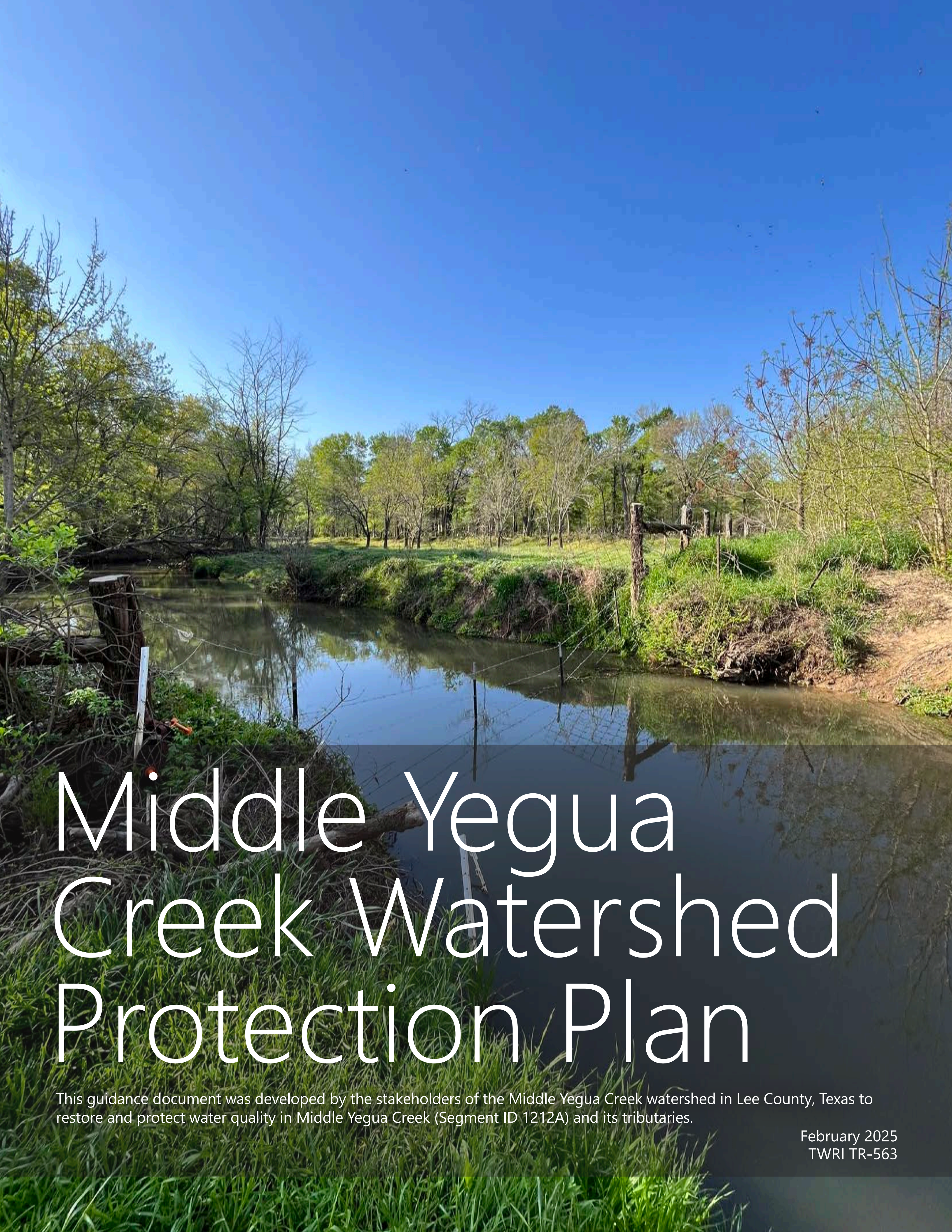

Middle Yegua Creek Watershed Protection Plan

This guidance document was developed by the stakeholders of the Middle Yegua Creek watershed in Lee County, Texas to restore and protect water quality in Middle Yegua Creek (Segment ID 1212A) and its tributaries.

February 2025
TWRI TR-563

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This guidance document was developed by the stakeholders of the Middle Yegua Creek watershed in Lee County, Texas to restore and protect water quality in Middle Yegua Creek (Segment ID 1212A) and its tributaries.

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Texas Water Resources Institute

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Cover photo: Middle Yegua Creek at FM 696 by Amanda Tague, TWRI.

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Texas Water Resources Institute *make every drop count*

Texas A&M AgriLife

Texas State Soil & Water Conservation Board

Acknowledgments

Middle Yegua Creek at FM 696 by Cameron Castilaw, TWRI.

The development of this watershed protection plan would not have been possible without the contributions of the stakeholders that desire to protect and restore Middle Yegua Creek. Special appreciation is extended to the many residents that provided meaningful feedback to ensure this plan represents the realities of the watershed. Spending time and effort attending the many stakeholder meetings and reading through the drafts of this plan was vital to its successful completion and is greatly appreciated by the authors of this document.

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- El Camino Real Chapter, Texas Master Naturalists
- Gideon Lincecum Chapter, Texas Master Naturalists
- Lee County Officials and County Judge
- Lee County Soil and Water Conservation District #359
- Lee County Wildlife Association
- Lost Pines Groundwater Conservation District
- Simsboro Aquifer Water Defense Fund
- Texas A&M AgriLife Research and Extension Service
- Texas Commission on Environmental Quality
- Texas State Soil and Water Conservation Board
- Texas Water Resources Institute
- United States Environmental Protection Agency
- United States Department of Agriculture – Natural Resources Conservation Service

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List of Abbreviations

Acronym	Meaning
µg	Microgram
amsl	Above Mean Sea Level
AnU	Animal Units
AU	Assessment Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
BRA	Brazos River Authority
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operations
CSA	Critical Source Area
cfu	Colony Forming Unit
CP	Conservation Plan
CRP	Clean Rivers Program
CWA	Clean Water Act
cfu	Colony Forming Unit
DAR	Drainage-Area Ratio
DEM	Digital Elevation Model
DMU	Deer Management Unit
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
ECHO	Enforcement and Compliance History Online
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
°F	Degree Fahrenheit
FDC	Flow Duration Curve
FSA	Farm Service Agency
GCD	Groundwater Conservation District
GIS	Geographic Information System
HSG	Hydrologic Soil Group
I&I	Inflow and Infiltration
L	Liter
lb	Pound
LDC	Load Duration Curve
LIP	Landowner Incentive Program
mg	Milligram
MGD	Million Gallons per Day
mL	Milliliter

Acronym	Meaning
MPN	Most Probable Number
MRLC	Multi-Resolution Land Characteristics Consortium
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Database
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
OSSF	On-site Sewage Facility
PFAS	Per- and polyfluoroalkyl substances
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RCPP	Regional Conservation Partnership Program
SEP	Supplemental Environmental Program
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic Database
SWCD	Soil and Water Conservation District
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TST	Texas Stream Team
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TxGIO	Texas Geographic Information Office
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Executive Summary

Middle Yegua Creek at FM 141 by Amanda Tague, TWRI.

This document presents a plan to restore and protect water quality in the Middle Yegua Creek watershed. By approaching water quality issues within a drainage area rather than political boundaries, this plan holistically identifies potential pollutant sources and solutions. This approach also incorporates the values, visions, and knowledge of individuals with a direct stake in the water quality conditions of the creek.

Problem Statement

Water quality monitoring indicates that segments of the Middle Yegua Creek do not meet water quality standards for primary contact recreation use because of elevated levels of *Escherichia coli (E. coli)* in the *2022 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d).* Because of these water quality impairments, there was a need to plan and implement measures that restore water quality and ensure safe and healthy water for stakeholders. To meet this need, an assessment and planning project was undertaken to develop the Middle Yegua Creek Watershed Protection Plan (WPP).

Action Taken

Prior to the development of the WPP, geospatial and statistical analyses were conducted to acquire a preliminary understanding of the characteristics and water quality in the watershed. This information was communicated with local stakeholders through various outreach activities. These activities then led to the development of a stakeholder group that helped identify other stakeholders and advise on how to approach plan development. During the planning process, the stakeholder group volunteered their time to discuss the plan and provide input. It was generally agreed that improved land and water resources management through expanded stewardship awareness and efforts is of great significance.

Watershed Protection Plan Overview

This document is a culmination of a stakeholder process to identify pollution sources and feasible methods to reduce pollutant loads in Middle Yegua Creek. By comprehensively assessing multiple potential pollutant sources, this plan describes management strategies that may effectively reduce pollutant loadings after implementation. In addition to the extensive amounts of information gathered during WPP development, understanding of the watershed and the effectiveness of the recommended management measures should continue to advance over time. That said, this plan is a living document that should evolve as needed through the adaptive management process.

Pollutant Sources

Stakeholder input, backed by scientific analysis, was used to identify potential sources of fecal-derived bacteria pollutants. Sources of bacteria loadings identified in the watershed include livestock, dogs, wildlife, on-site sewage facilities, feral hogs, and a wastewater treatment facility. While other sources of bacteria are likely present in the watershed, available information was insufficient to reliably estimate associated bacteria loading contributions.

Recommended Actions

Seven primary recommended management measures were made aiming to improve water quality in the Middle Yegua Creek watershed. Individual recommendations were crafted to address bacteria but, in many cases, will have ancillary effects on other pollutants, such as nutrients. A summary of these measures is described below.

Water Quality Management Plans or Conservation Plans

To manage bacteria loadings from cattle and other livestock, voluntary implementation of site-specific water quality management plans and/or conservation plans is recommended. These plans include technical assistance to help landowners/land managers implement best management practices (BMPs) that improve land stewardship and protect water quality. Each plan is unique to a landowner's needs and property. Examples of BMPs are alternate water and shade areas for livestock, fencing and buffer strips, and brush management. Meanwhile, these plans may help landowners obtain financial assistance to implement BMPs.

Soil Testing

Conducting soil tests in agricultural areas can also 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 fertilizer application. Similarly, lawns and parks in urban areas can be high in nutrients as well. Therefore, soil testing in both agricultural and urban areas is included to prevent nutrient runoff into nearby water bodies by ensuring the proper rates and timing of fertilizer applications.

Feral Hog Control

Reducing and maintaining feral hog populations was recognized as crucial in the Middle Yegua Creek watershed. Active and passive management strategies would be implemented throughout the watersheds to help control populations and reduce damage to lands and riparian areas. Landowners would be encouraged to continue voluntary trapping and removal of feral hogs on their own and with assistance from various agencies. Educational programs would be brought to the watershed to discuss proper management techniques.

On-Site Sewage Systems

Failing on-site sewage facilities (OSSFs), especially those located close to a water body, are known to impair water quality. Strategies to improve OSSF management include educational programs on how to operate and maintain septic systems. Priority would also be given to identifying, repairing, and replacing failing OSSFs as funding and resources allow.

Illicit and Illegal Dumping

Stakeholders indicate that illicit and/or illegal dumping can be another source of pollutants. These activities typically occur at or near bridge crossings where individuals may dispose of deer, feral hogs, or small livestock carcasses in addition to other trash. Stakeholders indicated that the bridge crossing on CR326 has become a dumping spot. The scope of the problem, however, is not entirely known or quantified, but it is assumed to impact the watershed's bacteria loadings.

New or Small Landowner Education

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 important to prevent bacteria and nutrients from getting into nearby water bodies. To this end, workshops would be helpful and should be conducted in various parts of the watershed. These workshops would further protect and improve local water resources by ensuring that appropriate people are informed about new techniques, requirements, and resources.

Other Management Activity – Volunteer Monitoring

In addition to the above recommended management measures, stakeholders recommended monitoring at more locations along Middle Yegua Creek and its tributaries to gain a better understanding of the spatial distribution of pollutants in the watershed. During the planning process, stakeholders recommended adding monitoring locations on West Yegua Creek and Cross Creek. These and other creeks should be considered for future monitoring as funding and resources allow.

Other Management Activity – Pet Waste Management

Pet waste was identified as a significant potential source of bacteria and nutrient loadings in the watershed. Outreach and education are key components to proper pet waste management by pet owners. Increasing the amount of pet waste stations in public parks and apartment complexes may also encourage proper waste disposal and consequently reduce pollutant loadings due to runoff events.

Chapter 1
Introduction to Watershed Management

Middle Yegua Creek at FM 141 by Amanda Tague, TWRI.

The Watershed Approach

The watershed approach is widely accepted by state and federal water resource management agencies to facilitate water quality management. The U.S. 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 supported by sound science (EPA 2008). One critical aspect of the watershed approach is that it focuses on hydrologic boundaries, rather than political boundaries, to address potential water quality impacts on all potential stakeholders.

A stakeholder is anyone who lives, works, has an interest within the watershed or may be affected by efforts to address water quality issues. Stakeholders may include individuals, groups, businesses, organizations or agencies. Continuous involvement of stakeholders throughout the watershed approach is critical for effectively selecting, designing and implementing management measures that address watershed water quality.

Watershed Protection Plan

Watershed protection plans (WPPs) are locally driven mechanisms to voluntarily address complex water quality problems across political boundaries. A WPP serves as a framework to better leverage and coordinate private, non-profit, local, and state and federal agency resources.

The Middle Yegua WPP follows the EPA's Nine Key Elements, which are designed to provide guidance for the development of an effective WPP (EPA 2008). WPPs vary in content, including methodology and strategy, based on local priorities and needs. However, common fundamental elements are included in successful plans and include (see Appendix D – Elements of Successful Watershed Protection Plans):

1. Identification of causes and sources of impairment
2. Expected load reductions from management strategies
3. Proposed management measures
4. Technical and financial assistance needed to implement management measures
5. Information, education, and public participation needed to support implementation
6. Schedule for implementing management measures
7. Milestones for progress of WPP implementation
8. Criteria for determining successes of WPP implementation
9. Water quality monitoring

Adaptive Management

Adaptive management consists of developing a natural resource management strategy to facilitate decision-making based on an ongoing science-based process. Such an approach includes results of continual testing and monitoring, evaluating applied strategies, and revising management approaches to incorporate new information, science, and societal needs (EPA 2000).

An adaptive management process allows the management measures recommended in a WPP to adjust their focus and intensity as determined by the plan's success and the dynamic nature of each watershed. Throughout the life of this WPP, water quality and other measures of success should be monitored, and adjustments should be made as needed to the implementation strategy.

Education and Outreach

WPP development and implementation depend on effective education, outreach, and engagement efforts to inform local stakeholders of associated activities and practices. Education and outreach events provide an information delivery platform for stakeholders throughout the WPP implementation process. Therefore, they are integrated into many management measures detailed in this WPP.

Chapter 2
Watershed Characterization

Middle Yegua Creek at FM 141 by Amanda Tague, TWRI.

This chapter provides an overview of the characteristics of the Middle Yegua Creek watershed, including land use/ land cover, soil property, topography, ecoregion, climate, and population. These characteristics are important for estimating potential pollutant sources. The compilation and synthesis of information within the watershed was largely dependent on the best available state and federal databases and stakeholder knowledge.

Watershed Characteristics

The Middle Yegua Creek watershed lies within the greater Brazos River Yegua Creek watershed. Middle Yegua Creek consists of one segment (1212A) and two assessment units (AUs; 1212A_01 and 1212A_02). An AU is a water body whose water quality condition is assessed and reported in the Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d) (EPA 2005). AU 1212A_01 stretches 13 miles from confluence with East Yegua Creek upstream to confluence with West Yegua Creek in Lee County; meanwhile, AU 1212A_02 stretches 49 miles from confluence with West Yegua Creek upstream to headwaters of the Middle Yegua Creek in Williamson County. Of the two AUs, 1212A_02 is identified as impaired for primary contact recreation use due to elevated concentrations of *Escherichia coli (E. coli)* in the *2022 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (TCEQ 2022; Figure 1).

Middle Yegua Creek watershed encompasses a total of 281,798 acres, and it consists of 11 subwatersheds, including Houghton Branch, Cross Creek, Walleye Creek, Mine Creek, Shaw Branch, Indian Camp Branch, Upper, Middle, and Lower West Yegua Creeks, Elm Creek, and Rocky Creek (Figure 2).

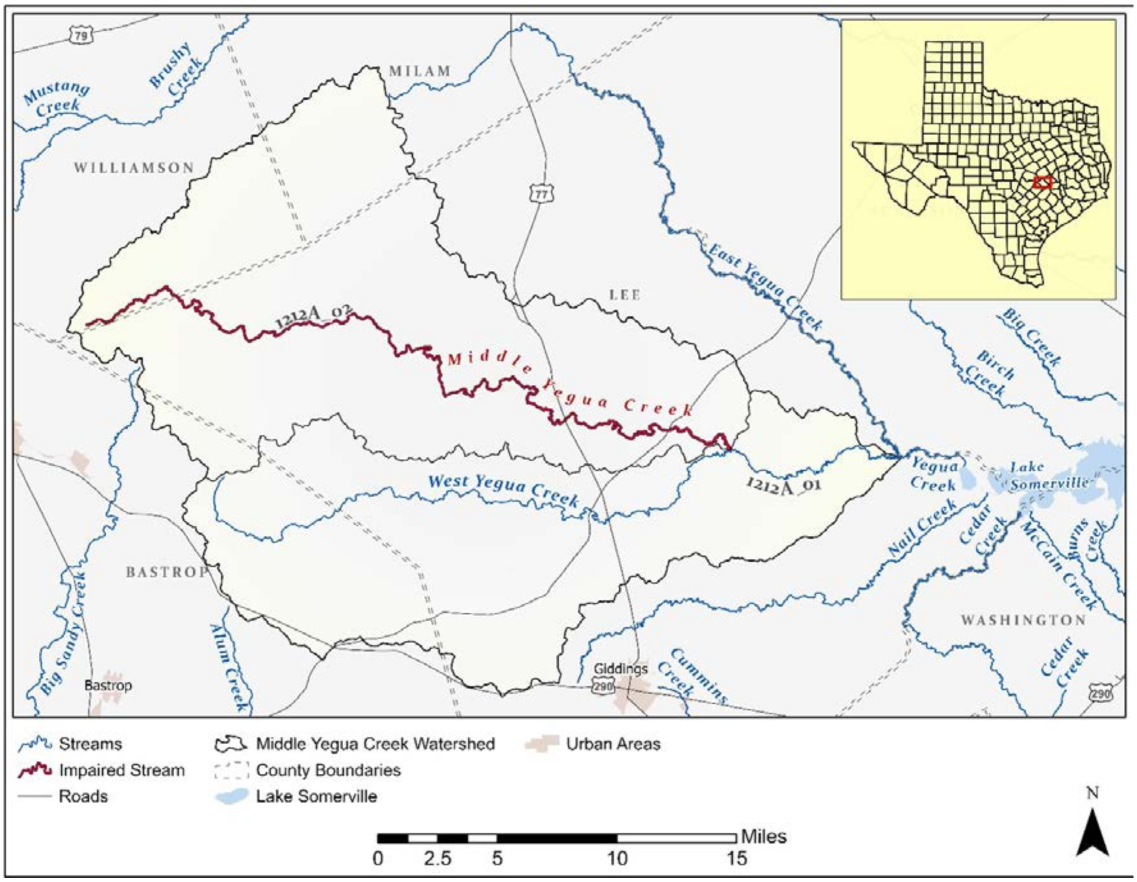

Figure 1. TCEQ AUs, streams, lake, urban areas, and county boundaries in the Middle Yegua Creek watershed.

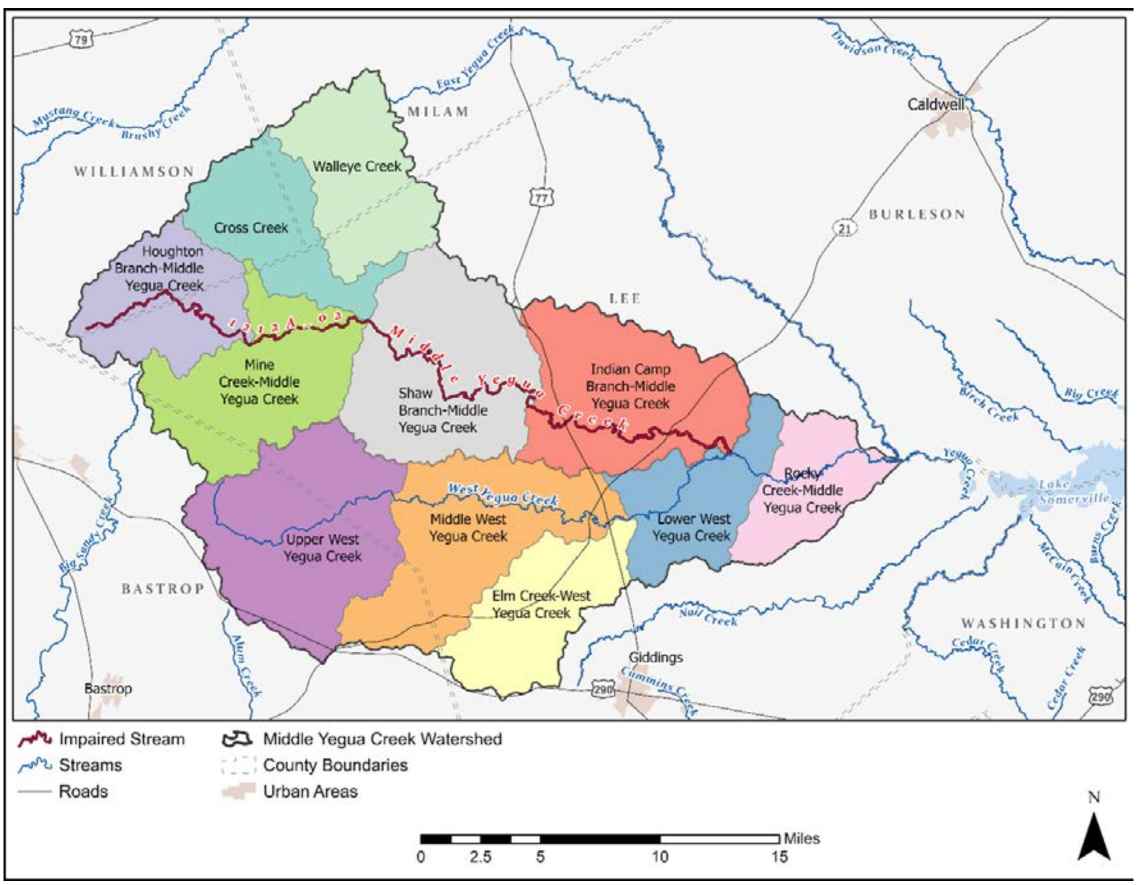

Figure 2. Middle Yegua Creek subwatersheds.

Figure 3. 20-year average monthly precipitation and average daily maximum, mean, and minimum temperature at Giddings station as archived in the Global Historical Climatology Network.

Climate

Based on the climate classification, the Middle Yegua Creek watershed is in the humid subtropical zone with high humidity, hot summers, and warm or mild winters (Larkin and Bomar 1983).

Climate data recorded at a weather station USW00053979, located in the Giddings/Lee County Airport (NOAA 2023) showed that precipitation normally peaked in April and May, and the driest months between 2011 and 2023 were February and July. Meanwhile, the warmest month on average was August; with a daily average temperature of 77-degree Fahrenheit (°F), and the coldest month on average was January with a daily average temperature of 43°F (Figure 3).

Based on the 30-year average climate data provided by the PRISM Climate Group (PRISM 2022), the mean annual total precipitation between 1991 and 2020 ranged from 36.5 inches in the northern portion of the watershed to 40 inches near the confluence of Middle Yegua Creek and Yegua Creek (Figure 4).

Precipitation data collected at the weather station in Figure 3 differed from that shown in Figure 4 because the data were collected at a single location near the watershed over a 20-year period as opposed to weather data averaged across the entire watershed area over a 30-year period.

Topography

Watershed hydrology is influenced by many landscape conditions, including topography. Slope and elevation determine the direction of water flow. The elevation across the watershed ranges from approximately 762 ft above mean sea level (amsl) maximum elevation in the northwestern portion of the watershed to a minimum elevation of about 248 ft where Middle Yegua Creek flows into Yegua Creek above Lake Somerville (Figure 5). This topographic information was compiled based on the 10-meter digital elevation models (DEMs) obtained from the U.S. Geological Survey (USGS) National Map database (USGS 2021).

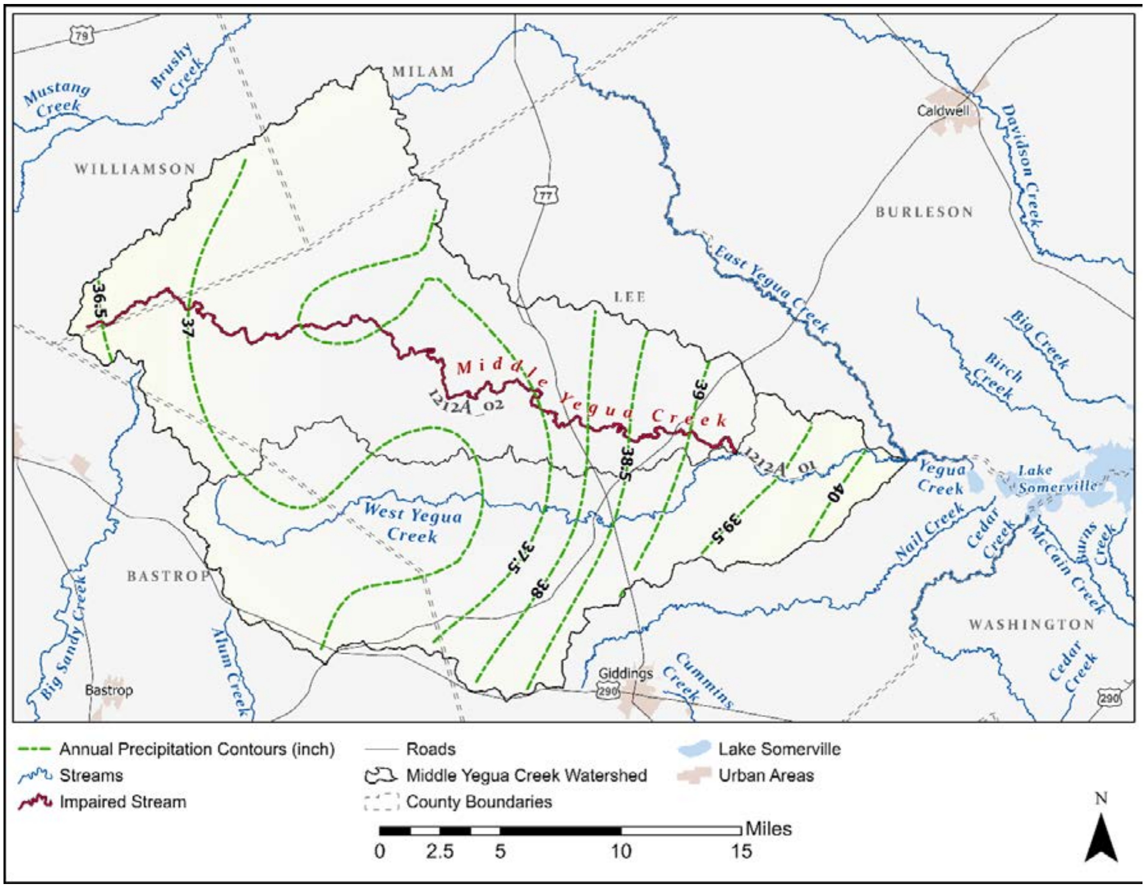

Figure 4. PRISM 30-year average monthly precipitation normal.

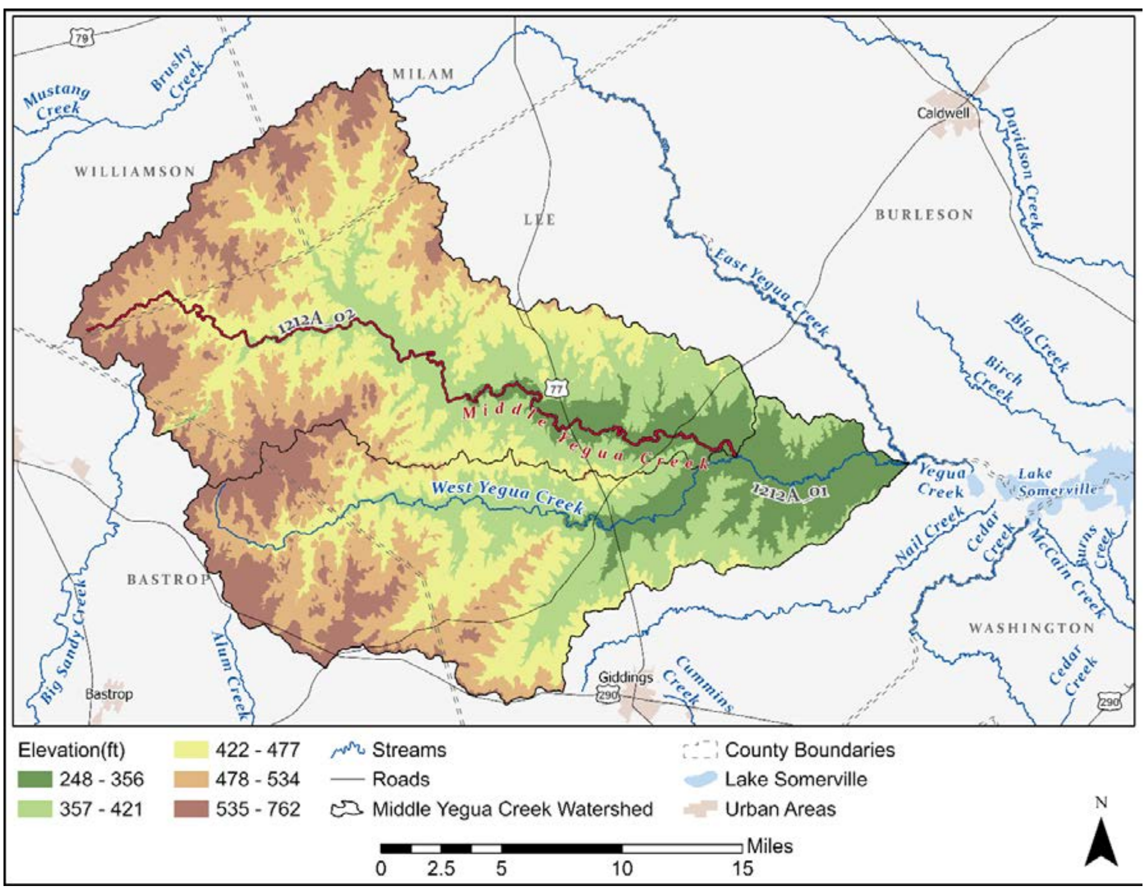

Figure 5. Elevation of the watershed.

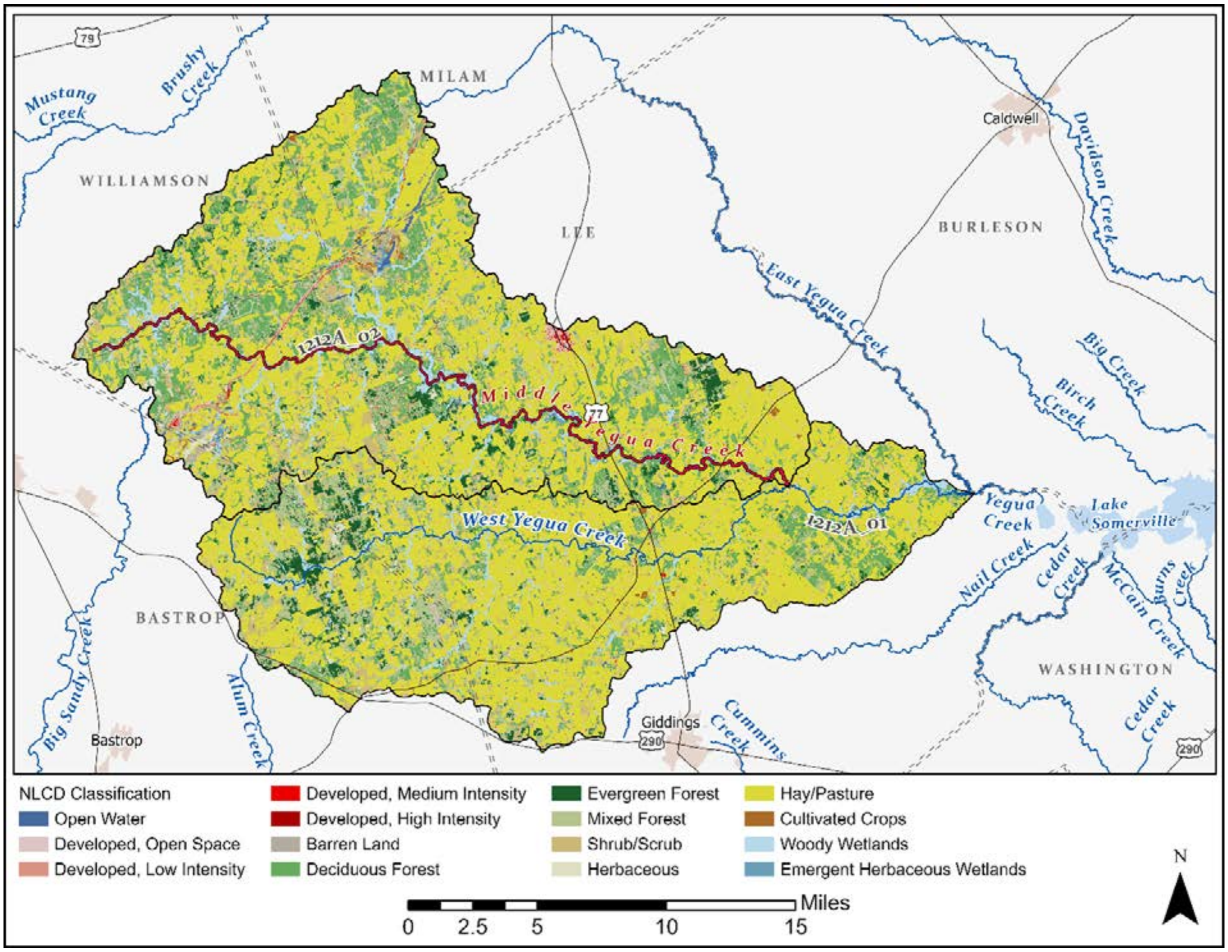

Figure 6. NLCD 2021 land use and land cover.

