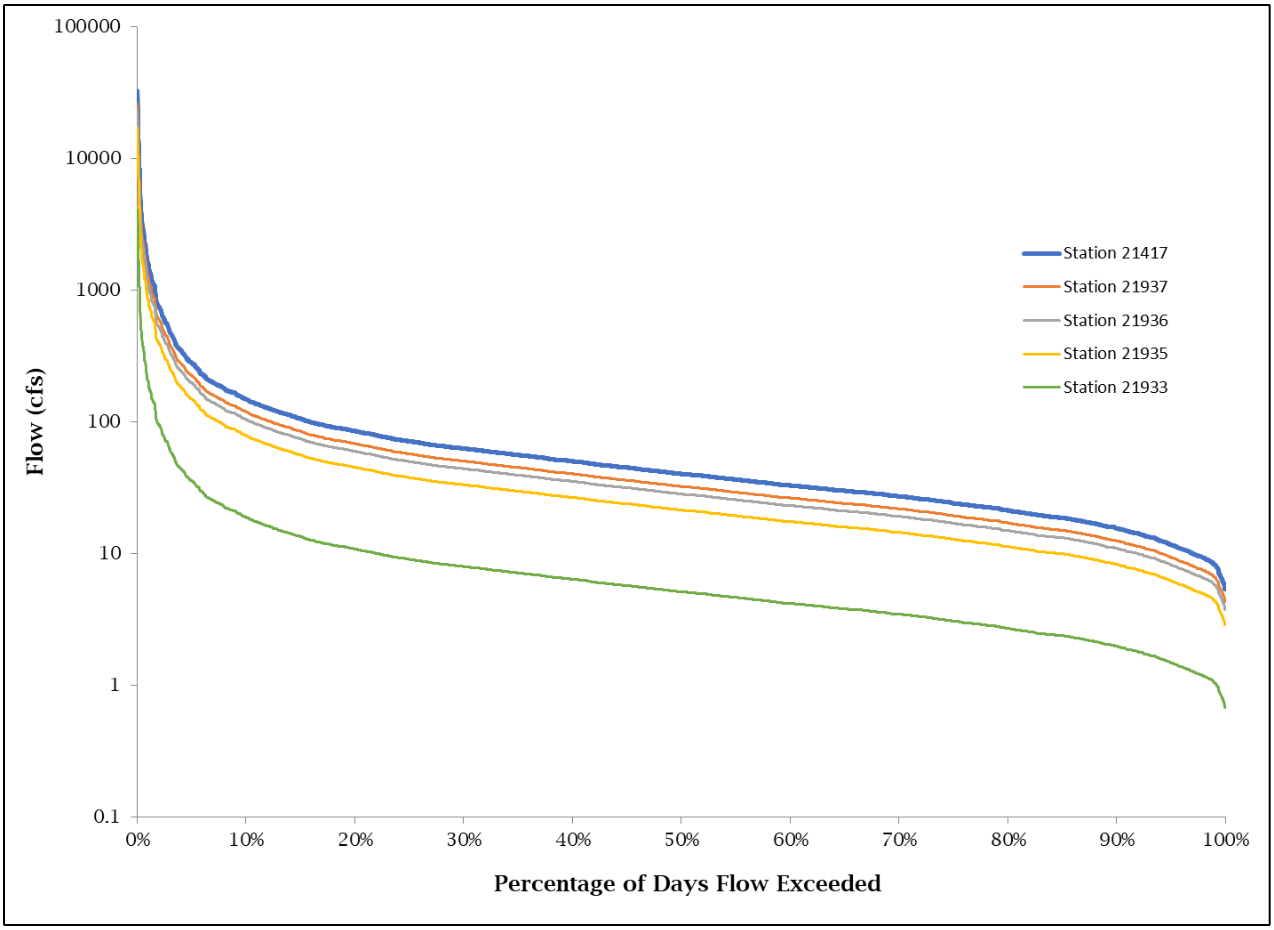

Figure 11. FDCs for SWQM stations along Winters Bayou AU 1003A_01

3.5. Load Duration Curve

LDCs were developed for each of the five monitoring stations within the TMDL watershed (Figures 12-16). A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curve. This approach can assist in determining streamflow conditions under which exceedances are occurring.

