Bois d'Arc Lake Watershed Protection Plan

A guidance document developed by the stakeholders of the Bois d'Arc Lake watershed to address water quality in Bois d'Arc Creek and Honey Grove Creek.

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Authored and prepared by:

Stephanie deVilleneuve[1], Allen Berthold[1], Luna Yang[1], David Cowan[2], and Galen Roberts[2]

Texas Water Resources Institute[1]

North Texas Municipal Water District[2]

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Cover photo: Bois d'Arc Lake.
Photo courtesy of the North Texas Municipal Water District.

Acknowledgments

This document and the efforts behind its completion are the result of collaboration and cooperation between many different groups and individuals. These stakeholders have played an important role in the Bois d'Arc Lake Watershed Partnership. First and foremost, the partnership wishes to express thanks to the members of the steering committee for their investments of time and energy in participating throughout the process. Without their direction and support, development of this plan would not have been possible. Through the Bois d'Arc Lake Watershed Protection Plan, their efforts serve as an example to all stakeholders of the importance of active stewardship of water resources.

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- Texas A&M AgriLife Research and Extension Service
- Texas Commission on Environmental Quality
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board
- U.S. Department of Agriculture Natural Resources Conservation Service

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Bois d'Arc Lake. Photo courtesy of the North Texas Municipal Water District.

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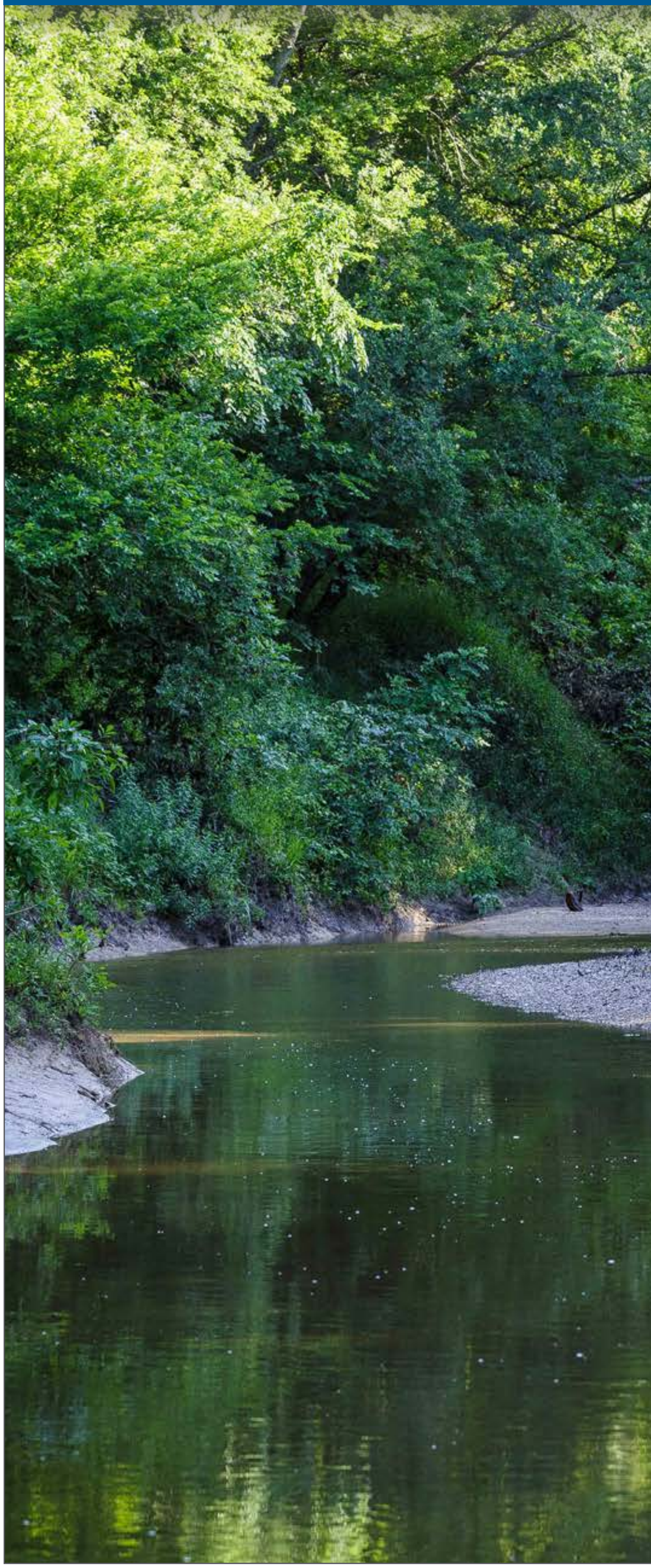
List of Abbreviations

Acronym	Meaning
μg	Microgram
AgriLife Extension	Texas A&M AgriLife Extension Service
AnU	Animal Units
AU	Assessment Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
cfu	Colony Forming Units
CP	Conservation Plan
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
DAR	Drainage-Area Ratio Method
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	Fahrenheit
FDC	Flow Duration Curve
FNI	Freese and Nichols, Inc.
FSA	Farm Service Agency
GIS	Geographic Information System
HSG	Hydrologic Soil Groups
I&I	Inflow and Infiltration
L	Liter
lb	pound
LDC	Load Duration Curve
LULC	Land Use Land Cover
mg	Milligram
MGD	Million Gallons per Day
mL	Milliliter
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer Systems
MSL	Mean Sea Level
NASS	National Agricultural Statistics Service
NHD	National Hydrography Dataset

Acronym	Meaning
NIWQP	National Integrated Water Quality Program
NLCD	National Land Cover Database
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
NTMWD	North Texas Municipal Water District
NWQI	National Water Quality Initiative
OSSF	On-site Sewage Facilities
PGMA	Priority Groundwater Management Area
RMU	Resource Management Unit
RRA	Red River Authority
RRGCD	Red River Groundwater Conservation District
RUAA	Recreational Use-Attainability Analysis
SCR1	Secondary Contact Recreation 1
SEP	Supplemental Environmental Projects
SMP	Shoreline Management Plan
SSO	Sanitary Sewer Overflow
SWCD	Soil and Water Conservation District
SWQM	Surface Water Quality Monitoring
TAG	Technical Advisory Group
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TST	Texas Stream Team
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TxWAC	Texas Water Action Collaborative
USACE	U.S. Army Corp of Engineers
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



Bois d'Arc Creek at State Highway 78. Photo by Ed Rhodes, TWRI.

A watershed is an area of land that drains to a common body of water. Within a watershed, water follows natural hydrologic boundaries and is influenced by the landscape it flows across and through. Both natural and human-influenced processes that occur within a watershed alter the quantity and quality of water within the system. This document presents a plan to restore and protect water quality in the Bois d'Arc Lake watershed. By approaching water quality issues at the watershed level rather than political boundaries, this plan holistically identifies potential pollutant sources and solutions. This approach also incorporates the values, visions, and knowledge of people with a direct stake in water quality conditions.

Problem Statement

Routine water quality monitoring indicates Bois d'Arc Creek and Honey Grove Creek do not meet water quality standards for recreation because of elevated levels of bacteria. Elevated nutrients (nitrate, total phosphorus, and chlorophyll-a) are also higher than normal when compared to similar water bodies.

Response

With the water quality impairments comes a need to plan and implement actions 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 Bois d'Arc Lake Watershed Protection Plan.

The planning process began with a stakeholder group meeting in the summer of 2021 to form a steering committee and establish structure and rules. Over the next eight months, North Texas Municipal Water District and Texas Water Resources Institute met with the steering committee and stakeholders to provide data and information and receive feedback on approaches used to assess and characterize water quality in the watershed. The steering committee and stakeholders provided direct input to assumptions used in the pollutant load analysis and decided upon the management measures most likely to be successful and be implemented by the watershed community.

Watershed Protection Plan Overview

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

Pollutant Reductions

Analysis of water quality and streamflow data indicate a bacterial load reduction of approximately 23% annually is needed to meet water quality standards for recreation in Bois d'Arc Creek. Furthermore, an approximate 88% reduction in bacterial load annually is required to meet water quality standards for recreation in Honey Grove Creek.

No single pollutant source is the primary cause of water quality impairments in Bois d'Arc Creek and Honey Grove Creek. A variety of sources, including livestock, wildlife, septic systems, urban stormwater, failing wastewater systems, and pets, may contribute bacterial and nutrient loads to the watershed. Therefore, stakeholders identified a variety of diverse and feasible management measures that will reduce bacteria and subsequently nutrient loads in Bois d'Arc Creek and Honey Grove Creek. Full implementation of the management measures over 10 years will reduce potential *E. coli* bacterial loads by approximately 5.3×10^{15} colonies per year.

Management Measures Identified to Reduce Pollutants

Developing and Implementing Water Quality Management Plans or Conservation Plans

Bacterial and nutrient loads from agriculture can be managed through a variety of best practices that reduce runoff, retain soil, and improve production. Producers can work with their local soil and water conservation district and U.S. Department of Agriculture Natural Resources Conservation Service office to identify, plan, and fund the implementation of these practices by developing a water quality management plan or conservation plan. This document establishes a goal of 100 water quality management plans or conservation plans developed across the watershed.

Promote Technical and Operational Assistance to Landowners for Feral Hog Control

Feral hog populations have expanded dramatically across Texas, causing substantial damage to riparian habitat and contributing fecal bacterial loads to water bodies. Furthermore, feral hogs cause substantial damage to crops and pastures. The complete eradication of feral hogs is not feasible; however, managing populations is important for water quality and to crop producers. The watershed protection plan recommends continued promotion of feral hog management activities. This includes construction of exclosures around deer feeders, trapping and removal of feral hogs, and delivery of feral hog management workshops. The goal of the plan is to reduce and maintain the current feral hog population by approximately 15%. This includes eliminating 66% of the population annually to keep numbers from increasing.

Identify, Inspect, and Repair or Replace Failing On-Site Sewage Facilities

Stakeholders identified failing and nonexistent septic systems (referred to as on-site sewage facilities in this document) as a prime concern. The exact number of failing on-site sewage facilities is unknown, but soils in the watershed are not suitable for conventional on-site sewage facilities, and literature suggest that at least 15% of systems in the area are failing. This document recommends repairing and replacing 30 systems across the watershed with stakeholder aspirations of replacing many more.

Reduce the Amount of Pet Waste Mixing into Water Bodies

Relative to other sources of fecal bacteria, pet waste contains high concentrations of fecal bacteria per unit volume. Therefore, dog waste can contribute relatively high amounts of bacterial loading, which can be easily managed. The low residential density and lack of public areas provide a substantial challenge in reaching pet owners and encouraging behavior change. The plan recommends that resident and visitor knowledge about pet waste impacts, especially in subdivisions around Bois d'Arc Creek and Honey Grove Creek, be increased by delivery of education and outreach materials. The goal is to change behavior of pet owners in the area, resulting in more pet waste being properly managed.

Implement and Expand Urban and Impervious Surface Stormwater Runoff Management

Urban stormwater is predicted to increase as the watershed continues to develop and grow. Proper management of urban stormwater includes stormwater planning and best management practices implementation to reduce bacterial and nutrient runoff from entering the creek. The plan includes working with cities to identify appropriate areas to implement green stormwater infrastructure, riparian restoration, and other practices.

Identify Potential Wastewater Conveyance System Failure and Prioritize System Repairs or Replacement

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

Reduce Illicit and Illegal Dumping

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

Volunteer Monitoring on Other Streams in the Watershed

Stakeholders expressed concern over the lack of water quality data on other streams in the watershed that drain into Bois d'Arc Lake. They recommended that additional water quality monitoring will help determine if there are any negative effects on bacterial loads in Bois d'Arc Lake from the other streams. This watershed protection plan recommends stakeholders work with the Texas Stream Team to develop a volunteer water quality monitoring program in the watershed to collect data on the water bodies stakeholders determine to be the biggest concerns.

Conduct Soil Tests for Agricultural and Urban Areas

Increased nutrient loading from runoff can lead to reduced dissolved oxygen in surface water bodies. This watershed protection plan recommends education and outreach to encourage both urban and rural landowners to conduct soil testing to prevent the over-fertilization of lawns and agricultural fields. Proper fertilization rates will help landowners save money and reduce nutrient loads in the watershed.

Conduct New or Small Landowner Education Workshop Program

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

As shown by the consistent integration of education into the recommended actions described above, education will be a mainstay of implementing the Bois d'Arc Lake Watershed Protection Plan. Stakeholder meetings will be held as needed and supplemented with topically relevant education and outreach events to maintaining local interest in watershed protection plan implementation. Additionally, they will provide a necessary local platform for conveying and illustrating implementation successes.

Goals

The primary goal of the Bois d'Arc Lake Watershed Protection Plan is to restore water quality in Bois d'Arc Creek and Honey Grove Creek to water quality standards set by the state of Texas through the long-term conservation and stewardship of the watershed's resources.

To achieve this goal, the plan establishes a 10-year implementation schedule with interim milestones and water quality targets to track progress toward reducing bacteria levels. The current water quality target, based on the primary contact recreation water quality standard, is 126 colony forming units (cfu) *E. coli*/100 milliliters (mL).

Because *E. coli* is the sole cause of water quality impairment in the watershed, reduction goals for other pollutants were not established. However, stakeholders recognize the dynamic nature of the Bois d'Arc Lake watershed and acknowledge the recommended measures will reduce pollution from sources of nutrients, sediment, and hazardous substances in order to prevent new water quality impairments from arising in the future.

Ultimately, this plan sets forth an approach to improve stewardship of the watershed resources that allows stakeholders to continue relying on the watershed as part of their livelihood while also restoring the quality of its water resources.

Chapter 1
Introduction to Watershed Management

Bois d'Arc Lake at sunset from Old FM 1396 South. Photo by Ed Rhodes, TWRI.

A watershed is the land area surrounding a water body that drains to a common waterway such as a stream, river, or lake. All the land surfaces that contribute runoff to a water body are considered part of the watershed. Watersheds can vary greatly in size. Some watersheds can be very small and drain only a few square miles. Conversely, larger watersheds can encompass many smaller watersheds and drain large portions of states or regions of the country. The Bois d'Arc Lake watershed is approximately 326 square miles (208,454 acres) and is composed of smaller watersheds that include Bois d'Arc Creek, Lake Bonham, and Honey Grove Creek.

Watersheds and Water Quality

Natural processes and human activities can influence water quality and quantity within a watershed. For example, rain falling on the land area within a watershed might generate runoff that then flows across agricultural fields, lawns, roadways, industrial sites, grasslands, or forests.

Point source pollution is categorized as being discharged from a defined point or location, such as a pipe or a drain, and can be traced back to a single point of origin. This type of pollution is typically discharged directly into a water body and subsequently contributes to the water body's flow. Point sources of pollution are permitted to discharge their effluent within specific pollutant limits must hold a permit through the Texas Pollutant Discharge Elimination Systems (TPDES).

Pollution that comes from a source that does not have a single point of origin is defined as nonpoint source pollution. This type of pollution is generally composed of pollutants that are picked up and carried by runoff in stormwater during rain events. Runoff that travels across land can pick up natural and anthropogenic pollutants impacting water quality. The concentrations and types of pollutants in stormwater also determine suitability of water uses such as irrigation, drinking or recreational contact. To effectively identify and address water quality issues in a watershed, this watershed protection plan (WPP) addresses potential contaminants from both point sources and nonpoint sources.

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 backed 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 to all potential stakeholders.

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

Watershed Protection Plan

WPPs are locally driven mechanisms for voluntarily addressing complex water quality problems that cross political boundaries. A WPP serves as a framework to better leverage and coordinate resources of local, state, and federal agencies, in addition to nongovernmental organizations.

The Bois d'Arc Lake WPP follows EPA's nine key elements, which are designed to provide guidance for the development of an effective WPP (EPA 2008). WPPs will vary in methodology, content, and strategy based on local priorities and needs. However, common fundamental elements are included in successful plans and include (see Appendix C – Elements of Successful Watershed Protection Plans):

A. Identification of causes and sources of impairment

B. Expected load reductions from management strategies

C. Proposed management measures

D. Technical and financial assistance needed to implement management measures

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

F. Schedule for implementing management measures

G. Milestones for progress of WPP implementation

H. Criteria for determining successes of WPP implementation

I. Water quality monitoring

Adaptive Management

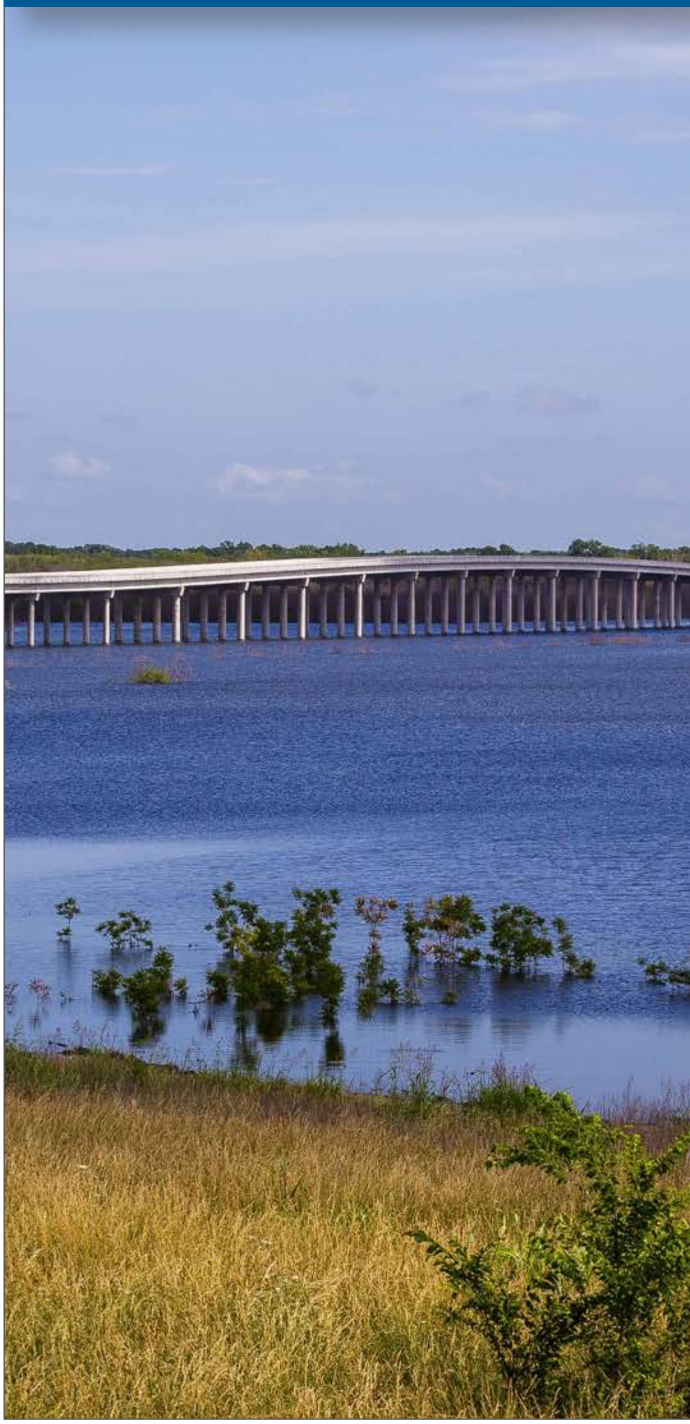
Adaptive management consists of developing a natural resource management strategy to facilitate decision-making based on an ongoing science-based process. Such an approach includes results of continual testing, monitoring, evaluating applied strategies, and revising management approaches to incorporate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

As management measures recommended in a WPP are put into action, water quality and other measures of success will be monitored so adjustments can be made as needed to the implementation strategy. The use of an adaptive management process will help to focus effort, implement strategies, and maximize impact on pollutant loadings throughout the watershed over time.

Education and Outreach

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

Chapter 2 Bois d'Arc Lake Watershed Partnership



FM 897 bridge from FM 897 boat ramp. Photo by Ed Rhodes, TWRI.

Partnership Formation

Local public involvement is critical for successful development and implementation of a WPP. To inform and educate citizens from across the watershed and engage them in the planning process, an information and education campaign was conducted at the outset of the project. Press releases were developed and delivered in the watershed in advance of the planning process using key media outlets including local newspapers and newsletters. Stakeholders were defined as those who make and implement decisions, those who are affected by the decisions made, and those who can assist with implementation of the decisions.

Following these efforts, a public meeting was announced and held in June 2021 in Bonham, Texas. Thirty-two stakeholders attended this public meeting, where information was provided regarding conditions in the Bois d'Arc Lake watershed and the proposed development of a WPP. Participants were invited to become members of the Bois d'Arc Lake Watershed Partnership and asked to help notify other potential stakeholders who should be part of the process.

Partnership Meetings

Monthly public meetings facilitated by North Texas Municipal Water District (NTMWD) were held in the watershed. Technical issues were presented in detail to the partnership for discussion and evaluation, and recommendations were developed and forwarded to the steering committee for consideration and approval. All meetings were open to the public, with announcements sent out via email and news release and posted on the project website. A total of six partnership meetings were conducted during the plan development process.

Partnership Structure

Steering Committee Structure

The Bois d'Arc Lake Watershed Partnership is made up of the steering committee, technical advisory committee, and other watershed stakeholders. The steering committee was formed from the stakeholder group to serve as a decision-making body for the partnership. To obtain equitable geographic and topical representation, solicitations for steering committee members were conducted using three methods: (1) as part of the public meetings held in the watershed, (2) at meetings with various stakeholder interest groups and individuals, and (3) following consultation with the Texas A&M AgriLife Extension Service county agent, soil and water conservation district (SWCD) in the watershed, and local and regional governments. Self-nomination or requests by various stakeholder groups or individuals were welcomed.

The steering committee was designed to reflect the diversity of interests within the Bois d'Arc Lake watershed and to incorporate the viewpoints of those who will be affected by the WPP. Members include both private individuals and representatives of organizations and agencies. The size of the steering committee was limited to 10 members solely for reasons of practicality.

Types of stakeholders represented on the steering committee were:

- Landowners
- Agriculture producers
- Business and industry representatives
- Academia
- County and city officials
- Educators
- Soil and water conservation districts
- Nonprofit organizations

Ground rules were developed for the members to understand their roles and responsibilities, as well as to provide guidance throughout the development and implementation of the WPP. Clear ground rules added structure and improved the efficiency of the group.

The steering committee considered and incorporated the following into the development of the WPP:

- Economic feasibility, affordability, and growth
- Unique environmental resources of the watershed
- Regional planning efforts
- Regional cooperation.

Development of the Bois d'Arc Lake WPP required a 10-month period. However, achieving water quality improvements likely will require significantly more time, because implementation is an iterative process of executing programs and practices with evaluation of results and interim milestones and reassessment of strategies and recommendations. Because of this, the steering committee will continue to function throughout implementation of the WPP.

Committee members assisted with identification of the desired water quality conditions and measurable goals, prioritization of programs and practices to achieve water quality and programmatic goals, development and review of the WPP document, and communication regarding implications of the WPP to other affected parties in the watershed.

As an expression of their approval and commitment to successful implementation of the plan, steering committee members approved the final WPP.

Technical Advisory Group

A technical advisory group (TAG) consisting of state and federal agencies with water quality responsibilities provided guidance to the steering committee and partnership. The TAG assisted with WPP development by serving as a technical resource and answering questions related to the jurisdictions of their agencies. The TAG included representatives from the following agencies:

- Texas A&M AgriLife Extension Service
- Texas Commission on Environmental Quality (TCEQ)
- Texas Parks and Wildlife Department (TPWD)
- Texas State Soil and Water Conservation Board (TSSWCB)
- EPA
- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)

Chapter 3
Watershed Characterization

Hay field and water tower north of Trenton, TX. Photo by Ed Rhodes, TWRI.

Introduction

This chapter provides geographic, demographic, and water quality overviews of the Bois d'Arc Lake watershed. Development of the information within this chapter relied heavily on state and federal data resources as well as local stakeholder knowledge. The collection of this information is critical for the reliable assessment of potential sources of water quality impairment and the recommendation of beneficial management measures.

Watershed Description

The Bois d'Arc Lake watershed lies within the larger Red River Basin, which begins in the Panhandle and runs east along the Texas-Oklahoma border for approximately 400 miles. The watershed captures runoff from 326 square miles (208,454 acres) of mostly grasslands and is located in portions of Fannin and Grayson counties (Figure 1). There are seven incorporated towns and cities (Table 1) in the watershed with the city of Bonham being the largest urban area. There are also seven unincorporated towns in the watershed: Allen's Chapel, Carson, Cotton Center, Ely, Lamasco, Lannius, and Randolph. The four main waterbodies within the watershed are Bois d'Arc Creek, Honey Grove Creek, Lake Bonham, and Bois d'Arc Lake.

Bois d'Arc Lake is located immediate upstream of the Bois d'Arc Lake dam and stretches throughout the northern area of the watershed adjacent to Lake Bonham. One of the lake's tributaries, Bois d'Arc Creek, begins from the southwestern arm of the lake and extends upstream approximately 30 miles to the headwater northwest of Whitewright. The Bois d'Arc Creek subwatershed drains approximately 96,525 acres into the lake (Table 2). In the 1940s, much of Bois d'Arc Creek was channelized to mitigate flooding. The lake's other major tributary, Honey Grove Creek, begins from the most eastern arm of the lake and extends upstream approximately 5 miles to the headwater west of the city of Honey Grove.

Table 1. Incorporated towns and cities in the Bois d'Arc Lake watershed (USCB 2019).

Name	U.S. Census Bureau population estimate	County
Bonham	10,386	Fannin
Boyd	1,518	Fannin
Dodd City	389	Fannin
Honey Grove	1,737	Fannin
Midway	236	Fannin
Whitewright	1,721	Grayson
Windom	205	Fannin

Table 2. Bois d'Arc Lake subwatershed drainage areas.

Subwatershed	Percentage of total	Acres	Square miles
Bois d'Arc Creek	46.2%	96,252	151
Honey Grove Creek	2.22%	4,645	7
Bois d'Arc Lake[1]	43.26%	90,203	141
Lake Bonham[2]	8.32%	17,354	27
Total	100.0%	208,454	326

[1] Surface area of Bois d'Arc Lake at conservation pool elevation and subwatershed drainage area
[2] Surface area of Lake Bonham at conservation pool elevation and subwatershed drainage area

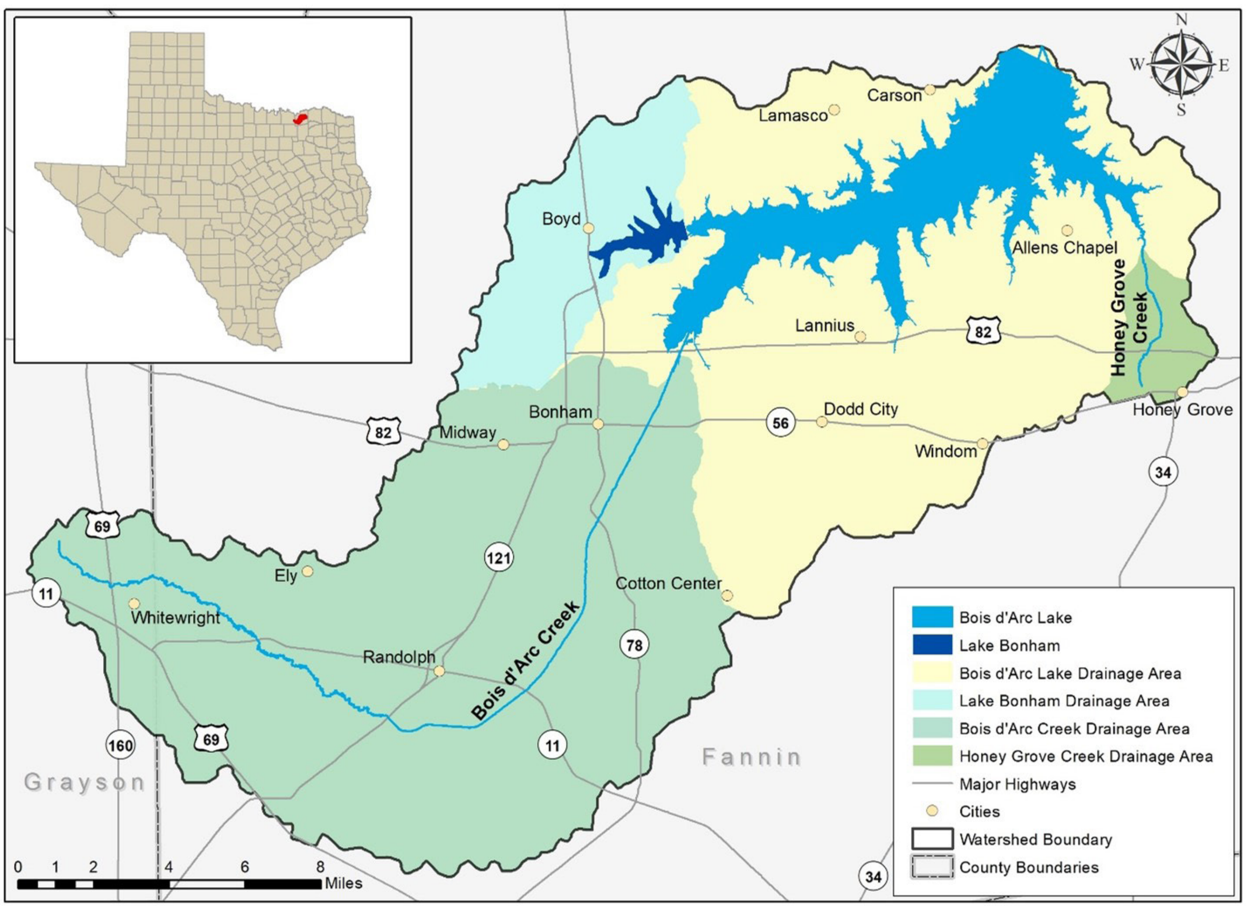


Figure 1. Bois d'Arc Lake watershed.

