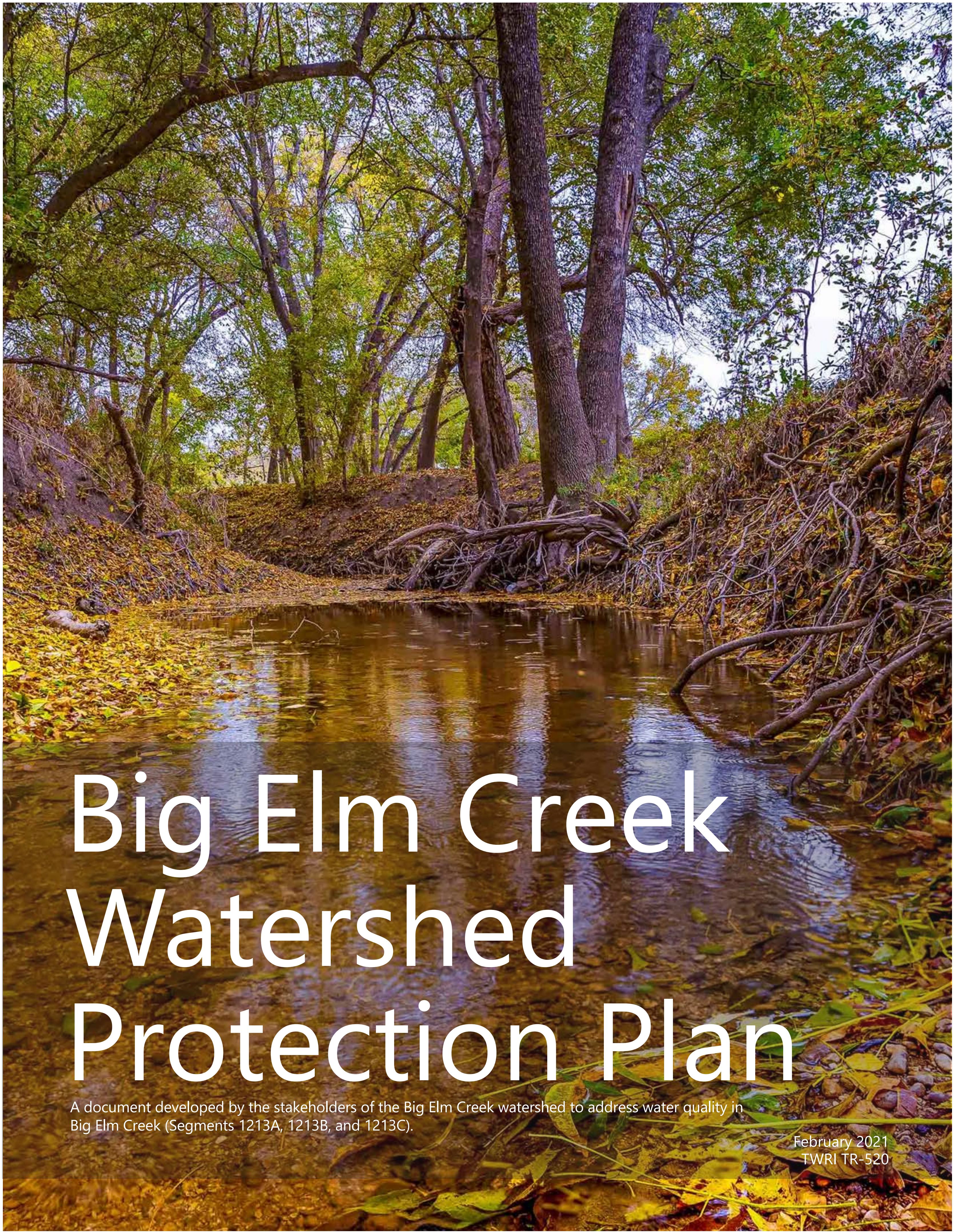

Big Elm Creek Watershed Protection Plan

A document developed by the stakeholders of the Big Elm Creek watershed to address water quality in Big Elm Creek (Segments 1213A, 1213B, and 1213C).

February 2021
TWRI TR-520

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Texas Water Resources Institute

Texas Water Resources Institute Technical Report – 520
February 2021

College Station, Texas

Funding support for this project provided by the Texas Commission on Environmental Quality through
a Clean Water Act Section 319 grant provided from the United States Environmental Protection Agency.

Front cover photo: Little Elm Creek near Oscar, TX. Photo by Ed Rhodes, TWRI.
Back cover photo: 1921 Pony truss bridge at Big Elm Creek near Troy, TX. Photo By Ed Rhodes, TWRI.

Acknowledgments

This document presents the strategy developed by the stakeholders of the Big Elm Creek watershed to restore and protect water quality in Big Elm Creek and the water bodies that flow into it. Stakeholders dedicated considerable time and effort in discussing the watershed, influences on water quality and potential methods to address water quality concerns, and selecting appropriate strategies to improve water quality. The ultimate success of the Big Elm Creek WPP achieving its goals depends heavily on the current and continued support from these individuals and agencies.

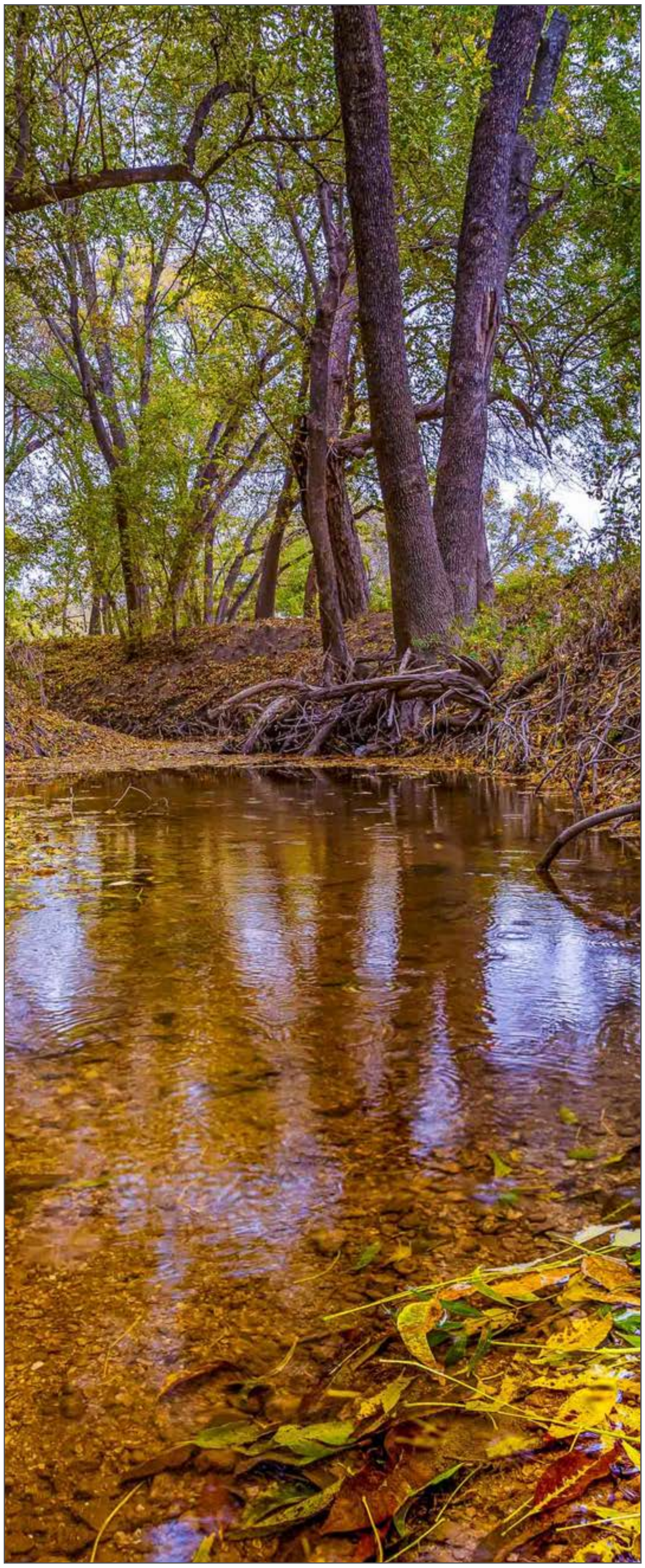
Special appreciation is extended to the many watershed landowners and residents who attended the numerous meetings and events to provide direct input to the plan. The direct involvement of landowners and residents was critical to ensuring the plan included feasible management measures that address sources of water quality impairments in the watershed. The time and effort of landowners and residents are greatly appreciated and are reflected in the contents of this plan.

Local and regional government agencies and organizations also played key roles in plan development. Representatives provided insight regarding their specific focus areas and ensured the inclusion of content in the plan that is appropriate for the watershed. Local and regional agencies that contributed to the development of this WPP include:

- City of Temple
- Bell and Milam Counties
- Elm Creek River Authority
- Texas Farm Bureau
- Central Texas Soil and Water Conservation District

Agency support and input was an integral part of the WPP development process. In particular, the following agencies provided technical guidance and willingness to provide specialized knowledge on a number of topics:

- Texas A&M AgriLife Extension Service
- Texas A&M AgriLife Research
- Texas A&M Forest Service
- Texas Master Naturalists
- Texas Commission on Environmental Quality
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board
- USDA Natural Resource Conservation Service



Little Elm Creek near Oscar, TX. Photo by Ed Rhodes, TWRI.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviations	Meaning
ac	Acre
AgriLife Extension	Texas A&M AgriLife Extension Service
AU	Assessment Units
BECWPP	Big Elm Creek Watershed Protection Plan
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
CCN	Certificate of Convenience and Necessity
cfu	Colony Forming Unit
CP	Conservation Plan
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
DAR	Drainage-Area Ratio
DO	Dissolved Oxygen
DR	Designated Representative
E. coli	*Escherichia coli*
ECRA	Elm Creek River Authority
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FSA	Farm Service Agency
FDC	Flow Duration Curve
FSA	Farm Service Agency
ft	Feet
GIS	Geographic Information System
Hwy	Highway
HUC	Hydrologic Unit Code
I&I	Inflow and Infiltration
in	Inch
LDC	Load Duration Curve
LID	Low Impact Development
LULC	Land Use and Land Cover
m	Meter
mg/L	Milligram per Liter
mL	Milliliters
MS4	Municipal Separate Storm Sewer System
MSL	Mean Sea Level
NASS	National Agricultural Statistics Service

Abbreviations	Meaning
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
RMU	Resource Management Unit
RT	Routine Sampling
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Projects
SH	State Highway
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic Database
SWMP	Storm Water Management Plan
SWQM	Surface Water Quality Monitoring Program
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination Systems
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWON	Texas Well Owners Network
TWRI	Texas Water Resources Institute
TXDOT	Texas Department of Transportation
TX	Texas
USDA	U.S. Department of Agriculture
USGS	U. S. Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTP	Wastewater Treatment Plant
yr	Year

Executive Summary

Big Elm Creek bridge at US 77. Photo by Lucas Gregory, TWRI.

A watershed is an area of land that drains to a common body of water. Within a watershed, water follows natural hydrologic boundaries and is influenced by the landscape through which it flows. Both natural and human influenced processes that occur within a watershed can cause changes in both the quantity and quality of water within the system.

This document presents a plan to restore and protect water quality in the Big Elm Creek watershed. By approaching water quality issues at the watershed level rather than political boundaries, this plan can better identify potential water quality sources and solutions. This approach also incorporates the values, visions, and knowledge of individuals with a direct stake in water quality conditions.

Problem Statement

Water quality monitoring conducted by the Texas Commission on Environmental Quality (TCEQ) indicated that a section of Big Elm Creek exceeded water quality standards for primary contact recreation. The cause of this impairment is excessive *Escherichia coli* (*E. coli*) bacteria. Big Elm Creek was first identified as impaired in the *2010 Texas Integrated Report* (TCEQ 2011), also known as the 303(d) list. Depressed dissolved oxygen levels, caused primarily by elevated nitrate loads, are also a concern in the watershed, as well as any other potential sources of nutrients and pollutants.

With the impairment listings comes a need to plan and implement actions to restore water quality and ensure safe and healthy water bodies in the Big Elm Creek watershed for residents and visitors. To meet this need, an assessment and planning project was undertaken to develop the Big Elm Creek Watershed Protection Plan (WPP).

Response

The planning process began with a stakeholder group meeting in summer of 2018 to form and establish stakeholder group structure and rules. Over the next year, the facilitator (Texas Water Resources Institute) met with the stakeholder group to provide data and information and receive feedback on approaches used to assess and characterize water quality in the watershed. Stakeholders provided direct input to assumptions used in the pollutant load analysis and decided upon what management measures were most likely to succeed and be implemented by the watershed community.

Watershed Protection Plan Overview

This document is a culmination of a stakeholder process to identify sources of pollution and the methods that are most likely to reduce pollutant loads in Big Elm Creek. By comprehensively considering the multitude of potential pollutant sources in the watershed, this plan describes management strategies that, when implemented, will reduce pollutant loadings in the most cost-effective methods available at the time of planning. Despite the extensive amounts of information gathered during the development of this WPP, a better understanding of the watershed and the effectiveness of management measures will undoubtedly develop as the plan is implemented. As such, this plan is a living document that will evolve as needed through the adaptive management process.

Pollutant Reductions

Analysis of water quality and streamflow data indicate a bacteria load reduction of approximately 2.57 x 10^{13} colony forming units (cfu)/year for moist conditions is needed to meet water quality standards for recreation in Big Elm Creek. This represents a 62% reduction in the current *E. coli* load measured during moist conditions.

No single pollutant source is the primary cause of water quality impairments in Big Elm Creek. A variety of sources, including livestock, wildlife, septic systems, and pets are likely to contribute bacteria loads to the watershed. Therefore, stakeholders identified a variety of diverse and feasible management measures that will reduce bacteria in Big Elm Creek. Full implementation of the management measures over ten years will reduce potential *E. coli* bacteria loads by approximately 7.62 x 10^{15} cfu/year, as well as reducing overall nutrient loads in the watershed.

Recommended Actions

Livestock

Livestock contributions to bacteria loads may be managed through a variety of grazing and land management practices. Identification, planning, and implementation of operation-specific goals and practices to reduce water quality impacts will be achieved through Texas State Soil and Water Conservation Board (TSSWCB) Water Quality Management Plans (WQMPs) or U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Conservation Plans. Cost share programs are available to producers to assist in the implementation and maintenance of these practices. This WPP also includes the delivery of education programs and workshops for producers and new or small acreage landowners to demonstrate new and innovative best management practices (BMPs).

Feral Hogs

Feral hogs not only contribute to crop and property damages, but their behavior also contributes to water quality and riparian habitat degradation. Destruction of fine herbaceous vegetation greatly reduces the ability of the landscape to filter out nutrients and bacteria before they get to the stream channel. Although many property owners already work hard to remove feral hogs from their property, this WPP recommends continued efforts to remove feral hogs from within the watershed. This WPP also recommends that all deer feeders should be fenced off to reduce the availability of free feed to feral hogs. Finally, delivery of feral hog management workshops will provide property owners and land managers with knowledge and tools to maximize their efforts at controlling and reducing feral hog populations.

On-Site Sewage Facilities

Although most on-site sewage facilities (OSSFs, also known as septic systems,) operate properly, failing OSSFs can result in untreated wastewater reaching the soil surface and running off into nearby water bodies. Ensuring that these systems function properly and are consistently maintained is crucial for water quality and minimizing potential human health risks. In some cases, owners may not have the resources to repair or replace a failing system; therefore, this WPP recommends the development of a program to facilitate and provide resources needed to locate, repair, or replace non-functioning systems. Additionally, this WPP recommends the delivery of education programs and workshops to prepare landowners on the proper maintenance of their OSSFs.

Pet Waste

Unmanaged pet waste, especially dog waste, can be a significant contributor to bacteria loads in subwatersheds throughout the area. Management of pet waste is dependent upon pet owner behavior, which could be difficult to encourage. This WPP recommends the installation of pet waste stations in parks and green spaces within the watershed. Development and delivery of targeted educational material is also recommended to encourage the proper disposal of pet waste.

Urban Stormwater

Stormwater from urban and impervious surface runoff is most likely limited to the northwestern portion of the watershed, near and within the city of Temple. Projected population growth over the next several decades suggests that populations and impervious surfaces will continue to increase in the watershed. This WPP recommends working with city officials and departments within the watershed to identify potential stormwater BMPs and to provide public educational events to local residents.

Wastewater

Wastewater conveyance system failure causes inflow and infiltration issues that may result in system overloads. Broken sewer line is a common source for inflow and infiltration issues. Within the watershed, inflow and infiltration were identified as the largest issues that centralized systems must deal with regardless of system size. Water can enter and leave the system if there are any infrastructure cracks and breaks due to system age and changing soil moisture condition. Furthermore, Inflow and Infiltration (I&I) can have a diluting effect that sometimes decreases treatment efficiency and can increase utility pumping and treatment cost. This WPP recommends the inspection and repair of any deteriorating conveyance lines to prevent I&I.

Illicit and Accidental Dumping

Based on stakeholders' input, illicit dumping, particularly of animal carcasses can contribute to bacteria loads, particularly during high runoff events. Given the illegal and often secretive nature of these activities, the potential contributions to water quality are unknown. At the very least, it is a public nuisance and creates undesirable conditions in area water bodies. This WPP recommends the delivery of education and outreach materials on proper waste disposal. Further work on identifying opportunities with local law enforcement and game wardens is also recommended. Accidental discharge of chemicals and other substances from automotive and railroad accidents fall under the purview of local emergency response and the Texas Department of Transportation (TXDOT).

Soil Testing

Although nutrient standards do not exist for this watershed, increased nutrient loading from runoff can lead to reduced dissolved oxygen (DO) in surface water bodies. This WPP recommends education and outreach to encourage both urban and rural landowners to conduct soil testing to prevent the over-fertilization of lawns and agricultural fields. Proper fertilization rates will help landowners save money and reduce nutrient loads in the watershed.

Additional Monitoring

Stakeholders expressed concern over a landfill within the watershed and recommended that additional water quality monitoring to better understand what, if any, effect the landfill may have within the watershed. This WPP recommends additional water quality monitoring upstream and downstream of the landfill.

Education and Outreach

Continued education and outreach is necessary to deliver the most current information and best practices to watershed stakeholders. Planned workshops and outreach events will provide information that enables landowners to improve and optimize production while also protecting and improving water quality. Further efforts will increase watershed residents' knowledge on proper maintenance and operations of OSSFs, pet waste disposal, stormwater BMPs, and feral hog management.

As shown by the consistent integration of education into the recommended actions described above, education will be a mainstay of implementing the Big Elm Creek WPP. Stakeholder meetings will be held as needed and supplemented with topically relevant education and outreach events to maintaining local interest in WPP implementation. Additionally, they will provide a necessary local platform for conveying and illustrating implementation successes.

Goals

The primary goal of the Big Elm Creek Watershed Protection Plan is to restore water quality in Big Elm Creek and its tributaries to water quality standards set by the State of Texas through the long-term conservation and stewardship of the watershed's resources.

To achieve this goal, the plan establishes a 10-year implementation schedule with interim milestones and water quality targets to track progress. The current water quality target, based on the primary contact recreation water quality standard, is 126 cfu *E. coli*/100 milliliters (mL). Ultimately, this plan sets forth an approach to improve stewardship of the watershed resources that allows stakeholders to continue relying on the watershed as part of their livelihood while also restoring the quality of its water resources.

Chapter 1 Introduction

Texas bluebonnets on US Hwy 53 in Falls County. Photo By Ed Rhodes, TWRI.

Watersheds

A watershed is the land area surrounding a water body that drains to a common waterway such as a stream, river, or lake. All the land surfaces that contribute runoff to a water body are considered part of the watershed. Watersheds can vary greatly in size. Some watersheds can be very small and drain only a few square miles. Conversely, larger watersheds can encompass many smaller watersheds and drain large portions of states or regions of the country. The Big Elm Creek watershed includes over 195,200 acres of land that drains into Big Elm Creek.

The natural processes and human activities that occur within a watershed have the potential to improve or degrade water quality. For example, rainfall in the watershed can run across agricultural fields, roads, lawns, or industrial sites. Along the way, the water has opportunities to either slow down and infiltrate into the soil or speed up as it flows towards the water body while picking up sediment, nutrients, or pollutants along the way.

With this in mind, the most effective way to address water quality issues in a water body are to examine the natural and human activities occurring in a watershed.

Types of Pollution

The discharge of a pollutant from a single point, such as a pipe, outfall, or channel is referred to as a point source. Point source discharges require permits through the National Pollutant Discharge Elimination System (NPDES) and Texas Pollutant Discharge Elimination System (TPDES) permitting systems. Examples of permitted point source discharges include wastewater treatment plants (WWTPs) and industrial dischargers.

Nonpoint source pollution, unlike pollution from an industrial facility or WWTP, typically come from many diffuse sources. Nonpoint source pollution is carried by rainfall moving over and through the ground, carrying natural and man-made pollutants, and finally depositing into surface waters. Surface water runoff represents a major nonpoint source in both urban and rural areas. Runoff from towns and cities can deliver pollutants from roadways and vegetated areas. Rural stormwater runoff can transport pollutant loads from cropland, pastures, and livestock operations. Additional nonpoint sources can include on-site sewage facilities (OSSFs) that are poorly installed, faulty, improperly located, or in close proximity to a stream.

The Watershed Approach

The watershed approach is widely accepted by state and federal water resource management agencies to facilitate water quality management. The United States Environmental Protection Agency (EPA) describes the watershed approach as "a flexible framework for managing water resource quality and quantity within a specified drainage area or watershed" (EPA 2008). The watershed approach requires engaging stakeholders to make management decisions that are backed by sound science. The critical aspect of the watershed approach is the focus on hydrologic boundaries rather than political boundaries to address potential impacts to anyone affected by management decisions.

Stakeholders are anyone that lives, works, or has interest within the watershed. Stakeholders may include individuals, groups, organizations, or agencies. The continuous involvement of stakeholders throughout the watershed approach is critical for effectively selecting, designing, and implementing management measures that improve or protect water quality throughout the watershed.

Watershed Protection Plans

Watershed protection plans are locally driven mechanisms for voluntarily addressing complex water quality problems across boundaries. A watershed protection plan serves as a framework to better leverage and coordinate resources of non-governmental organizations, private individuals, and governmental agencies.

The Big Elm Creek Watershed Protection Plan (BECWPP) follows the EPA's nine key elements, designed to provide guidance for the development of an effective watershed protection plan. Watershed protection plans vary in methodology, content, and strategy due to local priorities and needs. However, common fundamental elements are included in successful plans and are identified below:

A. Identification of causes and sources of impairments

B. Expected load reductions from management strategies

C. Proposed management measures

D. Identified technical and financial assistance to implement management measures

E. Information, education, and public participation needed to support implementation

F. Schedule for implementation

G. Milestones to track progress

H. Criteria to determine success

I. Water quality monitoring

Appendix D provides detailed information on EPA's Elements of Successful Watershed Protection Plans and references portions of the BECWPP that address each element.

Adaptive Management

The process of watershed planning is iterative. Initial management measures might not result in success during the first or second cycles. Therefore, adjustments are expected to be made as new information becomes available. Adaptive management consists of developing a natural resource management strategy to facilitate decision-making based on an on-going science-based process (EPA 2008). Such an approach includes results of continual testing, monitoring, evaluating applied strategies, and revising management approaches to incorporate new information, science, and societal needs.

As the management measures identified in the watershed protection plan are put into action, water quality and other measures of success will be monitored to make adjustments as needed. The utilization of an adaptive management approach will help focus effort, implement strategies, and maximize impact on pollutant loadings over time.

Education and Outreach

The development and implementation of a WPP depends on effective education, outreach, and engagement efforts to inform stakeholders, landowners and residents of the activities and practices associated with the WPP. Education and outreach events provide the platform for the delivery of new and/or improved information to stakeholders through the WPP implementation process. Education and outreach efforts are integrated into many of the management measures that are detailed in this WPP.

Chapter 2 Big Elm Creek Watershed Characterization

Cattle grazing in Milam County. Photo By Ed Rhodes, TWRI.

Introduction

This chapter provides geographic, demographic, and potential pollution source overviews of the Big Elm Creek watershed. Development of the information within this chapter relied heavily on state and federal data resources as well as local stakeholder knowledge. The collection of this information is a critical component to the reliable assessment of potential sources of water quality impairment and the recommendation of beneficial management measures.

Watershed Description

Big Elm Creek, a Hydrological Unit Code (HUC) 10 watershed, is located in the eastern portion of Central Texas, between the cities of Moody and Cameron (Figure 1). Big Elm Creek consists three segments (1213A, 1213B, and 1213C); with a single impaired segment (1213A). Segment 1213A is broken down into two assessment units (1213A_01 and 1213A_02). The headwaters of Big Elm Creek begin approximately a mile east of Moody in McLennan County and flows southeast through McLennan, Bell, and Milam counties until they reach Little River just north of Cameron. Big Elm Creek stretches 62.8 miles through a drainage area of 324 square miles of land area with about 253 miles of perennial and intermittent streams. The watershed is located predominately in Bell County (60%) and Milam County (30%), with Falls and McLennan counties making up the remaining 10 percent of the watershed area.

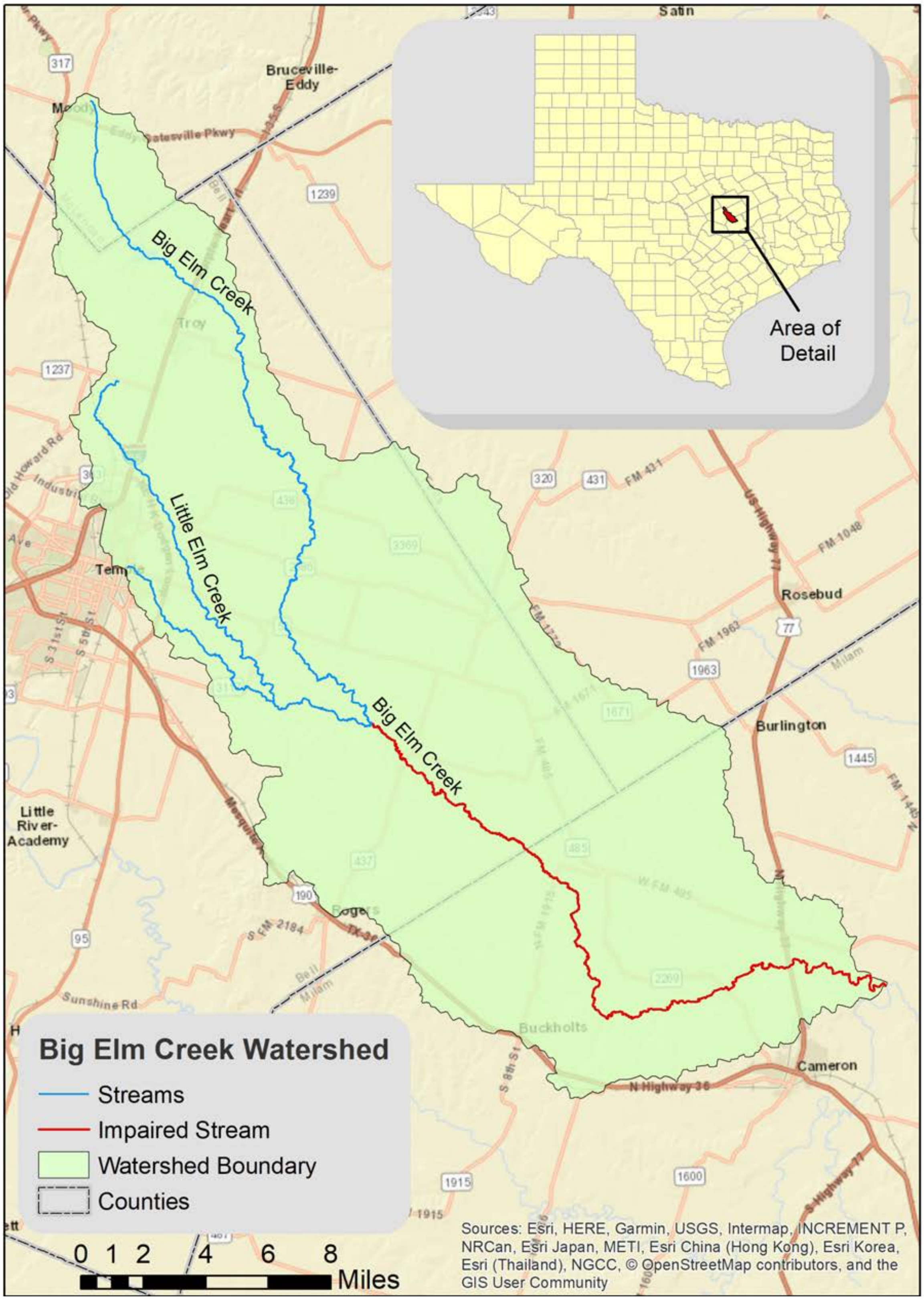


Figure 1. Big Elm Creek watershed map.

Table 1. HUC 12s within Big Elm Creek watershed (HUC 10) with abbreviated subwatershed IDs and acreage.

HUC 12	HUC 12 Name	Subwatershed ID (Figure 2)	Acres
120702040201	Pecan Creek-Big Elm Creek	1	32,701.08
120702040202	Little Elm Creek	2	22,716.01
120702040203	Cottonwood Creek-Big Elm Creek	3	19,610.70
120702040204	South Elm Creek	4	23,985.83
120702040205	Camp Creek-Big Elm Creek	5	37,563.36
120702040206	North Elm Creek	6	38,682.67
120702040207	Lipan Creek-Big Elm Creek	7	30,976.99

Subwatersheds

Subwatersheds were created to better analyze the watershed and help identify key areas of interest. The watershed is divided into seven hydrologically unique subwatersheds (Figure 2). This will allow resources, time, and funding to be directed to the areas that will have the highest impacts on water quality and expedite achievement of WPP goals. The subwatersheds were derived from HUC 12 divisions within the greater HUC 10 Big Elm Creek watershed. A list of the HUC 12s in the watershed are listed in Table 1.

Ecoregions

Ecoregions are land areas with ecosystems that contain similar quality and quantity of natural resources (Griffith et al. 2007). There are four separate delineated levels of ecoregions; level I is the most unrefined classification, and level IV is the most refined. The Big Elm Creek watershed is located predominately in the Level III Ecoregion 32, known as the Texas Blackland Prairies with less than 0.1% located in Level III Ecoregion 33, known as the East Central Texas Plains. Because the watershed is located predominantly in Ecoregion 32, this ecoregion will be used to characterize the watershed. Where the watershed is located in Ecoregion 32 is subdivided into the Level III Ecoregion 32a, known as the Northern Blackland Prairie. The Northern Blackland Prairie ecoregion encompasses portions of northern Texas up to Sherman and cuts through the middle of the state down until it reaches the San Antonio area. The landscape in the Northern Blackland Prairie is mainly underlain by vertisols with dark, fine-textured and calcareous characteristics. The main land cover types are cropland and non-native pasture, with a small portion of deciduous forest and woodlands. Dominant grasses are eastern gamagrass and switchgrass. Large portions of this ecoregion are converting to industrial and urban uses.

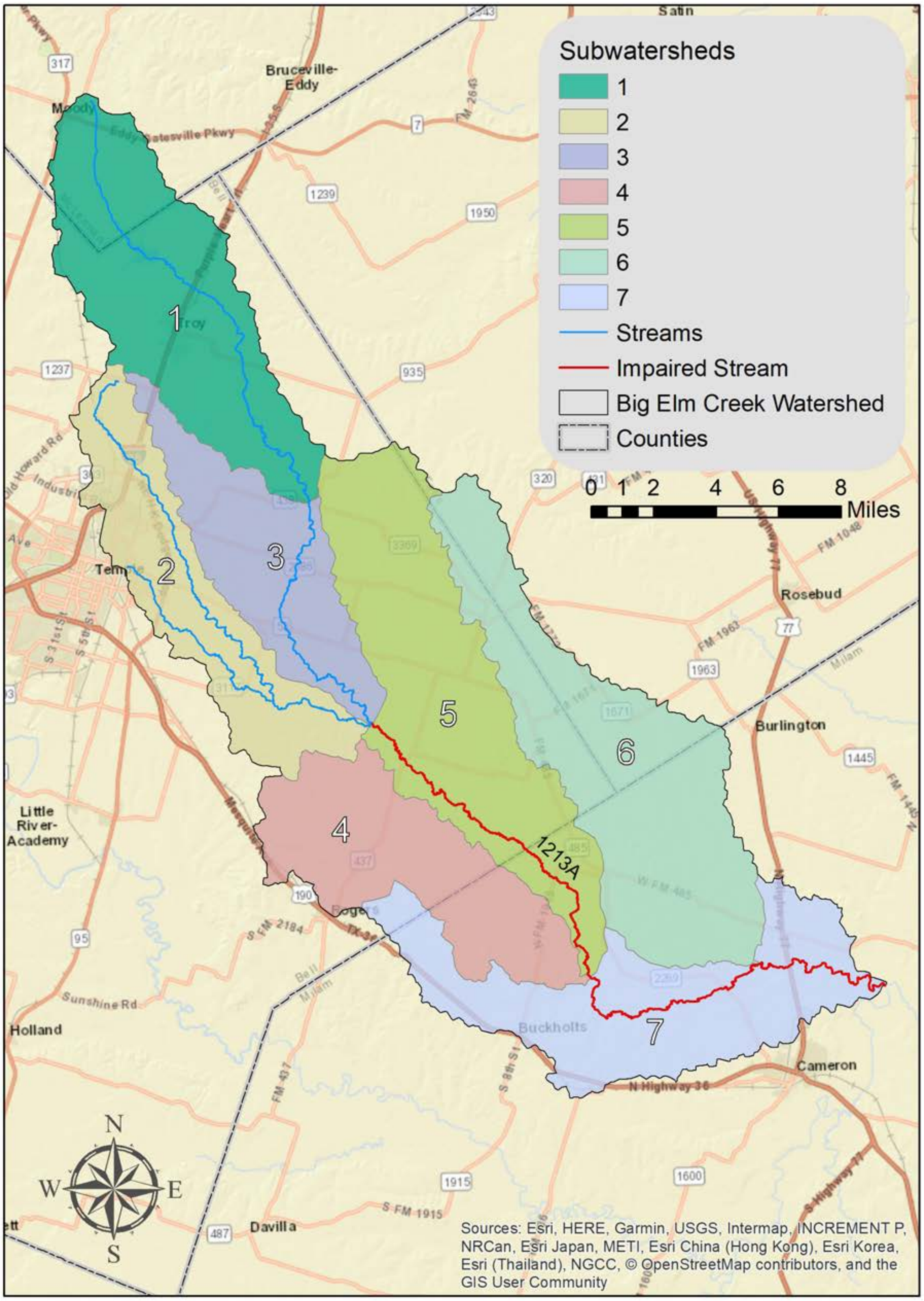


Figure 2. Big Elm Creek subwatersheds map.

