Adopted November 2, 2016
Approved by EPA December 7, 2016

Four Total Maximum Daily Loads for Indicator Bacteria in the Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Watersheds Upstream of Mountain Creek Lake

Segments 0841F, 0841K, 0841N, and 0841V

Assessment Units 0841F_01, 0841K_01, 0841N_01, and 0841V_01

Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Distributed by the
Total Maximum Daily Load Team
Texas Commission on Environmental Quality
MC-203
P.O. Box 13087
Austin, Texas 78711-3087
E-mail: tmdl@tceq.state.tx.us

TMDL project reports are available on the TCEQ website at:
<www.tceq.state.tx.us/waterquality/tmdl/>

The preparation of this report was financed in part through grants from
The U.S. Environmental Protection Agency.

This TMDL report is based in large part on the report titled:
"Technical Support Document for Four Total Maximum Daily Loads for Indicator Bacteria in the Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Watersheds Upstream of Mountain Creek Lake"
prepared by the Texas Institute for Applied Environmental Research.

In compliance with the Americans with Disabilities Act, this document may be requested in alternate formats by contacting the TCEQ at 512/239-0028,
Fax 239-4488, or 1-800-RELAY-TX (TDD), or by writing to
P.O. Box 13087, Austin, TX 78711-3087.

Contents

Executive Summary 1
Introduction 2
Problem Definition 4
Watershed Overview 5
Description of Study Area 5
Watershed Climate and Hydrology 6
Land Use 7
Watershed Population and Population Projections 8
Analysis of Bacteria Data 9
Endpoint Identification 12
Source Analysis 13
Regulated Sources 13
Domestic Wastewater Treatment Facilities 13
Sanitary Sewer Overflows 13
TPDES-Regulated Stormwater 16
Illicit Discharges 17
TPDES General Wastewater Permits 18
Unregulated Sources 19
Wildlife and Unmanaged Animal Contributions 19
On-Site Sewage Facilities 19
Unregulated Agricultural Activities and Domesticated Animals 19
Bacteria Survival and Die-off 21
Linkage Analysis 21
Load Duration Curve Analysis 22
Load Duration Curve Results 25
Margin of Safety 29
Pollutant Load Allocation 29
Wasteload Allocation 30
WWTFs 30
Stormwater 30
Implementation of Wasteload Allocations 31
Updates to Wasteload Allocations 33
Load Allocation 33
Margin of Safety Equation 34
Allowance for Future Growth 34
TMDL Calculations 35
Summary of TMDL Calculations 37
Seasonal Variation 39
Public Participation 39
Implementation and Reasonable Assurance 39
Key Elements of an I-Plan 40
References 42
Appendix A. Equations for Calculating TMDL Allocations for Changed Contact Recreation Standard 45

Figures

Figure 1. Overview map showing the total contributing drainage area for the study area, including AUs 0841P_01 and 0841Q_01. 4
Figure 2. Average minimum and maximum air temperature and total precipitation by month from January 1999 – December 2014 for Arlington Municipal Airport. 7
Figure 3. 2010 land use/land cover within the TMDL study area. 9
Figure 4. TMDL study area showing TCEQ surface water quality monitoring stations used to assess primary contact recreation. 12
Figure 5. Coverage area of the TRA Central Regional Wastewater System within the TMDL study area. 14
Figure 6. SSOs that occurred from January 2007 – December 2011 within the TMDL study area. 15
Figure 7. RSA based on Phase I and Phase II MS4s permits within the TMDL study area. ... 18
Figure 8. OSSFs located within the TMDL study area. 20
Figure 9. TMDL study area, Walnut Creek watershed, and USGS Station 08049700 location near Mansfield, Texas. 24
Figure 10. LDC for Station 17674, the most downstream station on Cottonwood Creek. 26
Figure 11. LDC for Station 17679, the most downstream station on Fish Creek. 27
Figure 12. LDC for Station 17675, Kirby Creek. 28
Figure 13. LDC for Station 17683, Crockett Branch. 28

Tables

Table 1. Land Use/Land Cover within TMDL study area. 10
Table 2. 2010 Population and 2040 Population Projections for the TMDL study area. 11
Table 3. *2012* and *2014 Integrated Report* Summary for the TMDL watersheds. 11
Table 4. Summary of SSO incidences reported in the TMDL study area from January 2007 – December 2011. 15
Table 5. Summary of SSO incidences reported for the cities of Arlington and Grand Prairie from January 2012 – August 2014. 16
Table 6. TPDES and NPDES MS4 permits associated with the TMDL study area. 17
Table 7. Estimated distribution of dog and cat populations. 21
Table 8. Summary of allowable loading calculations for segments within the TMDL watersheds. 35
Table 9. MOS calculations for the most downstream station in each TMDL watershed. 35
Table 10. Basis of unregulated stormwater area and computation of FDA_{SWP}. 36
Table 11. Regulated stormwater calculations for the TMDL watersheds. 37
Table 12. Unregulated stormwater calculations for the TMDL watersheds. 37
Table 13. TMDL allocation summary for the TMDL watersheds. 38
Table 14. Final TMDL allocations for the TMDL watersheds. 38

Abbreviations

AU	assessment unit
BMP	best management practice
CFR	Code of Federal Regulations
cfs	cubic feet per second
DFW	Dallas–Fort Worth Metroplex
DSLP	days since last precipitation
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency (U.S.)
FDA	fractional drainage area
FDC	flow duration curve
FG	future growth
GIS	Geographic Information System
I/I	inflow and infiltration
I-Plan	Implementation Plan
LA	load allocation
LDC	load duration curve
LULC	land use/land cover
mi^2	square miles
ML	milliliter
MGD	million gallons per day
MOS	margin of safety
MPN	most probable number
MS4	municipal separate storm sewer system
NCTCOG	North Central Texas Council of Governments
NHD RC	National Hydrography Dataset reach code
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OSSF	on-site sewage facility
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RSA	regulated stormwater areas
SSO	sanitary sewer overflow
SWMP	Stormwater Management Program
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TRA	Trinity River Authority
USCB	United States Census Bureau
USGS	United States Geological Survey
WLA	wasteload allocation
WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility

Four TMDLs for Indicator Bacteria in Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Watersheds Upstream of Mountain Creek Lake

Executive Summary

This document describes total maximum daily loads (TMDLs) for Cottonwood Creek, Fish Creek, Kirby Creek and Crockett Branch where concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the contact recreation use. The Texas Commission on Environmental Quality (TCEQ or commission) first identified the bacteria impairments within Cottonwood Creek, Fish Creek, and Kirby Creek in 2006 and within Crockett Branch in 2010 in the *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d) (*formerly called the *Texas Water Quality Inventory and 303(d) List)*. They are found in each subsequent edition of the report through 2014. The impaired segments and corresponding assessment units (AUs) are:

- Cottonwood Creek (0841F_01),
- Fish Creek (0841K_01),
- Kirby Creek (0841N_01), and
- Crockett Branch (0841V_01)

All four watersheds are located in urban areas in the Dallas–Fort Worth Metroplex (DFW) area. Cottonwood Creek and Fish Creek are adjacent water bodies located upstream of Mountain Creek Lake. Kirby Creek is a tributary of Fish Creek, and Crockett Branch is a tributary of Cottonwood Creek. The four impaired segments are each composed of only one AU that encompasses the entire segment. All are unclassified, perennial freshwater streams that eventually feed into the Lower West Fork of the Trinity River (Segment 0841) via Mountain Creek Lake and Mountain Creek.

There are no regulated wastewater treatment facilities (WWTFs) located in the TMDL watersheds. The entire area of the TMDL watersheds is within the service area of the Trinity River Authority (TRA) Central Regional Wastewater System, which discharges outside of the project area.

The TMDL watersheds contain entities that are regulated under municipal separate storm sewer system (MS4) Phase II general permits and Phase I individual permits. The area included within these permits was used to estimate the areas under stormwater regulation for construction, industrial, and MS4 permits. The Phase I and Phase II permits provide 100 percent coverage of the

TMDL watersheds. Based on stream length and width in each TMDL watershed, a small unregulated stormwater component was included for each impaired water body.

The discharges authorized by the stormwater permits (construction, industrial, and MS4) are considered intermittent and variable (subject to precipitation and runoff), and no flow limit is specified in the permits. These outfalls will be treated as part of the regulated stormwater discharge in the load allocations.

Escherichia coli (*E. coli*) are the preferred indicator bacteria for assessing the contact recreation use in freshwater and were used for development of the TMDLs. The criteria for assessing attainment of the contact recreation use are expressed as the number (or "counts") of *E. coli* bacteria, typically given as the most probable number (MPN). The primary contact recreation use is not supported when the geometric mean of ambient *E. coli* samples exceeds 126 MPN per 100 milliliters (mL).

Historical ambient water quality data for indicator bacteria were evaluated at the AU level for TCEQ water quality monitoring stations on Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch. For these four AUs, the geometric means of *E. coli* ranged from 740 MPN/100 mL for Crockett Branch (AU 0841V_01) to 215 MPN/100 mL for Fish Creek AU (0841K_01). The geometric mean of the combined samples for all stations within each water body exceeded 126 MPN/100 mL, indicating non-support of primary contact recreation.

A load duration curve (LDC) analysis was used to quantify allowable pollutant loads and specific TMDL allocations for point and nonpoint sources of indicator bacteria.

No wasteload allocation for WWTFs was established, because no permitted dischargers exist in the TMDL watersheds. Due to the 100 percent coverage of wastewater collection by the TRA Central Regional Wastewater System and the absence of any other discharges, no future growth component was required for the TMDL watersheds.

Compliance with these TMDLs is based on keeping the indicator bacteria concentrations in the selected waters below the geometric mean criterion of 126 MPN/100 mL. The TMDL calculations in this report will guide determination of the assimilative capacity of each stream under changing conditions.

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 listed water body. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

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

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

This TMDL addresses impairments to the primary contact recreation use due to exceeding indicator bacteria criteria in Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch. This TMDL takes a watershed approach to addressing bacterial impairment. While TMDL allocations are only being developed for the AUs identified in this report, the entire project watershed (Figure 1) and any facilities that discharge within it are included within the scope of this TMDL. No WWTFs are included in this TMDL because none discharge within the project watershed.

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

The TCEQ must consider certain elements in developing a TMDL. They are 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

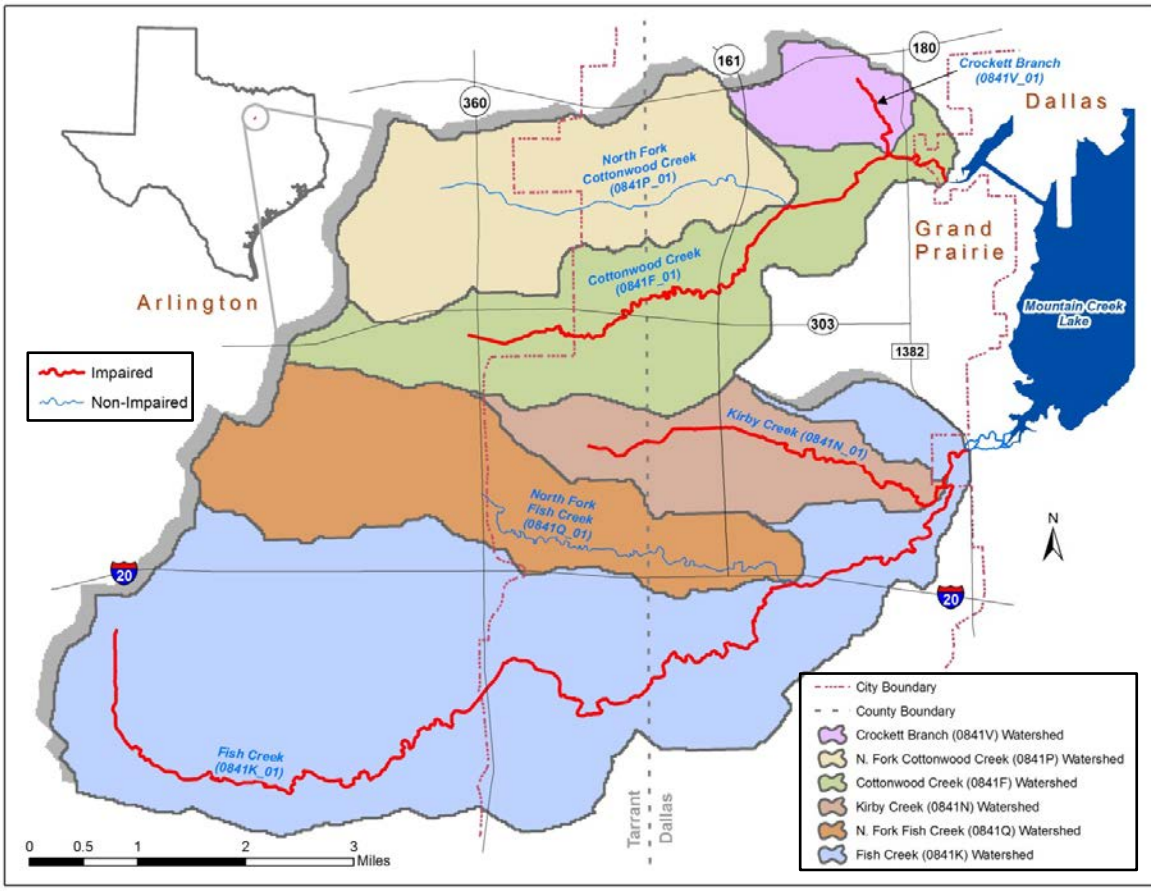

Figure 1. Overview map showing the total contributing drainage area for the study area, including AUs 0841P_01 and 0841Q_01.

Source: TCEQ (2012a)

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

Problem Definition

The TCEQ first identified the bacterial impairments within the Cottonwood Creek, Fish Creek, and Kirby Creek in 2006 and within Crockett Branch in 2010, and then in each subsequent edition of the *Texas Integrated Report of Surface Water Quality for Clean Water Sections 305(b) and 303(d) (*formerly called the *Texas Water Quality Inventory and 303(d) List)* through 2014 (TCEQ, 2013a and 2015a). The impaired AUs are 0841F_01, 0841K_01, 0841N_01, and 0841V_01. Because the four impaired segments are each composed of only one AU that encompasses the entire segment, the AU descriptor (_01) is often unnecessarily cumbersome. Throughout this document, AU and segment may be used interchangeably. For example, Cottonwood Creek may be referred to as AU 0841_01 or Segment 0841.

