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Four Draft Total Maximum Daily Loads for Indicator Bacteria in Tributaries of the Neches River below Lake Palestine

Assessment Units 0604A_02, 0604B_01, 0604C_01, and 0604M_03

Water Quality Planning Division, Office of Water
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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Total Maximum Daily Load Team
Texas Commission on Environmental Quality
MC-203
P.O. Box 13087
Austin, Texas 78711-3087
Email: tmdl@tceq.texas.gov

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Abbreviations

AU	assessment unit
BMP	best management practice
CCN	certificate of convenience and necessity
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
CGP	construction general permit
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
FDC	flow duration curve
FG	future growth
GIS	geographic information system
I-Plan	implementation plan
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SWMP	stormwater management program
SWQM	surface water quality monitoring
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
U.S.	United States
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture

USGS	U.S. Geological Survey
WLA	wasteload allocation
WQBELs	water quality-based effluent limits
WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility

Four Total Maximum Daily Loads for Indicator Bacteria in Tributaries of the Neches River below Lake Palestine

Executive Summary

This report describes total maximum daily loads (TMDLs) for four water bodies within the Cedar Creek, Hurricane Creek, Jack Creek, and Biloxi Creek watersheds where concentrations of indicator bacteria exceed the criterion used to determine attainment of the primary contact recreation 1 use. The Texas Commission on Environmental Quality (TCEQ) first identified the impairments to Cedar Creek, Hurricane Creek, and Jack Creek in the *2000 Texas Water Quality Inventory and 303(d) List*. Biloxi Creek was later identified in the *2004 Texas Water Quality Inventory and 303(d) List* (since 2010 called the *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* or Texas Integrated Report). This report will consider the bacteria impairments for the following assessment units (AUs):

- Cedar Creek (AU 0604A_02)
- Hurricane Creek (AU 0604B_01)
- Jack Creek (AU 0604C_01)
- Biloxi Creek (AU 0604M_03)

The TMDL watersheds are entirely in Angelina County and include portions of the cities of Lufkin and Hudson. The Cedar Creek TMDL watershed is 28,458.88 acres and includes Cedar Creek AU 0604A_02 and its upstream AU 0604A_03, along with AUs 0604B_01 and 0604B_02 of Hurricane Creek, which are tributaries of Cedar Creek AU 0604A_02. The Hurricane Creek TMDL watershed for AU 0604B_01 is 8,268.16 acres and includes upstream AU 0604B_02. The Jack Creek TMDL watershed is 18,593.92 acres and includes only AU 0604C_01. The Biloxi Creek TMDL watershed is 12,078.08 acres and includes only AU 0604M_03. The dominant land covers of the TMDL watersheds are forest, developed, and pastureland.

Escherichia coli (*E. coli*) are widely used as an indicator bacteria to determine attainment of the contact recreation use in freshwater. The criterion for determining attainment of the contact recreation use is expressed as the number (or "counts") of *E. coli* bacteria, typically given as colony forming units (cfu). The primary contact recreation 1 use is not supported when the geometric mean of all *E. coli* samples exceeds 126 cfu per 100 milliliters (mL).

E. coli data were collected at TCEQ surface water quality monitoring (SWQM) stations in each of the impaired AUs over a seven-year period from December 1, 2011 through November 30, 2018. These data were used in assessing attainment of the primary contact recreation 1 use and reported in the 2020 Texas Integrated Report (TCEQ, 2020a). The assessed data indicate non-attainment of the contact recreation standard in AUs 0604A_02, 0604B_01, 0604C_01, and 0604M_03.

Within the TMDL watersheds, probable sources of bacteria include domestic wastewater treatment facilities (WWTFs), regulated stormwater runoff, agricultural activities, sanitary sewer overflows (SSOs), illicit discharges, on-site sewage facilities (OSSFs), and contributions from wildlife and domesticated animals.

A review of the TCEQ Central Registry for active permits found two permitted domestic WWTFs within the TMDL watersheds, both of which have effluent limits for bacteria. Other permitted discharges in the watershed include one active water quality general permit authorization, 13 active industrial multi-sector general permit (MSGP) authorizations, and multiple construction general permit (CGP) authorizations. There are no active municipal separate storm sewer system (MS4) permits in the watersheds.

A load duration curve (LDC) analysis was done for all the TMDL watersheds to quantify allowable pollutant loads, as well as TMDL allocations for point and nonpoint sources of bacteria. Wasteload allocations (WLAs) were established for WWTFs discharging into Cedar Creek (AU 0604A_02) and Jack Creek (AU 0604C_01). The WLA was calculated as the full permitted daily-average flow rate multiplied by the instream geometric mean criterion. Future growth (FG) of existing or new domestic point sources was determined for all the TMDL watersheds using population growth projections.

The TMDL calculations in this report will guide determination of the assimilative capacity of each water body under changing conditions, including FG. Future WWTFs will be evaluated case by case.

Introduction

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 TMDL for each pollutant that contributes to the impairment of a water body included on a state’s 303(d) list of impaired waters. TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time but may be expressed in other ways.

The TMDL Program is a major part of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The program's primary objective is to restore and maintain water quality uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

This TMDL report addresses impairments to the primary contact recreation 1 use due to elevated levels of indicator bacteria in AUs 0604A_02, 0604B_01, 0604C_01, and 0604M_03. These TMDLs take a watershed approach to addressing bacteria impairments; while TMDL allocations were developed only for the impaired AUs identified in this report, the entire project watershed (Figure 1) and all WWTFs that discharge within it are included within the scope of this TMDL report. Information in this TMDL report was derived from the *Technical Support Document for Four Total Maximum Daily Loads for Indicator Bacteria in Tributaries of the Neches River below Lake Palestine* (Gitter, Yang, and Gregory, 2021)[1].

Section 303(d) of the Clean Water Act and the implementing regulations of the United States Environmental Protection Agency (EPA) in Title 40 of the Code of Federal Regulations, Part 130 (40 CFR 130) describe the statutory and regulatory requirements for acceptable TMDLs. EPA provides further direction in its *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA, 1991). This TMDL report has been prepared following those regulations and guidelines.

TCEQ must consider certain elements in developing a TMDL, described in the following sections of this report:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Analysis
- Margin of Safety
- Pollutant Load Allocation
- Seasonal Variation
- Public Participation
- Implementation and Reasonable Assurance

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[1] www.tceq.texas.gov/assets/public/waterquality/tmdl/118lufkin/118-as205-midneches-bacteria-tsd.pdf

Upon adoption of the TMDL report by TCEQ and EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan (WQMP).

Problem Definition

TCEQ first identified bacteria impairments to Cedar Creek, Hurricane Creek, and Jack Creek in the 2000 Texas Integrated Report and then in each later edition through the EPA-approved 2020 Texas Integrated Report. TCEQ first identified a bacteria impairment for Biloxi Creek in the 2004 Texas Integrated Report and then in each later edition through 2020.

This report will consider the bacteria impairments for the following AUs:

- Cedar Creek (AU 0604A_02)
- Hurricane Creek (AU 0604B_01)
- Jack Creek (AU 0604C_01)
- Biloxi Creek (AU 0604M_03)

The 2020 Texas Integrated Report (TCEQ, 2020a) found the geometric means for *E. coli* within AUs 0604A_02, 0604B_01, 0604C_01, and 0604M_03 to exceed the criterion of 126 cfu/100 mL (Table 1).

Table 1. 2020 Texas Integrated Report Summary for impaired AUs

Water Body	AU	Parameter	Station	Data Range	Number of Samples	Geometric Mean (cfu/100 mL)
Cedar Creek	0604A_02	*E. coli*	10478, 13528	12/01/2011-11/30/2018	40	291.49
Hurricane Creek	0604B_01	*E. coli*	10487, 13529	12/01/2011-11/30/2018	43	276.16
Jack Creek	0604C_01	*E. coli*	10492, 10493, 10494	12/01/2011-11/30/2018	61	185.35
Biloxi Creek	0604M_03	*E. coli*	10499	12/01/2011-11/30/2018	33	152.24

Watershed Overview

The TMDL watersheds are entirely in Angelina County and include portions of the cities of Lufkin and Hudson (Figure 1). The Cedar Creek TMDL watershed for impaired AU 0604A_02 includes the upstream AU 0604A_03 and upstream Hurricane Creek AUs 0604B_01 and 0604B_02. The Hurricane Creek TMDL watershed for AU 0604B_01 includes upstream AU 0604B_02. The Jack Creek TMDL watershed includes only AU 0604C_01, and the Biloxi Creek TMDL watershed includes only AU 0604M_03. The total area for all the TMDL watersheds is approximately 59,131 acres.

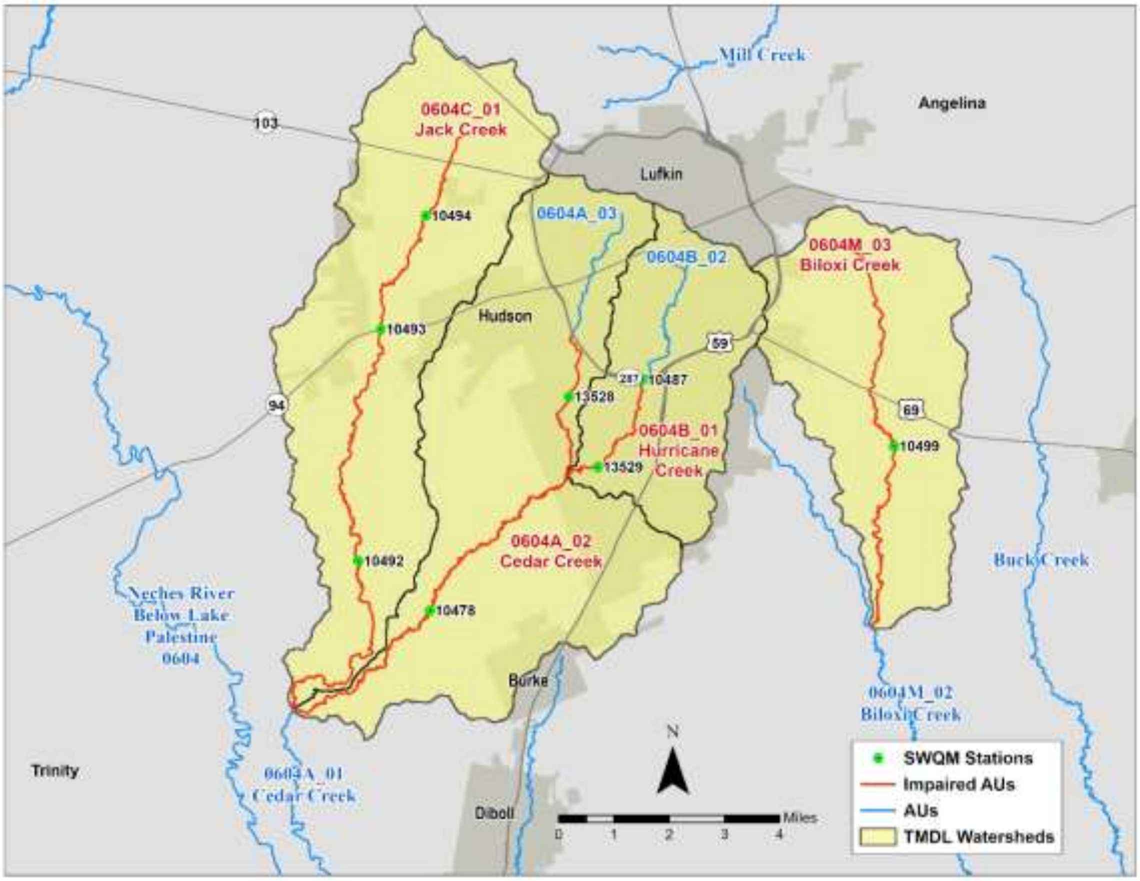

Figure 1. Map of the TMDL watersheds

The 2020 Texas Integrated Report (TCEQ, 2020a) provides the following segment and AU descriptions:

- Segment 0604A (Cedar Creek) – From the confluence of the Neches River southwest of Lufkin in Angelina County to the upstream perennial portion of the stream in Lufkin in Angelina County.
- AU 0604A_02 – From the confluence with Jack Creek (0604C) upstream to confluence with unnamed tributary adjacent to State Loop 287, per Appendix D in the Texas Surface Water Quality Standards, at National Hydrography Dataset reach code 12020002000436.
- AU 0604A_03 – From the confluence with unnamed tributary adjacent to State Highway Loop 287 upstream to headwaters near Hoo Hoo Avenue in the City of Lufkin.
- Segment 0604B (Hurricane Creek) – From the confluence with Cedar Creek upstream to the headwaters near Groesbeck Avenue in the City of Lufkin.

