Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria for Brushy Creek and Spring Branch

Segments: 1008J and 1010C
Assessment Units: 1008J_01 and 1010C_01

Brushy Creek at sampling station 20463

Spring Branch at sampling station 20451

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Prepared for
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Abbreviations

AU	assessment unit
cfs	cubic feet per second
cfu	colony-forming units
DAR	drainage-area ratio
DMU	Deer Management Unit
DSLP	days since last precipitation
ECHO	Enforcement and Compliance History Online
E. coli	*Escherichia coli*
FDA_{SWP}	fractional drainage area stormwater permit
FDC	flow duration curve
FIB	fecal indicator bacteria
FG	future growth
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
I&I	inflow and infiltration
IRNR	Institute of Renewable Natural Resources
LA	load allocation
LDC	load duration curve
MGD	millions of gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SWQM	surface water quality monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
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 listed water body. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. In addition to the TMDL an implementation plan is developed, which is a description of the regulatory and voluntary management measures necessary to improve water quality and restore full use of the water body.

The TCEQ's 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 primary objective of the TMDL Program is to restore and maintain the beneficial uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

The TCEQ identified the bacteria impairments within Brushy Creek and Spring Branch in the *Draft 2016 Texas Integrated Report of Surface Water Quality*, which in this document will be referred to as the Draft 2016 Integrated Report.

This document will consider bacteria impairments in two water bodies (segments), each consisting of a single assessment unit (AU) as shown below:

1) Brushy Creek AU 1008J_01;
2) Spring Branch AU1010C_01.

Because the two impaired segments are each composed of only one AU that encompasses the entire segment, the AU descriptor (_01) is often unnecessarily cumbersome. From this point forward, AU and segment may be used interchangeably. For example, Brushy Creek may be referred to as AU 1008J_01 or Segment 1008J. The phrase "TMDL watersheds" will be used when referring to only the area 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, water quality standards were established by the TCEQ. The water quality standards describe the limits for indicators that are monitored in an effort to assess the quality of available water for specific users. The TCEQ is charged with monitoring and assessing water bodies based on these water quality standards, and publishes the Texas Water Quality Integrated Report list biennially.

The *Texas Surface Water Quality Standards* (TCEQ, 2010) are rules that:

- *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; and*
- *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 of which the primary uses assigned in the *Texas Surface Water Quality Standards* to water bodies are:

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

Fecal indicator bacteria (FIB) are used to assess the risk of illness during contact recreation (*e.g.*, swimming) from ingestion of water. FIBs 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 the wastes that 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, 2006). *Escherichia coli* (*E. coli)* is a member of the fecal coliform bacteria group and is used in the State of Texas as the FIB in freshwater. *E. coli* is typically expressed as a colony-forming units (cfu).

On June 30, 2010, the TCEQ adopted revisions to the Texas Surface Water Quality Standards (TCEQ, 2010) and on June 29, 2011, the U.S. Environmental Protection Agency (USEPA) approved the categorical levels of recreational use and their associated criteria. Recreational use consists of four categories:

- Primary contact recreation is that with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for *E. coli* of 126 cfu per 100 milliliter (mL) and an additional single sample criterion of 399 cfu per 100 mL;

- Secondary contact recreation 1 covers activities with limited body contact and a less significant risk of ingestion of water (such as fishing), and has a geometric mean criterion for *E. coli* of 630 cfu per 100 mL;
- Secondary contact recreation 2 is similar to secondary contact 1, but activities occur less frequently. It has a geometric mean criterion for *E. coli* of 1,030 cfu per 100 mL; and
- Noncontact recreation is that with no significant risk of ingestion of water, where contact recreation should not occur due to unsafe conditions. It has a geometric mean criterion for *E. coli* of 2,060 cfu per 100 mL (TCEQ, 2010).

Brushy Creek and Spring Branch are both presumed for primary contact recreation and have the associated *E. coli* geometric mean criterion of a 126 cfu per 100 mL and single sample criterion of 399 cfu per 100 mL.

1.3 Report Purpose and Organization

The Brushy Creek and Spring Branch TMDL project was initiated through a contract between the TCEQ and Texas Institute for Applied Environmental Research (TIAER). The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist the 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 watersheds of Brushy Creek and Spring Branch. This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas 303(d) listings of impairment due to presence of indicator bacteria (*E. coli*),
- development of load duration curves (LDCs), and
- application of the LDC approach for the pollutant load allocation process.

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*: *Six Additional Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston* (TCEQ, 2013) and the original TMDL *Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston* (TCEQ, 2011).

SECTION 2
HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Description of Study Area

The Brushy Creek watershed is located in portions of Grimes, Waller, and Montgomery counties west of Magnolia, Texas (Figure 1). Brushy Creek has a drainage area of 49.2 square miles (31,508 acres). Brushy Creek (Segment 1008J) is a tributary of Spring Creek (Segment 1008). Segment 1008J is approximately 16.26 miles long and contains only one AU (1008J_01).

The Spring Branch watershed is located entirely within Montgomery County, east of Conroe, Texas (Figure 1). The Spring Branch watershed drains an area of 35.9 square miles (22,969 acres). Spring Branch (Segment 1010C) is a tributary of Caney Creek (Segment 1010). Segment 1010C is approximately 13.99 miles long and contains only one AU (1010C_01)

Brushy Creek and Spring Branch are both unclassified, perennial freshwater streams that eventually feed into Lake Houston. Both watersheds are predominantly rural areas with no municipal boundaries in either watershed (Figure 1). Brushy Creek and Spring Branch were considered fully supporting contributing watersheds in previous TMDL efforts within the Lake Houston watershed (Figure 2; TCEQ, 2011 and 2013). This study incorporates a watershed approach where the drainage areas of the streams are considered.

The Draft 2016 Integrated Report (TCEQ, 2018) provides the following segment and AU descriptions for Brush Creek and Spring Branch:

- Segment 1008J (Brushy Creek; AU 1008J_01) – From the Spring Creek confluence upstream to a point 5.6 km (3.5 mi) upstream of FM 1488
- Segment 1010C (Spring Branch; AU 1010C_01) – From the Caney Creek confluence to a point 0.54 km (0.34 mi) upstream of SH 105

Using a watershed-based approach, the entire watersheds of Brushy Creek and Spring Branch will be considered in this report.

2.2 Watershed Climate and Hydrology

The Brushy Creek and Spring Branch watersheds are located within the Lake Houston watershed of the San Jacinto River Basin. There are currently no municipalities located within either watershed.

The Brushy Creek and Spring Branch watersheds are within the Upper Coast and East Texas climatic divisions 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 15-year period from 2004-2018 weather data were obtained from the National Climatic Data Center for the Conroe North Houston Regional Airport (NOAA, 2019).

Data from this 15-year period indicates that the average high temperatures typically peak in August (94.7 °F). During winter, the average low temperature generally reaches a minimum of 38.8 °F in January (Figure 3). Annual rainfall averages 50.5 inches. The wettest month was May (5.2 inches) while September (2.9 inches) was the driest month, with rainfall occurring throughout the year.

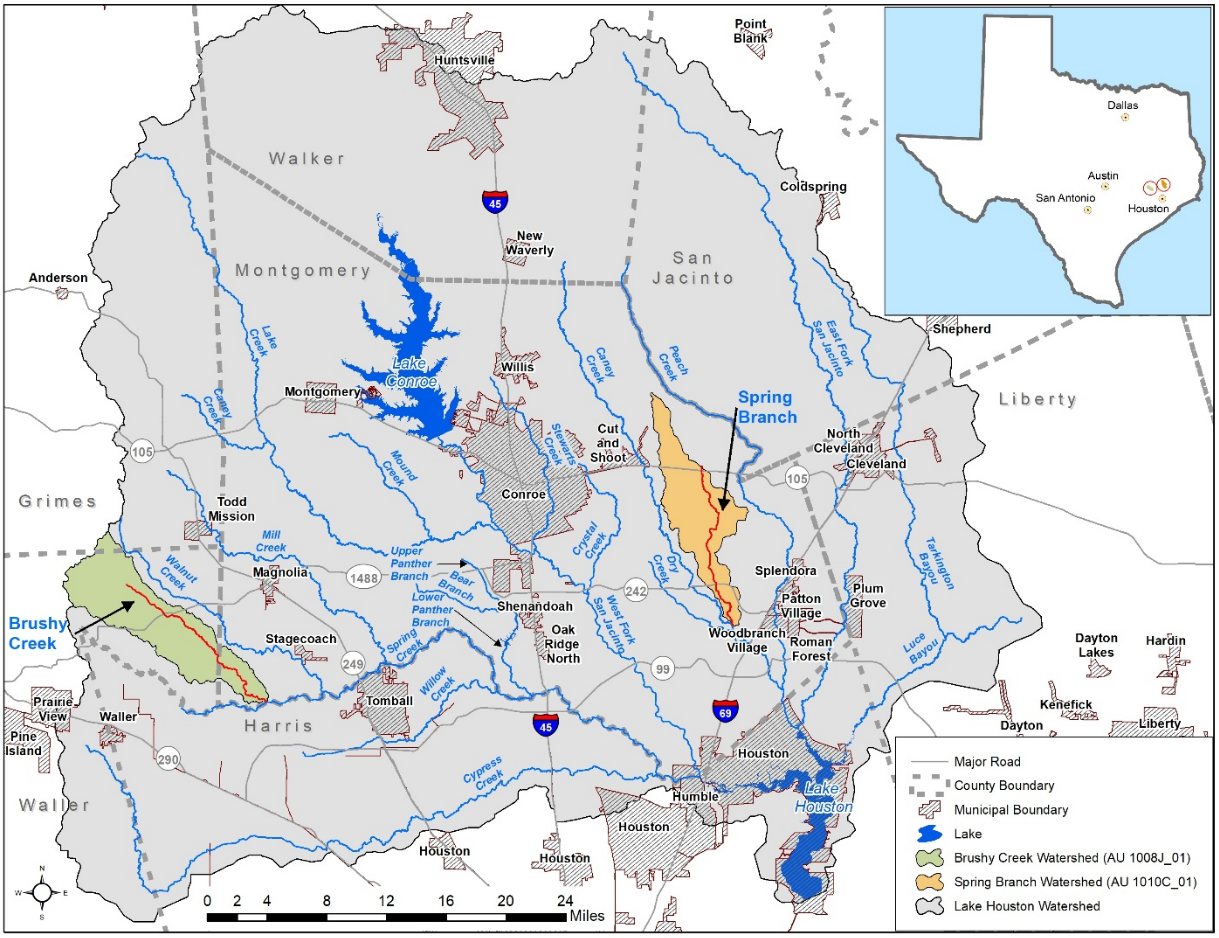

Figure 1. Overview map showing the total contributing drainage area for the Brushy Creek and Spring Branch watersheds and the drainage areas for the existing TMDLs for the Lake Houston watershed.

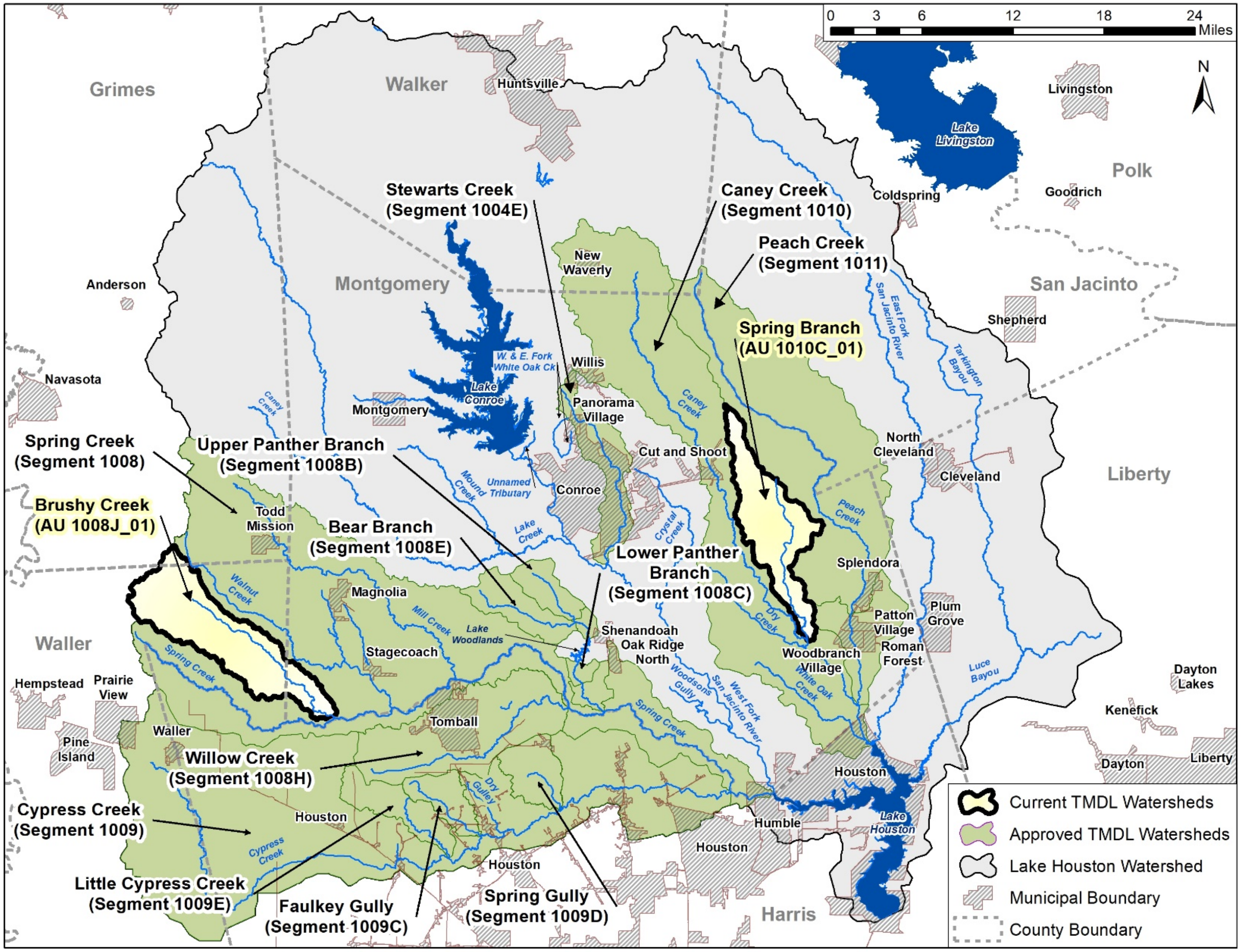

Figure 2. Map showing the previously approved fifteen TMDL watersheds, six addendum watersheds, and the current Brushy Creek and Spring Branch watersheds considered in this addendum.