The unimpaired North Fork Cottonwood Creek (Segment 0841P) is included in the drainage area of Cottonwood Creek, and North Fork Fish Creek (Segment 0841Q) is included in the drainage area of Fish Creek. TMDLs were not explicitly developed for those two water bodies because they are fully supporting the contact recreation use. Those water bodies, however, are considered to be part of the watershed of an impaired segment that receives their discharge. The water bodies and their stream networks in the TMDL area are depicted in Figure 1 with the map legend stream designation of non-impaired.

Watershed Overview

Description of Study Area

The TMDL study area, part of the Trinity River Basin, is located in the south-central portion of the DFW area (Figure 1). The TMDL watersheds include four urban segments located within city boundaries. The eastern part of the TMDL area is in Dallas County, and the western part is in Tarrant County.

Cottonwood Creek (Segment 0841F) and Fish Creek (Segment 0841K) are adjacent water bodies located upstream of Mountain Creek Lake, both of which flow into the Lower West Fork of the Trinity River (Segment 0841) via Mountain Creek Lake and Mountain Creek. Kirby Creek (Segment 0841N) is a tributary of Fish Creek, and Crockett Branch (Segment 0841V) is a tributary of Cottonwood Creek (Figure 1). All four are unclassified, perennial freshwater streams.

The four impaired AUs listed above comprise the TMDL watersheds addressed in this report. The phrase “TMDL watersheds” will hereafter be used when referring to only the area of the four impaired AUs addressed in this report. The term “TMDL area” will be used when referring to the entire drainage area of all four streams, which includes the two drainage areas not included in the TMDL.

Cottonwood Creek is approximately 6.5 miles in length and drains an area of approximately 8,111 acres. It has two major tributaries: North Fork Cottonwood Creek, an unimpaired stream with a watershed of 3,546 acres, and Crockett Branch, which is included in the TMDL watersheds. Crocket Branch is approximately one mile in length and drains an area of 767 acres.

Fish Creek is approximately 15 miles in length and drains an area of approximately 16,634 acres. It also has two major tributaries: North Fork Fish Creek, an unimpaired stream that drains an area of approximately 3,663 acres, and Kirby Creek, which is included in the TMDL watersheds. Kirby Creek is approximately four miles long and drains an area of approximately 1,978 acres.

The *2014 Texas Integrated Report* (TCEQ, 2015a) provides the following segment and AU descriptions for the impaired water bodies considered in this document:

- Segment 0841F (AU 0841F_01; entire segment) (Cottonwood Creek): A 6.5 mile stretch of Cottonwood Creek running upstream from approximately 0.1 miles upstream of Mountain Creek Reservoir in Dallas County, to SH 360 in Tarrant County.
- Segment 0841K (AU 0841K_01; entire segment) (Fish Creek): A 15 mile stretch of Fish Creek running upstream from the confluence with Mountain Creek Reservoir in Grand Prairie, Dallas County, to the upper end of the creek (National Hydrography Dataset reach code (NHD RC) 12030102000107) in Arlington, Tarrant County.
- Segment 0841N (AU 0841N_01; entire segment) (Kirby Creek): Four mile stretch of Kirby Creek running upstream from confluence with Fish Creek in Grand Prairie, Dallas County, to just upstream of Great Southwest Parkway in Arlington, Tarrant County.
- Segment 0841V (AU 0841V_01; entire segment) (Crockett Branch): A one mile (1.5 km) stretch of Crockett Branch extending upstream from the confluence with Cottonwood Creek to the upper end of the creek (NHD RC 12030102044745).

As previously noted, unclassified water bodies North Fork Cottonwood Creek (Segment 0841P) and North Fork Fish Creek (Segment 0841Q) are located within the TMDL study area shown in Figure 1, but are not designated as having bacterial impairments. While concern for *E. coli* is listed in the *2014 Texas Integrated Report* (TCEQ, 2015a) for Segments 0841P and 0841Q, both are still supporting the primary contact recreation use.

Watershed Climate and Hydrology

The TMDL study area is classified as humid subtropical climate (National Oceanic and Atmospheric Administration (NOAA) (NOAA, 2009). The average high temperatures recorded at the Arlington Municipal Airport weather station, located in the western part of the Fish Creek watershed, typically peak in August (97.2 °F) with highs above 100 °F occurring June through August. Average nightly lows range from 71.5 °F (June) to 74.3 °F (August) during the summer months. During winter, the average low temperature generally bottoms out at 35.8 °F in January (NOAA, 2015).

Annual precipitation occurs predominately in the form of thunderstorms that are typically brief in nature and are recurrent in the spring (NOAA, 2009). For the period from 1981 through 2010, average annual precipitation in the TMDL study area was 37.7 inches (Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group, 2012). Precipitation data obtained from the National Climatic Data Center for the Arlington Municipal Airport station, spanning a period from 1999 through 2014, indicate the wettest month is typically

October (3.7 inches), while August (1.6 inches) is normally the driest month, with rainfall occurring throughout the year (Figure 2; NOAA, 2015).

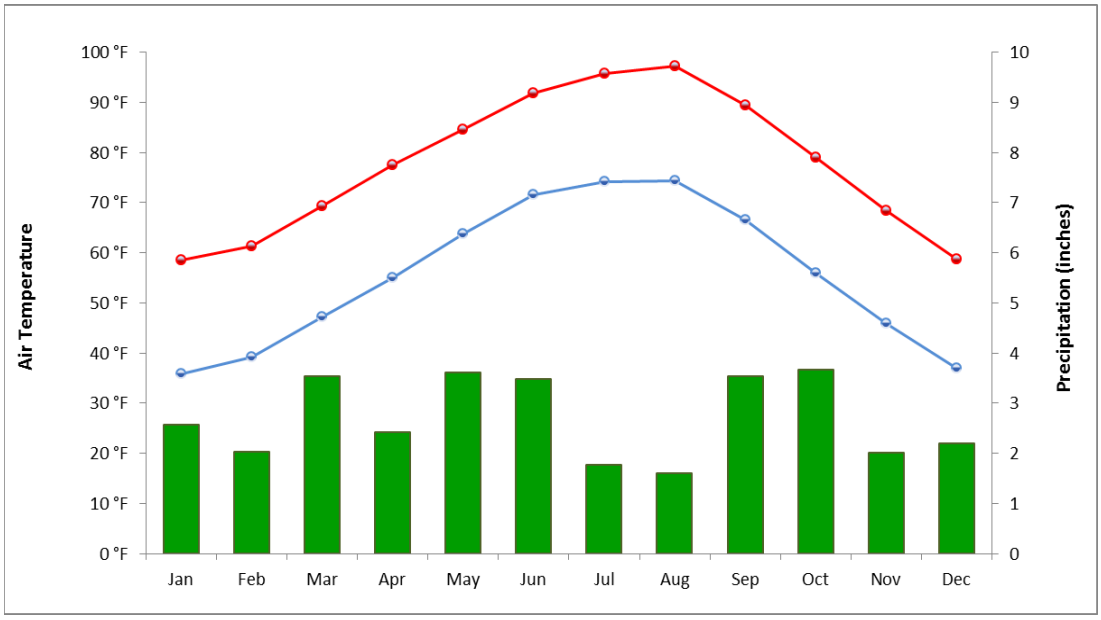

Figure 2. Average minimum (blue) and maximum (red) air temperature and total precipitation (green bars) by month from January 1999 – December 2014 for Arlington Municipal Airport.

Source: NOAA (2015)

Land Use

The land use/land cover data for the TMDL study area were obtained from the North Central Texas Council of Governments (NCTCOG) (NCTCOG, 2013a) and represent land use/land cover estimates for 2010. The land use/land cover is represented by the following categories and definitions:

- Commercial/Industrial: land occupied by office, retail, industrial (manufacturing, warehouses, salvage yards, quarries, mines), utilities (sewage/water treatment plants, power infrastructure), stadiums, communication (radio, television, cable, and phone infrastructure), construction sites, and parking.
- Group Quarters: land occupied by nursing homes, dormitories, jails, military personnel quarters, and hotels/motels.
- Residential: land occupied by single family, multi-family, and mobile home residences.
- Institution: land occupied by churches, schools, museums, hospitals, medical clinics, libraries, government facilities, and military bases.
- Transit: land occupied by roads, rail lines, rail stations, bus lines and bus facilities.

- Airport: land occupied by airport terminals and runways.
- Dedicated: land occupied by public and private parks, golf courses, tennis courts, pools, campgrounds, amusement parks, and cemeteries.
- Vacant: land that is undeveloped with the potential to be developed or reserved for recreational use.
- Ranch/Farmland: land occupied by livestock or crops.
- Timberland: land covered by trees.
- Water: land covered by lakes, rivers, and ponds.

The 2010 land use/land cover data from the NCTCOG are provided for the entire Cottonwood Creek and Fish Creek watersheds in Figure 3. A summary of the land use/land cover data for each watershed in the TMDL study area is provided in Table 1. The dominant land uses vary slightly throughout the TMDL study area, with Residential and Transit covering the largest portion of each TMDL watershed except for Cottonwood Creek (0841F), where Commercial and Residential are the two dominant land uses. In summary, the land use mix reflects that of a large urban area with some variations in category of dominance by geographic location.

Watershed Population and Population Projections

As depicted in Figure 1, the TMDL study area is geographically located within municipal incorporated boundaries and primarily within the jurisdictional boundaries of Arlington and Grand Prairie, with a small portion located within the Dallas city limits boundary. According to the 2010 Census (United States Census Bureau (USCB), 2014a), population data indicate the TMDL study area is highly urbanized with an average population density of 4,605 people per square mile (mi^2). North Fork Cottonwood Creek is the most densely populated watershed, with approximately 5,864 people/mi^2. Cottonwood Creek is the least dense watershed, with approximately 3,641 people/mi^2.

Population projections for the year 2040 were developed by the NCTCOG and indicate that populations will increase for each segment watershed with the exception of Crockett Branch (NCTCOG, 2015). A 2.5 percent decrease is projected for Crockett Branch. Projected population increases for the remaining TMDL study area range from a minimum of 1.5 percent to a maximum of 43.5 percent, with an average increase of 24.4 percent. Table 2 provides a summary of the 2010 population and the 2040 population projection.

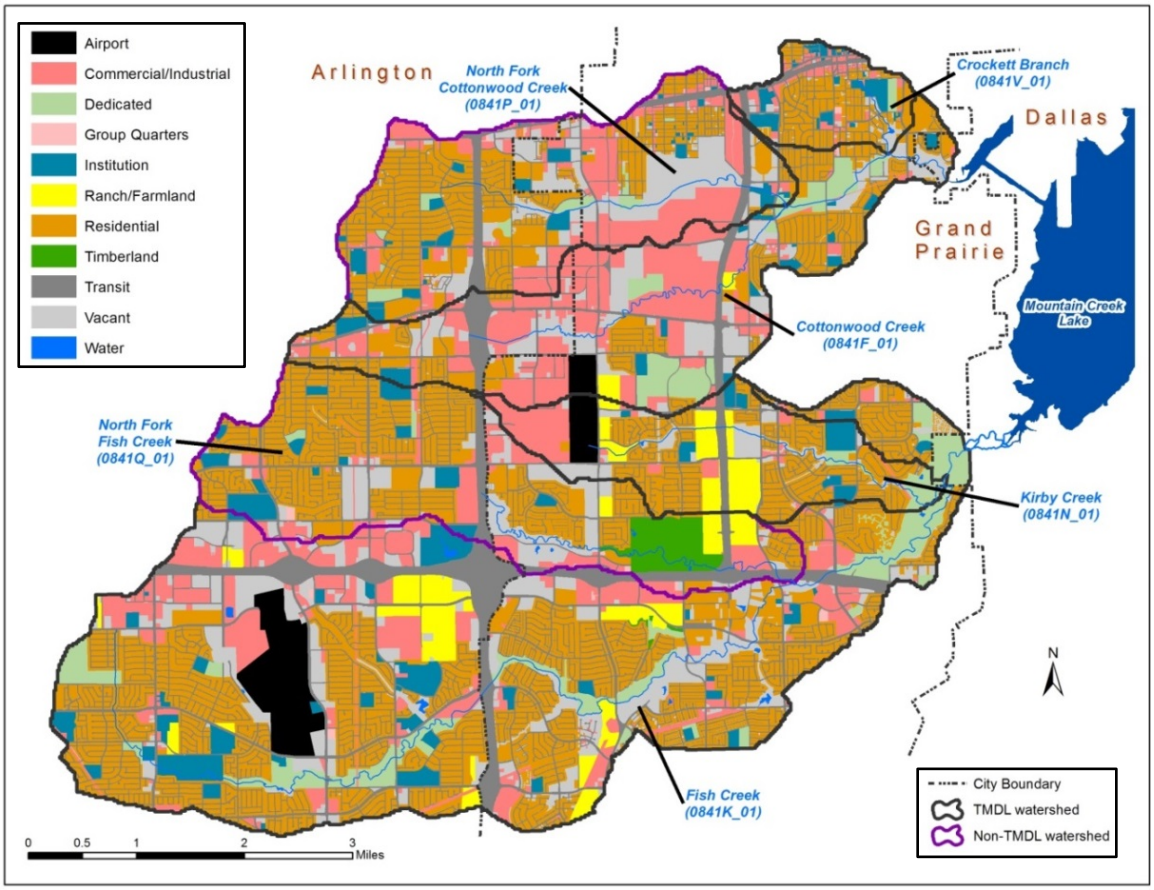

Figure 3. 2010 land use/land cover within the TMDL study area.

Source: NCTCOG (2013a)

Analysis of Bacteria Data

Environmental monitoring within the TMDL study area has occurred recently at 11 TCEQ monitoring stations (Figure 4). *E. coli* data collected at these stations over the seven-year period of December 1, 2003, through November 30, 2010, were used in assessing attainment of the primary contact recreation use as reported in the *2012 Texas Integrated Report* (TCEQ, 2013a) and summarized in Table 3. Additionally, *E. coli* data collected at these stations over the seven-year period of December 1, 2005, through November 30, 2012, were used in assessing attainment of the primary contact recreation use as reported in the *2014 Texas Integrated Report* (TCEQ, 2015a) and summarized in Table 3. The 2012 and 2014 assessment data indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 MPN/100 mL for the TMDL watersheds.

Table 1. Land Use/Land Cover within TMDL study area.

