Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Camp Meeting Creek

Assessment Unit: 1806A_01

Camp Meeting Creek upstream from Monroe Drive, June 2020.
Photo provided by Tara Bushnoe at the Upper Guadalupe River Authority.

By Stephanie Brady, Israel Olaoye, and Jimmy Millican
Texas Institute for Applied Environmental Research,
Tarleton State University

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P.O. Box 13087
Austin, Texas 78711-3087

Prepared by:
Stephanie Brady
Israel Olaoye
Jimmy Millican
Texas Institute for Applied Environmental Research
Tarleton State University
Stephenville, Texas

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As with the 2018 addendum to add TMDLs for Quinlan Creek and Town Creek, Ms. Tara Bushnoe at the Upper Guadalupe River Authority willingly provided information important to the development of this report. The guidance and thorough review of the draft versions of this report by the TCEQ Project Manager, Mr. Jason Leifester, were also important in developing this report.

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Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming unit
CGP	Construction General Permit
DAR	drainage-area ratio
DMU	Deer Management Unit
ECHO	Enforcement and Compliance History Online
E. coli	*Escherichia coli*
EPA	(United States) Environmental Protection Agency
FDA_{SWP}	fractional drainage area stormwater permit
FDC	flow duration curve
FG	future growth
gpcd	gallons per capita per day
IRNR	Texas A&M Institute of Renewable Natural Resources
I&I	inflow and infiltration
LA	load allocation
LDC	load duration curve
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	Multi-Sector General Permit
NEIWPCC	New England Interstate Water Pollution Control Commission
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic database
SWMP	stormwater management program
SWQM	surface water quality monitoring
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TMDL	total maximum daily load
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board

USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from 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 its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units in mass per period of time but may be expressed in other ways.

The TMDL Program is a major component of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The program's primary objective is to restore and maintain 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 Camp Meeting Creek in the 2018 *Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report, TCEQ, 2019). The bacteria impairment was identified again in the 2020 Texas 303(d) List, the latest United States Environmental Protection Agency (EPA)-approved (TCEQ, 2020a) edition.

This document will consider one bacteria impairment in one assessment unit (AU) of Camp Meeting Creek. The impaired water body and identifying AU number is:

- Camp Meeting Creek 1806A_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, 2018b). The Standards describe the limits for indicators that are monitored to assess the quality of available water for specific uses. TCEQ monitors and assesses water bodies based on these Standards and publishes the Texas Integrated Report list biennially.

The Standards are rules that do all of the following:

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

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

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

Fecal indicator bacteria are used to assess the risk of illness during contact recreation (e.g., swimming) from ingestion of water. Fecal indicator bacteria are 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 wastes may be reaching water bodies, because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2018a). The fecal indicator bacteria used for freshwater in Texas is *Escherichia coli* (*E. coli*), a species of fecal coliform bacteria.

On February 7, 2018, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2018b) and on May 19, 2020, 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.

Camp Meeting Creek is a freshwater stream and has a primary contact recreation 1 use. The associated criterion for *E. coli* is a geometric mean of 126 cfu per 100 mL.

1.3. Report Purpose and Organization

The Camp Meeting Creek TMDL project was initiated through a contract between TCEQ and the 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 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) listing 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 for Camp Meeting Creek AU 1806A_01 were consistent with the previously approved bacteria TMDL for the Guadalupe River Above Canyon Lake (TCEQ, 2007) adopted by TCEQ on July 25, 2007, and approved by EPA on September 25, 2007. Analyses were also consistent with Addendum One to the 2007 TMDL: *Two Total Maximum Daily Loads for Indicator Bacteria in Quinlan Creek and*

Town Creek approved by TCEQ in January of 2018 and approved by the EPA on May 8, 2018 (TCEQ, 2018c). Figure 1 shows the Camp Meeting Creek watershed within the Guadalupe River Above Canyon Lake watershed from the original TMDL project.

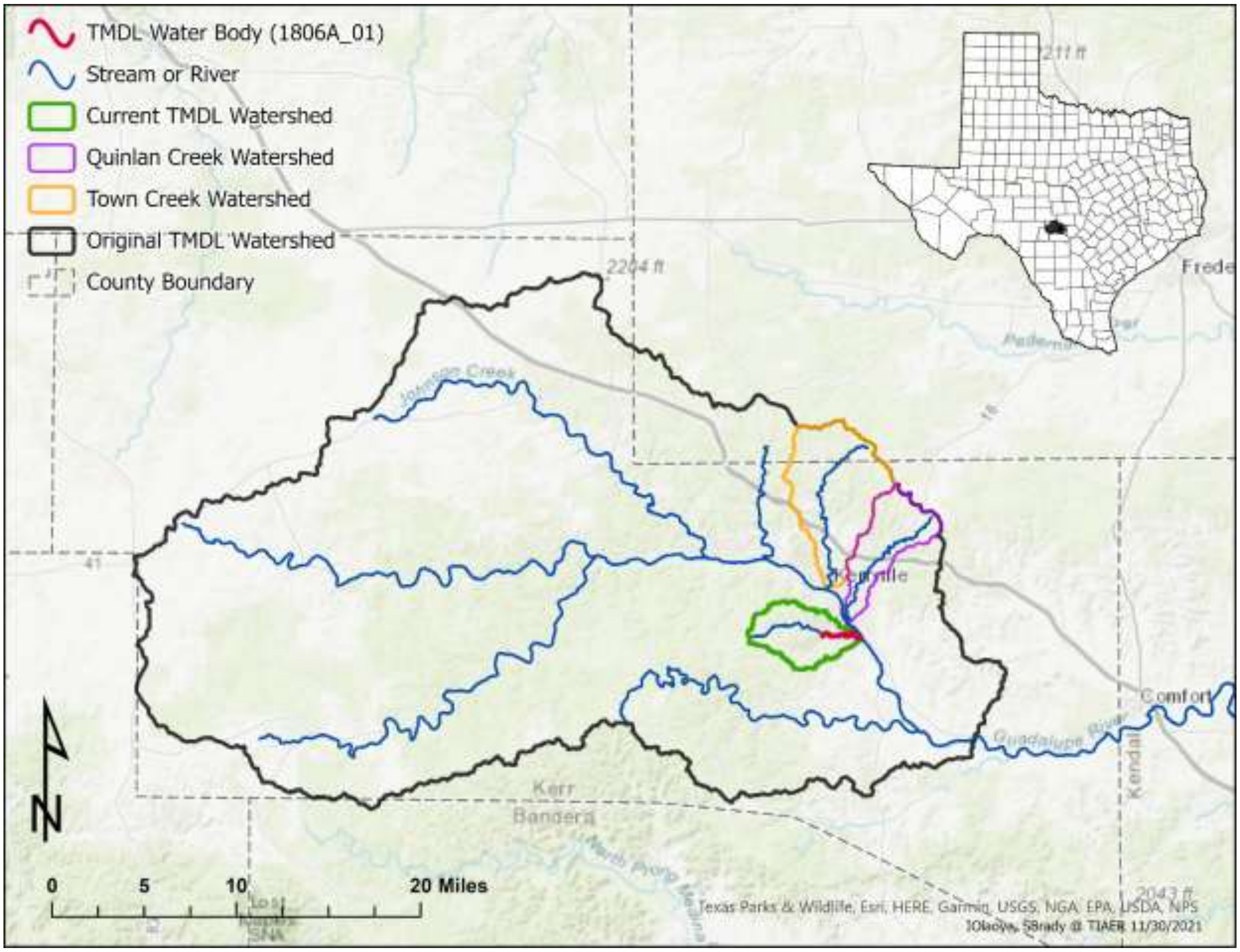

Figure 1. Map showing the previously approved TMDL and addendum watersheds in relation to the Camp Meeting Creek AU 1806A_01 watershed added by this addendum

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Camp Meeting Creek Watershed

Camp Meeting Creek (1806A) is a tributary of the Upper Guadalupe River above Canyon Lake (1806). The creek is an unclassified, freshwater stream composed of three AUs (from downstream to upstream: 1806A_01, 1806A_02, 1806A_03), all of which have a flow type of "Intermittent with pools" (TCEQ, 2020a) (Figure 2). Camp Meeting Creek is approximately 6.7 miles long; the impaired AU 1806A_01 is approximately 2.5 miles long. Camp Meeting Creek flows into the Guadalupe River in Kerrville, and at its mouth, drains an area of 10.22 square miles in Kerr County.