Table 2. Relative watershed land cover distribution.

Land Use Class	Acreage	Percentage
Open Water	1,219.61	0.59%
Developed, Open Space	13,168.23	6.39%
Developed, Low Intensity	1,725.12	0.84%
Developed, Medium Intensity	777.49	0.38%
Developed, High Intensity	359.39	0.17%
Barren Land	142.55	0.07%
Deciduous Forest	6,152.11	2.98%
Evergreen Forest	2,271.10	1.10%
Mixed Forest	158.57	0.08%
Shrub/Scrub	4,573.11	2.22%
Grassland/Herbaceous	60,282.83	29.23%
Pasture/Hay	26,726.21	12.96%
Cultivated Crops	82,204.09	39.86%
Woody Wetlands	6,443.67	3.13%
Emergent Herbaceous Wetlands	31.14	0.02%
Total	206,235.22	100.00%

Land Use and Land Cover

Watershed land cover data was obtained from the 2011 National Land Cover Database (NLCD; Homer et al. 2015) and shown in Figure 3. Cultivated crops (40%) and grassland/herbaceous (29%) are the dominate watershed land cover features (Table 2). The major crops in the watershed are corn, wheat, and cotton (USDA NASS 2012). The Big Elm Creek watershed is also predominantly rural in land-use; around 8 percent of the area is classified as Developed (open space, low intensity, medium intensity, and high intensity). Most of the developed urban areas within the watershed are concentrated near the city of Temple and north along the Interstate 35 corridor.

Soils and Topography

The hydrology of a watershed has many key components, including soil properties and topography. Slope and elevation determine the direction of water flow while elevation and soil properties effect the quantity and speed at which water will infiltrate into, flow over, or move through the soil into a water body. Development and other activities may be limited by soil properties in certain areas.

The elevation across the watershed ranges from approximately 260 ft. above mean sea level (MSL) maximum elevation in the northern portion of the watershed to about 85 ft. above MSL for the minimum elevation in the southern most portion of the watershed. Figure 4 shows the elevation of the watershed using information from the United States Geological Survey (USGS) 10-m national elevation dataset (USGS 2013) as well as the decreasing elevation trend from the northern to southern portions of the watershed. The average slope of the watershed is less than 1%.

USDA NRCS provides information about soils collected by the National Cooperative Soil Survey, made available through the Soil Survey Geographic (SSURGO) Database (USDA NRCS 2018b). This database contains tabular and spatial data describing components and properties of soils. The SSURGO database also provides a hydrologic rating for soils. These are groups of soils with similar runoff properties. These ratings are useful for considering the potential for runoff from properties under consistent rainfall and cover conditions. Within the watershed, a majority of the soils are classified as "Type B" soils that are indicative of moderate infiltration and having moderate runoff potential when wet (Figure 5, Table 3).

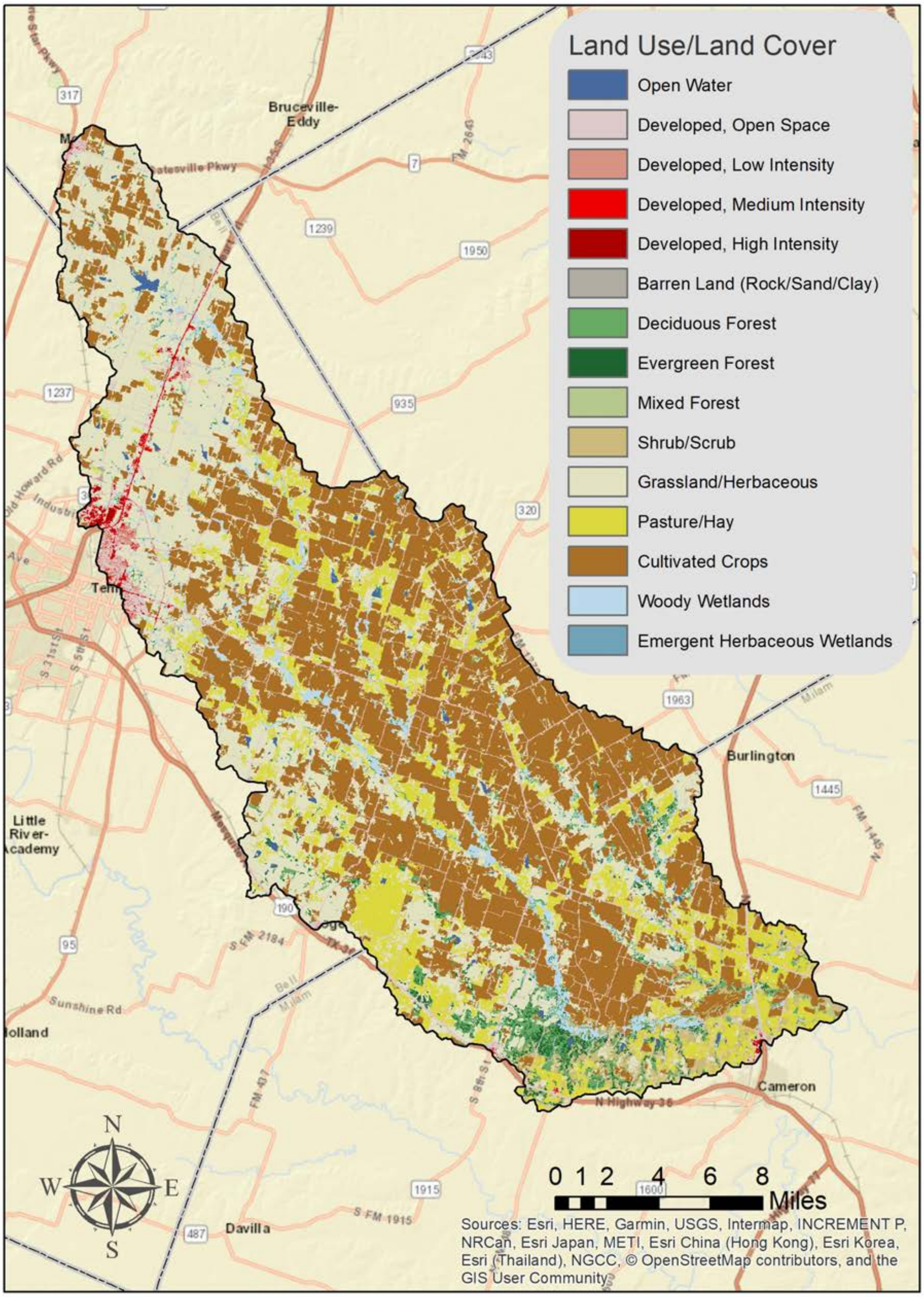


Figure 3. Land cover in the Big Elm Creek watershed .

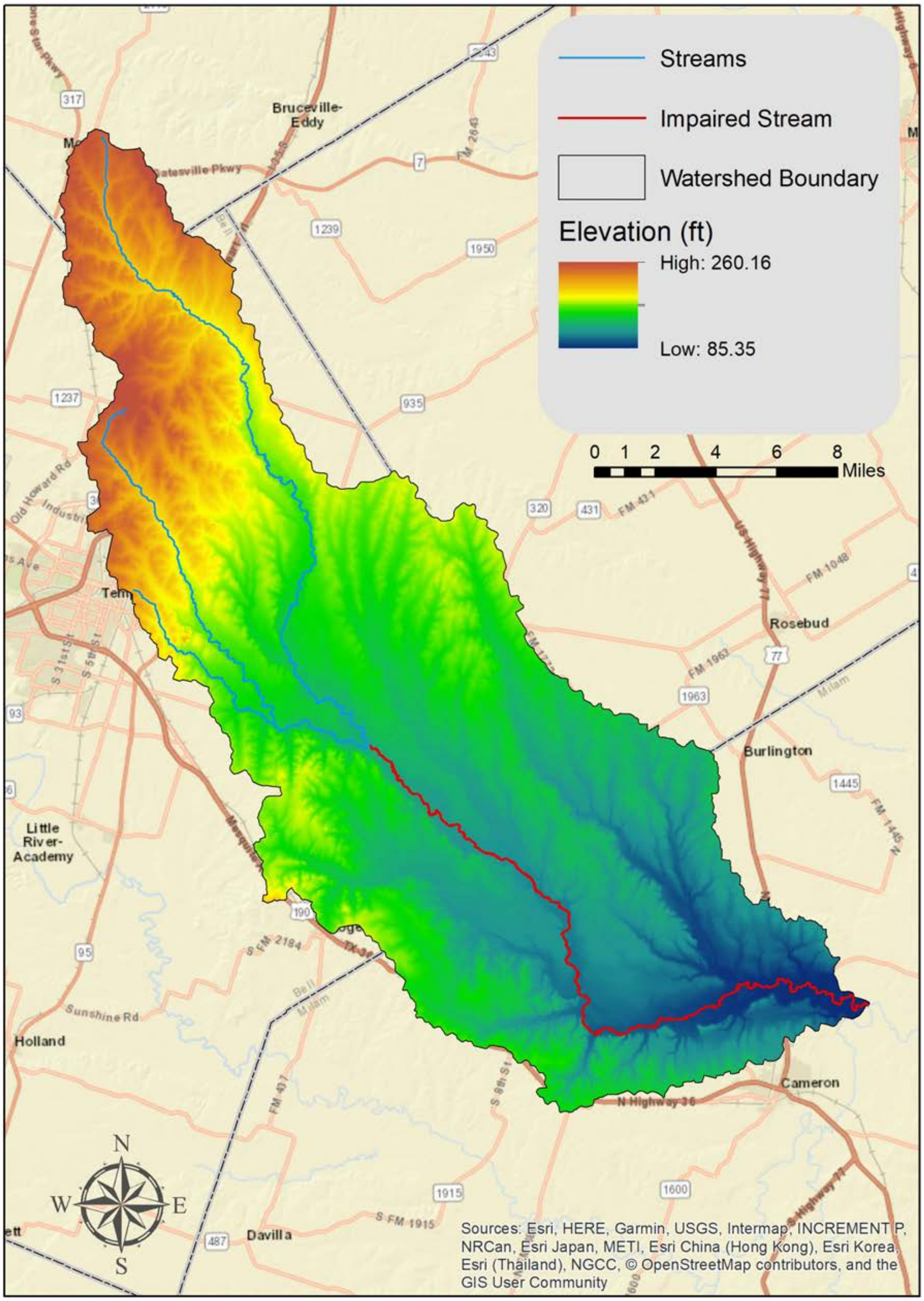


Figure 4. Big Elm Creek watershed elevation.

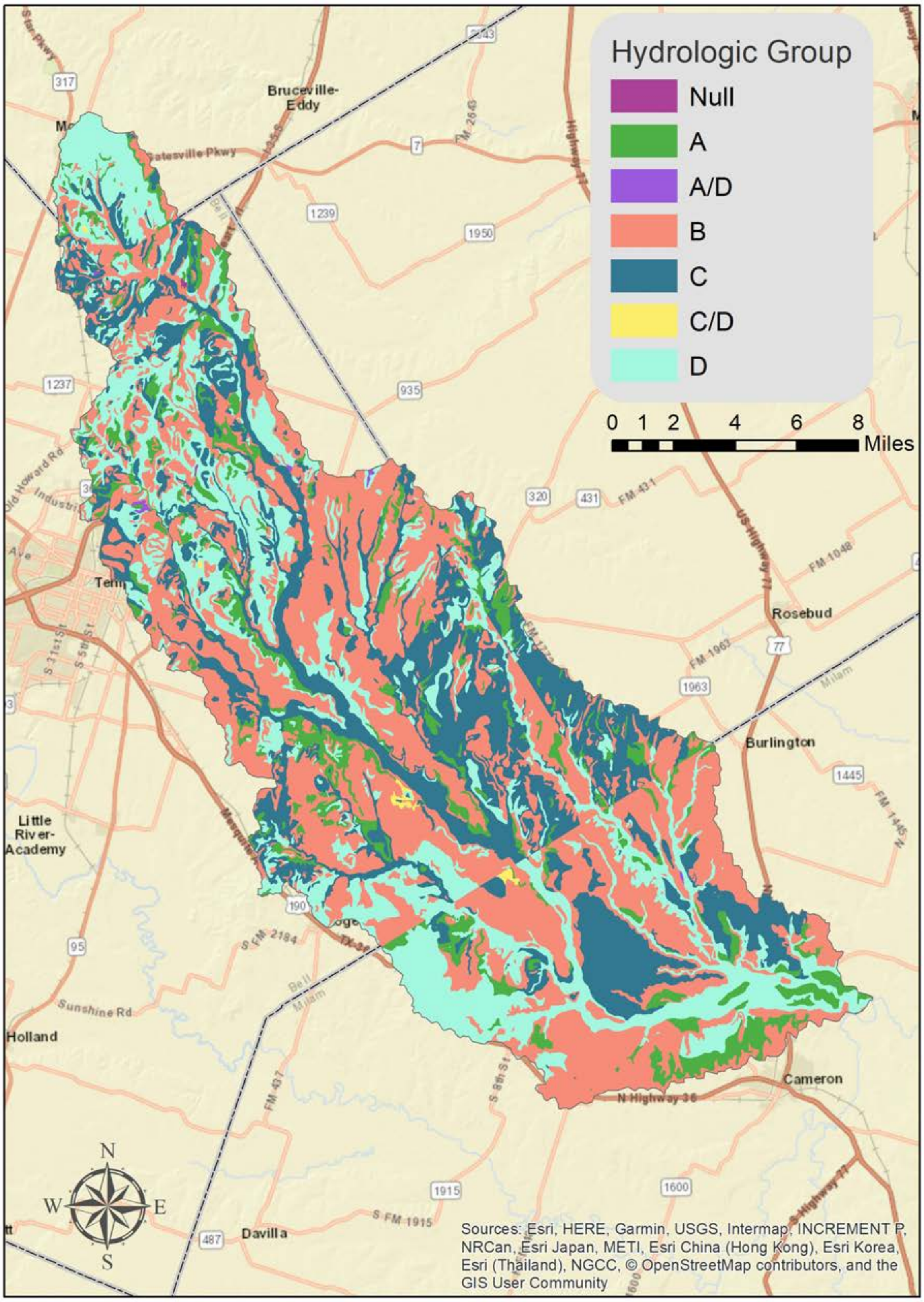


Figure 5. Big Elm Creek watershed hydrologic soil groups.

Table 3. Hydrologic soil groups and descriptions.

Hydrologic Soil Group	Description
Null	Not rated (not surveyed or water body)
A	Soils have a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
A/D	See below[1]
B	Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
B/D	See below[1]
C	Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
C/D	See below[1]
D	Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

[1]Per NRCS (USDA NRCS 2018a), "Certain wet soils are placed in Group D based solely on the presence of the water table within 60 centimeters [24 inches] of the surface, even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition. For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 60 centimeters [24 inches] below the surface in a soil where it would be higher in a natural state."

Climate

The Big Elm Creek watershed is located in the northeastern portion of the state of Texas and falls within the subtropical humid climate region as classified by Larkin and Bomar (1983). This regional climate is characterized as a modified marine climate including warm summers with the occasional invasion of drier, cooler continental airflow offsetting the prevailing flow of tropical maritime air from the Gulf of Mexico (Larkin and Bomar 1983). Monthly normal precipitation, from the McGregor, TX USC00415757 weather station located approximately 9 miles north of AU 1213A, indicate the watershed's mean annual rainfall from 1981-2010 was 35.87 inches (Arguez et al. 2010).

As depicted in Figure 6, for the period from 1981 – 2010 at the nearest National Oceanic and Atmospheric Administration (NOAA) weather station (McGregor TX - USC00415757; Figure 6), average high temperatures generally peak in August (95.3°F) with average monthly lows ranging from 69.3°F (June) to 72.1°F (August) during the summer months (NOAA 2018). During the winter, the average low temperature generally bottoms out at 34.2°F in January. Additionally, May (4.38 inches) is indicated to be the wettest month with July (1.99 inches) observed to be the driest month. Average annual precipitation values across the study area from the PRISM Climate Group at Oregon State (PRISM Climate Group 2016) indicate average annual rainfall ranges from 34 to 36 inches per year across the watershed (Figure 7).

Demographics

As of 2010, the Big Elm Creek watershed population was approximately 20,566, with a population density of 64 people per square mile (USCB 2011). However, the majority of the population is congregated near the city of Temple (Figure 8). Population projections by the Office of the State Demographer and the Texas Water Development Board (TWDB) for counties in the watershed are provided in Table 4 (TWDB 2017). From 2010 to 2070 the population of Bell County is expected increase by approximately 122%, Falls County is expected to increase by approximately 20%, McLennan County is expected to increase by approximately 46%, and Milam County is expected to increase by approximately 32%.

Table 4. Population projections in the Big Elm Creek watershed.

Group	Population by Year							Percent Increase
	2010	2020	2030	2040	2050	2060	2070	
Bell County	17,832	21,452	25,073	28,693	32,313	35,993	39,553	121.8%
Falls County	138	142	147	151	156	160	165	19.6%
McLennan County	1,193	1,285	1,376	1,467	1,558	1,650	1,741	45.9%
Milam County	1,403	1,477	1,551	1,626	1,700	1,774	1,849	31.8%
Total	20,566	24,357	28,147	31,937	35,727	39,518	43,308	110.6%

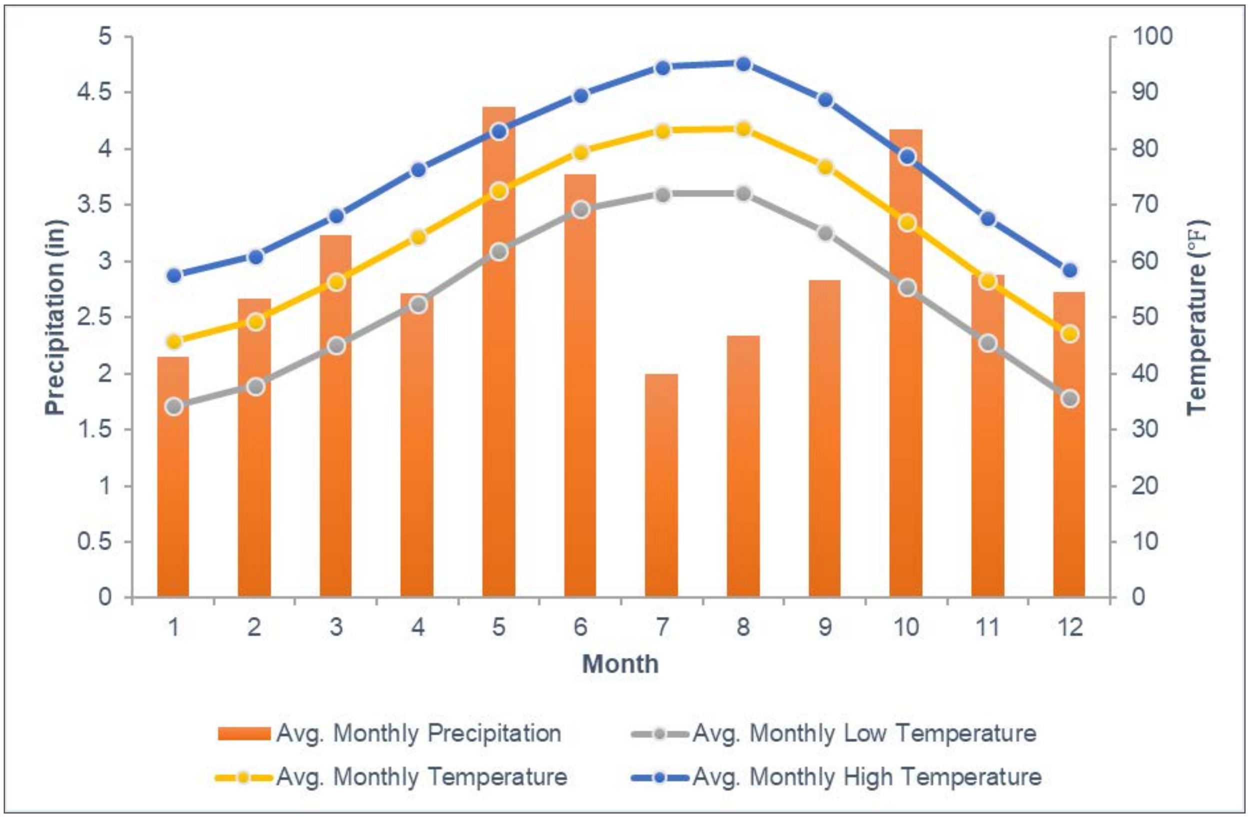


Figure 6. Watershed normal monthly precipitation by month and normal average, maximum, and minimum air temperature by month from 1981-2010.

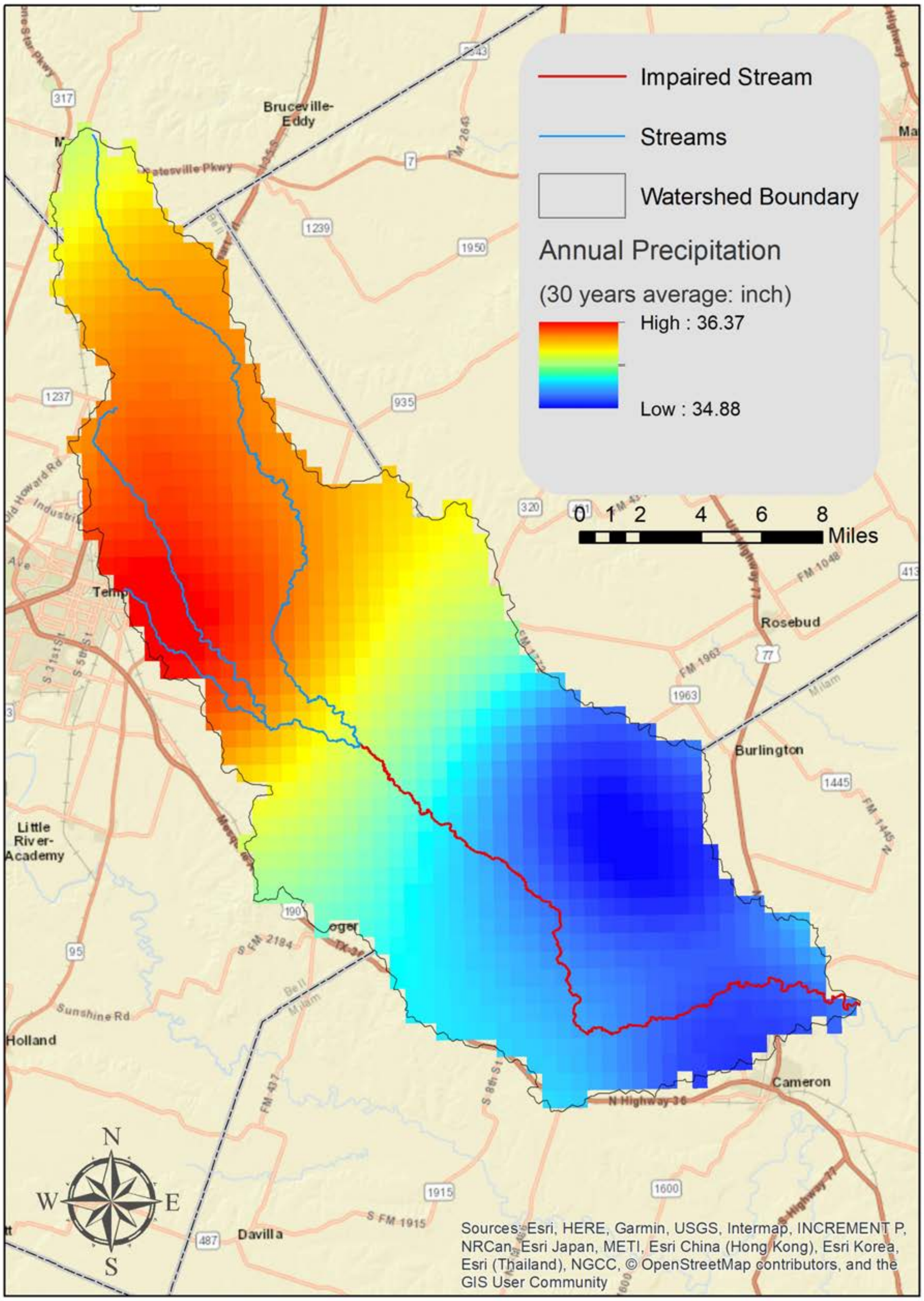


Figure 7. 30-year normal precipitation values in the Big Elm Creek watershed.

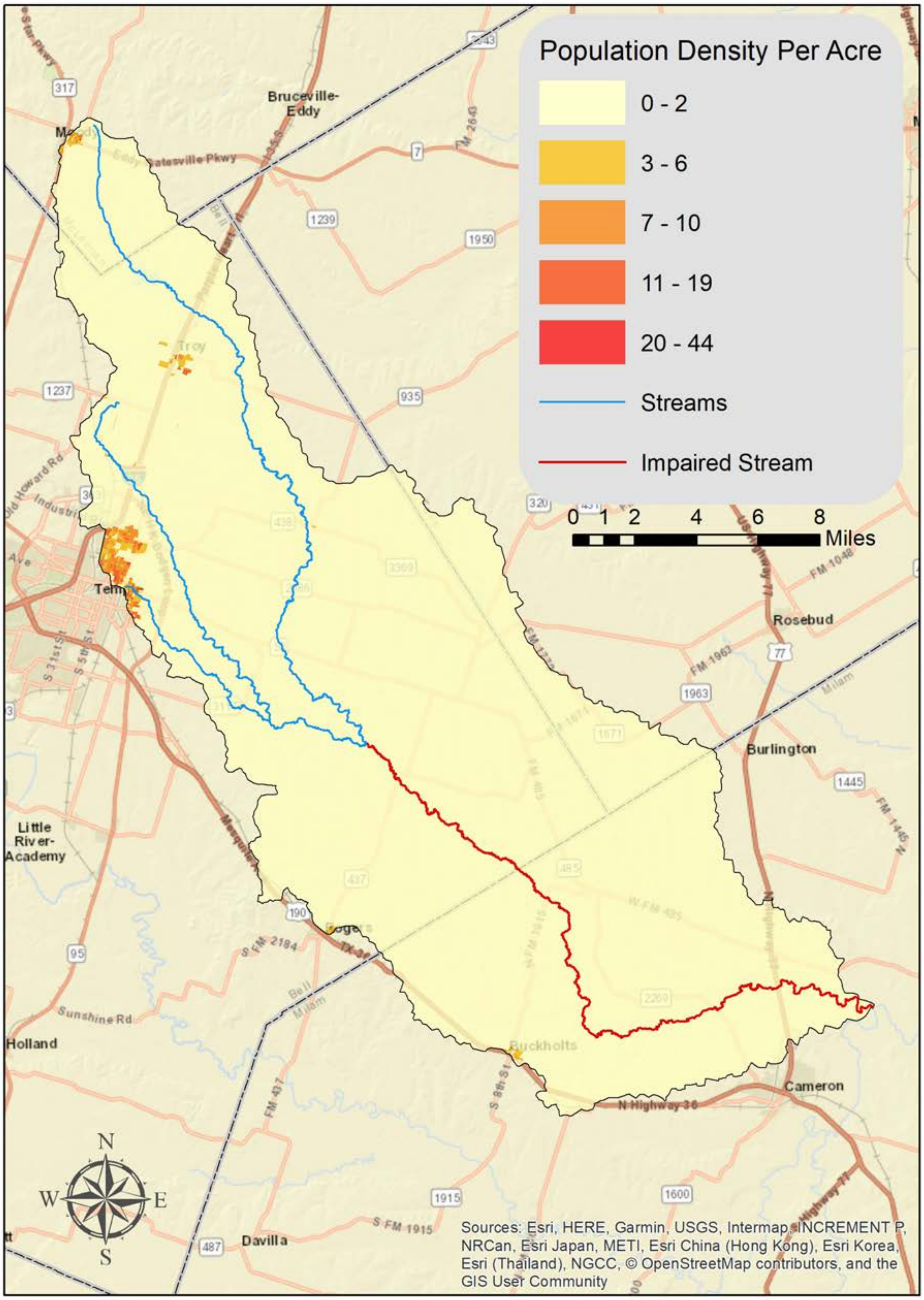


Figure 8. Big Elm Creek population density.

Table 5. Estimated educational attainment and primary language by county in the Big Elm Creek watershed in 2016.

County	High School Diploma (%)	College Degree (%)	English Primary (%)	Non-English Primary (%)
Bell	84.7	33.5	94.7	5.3
Falls	70.4	17.6	93.1	6.9
McLennan	78.2	32.0	90.8	9.2
Milam	75.1	22.7	95.6	4.4

The majority of the population in the watershed have at least a high school education, and approximately 17-34% of the population have a college degree (Table 5; USCB 2016). The majority of residents speak English as a primary language, with less than 10 percent speaking a language other than English as their primary language. These demographics are highlighted because understanding unique and differing needs of target audiences within the watershed is critical to successful stakeholder engagement.

Other Water Sources

Groundwater

There are two major aquifers that are present within the watershed, the Carrizo-Wilcox and Trinity aquifers. The Carrizo-Wilcox aquifer makes up less than one percent of the watershed area, while the Trinity aquifer spans across approximately 81 percent of the watershed area (Figure 9). The Trinity aquifer extends through the majority of the central and northeastern portions of Texas. It averages about 1,900 feet of saturated thickness in Central Texas and 600 feet of saturated thickness in North Texas (TWDB 2018). Quality ranges from fresh in the east and south east to slightly to moderately saline with an increase in aquifer depth. The groundwater in the aquifer is also considered very hard in the outcrop, but not within the watershed itself. Some of the largest declines in water levels in the state of Texas, from 350 to over 1,000 feet, have occurred along IH-35 from Grayson County down to McLennan County, where the Big Elm Creek watershed begins. The water level declines can be attributed to municipal pumping which has led to a heavier reliance on surface water in the region.

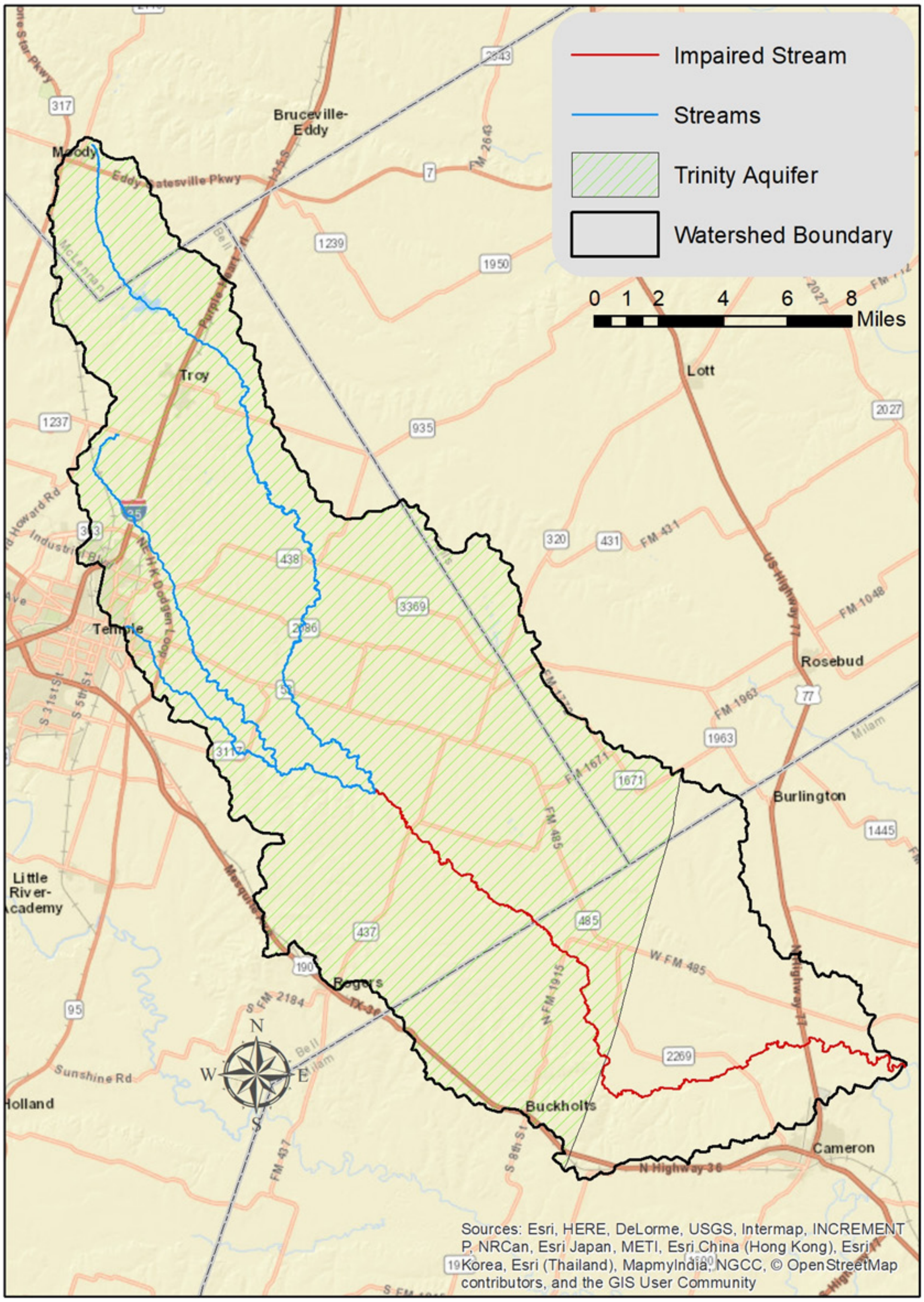
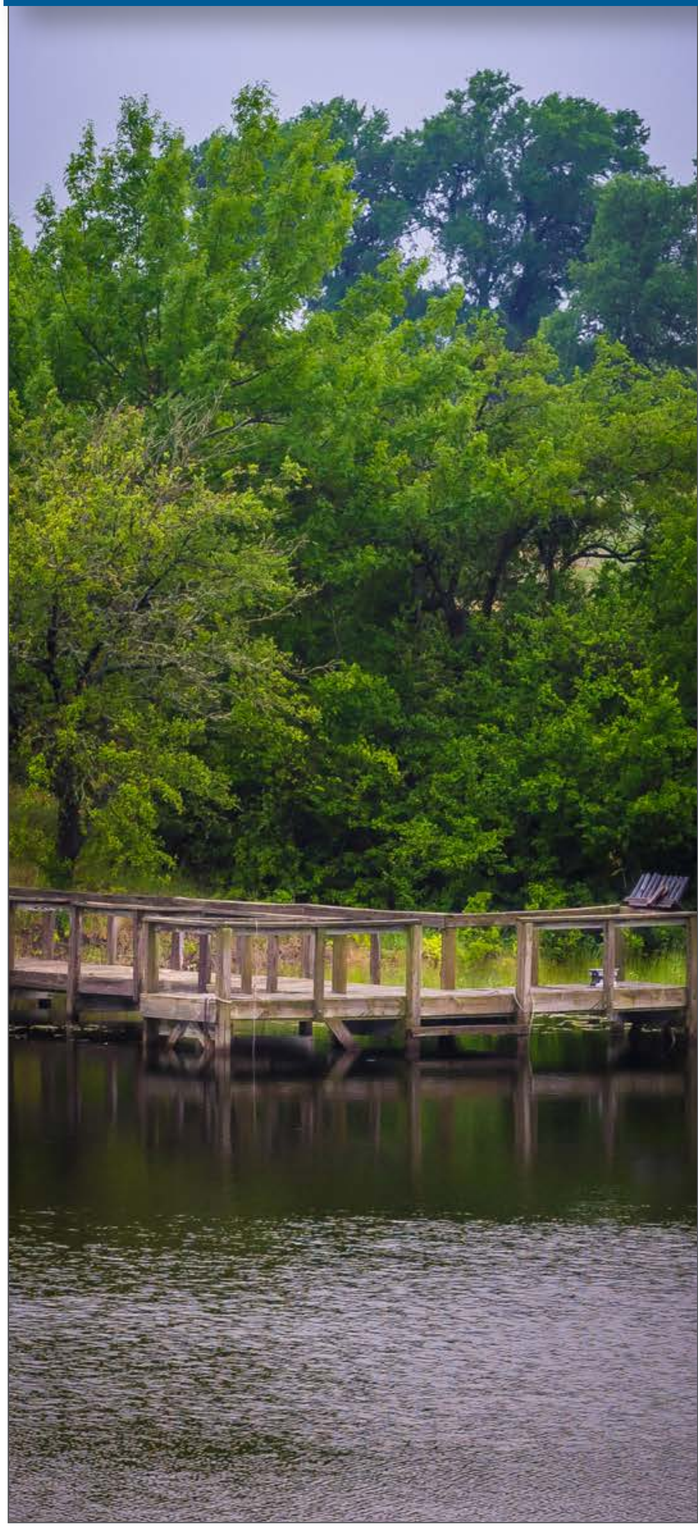


Figure 9. Trinity Aquifer in Big Elm Creek watershed. The Carrizo-Wilcox overlaps one-percent of the watershed in the southeast corner and is not visible at this scale.