Source: NCTCOG (2013a)

NCTCOG 2010 LULC[a]	Cottonwood Creek (0841F)		N. F. Cottonwood Creek (0841P)		Crockett Branch (0841V)		Cottonwood Creek Grand Total	
Classification	Acres	% of Total	Acres	% of Total	Acres	% of Total	Acres	% of Total
Airport	59	1.6%	NA[b]	NA	NA	NA	59	0.7%
Commercial/ Industrial	1,153	30.4%	766	21.6%	86	11.2%	2,006	24.7%
Dedicated	299	7.9%	94	2.6%	17	2.2%	409	5.0%
Group quarters	2	0.0%	5	0.1%	3	0.4%	10	0.1%
Institution	131	3.5%	169	4.8%	101	13.2%	402	5.0%
Ranch/Farmland	42	1.1%	NA	NA	NA	NA	42	0.5%
Residential	848	22.3%	1,237	34.9%	304	39.7%	2,390	29.5%
Timberland	NA	NA	NA	NA	NA	NA	NA	NA
Transit	618	16.3%	655	18.5%	202	26.3%	1,475	18.2%
Vacant	644	17.0%	617	17.4%	52	6.8%	1,313	16.2%
Water	1	0.0%	2	0.1%	2	0.2%	5	0.1%
Total[c]	3,798	100%	3,546	100%	767	100%	8,111	100%
NCTCOG 2010 LULC	**Fish Creek (0841K)**		**N. Fork Fish Creek (0841Q)**		**Kirby Creek (0841N)**		**Fish Creek Grand Total**	
Classification	Acres	% of Total	Acres	% of Total	Acres	% of Total	Acres	% of Total
Airport	425	3.9%	NA	NA	105	5.3%	530	3.2%
Commercial/ Industrial	1,351	12.3%	349	9.5%	247	12.5%	1,946	11.7%
Dedicated	787	7.2%	16	0.4%	89	4.5%	892	5.4%
Group quarters	15	0.1%	11	0.3%	NA	NA	26	0.2%
Institution	578	5.3%	206	5.6%	117	5.9%	901	5.4%
Ranch/Farmland	453	4.1%	103	2.8%	246	12.4%	801	4.8%
Residential	3,759	34.2%	1502	41.0%	642	32.4%	5,903	35.5%
Timberland	8	0.1%	238	6.5%	0.0002	0.0%	247	1.5%
Transit	2,289	20.8%	778	21.2%	339	17.1%	3,406	20.5%
Vacant	1,304	11.9%	455	12.4%	193	9.8%	1,952	11.7%
Water	25	0.2%	4	0.1%	1	0.1%	30	0.2%
Total[c]	10,993	100%	3,663	100%	1,978	100%	16,634	100%

[a] LULC is land use/land cover.

[b] NA is Not Applicable.

[c] Total acres and percentages may be slightly off due to rounding.

Table 2. 2010 Population and 2040 Population Projections for the TMDL study area.

Source: USCB (2014a) and NCTCOG (2015)

Water Body	Segment	2010 U.S. Census Population	2040 Projected Population	Projected Population Increase/ Decrease	Percent change (2010–2040)
Cottonwood Creek	0841F	21,480	26,979	5,499	25.6%
Fish Creek	0841K	68,511	88,086	19,575	28.6%
Kirby Creek	0841N	12,021	17,245	5,223	43.5%
Crockett Branch	0841V	5,843	5,695	-148	-2.5%
North Fork Cottonwood Creek	0841P	32,252	32,750	498	1.5%
North Fork Fish Creek	0841Q	30,749	37,588	6,839	22.2%

Table 3. *2012* and *2014 Integrated Report* Summary for the TMDL watersheds.

Source: TCEQ (2013a and 2015a)

Water Body	Segment	Parameter	Station(s)	*Integrated Report* Year	No. of Samples	Data Date Range	Geometric Mean (MPN/100 mL)
Cottonwood Creek	0841F	*E. coli*	10723, 17674, 17676	2012	200	2003 - 2010	275
				2014	229	2005 - 2012	252
Fish Creek	0841K	*E. coli*	10724*, 10725, 17677, 17679, 20342	2012	199	2003 - 2010	249
				2014	193	2005 - 2012	215
Kirby Creek	0841N	*E. coli*	17675	2012	99	2003 - 2010	621
				2014	100	2005 - 2012	582
Crockett Branch	0841V	*E. coli*	15295, 17683	2012	80	2003 - 2010	740
				2014	79	2005 - 2012	689

* The description and location of Station 10724 is North Fish Creek, though it was included in the stations used to assess Fish Creek (see Figure 4). Data from this station were *not* used in the development of TMDL allocations for this document.

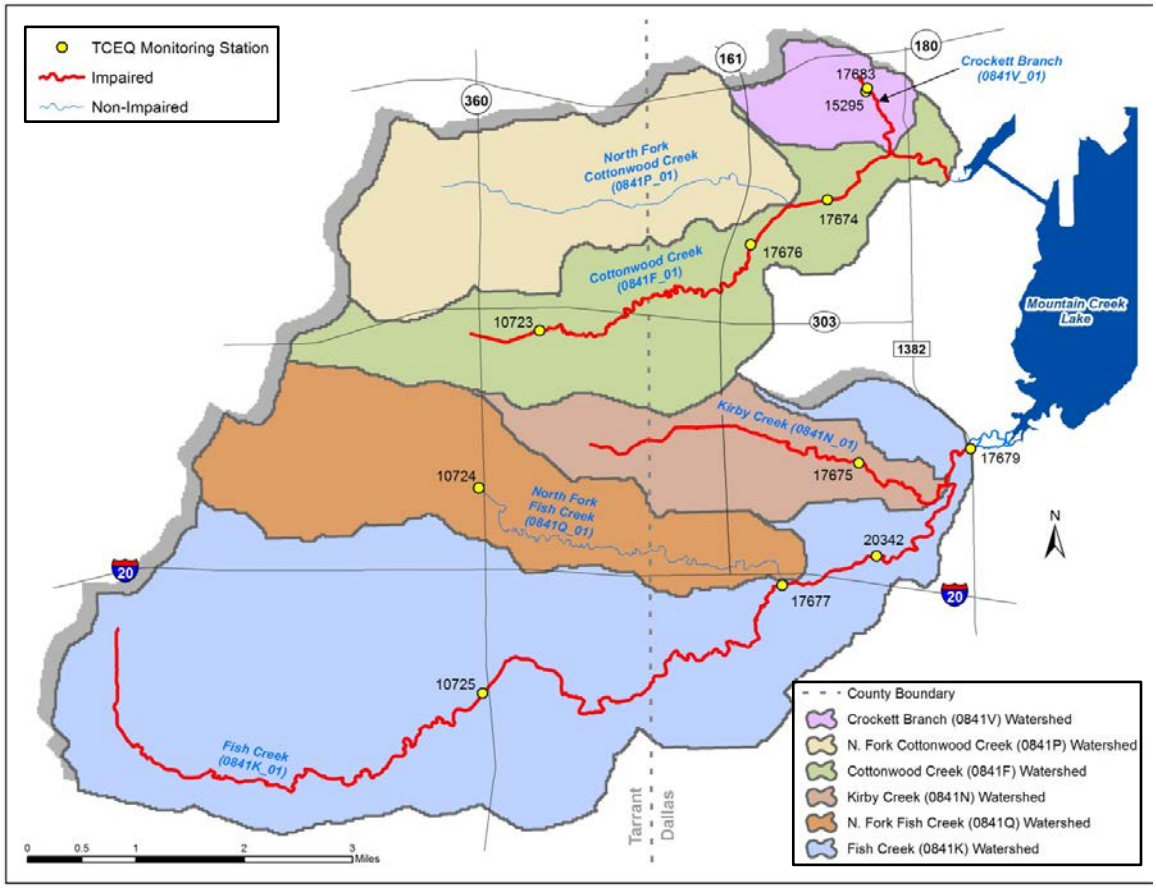

Figure 4. TMDL study area showing TCEQ surface water quality monitoring stations used to assess primary contact recreation.

Source: TCEQ (2012b)

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 water bodies within these four TMDL watersheds are designated as having a primary contact recreation use, which is measured against a numeric criterion for the indicator bacteria *E. coli*. Indicator bacteria are not generally pathogenic, but are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. The *E. coli* criterion to protect contact recreation in freshwater streams is a geometric mean concentration not to exceed 126 MPN/100 mL (TCEQ, 2010).

The endpoint for these TMDLs is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 MPN/100 mL. This endpoint was applied to all four watersheds addressed by this TMDL.

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). WWTFs and stormwater discharges from industries, construction, and the MS4s of cities are considered point sources of pollution.

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

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

Permitted sources are regulated under TPDES and National Pollutant Discharge Elimination System (NPDES) programs. The only permitted source located in the TMDL watersheds is regulated stormwater.

Domestic Wastewater Treatment Facilities

Domestic wastewater is collected by and transported to the TRA Central Regional Wastewater System, which is located outside the study area (Figure 5).

Sanitary Sewer Overflows

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

The TCEQ Region 4 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. SSO incidences that occurred from 2007 through 2011 for this dataset were refined by the NCTCOG by assigning latitude and longitude coordinates to each SSO event. These were plotted using Geographic Information System (GIS) software in an effort to characterize the frequency and magnitude of SSO events within the impaired segments covered

in this report (Figure 6). A summary of the refined data from 2007 through 2011 within the TMDL study area is shown in Table 4. Efforts were made to extract only the incidences that occurred within the TMDL study area from the SSO dataset. However, incompletely geo-referenced SSO events made geospatial distinction of SSOs that occurred from 2012 through 2014 difficult. Thus, a summary of the reported SSO incidences from January 2012 through August 2014 for the cities of Arlington and Grand Prairie can be found in Table 5. These incidences may or may not have occurred within the TMDL study area, but provide the best available information for 2012 through 2014.

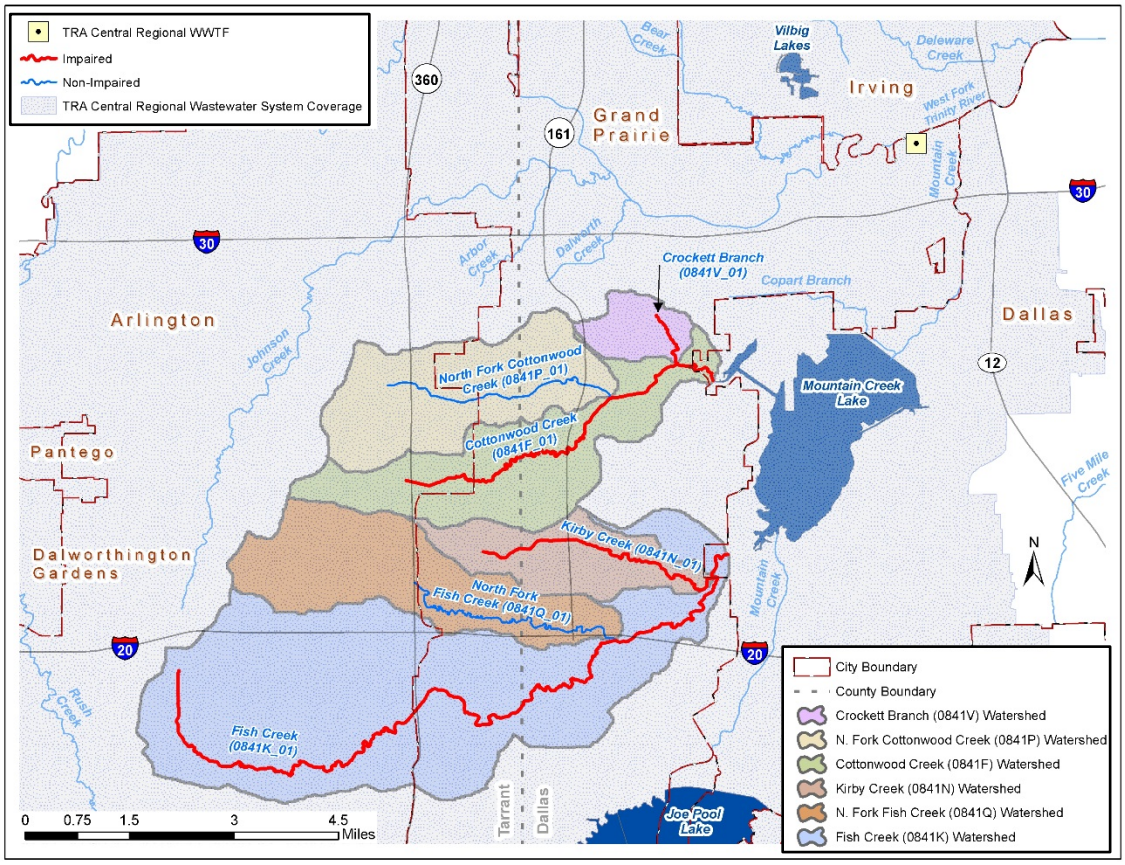

Figure 5. Coverage area of the TRA Central Regional Wastewater System within the TMDL study area.

Sources: TCEQ (2015b) and NCTCOG (2013b)

Table 4. Summary of SSO incidences reported in the TMDL study area from January 2007 – December 2011.