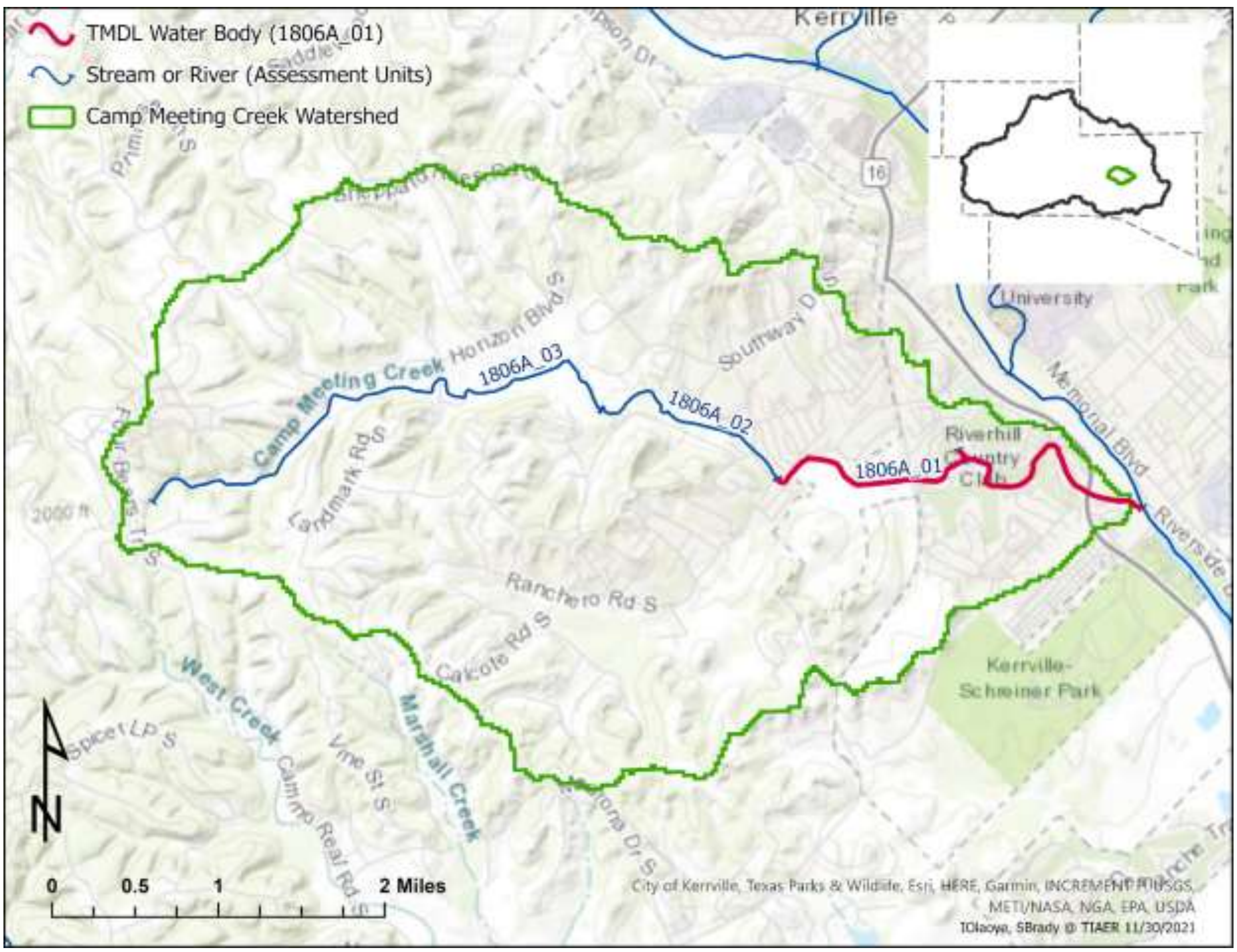

Figure 2. Map showing the Camp Meeting Creek AU 1806A_01 watershed

The water body and AU descriptions for Camp Meeting Creek have been updated since the publication of the 2020 Texas Integrated Report (TCEQ, 2020a). The updated descriptions are (TCEQ, 2020b):

- 1806A (Camp Meeting Creek) – From the confluence with the Guadalupe River up to the headwaters at Bear Skin Trail southwest of Kerrville in Kerr County.
  - AU 1806A_01 – From the confluence with the Guadalupe River upstream to the dam on an unnamed impoundment located 0.33 kilometers (km) downstream of Ranchero Road in the City of Kerrville.
  - AU 1806A_02 – From the dam on the unnamed impoundment located 0.33 km downstream of Ranchero Road in the City of Kerrville upstream to the dam on an unnamed impoundment approximately 0.65 km upstream of Tree Lane in the City of Kerrville.
  - AU 1806A_03 – From the dam of an unnamed impoundment approximately 0.65 km upstream of Tree Lane in the City of Kerrville up to the headwaters at Bear Skin Trail southwest of Kerrville in Kerr County.

The TMDL watershed includes the complete drainage area of all three AUs of Camp Meeting Creek. Throughout the document, the terms “TMDL watershed” and “Camp Meeting Creek watershed” are used interchangeably.

2.2. Review of Routine Monitoring Data for the TMDL Watershed

2.2.1. Analysis of Bacteria Data

Surface water quality monitoring has been done within the TMDL watershed at TCEQ surface water quality monitoring (SWQM) Station 12546 (Figure 3). *E. coli* data collected at SWQM Station 12546 on Camp Meeting Creek over the seven-year period of December 1, 2011, through November 30, 2018, were used in assessing attainment of the primary contact recreation 1 use as reported in the 2020 Texas Integrated Report (TCEQ, 2020a) and are summarized in Table 1. The 2020 assessment data for the TMDL watershed shows non-support of the primary contact recreation 1 use because geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 cfu/100 m.

Table 1. 2020 Texas Integrated Report Summary for Camp Meeting Creek

Water Body Name	AU	Parameter	TCEQ Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
Camp Meeting Creek	1806A_01	*E. coli*	12546	67	12/1/2011 – 11/30/2018	262.85

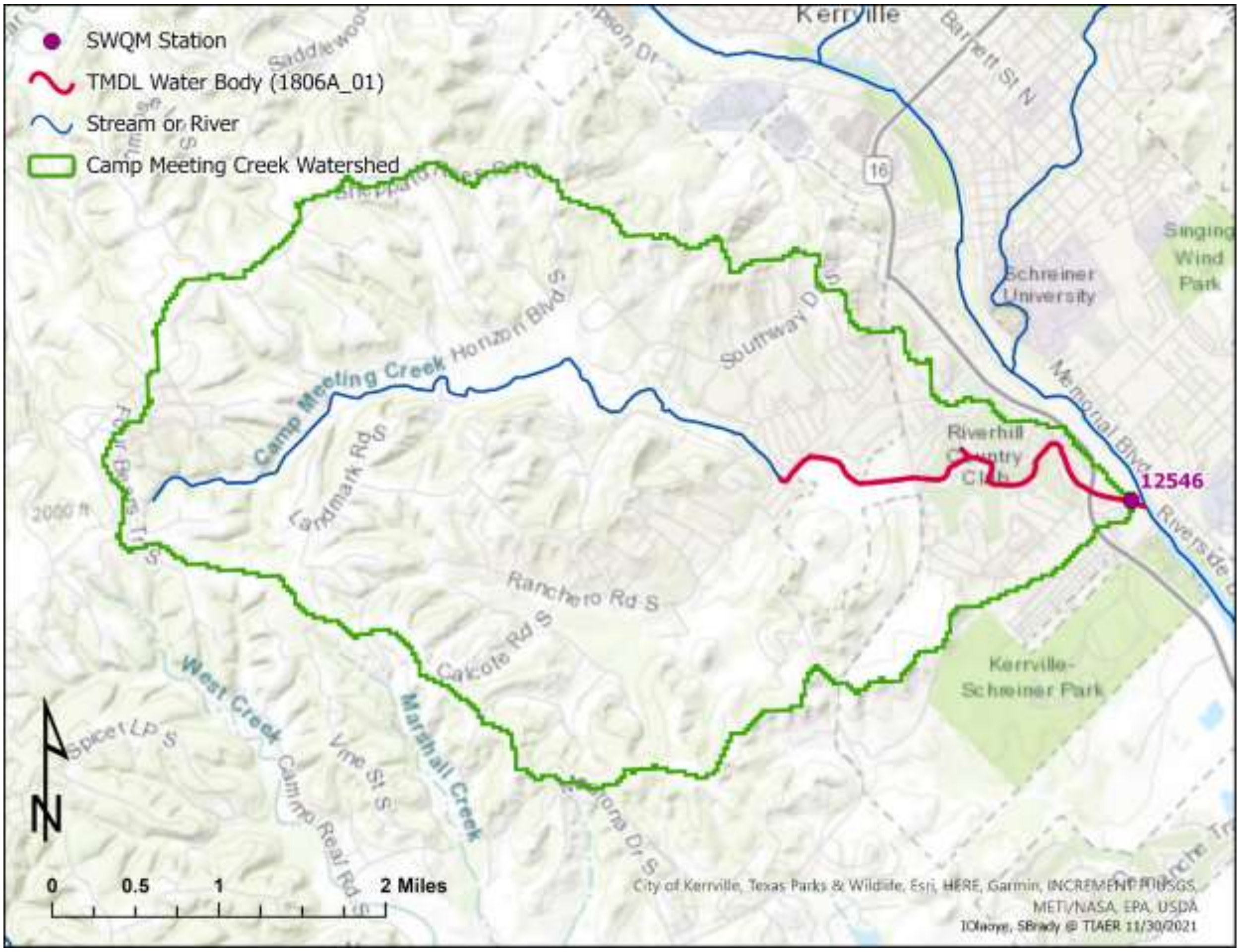

Figure 3. **Map showing the TCEQ SWQM station within the TMDL watershed**

2.3. Climate and Hydrology

The Camp Meeting Creek watershed is in the central portion of Texas, classified as the Subtropical Subhumid climate region (Larkin and Bomar, 1983). As in much of the state, the region's subtropical climate is caused by the "predominant onshore flow of tropical maritime air from the Gulf of Mexico," while the increasing moisture content (from west to east) reflects variations in "intermittent seasonal intrusions of continental air" (Larkin and Bomar, 1983).

Fifteen-year climate normal patterns (2006 – 2020) for the Kerrville 3 NNE weather station (USC00414782) indicate a bimodal precipitation pattern (Figure 4) (NOAA, 2020). Annual rainfall for the selected weather station averages 28.1 inches. The wettest month is typically May (5.3 inches) while the driest month is typically February (1.10 inches). Average high temperatures generally reach their peak of 93.6° F in August, while the average low temperature reaches a minimum of 33.1° F in January.