For the TMDL watershed, streamflow distribution was divided into three flow regimes: Wet, Moderate, and Dry conditions, which maintains consistency with the previously completed TMDLs (TCEQ, 2016, 2018b, and 2023c). Wet conditions correspond to large storm-induced runoff events. Moderate conditions typically represent periods of medium base flows but can also represent small runoff events and periods of flow recession following large storm events. Dry conditions represent relatively low flow conditions, resulting from extended periods of little or no rainfall and are maintained primarily by WWTF flows (Table 11).

Table 11. Flow regime classifications

Flow Regime Classification	Flow Exceedance Percentile
Wet Conditions	0 – 30%
Moderate Conditions	30 – 70%
Dry Conditions	70 – 100%

The LDCs with these three flow regimes for water quality monitoring stations are provided in Figures 12 through 16. The LDC for SWQM Station 21417 was constructed for developing the TMDL allocation for the Winters Bayou AU 1003A_01 watershed. Geometric mean loadings for the data points within each flow regime have also been distinguished on the figure to aid interpretation. The LDC for SWQM Station 21417 station provides a means of identifying the streamflow conditions under which exceedances in *E. coli* concentrations have occurred. The LDC depicts the allowable loadings at the station under the geometric mean criterion (126 cfu/100 mL) and shows that existing loadings often exceed the criterion. In addition, the LDC also presents the allowable loading at the stations under the single sample criterion (399 cfu/100 mL).

On the graph, the measured *E. coli* 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 "days since last precipitation" (DSLP) as noted on field data sheets associated with each sampling event. DSLP is a field parameter that may be noted during a sampling event to inform of the general climatic and hydrologic conditions. A sample taken with a DSLP ≤ 3 days was defined as a wet weather event. Note that a wet weather event can be indicated even under low flow conditions for only a small runoff event during a period of very low base flow in the stream.

The *E. coli* event data plotted on the LDC show exceedance of geomean criterion has occurred more frequently during elevated or wet streamflow conditions.

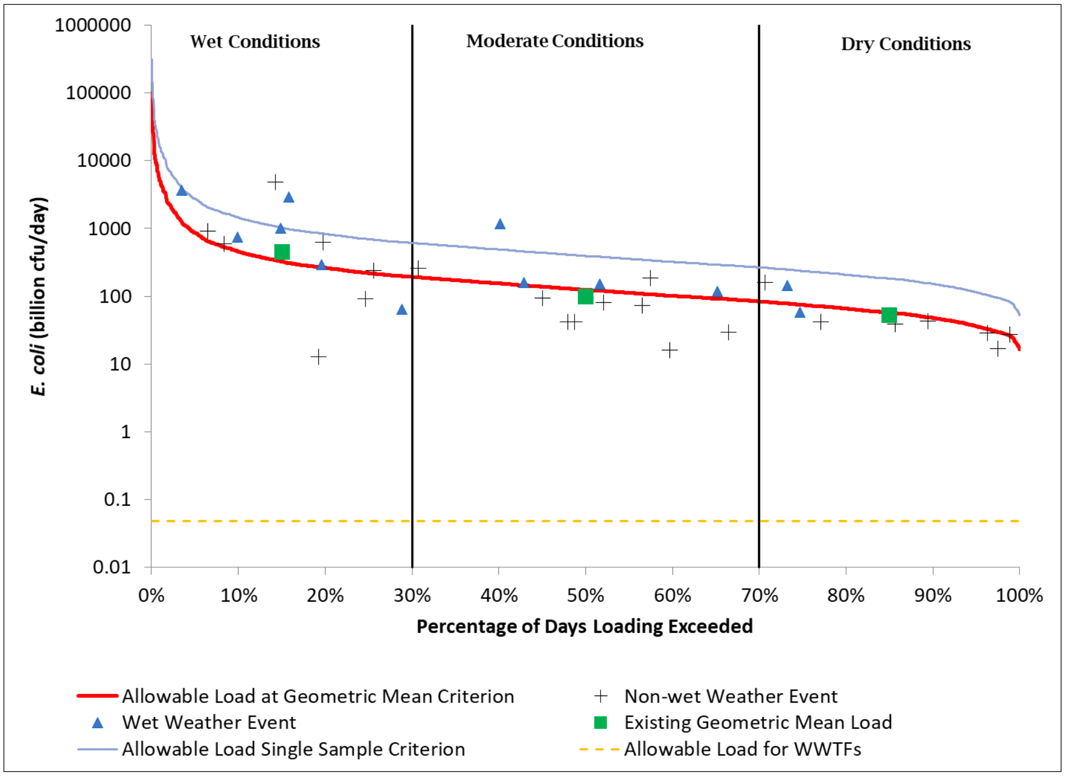

Figure 12. LDC for Winters Bayou AU 1003A_01 (SWQM Station 21417)