Chapter 3
Water Quality



Farm pond in Milam County. Photo By Ed Rhodes, TWRI.

Introduction

Under the Federal Clean Water Act (CWA) section 303 (d) and 305 (b), the State of Texas is required to identify the water bodies that are unable to meet water quality standards for their designated uses. Texas Commission on Environmental Quality (TCEQ) assigns unique "segment" identifiers to each water body. Locations within a segment are broken up into hydrologically distinct assessment units (AUs). The AUs are evaluated every two years to determine if they meet designated water quality standards, and those that are not meeting requirements are listed on the *Texas Integrated Report for the Texas 303(d) List*: https://www.tceq.texas.gov/waterquality/assessment.

TCEQ defines the designated uses for all water bodies, which in turn establishes the water quality criteria to which a water body must adhere. Currently, all water bodies in the Big Elm Creek watershed must meet "primary contact recreation" uses and support aquatic life use. The water quality for recreation use is evaluated by measuring concentrations of fecal indicator bacteria in 100 milliliters (mL) of water. Aquatic life use is a measure of a water body's ability to support a healthy aquatic ecosystem. Aquatic life use is evaluated based on the dissolved oxygen (DO) concentration, toxic substance concentrations, ambient water and sediment toxicity, and indices of habitat, benthic macroinvertebrates and fish communities. General use water quality requirements also include measures of temperature, pH, chloride, sulfate, and total dissolved solids (TDS).

Data Acquisition

Water quality is monitored at designated sampling sites throughout the watershed (Figure 10). The TCEQ Surface Water Quality Monitoring Program (SWQM) coordinates the collection of water quality samples at specified water quality monitoring sites throughout the watershed and the state. Surface water quality data was initially collected by the Brazos River Authority in 1999 (excluding *E. coli*); however, regular, routine monitoring did not begin until 2004 when TCEQ began conducting quarterly sampling events at monitoring station 16385 (US Hwy 77, Figure 10) as part of the Clean Rivers Program (CRP), Additional data was briefly

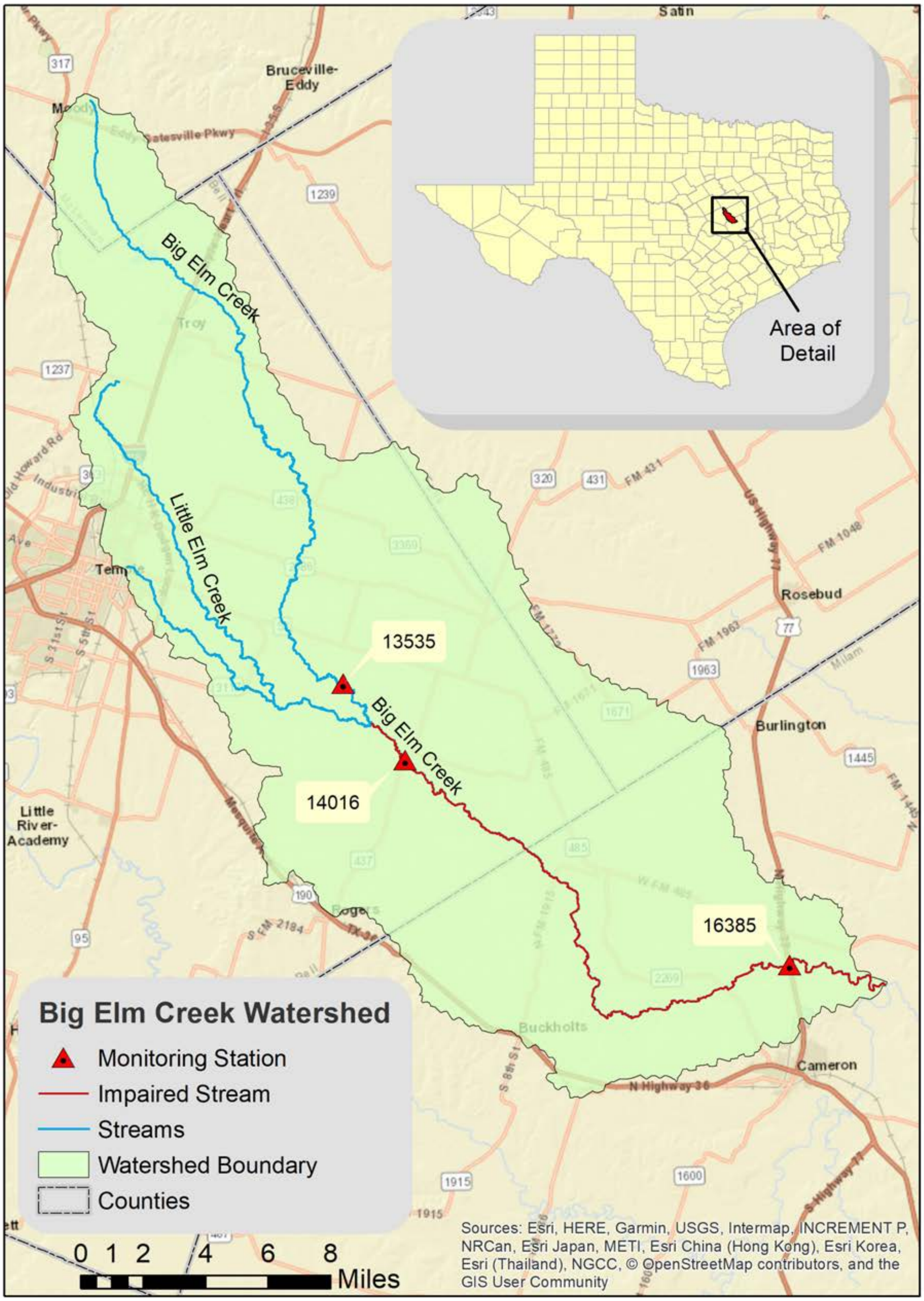


Figure 10. The Big Elm Creek watershed map with TCEQ impaired segments and SWQM stations.

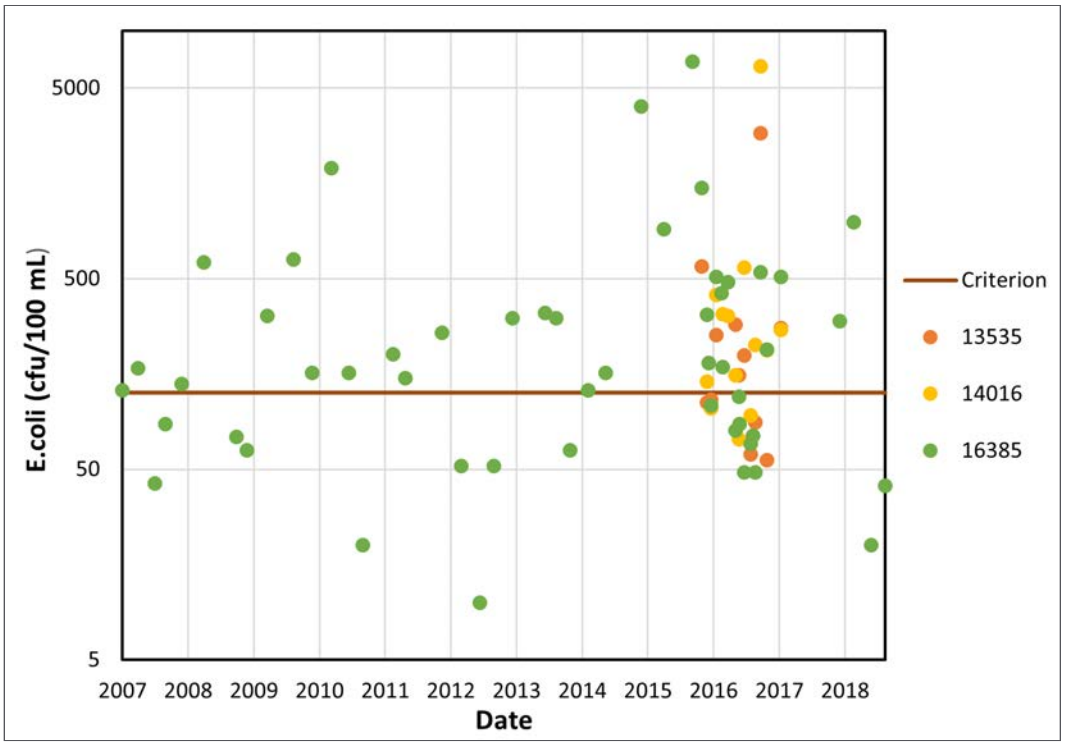


Figure 11. Historical *E. coli* data concentrations at monitored stations in the Big Elm Creek watershed. The solid line indicates 126 cfu/100ml criterion.

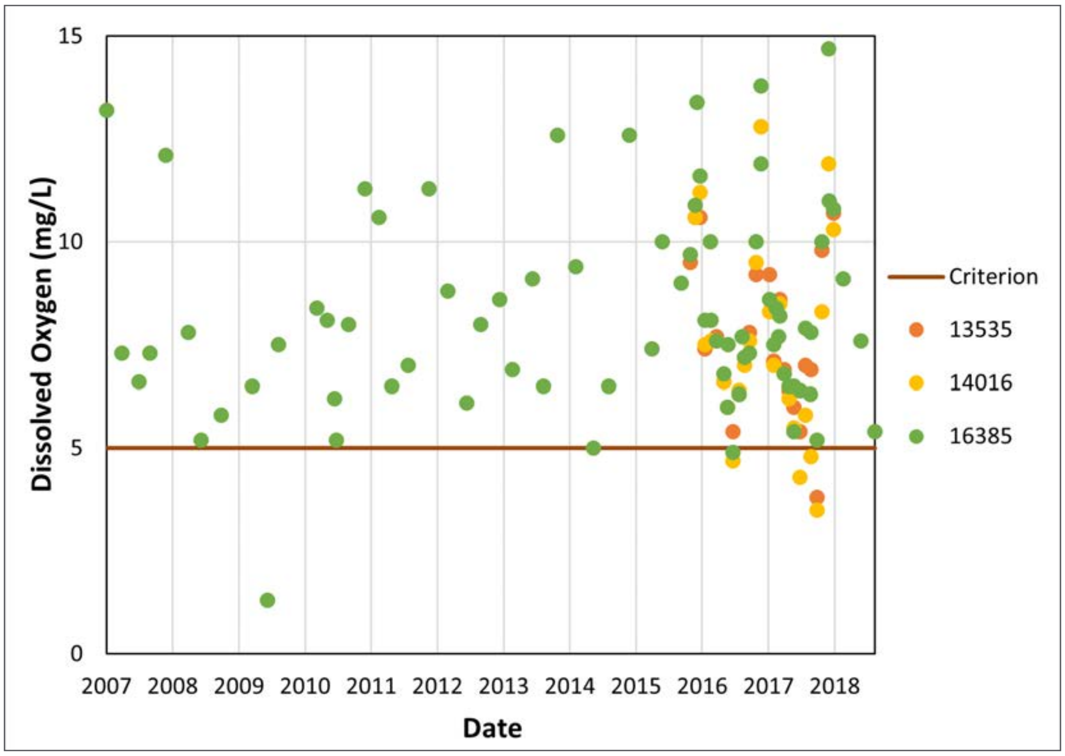


Figure 12. Historical dissolved oxygen concentrations at monitored segments in the Big Elm Creek watershed. The solid line indicates 5.0 mg/L criterion.

Table 6. Results of TWRI monthly water quality monitoring from December 2015 through February 2018.

Stations	Description	Current Standard	Samples	Geomean	Supporting/Not Supporting
13535	Big Elm Creek at Seaton Rd	126cfu/100 mL *E. coli*	22	179.93	Not Supporting
14016	Big Elm Creek at FM 437	126cfu/100 ml *E. coli*	26	244.31	Not Supporting
16385	Big Elm Creek at US 77	126cfu/100 ml *E. coli*	27	144.09	Not Supporting
Total			**75**	**184.50**	

collected by the Texas Institute for Applied Environmental Research in 2010.

The Texas Water Resources Institute (TWRI) collected supplemental routine monthly water quality monitoring data as part of a watershed characterization project from December 2015 through February 2018, at three locations within the watershed: the aforementioned station 16385, as well as stations 14016 and 13535 (Figure 10). The monthly (rather than quarterly) revisit time was intended to provide a more robust dataset on water quality under a greater variety of flow and climatic conditions. Sites 14016 and 13535 were strategically placed above and below the confluence of Little Elm Creek and Big Elm Creek to provide data from within and outside of the impaired segment and to capture the contributions of Little Elm Creek to the overall water quality in Big Elm Creek (Figure 10). All water quality data used in this chapter to discuss historical water quality conditions were retrieved from the SWQM database.

Bacteria

The concentrations of fecal indicator bacteria are evaluated to assess the risk of illness during contact recreation. In freshwater environments, concentrations of *E. coli* bacteria are measured to evaluate the presence of fecal contamination in water bodies from warm-blooded animals and other sources. The presence of these fecal indicator bacteria may indicate that associated pathogens from the intestinal tracts of warm-blooded animals could be reaching water bodies and can cause illness in people who recreate in them. Indicator bacteria can originate from numerous sources, including wildlife, domestic livestock, pets, malfunctioning OSSFs, urban and agricultural runoff, sewage system overflows, and direct discharges from wastewater treatment plants (WWTPs).

Currently, all water bodies in Big Elm Creek are assessed under the primary contact recreation standards, which is 126 cfu of *E. coli*/100 mL in freshwater. *E. coli* concentrations are measured at three stations throughout the watershed (Figure 10; Table 6). Figure 11 illustrates historical *E. coli* concentrations since 2007. Most of the data points have exceeded the criterion of 126 cfu/100 mL indicating issues with bacteria. The reductions needed to meet water quality standards are further discussed in upcoming chapters.

Results of TWRI watershed characterization water quality monitoring are shown in Table 6. Efforts were made to sample each site monthly from December 2015 through February 2018. Not every site has the same total number of samples because of inaccessibility of some sites during unsafe or impractical environmental conditions.

Dissolved Oxygen

Dissolved Oxygen (DO) is the main parameter used to determine a water body's ability to support and maintain aquatic life uses. Low levels of DO may limit the amount and types of aquatic species found in a water body. When DO levels fall too low, fish and other organisms may begin to die off. Oxygen is dissolved into water through simple diffusion from the atmosphere, aeration of water as it flows over surfaces, and aquatic plant photosynthesis. Typically, DO levels fluctuate throughout the day, with the highest levels of DO occurring in mid to late afternoon, due to plant photosynthesis. DO levels are typically lowest just before dawn as both plants and other organisms in the water consume oxygen through respiration. Furthermore, seasonal fluctuations in DO are common because of decreased oxygen solubility in water as temperature increases; therefore, it is common to see lower DO levels during the summer.

While DO can fluctuate naturally, human activities can also cause abnormally low DO levels. Excessive organic matter (vegetative material, untreated wastewater, etc.) can result in depressed DO levels as bacteria break down the material and subsequently consume oxygen. Excessive nutrients from fertilizers and manure can also depress DO as aquatic plant and algae growth increase in response to nutrients. The increased respiration from plants and decay of organic matter as plants die off can also drive down DO concentrations.

Figure 12 illustrates historical dissolved oxygen concentrations since 2007. Overall, grab samples indicate DO in monitored segments, with adequate data, are generally well above the 5.0 mg/L minimum across the watershed, indicating no issues with DO.

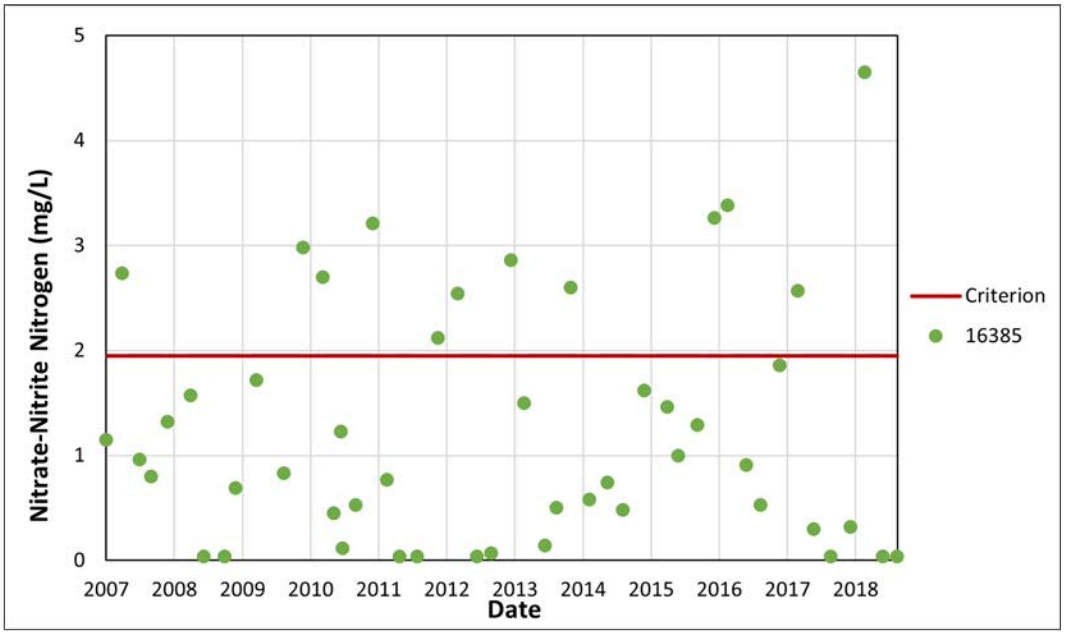


Figure 13. Nitrate-Nitrite Nitrogen concentration at monitored segment 1213A in the Big Elm Creek watershed since 2007. The graph represents nitrite and nitrate value measured at station 16385 only. The solid line indicates 1.95 mg/L criterion.

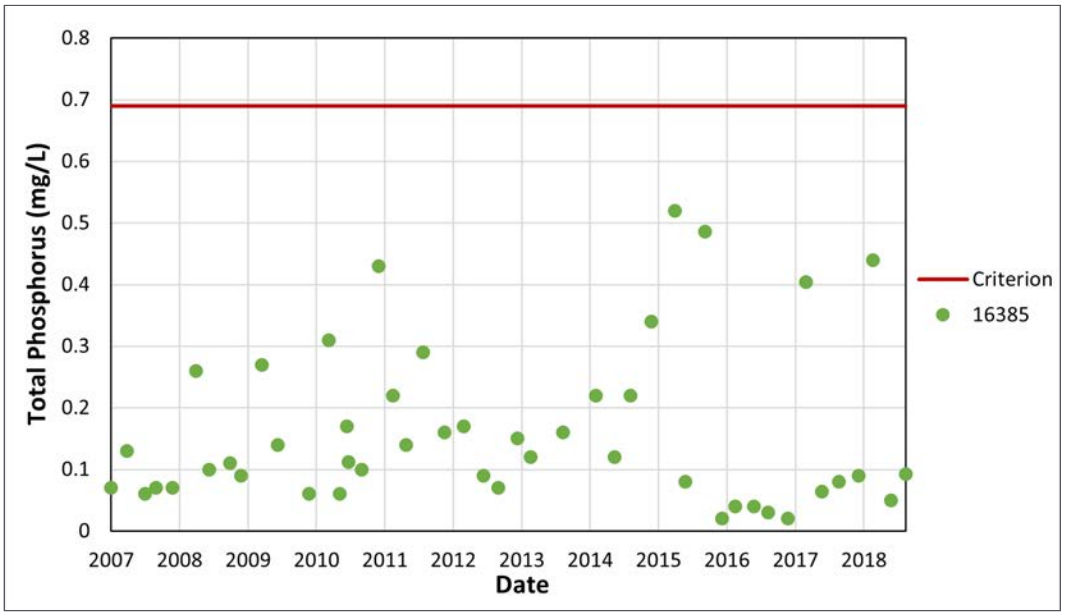


Figure 14. Total phosphorus concentrations at monitored segment 1213A in the Big Elm Creek watershed since 2007. The graph represents total phosphorus value measured at station 16385 only. The solid line indicates 0.69 mg/L criterion.

Nutrients

Nitrogen and phosphorus are primary nutrients required by aquatic plants and algae to grow. However, excessive nutrients can lead to plant and algale (chlorophyll a) blooms that can result in reduced DO levels, green scum, and foul odors in the waterbody. Some algae can produce toxins that could pose health concerns to the public and to wildlife (EPA 2020; TPWD 2020). High levels of nitrates and nitrites can directly impact respiration in fish. Potential discharge from WWTPs, agricultural runoff from cropland and urban runoff from lawns are common sources of fertilizer and nutrient loadings in watersheds. Nutrients also bind to soil and sediment particles. Therefore, runoff and erosion events that result in heavy loads of sediment can also increase nutrient levels in water bodies.

Currently, TCEQ does not have approved numeric criteria for nutrients in water bodies. Screening levels provided by TCEQ are used as a preliminary indication of possible concerns. Screening levels are set at the 85th percentile for parameters from similar waterbodies. If more than 20% of samples from a waterbody exceed the screening level, that water body is on average experiencing pollutant concentrations higher than 85% of the streams in Texas and is therefore considered to have an elevated nutrient concentration concern. Current screening levels in freshwater streams for nitrate is 1.95 mg/L and 0.69mg/L for total phosphorous (Figures 13 and 14). Currently, 24.5% of the Nitrate-Nitrite data are above the screening level (Figure 13), indicating a slight concern in the watershed. All phosphorus data going back to 2007 are well below the screening level (Figure 14), suggesting that there is currently no concern in the watershed regarding phosphorus. Plots are based on the data available on the SWQM website. The data points for phosphorus and nitrate levels are only available for station #16385 (the most downstream site).

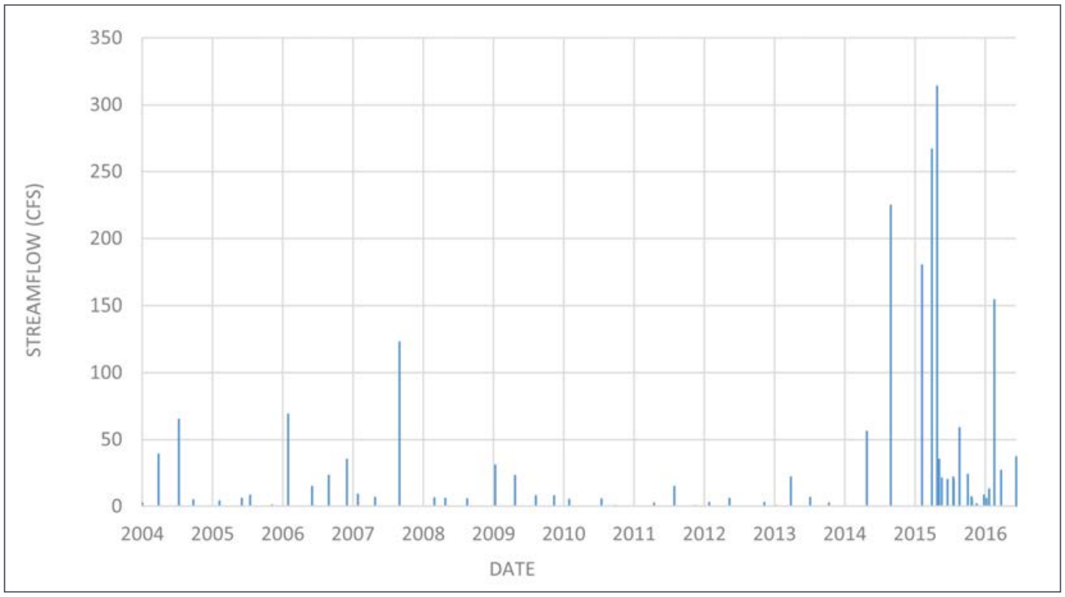


Figure 15. Historical streamflow data on monitored segment 1213A in the Big Elm Creek watershed.

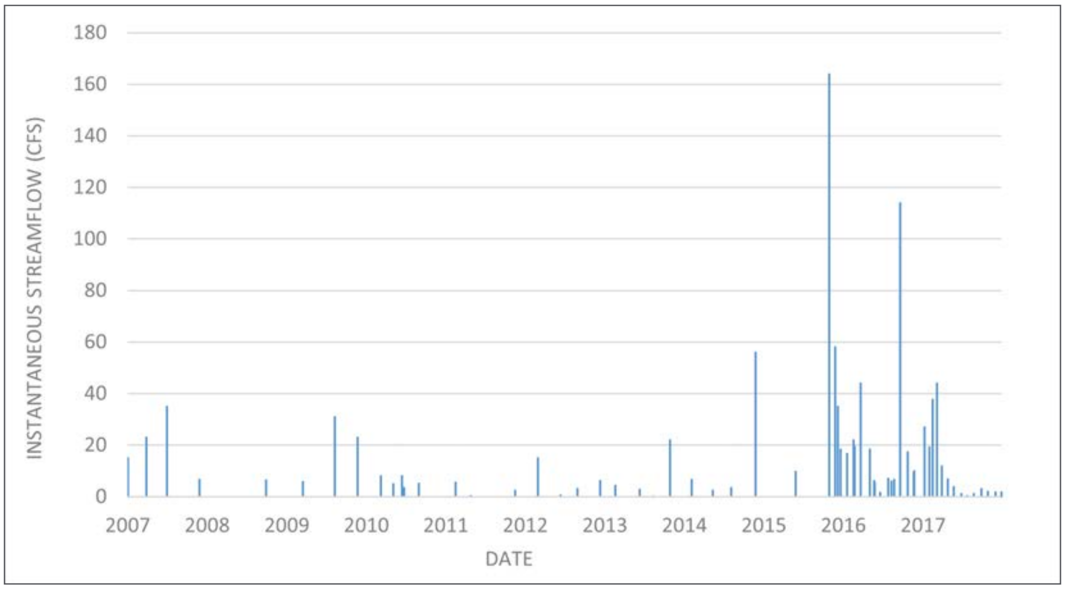


Figure 16. Instantaneous streamflow records at segment 1213A.

Flow

Streamflow varies with natural events like precipitation and anthropogenic events such as land cover changes. From a water quality perspective, streamflow is important because it influences the ability of a water body to assimilate pollutants.

The Station 16385 at US Highway (Hwy) 77 has a USGS stream flow gage, however, data from that gauge is only recorded on high flow conditions. Therefore, the streamflow data graphed below are the average values of each assessment station retrieved from the SWQM website. Figure 15 and 16 illustrates yearly streamflow and instantaneous streamflow of the Big Elm Creek watershed.

Potential Sources of Water Quality Issues

Nonpoint Sources

Nonpoint source pollution occurs when precipitation flows off the land, roads, buildings and other landscape features and carries pollutants into drainage ditches, lakes, rivers, wetlands, coastal waters and underground water resources. Nonpoint source pollution includes but is not limited to polluted runoff water from leaking or improperly functioning on-site sewage facilities (OSSFs), livestock, wildlife, domestic pets, fertilizers, herbicides, pesticides, oil, grease, toxic chemicals, sediment, bacteria, nutrients, and many other substances.

Table 7. Estimated watershed livestock populations.

Livestock	Estimated Watershed Population	Estimated Animal Units (1,000 lbs. of animal)
Cattle	11,799	11,799
Horses	942	1,130
Goats	2,990	514

Table 8. Estimated watershed wildlife populations.

Wildlife	Estimated Watershed Population	Estimated Animal Units (1,000 lbs. of animal)
Feral Hogs	14,527	712
Whitetail Deer	7,103	795

Domestic Livestock

Domestic livestock operations, particularly cattle, are common throughout the watershed. Runoff from rain events can transport fecal matter containing bacteria and nutrients from pastures and rangeland into nearby creeks and streams. Livestock with direct access to streams can also wade and defecate directly into water bodies resulting in direct contributions of bacteria to the water. Streamside riparian buffers, fencing, and grazing practices that reduce the time livestock spend near streams can reduce livestock impacts on water quality.

Because watershed-level livestock numbers are not available, populations were estimated using the USDA NASS and USGS NLCD datasets. Specifically, cattle were estimated using locally derived stocking rates of 1 animal unit per 6 acres of improved land (identified as pasture in the NLCD dataset), and 1 animal unit per 10 acres of unimproved land (identified as forest, shrub/scrub, herbaceous/grassland in the NLCD dataset). Based on these assumptions, there are an estimated 11,799 animal units of cattle in the watershed (Table 7).

For other types of livestock, we estimated population for each county using the USDA NASS dataset. The county-level data were multiplied by a ratio based on the acres of grazeable land divided by the total number of acres in the county. Then, the proportion of grazeable acres in the watershed within each county was used to estimate the number of cattle from each county that occur in the watershed. These assumptions resulted in estimates of 942 horses and 2,990 goats in the watershed. Other type of livestock occurred infrequently in the county NASS data and are not considered likely sources of bacteria.

Wildlife and Feral Hogs

Wildlife is naturally attracted to riparian corridors of streams and rivers and are a common source of *E. coli* and nutrients. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria and nutrient loading to a water body. Fecal bacteria from wildlife is also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. While a number of bird and mammal species are likely to contribute bacteria loads in area waterways, feral hogs and whitetail deer are the only species with reasonable density and population estimates.

A population estimate for feral hogs was derived using a density rate of 13 acres (ac)/hog based on studies in the Copano Bay watershed (Wagner and Moench 2009). Applied to the total acreage of hay/pasture, cultivated crops, shrub/scrub, herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands, and emergent herbaceous wetlands identified in 2011 NLCD data; there are an estimated 14,527 feral hogs in the watershed (Table 8).

The Texas Parks and Wildlife Department (TPWD) conducts deer population surveys within the state of Texas at the resource management unit (RMU) level. RMUs are developed based on similar ecological characteristics within a defined area. The Big Elm Creek watershed, which falls in the Cross Timbers and Prairies (RMU 20) and Blackland Prairie (RMU 23) areas, had an average deer density of 1 deer per 26.7 acres from 2005-2015. Applied to the same total acreage as the feral hogs, we estimated 7,103 deer in Big Elm Creek (Table 8).

Domestic Pets

Fecal matter from dogs and cats can contribute to bacterial and nutrient loads in the watershed when not disposed of properly. In rural areas, such as a large portion of the Big Elm Creek watershed, pets often spend much of their time roaming around outdoors, making proper disposal impractical. The American Veterinary Medical Association estimates there are approximately 0.584 dogs and 0.638 cats per home across the United States (AVMA 2012). Multiplying these ratios with the number of households (8,407) in the watershed suggests there are approximately 4,910 dogs and 5,364 cats across the watershed.

On-Site Sewage Facilities

Given the rural nature of the majority of the watershed, many homes are not connected to centralized sewage treatment facilities and therefore use on-site sewage facilities (OSSFs). Typical OSSF designs include either (1) anaerobic systems composed of septic tank(s) and an associated drainage or distribution field, or (2) aerobic systems with aerated holding tanks and typically an above ground sprinkler system to distribute the effluent. Failing or undersized OSSFs will contribute direct bacterial and nutrient loads as the effluent from the systems move through or over the ground into adjacent water bodies.

The USDA NRCS SSURGO database provides suitability ratings for septic tank absorption fields based on soil properties, depth to bedrock or groundwater, hydraulic conductivity, and other properties that may impact the absorption of on-site sewage effluent, installation, and maintenance. The Big Elm Creek watershed is overwhelmingly rated as "Very Limited" or "Somewhat Limited" for septic suitability indicating that most soils in the watershed are unfavorable for traditional OSSF use and poor performance and high amounts of maintenance for traditional systems can be expected (Figure 17).

Based on visually-validated county 911 data and areas of existing wastewater service, an estimated 2,439 OSSFs may occur in the watershed (Borel et al. 2012; Gregory et al. 2014). The highest densities of OSSFs appear in the upper portions of the watershed just outside existing service areas (Figure 18).

Although most well maintained OSSFs are likely to function properly, failing OSSFs can leak or discharge untreated waste onto distribution fields. Runoff generated during storm events can transport this waste overland and into nearby water bodies. Untreated OSSF effluent can contribute to levels of indicator bacteria, dissolved oxygen, nutrients, and other water quality parameters.

Point Sources

Point source pollution is any type of pollution that can be traced back to a single point of origin, such as a wastewater treatment plant (WWTP). Generally, WWTP discharges are permitted, which means they are regulated by permits under the Texas Pollutant Discharge Elimination System (TPDES). Other permitted discharges include industrial or construction site stormwater discharges, and discharges from municipal separate storm sewer systems (MS4) of regulated cities or agencies. Within the project watershed, these sources include WWTPs and regulated stormwater from one MS4, 10 industrial sites, and 11 construction sites.