- AU 0604B_01 – From the confluence with Cedar Creek (0604A) upstream to confluence with unnamed tributary 100 meters above State Loop 287 in Lufkin, per Texas Surface Water Quality Standards, Appendix D, at National Hydrography Dataset reach code 12020002000043.
- AU 0604B_02 – From the confluence with unnamed tributary 100m upstream of State Highway Loop 287 in the City of Lufkin upstream to headwaters near Groesbeck Avenue in Lufkin.
- Segment 0604C (Jack Creek) – From the confluence of Cedar Creek southwest of Lufkin in Angelina County to the upstream perennial portion of the stream in northeast Lufkin in Angelina County.
- AU 0604C_01 – From the confluence with Cedar Creek (0604A) upstream to confluence with unnamed tributary 1.6 kilometers southwest of U.S. Highway 69 northwest of Lufkin at National Hydrography Dataset reach code 12020002012470.
- Segment 0604M (Biloxi Creek) – From the confluence with the Neches River southeast of Diboll to Farm to Market 325 east of Lufkin in Angelina County.
- AU 0604M_03 – From the confluence with One Eye Creek in Angelina County southeast of Lufkin upstream to Farm to Market 325 east of Lufkin.

Watershed Climate and Hydrology

The project area is in east Texas which is characterized as a humid subtropical climate. Precipitation and temperature data from 2005 through 2018 were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center database. The nearest weather station to the TMDL watersheds is USW00093987 located at the Angelina County Airport (NOAA, 2020). The average monthly low temperatures range from 38.2°F (January) to 73.3°F (August), and the monthly average highs range from 61.5°F (January) to 95.5°F (August). The average monthly precipitation ranges from 2.9 to 4.8 inches, with the greatest precipitation occurring in October and the lowest precipitation occurring in November (Figure 2). From 2005 through 2018, the average annual precipitation was 46 inches, with a low of 28.5 inches occurring in 2010 and a high of 68.7 inches occurring in 2018 (Figure 3).

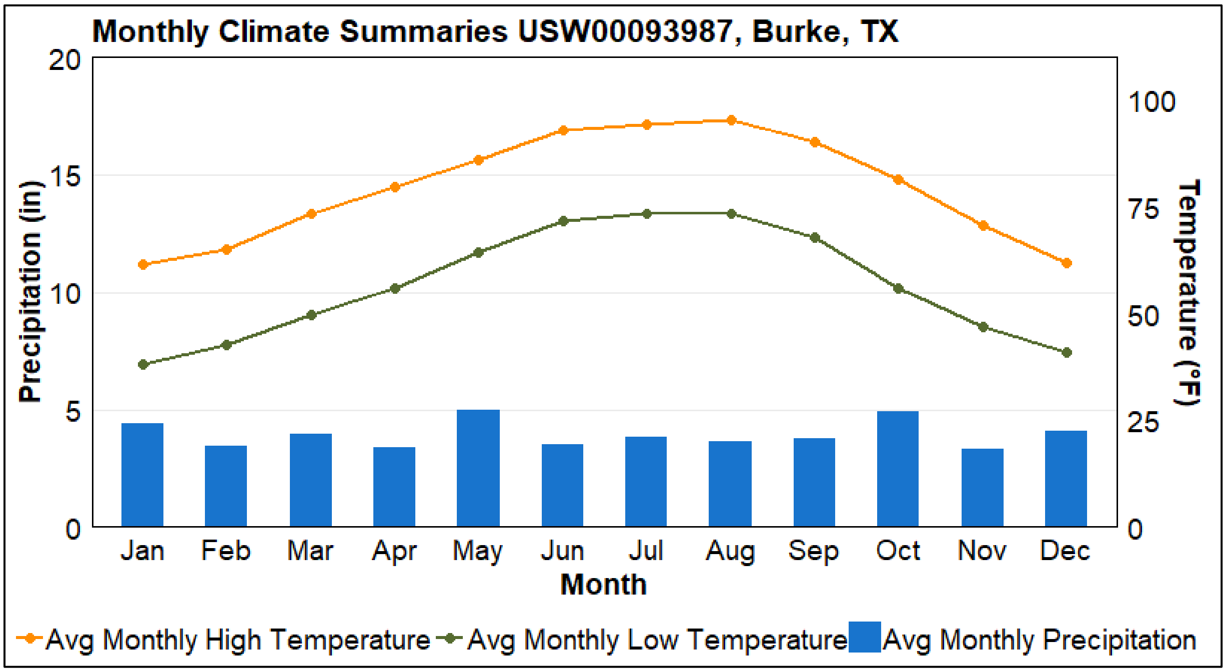

Figure 2. Average monthly temperature and precipitation at the Angelina County Airport, 2005-2018

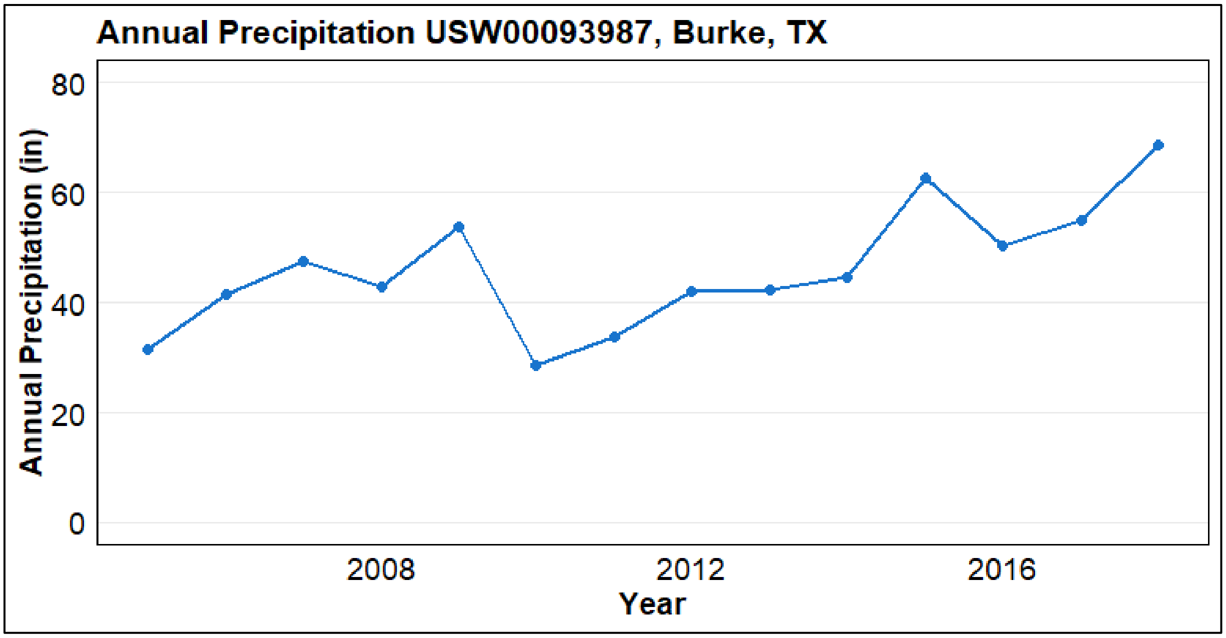

Figure 3. Annual precipitation at the Angelina County Airport, 2005-2018

Watershed Population and Population Projections

Watershed population estimates were developed using 2010 United States Census Bureau (USCB) census block geographic units and population data (USCB, 2010). Census blocks are the smallest geographic units used by USCB to tabulate population data. Using the methodology outlined in Appendix A, the TMDL watersheds population is estimated to be 42,647 people (Table 2) (Figure 4).

Population projections in Table 2 are estimated from the Texas Water Development Board (TWDB) 2021 Regional Water Plan Population and Water Demand Projection data (TWDB, 2019). The Angelina County population projections show a 7.5% increase from 2010 through 2020 and a 27.3% increase from 2020 through 2070. The 2070 TMDL watersheds population (Table 2) was estimated to be 58,361 using the method outlined in Appendix A.

Table 2. Population estimates and projections

AU	2010 U.S. Census	2020 Population Projected	2070 Population Projection	Projected Increase (2020-2070)	Percentage Increase (2020-2070)
0604A_02[a]	14,680	15,781	20,089	4,308	27.3%
0604B_01	16,067	17,272	21,987	4,715	27.3%
0604C_01	8,272	8,892	11,320	2,428	27.3%
0604M_03	3,628	3,900	4,965	1,065	27.3%
Total	**42,647**	**45,845**	**58,361**	**12,516**	**27.3%**

[a] Totals exclude upstream AU 0604B_01 subwatershed

Land Cover

The land cover data for the TMDL watersheds was obtained from the United States Geological Survey (USGS) 2016 National Land Cover Database (NLCD) (USGS, 2019) and is displayed in Figure 5. The following are the land cover categories and definitions represented in the NLCD found in the TMDL watersheds:

- **Open Water** – Areas of open water, generally with less than 25% cover of vegetation or soil.
- **Developed, Open Space** – Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

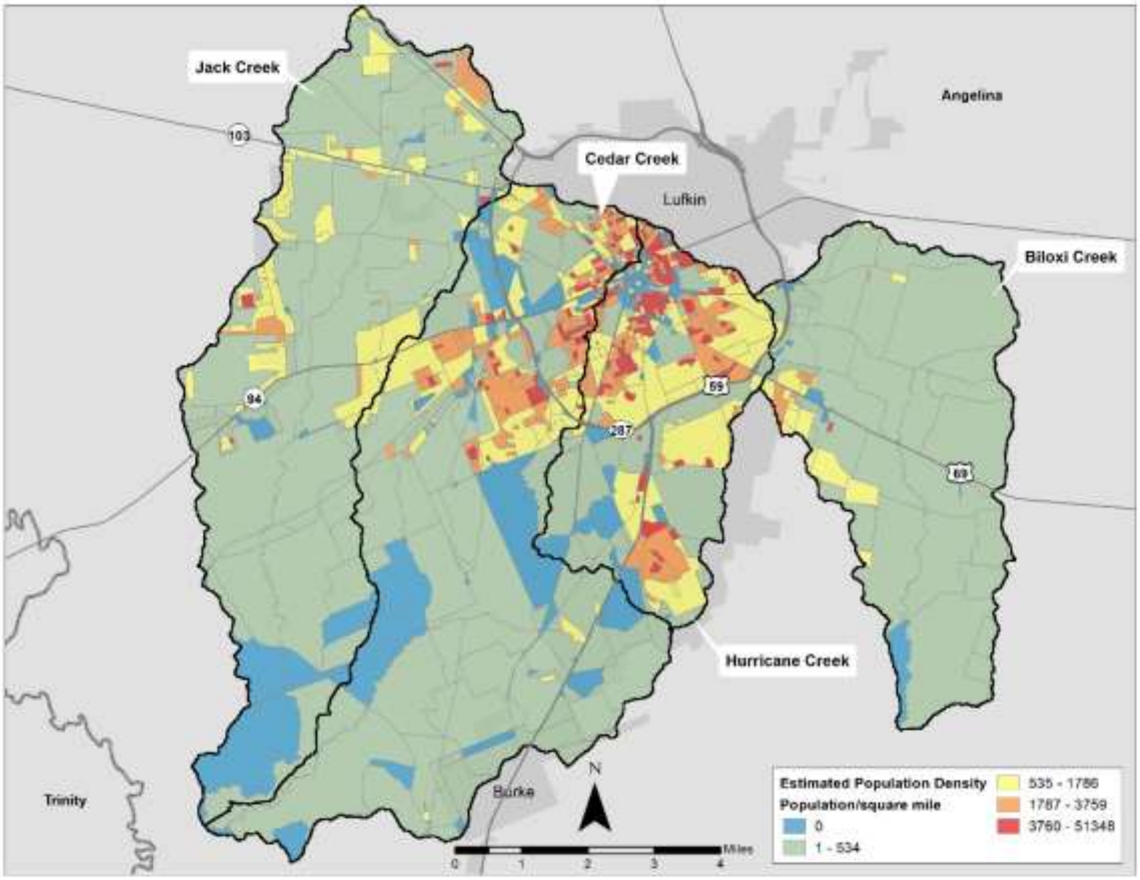

Figure 4. 2010 population density estimates using USCB census block data

- **Developed, Low Intensity** – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% of total cover. These areas most commonly include single-family housing units.
- **Developed, Medium Intensity** – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of total cover. These areas most commonly include single-family housing units.
- **Developed, High Intensity** – Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80% to 100% of 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% of total cover.
- **Deciduous Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.