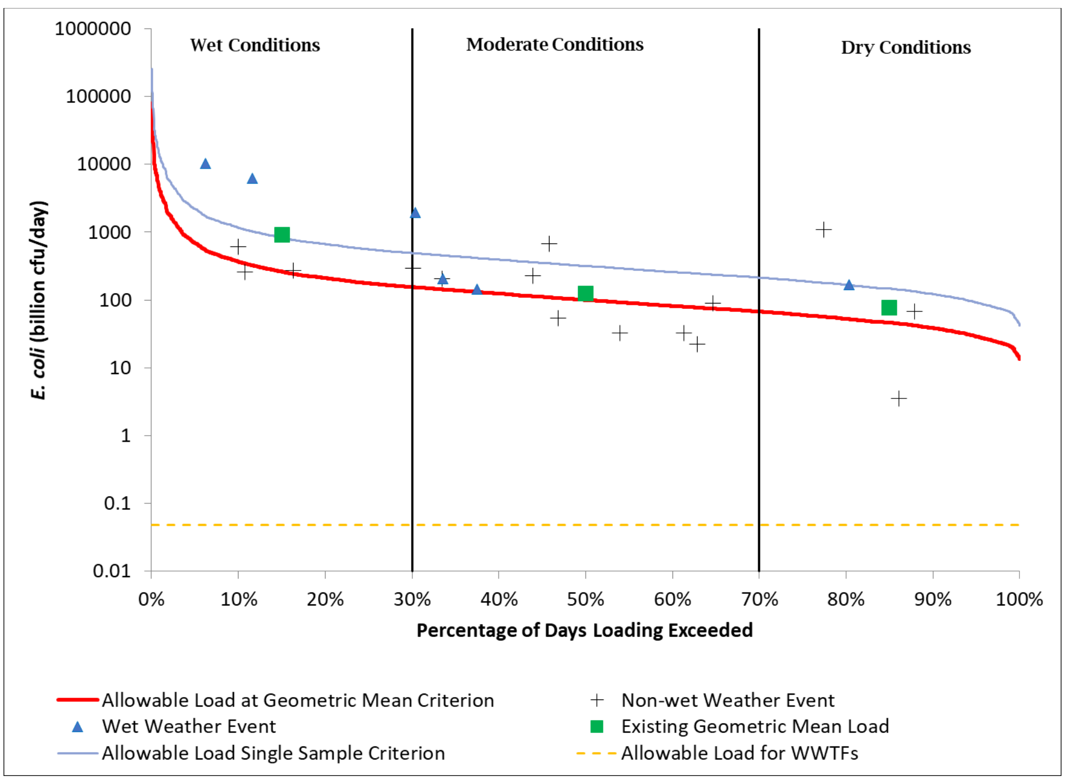

Figure 13. LDC for Winters Bayou AU 1003A_01 (SWQM Station 21937)