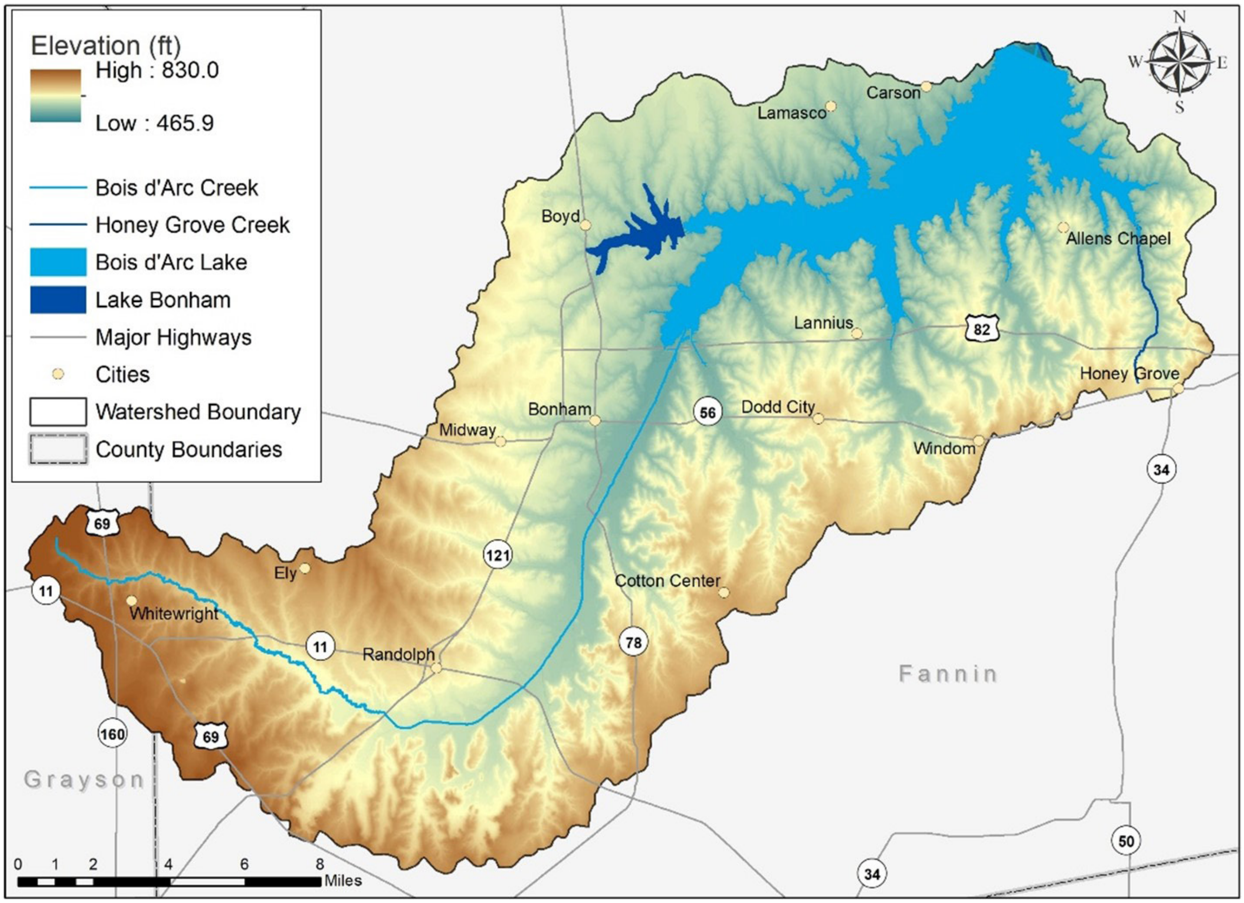


Figure 2. Watershed elevation.

Physical Characteristics

Soils and Topography

The soils and topography of a watershed are important components of watershed hydrology. Slope and elevation define where water will flow, while elevation and soil properties influence how much and how fast water will infiltrate into, flow over, or move through the soil into a water body. Soil properties may also affect the types of development and activities that can occur in certain areas.

The Bois d'Arc Lake watershed is predominantly flat and has moderate drainage. The watershed has a peak elevation of 830 feet with the lowest elevation point being 465.9 feet (USGS 2013; Figure 2). There is an average of a 3% slope gradient across the watershed, with more intense slopes restricted to areas such as cut banks near the creek systems.

The soils in the Bois d'Arc Lake watershed are mostly inceptisols (34.3%, 71,499.7 acres) and mollisols (31.2%; 65,037.6 acres; Figure 3). Inceptisols are young soils that have a wide range of characteristics depending on the environment they form in. They do not have any of the unique properties of mollisols, which are characterized by a dark surface layer indicative of high amounts of organic material and are very fertile and productive for agricultural uses. Mollisols are abundant throughout the watershed, while inceptisols are mainly distributed around the streams. There are also other soil types, such as alfisols (11.5%), aridisols (2.8%), entisols (6.3%), vertisols (4.9%), and other unclassified order (9%).

Hydrologic soil groups (HSG) are groups of soil with similar runoff potential properties. HSGs are useful to consider the potential for runoff from sites under similar storm and cover conditions. Group A soils have high infiltration rate when wet and therefore have low runoff potential. Group A soils are deep and well-drained (typical of well-drained sands or gravelly sands). Conversely, Group D soils have very slow infiltration rates with high runoff potential when wet. Group D soils are typically soils with high clay content, soils with high water tables, or shallow soils on top of clay or impervious material. Group B and C soils have moderate and slow infiltration rates, respectively. Most soils in the Bois d'Arc Lake watershed have an HSG of B (53.3% of the watershed) or A (17.45%; Figure 4). The remaining four groups are the least dominant HSGs in the watershed (Table 3; USDA NRCS 2020).

Table 3. Descriptions of the hydrologic soil groups in the Bois d'Arc Lake watershed.

Hydrologic soil group	Acres	Percent of total
A	36,382	17.45%
A/D	249	0.12%
B	111,102	53.3%
C	33,546	16.09%
C/D	1,874	0.9%
D	25,301	12.14%
Total	**208,454**	**100%**

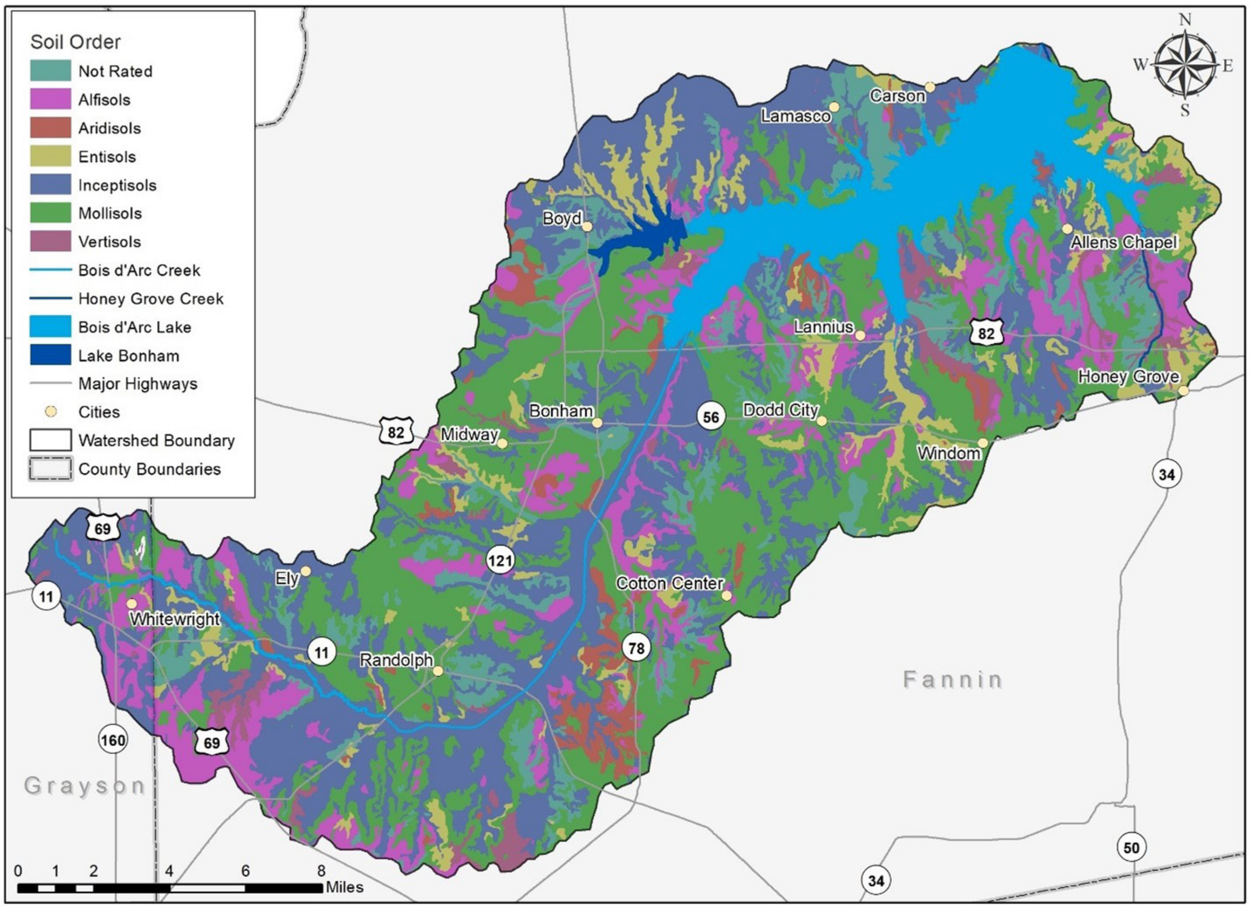


Figure 3. Hydrologic soil groups.

Table 4. Land use/land cover classifications for Bois d'Arc Lake watershed (MRLC 2019).

National Land Cover Database classification	Acres	Percent of total
Rangeland	80,789	38.8%
Forest	36,474	17.5%
Pasture	32,874	15.8%
Cultivated crops	25,611	12.3%
Open water	18,584	8.9%
Developed	14,122	6.8%
Total	**208,454**	**100%**

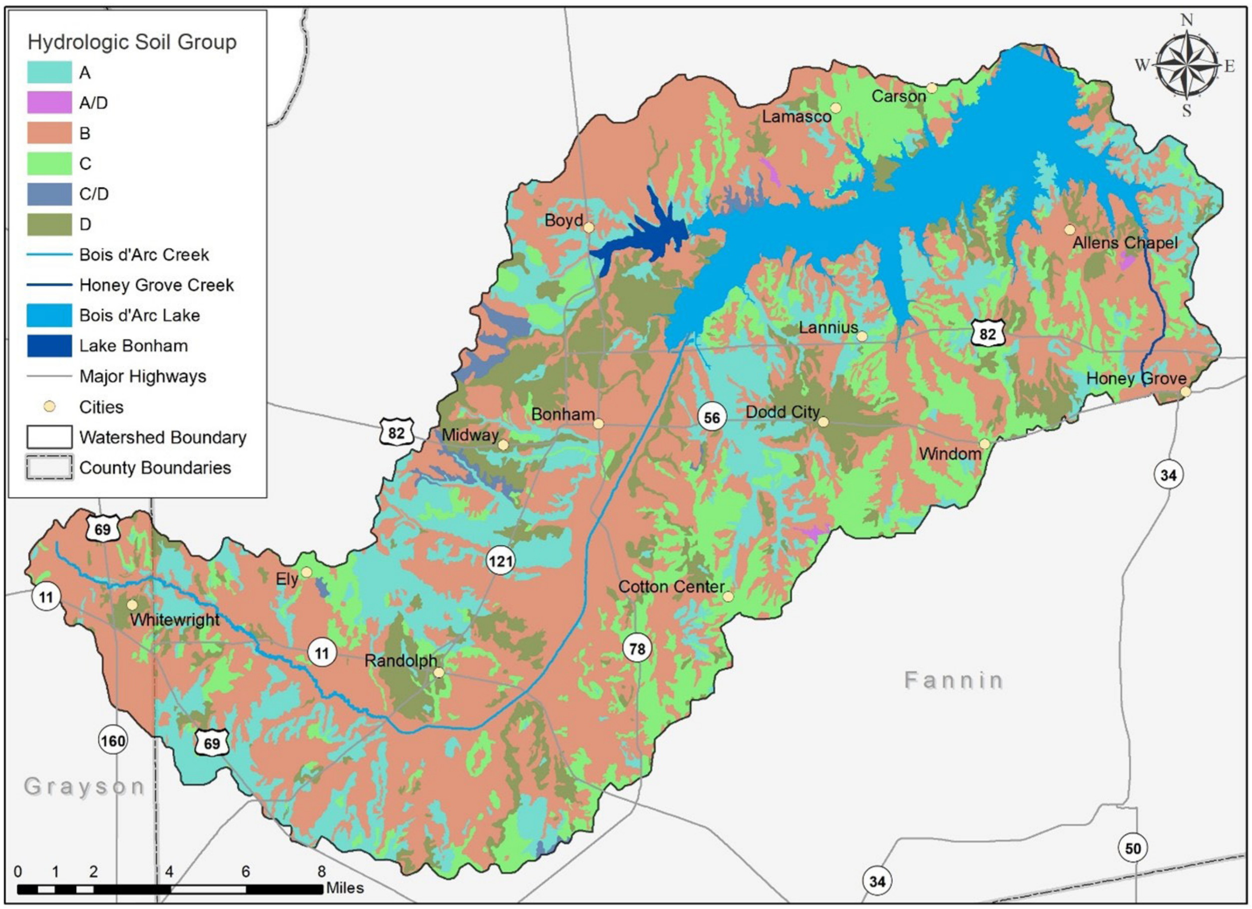


Figure 4. Bois d'Arc Lake watershed hydrologic soil groups.

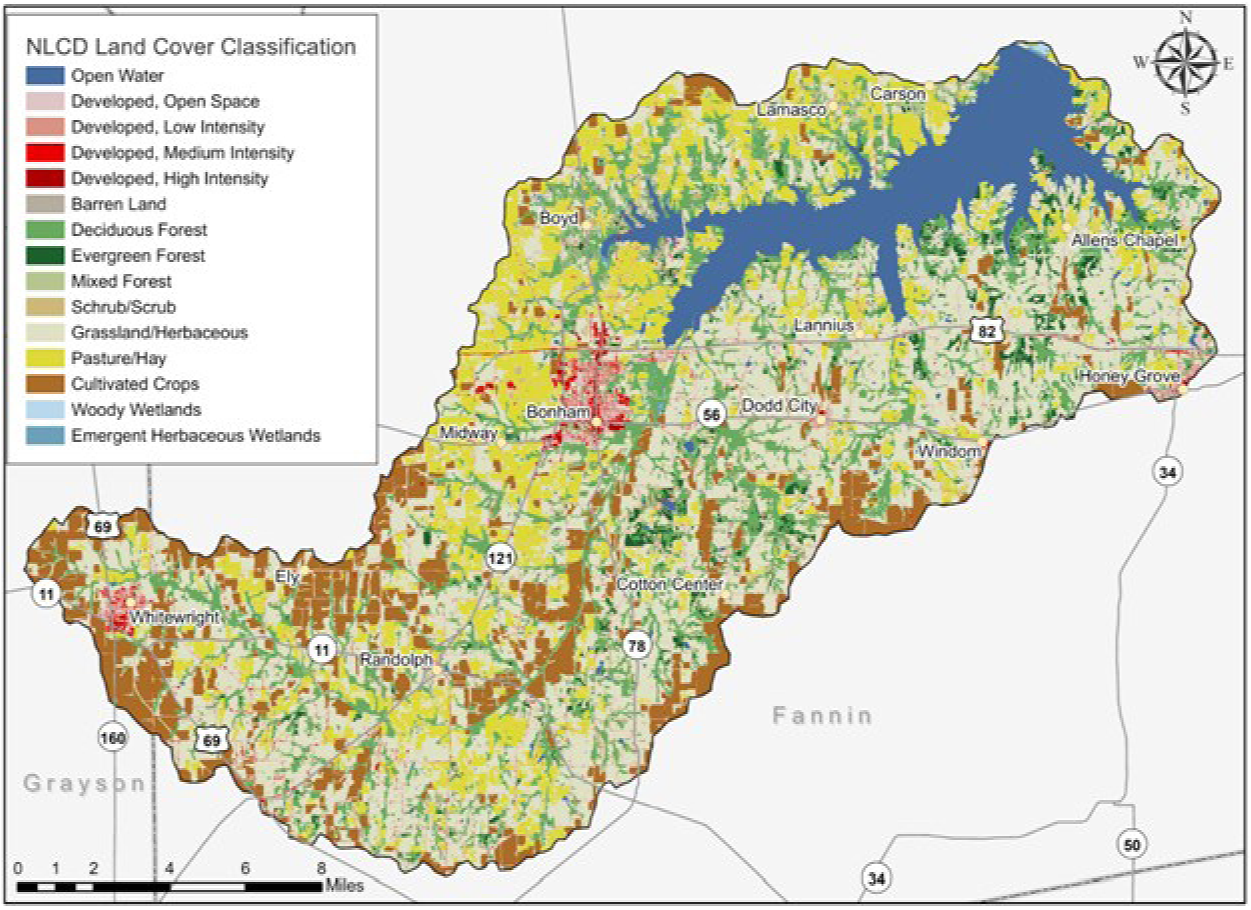


Figure 5. Land use and land cover classifications in the Bois d'Arc Lake watershed (MRLC 2019).

Land Use and Land Cover

The land use/land cover (LULC) data for the Bois d'Arc Lake watershed were obtained from the U.S. Geological Survey (USGS) 2019 National Land Cover Database (NLCD) and are displayed in Figure 5. For descriptive purposes, similar land uses were aggregated where appropriate. For example, the developed land use category includes four subcategory land uses: open, low, medium, and high intensity urban development, and the rangeland category includes grasslands and shrub/scrub. NLCD shows that rangeland (38.8%) is the predominant land use in the watershed. The watershed is mostly rural in land use; around 6.8% of the area is classified as developed. Table 4 illustrates the type of land uses within the watershed, as well as their corresponding percentage of land that each land use covers.

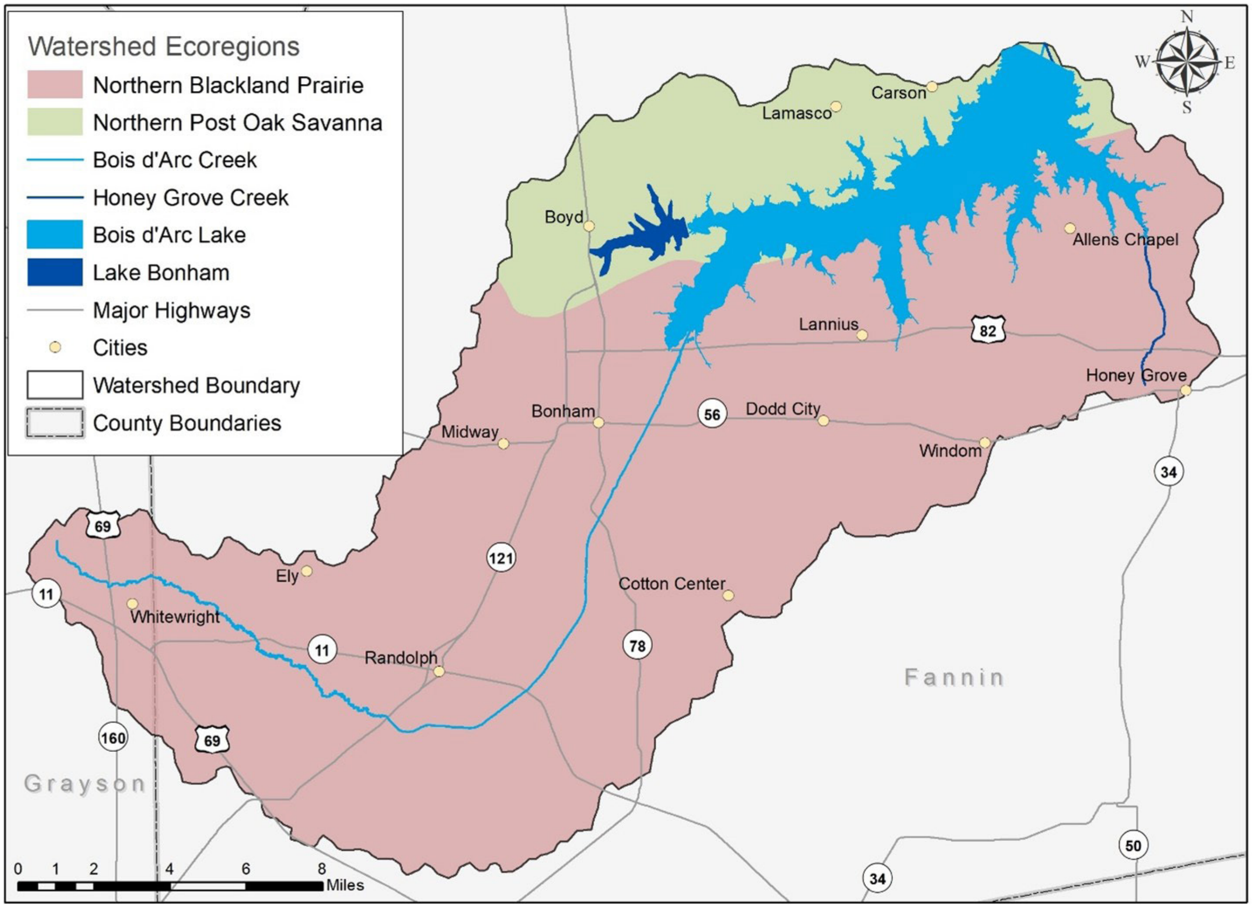


Figure 6. Bois d'Arc Lake watershed ecoregions.

Ecoregions

Ecoregions are land areas that contain similar quality and quantity of natural resources (Griffith 2007). The watershed flows through two major ecoregions: the Northern Blackland Prairie ecoregion, which encompasses most of the watershed, and the Northern Post Oak Savanna ecoregion in the northern portion of the watershed (Figure 6). The Northern Blackland Prairie ecoregion is dominated by tall grasses and characterized by deep, fertile black soils. Cattle ranching and crop production are the primary agricultural industries in the ecoregion. The Northern Post Oak Savanna ecoregion is oak savannah with areas of oak woodland interspersed with grasslands. Cattle ranching is the primary agricultural industry in this ecoregion. Animals native to these areas include white-tailed deer, beaver, nutria, bobcat, coyote, fox, skunk, raccoon, rabbit, gopher, squirrel, and a diverse array of other small mammals and birds. In addition, feral hog (non-native, invasive species) populations are known to be significant.

Water Resources

The Bois d'Arc Lake watershed is unique in that Bois d'Arc Lake is the first major reservoir constructed in Texas in nearly 30 years. It was developed by NTMWD to provide treated water for up to 80 communities in 10 North Texas counties, including Fannin County.

Planning for the 16,641-acre reservoir began in earnest after a series of meetings between Fannin County and NTMWD in 2004. In 2005, the Fannin County Commissioners Court passed a resolution supporting the lake and encouraging the formation of the Fannin County Water Supply Agency to represent the county, cities, and local water providers. Since then, NTMWD has collaborated with Fannin County to develop Bois d'Arc Lake as a regional water supply and a destination for outdoor recreation. The work put forth by these entities is expected to enhance economic opportunities in Fannin County for years to come.

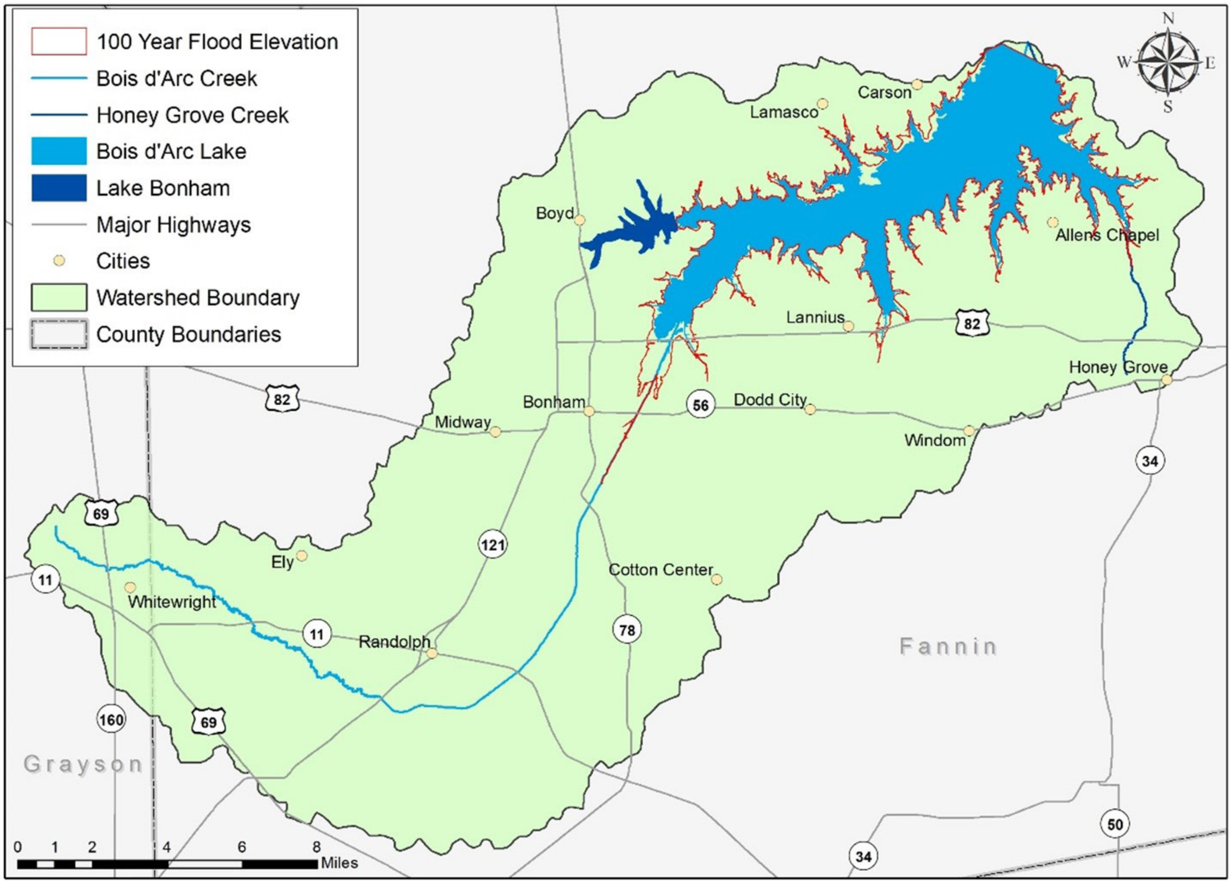


Figure 7. 100-year flood elevation for Bois d'Arc Lake.

After more than a decade of planning and permitting, construction of Bois d'Arc Lake, the dam, and the Leonard Water Treatment Plant began in Fannin County in 2018. The lake was impounded and began filling in 2021. NTMWD expects the reservoir to be filled enough to begin providing treated water to its customers and member cities in 2022. As a critical part of the state water plan, Bois d'Arc Lake will help meet projected North Texas water supply needs through 2040 with a firm yield of 120,000 acre-feet per year.

The lake can store up to 367,609 acre-feet of water and has a maximum depth of 70 feet. The elevation of the lake at conservation pool is 534 feet above mean sea level (MSL), and it covers 16,641 acres of surface area. When the Bois d'Arc Lake project is fully completed, it will help supply water to almost two million people in North Texas and provide recreation to the region.

To effectively balance and maintain a high-quality drinking water supply while also supporting recreation activities on and around Bois d'Arc Lake, NTMWD developed the Bois d'Arc Lake Shoreline Management Plan (SMP). The SMP details strategies for maintaining drinking water quality such as establishing erosion control requirements and implementing best management practices for vegetation removal and chemical hazardous material use. It also includes guidelines for the protection and use of the lake's shoreline on NTMWD-owned land up to 541 feet above MSL at about the 100-year floodplain (Figure 7). Flowage and flood easements also offer certain water quality protections up to 545 feet above MSL, which is approximately the 500-year floodplain (Figure 8). Additionally, Fannin County has the authority to apply land use zoning to the area within 5,000 feet of the lake's normal conservation pool. Collectively these measures will help reduce erosion and protect water quality in the reservoir. Additionally, upstream flood mitigation areas were selected in an area prone to localized flooding. Mitigation measures carried out by NTMWD aim to restore and enhance forested wetlands (FNI 2017).