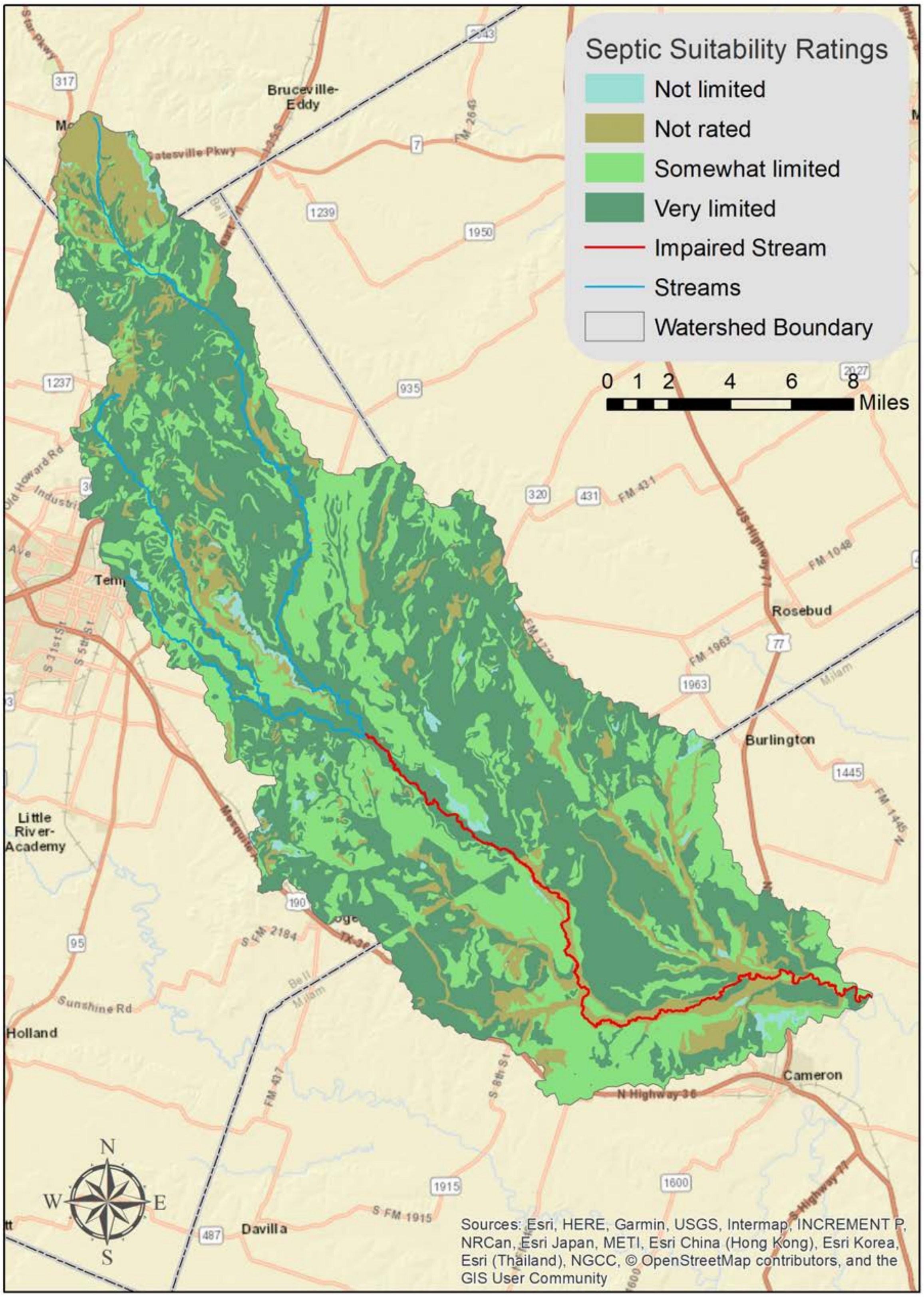


Figure 17. Septic suitability map.

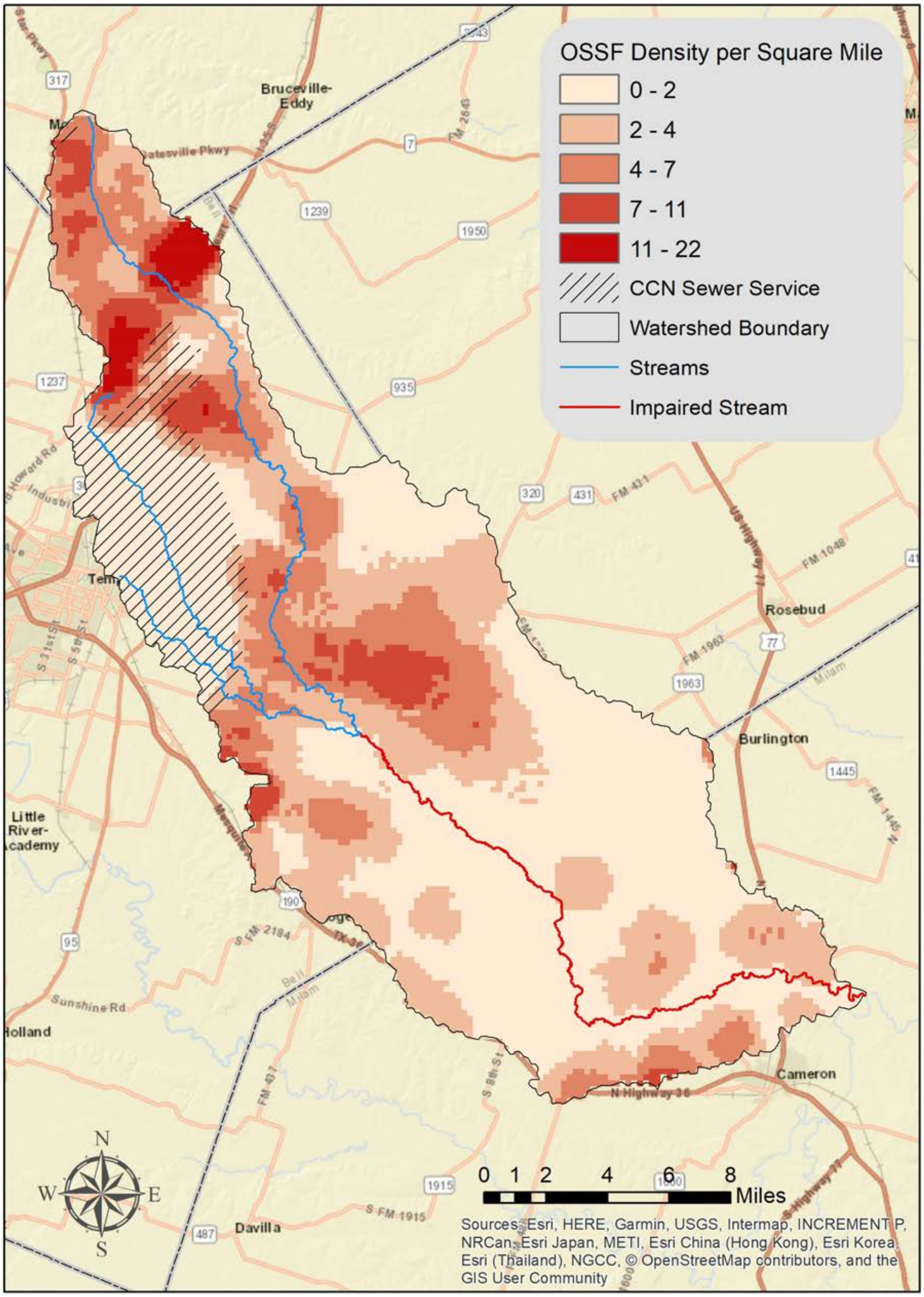


Figure 18. OSSF density and sewer service map.

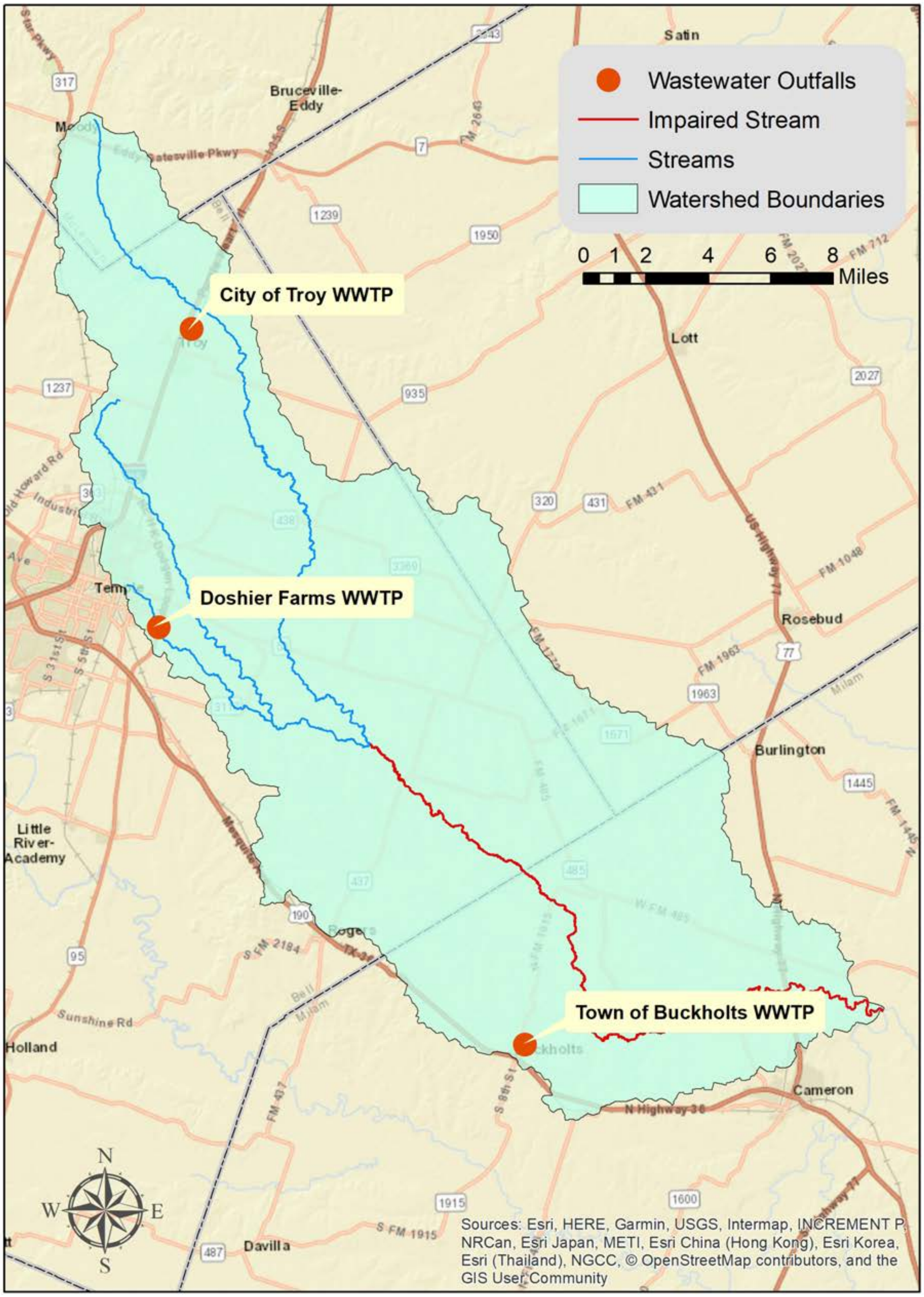


Figure 19. Active permitted wastewater discharge outfall locations.

Table 9. Permitted wastewater treatment plants in the Big Elm Creek watershed.

Facility Name	Receiving Stream	Flow (MGD)		Bacteria (cfu/100 mL)		Number of Quarters in Violation for Exceedance from 04/2015- 3/2018
		Permitted	Reported (3-year avg.)	Permit-ted (Daily Average)	Reported (3-year avg.)	
City of Troy	Kings Branch (1213A_02)	126cfu/100 mL *E. coli*		22	179.93	0
Doshier Farm	Unnamed tributary; Little Elm Creek (1213C_01)	7.50	*1.69*	*126*	3.01	0
Town of Buckholts	Lipan Creek (1213A_01)	*0.1000*	*0.0295*	126	1.08	4 (4 single grab *E. coli*)

Table 10. Final permitted discharges and recent discharge of permitted wastewater treatment plants in the Big Elm Creek watershed.

TPDES Permit No.	Facility	AU	Receiving Waters	Final Permitted Discharge (MGD)	Recent Discharge (MGD)
WQ0011263001	City of Troy WWTP	1213A_02	Kings Branch, Big Elm Creek, Little River	0.3090 (daily avg)	0.1215
WQ0010470002	Doshier Farm WWTP	1213C_01	Unnamed tributary; Little Elm Creek	7.50 (daily avg)	2.21
WQ0011875001	Town of Buckholts WWTP	1213A_01	Lipan Creek	0.1000 (daily avg)	0.0233

Table 11. Land area covered by stormwater permits in the watershed as of June 7, 2018.

AU	MS4 Permits (number)	MS4 Permits (acres)	Industrial General Permits (number)	Industrial General Permit (acres)	Construction Permits (number)	Construction Permits (acres)	Total Area of Permits (acres)
1213A	1	3,076.3	10	664.9	11	429.2	4,170.4

Table 12. Summary of potential bacteria sources contributing to Big Elm Creek watershed impairments.

Pollutant Source	Pollutant Type	Potential Cause	Potential Impact
Livestock	Bacteria, nutrients	• Runoff from pastures • Overgrazing • Manure transport to streams • Direct deposition into streams	Fecal material and bacteria directly deposited into stream or through runoff
Feral Hogs	Bacteria, nutrients	• Manure transport to streams • Direct deposition into streams • Riparian degradation	Fecal material and bacteria directly deposited into stream or through runoff
OSSFs	Bacteria, nutrients	• System failure • Improper design	Insufficiently or untreated water runoff to streams
Domestic Pets	Bacteria, nutrients	• Increased runoff from impervious surface • Improper disposal of pet waste	Increased velocity and volume of stormwater quickly transport bacteria laden water to streams
Permitted discharges/SSOs	Bacteria, nutrients	• Inflow and infiltration • Overloaded or aging infrastructure	Untreated waste enters water body

Permitted Wastewater Discharges

WWTPs treat municipal wastewater before discharging the treated effluent into a water body. WWTPs are required to test and report the levels of indicator bacteria and nutrients as a condition of their discharge permits. Plants that exceed their permitted levels may require infrastructure or process improvements in order to meet the permitted discharge requirements.

As of June 7, 2018, there are three facilities with TPDES/NPDES permits operating within the Big Elm Creek watershed, the City of Troy WWTP, the City of Temple Doshier Farm WWTP, and the Town of Buckholts WWTP (Figure 19). The City of Troy WWTP treats wastewater and discharges into Kings Branch (AU 1213A_02). The Doshier Farm WWTP treats domestic wastewater and discharges into an unnamed tributary and Little Elm Creek (AU 1213C_01). The Town of Buckholts WWTP treats wastewater and discharges directly into Lipan Creek (AU 1213A_01). Discharge for all three facilities is measured in millions of gallons per day (MGD; Tables 9 and 10).

Unauthorized Discharges

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 sewer 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 WWTP system. Blockages in the line may exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition. These overflows and spills can reach water bodies, resulting in significant bacterial and nutrient loading.

The TCEQ Region 9 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. A search of the database revealed that number discharges have been reported for the reporting period of January 2016 thru December 2018 (unpublished data file available upon request from TCEQ). Doshier Farm WWTP had reported discharges on 1/24/2017, 4/11/2017 and 4/27/2017 (Table 9). Troy and Buckholts had zero reported in that timeframe.

Permitted Stormwater Discharges

Although stormwater is generally considered a nonpoint source, stormwater is subject to regulation if it originates from a regulated MS4 or is associated with industrial and/or construction activities. MS4 permits refer to the permitting of municipal stormwater systems that are separate from sanitary sewer systems. They are broken down into "large" Phase I and "small" Phase II system permits based on population. The project watershed contains one Phase II MS4 permit for the City of Temple. Under this permit, Temple has developed a storm water management plan (SWMP) that includes:

- maintaining the storm drainage systems;
- inspecting industrial and construction sites;
- performing stormwater sampling;
- investigating suspicious discharges; and
- public outreach and education.

The MS4 permit for the city of Temple covers the area within the city of Temple limits that is located in the Temple urbanized area. The number of acres covered by this permit were estimated for the watershed (Table 11). More information on the city of Temple's SWMP can be found at: https://www.templetx.gov/departments/city_departments/public_works/drainage/storm_water_management_program/index.php.

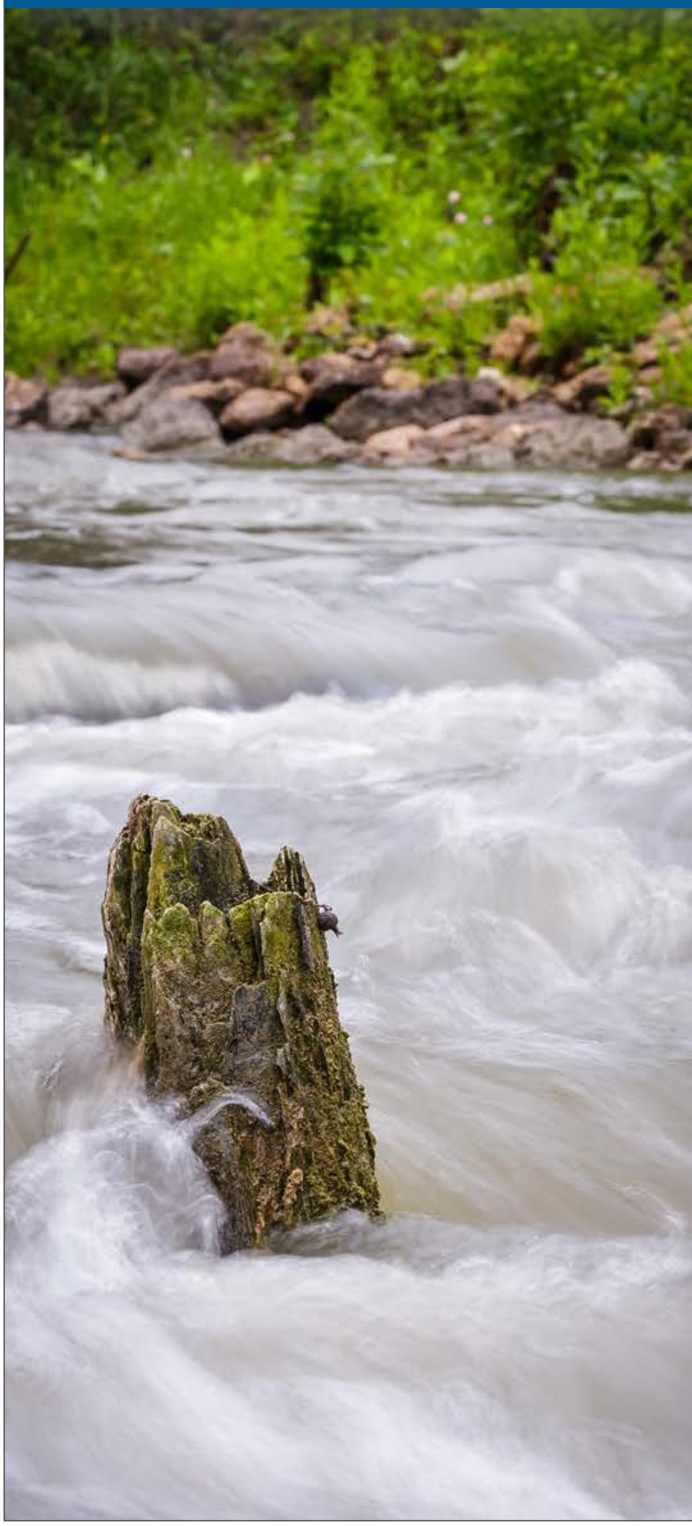
TPDES also issues stormwater permits for industrial facilities, construction activities over one acre, concrete production facilities, and petroleum terminals. These urban and industrial stormwater sources may contain elevated levels of bacteria as they wash accumulated materials from roads, parking lots, buildings, parks, and other developed areas. Potential pollutants can be managed from these sites through stormwater BMPs, including structures such as detention ponds, riparian buffers, pervious pavement, and low impact design. A review of active stormwater general permits in the watershed resulted in 10 active industrial permits and 11 active construction site permits as of June 7, 2018 (TCEQ 2018; Table 11). The acreage for the construction permits were given as acres disturbed in the authorization details of the permits and the permitted acres for the industrial permits were estimated using satellite imagery. The total number of acres permitted was 4,170.4.

Water Quality Summary

The Big Elm Creek watershed is a largely rural watershed, characterized by a vital agricultural community. Therefore, a significant portion of the watershed has been used for cropland, pasture, or grazing. The population of the watershed is mostly concentrated in the City of Temple and is projected to increase by significantly over the next 50 years.

The primary water quality concern is bacteria impairment in Big Elm Creek watershed. Potential contributors to the bacteria impairment likely include some combination of (1) unmanaged livestock/ cattle; (2) unmanaged wildlife/ feral hogs; (3) failing OSSFs; (4) fecal bacteria loadings from domestic pets; and (5) permitted discharges and SSOs.

Chapter 4
Pollutant Source Assessment



Big Elm Creek at US 77. Photo By Ed Rhodes, TWRI.

Introduction

The water quality sampling described in Chapter 3 established that the primary water quality impairment in the Big Elm Creek watershed is excessive fecal indicator bacteria. The current water quality standard established by TCEQ for primary contact recreation is 126cfu/100mL for *E. coli*. The *2018 Texas Integrated Report* (TCEQ 2019) lists the Big Elm Creek segment 1213A at US Hwy 77 is as impaired with geometric mean of 196.55 cfu/100mL.

In order to calculate the reductions needed to meet primary contact recreation standards, the bacteria load capacity of the Big Elm Creek was calculated. The current bacteria loads for the Big Elm Creek were calculated using water quality samples and the Load Duration Curve (LDC) method. By taking the difference between the load capacity and the current load, this WPP estimates the needed reductions to meet water quality standards. Nutrient LDCs were not developed since specific standards for Big Elm Creek are not established. Currently, only state-wide nutrient screening criteria exist. Using these screening values to develop local nutrient reduction goals was deemed inappropriate due to inherent uncertainty associated with application of a state-wide value to local water quality management. Despite the lack of nutrient water quality standards and exact load reduction targets, the management practices aimed at reducing bacteria loads will also yield nutrient load reductions when implemented in the watershed (See "Management Measures" in Chapter 5).

Furthermore, this chapter estimates the relative load contributions from different potential fecal bacteria sources. A Geographic Information Systems (GIS) analysis, which combined the best available data with stakeholder knowledge, provided relative load contribution estimates from each subwatershed. By estimating the relative potential contribution of different fecal bacteria sources across the watershed, areas can be prioritized as to when and where management measures should occur. The number of measures needed to reach water quality goals can also be estimated.

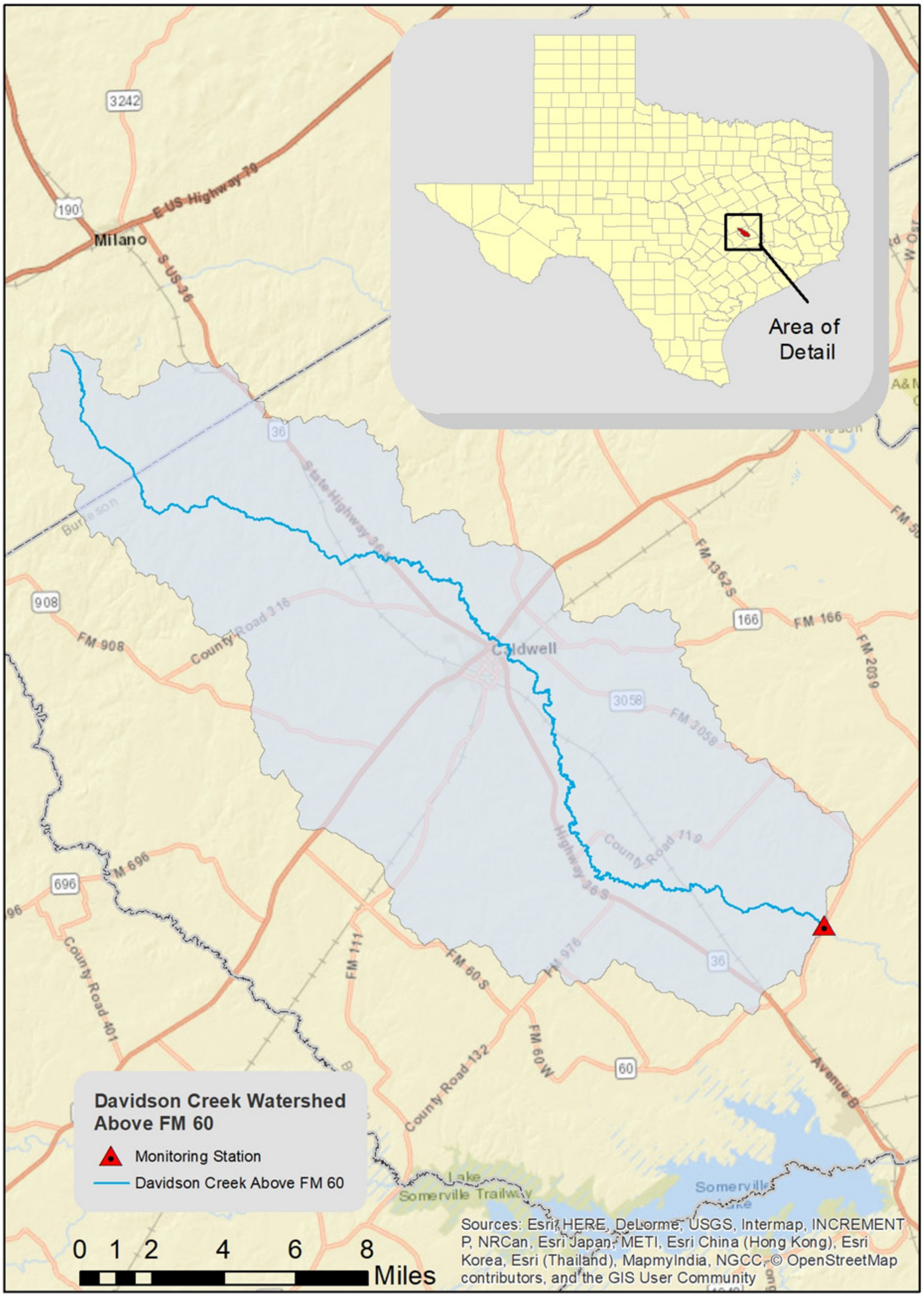


Figure 20. Davidson Creek watershed used in the drainage-area ratio method.

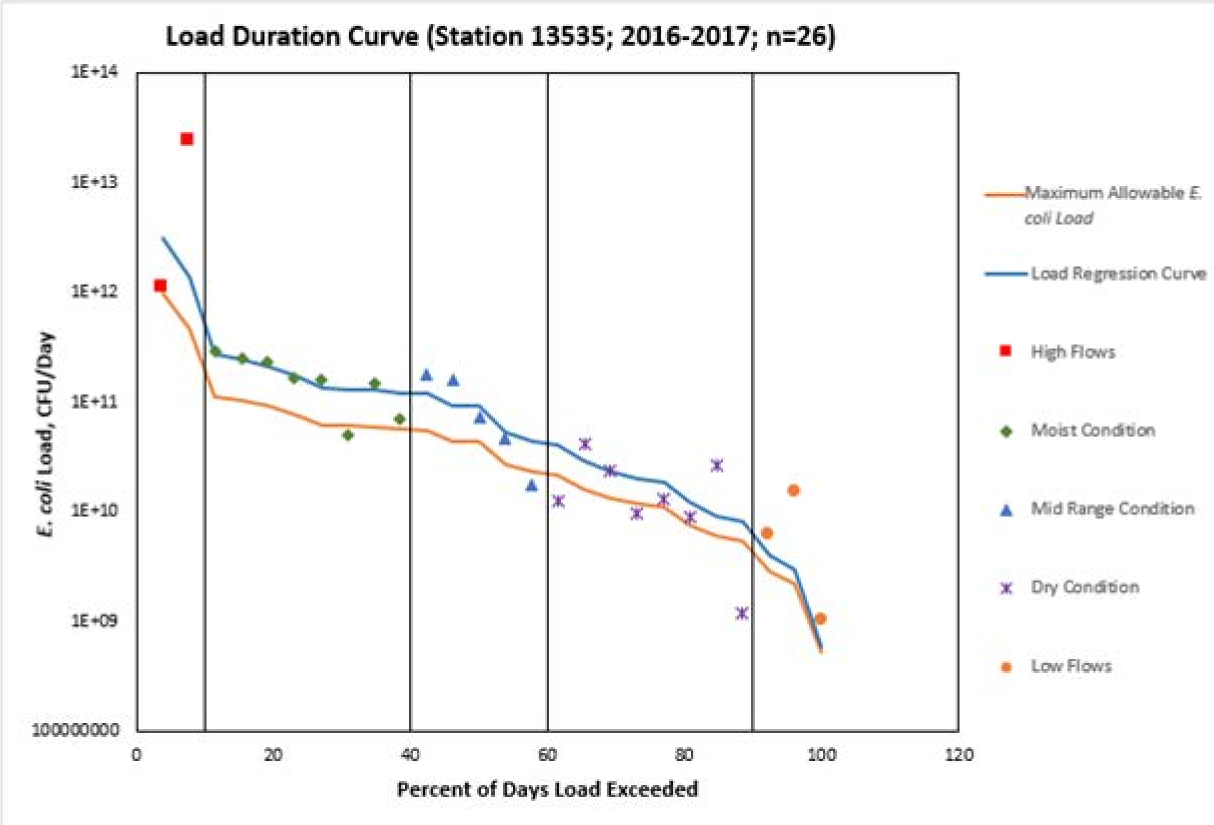


Figure 21. Load duration curve for Big Elm Creek Station 13535.

Source and Load Determination

Load Duration Curve

LDCs are a widely accepted methodology used to characterize water quality data across different flow conditions in a watershed. LDCs provide a visual display of streamflow, load capacity, and bacterial concentration exceedance. LDCs are first developed by constructing a flow duration curve (FDC) using historical streamflow data. FDCs are a summary of the hydrology of the stream, indicating the percentage of time that a given flow is exceeded. FDCs are constructed by ranking flow measurements from highest to lowest and determining the frequency of different flow measurements at the sampling location.

To construct an LDC, an FDC is multiplied by the allowable pollutant concentration minus a margin of safety (typically 5%) to identify the maximum acceptable pollutant load across all flow conditions. Using existing water quality and stream flow measurements, pollutant loads are plotted on the same figure. Points above the curve are out of compliance while points below the curve are within compliance. The difference between the predicted load and the allowable load is the estimated load reduction required to achieve the water quality standard. Additional guidance and information on LDCs are available in EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs* (EPA 2007).

LDC analysis further illustrates the dispersal of the data and how it relates to water quality for any given flow volume. See Figures 21, 22, and 23 below for LDCs for each sampling station. LDCs are calculated using measured flow and *E. coli* data at a sampling location. Unfortunately, there was insufficient flow data to construct proper LDCs for the three sampling stations. Station 16385 at US Hwy 77 did have a USGS flow gage; however, data from that gage is only recorded on high flow (flood) conditions. In order to properly create LDCs, we employed the drainage-area ratio (DAR) method as described by Asquith et al. (2006).

DAR is used to equate the ratio of streamflow of an unknown stream location to that of a nearby drainage area with enough data. This method was reviewed jointly by the USGS and TCEQ using 7.8 million values of daily streamflow data from 712 USGS streamflow gauges in Texas and was found to be a sufficient method in interpolating streamflow measurements.

For this DAR, we choose the USGS gauge on Davidson Creek, near Lyons, TX (Figure 20). The Davidson creek watershed was ideal, as it is near the Big Elm Creek watershed, and is similar in size, land use, and land cover. The dataset for Davidson Creek included 2,977 total daily flow records, dating back to October 2007. Flows are broken into five categories based on the percentage of days that any given flow exceeds the ranking of all flow data: High, Moist,

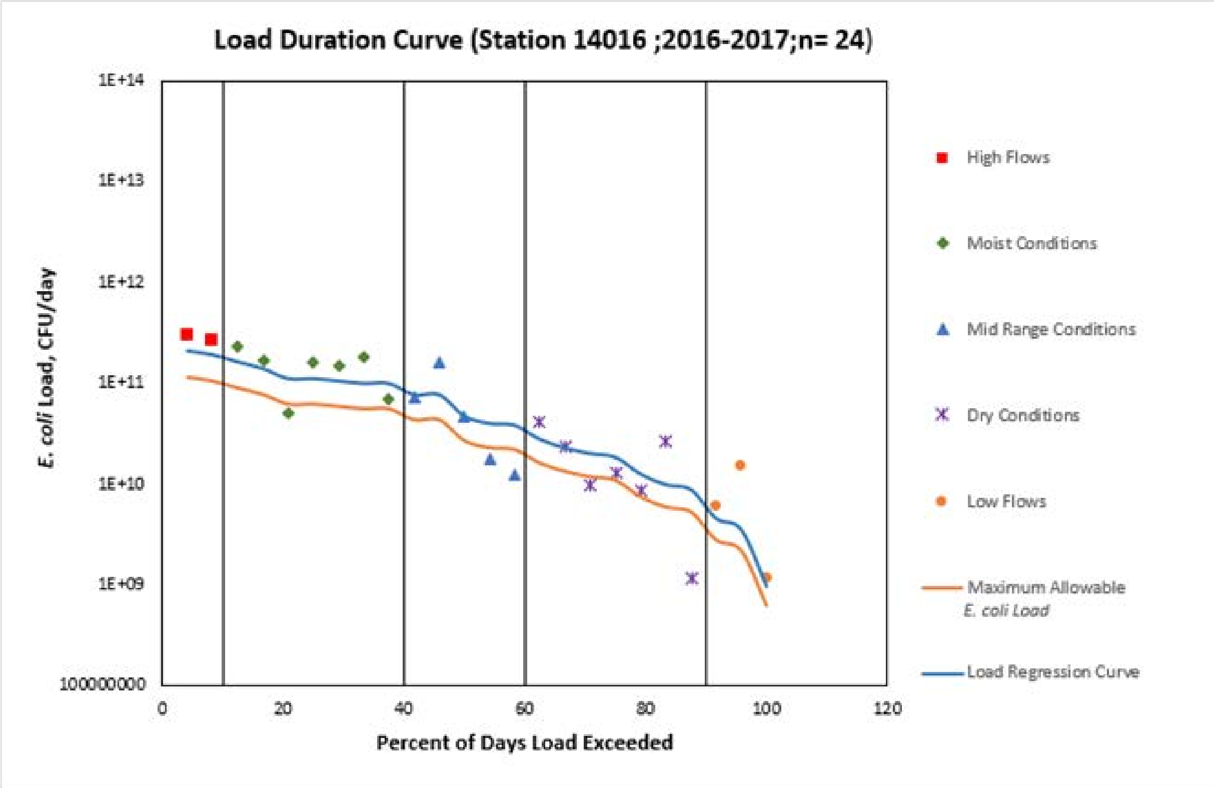


Figure 22. Load duration curve for Big Elm Creek Station 14016.