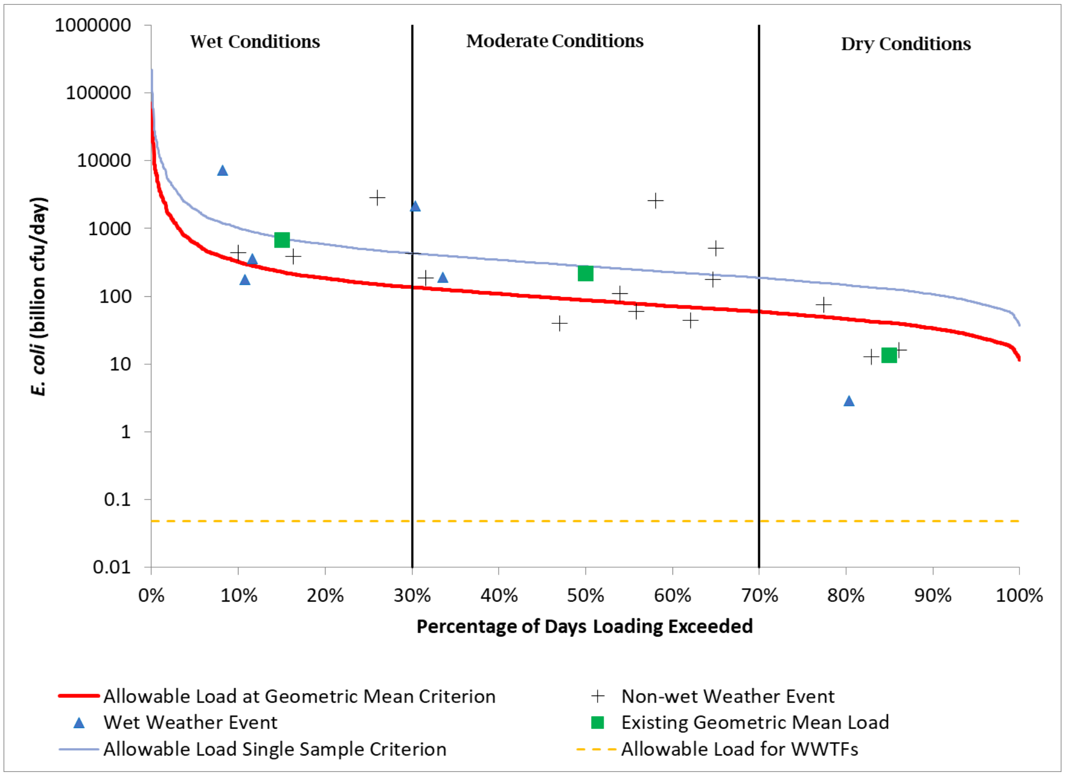

Figure 14. LDC for Winters Bayou AU 1003A_01 (SWQM Station 21936)

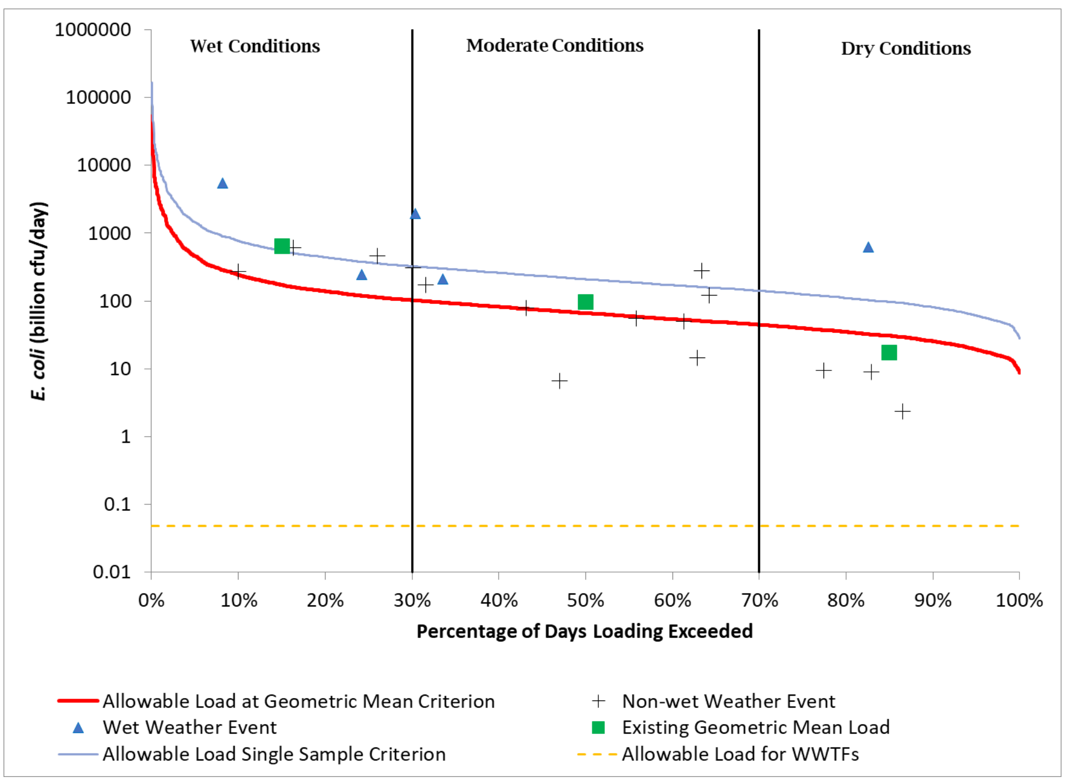

Figure 15. LDC for Winters Bayou AU 1003A_01 (SWQM Station 21935)