Land Use and Land Cover

The 2021 National Land Cover Database (NLCD), obtained from the Multi-Resolution Land Characteristics Consortium (Dewitz 2023), showed that the Middle Yegua Creek watershed was mostly rural with pasture/hay being the predominant land use (55%), followed by deciduous forest (14.6%), and only 4.6% of the area was classified as somewhat developed (Figure 6; Dewitz 2023). Table 1 shows the land use/land cover types within the watershed, as well as their corresponding acreage and percentage of the total watershed area.

Table 1. Land use and land cover types and corresponding areas and percentages of coverage in each AU watershed.

	AU 1212A_01		AU 1212A_02	
NLCD 2021 Classification	Watershed size (acres)	Percent of AU Watershed	Watershed area (acres)	Percent of AU Watershed
Open Water	587	<1%	1,095	0.7%
Developed, Open Space	4,036	3.3%	5,486	3.4%
Developed, Low Intensity	857	<1%	1,428	<1%
Developed, Medium Intensity	303	<1%	525	<1%
Developed, High Intensity	32	<1%	79	<1%
Barren Land	82	<1%	843	<1%
Deciduous Forest	12,503	10.2%	28,524	17.9%
Evergreen Forest	5,484	4.5%	5,205	3.3%
Mixed Forest	11,677	9.6%	11,867	7.4%
Shrub/Scrub	6,591	5.4%	10,729	6.7%
Grassland/Herbaceous	894	<1%	2,186	1.4%
Pasture/Hay	74,009	60.5%	81,260	50.9%
Cultivated Crops	140	<1%	514	<1%
Woody Wetlands	4,720	3.9%	8,748	5.5%
Emergent Herbaceous Wetlands	322	<1%	1,071	<1%
Total Acreage	122,237	100%	159,561	100%

AU- assessment unit; NLCD – National Land Cover Database.

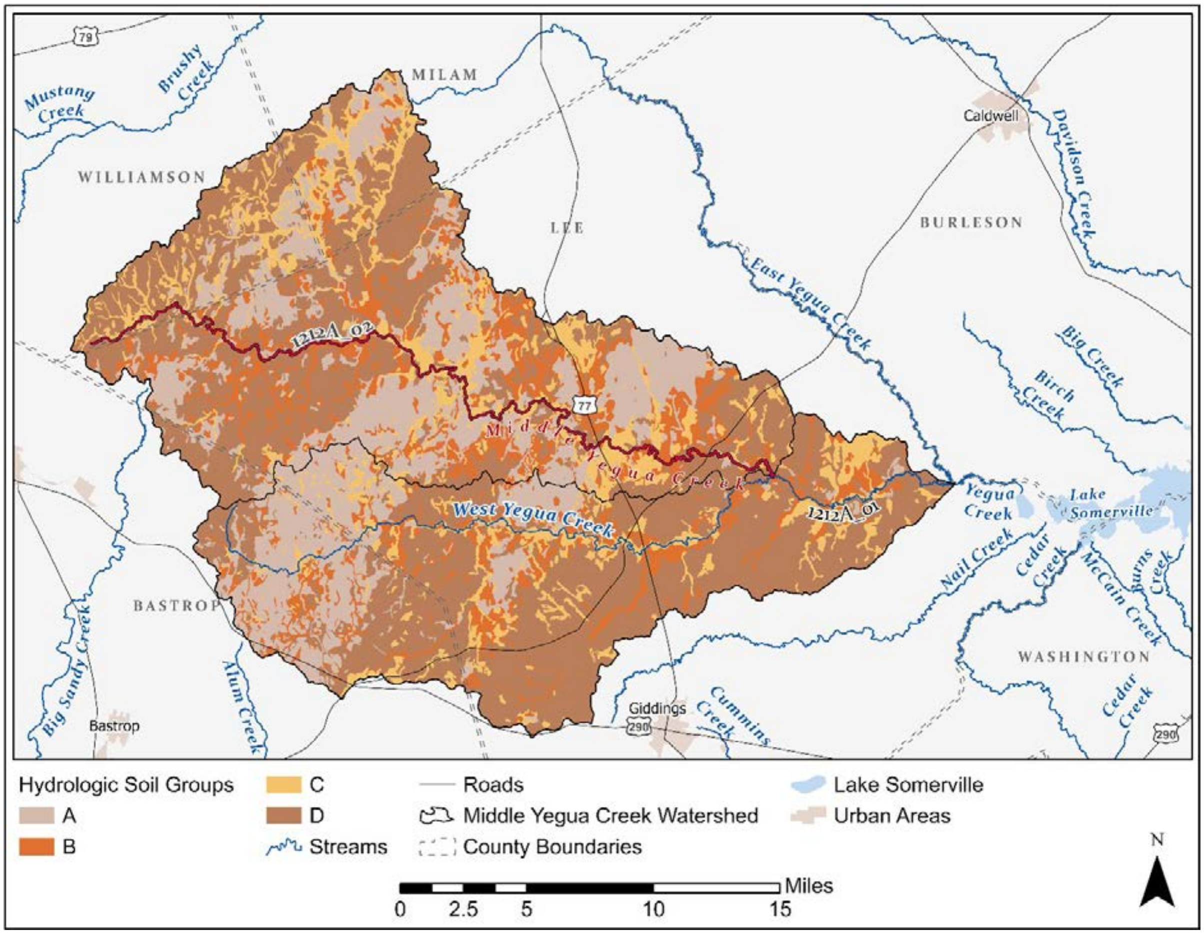

Figure 7. Hydrologic Soil Groups in the Middle Yegua Creek watershed.

Soils

Watershed hydrology is affected by soil properties as they influence the quantity and speed by 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.

For the Middle Yegua Creek watershed, soil property data are available through the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO; USDA 2019). This database describes soil components and properties and provides a hydrologic rating, which groups soils by similar runoff properties. These ratings are useful for considering the potential for runoff from properties under consistent rainfall and cover conditions. Based on the runoff potential, the majority of soils in the watershed are classified into Hydrologic Soil Group (HSG) A or HSG D (Figure 7; Table 2). HSG A means a high infiltration rate when thoroughly wet. This group consists mainly of soils having deep, well-drained to excessively drained sands or gravelly sands, and it has a high rate of water transmission. HSG D consists of soils with very slow infiltration rates (high runoff potential) when thoroughly wet. This group consists mainly of clays with a high shrink-swell potential, soils with a high water table, soils with 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.

Table 2. HSGs and corresponding acreage and percentages in the watershed.

Hydrologic Soil Group	Acres	Percent of Total Watershed Area	Description
A	67,445	23.9	Soils that have a high infiltration rate (low runoff potential) when thoroughly wet. These soils consist mainly of deep, well-drained to excessively drained sands or gravelly sands and have a high rate of water transmission.
B	40,960	14.6	Soils that have a moderate infiltration rate when thoroughly wet. These consist mainly of soils that have moderately deep or deep, moderately well-drained, or well-drained soils with moderately fine texture to moderately coarse texture and a moderate rate of water transmission.
C	41,204	14.6	Soils that have a slow infiltration rate when thoroughly wet. These consist mainly of soils that have a layer that impedes the downward movement of water, or soils of moderately fine tex-ture or fine texture, and have a slow rate of water transmission.
D	132,189	46.9	Soils that have a very slow infiltration rate (high runoff potential) when thoroughly wet. They consist mainly of clays with a high shrink-swell potential, soils with a high water table, soils with 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.
Total	281,798	100	

*Certain wet soils are placed in Group D based solely on the presence of the water table within 24 inches of the surface, even though 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 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 purposes of hydrologic soil group, adequately drained means that seasonal high-water tables are at least 24 inches below the surface in a soil where it would be higher in a natural state (USDA NRCS 2019).

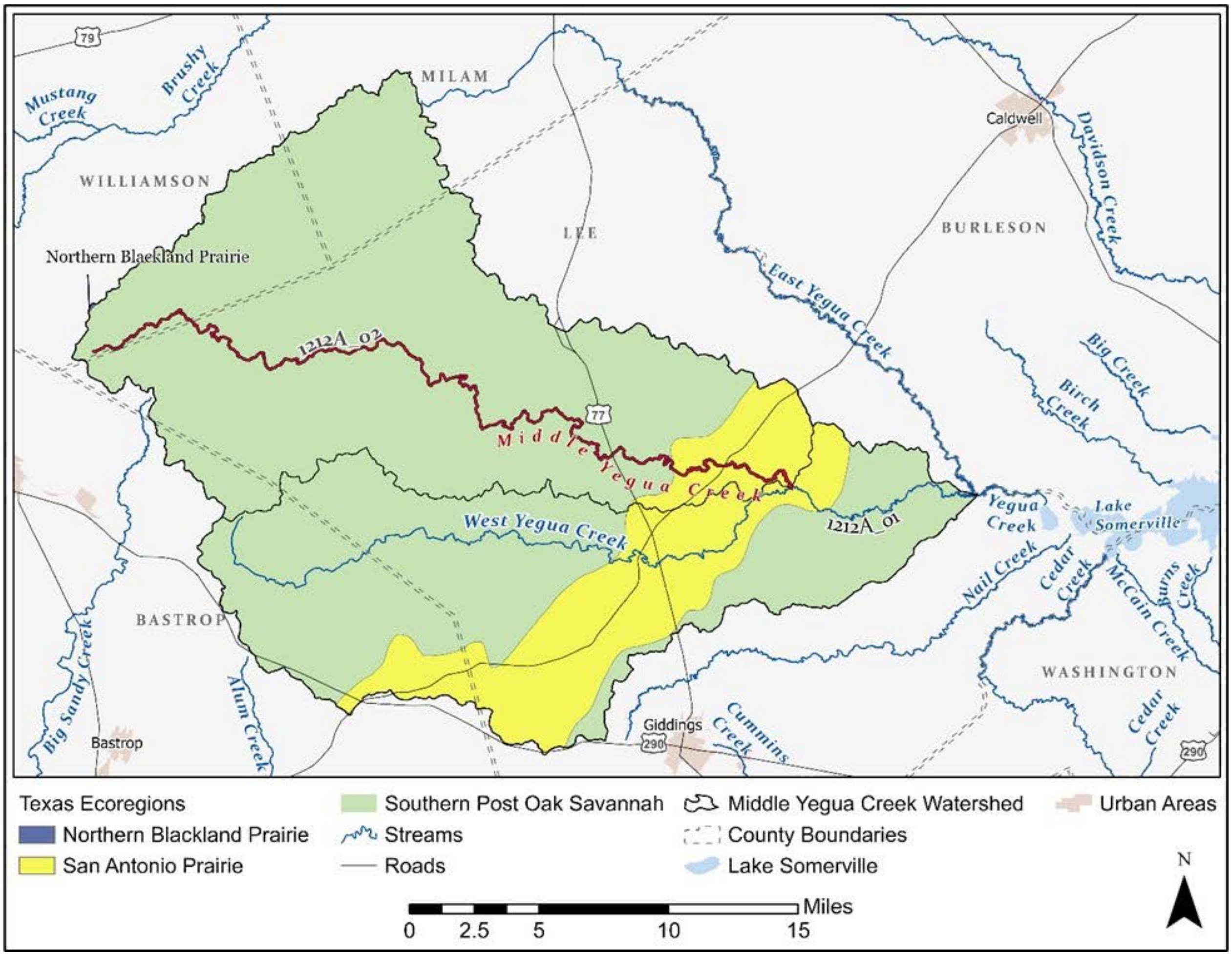

Figure 8. Level IV ecoregions.

Ecoregions

Ecoregions are land areas that contain similar quality and quantity of natural resources (Griffith 2007). The watershed flows primarily through two Level-IV ecoregions: San Antonio Prairie and Southern Post Oak Savannah, and the latter is the watershed's dominant ecoregion (Figure 8).

The Southern Post Oak Savannah ecoregion consists mostly of hardwoods, and its land cover is a mix of post oak woods, improved pasture, and rangeland, with some invasive mesquite to the south. The soil in this ecoregion is generally acidic. Many areas of this ecoregion have more dissected and irregular topography than the Northern Post Oak Savannah, which has a negligible appearance in the Middle Yegua Creek watershed.

In contrast with Southern Post Oak Savannah, the San Antonio Prairie is a treeless belt of grassland. Soils in this ecoregion are generally dark, loamy to clayey, blackland soils with stiff clayey subsoils. The land cover of this ecoregion is a mix of woodland, improved pasture, rangeland, and some cropland.

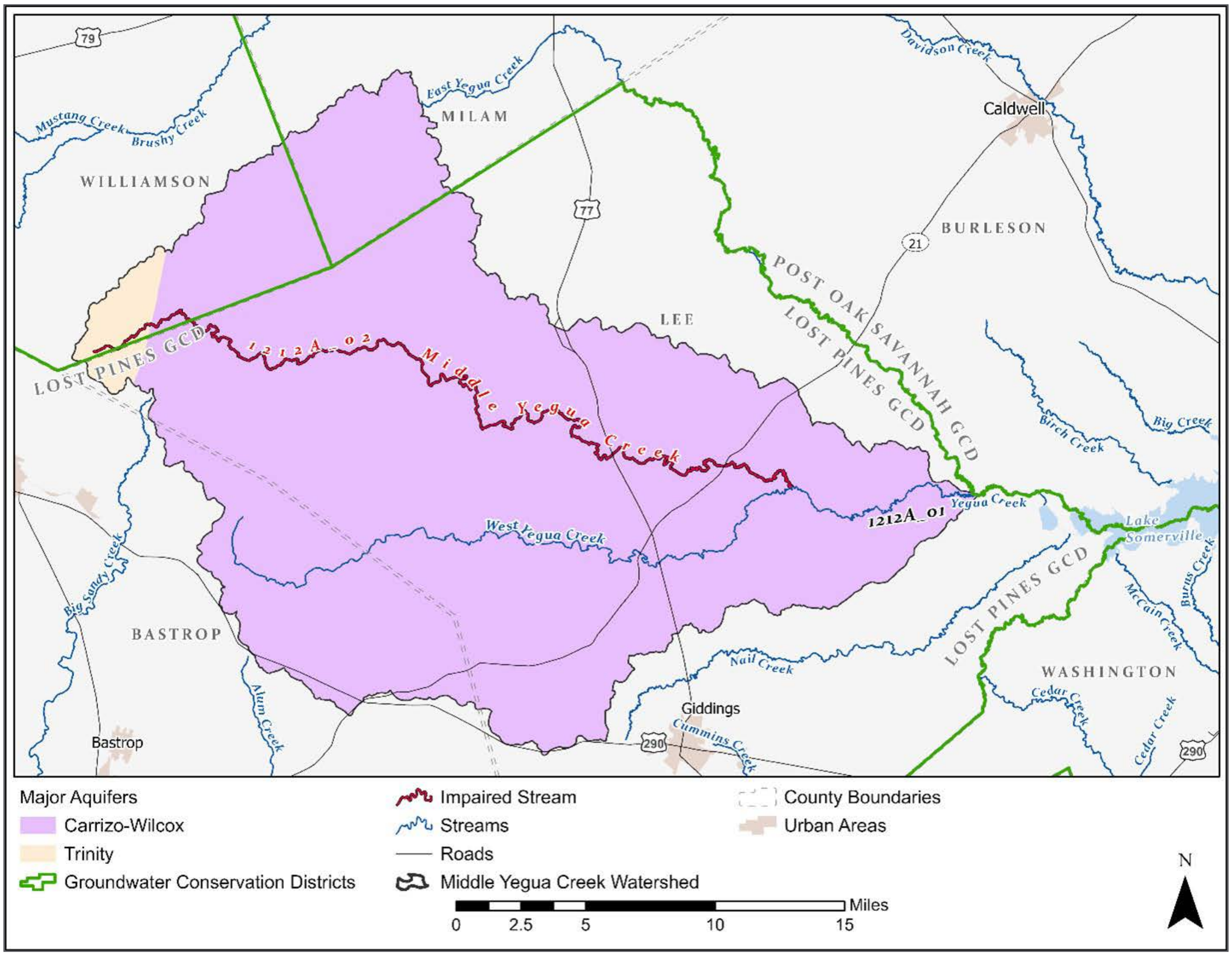

Figure 9. Aquifers underlain the Middle Yegua Creek watershed.

Groundwater

Besides surface water, another valuable water resource is groundwater. The Middle Yegua Creek watershed is underlain by two major aquifers: Carrizo-Wilcox and Trinity aquifers (Figure 9).

According to the Texas Water Development Board (TWDB) - Texas Aquifers Study (TWDB 2016), the Middle Yegua Creek watershed boundary intersects with unconfined area of the Carrizo-Wilcox Aquifer in Lee, Milam, and Williamson counties, and with confined area of the same aquifer in Lee and Bastrop counties. Groundwater in the confined areas of the Carrizo Wilcox is generally softer, with total dissolved solids concentrations mostly less than 1,000 mg per liter, except in southern and western portions of the aquifer. Moreover, in the Winter Garden area and parts of Brazos County, portions of the aquifer are slightly to moderately saline.

In addition, the Middle Yegua Creek watershed boundary also intersects with the unconfined area of the Trinity aquifer in Williamson County. In general, groundwater is fresh but very hard in this area, but the total dissolved solids in the outcrop area is usually less than 1,000 mg per liter.

To help conserve and protect groundwater, the Lost Pines Groundwater Conservation District (GCD) were created in Bastrop and Lee counties and the Post Oak Savannah GCD in Milam and Burleson counties.

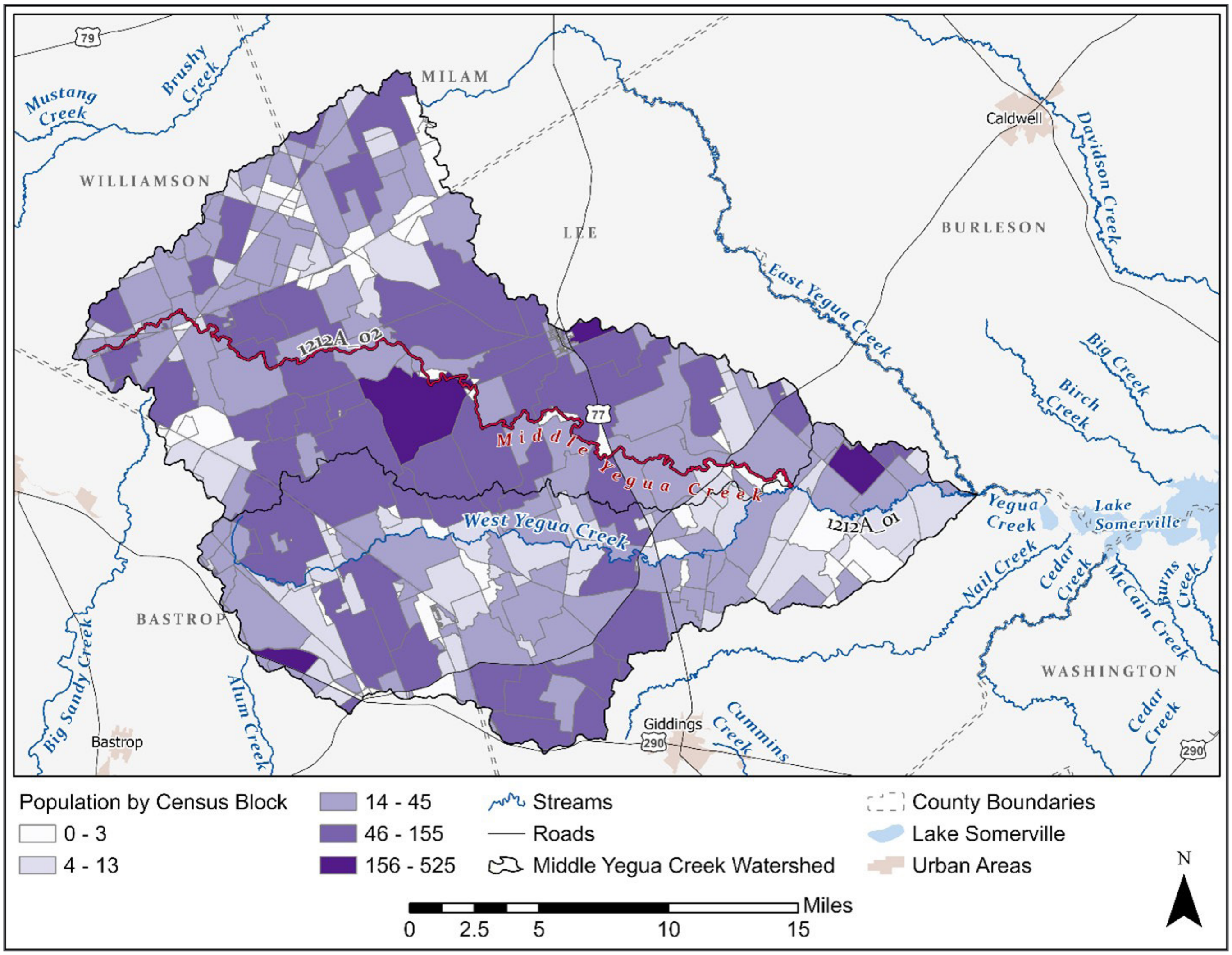

Figure 10. Estimated population by census block.

Population and Population Projections

Population within the Middle Yegua Creek watershed was estimated using the U.S. Census Bureau (USCB) population data by census block (the finest geographic area for which census data are collected) within the watershed (USCB 2020). Based on this decennial data, a total of 539 census blocks completely or partially fell within the watershed boundary and the population living in the watershed was estimated to be 9,363. Of the 9,363 people, 1,367 were in Bastrop County, 6,573 in Lee County, 466 in Milam County, and 947 in Williamson County (Table 3). Moreover, the most populous census block within the watershed had 525 people and the average number of people per census block was 17 (Figure 10).

TWDB provides the population projection every five years for each county in a Regional Water Plan (TWDB 2021). Table 3 shows the most recent 2021 projected population within each AU watershed by county and year. Between 2020 and 2070, the population of Bastrop County was expected to increase drastically by over 300%, followed by Willamson County with an increase of 160%; while the populations of Lee and Milam counties were expected to increase by around 25%.

Table 3. 2021 Regional Water Plan county population projections for 2020-2070 by AU watershed.

AU 1212A_01	Projected Population in the Watershed by Year						
County	2020	2030	2040	2050	2060	2070	Percent Increasec (2020-2070)
Bastrop	1,245	1,637	2,147	2,837	3,770	5,010	302
Lee	1,940	2,181	2,320	2,370	2,404	2,422	25
AU 1212A_02	**Projected Population in the Watershed by Year**						
County	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**Percent Increasec (2020-2070)**
Bastrop	131	172	226	299	397	527	302
Lee	4,634	5,210	5,541	5,662	5,743	5,787	25
Milam	466	494	513	538	560	580	24
Williamson	947	1,158	1,414	1,713	2,093	2,467	160

AU – assessment unit.

Chapter 3 Water Quality

Middle Yegua Creek at FM 696 by Amanda Tague, TWRI.

Surface water bodies are monitored in Texas to ensure that their quality supports designated uses defined in the Texas Surface Water Quality Standards (TSWQS; TCEQ 2022a). Designated uses and associated standards are developed by TCEQ to fulfill requirements of the federal Clean Water Act (CWA). Texas is required to set standards that: 1) maintain and restore biological integrity in the waters, 2) protect fish, wildlife, and recreation in and on the water (fishable/swimmable), and 3) consider the use and value of state waters for public supplies, wildlife, recreation, agricultural, and industrial purposes.

Water Body Assessments

Under the CWA (33 U.S. Code § 1251.303), administered by EPA (40 Code of Federal Regulations § 130.7), Texas is required to develop a list that describes all water bodies that are impaired and are not within established water quality standards. This list is commonly known as the "303(d) list," in reference to the *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (EPA 2005). Furthermore, the TCEQ conducts a water body assessment every two years and publishes the findings in the "305(b) report" in reference to the *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d).* This document is hereinafter referred to as the Texas Integrated Report (EPA 2005).

The most recent *2022 Texas Integrated Report* was based on water quality data collected between Dec 1, 2013 and Nov 30, 2020 (TCEQ 2022b). This period preceded the start of efforts to develop this WPP by over two years. In the *2022 Texas Integrated Report,* Middle Yegua Creek (Segment 1212A) is composed of two AUs: 1212A_01 and 1212A_02 (Figure 11; TCEQ 2022b). Historically, water quality was monitored on both AUs by different entities, including the Brazos River Authority (BRA), TCEQ, and Texas State Soil and Water Conservation Board (TSSWCB), during different periods of time at four surface water quality monitoring (SWQM) stations: 18751, 18750, 11841, and 11838 (Figure 11; TCEQ 2023). Between Dec 2018 and Dec 2023, the Texas Water Resources Institute (TWRI), funded

Table 4. TWRI water quality data collection schedule between 2018 and 2023.

SWQM Station			Number of Annual Samples Collected				
ID	AU ID	Collecting Entity	Metal in Water	Conventional	Field	Flow	Bacteria
18750	1212A_02	TWRI	-	12	12	12	12
11840	1212A_02	TWRI	-	12	12	12	12
11838	1212A_01	TWRI	-	12	12	12	12

AU – assessment unit; TWRI – Texas Water Resources Institute; SWQM – Surface Water Quality Monitoring.

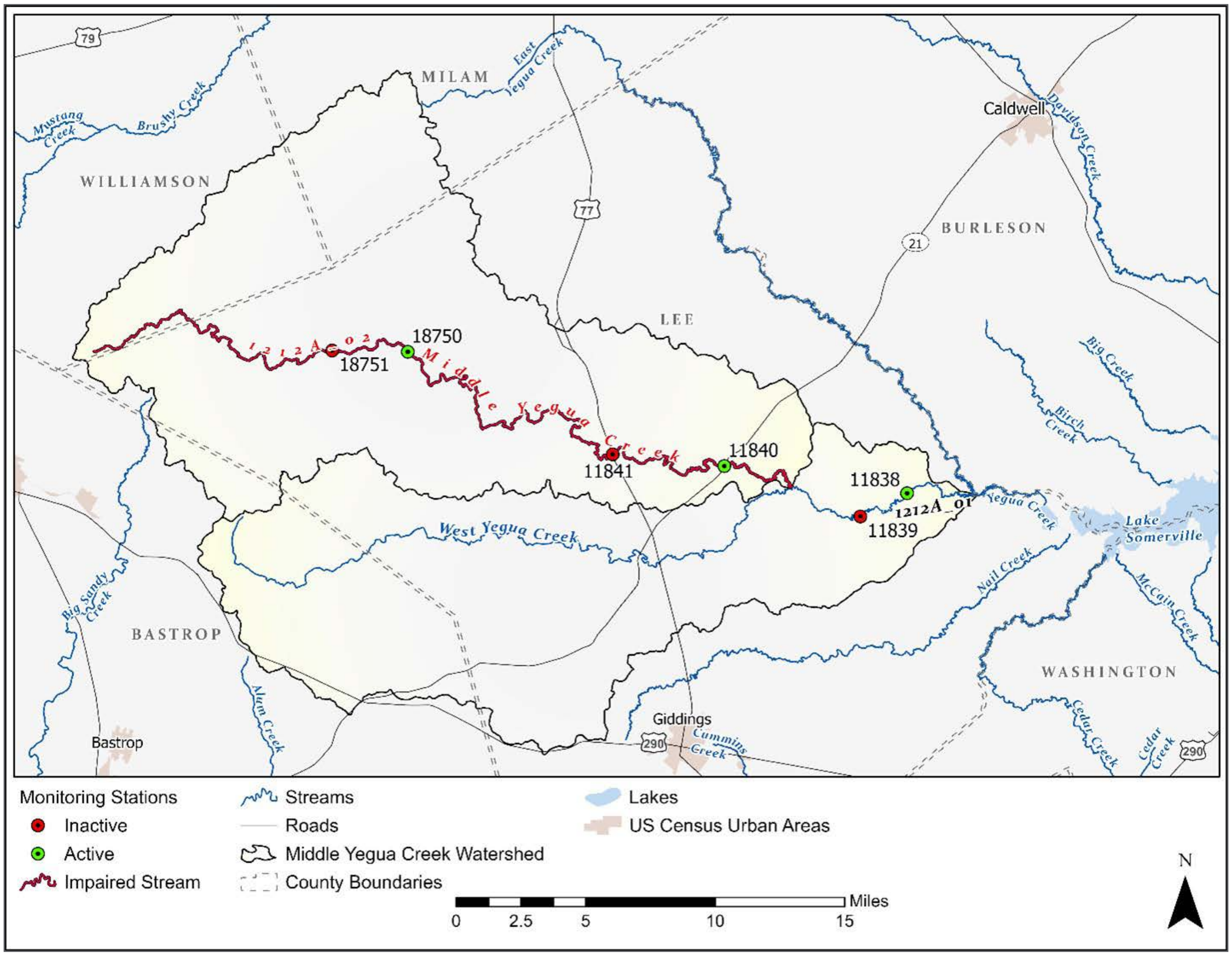

Figure 11. Stream segment, AUs, and SWQM stations.

by TSSWCB, conducted monthly routine water quality monitoring along Middle Yegua Creek at three SWQM stations, including 18750 and 11840 on AU 1212A_02 and 11838 on AU 1212A_01(Table 4; Figure 11; TCEQ 2023). Monitoring on both AUs allows independent water quality analysis for each AU within the segment. The data collected included instantaneous streamflow, bacteria, and field parameters, such as Secchi depth (water clarity), water temperature, dissolved oxygen (DO), specific conductivity, and pH.

Table 5. Designated uses for AUs in the Middle Yegua Creek watershed.

AU ID	Designated Use	Method	Criteria / Screening Level
1212A_01	Contact Recreation	*E. coli* / Geomean*	126 MPN/100 mL
	Aquatic Life Use	DO / grab screening level**	5 mg/L
		DO / grab minimum*	3 mg/L
1212A_02	Contact Recreation	*E. coli* / Geomean*	126 MPN/100 mL
	Aquatic Life	DO / grab screening level**	5 mg/L
		DO / grab minimum*	3 mg/L
		Habitat**	-
	General	Total phosphorus**	0.69 mg/L
		Nitrate**	1.95 mg/L
		Chlorophyll-a**	14.1 µg/L
		Ammonia**	0.33 mg/L

*** EPA-approved criteria, ** State screening level**
AU – assessment unit; MPN – most probable number; mL – milliliter; mg – milligram; µg – microgram; L – liter.

Table 6. Watershed impairments and concerns listed in the *2022 Texas Integrated Report.*

AU ID	Parameter	Criterion/ Screening Level	Number of Data Assessed	Geometric Mean Value	Mean Exceedances	Level of Support	Category
1212A_01	Bacteria	126 MPN/100 mL	12	181.05 MPN/100 mL	-	Use concern	-
1212A_02	Bacteria	126 MPN/100 mL	34	373.64 MPN/100 mL	-	Impaired	5c
	DO grab	5 mg/L	34		3.86 mg/L	Screening level concern	-
	Habitat	-	0	-	-	Screening level concern	-

AU- assessment unit; MPN – most probable number; mL – milliliter; mg – milligram; L – liter.

Texas Surface Water Quality Standards

TSWQS are implemented to ensure a water body's ability to support its designated use(s), which, in the case of Middle Yegua Creek, include primary contact recreation use (e.g., swimming, kayaking, wading), aquatic life use (fish, shellfish, and wildlife protection and propagation), and general use (Table 5; TCEQ 2022b).

For primary contact recreation use, the parameter used to measure whether a freshwater body supports this use is *E. coli,* and the seven-year geometric mean concentration of *E. coli* should be below 126 MPN per 100 mL.