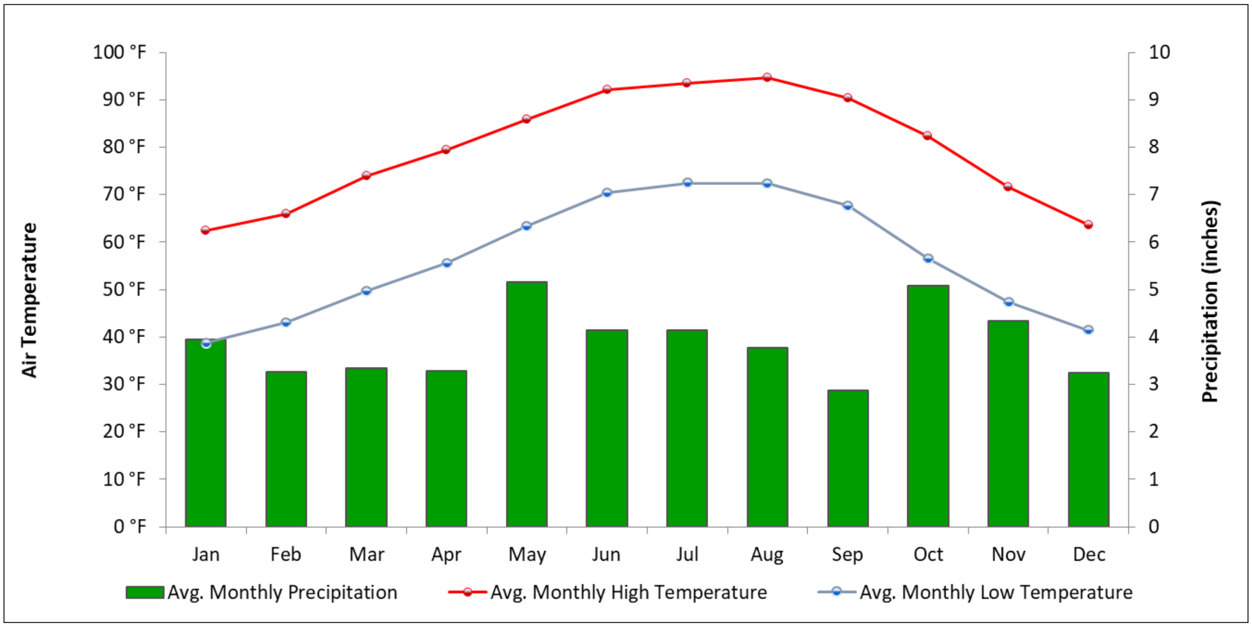

Figure 3. Average minimum and maximum air temperature and total precipitation by month from Jan 2004–Dec 2018 for Conroe North Houston Regional Airport.

2.3 Watershed Population and Population Projections

As depicted in Figure 1, the Brushy Creek watershed is geographically located within portions of Grimes, Montgomery, and Waller counties and outside of any municipal boundaries. The rural nature of the watershed is evident in that the predominant current population densities found throughout the watershed is zero to two people per acre (Figure 4). According to the 2010 Census data (USCB, 2019), the Brushy Creek watershed has an estimated population of 6,755 people.

Spring Branch is located entirely within Montgomery County and outside of any municipal boundaries. Indicative of a mostly rural watershed, current predominant population densities for this watershed is zero to two people per acre (Figure 4). The 2010 Census data (USCB, 2019) indicates there are an estimated 6,531 people in the Spring Branch watershed.

Population projections from 2010 – 2040 were developed by utilizing data from the 2010 U.S. Census and Houston-Galveston Area Council (H-GAC) 2040 regional growth forecast (H-GAC, 2019). The 2010 and projected 2040 populations were allocated based on proportion of the area within each of the TMDL watersheds. According to the growth projections, a population increase of 202.6 percent is expected in the Brushy Creek watershed and 83.1 percent in the Spring Branch watershed by 2040. Table 1 provides a summary of the 2010 populations and 2040 population projections for the Brushy Creek and Spring Branch watersheds.

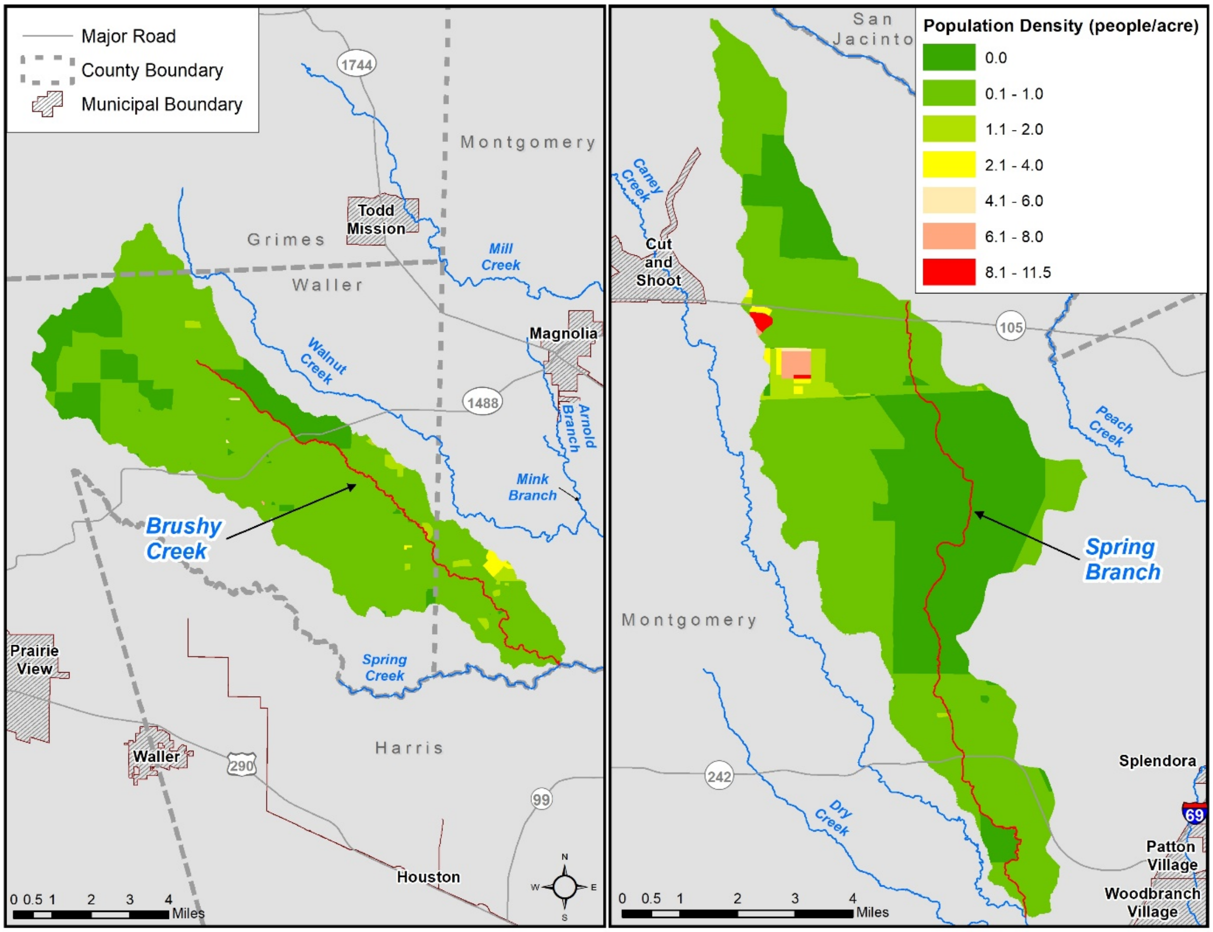

Figure 4. Population density for the Brushy Creek and Spring Branch watersheds based on the 2010 U.S. Census blocks.

Table 1. 2010 Population and Population Projections for the Brushy Creek and Spring Branch watersheds.

Location	2010 U. S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	Projected Population Increase (2010-2040)	Percent Change
Brushy Creek Watershed	6,755	8,522	10,307	20,441	13,686	202.6%
Spring Branch Watershed	6,531	7,998	8,874	11,958	5,427	83.1%

2.4 Review of Routine Monitoring Data

2.4.1 Analysis of Bacteria Data

Environmental monitoring within the Brushy Creek watershed has occurred at TCEQ Surface Water Quality Monitoring (SWQM) station 20463, and at stations 20451 and 21965 for the Spring Branch watershed (Figure 5). Sampling at station 21965 was initiated in March 2017 which is outside of the period used for assessment in the Draft 2016 Integrated Report. Additionally, the available dataset for station 21965 is comprised of only six sampling events with *E.* coli data. The sparse dataset and period of record associated with station 21965 necessitated excluding this station from further consideration within this report. E. *coli* data collected at 20463 on Brushy Creek and station 20451 on Spring Branch over the seven-year period of December 1, 2007, through November 30, 2014, were used in assessing attainment of the primary contact recreation use as reported in the Draft 2016 Integrated Report (TCEQ, 2018) and are summarized in Table 2. The 2016 assessment data for the TMDL watersheds indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 cfu/100 mL.

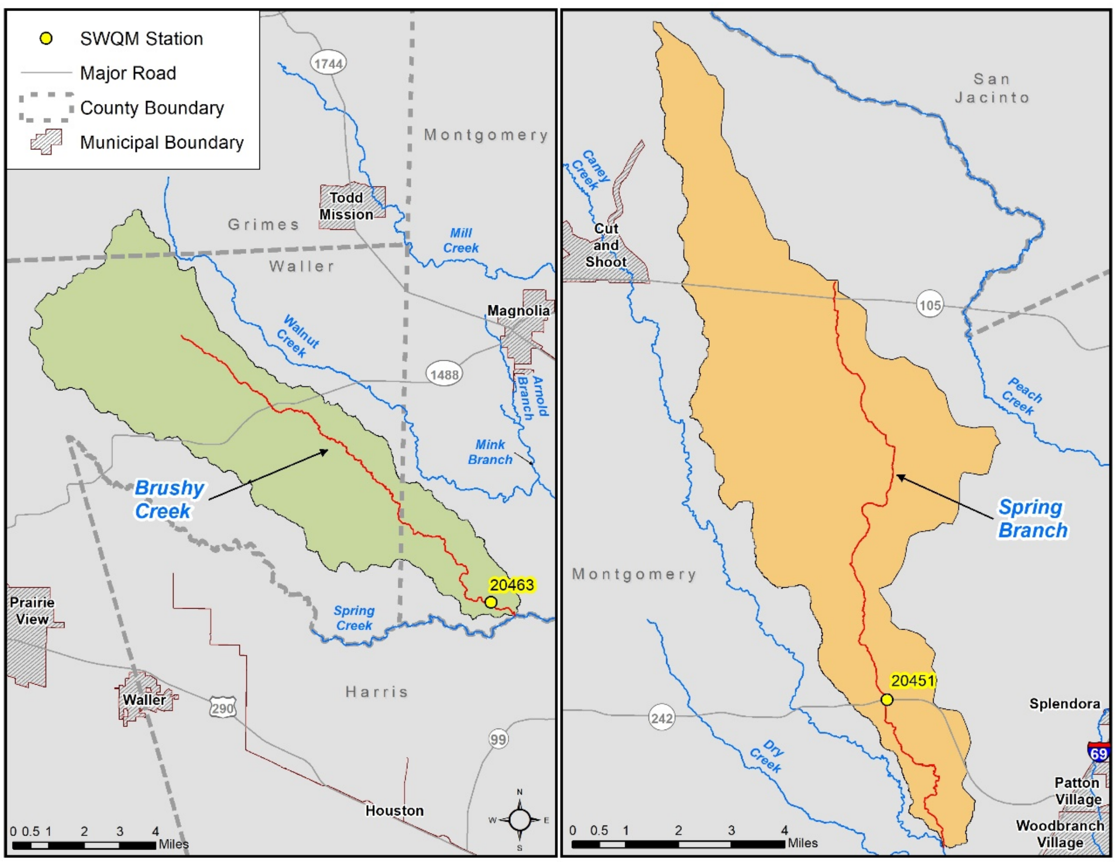

Figure 5. Brushy Creek and Spring Branch watersheds showing TCEQ surface water quality monitoring station used to assess primary contact recreation.

Table 2. Draft 2016 Integrated Report Summaries for the Brushy Creek and Spring Branch watersheds.

