Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in Sandy Creek and Wolf Creek

Segments: 0603A, 0603B

Assessment Units: 0603A_01, 0603B_01

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Prepared for
Total Maximum Daily Load Program
Texas Commission on Environmental Quality
MC-203
P.O. Box 13087
Austin, Texas 78711-3087

Prepared by:
Michael Schramm and Achla Jha
Texas Water Resource Institute
Texas A&M University
College Station, Texas

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List of Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
CCN	Certificate of Convenience and Necessity
cfs	cubic feet per second

CFR	Code of Federal Regulations
cfu	colony forming unit
DAR	drainage-area ratio
ECHO	Enforcement and Compliance History Online
E. coli	*Escherichia coli*
FDC	flow duration curve
FG	future growth
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
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
RMU	Resource Management Unit
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic
SWMP	Stormwater Management Program
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	wasteload allocation
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 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. In addition to the TMDL, an implementation plan is developed, which is a description of the regulatory and voluntary measures chosen by stakeholders to improve water quality and restore full use of the water body.

The TMDL Program is a major component of Texas's 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 uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

TCEQ first identified bacteria impairments within Sandy Creek in the *2000 Texas Water Quality Inventory and 303(d) List*, (Inventory and List, TCEQ, 2002). Wolf Creek was first identified as impaired for elevated indicator bacteria levels in the 2006 Texas Inventory and List (TCEQ, 2007). The bacteria impairments have been identified in each subsequent edition through the *2020 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report, TCEQ 2020).

This document will consider bacteria impairments in two water body segments, each consisting of two assessment units (AUs). TCEQ defines AUs as sub-areas of segments; they are the smallest area of use support reported in the assessment (TCEQ, 2015a). The water body and identifying AU numbers are shown below:

- Sandy Creek 0603A_01 and 0603A_02; and
- Wolf Creek 0603B_01 and 0603B_02.

The bacteria impairments considered in this document are for AUs 0603A_01 and 0603B_01. The other two AUs referenced are unimpaired.

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 TCEQ. The water quality standards specifically protect appropriate uses for each segment (water body) and list appropriate limits for water quality indicators to assure water quality and attainment of uses. TCEQ assesses water bodies based on the water quality standards and publishes the Texas Integrated Report list biennially.

The *Texas Surface Water Quality Standards* (TCEQ, 2018a) 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; 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 are indicators of the risk of illness during contact recreation (e.g., swimming) from ingestion of water. Fecal indicator bacteria are present in the intestinal tracts of human and other warm-blooded animals. The presence of these bacteria indicates that associated pathogens from fecal wastes may be reaching water bodies, because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2006). *Escherichia coli* (*E. coli)* is a member of the fecal coliform bacteria group and is used in the state of Texas as the fecal indicator bacteria in freshwater.

On February 7, 2018, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2018a) and on May 19, 2020, the U.S. Environmental Protection Agency (USEPA) approved the categorical levels of recreational use and their associated criteria. Recreational use consists of five categories:

- Primary contact recreation 1 is that with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for *E. coli* of 126 colony forming unit (cfu) per 100 milliliters (mL) and an additional single sample criterion of 399 cfu per 100 mL;
- Primary contact recreation 2 includes activities that involve a significant risk of ingestion of water (i.e. swimming, diving, wading and whitewater sports), but occurs less frequently than for primary contact recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean for the standard is 206 cfu/ 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 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.

Sandy Creek and Wolf Creek are primary contact recreation 1 use streams. The associated criterion for *E. coli* is a geometric mean of 126 cfu per 100 mL.

1.3. Report Purpose and Organization

TCEQ contracted with the Texas Water Resources Institute (TWRI) for the Sandy Creek and Wolf Creek TMDL project. The tasks of this project were to (1) acquire existing (historical) data; (2) perform the appropriate activities necessary to allocate *E. coli* loadings; (3) assist TCEQ in preparing a TMDL document; and (4) engage the public through education and outreach activities related to water quality impairments in the project area.

This project intends to use historical bacteria and flow data in order to (1) review the characteristics of the watershed and explore potential sources of *E. coli* for the impaired AUs; (2) develop an appropriate tool for development of a bacteria TMDL for the impaired AUs; and (3) submit the draft and final technical support document for the impaired AUs. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDLs for the Sandy Creek and Wolf Creek watersheds. This report contains:

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

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

Sandy Creek (Segment 0603A) and Wolf Creek (Segment 0603B) are located in southeast Texas (Figure 1). Sandy Creek is located entirely in Jasper County and consists of two AUs (0603A_01 and 0603A_02). Sandy Creek flows approximately 27 miles from the headwaters near Recreational Road 225 and south through the City of Jasper to its confluence with B. A. Steinhagen Lake. The total watershed area for Sandy Creek is 56.54 square miles (36,184.36 acres).

Wolf Creek is located entirely in Tyler County. Wolf Creek (0603B) consists of two AUs (0603B_01 and 0603B_02). Wolf Creek flows approximately 23 stream miles from the headwaters upstream of former Lake Amanda to the confluence with B. A. Steinhagen Lake. The total watershed area for Wolf Creek is 83.14 square miles (53,207.52 acres).

The 2020 Texas Integrated Report (TCEQ, 2020) provides the following segment and AU descriptions for the water bodies considered in this document:

- Segment 0603A (Sandy Creek) – From the confluence with B. A. Steinhagen Lake southwest of the City of Jasper in Jasper County upstream to the headwaters at Recreational Road 255 north of Jasper in Jasper County
  - 0603A_01 From the confluence with B. A. Steinhagen Lake upstream to 0.5 km below Hwy 776 east of the City of Jasper, per Water Quality Standards App. D.
  - 0603A_02 From 0.5 km below FM 776 east of the City of Jasper upstream to headwaters at Recreational Road 255 north of the City of Jasper.
- Segment 0603B (Wolf Creek) - From the confluence of B. A. Steinhagen Lake southeast of Colmesneil in Tyler County to the upstream perennial portion of the stream south of Colmesneil in Tyler County.
  - 0603B_01 From the confluence of B. A. Steinhagen Lake upstream to Lake Amanda Dam.
  - 0603B_02 From the confluence with Lake Amanda upstream to the headwaters.

The Sandy Creek (0603A) watershed is primarily rural with large swaths of pine forests contributing to the local forest and paper industries. The city of Jasper is the only municipality in the Sandy Creek (0603A) watershed. The Wolf Creek (0603B) watershed is also primarily rural with a large amount of pine forests. The town of Colmesneil, on the northwestern edge of the watershed, is the only municipality in the watershed. Both watersheds have relatively limited cattle grazing and agricultural production.

This document utilizes a watershed approach, where the entire contributing land area and potential sources within and upstream of the impaired AUs are considered. In both watersheds, the lowermost AUs are considered impaired. Although the upstream AUs are not impaired, the watershed boundaries include the drainage area contributing to both the upstream and downstream AUs as shown in Figure 1. However, TMDLs will only apply to the impaired AUs.

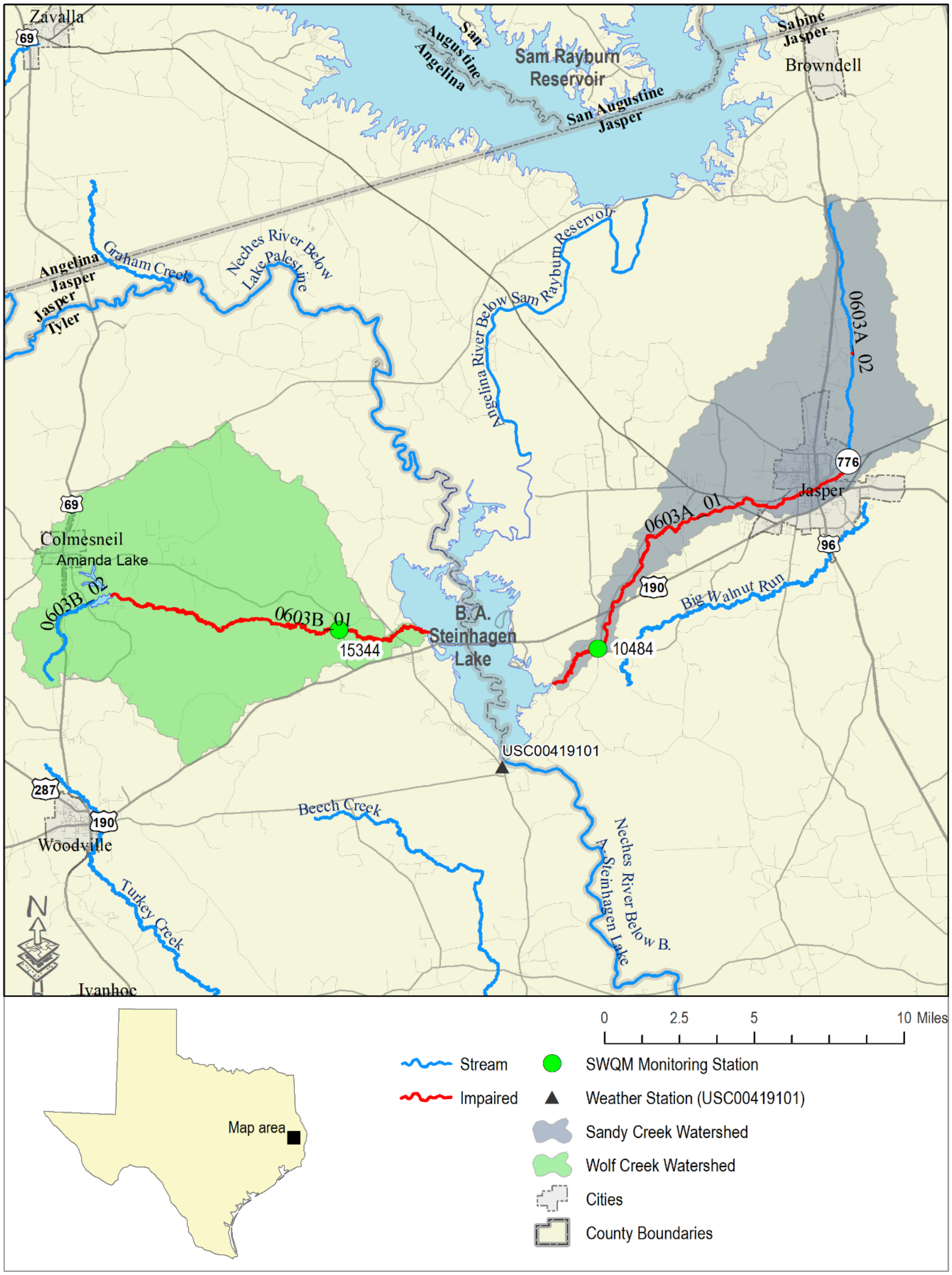

Figure 1. Overview map of the Sandy Creek and Wolf Creek watersheds.
Sources: TCEQ Monitoring Station Locations (TCEQ, 2018b), TCEQ Assessment Units (TCEQ 2015b).

2.2. Review of Routine Monitoring Data for TMDL Watersheds

2.2.1. Data Acquisition

All available ambient *E. coli* data records were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database (TCEQ, 2019a). The data represented all historical ambient *E. coli* data and field parameters collected in the project area. Sixty-eight ambient *E. coli* measurements were available at TCEQ surface water quality monitoring (SWQM) station 10484 (Sandy Creek at FM 777) from October 16, 2001 through October 17, 2018. Sixty-eight ambient *E. coli* measurements were available at SWQM station 15344 (Wolf Creek at FM 256) from October 16, 2001 through October 17, 2018.

2.2.2. Analysis of Bacteria Data

Water quality monitoring has occurred at a single SWQM station within each water body (Figure 1). *E. coli* data collected over the seven-year period of December 1, 2011, to November 30, 2018, were used in assessing attainment of the primary contact recreation use as reported in the 2020 Texas Integrated Report (TCEQ, 2020). The 2020 assessment data indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the geometric criterion of 126 cfu/100 mL, as summarized in Table 1.

Table 1. 2020 Texas Integrated Report summary.

Water Body	Assessment Unit	Parameter	Station	Data Range	No. of Samples	Geometric Mean (cfu/100 mL)
Sandy Creek	0603A_01	*E. coli*	10484	12/01/2011-11/30/2018	20	193.66
Wolf Creek	0603B_01	*E. coli*	15344	12/01/2011-11/30/2018	20	161.49

2.3. Watershed Climate and Hydrology

Regional precipitation and temperature data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center database. The nearest active weather station, Town Bluff Dam station USC00419101 located at B. A. Steinhagen Lake (Figure 1), was used to retrieve temperature and precipitation data from 2000 through 2018 (NOAA, 2019). Precipitation is relatively steady through the year with the highest average monthly precipitation occurring in November at 5.83 inches and the lowest average monthly precipitation occurring in January at 4.01 inches (Figure 2). The highest average monthly maximum temperatures occur in August (93.20° F) and the lowest average monthly minimum temperatures occur in January (38.50° F) (Figure 2). From 2000 through 2018, the mean annual precipitation was 58.59 inches, with a low of 31.69 inches recorded in 2005 and high of 92.82 inches occurring in 2018 (Figure 3).

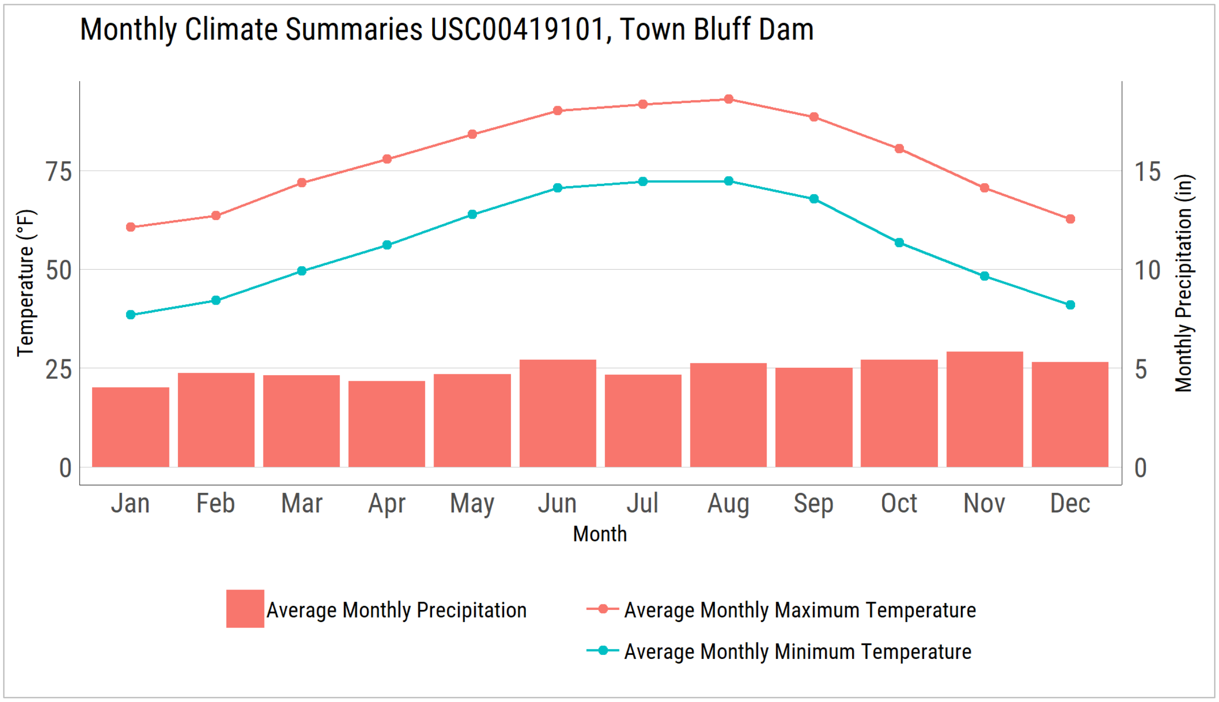

Figure 2. Average monthly temperature and precipitation (2000-2018) at Town Bluff Dam, TX Station USC00419101.
Source: NOAA (2019).