For aquatic life use, methods used to measure whether water quality is acceptable are DO grab screening level, DO grab minimum, and habitat. Grab screening level is used to identify potential concerns and to indicate further assessment needs to determine if conditions consistently pose risks to aquatic life. Meanwhile, grab minimum refers to the lowest acceptable DO concentration measured in an instantaneous sampling event, and when an instantaneous measurement of DO falls below the grab minimum threshold, it could indicate adverse conditions to aquatic life.

For general use, methods used to indicate whether water quality is acceptable include screening levels for total phosphorus, nitrate, chlorophyll -a, and ammonia.

It is also worth noting that while the *E. coli* and DO grab minimum are EPA-approved criteria for CWA purposes, the DO grab screening level and nutrient screening level methods are provisions of the State.

The *2022 Texas Integrated Report* identifies AU 1212A_02 as impaired for primary contact recreation uses because its *E. coli* levels (seven-year geometric mean value = 373.64 MPN per 100 mL) significantly exceeded EPA-approved bacteria criterion of 126 MPN per 100 mL for freshwater. Moreover, AU 1212A_02 is categorized as "5c" in the report because, at the time when the report was finalized, it was believed that additional data and information needed would be collected or evaluated before a management strategy is selected (Table

Table 7. Historical bacteria concentration in Middle Yegua Creek.

AU ID	Station ID	Begin Date	End Date	Geometric mean (MPN/100 mL)	Number of Measurements
1212A_01	11838	12/19/2018	9/7/2023	86.09	54
1212A_02	11840	11/5/2018	8/10/2023	227.94	56
1212A_02	18750	1/31/2006	9/7/2023	412.24	63
1212A_02	18751	1/31/2006	8/7/2007	617.75	5

AU- assessment unit; MPN – most probable number.

Figure 12. Historical *E. coli* concentrations.

6; TCEQ 2022b). In addition, AU 1212A_02 has concerns for depressed DO and impaired habitat determined based on respective screening levels (Table 6; TCEQ 2022b).

In the meantime, AU 1212A_01 has higher-than-criterion *E. coli* levels (seven-year geometric mean value = 181.05 MPN per 100 mL); however, it is not considered impaired, rather is considered having a concern for primary contact recreation use (Table 6; TCEQ 2022b).

Bacteria

Concentrations of fecal indicator bacteria are evaluated to assess the risk of illness during contact recreation. In freshwater, concentrations of *E. coli* bacteria are measured to evaluate the presence of fecal contamination in water bodies from warm-blooded animals The presence of these fecal indicator bacteria may indicate that associated pathogens from the intestinal tracts of warm-blooded animals or other sources could be reaching water bodies and could cause illness in people that recreate in them. Common sources include wildlife, domestic livestock, pets, malfunctioning on-site sewage facilities (OSSFs), urban and agricultural runoff, sewage system overflows (SSOs), and direct discharges from wastewater treatment facilities (WWTFs). For primary contact recreation use, geometric mean *E. coli* concentrations in freshwater needs to be less than 126 MPN per 100 mL based on at least 20 measurements between Dec 1, 2013 and Nov 30, 2020 (TCEQ 2021; TCEQ 2022b).

Table 7 summarizes the bacteria data collected in the recent 20 years throughout the Middle Yegua Creek watershed by monitoring station, which excludes station 11841 where no data were found for this period (TCEQ 2023). Figure 12 shows the *E. coli* measurements as well as the three-year rolling geometric mean using data collected in the recent 20 years (2003-2023). The black solid line indicates 3-year

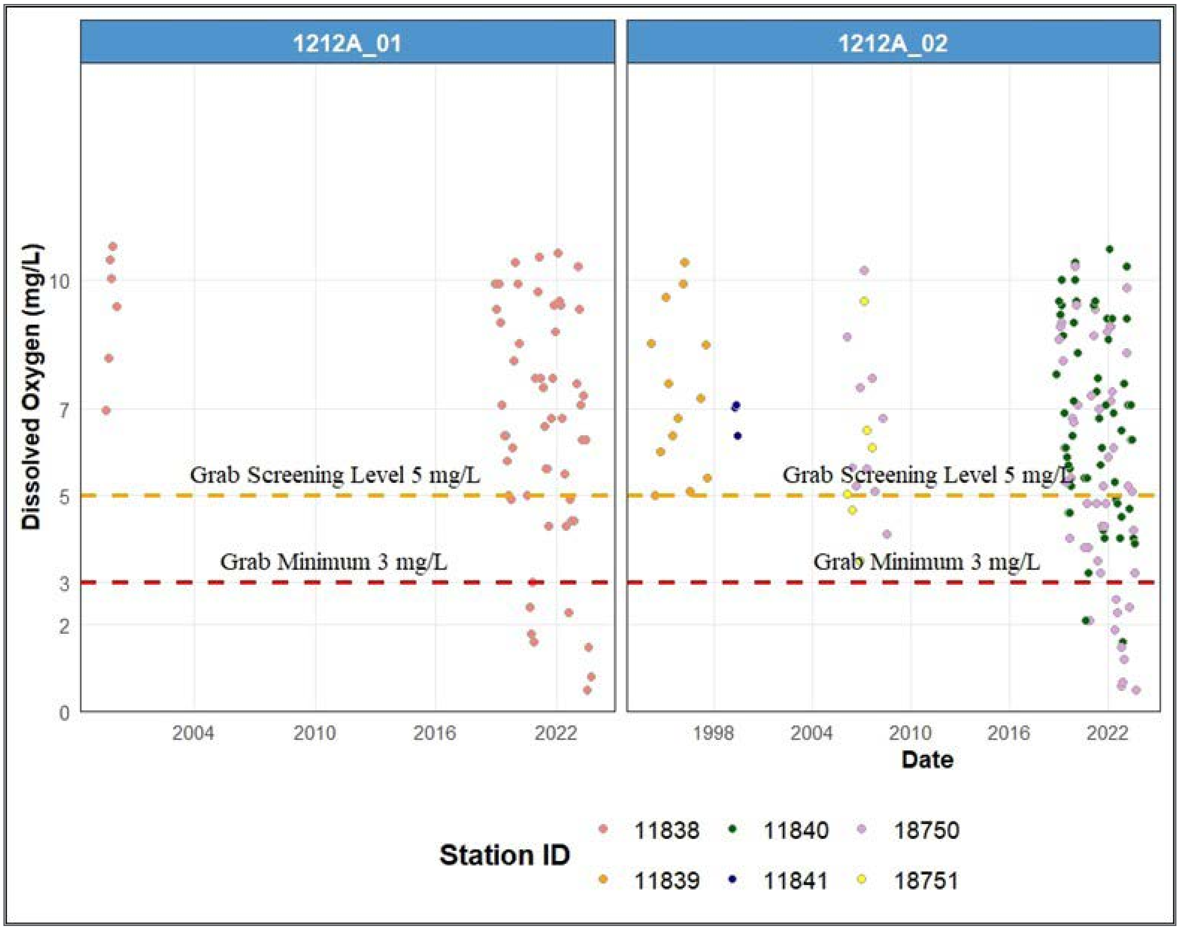

Figure 13. DO concentrations.

rolling geometric mean and the red dashed line indicates 126 MPN/100 mL criterion. The data showed that upstream stations 18751, 18750, and 11840 had higher *E. coli* concentrations than the downstream station 11838; and additionally, the upstream stations exceeded the bacteria criteria more frequently than the downstream station.

Dissolved Oxygen

DO is the main parameter used to determine a water body's ability to support and maintain aquatic life uses. If DO levels in a water body drop too low, fish and other aquatic species will not survive.

Typically, DO levels fluctuate throughout the day, with the highest levels of DO occurring in mid to late afternoon, due to plant photosynthesis. Meanwhile, DO levels are typically lowest just before dawn as both plants and animals in the water consume oxygen through respiration. Furthermore, seasonal fluctuations in DO are common because oxygen solubility decreases 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 materials and subsequently consume oxygen. Excessive nutrients from fertilizers and manures 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.

Fresh water DO levels are protected to support aquatic life use based on screening levels, which are determined based on streamflow type (perennial, intermittent with pools, or intermittent). For Middle Yegua Creek the screening level is 5 mg per liter and the grab minimum threshold is 3 mg per liter. According to the 2022 Texas Integrated Report, based on the data collected between Dec 2013 and Nov 2020, neither AU within the Middle Yegua Creek watershed are impaired for depressed DO. However, concerns for depressed DO in AU 1212A_02 is noted (TCEQ 2022b). Figure 13 shows the DO measurements available for Middle Yegua Creek. Many measurements were above the screening level, while other samples were either in between the screening level and the grab minimum or below the grab minimum, which indicates that occasionally aquatic life is exposed to low DO risks.

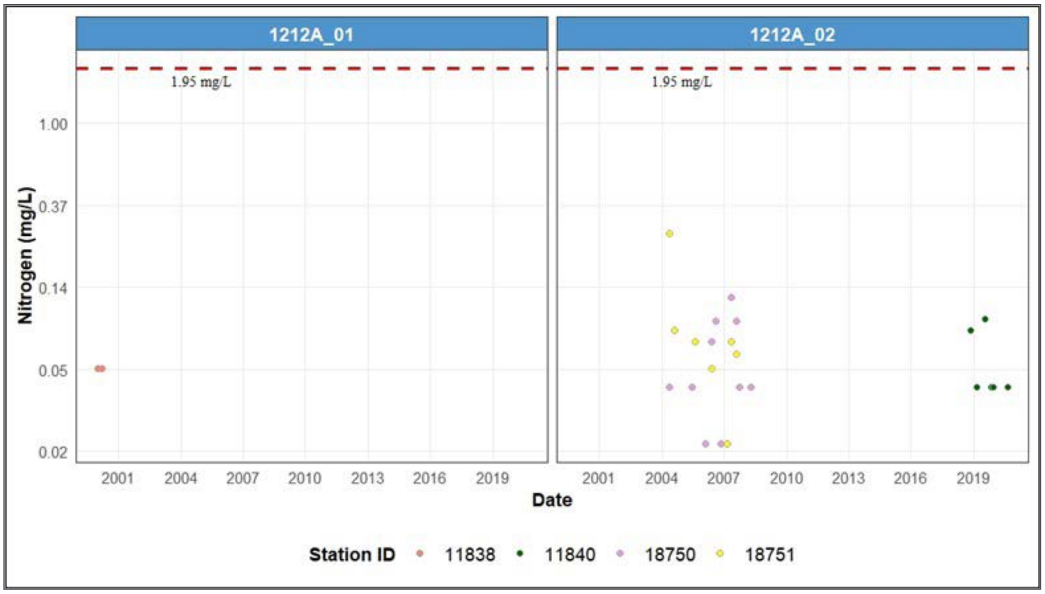

Figure 14. Nitrogen concentrations.

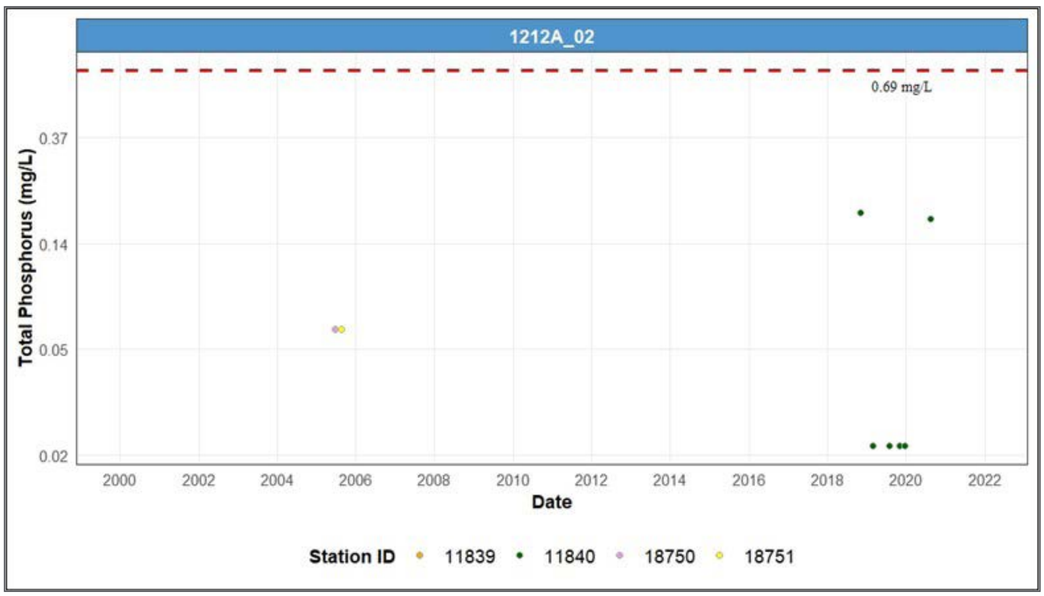

Figure 15. Total phosphorus concentrations.

Nutrients

Nutrients, specifically nitrogen and phosphorous, are used by aquatic plants and algae. However, excessive nutrients can lead to plant and algal blooms, which would result in reduced DO levels. Sources of nutrients include effluents from WWTFs and OSSFs, direct deposition of animal fecal matter, illegal dumping, groundwater return flows, and fertilizers that runoff from yards and agricultural fields. Additionally, nutrients bind to soil and sediment particles; therefore, runoff and erosion events that result in heavy sediment loads can increase nutrient levels in receiving water bodies.

Freshwater streams are protected from excessive nutrient levels to support general use using screening levels. Nutrient screening levels were designated for ammonia, nitrate, total phosphorus, and chlorophyll-a (Table 5; TCEQ 2022b). These levels are statistically derived from the SWQM monitoring data, and they are based on the 85th percentile values for each parameter in freshwater streams (TCEQ 2021). TCEQ identifies a "concern", which is not an impairment listing, for water quality if the screening level was exceeded more than 20 percent of the time based on the number of exceedances for a given number of samples collected (TCEQ 2021). As mentioned before, in the 2022 Integrated Report, data collected between Dec 2013 and Nov 2020 were used for assessments.

Nutrient data collected within the Middle Yegua Creek watershed included nitrogen (Figure 14) and total phosphorus (Figure 15). Measurements of those two parameters indicated no concerns.

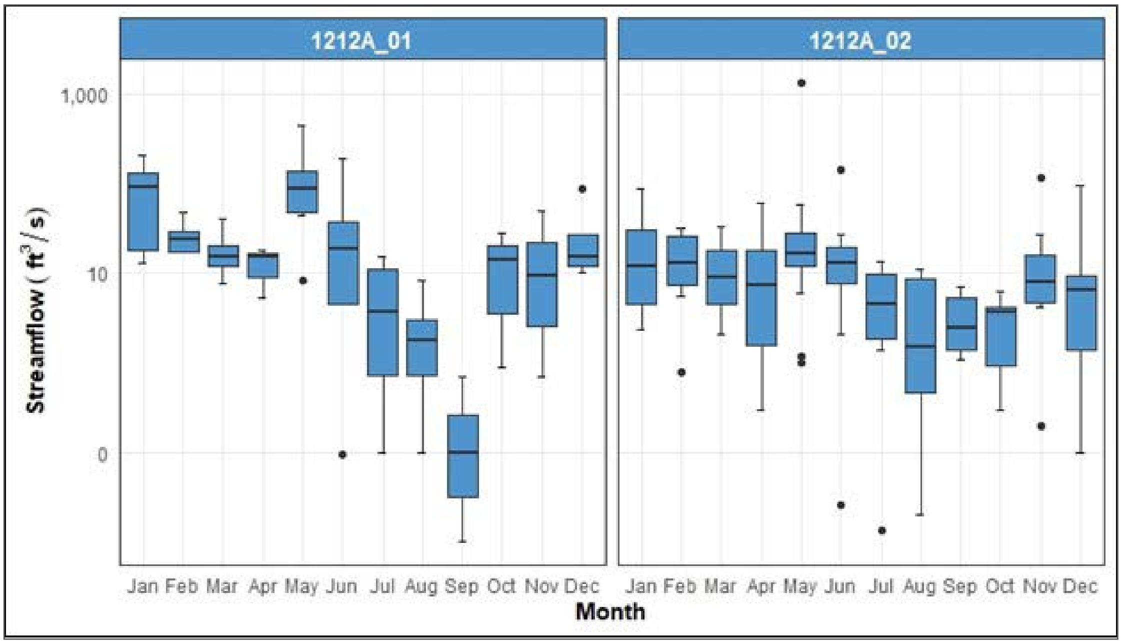

Figure 16. Box-and-whisker plot of monthly average instantaneous flows.

Flow

Streamflow (the amount of water flowing in a river at a given time) is dynamic and always changing in response to both natural (e.g., precipitation events) and man-made (e.g., changes in land cover) factors. From a water quality perspective, streamflow is important because it influences the ability of a water body to assimilate pollutants. Figure 16 shows the box-and-whisker plots of streamflow in Middle Yegua Creek by month. A box-and-whisker plot shows five values: minimum (bottom whisker), 25th percentile (bottom edge of the box), 50th percentile or median (black line in the box), 75th percentile (top edge of the box), maximum (top whisker), and outliers (black circles).

Based on the box-and-whisker plots, both AUs within the Middle Yegua Creek, in general, had less water in warmer months (Jul, Aug, Sep) and more water in winter and spring (Dec - May), which aligns with the precipitation seasonality in the watershed; however, the downstream AU 1212A_01 showed a more notable streamflow seasonality between warmer and colder months, while the upstream AU 1212A_02 had a more evenly distributed streamflow throughout a year.

Habitat

The soundness of aquatic habitat closely influences the integrity of fish and benthic macroinvertebrate communities. According to the *2022 TCEQ Integrated Report* (TCEQ 2022b), AU 1212A_02 in Middle Yegua Creek has concerns for impaired habitat in water; however, possible sources of this concern are noted as unknown.

Chapter 4
Potential Pollution Sources


Middle Yegua Creek at FM 696 by Amanda Tague, TWRI.

The previous chapters have discussed the impairment and concerns in Middle Yegua Creek, that is elevated indicator bacteria, namely *E. coli* concentrations and concerns for depressed DO. This chapter discusses potential sources of pollutants, which can be broadly categorized as point source and nonpoint source (NPS). While point source pollution comes from identifiable locations, such as WWTF outfalls, SSOs, and concentrated animal feeding operations (CAFOs), NPS pollution typically comes from many diffuse sources, such as failing OSSFs, livestock, wildlife, feral hogs, pets, and illicit/illegal dumping.

Potential sources of pollutants in the Middle Yegua Creek watershed were identified through stakeholder input, watershed surveys, project partners, and watershed monitoring (Table 8).

Point Source Pollution

Point sources of pollution are discernible outlets such as pipes, ditches, containers, or other vessel discharging pollutants (CWA §502) and they are regulated by the National Pollutant Discharge Elimination System and the Texas Pollutant Discharge Elimination System (TPDES). These can include municipal and industrial WWTP permits, general wastewater permits, and general stormwater permits. Other examples of point source pollution include confined animal feeding operations, concrete production, wastewater evaporation ponds, pesticide general permits, and Multi-Sector General Permits.

Wastewater Treatment Plants

WWTFs treat wastewater and then discharge the treated effluent into the environment. WWTFs are regulated by permits under the National Pollutant Discharge Elimination System (NPDES) and the Texas Pollutant Discharge Elimination System (TPDES). WWTFs are required to test and report effluent characteristics (e.g., *E. coli*, flow, total suspended solids, pH, and biochemical oxygen demand) as a condition of their NPDES/TPDES permits. Facilities that exceed effluent limits specified in their permit may be required to make improvements to facilities or procedures.

In the Middle Yegua Creek watershed, there is one operating WWTF, i.e., City of Lexington WWTF, located in the AU

Table 8. Summary of potential pollutant sources and their potential impacts and causes.

	Pollutant source	Pollutant impacts	Potential causes
Point sources	Wastewater Treatment Plants, Sanitary Sewer Overflows, and Concentrated Animal Feeding Operations	Contributing to bacteria and nutrient loads	• Overflow during severe storm events • Systemic failures due to age, lack of routine maintenance, etc.
	Texas Pollutant Discharge Elimination System - permitted stormwater	Contributing to bacteria and nutrient loads, litter, oils, etc.	• Excessive surface runoff due to impervious pavements
Non-point sources	Wildlife, Livestock and Feral hogs	Contributing to bacteria loads	• Animals defecating directly in water • Animals spending time in riparian areas and causing soil erosion and degradation
	Pets	Contributing to bacteria loads	• Improper disposal of pet waste
	On-site Sewage Facilities (Septic Systems)	Contributing to bacteria and nutrient loads	• System not properly designed for site-specific conditions • Improper function due to age or lack of maintenance/sludge removal
	Illegal dumping	Contributing to bacteria and nutrient loads	• Decaying animal carcasses and trash dumped near water bodies

Table 9. Reported data for WWTF discharge.

Facility	NPDES ID/ TPDES ID	Flow (MGD)		*E. coli* (cfu/100 mL)		Violations
		Permitted	Average	Permitted	Average	
City of Lex-ington WWTF	TX0054429/ WQ0010016001	0.20	0.1155	126	399	• 26 daily average *E. coli* • 23 single sample *E. coli* • 28 daily average biochemical oxygen demand (BOD) • 2 single sample BOD • 8 minimum DO • 4 daily average flow • 10 daily average total suspended solids

MGD – million gallons per day; cfu– colony forming unit; mL – milliliter; TPDES – Texas Pollutant Discharge Elimination System; WWTF – wastewater treatment facility.

1212A_02 subwatershed (Figure 17; TCEQ 2023). Table 9 shows the permit information of the WWTF and incidents where effluent limits are exceeded and reported through the U.S. EPA Enforcement Compliance History Online (ECHO) database between Jan 2019 and Dec 2023 (EPA 2024).

TPDES-Permitted Stormwater

Polluted urban stormwater runoff is commonly transported through Municipal Separate Storm Sewer Systems (MS4s). MS4s often have large numbers of discharge points, and permits for such systems are issued to cover all the outfalls. Any failures of MS4s, due to age, illicit connections, blockages, etc., may result in contaminated urban stormwater runoff, especially during wet seasons with frequent, intense precipitation events. As of Dec 2023, there were no MS4s in the Middle Yegua Creek watershed (TCEQ 2023).

Meanwhile, as of Dec 2023, there is one active construction permit and one active concrete production permit in the watershed. Based on the 2021 MRLC NLCD data, only a small fraction of the watershed was urbanized (4.6%). Given the above, contributions to surface water impairments from permitted stormwater and urban development were assumed

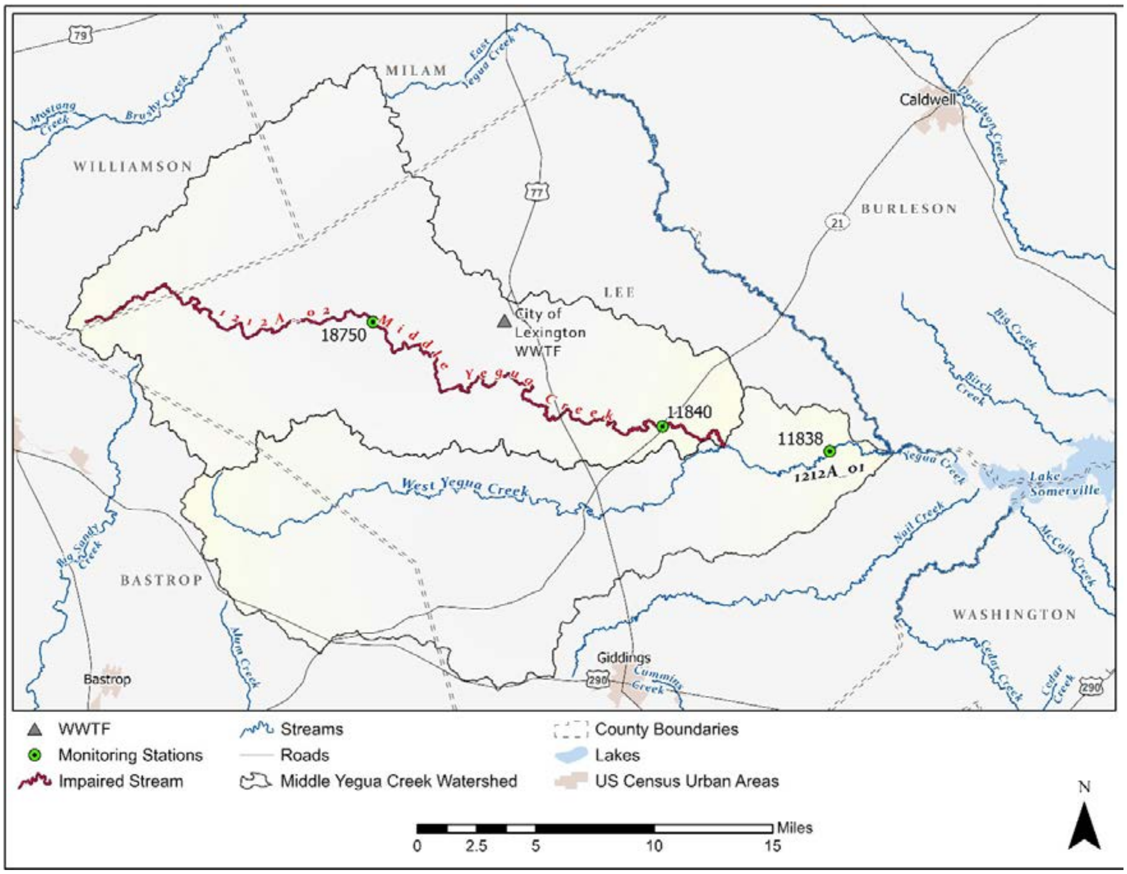

Figure 17. WWTF discharge outfalls.

to be minor based on the relatively low amount of stormwater permits and developed land. However, urban areas in the watershed may contribute to local stormwater pollution in their subwatersheds as populations grow and impervious surfaces increase.

Sanitary Sewer Overflows

Sanitary sewer systems collect and transport wastewater to WWTFs; however, SSOs of raw sewage from these systems may occur due to sewer line failures and/or overloaded sewer systems during severe rain events. SSOs are unauthorized discharges that should be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system.

SSOs in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris such as materials not recommended for flushing or pouring down drains. Inflow and infiltration (I&I) are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

According to the TCEQ regional office (TCEQ 2024), between Jan 2019 and Dec 2023, there are three SSO incidents reported by the City of Lexington WWTF. A total of one gallon of sewage was discharged to the WWTF pond. Other than self-reported SSO events, no compliance or pollutant loading data associated with SSOs are available. Pollutant loads associated with individual SSO events are likely to vary based on the amount and makeup of the discharge.

Concentrated Animal Feeding Operations

As of Dec 2023, there is one large CAFO permit (TXG921593) for cattle operation in the watershed, meaning that the CAFO can house 1,000 or more cattle. According to the permit, this facility is estimated to generate a total of 4,088 tons of solid waste and 6.86 acre-feet (2.24 million gallons) of wastewater annually.

Table 10. County-level livestock populations.

	Counties			
Livestock	Bastrop	Lee	Milam	Williamson
Cattle	46,801	91,280	99,601	44,765
Hogs/Pigs	290	217	669	493
Sheep/Lambs	1,610	510	2,498	4,113
Goats	2,436	1,215	3,644	6,056
Horse	2,565	1,114	1,634	1,787
Poultry	156,915	4,427	2,030,496	9,322

Nonpoint Source Pollution

Nonpoint source pollution occurs when rainfall causes runoff of pollutants into drainage ditches, lakes, rivers, or other water bodies (CWA §319(h)). Nonpoint source pollution can include bacteria from livestock or pet waste, wildlife waste, urban and agriculture runoff, failing OSSFs, and other sources.

Livestock

Livestock are a potential source of NPS pollution as animals graze over pastures and deposit fecal matter onto the land as well directly into accessible water bodies. Fecal matter deposited within the watershed is likely to be transported to adjacent creeks during rainfall events and can contribute to increased bacteria loads in water. Since watershed-level livestock populations are not available, the numbers of hogs/pigs, sheep/lambs, goats, horses, and poultry (layers and broilers) in the Middle Yegua Creek watershed were estimated using the 2022 USDA National Agricultural Statistics Service (NASS) county-level livestock populations (Table 10; USDA 2024) and land cover data (Dewitz 2023). The county-level NASS data were multiplied by the ratio of watershed-level grazeable land size to county-level grazeable land size. According to the 2021 NLCD classification (Figure 6 in Chapter 2) and stakeholder input, land cover types suitable for grazing livestock are herbaceous and hay/pasture. As to quantifying the cattle population, there are generally three ways: (1) estimating based on USDA (2024) and Dewitz (2023) as mentioned above, (2) estimating based on recommended stocking rates available from the USDA NRCS and USDA Farm Service Agency (FSA), or (3) stakeholder confirmed average local stocking rates to hay/pasture and herbaceous.

After discussions with stakeholders, cattle population, as well as other livestock populations were estimated using method 1. Overall, a total of 53,130 cattle, 170 hogs/pigs, 1,143 goats, 884 horses, 620 sheep, and 80,611 poultry (broilers and layers) were estimated to be in the Middle Yegua Creek watershed (Table 11).

On-site Sewage Facilities

OSSFs are widely used in the Middle Yegua Creek watershed and may contribute to bacteria loadings in water if not properly operated and/or maintained. The number of OSSFs, their locations, ages, types, and functional statuses in the watershed were unknown. Estimations of the number of OSSFs were done by using approximated locations of 911 address points and land parcel data acquired from the Texas Geographic Information Office DataHub (TxGIO 2023), certificated sewer service data (Public Utility Commission of Texas 2017), and aerial imageries.

911 address points located outside of sewer service areas were examined using land parcel data and aerial imagery as the background to determine whether it was located on or close to any structure. This method of locating potential OSSF sites was used given the lack of actual OSSF locations from regional databases. Based on this method, there is an estimated 5,293 OSSFs within the watershed (Table 12; Figure 18).

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. Many factors affect OSSF performance, such as system failure due to age, improper system design for specific site conditions, improper function from lack of maintenance/sludge removal and illegal discharge of untreated wastewater. Adsorption of field soil properties affects the ability of conventional OSSFs to treat wastewater by percolation. Soil suitability rankings were developed by the USDA NRCS to evaluate the ability of soils to treat wastewater based on soil characteristics such as topography, saturated hydraulic conductivity, depth to the water table, ponding, flooding effects and more (USDA 2019). Soil suitability ratings are divided into three categories: not limited, somewhat limited and very limited. Soil suitability dictates the type of OSSFs required to properly treat wastewater. If not properly designed, installed, or maintained, OSSFs

Table 11. Livestock populations in the watershed.

AU 1212A_01	Counties				
Livestock	**Bastrop**	**Lee**	**Milam**	**Williamson**	**Total**
Cattle	3,658	21,694	0	0	25,352
Hogs/Pigs	23	52		0	75
Sheep/Lambs	126	121	0	0	247
Goats	190	289	0	0	479
Horse	200	265	0	0	465
Poultry	12,266	1,052	0	0	13,318
AU 1212A_02	**Counties**				
Livestock	**Bastrop**	**Lee**	**Milam**	**Williamson**	**Total**
Cattle	484	22,487	3,151	1,656	27,778
Hogs/Pigs	3	53		18	95
Sheep/Lambs	17	126	79	151	373
Goats	25	299	115	225	664
Horse	27	274	52	66	419
Poultry	1,622	1,091	64,235	345	67,293
AU 1212A_03	**Counties**				
Livestock	**Bastrop**	**Lee**	**Milam**	**Williamson**	**Total**
Cattle	4,142	44,181	3,151	1,656	53,130
Hogs/Pigs	26	105		18	170
Sheep/Lambs	142	247	79	151	620
Goats	215	588	115	225	1,143
Horse	227	539	52	66	884
Poultry	13,888	2,143	64,235	345	80,611

Table 12. Number of OSSFs by subwatershed.

AU Subwatershed	Number of OSSFs
1212A_01	3,172
1212A_02	2,121
Total	5,293

in somewhat or very limited soils pose an increased risk of failure. The majority (75%) of the soils in the watershed are rated "Very Limited" for OSSF use, followed by smaller portion of the watershed rated "Somewhat Limited" (Figure 19).

Wildlife and Feral Hogs

Wildlife contribute nutrient and *E. coli* loads to water bodies. Riparian areas generally provide enhanced habitat for wildlife, causing them to frequent these areas and deposit their waste materials directly in and around the water. Depending on the size of the animal and their density, wildlife can be a significant potential contributor. However, wildlife population density estimates are not available for all wildlife species common to the watershed such as white-tailed deer, fox, raccoon, opossum, and many others. Therefore, in this WPP, population estimations were limited to white-tailed deer.