Watershed	AU	Parameter	Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
Brushy Creek	1008J_01	*E. coli*	20463	22	2007-2014	221
Spring Branch	1010C_01	*E. coli*	20451	20	2007-2014	384

2.5 Land Use

The land use/land cover data presented in this report are from the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program as obtained from H-GAC and indicated to be for the year 2011 (NOAA, 2011). The land use/land cover is represented by the following categories and definitions:

- **Cultivated** – Areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
- **Bare Land** – Areas of bedrock, scarps, talus, slides, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 10 percent of total cover.
- **Developed (Open Space)** – Areas with a mixture of constructed materials and vegetation. Constructed surfaces account for less than 20 percent 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.
- **Forest** – Areas characterized by tree cover greater than five meters tall and tree canopy accounting for greater than 20 percent of the cover. The forest category includes deciduous, evergreen, and mixed forests.
- **Grassland** – A combined category composed of grassland and scrub/shrub. Grassland areas are dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
- **Developed (High Intensity)** – High intensity includes heavily built up urban centers and large constructed surfaces in suburban and rural areas. Constructed surfaces account for 80 to 100 percent 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 21 to 49 percent of total cover.

- **Developed (Medium Intensity)** – Medium intensity developed areas most commonly include multi- and single-family housing areas. Constructed surfaces account for 50 to 79 percent of the total cover.
- **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 percent of total vegetation.
- **Scrub/Shrub** – Areas dominated by shrubs less than five meters tall with shrub canopy typically greater than 20 percent of the total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
- **Water** – Areas of open water, generally with less than 25 percent cover of vegetation or soil.
- **Wetland** – Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water, or areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

The land use/land cover data is provided for the entire Brushy Creek and Spring Branch watersheds in Figure 6. For the Brushy Creek watershed, forest (40.4 percent) and pasture/hay (34.0 percent) are the dominant land covers comprising approximately 74.4 percent of the total land cover. Forest (39.9 percent) and scrub/shrub (28.1 percent) are the dominant land covers of the Spring Branch watershed comprising approximately 68 percent of the total land cover. A summary of the land use/land cover data for the TMDL watersheds is provided in Table 3.

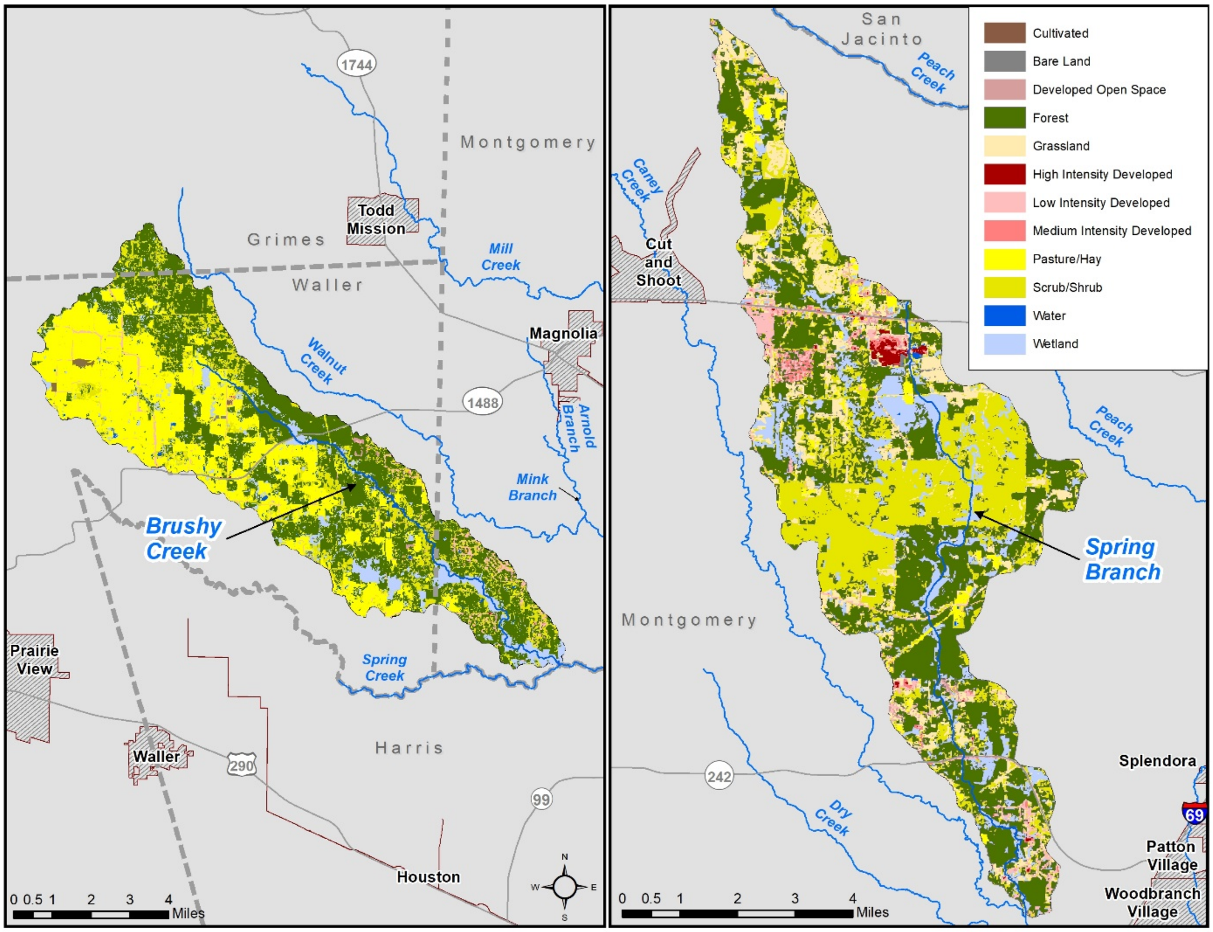

Figure 6. Land use / land cover within the Brushy Creek and Spring Branch watersheds.

Table 3. Land Use/Land Cover within the Brushy Creek and Spring Branch watersheds.

Classification	Brushy Creek (1008J)		Spring Branch (1010C)	
	Area (Acres)	% of Total	Area (Acres)	% of Total[a]
Cultivated	82.9	0.3%	NA	NA
Bare Land	86.4	0.3%	56.3	0.2%
Developed Open Space	94.5	0.3%	142.7	0.6%
Forest	12,744.2	40.4%	9,168.5	39.9%
Grassland	NA[b]	NA	2,821.4	12.3%
High Intensity Developed	6.6	0.0%	153.0	0.7%
Low Intensity Developed	772.3	2.5%	858.6	3.7%
Medium Intensity Developed	27.6	0.1%	224.1	1.0%
Pasture/Hay	10,725.2	34.0%	534.0	2.3%
Scrub/Shrub	4,337.5	13.8%	6,463.5	28.1%
Water	104.9	0.3%	25.6	0.1%
Wetland	2,525.5	8.0%	2,521.3	11.0%
Total	**31,507.6**	**100%**	**22,969.0**	**99.9%**

[a] Due to rounding the column does no add to exactly 100.0%
[b] NA is Not Applicable.

2.6 Soils

Soils within the TMDL watersheds, categorized by their septic tank absorption field ratings, are shown in Figure 7. These data were obtained through the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (NRCS, 2015).

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 and maintenance, and public health (NRCS, 2015). 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, 2015):

- *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, 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.*

The majority of the soils within the Brushy Creek watershed are categorized as "Not rated" with a fraction rated "Somewhat limited" and the balance rated as "Very limited" based on the dominant soil condition for septic drainage field installation and operation. Soils within the Spring Branch watershed are comprised of only two field ratings ("Not rated" and "Very limited") with the majority categorized as "Not rated".

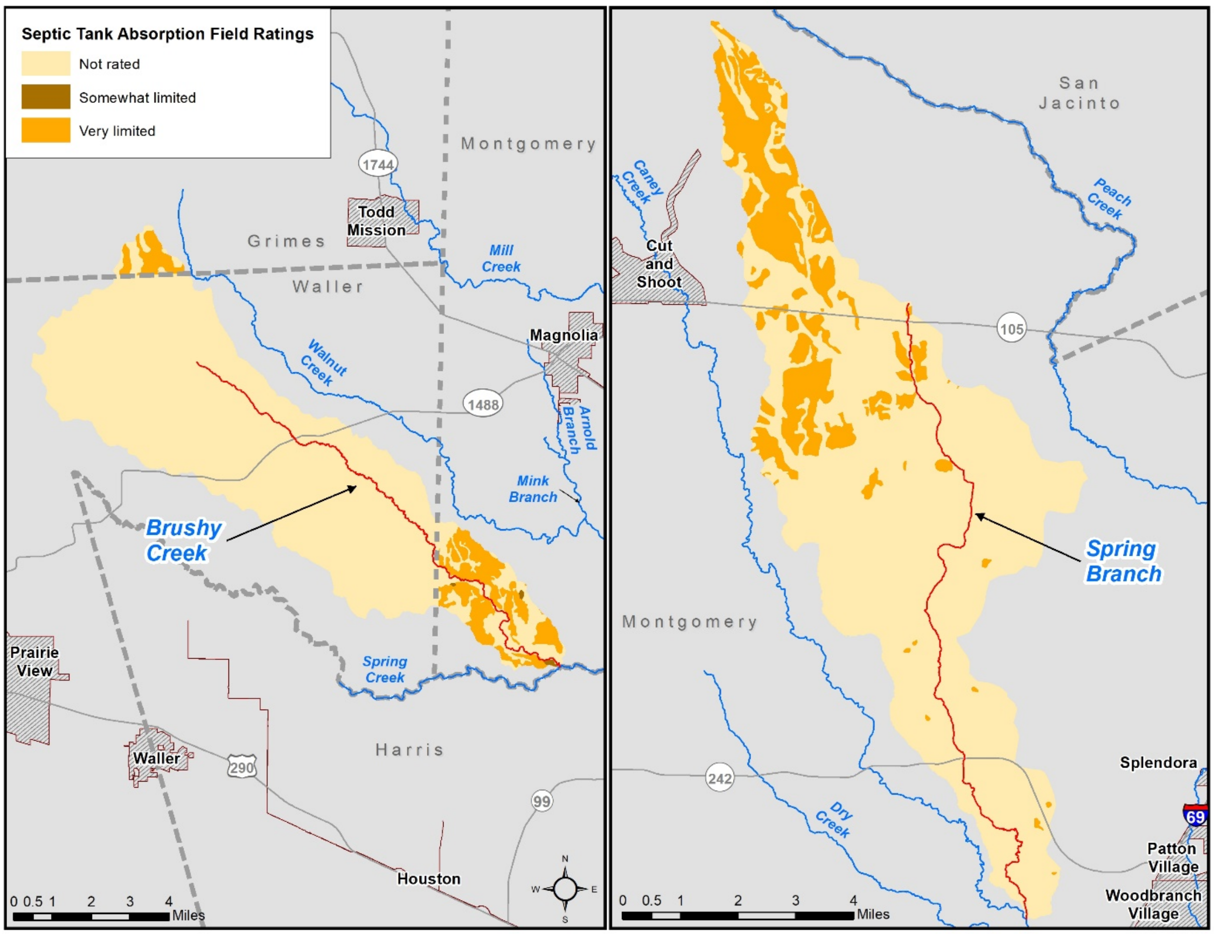

Figure 7. Septic tank absorption field limitation ratings within the Brushy Creek and Spring Branch watersheds.

2.7 Potential Sources of Fecal Indicator Bacteria

Potential sources of indicator bacteria pollution can be divided into two primary categories: *regulated* and *unregulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and National Pollutant Discharge Elimination System (NPDES) programs. Examples of regulated sources are wastewater treatment facility (WWTF) discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4) of cities.

Unregulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff. Nonpoint sources are not regulated by permit.

With the exception of WWTFs, which receive individual wasteload allocations or WLAs (see report Section 4.7.3, Waste Load Allocation), the regulated and unregulated sources in this section are presented to give a general account of the potential sources of bacteria in the watershed.

2.7.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES programs. One WWTF and stormwater discharges from one Phase II MS4 permittee represent the permitted sources in the Brushy Creek watershed. Permitted sources within the Spring Branch watershed include one WWTF and two industrial stormwater discharges.

2.7.1.1 Domestic Wastewater Treatment Facility Discharges

As of June 30, 2019, there is one domestic WWTF with TPDES/NPDES permits within the Brushy Creek watershed (Table 4 and Figure 8). There are two domestic WWTFs with TPDES/NPDES permits located within the Spring Branch watershed and one proposed facility. The C & R Water Supply Inc. (WQ0014285001) located within the Spring Branch watershed discharges effluent outside of the watershed into Caney Creek and is excluded from the Spring Branch TMDL development. Recent discharge data are presented in Table 4 from Discharge Monitoring Report data (USEPA, 2019).

2.7.1.2 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. SSOs 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 SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

The TCEQ Region 12 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. A summary of SSO incidents that occurred during a two-year period from 2016-2018 in the project counties (Grimes, Montgomery, and Waller) was obtained from the TCEQ Central Office in Austin. The summary data indicated no SSO incidents were reported for any locations within the Brushy Creek or Spring Branch watersheds.