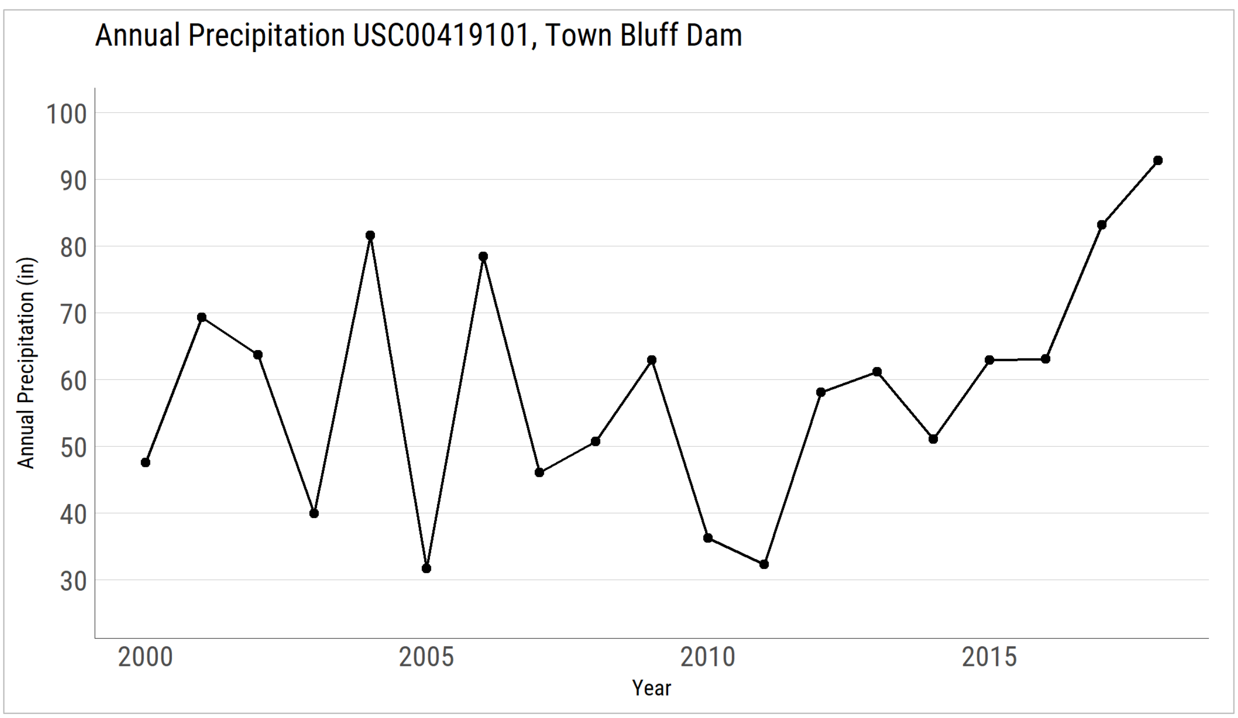

Figure 3. Annual precipitation (2000-2018) at Town Bluff Dam, TX Station USC00419101.
Source: NOAA (2019).

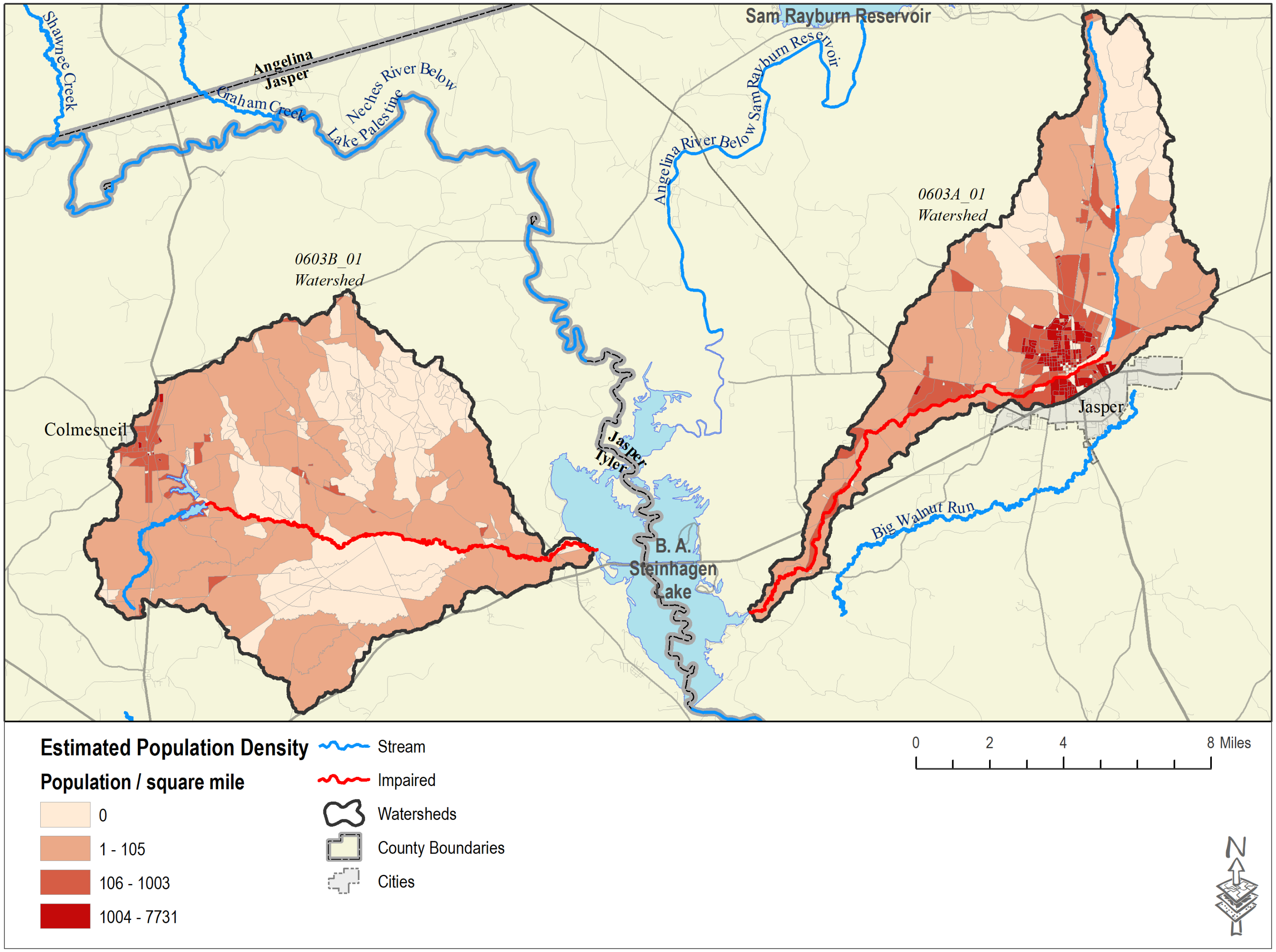

Figure 4. 2010 population estimates by US Census block.
Source: USCB (2010).

2.4. Watershed Population and Population Projections

Watershed population estimates were developed using United States Census Bureau (USCB) 2010 census block data (USCB, 2010). Census blocks are the smallest geographic units used by USCB to tabulate population data. The Sandy Creek watershed includes 455 census blocks located entirely or partially in the watershed. The Wolf Creek watershed includes 346 census blocks located entirely or partially in the watershed. Population was estimated for those census blocks partially located in the watershed by multiplying the census block population and the percent of each block within each watershed. It was assumed for this estimation that populations were evenly distributed within a census block. These estimated partial census block populations were then summed with the populations from the census blocks located entirely within the TMDL watersheds. Based on this method, the population of the Sandy Creek watershed is approximately 7,462 people (Figure 4). The population of the Wolf Creek watershed is estimated at 1,683 people.

Texas Water Development Board (TWDB) Regional Water Plan Population and Water Demand Projections for Jasper County and Tyler County (TWDB, 2019) were used to estimate population projections within the watershed (Table 2). These population projections, developed by TWDB, indicate a 0.5 percent population increase in the Wolf Creek watershed (Tyler County) from 2020 through 2070. A 2.6 percent increase is projected for the Sandy Creek watershed (Jasper County). Table 3 provides the estimated watershed population for 2070 based on 2010 census block populations and TWDB population growth rates. Based on these estimates, the 2070 population for the Sandy Creek watershed is anticipated to be 7,908. The estimated 2070 population for the Wolf Creek watershed is 1,723.

Table 2. 2020-2070 population projections.
Source: TWDB (2019).

County	2010 US Census Population	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	2060 Population Projection	2070 Population Projection
Jasper County	35,710	36,878	37,695	37,849	37,849	37,849	37,849
Tyler County	21,766	22,288	22,396	22,396	22,396	22,396	22,396

Table 3. Estimated population growth for the Sandy and Wolf Creeks watersheds.

Watershed	Estimated 2010 Population	2010 to 2020 Percent Growth	Estimated 2020 Population	2020-2070 Percent Growth	Estimated 2070 Population
Sandy Creek	7,462	3.3	7,708	2.6	7,908
Wolf Creek	1,683	2.4	1,723	0.5	1,723

2.5. Land Cover

Land cover for the watersheds were obtained from the 2016 National Land Cover Database (NLCD) of the US Geological Survey (USGS, 2019a), displayed in Figure 5. The following categories and definitions represent land cover in the NLCD database:

- Open Water – Areas of open water, generally with less than 25 percent 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 percent of total cover. These areas most commonly include large-lot single-family housing units, 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 constructed materials and vegetation. Impervious surfaces account for 20 percent to 49 percent of total cover. These areas most commonly include single-family housing units.
- Developed, Medium Intensity – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 percent to 79 percent of 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 percent to 100 percent of total cover.
- Barren Land (Rock/Sand/Clay) – 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 percent of total cover.
- Deciduous Forest – Areas dominated by trees generally greater than five meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent 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 percent of total vegetation cover. More than 75 percent of the species maintain their leaves all year. Canopy is never without green foliage.
- Mixed Forest – Areas dominated by trees generally greater than five meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent total tree cover.
- Shrub/Scrub – Areas dominated by shrubs; less than five meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
- Grasslands/Herbaceous – Areas dominated by graminoid 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.
- 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.

- Cultivated Crops – Areas used to produce annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class includes all land being actively tilled.
- Woody Wetlands – Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- Emergent Herbaceous Wetlands – Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil substrate is periodically saturated with or covered with water.

The predominant land cover classes in the Sandy Creek watershed are evergreen forest (44.9 percent) and shrub/scrub (12.8 percent) (Table 4). Total developed land uses account for 14.5 percent of the Sandy Creek watershed.

The predominant land covers in the Wolf Creek watershed are evergreen forest (49.9 percent) and grassland/herbaceous (13.9 percent). Total developed land covers only account for five percent of the Wolf Creek watershed.

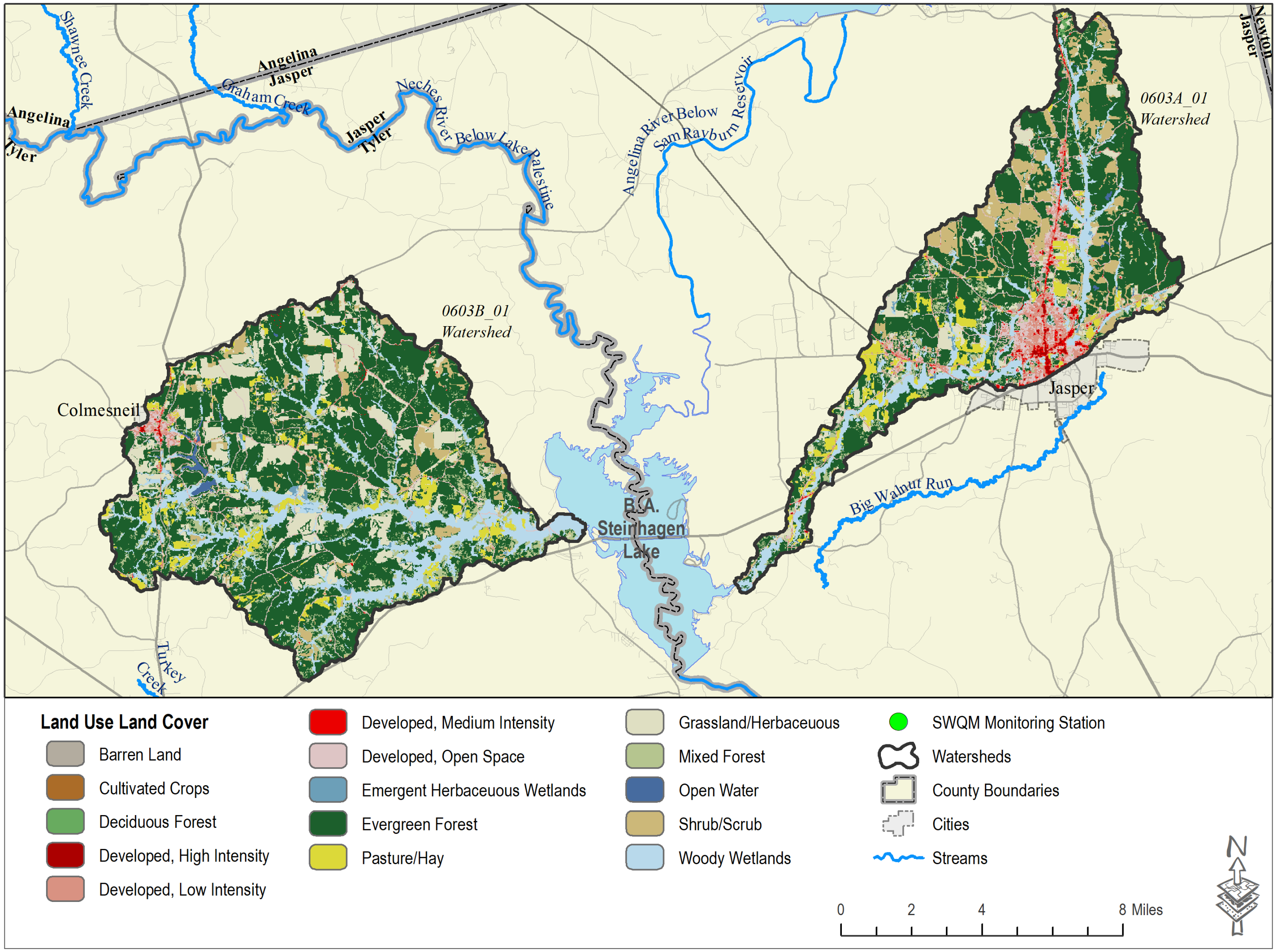

Figure 5. 2016 land cover within the Sandy Creek and Wolf Creek watersheds.
Source: National Land Cover Database (USGS, 2019a).