Source: NCTCOG (2012a)

Segment	No. of Incidences	Total Volume (gallons)	Average Volume (gallons)	Minimum Volume (gallons)	Maximum Volume (gallons)
0841F	26	14,815	570	10	10,000
0841K	25	18,623	745	7	6,000
0841N	5	1,295	259	15	600
0841V	7	552	79	2	200
0841P	43	35,085	816	15	22,500
0841Q	25	18,592	744	7	6,000

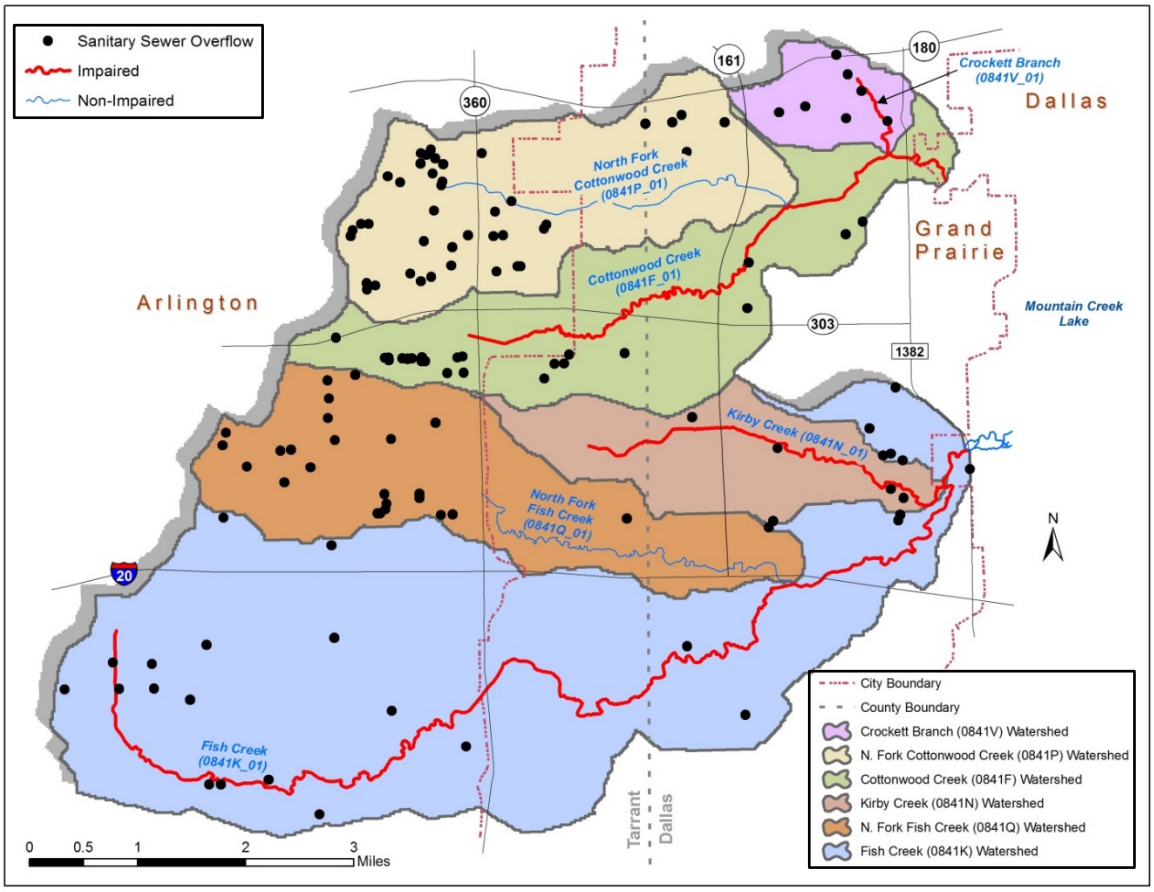

Figure 6. SSOs that occurred from January 2007 – December 2011 within the TMDL study area.

Source: NCTCOG (2012a)

Table 5. Summary of SSO incidences reported for the cities of Arlington and Grand Prairie from January 2012 – August 2014.

Source: TCEQ (2014)

Municipality	No. of Incidences	Total Volume (gallons)	Average Volume (gallons)	Min. Volume (gallons)	Max. Volume (gallons)
Arlington	187	65,444	350	2	15,895
Grand Prairie	48	24,755	516	10	15,000

TPDES-Regulated Stormwater

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

1) Stormwater subject to regulation, which is any stormwater originating from TPDES-regulated MS4s, industrial facilities, and regulated construction activities.
2) Stormwater runoff not subject to regulation.

The TPDES/NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain 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 an EPA-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 (BMPs) 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 geographic region of the TMDL watersheds covered by Phase I and II MS4 permits is that portion of the area within the jurisdictional boundaries of the regulated entity. For Phase I permits, the jurisdictional area is defined by the city limits. For Phase II permits, the jurisdictional area is defined as the intersection of the city limits and the 2000 or 2010 Census Urbanized Area. The regulated area for the Phase II permits in this report was based on the 2010 Census Urbanized Area from the USCB.

A review of active stormwater general permits coverage (TCEQ, 2015c) and a review of the central registry for Phase I MS4 permit coverage (TCEQ, 2015d) in the TMDL study area indicate that two Phase I and three Phase II permits (Table 6) provide 100 percent MS4 coverage for the TMDL study area.

Table 6. TPDES and NPDES MS4 permits associated with the TMDL study area.

Source: TCEQ (2015c and 2015d)

Entity	TPDES Permit #	NPDES Permit #
City of Arlington	WQ004635-000	TXS000301
City of Dallas	WQ004396-000	TXS000701
City of Grand Prairie	Phase II General Permit	TXR040065
Dallas County	Phase II General Permit	TXR040120
Tarrant County	Phase II General Permit	TXR040052

The areas in the TMDL watersheds containing entities with Phase II general MS4 permits and Phase I MS4 individual permits were used to estimate the regulated stormwater areas (RSA) for construction, industrial, and MS4 permits (Figure 7).

Illicit Discharges

Pollutant loads can enter streams from MS4 outfalls that carry authorized sources as well as illicit discharges under both dry and wet weather conditions. The term “illicit discharge” is defined in TPDES General Permit No. TXR040000 for Phase II MS4s as “Any discharge to a municipal separate storm sewer that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities.” Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

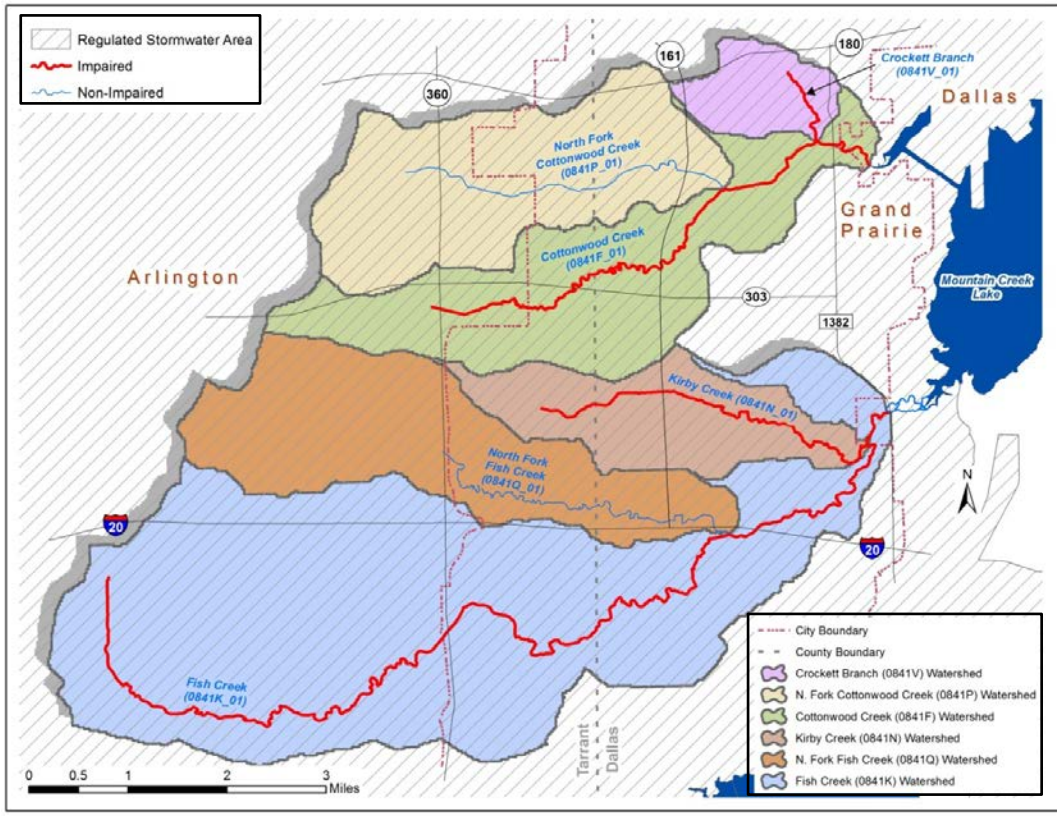

Figure 7. RSA based on Phase I and Phase II MS4s permits within the TMDL study area.

Source: USCB (2014b)

Direct illicit discharges**:**

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- 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; and
- a failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

TPDES General Wastewater Permits

Discharges of processed wastewater from certain types of facilities are required to be covered by one of several TPDES general permits:

- TXG110000 – concrete production facilities

- TXG130000 – aquaculture production facilities
- TXG340000 – petroleum bulk stations and terminals
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG920000 – concentrated animal feeding operations
- WQG20000 – livestock manure compost operations (irrigation only)

A review performed in July 2015 of active general permit coverage (TCEQ, 2015d) in the TMDL study area found no operations or facilities of the type described above.

Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint. Nonpoint source loading enters the impaired segments through distributed, nonspecific locations, and may include wildlife, urban runoff not covered by a permit, and domestic pets.

Wildlife and Unmanaged Animal Contributions

E. coli bacteria are common inhabitants of the intestines of all warm-blooded animals, including feral hogs and wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife and feral hogs. Wildlife and feral hogs are naturally attracted to the riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife and feral hogs are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff.

On-Site Sewage Facilities

Failing on-site sewage facilities (OSSFs) were not considered a major source of bacteria loading in the TMDL watersheds because the entire TMDL study area is served by a centralized wastewater collection and treatment system. Areas serviced by centralized treatment and collection systems typically contain very few OSSFs. This is the situation for the TMDL study area, where NCTCOG information indicates that only 31 OSSFs exist in the TMDL study area (Figure 8; NCTCOG, 2012b).

Unregulated Agricultural Activities and Domesticated Animals

Activities such as livestock grazing close to water bodies and farmers' use of manure as fertilizer can contribute fecal indicator bacteria such as *E. coli* to nearby water bodies. Due to the highly urbanized nature of the TMDL study area, livestock were not considered a major source of bacteria loading.

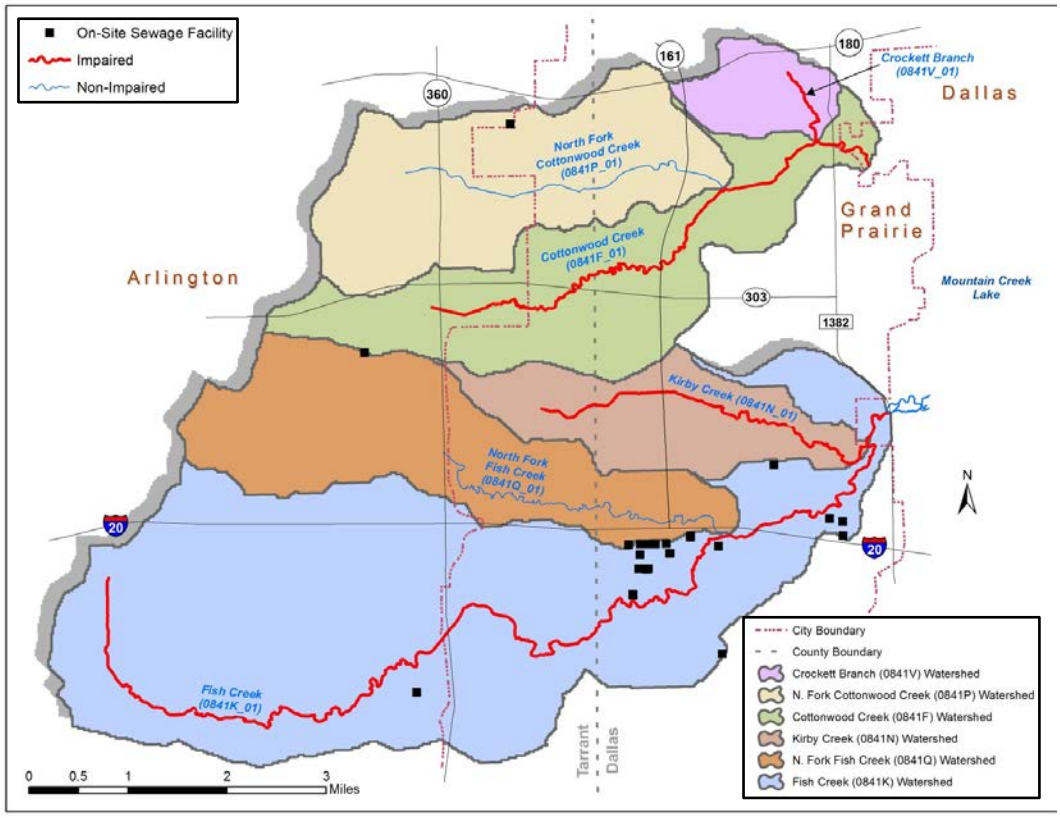

Figure 8. OSSFs located within the TMDL study area.

Source: NCTCOG (2012b)

Pets can also be sources of *E. coli*, because storm runoff carries the animal wastes into streams (EPA, 2013). The number of domestic pets in the TMDL study area was estimated based on human population and number of households obtained from the USCB (USCB, 2014a). The information obtained from the USCB included population and household projections based on the 2010 census for census blocks that encompass the watersheds of each AU. The block-level data were multiplied by the proportion of each census block within the watershed to generate an estimate of the watershed's population and number of households. This estimation assumes the population/households are uniformly distributed within the area of each census block, which is the best estimate that can be made with the available data.

Table 7 summarizes the estimated number of dogs and cats for each impaired segment in the TMDL study area. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household according to data from the American Veterinary Medical Association (AVMA) 2012 U.S Pet Statistics (AVMA, 2012). The actual contribution and significance of fecal coliform loads from pets reaching the water bodies of the TMDL watersheds is difficult to quantify.

Table 7. Estimated distribution of dog and cat populations.

Segment	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
0841F	9,454	5,521	6,032
0841K	22,422	13,094	14,305
0841N	3,342	1,952	2,132
0841V	1,850	1,081	1,180
0841P	10,056	5,873	6,416
0841Q	9,962	5,818	6,356

Bacteria Survival and Die-off

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

Linkage Analysis

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

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

Bacteria load contributions from stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, has the capacity to carry indicator bacteria from the land surface into the receiving stream.

Generally, this loading follows a pattern of lower concentrations in the water body before a rain event, followed by a rapid increase in bacteria concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

Load Duration Curve Analysis

LDC analyses were used to examine the relationship between instream water quality and the broad sources of indicator bacteria loads. The LDC analyses 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, or other conditions in the watershed.

The weaknesses of the LDC 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 determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (i.e., point source and stormwater), and provides a means to allocate allowable loadings.

Data requirements for the LDC are minimal, consisting of continuous daily streamflow records and historical bacteria data. A 25-year daily streamflow record from January 1, 1989, through December 31, 2013, was selected for LDC development, since the previously completed TMDLs in the Lower West Fork Trinity River watershed were based on a 25-year period. While the number of *E. coli* observations required to develop a flow duration curve (FDC) is not rigorously specified, the curves are usually based on more than five years of observations, and encompass inter-annual and seasonal variation. For this report, adequacy of data was defined as any station having at least 40 *E. coli* measurements.

For Cottonwood and Fish Creeks, multiple stations meet the requirement of 40 *E. coli* measurements, whereas only one station was available for both Kirby Creek and Crockett Branch. The most downstream monitoring station in each of the four

impaired water bodies was selected as the location for developing the pollutant load allocation in order to maximize the amount of each watershed included above the sampling location. Bacteria data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database for the period of January 1, 2001, through December 31, 2013.