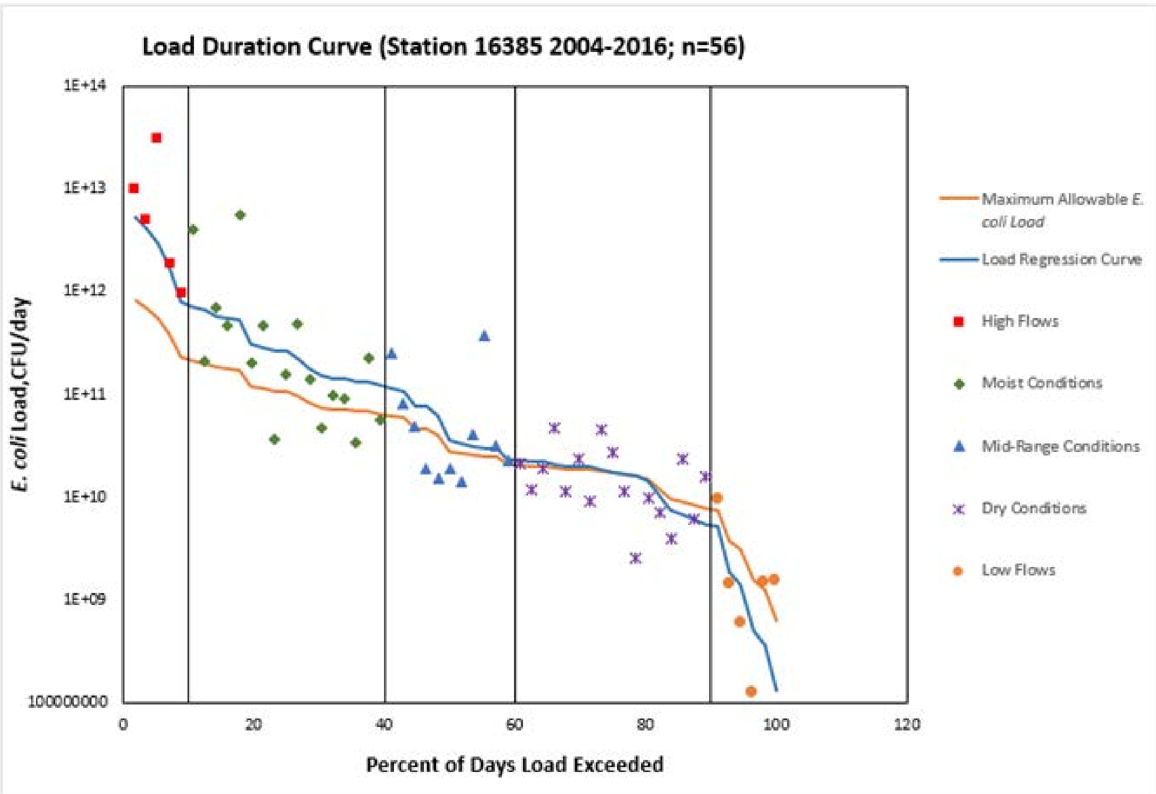


Figure 23. Load duration curve for Big Elm Creek Station 16386 US 77.

Table 13. Estimated daily loads and daily reductions required to meet primary contact water quality as determined by LDC analysis.

Flow Condition	Percent Days Flow Exceeded	Existing Daily Load (cfu/day)	Allowable Daily Load (cfu/day)	Reduction Needed (%)	Daily Load Reduction Required
Station 13535					
High flows	0-10	1.32×10^{10}	8.06×10^{9}	67.58	5.14×10^{9}
Moist Conditions	10-40	9.78×10^{9}	6.22×10^{9}	55.52	3.56×10^{9}
Mid-range flows	40-60	7.11×10^{9}	4.68×10^{9}	51.87	2.42×10^{9}
Dry conditions	60-90	5.04×10^{9}	3.45×10^{9}	40.74	1.58×10^{9}
Low flows	90-100	2.51×10^{9}	1.86×10^{9}	21.22	6.85×10^{8}
Station 14016					
High flows	0-10	1.99×10^{11}	1.09×10^{11}	45.23	9.04×10^{10}
Moist Conditions	10-40	1.17×10^{11}	6.56×10^{10}	44.28	5.22×10^{10}
Mid-range flows	40-60	5.54×10^{10}	3.15×10^{10}	42.87	2.38×10^{10}
Dry conditions	60-90	1.69×10^{10}	1.00×10^{10}	40.63	6.95×10^{9}
Low flows	90-100	2.96×10^{9}	1.84×10^{9}	37.03	1.12×10^{9}
Station 16385					
High flows	0-10	2.96×10^{12}	5.35×10^{11}	79.49	2.42×10^{12}
Moist Conditions	10-40	3.16×10^{11}	1.71×10^{11}	58.32	1.99×10^{11}
Mid-range flows	40-60	5.63×10^{10}	3.65×10^{10}	28.42	1.98×10^{10}
Dry conditions	60-90	1.55×10^{10}	1.55×10^{10}	-	8.89×10^{10}
Low flows	90-100	1.55×10^{9}	2.92×10^{9}	-	-

Mid-Range, Dry, and Low flows. Most of the field *E. coli* data collected occurred during Moist and Mid- Range flow conditions. LDCs derived from the DAR shown in Figures 21, 22, and 23.

The field sampling station at US Hwy 77 (Station #16385) was chosen for this WPP as the index site where bacterial loading reduction status would be observed. This station has the longest-running data history in the watershed, is the furthest downstream station, and is actively sampled on a quarterly basis as part of the state's Clean Rivers Program. The LDC for this station (Figure 23) indicates that the highest concentrations of *E. coli* occur under high and moist conditions. High flows are difficult to manage for, as they make up a small percentage of the total flow conditions, and generally occur after heavy precipitation events. The most practical approach is to manage for reductions under moist flow conditions. In order to meet water quality objectives in the Big Elm Creek watershed, a 58.32% reduction in *E. coli* loads is necessary under moist conditions (Tables 13 and 14).

Pollutant Source Load Estimates

GIS Analysis

A GIS-based analysis was applied using the methodology employed by Borel et al. (2012) to aid in identifying potential area of *E. coli* contributions within the watershed (Appendix A). Estimates of *E. coli* loads were derived from information gathered from the US Census, national land use/land cover (LULC) classifications, National Agricultural Statistics Service (NASS), NRCS soil boundaries, American Veterinary Medical Association pet ownership statistics, TPWD population estimates, TCEQ permits, and other geographically based data such as political boundaries and surface topology. Information is spatially referenced where possible from the data source, or from local stakeholder knowledge. Using this analysis approach, the relative potential for *E. coli* loading from each source can be compared and used to prioritize management.

Potential loads for identified sources are summarized for each of seven subwatersheds (Table 15, Figure 2) found in the Big Elm Creek. This approach allows prioritization of management measures in subwatersheds with the highest potential for *E. coli* loading. Figure 24 summarizes estimated daily *E. coli* loads by subwatershed.

Table 14. Estimated annual load reductions required to meet primary contact water quality criteria.

Flow Condition	Percent Days Flow Exceeded	Existing Annual Load (cfu/yr)	Reduction Needed (%)	Annual Load Reduction Required
Station 13535				
High flows	0-10	4.82×10^{12}	67.58	7.07×10^{14}
Moist Conditions	10-40	3.57×10^{12}	55.52	1.51×10^{14}
Mid-range flows	40-60	2.60×10^{12}	51.87	7.90×10^{12}
Dry conditions	60-90	1.84×10^{12}	40.74	1.61×10^{12}
Low flows	90-100	9.16×10^{11}	21.22	-
Total		1.37×10^{13}		8.67×10^{14}
Station 14016				
High flows	0-10	1.59×10^{15}	77.81	1.23×10^{15}
Moist Conditions	10-40	2.08×10^{14}	60.22	1.44×10^{14}
Mid-range flows	40-60	4.52×10^{13}	52.87	2.40×10^{13}
Dry conditions	60-90	2.49×10^{13}	44.76	1.19×10^{13}
Low flows	90-100	4.66×10^{12}	21.19	1.18×10^{12}
Total		1.87×10^{15}		1.42×10^{15}
Station 16385				
High flows	0-10	1.08×10^{15}	79.49	8.84×10^{14}
Moist Conditions	10-40	1.15×10^{14}	58.32	5.26×10^{13}
Mid-range flows	40-60	2.05×10^{13}	28.42	7.2×10^{12}
Dry conditions	60-90	5.65×10^{12}	-	-
Low flows	90-100	5.65×10^{11}	-	-
Total		1.22×10^{15}		9.34×10^{14}

Table 15. Big Elm Creek subwatershed based on NHD HUC12 description (USGS 2012).

Subwatershed ID	Name (HUC 12)	Acres
1	Pecan Creek- Big Elm Creek	32,705.85
2	Little Elm Creek	22,712.09
3	Cottonwood Creek- Big Elm Creek	19,609.23
4	South Elm Creek	23,981.86
5	Camp Creek- Big Elm Creek	37,574.97
6	North Elm Creek	38,673.38
7	Lipan Creek- Big Elm Creek	30,977.18

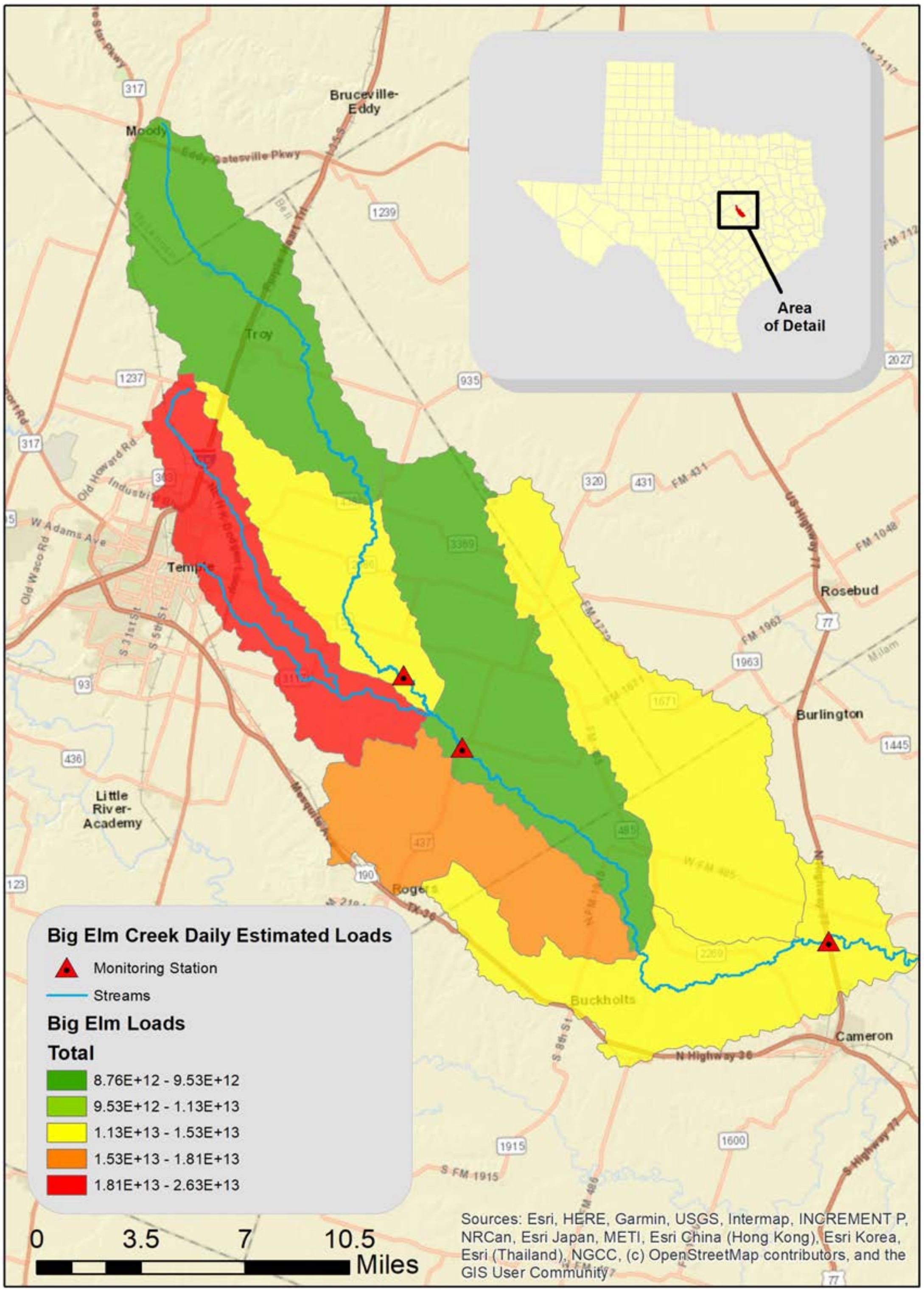


Figure 24. Estimated daily *E. coli* loads by subwatershed.

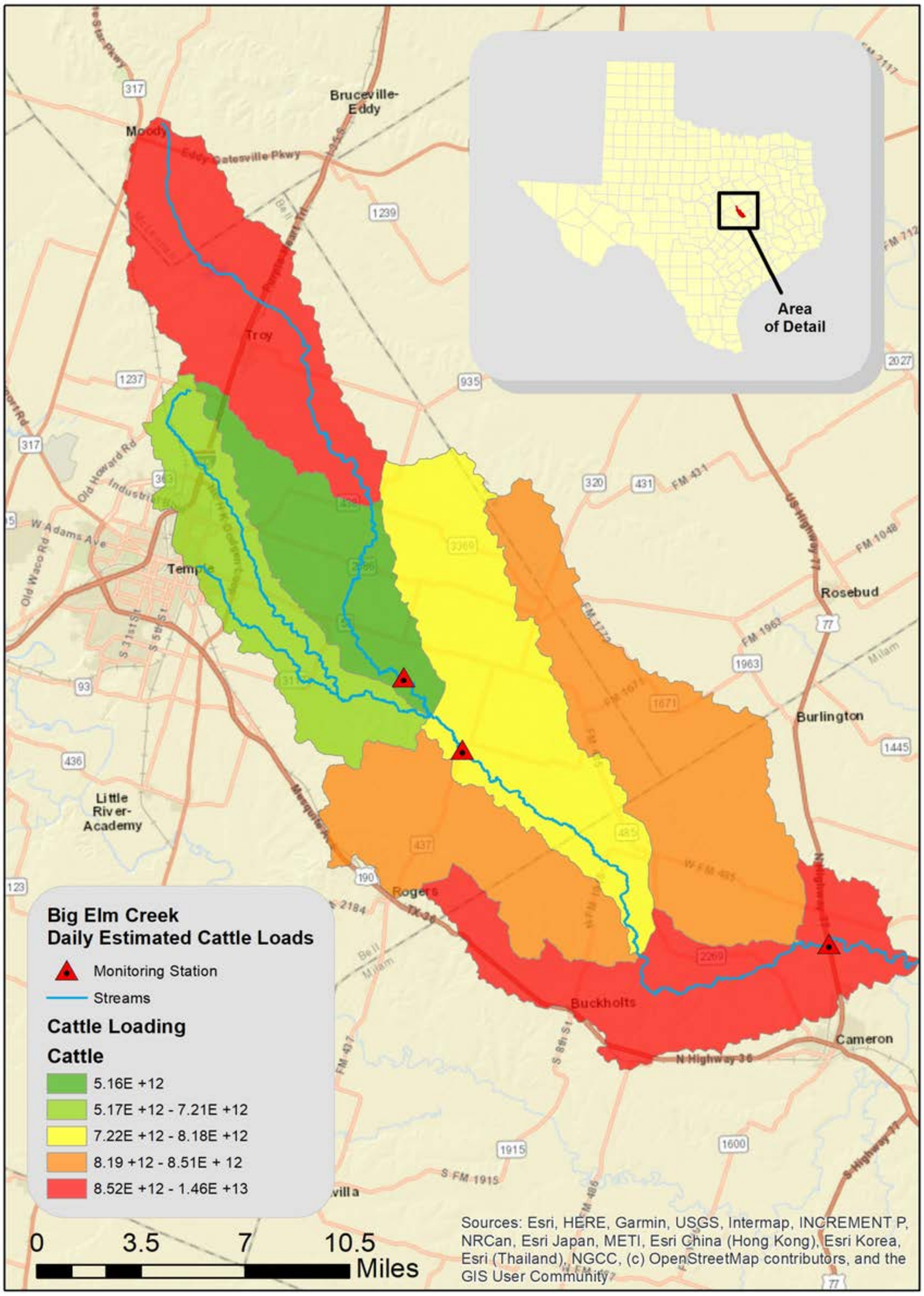


Figure 25. Estimated daily *E. coli* loads from cattle by subwatershed.

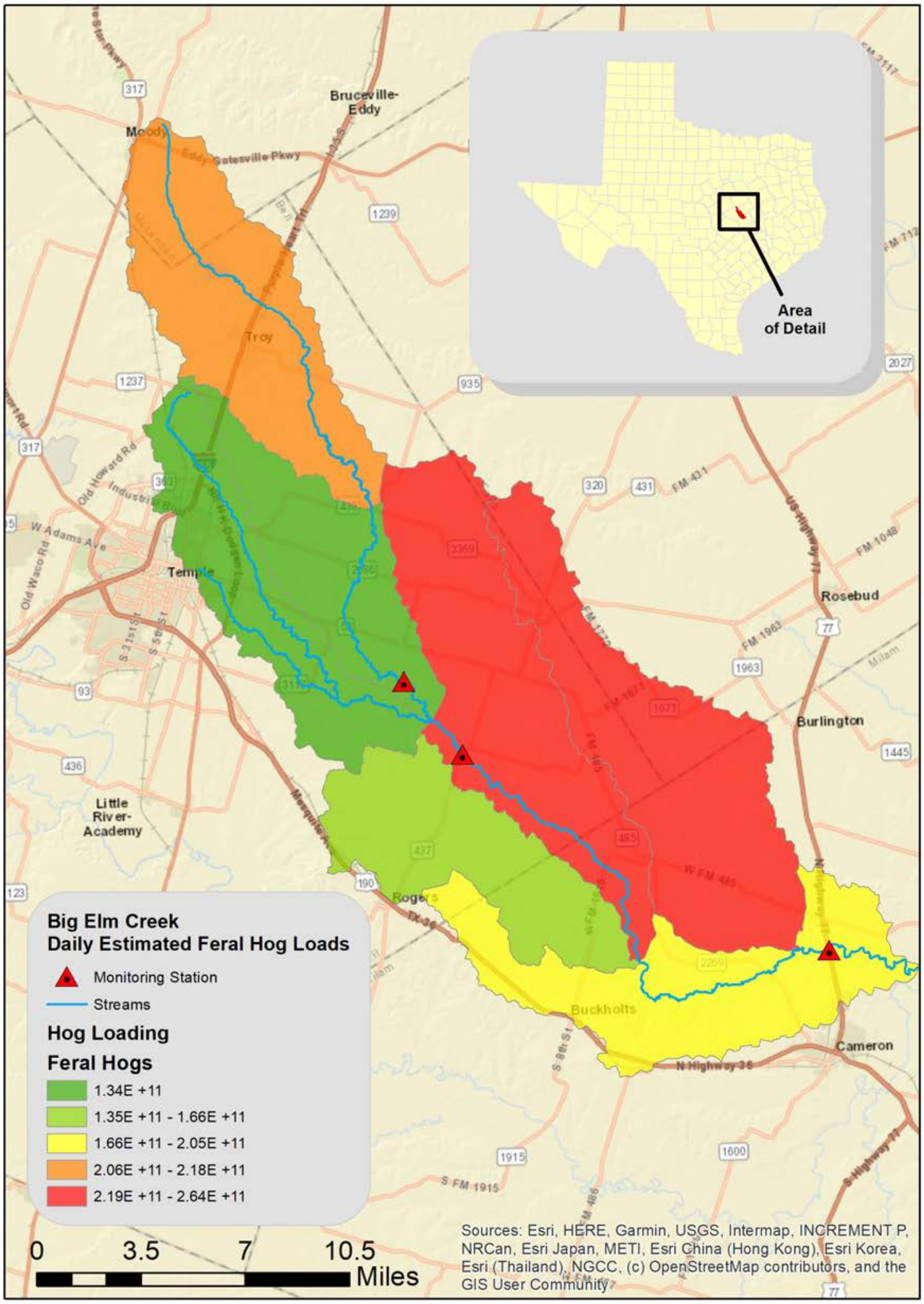


Figure 26. Estimated daily *E. coli* loads from feral hogs by subwatershed.

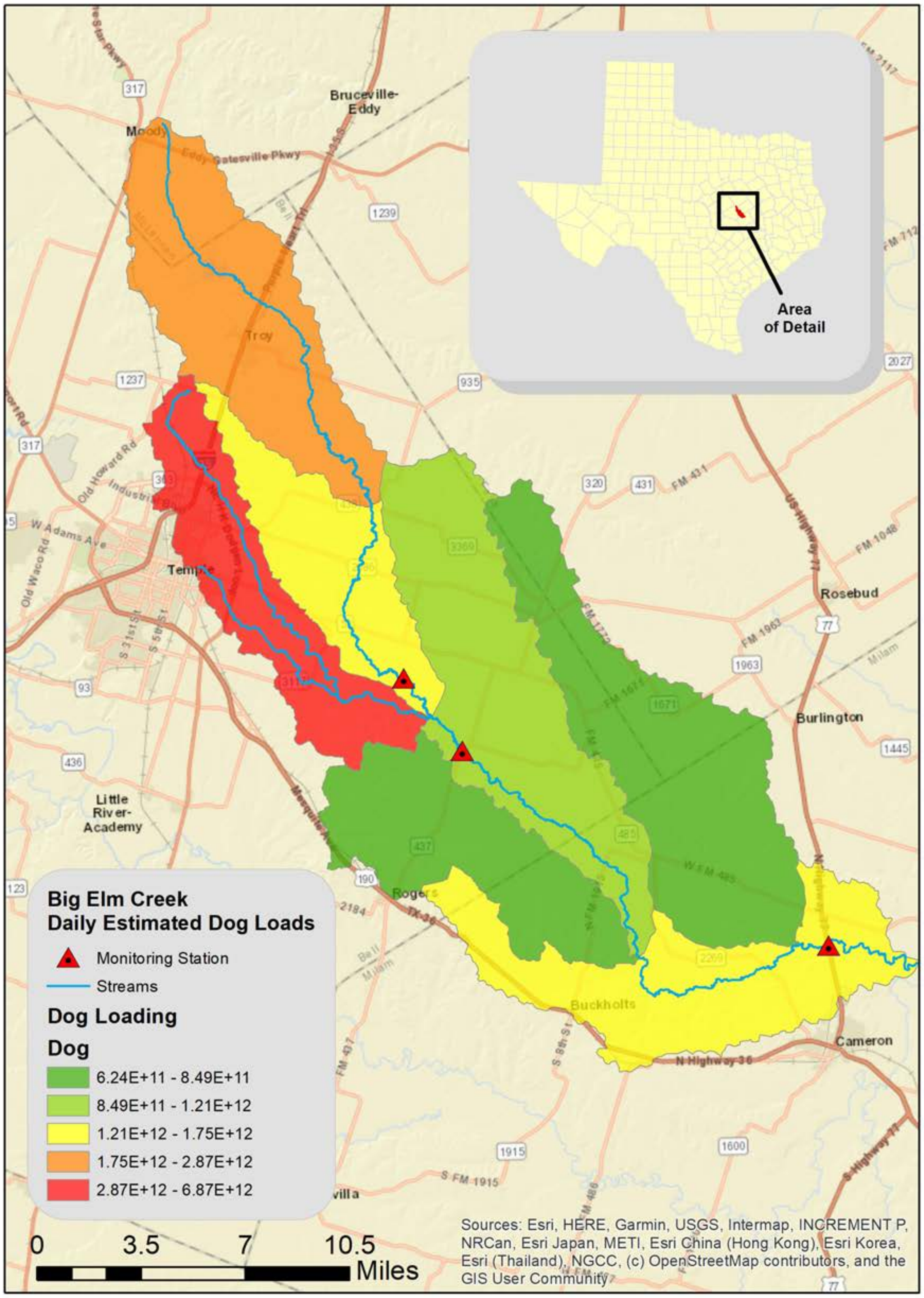


Figure 27. Estimated daily *E. coli* loads from dog waste by subwatershed.

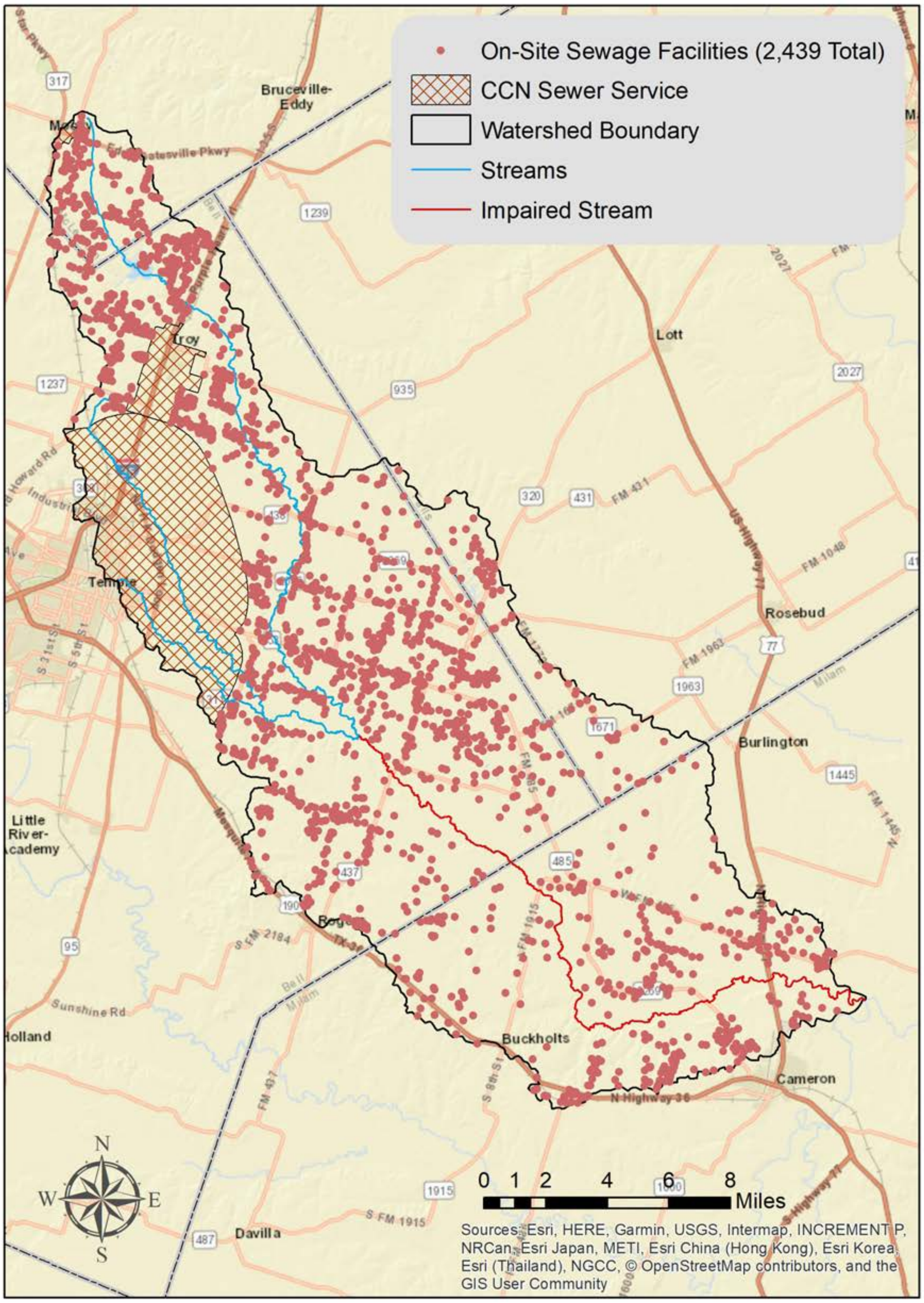


Figure 28. On-site sewage facilities.

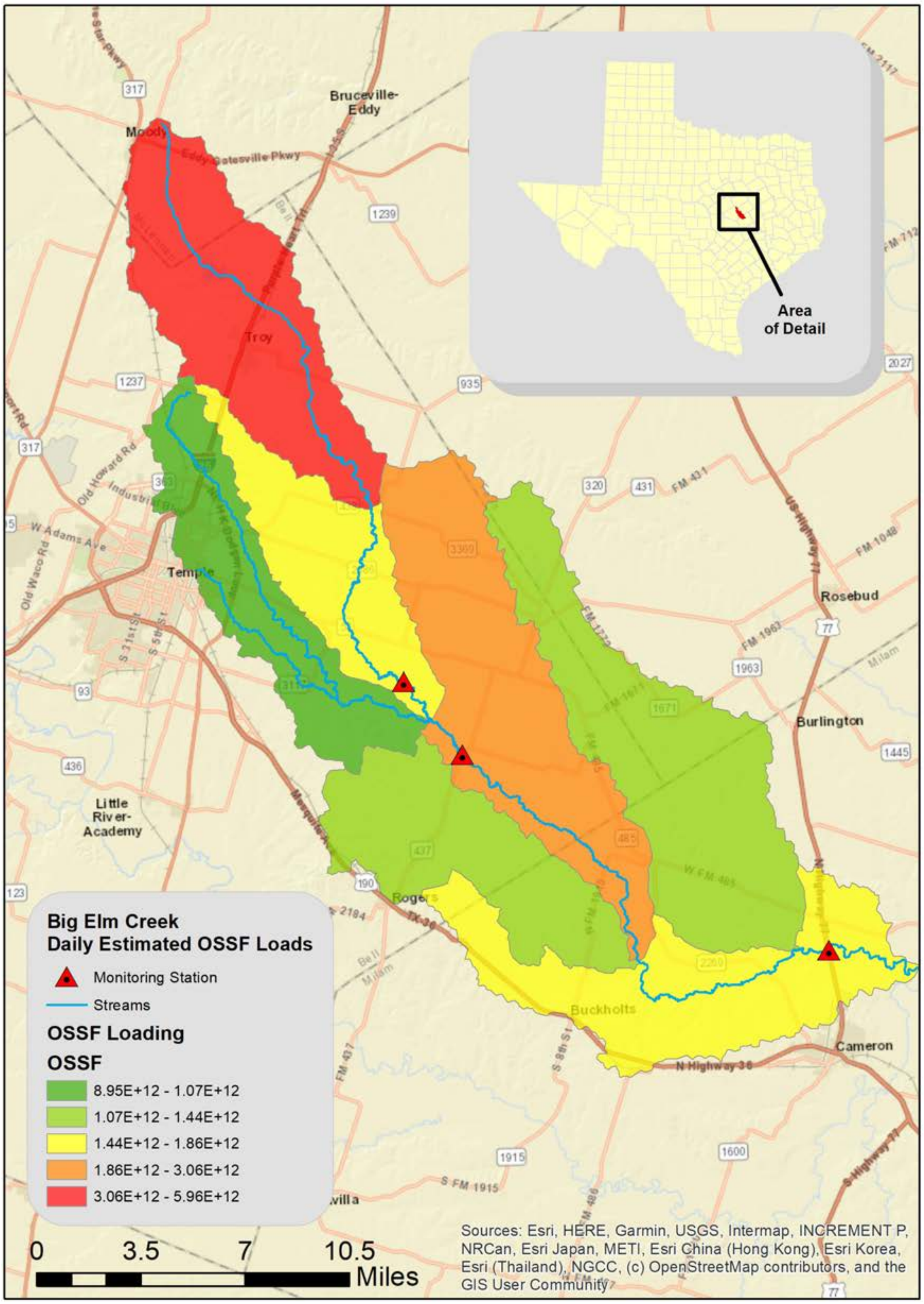


Figure 29. Estimated daily *E. coli* loads from OSSFs.

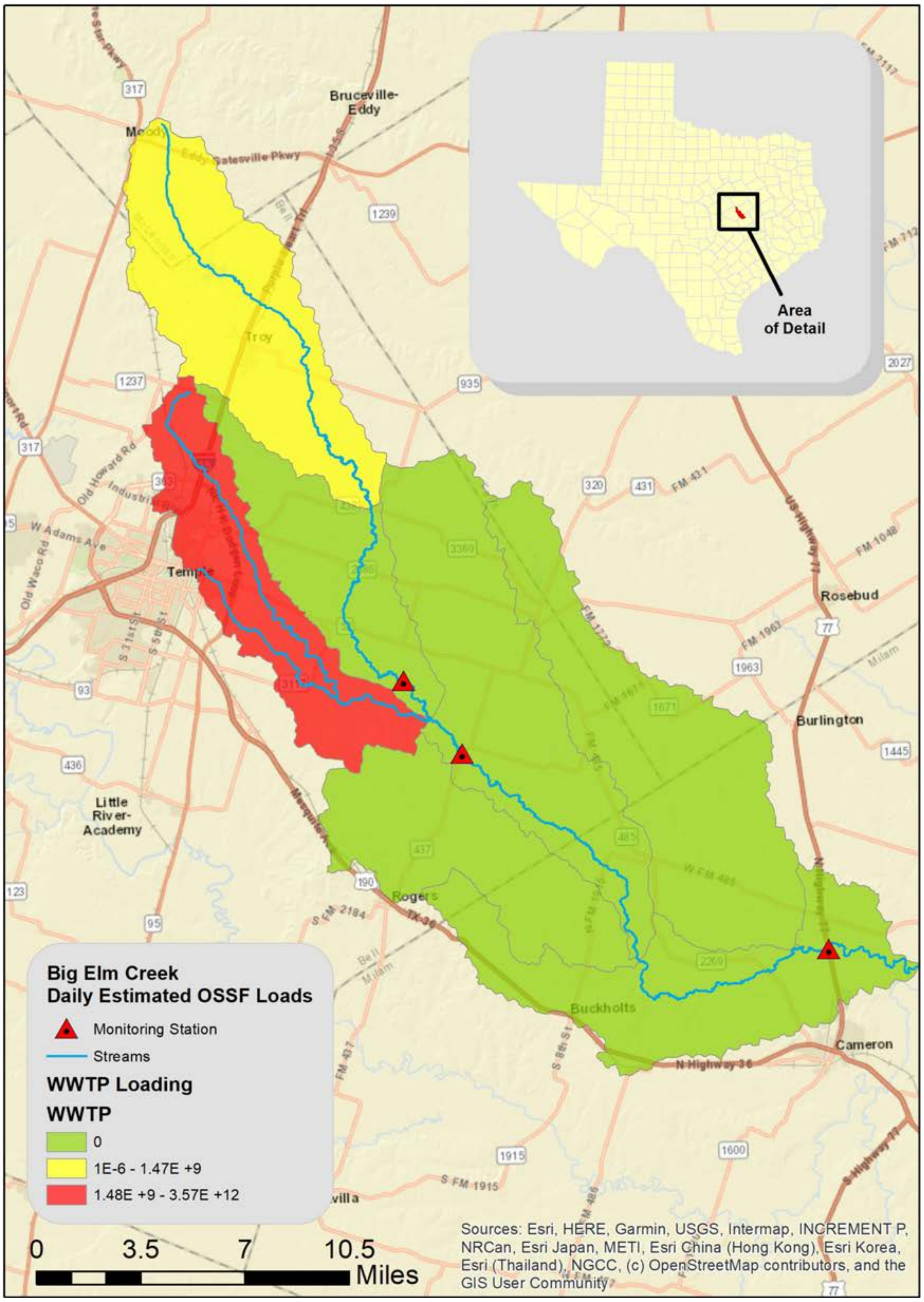


Figure 30. Estimated daily *E. coli* loads from WWTPs.