- **Evergreen Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. More than 75% of the species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% total tree cover.
- **Shrub/Scrub** – Areas dominated by shrubs; less than five meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
- **Grassland/Herbaceous** – Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be used for grazing.
- **Pasture/Hay** – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/Hay vegetation accounts for greater than 20% of total vegetation.
- **Woody Wetlands** – Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Emergent Herbaceous Wetlands** – Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil substrate is periodically saturated with or covered with water.

A summary of the land cover data is provided in

Table 3. The Cedar Creek watershed’s predominant land covers are developed (25.15%), Evergreen Forest (22.37%), and Pasture/Hay (18.70%). The Hurricane Creek watershed’s predominant land covers are developed (65.93%), Evergreen (11.25%), and Mixed Forest (10.82%). The Jack Creek watershed’s predominant land covers are Pasture/Hay (33.32%), Evergreen Forest (22.23%), and developed (13.27%). The Biloxi Creek watershed’s predominant land covers are Pasture/Hay (31.17%), Evergreen Forest (20.82%), and developed (17.43%).

Table 3. Land cover summary

2016 NLCD Classification	0604A_02 Area[a]	% Total	0604B_01 Area	% Total	0604C_01 Area	% Total	0604M_03 Area	% Total
Open Water	73	0.36	31	0.37	56	0.30	38	0.31
Developed, Open Space	1,713	8.48	1,257	15.14	1,230	6.61	1,097	9.08
Developed, Low Intensity	2,370	11.74	2,476	29.83	1,002	5.39	726	6.01
Developed, Medium Intensity	651	3.22	986	11.88	191	1.03	200	1.66
Developed, High Intensity	345	1.71	754	9.08	45	0.24	82	0.68
Barren Land	8	0.04	6	0.07	27	0.15	3	0.02
Deciduous Forest	173	0.86	30	0.36	143	0.77	56	0.46
Evergreen Forest	4,517	22.37	934	11.25	4,135	22.23	2,515	20.82
Mixed Forest	2,751	13.62	898	10.82	2,457	13.21	1,853	15.34
Shrub/Scrub	822	4.07	63	0.76	811	4.36	616	5.10
Grassland/ Herbaceous	777	3.85	126	1.52	818	4.40	394	3.26
Pasture/Hay	3,776	18.70	335	4.04	6,197	33.32	3,766	31.17
Woody Wetlands	2,163	10.71	395	4.76	1,404	7.55	701	5.80
Emergent Herbaceous Wetlands	54	0.27	10	0.12	81	0.44	35	0.29
Total[b]	**20,193**	**100%**	**8,301**	**100%**	**18,597**	**100%**	**12,082**	**100%**

All areas are expressed in acres.

[a] Totals exclude upstream 0604B_01 subwatershed.

[b] Total acreage for the TMDL watersheds differs from 59,131 acres as listed previously in the report due to calculations that included raster data in the geographic information system (GIS) analysis for land cover.

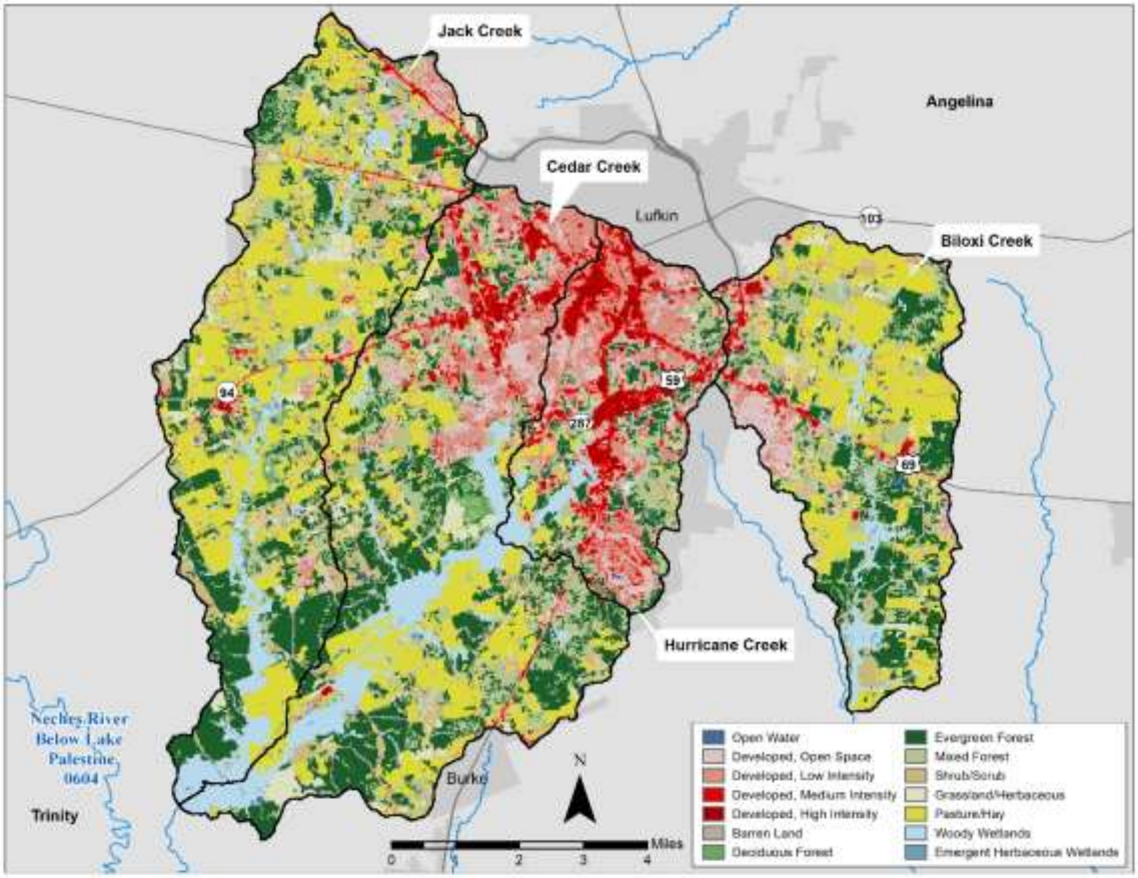

Figure 5. 2016 land cover

Soils

Soils within the TMDL watersheds are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (USDA NRCS, 2018). The Soil Survey Geographic Database assigns different soils to one of seven possible runoff potential classifications or hydrologic groups. These classifications are based on the estimated rate of water infiltration when soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The four main groups are A, B, C, and D, with three dual classes (A/D, B/D, C/D). The Soil Survey Geographic 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.

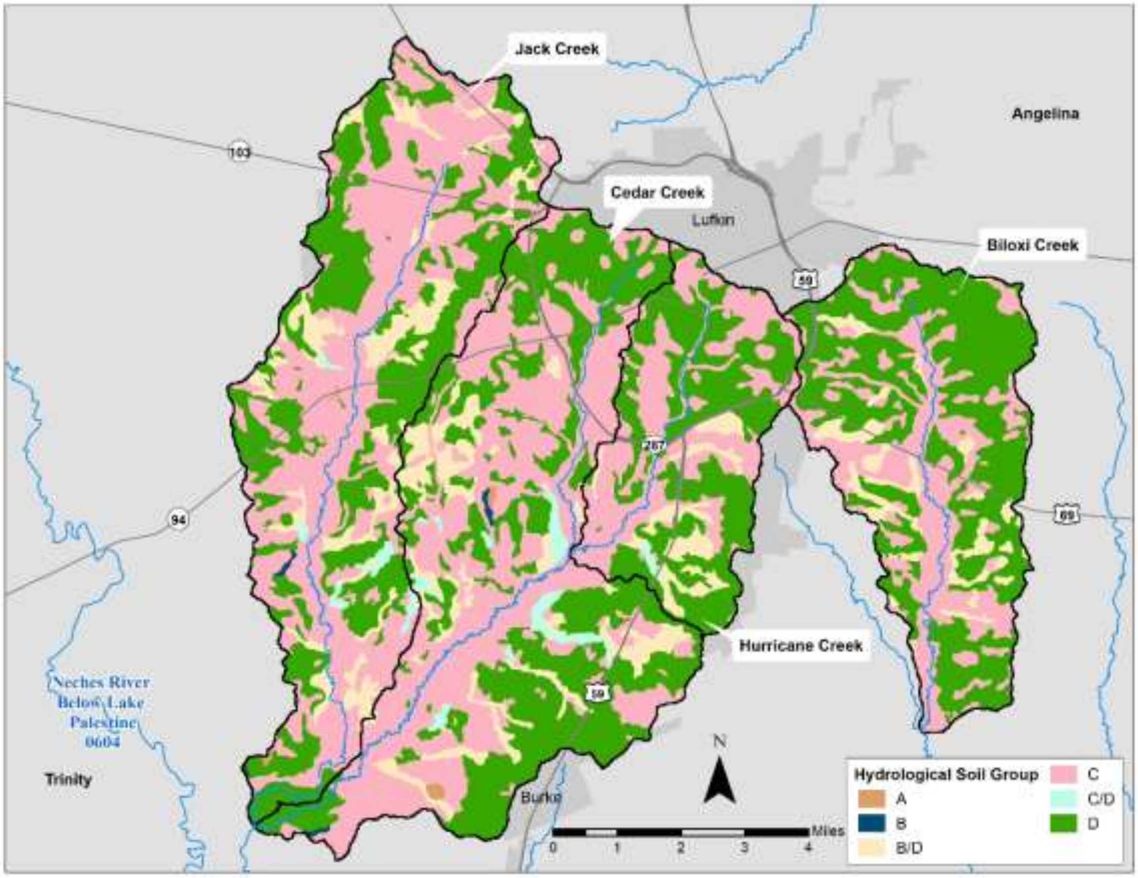

Figure 6. Hydrologic soil groups

- **Group B** – Soils having a moderate infiltration rate when thoroughly wet. These consist of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- **Group C** – Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- **Group D** – Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Soils with dual hydrologic classifications assign the first letter to drained areas and the second letter to undrained areas. Only soils that are in Group D in their natural condition are assigned to dual classes.

Soils within the TMDL watersheds are primarily categorized as groups C (46.22%) and D (42.43%) (Figure 6). When wet, Group C soils have moderately high runoff potential. Group D soils have a higher runoff potential when wet, and water movement is restricted in the soils (USDA NRCS, 2018). In general, soils in the watershed are loamy, with sand and clay, and strongly to moderately acidic (Angelina and Neches River Authority, 2015).

Water Rights Review

Surface water rights in Texas are administered and overseen by TCEQ. A search of the TCEQ active water rights and GIS files (TCEQ, 2021a, 2021b, and 2021c) indicated that there are three active water rights in the TMDL watersheds; however, a review of the Texas Water Rights Viewer (TCEQ, 2021a) and water use data files (TCEQ, 2021d) indicate that the diversions have no significant impact on streamflow or hydrology, and therefore were not included in the development of the streamflow records for Hurricane Creek (AU 0604B_01) and Jack Creek (AU 0604C_01).

Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for the TMDLs in this report is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 cfu/100mL, which is protective of the primary contact recreation 1 use for freshwater (TCEQ, 2018).

Source Analysis

Pollutants may come from several sources, both regulated and unregulated. Regulated pollutants, referred to as “point sources,” come from a single definable point, such as a pipe, and are regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES) program. WWTFs and stormwater discharges from industries, construction activities, and MS4s are considered point sources of pollution.

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

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

Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watersheds include domestic WWTF outfalls, SSOs, and stormwater discharges from industrial sites and regulated construction activities.

Domestic and Industrial WWTFs

As of May 2021, there are two facilities with individual TPDES permits that discharge within the TMDL watersheds (TCEQ, 2021e) (Table 4) (Figure 7). The City of Lufkin operates the Hurricane Creek WWTF (WQ0010214001), which treats domestic wastewater with a discharge limit of 11.3 million gallons per day (MGD). Although the Hurricane Creek WWTF discharges to AU 0604B_01, the discharge is downstream of SWQM station 13529, which was used to develop the AU-level TMDL for 0604B_01. Therefore, this facility's discharge is not in the flow estimation for AU 0604B_01, but *is* in the AU 0604A_02 flow estimation. This discharge is considered in the FG term for both AUs. The City of Hudson WWTF (WQ0011826001) discharges to Jack Creek AU 0604C_01. The City of Hudson operates this facility, which treats domestic wastewater with a discharge limit of 0.98 MGD. This facility's discharge is included in the flow estimation and loading allocations for AU 0604C_01.

Table 4. Permitted domestic WWTFs discharging in the TMDL watersheds

AU	TPDES Number	NPDES[a] Number	Permittee	Outfall Number	Bacteria Limits (cfu/ 100 mL)	Primary Discharge Type	Daily Average Flow – Permitted Discharge (MGD)
0604B_01	WQ0010214001	TX0024309	City of Lufkin	001	126	Treated domestic wastewater	11.3
0604C_01	WQ0011826001	TX0068985	City of Hudson	001	126	Treated domestic wastewater	0.98

[a] NPDES: National Pollutant Discharge Elimination System

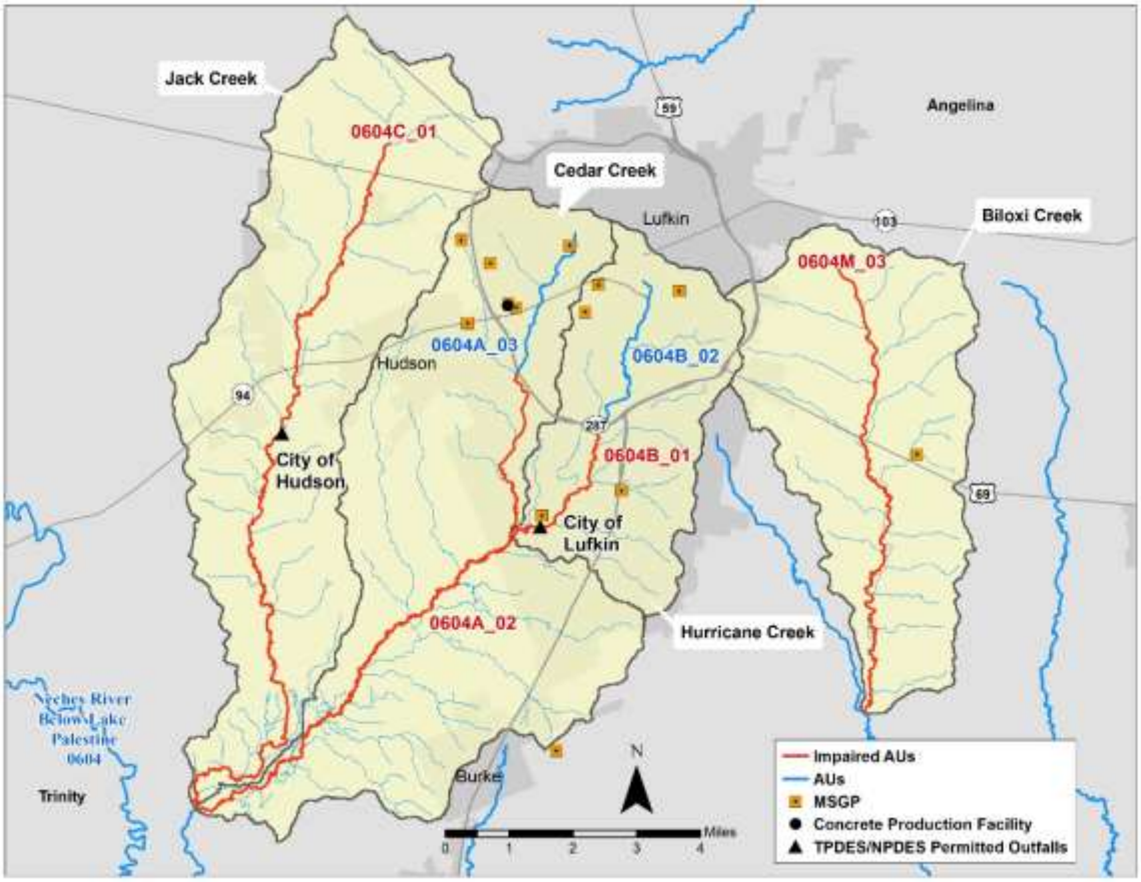

Figure 7. **Active regulated sources**

TCEQ/TPDES Water Quality General Permits

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

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

A review of active general permits in the TMDL watersheds on April 6, 2020 (TCEQ 2020c) indicated one general permit authorization for a concrete production facility (Authorization No. TXG110196) (Figure 7). The concrete production facility is authorized to discharge wastewater and stormwater and is included in the regulated stormwater allocations for AU 0604A_02. The concrete production facility covers approximately 17.90 acres. There were no other active general permit authorizations found for the TMDL watersheds.

There are commercial dry-litter poultry operations present in the TMDL watersheds. These types of operations are required by Texas Water Code, Sec. 26.302 – Regulation of Poultry Facilities to operate in accordance with a water quality management plan certified by the Texas State Soil and Water Conservation Board (TSSWCB).

Sanitary Sewer Overflows

SSOs are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. These overflows in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and infiltration are typical causes of overflows under conditions of high flow in the WWTF collection system. Blockages in the line may worsen the inflow and infiltration 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 2016 through 2019 and TCEQ Region 10 provided regional data from 2005 through 2015 (TCEQ, 2021f and 2020b). Table 5 summarizes the number of SSO incidents that have been reported by regulated entities in the TMDL watersheds from 2005-2019.

Table 5. Summary of reported SSOs from 2005 through 2019

AU	Estimated Incidents	Total Volume[a]	Minimum Volume	Maximum Volume
0604A_02	47	40,176	1	9,000
0604B_01	68	1,106,290	35	293,760
0604C_01	22	36,105	5	10,000
0604M_03	5	800	100	600

All volumes are expressed in gallons.

[a] Some reported SSOs did not include a volume.

TPDES-Regulated Stormwater

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

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

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

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

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

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

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

- TXR040000 – Phase II MS4 General Permit for small MS4s located in urbanized areas
- TXR050000 – MSGP for industrial facilities
- TXR150000 – CGP for construction activities disturbing more than one acre or are part of a common plan of development disturbing more than one acre

TCEQ Central Registry (2020) was reviewed on March 27, 2020 for MS4 permit authorizations. No permit authorizations were found that pertain to Phase II MS4s for the TMDL watersheds.

The MSGP authorizes the discharge of stormwater associated with industrial activity and those authorizations are more permanent in nature than authorizations for construction activities. MSGP authorizations (TXR050000) were reviewed in TCEQ's Central Registry in March 2020 (TCEQ, 2020d), with 13 active authorizations for industrial facilities discharging within the TMDL watersheds (Figure 7). Areas disturbed and covered by the permits were estimated using aerial imagery. Seven facilities discharge to Cedar Creek (86.99 acres), five discharge to Hurricane Creek (117.26 acres), none discharge to Jack Creek, and one discharges to Biloxi Creek (45.60 acres). The area for each site with an MSGP authorization was used in developing the TMDL allocations.

Due to the short-term and economy-driven nature of construction activities, project staff conducted a search of active, terminated, and expired CGP authorizations between March 2003 and December 2020. Construction activities can change in the project area and within each watershed and serve as a representative estimate of the acres of land disturbed. For 2020, Hurricane Creek watershed has the greatest number of acres affected by construction activities. Other construction activities may be occurring that are not required to have a CGP authorization. A full list of the CGP authorizations in the TMDL watersheds can be found in the *Technical Support Document for Four Total Maximum Daily Loads for Indicator Bacteria in Tributaries of the Neches River below Lake Palestine* (Gitter, Yang, and Gregory, 2021).[2] On average, 329 acres were under CGP authorizations annually in the TMDL watersheds. Jack Creek had the greatest number of acres under CGP authorizations with an annual average of 101 acres. Biloxi Creek has the fewest acres affected by CGP authorizations, with an annual average of 65 acres. Cedar Creek and Hurricane Creek had annual averages of 94 and 68 acres, respectively.

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[2] www.tceq.texas.gov/assets/public/waterquality/tmdl/118lufkin/118-as205-midneches-bacteria-tsd.pdf

Illicit Discharges

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

Direct Illicit Discharges

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

Indirect Illicit Discharges

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

Unregulated Sources

Unregulated sources of bacteria are generally nonpoint. Nonpoint source loading enters the impaired water body through distributed, nonspecific locations, which may include urban runoff not covered by a permit, wildlife, agricultural animals, failing OSSFs, unmanaged and feral animals, and domestic pets.

Unregulated Agricultural Activities and Domesticated Animals

A number of agricultural activities that do not require permits can be potential sources of fecal bacteria loading. Activities, such as livestock grazing close to water bodies and the use of manure as fertilizer, can contribute *E. coli* to nearby water bodies.

Table 6 provides estimated numbers of selected livestock in the TMDL watersheds based on the 2017 Census of Agriculture (USDA, 2019). Those populations were determined based on GIS calculations of 2016 NLCD suitable habitat in the TMDL watersheds, which included areas classified as Pasture/Hay and Grassland/Herbaceous. The area of suitable habitat was then divided by the total area of Angelina County classified as Pasture/Hay and Grassland/Herbaceous. The resulting ratio of suitable habitat was multiplied by USDA county-level livestock estimates. TSSWCB staff reviewed the watershed estimated livestock numbers. These livestock numbers were not used to develop an allocation of allowable bacteria loading to livestock.

Table 6. Estimated livestock numbers

AU	Cattle and Calves	Horses	Goats	Sheep	Hogs and Pigs
0604A_02 [a]	933	98	77	14	7
0604B_01	94	10	8	1	1
0604C_01	1,437	151	119	22	11
0604M_03	852	90	70	13	6

[a] Totals exclude upstream AU 0604B_01 subwatershed

Fecal matter from dogs and cats is transported to water bodies by runoff in both urbanized and rural areas and can be a source of bacteria loading. Table 7 summarizes the estimated number of dogs and cats in the TMDL watersheds. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household (American Veterinary Medical Association, 2018). The actual contribution and significance of bacteria loads from pets reaching the water bodies is unknown.

Table 7. Estimated households and pet populations

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
0604A_02 [a]	6,049	3,714	2,764
0604B_01	6,733	4,134	3,077
0604C_01	3,128	1,921	1,429
0604M_03	1,522	935	696

[a] Totals exclude upstream AU 0604B_01 subwatershed

Wildlife and Unmanaged Animals

Fecal bacteria, such as *E. coli*, inhabit the intestines of all warm-blooded animals, including wildlife such as mammals and birds. To develop bacteria TMDLs, it is important to consider bacteria contributions from wildlife. Riparian corridors of water bodies naturally attract wildlife, and with direct access to the stream channel, wildlife can deposit waste directly into the water body. Wildlife also deposit fecal bacteria on land surfaces, where they may be washed into nearby water bodies by rainfall runoff.