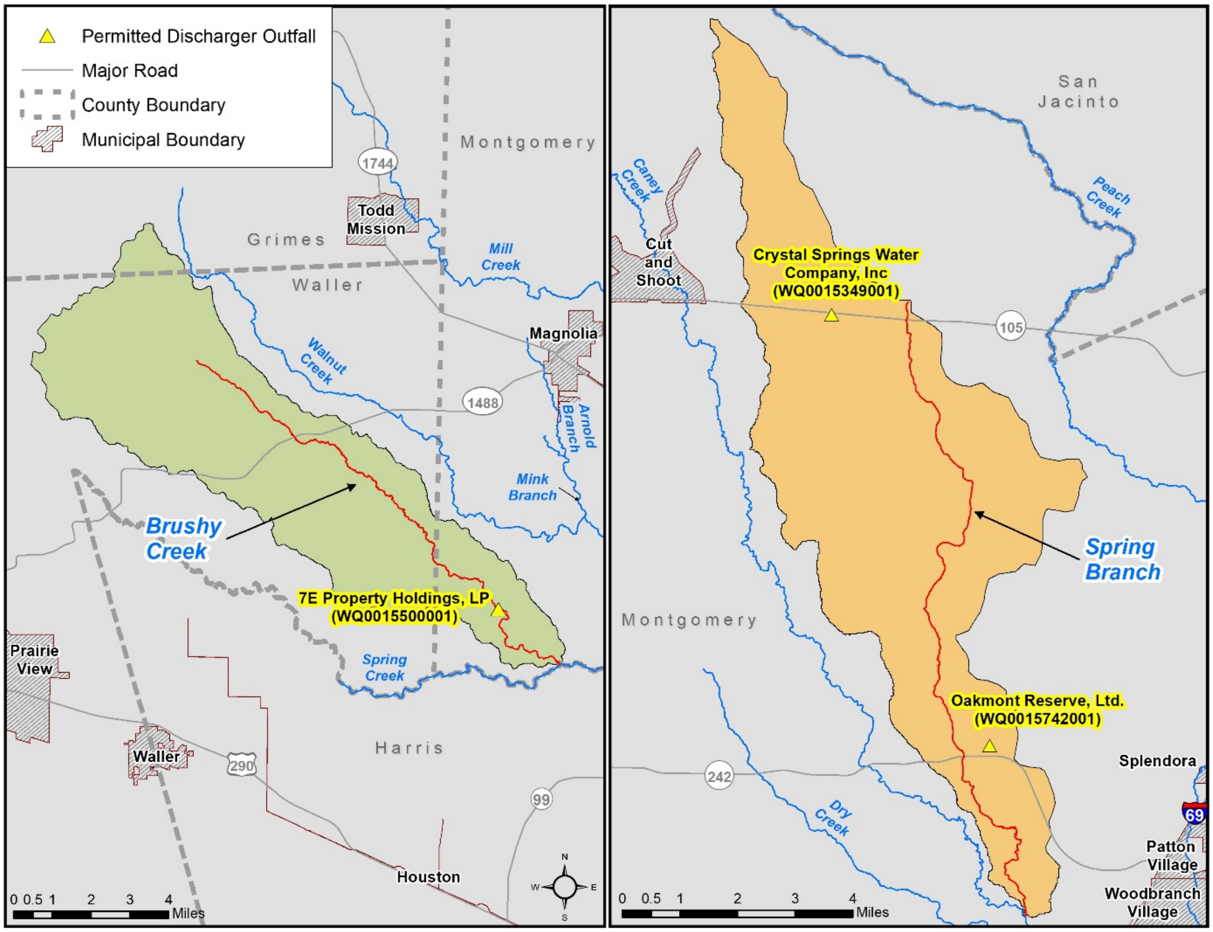

Figure 8. Brushy Creek and Spring Branch watersheds showing WWTFs.

Table 4. Permitted domestic wastewater treatment facilities in the Brushy Creek and Spring Branch watersheds.

Watershed	Permittee	Facility	TPDES No.	NPDES No.	Permitted Discharge (MGD)	Recent Discharge (MGD)
Brushy Creek	7E Property Holdings, LP	Mike Emmons Development WWTF	WQ0015500001	TX0137251	0.0095	0.0045[a]
Spring Branch	Crystal Springs Water Company, Inc.	Ponderosa Pines WWTF	WQ0015349001	TX0136263	0.075	-------[b]
Spring Branch	Oakmont Reserve, Ltd	Oakmont Reserve WWTF	WQ0015742001	TX0138860	0.495	-------[b]

[a] Reflects discharges available from March 1, 2019 – May 31, 2019.

[b] No available records.

2.7.1.3 TPDES General Wastewater Permits

In addition to the individual wastewater discharge permits listed in Table 5, discharges of processed wastewater from certain types of facilities are required to be covered by one of several TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production facilities
- TXG340000 – petroleum bulk stations and terminals
- TXG500000 – quarries in John Graves Scenic Riverway
- TXG670000 – hydrostatic test water
- TXG830000 – petroleum fuel or petroleum substances
- TXG870000 – pesticides
- TXG920000 – concentrated animal feeding operations
- TXG100000 – wastewater evaporation
- WQG20000 – livestock manure compost operations (irrigation only)

A review of active general permit coverage (TCEQ, 2019a) in the Brushy Creek and Spring Branch watersheds as of January 24, 2019, found no operations or facilities of the types described above.

2.7.1.4 Dry Weather Discharges/Illicit Discharges

Bacteria loads from regulated stormwater can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TXR040000 for Phase II (Small) Municipal Separate Storm Sewer Systems as "Any discharge to a municipal separate storm sewer 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 (*e.g.*, used motor oil) that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- 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; and
- a failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.7.1.5 TPDES Regulated Stormwater

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

1. Stormwater subject to regulation, which is any stormwater originating from TPDES/NPDES regulated Municipal Separate Storm Sewer System (MS4) entities, industrial facilities, and construction activities; and
2. stormwater runoff not subject to regulation.

The TPDES/NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban 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, whereas the Phase II general permit regulates smaller communities within a U.S. Census Bureau 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 will be implemented consistent with permit requirements to minimize the discharge of pollutants from the MS4. The 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 waterbodies. Phase II MS4 MCMs include:

- Public education, outreach, and involvement;
- Illicit discharge detection and elimination;
- Construction site stormwater runoff control;
- Post-construction stormwater management in new development and redevelopment;
- Pollution prevention and good housekeeping for municipal operations; and
- Industrial stormwater sources.

Phase I MS4 individual permits have similar MCMs organized a little differently and are further required to perform water quality monitoring.

For Phase I permits the jurisdictional area is defined by the city limits and for Phase II permits the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2010 Census Urbanized Area.

There is currently one Phase I MS4 permit within the urbanized area of the Brushy Creek watershed (Table 5). A review of active MS4 general permit coverage (TCEQ, 2019a) in the Brushy Creek watershed as of January 24, 2019 found one active Phase II MS4 permit (Table 5 and Figure 9). The same review revealed that there are currently no Phase I or Phase II MS4s in the Spring Creek watershed.

Table 5. TPDES and NPDES MS4 permit in the Brushy Creek watershed.

Watershed	Entity	TPDES Permit	NPDES Permit
Brushy Creek	Texas Department of Transportation	WQ0005011000	TXS002101
Brushy Creek	Montgomery County	Phase II General Permit (TXR040000)	TXR040348

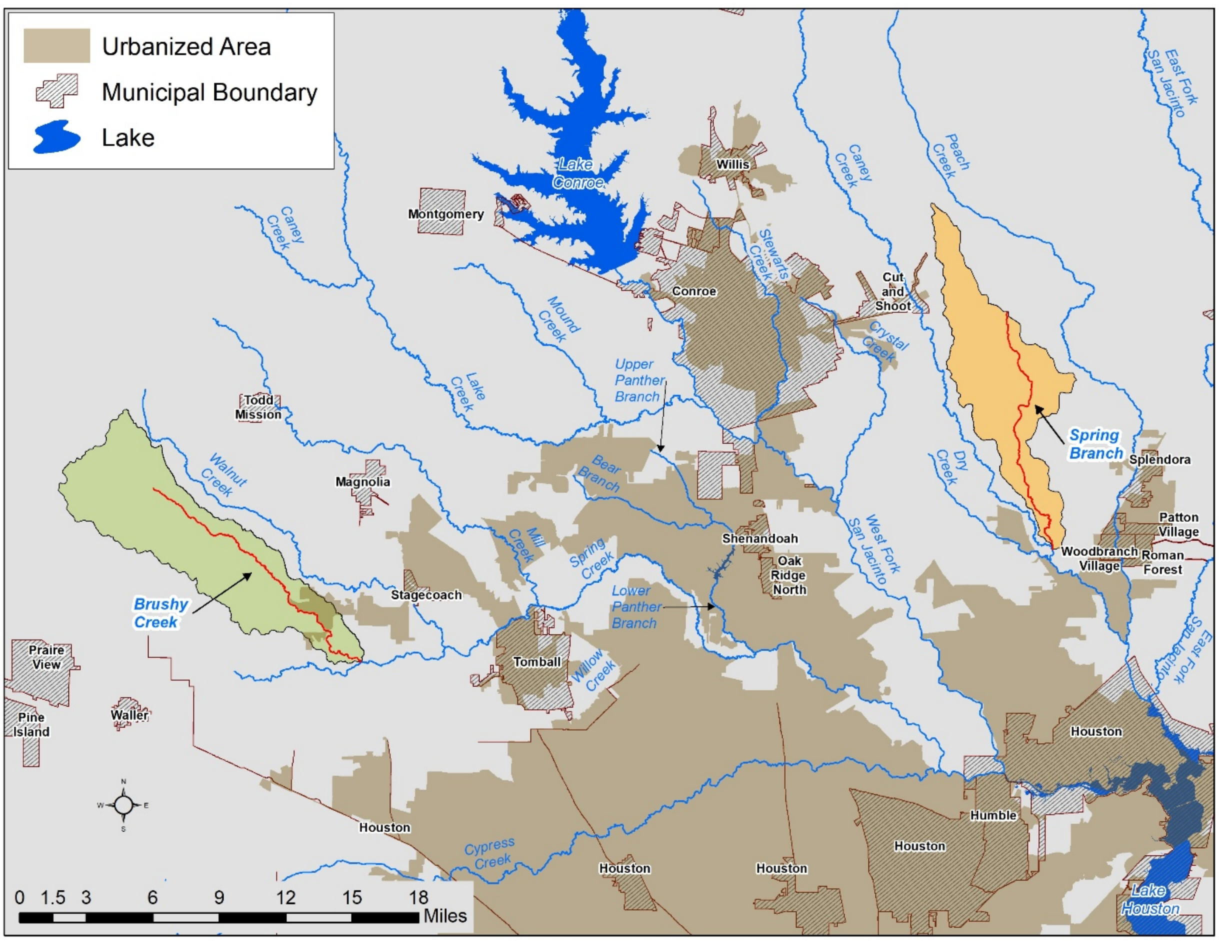

Figure 9. Regulated stormwater areas based on Phase I and Phase II MS4 permits within the Brushy Creek and Spring Branch watersheds.

2.7.1.6 Stormwater General Permits

Discharges of Stormwater from an industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

- TXR050000 – stormwater multi-sector general permit (MSGP) for industrial facilities
- TXR150000 – stormwater from construction activities disturbing more than one acre

A review of active stormwater general permit coverage (TCEQ, 2019a) in the Brushy Creek watershed as of January 24, 2019 found no active MSGPs or construction within the Brushy Creek watershed. The same review revealed two industrial MSGP facilities located in the Spring Branch watershed and five construction permits. See Section 4.7.3 for more detailed information.

2.7.1.7 Review of Compliance Information on Permitted Sources

A review of the USEPA Enforcement & Compliance History Online (ECHO) database (USEPA, 2019), conducted July 2, 2019, revealed no non-compliance issues at the Mike Emmons Development WWTF (WQ0015500001) located in the Brushy Creek watershed regarding *E. coli* limit violation (Table 6). It should be noted that this is a relatively new facility with the original permit issued March 2017 and only one *E. coli* value was available for this facility. No data was available for the Ponderosa Pines WWTF (WQ0015349001) located in the Spring Branch watershed. The *E. coli* permit limit for both facilities requires quarterly sampling. At the time of this report the Oakmont Reserve WWTF was in the permit application process with TCEQ. Except for the TPDES number and full permitted flow value there was no permitting data available for the Oakmont Reserve WWTF.

Table 6. Bacteria monitoring requirements and compliance status for the WWTFs in the Brushy Creek and Spring Branch watersheds.

Watershed	Facility	TPDES No.	Min. Self-Monitoring Requirement Frequency	Daily Average (Geometric Mean) Limitation	Single Grab (or Daily Max Limitation	% Monthly Exceedances Daily Average	% Monthly Exceedances Single Grab
Brushy Creek	Mike Emmons Development WWTF	WQ0015500001	One/quarter	63	200	0[a]	0[a]
Spring Branch	Ponderosa Pines WWTF	WQ0015349001	One/quarter	63	200	-----[b]	-----[b]
Spring Branch	Oakmont Reserve WWTF	WQ0015742001	-----[b]	-----[b]	-----[b]	-----[b]	-----[b]

[a] Only one quarter of *E. coli* self-monitoring data available

[b] No data available

2.7.2 Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint and can emanate from wildlife, feral hogs, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing onsite sewage facilities (OSSFs), and domestic pets.

2.7.2.1 Wildlife and Unmanaged Animal Contributions

E. coli bacteria are common inhabitants of the intestines of all warm-blooded animals, including feral hogs and 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 streams and rivers. 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. Fecal bacteria from wildlife and feral hogs are also deposited onto land surfaces, where it may be washed into nearby streams 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 the counties where the TMDL watersheds are located (eBird, 2019), but population sizes for individual species are not known. However, population estimates for feral hogs and deer are readily available for the TMDL watersheds.