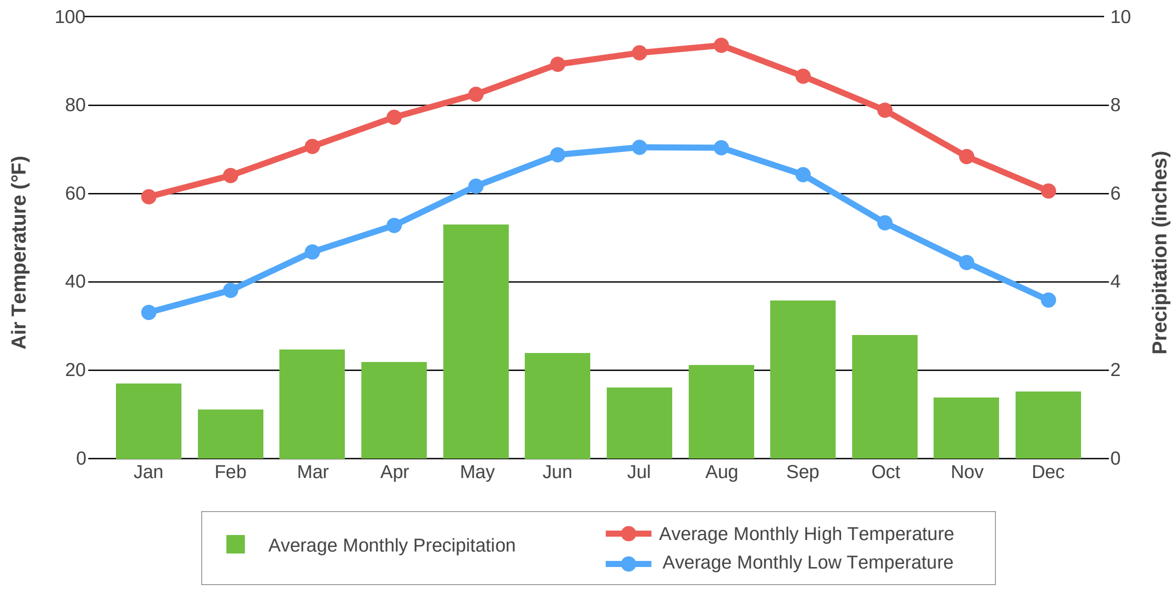

Figure 4. Average monthly air temperature and precipitation by month from 2006 – 2020 for the Kerrville 3 NNE weather station

2.4. Population and Population Projections

According to the 2020 Census (USCB, 2021), there were an estimated 5,417 people in the Camp Meeting Creek watershed, indicating a population density of 530 people/square mile. Approximately 14% of the watershed area (TxDOT, 2020) and 24% of watershed population are located within the Kerrville city limits. Figure 5 shows the population density of the watershed.

Population projections in Table 2 are estimated from the Texas Water Development Board (TWDB) 2021 Regional Water Plan Population and Water Demand Projection data (TWDB, 2019a; TWDB, 2019b). According to the growth projections, population is predicted to increase 10.1% for the Camp Meeting Creek watershed between 2020 and 2050. Additional information on this process can be found in Appendix A.

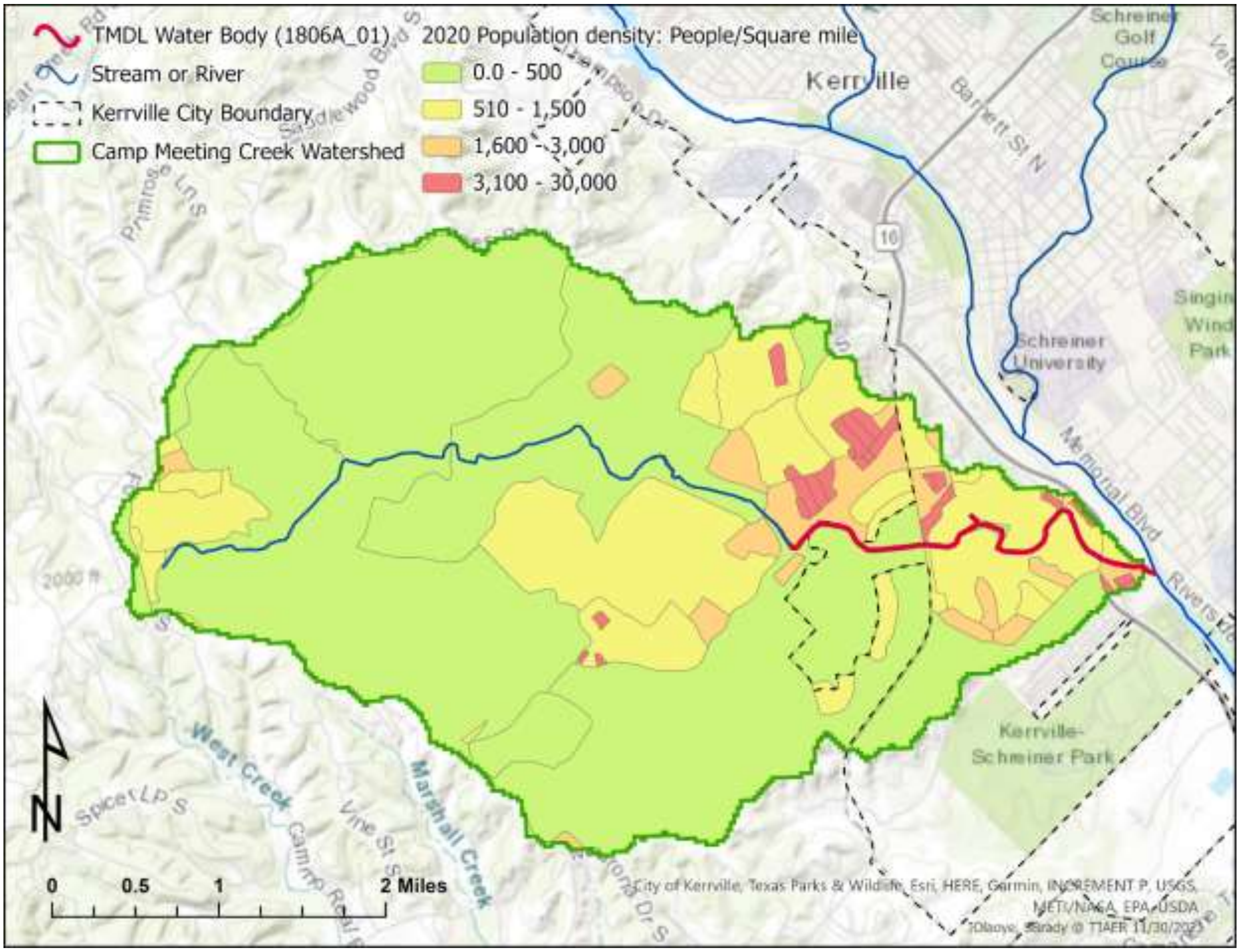

Figure 5. Population density based on 2020 population by census block along with the city of Kerrville boundary

Table 2. 2020 – 2050 Population Projections

Watershed	2020 US. Census	2030 Population Projection	2040 Population Projection	2050 Population Projection	Projected Population Increase	Percentage Change
Camp Meeting Creek	5,417	5,669	5,819	5,966	549	10.1%

2.5. Land Cover

The land cover data presented in this report were obtained from the Multi-Resolution Land Characteristics Consortium 2016 National Land Cover Database (NLCD) (Dewitz, Jon, and USGS, 2021) and are displayed in Figure 6. The land cover is represented by the following categories and definitions:

- Open Water – Areas of open water, generally with less than 25% cover of vegetation or soil.

- 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.
- 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% of total cover.
- Developed, Medium Intensity – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
- Developed, 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.
- 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.
- 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.
- 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.
- 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.
- 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.

As shown in Table 3, the area of the Camp Meeting Creek watershed is approximately 6,540.6 acres. Dominant land uses include Shrub/Scrub and Evergreen Forest (35% and 30%).

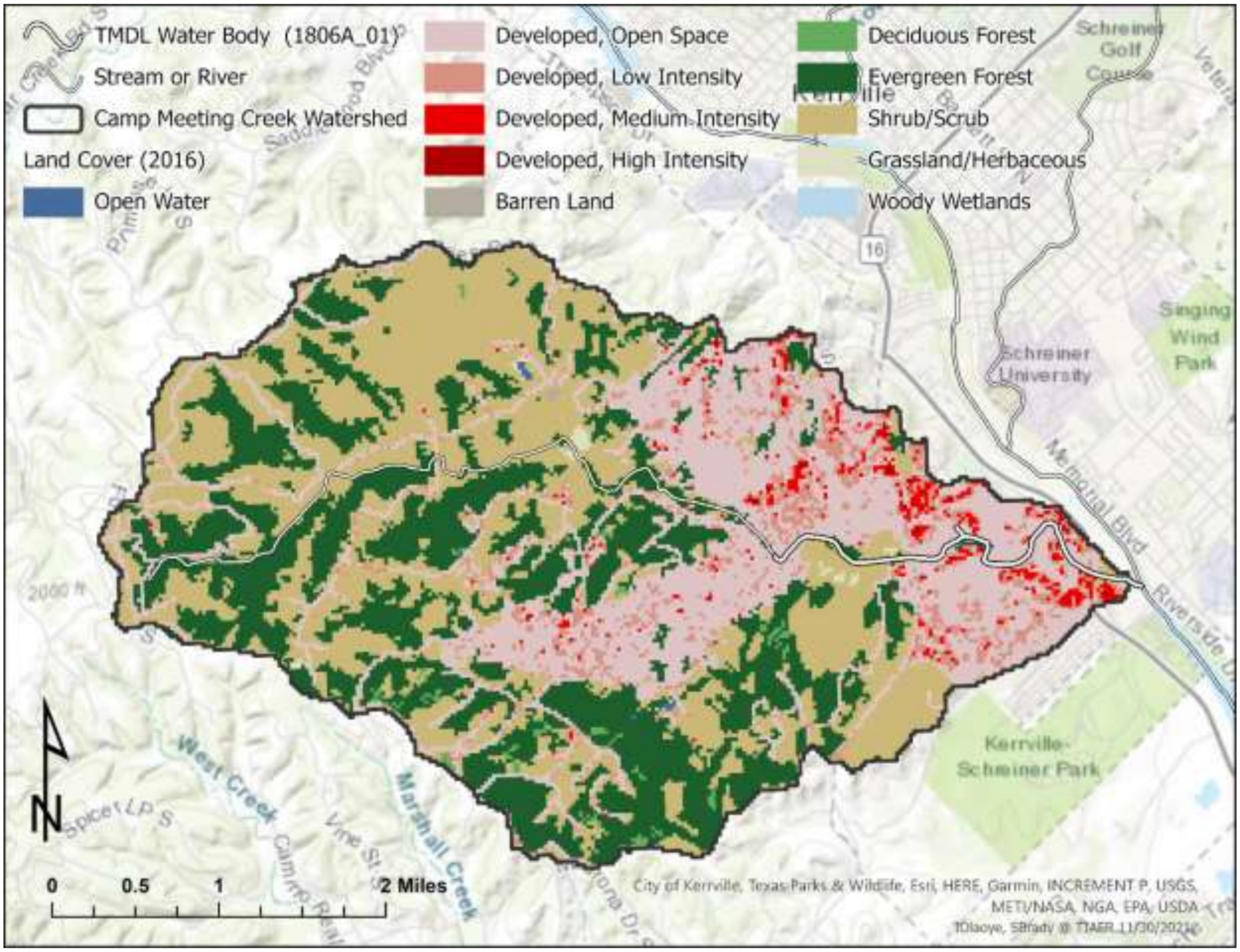

Figure 6. Land cover map showing classifications

Table 3. Land cover by area and percentage

Classification	Area (acres)	Percentage of Total
Open Water	7.6	0.1%
Developed, Open Space	1,691.3	25.9%
Developed, Low Intensity	416.1	6.4%
Developed, Medium Intensity	114.1	1.7%
Developed, High Intensity	9.6	0.1%
Barren Land	2.0	0.0%
Deciduous Forest	42.7	0.7%

Classification	Area (acres)	Percentage of Total
Evergreen Forest	1,960.4	30.0%
Shrub/Scrub	2,278.4	34.8%
Grassland/Herbaceous	18.2	0.3%
Woody Wetlands	0.2	0.0%
Total	**6,540.6**	**100.0%**

2.6. Soils

Soils within the Camp Meeting Creek watershed are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (SSURGO) (USDA NRCS, 2019). The SSURGO data assigns different soils to one of seven possible runoff potential classifications or hydrologic groups. These classifications are based on the estimated rate of water infiltration when soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The four main groups are A, B, C, and D, with three dual classes (A/D, B/D, C/D). The SSURGO database defines the classifications below.