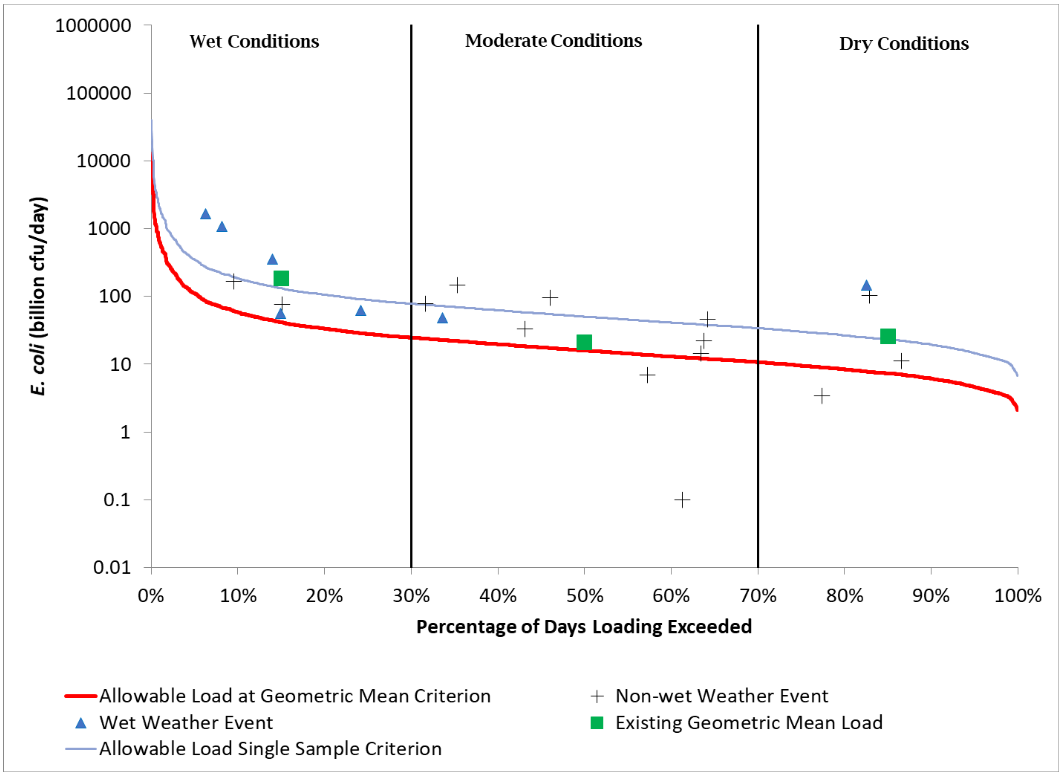

Figure 16. LDC for Winters Bayou AU 1003A_01 (SWQM Station 21933)

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 *E. coli* below the geometric mean criterion of 126 cfu/100 mL, which is protective of the primary contact recreation 1 use in freshwater.

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 *E. coli* concentrations obtained from routine monitoring collected at the five SWQM stations located on Winters Bayou. Differences in *E. coli* concentrations were evaluated by performing a Wilcoxon Rank Sum test. *E. coli* concentrations during warmer months (April - September) were compared against those during the cooler months (October – March), which maintains consistency with the previously completed TMDL (TCEQ, 2018). This analysis of *E. coli* data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Winters Bayou AU 1003A_01.

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 and 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 indicator 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 because the sources of indicator bacteria are attenuated as runoff washes fecal bacteria 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

LDC analyses were used to examine the relationship between instream water quality and the broad sources of indicator bacteria load, and they are the basis of the TMDL allocation. The strength of this TMDL is the use of the LDC method to determine the TMDL allocation. An LDC is a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders and uses available water quality and flow data. The LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. EPA supports the use of this approach to characterize pollutant sources. As discussed in more detail in Section 4.7. (Pollutant Load Allocations), the TMDL load was based on the median flow within the wet-conditions flow regime (or 15% load duration exceedance), where exceedances to the primary contact recreation 1 use criteria are most pronounced.