On numerous creeks and rivers in Texas, U.S. Geological Survey (USGS) streamflow gauging stations have been in operation for a sufficient period to be used as the source of the needed streamflow records. The streamflow gauge used for LDC development and the area of application is USGS gauging station 08049700. While this gauge is located outside of the TMDL watersheds, it was determined to be the nearest and most comparable watershed with respect to size and demographic characteristics, e.g., urbanized area, though this watershed is appreciably more rural than the TMDL study area (Figure 9). The required daily streamflow record for each LDC was estimated based on application of a drainage area ratio computed as the drainage area above the LDC location divided by the drainage area of USGS gauge 08049700.

FDCs and LDCs were developed for the most downstream TCEQ monitoring stations within each impaired AU (Figure 4). The daily flow data in units of cubic feet per second (cfs) were used to develop a FDC for each station. Each FDC was generated by

- ranking the daily flow data from highest to lowest,
- calculating the percent of days each flow was exceeded (rank ÷ quantity of the number of data points + 1), and
- plotting each flow value (y-axis) against its exceedance value (x-axis).

Exceedance values along the x-axis represent the percent of days that flow was at or above the associated flow value on the y-axis. Exceedance values near 100 percent occur during low flow or drought conditions while values approaching 0 percent occur during periods of high flow or flood conditions.

Bacteria LDCs were developed by multiplying each streamflow value along the FDCs by the *E. coli* criterion (126 MPN/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:

TMDL (MPN/day) = criterion * flow (cfs) * conversion factor

Where:

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

Conversion factor (to MPN/day) = 24,465,756 100 mL/ft^3 * seconds/day

The resulting curve 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.

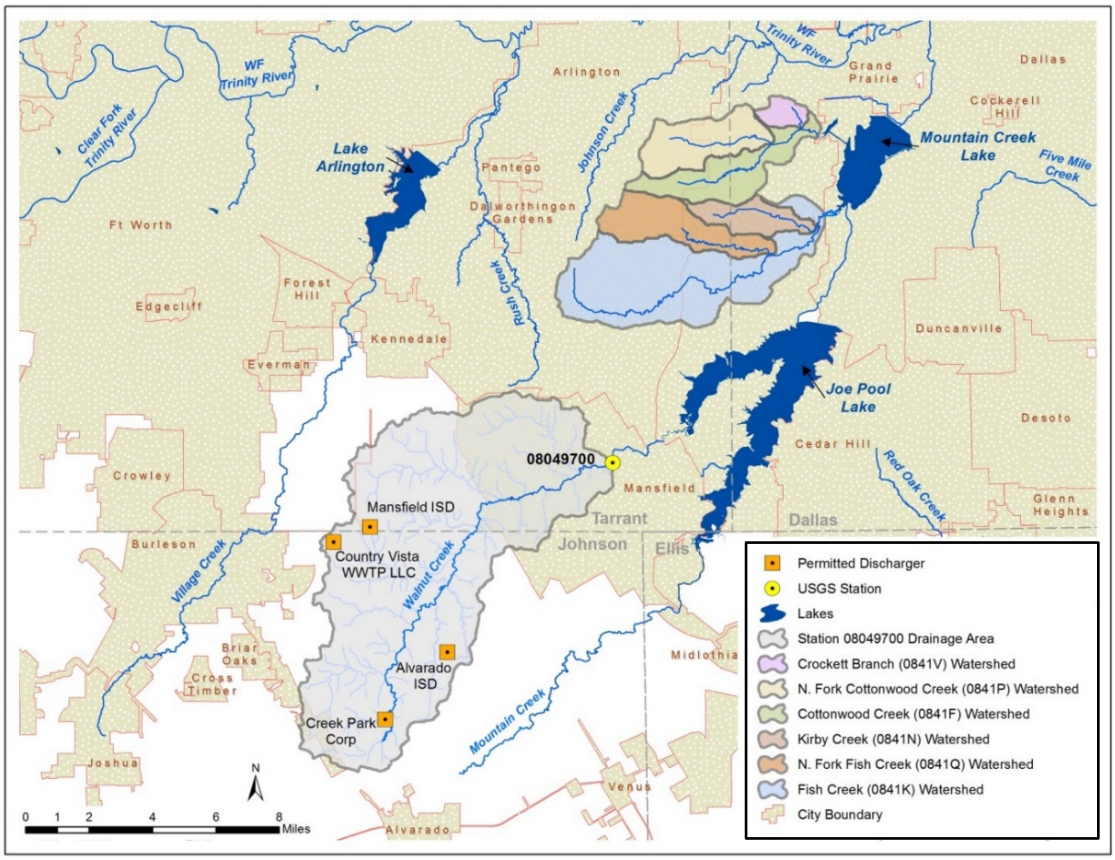

Figure 9. TMDL study area, Walnut Creek watershed, and USGS Station 08049700 location near Mansfield, Texas.

Sources: USGS (2015) and TCEQ (2015b)

For the LDCs at each TCEQ monitoring station, historical bacteria data obtained from the TCEQ SWQMIS database were superimposed on the allowable bacteria LDC. Each historical *E. coli* measurement was associated with the streamflow on the day of measurement and converted to a bacteria load. The associated streamflow for each bacteria loading was compared to the FDC data to determine its value for "percent days flow exceeded," which becomes the "percent of days load exceeded" value for purposes of plotting the *E. coli* loading. Each load was then plotted on the LDC at its percent exceedance. This process was repeated for each *E. coli* measurement at each station. Points above the LDC represent exceedances of the bacteria criterion and its associated allowable loadings.

The flow exceedance frequency can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of FDCs and LDCs. The hydrologic

classification scheme utilized for the TMDL watersheds is as follows: high flow regime (0–10 percent), mid-range flow regime (10–60 percent), and low flow regime (60–100 percent). Additional information explaining the LDC method may be found in Cleland (2003) and NDEP (2003).

The median loading of the high flow regime (0–10 percent exceedance) is used for the TMDL calculations of the four impaired AUs. The median loading of the very high flow regime (5 percent exceedance) is used for the TMDL calculations, because it represents a reasonable yet high value for the allowable pollutant load allocation.

More details on the methods used to develop the LDCs may be found in the *Technical Support Document for Total Maximum Daily Loads for Indicator Bacteria in Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Upstream of Mountain Creek Lake* (Adams and Hauck, 2015).

Load Duration Curve Results

The LDCs for the most downstream TCEQ monitoring station within each TMDL watershed were constructed in order to develop the TMDL allocation for each of the impaired AUs (Figures 10 through 13). Geometric mean loadings for the data points within each flow regime have also been distinguished on each figure to aid interpretation. The LDCs for the water quality monitoring stations provide a means of identifying the streamflow conditions under which exceedances in *E. co*li concentrations have occurred. The LDCs depict the allowable loadings at the stations under the geometric mean criterion (126 MPN/100 mL) and show that existing loadings often exceed the criterion. In addition, the LDCs also present the allowable loading at the stations under the single sample criterion (399 MPN/100 mL).

The hydrologic records for the FDCs and subsequent allowable loads from the LDCs did not require adjustment to reflect permitted discharges nor future capacity estimates that account for the probability that additional flows from WWTF discharges may occur as a result of future population increases. With 100 percent coverage of wastewater collection by the TRA Central Regional WWTF Collection System and the absence of WWTFs in the TMDL study area, these adjustments were not required (Figure 5).

On each graph, the measured *E. coli* data are presented as associated with a “wet weather event” or a “non-wet weather event.” A sample was determined to be influenced by a wet weather event based on the reported “days since last precipitation” (DSLP) as noted on field data sheets associated with each sampling event. DSLP (TCEQ water quality parameter code 72053) is a field parameter that may be noted during a sampling event to inform data users of the general climatic conditions. Because of the large range in sizes of the TMDL watersheds and the

concomitant variation in hydrologic response time to precipitation by watershed size, different values of DSLP were determined to best represent samples collected under wet weather conditions based on drainage area above each monitoring station. A sample taken with a DSLP value of two or less was defined as a wet weather event for the two larger watersheds, Cottonwood Creek and Fish Creek. A sample taken with a DSLP value of one or less was defined as a wet weather event for the two smaller watersheds, Kirby Creek and Crockett Branch. Note that a wet weather event can be indicated even under low flow conditions as a result of only a small runoff event during a period of very low base flow in the stream. The allocation goal used in the final TMDL equation for all four segments was based on the flow regime with the highest allowable bacteria load (0-10%).

Figure 10 represents the LDC for Cottonwood Creek (Segment 0841F) and is based on *E. coli* bacteria measurements at sampling location 17674 (Cottonwood Creek at SW 3rd Street in Grand Prairie). The LDC indicates that *E. coli* levels often exceed the single and geometric mean water quality criteria under the high flow regime and often exceed only the geometric mean criterion under the mid-range and low flows, except during wet weather events. *E. coli* measurements influenced by wet weather are found under all flow conditions and are more likely to exceed both criteria than measurements not influenced by wet weather.

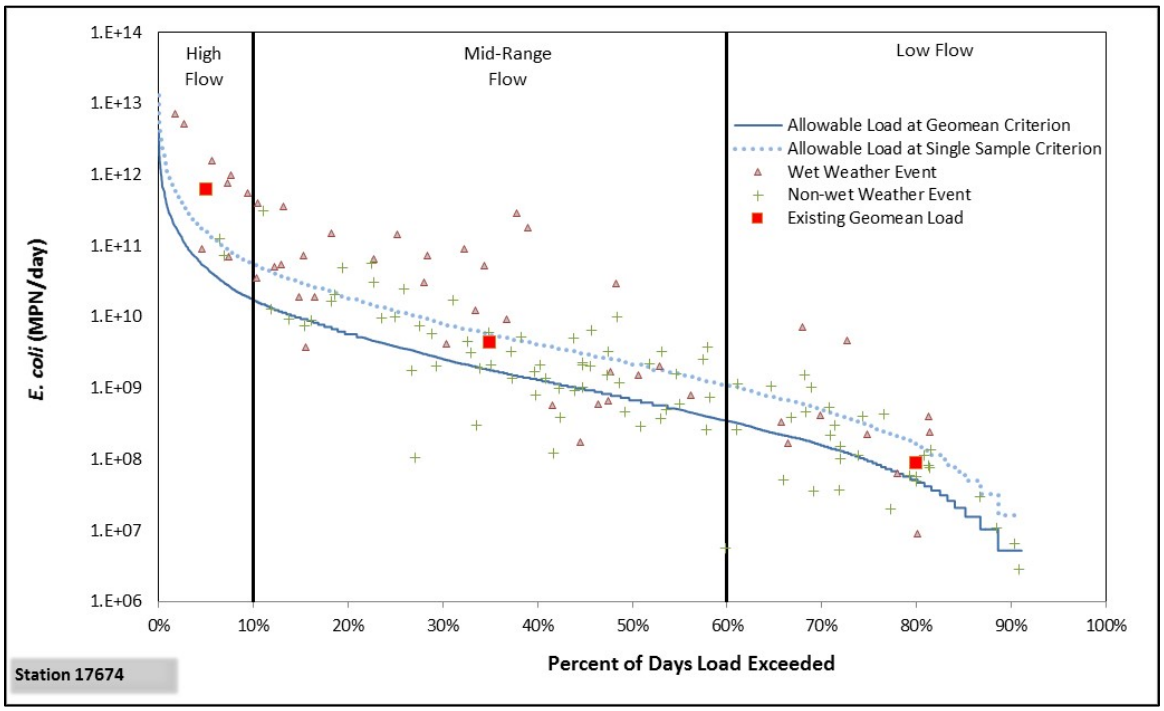

Figure 10. LDC for Station 17674, the most downstream station on Cottonwood Creek.

Figure 11 represents the LDC for Fish Creek (Segment 0841K) and is based on *E. coli* bacteria measurements at sampling location 17679 (Fish Creek at Beltline Road/FM 1382). The LDC indicates that *E. coli* levels often exceed the single and geometric mean water quality criteria under the high flow regime and are progressively less likely to exceed the criteria as flows decrease from high flows through mid-range flows to low flows. Wet-weather influenced *E. coli* measurements are found under all flow conditions and are more likely to exceed both criteria than non-wet weather influenced measurements.

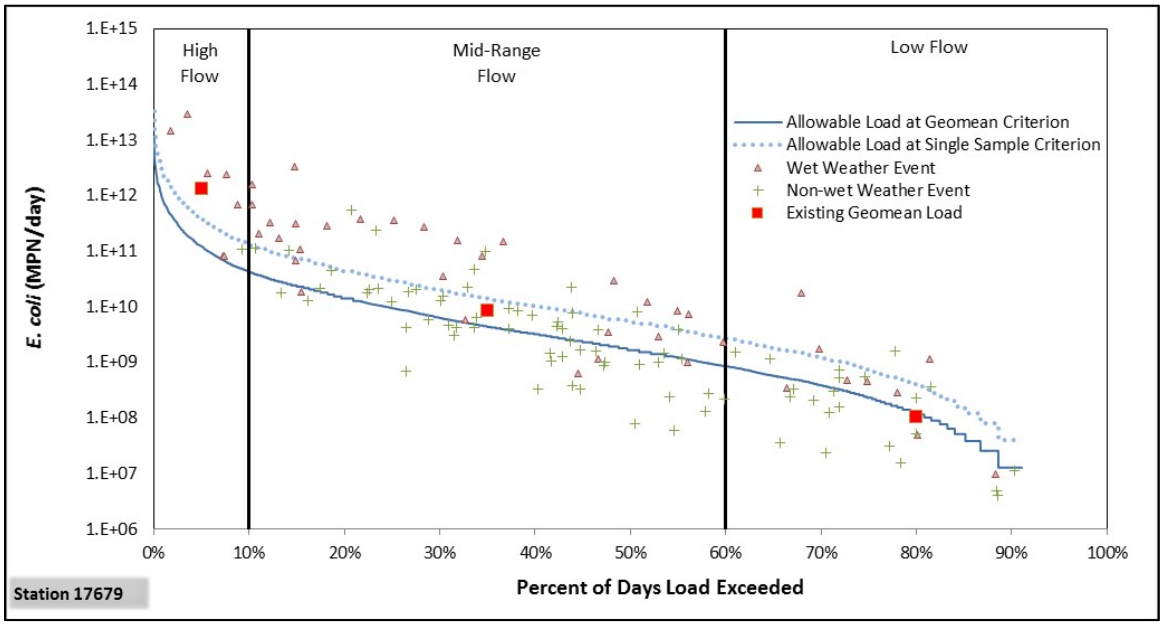

Figure 11. LDC for Station 17679, the most downstream station on Fish Creek.