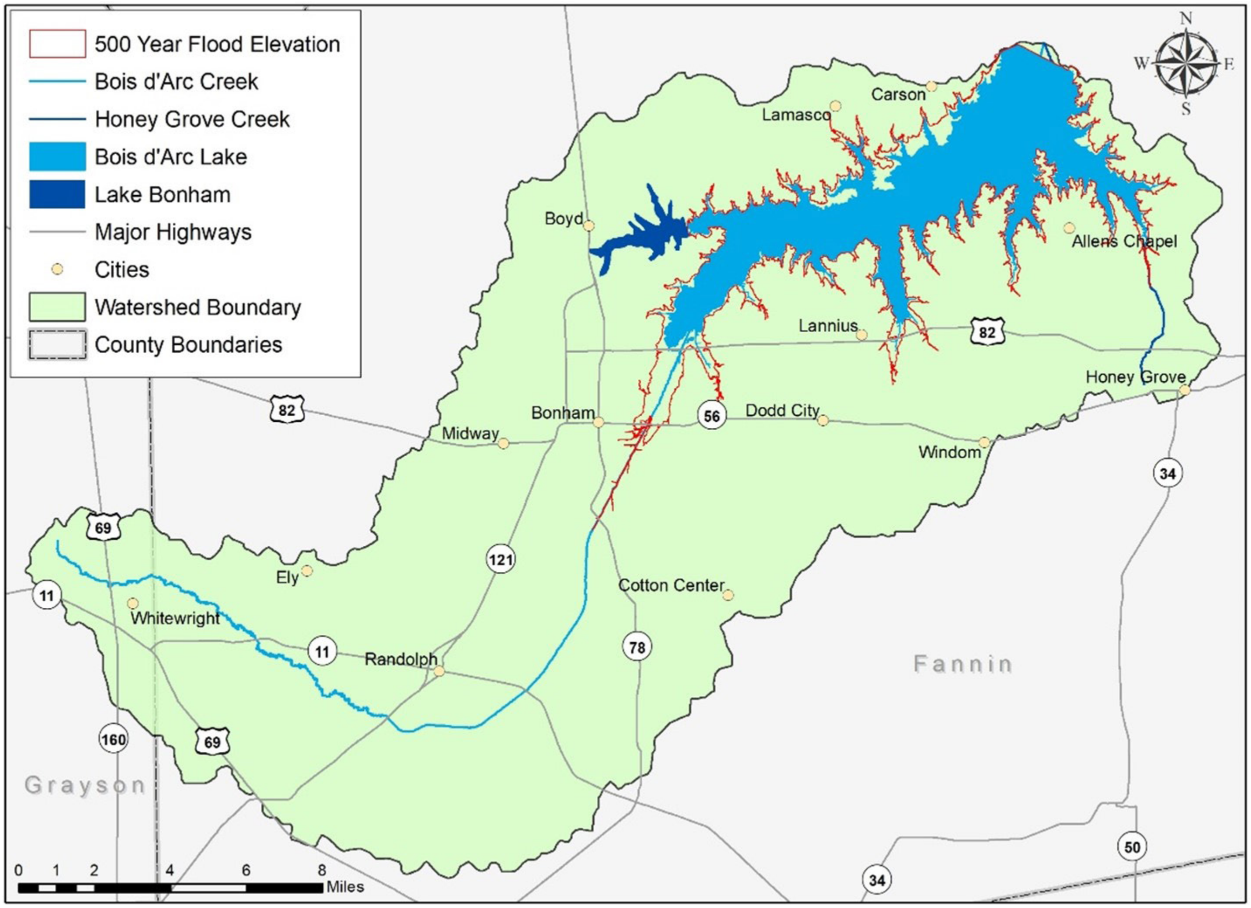


Figure 8. 500-year flood elevation for Bois d'Arc Lake.

The other surface water resource in the watershed, Lake Bonham, was developed in 1969 and is the primary drinking water supply for the city of Bonham. NTMWD holds water rights to divert and use up to 5,340 acre-feet of water per year from the lake. Lake Bonham has a maximum depth of approximately 29.9 feet and a storage capacity of 11,038 acre-feet of water. The surface area of the lake encompasses 1,012 acres and has a lake elevation of 565 feet above MSL.

The principal water-bearing strata under the watershed are Trinity and Woodbine aquifers. The watershed lies wholly within both. Trinity Aquifer is a major aquifer that spans across central and northeast Texas and consists of limestones, sands, clays, gravels, and conglomerates. Water quality is generally good in much of Trinity Aquifer, but levels of total dissolved solids (TDS) can range from 1,000 to 5,000 milligrams/liter (mg/L), or slightly to moderately saline, in deeper parts of the aquifer. The average saturated thickness of Trinity Aquifer in North Texas is approximately 600 feet. However, heavy usage has caused drastic declines in Trinity Aquifer throughout many parts of the state (TWDB 2020a). Woodbine Aquifer is classified as a minor aquifer by the Texas Water Development Board (TWDB) and consists of sandstone interbedded with shale and clay that form three water-bearing zones. Water quality and yield vary with the depth of Woodbine Aquifer. For example, water extracted from above 1,500 feet generally contains less than 1,000 mg/L of TDS, while lower water-bearing zones generally produce water that is slightly to moderately saline (1,000–5,000 mg/L; TWDB 2020b).

This watershed is also located in a priority groundwater management area (PGMA) designated by TCEQ. PGMAs are areas that are experiencing or are expected to experience critical groundwater issues within 50 years. These issues include shortages of surface and groundwater, contamination of groundwater resources, and land subsidence from groundwater withdrawals. The primary reason for TCEQ designating the area within and surrounding the Bois d'Arc Lake watershed a PGMA is to prevent a shortage of groundwater in the aquifers as the population is projected to grow rapidly over the next few decades.

To help manage and protect groundwater in Fannin and Grayson counties, the Red River Groundwater Conservation District (RRGCD) was created in 2009. Their primary goals include the promotion of conservation, protecting groundwater quality, protecting existing wells, and ensuring

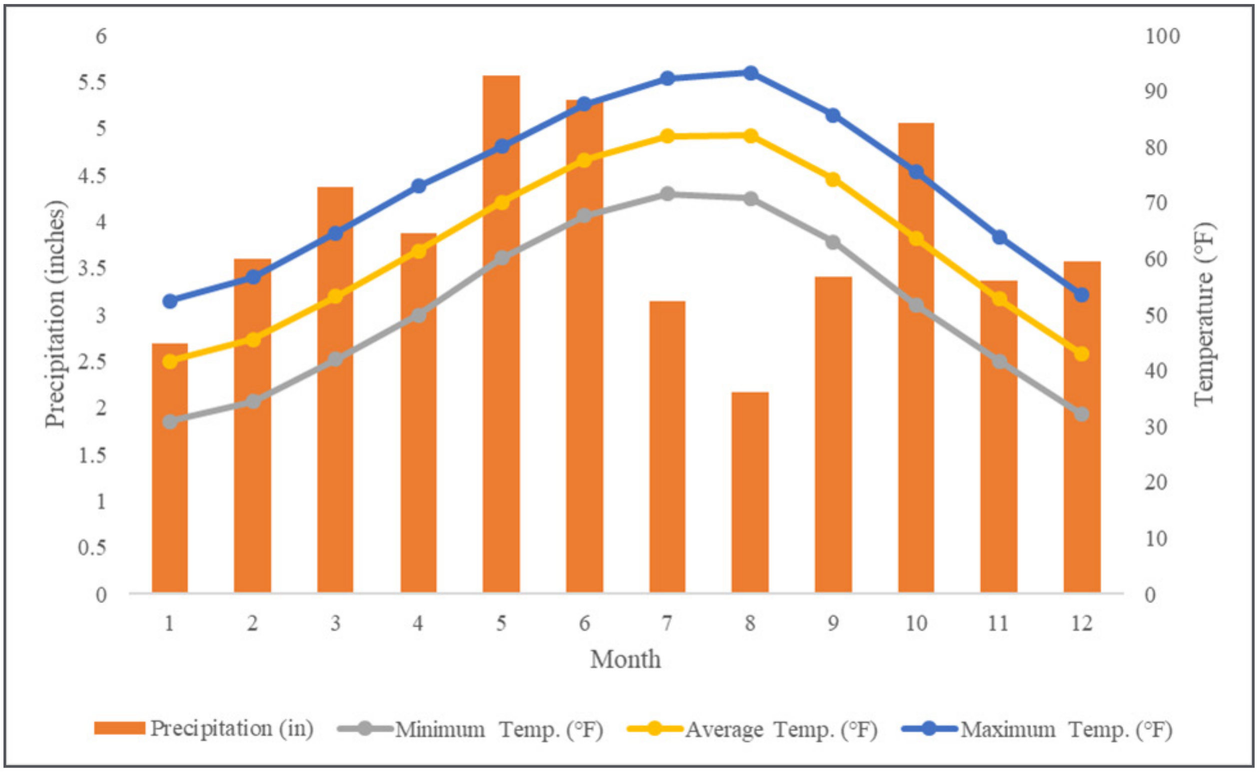


Figure 9. Monthly climate data, including precipitation, normal average, and maximum and minimum air temperature, for Bonham, Texas 1981–2010.

that local residents maintain control over their groundwater. RRGCD is also responsible for registering and permitting all non-exempt wells in the counties and tracking monthly well usage from well owner reported meter readings.

Fish and Benthic Macroinvertebrate Communities

To help characterize stream conditions in Bois d'Arc Creek prior to the construction of the reservoir and dam, NTMWD and other partners conducted the Instream Flow Study for Proposed Lower Bois d'Arc Creek Reservoir (FNI 2010) in 2010. One component of this study examined the aquatic biology in the creek, which was evaluated in the context of the current and future stream system. The primary purpose of this examination was to inform sound management of aquatic ecosystems downstream of the dam after completion of the lake.

From March to July 2009, 3,138 fish species were collected in Bois d'Arc and Honey Grove creeks. The results of the collection concluded that the dominant fish type in the creeks was generalist species with a tolerance for varying environmental conditions. Concurrently with the fish collection for the 2010 Instream Flow Study for Proposed Lower Bois d'Arc Creek Reservoir, a total of 2,621 aquatic and terrestrial insects were collected.

To help promote recreation on the lake, NTMWD partnered with TPWD on constructing fish habitats and seeding stock ponds with selected fish species. In 2019, TPWD stocked ponds in the lake area with 2,000 bass bred to have the greatest potential to reach trophy size.

Climate

The Bois d'Arc Lake watershed lies within the subtropical humid sub-climate zone. Measurements taken at the Bonham, Texas weather station note that the average daily temperature in the watershed is approximately 62.3°F (NOAA 2016; Figure 9). Average daily lows reach the lowest temperatures in January at 30.9°F. Meanwhile, average peak daily highs of 93.3°F occur in August. Monthly normal precipitation indicates that the area had a mean annual rainfall from 1981 to 2010 of 46.1 inches (NOAA 2016). Rainfall normally peaks in May (5.57 inches) with the lowest totals occurring in August (2.17 inches; NOAA 2016). Average annual precipitation values across the watershed from the PRISM Climate Group at Oregon State (2012) indicate average annual rainfall ranges from 42 to almost 46 inches per year, with a clear east to west decreasing gradient (Figure 10). The average annual precipitation from the Bonham, Texas weather station differs slightly from the average shown in Figure 10 because the weather station data is collected at a single point opposed to data averaged over a larger space.

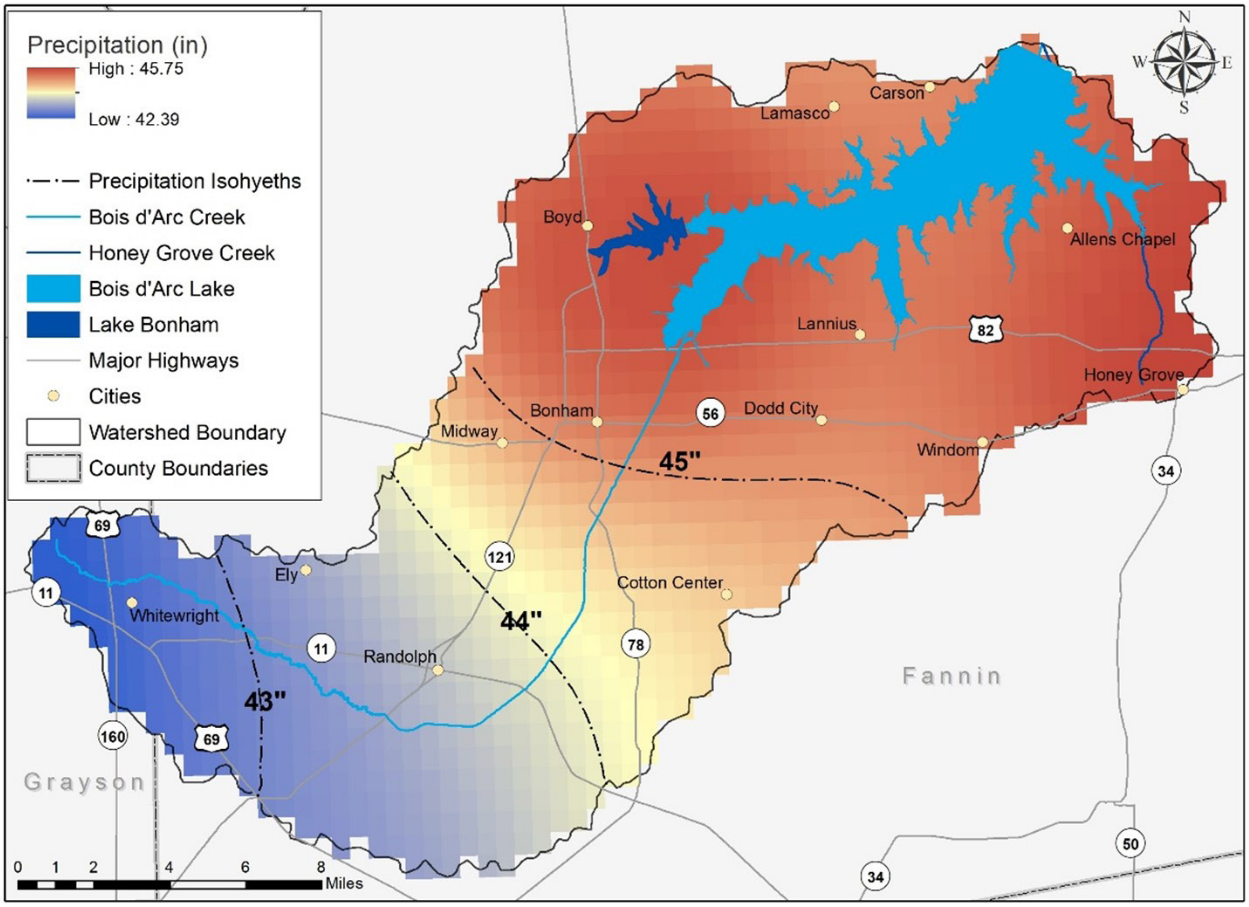


Figure 10. 30-year average precipitation in the Bois d'Arc Lake watershed.

Population Projections

According to the 2010 U.S. Census (USCB 2010), the total population of the Bois d'Arc Lake watershed was approximately 20,991 with a population density of 10 people/acre. Population is the densest within and near the cities of Bonham, Honey Grove, and Whitewright (Figure 11). Population projections by TWDB (2016) for the portions of both Fannin and Grayson counties in the watershed are provided in Table 5. From 2010 to 2070, the populations of both counties are expected to increase drastically with an estimated overall population increase for the watershed of almost 300%.

Table 5. Population projections by county for the Bois d'Arc Lake watershed.

County	2010 U.S Census	Projected population in the watershed by year						Percent increase (2010–2070)
		2020	2030	2040	2050	2060	2070	
Fannin	19,145	21,637	24,321	29,857	39,136	57,413	77,750	306.1
Grayson	1,846	2,066	2,283	2,437	2,732	3,709	5,148	178.9
Total	20,991	23,703	26,604	32,294	41,868	61,122	82,898	294.9

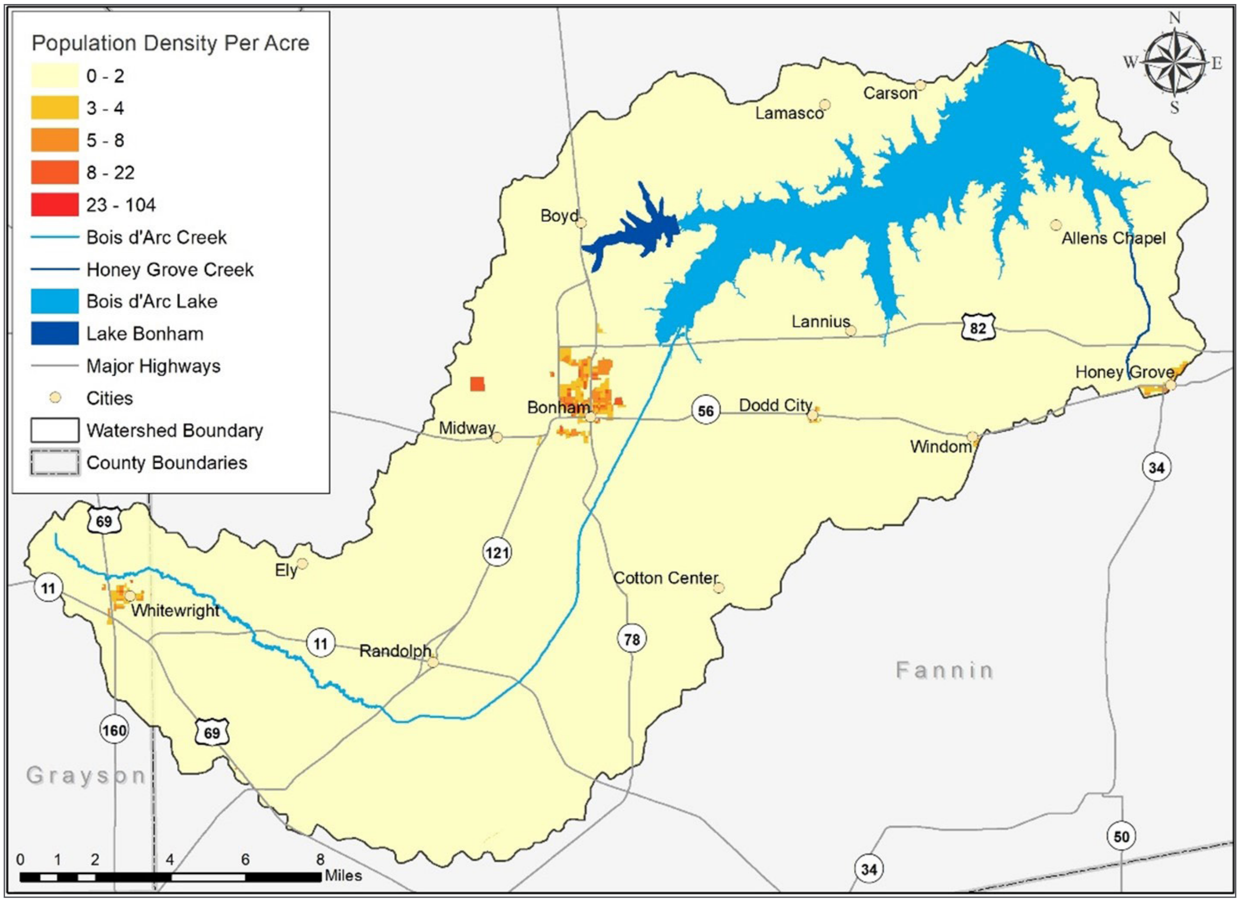


Figure 11. Bois d'Arc Lake watershed 2010 population by census block.

Chapter 4
Water Quality

Bird perched at No Wake Zone at Lake Bonham. Photo by Ed Rhodes, TWRI.

Introduction

Water is monitored in Texas to ensure that its quality supports designated uses defined in the Texas Water Code. Designated uses and associated standards are developed by TCEQ to fulfill requirements of the Clean Water Act (CWA), which addresses toxins and pollution in waterways and establishes a foundation for water quality standards. The CWA requires states to set standards that: maintain and restore biological integrity in the waters, protect fish, wildlife, and recreation in and on the water (must be fishable/swimmable), and consider the use and value of state waters for public supplies, wildlife, recreation, agricultural, and industrial purposes.

The CWA (33 USC § 1251.303), administered by EPA (40 CFR § 130.7), requires states to develop a list that describes all water bodies that are impaired and are not within established water quality standards (commonly called the 303(d) list, in reference to Texas Water Quality Inventory and 303(d) List). In addition, states are required to develop acceptable strategies to restore water quality of impaired water bodies. The development of a stakeholder-driven WPP is one of the potential strategies. By encouraging stakeholders to address possible causes and threats of impairments and giving them decision-making powers to set WPP goals, WPPs can provide a comprehensive, long-term restoration plan with water body assessments and protection strategies.

Water Body Assessments

TCEQ conducts a water body assessment on a biennial basis to satisfy requirements of federal CWA Sections 305(b) and 303(d). The resulting *Texas Integrated Report of Surface Water Quality (Texas Integrated Report)* describes the status of water bodies throughout the state of Texas. The most recent finalized *2020 Texas Integrated Report* includes an assessment of water quality data collected from December 1, 2011 to November 30, 2018. This period precedes the start of efforts to develop this WPP by almost 3 years.

The *Texas Integrated Report* assesses water bodies at the assessment unit (AU) level. An AU is a sub-area of a segment, defined as the smallest geographic area of use support reported in the assessment (TCEQ 2020). Each AU is intended to have relatively homogeneous chemical, physical,

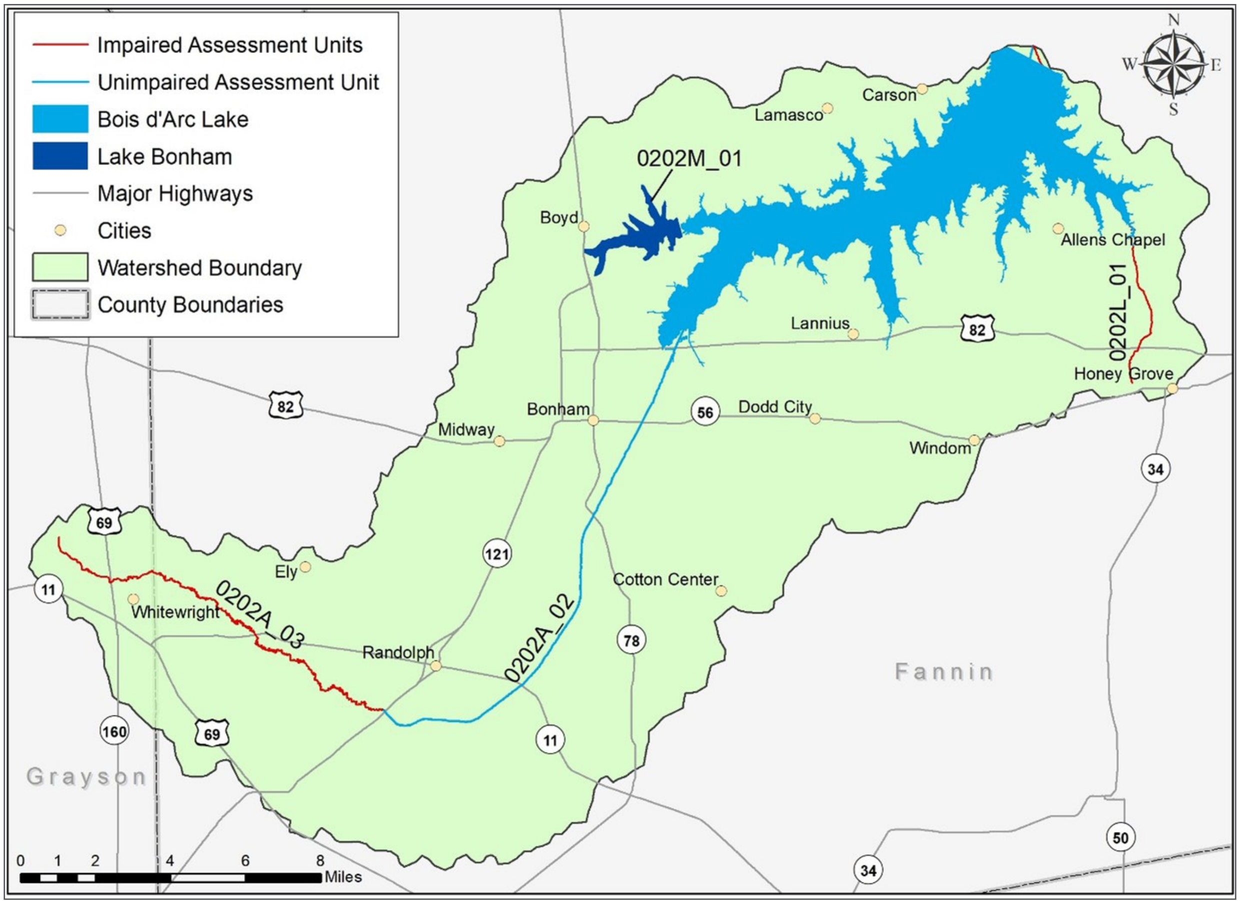


Figure 12. Texas Commission on Environmental Quality (TCEQ) assessment units and watershed impairments for Bois d'Arc Lake watershed.

and hydrological characteristics, which allows a way to assign site-specific standards (TCEQ 2020). A segment identification number and AUs are combined and assigned to each water body to divide a segment. For example, Bois d'Arc Creek is segment 0202A, and it has three AUs, designated 0202A_01, 0202A_02, and 0202A_03. Currently, AU 0202A_01 is still considered part of the Bois d'Arc Lake watershed. Once the lake is complete, TCEQ will realign the AUs, this AU will no longer be in the watershed, and the AU will instead end below the dam. For the purposes of this document, we are presenting data and maps as if Bois d'Arc Lake is already complete.

In total, there are currently four AUs in the Bois d'Arc Lake watershed (Figure 12). Monitoring stations are located on most AUs and allow independent water quality analysis for each AU within a segment. At least 10 data points within the most recent 7 years of available data are required for all water quality parameters except bacteria, which requires a minimum of 20 samples. According to the *2020 Texas Integrated Report and 303(d) List* (TCEQ 2020), there are two impaired AUs due to elevated levels of bacteria in the watershed: Bois d'Arc Creek AU 0202A_03 and Honey Grove Creek AU 0202L_01. All other designated uses meet Texas Surface Water Quality Standards in the watershed.

Furthermore, there are concerns for chlorophyll-a in Bois d'Arc Creek AU 0202A_02 and nitrate and total phosphorus in Bois d'Arc Creek AU 0202A_03. Honey Grove Creek AU 0202L_01 has concerns for chlorophyll-a and total phosphorus.

Water quality is monitored at designated sampling sites throughout the watershed (Figure 13). Through the Clean Rivers Program (CRP), the Red River Authority (RRA) and NTMWD conduct quarterly/monthly monitoring of field parameters (clarity, temperature, dissolved oxygen [DO], specific conductance, and pH), conventional parameters (total suspended solids, sulfate, chloride, ammonia, total hardness, nitrate-nitrogen, total phosphorous, alkalinity, total organic carbon, turbidity, and chlorophyll-a), flow, heavy metals, and bacteria. This type of monitoring is considered routine monitoring because all data and parameters are collected for each site routinely once every month/quarter. Conversely, continuous monitoring occurs at sites where parameters are being evaluated all the time. Continuous monitoring is typically associated with sites being monitored by TCEQ or USGS where stream flow gages and other monitoring devices have been set up to collect data year-round. The USGS did monitor flow in the watershed at USGS gage 07332620 (TCEQ surface water quality monitoring

Table 6. Sites currently monitored by North Texas Municipal Water District (NTMWD), Red River Authority (RRA), and the U.S. Geological Survey (USGS).

Surface water quality monitoring station			Number of annual samples collected				
ID	**Assessment unit**	**Collecting entity**	**Metal water**	**Conventional**	**Field**	**Flow**	**Bacteria**
15036	0202A_03	RRA		4	4	4	4
20167	0202A_01	NTMWD	12	12	12	12	12
21706	0202A_02	NTMWD	12	12	12	12	12
22105	0202A_02	NTMWD	12	12	12	12	12
22105	0202A_02	USGS			365	365	
21030	0202L_01	NTMWD	12	12	12	12	12
16943	0202M_01	NTMWD	12	12	12		12

Table 7 Designated water uses for water bodies in the Bois d'Arc Lake watershed.

Use	Use category	Measure	Criteria
Contact recreation	Primary contact recreation 1	*7-year geometric mean*	126 MPN/100 mL *E. coli*
Aquatic life use	High	*<10% exceedance based on the binomial method*	5.0/3.0 mg/L DO
	Intermediate		4.0/3.0 mg/L DO
	Minimal		2.0/1.5 mg/L DO
General use standards	The criteria for the general use include aesthetic parameters, radiological substances, toxic substances, temperature (when surface samples are above 5˚F and not attained due to permitted thermal discharges), and nutrients (screening standards or site-specific nutrient criteria)		

Most probable number, MPN; milliliter, mL; milligrams, mg; liter, L; dissolved oxygen, DO; Fahrenheit, F

Table 8. *2020 Texas Integrated Report* assessment results for bacteria in the Bois d'Arc Lake watershed.