The Texas Parks and Wildlife Department provides deer population-density estimates for the state by Resource Management Unit and Ecoregion. The TMDL watersheds lie within Resource Management Unit 14, with an average deer density of 45.5 acres per deer within suitable habitat over the period 2005 through 2015 (Texas Parks and Wildlife Department, 2018). Suitable NLCD classes for deer habitat classified in the 2016 NLCD include Pasture/Hay, Shrub/Scrub, Grassland/Herbaceous, Deciduous Forest, Evergreen Forest, Mixed Forest, Woody Wetlands, and Emergent Herbaceous Wetlands. Jack Creek had the greatest amount of suitable habitat with 16,046 acres, which corresponds to an estimated 353 deer (Table 8).

Texas A&M AgriLife Extension (2012) estimates one hog per 39 acres within suitable habitat as a statewide average density for feral hogs. The density was applied to NLCD classes suitable for feral hogs in the watershed, which include Pasture/Hay, Shrub/Scrub, Grassland/Herbaceous, Deciduous Forest, Evergreen Forest, Mixed Forest, Woody Wetlands, and Emergent Herbaceous Wetlands. Jack Creek had the greatest estimated feral hog population with 411 hogs (Table 8).

Table 8. Estimated feral hog and white-tailed deer populations

AU	Suitable Habitat Area	Estimated Number of Deer	Estimated Number of Feral Hogs
0604A_02 [a]	15,033	330	385
0604B_01	2,791	61	72
0604C_01	16,046	353	411
0604M_03	9,936	218	255

All areas are expressed in acres.

[a] Totals exclude upstream AU 0604B_01 subwatershed

On-Site Sewage Facilities

Private residential 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 liquids flow 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 working.

However, properly designed and operated OSSFs contribute virtually no fecal bacteria to surface waters. For example, less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system (Weiskel et al., (1996). Reed, Stowe, and Yanke LLC (2001) provide estimated failure rates of OSSFs for different regions of Texas. The TMDL watersheds are within Region V, which has a reported failure rate of about 19%, providing insight into expected failure rates in the watersheds.

Estimates of the number of OSSFs located in the watershed were determined using 911 addresses to identify residence locations that were verified with aerial imagery data. Residential and business addresses that were found to be located outside of city boundaries, the area covered by certificates of convenience and necessity (CCN), and outside of the city's sewer system were assumed to have an OSSF (Public Utility Commission of Texas, 2017; City of Lufkin, 2003) (Figure 8). Table 9 shows the total estimates.

Table 9. OSSF estimates

AU	Estimated OSSFs
0604A_02 [a]	716
0604B_01	0
0604C_01	1,434
0604M_03	947

[a] Totals exclude upstream AU 0604B_01 subwatershed

Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials under certain conditions (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 improperly treated compost and sewage sludge (or biosolids). While die-off of indicator bacteria has been shown in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less understood. Both replication and die-off are in-stream processes that are not considered in the bacteria source loading estimates for the TMDLs.

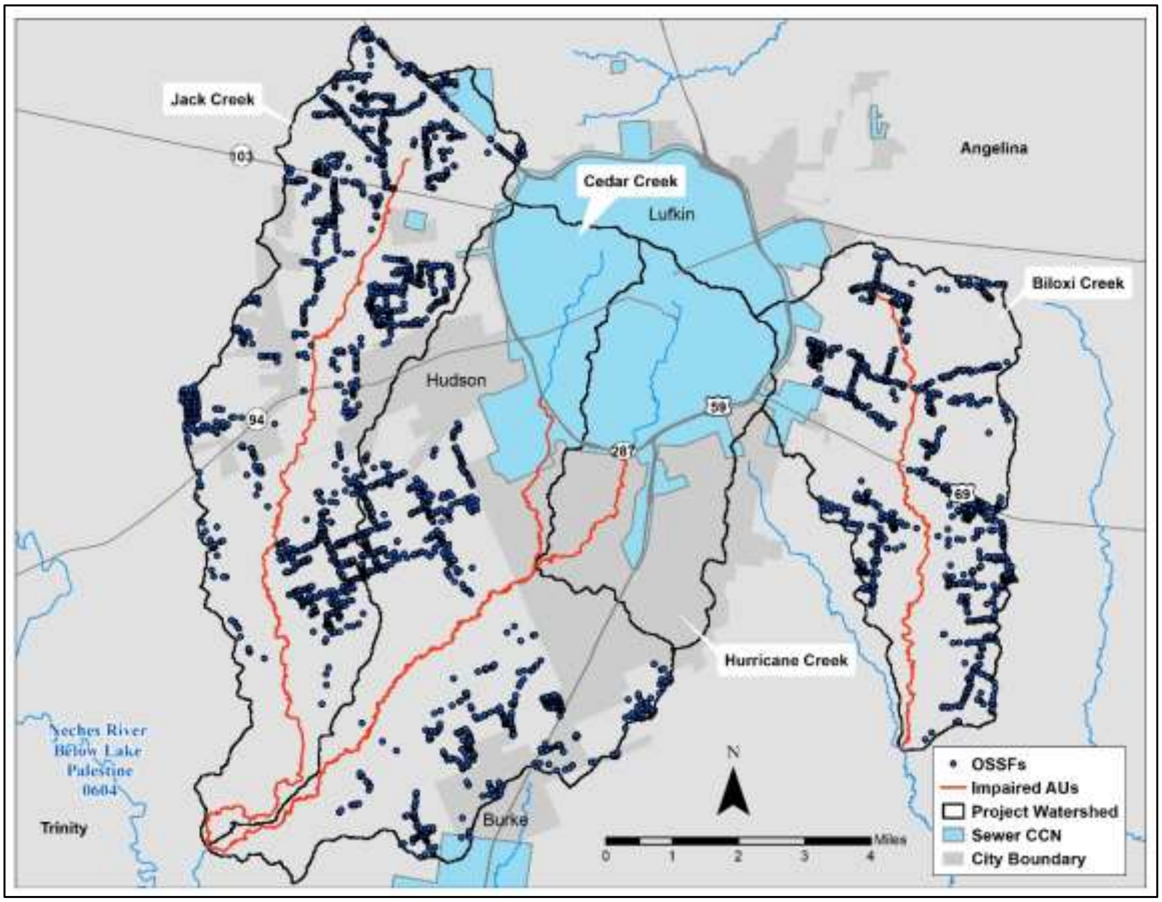

Figure 8. Estimated OSSFs

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. This relationship may be proven through a variety of techniques.

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

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

Load Duration Curve Analysis

LDCs are graphs of the frequency distribution of loads of pollutants in a water body. LDC analyses were used to examine the relationship between instream water quality and the broad sources of bacteria loads which are the basis of the TMDL allocations. In the case of these TMDLs, the loads shown are of *E. coli* bacteria in cfu/day. LDCs are derived from flow duration curves (FDCs). LDCs shown in the following figures represent the maximum acceptable load in the water bodies that will result in achievement of the TMDL water quality targets. The basic steps to generate LDCs include all of the following.

- Generating a daily flow record – the mean daily streamflow record incorporating full permitted discharges and FG was developed for a TCEQ SWQM station within each TMDL watershed using the drainage area ratio methodology.
- Developing the FDC – the mean daily streamflow is plotted against the exceedance probability of the mean daily streamflow for each day.
- Converting the FDC to an LDC – the mean daily streamflow for each day is multiplied by the primary contact recreation 1 use geometric mean criterion and a conversion factor to produce a graph of the frequency distribution of allowable loads.
- Overlaying the LDC with available indicator bacteria loading measurements to understand under what flow conditions indicator bacteria loading exceeds the primary contact recreation 1 use geometric mean criterion.

Hydrologic data in the form of daily streamflow records were unavailable for the TMDL watersheds. However, streamflow records are available in the nearby Long King Creek watershed (Figure 9). USGS collects and shares streamflow records for this watershed. Mean daily streamflow for the TMDL watersheds was developed using stream gauge 08066200 Long King Creek at Livingston (USGS, 2020). This gauge was chosen to develop naturalized streamflow records due to its proximity to the TMDL watersheds. The period of record for developing the FDCs was from January 1, 2001 through December 31, 2019.

The method used to develop the necessary streamflow records for the four FDC/LDC locations (TCEQ SWQM station locations) involved a drainage area ratio approach (Asquith et al., 2006). The drainage area ratio approach involves multiplying a USGS gauging station daily streamflow value by a factor to estimate the flow at a desired TCEQ SWQM station location. The factor is determined by dividing the drainage area above the desired monitoring station location by the drainage area above the USGS gauge (Table 10) and applying a streamflow percentile exponent factor. After estimating the mean daily streamflow values, the upstream full permitted discharges and FG allocations are added to complete the estimated streamflow record. Additional information about the daily streamflow development procedure is available in the *Technical Support Document for Four Total Maximum Daily Loads for Indicator Bacteria in the Tributaries of the Neches River below Lake Palestine* (Gitter, Yang, and Gregory, 2021).[3]

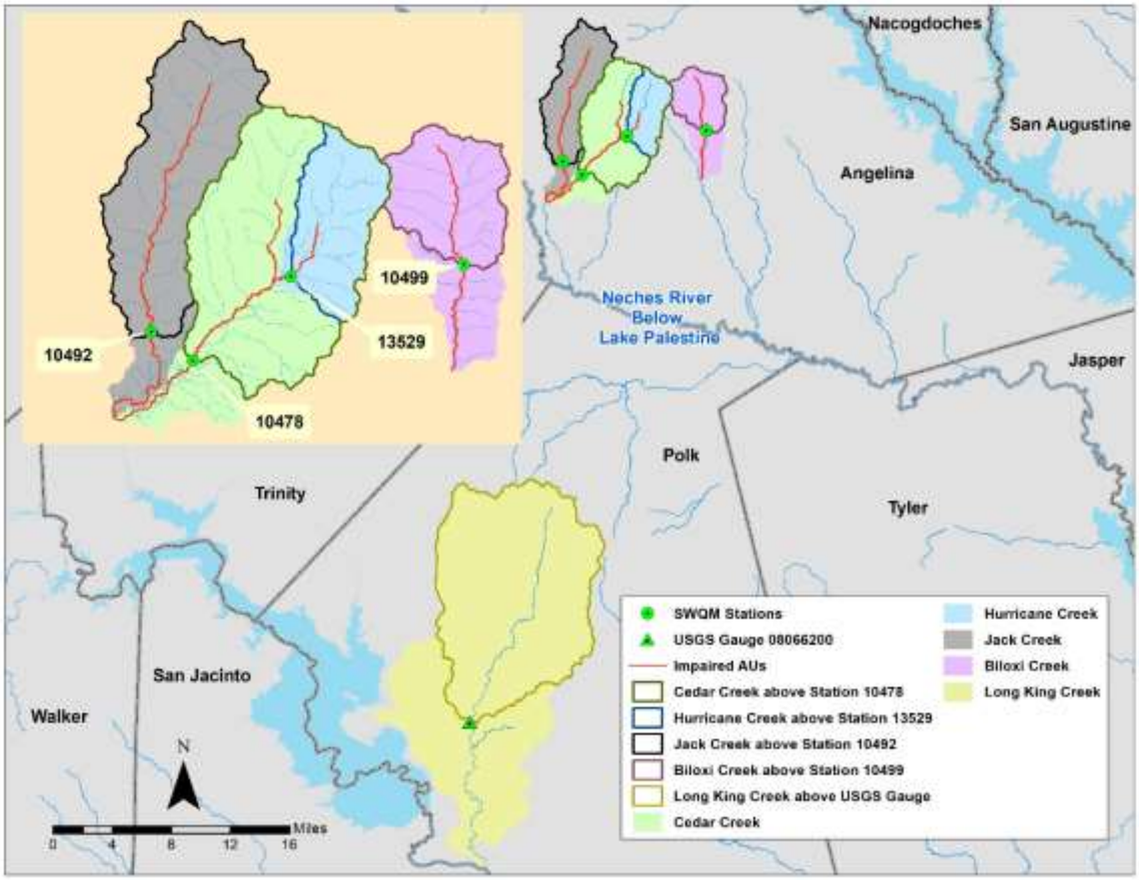

Figure 9. **USGS streamflow gauge and SWQM station watersheds used in streamflow development**

After development of the daily streamflow record, the FDC was generated by calculating the exceedance probability for each daily streamflow record and plotting the mean daily flow against the exceedance probability. Exceedance values along the x axis represent the percentage of days that flow was at or above the associated flow value on the y axis. Exceedance values near 100% occur

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[3] www.tceq.texas.gov/assets/public/waterquality/tmdl/118lufkin/118-as205-midneches-bacteria-tsd.pdf

during low flow or drought conditions while values approaching 0% occur during periods of high flow or flood conditions.