The Texas Parks and Wildlife Department (TPWD) conducts deer population surveys within Texas at the deer management unit (DMU) level. DMUs are delineated based on similar ecological characteristics within a defined area. The Middle Yegua Creek watershed is situated in DMU 19 South. Between 2005 and 2022, the average estimated deer

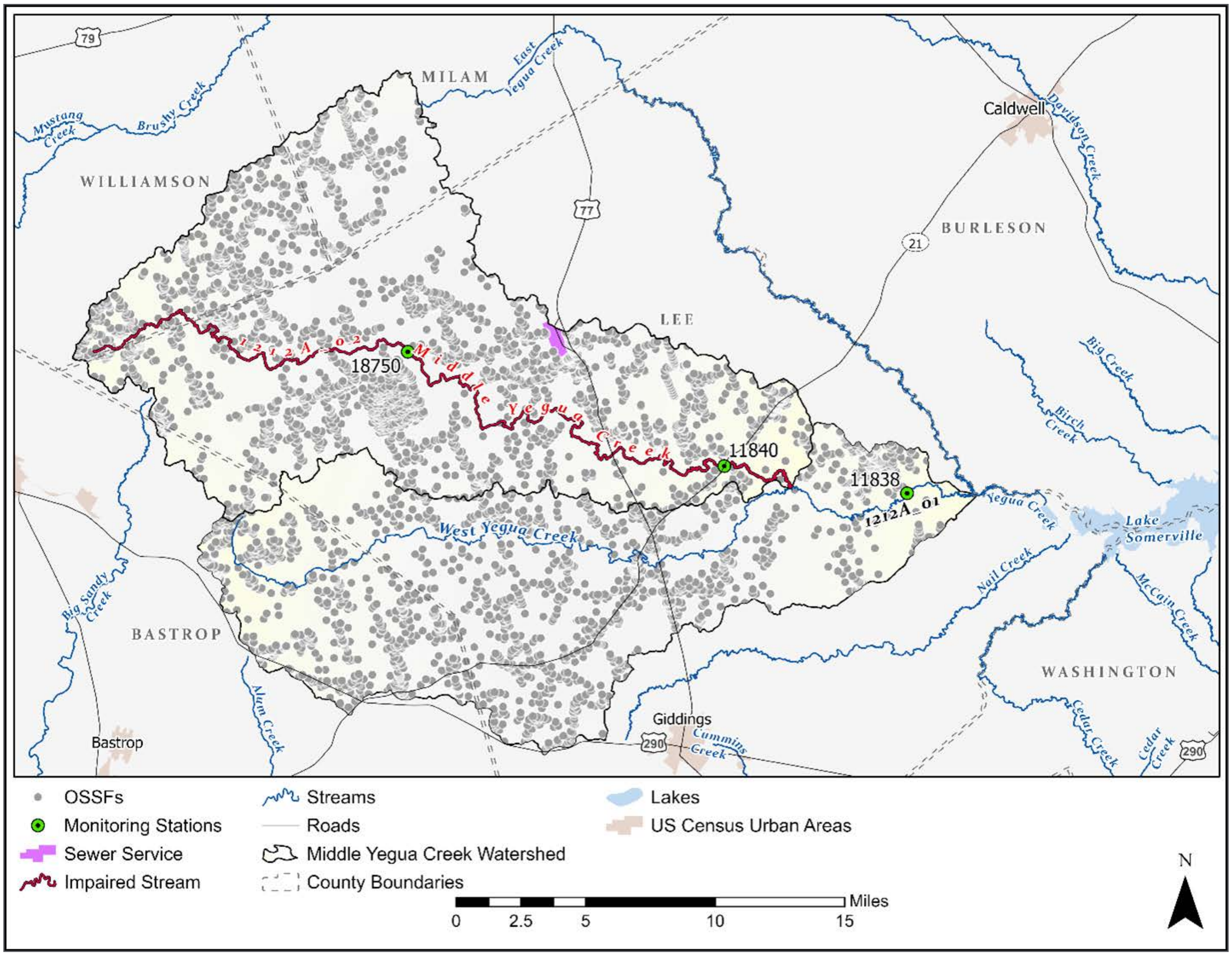

Figure 18. Estimated OSSFs.

density within this DMU was around 39 acres of suitable habitat per deer (TPWD 2024). For estimating deer populations, suitable habitat includes the following land cover types defined in the Dewitz (2023): forest, shrub/scrub, herbaceous, hay/pasture, cultivated crops, woody wetlands, and emergent herbaceous wetlands. In other words, deer densities were applied to all land cover types except open water, baren land, and developed land. This method estimated that there are 6,818 deer in the watershed (Table 13).

Besides wildlife, feral hogs are also a significant potential contributor of pollutants to water bodies. Feral hogs are a non-native, invasive species that are rapidly expanding throughout Texas and inhabit similar land use types as white-tailed deer. They are especially fond of places where there is dense cover with food and water readily available. Riparian corridors are prime habitat for feral hogs; therefore, they spend much of their time wallowing in or near creeks. This preference for riparian areas does not preclude their use of non-riparian areas during the night. Extensive rooting and wallowing in riparian areas also cause erosion and soil loss.

Statewide feral hog density estimates can range from 32 acres of suitable habitat per hog to 71 acres of suitable habitat per hog (Wagner and Moench 2009; Timmons et al. 2012). Suitable habitat includes the following MRLC NLCD land cover types: forest, shrub/scrub, herbaceous, hay/pasture, cultivated crops, and woody wetlands. Based on stakeholder suggestion, the feral hog density in the Middle Yegua Creek watershed is close to 32 acres of suitable habitat per hog. This method estimated that there are 8,283 feral hogs in the watershed (Table 13).

Pets

Dogs and cats can contribute to bacterial and nutrient loads via runoff from lawns, parks, and other areas. This type of loading is easily avoidable if pet owners properly dispose of pet waste. According to the 2020 American Veterinary Medical Association (AVMA) data, on average, a household in the U.S. has 0.657 dogs and 0.463 cats (AVMA 2022). According to stakeholder suggestion, population of dogs in the Middle Yegua Creek watershed was estimated using one dog per household. While the cat population was estimated based on the national average. Based on the 2020 U.S. Census Bureau (USCB) census block data (USCB 2020), a total of 4,250 households was estimated to be in the watershed. As a result, 4,250 dogs and 1,967 cats were estimated to be living in the watershed (Table 14).

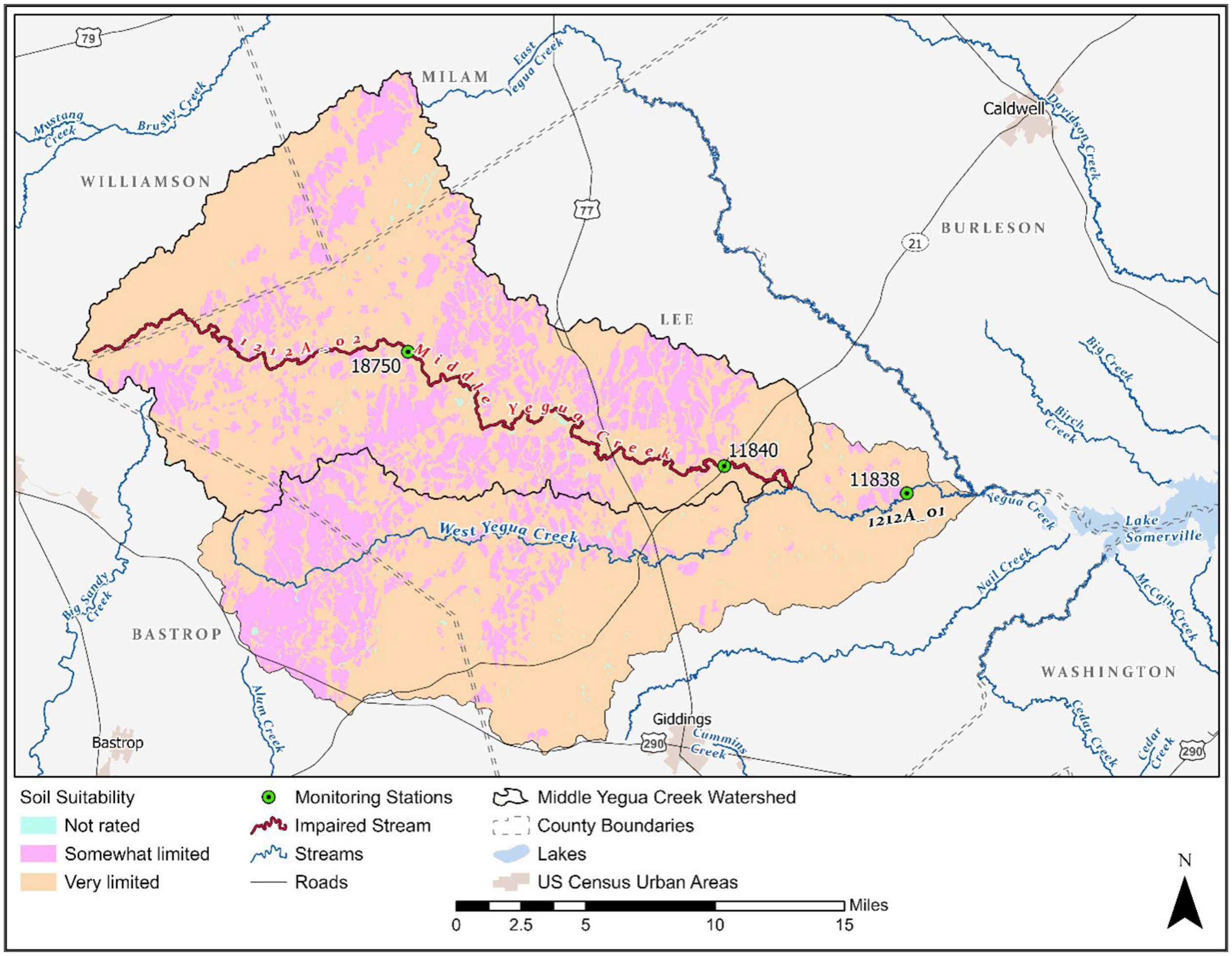

Figure 19. Soil suitability ratings for OSSFs.

Table 13. Estimated white-tailed deer and feral hog populations by subwatershed.

AU Subwatershed	White-Tailed Deer Population	Feral Hog Population
1212A_01	2,977	3,626
1212A_02	3,841	4,657
Total	6,818	8,283

AU- assessment unit.

Table 14. E.stimated dog and cat populations by AU subwatershed.

AU Subwatershed	Estimated Number of Household	Dog Population	Cat Population
1212A_01	1,503	1,503	696
1212A_02	2,747	2,747	1,271
Total	4,250	4,250	1,967

AU- assessment unit.

Illicit and Illegal Dumping

Improper waste disposal can contribute to water quality impairments. Areas that are frequently littered tend to become dumping areas for others as well, which can cause blockages and flooding or more surface area for bacteria to grow on. Although most items dumped are not necessarily major sources of bacteria and nutrient pollution, items like animal carcasses and household chemical containers, can contribute additional bacteria, nutrients, and hazardous waste to the watershed. For the Middle Yegua Creek watershed, local stakeholders indicated that the bridge crossing on CR326 over Middle Yegua Creek has become a dumping spot and the dumping of animal carcasses was a strong concern.

Biosolids

Compost is made from treated biosolids mixed with other recycled materials and has been widely used as fertilizers. Based on stakeholder knowledge, a turf grass farm is applying compost near the headwaters of West Yegua Creek. Despite such compost's utility values, stakeholders in the Middle Yegua Creek watershed expressed their concerns regarding the potential impact of compost application on water quality in the watershed, not only in terms of bacteria levels but in terms of heavy metals, soil erosion, and a group of "forever chemicals" named perfluoroalkyl and polyfluoroalkyl substances (PFAS), which are drawing increasing attention locally and on a national level.

Chapter 5
Pollutant Source Assessment

Middle Yegua Creek at SH 21 by Amanda Tague, TWRI.

This chapter estimates the bacteria load reductions needed to meet applicable water quality standards at three locations in the watershed: upstream (Station 11838), midstream (Station 11840), and downstream (Station 18750). These reductions were estimated using the load duration curve (LDC) method based on stakeholder input, water quality and flow data. These estimates will later serve as load reduction targets and the basis for planning recommended management activities in the watershed.

Moreover, potential sources of pollutants identified in Chapter 4 are further assessed in this chapter in terms of their contributions to potential *E. coli* loads and their spatial distribution across the watershed. This analysis should help identify critical source areas (CSAs) where management measures may be prioritized to effectively improve water quality.

E. coli Data Assessment

This assessment used data available in the SWQMIS for three monitoring stations in the Middle Yegua Creek watershed (Figure 20). These data demonstrate that streamflow and *E. coli* concentrations of the creek are spatially varied and temporally dynamic, meaning that factors influencing pollutant loadings in the watershed change with location and time. In addition, sampled *E. coli* concentrations exhibit a wide range across the watershed (Table 15).

Load Duration Curve Analysis

The LDC method is widely used for estimating needed pollutant load reductions to meet water quality standards and visualize the relationship between pollutant load capacity and existing pollutant loads in a water body. Additionally, LDCs can help determine whether direct depositions or NPS are primary contributors. For example, if excessive bacteria loading occurs mainly during higher flow conditions, it suggests pollutants originated from NPSs are washing off the landscape and being carried to the creek by stormwater runoff. Alternatively, if high bacteria loading occurs mainly during lower flow period, it suggests pollutants are primarily coming from point sources or direct depositions. Details regarding the LDC method are documented in Appendix A.

Table 15. Summary of *E. coli* measurements collected between Dec 2018 and Jan 2024.

Station	AU ID	Number of Measurements	Minimum (MPN/100 mL)	Maximum (MPN/100 mL)	Geometric Mean (MPN/100 mL)
11838	1212A_01	57	1	2,400	80.7
11840	1212A_02	58	1	5,500	229.2
18750	1212A_02	54	42	72,000	423.7

AU- assessment unit; MPN – most probable number; mL – milliliter.

Table 16. Needed bacteria reduction load by flow condition at monitoring station 18750.

	Flow Conditions			
	High Flow	Moist Condition	Mid-Range Flow	Low Flow
Days per year	36.5	73	109.5	73
Median Flow (cubic feet per second)	94.7	15	4.86	0.608
Existing Geomean Concentration (MPN/100 mL)	511	564	318	257
Allowable Annual Load (MPN)	1.07E+13	3.38E+12	1.64E+12	1.37E+11
Existing Annual Load (MPN)	4.32E+13	1.51E+13	4.14E+12	2.79E+11
Annual Load Reduction Needed (MPN)	3.26E+13	1.17E+13	2.50E+12	1.42E+11
Percent Reduction Needed	75.34%	77.66%	60.38%	50.97%

MPN – most probable number; mL – milliliter.

For planning purposes, bacteria LDCs were completed at SWQM stations 18750, 11840, and 11838 in the Middle Yegua Creek watershed, since they have the most robust data records. Streamflow data observed at USGS stream gage 08109700 were used to construct LDCs (Figure 20; Appendix A).

The LDC method was used to analyze measured *E. coli* loads and needed load reductions to meet the criterion of 126 MPN per 100 mL. This analysis considered four flow conditions: high flows (0 – 10% exceedance), moist conditions (10 – 30% exceedance), mid-range flows (30 – 60% exceedance), and low flows (60 – 80% exceedance). Samples collected under zero flow conditions (80 – 100% exceedance) were not included in load reduction estimation because water quality standards are not applicable to zero flows.

Station 18750

This station is located on FM 696 on AU 1212A_02. Monthly grab sampling and instantaneous flow measurements at this location were conducted by TWRI between 2018 and 2024. The LDC constructed for this station shows that measured *E. coli* loads generally exceeded geometric mean criterion (i.e., allowable loads) under all flow conditions (Figure 21). Based on *E. coli* loads recorded at this location, needed load reductions were estimated and tabulated in Table 16 (Appendix A).

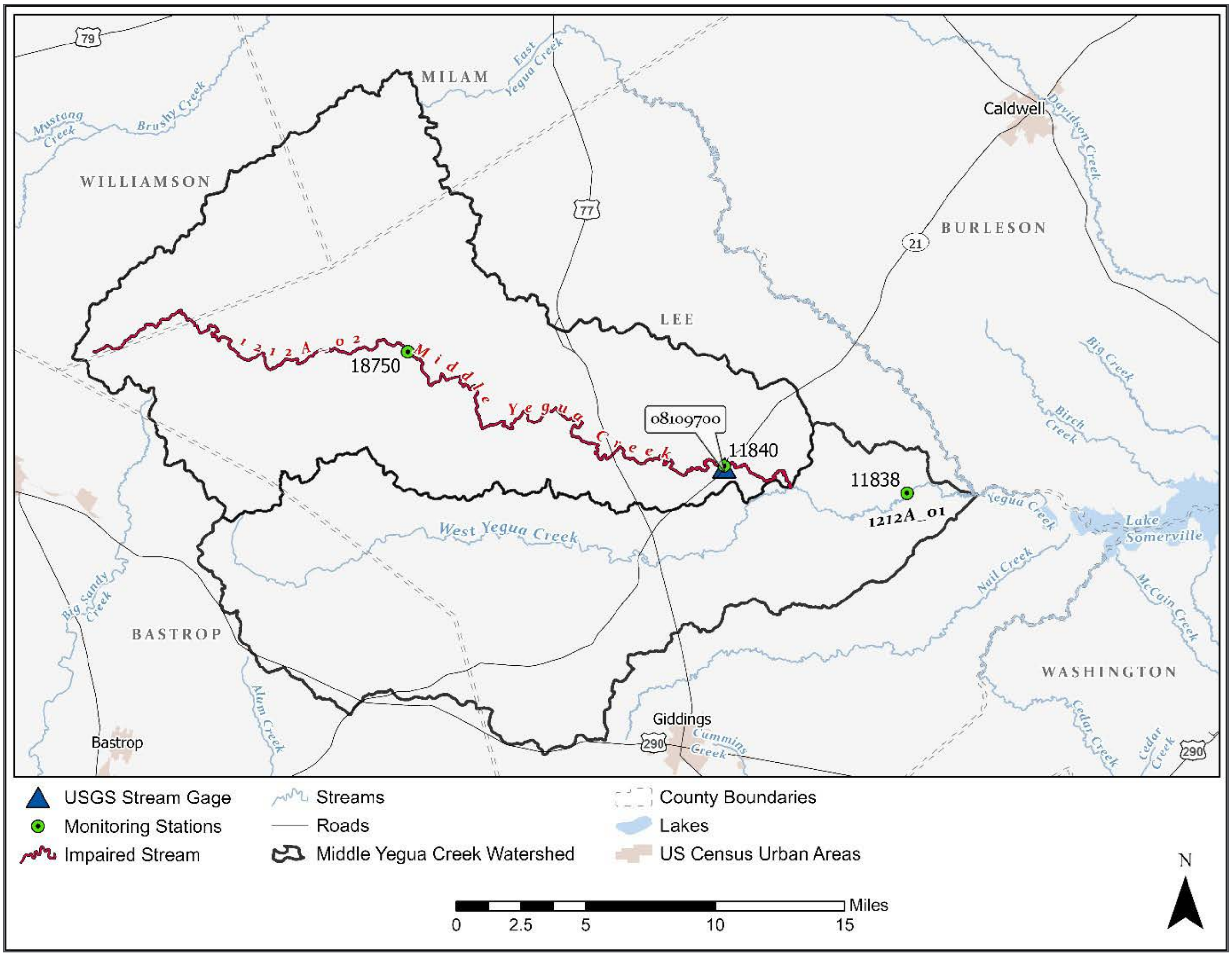

Figure 20. Locations of the monitoring stations and the USGS stream gage used in LDC analyses.

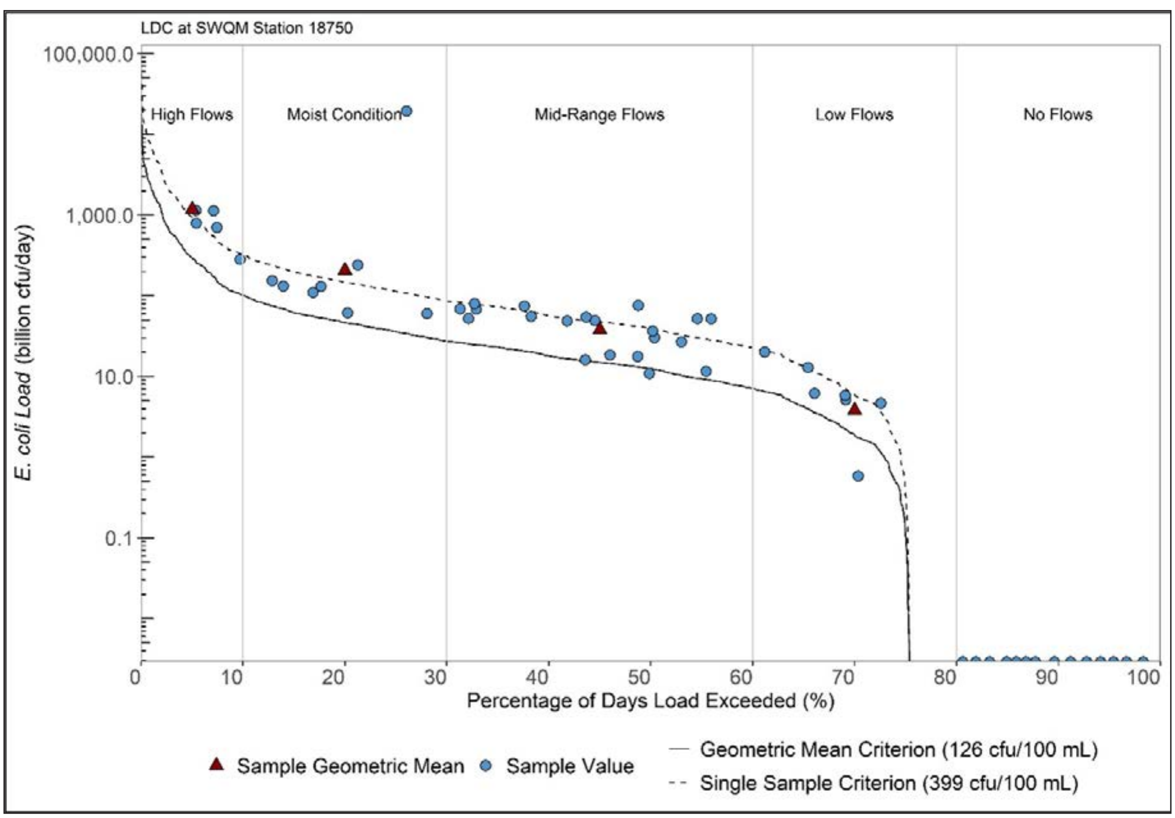

Figure 21. Middle Yegua Creek monitoring station 18750 *E. coli* load duration curve.

Table 17. Needed bacteria reduction load by flow condition at monitoring station 11840.

	Flow Conditions			
	High Flow	Moist Condition	Mid-Range Flow	Dry Condition
Days per year	36.5	109.5	73	73
Median Flow (cubic feet per second)	154	25.6	8.23	1.13
Existing Geomean Concentration (MPN/100 mL)	613	435	334	199
Allowable Annual Load (MPN)	1.73E+13	5.76E+12	2.78E+12	2.54E+11
Existing Annual Load (MPN)	8.43E+13	1.99E+13	7.36E+12	4.02E+11
Annual Load Reduction Needed (MPN)	6.70E+13	1.41E+13	4.59E+12	1.47E+11
Percent Reduction Needed	79.45%	71.03%	62.28%	36.68%

MPN – most probable number; mL – milliliter.

Table 18. Needed bacteria reduction load by flow condition at monitoring station 11838.

	Flow Conditions			
	High Flow	Moist Condition	Mid-Range Flow	Low Flow
Days per year	36.5	109.5	73	73
Median Flow (cubic feet per second)	154	25.6	8.23	1.13
Existing Geomean Concentration (MPN/100 mL)	613	435	334	199
Allowable Annual Load (MPN)	1.73E+13	5.76E+12	2.78E+12	2.54E+11
Existing Annual Load (MPN)	8.43E+13	1.99E+13	7.36E+12	4.02E+11
Annual Load Reduction Needed (MPN)	6.70E+13	1.41E+13	4.59E+12	1.47E+11
Percent Reduction Needed	79.45%	71.03%	62.28%	36.68%

MPN – most probable number; mL – milliliter.

Station 11840

This station is located on SH21 on AU 1212A_02. Monthly grab sampling and instantaneous flow measurements were conducted by TWRI at this location between 2018 and 2024. The LDC constructed for this station shows that measured *E. coli* loads generally exceeded allowable amounts under all flow conditions (Figure 22). Based on these measured *E. coli* loads at this location, needed load reductions were estimated and tabulated in Table 17 (Appendix A).

Station 11838

This station is located on FM141 on AU 1212A_01. Monthly grab sampling and instantaneous flow measurements were conducted by TWRI at this location since Dec 2018. The LDC for this station shows that measured *E. coli* loads generally exceeded allowable amounts under all flow conditions (Figure 23). Based on *E. coli* loads measured at this location, needed load reductions were estimated and tabulated in Table 18 (Appendix A).

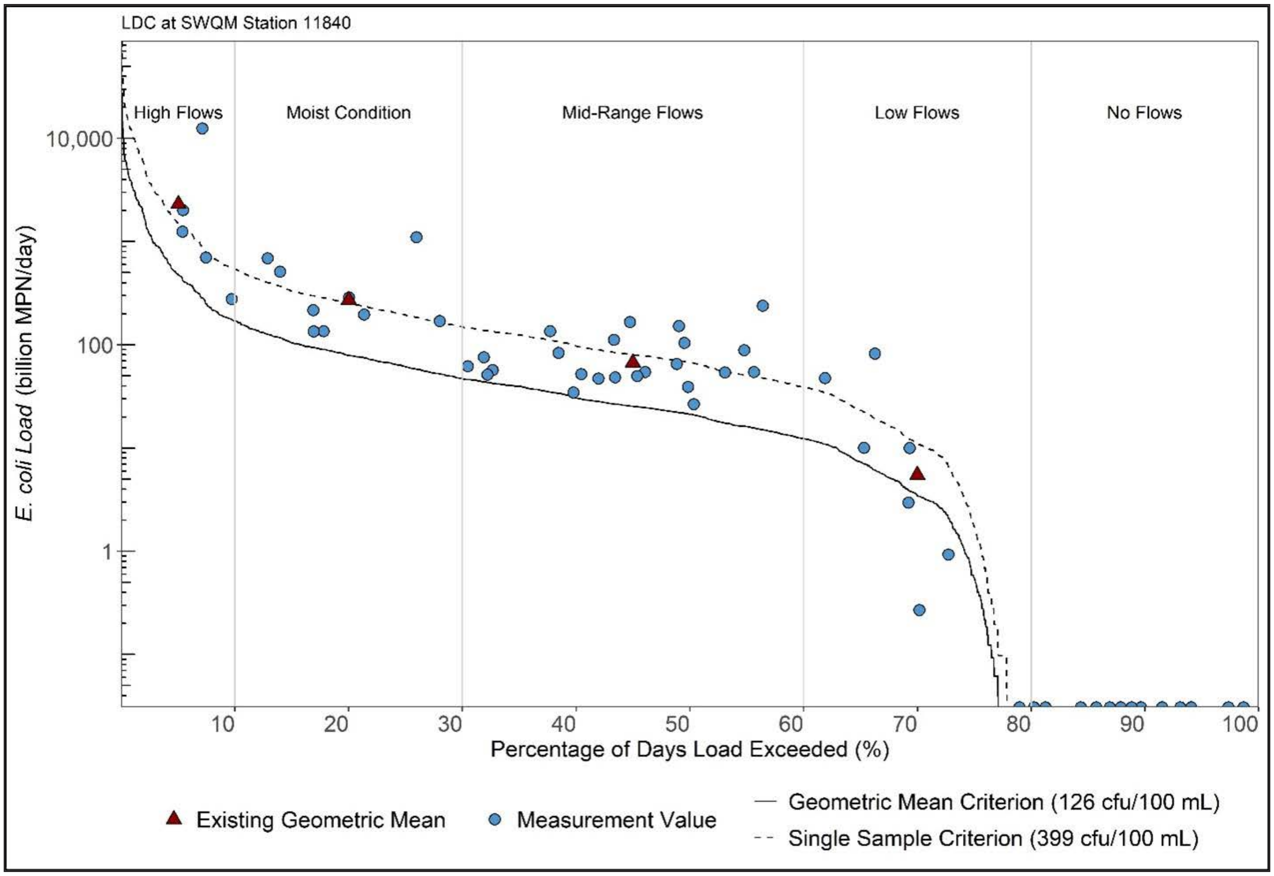

Figure 22. Middle Yegua Creek monitoring station 11840 *E. coli* load duration curve.

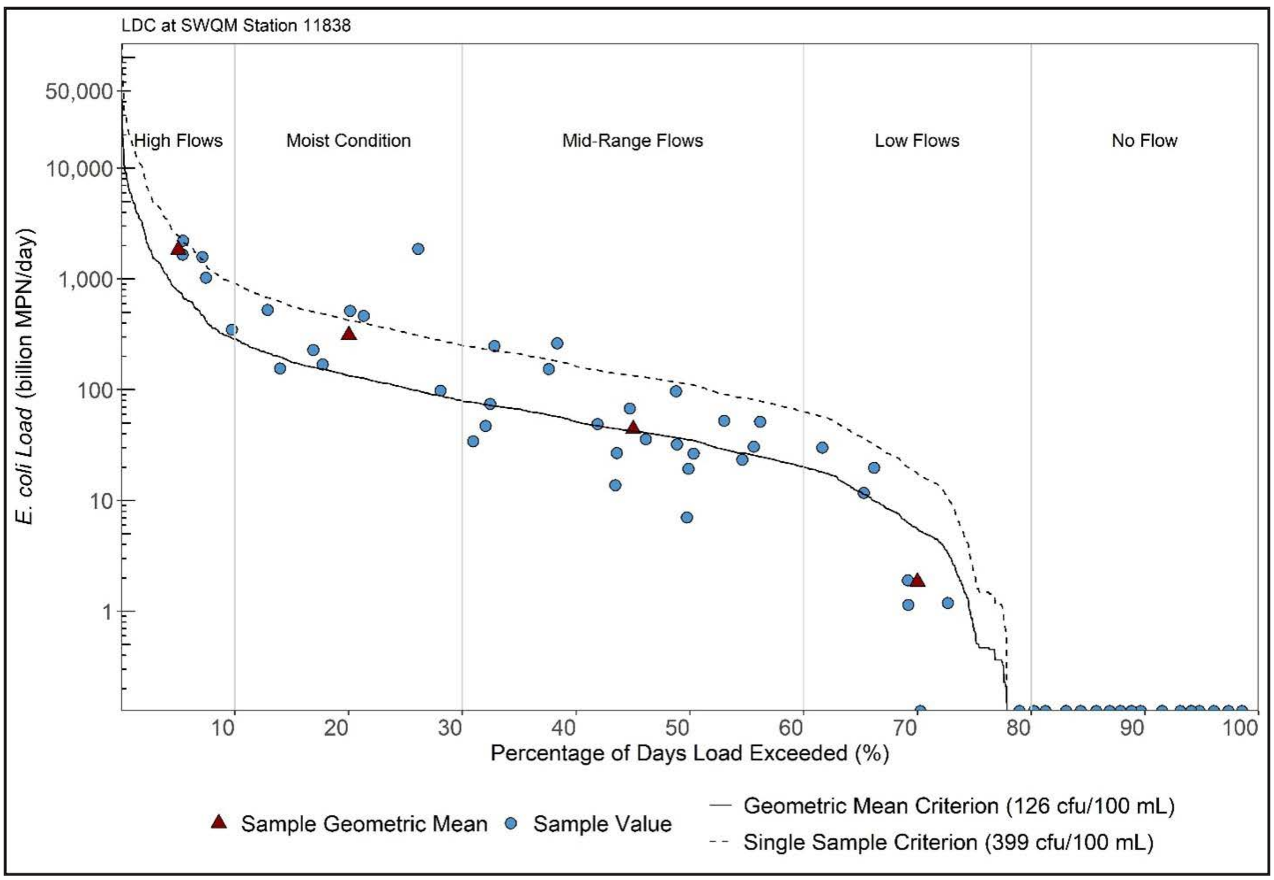

Figure 23. Middle Yegua Creek monitoring station 11838 *E. coli* load duration curve.

Spatial Analysis of Potential *E. coli* Loads

The distribution of potential bacteria loads across the watershed was evaluated using a geographic information system (GIS)-based approach similar to the method used in the Spatially Explicit Load Enrichment Calculation Tool (SELECT; Teague et al. 2009). Specific calculations for estimating loads using this approach are described in Appendix A. By estimating relative potential contributions of different fecal bacteria sources across the watershed, CSAs can be identified and prioritized for recommended management measures. Available information described in Chapter 4, regarding potential sources of *E. coli* was used to estimate potential loads for each source. Potential source loads evaluated are summarized by subwatershed (Figure 24). These 11 subwatersheds are tributary drainage areas of Middle Yegua Creek (Figure 2 in Chapter 2).

Loading estimates for each source do not account for bacteria fate and transport processes that occur in the natural environment, nor do they consider existing best management practices (BMPs). Therefore, the following analyses do not represent actual *E. coli* loadings entering the creek; rather they are potential worst-case bacteria loading scenarios.