Assessment unit	Description	Current standard	E. coli geometric mean (most probable number/100 milliliters [MPN/100 mL])	Supporting/ not supporting/ concern
0202A_01	Bois d'Arc Creek – From the confluence of the Red River upstream to the confluence of Sandy Creek north of Dodd City	126 MPN/100 mL *E. coli*	139	Use concern
0202A_02	Bois d'Arc Creek – Perennial stream from the confluence of Sandy Creek upstream to the confluence of Pace Creek	126 MPN/100 mL *E. coli*	126	Fully supporting
0202A_03	Bois d'Arc Creek – From the confluence of Pace Creek upstream to the headwater northwest of Whitewright	126 MPN/100 mL *E. coli*	178	Not supporting
0202L_01	Honey Grove Creek – From the confluence of Bois d'Arc Creek upstream to the headwater east of Honey Grove	126 MPN/100 mL *E. coli*	444	Not supporting
0202M_01	Lake Bonham – From the dam up to the normal pool elevation of 565 feet	126 MPN/100 mL *E. coli*	7	Fully supporting

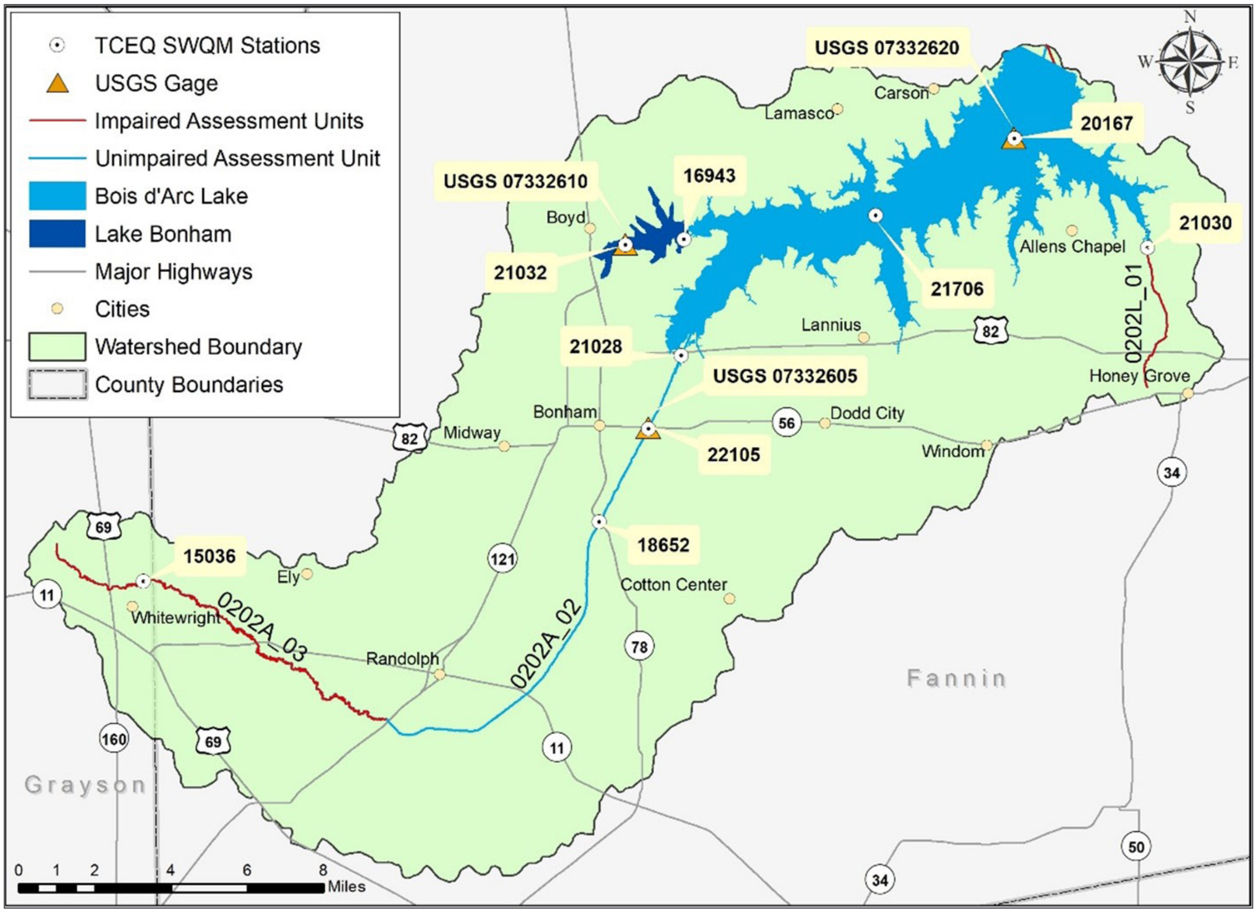


Figure 13. Current and historical surface water quality monitoring (SWQM) stations and U.S. Geological Survey (USGS) gages in the Bois d'Arc Lake watershed.

[SWQM] station 20167) and four conventional parameters (DO, pH, conductivity, and temperature) until the station was removed in October 2019. A new USGS gage (07332605) was installed at SWQM station 22105, and it began collecting those same parameters in March 2020. Both the current and previous USGS gage sites were established through cooperation between NTMWD and USGS. All sites currently being monitored by NTMWD, RRA, and USGS in the watershed are detailed in Table 6.

Texas Surface Water Quality Standards

Water quality standards are established by the state and approved by EPA to define a water body's ability to support its designated uses, which may include aquatic life use (fish, shellfish, and wildlife protection and propagation), primary contact recreation (swimming), public water supply, and fish consumption. Water quality indicators for these uses include DO (aquatic life use), *E. coli* (primary contact recreation), pH, temperature, total dissolved solids, sulfate and chloride (general uses), and a variety of toxins (fish consumption and public water supply; Table 7; TCEQ 2019).

Bacteria

Concentrations of fecal indicator bacteria are evaluated to assess the risk of illness during contact recreation. In freshwater environments, concentrations of *E. coli* are measured to evaluate the presence of fecal contamination in water bodies from warm-blooded animals and other sources. Common sources that indicator bacteria can originate from include wildlife, domestic livestock, pets, malfunctioning on-site sewage facilities (OSSFs), urban and agricultural runoff, sewage system overflows, and direct discharges from wastewater treatment facilities (WWTFs). The water quality standard for *E. coli* in freshwater for primary contact recreation is a geometric mean of 126 most probable number (MPN) of *E. coli* per 100 mL of water from at least 20 samples (30 TAC § 307.7 2014). Currently, all water bodies in the Bois d'Arc Lake watershed are evaluated under this standard.

As previously mentioned, two AUs (0202A_03 [Bois d'Arc Creek] and 0202L_01 [Honey Grove Creek]) are listed as impaired due to elevated indicator bacteria according to the *2020 Texas Integrated Report* (TCEQ 2020; Table 8). Bois d'Arc Creek AU 0202A_01 has a geometric mean slightly above the water quality standard, but it is classified as just a

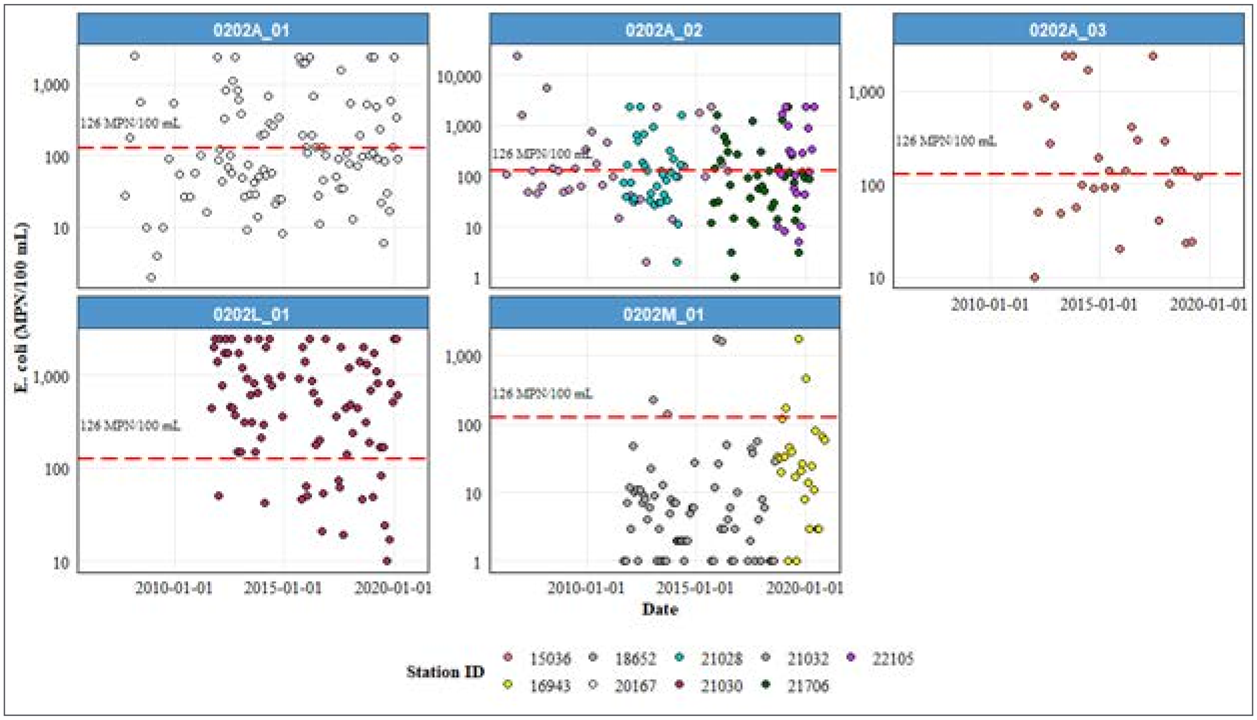


Figure 14. Historical *E. coli* concentrations for Bois d'Arc Creek assessment units (AUs) 0202A_01-03, Honey Grove Creek AU 0202L_01, and Lake Bonham AU 0202M_01. Red dashed line indicates the 126 most probable number (MPN)/100 milliliters (mL) criterion.

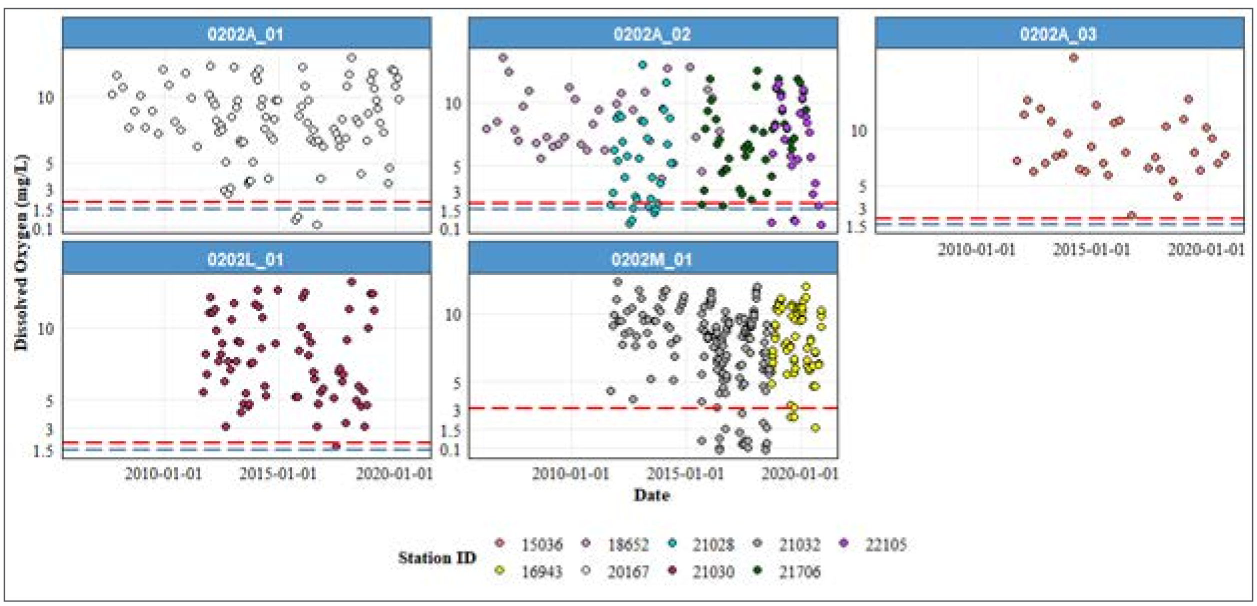


Figure 15. Historical dissolved oxygen (DO) concentrations for Bois d'Arc Creek assessment units (AUs) 0202A_01-03, Honey Grove Creek AU 0202L_01, and Lake Bonham AU 0202M_01. Red dashed line indicates the DO grab screening level, and the blue dashed line indicates the DO grab minimum AUs 0202A_01-03 and 0202L_01. Red dashed line indicates both the DO grab screening level and DO grab minimum for AU 0202M_01.

Table 9. Dissolved oxygen (DO) grab screening levels and DO grab minimums for all assessment units (AUs) in the Bois d'Arc Lake watershed.

AU	Waterbody	DO grab screening level (milligram [mg]/liter [L])	DO grab minimum (mg/L)
0202A_01	Bois d'Arc Creek	5	3
0202A_02	Bois d'Arc Creek	4	3
0202A_03	Bois d'Arc Creek	2	1.5
0202L_01	Honey Grove Creek	2	1.5
0202M_01	Lake Bonham	3	3

concern, not an impairment. This AU is classified this way because the statistical analysis performed during assessment indicated that the data was too variable to meet confidence intervals. The downstream portion of this AU will be inundated once the Bois d'Arc Lake is complete. Previous water quality data collected for this AU were included in this report to provide a complete analysis of historical water quality in the watershed. Bois d'Arc Lake has yet to be evaluated for water quality impairments or assigned a Segment ID by TCEQ.

Currently, *E. coli* concentrations are measured at five active stations throughout the watershed: three stations in Bois d'Arc Creek (Segment ID 0202A), one station in Honey Grove Creek (Segment ID 0202L), and one station in Lake Bonham (Segment ID 0202M). There are also sites on Bois d'Arc Creek (TCEQ SWQM stations 18652, 21028, and 20167) and Lake Bonham (TCEQ SWQM station 21032) that are no longer active but *E. coli* samples were collected at historically. *E. coli* measurements for the stream segments, including historical stations, are shown in Figure 14.

Recreational Use-Attainability Analysis

With the identification of water quality issues in Bois d'Arc Creek and Honey Grove Creek, TCEQ determined that a recreational use-attainability analysis (RUAA) should be conducted on both water bodies. These types of studies are done by TCEQ to ensure that surface water bodies are categorized under the appropriate recreational use and numeric criteria. The RUAA completed in the summer of 2014 for Bois d'Arc Creek concluded that the designated use of primary contact recreation should be changed to secondary contact recreation 1 (SCR1). Under SCR1, the geometric mean criterion is elevated to 630 MPN/100 mL because the risk of ingestion from recreation is considered less significant. This RUAA is still awaiting approval by EPA. The RUAA for Honey Grove Creek is currently underway and a draft report is expected to be available to the public by 2022. TCEQ has not made any recommendations for a change in recreational use for Honey Grove Creek at the time of publication. The Texas Surface Water Quality Standards are only subject to change for the waterbodies once their RUAAs have EPA approval.

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 photosynthesis. 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 of decreased oxygen solubility in water as temperature increases; therefore, it is common to see lower DO levels during the summer. While DO can fluctuate naturally, human activities can also cause abnormally low DO levels. Excessive organic matter (vegetative material, untreated wastewater, etc.) can result in depressed DO levels as bacteria break down the 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.

Under the *2020 Texas Integrated Report,* none of the AUs in the watershed were listed as impaired for depressed DO. All historical DO data for the watershed are shown in Figure 15, and each AU has a different DO grab screening level and DO grab minimum (Table 9).

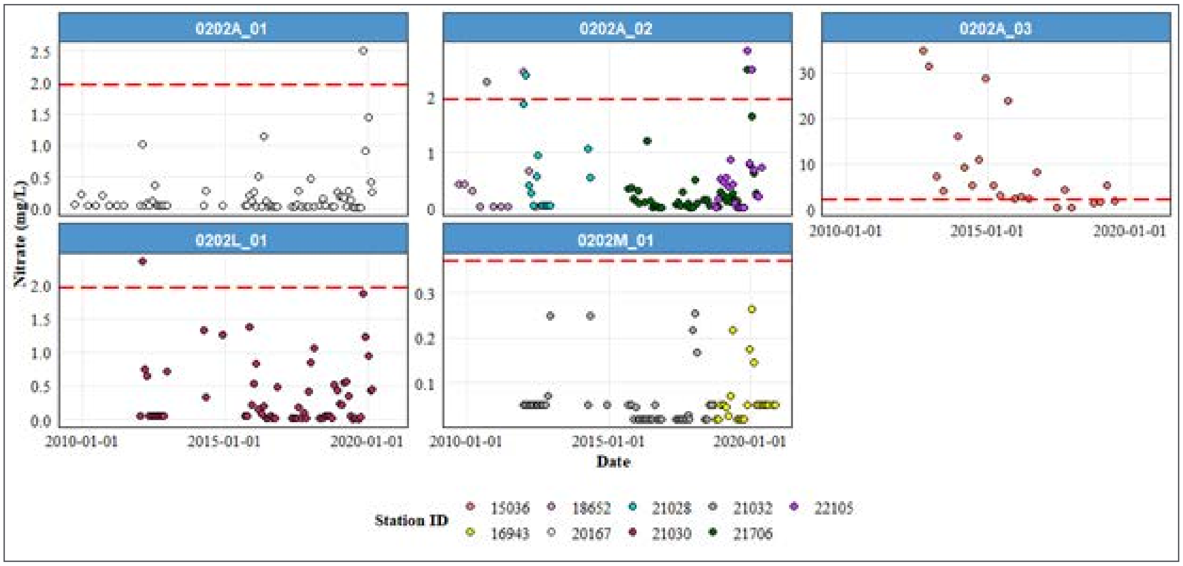


Figure 16. Historical total nitrate concentrations for Bois d'Arc Creek assessment units (AUs) 0202A_01-03, Honey Grove Creek AU 0202L_01, and Lake Bonham AU 0202M_01. Red dashed line indicates the 1.95 milligrams/liter (mg/L) screening level on Bois d'Arc Creek and Honey Grove Creek and the 0.37 mg/L screening level on Lake Bonham.

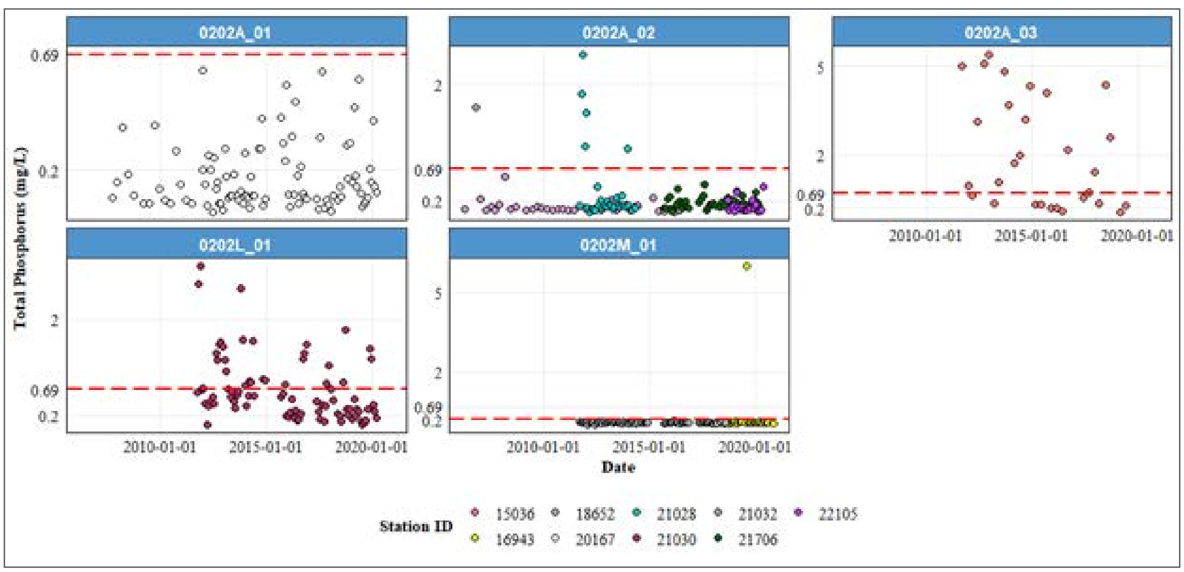


Figure 17. Historical total phosphorus concentrations for Bois d'Arc Creek assessment units (AUs) 0202A_01-03, Honey Grove Creek AU 0202L_01, and Lake Bonham AU 0202M_01. Red dashed line indicates the 0.69 milligrams/liter (mg/L) screening level on Bois d'Arc Creek and Honey Grove Creek and the 0.2 mg/L screening level on Lake Bonham.

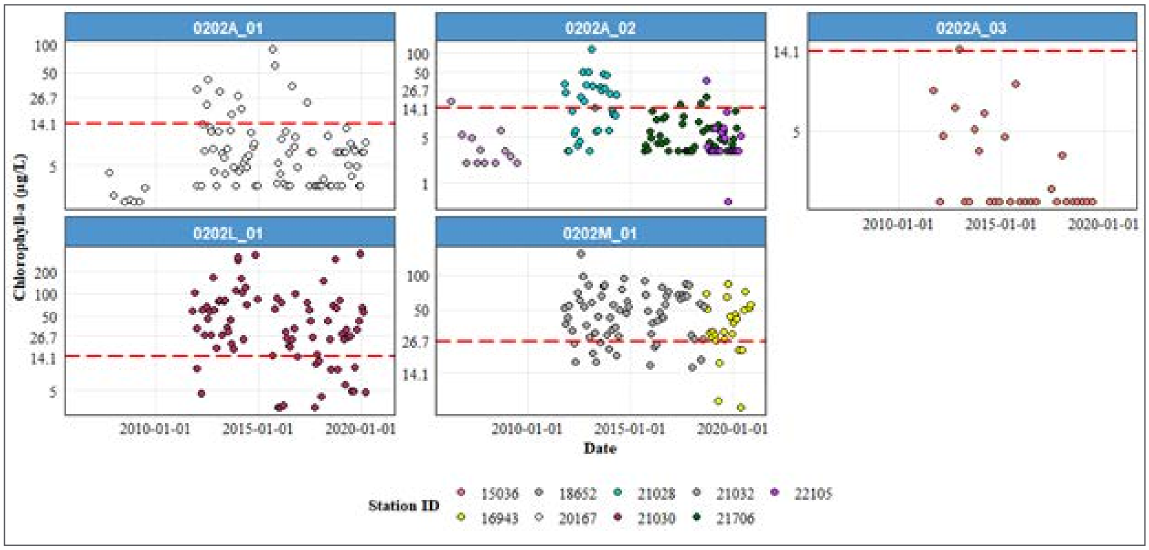


Figure 18. Historical chlorophyll-a concentrations for Bois d'Arc Creek assessment units (AUs) 0202A_01-03, Honey Grove Creek AU 0202L_01, and Lake Bonham AU 0202M_01. Red dashed line indicates the 14.1 micrograms (µg/L) screening level on Bois d'Arc Creek and Honey Grove Creek and the 26.7 µg/L screening level on Lake Bonham.

Nutrients

Nutrients, specifically nitrogen and phosphorous, are used by aquatic plants and algae. However, excessive amounts of nutrients can lead to plant and algal blooms, which can result in reduced DO levels and potential fish kills. High levels of nitrates and nitrites can affect respiration in fish. Sources of nutrients include effluents from discharges from WWTFs and fertilizers that run off from yards and agricultural fields. Nutrients also bind to soil and sediment particles. Therefore, runoff and erosion events that result in heavy sediment loads can increase nutrient levels in water bodies as well.

Currently, TCEQ does not have approved numeric criteria for these nutrients in water bodies. However, nutrient screening levels developed for statewide use were established to protect water bodies from excessive nutrient loadings. Screening levels are set at the 85th percentile for parameters from similar water bodies. If more than 20% of samples from a water body exceed the screening level, that water body is on average experiencing pollutant concentrations higher than 85% of the streams in Texas and is therefore considered to have an elevated nutrient concentration concern. Screening levels have been designated for ammonia, nitrate, orthophosphorus, total phosphorus, and chlorophyll-a. The current screening levels in freshwater streams are 1.95 mg/L for nitrate and 0.69 mg/L for total phosphorous. Lake Bonham has different screening levels than the freshwater streams in the watershed. The screening levels in Lake Bonham are 0.37 mg/L for nitrate and 0.2 mg/L for total phosphorus.

The *2020 Texas Integrated Report* identified screening concerns for nitrate and total phosphorus in Bois d'Arc Creek AU 0202A_03 and for total phosphorus in Honey Grove Creek AU 0202L_01 (Figures 16 and 17). Chlorophyll-a is also above current TCEQ screening levels (14.1 micrograms [µg]/L) for Bois d'Arc Creek AU 0202A_02 and Honey Grove Creek AU 0202L_01 (Figure 18). Elevated chlorophyll-a can be indicative of possible imbalances and nutrient loading occurring in the system.

Flow

Generally, 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 anthropogenic (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.

One active USGS gage collects streamflow data in the watershed. USGS streamflow gage 07332605 is located at SWQM station 22105 in Bois d'Arc Creek. Instantaneous streamflow data is available from this station dating back to March 2020. As previously mentioned, USGS streamflow gage (07332620), located at SWQM station 20167, was removed in October 2019 prior to the filling of Bois d'Arc Lake. Instantaneous streamflow information was available at that station dating back to July 2006. Data from this station was used to calculate the monthly aggregated streamflow for Bois d'Arc Creek because it has a more robust dataset (Figure 19).

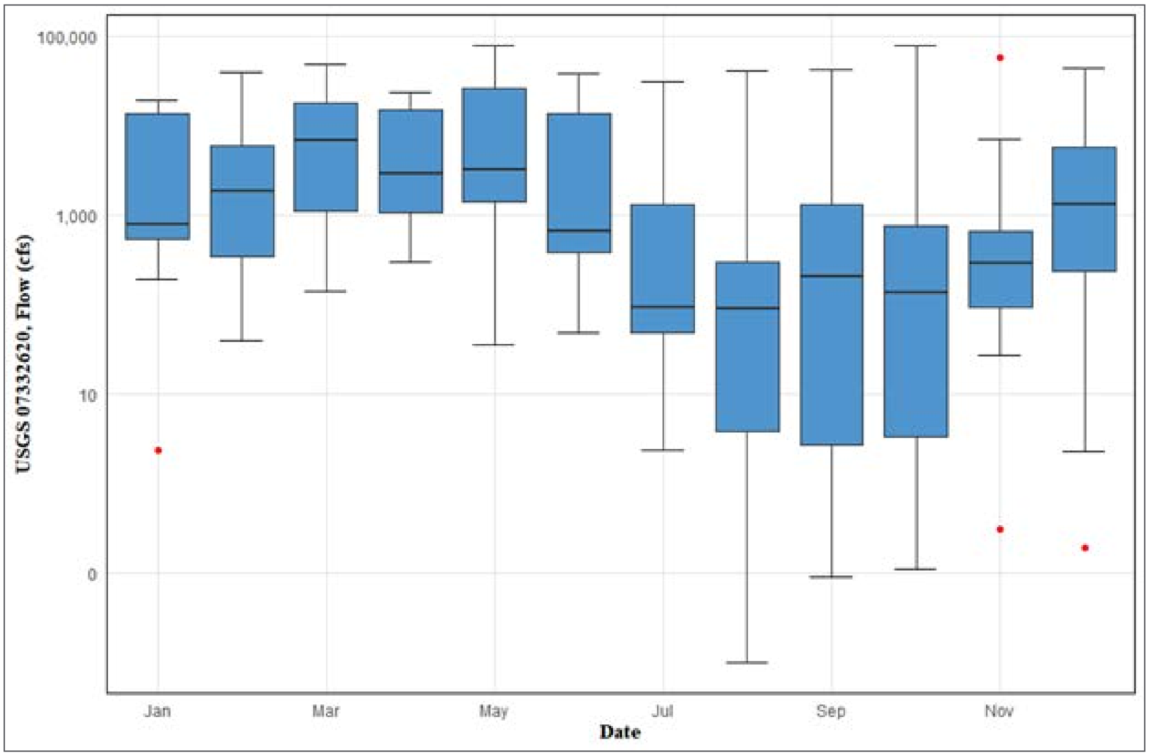


Figure 19. Aggregated monthly streamflow for Bois d'Arc Creek from July 2006 through September 2019.

Potential Sources of Pollution

Pollution sources are categorized as either a point or nonpoint source. Point sources enter receiving waters at identifiable locations, such as a pipe. Nonpoint sources include anything that is not a point source and enters the water body by runoff moving over and/or through the ground. Potential pollution sources in the watershed were identified through stakeholder input, project partners, and watershed monitoring.

Point Source Pollution

Point source pollution is any type of pollution that can be traced back to a single point of origin, such as a WWTF. Generally, WWTFs discharges are permitted, which means they are regulated by permits under TPDES. Other permitted discharges include industrial or construction site stormwater discharges and discharges from municipal separate storm sewer systems (MS4s) of regulated cities or agencies.