For feral hogs, the Institute of Renewable Natural Resources (IRNR; IRNR, 2013) estimated a range of feral hog densities within Texas (1.33 to 2.45 hogs/square mile). The average hog density (1.89 hogs/square mile) was multiplied by the hog-habitat area in the Brushy Creek (47.5 square miles) and Spring Branch (33.6 square miles) watersheds. Habitat deemed suitable for hogs followed as closely as possible to the land use selections of the IRNR study and include from the H-GAC 2015 land use: forest, cultivated crops, wetlands, pasture/hay, scrub/shrub, and grasslands. Using this methodology, there are an estimated 90 feral hogs in the Brushy Creek watershed and 64 feral hogs in the Spring Branch 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, 2017). The Brushy Creek watershed is located entirely within the DMU Urban Houston for which there is no deer density data. Spring Branch falls mainly within the Urban Houston DMU with partial coverage (19 percent) by DMU 14. Due to the close proximity of the Brushy Creek watershed to DMU 14 and partial coverage of Spring Branch by DMU 14, density data from this DMU was used to estimate deer populations for both watersheds. For the 2016 TPWD survey year, the estimated deer population density for DMU 14 was 21.4 deer/1000 acres. Applying this value to the entire area of both watersheds returns an estimated 674 deer within the Brushy Creek watershed and 492 deer within the Spring Branch watershed.

2.7.2.2 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 that 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 would be expected to contribute virtually no fecal bacteria to surface waters. For example, it has been reported that less than 0.01 percent of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drain field of a septic system (Weikel et al., 1996). Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. Brushy Creek is located within the east-central Texas Regions IV and V, which have a reported failure rate of about 12-19 percent, providing insights into expected failure rates for the area. Spring Branch is located exclusively within Region V with an estimated failure rate of 19 percent.

Estimates of the number of OSSFs in the Brushy Creek and Spring Branch watersheds were determined using H-GAC supplied data for Grimes, Montgomery, and Waller Counties. The H-GAC data indicate that there are 1,240 OSSFs located within the Brushy Creek watershed and 662 OSSFs in the Spring Branch watershed. (Figure 10).

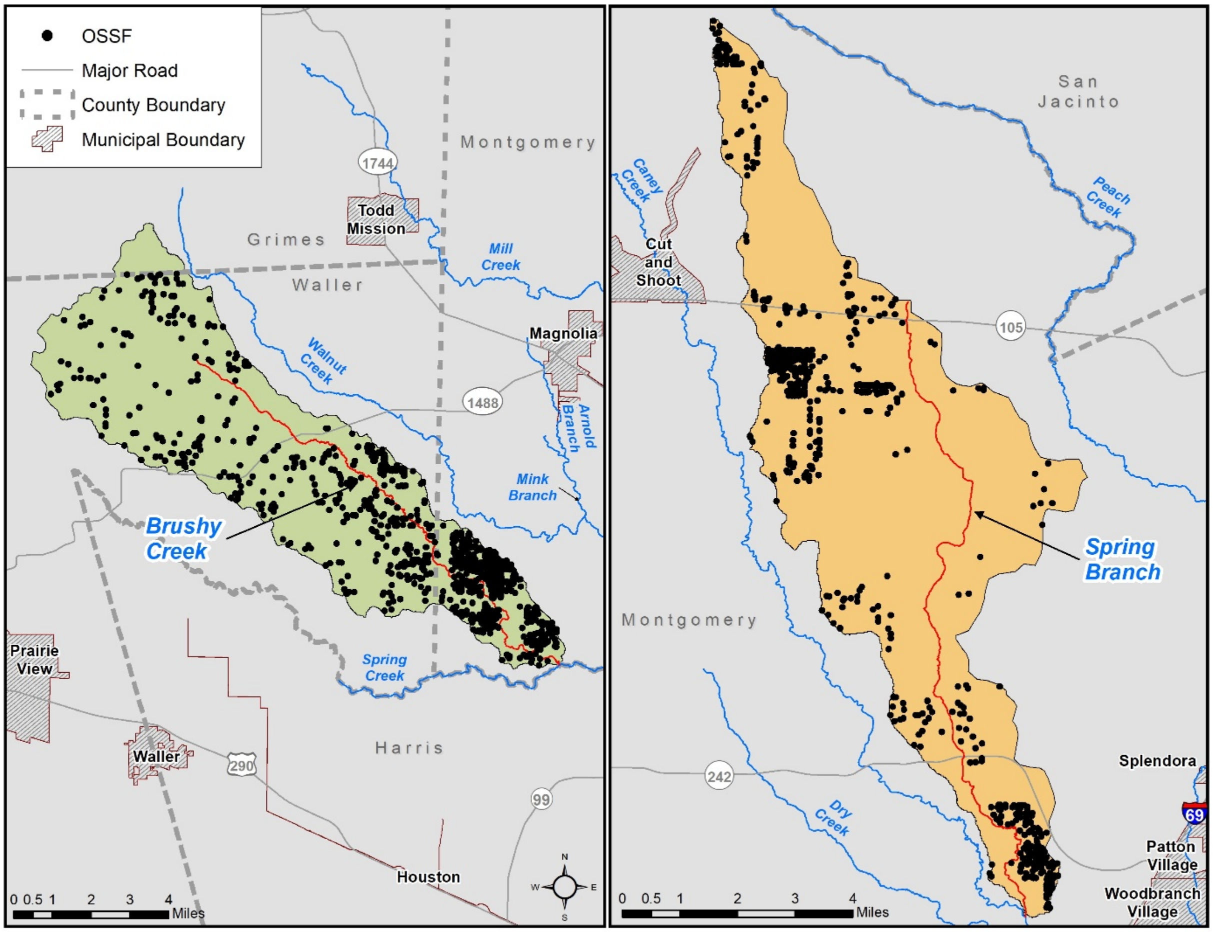

Figure 10. OSSFs located within the Brushy Creek and Spring Branch watersheds.

2.7.2.3 Unregulated Agricultural Activities and Domesticated Animals

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 were refined to better reflect actual numbers within the Brushy Creek and Spring Branch watersheds. The refinement was performed by dividing the total area of the each watershed by the total area of each county(s) within the watershed area. This ratio was then applied to the county-level livestock data (Table 7). The livestock numbers in Table 7 are provided to demonstrate that livestock are a potential source of bacteria in the TMDL watersheds. These livestock numbers are not used to develop an allocation of allowable bacteria loading to livestock.

Table 7. Estimated distributed domesticated animal populations within the Brushy Creek and Spring Branch watersheds, based on proportional area.

Watershed	Cattle and Calves	Hogs and Pigs	Sheep and Lambs	Goats	Horses and Ponies	Mules, Burros, and Donkeys	Poultry	Deer (captive)
Brushy Creek	3,985	34	147	22	428	58	688	130
Spring Branch	599	50	36	75	113	22	415	16

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 8 summarizes the estimated number of dogs and cats within the TMDL watersheds. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household according to data from the American Veterinary Medical Association 2012 U.S Pet Statistics (AVMA, 2015). The number of households in the TMDL watersheds was estimated using 2010 United States Census Bureau (USCB) data (USCB, 2019). Actual contribution and significance of fecal coliform loads from pets reaching the water bodies of the either watershed is unknown.

Table 8. Estimated distribution of dog and cat populations within the Brushy Creek and Spring Branch watersheds.

Watershed	Households	Dogs	Cats
Brushy Creek	2,392	1,397	1,526
Spring Branch	2,007	1,172	1,280

2.7.2.4 Bacteria Survival and Die-off

Bacteria are living organisms that survive and die in the environment. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (*e.g.*, 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 compost and sludge. 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 processes (replication and die-off) are in-stream processes and are not considered in the bacteria source loading estimates for Brushy Creek or Spring Branch.

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 Brushy Creek and Spring Branch TMDLs and the previously completed TMDLs in the Lake Houston watershed, the pollutant load allocation activities for Brushy Creek and Spring Branch used the LDC method. The LDC method has been previously used on TCEQ-adopted and USEPA-approved TMDLs for the *TMDL Addendum One*: *Six Additional Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston* (TCEQ, 2013) and *Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston* (TCEQ, 2011).

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 the 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 Brushy Creek and Spring Branch 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 Brushy Creek and Spring Branch watersheds; however, streamflow records were available for the nearby Bear Branch watershed. Streamflow records for Bear Branch are collected and made readily available by the U.S. Geological Survey (USGS; USGS, 2019), which operates the streamflow gauge (Figure 11, Table 9). USGS streamflow gauge 08068390 is located along the mainstem of Bear Branch and is in close enough proximity to Brushy

Creek and Spring Branch that the same precipitation events would likely impact each watershed. The determination was made to modify the streamflow records for Bear Branch 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 Bear Branch serve as the primary source for streamflow records in this document.

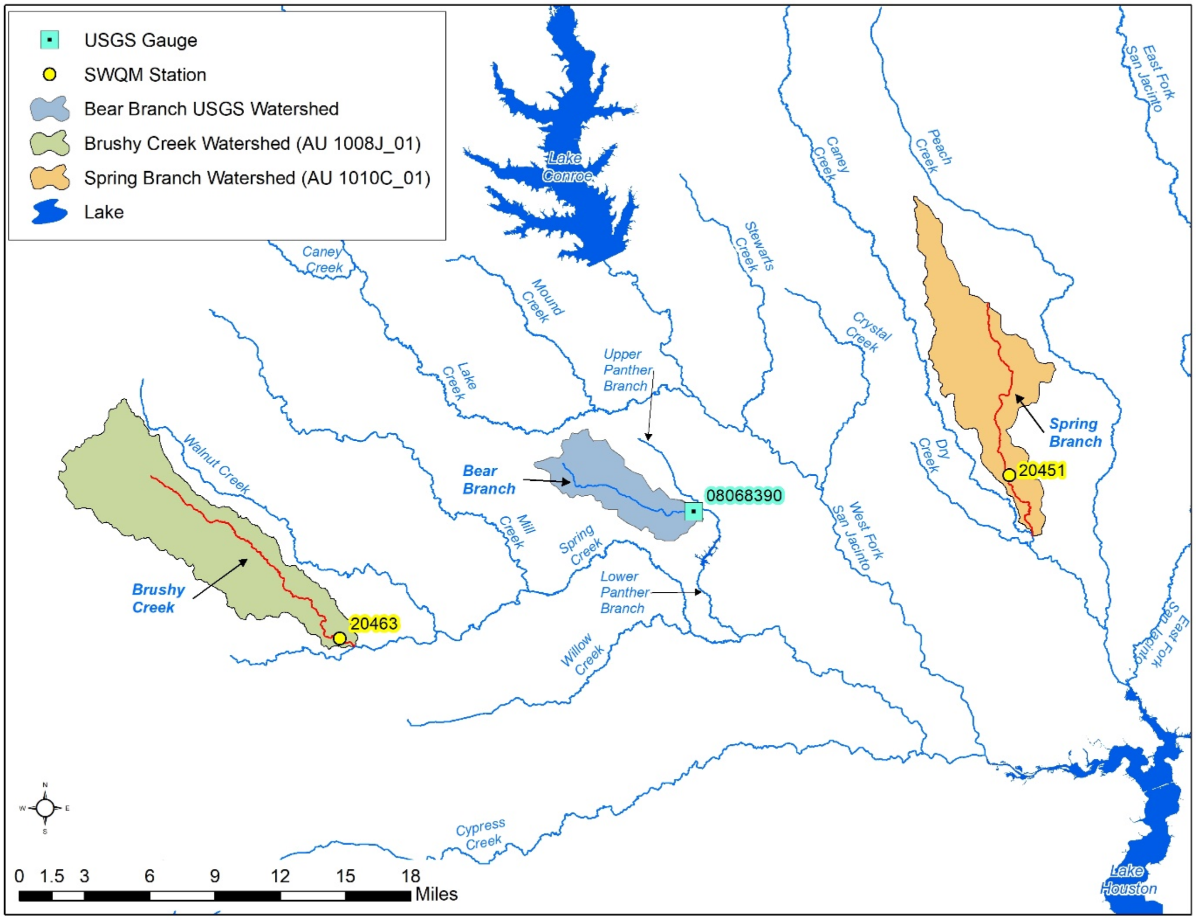

Figure 11. Brushy Creek, Spring Branch, and Bear Branch watersheds including USGS Station 08068390 and SWQM stations 20463 and 20451.

Table 9. Basic information on Bear Branch USGS streamflow gauge

Gauge No.	Site Description	Drainage Area (acres)	Daily Streamflow Record (beginning & end date)
08068390	Bear Branch at Research Boulevard, The Woodlands, TX	9,856	Jan. 1999 – present

Ambient *E. coli* data were available through the TCEQ SWQMIS for Brushy Creek sampling station 20463, and consisted of 33 *E. coli* sample results with a geometric mean of 183 cfu/100mL collected over a period from April 2009 to March 2018. Ambient *E. coli* data for Spring Branch sampling station 20451 consisted of 31 *E. coli* sample results with a geometric mean of 194 cfu/100mL collected over a period from March 2009 to October 2016.

3.3 Methodology for Flow Duration & Load Duration Curve Development

To develop the flow duration curve (FDC) and LDC, 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 FDC.
- **Step 2:** Determine stream location for which FDC and LDC development is desired.
- **Step 3:** Develop daily streamflow records at the desired stream location using the daily gauged streamflow records and DAR.
- **Step 4:** Develop a FDC at the desired stream location, segmented into discrete flow regimes.
- **Step 5** Develop the allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- **Step 6:** Superpose historical bacteria data on each allowable bacteria LDC.

Additional information explaining the LDC method may be found in Cleland (2003) and NDEP (2003).

3.3.1 Step 1: Determine Hydrologic Period

A 20-year daily hydrologic (streamflow) record was available for USGS gauge 08068390 located on nearby Bear Branch (Table 9, Figure 11). Optimally, the period of record to develop FDCs 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 experienced within the watershed and when the *E. coli* data were collected. Therefore, a 10-year record of daily streamflow from January 2009 through December 2018 was selected to develop the FDCs at the sampling station locations, and this period includes the collection dates of all available *E. coli* data at the time this work effort was undertaken. 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: Six Additional Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston* (TCEQ, 2013), which maintains consistency of the Brushy Creek and Spring Branch TMDLs with the previous TMDLs.