Cattle

Runoff from rangeland and improved pastureland is likely to carry *E. coli* deposited from cattle into the water body. The potential loads from cattle were developed based on recommendations from local stakeholder groups. Stakeholder input was critical in identifying commonly used stocking rates and the amount of grazed lands in the area. Based on stakeholder input and the best available data, this plan estimated approximately 11,799 cattle animal units across the entire watershed. Appendix A describes the assumptions and equations used to estimate potential bacteria loading in the Big Elm Creek watershed. Figure 25 shows daily estimated cattle loads by subwatershed. The highest totals are in subwatersheds 1 and 7. Across the watershed, it is estimated that total daily *E. coli* loads due to livestock are 6.36×10^{13} cfu/day.

Feral Hogs

Feral hogs (*Sus scrofa*) contribute to *E. coli* bacteria loadings through the direct deposition of fecal matter into streams while wading or wallowing in riparian areas. Riparian areas provide ideal habitats and migratory corridors for feral hogs as they search for food. While complete removal of feral hog populations is unlikely, habitat management and trapping programs can limit populations and associated damage.

It is estimated that the greatest total daily loads occur in subwatersheds 5 and 6 (Figure 26). Across the watershed, total estimated daily loads due to feral hogs as 1.38×10^{12} cfu/day. Appendix A describes the equations and assumptions used to generate total daily loads.

Domestic Pets

Domestic pets, with an emphasis on dogs, can contribute to bacteria loadings when pet waste is not properly disposed and subsequently washes into nearby water bodies during rain and storm events. The highest potential loads from domestic pets are anticipated to occur in developed and urbanized areas in subwatershed 2 (Figure 27). Across the watershed, it is projected that the total daily load from approximately 4,910 dogs is 7.73×10^{12} cfu/day. Appendix A describes the equations and assumptions used to generate potential daily loads.

On-Site Sewage Facilities

Failing or unmaintained OSSFs can contribute bacteria loads to water bodies, in particular those where effluent is released near the water bodies. The actual number of failing systems is unknown; however, it is estimated that as many as 2,439 OSSF systems may be in the watershed based on the most recent available 911 address data (Figures 28 and 29). Identifying and repairing or replacing 30 failing units could significantly reduce bacteria contamination within the watershed. GIS analysis indicated the highest potential daily loadings occur in subwatershed 1 (Figure 29). Across the watershed, the total daily loads due to failing OSSFs is estimated to be 2.43×10^{14} cfu/day. Appendix A describes the equations and assumptions used to generate total daily loads.

Urban Stormwater Runoff

Based on 2011 National Land Cover Database, there are approximately 360.54 acres of developed impervious surfaces across the watershed (Figure 3). The impervious surfaces in developed and urbanized areas increase the amount of rainfall that becomes runoff. This increased overland flow has the potential to pick up and carry pollutants to nearby water bodies, even during small rainfall events. The variables are too numerous to model with certainty (urban fertilizer and pesticide use, construction sites, urban avian and terrestrial wildlife, trash and other waste, and many other nonpoint sources); however, any reduction in runoff will result in a reduction of pollutants reaching surface waterbodies. Various stormwater BMPs are available to reduce the volume of stormwater that runs off developed sites, potentially decreasing the amount of pollutants entering the stream.

Wastewater Treatment Plants

According to TCEQ and EPA NPDES data, there are three permitted wastewater discharges in the watershed. These wastewater discharges are regulated by TCEQ and are required to report average monthly discharges and *E. coli* concentrations. The highest total daily loadings occur in subwatershed two (Figure 30); however, all subwatersheds with WWTPs are considered to be high priority. Across the watershed, the estimated total daily loads due to WWTPs as 3.76×10^{6} cfu/day. Appendix A describes the equations and assumptions used to generate total daily loads.

Table 16. Summary of potential source loads.

Source	Big Elm Creek	
	Potential Load (cfu/day)	Highest Priority Subwatersheds
Cattle	6.36×10^{13}	1, 7
Feral Hogs	1.38×10^{12}	5, 6
OSSFs	2.43×10^{14}	1
Dogs	7.73×10^{12}	2
WWTP	3.76×10^{6}	1, 2, 7
Total	3.15×10^{14}	

Load Reduction and Sources Summary

LDCs (Figures 21-23) indicate that *E. coli* entering Big Elm Creek exceeds its capacity to meet water quality standards under all flow conditions except stations 13535 and 16385 under low flow conditions. Based on these curves, it can be assumed that *E. coli* is entering water bodies mostly under high flow conditions and minimally under low flow conditions. Using the LDC approach, a total reduction of 9.34×10^{14} cfu *E. coli*/yr was estimated as needed to meet primary contact recreation standards at the Big Elm Creek Station 16385.

Bacteria in runoff are likely to contribute to exceedances during higher flow conditions. Sources of bacteria-laden runoff might include runoff from rangeland, pastures, and faulty OSSFs. Bacteria loading exceedances during low flow conditions are likely attributable to direct deposition in the water body from animals, failing OSSFs in or near riparian zones, and WTTPs. Chapter 5 recommends various management measures for load reductions to reach water quality goals.

Based on land use/land cover data, the watershed mostly consists of cultivated crops, grassland/herbaceous, grazed pasture, and rangeland. Implementing agricultural BMPs in these areas can help reduce and filter bacteria and nutrients from pasture and rangeland runoff. Relatively high potential for loadings from domestic pets in the City of Temple exists; therefore, addressing pet waste and stormwater runoff from impervious surfaces in these areas is logical. Feral hogs are also another source almost equal to pet waste that has potential for *E. coli* loadings. Repairing or replacing malfunctioning OSSFs could potentially reduce direct human waste contribution of *E. coli* and other pathogens. WWTPs have the lowest relative potential for loading amongst sources assessed but is a common concern to stakeholders.

Chapter 5 Watershed Protection Plan Implementation Strategies

White tailed deer near Troy, TX. Photo By Ed Rhodes, TWRI.

Introduction

Recommended management strategies to achieve needed *E. coli* reductions in Big Elm creek were developed based on local knowledge, loading estimations, effectiveness, and the understanding of current water quality stressors across the watershed. An analysis was completed to identify major sources of *E. coli* in the watershed, their potential loading distribution, and actual *E. coli* loads. This information was necessary to make informed decisions regarding needed management measures to imp¬rove water quality across the watershed.

The management measures detailed in this chapter address the following sources: livestock, feral hogs, OSSFs, pet waste, urban stormwater, SSOs, illicit and accidental dumping, runoff from agricultural and urban soils, runoff from landfill areas, and landowners without educational resources. These sources do not represent all prospective bacteria sources in the watershed but are the most manageable. For example, bacterial source tracking in similar watersheds nearby has identified wildlife as a significant contributor to *E. coli*; however, managing wildlife fecal deposition from all sources of wildlife in the watershed is not practical and does not have a high likelihood of success. Additionally, any management practice that reduces, retains, or filters runoff will have the added benefit of limiting nutrients of concern from reaching the waterbody as well.

Management Measures

No single source of *E. coli* in the watershed is the primary cause of current *E. coli* concentrations exceeding allowable levels. Instead, a variety of point and nonpoint sources contribute *E. coli* to the Big Elm Creek watershed. Therefore, a diverse approach to management is recommended to address *E. coli* loading across the watershed. This approach focuses on contributing sources that are most feasibly managed and have the highest chance of producing instream *E. coli* reductions.

Table 17. Available pasture and rangeland practices to improve water quality.

Best Management Practices	NRCS Code	Focus Area or Benefit
Brush management	314	Livestock, water quality/quantity, wildlife
Fencing	382	Livestock, water quality
Filter strips	33	Livestock, water quality, wildlife
Grade stabilization structures	410	Water quality
Grazing land mechanical treatment	548	Livestock, water quality, wildlife
Heavy use area protection	562	Livestock, water quality/quantity
Pond	378	Livestock, water quality/quantity, wildlife
Prescribed burning	338	Livestock, water quality, wildlife
Prescribed grazing	528	Livestock, water quality, wildlife
Range/Pasture planting	550/512	Livestock, water quality, wildlife
Shade structure	N/A	Livestock, water quality, wildlife
Stream crossing	578	Livestock, water quality
Supplemental feed location	N/A	Livestock, water quality
Water well	642	Livestock, water quantity, wildlife
Watering facility	614	Livestock, water quantity, wildlife

Based on a spatial analysis of potential pollutants, the recommended sources to address include feral hogs, humans, pet waste, and livestock. These sources do not represent all prospective *E. coli* contributions in the watershed but are manageable with feasible strategies. Further discussion into the possible sources of contamination is found in the *Little River Documentation of GIS Analysis* (Jonescu et al. 2017). Wildlife sources are generally the largest contributors of *E. coli* in rural watersheds. Generally, wildlife will receive little focus because managing their fecal deposition in the watershed is not practical and does not have a high likelihood of successfully reducing instream *E. coli* loads.

Priority locations for implementation in the watershed were identified for each management recommendation using results from spatial analysis. Priority locations were selected to maximize management effectiveness relative to instream water quality. Financial and technical resources regarding these measures are covered in Chapter 6.

Management Measure 1: Promote and implement water quality management plans (WQMP) or conservation plans (CP)

Daily potential *E. coli* loading from livestock (cattle, goats, and horses) is a large contributor of *E. coli*, and a potential source of nutrients, in the watershed. Unlike some other sources, livestock waste is mostly deposited in upland areas away from water bodies and is transported to downstream waters during runoff events. As a result, much of the *E. coli* in livestock waste dies before reaching a water body. However, livestock may access streams for water or cooling in some cases and can have a more direct impact on instream water quality.

Livestock resource utilization and fecal deposition are highly dependent upon availability and distribution of water, food, and shelter. This allows livestock to be managed more easily compared to non-domesticated species. Improving the quality and distribution of forage and supplemental feed locations, expanding water availability, and establishing fences to better control their movement within a property can effectively reduce *E. coli* concentrations in runoff entering nearby waterways. Due to the size of the potential *E. coli* load to the watershed and the ability to modify animal behavior through management changes, addressing *E. coli* loading in the watershed from livestock is likely to have considerable impacts on instream water quality.

A variety of BMPs can achieve the goals of improving forage quality and distribution, diversifying water resource locations, and better distributing livestock across a property. The NRCS and the Texas State Soil and Water Conservation Board (TSSWCB) provide technical and financial assistance to producers to plan for and implement property specific, incentive based BMPs. NRCS offers a variety of programs to develop and implement conservation plans (CPs) for entire operations or specific practices (Table 17). TSSWCB, through local soil and water conservation districts (SWCDs), provides technical and financial assistance to develop and implement property specific water quality management plans (WQMPs) that ensure water quality improvements through planning, implementation, and maintenance of

Table 18. Management measure 1: *E. coli* management strategy evaluation for cattle.

<table>
<tr><th colspan="4">Pollutant Source: Cattle and other livestock</th></tr>
<tr><td colspan="4">Problem: Livestock derived fecal loading into water bodies</td></tr>
<tr><td colspan="4">Objectives:
• Work with landowners to develop property-specific CPs and WQMPs to protect water quality
• Provide technical and financial assistance to producers
• Reduce fecal loading from livestock in riparian areas</td></tr>
<tr><td colspan="4">Location: Subwatersheds 1 and 7, with priority given in rural areas near waterbodies</td></tr>
<tr><td colspan="4">Critical Areas: Properties with creek and tributary access, especially those using them as a livestock watering source</td></tr>
<tr><td colspan="4">Goal: Develop up to 30 plans (Conservation and/or WQMPs) focused on minimizing the time spent by livestock in the riparian corridor and better use of available grazing resources across the property</td></tr>
<tr><td colspan="4">Description: CPs and WQMPs will be developed to address direct and indirect fecal deposition from cattle and other livestock. BMPs to reduce time spent in the creek or riparian corridor, improve grazing distribution, and grass quality, and decrease runoff will be recommended. Likely practices include prescribed grazing, cross-fencing, pasture planting, water wells, and watering facilities. Education program delivery will support and promote implementation adoption.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participation</th><th>Recommendations</th><th>Period</th><th>Capital Costs</th></tr>
<tr><td>Riparian Areas in the Watershed</td><td>Develop, implement, and provide financial assistance for livestock CPs and WQMPs @ $15,000 per plan for 20 plans</td><td>2019-2029</td><td>$300,000</td></tr>
<tr><td>Upland Areas in the Watershed</td><td>Develop, implement, and provide financial assistance for livestock CPs and WQMPs @ $15,000 per plan for 10 plans</td><td>2019-2029</td><td>$150,000</td></tr>
<tr><td>Texas A&M AgriLife Extension Service</td><td>Deliver Lone Star Healthy Streams programming to water-shed landowners</td><td>2019, 23,28</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Prescribed management will effectively reduce bacteria loads from the landscape and in some cases reduce direct fecal deposition to water bodies. Cattle are estimated to contribute 6.36×10^{13} cfu of E. coli to the watershed daily. Prescribed grazing and cross fencing are estimated to produce annual load reductions from cattle alone at 2.26×10^{14} cfu/year when implemented on the proposed areas (See Appendix B). This assumes that each CP and WQMP will include prescribed grazing and cross-fencing to minimize the amount of time livestock spend in riparian areas.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Decreasing the time that livestock spend in the riparian corridor and reducing surface runoff through effectively managing vegetative cover will significantly reduce nonpoint source contributions of bacteria and nutrients to the creek.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Landowners acknowledge the importance of good land stewardship practices and management plan objectives; however, financial incentives are needed in many cases to increase CP and WQMP implementation.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Landowners are largely willing to implement land stewardship practices that benefit the land and their operations; however, costs are often prohibitive and financial incentives are needed to increase implementation.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial assistance is the primary need to promote implementation and will likely not occur without it; education and outreach are needed to illustrate animal production and economic and water quality benefits of plan development and implementation to producers.</td></tr>
</table>

each practice. A variety of practices commonly implemented in the watershed through these programs have positive effects on forage health and utilization which improves water quality. Properly implemented and maintained fencing, prescribed grazing, and alternative water sources for livestock are documented to effectively reduce *E. coli* loading in runoff and instream water quality. As a result, these are the primary practices that are recommended for implementation in the watershed.

These BMPs will improve water quality regardless of where they are implemented in the watershed, but their effectiveness is greater if they are in close proximity to a water body. Riparian areas are thus considered a priority; however, implementation on properties without riparian habitat is also strongly encouraged. Priority areas and expected *E. coli* load reductions from implementing these practices are described in Table 18. Cattle make up more than 80% of the estimated livestock population within the watershed, and therefore are the primary focus of livestock management recommendations due to cost-benefit concerns. BMPs aimed at reducing runoff will have the added benefit of retaining nutrients on site, thus reducing loads in water bodies. Table 17 summarizes available pasture and rangeland practices to improve water quality.

Management Measure 2: Promote technical and direct operational assistance to landowners for feral hog control

Potential *E. coli* and nutrient loading from feral hogs across the watershed represents a considerable potential influence on instream water quality. While other sources of *E. coli* are potentially larger in volume, feral hogs' preference for dense habitat, available food resources, and water enhance the potential affects that they have on instream water quality. Behaviors including rooting and wallowing further affect water quality by degrading ground cover, increasing soil/sediment disturbances, and decreasing bank stability. Each of these effects increases erosion and causes enhanced pollutant (*E. coli*, nutrients, and sediment) transport to water bodies during runoff events. Wallowing in the edges of water bodies also affects water quality between runoff events.

Physically removing hogs from the watershed is the best strategy for reducing their impact on water quality. A variety of methods exist to accomplish this goal, and other tactics can also improve the success of removal efforts. In the watershed, trapping animals is the most effective means for removing large numbers of hogs. With proper planning and diligence, trapping can successfully remove large numbers of hogs at once, whereas shooting or catching with dogs typically results in fewer individuals being removed before they move to another part of the watershed. Hunting hogs is already common across the watershed and should certainly continue.

Excluding feral hogs from supplemental feed is also an effective management tool. Feral hogs are opportunistic feeders and are known to access supplemental feeding stations such as wildlife feeders. Erecting exclusionary fences around deer feeders has been shown to reduce the ability of feral hogs to access these food sources (Rattan et al. 2010). Additionally, exclusion from easily accessible food sources can enhance trapping success nearby.

Education resource delivery also improves feral hog removal effectiveness. Landowner participation and education is crucial to the management of feral hogs within the watershed. The Texas A&M AgriLife Extension Service has developed a variety of educational resources that are available at: http://feralhogs.tamu.edu. They include information on feral hog biology, trapping techniques and types, wildlife feeder exclusion techniques, trap designs, research studies, and more. Additionally, they deliver focused feral hog education programs that include hands-on trapping technology and technique demonstrations.

Trapping hogs may provide a potential source of income, or at least a means to recuperate some costs associated with repairing feral hog damage and trapping efforts. The State of Texas allows live feral hogs to be transported to approved feral hog holding facilities where they can be sold to the holding facility. Purchase prices vary by facility and are market driven. Three holding facilities are currently located in the watershed and several others are nearby. Hogs transferred to state-approved holding facilities are then processed for slaughter or moved to approved hunting facilities. It is recommended that trapped hogs be taken to a slaughter facility, rather than a hunting facility, where the risk of re-introduction into the watershed is a concern. An online mapping tool and listing of approved facilities is available at: https://tahc.maps.arcgis.com/apps/webappviewer/index.html?id=6406b01b5b284f2398c3117928869808. Other informational resources such as regulations regarding feral hog movement and holding restrictions are also available at this website. Each of these needs, priority management areas, and expected *E. coli* loading reductions are discussed further in Table 19.

Table 19. Management measure 2: *E. coli* management strategy evaluation for feral hogs.

Pollutant Source: Feral Hogs			
Problem: Direct and indirect fecal loading, riparian habitat destruction, soil damage from rooting			
Objectives: • Reduce fecal contaminant loading from feral hogs • Reduce hog population • Reduce food supply for hogs • Provide education and outreach to stakeholders			
Location: Entire Watershed, with highest priority in subwatersheds 5 and 6			
Critical Areas: Riparian areas and travel corridors from cover to feeding areas			
Goal: Manage the feral hog population through available means in efforts to reduce the total number of hogs in the watershed by 15% (2,188) and maintain them at this level			
Description: Voluntarily implement efforts to reduce feral hog populations throughout the watershed by reducing food supplies, removing hogs, and educating landowners on hog removal techniques			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Landowners, Land Managers, and Lessees	• Voluntarily construct fencing around deer feeders to prevent feral hog use • Voluntarily identify travel corridors and employ trapping and hunting in these areas to reduce hog numbers • Voluntarily shoot hogs on sight; ensure that lessees shoot hogs on sight	2019-2029	$200 per feeder N/A N/A
Texas A&M AgriLife Extension Service	Deliver Feral Hog Education workshops	2019, 2022, 2026	$7,500 ea
Estimated Load Reduction			
Removing feral hogs will reduce bacteria, nutrient, and sediment loading in the watershed and direct deposition to water bodies. This will primarily reduce direct deposition since hogs spend most of their time in riparian corridors. Sediment loading will be reduced through less landscape destruction. Feral hogs are estimated to contribute 1.38×10^{12} cfu of *E. coli* to the watershed daily. Reducing the population by 15% yields a maximum annual load reduction of 1.90×10^{13} cfu when a reasonable attenuation factor assumes that 25% of the fecal bacteria deposited by feral hogs occurs within the riparian corridor. Information is not available on nutrient or sediment contributions from feral hogs; however, it is assumed that a 15% reduction in hog population produces a significant pollutant reduction (See Appendix B).			
Effectiveness	Moderate: Reduction in feral hog population will result in a direct decrease in bacteria and nutrient loading to the streams; however, removing enough hogs to decrease their overall population will be difficult.		
Certainty	Low: Feral hogs are transient and adapt well to their environment. They move freely due to food and habitat availability, and hunting/trapping pressure. Removing 15% of the population each year will be difficult and is highly dependent upon the diligence of watershed landowners and leasees.		
Commitment	Moderate: Landowners are actively battling feral hog populations and will continue to do so as long as resources remain available. Hogs adversely affect their livelihood.		
Needs	Moderate: Funds are needed to provide education and outreach to further inform landowners about feral hog management options, adverse economic impacts.		

Management Measure 3: Identify, inspect, and repair or replace failing on-site sewage systems

Human waste is another potentially significant source of *E. coli* and nutrient loading in the watershed. OSSFs are used to treat wastewater in rural areas of the watershed. Both conventional and aerobic systems are found in the watershed. Conventional systems use a septic tank and gravity fed drain field that separates solids from wastewater prior to distribution of the water into soil where actual treatment takes place. Soil is the most critical component of these systems and it must be able to readily accept wastewater yet provide a sufficient level of treatment capacity to effectively retain pathogens. Within the watershed, most soils are not suitable for this type of OSSF. According to NRCS soil suitability ratings and soils maps, nearly all the soils within the watershed are considered to be very limited for OSSF drain field purposes. In these soils, advanced treatment systems must be used to effectively treat wastewater. Aerobic treatment units are the most common advanced treatment system used in the watershed. They utilize aerobic digestion to decompose many materials in wastewater and reduce the nutrient and bacteria content of the treated wastewater. Paired with disinfection processes, these systems produce highly treated wastewater that is safe for surface application as irrigation water. Operation and maintenance requirements for these systems are more rigorous than for conventional systems. Lack of proper maintenance is common and readily leads to system failures.

Identifying and repairing or replacing 30 failing units could significantly reduce bacteria contamination within the watershed. It is estimated that yearly *E. coli* loads could be reduced by 2.42x1014 cfu through recommended OSSF repairs or replacement.

A number of factors including improper design, system selection, insufficient maintenance, and lack of education regarding OSSFs are all cited by OSSF professionals as primary reasons for OSSF failures. Further, lack of knowledge regarding OSSFs and limited financial resources are cited as reasons that system failures are not being addressed. To address these needs, focused education efforts for OSSF owners, maintenance providers, installers, and inspectors are needed. Additionally, resources to assist limited resource owners with identifying OSSF problems, performing repairs, or even replacing these systems are needed.

Delivery of OSSF education programs within the watershed may be a valuable first step to reducing pollutants within the watershed. Many homeowners may not fully understand the big picture consequences of poor OSSF management, and educational programs may prompt some stakeholders to better maintain their OSSF systems. However, the effectiveness of an educational campaign is hard to quantify.

Each of these needs, priority management areas, and expected *E. coli* loading reductions from addressing OSSF failures are discussed further in the OSSF Management Measures table.

Table 20. Management measure 3: *E. coli* management strategy evaluation for OSSFs.

<table>
<tr><th colspan="4">Pollutant Source: Failing OSSFs</th></tr>
<tr><td colspan="4">Problem: Pollutant loading from failing or nonexistent OSSFs</td></tr>
<tr><td colspan="4">Objectives:
Identify and inspect failing OSSFs in the watershed
Secure funding to promote OSSF repairs/replacements in low income areas
Repair or replace OSSFs as funding allows</td></tr>
<tr><td colspan="4">Location: Entire Watershed, increased priority in subwatershed 1 and near water bodies</td></tr>
<tr><td colspan="4">Critical Areas: OSSFs situated on soils that are not suitable for OSSF drain fields and within 150 yards of a perennial waterway</td></tr>
<tr><td colspan="4">Goal: Identify, inspect, and repair or replace (as appropriate) 30 failing OSSFs in the watershed located within very limited soils, or within 150 yards of a waterway</td></tr>
<tr><td colspan="4">Description: OSSF failures will be addressed by working to identify and inspect failing OSSFs within critical areas. Failing systems will be repaired or replaced as appropriate to bring them into compliance with local requirements</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participation</th><th>Recommendations</th><th>Period</th><th>Capital Costs</th></tr>
<tr><td>Counties or TWRI</td><td>Administer OSSF repair/replacement program to address deficient systems identified during inspections</td><td>2019-2029</td><td>$10,000/yr</td></tr>
<tr><td>County DR or Contractor</td><td>Identify and inspect failing OSSFs within priority areas; increased priority for OSSFs near water body</td><td>2019-2029</td><td>$750/inspection</td></tr>
<tr><td>Contractor</td><td>Repair/Replace OSSFs as funding allows</td><td>2019-2029</td><td>~$7,500/system</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Estimated total daily load from failing OSSFs is estimated to be 2.43×10^{14} cfu. Repairing or replacing 30 failing OSSFs in very limited soils is estimated to reduce total annual E. coli loading by 7.27×10^{15} cfu (See Appendix B). Nutrients and BOD5 will also be reduced when systems are repaired. Reduction rates vary depending on the type of system installed and onsite conditions, but generally range from 10-40% for nitrogen, 83-95% for phosphorus and 90-98% for microbial 5-Day Biochemical Oxygen Demand (BOD5; EPA 2003). Additionally, educational efforts may yield additional reductions, but is not quantifiable.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Replacement or repair of failing OSSFs will yield direct E. coli reductions to the waterways and near waterway areas of the watershed.</td></tr>
<tr><td>Certainty</td><td colspan="3">Low: Funding available to identify, inspect, and repair or replace OSSFs is limited; thus, the actual level of implementation attainable is uncertain.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Depending on funding sources available and stakeholder buy-in on allowing outside assistance, this is a strategy that could potentially have the greatest effect on human health and should be a top priority.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Funding to identify, inspect and repair/replace OSSFs is limited. Costs to administer a program, identify, inspect, and repair/replace OSSFs are considerable. Many homeowners with failing OSSFs may not realize that their OSSF is failing, so delivering educational resources to them is critical. Some homeowners may know that they need a new OSSF but may not have funds available to acquire one.</td></tr>
</table>

Management Measure 4: Reduce the amount of pet waste mixing into water bodies

Dog waste is a large potential contributor to *E. coli* nutrient loads within the watershed, especially in densely populated urban areas. There are an estimated 4,910 dogs within the watershed. Since dog populations are typically associated with human dwellings, managing dog waste is relatively simple when compared to other sources within the watershed. If not properly managed, dog waste is transported to storm drains and local waterways via storm events, and home irrigation runoff. Collecting dog waste and disposing of it in a trash receptacle is a simple and effective way to reduce *E. coli* and nutrient loading in the watershed.

Installation of dog waste collection stations in public areas such as parks, as well as educational campaigns for the public, can be a cost-effective practice to reduce dog waste within the watershed. At home, citizens can use plastic grocery bags to collect and dispose of dog waste, where it will end up in a landfill instead of the waterways.

Assuming a conservative 75% bacterial removal rate (allowing that some waste may remain on the ground, stuck to blades of grass, etc.), disposing of dog waste could yield a yearly *E. coli* reduction of 1.06×10^{14} cfu.

Management Measure 5: Implement and expand urban and impervious surface stormwater runoff management

One of the sources of *E. coli* and nutrients entering into water bodies is stormwater generated in urban areas. Compared to other sources, the chances of bacteria loading from urban impervious surface is currently relatively low, based on percent total land cover (Table 2). The main objective of this management measure is to organize general stormwater management education and outreach programs and educate residents about stormwater BMPs. The entities involved are AgriLife Extension, TWRI, cities, property owners, and contractors. The second objective is to work with local municipalities to identify and install demonstration BMPs that manage stormwater runoff as appropriate and as funding permits. BMPs that are commonly known are rain gardens, rain barrels/cisterns, green roofs, permeable pavements, bio retention, swales, and detention ponds. These BMPs are adopted based on the precipitation amount, pattern, and local preferences. The third objective is to monitor the effectiveness of BMPs and suggest new techniques to manage stormwater. The initial BMPs are not always effective. Therefore, multiple processes can be introduced to identify the most effective one.

Management Measure 6: Identify potential wastewater conveyance system failure and prioritize system repairs or replacement

Wastewater conveyance system failure causes inflow and infiltration (I&I) issues that may result in system overloads. A broken sewer line is a common source for inflow and infiltration issues. Within the watershed, inflow and infiltration were identified as the largest issues that centralized systems must deal with regardless of system size. During localized flooding some homeowners open their sewer cleanouts to drain their property. If enough instances of this occur, a significant source of inflows can occur and contribute to sanitary sewer loading. The water can enter and leave the system if there are any infrastructure cracks and breaks due to system age and changing soil moisture condition. I&I can have a diluting effect that sometimes decreases treatment efficiency and can increase utility pumping and treatment cost. Currently, efforts are underway within all centralized systems to identify and address these issues. Sewer inspection cameras can be utilized to find conveyance systems failures. Furthermore, education and outreach are needed to reduce excessive inflows from opened cleanouts.

Recent engineering studies on the sanitary sewer infrastructure in Temple may directly benefit water quality in Big Elm Creek. Proposed upgrades in the Knob Creek, Williamson Creek, and Little Elm Creek sub-basins in eastern/southeastern Temple would increase the capacity of conveyance systems and reduce I&I from deteriorating vitrified clay pipe. Recommendations also include the addition of secured, water-tight manhole covers, and a proposed lift station near Little Elm Creek (City of Temple 2019).

The main goal of this management measure is to work with entities operating WWTPs to continue and expand inspection efforts and identify problematic areas within their WWTPs. Once identified, entities will work to repair or replace problematic infrastructure to reduce inflow and infiltration issues and minimize WWTP overload occurrences. Table 23 summarizes management measures for centralized wastewater systems.

Table 21. Management measure 4: *E. coli* management strategy evaluation for dog waste.

<table>
<tr><th colspan="4">Pollutant Source: Dogs</th></tr>
<tr><td colspan="4">Problem: Improperly disposed dog waste is left on the surface and washes into streams during rainfall or irrigation runoff</td></tr>
<tr><td colspan="4">Objectives:
• Expand education and outreach messaging regarding the need to properly dispose of dog fecal matter
• Properly stock and maintain pet waste stations</td></tr>
<tr><td colspan="4">Location: Entire watershed, with highest priority on subwatershed 2</td></tr>
<tr><td colspan="4">Critical Areas: Urban areas, homes with dogs near waterways</td></tr>
<tr><td colspan="4">Goal: To reduce the amount of dog waste in the watershed that may wash into water bodies during runoff events by providing educational and physical resources to increase stakeholder awareness of the water quality and potential health issues caused by excessive dog waste</td></tr>
<tr><td colspan="4">Description: Expand distribution of educational messaging regarding the need to properly dispose of pet waste in the watershed. Specifically target homeowners and the general public. Stock and maintain existing dog waste stations in parks and other public areas to facilitate increased collection and proper disposal of dog waste.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>Cities, Counties, HOAs</td><td>Provide needed maintenance supplies for pet waste stations: est. 25 stations</td><td>2019-2029</td><td>~$85/year/station</td></tr>
<tr><td>Cities, HOAs</td><td>Provide educational resources to residents through existing avenues: e.g., newsletters, websites, etc.</td><td>2019-2029</td><td>$25,000</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Effectively managing dog waste will reduce bacteria loads from the landscape and prevent it from entering water bodies during rainfall or irrigation induced runoff; however, it will not prevent all E. coli from entering the water body. It is currently estimated that the total daily load from approximately 4,910 dogs in the watershed 7.73E+12 cfu/day (See Appendix B). Collecting and disposing of dog waste into trash containers will move the E. coli load to a landfill where it will not affect water quality. Disposing of dog waste will result in a yearly load reduction of 1.06E+14 cfu, when assuming that 75% of the bacteria from collected feces is disposed of (assuming 25% may stay attached to the ground, grass, etc.).</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Collecting and properly disposing of dog waste is a sure way to prevent E. coli and nutrients from entering local waterways. This will directly reduce the quantity of E. coli in the watershed.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: A large number of dog owners already collect and properly dispose of dog waste. Those who do not may be a difficult audience to reach or convince that dog waste should be collected and discarded properly despite their respective reasons for not doing so.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Most parks currently have pet waste stations installed; however, maintenance is sometimes less frequent than it needs to be. Signage is up in many locations stating that dog owners are required to pick up after their pet; however, little to no enforcement occurs.</td></tr>
<tr><td>Needs</td><td colspan="3">Low: Increasing maintenance on existing pet waste stations is something that could easily occur.</td></tr>
</table>

Table 22. Management measure 5: *E. coli* management measures for stormwater runoff.

Pollutant Source: Urban Stormwater Runoff			
Problem: Fecal bacteria and nutrient loading from stormwater runoff in developed and urbanized area			
Objectives: • Organize general stormwater management education and outreach program • Educate residents about stormwater BMPs • Monitor the effectiveness of BMPs and suggest new techniques to manage stormwater			
Critical Areas: Urban areas of the watershed, with priority in subwatershed 2			
Goal: Reduce *E. coli* loading associated with urban stormwater runoff through implementation of stormwater BMPs as appropriate and to increase residents' awareness of stormwater pollution and management			
Description: Potential locations and types of stormwater runoff management BMP demonstration projects will be identified in coordination with cities, public works, and property owners			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Cities, property owners, contractors	Identify and install stormwater BMPs as funding becomes available	2019-2029	$4,000-$45,000/acre (estimate)
AgriLife Extension, TWRI	Deliver education and outreach (Riparian and Stream Ecosystem Education workshop or others as appropriate) to landowners	2020, 2025	N/A
Estimated Load Reduction			
Installation of stormwater BMPs that reduce runoff or treat bacteria will result in direct reductions in bacteria loadings in the watershed. Potential load reductions were not calculated because the location, type, and size of projects installed will dictate the potential load reductions; however, they have not been identified yet.			
Effectiveness	Moderate to High: The effectiveness of BMPs at reducing bacterial and nutrient loadings is dependent on the design, site selection and maintenance of the BMP.		
Certainty	Moderate: Installation of BMPs requires sustained commitment from city officials or property owners.		
Commitment	Moderate to Low: Urban stormwater management is not a high priority for local municipalities; financial or other incentives will be needed to encourage and secure long-term commitment.		
Needs	High: It is unlikely stormwater BMPs will be installed without financial assistance.		

Table 23. Management measure 6: *E. coli* management measures for centralized wastewater.