Table 10. DARs used at each SWQM station

Location	Drainage Area	Drainage Area Ratio
USGS 08066200 (Long King Creek)	90,268.160	NA
SWQM Station 10478 (Cedar Creek)	25,270.080[a]	0.2799
SWQM Station 13529 (Hurricane Creek)	7,782.848	0.0862
SWQM Station 10492 (Jack Creek)	16,368.064	0.1813
SWQM Station 10499 (Biloxi Creek)	8,007.488	0.0887

Area is expressed in acres.

[a] Drainage area above SWQM station 10478 includes all of the Hurricane Creek watershed area and the area above the station for the Cedar Creek watershed.

The FDC was converted to an LDC by multiplying each streamflow value by the primary contact recreation 1 use geometric mean criterion (126 cfu/100 mL) and a conversion factor, resulting in units of cfu/day. The resulting LDC plots each bacteria load value (y axis) against its exceedance value (x axis). Exceedance values along the x axis represent the percent of days that the bacteria load was at or above the allowable load on the y axis.

Historical bacteria data from January 1, 2001 through December 31, 2019 were obtained from TCEQ's Surface Water Quality Monitoring Information System for SWQM stations 10478, 13529, 10492, and 10499 (Figure 9). Bacteria concentrations were converted to a daily load by multiplying the measured concentration by the streamflow value on the day the measurement was collected and a conversion factor. The resulting measured daily load points were plotted against the load exceedance for the day the sample was collected.

The plots of the LDC display the frequency and magnitude at which measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above the maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below the curve show compliance.

A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curve. This approach can support determination of the streamflow conditions under which exceedances are occurring. A commonly used set of regimes, provided in Cleland (2003), is based on the following five intervals along the x axis of the FDCs and LDCs: 0-10% (high flows); 10-40% (moist conditions); 40-60% (mid-range flows); 60-90% (dry conditions); and 90-100% (low flows). The flow regime intervals were selected based on general observation of the developed LDC.

The high flow regime (0-10% exceedance) is used for the TMDL calculations. The median loading of the high flow regime (5% exceedance) is used because it represents a reasonable yet high value for the allowable pollutant load allocation.

Load Duration Curve Results

The LDCs for the TMDL watersheds are shown in Figure 10-13. Based on these LDC results, the following broad linkage statements can be made:

- For the Cedar Creek (AU 0604A_02) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under all flow conditions.
- For the Hurricane Creek (AU 0604B_01) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under high flow, moist, mid-range flow, and dry conditions. Under low-flow conditions, loadings fall below the geometric mean criterion.
- For the Jack Creek (AU 0604C_01) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under high flow, moist, and mid-range flow conditions. Under dry and low-flow conditions, loadings fall below the geometric mean criterion.
- For the Biloxi Creek (AU 0604M_03) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under high flow, moist, mid-range flow, and dry conditions. Under the low-flow condition, loadings fall below the geometric mean criterion.

Margin of Safety

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

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

The MOS is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning an MOS. These TMDLs incorporate an explicit MOS of 5% of the total TMDL allocation.