Livestock

Livestock, such as cattle, goats, horses, and sheep, can contribute to *E. coli* loadings in two ways. First, they can contribute through the direct deposition of fecal matter into streams while wading. Second, runoff from pasture and rangeland can contain elevated concentrations of *E. coli,* which in turn can increase bacteria loads in the stream.

Based on 2022 NASS data at county level, a total of 53,130 cattle, 1,143 goats, 620 sheep, and 884 horses were estimated to be living in the Middle Yegua Creek watershed and assumed to be evenly distributed across grazeable lands. Grazeable lands are identified as hay/pasture or herbaceous in Dewitz (2023) land cover map (Figure 6 in Chapter 3).

Spatial analysis indicated the highest potential *E. coli* loads may occur in subwatersheds 5 and 8 (Figure 25). These subwatersheds have the largest amount of grazeable land and thus have the highest potential *E. coli* load. Appendix B describes the assumptions and equations used to estimate potential bacteria loading.

Poultry

A total of 80,611 poultry were estimated in Chapter 4 as a potential source of bacteria. However, this chapter does not attribute potential *E. coli* loads in Middle Yegua Creek to poultry. This is because poultry operations should be managing animal mortality and waste according to TSSWCB-certified water quality management plans (WQMPs) and the Supplemental Guidance for Dry-Litter Poultry Operations. As of May 2024, no WQMPs were identified in the Middle Yegua Creek watershed. Additionally, larger poultry farms, categorized as confined animal feeding operations (CAFOs), may be required to obtain TCEQ permits to ensure proper waste management. As of Dec 2023, no CAFO permit was recorded for poultry in the Middle Yegua Creek watershed.

Domestic Pigs

Chapter 4 identifies a total of 170 domestic pigs in the Middle Yegua Creek; however, since they are not pastured in most cases, this chapter does not include them in the potential load calculation.

On-Site Sewage Facilities

Failing OSSFs can contribute bacteria loads to water bodies, particularly those where effluent is released near water bodies. There are an estimated 5,293 OSSFs within the watershed, according to a survey administrated in 2001 to the Designated Representatives across Texas, the failure rate in Region V, where the watershed is located, is 12% (Reed, Stowe, and Yanke 2001); however, stakeholder inputs suggested that the failure rate within the watershed may be close to 15%, meaning that approximately 794 OSSFs may fail and contribute to *E. coli* in the creek for a given year. Spatial analysis indicates the highest potential loads occur in subwatershed 5 due to the estimated population density around Lexington (Figure 28; Appendix B).

White-Tailed Deer

White-tailed deer are the primary deer species in the watershed (although game ranches may raise mule deer or exotics such as axis deer). They are warm-blooded mammals and can contribute to *E. coli* loadings in similar manners as feral hogs. A total of 6,818 white-tailed deer were estimated to be living in the Middle Yegua Creek watershed on habitable lands, which for deer are land covers defined as forest, shrub/scrub, herbaceous, hay/pasture, cultivated crops, woody wetlands, and emergent herbaceous wetlands in Dewitz (2023). Spatial analysis shows that the highest potential annual *E. coli* loadings from deer may occur in subwatersheds 5 and 7 (Figure 27; Appendix B).

Feral Hogs

The feral hog population in Texas was estimated to range from one to three million individuals (Timmons et al 2012). Based on stakeholder inputs regarding feral hog density, a total of 8,283 feral hogs were estimated to be distributed across habitable lands within the Middle Yegua Creek watershed (32 acres per hog; Wagner and Moench 2009). Habitable lands for feral hogs are those classified as forest, shrub/

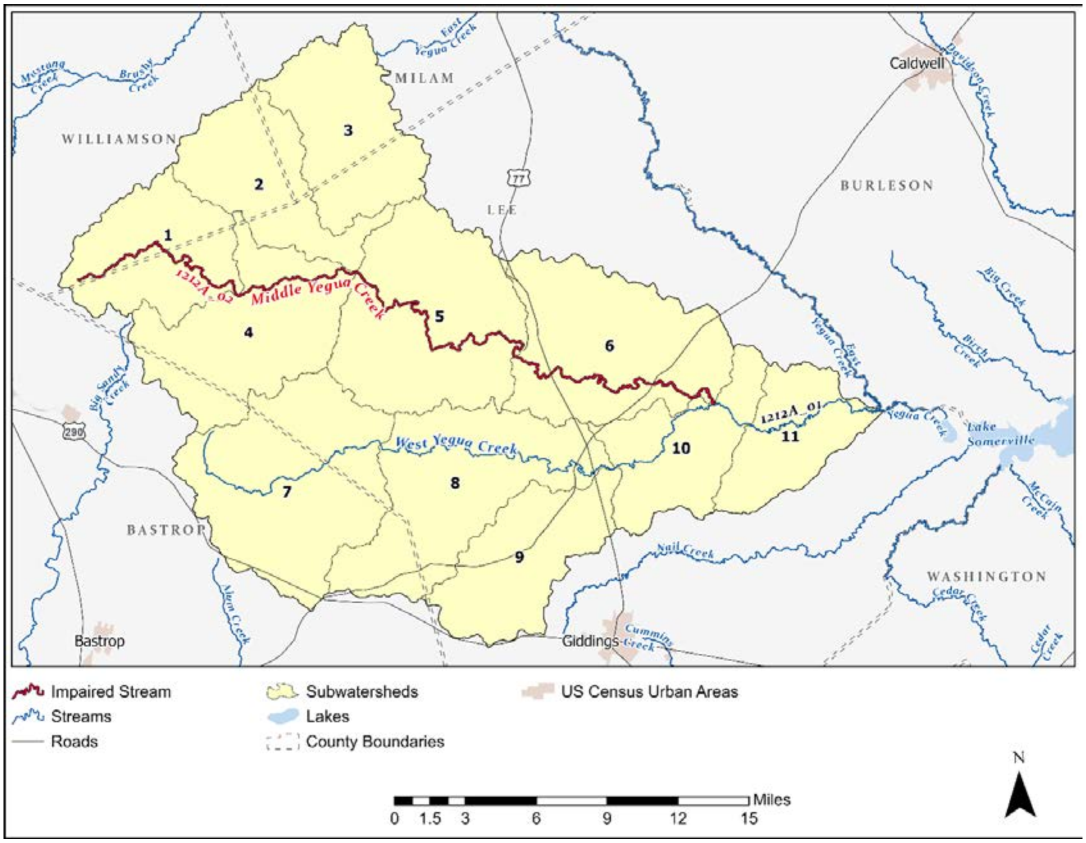

Figure 24. Middle Yegua Creek Subwatersheds.

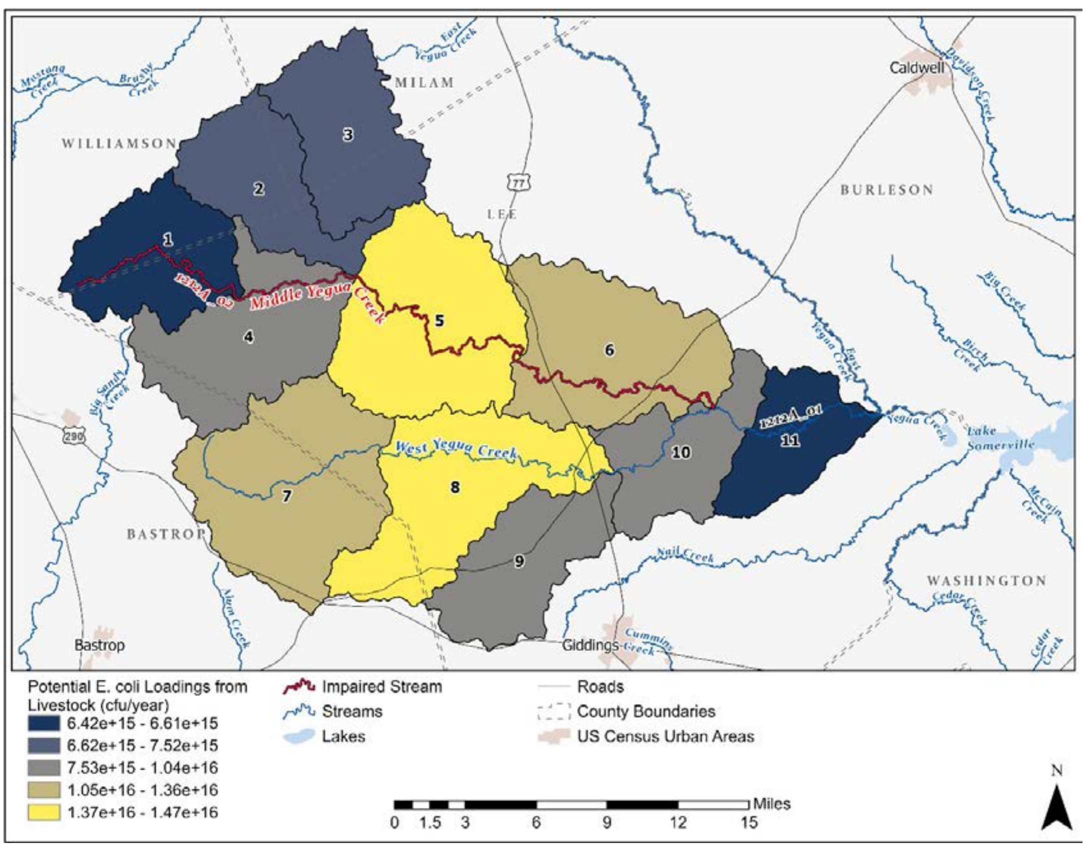

Figure 25. Potential annual bacteria loadings from livestock.

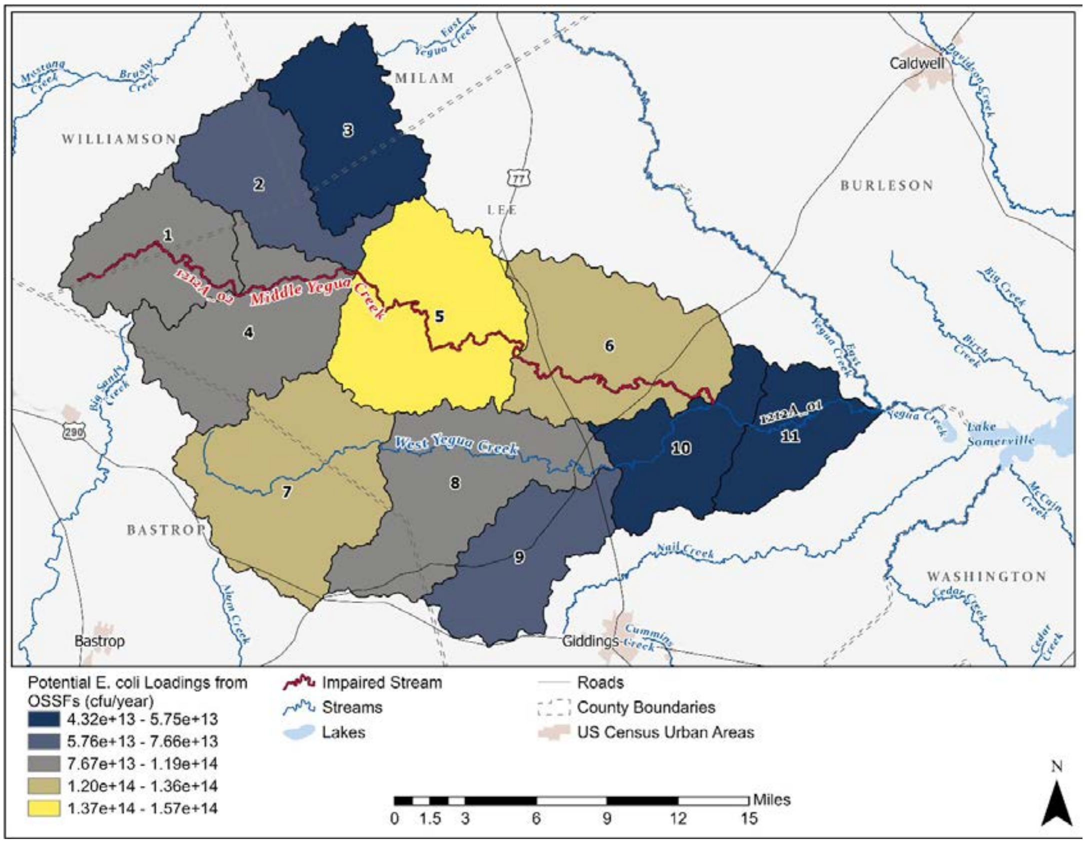

Figure 26. Potential annual bacteria loadings from OSSFs.

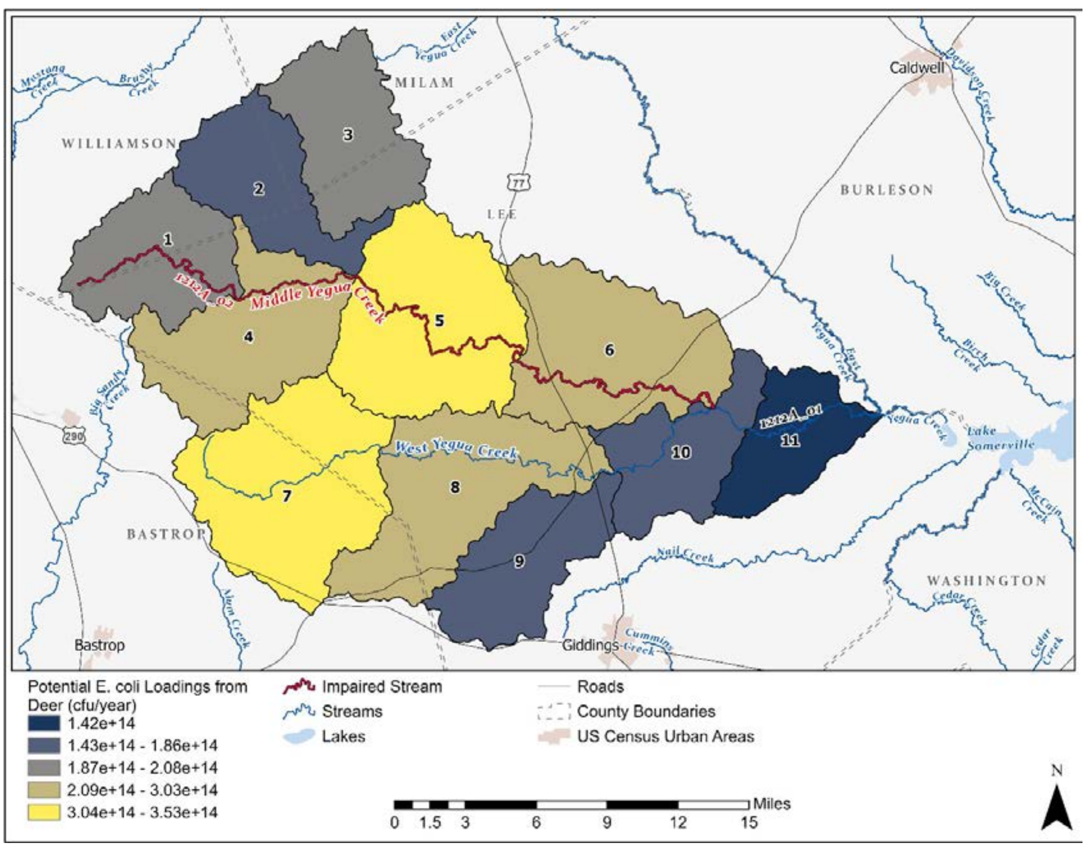

Figure 27. Potential annual bacteria loadings from deer.

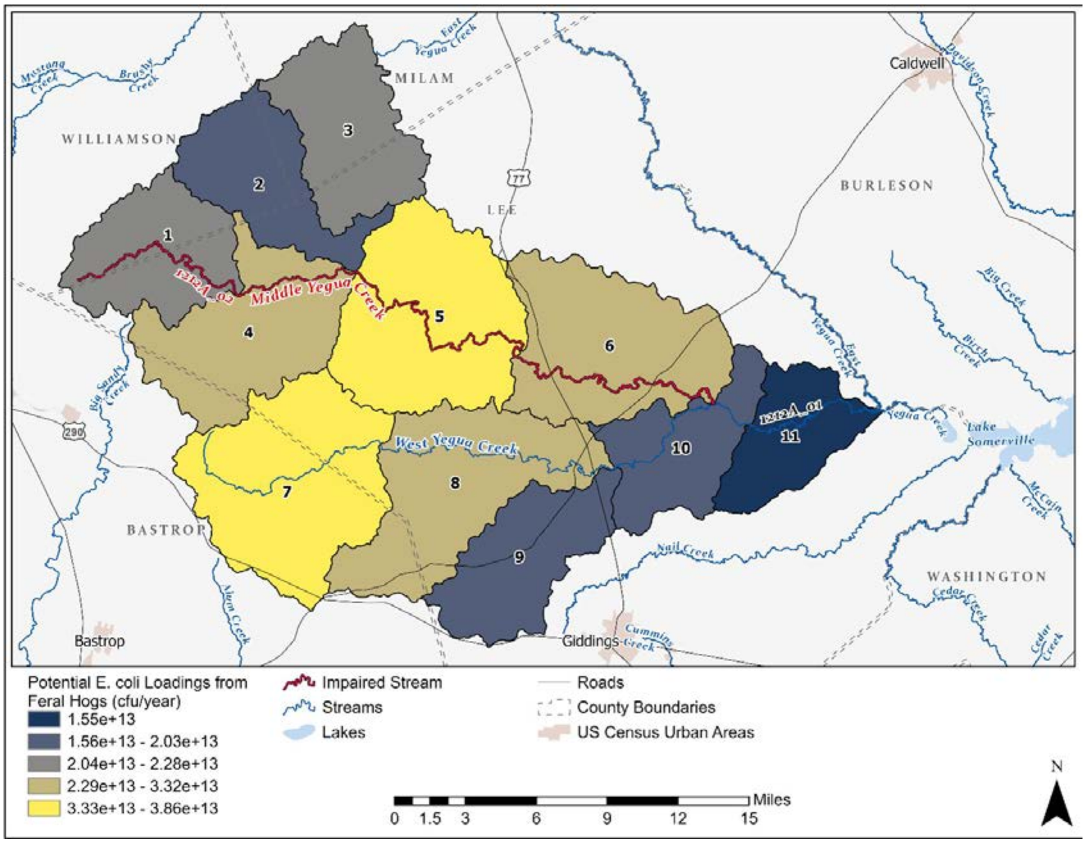

Figure 28. Potential annual bacteria loadings from feral hogs.

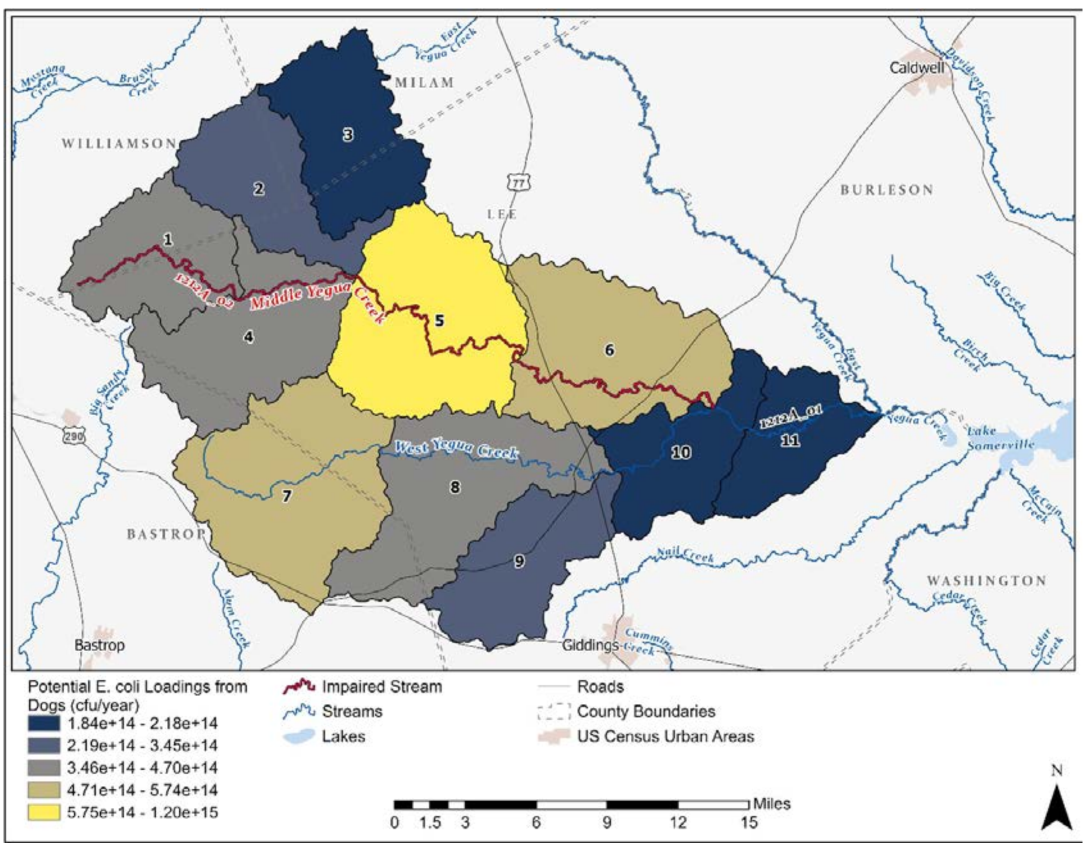

Figure 29. Potential annual bacteria loadings from dogs.

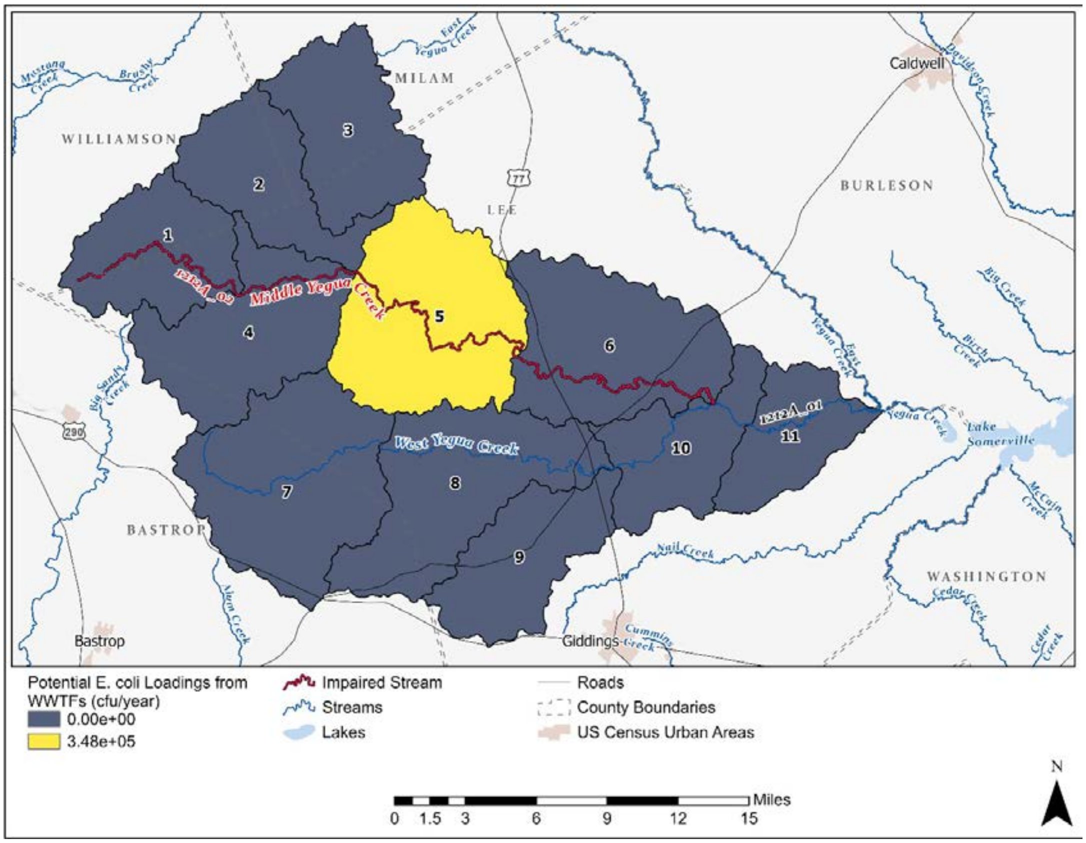

Figure 30. Potential annual loadings from WWTFs.

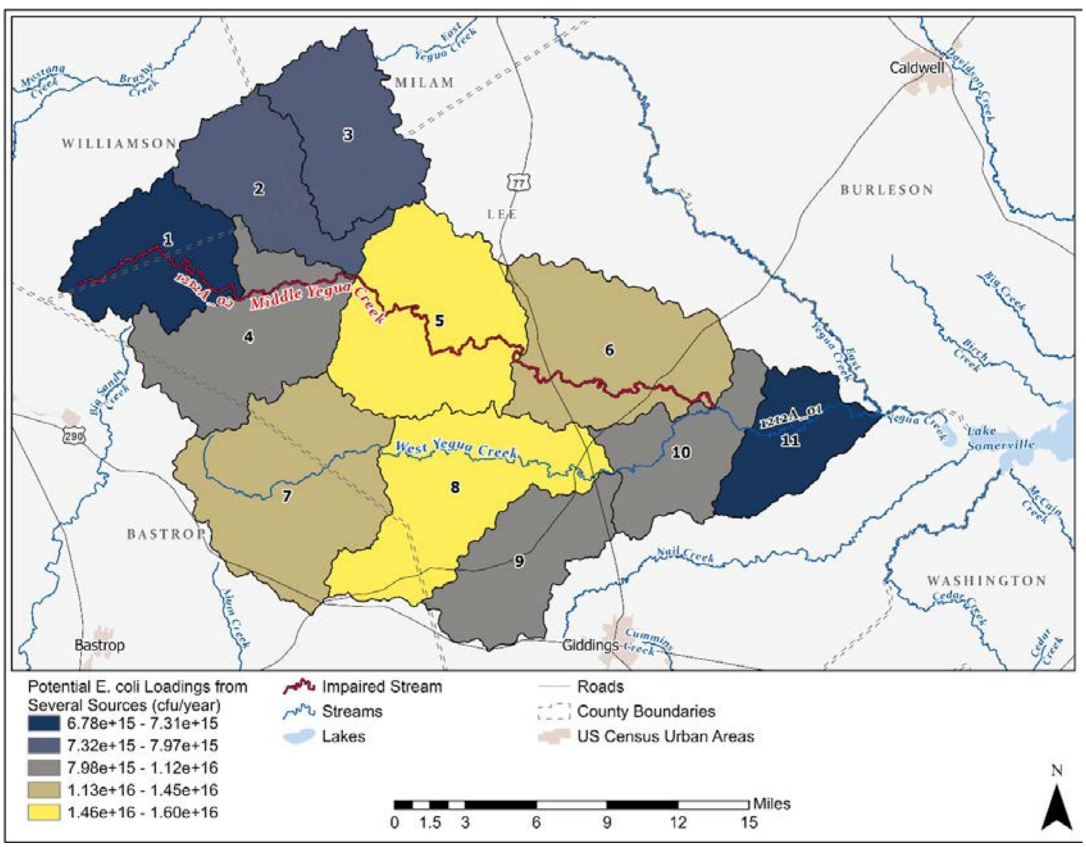

Figure 31. Estimated potential *E. coli* loads from the sources evaluated.

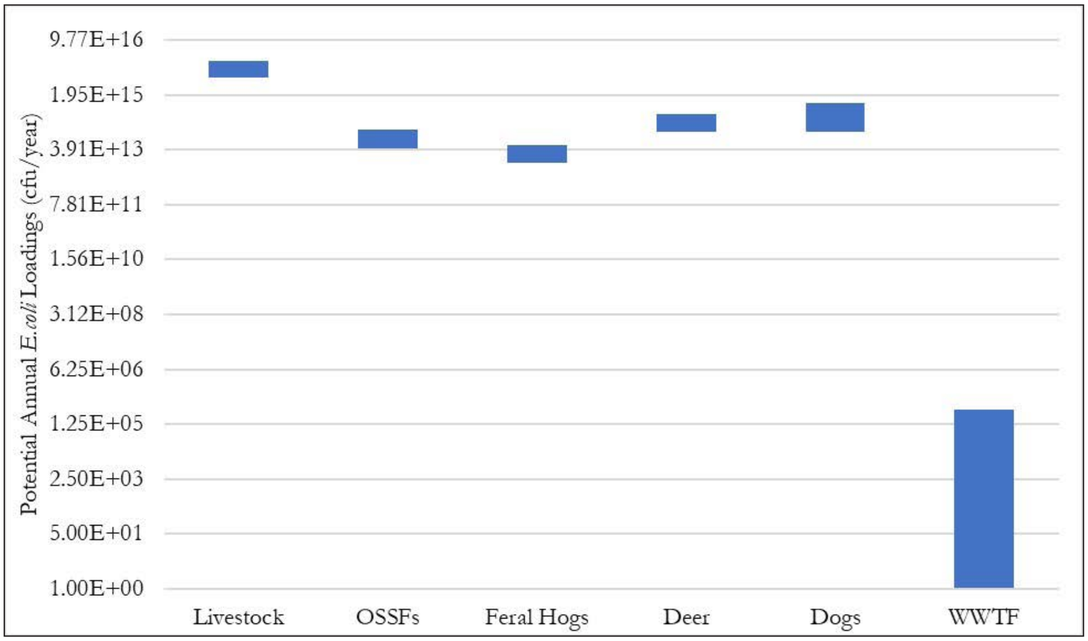

Figure 32. Comparison of potential annual *E. coli* Loadings attributed to various sources.

scrub, herbaceous, hay/pasture, cultivated crops, or woody wetlands in Dewitz (2023).

While complete removal of the feral hog population is unlikely, habitat management and trapping programs can limit populations and associated damage. Spatial analysis results indicate the highest potential annual loadings may occur in subwatersheds 5 and 7 (Figure 28; Appendix B).

Dogs

A total of 4,250 dogs were estimated to be living in the Middle Yegua Creek watershed (one dog per household). Stakeholders suggested that 100% of dog owners may not pick up dog waste. Based on this, all 4,250 dogs were used to estimate the potential *E. coli* loadings. Spatial analysis indicated the highest potential annual loadings may occur in subwatershed 5, where population is the highest (Figure 29; Appendix B).

Cats

Chapter 4 identifies cats as one of the potential sources of bacteria in the creek. However, potential loadings were not estimated for cats in this chapter in large part because indoor cats' wastes are contained in litter boxes and generally disposed of in the trash. Outdoor cats tend to bury their waste, which makes it less likely for them to contribute to bacteria loadings during runoff events.

Illicit and Illegal Dumping

Chapter 4 identifies illicit and/or illegal dumping of animal carcasses, among other wastes over bridge crossings as one of the potential sources of bacteria in the watershed. The extent of such activities, however, is unknown and its contribution to bacteria loadings cannot be quantified.

Biosolids

Chapter 4 identifies compost made from biosolids as one of the potential sources of bacteria in the creek; however, potential loadings were not estimated for it in this chapter because properly manufactured and applied compost should not be contributing to bacteria loadings in the watershed.

Wastewater Treatment Facilities

According to TPDES data, the City of Lexington WWTF is the only permitted wastewater discharger in the Middle Yegua Creek watershed and is required to report average monthly flow volume discharges and *E. coli* concentration. To estimate potential *E. coli* load from this WWTF, the maximum permitted discharge (0.2 MGD) and maximum allowed *E. coli* concentration in discharge (126 cfu per 100 mL) were used. Spatial analysis indicated the highest potential annual loads occur in subwatershed 5 where the WWTF is located (Figure 30; Appendix B). It is worth noting that, given WWTFs should follow TPDES permit requirements, the potential of this WWTF contributing to *E. coli* loadings in the Middle Yegua Creek watershed is low.

TPDES-Permitted Stormwater

Chapter 4 identifies contaminated urban stormwater runoff as a potential source of pollutants. However, as discussed previously, its impact is assumed to be negligible given that the number of stormwater permits and urbanized areas were very few in the Middle Yegua Creek watershed.

Sanitary Sewage Overflows

Chapter 4 identifies SSOs as one of the potential sources, and they are reported to the TCEQ regional offices by on-site personnel within 24 hours after becoming aware of the event. According to the TCEQ SSO records from the past five years (TCEQ 2024), only one incident was reported by the City of Lexington WWTF to have discharged one gallon of sewage to a pond at the facility. This suggests that SSO's contribution to pollutants in Middle Yegua Creek can be relatively insignificant, and they were not included in the potential load calculation.

Total Potential E. coli *Loads*

Total annual potential *E. coli* loadings across the watersheds were estimated by combining potential loadings from each source evaluated. In the Middle Yegua Creek watershed, the highest total potential loadings may occur in subwatersheds 5, 6, 7, and 8 (Figure 31). Potential annual *E. coli* loads attributed to identified sources are shown in Figure 32. Percentage of total potential loadings attributed to various sources is plotted in Figure 32. The percentage contribution of WWTF was almost negligible (0%) compared to other sources.