WWTFs

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

There are currently six facilities in the Bois d'Arc Lake watershed that treat domestic wastewater (Table 10; Figure 20). Discharge for all six facilities is measured in millions of gallons per day (MGD). Each WWTF has experienced non-compliance in the past. Five of the facilities have reported exceedances in bacteria concentration discharge limits. None of the bacteria effluent violations were reported as "significant" non-compliance. Significant non-compliance violations are defined as violations or events at a given facility that may pose a more severe level of concern for the environment. Regarding bacteria, these types of violations are typically issued when there are reports of excessively high monthly *E. coli* averages or grab samples from the effluent at a facility. Compliance status is based on the period of record available through the EPA Enforcement and Compliance History Online (ECHO) database, which shows history of facility compliance with National Pollutant Discharge Elimination System (NPDES) and TPDES permit requirements.

Sanitary Sewer Overflows (SSOs)

SSOs can occur when sewer lines lose capacity due to age, lack of maintenance, inappropriate connections, or overload during storm events. Inflow and infiltration (I&I) are common issues to all sanitary sewer systems. Inflow occurs primarily during large runoff events and can occur through uncapped cleanouts and gutter connections to the sewer system or through cross connections with storm sewers and faulty manhole covers. Infiltration happens slowly, as it

Table 10. Permitted wastewater facilities in the Bois d'Arc Lake watershed.

Facility name (TPDES permit number)	Receiving stream	Flow (million gallons per day)		Bacteria (MPN/100 mL)		Number of quarters in violation for exceedance 01/2017–12/2019
		Final permitted	Reported (3-year average)	Permitted (daily average)	Reported (3-year average)	
Bonham WWTF (WQ0010070-001)	Pig Branch to Bois d'Arc Creek (0202A)	2.50	1.16	126	7.7	1 (1 ammonia daily avg., 1 ammonia daily max.)
Windom WWTF (WQ0010666-001)	Burnett Creek to Bullard Creek to Bois d'Arc Lake	0.032	0.12	126	343.6	12 (5 DO monthly min., 10 BOD daily avg., 4 pH max, 1 pH min., 4 TSS daily avg., 7 flow daily avg., 2 chlorine monthly min., 3 *E. coli* daily avg., 2 *E. coli* single grab)
Randolph WWTF (WQ0014752-001)	Unnamed tributary to Bois d'Arc Creek (0202A)	0.0218	0.0099	126	796.4	12 (3 DO monthly min., 12 BOD daily avg., 4 BOD single grab, 2 pH max, 2 TSS daily avg., 4 flow daily avg., 8 *E. coli* daily avg., 9 *E. coli* single grab)
Whitewright WWTF (WQ0010644-001)	Bois d'Arc Creek (0202A)	0.627	0.25	126	19.5	9 (3 TSS daily avg., 2 TSS daily max., 3 ammonia daily avg., 4 ammonia daily max., 2 flow daily avg., 1 *E. coli* daily avg., 2 *E. coli* daily max.)
Dodd City WWTF (WQ0010538-001)	Long Branch Creek to Sloans Creek to Bois d'Arc Creek (0202A)	0.048	0.024	126	602.8	9 (5 DO monthly min., 8 BOD daily avg., 1 BOD single grab, 3 TSS daily avg., 7 pH max., 1 chlorine monthly min., 5 flow daily avg., 7 *E. coli* daily avg., 6 *E. coli* daily max.)
Honey Grove WWTF (WQ0010710-003)	Honey Grove Creek (0202L)	0.5	0.304	126	26.2	5 (1 DO monthly min., 3 flow daily avg., 2 *E. coli* daily avg., 2 *E. coli* daily max.)

Most probable number, MPN; milliliter, mL; dissolved oxygen, DO; Texas Pollutant Discharge Elimination System, TPDES, biochemical oxygen demand, BOD; total suspended solids, TSS; *Escherichia coli, E. coli;*

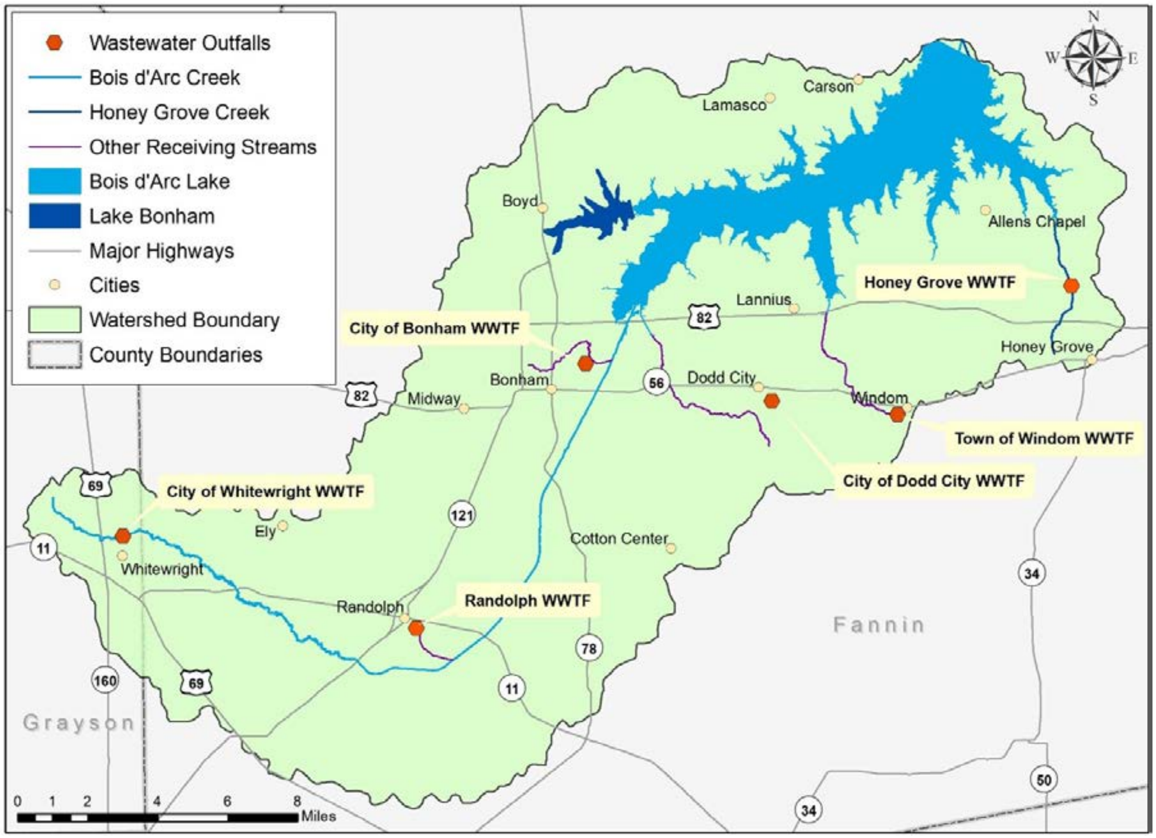


Figure 20. Active permitted wastewater discharge outfall locations for the Bois d'Arc Lake watershed.

generally occurs through cracks and breaks in lateral lines on private property or sewer mains, bad connections between laterals and sewer mains, and in deteriorated manholes.

These overflows and spills can reach water bodies, resulting in substantial periodic bacterial loading. Permit holders are required to report SSOs that occur in their system to TCEQ. According to TCEQ regional office, nine SSO events were reported in the region from January 1, 2017 through December 31, 2019 (Table 11). Almost half of the events were blockages caused by material that should not be flushed or poured down drainpipes. Other than SSO event reports, no compliance or pollutant loading data associated with SSOs are available. The pollutant loads associated with individual events such as SSOs are likely to vary widely depending on the amount and makeup of the discharge.

Regulated Stormwater

Regulated stormwater includes any stormwater originating from TPDES-regulated MS4s, industrial facilities, and regulated construction activities. Polluted urban stormwater runoff is commonly transported through MS4s. MS4s often have large numbers of discharge points, so permits for such systems are issued covering all the outfalls in a city's MS4. Any failures of MS4s—due to age, illicit connections, blockages, etc.—will lead to the potential pollution of urban stormwater, especially under wet weather with large urban runoff.

At the time of publication, there are no MS4s in the watershed. There are three active industrial facilities, 19 active construction sites, and one active concrete production facility. Based on the 2019 NLCD, only 22 square miles out of the 326 square mile watershed are urbanized or developed. From the watershed-wide perspective, contributions to surface water impairments from regulated stormwater and urbanized development are assumed to be small based on the relatively low amount of stormwater permits and developed land. However, urban areas in the watershed may contribute to stormwater pollution in their subwatersheds as populations grow and impervious surfaces increase.

Nonpoint Source Pollution

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

Table 11. Sanitary sewer overflow events since 2017 for the Bois d'Arc Lake watershed.

Facility	Date	Gallons	Cause
Bonham wastewater treatment facility (WWTF)	11/30/2017	7,500	Line blockage (non-grease)
Bonham WWTF	7/25/2018	5,000	Line blockage (non-grease)
Bonham WWTF	8/14/2018	200	Equipment failure
Bonham WWTF	8/27/2018	1,000	Grease blockage
Bonham WWTF	12/26/2018	3,500	Inflow and infiltration (I&I)
Bonham WWTF	2/5/2019	10,000	Line break
Bonham WWTF	9/24/2019	50,000	I&I
Randolph WWTF	4/4/2018	2,000	Line blockage (non-grease)
Whitewright WWTF	4/26/2018	500	Line blockage (non-grease)

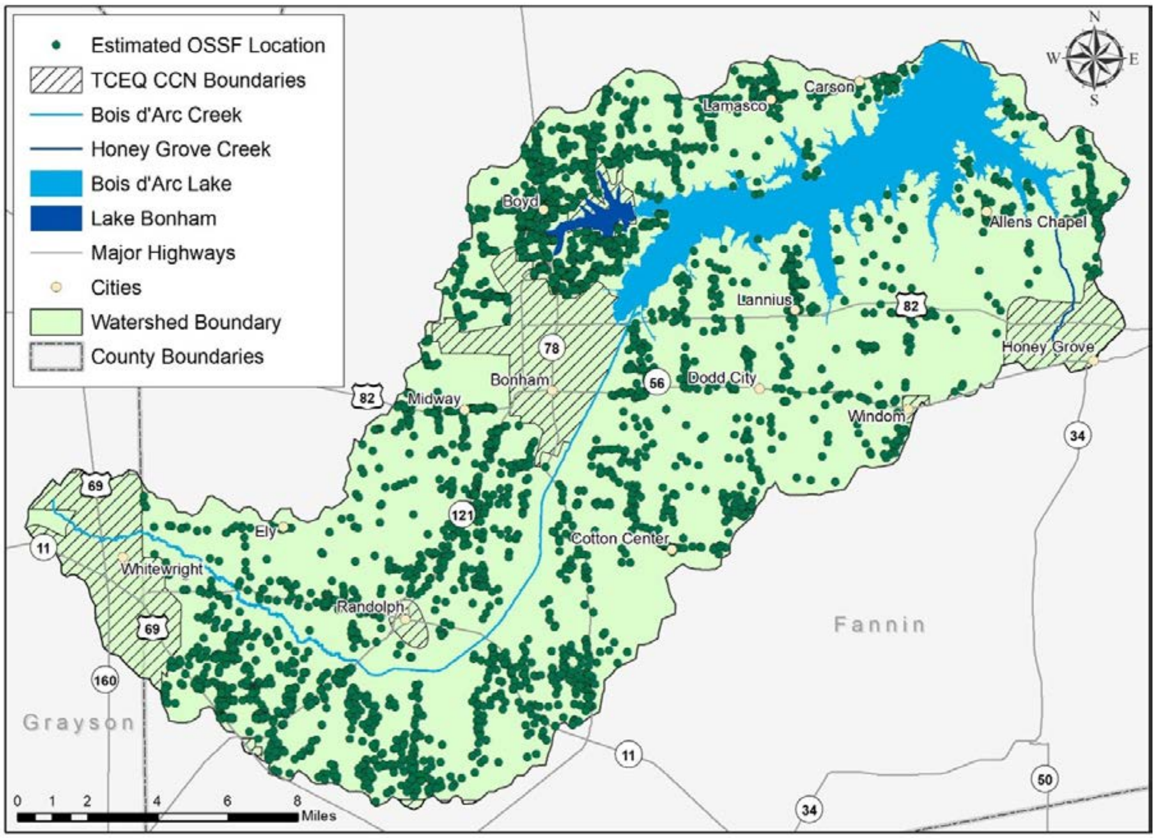


Figure 21. Estimated on-site sewage facility (OSSF) locations in the Bois d'Arc Lake watershed.

OSSFs

OSSFs are common in the watershed and may contribute *E. coli*, nutrients, and solids to water bodies if not properly functioning. The exact number of systems in the watershed and their locations, ages, types, and functional statuses is unavailable, making it difficult to determine their real effects on water quality. To estimate the number of systems and approximate their locations, an approach using 911 address points, 2010 U.S. Census data, and recent aerial imagery was used to estimate the number of OSSFs. OSSF locations were estimated by validating 911 addresses as household structures (determined by remote imagery) located outside of WWTF service areas. This method of locating potential OSSF sites was used because georeferenced OSSF locations were not available from local databases. This method produced an estimate of 2,932 OSSFs within the watershed (Figure 21).

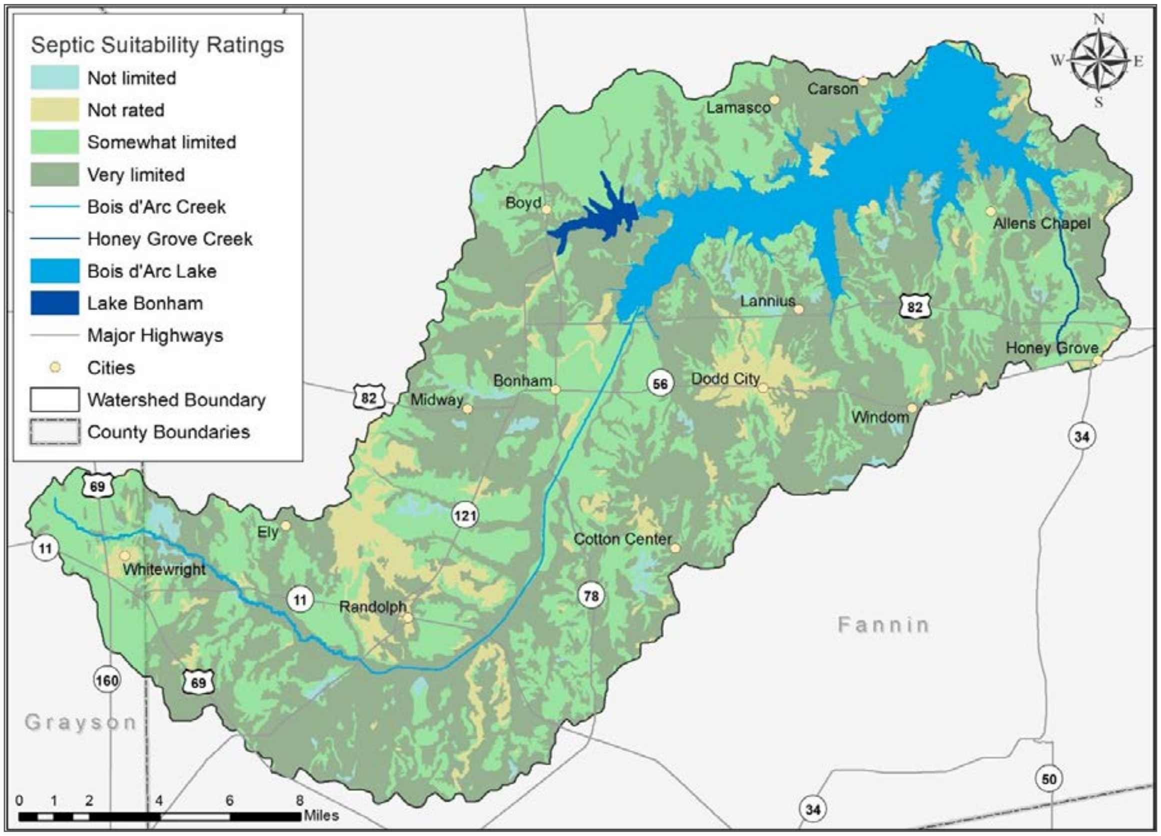


Figure 22. Bois d'Arc Lake watershed on-site sewage facility adsorption field ratings.

Typical OSSF designs include either anaerobic systems composed of a septic tank(s) and an associated drainage or distribution field or 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 anaerobic OSSFs to treat wastewater by percolation. Soil suitability rankings were developed by the NRCS to evaluate the soil's ability to treat wastewater based on soil characteristics such as topography, saturated hydraulic conductivity, depth to the water table, ponding, flooding effects, and more (USDA NRCS 2020). 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 in somewhat or very limited soils pose an increased risk of failure. Most soils in the watershed are rated very limited for OSSF use, followed by smaller areas rated somewhat limited (Figure 22).

Livestock

The grazing of livestock—predominantly cattle, and to a lesser extent goats, horses, and sheep—occurs throughout the Bois d'Arc Lake watershed. These animals also serve as potential sources of nonpoint source pollution. They graze over large tracts of land, rather than being confined, and deposit urine and fecal matter onto the land surface as well as directly into water bodies if accessible. Fecal matter deposited within the watershed is likely to be transported to creeks during runoff events, which contributes to the total bacterial load in the water body.

It is difficult to quantify the exact numbers of these animals within the watershed. However, county-level population estimates are available from the National Agricultural Statistics Service (NASS) that help to develop an approximation of the total livestock within the watershed (Table 12). Estimates for all livestock were derived from NASS county statistics applied to pasture and range land use types. The units for cattle in the watershed are in Animal Units (AnUs), while all other livestock numbers have not been converted to AnUs. The Society for Range Management defines an AnU as one mature cow approximately 1,000 pounds (lbs), either dry

Table 12. Estimated grazing livestock populations in the Bois d'Arc Lake watershed.

Cattle	Horses	Goats/sheep	Pigs/hogs	Poultry
26,572	1,053	2,348	176	3,381

or with a calf up to 6 months of age. Therefore, one head of cattle equates to approximately one AnU.

Wildlife and Feral Hogs

Wildlife is another contributor to *E. coli* and nutrient loads in the watershed. Riparian areas provide the most suitable wildlife habitat in the watershed, leading most wildlife to spend most of their time in these areas. The amount of fecal deposition is directly related to time spent in a given area; thus wildlife feces are considered as a major source in the watershed. Wildlife population density estimates are limited to deer and feral hogs because information regarding other species is not available.

TPWD conducts deer population surveys within the state of Texas at the resource management unit (RMU) level. RMUs are developed based on similar ecological characteristics within a defined area. The Bois d'Arc Lake watershed is situated in parts of the Blackland Prairie (RMU 21). The estimated deer population within RMU 21 is 26.69 acres/deer from 2005 to 2015. This population estimate was applied to every LULC class within the watershed except for open water, barren land, and developed land. Based on these assumptions, there are an estimated 6,583 head of deer in the watershed.

Feral hogs are a non-native, invasive species rapidly expanding throughout Texas, inhabiting similar areas than white-tailed deer. They are especially fond of places where there is dense cover, and food and water are readily available. They are also known to wallow in available water and mud holes. Riparian corridors are prime habitat for feral hogs, and they spend much of their time in or near creeks. This preference for riparian areas does not preclude their use of non-riparian areas. Reclusive by nature, feral hogs are something of a nocturnal species. They typically remain in thick cover during the day and venture away from this cover at night into more open areas of the watershed such as cropland, pastures, or rangeland. Feral hogs are significant contributors of pollutants to creeks and rivers across the state through direct and indirect fecal loading. In addition, extensive rooting and wallowing in riparian areas by feral hogs cause erosion and soil loss. The density of feral hogs was estimated at 33.3 acres/hog for non-developed LULC type based on Wagner and Moench (2009) and stakeholder input. In total, an estimated 5,276 head of feral hogs are in the watershed.

Pets

Dogs can contribute to fecal bacterial loading when waste and bacteria run off from lawns, parks, and other areas. This type of loading is easily avoided if pet owners properly dispose of pet waste. According to the American Veterinary Medical Association (AVMA), the average household in the United States is home to 0.614 dogs (AVMA 2018). We estimated the number pets in the watershed by multiplying these average densities by the number of households estimated from U.S. Census data. The stakeholders agreed with this methodology, and based on these assumptions, we estimated 5,174 dogs in the watershed.

Other Sources

Fertilizers, herbicides, and pesticides are commonly applied to cropland and pastures and may be washed into the Bois d'Arc Lake watershed during runoff events. These managed lands also provide a source of food and cover for livestock, wildlife, and other species that deposit fecal material as they use the land, resulting in potential *E. coli* and nutrient loading to Bois d'Arc Creek and Honey Grove Creek. To date, no Bois d'Arc Lake watershed-specific studies have been conducted to quantify nutrient or bacterial loading contributions from these lands. It is reasonable to conclude that load contributions vary substantially between and within watersheds based on local soil, land cover, and management practices based on results from studies conducted elsewhere.

Stakeholders identified illegal dumping as a potential source of bacteria in the watershed. Dumping of animal carcasses in or next to streams can directly contribute bacteria to the watershed. Illegal dumping of residential waste could feasibly contribute bacteria, as could illegal dumping of septic waste.

Chapter 5
Pollutant Source Assessment

Domesticated hogs on a farm near Lamasco, TX. Photo by Ed Rhodes, TWRI.

Introduction

The water quality sampling described in Chapter 4 established that the primary water quality impairment in the Bois d'Arc Lake watershed is excessive fecal indicator bacteria in Bois d'Arc Creek and Honey Grove Creek. The *2020 Texas Integrated Report* also identified screening concerns for nitrate and total phosphorus in Bois d'Arc Creek and total phosphorus in Honey Grove Creek. To calculate the reductions needed to meet primary contact recreation standards for bacteria, the load capacities of Bois d'Arc Creek and Honey Grove Creek were calculated. The current loads for both water bodies were calculated using water quality data and the load duration curve (LDC) method. By taking the difference between the load capacity and the current load, this WPP estimates the needed reductions to meet water quality standards.

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

LDC Analysis

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

To construct an LDC, an FDC is multiplied by the allowable pollutant concentration minus a margin of safety (10%)

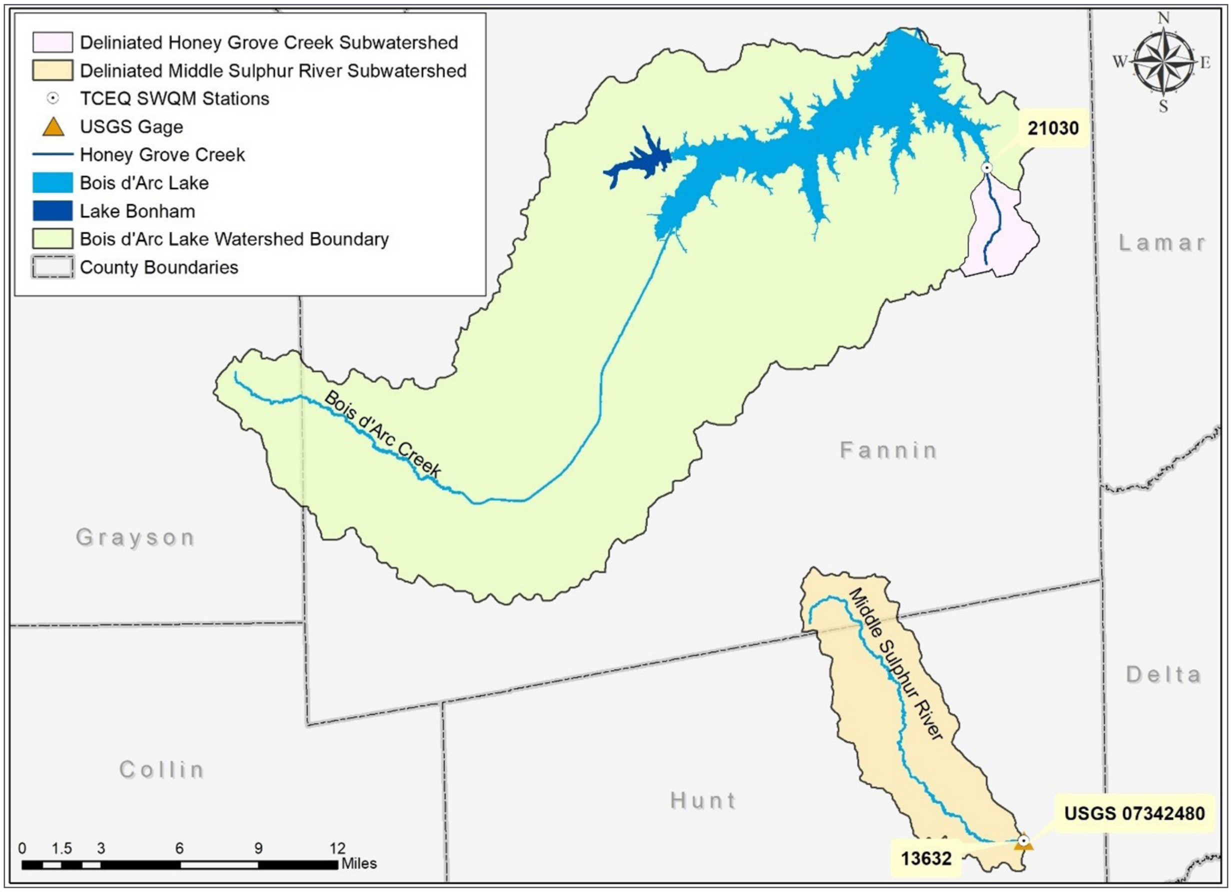


Figure 23. Middle Sulphur River subwatershed used in naturalized streamflow development for Honey Grove Creek subwatershed delineation at Texas Commission on Environmental Quality (TCEQ) surface water quality monitoring (SWQM) station 21030.

to identify the maximum acceptable pollutant load across all flow conditions. Using existing water quality and stream flow measurements, pollutant loads are plotted on the same figure. Points above the curve exceed criteria set forth in state water quality standards while points below the curve do not. The difference between the predicted load and the allowable load is the estimated load reduction required to achieve the water quality standard. Additional guidance and information on LDCs are available in EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs* (EPA 2007). LDC analysis further illustrates the dispersal of the data and how it relates to water quality for any given flow volume.

Ideally, daily streamflow records would be available for all the AUs in the watershed to provide a robust dataset for LDC development. Unfortunately, there was only one USGS gage (07332620) with daily historical flow data in the Bois d'Arc Lake watershed. Due to the construction of Bois d'Arc Lake, this gage was relocated in 2019 further upstream in Bois d'Arc Creek. As a result, daily streamflow records had to be simulated for TCEQ SWQM stations in the watershed using a method called the drainage area ratio (DAR; Asquith et al. 2006). This method was reviewed jointly by the USGS and TCEQ using 7.8 million values of daily streamflow data from 712 USGS streamflow gauges in Texas and was found to be a sufficient method in interpolating streamflow measurements.

After delineating the subwatersheds for the DAR, it was apparent that the total drainage area of the USGS gage in Bois d'Arc Creek is much larger than the drainage areas of stations 15036 on Bois d'Arc Creek and 21030 on Honey Grove Creek. Alternative nearby USGS gages with smaller drainage areas were chosen to simulate the naturalized flows of those sites. USGS gage 07342480 on the Middle Sulphur River in Hunt County was chosen for station 21030 (Figure 23) and USGS gage 08050840 on Range Creek in Grayson County was chosen for station 15306 (Figure 24). The date range used for developing daily naturalized streamflow at all stations was July 2006–September 2019. Daily streamflow data from the USGS gage in Bois d'Arc Creek met the requirements for estimating streamflow records for stations 18652 and 21028.