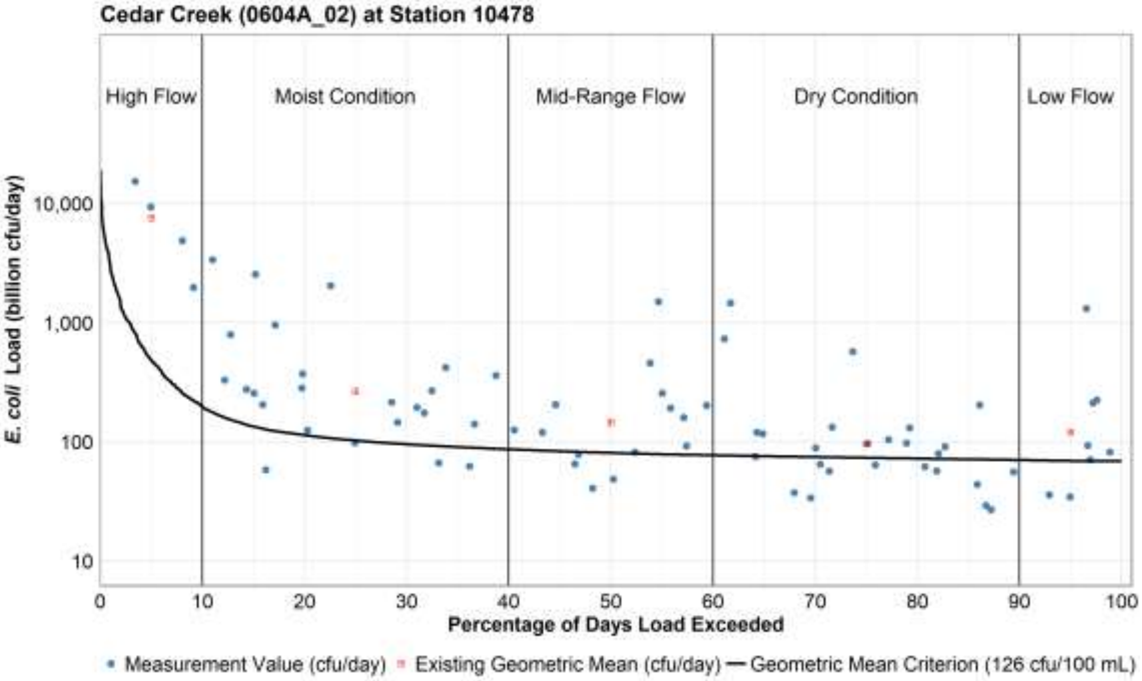

Figure 10. LDC for Cedar Creek AU 0604A_02 at SWQM Station 10478

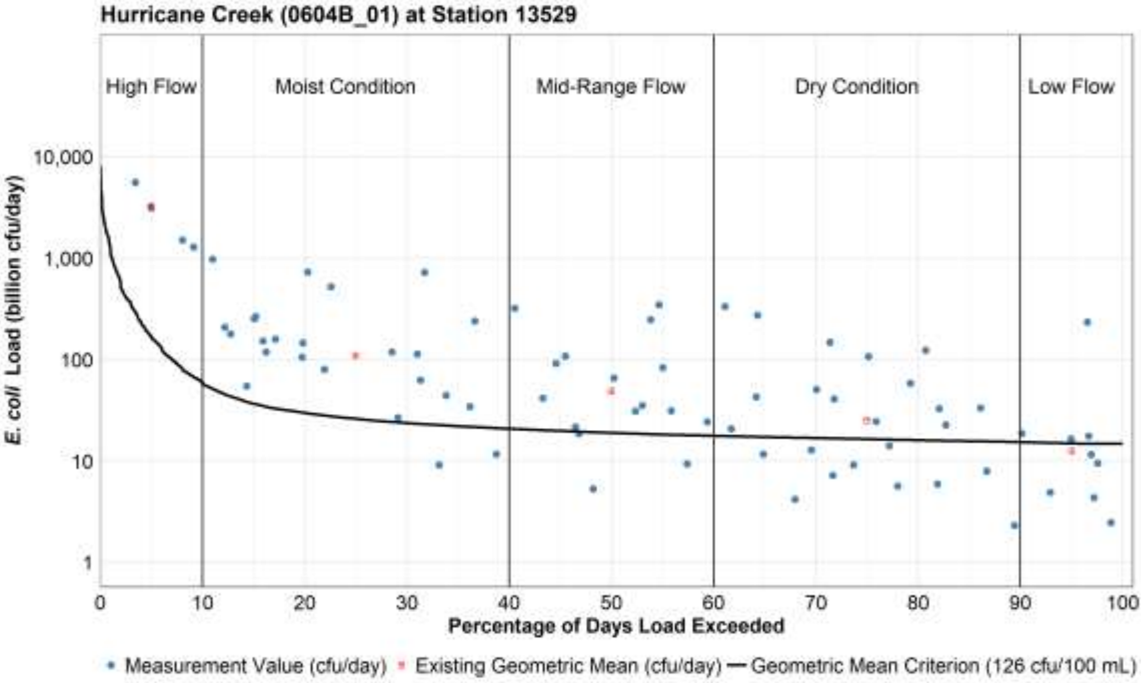

Figure 11. LDC for Hurricane Creek AU 0604B_01 at SWQM Station 13529

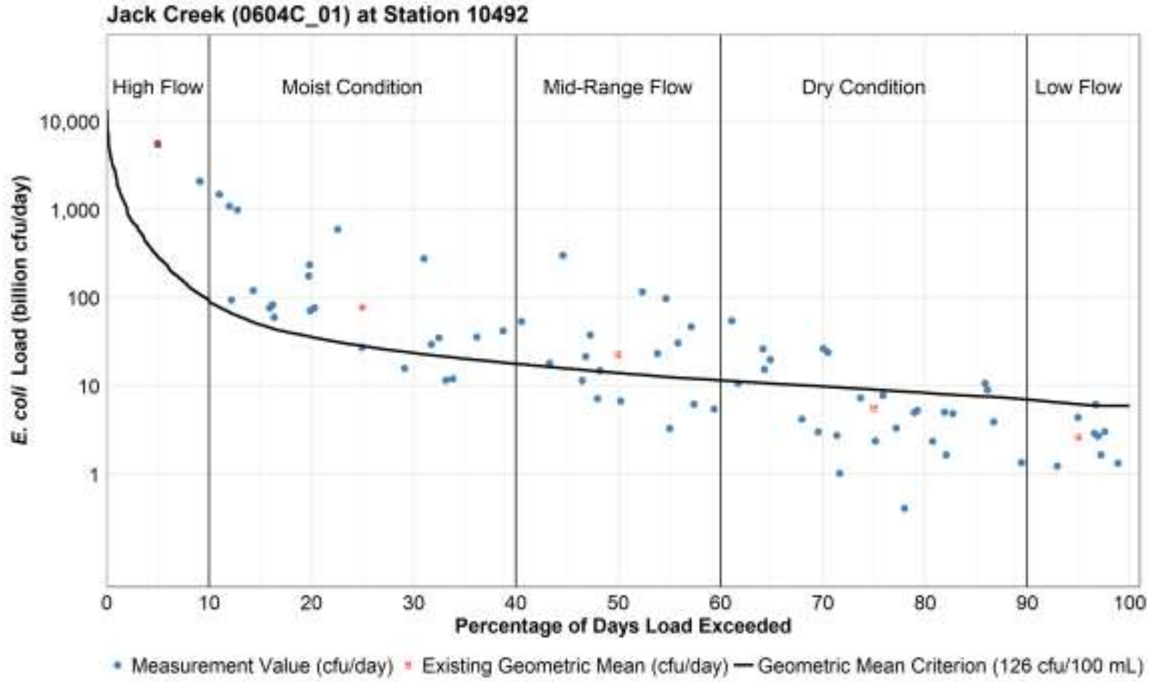

Figure 12. LDC for Jack Creek AU 0604C_01 at SWQM Station 10492

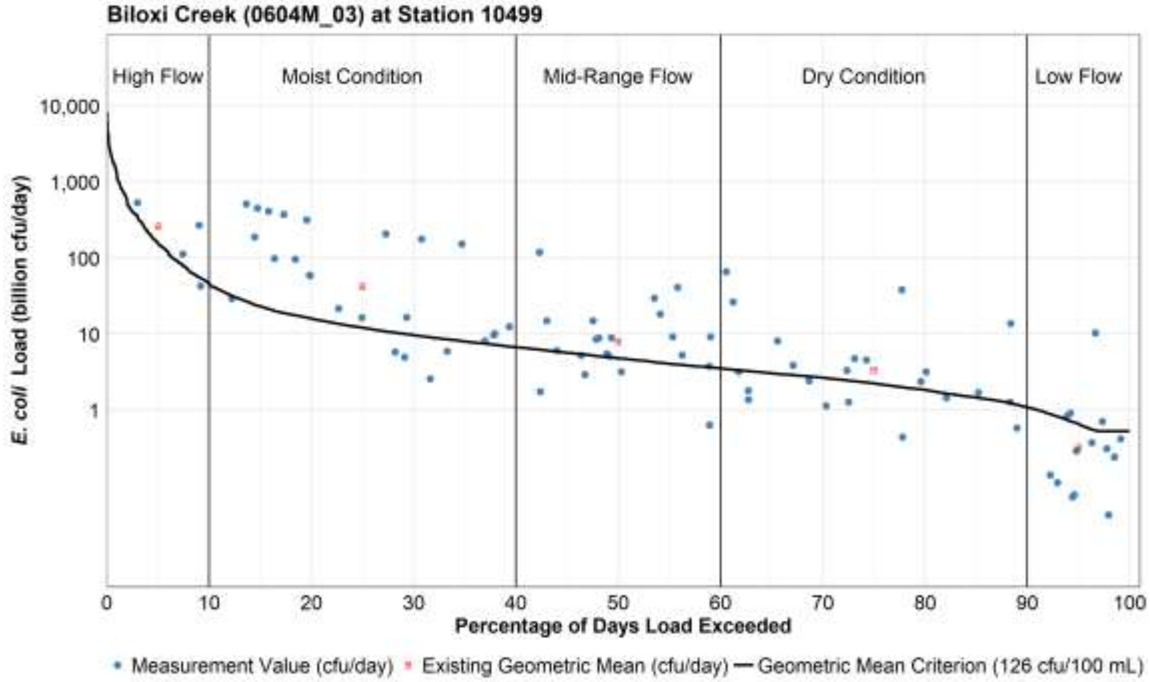

Figure 13. LDC for Biloxi Creek AU 0604M_03 at SWQM Station 10499

Pollutant Load Allocation

The TMDL is 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 following equation:

TMDL = WLA + LA + FG + MOS

Where:

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

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

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

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

The TMDL components for impaired AUs are derived using the median flow within the high flow regime (or 5% flow) of the LDCs developed for the Cedar Creek, Hurricane Creek, Jack Creek, and Biloxi Creek TMDL watersheds. 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.

Assessment Unit-Level TMDL Calculations

The TMDLs for the impaired AUs were developed as pollutant load allocations based on information from the LDCs developed for TCEQ SWQM stations 10478, 13529, 10492, and 10499 (Figure 10-13). As discussed earlier, a bacteria LDC was developed by multiplying the streamflow value along the FDC by the primary contact recreation 1 use geometric mean criterion for *E. coli* (126 cfu/100 mL) and by the conversion factor to convert to loading in cfu per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

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

Where:

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

Flow = 5% exceedance flow from FDC in cubic feet per second (cfs)

Conversion Factor (to billion cfu/day) = 28,316.8 mL/cubic feet * 86,400 seconds/day ÷ 1,000,000,000

Table 11 shows the TMDL values at the 5% load duration exceedance.

Table 11. Summary of allowable loadings

AU	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
0604A_02	154.66	4.77×10^{11}	476.767
0604B_01	52.61	1.62×10^{11}	162.180
0604C_01	92.89	2.86×10^{11}	286.350
0604M_03	49.20	1.52×10^{11}	151.668

Margin of Safety Formula

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

MOS = 0.05 * TMDL

Where:

TMDL = total maximum daily load

The MOS calculations for each AU are shown in Table 12.

Table 12. MOS calculations

AU	TMDL	MOS
0604A_02	476.767	23.838
0604B_01	162.180	8.109
0604C_01	286.350	14.318
0604M_03	151.668	7.583

All loads are expressed in billion cfu/day.

Wasteload Allocation

The WLA is the sum of loads from regulated sources. The WLA consists of two parts—the wasteload that is assigned to TPDES-permitted WWTFs (WLA_{WWTF}) and the wasteload that is assigned to regulated stormwater dischargers (WLA_{SW}).

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

Wastewater Treatment Facilities

Determination of the WLA_{WWTF} requires development of a daily WLA for each TPDES-permitted facility. The full permitted daily-average flow of each WWTF is multiplied by the instream geometric criterion for the water body and the conversion factor. This calculation is expressed by:

$$WLA_{WWTF} = Criterion * Flow * Conversion\ Factor$$

Where:

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

Flow = full permitted flow (MGD)

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

Using this equation, each WWTF's allowable loading was calculated using the permittee's full permitted flow. The individual results were summed for each AU. The criterion was the geometric mean of *E. coli* required for the segment in the Texas Surface Water Quality Standards.

Table 13 shows the load allocations for each WWTF and a total WLA_{WWTF} for the AUs.

Table 13. WLAs for TPDES-permitted facilities

AU	TPDES Number	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Flow (MGD)	WLA_{WWTF} (billion cfu/day)
0604A_02	WQ0010214001	City of Lufkin	126	11.3[a]	53.897[a]
0604B_01	NA	NA	NA	0.00	0.000
0604C_01	WQ0011826001	City of Hudson	126	0.98	4.674
0604M_03	NA	NA	NA	0.00	0.000

[a] The City of Lufkin WWTF discharges to AU 0604B_01, but because it is downstream of the SWQM station at which the TMDL is developed, it is accounted for in AU 0604A_02.

Regulated Stormwater

Stormwater discharges from MS4s, industrial facilities, concrete production, and construction areas are considered 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_{SW} for these areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading.

The percentage of each watershed that is under the jurisdiction of stormwater permits (i.e., defined as the area designated as urbanized area in the 2010 U.S. Census) was used to estimate the amount of the overall runoff load that should be allocated as the regulated stormwater contribution in the WLA_{SW} component of the TMDL (Table 14). The load allocation (LA) component of the TMDL corresponds to direct nonpoint source 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:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

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

The FDA_{SWP} must be calculated to arrive at the fractional proportion of the drainage area under jurisdiction of stormwater permits. FDA_{SWP} is calculated by first totaling the area of each stormwater permit and authorization. The stormwater sources and area estimates were discussed in the "TPDES Regulated Stormwater" section. Those area estimates were determined for each category and summed up to determine the total area under stormwater jurisdiction in each AU (A value for FG is necessary to complete the WLA_{SW}. The calculation for FG is presented later in this report, but the results are included here for continuity. All the information for calculating the WLA_{SW} is shown in Table 15.

In urbanized areas currently regulated by an MS4 permit, development or redevelopment of land must implement the control measures and programs outlined in an approved SWMP. Although additional flow may occur from development or redevelopment, loading of the pollutant of concern should be controlled or reduced through the implementation of BMPs as specified in both the TPDES permit and the approved SWMP.

Table 14).

To arrive at the proportion, the area under stormwater jurisdiction was then divided by the total watershed area. The FDA_{SWP} for AU 0604A_02 accounts for the upstream area contribution by adding the total area of regulated stormwater for the AU and that of the upstream AU 0604B_01 and then dividing by the watershed area.

A value for FG is necessary to complete the WLA_{SW}. The calculation for FG is presented later in this report, but the results are included here for continuity. All the information for calculating the WLA_{SW} is shown in Table 15.

In urbanized areas currently regulated by an MS4 permit, development or redevelopment of land must implement the control measures and programs outlined in an approved SWMP. Although additional flow may occur from development or redevelopment, loading of the pollutant of concern should be controlled or reduced through the implementation of BMPs as specified in both the TPDES permit and the approved SWMP.

Table 14. Regulated stormwater FDA_{SWP} calculations

AU	MS4 Area	MSGP Area	CGP Area	Concrete Production Facilities Area	Total Area of Permits	Watershed Area	FDA_{SWP}
0604A_02 [a]	0.0000	204.25	162.00	17.90	384.15	28,458.88	0.0135
0604B_01	0.0000	117.26	68.00	0.00	185.26	8,268.16	0.0224
0604C_01	0.0000	0.00	101.00	0.00	101.00	18,593.92	0.0054
0604M_03	0.0000	45.60	65.00	0.00	110.60	12,078.08	0.0092

All areas are expressed in acres

[a] FDA_{SWP} for AU 0604A_02 includes the watershed area and permit areas for upstream AU 0604B_01 watershed

Table 15. Regulated stormwater load calculations

AU	TMDL	WLA_{WWTF}	FG	MOS	FDA_{SWP}	WLA_{SW}
0604A_02	476.767	53.897	14.714	23.838	0.0135	5.188
0604B_01	162.180	0.000	14.714	8.109	0.0224	3.122
0604C_01	286.350	4.674	1.276	14.318	0.0054	1.437
0604M_03	151.668	0.000	0.525	7.583	0.0092	1.321

All loads are expressed in billion cfu/day.

With the WLA_{SW} and WLA_{WWTF} terms, the total WLA term can be determined by adding the two parts (Table 16).

Table 16. WLA calculations

AU	WLA_{WWTF}	WLA_{SW}	WLA
0604A_02	53.897	5.188	59.085
0604B_01	0.000	3.122	3.122
0604C_01	4.674	1.437	6.111
0604M_03	0.000	1.321	1.321

All loads are expressed in billion cfu/day.

An iterative, adaptive management approach will be used to address stormwater discharges. This approach encourages the implementation of structural or non-structural controls, implementation of mechanisms to evaluate the performance of the controls, and finally, allowance to make adjustments (e.g., more stringent controls or specific BMPs) as necessary to protect water quality.

Implementation of Wasteload Allocations

The TMDLs in this document will result in protection of existing uses and conform to Texas' antidegradation policy. The three-tiered antidegradation policy in the Texas Surface Water Quality Standards prohibits an increase in loading that would cause or contribute to degradation of an existing use. The antidegradation policy applies to point source pollutant discharges. In general, antidegradation procedures establish a process for reviewing individual proposed actions to determine if the activity will degrade water quality.

TCEQ intends to implement the individual WLAs through the permitting process as monitoring requirements and/or effluent limitations as required by the amendment of Title 30 Texas Administrative Code (TAC) Chapter 319, which became effective November 26, 2009. WWTFs discharging to TMDL water bodies will be assigned an effluent limit based on the TMDL. Monitoring requirements are based on permitted flow rates and are listed in 30 TAC Section 319.9.

Permit requirements are implemented during the routine permit renewal process. However, there may be a more economical or technically feasible means of achieving the goal of improved water quality, and circumstances may warrant changes in individual WLAs after these TMDLs are adopted. Therefore, the individual WLAs, as well as the WLAs for stormwater, are non-binding until implemented via a separate TPDES permitting action, which may involve preparation of an update to the state's WQMP. Regardless, all permitting actions will comply with the TMDLs.

The executive director or commission may establish interim effluent limits and/or monitoring-only requirements during amendment or renewal of a permit. These interim limits allow a permittee time to modify effluent quality in order to attain the final effluent limits necessary to meet TCEQ- and EPA-approved TMDL allocations. The duration of interim effluent limits may not be any longer than three years from the date of permit re-issuance. Compliance schedules are not allowed for new permits.

Where a TMDL has been approved, domestic WWTF TPDES permits require conditions consistent with the requirements and assumptions of the WLAs. For TPDES-regulated municipal, construction stormwater, and industrial stormwater discharges, water quality-based effluent limits (WQBELs) that implement the WLA for stormwater may be expressed as BMPs or other similar requirements, rather than as numeric effluent limits.

The November 26, 2014 memorandum from EPA relating to establishing WLAs for stormwater sources states:

> “Incorporating greater specificity and clarity echoes the approach first advanced by EPA in the 1996 Interim Permitting Policy, which anticipated that where necessary to address water quality concerns, permits would be modified in subsequent terms to include “more specific conditions or limitations [which] may include an integrated suite of BMPs, performance objectives, narrative standards, monitoring triggers, numeric WQBELs, action levels, etc.”