3.3.2 Step 2: Determine Desired Stream Locations

SWQM stations 20463 (Brushy Creek) and 20451 (Spring Branch) (Figure 11) are the only locations within Brushy Creek and Spring Branch where an adequate number of *E. coli* data have been collected. The 33 *E. coli* sampling results for station 20463 and 31 *E. coli* sampling results for station 20451 were determined to be adequate to develop pollutant load allocations, and exceed the minimum of 24 samples suggested in Jones *et al*. (2009).

3.3.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station location were determined, the next step was to develop the 10-year daily streamflow record for the monitoring stations in each watershed. The daily streamflow records were developed from extant 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 above the desired monitoring station by the drainage area above the USGS gauge (Table 10).

Because an assumption of the DAR approach is similarity of hydrologic response based on commonality of landscape features such as geology, soils, and land use/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. In practice, this complication was addressed by determining the average discharge for each of the WWTFs located above the Bear Branch USGS gauge. The average discharge for each WWTF was computed by averaging the data obtained from the USEPA Enforcement and Compliance History Online database (USEPA, 2019). The WWTF discharge averages were summed and then subtracted from the Bear Branch USGS daily record.

In addition to the WWTF discharges, surface water diversions associated with water rights permits have the potential of impacting stream hydrology in regards to the application of the DAR approach. A spatial query of water rights features (diversions, withdrawals, return flows) revealed that the TMDL watersheds did not contain any active water rights permits, and only one active water rights permit was located in the Bear Branch watershed (TCEQ, 2019b). A review of the water use data file containing historical reported water diversions (TCEQ, 2019b) indicates that the only water user, located above the USGS gauge 08049700, reported a diversion for only one month in 2003. Due to only one month of historical reported water diversions upstream of USGS 08049700, the absence of any recently reported diversions, and the lack of diversions within the TMDL watersheds it is assumed that water diversions will have an insignificant impact on stream hydrology and pollutant load allocations. Therefore, diversions associated with water rights permits were not considered in the development of the streamflow record. Additionally, water rights permits allow withdrawals of water, as opposed to discharges, and do not need to be assigned loadings in a TMDL.

After removing the average daily WWTF discharge values from the daily streamflow gauge record, each daily flow record was multiplied by the DAR. Following application of the DAR, the full permitted flows from WWTFs located within the Brushy Creek and Spring Branch watersheds (Table 4) were added to the streamflow record along with future growth 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 the Brushy Creek and Spring Branch watersheds based on the drainage area of the Bear Branch USGS gauge.

Water Body	Gauge/Station	Drainage Area (acres)	DAR
Bear Branch	USGS Gauge 08068390	9,856	1.0
Brushy Creek	Station 20463	31,019	3.147
Spring Branch	Station 20451	20,191	2.049

3.3.4 Steps 4-6: Flow Duration Curve and Load Duration Curve Method

FDCs and LDCs are graphs indicating the percentage of time during which a certain value of flow or load is equaled or exceeded. To develop a FDC for a location the following steps were undertaken:

- order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (1 for the highest flow, 2 for the second highest flow, and so on);
- compute the percent of days each flow was exceeded by dividing each rank by the total number of data point plus 1; and
- plot the corresponding flow data against exceedance percentages.

Further, when developing a 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 (2.44658×10^7), which gives a loading in units of cfu/day; and
- 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:

- using the unique data for the monitoring station, 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 (2.44658×10^7), which gives a loading in units of cfu/day; and
- 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 multiplied by the 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 Curves for Monitoring Stations within the TMDL Watersheds.

The FDCs were developed for monitoring stations within the TMDL watersheds (Figures 12 and 13). For this report, the FDC was developed by applying the DAR method using the Bear Branch USGS gauge 10-year period of record described in the previous sections. Flow exceedances less than 30 percent typically represent streamflow influenced by storm runoff while higher flow exceedances represent receding hydrographs after a runoff event, base flow and no flow conditions.

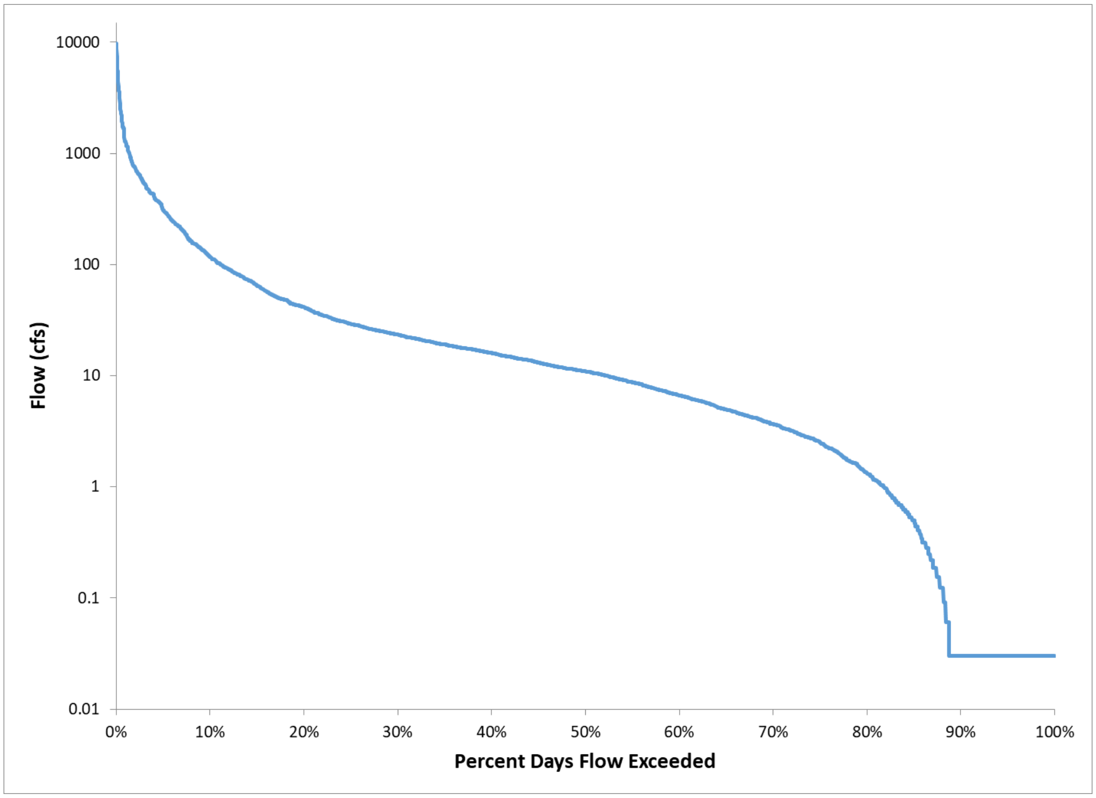

Figure 12. Flow duration curve for Brushy Creek AU 1008J_01 (Station 20463).

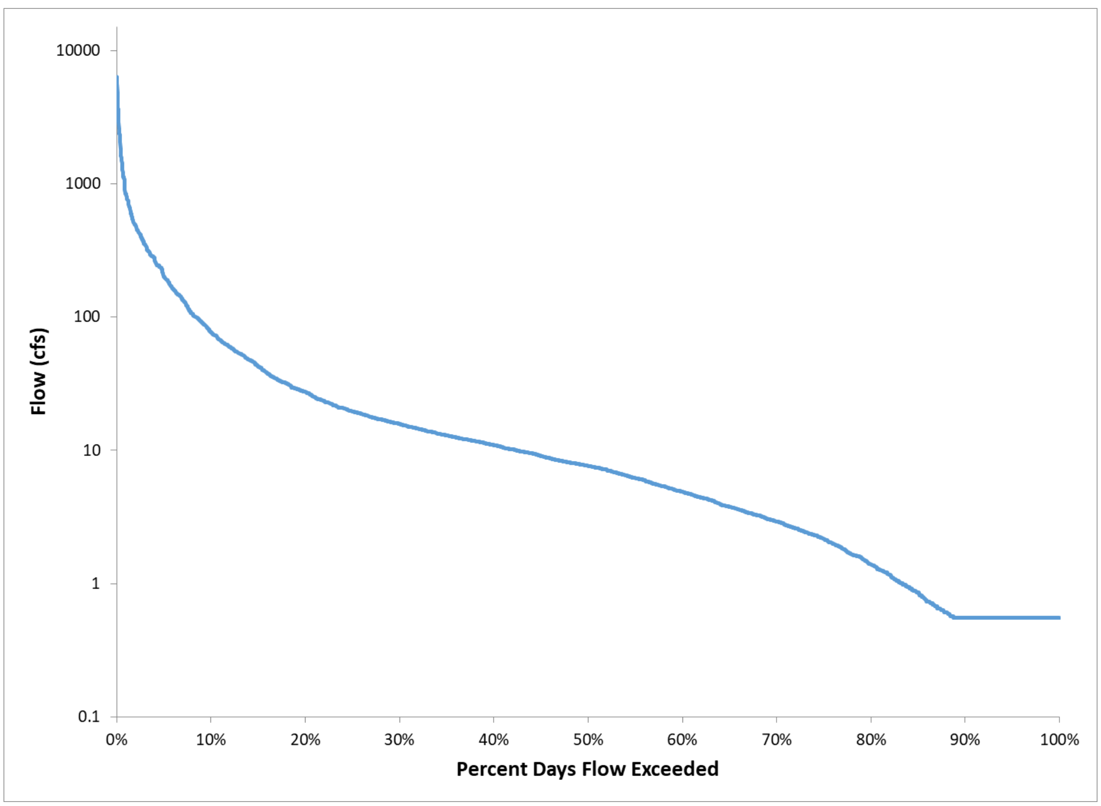

Figure 13. Flow duration curve for Spring Branch AU 1010C_01 (Station 20451).

3.5 Load Duration Curves for the Sampling Stations within the TMDL Watersheds

A LDC was developed for each monitoring station within the TMDL watersheds (Figures 14 and 15). 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 curves. This approach can assist in determining streamflow conditions under which exceedances are occurring. A commonly used set of regimes that is provided in Cleland (2003) is based on the following five intervals along the x-axis of the FDCs and LDCs: (1) 0-10 percent (high flows); (2) 10-40 percent (moist conditions); (3) 40-60 percent (mid-range flows); (4) 60-90 percent (dry conditions); and (5) 90-100 percent (low flows).

For the TMDL watersheds, streamflow distribution was divided into three flow regimes: Wet, Moderate, and Dry conditions, which maintains consistency with the previously completed TMDLs (TCEQ, 2011 and 2013). 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 LDC with these three flow regimes for monitoring stations are provided in Figures 14 and 15, and were constructed for developing the TMDL allocation for each of the TMDL watersheds. Geometric mean loadings for the data points within each flow regime have also been distinguished on each figure to aid interpretation. The LDC for the water quality monitoring station provides a means of identifying the streamflow conditions under which exceedances in *E. co*li 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 station 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 (TCEQ water quality parameter code 72053) 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 ≤ 2 days was defined as a wet weather event. Note that a wet weather event can be indicated even under low flow conditions as a result of 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 for station 20463 (Brushy Creek) in Figure 14 show a subtle pattern of increasing tendency for the *E. coli* event data to plot below the geometric mean criterion allowable loading curve as flows decrease, which is indicated in a left to right direction along the graph. This pattern is more noticeable for station 20451 (Spring Branch) as revealed in Figure 15. This pattern of decreasing occurrence of exceedances in the event data are summarized by the geometric means of the existing data plotted for each of the three flow regimes as compared to the allowable load line for the geometric mean criterion.

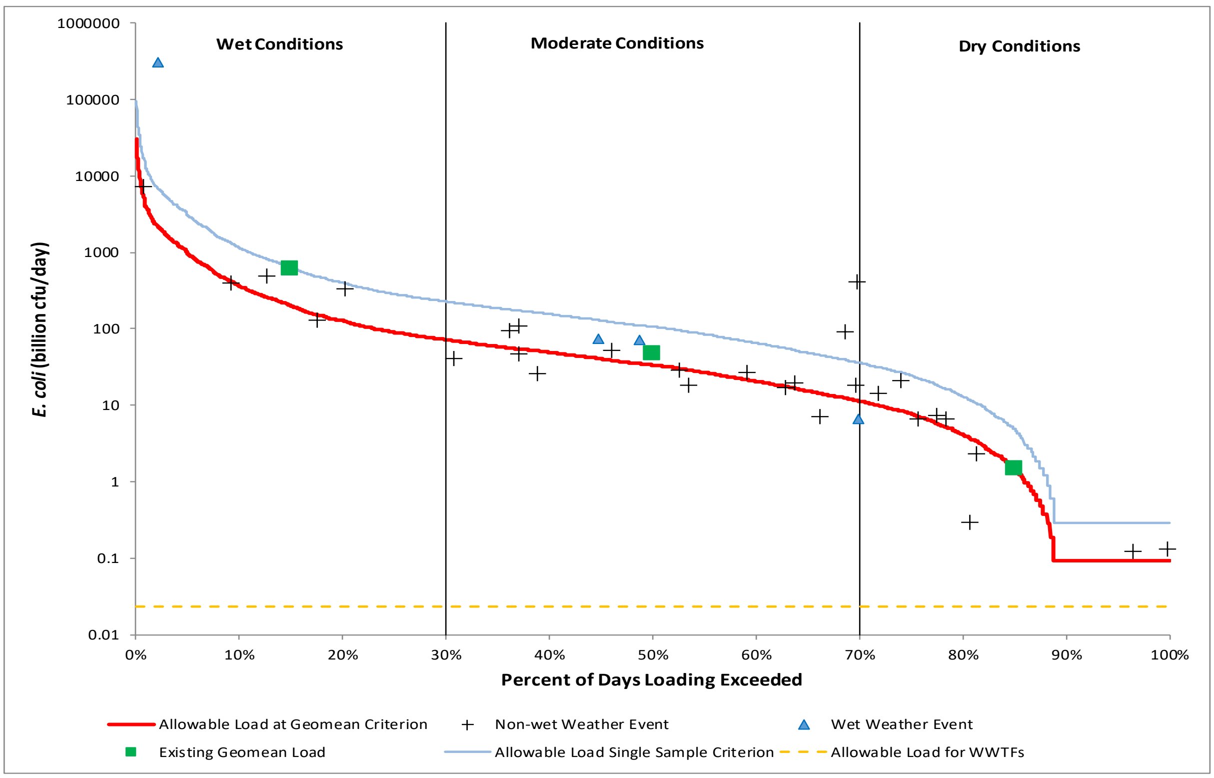

Figure 14. LDC for Brushy Creek AU 1008J_01 (Station 20463)