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

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

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

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

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

Geospatial analysis reveals that the Camp Meeting Creek watershed is primarily comprised of Group C and Group D soils, indicating that the soils generally have high runoff potential. Group C and Group D soils comprise 53% and 46% of the watershed, respectively (Figure 7).

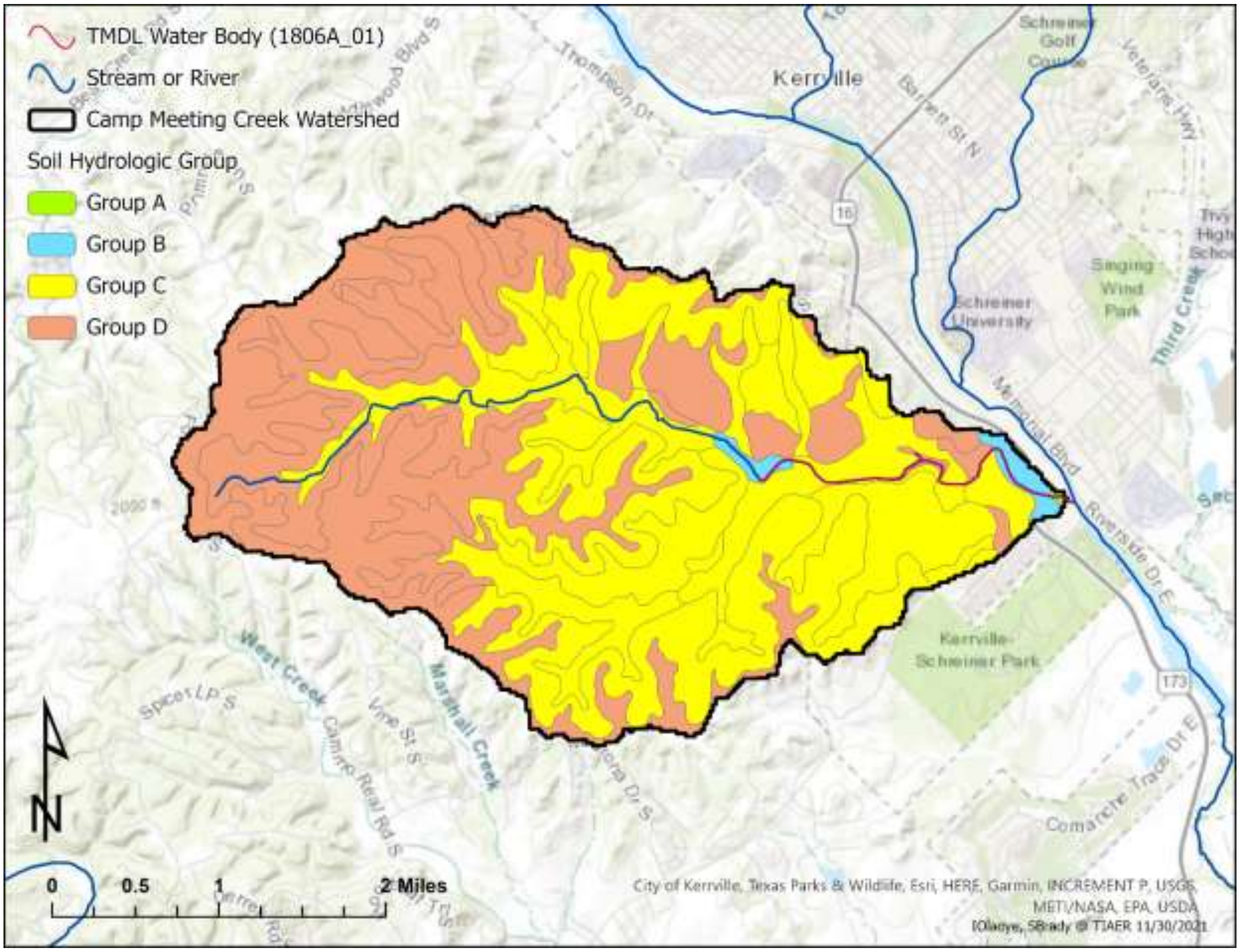

Figure 7. Hydrologic soil group categories

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 industrial sites, regulated construction activities, and the separate storm sewer systems of cities are considered point sources of pollution.

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

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

2.7.1. Regulated Sources

Regulated sources are controlled by permit under the TPDES program. Stormwater discharges from regulated construction sites represent the regulated sources in the TMDL watershed.

2.7.1.1. Domestic and Industrial Wastewater Treatment Facilities

As of June 2021, there were no WWTFs within the Camp Meeting Creek watershed.

2.7.1.2 TPDES General Wastewater Permits

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

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

A review of active general permit coverage (TCEQ, 2021a) in the Camp Meeting Creek watershed as of June 2021 found no operations or facilities of the types described above.

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 activities, and construction activities.
2. Stormwater runoff not subject to regulation.

TPDES MS4 Phase I and II rules require municipalities and certain other entities in urbanized areas to obtain permit coverage for their stormwater systems. A regulated MS4 is a publicly owned system of conveyances and includes ditches, curbs, gutters, and storm sewers that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized MS4s with populations of 100,000 or more based on the 1990 United States Census, while the Phase II General Permit regulates small MS4s within a United States Census Bureau (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 to meet several minimum control measures (MCMs) that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving water bodies. Phase II MS4 MCMs include all of the following:

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

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

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

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

- TXR040000 – Phase II MS4 General Permit for small MS4s located in urbanized areas
- 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

A review of active stormwater general permits coverage (TCEQ, 2021a) in the Camp Meeting Creek watershed as of June 2021 found no Phase I or Phase II MS4 permits and no MSGP authorizations. Three areas were under CGP authorizations; two of those authorizations reference the same site location. The total area disturbed is 30.5 acres; the total area of regulated stormwater is approximately 0.467% of the TMDL watershed.

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 SSOs 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.

The TCEQ Region 13 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. Of the 39 spills that occurred within Kerr County from 2016 through May of 2021, only one spill was determined to have occurred within the TMDL watershed. It is detailed in Table 4.

Table 4. Summary of reported SSO incidents from 2016 through 2021

AU	Number of Incidents	Total Volume in Gallons	Location
1806A_01	1	500	SH 173 bridge over Camp Meeting Creek

2.7.1.5. Dry Weather Discharges/Illicit Discharges

Pollutant loads can enter water bodies from MS4 outfalls that carry authorized sources as well as illicit discharges under both dry- and wet-weather conditions. The term "illicit discharge" is defined in TPDES General Permit TXR040000 for Phase II MS4s as "Any discharge to a municipal separate storm sewer system that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities." Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct Illicit Discharges:

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

Indirect Illicit Discharges:

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

2.7.2. Unregulated Sources

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

2.7.2.1. Wildlife and Unmanaged Animals

Fecal bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify the potential for bacteria contributions from wildlife and feral hogs. Wildlife and feral hogs are attracted naturally to riparian corridors of water bodies. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Wildlife and feral hogs also leave feces on land, where they may be washed into nearby water bodies by rainfall runoff. The *E. coli* contribution from wildlife and feral hogs could not be determined based on existing information.

For feral hogs, the Texas A&M Institute of Renewable Natural Resources (IRNR), recently renamed as the Texas A&M Natural Resources Institute, reported a range of feral hog densities within Texas of 8.9 to 16.4 hogs/square mile (Timmons et al., 2012). The average hog density (12.65 hogs/square mile) was multiplied by the hog-habitat area in the Camp Meeting Creek watershed (6.72 square miles). Habitat deemed suitable for hogs followed as closely as possible to the land use selections of the IRNR study and include from the 2016 NLCD: Deciduous Forest, Evergreen Forest, Shrub/Scrub, Grassland/Herbaceous, and Woody Wetlands. Using this methodology, there are an estimated 85 feral hogs in the Camp Meeting Creek watershed.

For deer, the Texas Parks and Wildlife Department (TPWD) publishes data showing deer population-density estimates by Deer Management Unit (DMU) across the state (TPWD, 2017). Spatial analysis using DMU and white-tailed deer range layers provided by TPWD reveals that the entire 6,541 acres are within DMU 7. The 2015 population density for that area was 7.16 acres/deer, returning an estimated 914 deer within the Camp Meeting Creek watershed.

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 Camp Meeting Creek watershed was estimated from county level data obtained from the 2017 Census of Agriculture (USDA, 2019). The county-level data were refined to better reflect actual numbers within the TMDL watershed. Using the 2016 NLCD, the county numbers were refined by determining the total area of the suitable livestock land cover categories of “Grassland/Herbaceous” and “Hay/Pasture” within the Camp Meeting Creek watershed and Kerr County. A ratio was then computed by dividing the livestock total land use area of the TMDL watershed by the livestock total land use area of the county. The county-level agricultural census data were then multiplied by the ratio to determine the estimated domestic animal populations (Table 5). Only 0.2628% of the livestock acreage within Kerr County is located within the Camp Meeting Creek watershed.