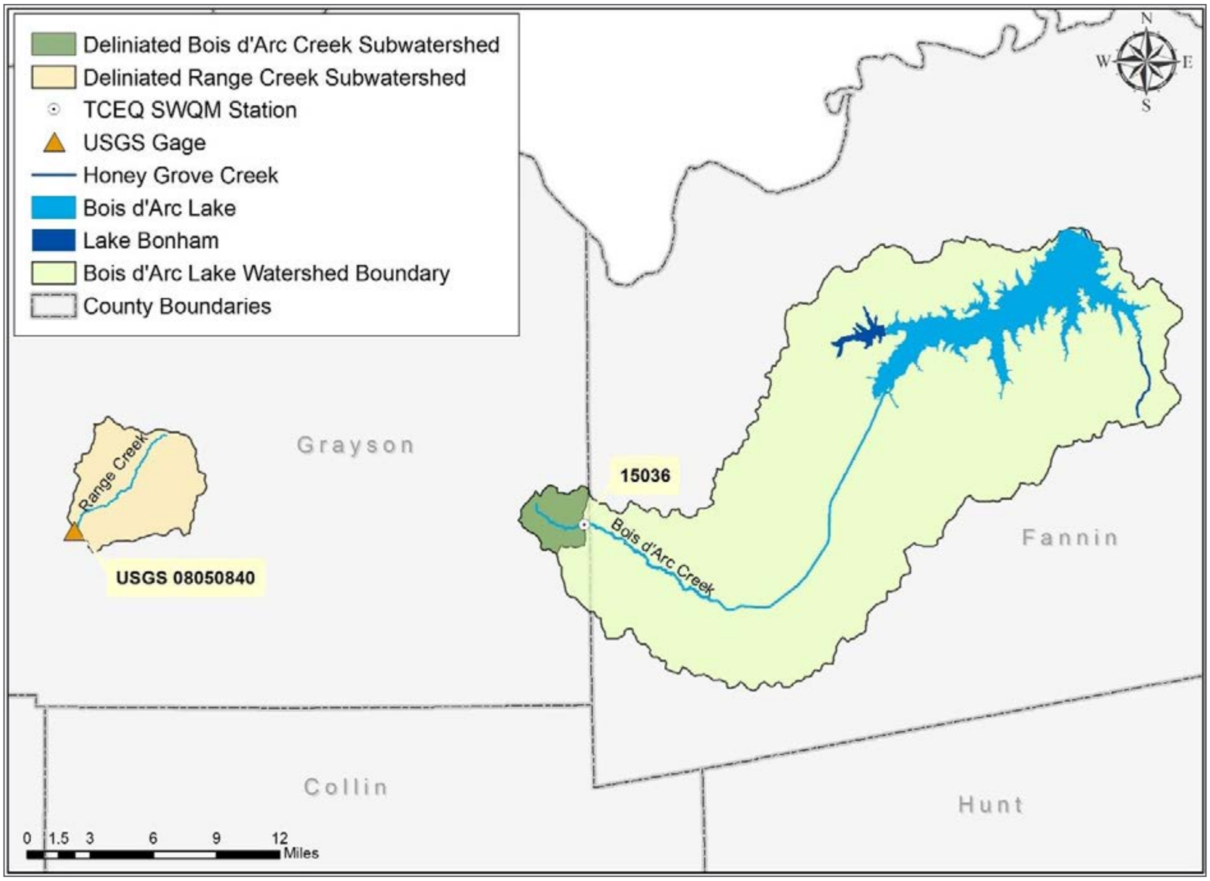


Figure 24. Range Creek subwatershed used in naturalized streamflow development for Bois d'Arc Creek subwatershed delineation at Texas Commission on Environmental Quality (TCEQ) surface water quality monitoring (SWQM) station 15036.

Bacteria LDCs

In total, four *E. coli* LDCs were produced for the Bois d'Arc Lake watershed. One LDC was created from data at SWQM station 15036 (Figure 25) to represent the impaired Bois d'Arc Creek AU 0202A_03. This LDC indicates the *E. coli* loadings exceeded allowable loads across the mid-range and low flow conditions.

Two LDCs were created to represent the unimpaired Bois d'Arc Creek AU 0202A_02 because the calculated geomean in the *2020 Texas Integrated Report* barely met water quality standards and a number of samples taken in the AU exceeded the 126 MPN/100 mL criterion. These LDCs were created from data collected at SWQM stations 18652 (Figure 26) and 21028 (Figure 27). The LDC for SWQM station 18652 indicates the *E. coli* loadings exceed allowable loads at all flow conditions but the largest exceedances occurred at the high flows. The LDC at SWQM station 21028 shows that exceedances are occurring near the loading numeric criteria at all flow conditions.

The final LDC was developed for the impaired Honey Grove Creek from data at SWQM station 21030 (Figure 28). The Honey Grove Creek LDC indicates loads exceeded capacity under all flow conditions.

Flow is imperative to the development of LDCs and plays an important role in how we interpret them. The flow conditions in which exceedances occur can help link pollutant concentrations with potential point or nonpoint sources of pollution. In general, if exceedances observed on the LDC only occur during high flows, nonpoint sources are considered to be the primary causes of impairment. This is because high flows are typically associated with higher rainfall events that generate surface runoff, which can carry pollutants to the stream. Exceedances that only occur during high flows can also be indicative of bacteria present within stream sediments that are resuspended under increased flow. In contrast, exceedances during low flow conditions are generally indicative of point sources or direct fecal deposition to streams from wildlife or domestic livestock because no runoff is entering the stream.

The above observations can be applied to help interpret the LDCs created for the Bois d'Arc Lake watershed. The curve for station 15036 shows that exceedances occur at

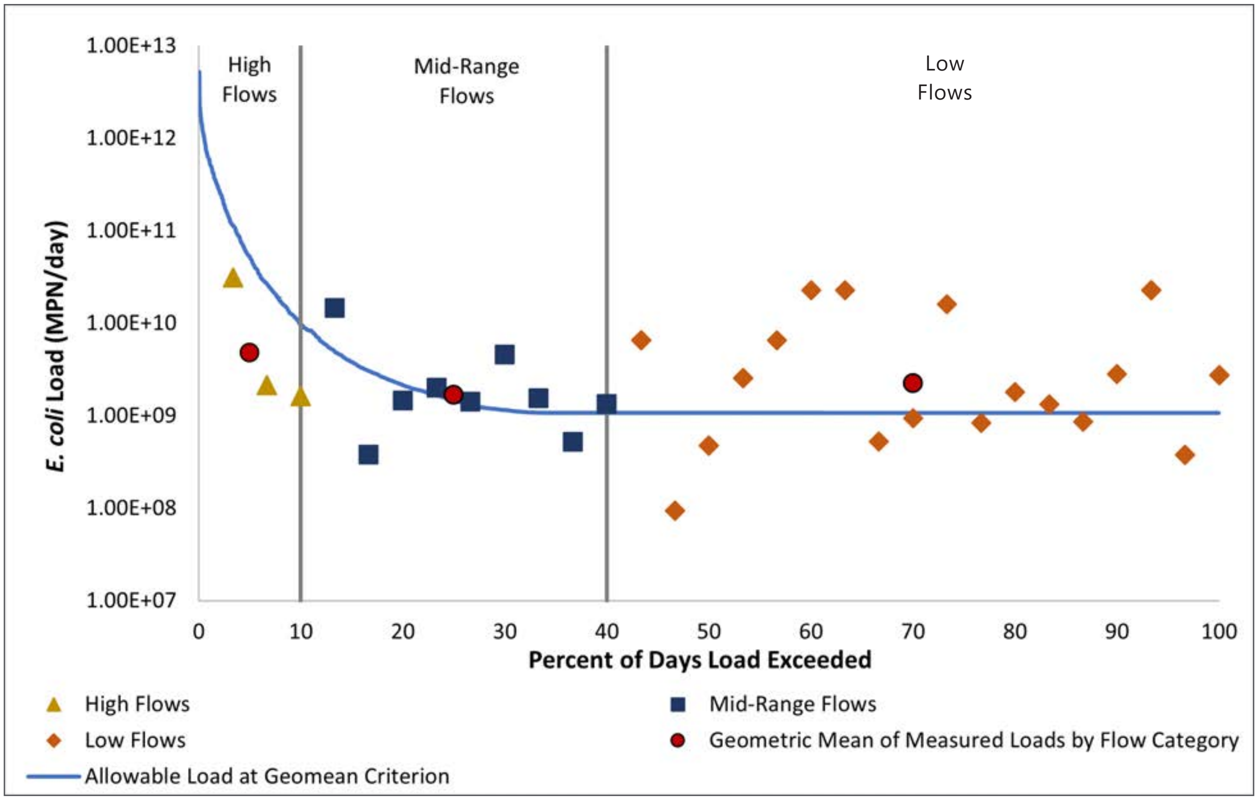


Figure 25. *E. coli* load duration curve for Bois d'Arc Creek surface water quality monitoring station 15036. The solid blue line indicates the allowable load (with a 10% margin of safety [MOS]) at geomean criterion (113 most probable number [MPN]/100 milliliters [mL]).

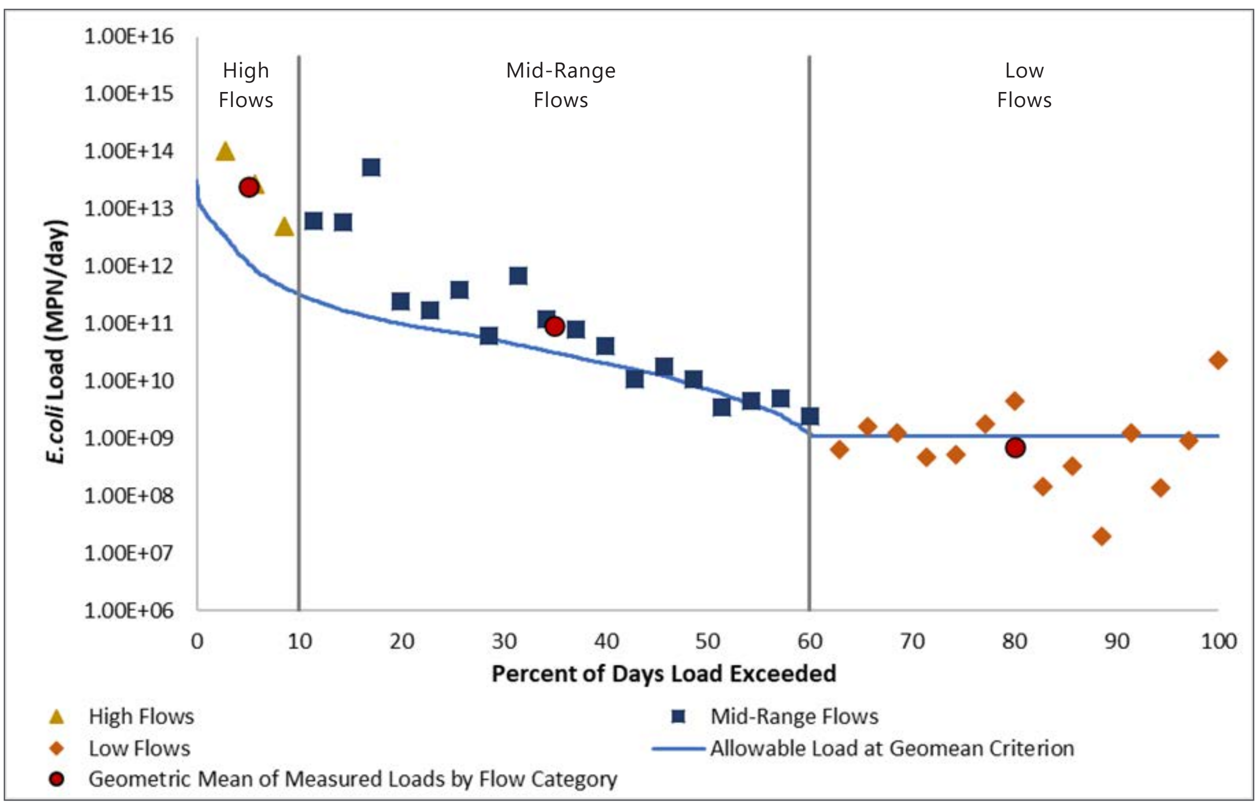


Figure 26. *E. coli* load duration curve for Bois d'Arc Creek surface water quality monitoring station 18652. The solid blue line indicates the allowable load (with a 10% margin of safety [MOS]) at geomean criterion (113 most probable number [MPN]/100 milliliters [mL]).

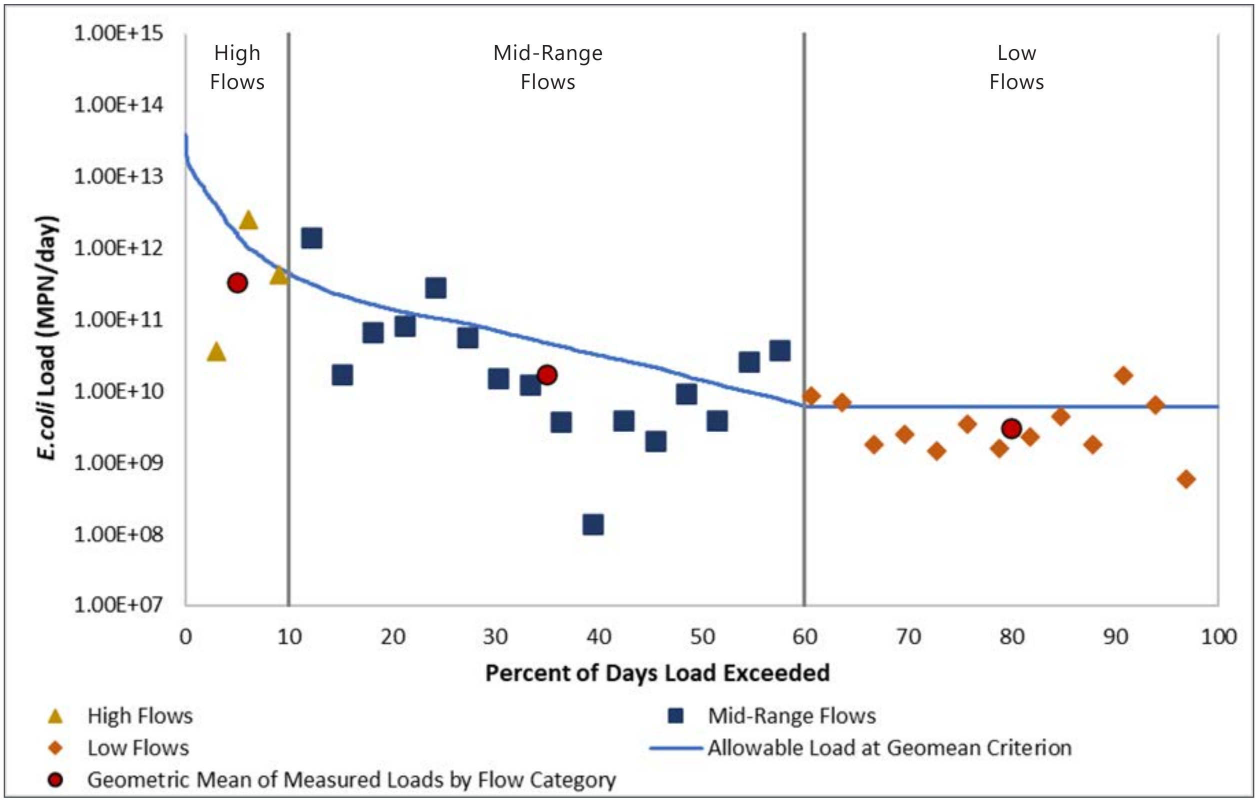


Figure 27. *E. coli* load duration curve for Bois d'Arc Creek surface water quality monitoring station 21028. The solid blue line indicates the allowable load (with a 10% margin of safety [MOS]) at geomean criterion (113 most probable number [MPN]/100 milliliters [mL]).

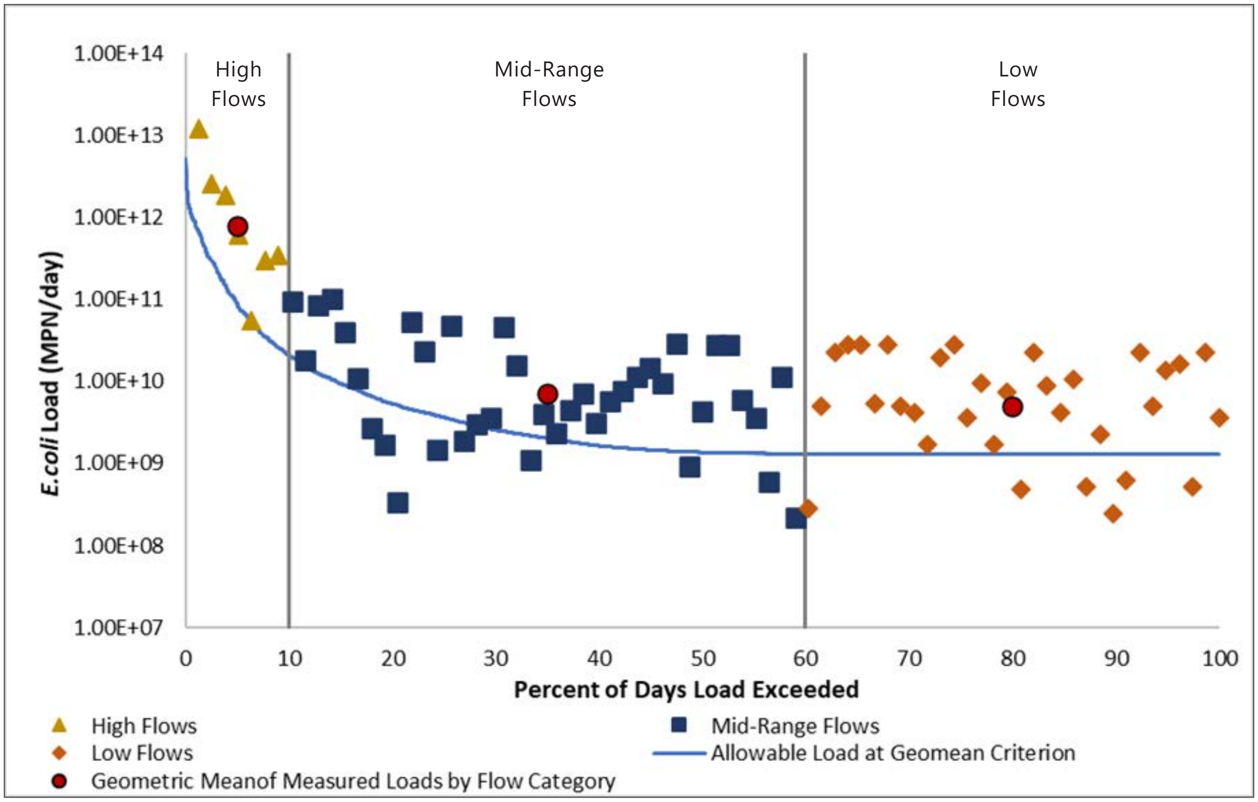


Figure 28. *E. coli* load duration curve for Honey Grove Creek surface water quality monitoring station 21030. The solid blue line indicates the allowable load (with a 10% margin of safety [MOS]) at geomean criterion (113 most probable number [MPN]/100 milliliter [mL]).

Table 13. Summary of estimated annual loads and load reductions required to meet primary contact water quality criteria.

Flow condition	Percent days flow exceeded	Existing annual load (colony forming units/year)	Reduction needed (%)	Annual load reduction required
Station 15036 (Bois d'Arc Creek assessment unit [AU] 0202A_03)				
High flows	0–10	5.85×10^{11}	0%	0
Mid-range flows	10–40	1.86×10^{11}	14.8%	2.76×10^{10}
Low flows	40–100	4.95×10^{12}	52.6%	2.60×10^{11}
Total	N/A	1.27×10^{12}	22.7%	2.88×10^{11}
Station 18652 (Bois d'Arc Creek AU 0202A_02)				
High flows	0–10	7.72×10^{14}	93.5%	7.21×10^{14}
Mid-range flows	10–60	1.02×10^{13}	37.6%	3.83×10^{12}
Low flows	60–100	1.01×10^{11}	0%	0
Total	N/A	7.82×10^{14}	92.7%	7.25×10^{14}
Station 21028 (Bois d'Arc Creek AU 0202A_02)				
High flows	0–10	1.94×10^{14}	65.8%	1.28×10^{14}
Mid-range flows	10–60	9.53×10^{12}	0.24%	2.27×10^{10}
Low flows	60–100	5.74×10^{11}	0%	0
Total	N/A	2.04×10^{14}	62.5%	1.28×10^{14}
Station 21030 (Honey Grove Creek AU 0202L_01)				
High flows	0–10	3.38×10^{13}	89.1%	3.01×10^{13}
Mid-range flows	10–60	1.10×10^{12}	62.3%	6.85×10^{11}
Low flows	60–100	7.34×10^{11}	71.2%	5.23×10^{11}
Total	N/A	3.56×10^{13}	87.9%	3.13×10^{13}
Total				8.84×10^{14}

mid-range and low flows, so pollutants are likely point source driven. The curve for station 18652 indicates that the greatest exceedances are occurring during high flow conditions therefore a majority of the pollutants are likely coming from nonpoint sources. With exceedances occurring well above the criterion at all flow conditions for station 21030, it can be assumed that a combination of nonpoint and point sources are responsible for contributing. Station 21028 shows few exceedances across all flow conditions, so similar to station 21030, the largest bacteria contributions are probably a result of both nonpoint and point sources. It is also important to note that there are few data points in the high flows for all three Bois d'Arc Creek LDCs.

Based on the LDC developed for the impaired Bois d'Arc Creek AU 0202A_03, a total reduction of 2.88×10^{11} MPN/year is required at SWQM station 15036 to meet primary contact recreation standards. The largest reduction is needed at the low flows. A total reduction of 7.25×10^{14} MPN/year is required at the unimpaired Bois d'Arc Creek AU 0202A_02 SWQM station 18652 as well as a total reduction of 1.28×10^{14} MPN/year is required at SWQM station 21028. The largest reductions for these stations are needed during higher flows where nonpoint sources of bacteria are a primary concern. For Honey Grove Creek SWQM station 21030, a total reduction of 3.13×10^{13} MPN/year is required. Similar to Bois d'Arc Creek AU 0202A_02, the largest reduction is needed during the higher flows. A summary of total loads and load reductions for each station can be found in Table 13.

Nutrient LDCs

As previously discussed in Chapter 4, the state of Texas does not currently have numeric nutrient criteria for surface waters. Historically, the state evaluates chlorophyll-a and nutrients such as nitrate and total phosphorus based on screening levels, which are not approved by EPA. These criteria can be used to assess the trophic status of surface waters, which is driven by nitrogen and phosphorus loading. Nitrate and total phosphorus were selected for LDC analysis. Total annual loads were calculated from the LDCs. Due to the absence of statewide numeric criteria, total allowable loads for nitrogen and phosphorus were not calculated for the Bois d'Arc Lake watershed.

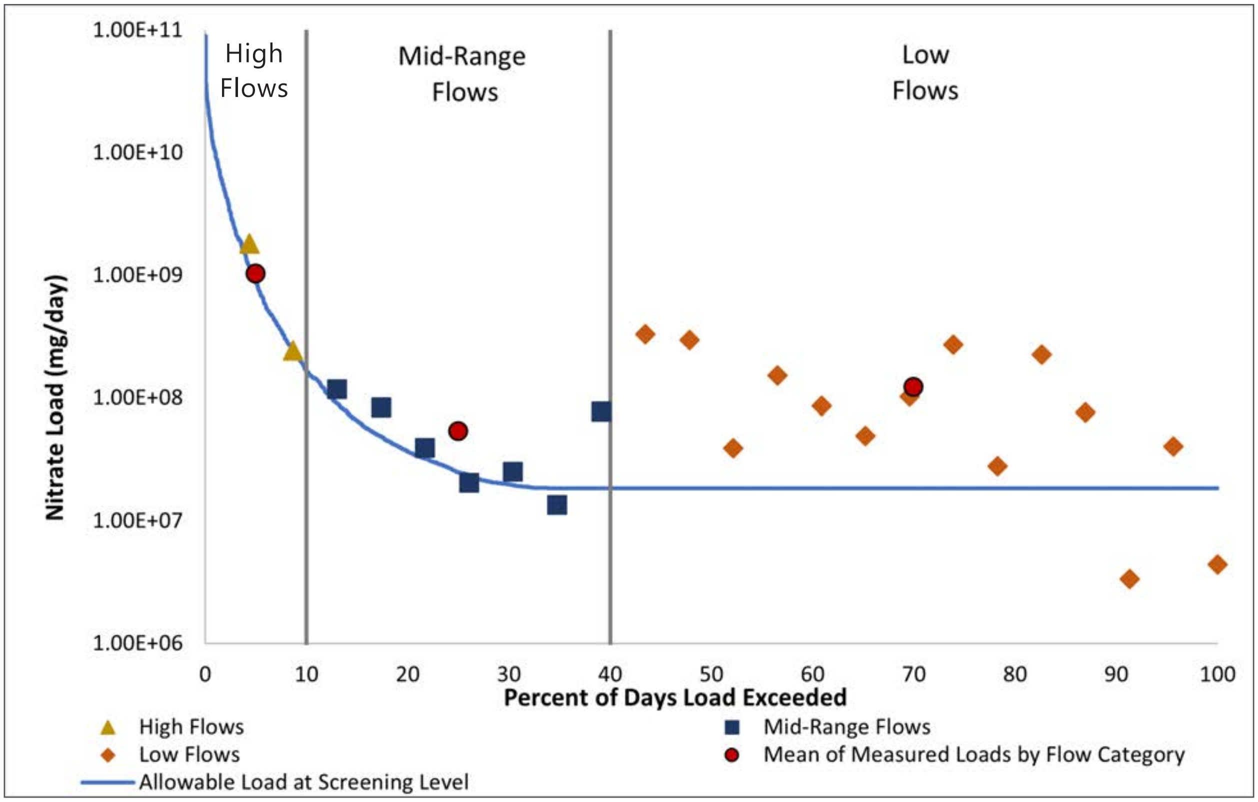


Figure 29. Nitrate load duration curve for Bois d’Arc Creek surface water quality monitoring station 15036. The solid blue line indicates the allowable load at the screening level (1.95 milligrams/liter [mg/L]).

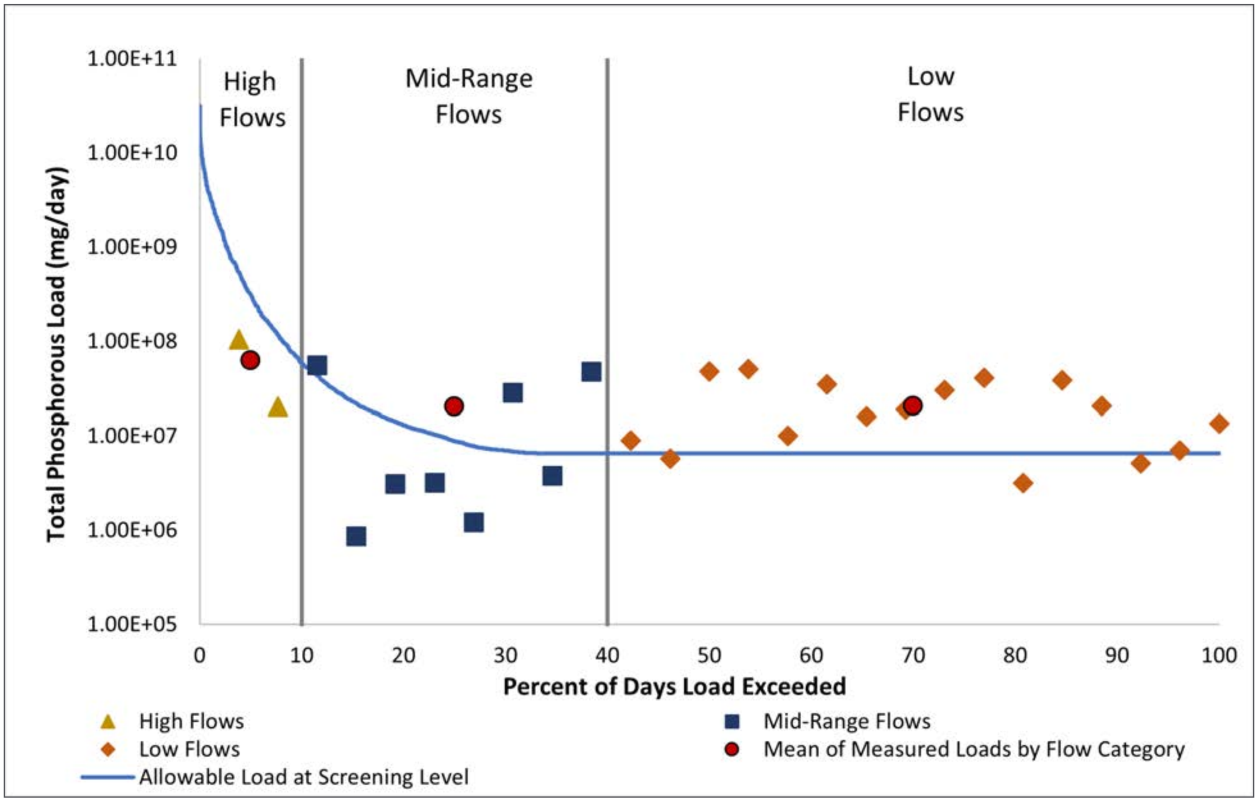


Figure 30. Total phosphorus load duration curve for Bois d’Arc Creek surface water quality monitoring station 15036. The solid blue line indicates the allowable load at the screening level (0.69 milligrams/liter [mg/L]).