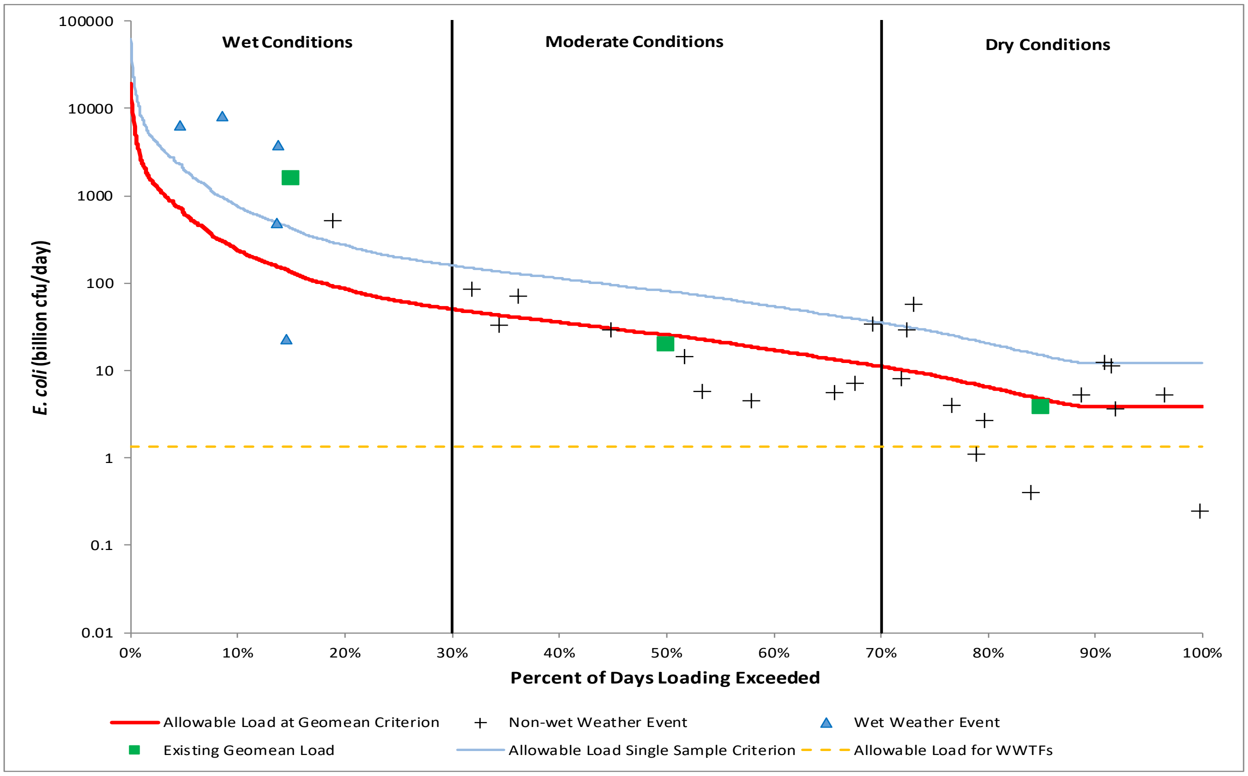

Figure 15. LDC for Spring Branch AU 1010C_01 (Station 20451)

SECTION 4
TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocations for the Brushy Creek and Spring Branch watersheds. The tool used for developing TMDL allocations was the LDC method previously described in Section 3– Bacteria Tool Development. Endpoint identification, margin of safety (MOS), load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The LDC method provided a flow-based approach to determine necessary reductions in bacteria loadings and allowable loadings within the two TMDL watersheds. As developed previously in this report, the LDC method uses frequency distributions to assess a bacteria criterion over the historical range of flows, providing a means to determine maximum allowable loadings and the load reduction necessary to achieve support of the primary contact recreation use.

For the purposes of this TMDL study, the TMDL watershed is considered to be the entire Brushy Creek watershed (AU 1008A_01) and Spring Branch watershed (AU 1010C_01) as shown in the overview map (Figure 1). An adequate amount of data from only one SWQM station in each watershed was available for TMDL development; therefore, TMDL calculations are based on the location of the SWQM station 20463 within the Brushy Creek watershed and station 20451 located within the Spring Branch watershed.

Additionally, a DAR approach using historical streamflow records from a nearby USGS gauge on Bear Branch was employed to estimate the daily flow for each station within the TMDL watersheds.

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 Brushy Creek and Spring Branch watersheds have a use of primary contact recreation, which is measured against a numeric criterion for the indicator bacteria *E. coli*. Indicator bacteria are not generally pathogenic and are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. The *E. coli* criterion to protect contact recreation in freshwater streams consists of a geometric mean concentration not to exceed 126 cfu/100 mL (TCEQ, 2010).

The endpoint for this TMDL is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 cfu/100 mL. This endpoint is identical to the geometric mean criterion in the 2010 Surface Water Quality Standards (TCEQ, 2010).

4.2 Seasonality

Seasonal variations or seasonality occur(s) when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* concentrations obtained from ten years (2009 – 2018) of routine monitoring collected in the warmer months (April – September) against those collected during the cooler months (October – March). Differences in *E. coli* concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the natural log transformed dataset. 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 either Brushy Creek AU 1008_01 (α=0.1674) or Spring Branch AU 1010C_01 (α=0.3029).

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 fecal material 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, has the capacity to carry indicator bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of lower concentrations in the water body just before the rain event, followed by a rapid increase in bacteria 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 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 one-to-one relationship between instream loadings and loadings originating from point sources and the landscape as regulated and non-regulated sources. Further, this one-to-one relationship was also inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7).

4.4 Load Duration Curve Analysis and Results

A LDC method was used to examine the relationship between instream water quality, the broad sources of indicator bacteria load, and are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. LDCs are 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. The USEPA supports the use of the basic LDC approach to characterize pollutant sources. In addition, many other states are using this basic method to develop TMDLs. As discussed in more detail in Section 4.7 (Pollutant Load Allocation), the TMDL loads were based on the median flow within the Wet Conditions flow regime (or 15 percent flow), where exceedances to the primary contact recreation criteria are most pronounced.

The LDC method allows for estimation of existing and TMDL loads by utilizing 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 graphs (Figures 14 and 15) and Section 2.7 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. For the TMDL watersheds, the historical *E. coli* data indicate that elevated bacteria loadings occur under all three flow regimes. There is some moderation of the elevated loadings under moderate and dry conditions for the Brushy Creek watershed. This trend is more evident in the Spring Branch watershed (Figure 15). On Figures 14 and 15, the geometric means of the measured data for each flow regime generally support these observations of decreasing concentration with decreasing flow.

4.5 Margin of Safety

The 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 USEPA guidance (USEPA, 1991), the MOS can be incorporated into the TMDL using two methods:

1) Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
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 a margin of safety. The TMDLs in this report incorporate an explicit MOS of five percent.

4.6 Load Reduction Analysis

While the TMDLs for the Brushy Creek and Spring Branch watersheds were developed using LDCs and associated load allocations, additional insight may, in certain situations, be gained through a load reduction analysis. A single percent 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 the monitoring station within the impaired water body.

For each flow regime the percent 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. Percent reduction calculations for stations within the water bodies of the TMDL watersheds.

Watershed (Monitoring Station)	AU	Wet Conditions (0-30%)		Moderate Conditions (30-70%)		Dry Conditions (70-100%)	
		Geometric Mean (cfu/100mL)	Required Percent Reduction	Geometric Mean (cfu/100mL)	Required Percent Reduction	Geometric Mean (cfu/100mL)	Required Percent Reduction
Brushy Creek (20463)	1008J_01	386	67.4%	178	29.2%	118	0%
Spring Branch (20451)	1010C_01	1,451	91.3%	95	0%	98	0%

4.7 Pollutant Load Allocation

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:

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

Where:

TMDL = total maximum daily load

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

As stated in 40 CFR, §130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. 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 AU-Level TMDL Calculations

The bacteria TMDL for each of the TMDL water bodies was developed as a pollutant load allocation based on information from the LDC for the monitoring stations located within the TMDL watersheds (Figures 14 and 15). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the flow duration curve 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 percent exceedance (the median value of the wet conditions-flow regime) is the TMDL:

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

Where:

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

Conversion Factor (to billion cfu/day) = (283.1685 100 mL/ft^3 * 86,400 sec/day)/1.0E+9

The allowable loading of *E. coli* that the impaired watersheds can receive on a daily basis was determined using Equation 2 based on the median value within the high flows regime of the FDC (or 15 percent flow exceedance value) for the monitoring stations (Table 13).

Table 13. Summary of allowable loading calculations for Brushy Creek (AU 1008J_01) and Spring Branch (AU 1010C_01).

Water Body	AU	15% Exceedance Flow (cfs)	15% Exceedance Load (Billion cfu/day)	TMDL (Billion cfu/day)
Brushy Creek	1008J_01	65.078	200.615	200.615
Spring Branch	1010C_01	43.601	134.408	134.408

4.7.2 Margin of Safety

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

MOS = 0.05 * TMDL (Eq. 3)

Where:

MOS = margin of safety load

TMDL = total maximum daily load

Using the values of TMDL for each AU provided in Table 12, the MOS may be readily computed by proper substitution into Equation 3 (Table 14).

Table 14. MOS calculations for the Brushy Creek and Spring Branch watersheds.

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

Water Body	AU	TMDL[a]	MOS
Brushy Creek	1008J_01	200.615	10.031
Spring Branch	1010C_01	134.408	6.720

[a] TMDL from Table 13.

4.7.3 Wasteload Allocation

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

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

TPDES-permitted wastewater treatment facilities are allocated a daily wasteload (WLA_{WWTF}) 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/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:

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

Where:

Target= 63 cfu/100 mL

Flow = full permitted flow (MGD)

Conversion Factor (to billion cfu/day) = 37,854,000 mL/MGD

The daily allowable loading of *E. coli* assigned to WLA_{WWTF} was determined based on the combined full permitted flow of the permitted WWTFs within each TMDL watershed, using equation 5. Table 15 presents the wasteload allocation for each WWTF and the resulting total allocation for the AUs within the TMDL watersheds.

Stormwater discharges from MS4, industrial, and construction areas are considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading. The percentage of the land area included in the TMDL watersheds 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}.

Table 15. Wasteload allocations for TPDES-permitted facilities in the TMDL watersheds.

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

Watershed (AU)	TPDES Permit No.	NPDES Permit No.	Facility	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{WWTF}
Brushy Creek (AU 1008J_01)	WQ0015500001	TX0137251	Mike Emmons Development WWTF	0.0095	0.023
Spring Branch (AU 1010C_01)	WQ0015349001	TX0136263	Ponderosa Pines WWTF	0.075	0.179
Spring Branch (AU 1010C_01)	WQ0015742001	TX0138860	Oakmont Reserve WWTF	0.495	1.180

[a] Full Permitted Flow from Table 4.

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

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \qquad \text{(Eq. 6)}$$

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

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 2.7.1.5, a search for all five categories of stormwater general permits was performed. The search results are presented in Table 16.

A portion of the Brushy Creek watershed lies within the jurisdiction of one MS4 phase II permit. Two multi-sector general permits and five construction permits exist within the Spring Branch watershed. The area associated with the 2010 Houston urbanized area located within the Brushy Creek watershed provides stormwater coverage for Brushy Creek. For Spring Branch, the acreage associated with the two industrial storm water permits was estimated by importing the location information associated with the facility into a Geographic Information System (GIS), and measuring the estimated disturbed area based on the most recently available aerial imagery. Additionally, the areas disturbed associated with each of the five construction permits within the Spring Branch watershed was summed. The combined areas of the industrial and construction stormwater permits provides stormwater coverage for Spring Branch.

Table 16. Stormwater General Permit areas and calculation of the FDA_{SWP} term for the Brushy Creek (AU 1008J_01) and Spring Branch watersheds (AU 1010C_01).

Waterbody	AU	MS4 General Permit (acres)	Multi-sector General Permit (acres)	Construction Activities (acres)	Concrete Production Facilities (acres)	Petroleum Bulk Stations (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
Brushy Creek	1008J_01	1,332	-	-	-	-	1,332	31,508	0.0423
Spring Branch	1010C_01	-	411	448	-	-	859	22,969	0.0374

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. In order to calculate the WLA_{SW} (Eq. 6), the FG term must be known. The calculation for the FG 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 for the Brushy Creek and Spring Branch watersheds.