<table>
<tr><th colspan="4">Pollutant Source: Centralized Wastewater</th></tr>
<tr><td colspan="4">Problem: Inflow and infiltration issues caused by wastewater conveyance system failures</td></tr>
<tr><td colspan="4">Objectives:
• Continue and expand system inspections by working with WWTPs to identify problem areas
• Increase rate of WWTP conveyance system repairs</td></tr>
<tr><td colspan="4">Location: WWTP Service areas</td></tr>
<tr><td colspan="4">Critical Areas: All WWTPs</td></tr>
<tr><td colspan="4">Goal: Work with WWTPs entities to identify problematic areas within their WWTPs. Once the problem is identified, work to replace or repair problematic infrastructure. Reduce E. coli loading associated with sewer system failures that occur during high rain events an unauthorized discharged.</td></tr>
<tr><td colspan="4">Description: Smoke tests, camera inspections etc. can be used to identify connections where I&I problem exist. Prioritize system repairs or replacements based on system impacts (largest impact areas addressed first). Deliver education and outreach to residents.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>WWTP Operating Entities</td><td>Perform WWTP conveyance system testing to ID inflow and infiltration problem areas; prioritize problem areas for repair/replacement</td><td>2019-2029</td><td>$3000-$10,000/site</td></tr>
<tr><td>WWTP Operating Entities</td><td>As funds allow, repair or replace WWTP conveyance infrastructure</td><td>2019-2029</td><td>$~26.9Million</td></tr>
<tr><td>WWTP Operating Entities</td><td>Provide educational resources regarding inflow and infiltration (uncapped cleanouts; faulty sewer lines) and effect of malfunctions with utility bill inserts</td><td>2019-2029</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Load reductions from inspections and subsequent repairs or replacements of wastewater conveyance infrastructure and education delivery cannot be accurately estimated. Not all inflow and infiltration to WWTP conveyance systems results in WWTP overloading. Instead, the number of inflows and infiltration locations repaired and the reduced number of WWTP overloads will signify progress made in reducing pollutant loading to the Big Elm Creek.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Reducing the number and volume of inflow and infiltration issues will directly reduce E. coli and nutrient loading to receiving waters.
Moderate: Education deliver via utility bill inserts will reach some people but not all. The number of people changing their behavior cannot be quantified.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Each entity operating a WWTP in the watershed already performs inflow and infiltration inspection and makes repairs as needed and as funding allows.
High: Utility bill inserts are common and information on inflow and infiltration can easily be included.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Each entity operating a WWTP indicated that they will continue to perform inspections and repairs within their respective collection system.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial assistance needs are great. Operating budgets for entities are small and already strained, making financial assistance to inspect and repair conveyance system a must.</td></tr>
</table>

Table 24. Management measure 7: *E. coli* management measures for illicit dumping.

<table>
<tr><th colspan="4">Pollutant Source: Illicit and Illegal Dumping</th></tr>
<tr><td colspan="4">Problem: Illicit and illegal dumping of trash and animal carcasses in and along waterways</td></tr>
<tr><td colspan="4">Objective:
• Promote and expand education and outreach efforts in the watershed</td></tr>
<tr><td colspan="4">Critical Areas: Entire watershed with focus at bridge crossings and public access areas</td></tr>
<tr><td colspan="4">Goal: Increase awareness of proper disposal techniques and reduce illicit dumping of waste and animal carcasses in water bodies throughout the watershed</td></tr>
<tr><td colspan="4">Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on the proper disposal of carcasses and waste materials</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>AgriLife Extension, TWRI, Counties</td><td>Develop and deliver E&O materials to residents</td><td>2019-2029</td><td>~$5,000</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Load Reductions are likely minimal from this management measure and were not quantified</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Low: Preventing illicit dumping, especially animal carcasses, is likely to reduce bacteria loads by some amount, although this loading is likely limited to areas with public access.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that illegally dump is likely difficult.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Many stakeholders indicate illicit dumping occurs; however, enforcement is difficult in rural areas. The issue is not a high priority and commitment of limited resources will likely remain low.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Some financial resources will be required to develop educational materials. Information could be incorporated into ongoing watershed related educational and outreach efforts.</td></tr>
</table>

Management Measure 7: Reduce illicit and accidental dumping

Based on stakeholders' input, illicit dumping, particularly of animal carcasses can contribute to bacteria loads, especially during high runoff events. People might dispose of deer, hogs, or small livestock carcasses in addition to other trash at or near bridge crossings. Stakeholders say that the scope of the problem is not entirely known or quantified but anticipated to be a relatively minor contributor to bacteria loadings in the watershed compared to other sources. In order to reduce this issue, development and delivery of educational and outreach materials to residents on proper disposals of carcasses and other trash could be constructive. Table 24 summarizes management measures for illicit dumping.

Stakeholders also voiced concerns about accidental dumping of chemicals and other substances in the watershed from automotive and railroad accidents. While not having a direct impact on bacterial loads in the watershed, direct deposition at road and rail crossings could have detrimental effects on instream water quality. The Texas Department of Transportation (TXDOT) has jurisdiction over spills occurring on highways and railways in Texas.

Table 25. Management measure 8: Management measures for reducing nutrient runoff in the soils of agriculture and urban areas.

<table>
<tr><th colspan="4">Pollutant Source: Soils in the agriculture and urban areas</th></tr>
<tr><td colspan="4">Problem: Excessive soil nutrients in agricultural and urban areas due to over-fertilization could runoff into surface water during high rainfall events</td></tr>
<tr><td colspan="4">Objective:
• Promote and expand education and outreach efforts in the watershed in order to prevent nutrient contamination</td></tr>
<tr><td colspan="4">Critical Areas: Entire watershed, with focus on areas closer to water bodies</td></tr>
<tr><td colspan="4">Goal: Reduce nutrient runoff through application of proper fertilization rates</td></tr>
<tr><td colspan="4">Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on soil nutrients and water quality</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>AgriLife Extension, TWRI, Counties</td><td>Develop and deliver educational and outreach materials</td><td>2019-2029</td><td>~$25,000</td></tr>
<tr><td>Healthy Lawns and Healthy Waters</td><td>Conduct workshops on soil testing and ways to determine nutrients application amounts</td><td>2019-2029</td><td>N/A</td></tr>
<tr><td>Local stakeholders, landowners, land managers</td><td>Conduct soil tests before applying fertilizer</td><td>2019-2029</td><td>$12/soil test</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">N/A: No available nutrient load standards, though a reduction will be beneficial to water quality overall</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Moderate: Extra time and effort involved may hinder implementation</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Many stakeholders indicate that soil test is necessary; however, administration may be difficult in all the areas. The issue is not a high priority and commitment of limited resources will likely remain low.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Some financial resources will be required to develop educational materials. Information could be incorporated into ongoing watershed related educational and outreach efforts.</td></tr>
</table>

Management Measure 8: Conduct soil tests for both agricultural and urban areas

Stakeholders indicated that conducting soil tests in both agricultural and urban areas can also be part of management measures to reduce nutrient loadings due to high runoff events. The composition of soil can vary from place to place within the watershed. Soil compositions in agricultural areas tend to be high in nutrients due to application of fertilizers. Similarly, lawns and parks in urban areas can be high in fertilizer as well. Therefore, soil testing in both agricultural and urban areas are included to prevent nutrient runoff into nearby water bodies by ensuring the proper rates and timing of fertilizer applications. Table 25 summarizes management measures for soil tests in agricultural and urban areas.

Table 26. Management measure 9: Management measures to prevent runoff from the landfill areas.

Pollutant Source: Runoff from the landfill sites			
Problem: Runoff from the landfill areas			
Objectives: • Promote and expand education and outreach efforts in the watershed and encourage residents to adopt BMPs • Setting up meeting with county or municipal contacts to educate stakeholders about rules and regulations of landfill operations			
Critical Areas: Upstream and downstream of streams close to the landfill sites			
Goal: To determine the affect (if any) that a landfill might play within the watershed			
Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on BMPs to handle and proper disposals of waste			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
AgriLife Extension, TWRI, Counties	Develop and deliver educational and outreach materi-als.	2019-2029	TBD
TWRI, TCEQ, BRA	Monitor water quality at pre-determined sites, or via intensive sampling studies.	2019-2029	TBD
Estimated Load Reduction			
Load reductions are likely minimal from this management measure and were not quantified.			
Effectiveness	Moderate: Landfills are closely monitored and must follow environmental regulations. Educating the public and following up with data could ease public concerns.		
Certainty	Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best.		
Commitment	Moderate: Many stakeholders are concerned about having a landfill in the watershed and would anticipate scientific-based findings.		
Needs	Moderate: Some financial resources will be required to develop educational materials and conduct field/lab work.		

Management Measure 9: Additional monitoring on the upstream and downstream on Big Elm Creek close to the landfill areas

Landfill sites have been identified as a local concern among stakeholders. Stakeholders of the Big Elm Creek watershed suggested that additional monitoring on the upstream and downstream areas close to the landfill was a priority. Therefore, additional monitoring near the landfill as a special study may help to shed light on its role within the watershed. This could be through additional routine monitoring or targeted intensive sampling, whereby a specific portion of the watershed is sampled at multiple locations in a single day to look for hot spots of pollutant concentrations. Furthermore, hosting public officials at stakeholder meetings to further educate the public on the rules and regulations surrounding the operation of landfill sites may help to ease stakeholder concerns.

Table 27. Management measure 10: Management measures to conduct landowner educational workshops.

Pollutant Source: Landowners without education resources			
Problem: Due to lack of knowledge about stormwater, pet waste, OSSFs, grazing lands, and water resource management, landowners might adopt incorrect methods to manage them			
Objectives: • Promote and expand education and outreach efforts in the watershed			
Critical Areas: Entire watershed			
Goal: Educate landowners about sources of *E. coli* and other pollutants in the watershed and various ways to manage them.			
Description: Education delivery will mainly focus on landscape and water resource management, OSSF operation and maintenance, OSSF design and installation.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
AgriLife Extension, TWRI, Counties	Develop and deliver ed-ucational and outreach materials to landowners	2019-2029	~$25,000
Estimated Load Reduction			
Load Reductions from this management measure were not quantified.			
Effectiveness	High: Educating landowners to effectively manage stormwater, pet waste and OSSFs prevents *E. coli* and nutrients from contaminating streams.		
Certainty	Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that needs assistance will be beneficial.		
Commitment	Moderate: Many stakeholders indicate that they would like to attend educational workshops		
Needs	Moderate: Some financial resources will be required to develop educational materials. Information could be incorporated into ongoing watershed related educational and outreach efforts.		

Management Measure 10: Conduct new or small landowner education workshop program

The main objective of this workshop will be educating landowners to identify sources of *E. coli*, nutrients and other pollutants in the watershed. Often, new and/or small acreage landowners may be unaware of BMPs and resources available for implementation. Educating landowners to manage stormwater, pet waste, OSSFs, feral hogs, and water resource management is very important to prevent *E. coli* and nutrients from getting into nearby water bodies. Stakeholders indicated that workshops like this will be helpful and should be conducted in different parts of the watershed. These education workshops will further protect and improve local water resources by ensuring that appropriate persons are informed by new techniques, requirements, and resources.

Table 28. Big Elm Creek watershed management measures, responsible party, goals, and estimated costs.

<table>
<tr><th rowspan="2">Management Measure</th><th rowspan="2">Responsible Party</th><th rowspan="2">Unit Cost</th><th colspan="10">Implementation Goals (years after implementation begins)</th><th rowspan="2">Total Cost</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th></tr>
<tr><td colspan="14">Livestock</td></tr>
<tr><td>Develop 30 WQMPs/ conservation plans</td><td>TSSWCB, SWCDs, NRCS</td><td>$15,000 per plan</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">6</td><td>$450,000</td></tr>
<tr><td>Lone Star Healthy Streams Programs</td><td>Texas A&M AgriLife Extension Service</td><td>N/A</td><td colspan="10">Approximately once every 3 years</td><td>N/A</td></tr>
<tr><td colspan="14">Feral Hogs</td></tr>
<tr><td>Install feral hog enclosures</td><td>Landowners</td><td>$200 per feeder</td><td colspan="10">As many as possible</td><td>Varies</td></tr>
<tr><td>Feral Hog Removal</td><td>Landowners</td><td>Varies</td><td colspan="10">15% reduction or 2,188 hogs/year</td><td>Varies</td></tr>
<tr><td>Feral hog removal workshop</td><td>Texas A&M Extension Service</td><td>$7,500 each</td><td colspan="10">3</td><td>$22,500</td></tr>
<tr><td colspan="14">OSSFs</td></tr>
<tr><td>Develop OSSF repair/replacement education program</td><td>Watershed Coordinator, counties, AgriLife Extension</td><td>N/A</td><td colspan="10">1</td><td>N/A</td></tr>
<tr><td>Identify and inspect 30 failing OSSFs</td><td>Homeowner, county DR or contractor</td><td>$7,500 per system</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">6</td><td>$225, 000</td></tr>
<tr><td colspan="14">Pet Waste</td></tr>
<tr><td>Install and maintain pet waste stations; Est. 25 stations</td><td>Cities, Counties, HOAs</td><td>~ $85/year/station</td><td colspan="2">5</td><td colspan="2">5</td><td colspan="2">5</td><td colspan="2">5</td><td colspan="2">5</td><td>$2,125</td></tr>
<tr><td>Develop and deliver educational and outreach materials</td><td>Cities, AgriLife Extension, Watershed Coordinator</td><td>~$5,000</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td>$25,000</td></tr>
<tr><td colspan="14">Urban Stormwater</td></tr>
<tr><td>Identify and install potential stormwater BMP projects</td><td>Cities, property owners, contractors</td><td>$4,000 to $45,000/ acre treated</td><td colspan="10">As many as possible</td><td>Varies</td></tr>
<tr><td colspan="14">Centralized Wastewater</td></tr>
<tr><td>WWTP conveyance system testing to ID inflow and infiltration problem areas</td><td>WWTP Operating Entities</td><td>$3,000-$10,000/site</td><td colspan="10">As many as possible</td><td>Varies</td></tr>
<tr><td>Repair or replace WWTP conveyance infrastructure</td><td>WWTP Operating Entities</td><td>N/A</td><td colspan="10">As many as possible</td><td>$~26.9Million[1]</td></tr>
</table>

Table 28. (Continued).

Management Measure	Responsible Party	Unit Cost	Implementation Goals (years after implementation begins)										Total Cost
			1	2	3	4	5	6	7	8	9	10	
Illicit Dumping													
Develop educational and outreach materials	Counties, AgriLife Extension, Watershed Coordinator	N/A	Develop and deliver annually										TBD
Soil Testing													
Develop and deliver educational and outreach materials	AgriLife Extension, TWRI, Counties	~$5,000	1		1		1		1		1		~$25,000
Soil testing	AgriLife Extension	$12/test											TBD
Additional Monitoring													
Monitor water quality on the stream as often as possible	AgriLife Extension, TWRI, Counties	N/A	Every year										TBD
Landowner Education													
Develop and deliver educational and outreach materials to landowners	AgriLife Extension, TWRI, Counties	N/A	Develop and deliver annually										N/A
General Watershed Management													
Hire Watershed Coordinator	TWRI	$75,000/yr	1										
Semi-annual meetings	TWRI, Watershed Coordinator	$300/meeting	Semi-annually										$6,000

[1] 2019 Estimate Provided by City of Temple

Table 29. Total estimated loading reduction.

Management Measure	Expected *E. coli* Load Reduction (from previous section)
Agricultural Management Measures	
Water Quality Management Plans (TSSWCB/Local SWCDs)	2.26×10^{14} cfu/year
Conservation Plans (NRCS)	
Livestock Management Education and Outreach	
Feral Hog Management	
Feral Hog Removal	1.90×10^{13} cfu/year
Supplemental Feeding Exclosures	
Feral Hog Education and Outreach Programming	
OSSF Management	
OSSF Repair and Replacement	7.27×10^{15} cfu/year
OSSF Owner Education and Outreach	
OSSF Installer and Service Provider Education and Outreach	
Dog Management	
Dispose of Dog Waste into trash receptacles	1.06×10^{14} cfu/year
Total Reduction	7.62×10^{15} cfu/year

Expected Loading Reductions

Reducing *E. coli* loads across the watershed and the amount of *E. coli* in the river is the goal of these management objectives. Any one of the below management objectives would more than reduce yearly *E. coli* loads by the necessary 2.57E+13 cfu. However, due to human nature and other unforeseen errors in the application, follow through, or maintenance of these practices, a multi-faceted approach would be more practical and more likely successful in the overall reduction of *E. coli* loads to Big Elm Creek. Other actions planned such as general education and outreach programs, will also provide load reductions that are not easily quantified.

Following the development of these management strategies, a watershed protection planning process will proceed with stakeholder involvement. These practices will be presented to stakeholders for further discussion, feedback, and suggestions. Other possible practices that may warrant discussion could include low impact development (LID) in urban areas, wastewater treatment plant (WWTP) upgrades, and riparian area restoration.

Chapter 6 Financial and Technical Resources Needed for WPP Implementation

Firewheel flower near Cameron, TX. Photo By Ed Rhodes, TWRI.

Introduction

A successful WPP requires multiple sources of support and assistance that can vary depending on the level of complexities and the BMPs adopted. To achieve the common goal of improving water quality in Big Elm Creek, it is important to identify the sources that play an important role in WPP implementation. The sources for WPP implementation for Big Elm Creek include but are not limited to technical, financial, and educational outreach assistance. This chapter identifies various technical and financial sources available to maximize the implementation of management measures.

Technical Assistance

Various sources of technical assistance will be required to design and implement the management recommendations in this plan. Some technical assistance relies on funding that may come from a variety of other sources. A summary of some potential sources of technical assistance is listed in Table 30.

Agricultural and Livestock Management

The proposed approach for managing bacteria loadings from livestock is to adopt a variety of best management practices (BMPs) to reduce and filter bacteria and nutrient depositions. In order to achieve agricultural and livestock management goals, producers require significant technical assistance from the USDA – Natural Resources Conservation Services (NRCS) and the Texas State Soil and Water Conservation Board (TSSWCB). Landowners and producers seeking planning and implementation assistance will work with these entities to develop a management plan, CPs, and WQMPs.

Table 30. Summary of potential sources of technical assistance.

Technical Assistance	
Management Measure (MM)	**Potential Sources of Assistance**
MM1: Promote and implement Water Quality Management Plans or Conservation Plans	AgriLife Extension; NRCS; TSSWCB; local SWCDs
MM2: Promote technical and direct operational assistance to landowners for feral hog control	AgriLife Extension; NRCS; TSSWCB; local SWCDs
MM3: Identify, inspect, and repair or replace failing on-site sewage systems	AgriLife Extension; Designed technicians from Bell, McLennan and Milam counties
MM4: Reduce the amount of pet waste mixing into water bodies	Cities; Counties; HOAs; AgriLife Extension
MM5: Implement and expand urban and impervious surface stormwater runoff management	City public works departments; AgriLife Extension
MM6: Identify potential wastewater conveyance system failure and prioritize system repairs or replacement	WWTP Operating Entities; City public works departments; Contractors; Consulting enginees
MM7: Reduce illicit and accidental dumping	AgriLife Extension; County law enforcement; TPWD game wardens; TXDOT
MM8: Conduct soil test for both agriculture and urban areas	AgriLife Extension; TWRI; Counties
MM9: Additional monitoring on the upstream and downstream close to landfill areas	AgriLife Extension; TWRI; Counties
MM10: Conduct old and new landowner education workshop program	AgriLife Extension; TWRI; Counties

Texas A&M AgriLife Extension Service, AgriLife Extension; Natural Resources Conservation Service, NRCS; Texas State Soil and Water Conservation Board, TSSWCB; Soil and Water Conservation Districts, SWCDs; Home Owners Associations, HOAs; Wastewater Treatment Plant, WWTP; Texas Parks and Wildlife Department, TPWD; Texas Department of Transportation, TXDOT; Texas Water Resources Institute, TWRI

Feral Hog Management

Landowners and watershed stakeholders need to be familiar with feral hog control approaches, options, and best practices for various feral hog control activities. Texas A&M AgriLife Extension Service and TPWD could be utilized to deliver feral hogs education workshops to better assist the public in understanding and managing feral hog populations. Additional information regarding trap and transport regulations, trap construction, and designs, is available at: http://feralhogs.tamu.edu/.

OSSF Management

To identify, inspect, and repair or replace failing OSSFs requires technical assistance. County designated representatives (DR) or local septic contractors could be helpful in identifying and inspecting failing OSSFs for repair or replacement. Other needs include assisting in funding acquisition, program design, assisting homeowners in applying for funding support, and collaborating with inspectors, designers, and installers. Technical assistance for education and outreach may be available through Texas A&M AgriLife Extension Service.

Pet Waste

City public works and park departments are relied upon to identity appropriate dog waste management sites. These entities provide technical assistance in installing dog waste stations in the parks that are nearby water sources. Moreover, homeowners should be provided educational resources through existing avenues such as newsletters, website, etc. Technical assistance for educational materials will be provided through Texas A&M AgriLife Extension.

Urban Stormwater

Technical assistance is required to identify potential locations and types of stormwater runoff BMPs. City public work departments, and engineering firms could be utilized to develop and oversee large scale urban BMP projects. Urban runoff BMP workshops can be coordinated through Texas A&M AgriLife Extension. For structural projects, engineering designs may need to be integrated into the project cost.

Table 31. Sources of Potential Financial assistance for WPP implementation.

Financial Assistance	
Management Measure (MM)	**Potential Sources of Financial Assistance**
MM1: Promote and implement Water Quality Management Plans or Conservation Plans	Environmental Quality Incentives Program; Conservation Stewardship Program; Conservation Reserve Program; National Integrated Water Quality Program; National Water Quality Initiative; Federal and State CWA §319(h) Grants; TSSWCB WQMP Program
MM2: Promote technical and direct operational assistance to landowners for feral hog control	State CWA §319(h) Grants (TSSWCB, cannot be used for control or removal); Texas Department of Agriculture; Texas Wildlife Services
MM3: Identify, inspect, and repair or replace failing on-site sewage systems	State CWA §319(h) Grants (TCEQ); Texas Department of Agriculture; Texas SEP Fund
MM4: Reduce the amount of pet waste mixing into water bodies	State CWA §319(h) Grants (TCEQ); Environmental Education Grants
MM5: Implement and expand urban and impervious surface stormwater runoff management	State CWA §319(h) Grants (TCEQ); Environmental Education Grants
MM6: Identify potential wastewater conveyance system failure and prioritize system repairs or replacement	Water and waste disposal loans and grants; City fees and bonds
MM7: Reduce illicit and accidental dumping	State CWA §319(h) Grants (TCEQ/TSSWCB); USDA Water and Waste Disposal Loan and Grant Program
MM8: Conduct soil test for both agriculture and urban areas	State CWA §319(h) Grants (TCEQ/TSSWCB); Environmental Education Grants
MM9: Additional monitoring on the upstream and downstream close to landfill areas	State CWA §319(h) Grants (TCEQ/TSSWCB); Clean Rivers Program
MM10: Conduct old and new landowner education workshop program	State CWA §319(h) Grants (TSSWCB)

Clean Water Act, CWA; Texas State Soil and Water Conservation Board, TSSWCB; Water Quality Management Plan, WQMP; Supplemental Environmental Project, SEP; Texas Commission on Environmental Quality, TCEQ; United States Department of Agriculture, USDA

Centralized Wastewater

Technical assistance needs for addressing inflow and infiltration issues within wastewater collection systems will vary depending on the capacity to perform needed tasks within each entity. Collection system inspections using smoke testing or autonomous video technology and making needed repairs may require contractors to conduct or consulting engineers to design these projects.

Illicit and Accidental Dumping

Efforts to reduce illicit and accidental dumping will focus on education and outreach. Texas A&M AgriLife Extension may provide technical assistance with education and outreach efforts. County law enforcement and TPWD game wardens are the primary source of enforcement and monitoring activities associated with illicit dumping. Accidental discharge on roads and railways are under TXDOT jurisdiction.

Financial Assistance

Diverse sources of funding will be required to meet the management measures described in the WPP. Resources will be leveraged where possible to extend the impacts of acquired and contributed implementation funds.

Grant funds will be relied upon to initiate implementation efforts. Existing state and federal programs will also be expanded or leveraged with acquired funding to further implementation activities. Grant funds are not a sustainable source of financial assistance but are necessary to assist in WPP implementation. Other sources of funding will be used, and creative funding approaches will be sought where appropriate. Appropriate funding sources applicable to this WPP will be sought and are described in this chapter.

Federal Funding Sources

Clean Water Act §319(h) Nonpoint Source Grant Program

The EPA provides grant funding to the State of Texas to implement projects that reduce nonpoint source pollution through the §319(h) Nonpoint Source Grant Program. These grants are administered by TCEQ and TSSWCB in Texas. WPPs that satisfy the nine key elements of successful watershed-based plans are eligible for funding through this program. To be eligible for funding, implementation measures must be included in the accepted WPP and meet other program rules. Some commonly funded items include:

- Development and delivery of educational programs
- Water quality monitoring
- OSSF repairs and replacements, land BMPs, water body clean-up events, and others

Further information can be found at: https://www.tceq.texas.gov/waterquality/nonpoint-source/grants and https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program.

Environmental Education Grants

Under the Environmental Education Grant Program, EPA seeks grant proposals from eligible applicants to support environmental education projects that promote environmental stewardship and help develop knowledgeable and responsible students, teachers, and citizens. This grant program provides financial support for projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques as described in the Environmental Education Grant Program solicitation notices.

Environmental Quality Incentives Program (EQIP)

USDA-NRCS operates a voluntary conservation program, the Environmental Quality Incentives Program (EQIP), which provides assistance to farmers and ranchers to address natural resource concerns by implementing activities to improve soil, water, plant, animal, air, and other resources associated with agricultural land. An EQIP contract extends up to 10 years, which provides financial and technical assistance for planning and implementing prescribed conservation practices. EQIP participants includes individuals engaged in livestock or agricultural production on eligible land. Selected practices address natural resource concerns and are subject to the NRCS technical standards adapted for local conditions. They also must be approved by the local SWCD. Local work groups are formed to provide recommendations to the USDA NRCS that advise the agency on allocations of EQIP county-based funds and identify local resource concerns. Watershed stakeholders are strongly encouraged to participate in their local work group to promote the objectives of this WPP with the resource concerns and conservation priorities of EQIP.

Information regarding EQIP can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.

Conservation Stewardship Program (CSP)

USDA-NRCS administers a voluntary conservation program known as Conservation Stewardship Program (CSP) that encourages producers to address resource concerns in a comprehensive manner by adding, maintaining, improving, and managing conservation activities. The program is available for private agricultural lands including cropland, grassland, prairie land, improved pasture, and rangeland. CSP encourages landowners and stewards to improve conservation activities on their land by installing and adopting additional conservation practices. Practices may include, but are not limited to, prescribed grazing, nutrient management planning, precision nutrient application, manure application, and integrated pest management. Program information can be found at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/.

Conservation Reserve Program

The Conservation Reserve Program is a voluntary program for agricultural landowners administered by the USDA Farm Service Agency (FSA). Individuals may receive annual rental payments to establish long-term, resource-conserving covers on environmentally sensitive land. The goal of the program is to reduce runoff and sedimentation to protect and improve lakes, rivers, ponds, and streams. Financial assistance covering up to 50% of the costs to establish approved conservation practices, enrollment payments and performance payments are available through the program. Information on the program is available at: http://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index.

Contact your local FSA office for more information on this and other programs or to enroll:

McLennan County: (254) 662-2273

Bell County: (254) 939-5804

Milam County: (254) 697-4949

Falls County: (254) 883-5577

National Integrated Water Quality Program (NIWQP)

The NIWQP, administered by the USDA, provides funding for research, education, and extension projects aimed at improving water quality in agricultural and rural watershed, and has identified eight themes that are being promoted: (1) animal manure and waste management, (2) drinking water and human health, (3) environmental restoration, (4) nutrient and pesticide management, (5) pollution assessment and prevention, (6) watershed management, (7) water conservation and agricultural water management, and (8) water policy and economics. Awards are made in four program areas – National Projects, Regional Coordination Projects, and Extension Education Projects. It is important to note that funding from this program is only available to universities. More information is available at: https://nifa.usda.gov/national-integrated-water-quality-program-frequently-asked-questions.

National Water Quality Initiative (NWQI)

The NWQI is administered by the NRCS, and is a partnership between the NRCS, state water quality agencies, and the EPA to identify and address impaired water bodies through voluntary conservation. Conservation systems include practices to promote soil health, reduce erosion and nutrient runoff. Further information is available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/initiatives/?cid=stelprdb1047761.

State Funding Sources

Clean Rivers Program (CRP)

TCEQ administers the Texas CRP, a state fee-funded program that provides surface water quality monitoring, assessment, and public outreach. Allocations are made to 15 partner agencies (primarily river authorities) throughout the state to assist in routine monitoring efforts, special studies, and outreach efforts. The Elm Creek River Authority (ECRA) is CRP partner for the Big Elm Creek watershed. The program supports water quality monitoring and annual water quality assessments and engages stakeholders in addressing water quality concerns in the Big Elm Creek River Basin. More information about the Clean Rivers Program is available at: https://brazos.org/About-Us/Water-Quality/Clean-Rivers-Program.

Clean Water State Revolving Fund

The TWDB provides low-cost financing for a variety of wastewater, stormwater, reuse, and other pollution control projects. Political subdivisions and private entities are eligible to apply for loans at lower than market rates to plan, design, acquire or construct projects. The loans can spread project costs over a repayment period of up to 20 years. Repayments are cycled back into the fund and used to pay for additional projects. Through 2016, the program committed over $9.8 billion for projects across Texas. More information on CWSRF is available at: http://www.twdb.texas.gov/financial/programs/CWSRF/.

Landowner Incentive Program

Landowner Intensive Program, administered by TPWD, work with private landowners to implement conservation practices that benefit healthy aquatic and terrestrial ecosystem. The program provides financial assistance but does not require the landowner to contribute through labor, materials, or other means. Further information about this program is available at: http://tpwd.texas.gov/landwater/land/private/lip.

Supplemental Environmental Projects (SEP)

SEP program is administered by TCEQ, which is responsible for directing fines, fees, and penalties for environmental violations to reduce environmental pollution. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. Improvement activities such as OSSF repair, trash dump clean-up, and wildlife habitat restoration can be directed by program dollars. Some pre-approved SEP projects eligible in the watershed are cleanup of unauthorized dumpsites, household hazardous waste collection and wastewater treatment assistance (repair or replace failing OSSFs). Further information about SEPs and how to apply can be found at: https://www.tceq.texas.gov/compliance/enforcement/sep.

Texas Wildlife Services Program

The Texas Wildlife Services Program is available to provide assistance in addressing feral hog issues to all citizens of the state. While direct control will be limited to availability of personnel in cooperative association areas (i.e., areas designated by groups of landowners to improve wildlife habitats and other associated wildlife programs), technical assistance can be provided to individuals on how to best resolve feral hog problems. Since 2008, TDA has awarded grants to Texas Wildlife Services for feral hog abatement programs. The grants are used to carry out a number of specifically identified direct control projects where control efforts can be measured. Certain areas of the state have been targeted due to the contribution from feral hogs to impaired water quality and bacteria loading.

Water Quality Management Plan Program (WQMP)

WQMPs are management plans developed and implemented to improve land and water quality. TSSWCB and local SWCDs provide necessary technical assistance to develop plans that meet producer and state goals. Once the plan is developed, TSSWCB may financially assist implementing a portion of prescribed BMPs. As of 2019, TSSWCB has developed and certified 73 WQMPs in the watershed. Through these plans, over 11,180 acres are currently enrolled in the Big Elm Creek watershed area and include practices such as conservation cover, prescribed grazing, fencing, heavy-use area protection, water facilities, wells, and upland wildlife management.

Other Sources

Private foundations, non-profit organizations, land trusts and individuals can potentially assist with implementation funding of some aspects of the WPP. Funding eligibility requirements for each program should be reviewed before applying to ensure applicability. Some groups that may be able to provide funding include but are not limited to:

- Cynthia and George Mitchell Foundation: provides grants for water and land conservation programs to support sustainable protection and conservation of Texas' land and water resources.
- Dixon Water Foundation: provides grants to non-profit organizations to assist in improving/maintaining watershed health through sustainable land management.
- Meadows Foundation: provides grants to non-profit organizations, agencies and universities engaged in protecting water quality and promoting land conservation practices to maintain water quality and water availability on private lands.
- Texas Agricultural Land Trust: provides funding to assist in establishing conservation easements for enrolled lands.

Chapter 7
Education and Outreach

Rural water tower on FM 485. Photo By Ed Rhodes, TWRI.

Introduction

The education and outreach components of implementation focuses on keeping the public, landowners, and agency personnel informed of project activities, provides information about appropriate management practices, and assists in identifying and forming partnerships to lead the effort. Long-term commitments from local citizens and landowners is important to accomplish comprehensive improvements in the Big Elm Creek watershed. Similarly, training for city and county staff is also necessary for effectively reducing pollutant loading in the watershed.

Education will mainly focus on primary sources of *E. coli* and other pollutants identified throughout the watershed. Similarly, landscape and water resource management, OSSF operation and maintenance, OSSF design and installation, feral hog, dog waste, cattle and livestock management, and nutrient management programs will be delivered in the watershed in multiple locations.

Watershed Coordinator

The watershed coordinator leads efforts to establish and maintain the working partnerships with stakeholders. The role of watershed coordinator is also to serve as a point of contact for all things related to WPP development, implementation, and the WPP itself. Currently, TWRI has taken the lead on this role. However, a full-time position is recommended to support WPP implementation.

The future role of the Watershed Coordinator is perhaps most important. The Watershed Coordinator will be tasked with maintaining stakeholder support for years to come, identifying, and securing funds to implement the WPP, tracking success of implementation, and working to implement adaptive management strategies. Simply put, the Watershed Coordinator is the catalyst to keeping WPP implementation on track.

Table 32. Big Elm Creek watershed stakeholders that will need to be engaged throughout the implementation of the WPP.

Big Elm Creek Stakeholders
Private entities: Residents, landowners, businesses
Local governments: Bell, Milam, Falls, and McLennan counties, City of Temple
State agencies: TCEQ, TSSWCB, TWDB, TPWD, AgriLife Extension
Federal agencies: USDA, NRCS
Regional entities: ECRA Staff and board members, SWCD boards

Texas Commission on Environmental Quality, TCEQ; Texas State Soil and Water Conservation Board, TSSWCB; Texas Water Development Board, TWDB; Texas Parks and Wildlife Department, TPWD; Texas A&M AgriLife Extension Service, AgriLife Extension; United States Department of Agriculture, USDA; Natural Resources Conservation Service, NRCS; Elm Creek River Authority, ECRA; Soil and Water Conservation District, SWCD

Public Meetings

Developing a WPP is a lengthy process and throughout the course of developing the WPP, stakeholder engagement has been critical. Public meetings held to develop the WPP with local stakeholders began in August 2018 for Big Elm Creek (Appendix C). Throughout the process, numerous local stakeholders have participated in the many public meetings, one-on-one meetings and workshops associated with WPP development (Table 32).