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 LDC method allows for estimation of existing and allowable TMDL loads by using the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, this method allows for the determination of the 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 LDCs used in the pollutant load allocation process with historical *E. coli* data added to the graph (Figures 12-16) and Section 2.7 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. For the TMDL watershed, the historical *E. coli* data indicate that elevated bacteria loadings have occurred under all three flow regimes. Nearly all of the samples collected during wet weather events contained concentrations that exceeded the geometric mean criterion. The frequency of elevated concentrations that exceed the criteria appears to be greater during wet and moderate conditions. The geometric means of the measured data for each flow regime generally support the observation of frequent occurrence of exceedances during elevated streamflow conditions. The geometric means for samples collected at SWQM Stations 21936 and 21935 indicate that concentrations were below the geometric mean criterion during dry conditions. At the most downstream station (21417), the geometric means indicate that concentrations were below the geometric mean criterion during both moderate and dry flow regimes.

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 into the TMDL using either of the following two methods:

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

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 Winters Bayou AU 1003A_01 watershed was developed using an LDC 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 *E. coli* data obtained from SWQM Station 21417.

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 126 cfu/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 12).

Table 12. Percentage reduction calculations for SWQM Station 21417

Flow Regime	Number of Samples	Geometric Mean by Flow Regime (cfu/100mL)	Required Percentage Reduction by Flow Regime
Wet Conditions (0–30%)	13	172	26.7%
Moderate Conditions (30–70%)	13	101	0%
Dry Conditions (70–100%)	9	116	0%

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 1)

Where:

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

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

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures [40 CFR, 130.2(i)]. For *E. coli*, 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 AU 1003A_01 was developed as a pollutant load allocation based on information from the LDC for SWQM Station 21417 which is the most downstream station located on Winters Bayou (Figure 12). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the FDC by the *E. coli* criterion (126 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 15% exceedance (the median value of the wet conditions flow regime) is the TMDL:

TMDL (cfu/day) = Criterion * Flow (cfs) * Conversion Factor (Equation 2)

Where:

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

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

The allowable loading of *E. coli* that the impaired watershed can receive daily was determined using Equation 2 based on the median value within the wet conditions flow regime of the FDC (or 15% flow exceedance value) for the SWQM station (Table 13).

Table 13. Summary of allowable loading calculation

Water Body	AU	15% Exceedance Flow (cfs)	15% Exceedance Load (cfu/Day)	TMDL (Billion cfu/Day)
Winters Bayou	1003A_01	105.936	3.27E+11	326.567

4.7.2. Margin of Safety Allocation

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

$$MOS = 0.05 * TMDL \qquad \text{(Equation 3)}$$

Using the value of TMDL for the AU provided in Table 13, the MOS may be readily computed by proper substitution into Equation 3 (Table 14).

Table 14. MOS calculations

Load units expressed as billion cfu/day *E. coli*

Water Body	AU	TMDL[a]	MOS
Winters Bayou	1003A_01	326.567	16.328

[a] TMDL from Table 13.

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}).

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

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 (63 cfu/100 mL) 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:

$$WLA_{WWTF} = Target * Flow * Conversion\ Factor \qquad \text{(Equation 5)}$$

Where:

Target= 63 cfu/100 mL

Flow = full permitted flow (MGD)

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

Using this equation, the WWTF's allowable loading was calculated using the permittee's full permitted flow. Table 15 presents the WLA for the WWTF and the resulting total allocation for the AU within the TMDL watershed.

Table 15. WLAs for TPDES-permitted facilities

Load units expressed as billion cfu/day *E. coli*

AU	TPDES Permit	NPDES Permit	Permittee	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{WWTF}
1003A_01	WQ0014996001	TX0028169	Universal Forest Products TX LLC	0.02	0.048

[a] Full Permitted Flow from Table 4.

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 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 load allocation (LA) component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

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

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

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

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

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) 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 within the TMDL watershed. As described in Section 2.7.1.3, a search for all five categories of stormwater general permits was performed. The search results are presented in Table 16.

There are no MS4 permits held in the Winters Bayou AU 1003A_01 watershed. The acreage associated with the general stormwater permit for one concrete production facility was estimated by importing the location information associated with the facility into a geographic information system, and measuring the estimated disturbed area based on the most recently available aerial imagery. For this TMDL, the area disturbed associated with the concrete production facility represents the regulated stormwater coverage for Winters Bayou AU 1003A_01.