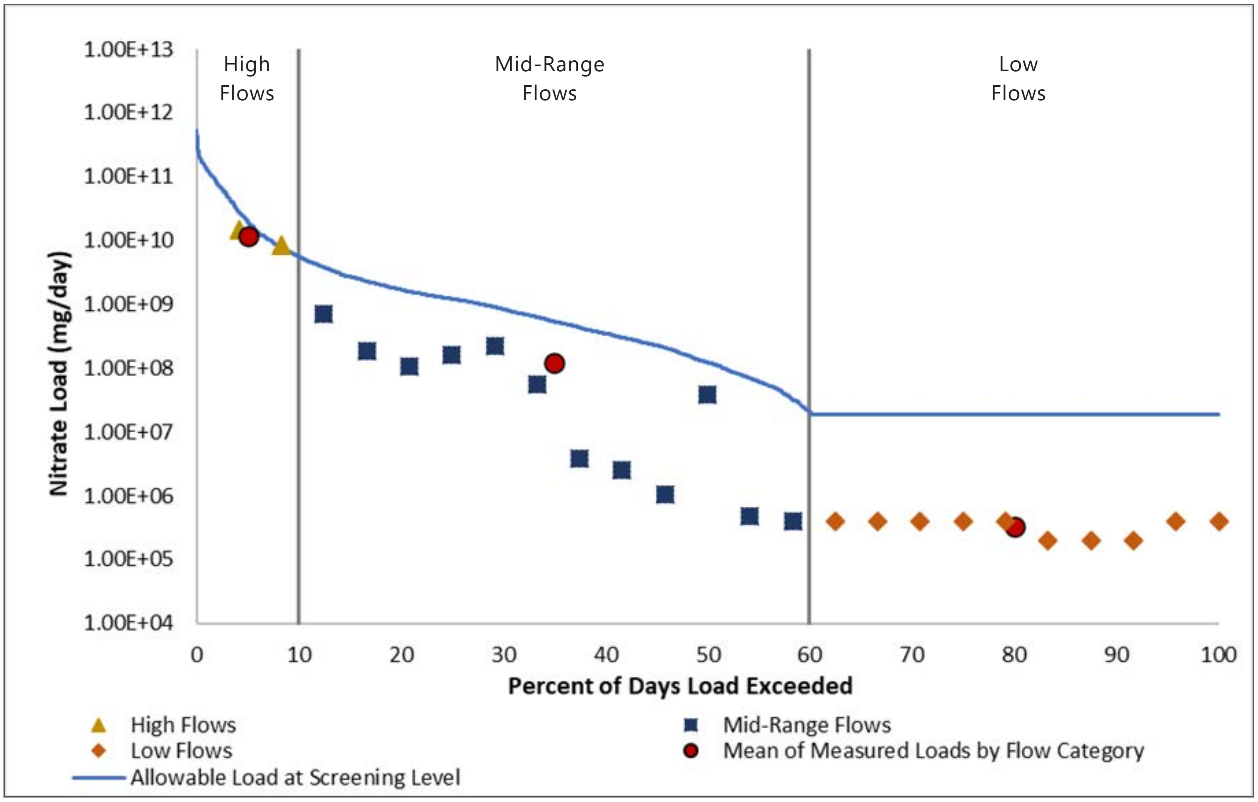


Figure 31. Nitrate load duration curve for Bois d'Arc Creek surface water quality monitoring station 18652. The solid blue line indicates the allowable load at the screening level (1.95 milligrams/liter [mg/L]).

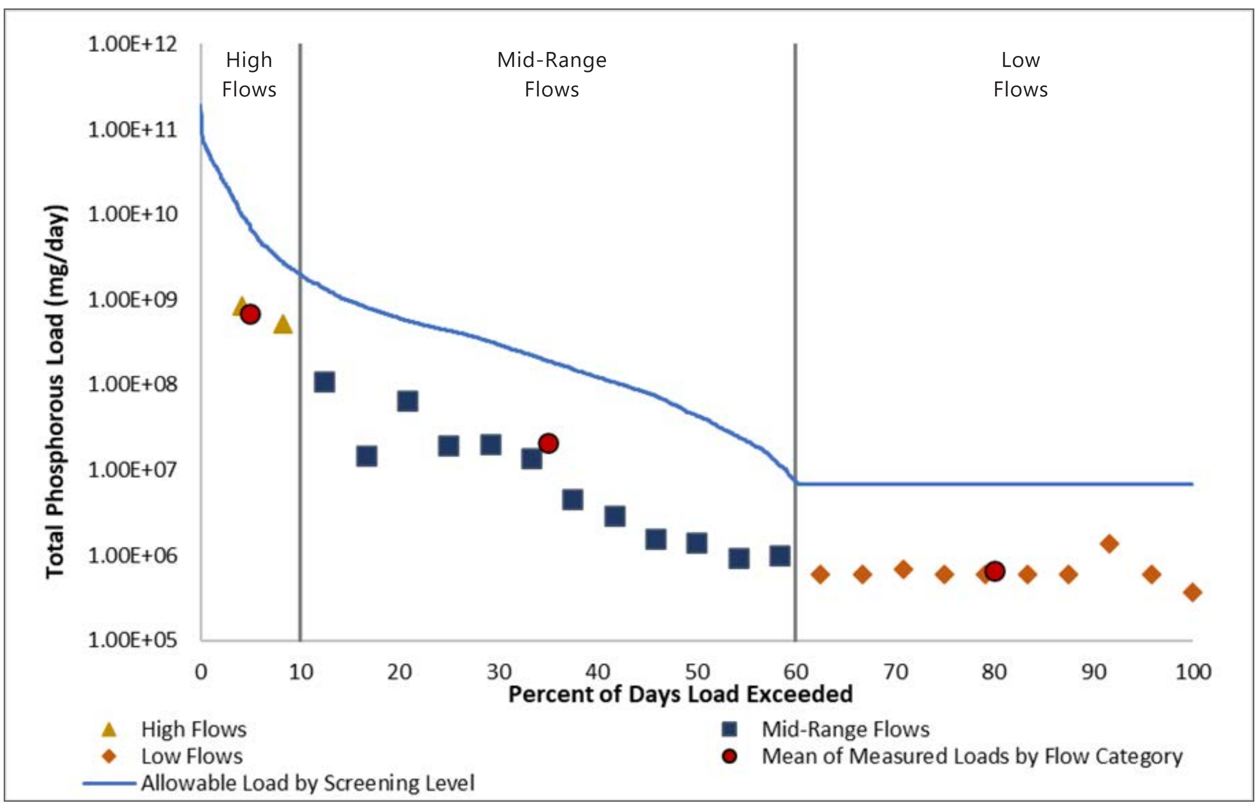


Figure 32. Total phosphorus load duration curve for Bois d'Arc Creek surface water quality monitoring station 18652. The solid blue line indicates the allowable load at the screening level (0.69 milligrams/liter [mg/L]).

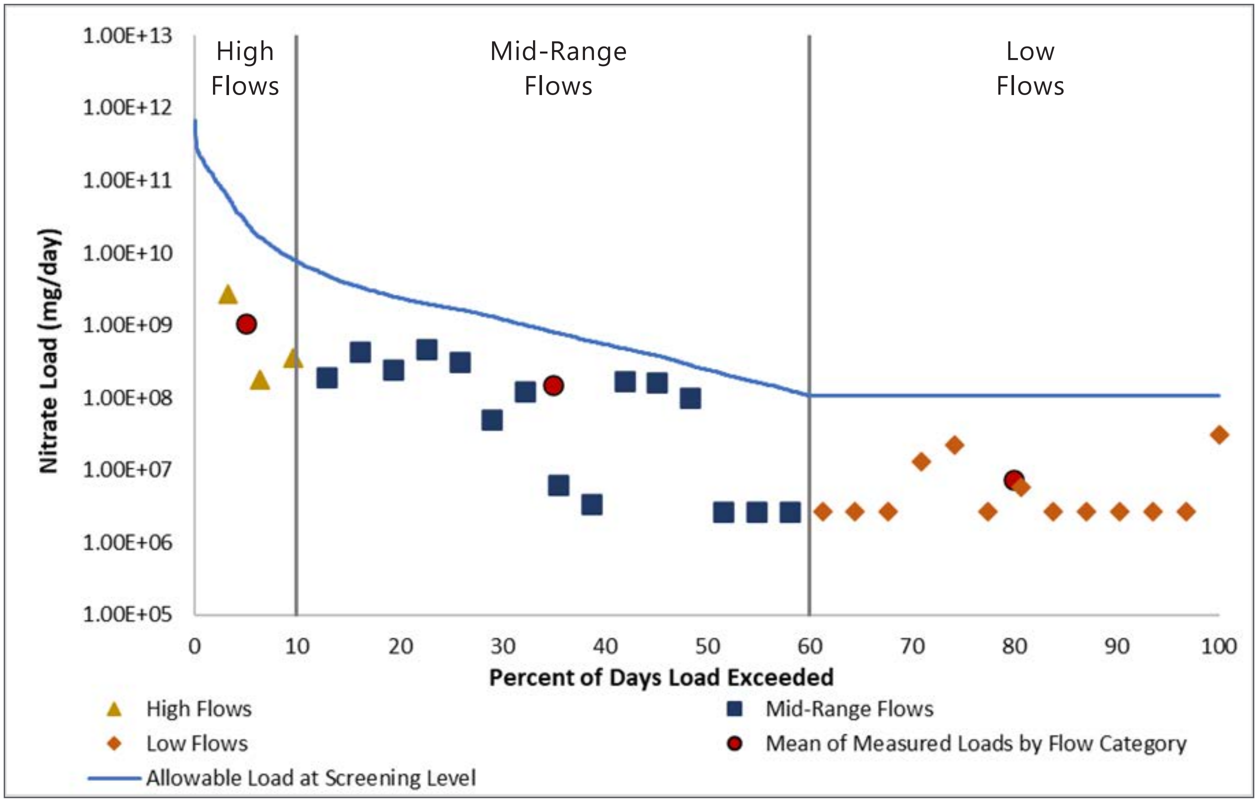


Figure 33. Nitrate load duration curve for Bois d'Arc Creek surface water quality monitoring station 21028. The solid blue line indicates the allowable load at the screening level (1.95 milligrams/liter [mg/L]).

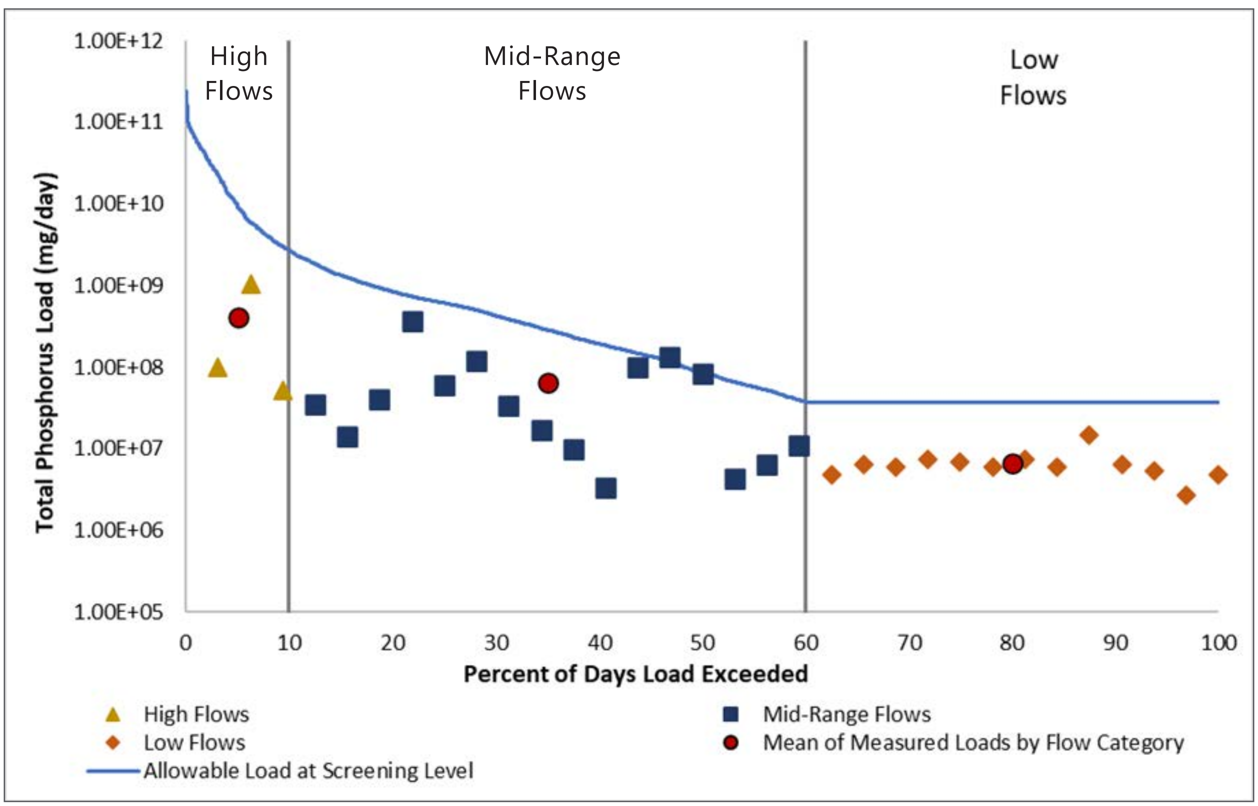


Figure 34. Total phosphorus load duration curve for Bois d'Arc Creek surface water quality monitoring station 21028. The solid blue line indicates the allowable load at the screening level (0.69 milligrams/liter [mg/L]).

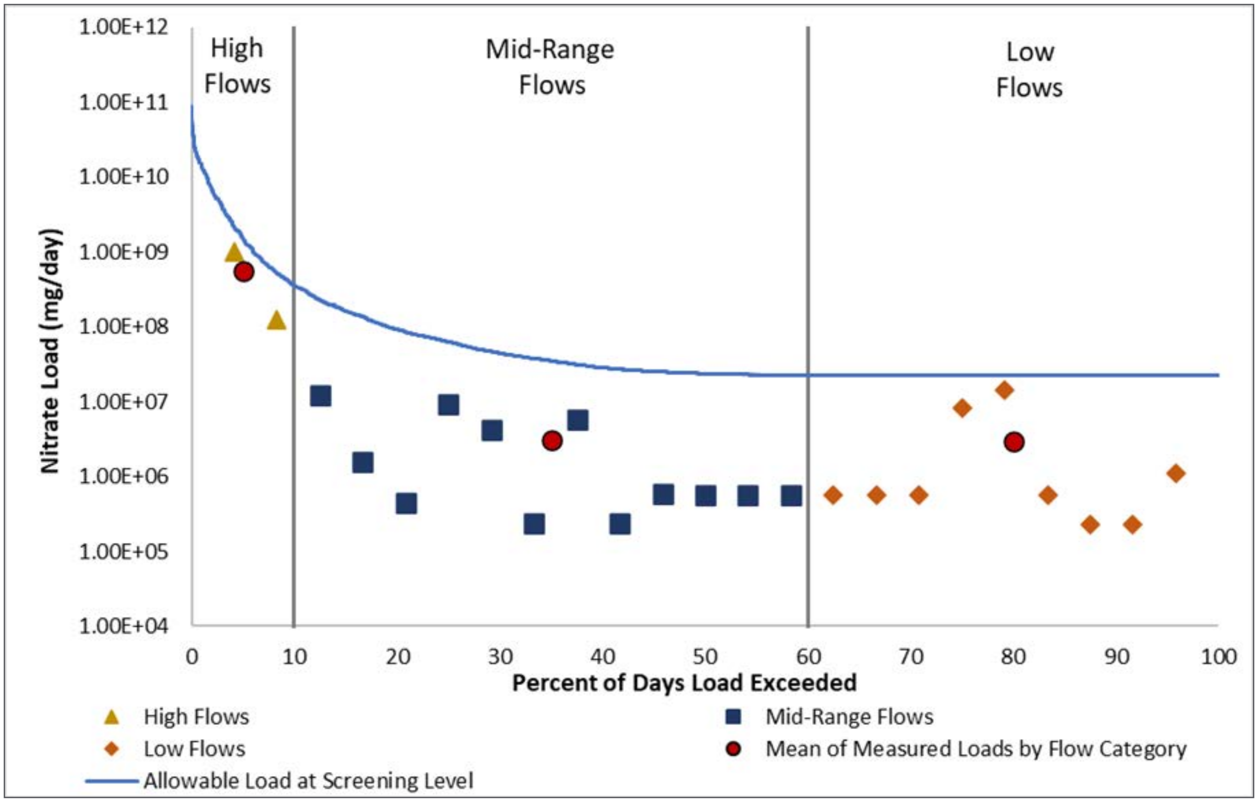


Figure 35. Nitrate load duration curve for Honey Grove Creek surface water quality monitoring station 21030. The solid blue line indicates the allowable load at the screening level (1.95 milligrams/liter [mg/L]).

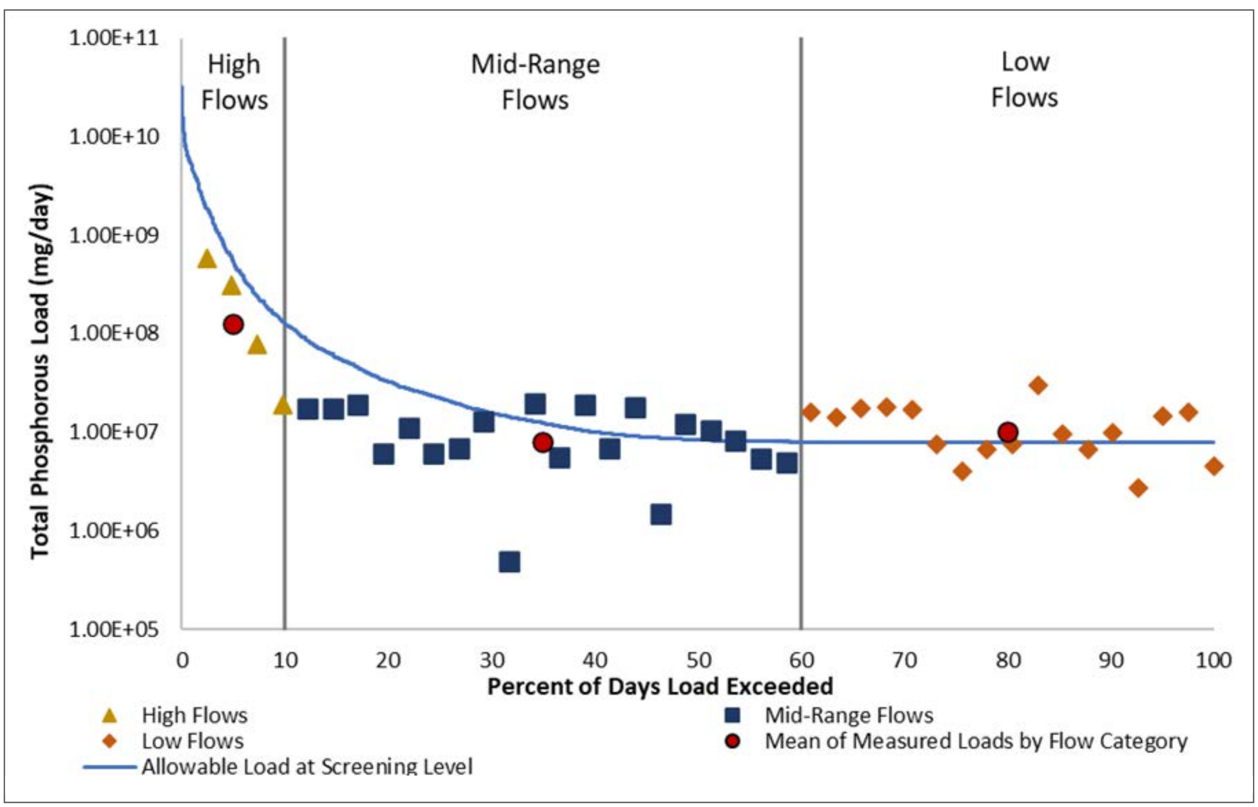


Figure 36. Total phosphorus load duration curve for Honey Grove Creek surface water quality monitoring station 21030. The solid blue line indicates the allowable load at the screening level (0.69 milligrams/liter [mg/L]).

Table 14. Total nutrient load calculations in Bois d'Arc Creek assessment unit 0202A_03 for Texas Commission on Environmental Quality surface water quality monitoring station 15036.

	Flow conditions		
	High	Mid-range	Low
Days per year	36.5	109.5	219
Median flow (cubic feet per second)	18.88	0.52	0.39
Existing nitrate concentration (milligrams/liter [mg/L])	3.76	3.16	12.90
Existing nitrate daily load (billion mg)	0.17	0.004	0.012
Existing nitrate annual load (billion mg)	6.33	0.44	2.67
Total nitrate annual load (billion mg)	9.45		
Existing total phosphorus concentration (mg/L)	0.25	1.46	2.33
Existing total phosphorus daily load (billion mg)	0.01	0.002	0.002
Existing total phosphorus annual load (billion mg)	0.42	0.21	0.48
Total total phosphorus annual load (billion mg)	1.11		

Table 15. Total nutrient load calculations in Bois d'Arc Creek assessment unit 0202A_02 for Texas Commission on Environmental Quality surface water quality monitoring station 18652.

	Flow conditions		
	High	Mid-range	Low
Days per year	36.5	182.5	146
Median flow (cubic feet per second)	447.15	11.29	0.40
Existing nitrate concentration (milligrams/liter [mg/L])	4.00	0.40	0.03
Existing nitrate daily load (billion mg)	4.37	0.01	<0.001
Existing nitrate annual load (billion mg)	159.52	2.03	0.004
Total nitrate annual load (billion mg)	161.59		
Existing total phosphorus concentration (mg/L)	0.24	0.07	0.07
Existing total phosphorus daily load (billion mg)	0.26	0.002	<0.001
Existing total phosphorus annual load (billion mg)	9.46	0.36	0.010
Total total phosphorus annual load (billion mg)	9.83		

Table 16. Total nutrient load calculations in Bois d'Arc Creek assessment unit 0202A_02 for Texas Commission on Environmental Quality surface water quality monitoring station 21028.

	Flow conditions		
	High	Mid-range	Low
Days per year	36.5	182.5	146
Median flow (cubic feet per second)	589.87	16.90	2.20
Existing nitrate concentration (milligrams/liter [mg/L])	1.09	0.97	0.14
Existing nitrate daily load (billion mg)	1.57	0.04	<0.001
Existing nitrate annual load (billion mg)	57.42	7.27	0.11
Total nitrate annual load (billion mg)	64.80		
Existing total phosphorus concentration (mg/L)	0.40	0.54	0.12
Existing total phosphorus daily load (billion mg)	0.58	0.02	<0.001
Existing total phosphorus annual load (billion mg)	21.25	4.05	0.10
Total total phosphorus annual load (billion mg)	25.39		

Table 17. Total nutrient load calculations in Honey Grove Creek for Texas Commission on Environmental Quality surface water quality monitoring station 21030.

	Flow conditions		
	High	Mid-range	Low
Days per year	36.5	182.5	146
Median flow (cubic feet per second)	32.84	0.74	0.47
Existing nitrate concentration (milligrams/liter [mg/L])	0.99	0.17	0.26
Existing nitrate daily load (billion mg)	0.08	<0.001	<0.001
Existing nitrate annual load (billion mg)	2.90	0.06	0.04
Total nitrate annual load (billion mg)	3.00		
Existing total phosphorus concentration (mg/L)	0.55	0.77	1.04
Existing total phosphorus daily load (billion mg)	0.04	0.001	0.001
Existing total phosphorus annual load (billion mg)	1.62	0.25	0.17
Total total phosphorus annual load (billion mg)	2.05		

In total, four nitrate LDCs and four total phosphorus LDCs were produced for the Bois d'Arc Lake watershed. The LDCs created from SWQM station 15036 (Figures 29 and 30) represent Bois d'Arc Creek AU 0202A_03. The nitrate LDC for this station indicates the loadings exceed screening level allowable loads across all flow conditions. The total phosphorus LDC for this station indicates the loadings only exceed screening level allowable loads at mid-range and low flow conditions.

LDCs created from data collected at SWQM stations 18652 (Figures 31 and 32) and 21028 (Figures 33 and 34) represent Bois d'Arc Creek AU 0202A_02. The nitrate and total phosphorus LDCs for SWQM station 18652 indicate the loadings primarily do not exceed screening level allowable loads at any flow condition. The nitrate and total phosphorus LDCs at SWQM station 21028 show that there are no exceedances at any flow condition.

The nutrient LDCs developed for Honey Grove Creek were derived from data at SWQM station 21030 (Figures 35 and 36). The Honey Grove Creek nitrate LDC indicates loads did not exceed screening level capacity under any flow conditions while the total phosphorus LDC indicated screening level loading exceedances occurred at mid-range and low flow conditions.

Based on the nutrient LDCs developed for Bois d'Arc Creek AU 0202A_03, nitrate has a total load of 9.45×10^9 mg/year and total phosphorus has a total load of 1.11×10^9 mg/year at SWQM station 15036 (Table 14). The nitrate total load is 1.62×10^{11} mg/year and the total phosphorus total load is 9.83×10^9 mg/year at Bois d'Arc Creek AU 0202A_02 SWQM station 18652 (Table 15). The total load of nitrate is 6.48×10^{10} mg/year and the total load of total phosphorus is 2.54×10^{10} mg/year at SWQM station 21028 on the same AU (Table 16). For Honey Grove Creek SWQM station 21030, the nitrate total load is 3.00×10^9 mg/year and the total phosphorus total load is 2.05×10^9 mg/year (Table 17).

Pollutant Source Load Estimates

GIS Analysis

A GIS-based analysis was applied using the methodology employed by Borel et al. (2012) to aid in identifying potential area of *E. coli* contributions within the watershed (Appendix A). Estimates of *E. coli* loads were derived from information gathered from the U.S. Census Bureau, LULC classifications, NASS, NRCS soil boundaries, AVMA pet ownership statistics, TPWD population estimates, TCEQ permits, and other geographically based data such as political boundaries and surface topology. Information is spatially referenced where possible from the data source or local stakeholder knowledge.

Using this analysis approach, the relative potential for *E. coli* loading from each source can be compared and used to prioritize management practices that best facilitate load reductions. The loading estimates for each source do not account for bacteria fate and transport processes that occur in the natural environment. As such, these analyses do not represent actual *E. coli* loadings expected to enter the creeks. Potential loads for identified sources are summarized for

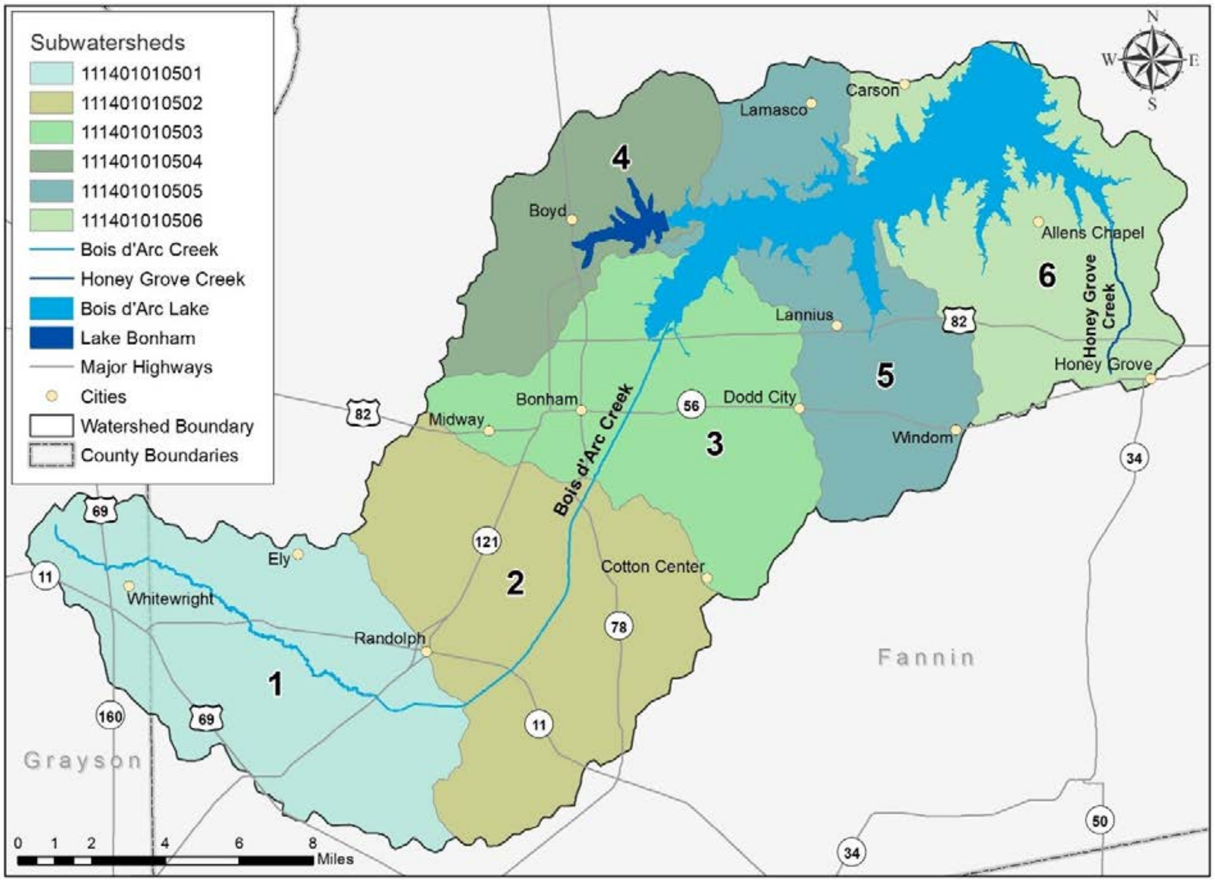


Figure 37. Bois d'Arc Lake subwatersheds.

each of the subwatersheds (Figure 37) found in the watershed. It is also important to note that shoreline development is likely to occur in subwatersheds 5 and 6, which will affect future loading in the lake.

Cattle

Cattle can contribute to *E. coli* bacterial loading 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 levels of *E. coli,* which in turn can increase bacterial loads in the stream. Improved grazing practices and land stewardship can dramatically reduce runoff and bacterial loadings. For example, research in Texas watersheds indicate that rotational grazing and grazing livestock in upland pastures during wet seasons results in significant reductions in *E. coli* levels (Wagner et al. 2012). Furthermore, alternative water sources and shade structures located outside of riparian areas significantly reduce the amount of time cattle spend in and near streams, thus resulting in improved water quality (Wagner et al. 2013; Clary et al. 2016).