Summary of Potential Pollutant Loads

Analysis indicates that potential *E. coli* loads in Middle Yegua Creek, particularly in AU 1212A_02, are higher than applicable water quality standards. *E. coli* loads measured at monitoring stations 18750 and 11840 on the impaired segment of the creek indicate that excessive loads can be found during almost all flow conditions (Figure 21 and Figure 22).

Spatial analysis of potential *E. coli* loads across the watershed indicates that, based on the sources evaluated, management efforts should be prioritized in subwatersheds 5, 6, 7, and 8 (Figure 31). Total potential *E. coli* loads by source (Figure 32) suggests that contributions from animals are dominant sources.

Potential loads estimated for the sources evaluated can be large; however, not all bacteria make it to the creek. It is also worth remembering that estimated loads did not take into account naturally occurring bacteria fate and transport processes in the environment. Additionally, the presence of existing land management practices that can reduce bacteria loads, such as improved grazing management strategies, riparian buffers, and other structural and nonstructural BMPs, were not considered in this load estimation exercise. That being said, analyses conducted in this chapter present potential scenarios and do not represent the actual bacteria loadings in Middle Yegua Creek.

Chapter 6 Recommended WPP Implementation Strategies

Middle Yegua Creek at SH 21 by Amanda Tague, TWRI.

In Chapters 4 and 5, various potential sources of pollutants in the Middle Yegua watershed are identified and their potential contributions to the bacteria load are assessed.

The load assessment results suggest that there is no single source of bacteria in the watershed that caused the elevated *E. coli* levels in water. It was estimated that livestock (cattle, sheep, horses, and goats), dogs, and deer may have relatively higher potentials to contribute to *E. coli* loads in the Middle Yegua watershed, while other possible sources, including OSSFs, feral hogs, and a WWTF, may have relatively lower potentials.

Due to the diversity of potential pollutant sources, a range of management strategies are recommended in this chapter. Recommended management measures were strategized based on stakeholder feedback and their effectiveness in reducing bacteria loading. Estimated potential load reductions from each management measure are presented with each recommended action.

It is worth restating that bacteria loads presented were estimated based on worst-case scenarios, since it is not feasible to model actual loadings in Middle Yegua. Likewise, the estimated potential load reductions from management measures may not be realized. Actual reductions are dependent on several factors that may trigger the need for adaptive implementation. Nonetheless, potential annual load reductions from management measures discussed in this chapter suggest that it is feasible to reduce the bacteria loadings in Middle Yegua Creek to a point where applicable water standards are met.

Priority implementation areas for each recommended management strategy were identified based on the CSA analysis presented in Chapter 5 and stakeholder feedback. While management measures can be implemented throughout the watershed, priority locations were selected to maximize the effectiveness of reducing potential loadings.

Stakeholder input was crucial throughout the decision-making process for these recommended management strategies. These measures are voluntary, and their successful implementation would rely on stakeholder acceptance. Therefore, receiving stakeholder input on willingness to adopt these

Table 19. Commonly implemented cropland, pasture, and rangeland practices to improve water quality.

Practice	NRCS Code	Focus Area or Benefit
Focus Area: Livestock		
Brush Management	314	Livestock, water quality, water quantity, wildlife
Prescribed Burning	338	Livestock, water quality, wildlife
Pond	378	Livestock, water quantity, water quality, wildlife
Fencing	382	Livestock, water quality
Filter Strips	393	Livestock, water quality, wildlife
Livestock Pipeline	516	Livestock, water quality, wildlife
Prescribed Grazing	528	Livestock, water quality, wildlife
Pumping Plant	533	Livestock, water quality, wildlife
Grazing Land Mechanical Treatment	548	Livestock, water quantity, wildlife
Range/Pasture Planting	550/512	Livestock, water quality, wildlife
Heavy Use Area Protection	561	Livestock, water quantity, water quality
Shade Structure	576	Livestock, water quality
Stream Crossing	578	Livestock, water quality
Supplemental Feed Location	N/A	Livestock, water quality
Water Well	642	Livestock, water quality, wildlife
Watering Facility	614	Livestock, water quantity
Focus Area: Cropland		
No Tillage	329	Water quality, soil moisture
Reduced Tillage	345	Water quality, soil moisture
Focus Area: General Water Quality		
Conservation Cover	327	Water quality, soil moisture, wildlife
Grade Stabilization Structures	410	Water quality

NRCS – National Resources Conservation Service.

practices is important throughout this process. All management measures were discussed with and approved by stakeholders to ensure community support and successful implementation.

Management Measure 1 – Water Quality Management Plans and/or Conservation Plans

Potential bacteria loadings in the Middle Yegua Creek watershed from cattle and other livestock are relatively high compared to other evaluated sources. Livestock waste is mostly deposited in upland areas and transported to water bodies during runoff events. Therefore, it is likely that much of the *E. coli* bacteria in livestock waste dies before reaching a water body. However, depending on grazing practices, livestock may spend significant amounts of time in and near water and cause a more direct impact on water quality.

Livestock distribution is highly dependent upon availability and distribution of water, food, and shelter. This allows livestock to be managed easily compared to non-domesticated species. The time livestock spend in, and around riparian areas can be reduced by providing supplemental water, feed, shade, and forage away from riparian areas. As a result, it can effectively reduce the potential of *E. coli* loads entering nearby water bodies.

Various best management practices (BMPs) are available to improve forage quality, diversify water resource availability, and better distribute livestock across a property (Table 19). However, what is considered appropriate to implement can vary due to landscape characteristics and landowner goals. Technical assistance is available to landowners upon request to help identify appropriate practices to meet specific property goals. NRCS develops conservation plans (CPs), while TSSWCB, in partnership with local soil and water conservation districts (SWCDs) and NRCS, develops

Table 20. Management Measure 1: develop and implement WQMPs/CPs.

<table>
<tr><th colspan="4">Pollutant Source: Cattle and Other Livestock in the Watershed</th></tr>
<tr><td colspan="4">Problem: direct and indirect fecal bacteria loading, riparian degradation, overgrazing.</td></tr>
<tr><td colspan="4">Objectives:
• Work with landowners with riparian/creek access to develop 100 CPs/WQMPs.
• Deliver education and outreach information, programs, and workshops to landowners/producers.</td></tr>
<tr><td colspan="4">Critical Areas: Subwatersheds 5 and 8 and farms close to water bodies should also be given priority.</td></tr>
<tr><td colspan="4">Goal: Develop and implement CPs/WQMPs that focus on minimizing bacteria loadings from livestock.</td></tr>
<tr><td colspan="4">Description: Developed CPs/WQMPs to address direct and indirect fecal deposition from cattle and other livestock. Prescribe BMPs that will reduce time spent in the creek or riparian corridor, likely focusing on prescribed grazing, cross-fencing, and watering facilities. Deliver education programs to support and promote BMP adoption.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Participants</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>TSSWCB and local SWCD</td><td>Develop funding to hire a WQMP technician</td><td>2025-2035</td><td>~$75,000 per year (including fringe benefits)</td></tr>
<tr><td>Producers, landowners, NRCS, TSSWCB, and local SWCDs</td><td>Develop, implement, and provide financial assistance for WQMPs/CPs</td><td>2025-2035</td><td>$3,000,000</td></tr>
<tr><td>TAMU AgriLife Extension, stakeholders, local SWCDs, counties</td><td>Deliver education and outreach programs and workshops</td><td>2025-2035</td><td>TBD*</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Prescribed management will effectively reduce direct deposition and thus reduce bacteria loadings from livestock. By implementing prescribed grazing, cross fencing, watering facilities, and other BMPs on approximately 10 farms per year, potential loading reductions from livestock are estimated to be 1.90×10^{14} cfu of E. coli annually (Appendix C).</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Decreasing the time that livestock spend in riparian areas and reducing runoff through effectively managing vegetative cover will directly reduce NPS contributions of bacteria and other pollutants to creeks.</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 often needed to promote WQMP/CP implementation.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Landowners are willing to implement stewardship practices shown to improve productivity; however, costs are often prohibitive and financial incentives are needed to increase implementation rates.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial costs are a major barrier to promote implementation. Education and outreach are needed to demonstrate the benefits of plan development and implementation to producers.</td></tr>
</table>

BMP – best management practice; CP – conservation plan; cfu – colony forming unit; NRCS – Natural Resources Conservation Service; NPS – nonpoint source; TAMU – Texas A&M University; TSSWCB – Texas State Soil and Water Conservation Board; SWCD – Soil and Water Conservation District; TWRI – Texas Water Resources Institute; WQMP – water quality management plan.

water quality management plans (WQMPs). A WQMP is a site-specific plan developed to address water pollution from nonpoint sources by preventing or reducing agricultural and forestry runoff that can contaminate surface water bodies. It is a collaborative effort between a landowner and their local SWCD. An NRCS CP, on the other hand, aims at improving and protecting the natural resources on one's land based on their specific objectives, such as improving crop yield, enhancing wildlife habitat, or controlling soil erosion. These plans are collaborative efforts between landowners and NRCS specialists. Practices commonly implemented to effectively improve forage and water quality are listed in Table 19. The actual practices, however, vary by operation and should be determined through technical assistance from NRCS, TSSWCB, and local SWCDs. In 2023, a total of 56 individual CPs were applied in the Middle Yegua Creek watershed for grazing and brush management.

Stakeholders suggested that developing an additional 100 plans (CPs or WQMPs) for grazeable land is feasible in the watershed over the next ten years. Bacteria loads from cropland are predominantly from wildlife and are not considered manageable through land conservation practices. Bacteria load reductions that may be achieved from CPs or WQMPs are dependent on specific conservation measures implemented. Potential reduction in bacteria loads from livestock

Table 21. Management Measure 2: soil testing in agricultural areas.

Pollutant Source: Fertilized Soils			
Problem: Excessive nutrients in soils due to over-fertilization could runoff into surface water during intense rainfall events.			
Objectives: • Promote and expand education and outreach efforts in the watershed to prevent nutrient contamination.			
Critical Areas: Entire watershed with focus on areas closer to water bodies			
Goal: Reduce nutrient runoff through proper application of fertilizers.			
Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on soil nutrients and water quality.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Capital costs**
TAMU AgriLife Extension and counties	Develop and deliver educational and outreach materials to residents	2025-2035	~$20,000
Landowners, counties, and TAMU AgriLife Extension	Conduct soil tests before applying fertilizer	2025-2035	~$12 per soil test
Estimated Load Reduction			
Load reductions from this management measure were not quantified.			
Effectiveness	Moderate: Extra time and effort involved may hinder implementation.		
Certainty	Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best.		
Commitment	Moderate: Many stakeholders indicate that soil tests are necessary; however, administration may be difficult in all areas. The issue is not a high priority and com-mitment of limited resources will likely remain low.		
Needs	Moderate: Some financial resources will be required to develop educational materials. Information could be incorporated into ongoing watershed related educational and outreach efforts.		

TAMU – Texas A&M University.
*There is a cost associated with the activity, but it may be provided at no cost for this project.

was estimated based on the number of CPs and WQMPs and management practices that are likely to be implemented and known to be effective.

Implementing CPs and WQMPs is beneficial, regardless of location in the watershed, because these practices aim to keep water on the landscape by improving forage for livestock and wildlife and maintaining ground cover. Increasing vegetation amount and quality on a landscape aids the natural filtration process that can reduce pollutant loading to nearby water bodies. Overall, the effectiveness of a CP or WQMP can be maximized on properties with riparian habitat. Therefore, all properties with riparian areas are considered a priority. Properties without riparian habitat are also encouraged to participate in implementation activities. Based on the CSA analysis in Chapter 5, livestock related practice implementation may prioritize subwatersheds 5 and 8 (Figure 25 in Chapter 5). Appendix C describes the assumptions and equations used to estimate potential bacteria load reduction.

Management Measure 2 – Soil Testing

Conducting soil tests in agricultural 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 is included to prevent nutrient runoff into nearby water bodies by ensuring the proper rates and timing of fertilizer applications (Table 21).

Management Measure 3 – On-Site Sewage System Management

OSSFs are used to treat wastewater in areas of the watershed where centralized wastewater treatment facilities are not available. 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. In the Middle Yegua Creek watershed, approxi-

Table 22. Management Measure 3: repair or replace failing OSSFs.

<table>
<tr><th colspan="4">Pollutant Source: Failing OSSFs</th></tr>
<tr><td colspan="4">Problem: Pollutant loading from failing OSSFs</td></tr>
<tr><td colspan="4">Objectives:
• Identify and inspect failing OSSFs in the watershed.
• Maintain OSSF database.
• Repair or replace OSSFs as funding allows.</td></tr>
<tr><td colspan="4">Critical Areas: Subwatershed 5 and systems within close proximity to the water body.</td></tr>
<tr><td colspan="4">Goal: Identify, inspect, and repair or replace (as appropriate) a total of 80 failing OSSFs within critical areas.</td></tr>
<tr><td colspan="4">Description: Potential OSSF failures will be addressed by working with homeowners to identify and inspect all OSSFs within critical areas. Deficient 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>Participants</th><th>Recommendations</th><th>Period</th><th>Capital costs</th></tr>
<tr><td>County designated representatives and contractors</td><td>Identify and inspect OSSFs in critical areas.</td><td>2025-2035</td><td>~$640,000 - $1,000,000</td></tr>
<tr><td>Counties and homeowners</td><td>Maintain an OSSF database</td><td>2025-2035</td><td>TBD*</td></tr>
<tr><td>Contractors and TAMU AgriLife Extension</td><td>Repair/replace OSSFs as funding allows</td><td>2025-2035</td><td>~$8,000 – $12,500 per system</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Repair or replacement of 8 failing OSSFs per year in the Middle Yegua Creek watershed will result in a potential reduction of 1.29×10^{12} cfu of E. coli per year (Appendix C).</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">Moderate: The level of funding available to identify, inspect, and repair or replace OSSFs is uncertain; however, funding sources are available for assistance.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Watershed stakeholders acknowledge failing OSSFs can be a considerable bacteria source. Addressing this source has been an ongoing effort.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Funding to identify, inspect, and repair/replace OSSFs as well as to maintain a watershed database is limited; however, there is high need of funding for systems that are out of compliance. .</td></tr>
</table>

cfu – colony forming unit; TAMU – Texas A&M University.
*There is a cost associated with the activity, but it may be provided at no cost for this project.

mately 75% of the watershed's soil is considered very limited and 25% somewhat limited. This indicates that conventional septic tank systems are less than suitable for the proper treatment of household wastewater.

In these areas, advanced treatment systems, most commonly aerobic treatment units, are suitable alternative options for wastewater treatment. While advanced treatment systems are highly effective, operation and maintenance needs for these systems are rigorous compared to conventional septic systems. Limited awareness and lack of maintenance can lead to system failures. Failing OSSFs can contribute significant bacteria and nutrient loadings to the water bodies.

The exact number of failing OSSFs is unknown; however, stakeholders suggested that 15%, or 794 systems, may be chronically malfunctioning across the watersheds annually. Specific locations of failing OSSF are not known and can only be determined through physical inspections. Factors contributing to OSSF failure include improper system design or selection, improper operation and maintenance, and lack of financial resources for proper maintenance. Providing educational workshops to homeowners regarding OSSF operation and maintenance should help address these issues. In addition, repairs and replacements are also needed. Over the next 10 years, it is recommended that 80 failing septic systems in the watersheds be replaced or connected to a centralized sewer system if feasible (Table 22; Appendix C). While OSSFs should be replaced and repaired as needed across the entire watershed, subwatershed 5 may be prioritized due to the estimated number of OSSFs (Figure 26 in Chapter 5). Additional priority should be given to OSSFs within 100 yards of perennial water bodies. Significant technical and financial resources are needed to support OSSF repairs and replacements.

Table 23. Management Measure 4: feral hog control.

<table>
<tr><th colspan="4">Pollutant Source: Feral Hogs</th></tr>
<tr><td colspan="4">Problem: Direct and indirect fecal loading, riparian habitat destruction, and pasture and crop damage.</td></tr>
<tr><td colspan="4">Objectives:
• Reduce/maintain feral hog population</td></tr>
<tr><td colspan="4">Critical Areas: Subwatersheds 5 and 7 as well as riparian areas along water bodies</td></tr>
<tr><td colspan="4">Goal: Manage the feral hog population through available means to reduce the total number of hogs in the watershed by 15% annually and maintain them at this level.</td></tr>
<tr><td colspan="4">Description: Voluntarily implement efforts to reduce feral hog populations throughout the watershed by reducing food supplies, removing hogs as practical, and educating landowners on BMPs for feral hog removal.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participants</th><th>Recommendations</th><th>Period</th><th>Capital costs</th></tr>
<tr><td>Landowners</td><td>Voluntarily construct fencing around deer feeders to prevent feral hog use.</td><td>2025-2035</td><td>~$300 per feeder</td></tr>
<tr><td>Counties and hunters</td><td>Feral hog bounty program</td><td>2025-2035</td><td>~$10 per hog</td></tr>
<tr><td>Landowners and hunters</td><td>Voluntarily identify travel corridors and employ trapping and hunting in these areas to reduce hog numbers.</td><td>2025-2035</td><td>TBD*</td></tr>
<tr><td>Landowners, TWS, and TPWD</td><td>Develop and implement wildlife management plans and wildlife management practices.</td><td>2025-2035</td><td>TBD*</td></tr>
<tr><td>TWS and TAMU AgriLife Extension</td><td>Hire a feral hog trapper</td><td>2025-2035</td><td>~$75,000 per year (including fringe benefits)</td></tr>
<tr><td>TAMU AgriLife Extension, TWS, and TPWD</td><td>Deliver feral hog education workshops.</td><td>2025-2035</td><td>~$3,000 per workshop</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Removing and maintaining feral hog populations directly reduces fecal loading potential to water bodies in the watershed. Reducing the population by 15% (1,242) annually in the Middle Yegua Creek watershed is estimated to reduce potential bacteria loads by 4.32×10^{13} cfu E. coli per year (Appendix C).</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Moderate: Reduction in feral hog population will result in a direct decrease in bacteria loading to streams; however, removing enough hogs to decrease their overall population will be difficult.</td></tr>
<tr><td>Certainty</td><td colspan="3">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 will be difficult and is highly dependent upon the diligence of watershed landowners.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Landowners are actively trying to decrease feral hog populations and will continue to do so as long as resources remain available.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Additional funds are needed to provide an additional incentive to landowners to actively remove feral hogs. Education and outreach delivery is needed to further inform landowners about feral hog management options, adverse economic impacts of feral hogs and what their options for dealing with feral hogs are.</td></tr>
</table>

cfu – colony forming unit; *Escherichia coli, E. coli;* TAMU – Texas A&M University; TPWD – Texas Parks and Wildlife Department; TWS – Texas Wildlife Services.

*There is a cost associated with the activity, but it may be provided at no cost for this project.

Management Measure 4 – Feral Hog Control

The potential impact of feral hogs on instream water quality can be considerable in the Middle Yegua Creek watershed. As discussed in Chapter 4, feral hogs congregate in riparian areas due to the presence of dense habitat, food sources, and water. Common feral hog activities, such as rooting and wallowing, affect water quality by degrading ground cover in upland, but more importantly in riparian corridors, which increases erosion.

To reduce and maintain feral hog populations at 15% below current numbers in the Middle Yegua Creek watershed, it requires collaborative efforts of agency assistance, education, and landowner implementation of feral hog management techniques. A 15% reduction in current feral hog populations annually would amount to removing 1,242 feral hogs annually from the watershed (Table 23; Appendix C).

Physically removing hogs is the best strategy for reducing their impact on water quality. While the complete eradication of feral hogs is not feasible, a variety of methods are available to manage or reduce populations. Trapping is the most effective method currently available to landowners. With proper planning and diligence, trapping can successfully remove large numbers of feral hogs at once. Furthermore, costs of purchasing or building live traps can be split among landowners. Comparatively, shooting feral hogs removes fewer than trapping because the animals tend to quickly move away from hunting pressure. However, aerial gunning has been successful in other areas of Texas and should be considered a viable option to further reduce the feral hog population within the watershed. In addition, stakeholders suggested that bounties for feral hogs through a grant program can also help promote feral hog control.

Excluding feral hogs from supplemental feed is also an effective management tool. Given the opportunistic feeding nature of feral hogs, minimizing available food from deer feeders is important. Constructing exclusionary fences around feeders can reduce food ability (Rattan et al. 2010). Locating feeders away from riparian areas can also reduce feral hog's impact on water quality. Education programs and workshops would be used to improve feral hog removal efficiency. Texas A&M AgriLife Extension provides various educational resources for landowners that are available online at http://feralhogs.tamu.edu. Programs and resources are available virtually and in-person to increase outreach. Delivering up-to-date information and resources to landowners through these workshops can lead to more landowner success removing feral hog populations in the watersheds. Landowner-developed wildlife management plans outlining their goals and management practices can also benefit the watersheds' wildlife, habitat, and water quality.

Based on CSA analysis, subwatersheds 5 and 7 (Figure in Chapter 5) have the highest potential bacteria loadings from feral hogs estimated based on available habitable areas. However, given feral hog propensity to travel great distances along riparian corridors in search of food and habitat, priority areas would include all subwatersheds with higher importance placed on properties containing or adjacent to riparian habitat.

Table 24. Management Measure 5: reduce illicit and illegal dumping.

<table>
<tr><th colspan="5">Pollutant Source: Illicit and Illegal Dumping</th></tr>
<tr><td colspan="5">Problem: Illicit and illegal dumping of animal carcasses, among other wastes, in and along waterways</td></tr>
<tr><td colspan="5">Objectives:
• Promote and expand education and outreach efforts in the watershed.
• Provide additional disposal locations across the watershed.</td></tr>
<tr><td colspan="5">Critical Areas: Entire watershed with focus at bridge crossing and public access areas</td></tr>
<tr><td colspan="5">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="5">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="5">Implementation Strategy</th></tr>
<tr><th colspan="2">Participants</th><th>Recommendations</th><th>Period</th><th>Capital costs</th></tr>
<tr><td colspan="2">Local stakeholders and TAMU AgriLife Extension</td><td>Organize cleanup events</td><td>2025-2035</td><td>TBD*</td></tr>
<tr><td colspan="2">TAMU AgriLife Extension and counties</td><td>Develop and deliver educational and materials to watershed residents</td><td>2025-2035</td><td>~$21,000</td></tr>
<tr><th colspan="5">Estimated Load Reduction</th></tr>
<tr><td colspan="5">Load reductions cleanup events and education and were not quantified.</td></tr>
<tr><td>Effectiveness</td><td colspan="4">Low: Preventing illicit dumping, especially animal carcasses, is likely to reduce bacteria loads; however, reduction may be limited to areas with public access.</td></tr>
<tr><td>Certainty</td><td colspan="4">Low: 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="4">Moderate: Stakeholders inputs indicated that illicit dumping occurs; however, enforcement can be difficult. Addressing the issue is not a high priority and resource availability is low.</td></tr>
<tr><td>Needs</td><td colspan="4">Moderate: Financial resources are required to develop and distribute educational materials and provide additional waste collection events/facilities.</td></tr>
</table>

*There is a cost associated with the activity, but it may be provided at no cost for this project.

Management Measure 5 – Reduce Illicit and Illegal Dumping

Stakeholders indicate that illicit and/or illegal dumping can be another source of pollutants. These activities typically occur at or near bridge crossings where individuals may dispose of deer, feral hogs, or small livestock carcasses in addition to other trash. Stakeholders indicated that the bridge crossing on CR326 has become a dumping spot. The scope of the problem, however, is not entirely known or quantified but assumed to have an impact on bacteria loadings in the watershed. Table 24 summarizes management measures for illicit and illegal dumping.

Table 25. Management Measure 6: conduct new and small landowner educational workshops.

<table>
<tr><th colspan="5">Pollutant Source: Landowners without Educational Resources</th></tr>
<tr><td colspan="5">Problem: Due to a lack of knowledge about stormwater, pet waste, OSSFs, grazing lands, and water resource management, landowners might adopt incorrect methods to manage them.</td></tr>
<tr><td colspan="5">Objectives:
• Promote and expand education and outreach efforts in the watershed.</td></tr>
<tr><td colspan="5">Critical Areas: Entire watershed</td></tr>
<tr><td colspan="5">Goal: Educate landowners about sources of E. coli and other pollutants in the watershed and several ways to manage them.</td></tr>
<tr><td colspan="5">Description: Education delivery will focus on landscape and water resource management, OSSF operation and maintenance, OSSF design and installation.</td></tr>
<tr><th colspan="5">Implementation Strategy</th></tr>
<tr><td colspan="2">Participants</td><td>Recommendations</td><td>Period</td><td>Capital costs</td></tr>
<tr><td colspan="2">TAMU AgriLife Extension</td><td>Develop and deliver educational and outreach materials to residents</td><td>2025-2035</td><td>~$25,000 each</td></tr>
<tr><th colspan="5">Estimated Load Reduction</th></tr>
<tr><td colspan="5">Load reductions from education-based management measures were not quantified.</td></tr>
<tr><td>Effectiveness</td><td colspan="4">High: Educating landowners to effectively manage stormwater, pet waste and OSSFs prevents pollutants from contaminating streams.</td></tr>
<tr><td>Certainty</td><td colspan="4">Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that need assistance will be beneficial.</td></tr>
<tr><td>Commitment</td><td colspan="4">Moderate: Stakeholders indicate that they would like to attend educational workshops.</td></tr>
<tr><td>Needs</td><td colspan="4">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>

Escherichia coli, E. coli; OSSF – on-site sewage facility; TAMU – Texas A&M University.

Management Measure 6 – New or Small Landowner Education

This management measure aims at 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 properly manage wetlands, properly maintain and use their OSSFs, control feral hog populations, among other activities is important to prevent pollutants from getting into nearby water bodies. Education workshops would be helpful and should be conducted in various parts of the watershed. These workshops would further protect and improve local water resources by ensuring that appropriate persons are informed by new techniques, requirements, and resources. Table 25 summarizes management measure for conducting landowner education workshops.

Table 26. Other recommended activity: volunteer monitoring in the watershed.

<table>
<tr><th colspan="5">Pollutant Source: Unknown Sources</th></tr>
<tr><td colspan="5">Problem: Due to limited resources, monitoring activities were conducted at three locations along Middle Yegua Creek, which may not result in comprehensive understanding of the spatial distribution of potential sources of pollutants.</td></tr>
<tr><td colspan="5">Objectives:
• Expand existing water quality data collection and improve understanding of the spatial distribution of pollutants across the watershed.
• Coordinate with CRP and TCEQ about monitoring in the watershed to share information and ensure efficient use of monitoring resources.</td></tr>
<tr><td colspan="5">Critical Areas: West Yegua Creek and other unmonitored locations in the watershed.</td></tr>
<tr><td colspan="5">Goal: Collect preliminary water quality monitoring data on additional locations in the watershed to determine whether they need routine monitoring due to excess nutrients and bacteria.</td></tr>
<tr><td colspan="5">Description: Residents in watershed are encouraged to be trained by the TST to conduct volunteer monitoring at several locations in the watershed.</td></tr>
<tr><th colspan="5">Implementation Strategy</th></tr>
<tr><td colspan="2">Participants</td><td>Recommendations</td><td>Period</td><td>Capital costs</td></tr>
<tr><td colspan="2">Local stakeholders</td><td>Select monitoring locations</td><td>2025</td><td>N/A</td></tr>
<tr><td colspan="2">TST, Meadows Center for Water and Environment, and local stakeholders</td><td>TST helps train, equip, manage, and offer general support to the residents in the watershed</td><td>2025-2035</td><td>~$550 initial cost for streamflow and nutrient kit
~$650 initial cost for E. coli bacteria monitoring supplies kit</td></tr>
<tr><th colspan="5">Estimated Load Reduction</th></tr>
<tr><td colspan="5">Load reductions from education-based management measures were not quantified.</td></tr>
<tr><td>Effectiveness</td><td colspan="4">Moderate: Data collected from the TST program can be used for research and educational purposes. Educating the public and following up with citizen scientist data could ease public concerns.</td></tr>
<tr><td>Certainty</td><td colspan="4">Moderate: The volunteer monitoring program requires sustained commitment from citizens scientists to produce enough data to use for determining potential water quality issues.</td></tr>
<tr><td>Commitment</td><td colspan="4">High: Many stakeholders are concerned about the water quality in these creeks, and some would be willing to participate in the volunteer monitoring program.</td></tr>
<tr><td>Needs</td><td colspan="4">Moderate: Some financial resources will be required to purchase the initial kits and replace and replenish supplies.</td></tr>
</table>

CRP – Clean Rivers Program; *Escherichia coli, E. coli;* TST – Texas Stream Team; TCEQ – Texas Commission on Environmental Quality.

Other Recommended Activity – Volunteer Monitoring

Stakeholders recommended establishing more monitoring locations on Middle Yegua Creek and its tributaries to help better understand the spatial distribution of pollutants in the watershed. During the planning process, stakeholders recommended collecting water quality samples from more monitoring locations on Middle Yegua Creek, adding locations on tributaries, such as West Yegua Creek, Cross Creek, and Shaw Branch Creek. These and other locations should be considered for future monitoring as funding and resources allow. Additionally, monitoring locations and frequencies should be coordinated with stakeholders, TCEQ, and Clean Rivers Program (CRP) partners.

The Texas Stream Team (TST) coordinates and trains volunteers to conduct water quality monitoring on local rivers, lakes, streams, and estuaries throughout Texas. Across the state, TST already has trained volunteers to monitor over 350 sites. Helping support a TST monitoring program in the watershed would provide the equipment and training resources necessary for volunteer monitoring to occur on creeks that stakeholders have expressed concerns about due to a lack of historical data. Table 26 summarizes management measures for volunteer monitoring in the watershed.

Table 27. Other recommended activity: pet waste management.

Pollutant Source: Dogs			
Problem: Direct and indirect fecal loading from household pet waste.			
Objectives: • Increase stakeholder awareness on the importance of proper disposal of pet waste.			
Critical Areas: Subwatershed 5 as well as riparian areas along water bodies			
Goal: To reduce the amount of pet waste in the watershed that may be washed into water bodies during runoff events by providing educational and physical resources to increase stakeholder awareness of local water quality.			
Description: Expand distribution of educational messaging regarding the need to properly dispose of pet waste in the watershed. Specifically target homeowners and the public. Stock and maintain existing pet waste stations in parks and other public areas to facilitate increased collection and proper disposal of pet waste.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Capital costs**
Cities, counties, and TAMU AgriLife Extension	Install at least 5 pet waste stations in area parks and other potentially high dog concentration areas	2025-2035	~$500 per station
Cities and TAMU AgriLife Extension	Develop and provide educational resources to residents	2025-2035	TBD*
Estimated Load Reduction			
Load reductions resulting from this management measure are reliant on changes in people's behavior, and therefore uncertain. Assuming 12% of 3,349 targeted individuals respond by properly disposing of pet waste 75% of the time, an annual load reduction 3.47×10^{14} cfu *E. coli* per year (Appendix C).			
Effectiveness	High: Collecting and properly disposing of pet 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.		
Certainty	Low: Pet owners who do not pick up pet waste may be difficult to reach or convinced that pet waste should be collected and discarded properly despite their respective reasons for not doing so.		
Commitment	Low: Uptake of behavior change is often very low.		
Needs	Low: Resources required to create and distribute materials are relatively low compared to other measures.		

Escherichia coli, E. coli; Independent school district, ISD; Texas A&M AgriLife Extension Service, AgriLife Extension;
*There is a cost associated with the activity, but it may be provided at no cost for this project.

Other Recommended Activity – Pet Waste Management

Pet waste, dog waste in particular, was identified as one of the dominant potential bacteria sources in the watershed. Typical methods used to reduce the amount of pet waste include education programs and adding pet waste stations. To increase awareness and incite behavior change, education and outreach materials should be delivered to watershed residents, as resources are made available. Resources would include flyers, factsheets, signage, and other outreach materials that are determined to be most effective at reaching area residents. Based on previous survey results from the Chesapeake Bay basin, approximately 12% of dog owners were assumed to adjust behavior based on outreach efforts (Swann 1999) and those actions would be approximately 75% effective at reducing bacteria loads (Table 27; Appendix C). The priority areas for this management measure are urbanized and public areas located in subwatershed 5 (Figure 29 in Chapter 5). Additional priority should be given to areas close to water bodies. However, it is worth mentioning that local stakeholders suggested that reduction in pollutant load through this activity is unlikely.

Table 28. Total estimated load reductions.