Figure 12 represents the LDC for Kirby Creek Segment 0841N and is based on *E. coli* bacteria measurements at sampling location 17675 (Kirby Creek at Corn Valley Road in Grand Prairie). The LDC indicates that *E. coli* levels often exceed the single and geometric mean water quality criteria under all three regimes. Wet-weather influenced *E. coli* measurements are found under all flow conditions and both wet weather and non-wet weather events frequently exceed the geometric mean criterion.

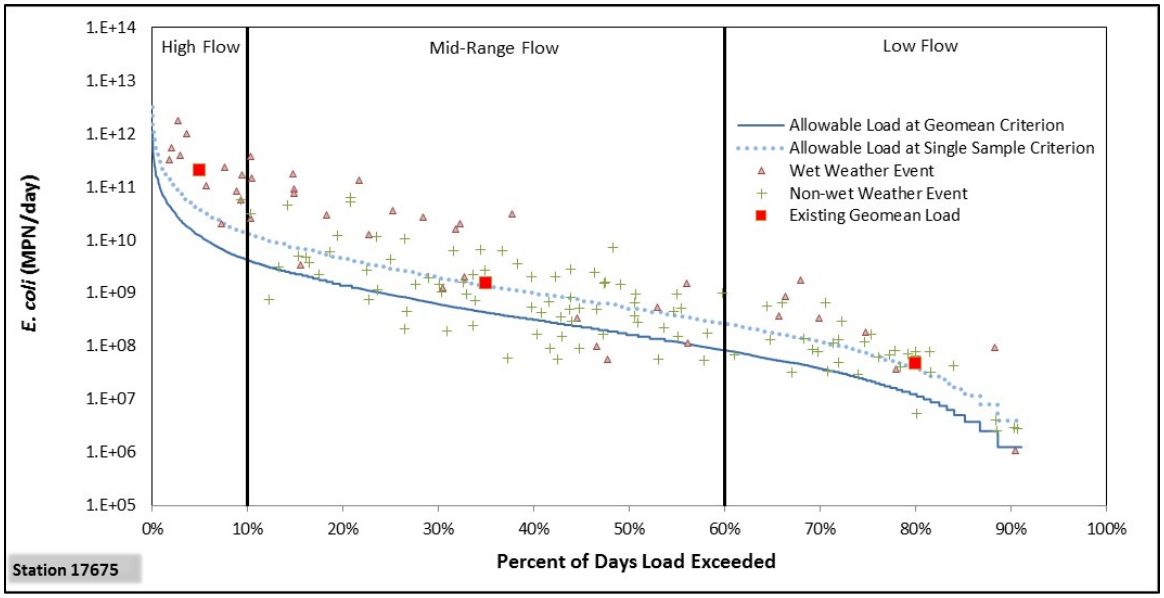

Figure 12. LDC for Station 17675, Kirby Creek.

Figure 13 represents the LDC for Crockett Branch Segment 0841V and is based on *E. coli* bacteria measurements at sampling location 17683 (Crockett Branch 179 meters downstream of East Grand Prairie Road in Grand Prairie). The LDC indicates that *E. coli* levels often exceed the single sample and geometric mean water quality criteria under all three regimes. Wet-weather influenced *E. coli* measurements are found under all flow conditions and both wet weather and non-wet weather events frequently exceed the single sample and geometric mean criteria.

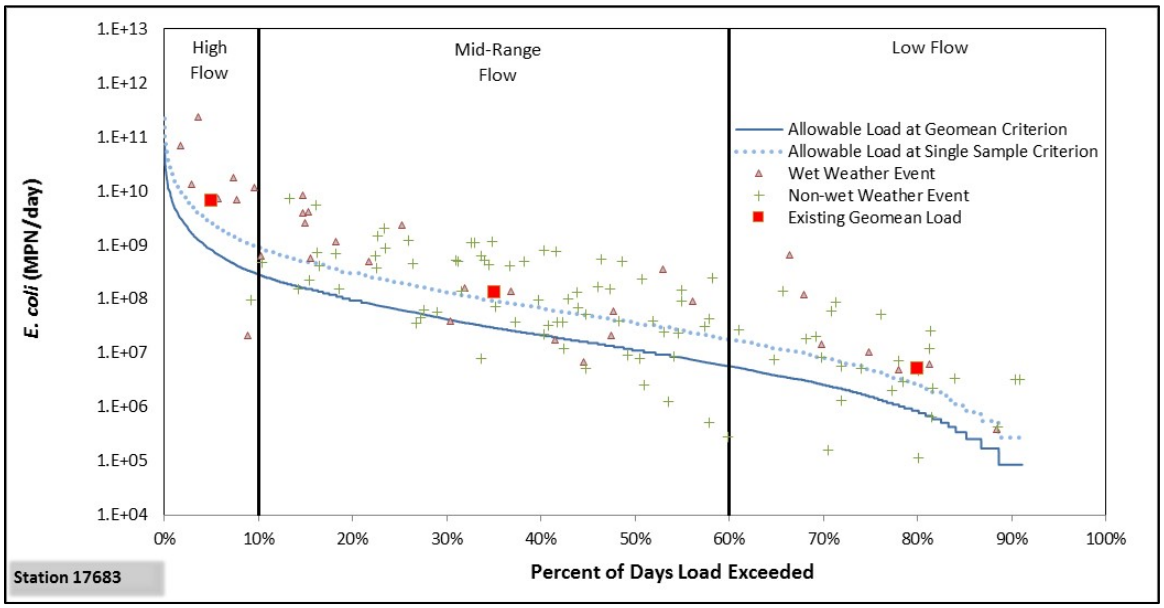

Figure 13. LDC for Station 17683, Crockett Branch.

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 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 by setting a target for indicator bacteria loads that is 5 percent lower than the geometric mean criterion. For primary contact recreation, this equates to a geometric mean target for *E. coli* of 120 MPN/100 mL. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each water body is slightly reduced.

Pollutant Load Allocation

The 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 following equation:

$$TMDL = \Sigma WLA + \Sigma LA + \Sigma FG + MOS$$

Where:

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

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

FG = loadings associated with future growth from regulated facilities

MOS = margin of safety load

As stated in 40 CFR 130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For *E. coli*, TMDLs are expressed as MPN/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

The TMDL components in this report are derived using the median flow within the high flow regime (or 5 percent flow) of the LDC for each segment.

Wasteload Allocation

The wasteload allocation is the sum of loads from regulated sources, which consists of wasteloads allocated to TPDES-regulated WWTFs (WLA_{WWTF}) and wasteloads allocated to regulated stormwater dischargers (WLA_{SW}):

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

WWTFs

Due to the absence of any permitted dischargers in the TMDL watersheds, the WLA_{WWTF} component is zero. However, in the event that one or more WWTFs are constructed in the TMDL watersheds, the following method would be used to determine the WLA_{WWTF}.

TPDES-permitted WWTFs would be allocated a daily wasteload (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by one-half the instream geometric criterion. One-half of the water quality criterion (63 MPN/100mL) would be used as the WWTF target to provide instream and downstream load capacity and to be consistent with the approach taken in previously completed TMDLs of the Lower West Fork Trinity River (TCEQ, 2013b). Thus, WLA_{WWTF} would be expressed using the following equation:

$$WLA_{WWTF} = \text{Target} * \text{Flow} * \text{Conversion Factor}$$

Where:

Target = 63 MPN/100 mL

Flow = full permitted flow in million gallons per day (MGD)

Conversion Factor (to MPN/day) = 1.54723 cfs/MGD *283.168 100 mL/ft3 * 86,400 s/d

Stormwater

Stormwater discharges from MS4, industrial, and construction areas are considered permitted or regulated point sources. Therefore, the wasteload allocation calculations must also include an allocation for regulated stormwater discharges (WLA_{SW}). A simplified approach for estimating the stormwater allocation 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 is used to estimate the amount of the overall runoff load to be allocated as the regulated stormwater contribution in the WLA_{SW} component of the TMDL. The load allocation component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

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

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

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

LA_{TRIB} = loadings from tributary water bodies for which TMDLs have been developed

FG = sum of future growth loads from permitted facilities

MOS = margin of safety load

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

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

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 beneficial uses and conform to Texas's antidegradation policy. The three-tiered antidegradation policy in the 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.

The TCEQ intends to implement any individual wasteload allocations through the permitting process as monitoring requirements and/or effluent limitations as required by the amendment of 30 Texas Administrative Code Chapter 319 which became effective November 26, 2009. Should any WWTFs begin discharging to the TMDL watersheds, they will be assigned an effluent limit based on the TMDL. Monitoring requirements are based on permitted flow rates and are listed in §319.9.

The permit requirements will be 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 wasteload allocations after this TMDL is adopted. Therefore the wasteload allocations for stormwater in this report 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 demonstrate compliance with the TMDL.

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

Where a TMDL has been approved, TPDES permits for domestic WWTFs will require conditions consistent with the requirements and assumptions of the wasteload allocations. For NPDES/ TPDES-regulated municipal discharges, construction stormwater discharges, and industrial stormwater discharges, water quality-based effluent limits that implement the wasteload allocation 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 wasteload allocations 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 [water quality-based effluent limits], action levels, etc."

Using this iterative, adaptive BMP approach to the maximum extent practicable is appropriate to address the stormwater component of this TMDL.

Updates to Wasteload Allocations

This TMDL is, by definition, the total of the sum of the wasteload allocation, the sum of the load allocation, and the MOS. Changes to individual wasteload allocations may be necessary in the future in order to accommodate growth or other changing conditions. These changes to individual wasteload allocations do not ordinarily require a revision of the TMDL document; instead, any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

Load Allocation

The load allocation component is the sum of loads from unregulated sources within the TMDL watershed. A complexity to the load allocation term occurs as a result of loadings from tributaries for which TMDLs have been developed. The tributary loadings must be factored into the load allocation component. Therefore, the total load allocation (LA_{TOTAL}) is defined as the bacteria load that arises from unregulated sources within the AU (LA_{AU}) plus the loads from impaired tributaries entering the AU (LA_{TRIB}). The load allocation term becomes fully expressed as:

$$LA_{TOTAL} = LA_{AU} + LA_{TRIB}$$

Where:

LA_{TOTAL} = total allowable load from unregulated sources (predominately nonpoint sources)

LA_{AU} = allowable loads from unregulated sources assigned to the AU

LA_{TRIB} = loadings from tributary water bodies for which TMDLs are developed

The calculated TMDL allocations for the tributary Crockett Branch (Segment 0841V) will be included in the load allocation for Cottonwood Creek (Segment 0841F) as a LA_{TRIB} term. Similarly, the calculated TMDL allocation for the tributary Kirby Creek (Segment 0841N) will be included in the load allocation for Fish Creek (Segment 0841K) as a LA_{TRIB} term.

The unregulated loading within the AU (LA_{AU}) is calculated as:

$$LA_{AU} = TMDL - WLA_{WWTF} - WLA_{SW} - LA_{TRIB} - FG - MOS$$

Where:

LA_{AU} = allowable loads from unregulated sources within the AU

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all permitted stormwater loads

LA_{TRIB} = loadings from tributary water bodies for which TMDLs are developed

FG = sum of future growth loads from permitted facilities

MOS = margin of safety load

The TMDL equation can thus be expanded to show the components of wasteload allocations and load allocation:

$$TMDL = WLA_{WWTF} + WLA_{SW} + LA_{AU} + LA_{TRIB} + FG + MOS$$

Margin of Safety Equation

The MOS is only applied to the allowable loading for an AU and is not applied to the LA_{TRIB} that enters the segment as an external loading from another water body. Therefore the MOS is expressed mathematically as the following:

$$MOS = 0.05 * (TMDL – LA_{TRIB})$$

Where:

MOS = margin of safety load

TMDL = total maximum allowable load

LA_{TRIB} = loadings from tributary water bodies for which TMDLs are developed

Allowance for Future Growth

The future growth 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 addresses the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of streams increases as the amount of flow

increases. However, since there is 100 percent coverage of wastewater collection by the TRA Central Regional WWTF Collection System and no WWTFs exist in the TMDL study area, the future growth component for all four impaired segments is zero.

Compliance with these TMDLs is based on keeping the bacteria concentrations in the selected waters below the limits that were set as criteria. Future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause bacteria to exceed the limits.

TMDL Calculations

The allowable loading of *E. coli* that the impaired AUs within the TMDL watersheds can receive on a daily basis was based on the median value within the high flow regime of the LDC (or 5 percent flow exceedance value) for the most downstream station of each AU (Figures 10 through 13). Table 8 summarizes the calculation of the TMDL for each segment.

Table 8. Summary of allowable loading calculations for segments within the TMDL watersheds.

Water Body	Segment	5% Exceedance Flow (cfs)	5% Exceedance Load = TMDL (Billion MPN/day)
Cottonwood Creek	0841F	16.057	49.498
Fish Creek	0841K	39.327	121.234
Kirby Creek	0841N	3.863	11.910
Crockett Branch	0841V	0.2625	0.809

Based on the information in Table 8, the MOS can be computed (Table 9).

Table 9. MOS calculations for the most downstream station in each TMDL watershed.

All loads are expressed as billion MPN/day *E. coli*

Water Body	Segment	TMDL	LA_{TRIB}	MOS
Cottonwood Creek	0841F	49.498	0.809	2.434
Fish Creek	0841K	121.234	11.910	5.466
Kirby Creek	0841N	11.910	0	0.595
Crockett Branch	0841V	0.809	0	0.040

As described previously, each TMDL watershed is covered 100 percent by MS4 Phase II general permits and/or a Phase I individual permit (Figure 7). However,

even in highly urbanized areas such as the TMDL study area, there remain small areas of streams within each watershed that are not strictly regulated by stormwater permits and which may receive bacteria loadings from unregulated sources such as wildlife and feral hogs. In order to calculate the amount of overall runoff load that should be allocated to WLA_{SW}, the percentage of the watershed drainage area under the jurisdiction of a stormwater permit (FDA_{SWP}) must be estimated. To account for the small unregulated areas in each impaired watershed, the stream length based on the TCEQ definition of each AU and a stream width estimated from aerial imagery was used to compute an area of unregulated stormwater contribution (Table 10).

Table 10. Basis of unregulated stormwater area and computation of FDA_{SWP}.