Table 5. Estimated livestock populations

AU	Cattle and Calves	Hogs and Pigs	Poultry	Goats and Sheep	Horses
1806A_01	32	1	111	55	4

Fecal bacteria 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 6 summarizes the estimated number of dogs and cats in the 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 (AVMA) U.S. Pet Statistics (AVMA, 2018). The number of households was estimated using 2020 Census data (USCB, 2021). The actual contribution and significance of bacteria loads from pets is unknown.

Table 6. Estimated households and pet populations

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
1806A_01	2,500	1,535	1,143

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 would be expected to 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 drainfield of a septic system. Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The Camp Meeting Creek watershed is within the Region II area, which has a reported failure rate of about 12%, providing insights into expected failure rates for the area.

Estimates of the number of OSSFs in the Camp Meeting Creek watershed were determined using the 911 building locations that were available through the Texas Natural Resources Information System (TNRIS) (2019). Buildings that were located within the Kerrville city limits were assumed to have sewer collection and were removed from the estimate. Initially, an attempt was made to locate any CCN sewered areas within the watershed (PUC, 2021). Communications with staff at the Upper Guadalupe River Authority revealed an area within the Camp Meeting Creek watershed outside of the Kerrville city limits (in the Extra-Territorial Jurisdiction) where the properties are served by the city wastewater collection system (UGRA, 2021). The new sewer lines (Kerrville Public Works, 2021) were added to the map, and any 911 addresses that were within 40 meters of the sewer lines were removed from the estimate (Figure 8). Data from these sources indicate that there are 1,744 OSSFs within the Camp Meeting Creek watershed. If 12% of the OSSFs were currently failing, that would result in approximately 209 septic systems that may be releasing untreated sewage.

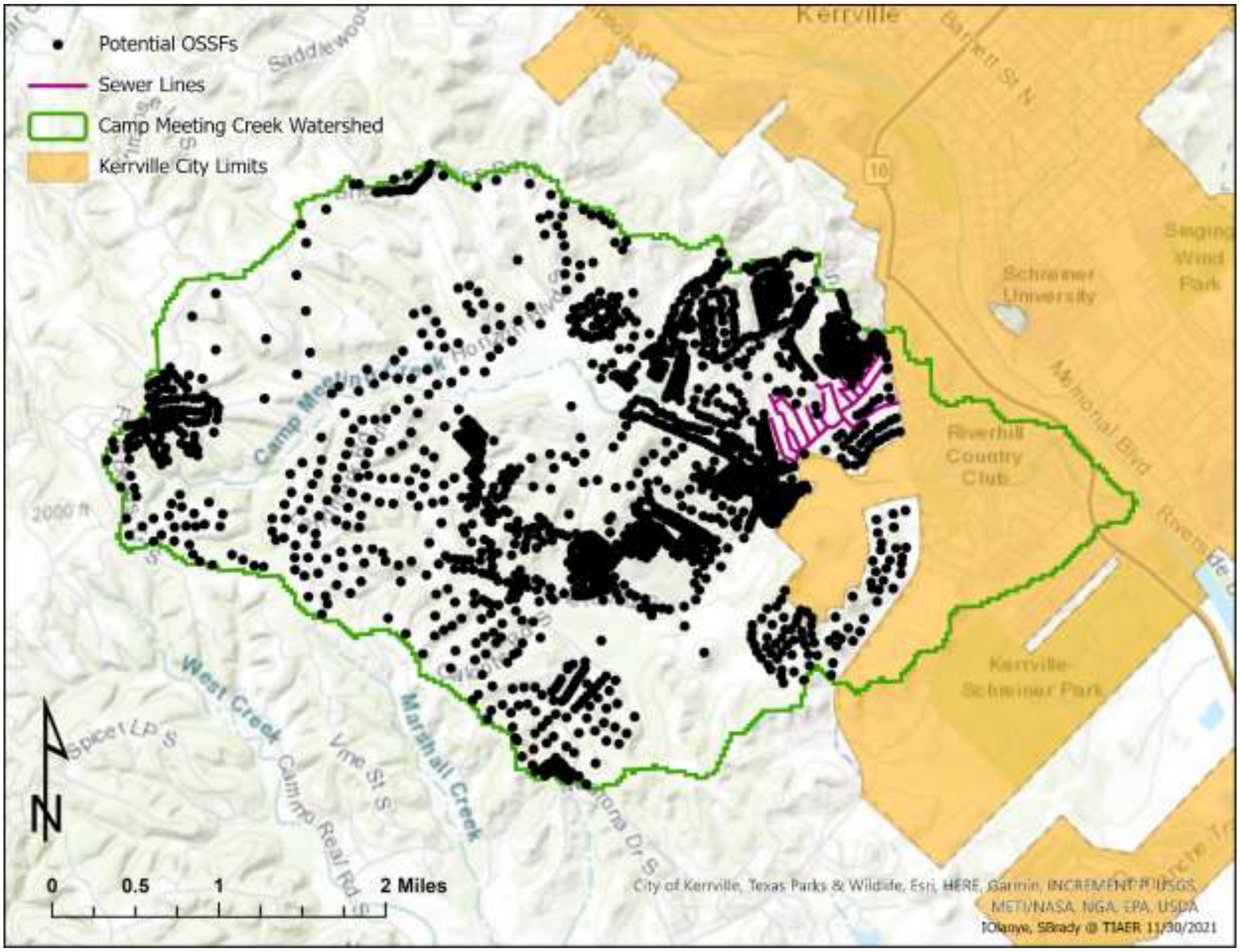

Figure 8. Map of the estimated OSSF locations

2.7.2.4. Bacteria Survival and Die-off

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

Section 3. Bacteria Tool Development

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

3.1. Tool Selection

For consistency between the Camp Meeting Creek TMDL and the previously completed Guadalupe River Above Canyon Lake TMDL (TCEQ, 2007) as well as the first addendum (*Two Total Maximum Daily Loads for Indicator Bacteria in Quinlan Creek and Town Creek*) (TCEQ, 2018c), the development activities for the present TMDL builds upon the LDC method used and reported in the previously completed TMDLs. Details on the previous LDC development are found in a technical support document by James Miertschin & Associates, Inc. (2006) and the TCEQ TMDL report (2007). Development activities of LDCs under the present project were covered under a TCEQ-approved QAPP (TIAER, 2021).

The LDC method allows for estimation of existing and allowable loads by using 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, that is, point source and nonpoint source.

3.2. Data Resources

To develop the LDC method for Camp Meeting Creek, various data resources were required. The two main sources were hydrologic data in the form of daily streamflow records for multiple years and historical indicator bacteria data, in this case, *E. coli*.

Hydrologic data in the form of daily streamflow records were unavailable for the TMDL watershed. Streamflow records, however, were available for the Johnson Creek watershed, which was determined to be the nearest and most comparable watershed with respect to size and land cover, though the Johnson Creek watershed is more rural than that of the TMDL area (Figure 9).

The Johnson Creek streamflow record was also used as the reference for developing LDCs for Quinlan and Town Creeks in the previous TMDLs (TCEQ, 2018c; TCEQ, 2007). Streamflow records for the Johnson Creek watershed are collected and made readily available by the United States Geological Survey (USGS, 2021), which operates the Johnson Creek streamflow gauge (Table 7 and Figure 9). USGS Streamflow Gauge 08166000 is located along the mainstem of Johnson Creek within Segment 1816 and serves as the primary source for streamflow records used in this document.

Table 7. Information about the Johnson Creek USGS streamflow gauge

Gauge No.	Site Description	Drainage Area (sq. miles)	Daily Streamflow Record (beginning and end dates)
08166000	Johnson Creek near Ingram, TX	113.75	September 1941 – present (inactive periods: December 1959 – September 1961 October 1993 – April 1999)