Management Measures and Recommended Activities	Expected *E. coli* Load Reduction (cfu per year)
Agricultural Management Measures	
CPs/WQMPs	1.90×10^{14}
Livestock Management Education and Outreach	N/A*
Soil Testing	N/A*
OSSF Management	
OSSF Repair and Replacement	1.29×10^{12}
OSSF Owner Education and Outreach	N/A*
OSSF Installer and Service Provider Education and Outreach	N/A*
Feral Hog Control	
Feral Hog Removal	4.32×10^{13}
Install Feeding Enclosures	N/A*
Hire Feral Hog Trapper	N/A*
Feral Hog Education and Outreach Programming	N/A*
Reduce Illicit and Illegal Dumping	N/A*
New and Small Landowner Education	N/A*
Volunteer Monitoring	N/A*
Pet Waste Management	
Dispose of pet waste into trash receptacles	4.40×10^{14}
Total Reduction	$\mathbf{6.74\times10^{14}}$
Total Reduction Needed	$\mathbf{1.85\times10^{14}}$

cfu – colony forming unit; *Escherichia coli, E. coli;* OSSF – on-site sewage facility.
*N/A – load reductions were not quantified.

Expected Load Reductions

Implementation of the management measures recommended in this WPP can reduce *E. coli* loads across the watershed. While certain management measures can provide direct *E. coli* load reductions, others, such as education and outreach programs, can result in reductions that are not quantifiable. Load reductions are largely expected for management measures recommended for agricultural management, OSSF management, feral hog control, and pet waste management (Table 28).

Chapter 7
Education and Outreach

Middle Yegua Creek at FM 696 by Amanda Tague, TWRI.

An essential element to WPP implementation is effective education and outreach. Long-term commitments from local residents and landowners/producers are necessary to achieve comprehensive improvements in the Middle Yegua creeks watershed. The education and outreach component of implementation would focus on keeping the public, landowners, and agency personnel informed of project activities, provide information about appropriate management practices, and assist in identifying and forming partnerships to implement WPP components.

Watershed Coordinator

The role of the watershed coordinator is to lead efforts to establish and maintain the working partnerships with stakeholders. Establishing a watershed coordinator role is an important step towards successful WPP implementation. The watershed coordinator would 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 strategies. A full-time watershed coordinator position in or near the watersheds is recommended to effectively support WPP implementation.

Public Meetings

During WPP development, stakeholder engagement was critical. Public meetings to develop the WPP began in January 2024 with local stakeholders. In total, eight meetings were held to discuss plan development, including general stakeholder meetings and specialized workgroup meetings.

Throughout the process, local stakeholders participated in public meetings, individual meetings, phone calls, and virtual meetings associated with WPP development. Stakeholders attended the meetings represented landowners, agencies, nonprofit organization, etc. Groups and entities involved in the planning process include the Lee County elected officials, Lee County SWCD, Lee County AgriLife Extension Office, NRCS, and TSSWCB.

Future Stakeholder Engagement

Watershed stakeholders would continue to be engaged throughout the WPP implementation process. The watershed coordinator would facilitate engagement by continuing to coordinate, organize, and host periodic public meetings and educational events and by seeking out and meeting with stakeholder groups to identify and secure implementation funds. The Middle Yegua Creek Stakeholder Group is an existing group concerned with Middle Yegua Creek and its water quality. Many members of this group participated in meetings to develop the WPP and should remain engaged in implementation. The watershed coordinator should also provide content to maintain and update a project website, track the WPP implementation progress, and participate in local events to promote watershed awareness and stewardship. News articles, newsletters, and the project website would be primary tools used to communicate with watershed stakeholders on a regular basis. Content should be developed to periodically update readers on implementation progress, provide information on new implementation opportunities, and inform them of available technical or financial assistance and information regarding the WPP effort.

Education Programs

Delivering applicable and desired educational programming is a critical part of the WPP implementation process. Multiple programs providing information on potential pollutant sources and feasible management strategies should be delivered in and near the watersheds and would be advertised to watershed stakeholders. These programs would be coordinated with the efforts of other entities operating in and near the watersheds. An approximate program delivery schedule is provided in the management measures described in Chapter 6. As implementation and data collection continues, the adaptive management process should be used to modify this schedule and respective educational needs as appropriate. Potential programs that can meet educational needs are described in subsequent sections.

Riparian and Stream Ecosystem Education Training

Healthy watersheds and good water quality are synonymous with well-managed riparian and stream ecosystems. Delivering the Riparian and Stream Ecosystem Education Program should increase stakeholder awareness, understanding, and knowledge about the nature and function of riparian zones. The program would highlight the benefits of riparian zones and BMPs that can be implemented to protect them while minimizing NPS pollution. Through this program, riparian landowners would be connected with local technical and financial resources to improve management opportunities and promote healthy watersheds and riparian areas on their land.

Wildlife Management Workshops

Wildlife has numerous significant impacts on water quality and as a result, periodic wildlife management workshops are warranted to provide information on management strategies and available resources to those interested. The watershed coordinator should work with Texas A&M AgriLife Extension wildlife specialists and TPWD as appropriate to plan and secure funding to deliver workshops in and near the Middle Yegua Creek watershed. Wildlife management workshops would be advertised through newsletters, news releases, the project website and other avenues as appropriate.

OSSF Operation and Maintenance Workshop

A training program that focuses on OSSF rules, regulations, operation, and maintenance needs should be delivered in one or more locations in the watersheds. This training consists of education and outreach practices to promote the proper OSSF management and garners support for efforts to further identify and address failing OSSFs through inspections and remedial actions. Texas A&M AgriLife Extension provides the needed expertise to deliver this training. 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 should be made available to anyone interested through the partnership website.

OSSF Installer and Maintenance Provider Training

Continuing education courses for licensed OSSF Installers and Maintenance Providers are available through Texas A&M 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.

Lone Star Healthy Streams Workshop

The watershed coordinator should coordinate with Texas A&M AgriLife Extension personnel to deliver the Lone Star Healthy Streams curriculum. This program provides information regarding management practices that can be implemented to reduce potentially adverse water quality impacts resulting from cattle, feral hogs, and horses. For livestock, content focuses on improving grazing land management and presents practices that can reduce NPS pollution. There is a separate feral hog program offered through Lone Star Healthy Streams that differs in that it largely discusses population control options. This statewide program promotes BMP adoption that is proven to effectively reduce bacterial contamination of streams. This program provides educational support for developing CPs and WQMPs by illustrating the benefits of many practices included in those plans.

Texas Well Owners Network

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network Program delivered by Texas A&M AgriLife Extension provides needed education and outreach that focuses on private drinking water wells and the impacts on human health and the environment that can be mitigated by using proper management practices. This includes a brief session on proper operation and maintenance of OSSFs because they are commonly used near private drinking water wells. Well screenings are conducted through this program and provide useful water test information to well owners that aids them in better managing their water supplies.

Healthy Lawns Healthy Waters Workshop

The Healthy Lawns and Healthy Waters Program aims to improve and protect surface water quality by enhancing awareness, knowledge, and implementation of residential landscape BMPs. This program is most beneficial in urbanized portions of the watersheds and can teach homeowners how to care for their lawns appropriately to reduce the risk of NPS pollution entering Middle Yegua Creek.

Clean Rivers Program Annual Meeting

Each year, BRA hosts an annual Clean Rivers Program (CRP) stakeholder meeting. This meeting covers their entire river basin and includes Middle Yegua Creek. Discussions in these meetings focus on water quality and quantity issues across the basin and other issues of concern. These are good meetings for high level issues and concerns and an excellent location to bring up localized water resource concerns.

Public Meetings

Periodic public stakeholder meetings should achieve several WPP implementation goals. Public meetings would provide a platform for the watershed coordinator and project personnel 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 would 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 would be accomplished by reviewing implementation goals and milestones and actively discussing how watershed needs can be better served. Feedback would be incorporated into WPP addendums as appropriate.

Newsletters and News Releases

Watershed newsletters should be developed and sent directly to actively engaged stakeholders at least annually or more often if warranted. News releases would be developed and distributed through the mass media outlets in the area to highlight significant happenings related to WPP implementation and to continue raising public awareness and support for watershed protection. These means would be used to inform stakeholders of implementation programs, eligibility requirements, and when and where to sign up for specific programs. Lastly, public meetings and other WPP-related activities should be advertised through these outlets.

Chapter 8
Implementation Schedule

Middle Yegua Creek at FM 141 by Amanda Tague, TWRI.

Implementation of this WPP is a ten-year commitment that would require active participation from various parties, including stakeholders and local entities. To successfully implement the management measures discussed in Chapter 6, financial and technical assistance are key. In this chapter, a complete list of management measures, which are voluntary actions, implementation goals, participants, and estimated associated costs are organized in Table 29. The implementation goals are designed to be achieved gradually, allowing for timely progress measurement. If targeted goals are not met within the scheduled time frames, adjustments can be made. Additionally, adaptive management strategies may be employed if the original goals become unfeasible or if better alternative management measures arise.

It is worth mentioning that the watershed coordinator, although not specifically included in the participant column for the recommended management measures, would be responsible for working closely with stakeholders to identify implementation needs and coordinate technical and financial resources for such needs.

Table 29. Middle Yegua Creek watershed management measures/recommended activity, participants, goals, and estimated costs.

Management Measure	Participants	Estimated Unit Cost	Implementation Goals (years after implementation begins)			Estimated total cost
			1-3	4-7	8-10	
General Watershed Management						
Hire a watershed coordinator	TAMU AgriLife Extension and counties	~$75,000 per year (including fringe benefits)	3	4	3	~$750,000
Semi-annual meetings	Watershed Coordinator	~$300 per meeting	6	8	6	~$6,000
Water Quality Management Plans/Conservation Plans						
CPs/WQMPs	Landowners, producers, TSSWCB, local SWCDs, and NRCS	Up to $30,000 per WQMP	30	40	30	Up to $3,000,000
Hire a WQMP technician	TSSWCB and local SWCDs	~$75,000 per year (including fringe benefits)	3	4	3	~$750,000
Education and outreach	TAMU AgriLife Extension, stakeholders, local SWCDs, counties	TBD*	1	1	1	TBD*
Soil Testing						
Develop and deliver educational and outreach materials	TAMU AgriLife Extension and counties	~$5,000	1	1	1	~$20,000
Soil testing	Landowners, counties, and TAMU AgriLife Extension	~$12 per test	Varies			TBD*
Feral Hog Removal						
Install fencing around feeders	Landowners	~$300 per fence	As many as possible			Varies
Feral hog bounty program	Hunters and landowners	$10 per hog	As many as possible			Varies
Volunteer feral hog removal	Landowners and hunters	Varies	As many as possible			Varies
Wildlife management plans and practices.	Landowners, TWS, and TPWD	TBD*	As many as possible			TBD*
Feral hog education workshop	TAMU AgriLife Extension, TWS, and TPWD	~$3,000 per workshop	1	1	1	~$9,000
Hire a feral hog trapper	TWS, TAMU AgriLife Extension and counties	~$75,000 per year (including fringe benefits)	3	4	3	~$750,000

Management Measure	Participants	Estimated Unit Cost	Implementation Goals (years after implementation begins) 1-3	4-7	8-10	Estimated total cost
OSSF Management						
Build OSSF database	County designated representatives	TBD*		1		TBD*
Identify, inspect, and replace/ repair failing OSSFs	Homeowners and county designated representatives	~$8,000 - $12,500 per system	24	32	24	~$640,000 - $1,000,000
Education and outreach	TAMU AgriLife Extension, TWRI, counties, Watershed Coordinator	TBD*	1	1	1	TBD*
Reduce Illicit and Illegal Dumping						
Education and outreach	Counties, TAMU AgriLife Extension	TBD*		Varies		TBD*
New/Small Landowner Education						
Education and outreach	TAMU AgriLife Extension and counties	TBD*	1	1	1	TBD*
Other Recommended Activity: Volunteer Monitoring						
Establish a volunteer monitoring program in the watershed	Volunteers, TST, Meadows Center for Water and Environment	~$550 per nutrient kit ~$650 per *E. coli* kit		Varies		~$1,200*
Other Recommended Activity: Pet Waste Management						
Install and maintain 5 pet waste stations	Cities and counties	~$500 per station	1	2	2	~$2,500
Education and outreach	Cities, TAMU AgriLife Extension	TBD*	1	1	1	TBD*

CP – conservation plan; *Escherichia coli, E. coli;* HLHW – Healthy Lawn Healthy Waters; NRCS – Natural Resources Conservation Service; NPS – nonpoint source; OSSF – on-site sewage facilities; SWCD – Soil and Water Conservation District; TSSWCB – Texas State Soil and Water Conservation Board; TAMU – Texas A&M University; TWRI – Texas Water Resources Institute; TST – Texas Stream Team; TPWD – Texas Parks and Wildlife Department; TWS – Texas Wildlife Service; WQMP – water quality management plan.

*There is a cost associated with the activity, but it may be provided at no cost for this project.

Chapter 9
Implementation Resources

Middle Yegua Creek at FM 141 by Amanda Tague, TWRI.

This chapter identifies potential sources of technical and financial assistance for management measure implementation in the Middle Yegua Creek watershed. Grant funding should be a major source given the management measures outlined in previous chapters. Funding support for a local watershed coordinator to guide and facilitate the implementation of the WPP is also critical.

Technical Assistance

Designing, planning, and implementing many management recommendations in the plan will require technical expertise. In these cases, appropriate technical support would be sought. Funding required to secure needed expertise should be included as appropriate in requests for specific projects. Potential technical assistance sources for each management measure are listed below (Table 30).

Livestock Management

Technical assistance to develop and implement practices to improve livestock management is available from TSSWCB, local SWCDs, and NRCS. Interested producers should request planning assistance and these agencies would work with the producer to define operation-specific management goals and objectives and develop a plan that prescribes effective practices that would achieve stated goals while also improving water quality.

Soil Testing for Agricultural Areas

Soil testing efforts should focus on education and outreach. Texas A&M AgriLife Extension, counties, and other entities as appropriate would provide technical assistance with developing and delivering educational and outreach materials to landowners in the watershed.

Feral Hog Control

Watershed stakeholders can benefit from technical assistance regarding feral hog control approaches, options, best practices, and regulations. Texas A&M AgriLife Extension and TPWD can provide educational resources through local programs and public events. Online resources regarding feral hog trap and transport regulations, trap construction and design, and trapping techniques are also available at: http://feralhogs.tamu.edu/.

Table 30. Summary of potential sources of technical assistance.

Management Measure (MM)	Technical Assistance
MM1: Mitigate Urban Stormwater Runoff Issues	TSSWCB, local SWCDs, and NRCS
MM2: Promote the Development of Water Quality Management Plans or Conservation Plans	TAMU AgriLife Extension and counties
MM3: Technical Assistance for Urban Waterfowl Management	TAMU AgriLife Extension, TWS, and TPWD
MM4: Promote BMPs for Managing Feral Hog Populations	TAMU AgriLife Extension and counties
MM5: Promote Proper Disposal of Pet Waste in Urban Areas	TAMU AgriLife Extension and counties
MM6: Identify, Inspect, and Remediate Failing On-Site Sewage Facilities	TAMU AgriLife Extension and counties
Other Recommended Activity: Volunteer Monitoring	TST and Meadows Center for Water and Environment
Other Recommended Activity: Pet Waste Management	TAMU AgriLife Extension and cities

CP – conservation plan; NRCS – Natural Resources Conservation Service; SWCD – Soil and Water Conservation District; TAMU – Texas A&M University; TPWD – Texas Parks and Wildlife Department; TWS – TST – Texas Stream Team; TSSWCB – Texas State Soil and Water Conservation Board; Texas Wildlife Service; WQMP – water quality management plan.

OSSF Management

Building an OSSF database and identifying failing OSSFs requires trained personnel and their time. County designated representatives or septic service providers can provide expertise and help identify systems in need of repairs or replacement. Technical support is also needed to help secure funding for large-scale programs to repair or replace failing OSSFs. Education and outreach content for OSSF owners is also technical in nature and requires trained personnel. Texas A&M AgriLife Extension personnel can provide these educational resources.

New or Small Landowner Education

Texas A&M AgriLife Extension would provide technical assistance with developing and delivering educational and outreach materials to new or small landowners in the watershed.

Reduce Illicit and Illegal Dumping

Efforts to reduce illicit and illegal dumping should focus on education and outreach in conjunction with hazardous waste collection events throughout the watersheds. Texas A&M AgriLife Extension should provide technical assistance with education and outreach efforts. County law enforcement and TPWD game wardens are the primary source for enforcement and monitoring activities associated with illicit dumping.

Volunteer Monitoring

TWRI would assist, as funding allows, in coordinating the establishment of a volunteer monitoring program with TST and volunteers in the watershed. TST would train citizen scientists to collect and submit water quality monitoring data and provide information on the purchase of the necessary monitoring kits.

Pet Waste Management

Limited technical assistance is available to directly address improper disposal of pet waste. County public works departments, homeowner associations, and other entities as appropriate should be relied upon to identify viable sites for pet waste stations. These entities may also be able to provide operation and maintenance of collection sites. Educational materials can be provided to cities through Texas A&M AgriLife Extension.

Technical Resources

Texas A&M AgriLife Extension

Texas A&M AgriLife Extension is a statewide outreach education agency with offices in every county of the state. It provides a network of professional educators, volunteers, and local county extension agents. Texas A&M AgriLife Extension should be consulted to develop and deliver education programs, workshops, and materials as needed.

County or City Designated Representatives

OSSF construction or replacement in Bastrop, Lee, Milam, and Williamson counties requires a permit on file with local authorized agents. Permits should be applied for through a TCEQ-licensed professional installer. The county designated representative is responsible for approving or denying permits. Site evaluations should be done by a TCEQ-licensed site and soil evaluator, licensed maintenance provider, or licensed professional installer.

Natural Resources Conservation Service

USDA NRCS provides conservation planning and technical assistance to private landowners. For decades, private landowners have voluntarily worked with NRCS personnel to prevent erosion, brush encroachment, among other BMPs to directly or indirectly improve water quality and promote sustainable agriculture. Assistance is available to help landowners maintain and improve private lands, implement improved land management technologies, protect water quality and quantity, improve wildlife and fish habitat, and enhance recreational opportunities. Local NRCS centers for Middle Yegua Creek watershed stakeholders are in Giddings, Cameron, Bastrop, and Georgetown.

Soil and Water Conservation Boards

A SWCD, like a county or school district, is a subdivision of the state government. SWCDs are administered by a board of five directors who are elected by their fellow landowners. There are 216 individual SWCDs organized in Texas. It is through this conservation partnership that local SWCDs can furnish technical assistance to farmers and ranchers for the preparation of a complete soil and water CP to meet each land unit's specific capabilities and needs. The local SWCDs include Bastrop County SWCD, Lee County SWCD, Taylor SWCD (Milam, Williamson, and Travis Counties).

Texas State Soil and Water Conservation Board

TSSWCB supports the operation of local SWCDs and leads the WQMP program by providing technical assistance for developing management and conservation plans at no charge to agricultural producers. A visit to the local SWCD offices is the first step for operators to begin the plan development process.

Texas Commission on Environmental Quality

TCEQ offers a variety of programming and personnel resources that can provide technical support for publically owned permitted facilities. TCEQ's SSO Initiative is a voluntary program in which municipalities develop a plan to prevent unauthorized discharge of untreated or partially treated wastewater from a collection system or its components (e.g., a manhole, lift station, or cleanout) before it reaches a wastewater treatment facility. The SSO plan outlines the causes of SSOs, mitigative and corrective actions, and a timeline for implementation. Assistance for SSO planning and participation in the SSO Initiative is available through the TCEQ regional office (Region 9, Waco; Region 11, Austin) and the TCEQ Small Business and Environmental Assistance Division. Funding resources are also available through the Texas Water Development Board, Texas Water Infrastructure Coordination Committee website: https://twicc.org/index.html.

Texas Parks and Wildlife Department

TPWD's Private Land Services is a program to provide landowners with practical information on ways to manage wildlife resources that are consistent with other land use goals, to ensure plant and animal diversity, to provide aesthetic and economic benefits and to conserve soil, water, and related natural resources. TPWD offers assistance in developing property-specific wildlife habitat management plans and can aid in tracking the expected water quality improvements. Additionally, TPWD offers a habitat management workshop through their regional biologists. To participate, landowners may request assistance by contacting the TPWD district serving their county.

Financial Resources Descriptions

Successful WPP implementation would require substantial fiscal resources. Diverse funding sources should be sought for the recommended management measures. Resources should be leveraged where possible to extend the impacts of acquired and contributed implementation funds.

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

Federal Sources

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

EPA provides grant funding to Texas to implement projects that reduce NPS pollution through the §319(h) Nonpoint Source Grant Program. These grants are administered by TCEQ and TSSWCB. WPPs that satisfy EPA's Nine Key Elements of successful watershed-based plans are eligible for funding through this program. To be eligible for funding, implementation measures should be included in the accepted WPP and meet other program rules. Some commonly funded items include but are not limited to:k

- development and delivery of education programs;
- water quality monitoring;
- OSSF repairs and replacements;
- BMP installation and demonstrations; and
- water body cleanup events.

Further information can be found on the TCEQ Nonpoint Source Grant Program: https://www.tceq.texas.gov/water-quality/nonpoint-source/grants/grant-pgm.html and the TSSWCB Nonpoint Source Management Program: https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program webpages.

Conservation Stewardship Program

The Conservation Stewardship Program is a voluntary conservation program administered by NRCS that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities. The program is available for private agricultural lands including cropland, grassland, prairie land, improved pasture, and rangeland. The program encourages landowners and stewards to improve conservation activities on their land by installing and adopting additional conservation practices including but not limited to prescribed grazing, nutrient management planning, precision nutrient application, manure application, and integrated pest management. Program information can be found at: https://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 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: https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index.

Environmental Quality Incentives Program

NRCS operates the Environmental Quality Incentives Program (EQIP), which is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and provides opportunities to improve soil, water, plant, animal, air, and related resources on agricultural land and nonindustrial private forestland. Individuals engaged in livestock or agricultural production on eligible land are permitted to participate in EQIP. Practices selected address natural resource concerns and are subject to NRCS technical standards adapted for local conditions. They should also be approved by the local SWCD. Local work groups are formed to provide recommendations to 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/.

National Water Quality Initiative

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

Regional Conservation Partnership Program

The Regional Conservation Partnership Program (RCPP) is a comprehensive and flexible program that uses partnerships to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale. Through RCPP and NRCS, state, local, and regional partners coordinate resources to help producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved. Information regarding RCPP can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/rcpp/.

Rural Development: Water and Environmental Programs

Water and Environment Development Program, administered by the USDA Rural Development, provides grants and low interest loans to rural communities for potable water and wastewater system construction, repair, or rehabilitation. Funding options include:

- Rural Repair and Rehabilitation Loans and Grants: provide assistance to make repairs to low-income homeowners' housing to improve or remove health and safety hazards.
- Technical Assistance and Training Grants for Rural Waste Systems: provide grants to nonprofit organizations that offer technical assistance and training for water delivery and waste disposal.
- Water and Waste Disposal Direct Loans and Grants: assist in developing water and waste disposal systems in rural communities with populations less than 10,000 individuals.

More information about the USDA Rural Water and Environment Development program can be found at: https://www.rd.usda.gov/programs-services/water-environmental-programs.

State Sources

Clean Rivers Program

TCEQ administers the 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. BRA is the partner for the Yegua Creek watersheds. More information about the BRA CRP is available at: https://brazos.org/About-Us/Environmental/Texas-Clean-Rivers-Program.

Clean Water State Revolving Fund

The Clean Water State Revolving Fund, authorized through the CWA and administered by the Texas Water Development Board (TWDB), provides low-interest loans to local governments and service providers for infrastructure projects that include stormwater BMPs, WWTFs, and collection systems. More information on Clean Water State Revolving Fund is available at: http://www.twdb.texas.gov/financial/programs/CWSRF/.

Landowner Incentive Program

TPWD administers the Landowner Incentive Program (LIP) for private landowners to implement conservation practices that benefit healthy aquatic and terrestrial ecosystems and create, restore, protect, or enhance habitat for rare or at-risk species. The program provides financial assistance but does require the landowner to contribute through labor, materials, or other means. Further information about this program is available at: https://tpwd.texas.gov/landwater/land/private/lip/.

Supplemental Environmental Projects

The Supplemental Environmental Program (SEP) program, administered by TCEQ, directs fines, fees, and penalties for environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars to improve the environment, rather than paying into the Texas General Revenue Fund. Program funds may be directed to OSSF repair, trash clean up, and wildlife habitat restoration or improvement, among other things. The funds may also be directed to entities for single, one-time projects that require special approval from TCEQ or directed entities (such as the Resource Conservation and Development Councils) with pre-approved “umbrella” projects. More information about SEP is available at: https://www.tceq.texas.gov/compliance/enforcement/sep/sep-main.

Texas Farm and Ranch Lands Conservation Program

The Texas Farm and Ranch Lands Conservation Program was established and is administered by TPWD to conserve high value working lands to protect water, fish, wildlife, and agricultural production that are at risk of future development. The program’s goal is to educate citizens on land resource stewardship and establish conservation easements to reduce land fragmentation and loss of agricultural production. More information about this program is available at: https://tpwd.texas.gov/landwater/land/private/farm-and-ranch/.

Additional Sources

Private foundations, nonprofit organizations, land trusts, and individuals can potentially assist with implementing 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:

- Lee County Wildlife Association provides financial assistance to local workshops that help local landowners to adopt environmentally sound management and conservation practices for wildlife to improve the quality of life;
- 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 nonprofit organizations to assist in improving/maintaining watershed health through sustainable land management;
- Meadows Foundation: provides grants to nonprofit 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: funding provided by the trust assists in establishing conservation easements for enrolled lands; and
- Local industries in the watersheds could also provide in-kind donations or additional funding for implementation projects.

Chapter 10 Measuring Success

Middle Yegua Creek at FM 696 by Amanda Tague, TWRI.

Implementing this WPP requires coordination with many stakeholders over the next 10 years. Implementation should focus on addressing readily manageable bacteria sources in the watersheds to achieve water quality targets. This plan identified substantial financial resources, technical assistance, and education required to achieve these targets. Management measures identified in this WPP are voluntary but supported at the recommended levels by watershed stakeholders.

Measuring WPP implementation impacts on water quality is a critical process. Planned water quality monitoring at critical locations would provide data needed to document progress toward water quality goals. While improvements in water quality are the preferred measure of success, documenting implementation accomplishments can also be used. Combining water quality data and implementation accomplishments helps facilitate adaptive management by illustrating which recommended measures are working and which measures need modification.

Water Quality Targets

An established water quality goal defines the target for future water quality and allows the needed bacteria load reductions to be defined. The stakeholder-selected water quality goal in Middle Yegua Creek is the existing primary contact recreation standard for *E. coli* of 126 MPN per 100 milliliters. The concentrations of *E. coli* after five and ten years of implementation were estimated based on the assumption that 50% and 100% of needed pollutant concentration reduction is removed from the waterbody, respectively (Table 31). If there are revisions or adoption of new water quality standards, such as for nutrients, these targets may be revised or amended as appropriate.

Additional Data Collection Needs

Continued water quality monitoring in the Middle Yegua Creek watershed is essential to track changes resulting from WPP implementation. Currently, TWRI conducts monthly water quality monitoring at two stations within the watershed. Continuing this level of monitoring effort is critical for future evaluations and should be maintained.

Table 31. Water quality targets for impaired water bodies.

Station	Segment	Current Concentration*	5 Years After Implementation*	10 Years After Implementation*
18750	1212A_02	423.7	274.9	≤126
11840	1212A_02	229.2	≤126	≤126
11838	1212A_01	80.7	≤126	≤126

MPN – most probable number; mL – milliliter; mg – milligram; L – liter.
*Geometric mean in units of cfu of *E. coli* per 100 mL of water

The current distribution of monitoring sites and the frequency of data collection limit the ability to detect subtle water quality changes resulting from WPP implementation. Defining localized impacts from specific WPP activities will require focused water quality monitoring efforts, which can only be planned once specific WPP activities and locations are known. To provide an improved spatial and temporal view of water quality across the watershed, funding will be sought to continue and expand the current monthly monitoring regime in the watershed. Additionally, as specific implementation activities occur, monitoring needs will be evaluated. Funding to conduct additional needed monitoring will be sought to enable implementation effectiveness to be assessed.

Targeted water quality monitoring could involve paired watershed studies, multiple watershed studies, or edge-of-field runoff analysis where different land use or management measures have been implemented. Data from this monitoring could demonstrate the applicability of different BMPs within the watershed. Additionally, targeted monitoring may include more intensive sampling in other stream segments to identify potential pollutant sources.

Through the adaptive management process and WPP updates, future water quality monitoring needs would be evaluated and adjusted as necessary. Additional monitoring needs will be discussed with stakeholders during watershed meetings.

Data Review

Watershed stakeholders, specifically the watershed coordinator, are responsible for evaluating WPP implementation impacts on instream water quality. This would use TCEQ's statewide biennial water quality assessment approach, which utilizes a moving seven-year geometric mean of bacteria data as the primary means of assessing implementation success. This assessment is published in the *Texas Integrated Report* and 303(d) List.

It is noted that a two-to-three-year lag occurs in data reporting and assessment; therefore, the 2028 or 2030 *Texas Integrated Report* would likely be the first to include water quality data collected during WPP implementation.

Identifying water quality improvements from WPP implementation is challenging if relying only 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 SWQMIS.

To support data assessment as needed, trend analysis and other appropriate statistical analyses would be used. Regardless of the method used, water quality changes resulting from WPP implementation could be difficult to determine and may be overshadowed by activities in the watershed that may negatively influence water quality. As such, data review would not be relied on exclusively to evaluate WPP effectiveness. Data should be summarized and reported to watershed stakeholders at least annually through stakeholder meetings and BRA's annual CRP meetings.

The watershed coordinator will be responsible for tracking implementation targets and water quality in the watershed. Implementation progress and water quality will be evaluated to describe the success of WPP implementation to that point. Should implementation targets or water quality lag significantly, adaptive management efforts will be initiated to reevaluate management recommendations and targets included in the WPP.

Interim Measurable Milestones

WPP implementation would span ten years. Milestones are essential for evaluating the incremental progress of the management measures outlined in the WPP. These milestones provide a clear roadmap for implementation. Interim measurable milestones for management measures and education and outreach activities are detailed in Table 29 in Chapter 9. The schedule includes responsible parties and estimated costs where available. In some instances, the start of certain items may be delayed due to funding acquisition, personnel hiring, or program initiation. This approach offers incremental targets to track progress throughout the WPP implementation. Adaptive management would be employed as needed to reorganize or reprioritize various implementation aspects to achieve the overarching water quality goals.

Adaptive Management

Watersheds are influenced by numerous variables, which introduce uncertainties in the management measures outlined in this plan. As WPP implementation progresses, it is essential to monitor water quality over time and make necessary adjustments to the implementation strategy. The inclusion of an adaptive management approach in the WPP provides the flexibility needed for these adjustments.

Adaptive management is the ongoing process of accumulating knowledge regarding impairment causes and water quality response as implementation efforts progress and adjusting management efforts as needed. As implementation activities are instituted, water quality is tracked to assess impacts. This information can be used to guide adjustments to future implementation activities. This ongoing, cyclical implementation and evaluation process can focus project efforts and optimize its impacts. Watersheds where impairments are dominated by NPS pollutants are good candidates for adaptive management. Progress toward achieving established water quality targets would also be used to evaluate the need for adaptive management. An annual implementation progress and water quality trends review should be presented to stakeholders during meetings. Due to 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 before triggering adaptive management. In addition to water quality targets, if satisfactory progress toward achieving milestones is determined to be infeasible due to funding, implementation scope, 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 would be made to increase BMP adoption and adjust strategies or focus areas as appropriate.

References

AVMA. 2022. AVMA 2022 Pet Ownership and Demographic Sourcebook. https://ebusiness.avma.org/files/ProductDownloads/eco-pet-demographic-report-22-low-res.pdf.

Clary, C. R., Redmon, L., Gentry, T., Wagner, K., Lyons, R. 2016. Nonriparian shade as a water quality best management practice for grazing-lands: a case study. Rangelands. 38 (3): 129-137. https://doi.org/10.1016/j.rala.2015.12.006.

Dewitz, J. 2023. National Land Cover Database (NLCD) 2021 Products: U.S. Geological Survey data release, https://doi.org/10.5066/P9JZ7AO3.

EPA. 2024. Enforcement and Compliance History Online database. https://www.epa.gov/accessibility.

EPA. 2005. Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d) and 305(b) of the Clean Water Act. https://www.epa.gov/tmdl/integrated-reporting-guidance-under-cwa-sections-303d-305b-and-314.

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. United States Environmental Protection Agency Office of Water Nonpoint Source Control Branch. Washington, DC 20460. EPA 841-B-08-002.

EPA Office of Water. 2000. Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management. Federal Register, October 18, 2000.

Griffith, G.E., S.B. Bryce, J.M. Omernik, and A. Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality. Austin, TX. 125p.

Larkin, T.J., and Bomar, G.W. 1983. Climatic Atlas of Texas. Texas Water Development Board. LP-192. https://www.twdb.texas.gov/publications/reports/limited_printing/doc/LP192.pdf.

NOAA. 2023. National Climatic Data Center: www.ncdc.noaa.gov/cdo-web/search?datasetid=GHCND.