Water Body	Total Watershed Area (acres)	Stream Length (feet)[a]	Estimated Average Stream Width (feet)	Estimated Stream Area (acres)	Fraction Unregulated Area	FDA_{SWP}
Cottonwood Creek	3,798	34,857	23	18.40	0.00485	0.99515
N. F. Cottonwood Creek	3,546	19,808	30	13.64	0.00385	0.99615
Entire Cottonwood Creek (Excluding Crockett Branch)	7,344	54,664	25.5	32.05	0.00436	0.99564
Crockett Branch	767	4,920	11	1.24	0.00162	0.99838
Fish Creek	10,993	73,354	30	50.52	0.00460	0.99540
N. F. Fish Creek	3,663	25,328	26	15.12	0.00413	0.99587
Entire Fish Creek (Excluding Kirby Creek)	14,656	98,682	29.0	65.64	0.00448	0.99552
Kirby Creek	1,978	22,114	18	9.14	0.00462	0.99538

[a] Stream lengths were determined by GIS analysis and may not exactly match lengths from AU descriptions in the *Integrated Report*.

Due to the absence of permitted dischargers in the TMDL study area, the WLA_{WWTF} term is zero. Likewise, since it is unforeseen that any permitted discharges with a human waste component will occur in the TMDL study area, the future growth term is also zero. Using values provided in Tables 8 through 10 and the zero values for WLA_{WWTF} and future growth, the WLA_{SW} term was calculated and is provided in Table 11.

Table 11. Regulated stormwater calculations for the TMDL watersheds.

All loads expressed as billion MPN/day *E. coli*

Water Body	Segment	TMDL	WLA_{WWTF}	LA_{TRIB}	FG	MOS	FDA_{SWP}	WLA_{SW}
Cottonwood Creek	0841F	49.498	0	0.809	0	2.434	0.99564	46.053
Fish Creek	0841K	121.234	0	11.910	0	5.466	0.99552	103.393
Kirby Creek	0841N	11.910	0	0	0	0.595	0.99538	11.263
Crockett Branch	0841V	0.809	0	0	0	0.040	0.99838	0.768

The last term in the TMDL requiring computation is LA_{AU}, which is the allowable bacteria loading assigned to unregulated sources within each AU watershed. All AUs within the TMDL watersheds were assigned a small area not regulated by stormwater permits as detailed in Table 10. Based on the information in Table 11, the load allocation terms can be computed (Table 12). As discussed previously, the LA_{TRIB} term represents the tributary loading of the Crockett Branch TMDL as part of the Cottonwood Creek TMDL and the tributary loading of the Kirby Creek TMDL as part of the Fish Creek TMDL.

Table 12. Unregulated stormwater calculations for the TMDL watersheds.

Units expressed as billion MPN/ day *E. coli*

Water Body	Segment	TMDL	WLA_{WWTF}	WLA_{SW}	LA_{TRIB}	FG	MOS	LA_{AU}
Cottonwood Creek	0841F	49.498	0	46.053	0.809	0	2.434	0.202
Fish Creek	0841K	121.234	0	103.393	11.910	0	5.466	0.465
Kirby Creek	0841N	11.910	0	11.263	0	0	0.595	0.052
Crockett Branch	0841V	0.809	0	0.768	0	0	0.040	0.001

Summary of TMDL Calculations

Table 13 summarizes the TMDL calculations for the four TMDL watersheds. Each of the TMDLs was calculated based on the median flow in the 0-10 percentile range (5 percent exceedance, high flow regime) for flow exceedance in the LDC developed for the most downstream monitoring station within each watershed. Allocations are based on the current geometric mean criterion for *E. coli* of 126 MPN/100 mL for each component of the TMDL.

Table 13. TMDL allocation summary for the TMDL watersheds.

Units expressed as billion MPN/ day *E. coli.*

Water Body	Segment	TMDL	WLA_{WWTF}	WLA_{SW}	LA_{AU}	LA_{TRIB}	FG	MOS
Cottonwood Creek	0841F	49.498	0	46.053	0.202	0.809	0	2.434
Fish Creek	0841K	121.234	0	103.393	0.465	11.910	0	5.466
Kirby Creek	0841N	11.910	0	11.263	0.052	0	0	0.595
Crockett Branch	0841V	0.809	0	0.768	0.001	0	0	0.040

The final TMDL allocations (Table 14) needed to comply with the requirements of 40 CFR 130.7 include the future growth component within the WLA_{WWTF}, which for all the TMDL watersheds was zero due to the absence of any permitted discharges and the anticipation of no future permitted discharges with a human waste component. The final TMDL allocation also included allocations to permitted MS4 entities and permitted construction and industrial activities, which are designated as WLA_{SW}. The LA_{TOTAL} component of the final TMDL allocations is the sum of unregulated stormwater loadings arising from within each AU and any loadings associated with TMDL segments that are tributaries to another TMDL segment.

Table 14. Final TMDL allocations for the TMDL watersheds.

Units expressed as billion MPN/ day *E. coli*

Water Body	Segment	TMDL	WLA_{WWTF}[a]	WLA_{SW}	LA_{TOTAL}[b]	MOS
Cottonwood Creek	0841F	49.498	0	46.053	1.011	2.434
Fish Creek	0841K	121.234	0	103.393	12.375	5.466
Kirby Creek	0841N	11.910	0	11.263	0.052	0.595
Crockett Branch	0841V	0.809	0	0.768	0.001	0.040

[a] $WLA_{WWTF} = WLA_{WWTF} + FG$

[b] $LA_{TOTAL} = LA_{AU} + LA_{TRIB}$

In the event that the *E. coli* criterion changes due to future revisions in the state's surface water quality standards, Appendix A provides guidance for recalculating the allocations in Table 14. Figures A-1 through A-4 of Appendix A were developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for *E. coli*. The equations provided, along with Figures A-1 through A-4, allow calculation of new TMDLs and pollutant load allocations based on any potential new water quality criterion for *E. coli*.

Seasonal Variation

Seasonal variations occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* concentrations obtained from 12 years (2002 through 2013) of routine monitoring collected in the warmer months (April through September) against those collected during the cooler months (October through March). Differences in *E. coli* concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the natural log-transformed dataset. This analysis of *E. coli* data indicated that there was a significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Cottonwood Creek (α=0.0085) and Crockett Branch (α=0.0024) with the warm season having the higher concentrations. Seasonality was not detected in the Fish Creek or Kirby Creek watersheds.

Public Participation

The 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.

Through the TCEQ, the NCTCOG and members of the Coordination Committee for the Greater Trinity River Bacteria Implementation Plan (I-Plan) have remained informed about the TMDL project for the Mountain Creek Lake watershed. This communication included a June 3, 2015, presentation of the status of the four TMDLs at the annual meeting of the Coordination Committee. At the meeting, the impaired segments, the reason for the impairment, historical data, and potential sources of bacteria within the watershed were presented. In addition, the meeting gave TCEQ the opportunity to solicit input from all interested parties within the study area. Finally, at this same June 2015 meeting, the stakeholder Coordination Committee, by resolution, added these four segments (0841F, 0841K, 0841N, and 0841V) to their existing I-Plan.

Implementation and Reasonable Assurance

The issuance of TPDES permits consistent with TMDLs provides reasonable assurance that wasteload allocations 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 Sec. 130.6(c)). Commission adoption of a TMDL is the state's certification of the associated WQMP update.

Because the TMDL does not reflect or direct specific implementation by any single pollutant discharger, the TCEQ certifies additional elements to the WQMP after the I-Plan is approved by the commission. Based on the TMDL and I-Plan, the TCEQ will propose and certify WQMP updates to establish required water-quality-based effluent limitations necessary for specific TPDES wastewater discharge permits.

For MS4 permits, the TCEQ will normally establish BMPs, which are a substitute for effluent limitations, as allowed by federal rules, where numeric effluent limitations are infeasible. When such BMPs are established in an MS4 permit, the TCEQ will not identify specific implementation requirements applicable to a specific TPDES stormwater permit through an effluent limitation update. Rather, the TCEQ might revise a stormwater permit, require a revised SWMP or Pollution Prevention Plan, or implement other specific revisions affecting stormwater dischargers in accordance 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. The 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 allocations 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.

As noted in the Public Participation section, the implementation of these TMDLs will be conducted through an existing I-Plan. The NCTCOG initiated efforts in spring 2011 with the TCEQ to lead development of the Greater Trinity River Bacteria I-Plan for three closely related projects in the DFW area. The I-Plan effort

includes a Coordination Committee and three (formerly eight) technical subcommittees. Between May 2011 and July 2012, the NCTCOG facilitated four stakeholder meetings, four Coordination Committee meetings, and 40 technical subcommittee meetings. The Coordination Committee completed the "peer review" draft I-Plan and submitted the document to TCEQ for review in August 2012. The draft I-Plan was released for a formal public review in July 2013. The TCEQ Commission approved the I-Plan on December 11, 2013.

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.

The TCEQ worked with stakeholders and interested governmental agencies to develop and support the Greater Trinity River Bacteria I-Plan and track their progress.

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 TMDL 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 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.

The NCTCOG worked with the TCEQ to lead development of the I-Plan. Through the stakeholder group led by the NCTCOG, the resources and expertise of the local organizations and individuals were brought together to set priorities, provide flexibility, and consider appropriate social and economic factors. Information on I-Plan development and related material are on the NCTCOG website at <www.nctcog.org/envir/SEEclean/wq/tmdl/index.asp>.

References

Adams, T. and L. Hauck. 2015. Technical Support Document for Total Maximum Daily Loads for Indicator Bacteria in Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Upstream of Mountain Creek Lake. (PR1503). Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville, TX.

AMVA 2012. U.S. Pet Ownership Statistics. Retrieved July 16, 2015, from: <www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx>.

Cleland, B. 2003. *TMDL Development From the "Bottom Up" - Part III: Duration Curves and Wet-Weather Assessments.* Retrieved May 23, 2013, from: <engineering.purdue.edu/~ldc/JG/duration/PDF/TMDL_Development_from_the_Bottom_UP_PartIII.pdf>.

EPA (United States Environmental Protection Agency). 1991. *Guidance for Water Quality-Based Decisions: The TMDL Process.* Retrieved July 8, 2013, from Office of Water: Total Maximum Daily Loads (303d): <water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/decisions_index.cfm>.

EPA (United States Environmental Protection Agency). 2013. *Basic Information about Pathogens and Indicators in Drinking Water.* Retrieved August 4, 2015, from Water: Basic Information about Regulated Drinking Water Contaminants: <water.epa.gov/drink/contaminants/basicinformation/pathogens.cfm>.

EPA (United States Environmental Protection Agency). 2014. Memorandum: Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on LAs." November 26, 2014 (Andrew D. Sawyers and Benita Best-Wong to Water Division Directors).

NEIWPCC (New England Interstate Water Pollution Control Commission). 2003. *Illicit Discharge Detection and Elimination Manual.*

NCTCOG (North Central Texas Council of Governments). 2012a. *SSO shapefile.* Retrieved February 3, 2015, from NCTCOG ftp link: <https://filehouse.nctcog.org/index.php?action=Authenticate.login&cookies_enabled=1&login=1&js_enabled=yes&username=jRVOC74b_aukNb7T9BJk4A>.

NCTCOG (North Central Texas Council of Governments). 2012b. *OSSF shapefile.* Retrieved February 3, 2015, from NCTCOG ftp link: <https://filehouse.nctcog.org/index.php?action=Authenticate.login&cookies_enabled=1&login=1&js_enabled=yes&username=jRVOC74b_aukNb7T9BJk4A>.

NCTCOG (North Central Texas Council of Governments). 2013a. *2010 Land Use.* Retrieved January 27, 2015, from Regional Data Center: <http://rdc.nctcog.org/Members/ServiceGroup.aspx?id=9>.

NCTCOG (North Central Texas Council of Governments). 2013b. *WWTF shapefile.* Retrieved February 3, 2015, from NCTCOG ftp link: <https://filehouse.nctcog.org/index.php?action=Authenticate.login&cookies_enabled=1&login=1&js_enabled=yes&username=jRVOC74b_aukNb7T9BJk4A>.

NCTCOG (North Central Texas Council of Governments). 2015. *Traffic Survey Zones*. Retrieved January 26, 2015, from Regional Data Center: <http://rdc.nctcog.org/Members/ServiceGroup.aspx?id=9>.

NDEP (Nevada Division of Environmental Protection). 2003. *Load Duration Curve Methodology for Assessment and TMDL Development*. Retrieved May 23, 2013, from: <ndep.nv.gov/bwqp/loadcurv.pdf>.

NOAA (National Oceanic and Atmospheric Administration). 2009. *Dallas/Fort Worth Climate Narrative*. Retrieved July 2015 from National Weather Service Forecast Office: < www.srh.noaa.gov/fwd/?n=dnarrative>.

NOAA (National Oceanic and Atmospheric Administration). 2015. *Station USW00053907, Arlington Municipal Airport, Arlington, TX, US*. Retrieved January 2015 from National Climatic Data Center: <www.ncdc.noaa.gov/cdo-web/search>.

PRISM Climate Group at Oregon State University. 2012. *30-Year Average Annual Normal Precipitation Isohyets(1981-2010):*Raster file. Retrieved May 18, 2015, from PRISM Climate Group: <www.prism.oregonstate.edu/normals/>.

TCEQ (Texas Commission on Environmental Quality). 2010. *Texas Surface Water Quality Standards, 2010 Rule Amendment, 30 TAC 307*. Retrieved August 4, 2015, from 2010 Texas Surface Water Quality Standards: <www.tceq.texas.gov/assets/public/permitting/waterquality/standards/docs/TSWQS2010/TSWQS2010_rule.pdf>.

TCEQ (Texas Commission on Environmental Quality). 2012a. *Assessment Units*: Shapefile. Retrieved January 28, 2015, from Download TCEQ GIS data: <www.tceq.texas.gov/gis/download-tceq-gis-data>.

TCEQ (Texas Commission on Environmental Quality). 2012b. *Surface Water Quality Monitoring Stations*. Retrieved April 17, 2015, from Download TCEQ GIS data: <www.tceq.texas.gov/gis/download-tceq-gis-data>.

TCEQ (Texas Commission on Environmental Quality). 2013a. *2012 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)*. Retrieved September 29, 2015, from: <www.tceq.state.tx.us/waterquality/assessment/waterquality/assessment/12twqi/twqi12>.

TCEQ (Texas Commission on Environmental Quality). 2013b. *Thirteen Total Maximum Daily Loads for Indicator Bacteria in the Lower West Fork Trinity River Watershed*. Retrieved August 6, 2015, from: <www.tceq.state.tx.us/assets/public/waterquality/tmdl/66trinitybact/66d-adopted-LowerWestForkTrinityBacteria.pdf>.

TCEQ (Texas Commission on Environmental Quality). 2014. SSO data. Retrieved October 29, 2014, and December 2, 2014, via e-mail from Region 4 (Greg Diehl).

TCEQ (Texas Commission on Environmental Quality). 2015a. *2014 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)*. Retrieved September 29, 2015 from: <www.tceq.texas.gov/waterquality/assessment/14twqi/14txir>.