Table 4. Land cover.
Source: NLCD (USGS, 2019).

Land Cover Class	Sandy Creek Acres	Sandy Creek Percent of Total	Wolf Creek Acres	Wolf Creek Percent of Total
Open Water	67.83	0.2	262.87	0.5
Developed, Open Space	2,375.00	6.6	1,856.56	3.5
Developed, Low Intensity	2,137.58	5.9	761.26	1.4
Developed, Medium Intensity	505.17	1.4	72.74	0.1
Developed, High Intensity	225.87	0.6	21.78	0.0
Barren Land	117.82	0.3	13.12	0.0
Deciduous Forest	110.04	0.3	63.46	0.1
Evergreen Forest	16,256.27	44.9	26,554.04	49.9
Mixed Forest	1,489.68	4.1	4,054.73	7.6
Shrub/Scrub	4,623.63	12.8	2,491.86	4.7
Grassland/Herbaceous	2,313.39	6.4	7,410.86	13.9
Pasture/Hay	2,077.86	5.7	2,344.32	4.4
Cultivated Crops	0	0	0	0
Woody Wetlands	3,790.16	10.5	7,109.46	13.4
Emergent Herbaceous Wetlands	94.05	0.3	190.46	0.4
Total	**36,184.36[a]**	**100**	**53,207.52**	**100[b]**

[a] Sum of rounded acreage is 36,184.35. The actual acreage is 36,184.36. This discrepancy is due to rounding of the category acreage.
[b] Total differs slightly from 100% due to rounding.

2.6. Soils

Soil data was obtained from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (NRCS, 2018). 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). 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. 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.

The Sandy Creek watershed is composed mostly of soils in Hydrologic Soil Group A (69.54 percent) (Table 5). Spatial distribution of soil hydrologic groups within the project watershed is depicted in Figure 6. The figure shows that most of the Group A soils are found in the upper portion of the watershed. In the downstream portions of the watershed, less well draining soils become more prevalent.

The Wolf Creek watershed is predominately composed of Group A (38.83 percent) and Group B (26.92 percent) soils. The Group A and B soils are mainly found north of Wolf Creek. South of Wolf Creek, Group C and D soils become more prevalent.

Table 5. Hydrologic soil group breakdowns.
Source: SSURGO Database (NRCS, 2018).

Hydrologic Group	Sandy Creek Watershed Acres	Sandy Creek Percent of Total	Wolf Creek Watershed Acres	Wolf Creek Percent of Total
A	25,163.21	69.54	20,660.85	38.83
A/D	725.80	2.01	0	0
B	4,321.79	11.94	14,320.94	26.92
B/D	1,163.91	3.22	208.31	0.39
C	4,043.34	11.17	5,664.50	10.65
C/D	0	0	63.63	0.12
D	766.31	2.12	12,289.29	23.10
Total	**36,184.36**	**100**	**53,207.52**	**100***

* Total differs slightly from 100% due to rounding.

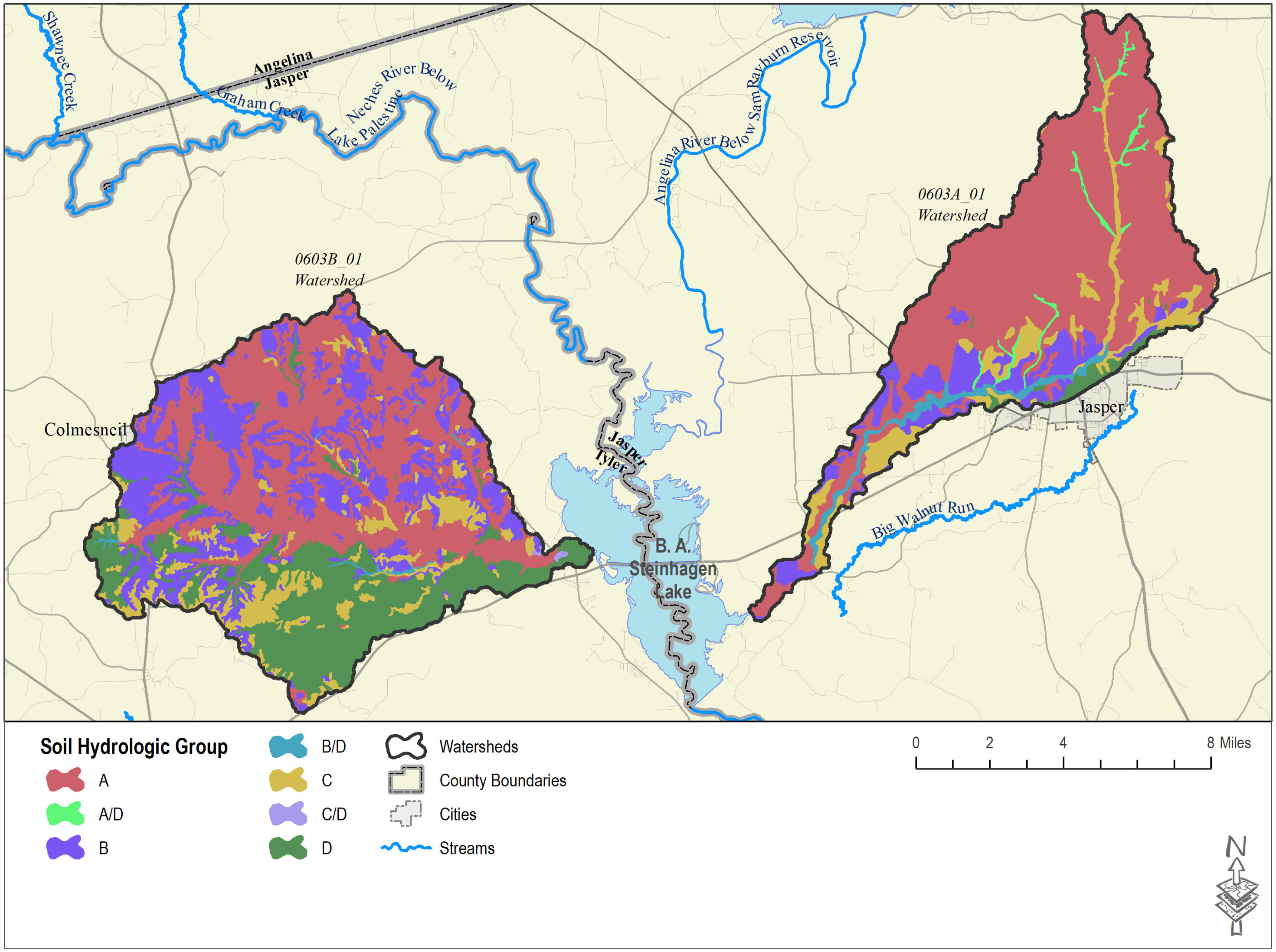

Figure 6. Hydrologic soil groups Source: SSURGO database (NRCS, 2018).

2.7. Potential Sources of Fecal Indicator Bacteria

Potential sources of bacteria pollution are divided into two primary categories: *regulated* and *unregulated*. Regulated pollution sources have permits under the Texas Pollutant Discharge Elimination System (TPDES) and National Pollutant Discharge Elimination System (NPDES) programs. Wastewater treatment facility (WWTF) discharges and stormwater discharges from industry, construction, and municipal separate storm sewer systems (MS4s) of cities are examples of regulated sources. Unregulated sources are typically nonpoint source in nature and are not regulated by a permitting system.

Except for WWTFs, which receive individual wasteload allocations (WLAs) (Section 4.7.3) 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 source descriptions are not precise inventories and/or loadings.

2.7.1. Regulated Sources

Regulated sources are controlled by permit under the TPDES program. Domestic WWTFs and municipal, construction, and industrial stormwater discharges represent the permitted sources in the Sandy Creek watershed. No regulated sources were identified in the Wolf Creek watershed.

2.7.1.1. – Domestic and Industrial Wastewater Treatment Facilities

As of April 2019, there is one facility with a TPDES permit that operates within the Sandy Creek watershed (Table 6, Figure 7). No TPDES permitted WWTFs discharge within the Wolf Creek watershed.

Table 6. Summary of permitted WWTFs in the Sandy Creek watershed.
Source: Individual permits (TCEQ, 2019c) and USEPA Environmental Compliance and History Online (ECHO) database (USEPA, 2019).

AU	TPDES Permit No. (NPDES ID)	Facility	Held By	Annual Average Permitted Discharge (MGD†)	Recent Discharge (MGD)*
0603A_01	WQ0010197001 (TX0024368)	City of Jasper WWTF	City of Jasper	3.25	1.23

† Million gallons per day (MGD)
* Based on mean reported discharges in Discharge Monitoring Reports for the reporting periods ending October 31, 2008 through November 30, 2018 (USEPA, 2019)

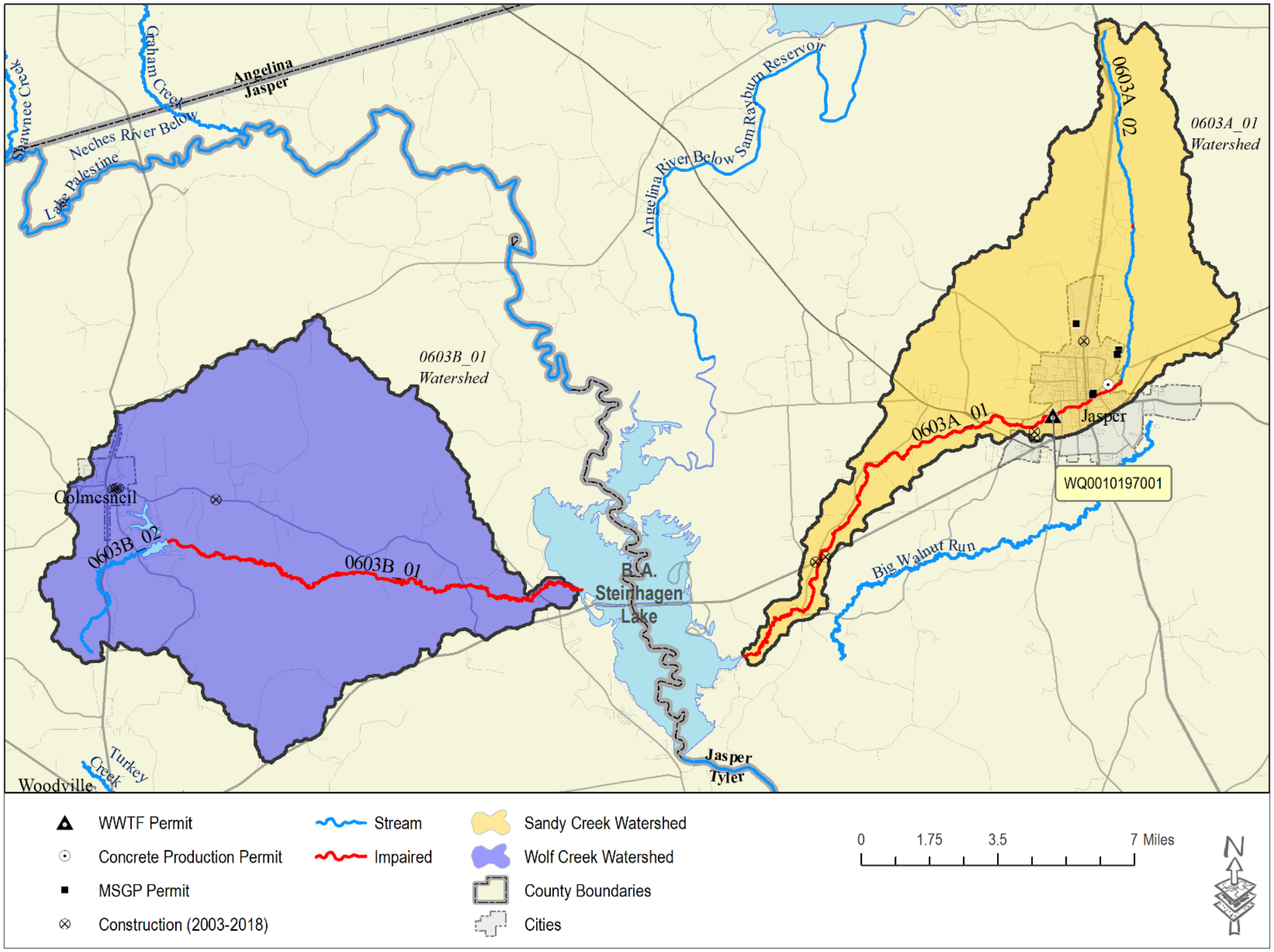

Figure 7. Regulated sources in the Sandy Creek and Wolf Creek watersheds.
Source: WWTF permits (TCEQ, 2019c), General Permits (TCEQ, 2019d).

2.7.1.2 – TPDES Water Quality General Permits

In addition to the individual wastewater discharge permit listed in Table 6, certain types of activities are required to be covered by one of several TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production
- TXG340000 – petroleum bulk stations and terminals
- TXG670000 – hydrostatic test water
- TXG830000 – 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, 2019d) in the Sandy Creek watershed as of December 31, 2018 indicated there is one concrete production facility permit (Figure 7). The permit (TXG110385) authorizes the discharge of stormwater and will be included in the regulated stormwater allocations. The concrete production facility covers approximately 0.028 square miles (Table 8, Figure 7). No other general wastewater permits were found for the Sandy Creek watershed. No general wastewater permits were found in the Wolf Creek watershed.

2.7.1.3. – 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.

TCEQ Central Office in Austin provided statewide data on SSO incidents from January 2016 through December 2018 (TCEQ, 2019e) and basin wide data on SSO incidents from 2005 through 2015 (TCEQ, 2019f). Table 7 summarizes the number of SSO incidents reported by regulated entities operating within the watershed.

Table 7. Summary of reported SSO events (2005-2018) for permitted WWTFs operating within the Sandy and Wolf Creeks watersheds.
Source: Data files from TCEQ (TCEQ, 2019e; TCEQ, 2019f).

Segment	No. of incidents	Total Volume	Average Volume	Minimum Volume	Maximum Volume
0603A	196	947,860	4,989[a]	10	240,000
0603B[b]	4	8,500	2,125	1,500	3,000

[a] Average volume is the average of all report volumes. Six events did not include a reported spill volume. Therefore, the average volume does not equal total volume divided by number of incidents.
[b] Although the Wolf Creek watershed does not have any permitted discharges, the service area for the Colmesneil WWTF collection system is within the watershed and reported SSOs are noted in the table.

2.7.1.4. TPDES Regulated Stormwater

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

1) stormwater subject to regulation, which is any stormwater originating from TPDES-regulated Phase I and Phase II MS4s, stormwater discharges associated with industrial activities, and stormwater from regulated construction activities; and
2) stormwater runoff not subject to regulation.

The TPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permits for their stormwater systems. Both the Phase I and II permits include any conveyance such as 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 exceeding 100,000, whereas Phase II permits are for smaller communities within a USEPA-defined urbanized area that are regulated by a general permit. 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 SWMPs require specification of best management practices for six minimum control measures:

- Public education and outreach;
- Public participation/involvement;
- Illicit discharge detection and elimination;
- Construction site runoff control;
- Post-construction runoff control; and
- Pollution prevention/good housekeeping.

The Sandy Creek and Wolf Creek watersheds do not include any Phase I MS4 permits.