PRISM Climate Group at Oregon State University. 2022. 30-Year Normals 1991-2020. http://www.prism.oregonstate.edu/normals/.

Public Utility Commission of Texas. 2017. Sewer Certificate of Convenience and Necessity Service Areas. https://www.puc.texas.gov/industry/water/utilities/gis.aspx.

Rattan, J. M.; Higginbotham, B. J.; Long, D. B.; and Campbell, T. A. 2010. "Exclusion Fencing for Feral Hogs at White-tailed Deer Feeders". USDA National Wildlife Research Center - Staff Publications. 1274. https://digitalcommons.unl.edu/icwdm_usdanwrc/1274.

Reed, Stowe, and Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas. Austin, TX: Texas Commission on Environmental Quality. http://www.tceq.texas. gov/assets/public/compliance/compliance_support/regulatory/ossf/StudyToDetermine.pdf

Swann, C. 1999. A Survey of Residential Nutrient Behaviors in the Chesapeake Bay. Prepared for Chesapeake Research Consortium. Ellicott City, MD: Center for Watershed Protection. https://cfpub.epa.gov/npstbx/files/UNEP_all.pdf.

TWDB. 2016. Texas Aquifers Study. https://www.twdb.texas.gov/groundwater/docs/studies/TexasAquifersStudy_2016.pdf#page=151.

TWDB. 2021. Regional Water Planning: 2016 Regional and 2017 State Water Plan Projections Data https://www.twdb.texas.gov/waterplanning/data/projections/index.asp.

TCEQ. 2021. Draft 2022 Guidance for Assessing and Reporting Surface Water Quality in Texas. https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/22txir/2022-guidance.pdf.

TCEQ. 2022a. Texas Surface Water Quality Standards §§ 307.1 – 307.10. https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y.

TCEQ. 2022b. Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d). https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/22txir/2022_303d.pdf.

TCEQ. 2023. Surface Water Quality Web Reporting Tool. https://www80.tceq.texas.gov/SwqmisPublic/index.htm.

TCEQ. 2023. Central Registry Query. https://www15.tceq.texas.gov/crpub/.

TCEQ. 2024. Statewide sanitary sewer overflow records acquired through email. 2024. J. Howard.

TxGIO. 2023. DataHub. https://data.tnris.org/.

Teague, A., R. Karthikeyan, M. Babar-Sebens, R. Srinivasan, and R. Persyn. 2009. Spatially explicit load enrichment calculation tool to identify *E. coli* sources in watersheds. Transactions of ASABE. 52(4): 1109-1120.

Timmons, J.B., Higginbotham, B., Lopez, R., Cathey, J. C., Mellish, J., Griffin, J., Sumrall, A., and Skow, K. 2012. Feral Hog Population Growth, Density and Harvest in Texas, College Station, TX: Texas A&M AgriLife. SP-472. https://nri.tamu.edu/media/3203/sp-472-feral-hog-population-growth-density-and-harvest-in-texas-edited.pdf.

TPWD. 2024. Statewide white-tailed deer density data request through email. J. Salmeron.

TWDB. 2021. Regional Water Plan County Population Projections for 2020-2070. https://www3.twdb.texas.gov/apps/reports/Projections/2022%20Reports/pop_county.

USCB. 2020. TIGER/Line Census Block Shapefiles. https://www.census.gov/cgi-bin/geo/shapefiles/index.php.

USDA. Natural Resources Conservation Service. 2019. Soil Survey Geographic Database. https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo.

USDA. National Agricultural Statistics Service. 2024. 2022 Census of Agriculture United States Summary and State Data. https://www.nass.usda.gov/Publications/AgCensus/2022/index.php#full_report.

USGS. 2021. 3D Elevation Program 10-Meter Resolution Digital Elevation Model. https://apps.nationalmap.gov/downloader/.

Wagner, K. L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay Task Two Report, College Station, TX: Texas Water Resources Institute. TR-347. https://hdl.handle.net/1969.1/93181.

Wagner, K. L., Redmon, L. A., Gentry, T. J., Harmel, R. D. 2012. Assessment of cattle grazing effects on *E. coli* runoff. Transactions of the ASABE. 55 (6): 2111-2122. https://doi.org/10.13031/2013.42503.

Appendix A: Load Duration Curve Analysis

A widely accepted approach for analyzing water quality is the use of LDCs. An LDC allows for visual determination of how water quality changes with changes in streamflow. The main steps involved in LDC development are:

1. determine the period of record used in developing flow duration curves (FDCs);
2. develop naturalized flows;
3. develop daily streamflow records using naturalized flows in step 2, permitted discharges, and water rights diversions;
4. develop the FDC; and
5. develop the LDC.

To construct an LDC, an FDC is constructed first, which shows the fraction of time a given flow (in cubic feet per second) is expected to be exceeded. An FDC is generated following these steps:

1. ranking the daily flow values from highest to lowest (rank = 1, 2, 3..., N);
2. calculating the percentage of days each flow was exceeded = 100×rank / (N + 1); and
3. plotting each flow value (y-axis) against percentage of days flow exceeded (x-axis).

The FDC is then multiplied by the *E. coli* criterion (126 MPN per 100 milliliters) for primary contact recreation use, to calculate allowable bacteria loads across different streamflow conditions. As a result, the y-axis indicates *E. coli* loads, and x-axis indicates the percentage of days a certain load of *E. coli* is exceeded. Afterwards, each *E. coli* concentration sample was associated with a streamflow value by the date of sampling. An *E. coli* concentration value (in MPN per 100 milliliters) multiplied by a streamflow value (in cubic feet per second) and a conversion factor (28,316.8 milliliters per cubic foot×86,400 seconds per day) will result in a sampled *E. coli* load value for that day (in MPN per day). Afterwards, sampled *E. coli* loads were overlain on the allowable LDC. Points above the allowable LDC are out of compliance, while points below the curve are under compliance. The difference between measured loads and the allowable load was considered needed load reduction to achieve the applicable water quality standards. Additional information explaining the LDC method can be found in Cleland (2003) and EPA (2007).

Given the above, streamflow data are essential for calculating FDC, as well as sampled *E. coli* loads. For the Middle Yegua Creek, although instantaneous flows were collected during the sampling events, they are limited and not representative of the overall flow regime behavior of the creek. To account for more comprehensive flow characteristics, FDCs constructed at SWQM stations 18750 and 11840 were based on continuous streamflow data estimated using the drainage area-ratio (DAR) method (Asquith et al. 2006). The stream gage used in DAR for generating continuous streamflow data was the USGS gage 08109700 near Dime Box.

The generalized loading capacity for each of the three flow categories was computed by using the median daily loading capacity within that flow regime (12.5 percent, 50 percent, and 87.5 percent load exceedances). The required daily load reduction was calculated as the difference between the median loading capacity and the geometric mean of observed *E. coli* loading within each flow category. To estimate the needed annual bacteria load reductions, the required daily load was multiplied by the number of days per year in each flow condition. Table A-1 includes the calculations used to determine annual reductions in each flow condition. The sum of load reductions within each flow condition is the estimated annual load reductions required in the watersheds.

Table 32. Bacteria load reduction calculations by flow condition.

	Flow Conditions			
	High Flow	Moist Condition	Mid-Range	Low Flow
Days per year	10%×365	20%×365	30%×365	20%×365
Median Flow (cfs)	Median observed or median estimated flow in each flow category			
Existing Geomean Concentration (MPN/100 mL)	Geometric mean of observed *E. coli* samples in each flow category			
Allowable Daily Load (MPN)	Median Flow (cfs) ×126 MPN/100 mL×283.2 100 mL/cubic foot × 86,400 seconds/day			
Allowable Annual Load (MPN)	Allowable Daily Load × Days per year			
Existing Daily Load (MPN)	Median Flow × Existing Geomean Concentration (MPN/100 mL) × 283.2 100 mL/cfs × 86,400 seconds/day			
Existing Annual Load (MPN)	Existing Daily Load × Days per year			
Annual Load Reduction Needed (MPN)	Existing Annual Load – Allowable Annual Load			
Percent Reduction Needed	100%× (Existing Annual Load – Allowable Annual Load)/Existing Annual Load			
Total Annual Load (MPN)	Sum of Existing Annual Loads			
Total Annual Load Reduction (MPN)	Sum of Annual Load Reductions Needed			
Total Percent Reduction	100%×Total Annual Load Reduction/Total Annual Load			

cfs – cubic foot per second; *E. coli – Escherichia coli,* MPN – most probable number; mL – milliliter.

Appendix A. References

Asquith, W. H., Roussel, M. C., and Vrabel, J. 2006. Statewide analysis of the drainage-area ratio method for 34 streamflow percentile ranges in Texas. 2328-0328. US Geological Survey.

Cleland, B. 2003. TMDL Development From the “Bottom Up” - Part III: Duration Curves and Wet-Weather Assessments. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.566.9879&rep=rep1&type=pdf.

EPA. 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA Watershed Branch. 841-B-07-006. https://www.epa.gov/sites/default/files/2015-07/documents/2007_08_23_tmdl_duration_curve_guide_aug2007.pdf.

Appendix B: Potential Load Calculations

Estimates for potential loads are based on the best available data (e.g., local, state, and federal databases, scientific research) and local stakeholder input (e.g., local livestock stocking practices, feral hog density, pet populations). Potential loading calculations assume the worst-case scenario and are primarily used to assist identification of where management measures should be implemented first to maximize potential load reductions.

Spatial analysis using GIS was performed to estimate the distribution of potential bacteria loads from various sources across the Middle Yegua Creek watershed at subwatershed level, which was defined in the National Hydrography Dataset Plus dataset (EPA 2024). Sources considered in this WPP included livestock, including cattle, horses, goats, and sheep, OSSFs, dogs, feral hogs, and a WWTF.

Cattle

Cattle are the dominant livestock species in the Middle Yegua Creek watersheds. A total of 53,130 cattle were estimated based on the USDA NASS (2024) reported cattle populations at county level and stakeholder input. The USDA NASS estimated cattle populations in Bastrop, Milam, Lee, and Williamson Counties were scaled to the watershed based on the percentage of the cattle population that may be in the Middle Yegua Creek watershed. This percentage is the ratio grazeable land cover in the watershed to that in the county. Potential annual *E. coli* load from cattle was calculated as:

$$PAL_{cattle} = N_{cattle} \times AnU_{cattle} \times FC_{cattle} \times Conversion \times 365\,\frac{days}{year}$$

Where:

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

N_{cattle} = Estimated number of cattle in the watershed

AnU_{cattle} = Animal units of cattle; 1 (Wagner and Moench 2009)

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

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

The estimated potential annual loadings across all subwatersheds due to cattle range between 5.89×10^{6} and 1.35×10^{7} billion cfu.

Goats

A total number of 1,143 goats were estimated based on NASS (2024) estimated county-level goat population and scaled to the watershed in grazeable land cover. Potential annual *E. coli* load from goats was calculated as:

$$PAL_{goat} = N_{goat} \times AnU_{goat} \times FC_{goat} \times Conversion \times 365\,\frac{days}{year}$$

Where:

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

N_{goat} = Estimated number of goats in the watershed

AnU_{goat} = Animal units of goats; 0.17 (Wagner and Moench 2009)

FC_{goat} = Fecal coliform loading rate of goats; 2.54×10^{10} cfu fecal coliform per AnU per day (Wagner and Moench 2009)

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to goats ranged from 6.35×10^{4} to 1.47×10^{5} billion cfu *E. coli* per year.

Horses

A total number of 884 horses were estimated based on NASS (2024) estimated county-level goat population and scaled to the watershed in grazeable land cover. Potential annual *E. coli* load from horses was calculated as:

$$PAL_{horse} = N_{horse} \times AnU_{horse} \times FC_{horse} \times Conversion \times 365\,\frac{days}{year}$$

Where:

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

N_{horse} = Estimated number of horses in the watershed

AnU_{horse} = Animal units of horses; 1.25 (Wagner and Moench 2009)

FC_{horse} = Fecal coliform loading rate of horses; 2.91×10^{8} cfu fecal coliform per AnU per day (Wagner and Moench 2009)

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to horses ranged from 4.18×10^{3} to 9.54×10^{3} billion cfu *E. coli.*

Sheep

A total number of 620 were estimated based on NASS (2024) estimated county-level goat population and scaled to the watershed in grazeable land cover. Potential annual *E. coli* load from sheep was calculated as:

$$PAL_{sheep} = N_{sheep} \times AnU_{sheep} \times FC_{sheep} \times Conversion \times 365\,\frac{days}{year}$$

Where:

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

N_{sheep} = Estimated number of sheep in the watershed

AnU_{sheep} = Animal units of sheep; 0.2 (Wagner and Moench 2009)

FC_{sheep} = Fecal coliform loading rate of sheep; 2.90×10^{11} cfu fecal coliform per AnU per day (Wagner and Moench 2009)

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to sheep ranged from 4.67×10^{5} to 1.07×10^{6} billion *E. coli.*

OSSFs

Based on 911 addresses and satellite imagery, a total of 5,293 OSSFs and their spatial distribution were estimated using GIS spatial analysis. A failure rate of 15% was assumed based on Reed et al. (2001) and adjusted based on stakeholder suggestions. Potential *E. coli* load from OSSFs was calculated as:

$$PAL_{ossf} = N_{ossf} \times N_{hh} \times Production \times Failure\ Rate \times FC_{s} \times Conversion \times 365\,\frac{days}{year}$$

Where:

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

N_{ossf}= Estimated number of OSSFs in the watershed

N_{hh} = Estimated average number of people per household; 2.05

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

Failure Rate = Assumed failure rate; 15%

FC_{s} = Fecal coliform concentration in sewage; 1.0×10^{6} cfu per 100 mL (EPA 2001)

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009) and conversion from mL to gallon; 3785.4 mL per gallon

The estimated potential loading across all subwatersheds due to OSSFs ranges from 4.32×10^{4} to 1.57×10^{5} billion cfu *E. coli* per year.

Feral Hogs

A total of 8,283 feral hog populations were estimated based on an assumed population density of 32 acres per hog. This number was chosen based on stakeholder input and 265,051 acres of available habitat identified in the NLCD. Using the feral hog population estimates, the potential *E. coli* loading across the watersheds was estimated as:

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

Where:

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

N_{fh} = Estimated number of feral hogs

AnU_{fh} = Animal units of feral hogs; 0.125 (Wagner and Moench 2009)

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

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

The estimated potential loading across all subwatersheds due to feral hogs' ranges from 1.55×10^4 to 3.86×10^4 billion cfu of *E. coli* per year.

Dogs

Based on the USCB (2020) data, a total of 4,250 households were estimated in the Middle Yegua Creek watershed. Stakeholders suggested that there was approximately one dog per household, resulting in 4,250 dogs. Additionally, stakeholders indicated that approximately 100% of dog owners do not pick up dog waste. As a result, 4,250 dogs were used to calculate *E. coli* loadings as follows:

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

Where:

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

N_{dog} = Estimated number of dog in the watershed

FC_{dog} = Fecal coliform loading rate of dog; 5.00×10^9 cfu fecal coliform per dog per day

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

Therefore, the estimated potential loading attributed to dogs' ranges from 1.84×10^5 to 1.20×10^6 billion cfu of *E. coli* per year.

WWTFs

Potential loadings from WWTFs were calculated for only one permitted discharger with bacteria monitoring requirements in the Middle Yegua Creek watershed. Potential loads were calculated as the sum of the maximum permitted discharges of all WWTFs multiplied by the maximum permitted *E. coli* concentration:

$$PAL_{wwtf} = Discharge \times Concentration \times Conversion \times 365 \frac{days}{year}$$

Where:

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

Discharge = Maximum permitted daily discharge; 0.2 million gallons per day

Concentration = Maximum average permitted concentration of *E. coli* in wastewater discharge; 126 cfu/100 mL

Conversion = conversion from gallons to mL; 3785.4 mL per gallon

The estimated potential loading across all subwatersheds due to WWTF discharges ranges from 0 to 0.000348 billion cfu *E. coli* per year.

Appendix B. References

AVMA. 2022. AVMA 2022 Pet Ownership and Demographic Sourcebook. https://ebusiness.avma.org/files/ProductDownloads/eco-pet-demographic-report-22-low-res.pdf.

EPA. 2001. Protocol for Developing Pathogen TMDLs: Source Assessment. First Edition. EPA Office of Water. 841-R-00-002. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt.

EPA. 2024. National Hydrography Dataset Plus Data. https://www.epa.gov/waterdata/get-nhdplus-national-hydrography-dataset-plus-data#Download.

Swann, C. 1999. A Survey of Residential Nutrient Behaviors in the Chesapeake Bay. Prepared for Chesapeake Research Consortium. Ellicot City, MD: Center for Watershed Protection. https://cfpub.epa.gov/npstbx/files/UNEP_all.pdf.

USCB. 2020. TIGER/Line Census Block Shapefiles. https://data.census.gov/cedsci/.

USDA. National Agricultural Statistics Service. 2024. 2022 Census of Agriculture United States Summary and State Data. https://www.nass.usda.gov/Publications/AgCensus/2022/index.php#full_report.

Wagner, K. L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, TX: Texas Water Resources Institute. TR-347. https://oaktrust.library.tamu.edu/handle/1969.1/93181.

Appendix C: Calculations for Potential Bacteria Load Reductions

Estimates for bacteria load reductions in the Middle Yegua Creek watershed are based on the best available information regarding the effectiveness of management measures agreed upon by local stakeholders. Real world conditions based on where implementation is completed would ultimately determine the actual load reduction achieved and might differ from estimated values. Local stakeholders determined the types and numbers of management measures to be implemented over a ten-year period based on perceived local acceptability, effectiveness, and available resources.

Livestock Management

The potential load reductions that are achieved through WQMPs/CPs would depend on the specific practices implemented by landowners. Load reduction through this management measure would vary based on the type of practice, the number of cattle (dominant livestock) in each operation, and the effectiveness of the practice.

Substantial research has been conducted on bacteria reduction efficiencies of practices. By reviewing the median effectiveness of practices in the literature and an average bacteria load reduction effectiveness of 62.8% was used (Table 33).

The number of cattle per operation was estimated using the ratio of the estimated number of total cattle in the watershed to the estimated number of operations, which was scaled from the USDA (2024) county-level number of operations to the grazeable lands in the watershed. A total of 865 operations were estimated to be in the watershed, and the average number of cattle per operation was estimated to be 61.42.

The plan type coefficient describes the percentage of the adopted WQMPs/CPs that involve conservation practices that are 62.8% effective at reducing bacteria loads and are applied to manage primary cattle. Since actual practices are unknown, we assumed that 25% of the total WQMPs/CPs implemented per year include practices related to reducing bacteria loads attributable to cattle.

Table 33. Conservation practice effectiveness in reducing bacteria loads.

	Effectiveness		
Conservation Practice	**Low**	**High**	**Median**
Exclusionary Fencing[1]	30%	94%	62%
Prescribed Grazing[2]	42%	66%	54%
Watering Facility[3]	51%	94%	73%

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

Using the above assumptions, the potential annual load reduction from cattle management was estimated as:

$$LR_{cattle} = N_{plan} \times \frac{AnU}{Plan} \times FC_{cattle} \times Conversion \times 365 \frac{days}{year} \times BMP\ Efficacy \times Plan\ Type\%$$

Where:

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

N_{plan} = Number of WQMPs/CPs; 10 per year

$\frac{AnU}{Plan}$ = Animal Units of cattle per WQMP/CP; 61.42

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

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

BMP Efficacy = Average BMP efficacy value; 62.8%

Plan Type% = Assumed percentage of the WQPMs/CPs that involve conservation practices in Table 33 or similar practices; 25%

The WPP recommends the adoption of 10 voluntary WQMPs/CPs per year across the entire Middle Yegua watershed, resulting in a total potential reduction of 1.90×10^{14} billion cfu of *E. coli* per year.

Additionally, nutrient reductions can be anticipated with each WQMP/CP. The Tres Palacios WPP and Carancahua Bay WPP estimated annual load reductions ranging from 733 to 983 lbs of nitrogen and 276 to 511 lbs of phosphorus per WQMP/CP depending on presumed size and type of agricultural operation (Schramm et al. 2017; Schramm et al. 2019).

Feral Hog Control

Load reduction through feral hog control will vary based on the number of feral hogs reduced from the existing population in the watershed. Based on discussions with the stakeholder group, the goal was set to reduce and maintain the feral hog population 15% below the current population.

It was also assumed that removal of a feral hog from the watershed will completely remove the potential bacteria load generated by that feral hog. Accordingly, a 15% reduction in bacteria loads attributed to feral hogs was assumed.

Potential annual load reduction was estimated as:

$$LR_{fh} = N_{fh} \times AnU_{fh} \times FC_{fh} \times Conversion \times 365\frac{days}{year}$$

Where:

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

N_{fh} = Number of feral hogs estimated to be removed annually

AnU = Animal Unit conversion factor; 0.125 (Wagner and Moench 2009)

FC_{fh} = Fecal coliform loading rate of feral hogs; 1.21×10^9 (Wagner and Moench 2009)

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

The estimated potential load reduction across the Middle Yegua Creek watershed based on reducing and maintaining the feral hog population by 15% (1,242 feral hogs) is 4.32×10^{13} billion cfu of *E. coli* annually.

Additionally, nutrient reductions can be anticipated for each feral hog removed. The Tres Palacios WPP and Carancahua Bay WPP estimated annual load reductions of 6 lbs of nitrogen and 2 lbs of phosphorus per feral hog removed (Schramm et al. 2017; Schramm et al. 2019).

Pet Waste Management

Potential load reductions from pet (primarily dog) waste management varies depending on the number of dog owners that change their behavior to properly dispose of dog waste and the efficacy of such a practice.

Assessing the number of dog owners who do not pick up waste and would change behavior based on education is inherently difficult. It is estimated that 3,349 households with dogs located close to water bodies in the Middle Yegua Creek watershed and, assuming 12% of dogs in the watershed would change their behavior (Swan 1999), and the efficacy of this practice is 75%, potential annual load reduction was estimated as:

$$LR_{dog} = N_{dog} \times Change\% \times FC_{dog} \times Conversion \times 365\frac{days}{year} \times Efficacy$$

Where:

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

N_{dog} = Estimated number of dogs close to water bodies; 4,250

Change% = Estimated percentage of dog owners change behavior; 12%

FC_{fh} = Fecal coliform loading rate of dogs; 5.0×10^9 (Wagner and Moench 2009)

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

Efficacy = Assumed the efficacy of proper dog waste disposal in load reduction; 75%

The estimated potential load reduction attributed to this management measure in the Middle Yegua Creek watershed is 4.40×10^{14} billion cfu of *E. coli* annually.

Additionally, nutrient reductions can be anticipated for every additional dog managed. The Tres Palacios WPP and Carancahua Bay WPP estimated annual load reductions between 0.8 and 1.0 lbs of nitrogen and 0.2 lbs of phosphorus per additional dog managed (Schramm et al. 2017; Schramm et al. 2019).

OSSFs

OSSFs are commonly installed and used in the Middle Yegua watershed with an estimated 5,293 OSSFs. OSSF failures are factors of system age, soil suitability, system design and maintenance. For this area of the state, a 15% failure rate was suggested by stakeholders. Given the difficulty and cost of replacing 15% of the total OSSF systems in the watershed, stakeholders decided to target 1.5% of the potentially failing systems, i.e., 8 OSSFs, for repair or replacement per year. Load reductions can be calculated as the number of assumed failing OSSFs replaced. Potential annual load reduction was estimated as:

$$LR_{ossf} = N_{ossf} \times N_{hh} \times Production \times FC_s \times Conversion \times 3{,}578.2\ \frac{mL}{gallon} \times 365\,\frac{days}{year}$$

Where:

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

N_{ossf}= Number of OSSFs repaired/replaced annually; 8

N_{hh} = Average number of people per household; 2.20

Production = Assumed sewage production rate; 70 gallons per person per day (XXX)

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

Conversion = Conversion from estimated fecal coliform to *E. coli;* 126/200 (Wagner and Moench 2009)

In the Middle Yegua Creek watershed, it is assumed that 8 OSSFs to be repaired or replaced. It results in a potential reduction of 1,286.88 billion cfu *E. coli* annually.

Additionally, nutrient reductions can be anticipated for every OSSF replaced. The Tres Palacios WPP and Carancahua Bay WPP estimated annual load reductions between 11.6 and 20.5 lbs of nitrogen and 2.9 and 4.8 lbs of phosphorus per additional OSSF repaired or replaced (Schramm et al. 2017; Schramm et al. 2019).

Appendix C References

Borel, K., Karthikeyan, R., Berthold, A. T., Wagner, K. 2015. Estimating *E. coli* and Enterococcus loads in a coastal Texas watershed. Texas Water Journal. 6 (1):33-44. https://doi.org/10.21423/twj.v6i1.7008.

Brenner, F.J., Mondok, J.J, McDonald, Jr, R.J. 1996. Watershed Restoration through Changing Agricultural Practices. Proceedings of the AWRA Annual Symposium Watershed Restoration Management: Physical, Chemical and Biological Considerations. Herndon, VA: American Water Resources Association, TPS-96-1, pp. 397-404.

Byers, H.L., Cabrera, M.L., Matthews, M.K., Franklin, D.H., Andrae, J.G., Radcliffe, D.E., McCann, M.A., Kuykendall, H.A., Hoveland, C.S., Calvert II, V.H. 2005. Phosphorus, sediment, and Escheria coli loads in unfenced streams of the Georgia Piedmont, USA. Journal of Environmental Quality. 34: 2293-2300. https://acsess.onlinelibrary.wiley.com/doi/abs/10.2134/jeq2004.0335.

Cook, M.N. 1998. Impact of animal waste best management practices on the bacteriological quality of surface water. Master's Thesis. Virginia Polytechnic Institute and State University. http://hdl.handle.net/10919/36762.

EPA. 2001. Protocol for Developing Pathogen TMDLs: Source Assessment. First Edition. EPA Office of Water. 841-R-00-002. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt.

EPA. 2010. Implementing Best Management Practices Improves Water Quality. Washington D.C.: EPA Office of Water. 841-F-10-001F. https://www.epa.gov/sites/production/files/2017-07/documents/va_robinson_508.pdf.

Hagedorn, C., Robinson, S.L., Filts, J.R., Grubbs, S.M., Angier, T.A., Reneau Jr., R.B. 1999. Determining sources of fecal pollution in a rural Virginia watershed with antibiotic resistance patterns in fecal streptococci. Applied and Environmental Microbiology. 65: 5522-5531. https://pubmed.ncbi.nlm.nih.gov/10584013/.

Line, D.E. 2002. Changes in land use/management and water quality in the Long Creek watershed. Journal of the American Society of Agronomy. 38(6): 1691-1701. https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1111%2Fj.1752-1688.2002.tb04374.x.

Line, D.E. 2003. Changes in a stream's physical and biological conditions following livestock exclusion. Transactions of the ASAE. 46(2): 287-293. https://elibrary.asabe.org/abstract.asp?aid=12979.

Lombardo, L.A., Grabow, G.L., Spooner, J., Line, D.E., Osmond, D.L., Jennings, G.D. 2000. Section 319 Nonpoint Source National Monitoring Program: Successes and Recommendations. Raleigh, NC: NCSU Water Quality Group, Biological and Agricultural Engineering Department, NC State University. https://www.epa.gov/sites/production/files/2015-10/documents/nmp_successes.pdf.

Meals, D.W. 2001. Water quality response to riparian restoration in an agricultural watershed in Vermont, USA. Water Science Technology 43(5):175-182. https://doi.org/10.2166/wst.2001.0280.

Meals, D.W. 2004. Water quality improvements following riparian restoration in two Vermont agricultural watersheds. In Manley, T.O., Manley, P.L., and Mihuc, T.B. (Editors.), Lake Champlain: Partnerships and Research in the New Millennium. New York: Kluwer Academic/Plenum Publishers. https://link.springer.com/chapter/10.1007/978-1-4757-4080-6_6.

Peterson, J.L., Redmon, L.A., McFarland, M.L. 2011. Reducing Bacteria with Best Management Practices for Livestock: Heavy Use Area Protection. College Station, TX: Texas A&M AgriLife Extension Service. ESP-406. https://agrilifeextension.tamu.edu/library/ranching/reducing-bacteria-heavy-use-area-protection/.

Reed, Stowe & Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas. Austin, TX: Reed, Stowe & Yanke, LLC. www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/ossf/StudyToDetermine.pdf.

Schramm, M., Berthold, A., Entwistle, C. 2017. Tres Palacios Watershed Protection Plan. TR-500. College Station, TX: Texas Water Resources Institute. http://matagordabasin.tamu.edu/media/1247/tr-500.pdf.

Schramm, M., Ruff, S., Jain, S., Berthold, A., Mohandass, U. 2019. Carancahua Bay Watershed Protection Plan. TR-514. College Station, TX: Texas Water Resources Institute. https://twri.tamu.edu/media/4974/tr-514.pdf.

Sheffield, R.E., Mostaghimi, S., Vaughan, D.H., Collins Jr., E.R., Allen, V.G. 1997. Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. Transactions of the ASAE. 40(3): 595-604. https://elibrary.asabe.org/abstract.asp?aid=21318.

Swann, C. 1999. A Survey of Residential Nutrient Behaviors in the Chesapeake Bay. Prepared for Chesapeake Research Consortium. Ellicot City, MD: Center for Watershed Protection. https://cfpub.epa.gov/npstbx/files/UNEP_all.pdf.

Tate, K.W., Pereira, M.D.G., Atwill, E.R. 2004. Efficacy of vegetated buffer strips for retaining Cryptosporidium parvum. Journal of Environmental Quality. 33(6): 2243-2251. https://doi.org/10.2134/jeq2004.2243.

Wagner, K. L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, TX: Texas Water Resources Institute. TR-347. https://oaktrust.library.tamu.edu/handle/1969.1/93181.

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 should be 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

Identify 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 or extrapolated from a subwatershed inventory, aerial photos, GIS data, or other sources.

B: Estimated Load Reductions

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

C: Proposed Management Measures

Describe 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

Estimate 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

Information/education components 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: Implementation Schedule

Schedule implementing the nonpoint source pollution management measures identified in the plan that is reasonably expeditious.

G: Milestones

Provide 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

Determine 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

Include 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.

Name of Water Body	Middle Yegua Creek
Assessment Units	1212A_01; 1212A_02
Impairments Addressed	Bacteria

Element	Report Section(s)
Element A: Identification of Causes and Sources of Impairment	
1. Sources identified, described and mapped	Chapters 3, 4, 5, and Appendix B
2. Subwatershed sources	Chapter 5
3. Data sources are accurate and verifiable	Chapter 5 and Appendix B
4. Data gaps identified	Appendices A and B
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	Chapter 5 and Appendix C
2. Load reductions linked to sources	Chapter 5
3. Model complexity is appropriate	Appendix C
4. Basis of effectiveness estimates explained	Chapter 6 and Appendix C
5. Methods and data cited and verifiable	Appendix C
Element C: Management Measures Identified	
1. Specific management measures are identified	Chapter 6
2. Priority areas	Chapter 6
3. Measure selection rationale documented	Chapter 6
4. Technically sound	Chapter 6
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	Chapter 9
2. Estimate of financial assistance	Chapter 9
Element E: Education/Outreach	
1. Public education/information	Chapter 7
2. All relevant stakeholders are identified in outreach process	Chapter 7
3. Stakeholder outreach	Chapter 7
4. Public participation in plan development	Chapter 7
5. Emphasis on achieving water quality standards	Chapter 7
6. Operation and maintenance of BMPs	Chapter 8
Element F: Implementation schedule	
1. Includes completion dates	Chapter 8
2. Schedule as appropriate	Chapter 8

Element	Report Section(s)
Element G: Milestones	
1. Milestones are measurable and attainable	Chapters 8 and 10
2. Milestones include completion dates	Chapters 8 and 10
3. Progress evaluation and course correction	Chapters 8 and 10
4. Milestones linked to schedule	Chapters 8 and 10
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	Chapter 6
2. Criteria measure progress toward load reduction goal	Chapter 6
3. Data and models identified	Chapter 6
4. Target achievement dates for reduction	Chapter 10
5. Review of progress towards goals	Chapter 10
6. Criteria for revision	Chapter 10
7. Adaptive management	Chapter 10
Element I: Monitoring	
1. Description of how monitoring is used to evaluate implementation	Chapter 10
2. Monitoring measures evaluation criteria	Chapter 10
3. Routine reporting of progress methods	Chapter 10
4. Parameters are appropriate	Chapter 10
5. Number of sites is adequate	Chapter 10
6. Frequency of sampling is adequate	Chapter 10
7. Monitoring tied to QAPP	Chapter 10
8. Can link implementation to improved water quality	Chapter 10

Appendix D. References

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Washington, DC: United States Environmental Protection Agency Office of Water, Nonpoint Source Control Branch. EPA 841-B-08-002. https://www.epa.gov/sites/production/files/2015-09/documents/2008_04_18_nps_watershed_handbook_handbook-2.pdf.

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