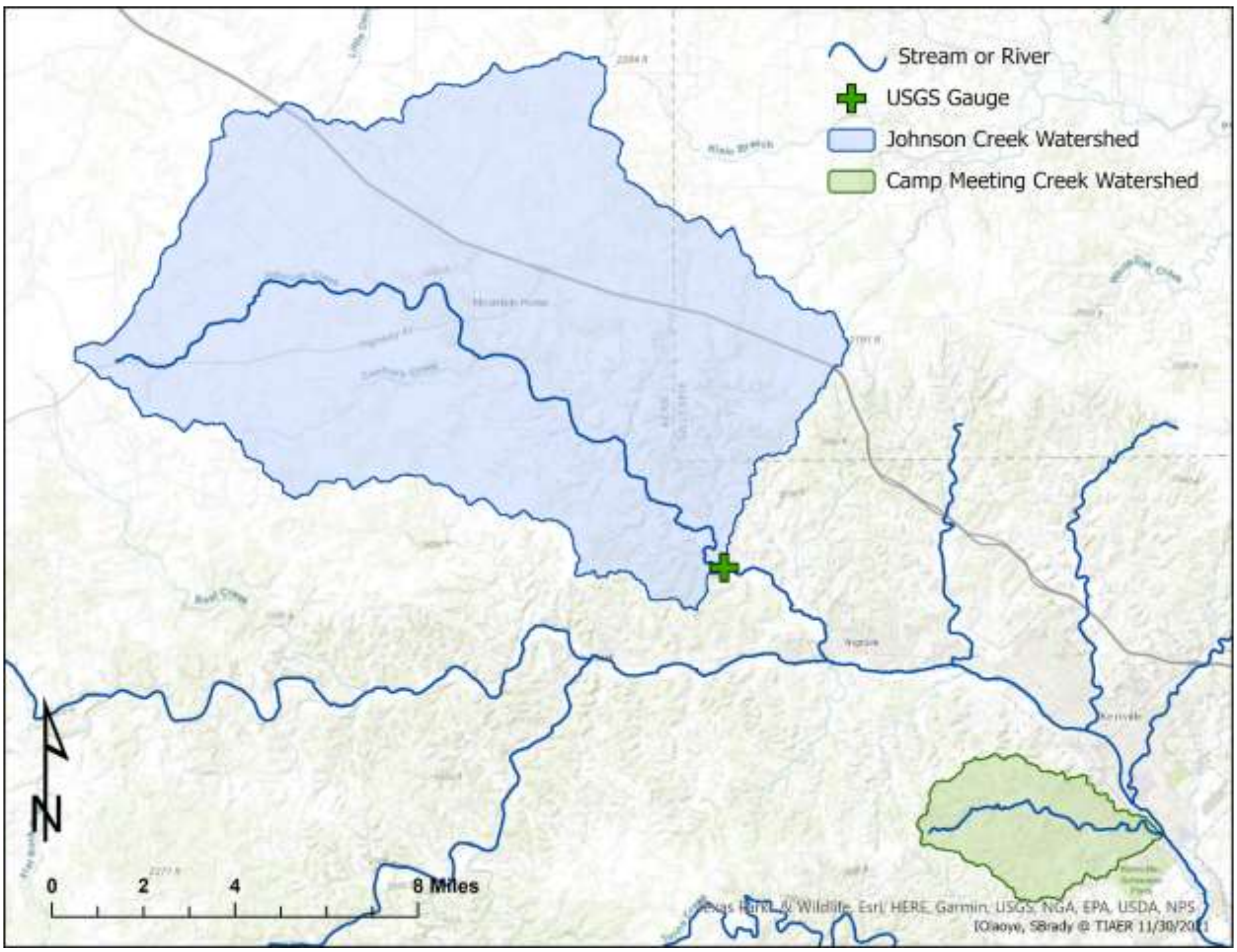

Figure 9. TMDL watershed, Johnson Creek watershed, and USGS Station 08166000 near Ingram, Texas

Ambient *E. coli* data were retrieved from the TCEQ Surface Water Quality Monitoring Information System on October 8, 2021, for SWQM Station 12546 located along Camp Meeting Creek. The *E. coli* data that was collected at SWQM Station 12546 consisted of 201 samples collected from July 2003 through December 2020.

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 series of 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 drainage-area ratio (DAR) parameter estimates.
- Step 4: Develop daily streamflow record at desired location.
- Step 5: Develop FDC at the desired stream location, segmented into discrete flow regimes.
- Step 6: Develop allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- Step 7: Superimpose historical bacteria data on the 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 roughly 80-year period of continuous daily streamflow was available for USGS Gauge 08166000 located on nearby Johnson Creek, which includes two gaps (of about two years and five years) when the gauge was inactive (Table 7 and Figure 9).

Optimally, the period of record to develop FDCs should include as much data as possible 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. For development of the FDC at SWQM Station 12546, an 18-year record of daily streamflow from June 7, 2003 through June 6, 2021 was selected; this is consistent with the timeframe that was used for Addendum One (TCEQ, 2018c). An 18-year period is of sufficient duration to contain a reasonable variation of dry and wet periods and, at the same time, is short enough in duration to reflect recent and current conditions in the watershed.

3.3.2. Step 2: Determine Desired Stream Location

When using the LDC method, the best location for developing the pollutant load allocation is a currently monitored SWQM station near the outlet of the watershed with an abundance of historical bacteria data. The most downstream SWQM station on Camp Meeting Creek is 12546, which is very close to the outlet of the watershed (Figure 3). Additionally, all of the bacteria data that was available for AU 1806A_01 through the Surface Water Quality Monitoring Information System was collected at SWQM Station 12546 (Clean Rivers Program, 2021). The LDC developed for this location will serve as the basis for developing the pollutant load allocations for Camp Meeting Creek.

3.3.3. Step 3: Develop Drainage-Area Ratio Parameter Estimates

Once the hydrologic period of record and station locations were determined, the next step was to develop the 18-year daily streamflow record for SWQM Station 12546. The daily streamflow records were developed from extant USGS records (Table 7).

The method to develop the necessary streamflow record involved a DAR approach. With this basic approach, the USGS Gauge 08166000 daily streamflow value within the 18-year period was multiplied by a factor to estimate the flow at a desired SWQM station location. The factor was determined by dividing the drainage area above the desired SWQM station location by the drainage area above the USGS gauge.

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 should first be considered for removal from the flow record of the Johnson Creek gauge prior to application of the ratio. A search for TPDES permitted facilities within the Johnson Creek watershed returned one active permit upstream of the gauge (TCEQ, 2021a). Under the Aquaculture General Permit (TXG130000), the Heart of the Hills Fishery Science Center (TXG130006) does not have a permitted flow but does have reporting requirements. The small and intermittent nature of this reported discharge leads to the assumption that it does not significantly impact the gauged streamflow record.

Therefore, no adjustments for discharges were made to the Johnson Creek USGS gauge record prior to application of the DAR. This approach appears to be consistent with what was done in the previously completed TMDL (TCEQ, 2007) based on the absence of any information to the contrary.

The DAR for the TMDL study area is presented in Table 8. The computation of the daily streamflow record at SWQM Station 12546 was performed by multiplying each daily streamflow in the 18-year Johnson Creek gauge record by the DAR.

Table 8. DARs for the Johnson Creek USGS gauge and the Camp Meeting Creek watershed

Water Body	Segment/ AU	Gauge/ SWQM Station	Drainage Area (square miles)	DAR
Johnson Creek	1806	08166000	113.75	1.00
Camp Meeting Creek	1806A_01	12546	9.43	0.0829

3.3.4. Step 4: Develop Daily Streamflow Record at Desired Location

Since there are no WWTFs within the Camp Meeting Creek watershed, no adjustment to the flow record due to WWTF outflows was necessary.

Regarding water rights in the Johnson Creek and Camp Meeting Creek watersheds, average monthly water diversion records were obtained from Texas Water Rights Viewer (TCEQ, 2021b). To correct the gauged flow at the Johnson Creek USGS gauge, average monthly diversions for water rights upstream of the gauge were added back into the flow record. The resulting flow record with average monthly surface water diversions included, represents the naturalized flow of the gauged watershed. The DAR was then applied to the naturalized flow record. Next the diversions associated with surface water rights located upstream of SWQM Station 12546 were subtracted from the flow record.

Future growth flows (calculated in Section 4.7.4) were added to the streamflow for Camp Meeting Creek. A future potential community of 1,000 persons was assumed, which is consistent with what was used in Addendum One (TCEQ, 2018c). This number, which would be large enough to accommodate the construction of a residential development typical to areas of the Hill Country, greatly exceeds the projected population growth for the unsewered areas (Table 2) but allows a reasonable buffer for uncertainty related to future development. Based on the TCEQ design guidance for WWTFs (Texas Administrative Code (TAC), 2008), the daily wastewater flow of 100 gallons/person was assumed, resulting in a future growth flow of 0.1 MGD.

3.3.5. Steps 5 through 7: Flow Duration and Load Duration Curves

FDCs and LDCs are graphs that visualize 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 points plus one.
- Plot the corresponding flow data against exceedance percentages.

Further, when developing an LDC:

- Multiply the streamflow in cfs by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL or 1.26 cfu/mL) and by a conversion factor (2.44658×10^9), which gives you a loading unit of cfu/day.
- Plot the exceedance percentages, which are identical to the value for streamflow data points, against the geometric mean criterion for *E. coli*.

The resulting curve represents the maximum daily allowable loadings for the geometric mean criterion. The next step was to plot the measured *E. coli* data on the developed LDC using the following 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 for each SWQM station the load for each measurement at the exceedance percentage for its corresponding streamflow.

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

3.4. Flow Duration Curve

The FDC was developed for SWQM Station 12546, which is the most downstream monitoring station along Camp Meeting Creek and is near the outlet of the watershed (see Figure 3). For this report, the FDC was developed by applying the DAR method and using the Johnson Creek USGS gauge and 18-year period (2003–2021) described in the previous sections.

Flow exceedances less than 10% typically represent streamflows influenced by storm runoff, while higher flow exceedances represent receding hydrographs after a runoff event and base flow conditions.

A useful refinement of the FDC/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 aid 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% (high flows); (2) 10–40% (upper/mid-range flows); (3) 40–60% (mid-range flows); (4) 60–90% (lower/mid-range flows); and (5) 90–100% (low flows). These flow regimes were applied to the LDCs (Figure 10), consistent with the previous TMDLs (TCEQ, 2007; TCEQ, 2018c).