A search of TCEQ central registry was conducted for active TPDES stormwater general permits. Discharges of stormwater from a Phase II MS4 area, industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

- TXR040000 – stormwater Phase II MS4 general permit for urbanized areas
- TXR050000 – stormwater multi-sector general permit (MSGP) for industrial facilities
- TXR150000 – stormwater from construction activities disturbing more than one acre

TCEQ Central Registry of active stormwater general permits in the Sandy Creek watershed, as of December 31, 2018, shows six MSGP permits and one concrete production authorization covering approximately 0.150 square miles (Figure 7, Table 8) (TCEQ, 2019d). A search of active stormwater general permits in the Wolf Creek watershed, as of December 31, 2018, found no permits

Table 8. Summary of active TPDES general stormwater permits.
Source: General Permits (TCEQ, 2019d).

Watershed	Permit Holder	TPDES General Permit Type	Permit Number	Estimated Site Area (square miles)
Sandy Creek	City of Jasper	MSGP	TXR05V360	0.009
Sandy Creek	APAC-Texas, Inc.	MSGP	TXR05AK68	0.044
Sandy Creek	APAC-Texas, Inc.	MSGP	TXR05AK73	0.005
Sandy Creek	Terra Biochem, L.L.C.	MSGP	TXR05AX84	0.019
Sandy Creek	North Star RMS, LLC	MSGP	TXR05BW41	0.042
Sandy Creek	Beaumont Iron & Metal Corporation DBA Jasper Iron & Metal	MSGP	TXR05P538[a]	0.003
Sandy Creek	Few Ready Mix Concrete Co.	Concrete Production	TXG110385	0.028
			Sandy Creek watershed Total Estimated Area:	**0.150**
			Wolf Creek watershed Total Estimated Area	**0**

[a] TXR05P538 was terminated 2/27/2020 but not removed from total area since the estimation is reasonable.

A search of active, terminated, and expired construction permits between March 2003 and December 2018 was conducted. Table 9 summarizes the historical construction permits found in the Sandy Creek and Wolf Creek watersheds. Based on increased recent construction activity, an annual average area covered by constructions permits was determined for the years 2015 through 2018 for the Sandy Creek and Wolf Creek watersheds (Table 10).

On average, 35.51 acres per year were under construction permits in the Sandy Creek watershed from 2015 - 2018, with four permits during that time span (Table 10). No Phase II MS4 permits were identified in the Sandy Creek watershed.

On average, 7.04 acres per year were under construction permits from 2015-2018 with three permits during that time span in the Wolf Creek watershed (Table 10). No Phase II MS4 or other general permits were identified in the Wolf Creek watershed.

Table 9. Summary of active, terminated, and expired construction permits between March 2003 and December 2018 in Sandy and Wolf Creek watersheds.
Source: General Permits (TCEQ, 2019d).

Watershed	Permit Number	Permit Holder	Acres Disturbed	Date Range
Sandy Creek	TXR150020830	Hammer Equipment LLC	7.5	09/24/2015-06/05/2018
Sandy Creek	TXR150019834	Texas Department of Transportation	33	08/11/2015-03/06/2017
Sandy Creek	TXR15152J	Texas Department of Transportation	6.52	02/13/2018-03/23/2018
Sandy Creek	TXR15313K	Texas Department of Transportation	6.52	03/23/2018-08/24/2018
Sandy Creek	TXR15JS73	WOB-Prospect Point Apts LLC	6	01/16/2008-06/03/2008
Sandy Creek	TXR15L648	AT&T Services Inc.	10	08/01/2004-06/03/2008
Wolf Creek	TXR15117L	Oldcastle Materials Texas, Inc.	9.38	04/11/2018-08/27/2018
Wolf Creek	TXR15153J	Texas Department of Transportation	9.38	02/13/2018-03/27/2018
Wolf Creek	TXR15503K	Texas Department of Transportation	9.38	03/27/2018-08/24/2018
Wolf Creek	TXR15M163	Texas Department of Transportation	15.64	08/27/2004-01/10/2007

Table 10. Annual total and average acres under construction permits.

Year	Construction Permit Acres Sandy Creek watershed	Construction Permit Acres Wolf Creek watershed
2003	0	0
2004	10	15.64
2005	10	15.64
2006	10	15.64
2007	10	15.64
2008	16	0
2009	0	0
2010	0	0
2011	0	0
2012	0	0
2013	0	0
2014	0	0
2015	40.5	0
2016	40.5	0

Year	Construction Permit Acres Sandy Creek watershed	Construction Permit Acres Wolf Creek watershed
2017	40.5	0
2018	20.54	28.14
Annual Average 2015-2018	35.51	7.04

2.7.1.5. Review of Compliance Information on Permitted Sources

The ECHO database was reviewed for non-compliance issues regarding indicator bacteria for permitted wastewater dischargers in the watersheds (USEPA, 2019). The City of Jasper WWTF permit requires weekly monitoring of *E. coli* bacteria concentrations. According to submitted self-monitoring records, the City of Jasper WWTF reported no exceedances of the daily average limit for *E. coli* bacteria from January 1, 2015 through December 31, 2018. Three out of the forty-eight monthly reported daily max measurements exceeded the 399 cfu/100 mL limit (6.25 percent of reported records).

2.7.2. Unregulated Sources

Unregulated sources include non-permitted, typically nonpoint source, discharges that can contribute to fecal bacteria loading in the watershed. Potential sources, detailed below, include wildlife, agricultural runoff, and domestic pets.

2.7.2.1. Wildlife and Unmanaged Animal Contributions

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. Riparian corridors of streams and rivers naturally attract wildlife. With direct access to the stream channel, direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Wildlife also deposit fecal bacteria onto land surfaces, where rainfall runoff may wash bacteria into nearby streams.

The Texas Parks and Wildlife Department (TPWD) provided deer population-density estimates by Resource Management Unit (RMU) and Ecoregion in the state (TPWD, 2018). Both watersheds are within RMU 14 (Pineywoods Ecoregion), with an average deer density of one deer per 48.49 acres over the period 2005-2016. This density was applied to land use/land cover acreage considered suitable for deer habitat (land classified in the 2016 NLCD as pasture/hay, shrub/scrub, grasslands/herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands, and emergent herbaceous wetlands). Based on an estimated 30,755 acres of suitable habitat, there are an estimated 634 deer in the Sandy Creek watershed (Table 11). Based on an estimated 50,219 acres of suitable habitat, there are an estimated 1,036 deer in the Wolf Creek watershed.

AgriLife Extension (2012) estimates one hog per 39 acres as a statewide average density for feral hogs. This density was applied to land classified in the 2016 NLCD as pasture/hay, shrub/scrub, grasslands/herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands, and emergent herbaceous wetlands. Based on these assumptions, there are an estimated 789 and 1,288 feral hogs in Sandy Creek and Wolf Creek watersheds respectively (Table 11).

Table 11. Estimated deer and feral hog populations in the Sandy and Wolf Creeks watersheds.
Source: Estimates derived from TPWD and AgriLife Extension reports (AgriLife Extension, 2012; TPWD, 2018).

Watershed	Deer	Feral Hogs
Sandy Creek	634	789
Wolf Creek	1,036	1,288

2.7.2.2. Unregulated Agricultural Activities and Domesticated Animals

Activities such as livestock grazing close to water bodies and farmers' use of manure as fertilizer can contribute bacteria to nearby water bodies. Watershed livestock counts were estimated using county-level data available from the 2017 Census of Agriculture (USDA, 2019). The county-level data were refined to reflect acres of grazeable land within each TMDL watershed. The refinement was determined by the grazeable area of each county and the grazeable acres of each watershed. The ratio was the grazeable area of each watershed that resides within a county divided by the total area of the county. Watershed-level livestock numbers are the ratio multiplied by county-level livestock population data (Table 12).

Table 12. Livestock estimates for the Sandy and Wolf Creeks watersheds.
Source: Estimates derived from USDA Census of Agriculture (USDA, 2019).

Watershed	Cattle and Calves	Hogs and Pigs	Goats and Sheep	Horses
Sandy Creek	856	16	72	68
Wolf Creek	1,827	46	201	111

Pets can also be a source of bacteria, because stormwater runoff carries the animal wastes into streams. The American Veterinary Medical Association (AVMA) estimates there are 0.614 dogs and 0.457 cats per American household. The number of domestic cats and dogs in the watersheds was estimated by applying the AVMA estimates to the number of households in the watersheds. The number of watershed households was estimated with 2010 Census Block household counts, multiplied by the proportion of the Census Block within the watershed. Table 13 summarizes the estimated number of households and pets in each project watershed.

Table 13. Estimated number of households and pet populations.
Source: Estimates derived from USCB Census blocks (USCB, 2010) and AVMA household pet estimates (AVMA, 2018).

Watershed	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
Sandy Creek	3,447	2,116	1,575
Wolf Creek	1,077	661	492

2.7.2.3. Failing On-Site Sewage Facilities

Private residential on-site sewage facilities (OSSFs), commonly referred to as septic systems, consist of various designs based on physical conditions of the local soil. 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. However, properly designed and operated OSSFs are expected to contribute virtually no fecal bacteria to surface waters. For example, it is reported that less than 0.01 percent of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system (Weiskel, 1996). Reed, Stowe, and Yanke (2001) break the state into five "OSSF regions." The estimated OSSF failure rate in this region of Texas (Region 5) is estimated at 19 percent (Reed, Stowe, and Yanke, 2001).

Estimates of the number of OSSFs in the project watershed were determined by using 911 addresses to estimate residence locations and these were verified with aerial imagery data (Arctur and Maidment, 2018). OSSFs were estimated to be residential and business addresses that were outside of city boundaries and Certificates of Convenience and Necessity (CCN) areas (Public Utility Commission of Texas, 2017). Table 14 and Figure 8 show the total estimated OSSFs and OSSF densities in the project watershed.

Table 14. OSSF estimate for the Sandy and Wolf Creeks watersheds.
Source: Estimates derived from address data (Arctur and Maidment, 2018) and CCN locations (Public Utility Commission of Texas, 2017).

Watershed	Estimated OSSFs
Sandy Creek	1,433
Wolf Creek	936

2.7.2.4. Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (e.g., warm temperature). Fecal organisms can survive and replicate from improperly treated effluent during their transport in pipe networks, and they can survive and replicate in organic-rich materials such as compost and sludge. While die-off of 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 instream processes and are not considered in the bacteria source loading estimates of either water body in the TMDL watersheds.

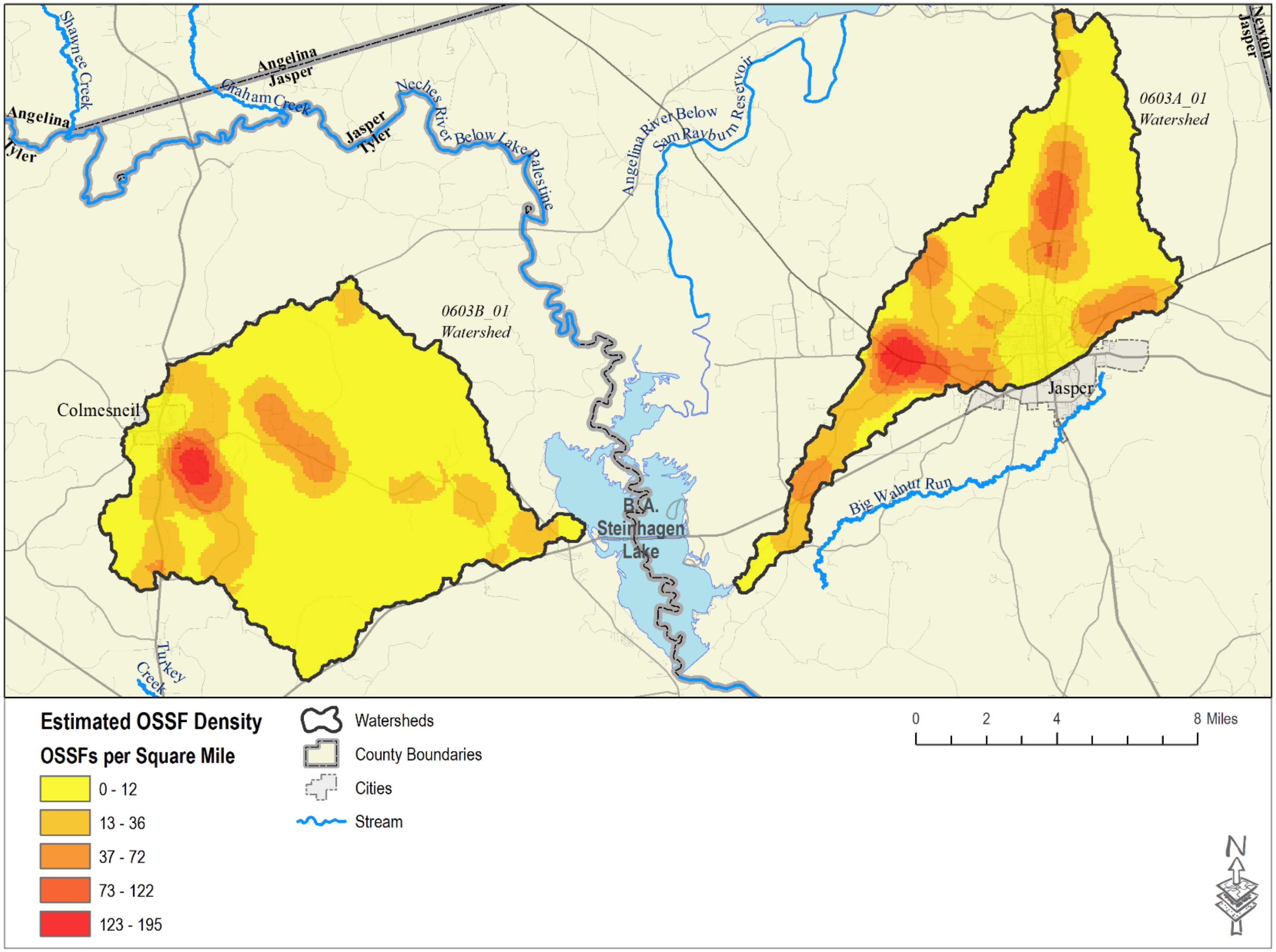

Figure 8. Estimated OSSF density in Sandy and Wolf Creek watersheds.
Sources: Estimates derived from address data (Arctur and Maidment, 2018) and CCN locations (Public Utility Commission of Texas, 2017).

Section 3. Bacteria Tool Development

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

3.1. Tool Selection

The TMDL allocation process for bacteria involves assigning bacteria, e.g., *E. coli*, loads to their sources such that the total loads do not violate the pertinent numeric criterion protecting contact recreation use. To perform the allocation process, a tool must be developed to assist in allocating bacteria loads. Selection of the appropriate bacteria tool for the impaired AUs in the TMDL watersheds considered the availability of data and other information necessary for the supportable application of the selected tool and guidance in the Texas Bacteria Task Force report (TWRI, 2007). Mechanistic models and empirically derived LDCs are the two approaches commonly used for bacteria TMDLs in the Texas.