Using this iterative, adaptive BMP approach to the maximum extent practicable is appropriate to address the stormwater components of these TMDLs.

Updates to Wasteload Allocations

These TMDLs are, by definition, the total of the sum of the WLA (including FG), the sum of the LA, and the MOS. Changes to individual WLAs may be necessary in the future in order to accommodate growth or other changing conditions. These changes to individual WLAs do not ordinarily require a revision of the TMDL document; instead, changes will be made through updates to the state’s WQMP. Any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

Load Allocation

The LA is the sum of loads from unregulated sources, and is calculated as:

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

Table 17 summarizes the LA calculations.

Table 17. LA calculations

AU	TMDL	WLA_{WWTF}	WLA_{SW}	FG	MOS	LA
0604A_02	476.767	53.897	5.188	14.714	23.838	379.130
0604B_01	162.180	0.000	3.122	14.714	8.109	136.235
0604C_01	286.350	4.674	1.437	1.276	14.318	264.645
0604M_03	151.668	0.000	1.321	0.525	7.583	142.239

All loads are expressed in billion cfu/day.

Allowance for Future Growth

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

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

To account for FG, the loadings from WWTFs are included in the FG computation, which is based on the WLA_{WWTF} formula. The FG equation includes an additional term to account for projected population growth within WWTF service areas between 2020 and 2070, based on TWDB Regional Water Plan Population and Water Demand Projections (TWDB, 2019).

FG (billion cfu/day) = Criterion * ($\%POP_{2020\text{-}2070}$ * $WWTF_{FP}$) * Conversion Factor

Where:

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

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

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

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

For Hurricane Creek and Biloxi Creek, project staff took a slightly different approach.

For Hurricane Creek AU 0604B_01, the outfall of the Lufkin WWTF discharges downstream of SWQM station 13529, which was used to develop the TMDL. Therefore, a WLA_{WWTF} was not included, but an FG was calculated to account for the possibility of future WWTF expansion or infrastructure changes. The Lufkin WWTF's full permitted discharge was used to calculate the FG.

For Biloxi Creek AU 0604M_03, projecting FG is hindered by the absence of WWTFs. The Biloxi AU watershed is projected to grow from 3,900 in 2020 to 4,965, a population increase of 1,065 by 2070. To account for this 27.3% increase in population and the possibility that future development may require centralized wastewater treatment, an alternative approach was used.

A new WWTF must accommodate daily wastewater of 75-100 gallons per capita per day (30 TAC Section 217.32). Using the daily wastewater upper value 100, and multiplying it by the estimated population change, would produce a conservative future permitted flow and FG value. Rounding the population increase up to 1,100 individuals and multiplying it by 100 gallons per capita per day results in a future WWTF with a permitted capacity of 0.11 MGD. Table 18 presents the FG calculations.

Compliance with these TMDLs is based on keeping bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. FGs of existing or new point sources are not limited by these TMDLs as long as the sources do not cause bacteria to exceed the limits. The assimilative capacity of water bodies increases as the amount of flow increases; consequently, increases in flow allow for increased loadings. The LDCs and tables in this TMDL report will guide determination of the assimilative capacity of the water bodies under changing conditions, including FG.

Table 18. FG calculations

AU	Full Permitted Flow (MGD)	Percentage Population Increase (2020-2070)	FG Flow (MGD)	FG
0604A_02	11.30[a]	27.3%	3.085	14.714

AU	Full Permitted Flow (MGD)	Percentage Population Increase (2020-2070)	FG Flow (MGD)	FG
0604B_01	0.00[b]	27.3%	3.085	14.714
0604C_01	0.98	27.3%	0.268	1.276
0604M_03	0.00	27.3%	0.110[c]	0.525

All loads are expressed in billion cfu/day.

[a] Permitted flow for AU 0604A_02 based on WWTF located in upstream AU 0604B_01.

[b] The permitted flow for AU 0604B_01 11.30 MGD is used for the FG calculations for AU 0604B_01 but not included for WLA_{WWTF} as described previously.

[c] Hypothetical future, unnamed and without permit, WWTF in AU 0604M_03 with a projected future full permitted flow of 0.11 MGD.

Summary of TMDL Calculations

The TMDLs were calculated based on median flow in the 0-10 percentile range (5% exceedance, high-flow regime) for flow exceedance based on the LDCs developed from TCEQ SWQM stations 10478, 13529, 10492, and 10499. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDLs. The TMDL allocations are summarized in Table 19.

Table 19. TMDL allocations

AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
0604A_02	476.767	53.897	5.188	379.130	14.714	23.838
0604B_01	162.180	0.000	3.122	136.235	14.714	8.109
0604C_01	286.350	4.674	1.437	264.645	1.276	14.318
0604M_03	151.668	0.000	1.321	142.239	0.525	7.583

All loads are expressed in billion cfu/day.

The final TMDL allocations (Table 20) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 20. Final TMDL allocations

AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
0604A_02	476.767	68.611	5.188	379.130	23.838
0604B_01	162.180	14.714	3.122	136.235	8.109
0604C_01	286.350	5.950	1.437	264.645	14.318
0604M_03	151.668	0.525	1.321	142.239	7.583

All loads are expressed in billion cfu/day.

Seasonal Variation

Federal regulations [40 CFR 130.7(c)(1)] require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. To evaluate potential seasonal differences, ambient monitoring data were grouped into cool seasons (November through March) and warm seasons (May through September). Data collected in April and October were excluded, assuming those months are transitions between the two seasons. Differences in seasonal concentrations were then evaluated with a Wilcoxon Rank Sum test (also known as the "Mann-Whitney" test). The test was considered significant at the $\alpha = 0.05$ level.

The Wilcoxon Rank Sum test detected a slight seasonal difference in *E. coli* concentrations for Biloxi Creek AU 0604M_03 with *E. coli* concentrations being higher in the cool season. The test suggests there is no significant seasonal differences in *E. coli* concentrations in the other AUs. Seasonal variation is addressed in these TMDLs by incorporating many years of flow and bacteria data spanning all seasons for development of the LDCs.

Public Participation

TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. Communication and comments from the stakeholders in the watershed strengthen TMDL projects and their implementation.

TCEQ and the Texas Water Resources Institute (TWRI) are jointly coordinating public participation in development of both the TMDL and implementation plan (I-Plan). The first of a series of public meetings to engage stakeholders was held on November 22, 2019 in Lufkin to discuss the project and make the public aware of the TMDL. A webinar on July 7, 2020 provided an update on the project's status. Another webinar was held on November 30, 2020 to discuss the technical support document and preliminary TMDL allocations. A webinar on March 25, 2021 initiated I-Plan development. Meetings will continue through 2022 to complete the I-Plan.

Notices of meetings were posted on the project webpages for both TCEQ and TWRI. At least two weeks prior to scheduled meetings, TWRI issued media releases through Texas A&M AgriLife and formally invited stakeholders via email to attend. To ensure that absent or new stakeholders could get information about past meetings and pertinent material, the TCEQ project webpage[4]

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[4] www.tceq.texas.gov/waterquality/tmdl/nav/118-lufkinwatersheds-bacteria

provided meeting summaries, presentations, ground rules, and documents produced for stakeholder review.

Implementation and Reasonable Assurance

The issuance of TPDES permits consistent with TMDLs provides reasonable assurance that WLAs in this TMDL report will be achieved. Per federal requirements, each TMDL is included in an update to the Texas WQMP as a plan element.

The WQMP coordinates and directs the state's efforts to manage water quality and maintain or restore designated uses throughout Texas. The WQMP is continually updated with new, more specifically focused plan elements, as identified in federal regulations [40 CFR 130.6(c)]. Commission adoption of a TMDL is the state's certification of the associated WQMP update.

Because the TMDLs do not reflect or direct specific implementation by any single pollutant discharger, TCEQ certifies additional elements to the WQMP after the I-Plan is approved by the commission. Based on the TMDLs and I-Plan, TCEQ will propose and certify WQMP updates to establish required WQBELs for specific TPDES wastewater discharge permits.

Currently, there are no Phase II MS4 general permit authorizations or Phase I MS4 individual permits held in the TMDL watersheds. However, future population growth within the watersheds may require some entities to obtain authorizations under the Phase II MS4 general permit, depending on future changes in USCB urbanized areas. Where numeric effluent limitations are infeasible for MS4 entities, TCEQ normally establishes BMPs, which are a substitute for effluent limitations, as allowed by federal rules. When such practices are established in Phase II MS4 general permit authorizations or Phase I MS4 individual permits, TCEQ will not identify specific implementation requirements applicable to a specific TPDES stormwater permit or general permit authorization through an effluent limitation update. Rather, TCEQ will revise its Phase II MS4 general permit during the renewal process or amend or revise a permittee's Phase I MS4 individual permit as needed to require a revised SWMP or the implementation of other specific BMPs or controls consistent with an approved I-Plan.

Strategies for achieving pollutant loads in TMDLs from both point and nonpoint sources are reasonably assured by the state's use of an I-Plan. TCEQ is committed to supporting implementation of all TMDLs adopted by the commission.

I-Plans for Texas TMDLs use an adaptive management approach that allows for refinement or addition of methods to achieve environmental goals. This adaptive approach reasonably assures that the necessary regulatory and voluntary activities to achieve pollutant reductions will be implemented. Periodic, repeated evaluations of the effectiveness of implementation methods ascertain whether progress is occurring and may show that the original distribution of loading among sources should be modified to increase efficiency. I-Plans will be adapted as necessary to reflect needs identified in evaluations of progress.

Key Elements of an I-Plan

An I-Plan includes a detailed description and schedule of the regulatory and voluntary management measures to implement the WLAs and LAs of particular TMDLs within a reasonable time. I-Plans also identify the organizations responsible for carrying out management measures, and a plan for periodic evaluation of progress.

Strategies to optimize compliance and oversight are identified in an I-Plan when necessary. Such strategies may include additional monitoring and reporting of effluent discharge quality to evaluate and verify loading trends, adjustment of an inspection frequency or a response protocol to public complaints, and escalation of an enforcement remedy to require corrective action of a regulated entity contributing to an impairment.

TCEQ works with stakeholders and interested governmental agencies to develop and support I-Plans and track their progress. Work on the I-Plan begins during development of TMDLs. Because these TMDLs address agricultural sources of pollution, TCEQ will also work in close partnership with the TSSWCB when developing the I-Plan. The TSSWCB is the lead agency in Texas responsible for planning, implementing, and managing programs and practices for preventing and abating agricultural and silvicultural nonpoint sources of water pollution. The cooperation required to develop an I-Plan will become a cornerstone for the shared responsibility necessary to carry it out.

Ultimately, the I-Plan identifies the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the approved I-Plan may not approximate the predicted loadings identified category by category in the TMDLs and its underlying assessment. The I-Plan is adaptive for this very reason; it allows for continuous update and improvement.

In most cases, it is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction is required by the TMDL, there is high uncertainty with the TMDL analysis, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

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Appendix A.
Population and Population Projections

The following steps were followed to estimate the watershed population and future population projections for the TMDL watersheds:

Estimate 2010 watershed population

1) Census block level population and spatial data for Angelina County for the year 2010 was obtained from the USCB.
2) The watershed population was estimated by adding the total population of the census blocks that lie entirely within the watershed
3) Population for blocks that do not lie entirely in the watershed was determined by multiplying the block population by the proportion of the block area within the watershed.

Estimate 2020-2070 watershed population

4) Angelina County decadal population projections for 2020 through 2070 were obtained from the 2021 Regional Water Plan Population and Water Demand Projection data (TWDB, 2019).
5) The population percentage increase from the published USCB 2010 county population and the 2020 county population projection (TWDB, 2019) was calculated to be 7.5%. The county projected increase was multiplied by the 2010 watershed population to calculate the 2020 watershed population.
6) The projected population percentage increase from 2020 to 2070 was calculated from the TWDB Regional Water Plan Population and Water Demand Projections data (TWDB, 2019). A county projected increase of 27.3% was multiplied by the 2020 watershed population to calculate the 2070 watershed population.