Table 16. Stormwater general permit areas and calculation of the FDA_{SWP} term

Water Body	MS4 General Permit (acres)	MSGP (acres)	Construction Activities (acres)	Concrete Production Facilities (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
Winters Bayou	0	0	0	62	62	109,266	0.0006

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the area under the general stormwater permits. To calculate the WLA_{SW} (Equation 6), the FG term must be known. The calculation for that term is presented in the next section, but the results will be included here for continuity. Table 17 provides the information needed to compute WLA_{SW}.

Table 17. Regulated stormwater calculations

Load units expressed as billion cfu/day *E. coli*

Water Body	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	FG[d]	FDA_{SWP}[e]	WLA_{SW}[f]
Winters Bayou	1003A_01	326.567	16.328	0.048	0.005	0.0006	0.186

[a] TMDL from Table 13

[b] MOS from Table 14

[c] WLA_{WWTF} from Table 15

[d] FG from Table 18

[e] FDA_{SWP} from Table 16

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

4.7.4. Future Growth

The FG component of the TMDL equation addresses the requirement to account for future loadings that may occur due to population growth, changes in community infrastructure, and development. Specifically, this TMDL component considers the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of water bodies increases as the amount of flow increases.

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

The FG component was based on population projections and current permitted wastewater dischargers for the entire TMDL watershed. Recent population and projected population growth between 2020 and 2070 for the TMDL watershed are provided in Table 2. The projected population percentage increase within the watershed was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. The permitted flows were increased by the expected population growth for AU 1003A_01 between 2020 and 2070 to determine the estimated future flows.

Thus, the FG is calculated as follows:

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

Where:

Target = 63 cfu/100 mL

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

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

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

The calculation results for the TMDL watershed are shown in Table 18.

Table 18. FG calculation

Water Body	AU	Full Permitted Flow (MGD)	% Population Increase (2020–2070)	FG (MGD)	FG (*E. coli* Billion cfu/day)[a]
Winters Bayou	1003A_01	0.02	8.0%	0.002	0.005

[a] FG = Target * (%$Pop_{2020-2070}$ * $WWTF_{FP}$) * Conversion Factor (Equation 7)

4.7.5. Load Allocations

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

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

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The calculation results are shown in Table 19.

Table 19. LA calculation

Load units expressed as billion cfu/day *E. coli*

Water Body	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	FG[e]	LA[f]
Winters Bayou	1003A_01	326.567	16.328	0.048	0.186	0.005	310.000

[a] TMDL from Table 13
[b] MOS from Table 14
[c] WLA_{WWTF} from Table 15
[d] WLA_{SW} from Table 17
[e] FG from Table 18
[f] LA = TMDL – WLA_{WWTF} – WLA_{SW} – FG – MOS (Equation 8)

4.8. Summary of TMDL Calculations

Table 20 summarizes the TMDL calculation for the TMDL watershed. The TMDL was calculated based on the median flow in the 0–30 percentile range (15% exceedance, wet conditions flow regime) for flow exceedance from the LDC developed for SWQM Station 21417. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL (except for the WLA_{WWTF} and FG terms, which used one-half the criterion).

Table 20. TMDL allocation summary

Load units expressed as billion cfu/ day *E. coli*

AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
1003A_01	326.567	16.328	0.048	0.186	310.000	0.005

[a] TMDL from Table 13

[b] MOS from Table 14

[c] WLA_{WWTF} from Table 15

[d] WLA_{SW} from Table 17

[e] LA from Table 19

[f] FG from Table 18

The final TMDL allocation (Table 21) needed to comply with the requirements of 40 CFR 130.7 includes the FG component within the WLA_{WWTF}.

Table 21. Final TMDL allocation

Load units expressed as billion cfu/ day *E. coli*

AU	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
1003A_01	326.567	16.328	0.053	0.186	310.000

[a] WLA_{WWTF} includes the FG component

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Appendix A. Estimation of the 2020 Census Population and 2070 Population Projections

The following steps detail the method used to estimate the 2020 and projected 2070 populations in the Winters Bayou AU 1003A_01 watershed.

1. Obtained 2020 USCB data at the block level.
2. Developed the 2020 watershed population using the USCB block level data for the portion of 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 WUG data from the 2021 TWDB Regional Water Plan to be used for population projections (TWDB, 2021).
5. Projected 2070 populations were allocated based on proportion of the WUG area within the TMDL watershed.
6. Subtracted the 2020 watershed population from the 2070 population projections 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.