Mechanistic models, also referred to as process models, are based on theoretical relationships that numerically describe the physical processes that determine streamflows and bacteria concentrations, in addition to other related response variables. Mechanistic models are available that reliably represent streamflow and bacteria response to land-use, rainfall, tidal inputs, and other processes. While hydrologic processes integrated within these models are quite robust, the numeric representations of bacteria transport processes are considered less reliable (TWRI, 2007). Painter et al. (2017) also note that while mechanistic bacteria modeling has progressed significantly, the application of these models relies on more specific watershed information than is required for representation of hydrologic processes. As a result, decisions on input parameters that affect bacteria response must be made by the modeler when the actual numeric values may not be available within an acceptable range of certainty (Painter et al., 2017). However, under circumstances where the governing physical processes are acceptably quantifiable, the mechanistic model provides an understanding of the important biological, chemical, and physical processes of the prototype system and reasonable predictive capabilities to evaluate alternative allocations of pollutant load sources.

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 regulated community recognizes the frequent information limitations with the bacteria TMDLs that constrain the use of the more powerful mechanistic models. Further, the Bacteria Task Force appointed by TCEQ and Texas State Soil and Water Conservation Board supports the application of the LDC method within their three-tiered approach to TMDL development (TWRI, 2007). The LDC method lacks the predictive capabilities to evaluate alternative allocation approaches to reach TMDL goals, nor can it be used to quantify specific source contributions and instream fate and transport processes. However, the method does provide 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.

3.1.1. Available Data Resources

Streamflow and *E. coli* data availability were used to provide guidance in the allocation tool selection process. The necessary information and data are largely unavailable for the project watersheds to allow the adequate definition of many of the physical and biological processes influencing instream bacteria concentrations for mechanistic model application, and these limitations became an important consideration in the allocation tool selection process.

Hydrologic data in the form of daily streamflow records were unavailable in the TMDL watersheds. However, streamflow records are available in the nearby Menard Creek and Big Cow Creek watersheds (USGS, 2019b). Streamflow records for both watersheds are collected and made available by the USGS, which operates streamflow gages 08029500 (Big Cow Creek) and 08066300 (Menard Creek). These gages were used to develop estimated naturalized mean daily streamflow for Sandy Creek (0603A_01) and Wolf Creek (0603B_01) (Table 15). The gages were chosen due to their proximity to the project watersheds and lack of streamflow alterations from permitted discharges and withdrawals. Further discussion about streamflow development is in Section 3.2.3. Step 3: Develop Daily Streamflow Records.

Table 15. Basic information on the USGS streamflow gage used for streamflow development.

Gage Number	Site Description	Drainage Area (square miles)	Daily Streamflow Record
08029500	Big Cow Ck nr Newton, TX	128.18	01-01-2000 – 12-31-2018
08066300	Menard Ck nr Rye, TX	147.48	01-01-2000 – 12-31-2018

Historical ambient *E. coli* data used for the development of LDCs was obtained through the TCEQ SWQMIS database (TCEQ, 2019a) (Figure 9, Figure 10, Table 16).

A search of TCEQ Texas Water Rights Viewer (TCEQ, 2019b) as of July 2019 revealed that within the Sandy Creek watershed, there are no surface water diversion rights owners. The Wolf Creek watershed contains four surface water rights owners with only one water right allowing diversions for irrigation (TCEQ, 2019b).

A review of the water use data in the Texas Water Rights Viewer containing self-reported diversions indicates that the water rights owners did not report any surface water diversions from 2013 through 2018 (TCEQ, 2019b). Because of the absence of reported diversions, it is assumed that water diversions have an insignificant impact on stream hydrology and pollutant load allocations. In addition, water rights permits allow withdrawals of water, as opposed to discharges, and do not need to be assigned loadings in a TMDL.

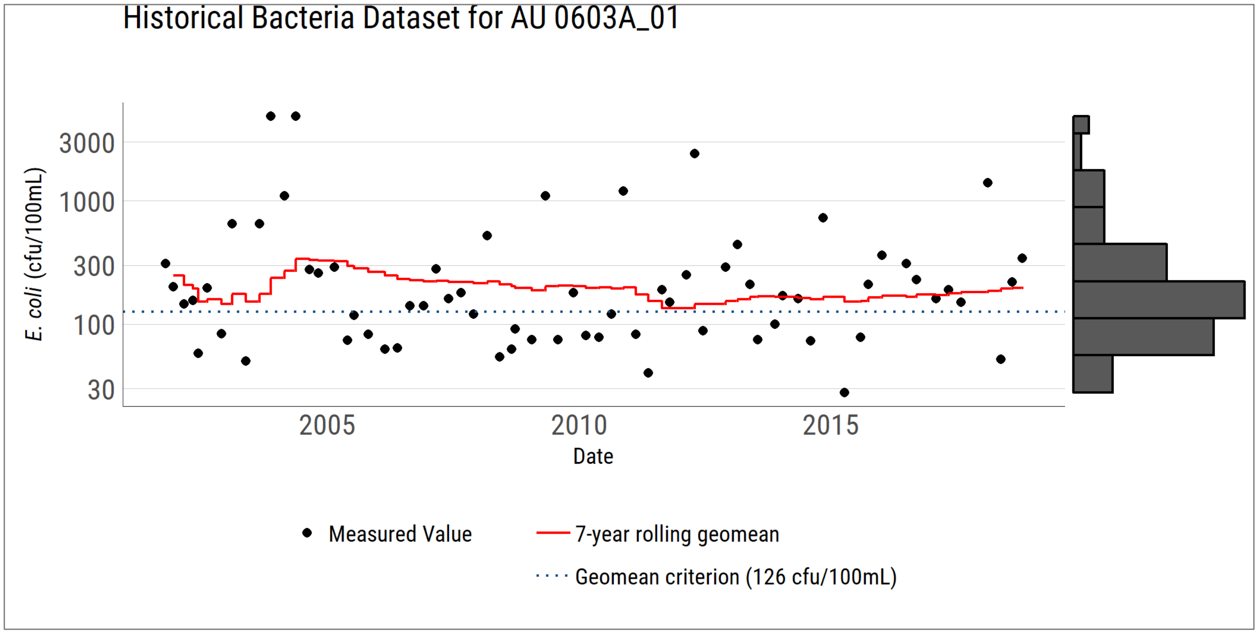

Figure 9. Summary plot of historical bacteria dataset for Sandy Creek (0603A_01, 10/16/2001-10/17/2018) including 7-year rolling geometric mean and histogram depicting the distribution of measured values.
Source: TCEQ SWQMIS (TCEQ, 2019a).

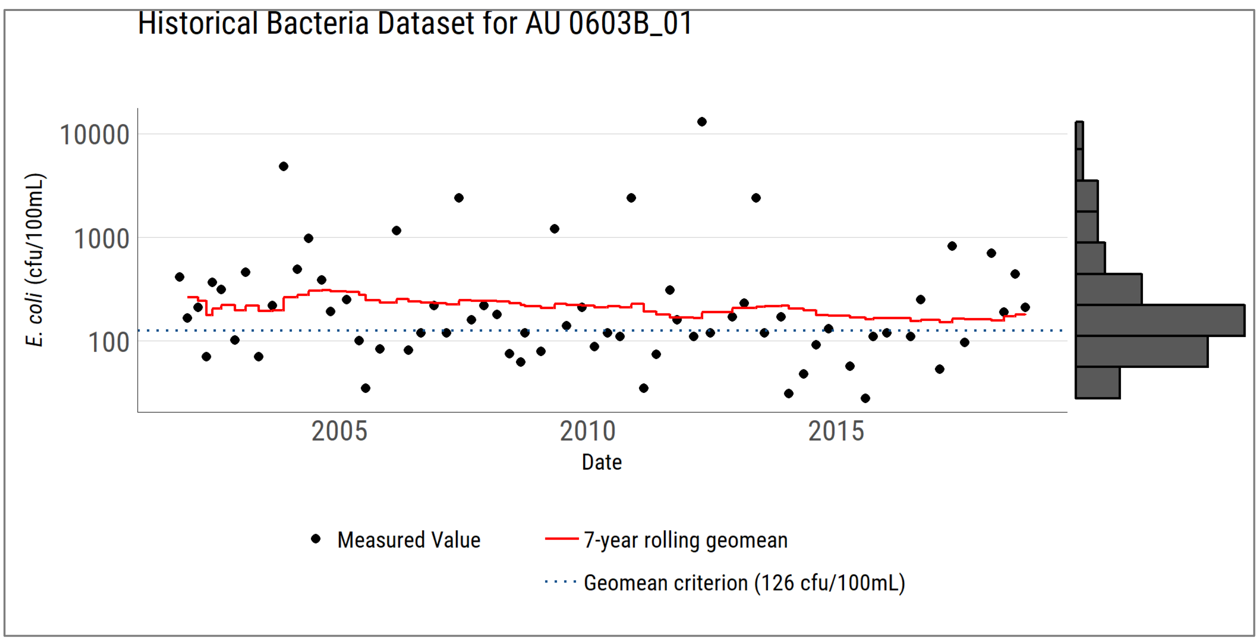

Figure 10. Summary plot of historical bacteria dataset for Wolf Creek (0603B_01, 10/16/2001 – 10/17/2018) including 7-year rolling geometric mean and histogram depicting the distribution of measured values.
Source: TCEQ SWQMIS (TCEQ, 2019a).

Table 16. Summary of historical bacteria dataset for Sandy Creek and Wolf Creek watersheds.
Source: TCEQ SWQMIS (TCEQ, 2019a).

Water Body	AU	Station	Station Location	No. of Samples	Data Date Range	Geomean	Percent exceeding single sample criterion
Sandy Creek	0603A_01	10484	Sandy Creek at FM 777	68	10/16/2001 – 10/17/2018	188.76	17.6
Wolf Creek	0603B_01	15344	Wolf Creek at FM 256	68	10/16/2001 - 10/17/2018	194.56	20.6

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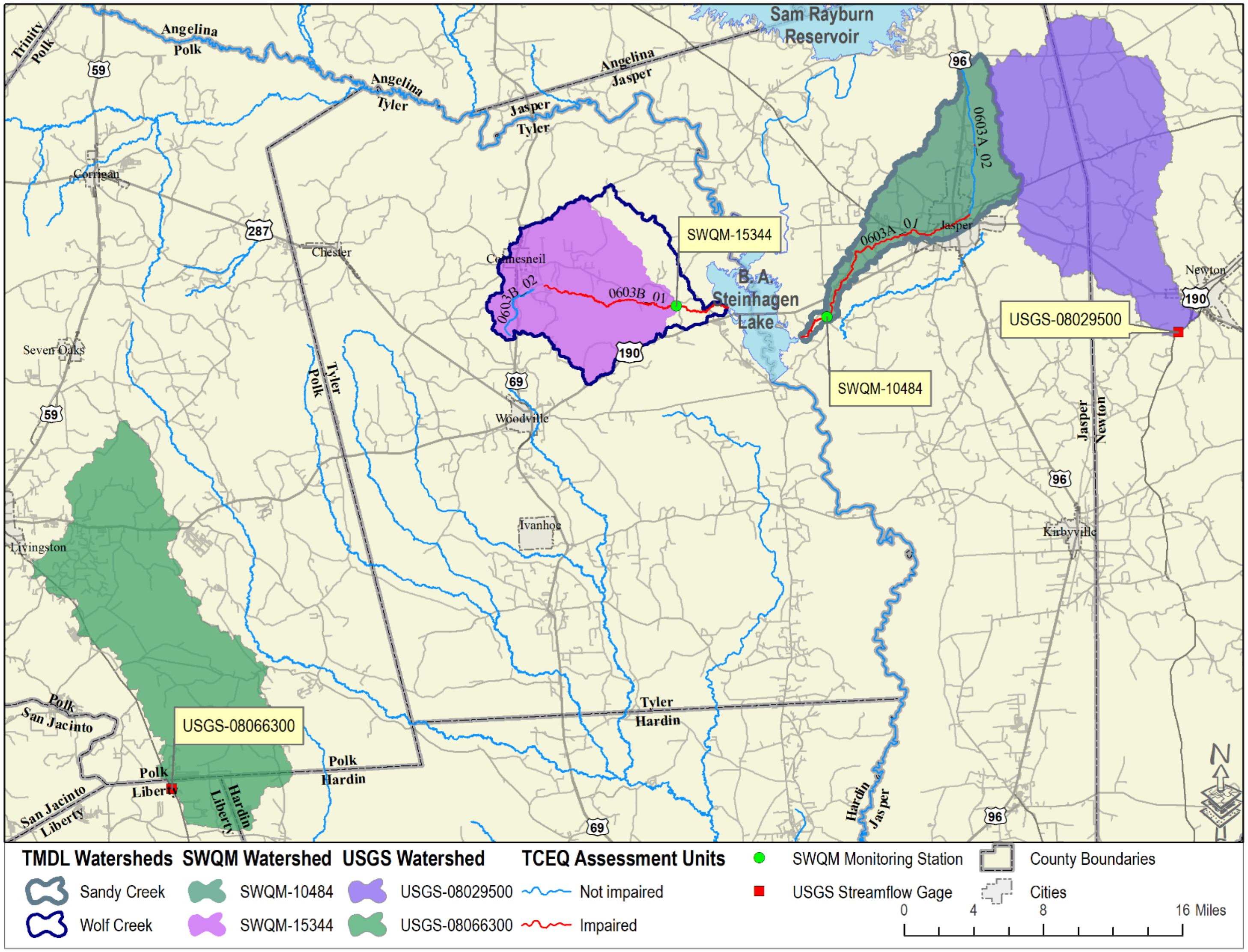

Figure 11. USGS streamflow gages and watersheds used in streamflow development for Sandy Creek and Wolf Creek watersheds.
Sources: USGS Gage Locations (USGS, 2019), TCEQ Monitoring Station Locations (TCEQ, 2018b), TCEQ Assessment Units (TCEQ 2015b).