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

Waterbody	AU	TMDL[a]	WLA_{WWTF}[b]	FG[c]	MOS[d]	FDA_{SWP}[e]	WLA_{SW}[f]
Brushy Creek	1008J_01	200.615	0.023	0.045	10.031	0.0423	8.059
Spring Branch	1010C_01	134.408	1.359	1.130	6.720	0.0374	4.682

[a] TMDL from Table 13

[b] WLA_{WWTF} from Table 15

[c] FG from Table 18

[d] MOS from Table 14

[e] FDA_{SWP} from Table 16

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

4.7.4 Future Growth

The FG component of the TMDL equation addresses the requirement of TMDLs to account for future loadings that may occur because of population growth, changes in community infrastructure, and development. The assimilative capacity of streams increases as the amount of flow increases due to future growth of permitted discharges. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

The allowance for future growth will result in protection of existing beneficial uses and conform to Texas's antidegradation policy.

While the FG allowance is often computed for bacteria TMDLs using information from existing WWTF permits, it is not intended to restrict any future assignments of the allocation solely to expansions at these facilities. Rather, the future growth allocation is purposed for any new facilities that may occur and expansions of existing facilities. This definition of future growth is relevant as one WWTF has been proposed for development within the Spring Branch watershed. The proposed facility was still in the permit application/review phase of the permitting process at the time of this report with very limited information available; however, preliminary data indicate an effluent discharge rate of 0.5 MGD for this facility.

The future growth component of the TMDL watersheds was based on population projections and current permitted wastewater dischargers for the entire TMDL watersheds. Recent population and projected population growth between 2010 and 2040 for the TMDL watersheds are provided in Table 1. The projected population percentage increase within the watershed was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. The permitted flows were increased by the expected population growth per AU between 2010 and 2040 to determine the estimated future flows.

Thus, the FG is calculated as follows:

$$FG = WWTF_{FP} * POP_{2010\text{-}2040} * \text{conversion factor} * \text{target} \qquad \text{(Eq. 7)}$$

Where:

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

$POP_{2010\text{-}2040}$ = estimated percent increase in population between 2010 and 2040

Conversion factor = (37,854,000 100mL/MGD)/1.0E+9

Target = 63 cfu/100 mL

Additionally, to allow for future growth expansion specific to the Spring Branch watershed, 0.5 MGD was added directly to the computed "Future Growth (MGD)" flow to account for the proposed facility's flow. The calculation results for the impaired TMDL watersheds are shown in Table 18.

Table 18. Future Growth calculations for the Brushy Creek (AU 1008J_01) and Spring Branch (AU 1010C_01) watersheds.

Waterbody	AU	Full Permitted Flow (MGD)	% Population Increase (2010-2040)	Future Growth (MGD)	Future Growth (*E. coli* Billion cfu/Day)[a]
Brushy Creek	1008J_01	0.0095	202.6%	0.019	0.045
Spring Branch	1010C_01	0.57	83.1%	0.474	1.130

[a] $FG = WWTF_{FP} * POP_{2010\text{-}2040} * \text{conversion factor} * \text{target}$ (Eq. 7)

4.7.5 Load Allocation

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

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

Where:

LA = allowable loads from unregulated sources within the AU

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. Load allocation calculations for the Brushy Creek (AU 1008J_01) and Spring Branch (AU 1010C_01) watersheds.

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

Waterbody	AU	TMDL[a]	WLA_{WWTF}[b]	WLA_{SW}[c]	FG[d]	MOS[e]	LA[f]
Brushy Creek	1008_01	200.615	0.023	8.059	0.045	10.031	182.457
Spring Branch	1010C_01	134.408	1.359	4.682	1.130	6.720	120.517

[a] TMDL from Table 13

[b] WLA_{WWTF} from Table 15

[c] WLA_{SW} from Table 17

[d] FG from Table 18

[e] MOS from Table 14

[f] LA = TMDL – WLA_{WWTF} – WLA_{SW} – FG – MOS (Eq. 8)

4.8 Summary of TMDL Calculations

Table 20 summarizes the TMDL calculations for the TMDL watersheds. The TMDLs were calculated based on the median flow in the 0-30 percentile range (15 percent exceedance, Wet Conditions flow regime) for flow exceedance from the LDC developed for the SWQM stations 20463 (Brushy Creek) and 20451 (Spring Branch). Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 20. TMDL allocation summary for Brushy Creek AU 1008J_01 and Spring Branch AU 1010C_01.

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

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	WLA_{SW}[c]	LA[d]	FG[e]	MOS[f]
Brushy Creek	1008J_01	200.615	0.023	8.059	182.457	0.045	10.031
Spring Branch	1010C_01	134.408	1.359	4.682	120.517	1.130	6.720

[a] TMDL = from Table 13

[b] WLA_{WWTF} = from Table 15

[c] WLA_{SW} = from Table 17

[d] LA = from Table 19

[e] FG = From Table 18

[f] MOS = from Table 14

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

In the event that the criterion changes due to future revisions in the state's surface water quality standards, Appendix A provides guidance for recalculating the allocations in Table 21. Figures A-1 through A-2 and Tables A-1 through A-2 of Appendix A were developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for *E. coli*. The equations provided, along with Figures A-1 through A-2 and Tables A-1 through A-2 allow calculation of new TMDLs and pollutant load allocations based on any potential new water quality criterion for *E. coli*.

Table 21. Final TMDL allocations for the Brushy Creek (AU 1008J_01) and Spring Branch (AU 1010C_01) watersheds.

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

Water Body	AU	TMDL	WLA_{WWTF} [a]	WLA_{SW}	LA	MOS
Brushy Creek	1008J_01	200.615	0.068	8.059	182.457	10.031
Spring Branch	1010C_01	134.408	2.489	4.682	120.517	6.720

[a] WLA_{WWTF} = WLA_{WWTF} includes the FG component

Section 5
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APPENDIX A
EQUATIONS FOR CALCULATING TMDL ALLOCATIONS FOR CHANGED CONTACT RECREATION STANDARD

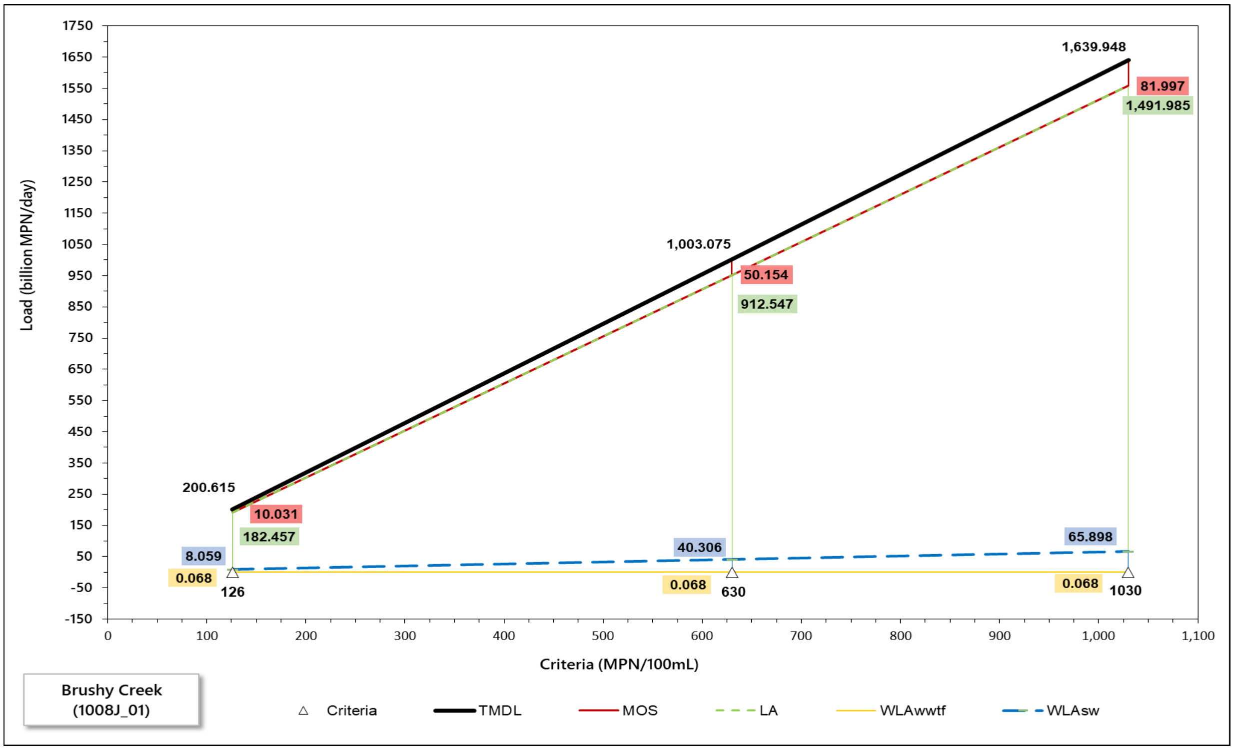

Figure A-1. Allocation loads for the Brushy Creek watershed (AU 1008J_01) as a function of water quality criteria

Equations for calculating new TMDL and allocations (in billion cfu/day)

TMDL = 1.59218250 * Std

MOS = 0.07960840 * Std + 0.0004434

LA = 1.44859267 * Std - 0.0659434

WLA_{WWTF} = 0.068

WLA_{SW} =0.06398120 * Std - 0.0024953

Where:

Std = Revised Contact Recreation Standard

MOS = Margin of Safety

LA = Total load allocation (unregulated sources)

WLA_{WWTF} = Wasteload allocation (permitted WWTF load + future growth)

WLA_{SW} = Wasteload allocation (permitted stormwater)

Table A-1 TMDL allocations for the Brushy Creek watershed for potential changed contact recreation standards.

Units expressed as billion cfu/day *E. coli* except contact recreation criterion

Contact Recreation Criterion (cfu/100 mL)	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
126	200.615	0.068	8.059	182.457	10.031
630	1,003.075	0.068	40.306	912.547	50.154
1,030	1,639.948	0.068	65.898	1,491.985	81.997

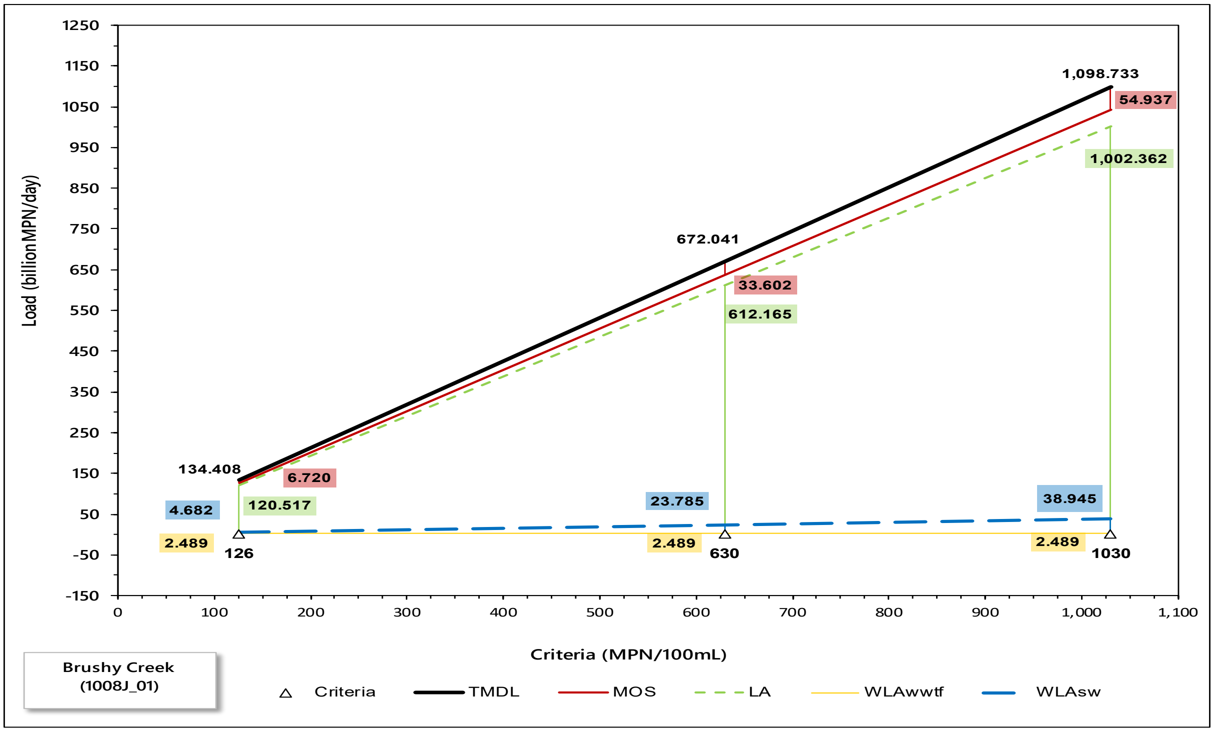

Figure A-2. Allocation loads for the Spring Branch watershed (AU 1010C_01) as a function of water quality criteria

Equations for calculating new TMDL and allocations (in billion cfu/day)

TMDL = 1.0667312 * Std
MOS = 0.0533374 * Std - 0.0005236
LA = 0.975492248 * Std - 2.3950519
WLA_{WWTF} = 2.489
WLA_{SW} =0.037901601 * Std - 0.0934

Where:

Std = Revised Contact Recreation Standard
MOS = Margin of Safety
LA = Total load allocation (unregulated sources)
WLA_{WWTF} = Wasteload allocation (permitted WWTF load + future growth)
WLA_{SW} = Wasteload allocation (permitted stormwater)

Table A-2 TMDL allocations for the Spring Creek watershed for potential changed contact recreation standards.

Units expressed as billion cfu/ day *E. coli* except contact recreation criterion

Contact Recreation Criterion (cfu/100 mL)	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
126	134.408	2.489	4.682	120.517	6.720
630	672.041	2.489	23.785	612.165	33.602
1,030	1,098.733	2.489	38.945	1,002.362	54.937