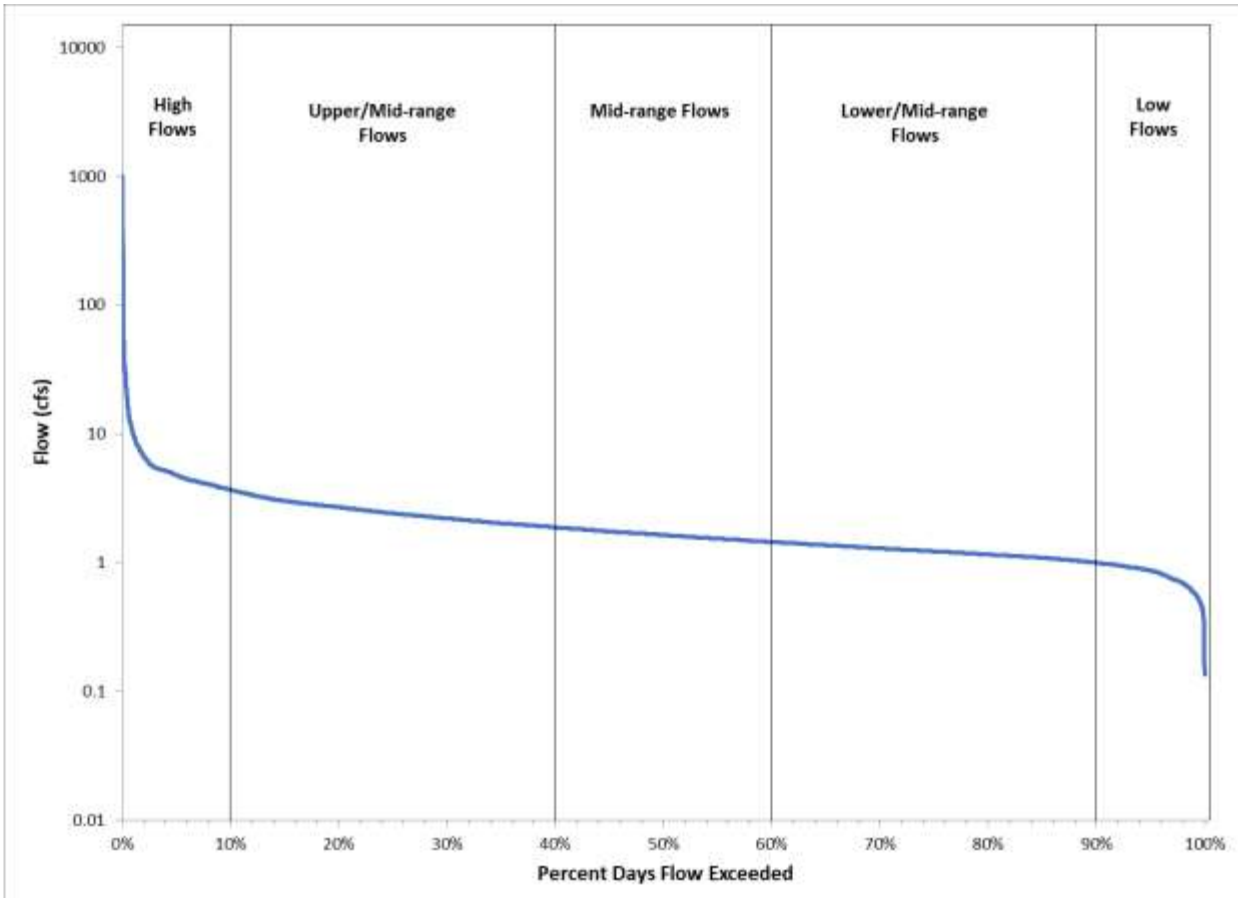

Figure 10. FDC for SWQM Station 12546

3.5. Load Duration Curve

Historical bacteria measurements (*E. coli*) were aligned with the streamflow on the day of measurement. The historical bacteria measurements were then multiplied by the streamflow value and the conversion factor, as described in Section 3.3.4 and 3.3.5, to calculate a loading associated with each measured bacteria concentration. The measured *E. coli* data are associated with a "wet weather event" or a "non-wet weather event." This determination was made based on at least one of the three following criteria:

- "Days since last precipitation" value (if available) was less than or equal to three days.
- "Flow severity" value (if available) was equal to four (Flood) or five (High).
- Instantaneous flow value (if available) was greater than two cfs

The LDC was then calculated for the TMDL watershed. The LDC for TCEQ SWQM Station 12546 provides a means of identifying the streamflow conditions under which exceedances in *E. coli* concentrations have occurred. The LDC depicts the allowable loadings under the geometric mean criterion (126 cfu/100 mL) as well as the allowable loading under the single sample criterion (399 cfu/100 mL) (Figure 11).

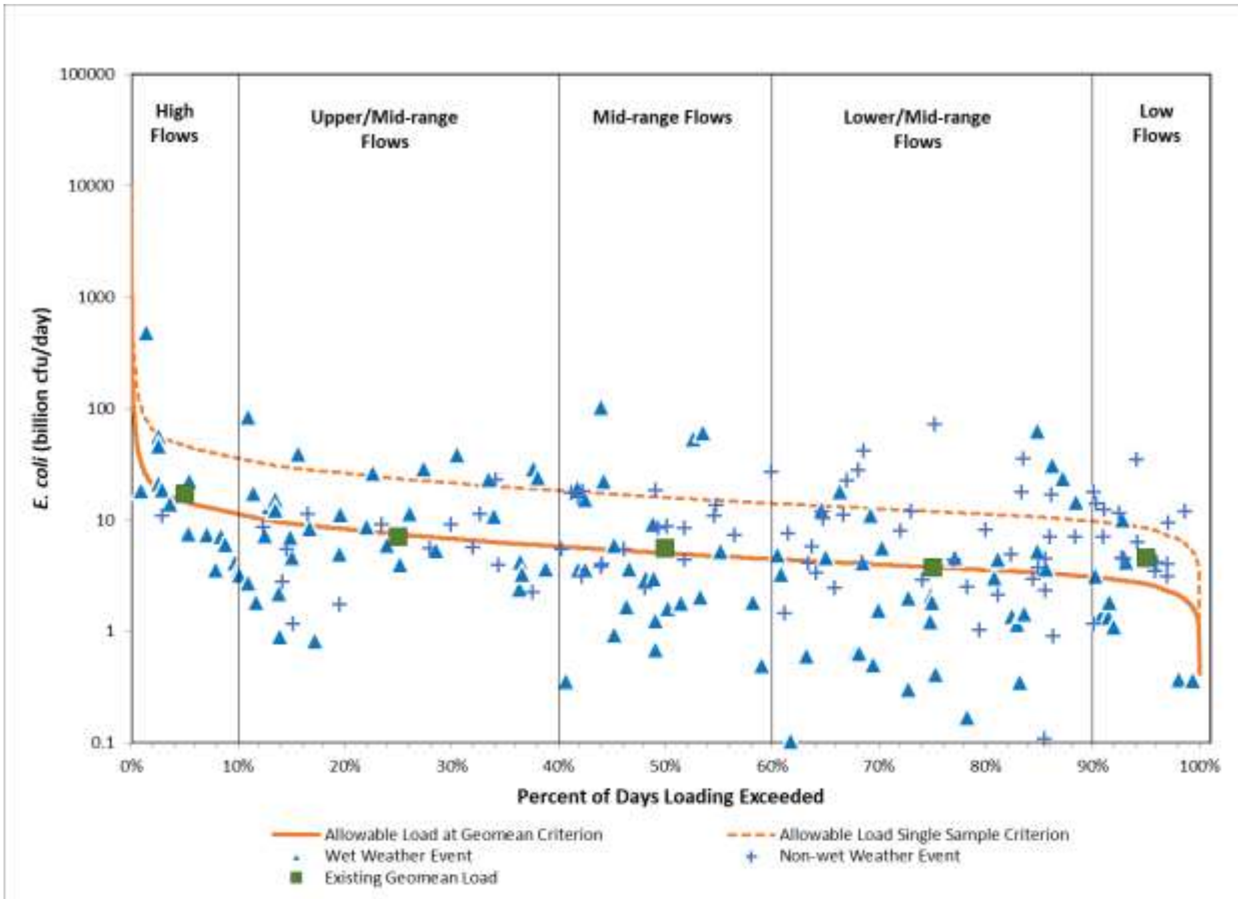

Figure 11. LDC for SWQM Station 12546

For the Camp Meeting Creek LDC, the wet weather data points occurred during all flow regimes. Wet-weather data points in the lowest flow regime typically represent bacteria data collected after a small rainfall-runoff event when conditions before the event were very dry. Often, both the wet-weather and non-wet-weather event data points exceed the geometric mean criterion for Camp Meeting Creek. The geometric mean of existing data shown by flow regime indicates that the geomean criterion is being exceeded during the high-, mid-range, and low-flow regimes.

Further interpretation of these curves is provided in Section 4.

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.

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 *E. coli* concentrations from nine years (2011 – 2020) of routine monitoring in the warmer months (May through September) against those during the cooler months (November through March). Differences in *E. coli* concentrations obtained in warmer versus cooler months were then evaluated by performing the Wilcoxon rank-sum test on the original dataset. This analysis of *E. coli* data indicated that there was a significant difference in indicator bacteria between cool and warm weather seasons for Camp Meeting Creek ($n = 77$, $p=0.0125$) with the warm season having the higher concentrations.

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

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

LDCs were used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a direct relationship between pollutant load sources (regulated and unregulated) and instream loads. Further, this one-to-one relationship was also inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7). That allocation was based on the flows associated with the 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 loads, and they are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. 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 about loading rates, hydrology, land use conditions, and other conditions in the watershed. The EPA supports the use of this approach to characterize pollutant sources. In addition, many other states are using this method to develop TMDLs.

The weaknesses of this method include the limited information it provides about the magnitude or specific origin of the various sources. Information gathered about point and nonpoint sources 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 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 hydrological conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (i.e., point source and stormwater), and provides a means to allocate allowable loadings. As discussed in more detail in Section 4.7, the TMDL loads were based on the median flow within the high-flows regime (or 5% flow).

Based on the LDC with historical *E. coli* data added to the graph (Figure 11) and information in Section 2.7, the following broad linkage statements can be made. For the Camp Meeting Creek watershed, historical *E. coli* data show that elevated bacteria loadings occur under all flow conditions, but the geometric mean becomes most elevated under the high-, mid-range, and low-flows regimes. Regulated stormwater comprises a small portion of the watershed (0.47%) and must be considered only a minor contributor. There are currently no WWTFs in the watershed; therefore, other sources of bacteria loadings under lower flows and in the absence of overland flow contributions (i.e., without stormwater contribution) are most likely contributing bacteria directly to the water body, as could occur through direct deposition of fecal material from wildlife and pets. Additionally, there are a significant number of septic systems concentrated within the watershed. The actual contribution of bacteria loadings attributable to these sources of fecal matter cannot be determined using LDCs.

4.5. Margin of Safety

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

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

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

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

4.6. Load Reduction Analysis

While the TMDL for Camp Meeting Creek 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 five flow regimes was determined using the historical *E. coli* data obtained from SWQM Station 12546 within the impaired reach.

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 9).

Table 9. Percentage reduction calculations

Flow Regime	Number of Samples	Geometric Mean by Flow Regime (cfu/100mL)	Required Percentage Reduction by Flow
High Flows (0–10%)	16	147	14%
Upper/Mid-range Flows (10–40%)	49	119	0%
Mid-range Flows (40–60%)	42	140	10%
Lower/Mid-range Flows (60–90%)	68	124	0%
Low Flows (90–100%)	25	216	42%

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:

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

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.

For the original TMDL on the Guadalupe River (TCEQ, 2007), pollutant load allocations were determined from the median flow of each of the five flow regimes comprising the LDCs: 5% exceedance for the high flows (0–10%), 25% exceedance for the upper/mid-range flows (10–40%), 50% exceedance for mid-range flows (40–60%), 75% exceedance for the lower/mid-range flows (60–90%), and 95% exceedance for the low flows (90–100%).