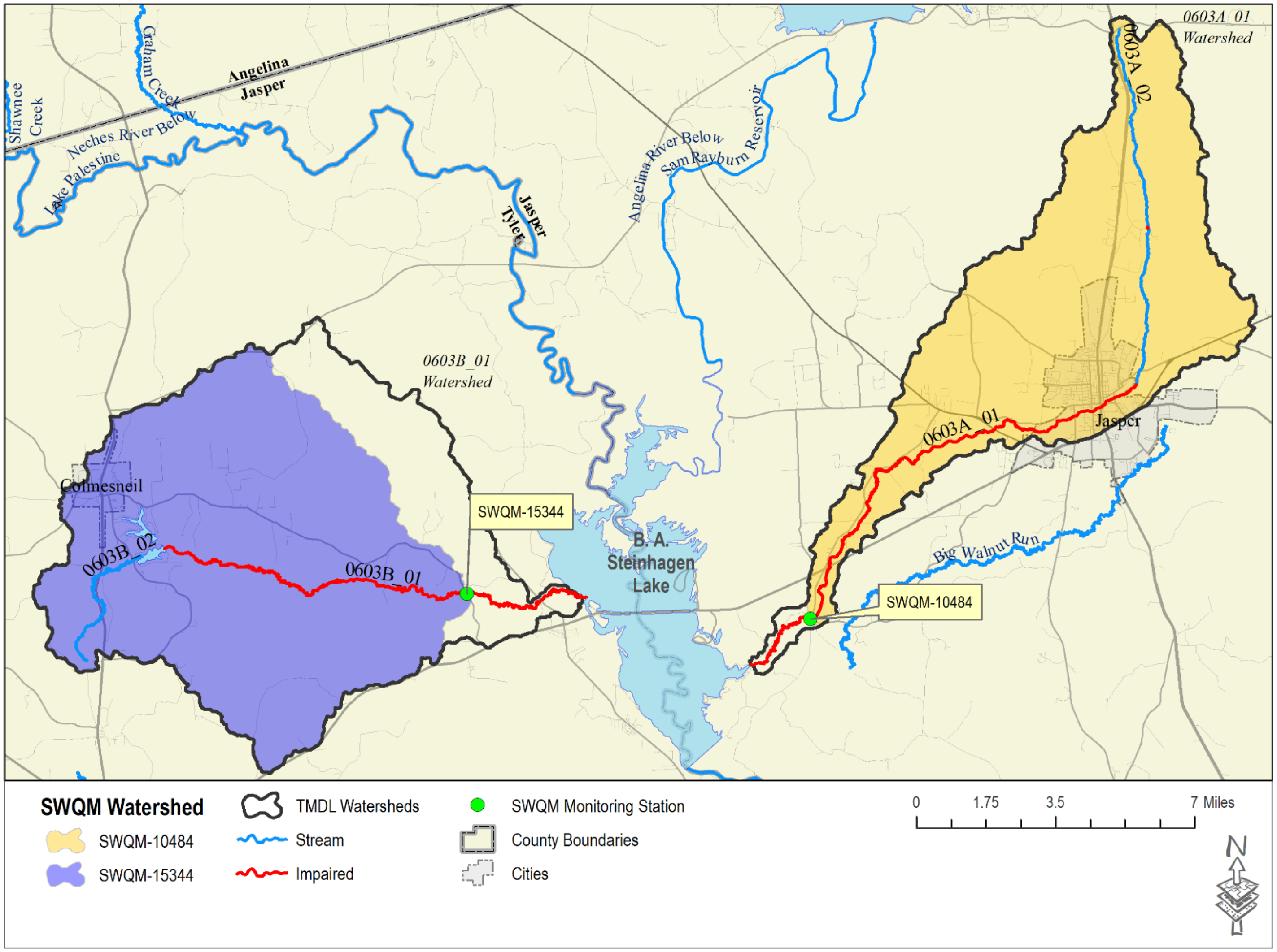

Figure 12. Detailed map of SWQM station watersheds used for FDC and LDC development.

3.1.2. Allocation Tool Selection

Watershed-specific data required for the reliable development of bacteria mechanistic models in the Sandy and Wolf Creeks watersheds is lacking. Based on availability of ambient *E. coli* data and streamflow records from nearby locations, the empirically based LDC approach is considered the preferred allocation tool for Sandy Creek and Wolf Creek.

3.2 Methodology for Flow Duration & Load Duration Curve Development

To develop the flow duration curves (FDCs) and LDCs, 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 FDCs.
- Step 2: Determine the desired stream location for which FDC and LDC development is desired.
- Step 3: Develop daily streamflow records at desired stream location using daily gaged streamflow records and drainage area ratios.
- Step 4: Develop FDC at the desired stream location, segmented into discrete flow regimes.
- Step 5: Develop allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- Step 6: Superimpose historical bacteria data on the allowable bacteria LDC.

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

3.2.1. Step 1: Determine Hydrologic Period

Optimally, the period of record to develop FDCs should include as much data as possible to capture extremes of high and low streamflows and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of conditions experienced when the *E. coli* data were collected. The period of record for available *E. coli* data was October 2001 through October 2018. Daily mean streamflow records from January 1, 2000, to December 31, 2018, were utilized for FDC development. This period of record was selected to capture a reasonable range of extreme high and low streamflow and represents a period in which all the *E. coli* data were collected.

3.2.2. Step 2: Determine Desired Stream Location

For each water body, there was a single impaired AU with a single water quality monitoring station. Both water bodies had 68 *E. coli* samples meeting the 24 minimum-sample suggestion for development of LDCs (TWRI, 2007). The FDCs and LDCs were developed at SWQM Station 10484 in Sandy Creek (0603A_01) and SWQM Station 15344 in Wolf Creek (0603B_01) (Figure 11, Figure 12).

3.2.3. Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and the stream location were determined, the next step was to develop the daily streamflow record for the station. The daily streamflow record was developed from available USGS streamflow records at nearby streams. The method to develop the necessary streamflow record involved a drainage-area ratio (DAR) approach. With this basic approach, each USGS gage's mean daily streamflow value was multiplied by a factor to estimate flow at the desired SWQM station location (Eq.1). With this approach, a factor is determined by dividing the drainage area above the location of interest by the drainage area above the USGS gage (Figure 12, Table 17)

$$Y = X\left(\frac{A_y}{A_x}\right)^{\phi} \qquad \text{(Eq.1)}$$

Where:

Y = streamflow for the ungaged location,

X = streamflow for the gaged location,

A_y = drainage area for the ungaged location,

A_x = drainage area for the gaged location,

ϕ = conditional exponent that is a function of streamflow percentile (Asquith et al. 2006)

Often, $\phi = 1$ is used in the DAR approach. However, empirical analysis of streamflows in Texas indicates that $\phi = 1$ results in substantial bias in streamflow estimates at very low and very high streamflow percentiles (Asquith et al. 2006). Based on these observations, values of ϕ are used based on suggestions by Asquith et al (2006). The value of ϕ varies with streamflow percentiles and lies between 0.7 and 0.935.

The choice in source streams used to develop streamflows at the locations of interest is not straightforward. The analyst must consider separation distance, relative drainage areas, and hydrologic similarity. Furthermore, discharges and diversions in both the source stream and location of interest complicate the application of the DAR.

In practice, the understanding about actual streamflow characteristics is uncertain and reliant upon local knowledge. Based on discussions with local stakeholders, it is assumed that both Sandy Creek and Wolf Creek are perennial streams, possibly running dry only during intense drought conditions. In order to minimize complications from discharges and diversions, source stream gages with minimal diversions and discharges were desired. Furthermore, Asquith et al. (2006) suggest a 100-mile maximum separation distance between the source gage and location for which the streamflow is being developed.

Two stream gages within the 100-mile distance with no upstream discharges or diversions were located: USGS gage 08029500 at Big Cow Creek near Newton and USGS gage 08066300 at Menard Creek near Rye (Figure 11) (USGS, 2019b). Both source watersheds are minimally developed and highly rural, exhibiting similar land use and precipitation characteristics as the Sandy Creek and Wolf Creek watersheds. Inspection of TCEQ water rights viewer indicate no active water right holders or diversions in the source watersheds (TCEQ, 2019b). A search for active TPDES wastewater permits indicated no discharges in the source watersheds. No additional adjustments were considered necessary for the daily streamflow values at the source watersheds.

For a given day, each source stream will have a different flow and different streamflow percentile due to difference in localized precipitation and runoff characteristics. Under these conditions, unless we know that the hydrology, precipitation, and runoff in one source stream is better representative than the other source stream, it is appropriate to apply the mean of estimated streamflows from both gaged locations as the streamflow in the area of interest, as follows (Asquith et al., 2006):

$$Y_j = \frac{X_{1j}\left(\frac{A_y}{A_{x1}}\right)^{\phi} + X_{2j}\left(\frac{A_y}{A_{x2}}\right)^{\phi}}{2}$$

(Eq.2)

Where:

Y_j = streamflow for the ungaged location on day j,

X_{1j} = streamflow for the gaged location 1 on day j,

X_{2j} = streamflow for the gaged location 2 on day j,

A_y = drainage area for the ungaged location,

A_{x1} = drainage area for the gaged location 1,

A_{x2} = drainage area for the gaged location 2,

ϕ = conditional exponent that is a function of streamflow percentile (Asquith et al. 2006)

Table 17 provides the drainage areas used to develop streamflows for Sandy Creek and Wolf Creek. The areas above each source gage were determined by delineating the watershed and calculating the area using ArcGIS. In Step 2, the desired stream locations were determined to be SWQM station 10484 on Sandy Creek and SWQM station 15344 on Wolf Creek. These stations are upstream of each respective AU outlet. Therefore, the watersheds at each station were delineated and areas calculated in ArcGIS using the same geographic projections used to calculate the areas for the source watersheds (Figure 12).

After applying the DAR to daily streamflow values (Eq.2), the output is the "naturalized streamflow" estimate at the location of interest. The naturalized streamflow is the streamflow without alterations due to diversions and discharges. For Sandy Creek, the streamflows were further adjusted to account for the influence of daily discharges from the single upstream permitted discharger (City of Jasper WWTF). The full permitted discharge flows plus future growth (FG) flows were added to the daily naturalized flow estimates. The calculation of FG flows is described in 4.7.4. Future Growth. For Wolf Creek, streamflows were adjusted using only potential FG flows.

Table 17. Drainage-area ratio calculation.

Watershed	Drainage Area (square miles)	DAR Big Cow Creek	DAR Menard Creek
USGS 08029500 (Big Cow Creek)	128.18	NA	NA
USGS 08066300 (Menard Creek)	147.48	NA	NA
Sandy Creek– Station 10484 (0603A_01)	55.42	0.43	0.38
Wolf Creek – Station 15344 (0603B_01)	67.26	0.52	0.46

3.2.4. Steps 4 through 6: Flow Duration Curve and Load Duration Curve

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 the following steps were undertaken:

1. 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);
2. Compute the percent of days each flow was exceeded by dividing each rank by the total number of data points plus 1; and
3. Plot the corresponding flow data against exceedance percentages.

Further, when developing an LDC:

- Multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL or 1.26 cfu/mL) and by a conversion factor (28,316.8 mL/cubic feet (ft^3) × 86,400 seconds/day (s/d)), which gives you a loading unit of billion cfu/day; and
- 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 (28,316.8 mL/cubic feet (ft^3) × 86,400 seconds/day (s/d)); and
- Plot on the LDC for each 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 that measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above a maximum allowable loading curve indicated an exceedance of the water quality criterion, while those below a curve show compliance.

3.3. Flow Duration Curve for TMDL Watershed

FDCs were developed for the impaired AUs of Sandy Creek (0603A_01) and Wolf Creek (0603B_01) at SWQM stations 10484 and 15344 respectively (Figure 13, Figure 14). For this report, the FDC was developed by applying the DAR method and using both USGS gages and period of record (2000-2018) described in the previous section.

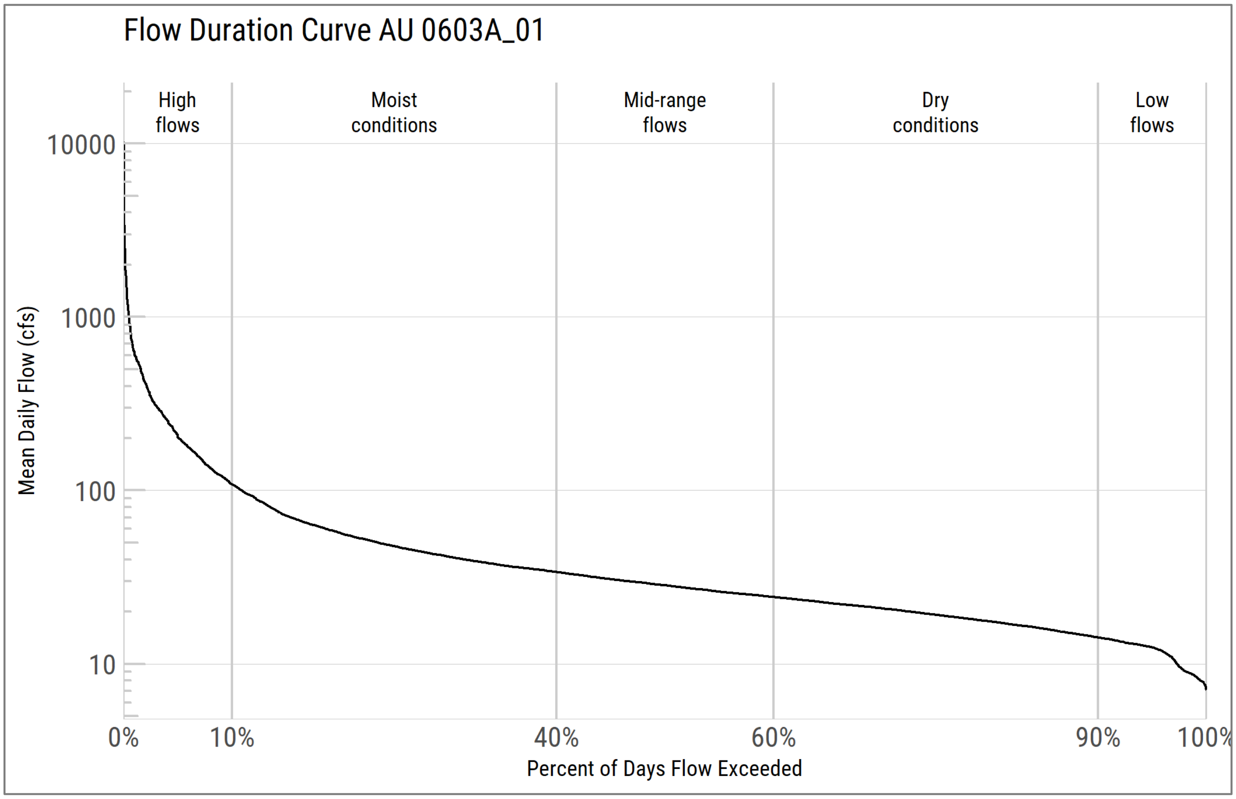

Figure 13. Flow duration curve for Sandy Creek (0603A_01).

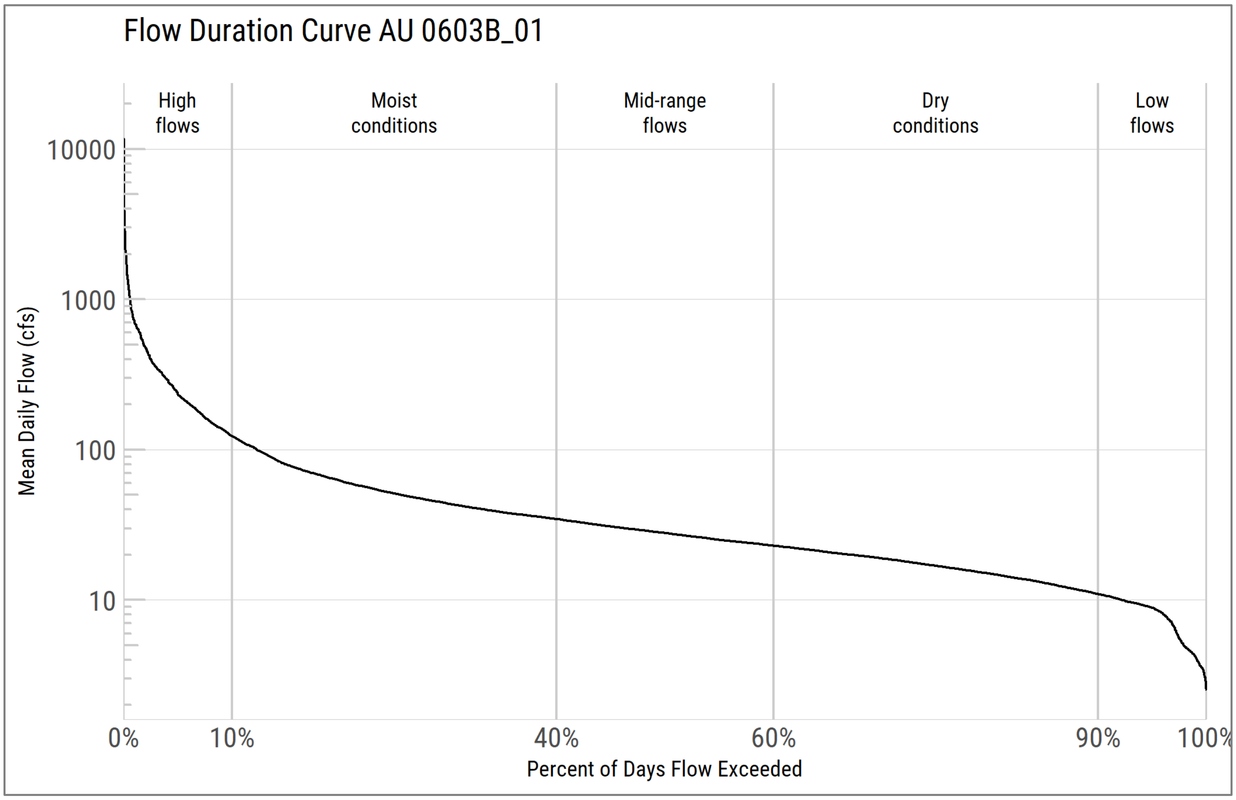

Figure 14. Flow duration curve for Wolf Creek (0603B_01).