TCEQ (Texas Commission on Environmental Quality). 2015b. *Permitted Wastewater Outfalls*. Retrieved January 28, 2015, from Download TCEQ GIS data: <www.tceq.texas.gov/gis/download-tceq-gis-data>.

TCEQ (Texas Commission on Environmental Quality). 2015c. *Central Registry Query – Customer Search* Phase I MS4 search. Retrieved July 9, 2015, from: <www15.tceq.texas.gov/crpub/index.cfm?fuseaction=cust.CustSearch>.

TCEQ (Texas Commission on Environmental Quality). 2015d. *Water Quality General Permits & Registration Search*. Retrieved July 9, 2015, from: <www2.tceq.texas.gov/wq_dpa/index.cfm>.

USCB (United States Census Bureau). 2014a. GIS data from: *2010 Census Block Shapefiles for Dallas and Tarrant County*. Retrieved February 6, 2015 from: <www.census.gov/cgi-bin/geo/shapefiles2010/main>. Tabular data from: *2010 Census Block Households and Families*. Retrieved February 5, 2015, from American FactFinder: <http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.

USCB (United States Census Bureau). 2014b. 2010 *Urban Areas Shapefile*. Retrieved March 20, 2015 from: <www.census.gov/cgi-bin/geo/shapefiles2010/main>.

USGS (United States Geological Survey). 2015. *USGS Streamflow Data for Station 08049700, Walnut Creek nr Mansfield, TX*. Retrieved May 19, 2015, from: <waterdata.usgs.gov/tx/nwis/dv/?site_no=08049700&agency_cd=USGS&referred_module=sw>.

Appendix A.
Equations for Calculating TMDL Allocations for Changed Contact Recreation Standard

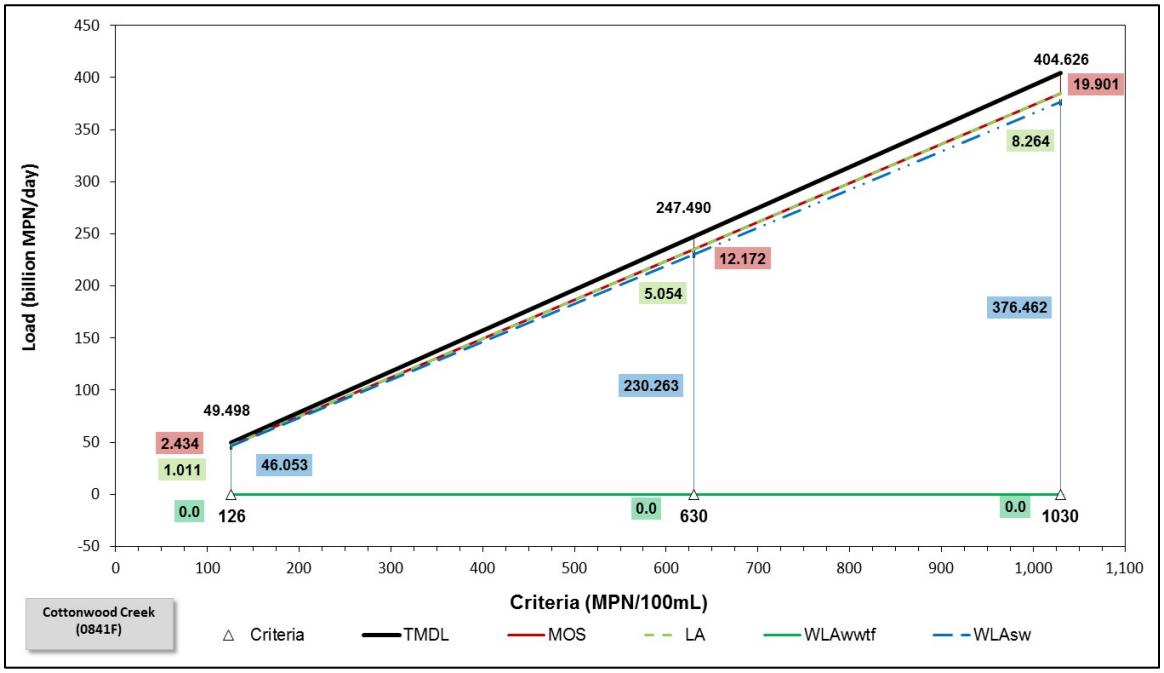

Figure A-1. Allocation loads for the Cottonwood Creek watershed (0841F) as a function of water quality criteria

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

TMDL =0.39284 * Std

MOS = 0.01932* Std

LA = 0.00802 * Std

WLA_{WWTF} = 0

WLA_{SW} =0.36550* Std

Where:

Std = revised contact recreation standard

MOS = margin of safety

LA = total load allocation (unregulated sources)

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

WLA_{SW} = wasteload allocation (permitted stormwater)

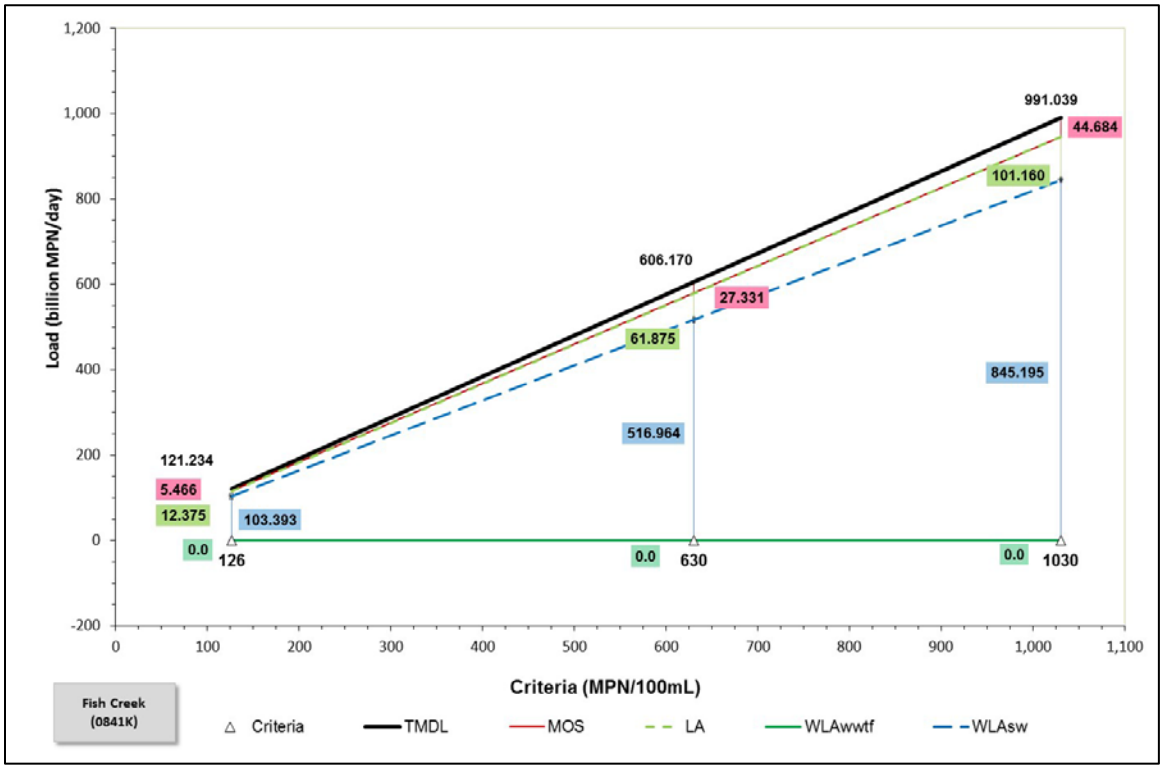

Figure A-2. Allocation loads for the Fish Creek watershed (0841K) as a function of water quality criteria

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

$$TMDL = 0.96217 * Std$$

$$MOS = 0.04338 * Std$$

$$LA = 0.09821 * Std$$

$$WLA_{WWTF} = 0$$

$$WLA_{SW} = 0.82058 * Std$$

Where:

Std = revised contact recreation standard

MOS = margin of safety

LA = total load allocation (unregulated sources)

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

WLA_{SW} = wasteload allocation (permitted stormwater)

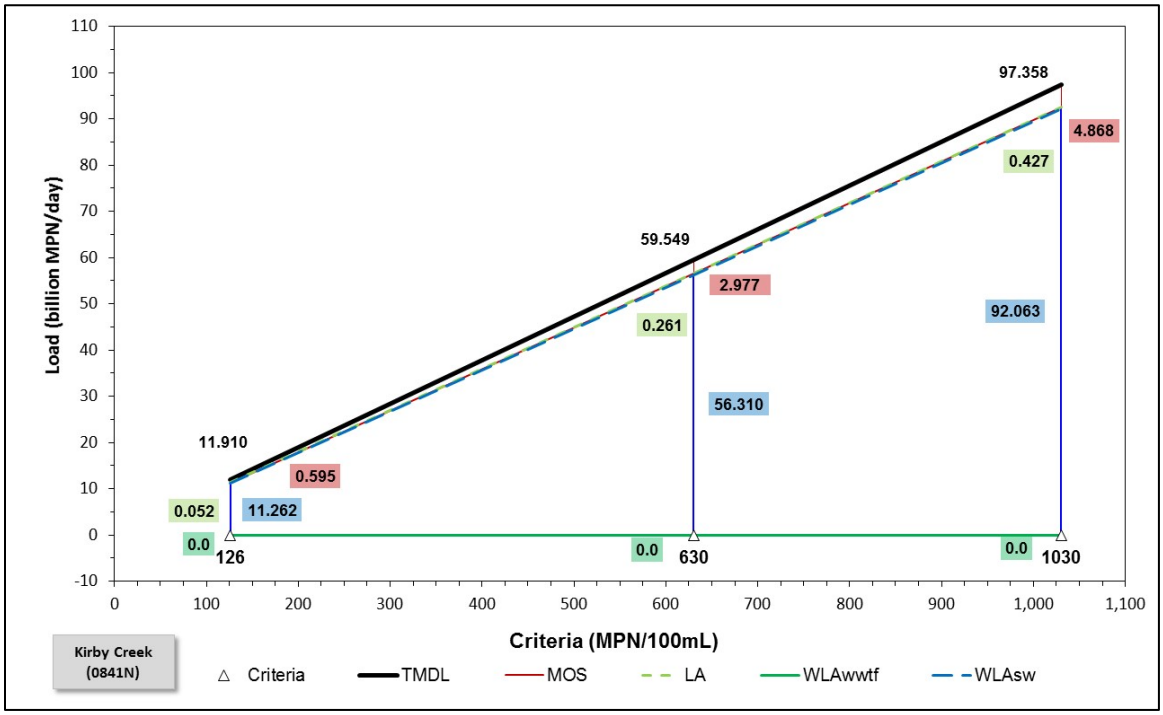

Figure A-3. Allocation loads for the Kirby Creek watershed (0841N) as a function of water quality criteria.

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

$$TMDL = 0.094522 * Std$$

$$MOS = 0.004727 * Std$$

$$LA = 0.000415 * Std$$

$$WLA_{WWTF} = 0$$

$$WLA_{SW} = 0.089382 * Std$$

Where:

Std = revised contact recreation standard

MOS = margin of safety

LA = total load allocation (unregulated sources)

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

WLA_{SW} = wasteload allocation (permitted stormwater)

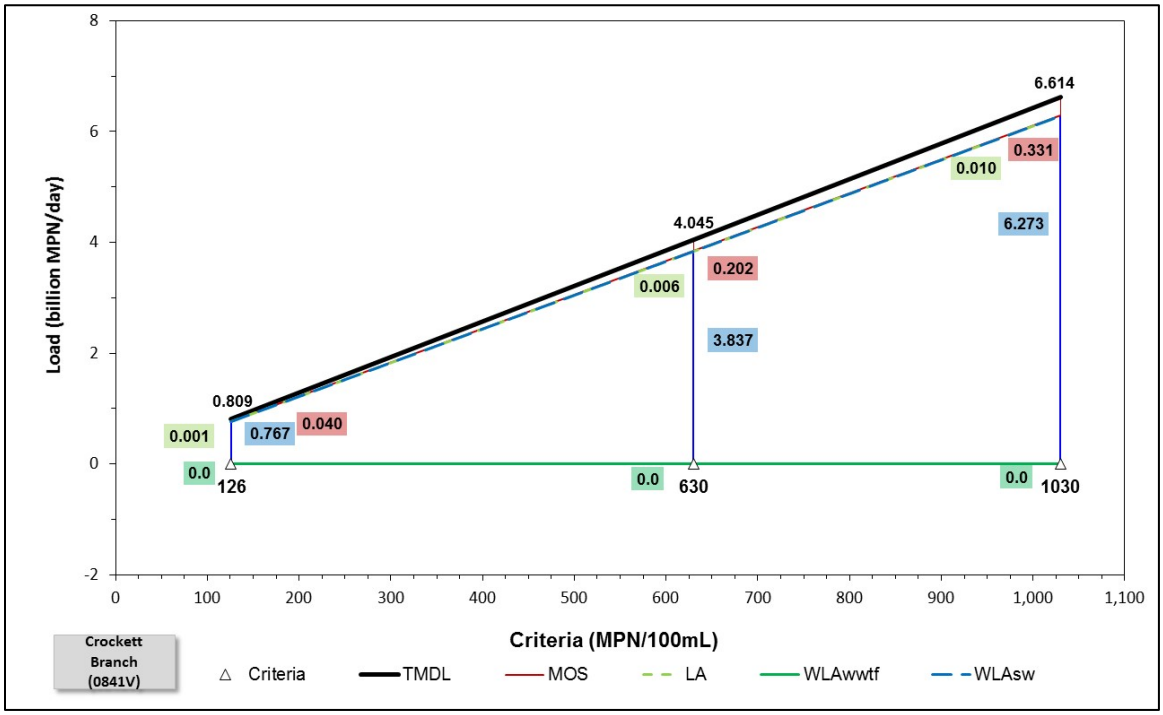

Figure A-4. Allocation loads for the Crockett Branch watershed (0841V) as a function of water quality criteria.

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

$$TMDL = 0.0064214 * Std$$

$$MOS = 0.0003219 * Std$$

$$LA = 0.0000100 * Std$$

$$WLA_{WWTF} = 0$$

$$WLA_{SW} = 0.0060907 * Std$$

Where:

Std = revised contact recreation standard

MOS = margin of safety

LA = total load allocation (unregulated sources)

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

WLA_{SW} = wasteload allocation (permitted stormwater)