Future Stakeholder Engagement

Watershed stakeholders (Table 32) will be continually engaged throughout the entire process and following the transition of efforts from development to implementation of the WPP. The Watershed Coordinator will play a critical role in this transition by continuing to organize and host periodic public meetings and needed educational events in addition to seeking out and meeting with focused groups of stakeholders to find and secure implementation funds. The coordinator will also provide content to maintain and update the project website, track WPP implementation progress, and participate in local events to promote watershed awareness and stewardship. News articles, newsletters and the project website will be primary tools used to communicate with watershed stakeholders on a regular basis and will be developed to update readers periodically on implementation progress, provide information on new implementation opportunities, inform them on available technical or financial assistance, and other items of interest related to the WPP effort.

Education Programs

Educational programming will be a critical part of the WPP implementation process. Multiple programs geared toward providing information on various sources of potential pollutants and feasible management strategies will be delivered in and near the Big Elm Creek watershed and advertised to watershed stakeholders. An approximate schedule for planned programming is provided in Table 33. This schedule will be used as a starting point, and efforts will be made to abide by this schedule as much as possible. As implementation and data collection continues, the adaptive management process will be used to modify this schedule and respective educational needs as appropriate.

Feral Hog Management Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver periodic workshops focusing on feral hog management. This workshop will educate landowners on the negative impacts of feral hogs, effective control methods and resources to help them control these pests. Workshop frequency will be approximately every 3–5 years, unless there are significant changes in available means and methods to control feral hogs. Management of other wildlife species may be of interest and presented as a section of this workshop as well.

Lone Star Healthy Streams Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver the Lone Star Healthy Streams curriculum. This program is geared toward expanding stakeholders' knowledge on how beef cattle producers can improve grazing lands to reduce nonpoint source pollution. This statewide program promotes the adoption of BMPs that have been proven to effectively reduce bacterial contamination of streams. This program provides educational support for the development of conservation plans by illustrating the benefits of many practices available for inclusion in a conservation plan to program participants. This program will likely be delivered in the watershed once every 3-5 year period, or as needed.

Healthy Lawns Healthy Waters Workshop

The Healthy Lawns and Healthy Waters program is an educational training program that aims to improve and protect surface water quality by enhancing Texas residents' awareness and knowledge of best management practices for residential landscapes. Funding for the Healthy Lawns and Healthy Waters Program is provided in part through Clean Water Act 319 grants from the Texas Commission on Environmental Quality through the U.S Environmental Protection Agency. This program is designed to train homeowners and landowners to design and install residential rainwater capture devices, educate them about the key importance of soil testing, and how to determine nutrient application amounts. The goal of this program is to train Texans regarding reduced runoff, water quality, and best management practices for protecting their home landscape, watershed, and surface waters. More information can be found at: https://hlhw.tamu.edu/.

OSSF Operation and Maintenance Workshop

Once OSSFs in the watershed and their owners have been identified, an OSSF rules, regulations, operation, and maintenance training may be delivered in the watershed. This training will consist of education and outreach practices to promote the proper management of existing OSSFs and to garner support for efforts to further identify and address failing OSSFs through inspections and remedial actions. AgriLife Extension provides the needed expertise to deliver this training. Based on needs identified early during WPP planning, trainings will be scheduled once per every 3 years. Additionally, an online training module that provides an overview of septic systems, how they operate, and what maintenance is required to sustain proper functionality and extend system life will be made available to anyone interested through the partnership website. This training module was developed by the Guadalupe-Blanco River Authority in cooperation with AgriLife Extension and is currently available online at: https://www.gbra.org/septic.swf.

OSSF Installer & Maintenance Provider Training

Continuing education courses for licensed OSSF Installers and Maintenance Providers are available through AgriLife Extension. The courses are designed for professional wastewater site evaluators, designers, installers, regulators, operations, maintenance, and monitoring service providers. Topics may include: (1) basic information on design, operation and maintenance, (2) laws and regulations, (3) overview of new and existing technologies, (4) relationships between soil types and application systems, (5) real world examples and discussion, (6) new and emerging topics.

Texas Well Owners Network Training

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network (TWON) Program provides necessary education and outreach focusing on private drinking water wells and the impacts on human health and the environment that can be mitigated by using proper management practices. Well screenings are conducted through this program. The Watershed Coordinator is currently coordinating with AgriLife Extension personnel to deliver this program in the Big Elm Creek watershed. Information on this program can be found at: https://twon.tamu.edu.

Riparian and Stream Ecosystem Education Program

Healthy watersheds and good water quality go hand in hand with properly managed riparian and stream ecosystems. Delivery of the Riparian and Stream Ecosystem Education Program will increase stakeholder awareness, understanding and knowledge about the nature and function of riparian zones. Additionally, the program will educate stakeholders on the benefits of riparian zones and the BMPs that can be implemented to protect them while minimizing nonpoint source pollution. Through this program, riparian landowners will be connected with local technical and financial resources to improve management and promote healthy watersheds and riparian areas on their land. The watershed coordinator will work with AgriLife Extension personnel to deliver this program in the Big Elm Creek watershed.

Public Stakeholder Meetings

Periodic public stakeholder meetings will be used to achieve several major goals of WPP implementation. Public stakeholder meetings will provide a platform for the Watershed Coordinator and project personnel, as appropriate, to provide WPP implementation information including implementation progress, near-term implementation goals and projects, information on how to sign-up or participate in active implementation programs, appropriate contact information for specific implementation programs and other information as appropriate. These meetings will also keep stakeholders engaged in the WPP process and provide a platform to discuss adaptive management to keep the WPP relevant to watershed and water quality needs. This will be accomplished by reviewing water quality data, implementation goals and milestones during at least one public meeting annually and actively discussing how watershed needs can be better served. Feedback will be incorporated into WPP addendums as appropriate. It is anticipated that public meetings will be held on a semiannual basis but will largely be scheduled based on need.

Newsletters and News Releases

Watershed newsletters will be developed and sent directly to actively engaged stakeholders. Newsletters will be sent annually and staged to be published between project meetings. News releases will also be developed and distributed as needed through the mass media outlets in the area and will be used to highlight significant happenings related to WPP implementation and to continue to raise public awareness and support for watershed protection. These means will be used to inform stakeholders of implementation programs, eligibility requirements, when and where to sign-up, and what the specific program will entail. Lastly, public meetings and other WPP-related activities will be advertised through these outlets.

Table 33. Education and outreach implementation schedule, responsible party, and estimated costs.

Management Measure	Responsible Party	Number Implemented Time Frame (year) 1–3	4–6	7–10	Total Cost
General Resource Management Programming and Resources					
Texas Watershed Steward Trainings	Texas A&M AgriLife Extension Service	---	1	1	N/A*
Texas Well Owner Network Training		1	1	---	N/A*
Texas Riparian Ecosystem Trainings		1	1	---	N/A*
Healthy Lawns Healthy Waters Training		1	1	1	N/A*
Watershed Newsletter	Watershed Coordinator	3	3	4	$5,000
Cattle and Other Livestock					
Lone Star Healthy Streams Training	Texas A&M AgriLife Extension Service	1	1	1	N/A*
Forage Management Seminars (Nutrients, Pesticides, Water Quality)		1	1	1	N/A+
Management Practice Field Days	Texas A&M AgriLife Extension Service/ Watershed Coordinator/ NRCS	1	1	1	N/A+
Feral Hog Education and Outreach Programming					
Feral Hog Management Workshops	Texas A&M AgriLife Extension Service/TPWD	1	1	1	$22,500
OSSF Management Programming					
OSSF Operation and Maintenance Workshop	Texas A&M AgriLife Extension Service/ Counties/TWRI	1	1	1	$30,000
OSSF Installer and Maintenance Provider Training		1	1	1	$22,500

Natural Resources Conservation Service, NRCS; Texas Parks and Wildlife Department, TPWD; On-site sewage facility, OSSF; Texas Water Resources Institute, TWRI

*additional funding not required, currently funded through existing resources.

+additional funding not required; local programs, participants cover program costs

Chapter 8
Measuring Success

Wheat field near Temple, TX. Photo By Ed Rhodes, TWRI.

Introduction

Over the next ten years, implementation of this WPP will require the coordination of many dedicated stakeholders. The goal is to achieve water quality targets by addressing the most readily manageable sources of *E. coli* in the watershed. To achieve these targets, this plan has identified the needed substantial financial commitments, technical assistance, and education and outreach programs. The management measures identified in this WPP are voluntary but supported at the recommended levels by watershed stakeholders.

Implementing a WPP on water quality and measuring its impacts is a critical process. The data needed to document progress toward water quality goals are obtained through planned water quality monitoring. Water quality data collected over time and implementation accomplishments will facilitate adaptive management by illustrating which recommended measures are working and which measures need modification. While improvements in water quality are the preferred measure of success, documentation of implementation accomplishments can also be used to measure success.

Water Quality Target

The primary contact recreation water quality standard for *E. coli* of 126 cfu/100 mL is the target value for Big Elm Creek and was the basis for establishing the needed *E. coli* load reductions.

The LDC approach was used to convert this water quality goal into a needed load reduction. Monitoring station 16385 at US Hwy 77 (Figure 10) was chosen as the index station to establish the needed reduction due to its proximity to the watershed outlet. It is the furthest monitoring station downstream where enough streamflow data existed to develop a reasonable LDC. Further, the moist conditions category was selected as the basis for identifying the needed amount of *E. coli* reduction. This scenario represents conditions where much of the measured excess loading occurs but does not include extreme flow situations where management is not feasible. For moist conditions, the needed load reduction to meet the water quality standards and goal established by stakeholders is 2.57 x 10^{13}cfu/year. This represents a 62%

Table 34. Water quality targets.

Segment	Station	Samples	Geomean+	10-Year Goal+
1213A	13535	22	179.93	≤126
	14016	26	244.31	≤126
	16385	27	144.09	≤126

+in units of cfu *E. coli*/100 mL

reduction in the current *E. coli* load measured in moist conditions.

Data shows loading increases from the uppermost site at station 13535 down to station 14016; but some dilution occurs before reaching station 16385 at US Hwy 77. This is likely due to dilution from additional flow from Camp Creek, South Elm Creek, and North Elm Creek. These three drainages all enter Big Elm Creek between stations 14016 and 16385. Our results support prior findings that Big Elm Creek segment 1213A is impaired due to bacterial contamination of *E. coli* that exceeds the contact recreation threshold of 126 cfu/100mL.

Additional Data Collection Needs

Continued monitoring of water quality in the Big Elm Creek watershed will be necessary to track progress toward to goal of improved water quality. Field monitoring data is crucial to determine success and trajectory of watershed management applications. Currently water quality monitoring data is only captured quarterly at the index station at US Hwy 77 (16385) as part of the CRP.

Sampling all three stations monthly would greatly improve the data availability in the watershed and allow stakeholders to monitor the trend of water quality in Big Elm Creek. It is also recommended that a fourth monitoring site should be added at an appropriate location on Little Elm Creek in preparation for future urban growth in the City of Temple. Frequent, monthly monitoring will help to illustrate seasonal trends and variations in stream flow and water quality. Additionally, it is suggested that nutrients, namely nitrogen and phosphorous, be monitored at all three stations in the watershed to better understand the potential effects they may have on water quality indicators such as dissolved oxygen.

Through the adaptive management process and WPP updates, future water quality monitoring sites may be added to address any new concerns or areas of interest in the watershed. Targeted water quality monitoring could include paired watershed studies, multiple watershed studies, or edge of field runoff analysis where different land uses or management measures have taken place. Data derived from this could demonstrate the applicability of different BMPs within the watershed. Targeted monitoring may also include more intensive sampling in other stream segments to identify potential pollutant sources.

Data Review

Watershed stakeholders are responsible for evaluating WPP implementation impacts on instream water quality. Stakeholders will use TCEQ's statewide biennial water quality assessment approach, which uses a moving seven-year geometric mean of *E. coli* data collected through the state's CRP program. This assessment is published in the *Texas Integrated Report and 303(d) List*, which is available online at: https://www.tceq.texas.gov/waterquality/assessment/305_303.html. It is noted that a two-year lag occurs in data reporting and assessment, therefore the 2020 or 2022 report will likely be the first to include water quality data collected during implementation of the WPP.

Identifying water quality improvements is challenging if only relying on the seven-year-data window used for the *Texas Integrated Report*. Therefore, another method to evaluate water quality improvements is using the geometric mean of the most recent three years of water quality data identified within TCEQ's Surface Water Quality Monitoring Information System. To support data assessment as needed, trend analysis and other appropriate statistical analyses will also be used.

The Watershed Coordinator will be responsible for tracking implementation targets and water quality in the watershed to quantify WPP success. Data will be summarized and reported to watershed stakeholders at least annually.

Interim Measurable Milestones

Implementation of the Big Elm Creek WPP will occur over a 10-year timeframe. Milestones can be use-ful for incremental evaluation of implementation progress of management measures within the WPP. Milestones outline a clear process for progression throughout implementation. Interim measurable milestones for management measures and education and outreach are addressed in Tables 28 and 33. Responsible parties and estimated costs (where available) have been included in the schedule. In some cases, funding acquisition, personnel hiring, or program initiation may delay the start of some items. This approach provides incremental targets to measure progress through the WPP implementa-tion. Adaptive management may be used where necessary to reorganize or prioritize varying aspects of the approach to implementation in order to achieve the overarching goal of water quality.

Adaptive Management

Due to the dynamic nature of watersheds and the countless variables governing landscape processes, some uncertainty is to be expected when a WPP is developed and implemented. As the recommend-ed restoration measures of the Big Elm Creek WPP are put into action, it will be necessary to track the water quality response over time and make any needed adjustments to the implementation strategy. To provide flexibility and enable such adjustments, adaptive management will be used throughout the implementation process.

Adaptive management is often referred to as "learning by doing" (Franklin et al. 2007). It is the ongoing process of accumulating knowledge of the causes of impairment as implementation efforts progress, which results in reduced uncertainty associated with modeled loads. As implementation activities are instituted, water quality is tracked to assess impacts and guide adjustments, if necessary, to future implementation activities. This ongoing, cyclical implementation and evaluation process serves to focus project efforts and optimize impacts. Watersheds in which the impairment is dominated by nonpoint source pollutants, such as the Big Elm Creek, are good candidates for adaptive management. Progress toward achieving the established water quality target will also be used to evaluate the need for adap-tive management. An annual review of implementation progress and water quality trends will be dis-cussed with stakeholders during semiannual meetings. Due to the numerous factors that can influence water quality and the time lag that often appears between implementation efforts and resulting water quality improvements, sufficient time should be allowed for implementation to occur fully before trig-gering adaptive management. In addition to water quality targets, if satisfactory progress toward achieving milestones is determined to be infeasible due to funding, scope of implementation or other reasons that would prevent implementation, adaptive management provides an opportunity to revisit and revise the implementation strategy. If stakeholders determine inadequate progress toward water quality improvement or milestones is being made, efforts will be made to increase adoption of BMPs and adjust strategies or focus area if and when necessary.

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Appendix A: Potential Load Calculations

Estimates for potential loads are based on the best available data (local, state, and federal databases; scientific research) and local knowledge developed from stakeholder input (e.g., local livestock stocking practices, wildlife densities, etc.). The developed potential loading rates assume a worst-case scenario and are primarily used to calculate where management measures should be implemented first in order to maximize effectiveness and estimate potential load reductions.

Livestock

The first step to calculate potential bacteria loads from cattle is to develop cattle population estimates. Stakeholder input was critical to develop livestock population estimates across the watershed. Based on input from the agricultural work group, we estimated stocking rates of 1 animal unit (AnU)/6 acres of improved pasture and 1 AnU/10 acres of unimproved land. This stocking rate likely fluctuates annually based on local conditions but provides a baseline to estimate potential loadings that can be adjusted and fine-tuned if new data becomes available. Other difficulties in developing cattle population estimates include the reliance on the NLCD to identify pasture and rangeland. From this dataset, it is impossible to parse out land that is used for hay production versus grazed pasture. Furthermore, identifying the actual stocking rate used by a particular landowner is not possible with this dataset. Therefore, reliance on local stakeholders was critical to properly estimating cattle populations. Finally, estimates were compared to NASS cattle population estimates for watershed counties to evaluate if the generated estimates compared to USDA census figures. Based on these inputs, there are an estimated 11,799 AnU of cattle across the entire watershed.

Using cattle population estimates generated with GIS analysis, potential *E. coli* loading across the watershed and for individual subwatersheds was estimated. The annual load from cattle was calculated as:

$$PAL_{cattle} = AnU \times FC_{cattle} \times Conversion \times 365\ \frac{days}{year}$$

Where:

PAL_{cattle} = Potential annual *E. coli* loading attributed to cattle

AnU = Animal Units of cattle (~1,000 lbs of cattle)

FC_{cattle} = Fecal coliform loading rate of cattle, 8.55×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)

Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to cattle is: 2.3296×10^{16} cfu *E. coli*/year.

Feral Hogs

Feral hog populations were estimated using an estimated population density of 1 feral hog/13 acres of suitable habitat. GIS analysis was used to estimate watershed-wide and subwatershed feral hog populations. Based on this analysis, an estimated 14,527 feral hogs exist across the watershed. Like cattle, these numbers provide general estimates that likely change based on annual conditions. Furthermore, feral hogs likely roam across large areas that might be larger than individual subwatersheds; however, these estimates provide initial guidance on where to focus control efforts based on suitable habitats.

Using the feral hog population estimates, we estimated potential *E. coli* loading across the watershed and for individual subwatersheds. The annual load from feral hogs was calculated as:

$$PAL_{fh} = N_{fh} \times AnUC \times FC_{fh} \times Conversion \times 365\ \frac{days}{year}$$

Where:

PAL_{fh} = Potential annual *E. coli* loading attributed to feral hogs

N_{fh} = Number of feral hogs

$AnUC$ = Animal Unit Conversion; 0.125 animal units/feral hog (Wagner and Moench 2009)

FC_{fh} = Fecal coliform loading rate of feral hogs, 1.21×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)

Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to feral hogs is: 5.05×10^{14} cfu *E. coli*/year.

Domestic Pets

Dog estimates were generated using an estimated population density of 0.584 dogs/household that was applied to weighted census block household data (AVMA 2012). The number of households in the watershed is 8,407. Multiplying this number with 0.584 gives 4,910 dogs in the watershed. Using the resulting dog population estimate, the annual load due to dogs was estimated as:

$$PAL_d = N_d \times \times FC_d \times Conversion \times 365\ \frac{days}{year}$$

Where:

PAL_d = Potential annual *E. coli* loading attributed to dogs

N_d = Number of dogs that owners do not pick up after

FC_d = Fecal coliform loading rate of dogs, 2.50×10^9 cfu fecal coliform/dog/day (Teague et al. 2009)

Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

Therefore, the estimated potential annual loading attributed to dogs is: 2.82×10^{15} cfu *E. coli*/year.

OSSFs

Using the OSSF estimates, potential *E. coli* loading across the watershed and for individual subwatersheds was estimated. Methods to estimate OSSF locations and numbers are described in Chapter 4 of this WPP. The annual load from OSSFs was calculated as:

$$PAL_{ossf} = N_{ossf} \times N_{hh} \times Production \times Failure\ Rate \times FC_S \times 365\ \frac{days}{year}$$

Where:

PAL_{ossf} = Potential annual *E. coli* loading attributed to OSSFs

N_{ossf} = Number of OSSFs

N_{hh} = Average number of people/household (2.65)

Production = Assumed sewage discharge rate; 70 gallons per person per day (Borel et al. 2015)

Fail Rate = Assumed failure rate; 15% (Reed, Stowe & Yanke 2001)

FC_s = Fecal coliform concentration in sewage; 1.0×10^6 cfu/100mL (EPA 2001)

Conversion = Conversion rate from fecal coliform to *E. coli* (Wagner and Moench 2009)

and mL to gal (3,578.4 mL/gallon)

The estimated potential annual loading across all subwatersheds due to OSSFs is: 8.86×10^{16} cfu *E. coli*/year.

WWTPs

Potential loadings from WWTPs were calculated for all permitted dischargers with a bacteria monitoring requirement. Potential loads were calculated as the sum of the maximum permitted discharges of all WWTPs multiplied by the maximum permitted *E. coli* concentration:

$$PAL_{WWTP} = Discharge \times Concentration_{max} \times Conversion \times 365 \frac{days}{year}$$

Where:

PAL_{wwtp} = Potential annual *E. coli* loading due to wastewater treatment plant discharges

Discharge = Maximum permitted daily discharge (MGD; 7.90 MGD)

$Concentration_{max}$ = Maximum average permitted concentration of *E. coli* in wastewater discharge (126 cfu/100 mL)

Conversion = Unit conversion (3,785.2 mL/gal)

The estimated potential annual loading across all subwatersheds due to WWTP discharges is: 1.37×10^9 cfu *E. coli*/year.

Appendix A. References

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Appendix B: Load Reduction Calculations

Livestock

E. coli loading reductions resulting from implementation of conservation plans and WQMPs involves potential reductions from a variety of livestock. However, since cattle are the dominant livestock in the watershed, cattle were assumed the species managed through livestock-focused management.

According to USDA NASS data, there are 11,799 AnU of cattle in the Big Elm Creek watershed (see Appendix A). In reality, each WQMP or conservation plan will vary in size and number of animal units addressed. Actual potential load reductions will vary by actual existing land conditions, proximity to water bodies, number of animal units addressed by the management measure and the types of BMPs implemented by the plan.

To estimate expected *E. coli* reductions, efficacy values of likely BMPs were calculated from median literature reported values (B-1). These BMPs were determined based on feedback from members of the Agriculture Work Group. Because the actual BMPs implemented per WQMP or conservation plan are unknown, an overall median efficacy value of 0.58 (58%) was used to calculate load reductions. Finally, the proximity of implemented BMPs to water bodies will influence the effectiveness at reducing loads. Typically, a proximity factor of 0.05 (5%) is used for BMPs in upland areas and 0.25 (25%) is used in riparian areas.

Table 35. BMP effectiveness.

Management Practice	*E. coli* Removal Efficacy		
	Low	High	Median
Exclusionary fencing[1]	30%	94%	62%
Prescribed grazing[2]	42%	66%	54%
Stream crossing[3]	44%	52%	48%
Watering facility[4]	51%	94%	73%

[1]Brenner et al. 1996; Cook 1998; Hagedorn et al. 1999; Line 2002; Line 2003; Lombardo et al. 2000; Meals 2001; Meals 2004; Peterson et al. 2011
[2]Tate et al. 2004; EPA 2010.
[3]Inamdar et al. 2002; Meals 2001
[4]Byers et al. 2005; Hagedorn et al. 1999; Sheffield et al. 1997

Total potential load reductions from WQMPs and conservation plans were calculated with the following equation:

$$LRcattle = Nplans \times \frac{AnU}{Plan} \times FCcattle \times Conversion \times 365\,\frac{days}{year} \times Efficacy \times Proximity\ factor$$

Where:

LR_{cattle} = Potential annual load reduction of *E. coli*

N_{plans} = Number of WQMPs and conservation plans

AnU/Plan = Animal Units of cattle (~1,000 lbs of cattle)/management plan, 74 AnU

FC_{cattle} = Fecal coliform loading rate of cattle, 8.55×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)

Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

Efficacy = Median BMP efficacy value, 0.42 for fencing, 0.69 for grazing

Proximity Factor = Percentage based factor based on the assumed proximity of the management measure to the water body, 0.25 for riparian, 0.05 for upland

Table 36. BMP application days.

Applied BMPs	*Livestock Accessibility (Days)*
Prescribed Grazing	73 (riparian), 292 (upland)
Cross fencing	73 (riparian), 292 (upland)

Prescribed grazing load reduction estimate:

Riparian area

$$LRcattle = Nplans \times \frac{AnU}{Plan} \times FCcattle \times Conversion \times riparian\ grazing\ days \times Efficacy \times Proximity\ factor$$

$= 20 \times 74 \times 8.55 \times 10^9 \times 0.63 \times 73 \times 0.69 \times 0.25$

$= 1.00 \times 10^{14}$ cfu *E. coli*/year

Upland area

$$LRcattle = Nplans \times \frac{AnU}{Plan} \times FCcattle \times Conversion \times upland\ grazing\ days \times Efficacy \times Proximity\ factor$$

$= 10 \times 74 \times 8.55 \times 10^9 \times 0.63 \times 292 \times 0.69 \times 0.05$

$= 4.02 \times 10^{13}$ cfu *E. coli*/year

Prescribed fencing load reduction estimate:

Riparian area

$$LRcattle = Nplans \times \frac{AnU}{Plan} \times FCcattle \times Conversion \times riparian\ grazing\ days \times Efficacy \times Proximity\ factor$$

$= 20 \times 74 \times 8.55 \times 10^9 \times 0.63 \times 73 \times 0.42 \times 0.25$

$= 6.11 \times 10^{13}$ cfu *E. coli*/year

Upland area

$$LRcattle = Nplans \times \frac{AnU}{Plan} \times FCcattle \times Conversion \times upland\ grazing\ days \times Efficacy \times Proximity\ factor$$

$= 10 \times 74 \times 8.55 \times 10^9 \times 0.63 \times 292 \times 0.42 \times 0.05$

$= 2.44 \times 10^{13}$ cfu *E. coli*/year

The WPP recommends the implementation of 30 WQMPs or conservation plans across the entire Big Elm Creek watershed, among them 20 WQMPs in riparian areas and 10 WQMPs in upland areas, resulting in a total potential reduction of 2.26×10^{14} cfu *E. coli*/year.

Feral Hogs

Loading reductions for feral hogs assume that existing feral hog populations can be reduced and maintained by a certain amount on an annual basis. Feral hog removal from the watershed is assumed to completely remove potential bacteria loads generated by that feral hog. Therefore, the total potential load reduction is calculated as the population reduction in feral hogs achieved in the watershed. Based on estimates, there are approximately 14,588 feral hogs in the Big Elm Creek watershed (see

Appendix A for details). The established goal is to reduce and maintain the feral hog population 15% below current population estimates, thus resulting in a 15% reduction in potential loading that is attributable to feral hogs. Load reductions were calculated based on the following:

$$LR_{fh} = N_{fh} \times ANuC \times FC_{fh} \times Proximity\ Factor\ x\ Conversion \times 365\ \frac{days}{year}$$

Where:

LR_{fh} = Potential annual load reduction of *E. coli* attributed to feral hog removal

N_{fh} = Number of feral hogs removed

FCfh = Fecal coliform loading rate of feral hogs, 1.21×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)

Proximity Factor = 0.25

Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across the Big Elm Creek watershed based on reducing and maintaining the population by 15% (2,188 feral hogs) is 1.90×10^{13} cfu *E. coli* annually.

Domestic Pets

The Big Elm Creek watershed contains approximately 4,910 dogs. Load reductions assume that 75% of the bacteria from collected feces is disposed and 25% may attach to the ground, grass etc.) The effectiveness used for calculating load reduction is 0.75. The resulting reductions are calculated by:

$$LR_d = N_d \times FC_d \times Conversion \times Proximity\ Factor\ x\ Efficacy \times 365\ \frac{days}{year}$$

Where:

LR_d = Potential annual load reduction of *E. coli* attributed to proper dog waste disposal

N_d = Number of additional dog owners disposing of pet waste

FC_d = Fecal coliform loading rate of dogs, 2.50×10^9 cfu fecal coliform/dog/day (Teague et al. 2009)

Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner & Moench 2009)

*Proximity Facto*r = Percentage based factor based on the assumed proximity of the management measure to the water body, 0.05.

Efficacy = 0.75

The estimated potential load reduction attributed to this management measure in the Big Elm Creek is 1.06×10^{14} cfu *E. coli* annually.

OSSFs

OSSFs are common in the Big Elm Creek watershed with an estimated 2,439 OSSFs. OSSF failures are factors of system age, soil suitability, system design and maintenance. For this area of the state, a 15% failure rate is typically assumed (Reed, Stowe & Yanke 2001). Given the difficulty and cost of replacing 15% of the total OSSF systems in the watershed, stakeholders decided to target 30 failing systems for repair or replacement. Load reductions can be calculated as the number of assumed failing OSSFs replaced. The following equation was used to calculate potential load reductions:

$$LR_{ossf} = N_{ossf} \times N_{hh} \times Production \times FC_s \times Conversion \times 365\ \frac{days}{year}$$

Where:

LR_{ossf}= Potential annual load reduction of *E. coli* attributed to OSSF repair/replacement

N_{ossf} = Number of OSSFs repaired/replaced

N_{hh} = Average number of people per household (2.65)

Production = Assumed sewage discharge rate; 70 gallon/person/day (Borel et al. 2015)

FC_s = Fecal coliform concentration in sewage; 1.0×10^6 cfu/100mL (EPA 2001)

Conversion = Conversion rate from fecal coliform to *E. coli* (Wagner and Moench 2009) and mL to gallon (3,578.4 mL/gallon)

Proximity Factor = 0.5 for very limited soil suitability

Repair or replacement of 30 systems results in a potential reduction of 7.27×10^{15} cfu *E. coli* annually.

Appendix B. References

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Appendix C: Public Stakeholder Engagement

Date	Event	Discussion Topic(s)	Location
5/15/2018	Texas Watershed Stewards Workshop	Big Elm Creek Water Quality	Cameron, TX
8/23/2018	Stakeholder Meeting	Big Elm Creek Water Quality and next steps	Belton, TX
9/20/2018	Bell County Conservation Expo	Big Elm Creek Informational Booth	Belton, TX
11/29/2018	Belton Urban Stream Restoration Workshop	Bell Elm Creek Water Quality	Belton, TX
2/19/2019	Stakeholder Meeting	Water Quality, Stakeholder Structure, Big Elm Creek Characteristics	Rogers, TX
4/11/2019	Brazos River Authority CRP Meeting	Big Elm Creek WPP Progress Update	Waco, TX
4/16/2019	Stakeholder Meeting	LDC, Sources of Pollution, Stocking Rates, Management Measures	Rogers, TX
4/18/2019	Bell County Farm Bureau Meeting	Big Elm Creek Stocking Rates and Water Quality	Temple, TX
5/21/2019	Stakeholder Meeting	Recap LDC, Sources of Pollution, Stocking Rates and Management Measures	Rogers, TX
6/18/2019	Central TX SWCD Board Meeting	Big Elm Creek Stocking Rates and Water Quality	Belton, TX
6/18/2019	Stakeholder Meeting	Water Quality Trends, Pollutant Source Assessment, Management Measures	Rogers, TX
7/30/2019	Stakeholder Meeting	Management Measures, Sources of Implementation and Education Resources, Measures of Success	Rogers, TX
9/10/2019	City of Temple Public Works	Big Elm Creek Stormwater and Urban Growth	Temple, TX
9/11/2019	Bell County Public Health District	Big Elm Creek OSSF Numbers, Locations, and Management Measures	Temple, TX
9/17/2019	Central TX SWCD Board Meeting	Big Elm Creek Updated Stocking Rates and Water Quality Update	Belton, TX
9/19/2019	Bell County Conservation Ex-po	Big Elm Creek water quality and WPP progress presentation; and informational booth	Killeen, TX
10/22/2019	Stakeholder Meeting	Final Draft WPP Review, Questions/Discussion, TPWD Guest discussion	Rogers, TX
11/13/2019	Texas Riparian and Stream Ecosystem Training	Proper Creek and Riparian Functions, Riparian vegetation ID, and WPP progress	Oscar, TX

Appendix D: Elements of Successful Watershed Protection Plans

EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA 2008) describes the nine elements critical for achieving improvements in water quality that must be sufficiently included in a WPP for it to be eligible for implementation funding through the Clean Water Act Section 319(h) funds. These elements do not preclude additional information from being included in the WPP. This Appendix briefly describes the nine elements and references the chapters and sections that fulfill each element.

A: Identification of Causes and Sources of Impairment

An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan). Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed. Information can be based on a watershed inventory, extrapolated from a subwatershed inventory, aerial photos, GIS data or other sources.

B: Estimated Load Reductions

An estimate of the load reductions expected for the management measures proposed as part of the watershed plan.

C: Proposed Management Measures

A description of the management measures that will need to be implemented to achieve the estimated load reductions and identification (using a map or description) of the critical areas in which those measures will be needed to implement the plan. Proposed management measures are defined as including BMPs and measures needed to institutionalize changes. A critical area should be determined for each combination of source BMP.

D: Technical and Financial Assistance Needs

An estimate of the amounts of technical and financial assistance needed, associated costs and/or the sources and authorities that will be relied upon to implement this plan. Authorities include the specific state or local legislation that allows, prohibits, or requires an activity.

E: Information, Education and Public Participation Component

An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the appropriate nonpoint source pollution management measures.

F: Schedule

A schedule for implementing the nonpoint source pollution management measures identified in the plan that is reasonably expeditious.

G: Milestones

A description of interim, measurable milestones for determining whether nonpoint source pollution management measures or other control actions are being implemented. Milestones should be tied to the progress of the plan to determine if it is moving in the right direction.

H: Load Reduction Evaluation Criteria

A set of criteria that can be used to determine whether loading reductions are being achieved over time and if substantial progress is being made toward attaining water quality standards. If not, it is also the criteria for determining if the watershed-based plan needs to be revised. The criteria for the plan needing revision should be based on the milestones and water quality changes.

I: Monitoring Component

A monitoring component to evaluate the effectiveness of the implementation efforts over time that is measured against the evaluation criteria. The monitoring component should include required project-specific needs, the evaluation criteria and local monitoring efforts. It should also be tied to the state water quality monitoring efforts.

Element	Report Section(s) and Page Number(s)
Element A: Identification of Causes and Sources	
Chapter 2	• Land Use, Page 10 • Soils, Page 10 • Demographics, Page 14
Chapter 3	• Bacteria, Page 23 • Dissolved Oxygen, Page 23 • Nutrients, Page 25
Chapter 4	• Table 13, Page 38 • Pollutant Source Assessment, Pages 34-48
Element B: Estimated Load Reductions	
Chapter 5	• Table 29, Page 66
Appendix B	• Pages 86-90
Element C: Proposed Management Measures	
Chapter 5	• Management Measures, Pages 49-63
Element D: Technical and Financial Assistance Needs	
Chapter 5	• Table 18, Page 51 • Table 19, Page 53 • Table 20, Page 55 • Table 21, Page 57 • Table 22, Page 58 • Table 23, Page 59 • Table 24, Page 60 • Table 25, Page 61 • Table 26, Page 62 • Table 27, Page 63 • Table 28, Pages 64-65
Chapter 6	• Pages 67-72 • Table 30, Page 68 • Table 31, Page 69

Element	Report Section(s) and Page Number(s)
Element E: Information, Education and Public Participation Component	
Chapter 5	• Management Measures, Pages 49-63
Chapter 7	• Pages 73-77 • Table 33, Page 77
Element F: Schedule	
Chapter 5	• Table 28, Pages 64-65
Chapter 7	• Table 33, Page 77
Element G: Milestones	
Chapter 5	• Table 28, Pages 64-65
Chapter 7	• Table 33, Page 77
Chapter 8	• Page 79
Element H: Load Reduction Evaluation Criteria	
Chapter 8	• Water Quality Target, Pages 78-79 • Table 34, Page 79 • Adaptive Management, Page 80
Element I: Monitoring Component	
Chapter 8	• Additional Data Collection Needs, Page 79

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