3.4. Load Duration Curve for TMDL Watershed

LDCs were developed for impaired AUs of Sandy Creek (0603A_01) and Wolf Creek (0603B_01) at SWQM stations 10484 and 15344 respectively. 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).

The selection of the flow regime intervals was based on general observation of the developed LDCs. Figure 15 depicts the LDC for Sandy Creek (0603A_01) and Figure 16 depicts the LDC for Wolf Creek (0603B_01). The geometric mean loading in each flow regime is also shown to aid interpretation.

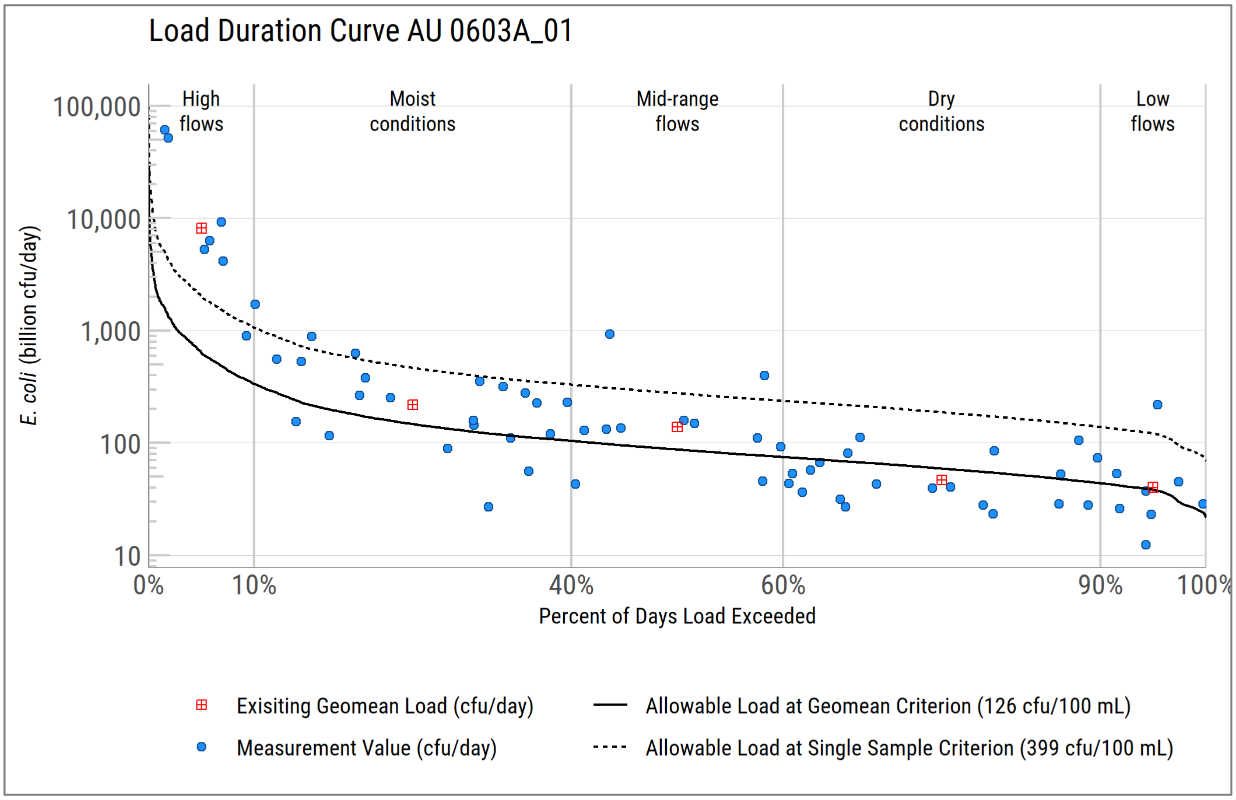

Figure 15. Load Duration Curve for Sandy Creek (0603A_01).

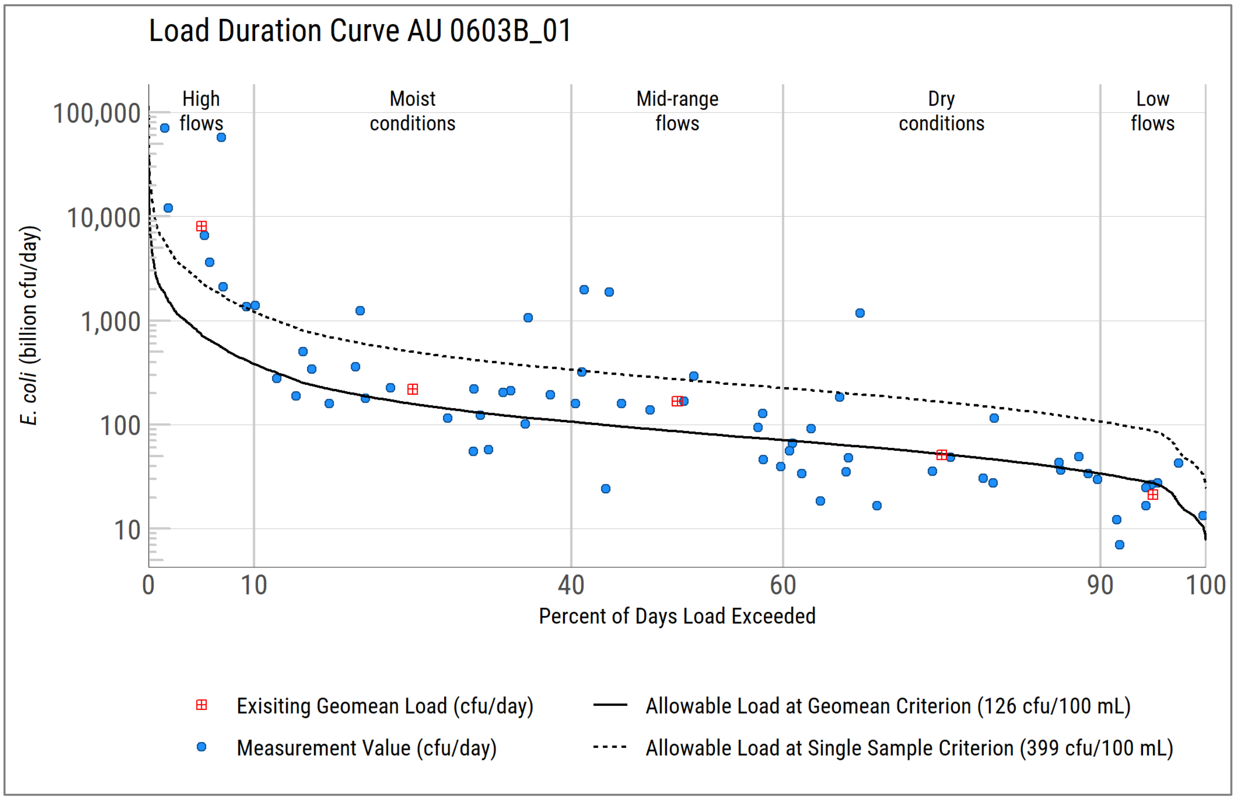

Figure 16. Load Duration Curve for Wolf Creek (0603B_01).

Section 4. TMDL Allocation Analysis

4.1. Endpoint Identification

The AUs within the TMDL watersheds have a use of primary contact recreation, which utilizes a geometric mean numeric criterion of 126 cfu/100 mL for *E. coli* indicator bacteria and a single sample criterion of 399 cfu/100 mL (TCEQ, 2018a). All TMDLs must identify a quantifiable water quality target that indicated the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for the TMDLs is to maintain the concentration of *E. coli* below the geometric mean criterion of 126 cfu/100 mL. This endpoint was applied to each AU addressed in these TMDLs. This endpoint should also result in compliance with the single sample criterion of 399 cfu/100 mL.

4.2. Seasonality

Seasonal variations or seasonality occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. The Code of Federal Regulations [40 CFR §130.7(c)(1)] requires that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations was assessed by comparing *E. coli* during warmer months (May-September) against those collected during cooler months (November-March). The months of April and October were considered transitional between warm and cool seasons and were excluded from the seasonal analysis. Differences in seasonal concentrations were then evaluated with a Wilcoxon Rank Sum test (also known as the "Mann-Whitney" test). The Wilcoxon Rank Sum test was chosen for its ability to handle non-normal data without requiring data transformation. The test was considered significant at the $\alpha = 0.05$ level.

The Wilcoxon Rank Sum test suggests there is a slight seasonal difference in *E. coli* concentrations in Sandy Creek (0603A_01) ($W = 245$, $p < 0.01$, Figure 17) but did not detect a difference in seasonal concentrations in Wolf Creek (0603B_01) ($W = 358$, $p = 0.285$, Figure 18). Based on the boxplots in Figure 17, *E. coli* samples collected during cool months are higher than samples collected during warmer months. Although Sandy Creek (0603A_01) exhibits a seasonal difference in *E. coli* concentration, the contact recreation use standard applies during all seasons.

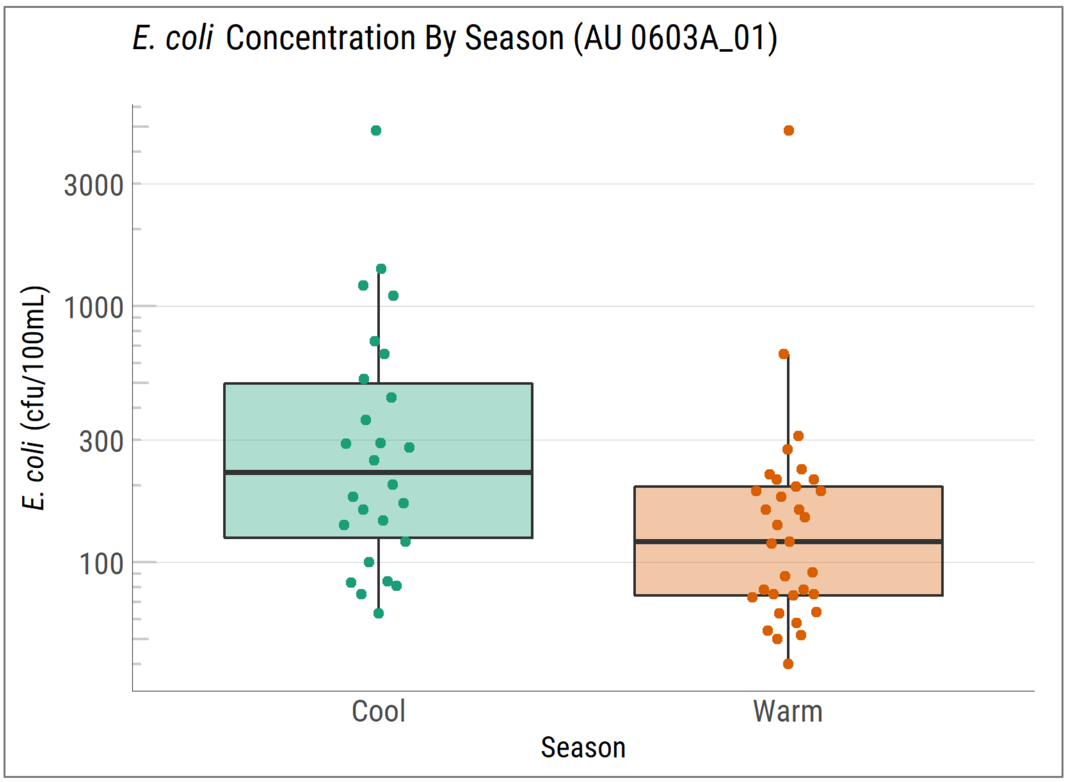

Figure 17. Distribution of *E. coli* concentration by season in Sandy Creek (0603A_01).

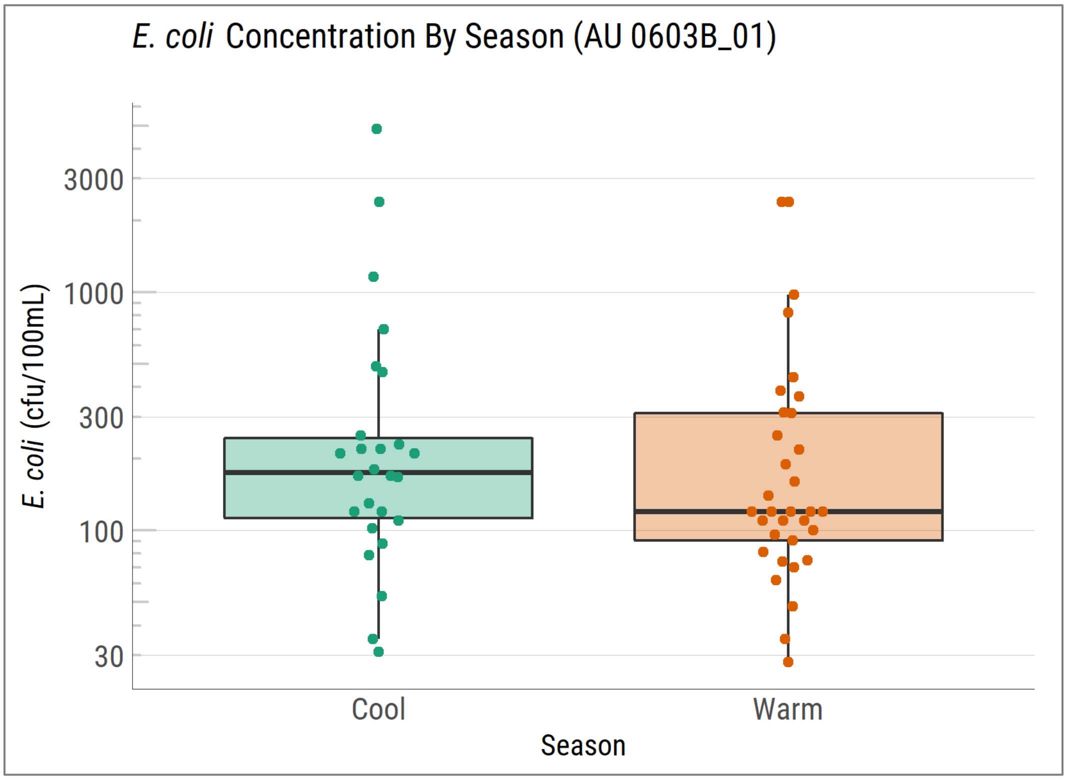

Figure 18. Distribution of *E. coli* concentration by season in Wolf Creek (0603B_01).