For more recent bacteria TMDLs across Texas, including the Quinlan and Town Creek addendum, TCEQ considered only the 5% exceedance (the median value of the high flows) in the pollutant load allocations. The 5% exceedance loading for Camp Meeting Creek will be developed in the remainder of this section. For consistency with the Guadalupe River TMDL, however, the pollutant load allocations for each of the five flow regimes are provided in Appendix B.

4.7.1. Assessment Unit-Level TMDL Calculations

The bacteria TMDL for Camp Meeting Creek was developed as a pollutant load allocation based on information from the LDC for SWQM Station 12546, which is at the outlet of the watershed (Figure 3). 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 5% exceedance (the median value of the high-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 (ft^3) * 86,400 seconds/day (s/d) ÷ 1,000,000,000

The allowable loading of *E. coli* that AU 1806A_01 can receive daily was determined using Equation 2 based on the median value within the high-flows regime of the FDC (or 5% flow exceedance value) for the SWQM station (Table 10).

Table 10. Summary of allowable loading calculation

Water Body Name	AU	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
Camp Meeting Creek	1806A_01	4.7725	1.4712E+10	14.712

4.7.2. Margin of Safety Allocation

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

MOS = 0.05 * TMDL (Equation 3)

Using the value of TMDL for the AU provided in Table 10, the MOS may be readily computed by proper substitution into Equation 3 (Table 11).

Table 11. MOS calculations

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

Water Body Name	AU	TMDL[a]	MOS
Camp Meeting Creek	1806A_01	14.712	0.736

[a] TMDL from Table 10.

4.7.3. Waste Load Allocations

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

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

4.7.3.1. Wastewater

TPDES-permitted WWTFs are allocated a daily wasteload calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion. The water quality criterion (126 cfu/100mL) is used as the WWTF target to provide instream and downstream load capacity and to be consistent with previously developed TMDLs. Thus, WLA_{WWTF} is expressed in the following equation:

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

Where:

Target = 126 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

Since there are no WWTFs within the Camp Meeting Creek watershed, the WLA_{WWTF} is zero.

4.7.3.2. Regulated Stormwater

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

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

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

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

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. As described in Section 2.7.1.3, a search for all five categories of stormwater general permits was performed. It was determined that 0.467% of the Camp Meeting Creek watershed is currently covered by stormwater authorizations (all CGPs). (Note: a temporal-averaging approach was attempted, based on the work that was done in Addendum One (TCEQ, 2018c), the results of that work indicated an even lower percentage of the watershed has been under stormwater permits, on average.) The results were used to compute an area of regulated stormwater contribution (Table 12).

Table 12. Basis of unregulated stormwater area and computation of FDA_{SWP} term

Water Body Name	AU	Total Area (acres)	Area Under CGP (acres)	FDA_{SWP}
Camp Meeting Creek	1806A_01	6,535.45	30.5	0.00467

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the combined area under regulated 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 13 provides the information needed to compute WLA_{SW}.

Table 13. Regulated stormwater calculations

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

Water Body Name	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	FG[d]	FDA_{SWP}[e]	WLA_{SW}[f]
Camp Meeting Creek	1806A_01	14.712	0.736	0	0.477	0.00467	0.063

[a] TMDL from Table 10

[b] MOS from Table 11

[c] $WLA_{WWTF} = 0$

[d] FG from Table 14

[e] FDA_{SWP} from Table 12

[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 takes into account the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of water bodies increases as the amount of flow increases.

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

For this TMDL, the conventional FG calculation is hampered by the fact that there are no WWTFs within the watershed. By using TCEQ design guidance for domestic WWTFs, and assuming the potential for a residential development of a density sufficient to require centralized sewer collection, an alternative method was implemented.

A new WWTF must accommodate daily wastewater flow of 75-100 gallons per capita per day (gpcd) as required under Title 30, Texas Administrative Code, Chapter 217, Subchapter B, Section 217.32 (30 TAC 217.32 (TCEQ, 2015). Conservatively taking the higher daily wastewater flow capacity (100 gallons) and multiplying it by a potential population change would result in a permitted flow for FG. Based on the information in Table 2, the projected population change for unincorporated areas of the Camp Meeting Creek watershed for 2020 to 2050 is 549. Conservatively assuming a larger population consistent with a potential residential development—1,000 people—and multiplying that by the higher daily wastewater flow capacity, yields a value of 0.10 MGD. This value would be considered the full permitted discharge of a potential future WWTF.

To remain consistent with the previously completed TMDL, no MOS was included in the computation of FG. Thus, the FG is calculated as follows:

$$FG = WWTF_{FP} * \text{Conversion Factor} * \text{Target} \qquad \text{(Equation 7)}$$

Where:

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

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

Target = 126 cfu/100 mL

The calculation results for the impaired TMDL watershed are shown in Table 14.

Table 14. FG calculation

Water Body Name	AU	Assumed Service Population	Daily Wastewater (gpcd)	FG (MGD)	FG (*E. coli* Billion cfu/Day)[a]
Camp Meeting Creek	1806A_01	1,000	100	0.10	0.477

[a] $FG = WWTF_{FP}$ * conversion factor * target (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 15.

Table 15. 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]
Camp Meeting Creek	1806A_01	14.712	0.736	0.000	0.063	0.477	13.436

[a] TMDL from Table 10

[b] MOS from Table 11

[c] $WLA_{WWTF} = 0$

[d] WLA_{SW} from Table 13

[e] FG from Table 14

[f] $LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS$ (Equation 8)

4.8. Summary of TMDL Calculations

Table 16 summarizes the TMDL calculation for the TMDL watershed. The TMDL was calculated based on the median flow in the 0– 10th percentile range (5% exceedance, high flows regime) for flow exceedance from the LDC developed for SWQM Station 12546. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 16. TMDL allocation summary

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

Water Body	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
Camp Meeting Creek	1806A_01	14.712	0.736	0.000	0.063	13.436	0.477

[a] TMDL from Table 10
[b] MOS from Table 11
[c] WLA_{WWTF} = 0
[d] WLA_{SW} from Table 13
[e] LA from Table 15
[f] FG from Table 14

The final TMDL allocation (Table 17) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 17. Final TMDL allocation

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

Water Body	AU	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
Camp Meeting Creek	1806A_01	14.712	0.736	0.477	0.063	13.436

[a] WLA_{WWTF} includes the FG component

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Appendix A.
Estimation of the 2020 Census population and 2030 – 2050 population projections for the Camp Meeting Creek Watershed

The following steps detail the method used to estimate the 2020 and projected 2050 populations in the Camp Meeting Creek watershed.

- Obtained 2020 USCB data at the block level.
- Developed the 2020 watershed population using the USCB block level data for the portion of Kerr County within the watershed.
- 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.
- Obtained the TWDB Population Projections by Regional Water Planning Group for region J. Used projections for "County-Other" to determine population increases for the rural areas in Kerr County (TWDB, 2019a).
- Located the relevant Water User Groups (WUGs) with areas within the Camp Meeting Creek watershed and Kerr County and determined the proportion of each WUG within the watershed (TWDB, 2019b).
- Calculated decadal percentage increases in population using the TWDB (2019b) decadal population projections for Region J in TWDB Projections by Water User Group.
- Summed the projected population increases obtained in Steps 4 and 6 to the 2020 population to obtain decadal population projections out to 2050.

Appendix B.
Pollutant Load Allocations for Camp Meeting Creek

For the previous TMDL on the Guadalupe River (TCEQ, 2007), pollutant load allocations were determined from the median flow of each of the five flow regimes comprising the LDCs:

1. 5% exceedance for the high flows (0–10%),
2. 25% exceedance for the upper/mid-range flows (10–40%),
3. 50% exceedance for mid-range flows (40–60%),
4. 75% exceedance for the lower/mid-range flows (60–90%), and
5. 95% exceedance for the low flows (90–100%).

For more recent bacteria TMDLs across Texas, TCEQ considered only the 5% exceedance (the median value of the high flows) in the pollutant load allocations.

This appendix provides the pollutant load allocation information for each of the five flow regimes of Camp Meeting Creek. Table B-1 contains the summary of allowable loadings, Table B-2 contains the TMDL allocation summary, and Table B-3 contains the final TMDL allocations. These tables correspond to Tables 10, 16, and 17, respectively, which include only values for the High Flow regime. The values contained in Appendix B tables were derived from the information and equations provided in Section 4.7.

Table B-1. Summary of allowable loading calculation for each flow

Water Body Name	AU	Flow Regime	Median Flow of Flow Regime (cfs)	Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
Camp Meeting Creek	1806A_01	High Flows	4.7725	1.4712E+10	14.712
		Upper/Mid-range Flows	2.4072	7.421E+09	7.421
		Mid-range Flows	1.6357	5.042E+09	5.042
		Lower/Mid-range Flows	1.2212	3.765E+09	3.765
		Low Flows	0.8628	2.66E+09	2.660

Table B-2. TMDL allocation summary by flow regime for Camp Meeting Creek

Water Body Name	AU	Flow Regime	TMDL	MOS	WLA_{WWTF}	WLA_{SW}	LA	FG
Camp Meeting Creek	1806A_01	High Flows	14.712	0.736	0.000	0.063	13.436	0.477
		Upper/Mid-range Flows	7.421	0.371	0.000	0.031	6.542	0.477
		Mid-range Flows	5.042	0.252	0.000	0.020	4.293	0.477
		Lower/Mid-range Flows	3.765	0.188	0.000	0.014	3.086	0.477
		Low Flows	2.660	0.133	0.000	0.010	2.040	0.477

Table B-3. Final TMDL allocation by flow regime for Camp Meeting Creek

Water Body Name	AU	Flow Regime	TMDL	MOS	WLA_{WWTF}	WLA_{SW}	LA
Camp Meeting Creek	1806A_01	High Flows	14.712	0.736	0.477	0.063	13.436
		Upper/Mid-range Flows	7.421	0.371	0.477	0.031	6.542
		Mid-range Flows	5.042	0.252	0.477	0.020	4.293
		Lower/Mid-range Flows	3.765	0.188	0.477	0.014	3.086
		Low Flows	2.660	0.133	0.477	0.010	2.040