4.3. Linkage Analysis

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

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

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

Load duration curves were used to examine the relationship between instream water quality and the source of 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). The pollutant load allocation was based on the flows associated with the watershed areas under stormwater regulation, and the remaining portion was assigned to the unregulated stormwater.

4.4. Load Duration Curve Analysis

LDC analyses were used to examine the relationship between instream water quality, 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. 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 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 regarding the magnitude or specific origin of the various sources. Only limited information is gathered regarding point and nonpoint sources in the watershed. 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 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 hydrological conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (i.e., point source and stormwater) and provides a means to allocate allowable loadings.

Based on the LDCs to be used in the pollutant load allocation process with historical *E. coli* data added to the graphs (Figure 15, Figure 16) and 2.7. Potential Sources of Fecal Indicator Bacteria, the following broad linkage statements can be made.

For the Sandy Creek watershed, historical *E. coli* data indicate that elevated bacteria loading primarily occurs under high, moist conditions, and mid-range flow conditions. However, bacteria loads are most elevated under the high flow conditions. Under dry conditions, loadings fall below the geometric mean criterion. Under low flow conditions, bacteria loads are typically under the single sample criterion and approach the geometric mean criterion.

For the Wolf Creek watershed, historical *E. coli* data indicate that elevated bacteria loading primarily occurs under high flow, moist conditions, and mid-range flow conditions. However, bacteria loads are most elevated under the high flow conditions. Under dry conditions and low flows, loadings fall below the allowable load for the geometric mean criterion.

Regulated stormwater comprises a minor portion of both watersheds; therefore, unregulated stormwater likely contributes to the majority of high-flow related loadings. Within the Wolf Creek watershed, there are no WWTFs to contribute point source loadings under dry and low flow conditions. Low flow exceedances in the Sandy Creek watershed likely cannot be attributed to regulated point sources alone because there is only one permitted discharger in the watershed with a limited number of non-compliance events related to indicator bacteria discharges. Other sources of bacteria loadings under dry and low flow conditions and in the absence of overland flow contributions (i.e., without stormwater contribution) are most likely to contribute bacteria directly to the water. These sources may include direct deposition of fecal material from sources such as wildlife, feral hogs, and livestock. However, the actual contributions of bacteria loadings directly attributable to these sources 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 USEPA guidance (USEPA, 1991), the MOS can be incorporated in 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 an MOS. The TMDLs covered by this report incorporate an explicit MOS of five percent.

4.6. Load Reduction Analysis

While the TMDLs for the project watershed will be developed using load allocations, additional insight may be gained through a load reduction analysis. A single percent load reduction required to meet the allowable loading for each flow regime was determined using the historical *E. coli* data obtained from the stations in the impaired watersheds (Table 18). The estimated existing load in each flow regime was calculated with the geometric mean concentration in each flow category and the median flow in each flow category (excluding days with zero flow) as estimated in Section 3.3 (Eq. 3).

$$\text{Existing Load}_{FC} = \widetilde{Q}_{FC} \times G_{FC} \times \text{Conversion Factor} \qquad \text{(Eq. 3)}$$

Where:

Existing Load $_{FC}$ = Existing bacteria load at the median flow for flow category (FC)
FC = Respective flow category
$\widetilde{Q}_{FC}$ = Median flow for flow category (FC)

G_{FC} = Geometric Mean of bacteria (cfu *E. coli*/100 mL) samples for flow category (FC)
Conversion Factor = 28,316.8 mL/ft^3 × 86,400 seconds/day ÷ 1×10^9

The allowable load (Eq.4) was calculated as:

$$\text{Allowable Load}_{FC} = \tilde{Q}_{FC} \times \text{Criterion} \times \text{Conversion Factor}$$

(Eq.4)

Where:

Allowable Load $_{FC}$ = Allowable load at the median flow for flow category (FC)
$\tilde{Q}_{FC}$ = Median flow in each flow category
Criterion = 126 cfu/100 mL (*E. coli*)
Conversion Factor = 28,316.8 mL/ft^3 × 86,400 seconds/day ÷ 1×10^9

Percent reduction for each flow category (PR_{FC}) (Eq.5) was then calculated as:

$$PR_{FC} = \frac{(\text{Existing Load}_{FC} - \text{Allowable Load}_{FC})}{\text{Existing Load}_{FC}}$$

(Eq.5)

Table 18. Percent reductions needed to meet water quality standards in Sandy Creek and Wolf Creek.

Flow Regime	Median Flow (cfs)	Existing Load (Billion cfu/day)	Allowable Load (Billion cfu/day)	Percent Reduction Required
Sandy Creek (0603A_01)				
High Flows	205.85	8155.71	634.57	92
Moist Conditions	47.62	218.95	146.8	33
Mid-Range Flows	28.35	139.09	87.39	37
Dry Conditions	19.16	46.73	59.06	NA
Low Flows	12.43	40.22	38.32	5
Wolf Creek (0603B_01)				
High Flows	236.78	8,088.15	729.92	91
Moist Conditions	51.09	218.28	157.49	28
Mid-Range Flows	27.9	167.02	86.01	49
Dry Conditions	16.86	50.85	51.97	NA
Low Flows	8.87	21.24	27.34	NA

4.7. Pollutant Load Allocations

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

$$\mathrm{TMDL} = \mathrm{WLA} + \mathrm{LA} + \mathrm{FG} + \mathrm{MOS} \tag{Eq.6}$$

Where:

TMDL = total maximum daily load
WLA = wasteload allocation, the amount of pollutant allowed by existing regulated dischargers
LA = load allocation, the amount of pollutant allowed by unregulated sources
FG = loading associated with future growth from potential regulated facilities
MOS = margin of safety load

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

The TMDL component for the impaired AUs covered in this report is derived using the median flow within the high flow regime (or five percent flow) of the LDCs developed for Sandy Creek and Wolf Creek. For the remainder of this report, each section will present an explanation of the TMDL component first, followed by the results of the calculation for that component.

4.7.1. AU-Level TMDL Calculations

The TMDLs for the impaired AUs were developed as a pollutant load allocation based on information from the LDCs developed for SWQM station 10484 on Sandy Creek and SWQM station 15344 on Wolf Creek (Figure 15, Figure 16). As discussed in more detail in Section 3, a bacteria LDC was developed by multiplying the streamflow value along the FDC by the primary contact recreation *E. coli* criterion (126 cfu/100 mL) and by the conversion factor to convert to loading in colonies per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

$$\text{TMDL} = \text{Criterion} \times \text{Flow} \times \text{Conversion Factor}$$

(Eq.7)

Where:

Criterion = 126 cfu/100 mL (*E. coli*)
Conversion Factor (to billion cfu/day) = 28,316.8 mL per cubic foot(ft^3) × 86,400 seconds/day (s/d) ÷ 1×10^9

At the five percent load duration exceedance, the TMDL values are provided in Table 19.

Table 19. Summary of allowable loadings for Sandy Creek (0603A_01) and Wolf Creek (0603B_01).

AU	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
0603A_01	205.853	634,578,949,754	634.579
0603B_01	236.782	729,923,163,037	729.923

4.7.2. Margin of Safety

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

$$\text{MOS} = 0.05 \times \text{TMDL}$$

(Eq.8)

Where:

MOS = margin of safety load
TMDL = total maximum daily load

The MOS for each AU is presented in Table 20.

Table 20. Summary of MOS calculation.

AU	TMDL (Billion cfu/day)	MOS (Billion cfu/day)
0603A_01	634.579	31.729
0603B_01	729.923	36.496

4.7.3. Wasteload Allocation

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}).

$$WLA = WLA_{WWTF} + WLA_{SW}$$

(Eq.9)

Wastewater

TPDES-regulated WWTFs are allocated a daily wasteload calculated as their full regulated discharge flow rate multiplied by the instream geometric mean criterion. The *E. coli* primary contact recreation geometric mean criterion of 126 cfu/100 mL is used as the WWTF target. This is expressed as:

$$WLA_{WWTF} = \text{Criterion} \times \text{Flow} \times \text{Conversion Factor}$$

(Eq.10)

Where:

Criterion = 126 cfu/100 mL *E. coli*
Flow = full permitted flow (MGD)
Conversion Factor (to billion cfu/day) = 1.54723 cfs/MGD × 28,316.8 mL/ft^3 × 86,400 s/d ÷ 1×10^9

The daily allowable loading of *E. coli* assigned to WLA_{WWTF} was determined to be zero in Wolf Creek (0603B_01) because there are no WWTFs in the watershed, therefore there are no regulated flows from any WWTFs. The WLA_{WWTF} for Sandy Creek (0603A_01) is shown in (Table 21).

Table 21. Summary of WLA_{WWTF} calculation.

AU	TPDES Identifier	Facility	Full Permitted Flow (MGD)	WLA_{WWTF} (Billion cfu/day)
0603A_01	WQ0010197001	Jasper WWTF	3.25	15.501
0603B_01	NA	NA	0	0
		Sandy Creek Total	**3.25**	**15.501**
		Wolf Creek Total	**0**	**0**

Regulated Stormwater

Stormwater discharges from MS4, industrial, concrete production, and construction sites are considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for the area was used in the development of the 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 land area included in each watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of overall runoff load that should be allocated as the regulated 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}.

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

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) \times FDA_{SWP} \tag{Eq.11}$$

Where:

WLA_{SW} = sum of all regulated stormwater loads
TMDL = total maximum daily load
WLA_{WWTF} = sum of WWTF loads
FG = sum of future growth loads from potential regulated facilities
MOS = margin of safety load
FDA_{SWP} = proportion of drainage area under jurisdiction of stormwater permits

In order to calculate the WLA_{SW} component of the TMDL, the fractional proportion of the drainage under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined to estimate the amount of 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 2.7.1.4., a search of stormwater general permits was performed (refer to the table from section 2.7.1.4). The summarized results are displayed in Table 22.

Table 22. Regulated stormwater area and FDA_{SWP} calculations.

AU	MS4 Permit (square miles)	Multi-sector General Permit (square miles)	Construction Activities (square miles)	Concrete Production Facilities (square miles)	Total Area of Permits (square miles)	Watershed Area (square miles)	FDA_{SWP}
0603A_01	0	0.122	0.06	0.028	0.21	56.54	0.0037
0603B_01	0	0	0.01	0	0.01	83.14	0.0001

The FG term required to calculate WLA_{SW} is described in the next section. However, the WLA_{SW} calculations are presented in Table 23 for continuity.

Table 23. Regulated stormwater calculations.

AU	TMDL†	WLA_{WWTF}†	FG†	MOS†	FDA_{SWP}	WLA_{SW}†
0603A_01	634.579	15.501	0.403	31.729	0.0037	2.172
0603B_01	729.923	0	0.715	36.496	0.0001	0.069

† in units of billion cfu/day *E. coli*

With the WLA_{SW} and WLA_{WWTF} terms, the total WLA term can be determined using (Eq.9)(Table 24).

Table 24. Wasteload allocation summary.
(in units of billion cfu per day *E. coli*)

AU	WLA_{WWTF}	WLA_{SW}	WLA
0603A_01	15.501	2.172	17.673
0603B_01	0	0.069	0.069

4.7.4. Future Growth

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

To account for the FG component of the impaired AUs, the loadings from WWTFs are included in the FG computation, which is based on the WLA_{WWTF} formula (Eq.10). The FG equation (Eq.12) contains an additional term to account for project population growth within WWTF service areas between 2020 and 2070, based on data obtained from the TWDB 2021 Regional Water Plan (TWDB, 2019) (Table 3). The FG calculation for Sandy Creek is shown in Table 25.

$$\text{FG} = \text{Criterion} \times (\%\text{POP}_{2020\text{-}2070} \times \text{WWTF}_{\text{FP}}) \times \text{Conversion Factor}$$

(Eq.12)

Where:

FG = Future growth from existing WWTFs
Criterion = 126 cfu/100 mL (*E. coli*)
$\%POP_{2020\text{-}2070}$ = Estimated percent increase in population between 2020 and 2070
$WWTF_{FP}$ = Full permitted discharge (MGD)
Conversion Factor = 1.54723 cfs/MGD × 28,316.8 mL/ft^3 × 86,400 seconds/day ÷ 1×10^9

Table 25. Future growth calculation for Sandy Creek (0603A_01).

AU	**TPDES Identifier**	**Facility**	**Full Permitted Flow (MGD)**	**Percent increase (2020-2070)**	**2070 Permitted Flow (MGD)**	***E. coli* FG (Billion cfu/day)**
0603A_01	WQ0010197001	Jasper WWTF	3.25	2.6	3.3345	0.403
				Sandy Creek Total	**3.3345**	**0.403**

For Wolf Creek, the conventional FG calculations are hampered by the $WWTF_{FP}$ being zero. While there are no plans for a WWTF to be built in the watershed, the TMDL must still account for the possibility of FG for the impaired AU. In order to address this shortcoming, an FG term was calculated for the Wolf Creek (0603B_01) watershed to accommodate the potential of a WWTF to serve residents within the watershed.

Colmesneil currently has a permitted WWTF that discharges outside of the watershed. Because of the low population density and minimal project population growth, FG is set as the current permit limit for the Colmesneil WWTF (0.15 MGD). This is based on the assumption that if another WWTF plant is required in the future, it would be a similar size as the existing Colmesneil WWTF.

Under this scenario, FG is calculated as shown in Table 26.

Table 26. Future growth calculation attributed to potential WWTF service in Wolf Creek (0603B_01).

AU	TPDES Identifier	Facility	FG Flow (MGD)	FG (Billion cfu/day)
0603B_01	WQ0010197001	Colmesneil WWTF	0.15	0.715
		Wolf Creek Total	**0.15**	**0.715**

4.7.5. Load Allocation

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

$$LA = TMDL - WLA - FG - MOS$$

(Eq.13)

Where:

LA = allowable loads from unregulated sources
TMDL = total maximum daily load
WLA = sum of all WWTF loads and all regulated stormwater loads
FG = sum of future growth loads from potential regulated facilities
MOS = margin of safety load

Table 27 summarizes the LA calculations.

Table 27. Load allocation summary
(in units of billion cfu per day *E. coli*)

AU	TMDL	WLA	FG	MOS	LA
0603A_01	634.579	17.673	0.403	31.729	584.774
0603B_01	729.923	0.069	0.715	36.496	692.643

Table 28 summarizes the TMDL calculations for the project watersheds. The TMDLs were calculated based on median flow in the 0-10 percentile range (five percent exceedance, high flow regime) for flow exceedance from the LDC developed for the outlet of the AUs. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 28. TMDL allocation summary.
(in units of billion cfu per day *E. coli*)

AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
0603A_01	634.579	15.501	2.172	584.774	0.403	31.729
0603B_01	729.923	0	0.069	692.643	0.715	36.496

The final TMDL allocations (Table 29) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}. The WLA_{WWTF} for each AU is the sum of the WWTF allocations for the AU. Similarly, the WLA_{SW} for each AU includes the sum of all regulated stormwater areas of the AU. The LA component of the final TMDL allocations is comprised of the sum of loadings arising from within the AUs that are associated with unregulated sources.

Table 29. Final TMDL allocations.
(in units of billion cfu per day *E. coli*)

AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
0603A_01	634.579	15.904	2.172	584.774	31.729
0603B_01	729.923	0.715	0.069	692.643	36.496

Section 5. References

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