Based on 2019 NLCD (MRLC 2019) and NASS (USDA NASS 2017) population numbers, it was estimated that there are approximately 26,572 head of cattle within the Bois d'Arc Lake watershed. A GIS analysis was conducted by calculating the total head of cattle per subwatershed and then multiplying that number by the NLCD data and the bacteria production assumptions for cattle in Appendix A. The analysis indicated the highest potential annual loading for Bois d'Arc Lake occurs in subwatershed 2 (Figure 38).

Other Livestock

Besides cattle, other livestock—goats, horses, and sheep—can contribute to *E. coli* bacterial loading. Livestock estimates were also derived from the 2017 NASS population estimates for each county. The spatial distribution of relative *E. coli* loading potential for each type of livestock is similar to cattle due to the reliance on land use to distribute potential loads over the entire watershed. Therefore, the GIS analysis prioritizes subwatersheds 1 and 2 for potential loads (Figures 39, 40, and 41).

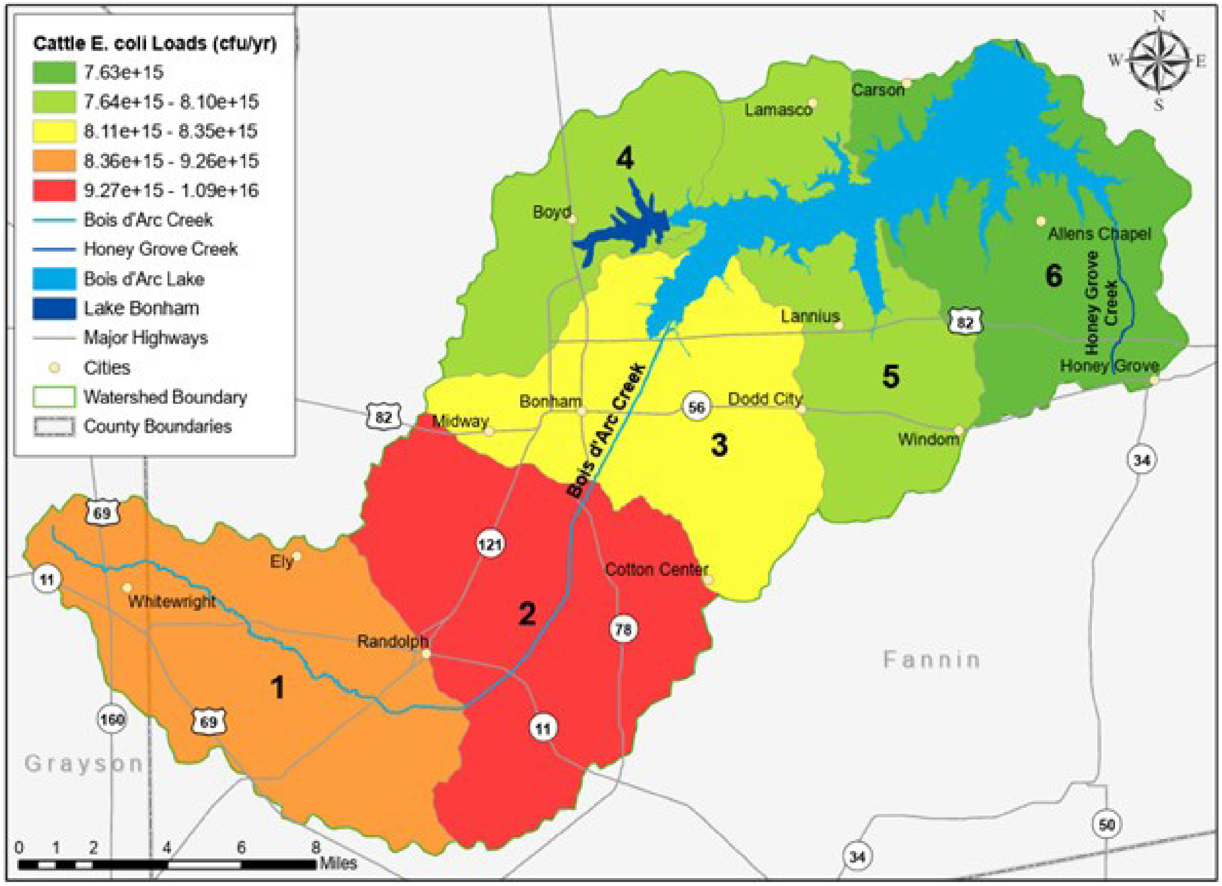


Figure 38. Potential annual bacterial loadings from cattle in the Bois d'Arc Lake watershed.

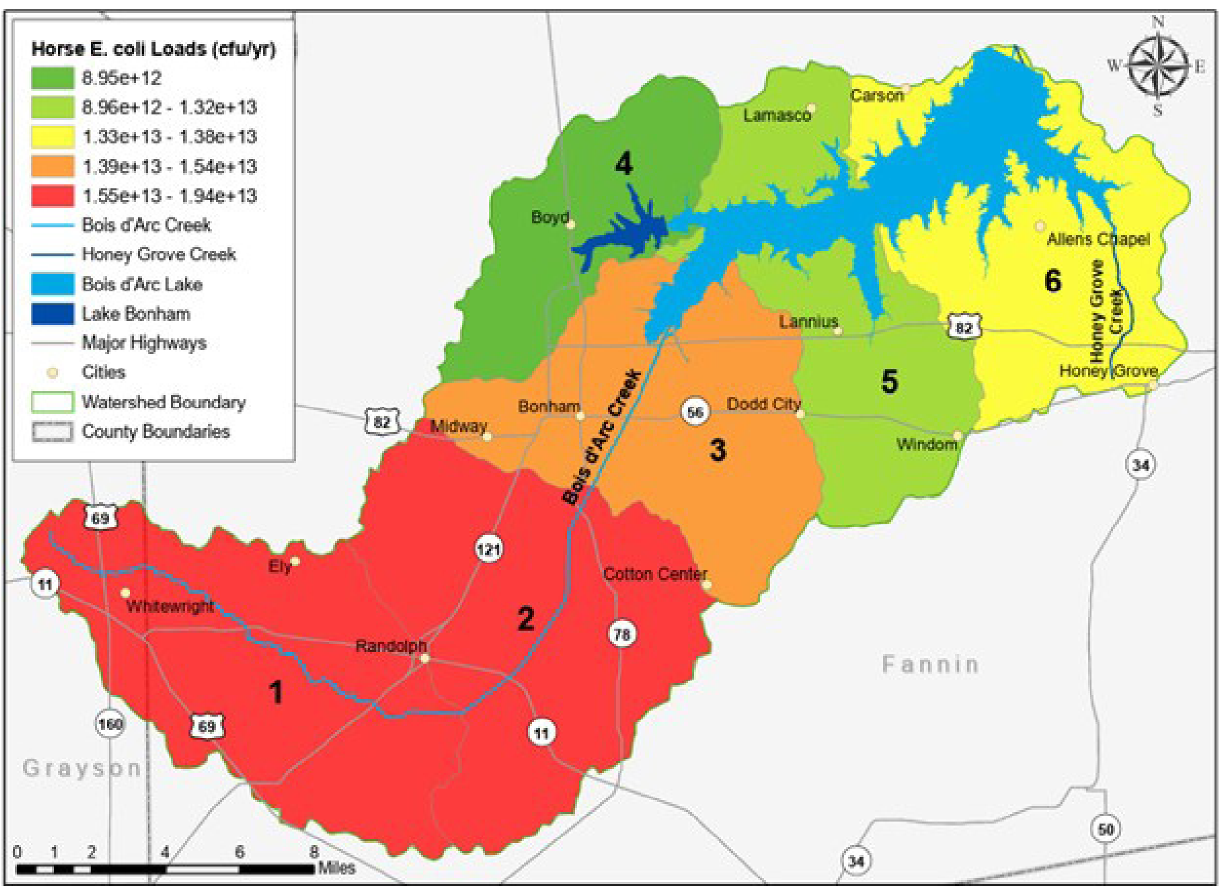


Figure 39. Potential annual bacterial loadings from horses in the Bois d'Arc Lake watershed.

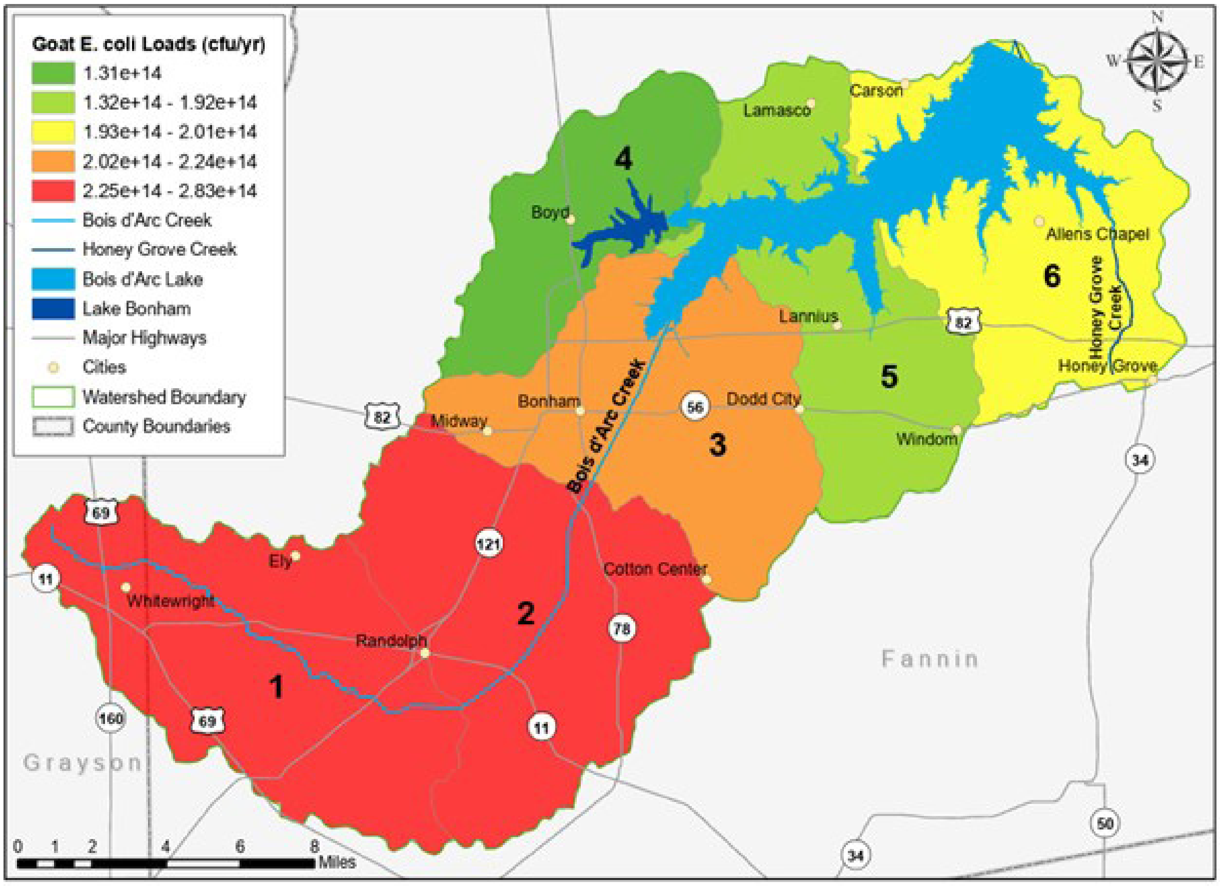


Figure 40. Potential annual bacterial loadings from goats in the Bois d'Arc Lake watershed.

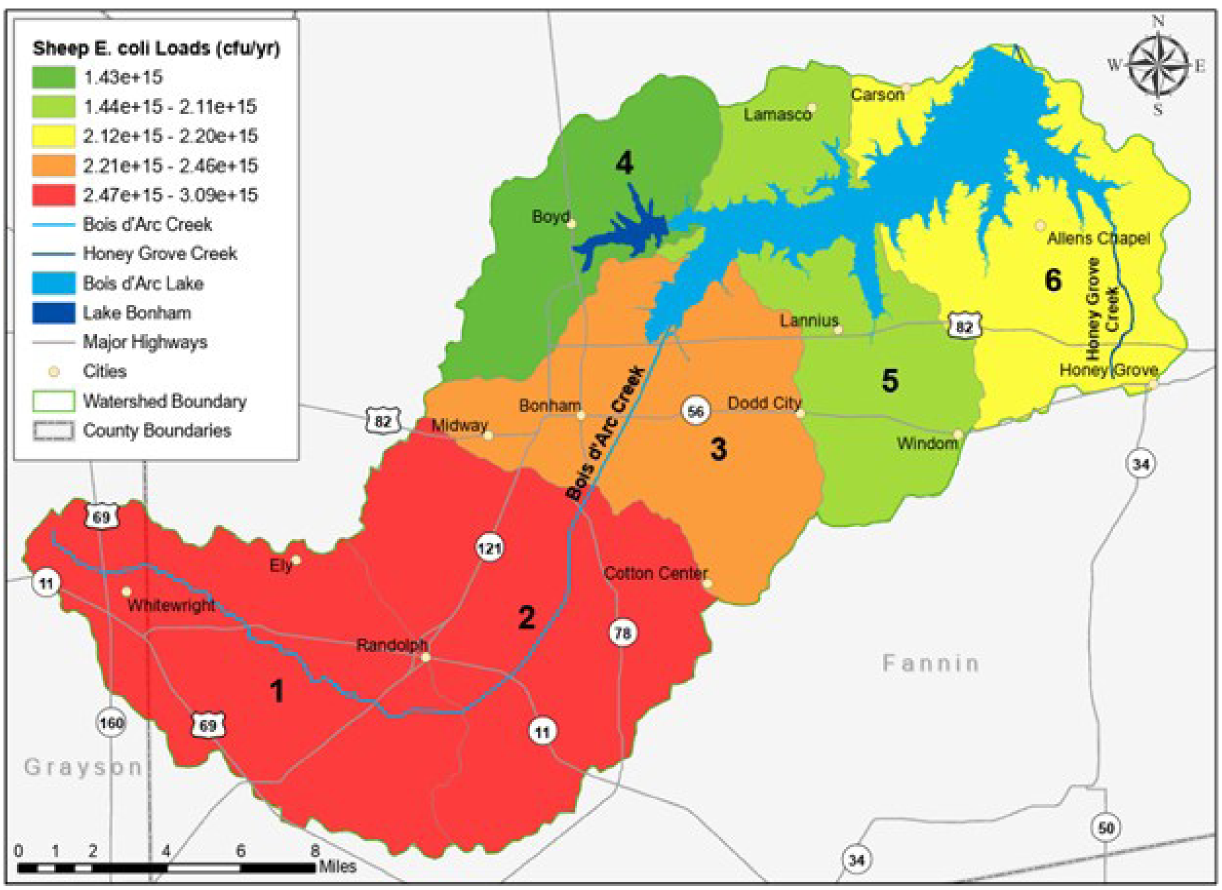


Figure 41. Potential annual bacterial loadings from sheep in the Bois d'Arc Lake watershed.

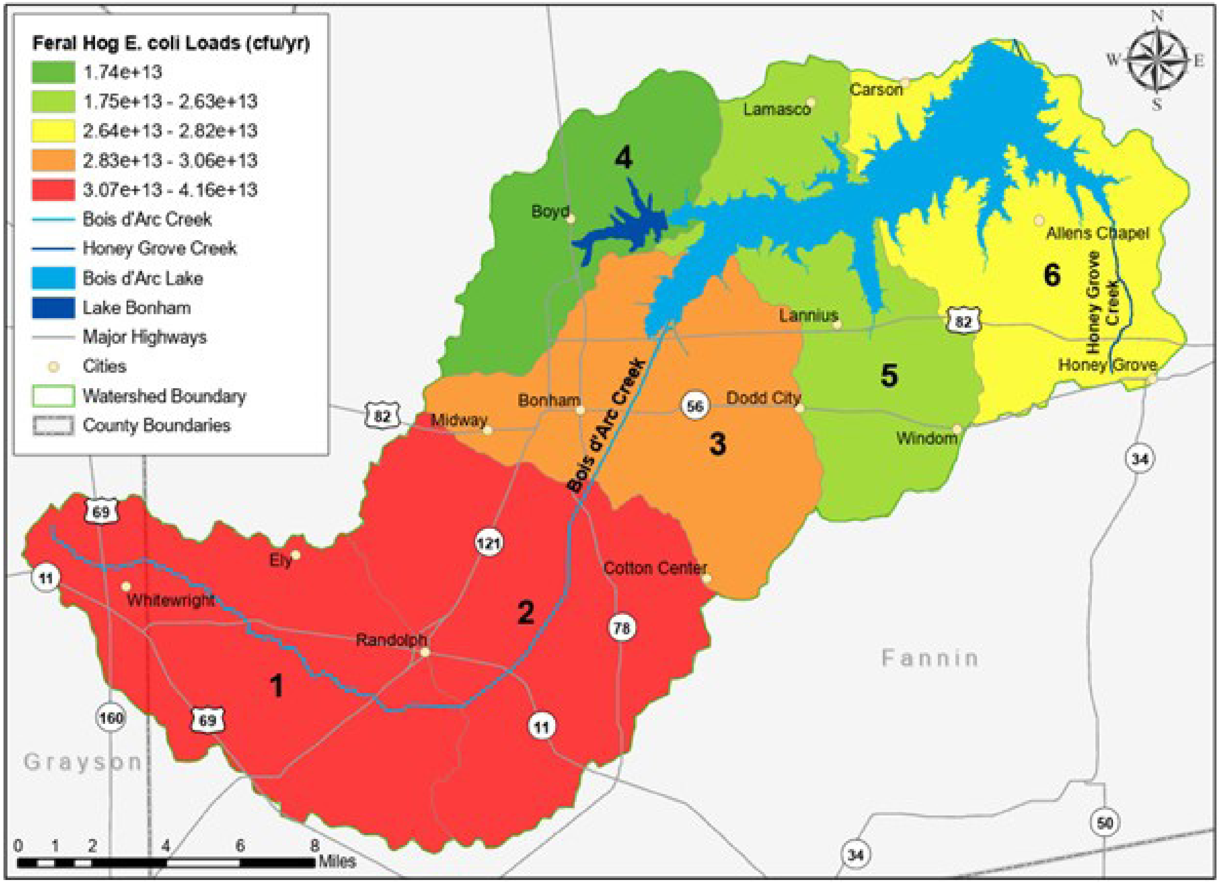


Figure 42. Potential annual bacterial loadings from feral hogs in the Bois d’Arc Lake watershed.

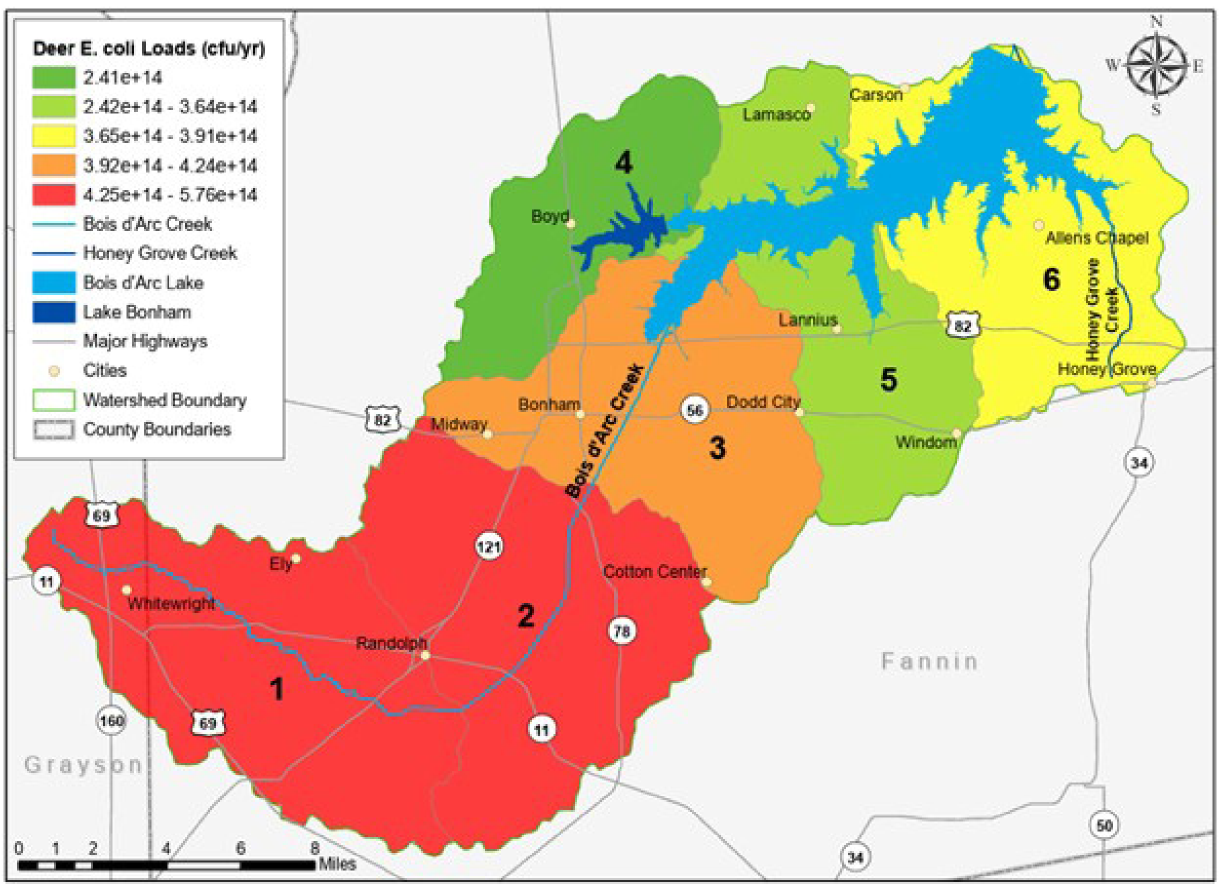


Figure 43. Potential annual bacterial loadings from deer in the Bois d’Arc Lake watershed.

Table 18. Summary of potential source loads in the Bois d’Arc Lake watershed.

Source	Potential load colony forming units/year	Highest priority subwatersheds
Cattle	5.22×10^{16}	2
Horses	8.81×10^{13}	1 and 2
Goats	1.28×10^{15}	1 and 2
Sheep	1.41×10^{16}	1 and 2
Deer	2.54×10^{15}	1 and 2
Feral hogs	1.84×10^{14}	1 and 2
On-site sewage facilities	6.62×10^{15}	2
Dogs	5.95×10^{15}	3
Wastewater treatment facilities	6.44×10^{12}	3
Total	8.30×10^{16}	

Feral Hogs

Current population estimates of feral hogs in Texas alone range from one to three million individuals (Mayer 2009; Mapston 2007). Feral hogs contribute to *E. coli* bacterial loadings through the direct deposition of fecal matter into streams while wading or wallowing in riparian areas. Riparian areas provide ideal habitats and migratory corridors for feral hogs as they search for food. While complete removal of feral hog populations is unlikely, habitat management and trapping programs can limit populations and associated damage. The GIS analysis results indicate the highest potential annual loadings occur in subwatersheds 1 and 2 (Figure 42). Appendix A describes the equations and assumptions used to generate potential annual loads.

Deer

White-tailed deer are the primary wild deer species in the watershed (although game ranches may raise mule deer or exotics such as axis deer). The white-tailed deer is a warm-blooded mammal. Texas has more white-tailed deer than any other state. Population estimates in recent years range from three to four million. An estimated 430,000–500,000 whitetails are harvested by hunters in Texas annually. Deer contribute to *E. coli* bacterial loadings similarly to feral hogs. The highest potential annual *E. coli* loadings from deer occur in subwatersheds 1 and 2 (Figure 43).

Dogs

Pet dogs contribute to bacterial loadings when pet waste is not disposed of properly and subsequently washes into nearby water bodies during rain and storm events. The highest potential loads from dogs are anticipated to occur in developed and urbanized areas. GIS analysis results for dogs indicate relatively high potential loadings occur in subwatershed 3 (Figure 44). Appendix A describes the equations and assumptions used to generate potential annual loads.

OSSFs

Failing or unmaintained OSSFs can contribute bacterial loads to water bodies, in particular those where effluent is released near the water bodies. Within the Bois d’Arc Lake watershed, approximately 15% of OSSFs are assumed to fail during a given year. It was estimated that there are approximately 2,932 OSSFs within the watershed based on the most recently available 911 address data. GIS analysis indicates 28 OSSFs within 500 yards of Bois d’Arc and Honey Grove creeks with the highest potential loadings occur in subwatershed 2 (Figure 45). Appendix A describes the equations and assumptions used to generate potential annual loads.

WWTFs

According to TCEQ and NPDES data, there are six permitted wastewater dischargers in the Bois d’Arc Lake watershed. These wastewater discharges are regulated by TCEQ and are required to report average monthly discharges and *E. coli* concentrations.

Although the permitted discharge volumes and bacteria concentrations are below permitted values, potential loading was calculated using the maximum permitted discharges and concentrations to assess the maximum potential load. The highest potential load occurs in subwatershed 3 (Figure 46). As previously mentioned, the *E. coli* LDC for AU 0202A_03 indicates that the impairment is likely from point sources. However, more investigation is needed to determine the cause.

Total Potential *E. coli* Load

Table 18 shows total estimated potential *E. coli* loadings across the watershed based on the combined total potential loadings from sources used in the GIS analysis. Here we see that the highest potential loadings exist in subwatersheds 1 and 2.

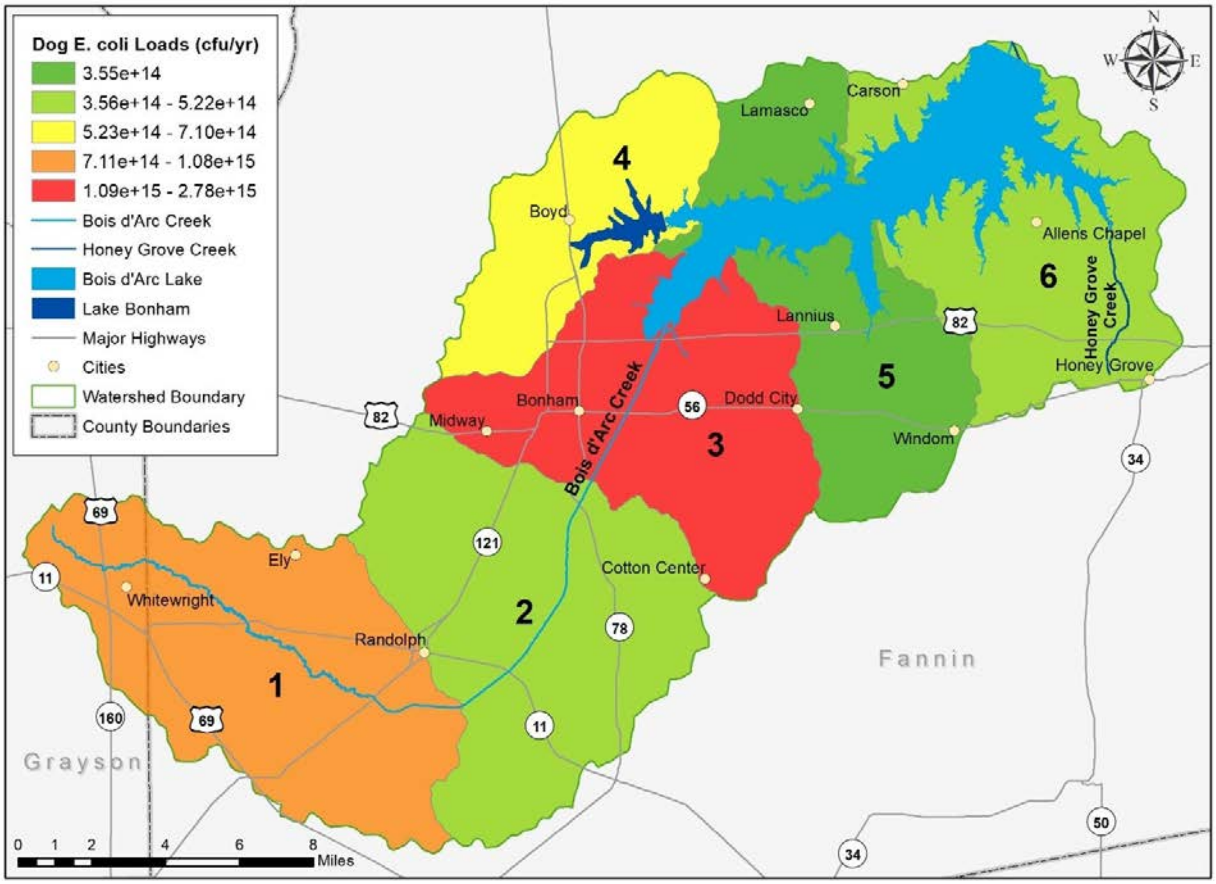


Figure 44. Potential annual bacterial loadings from dogs in the Bois d’Arc Lake watershed.

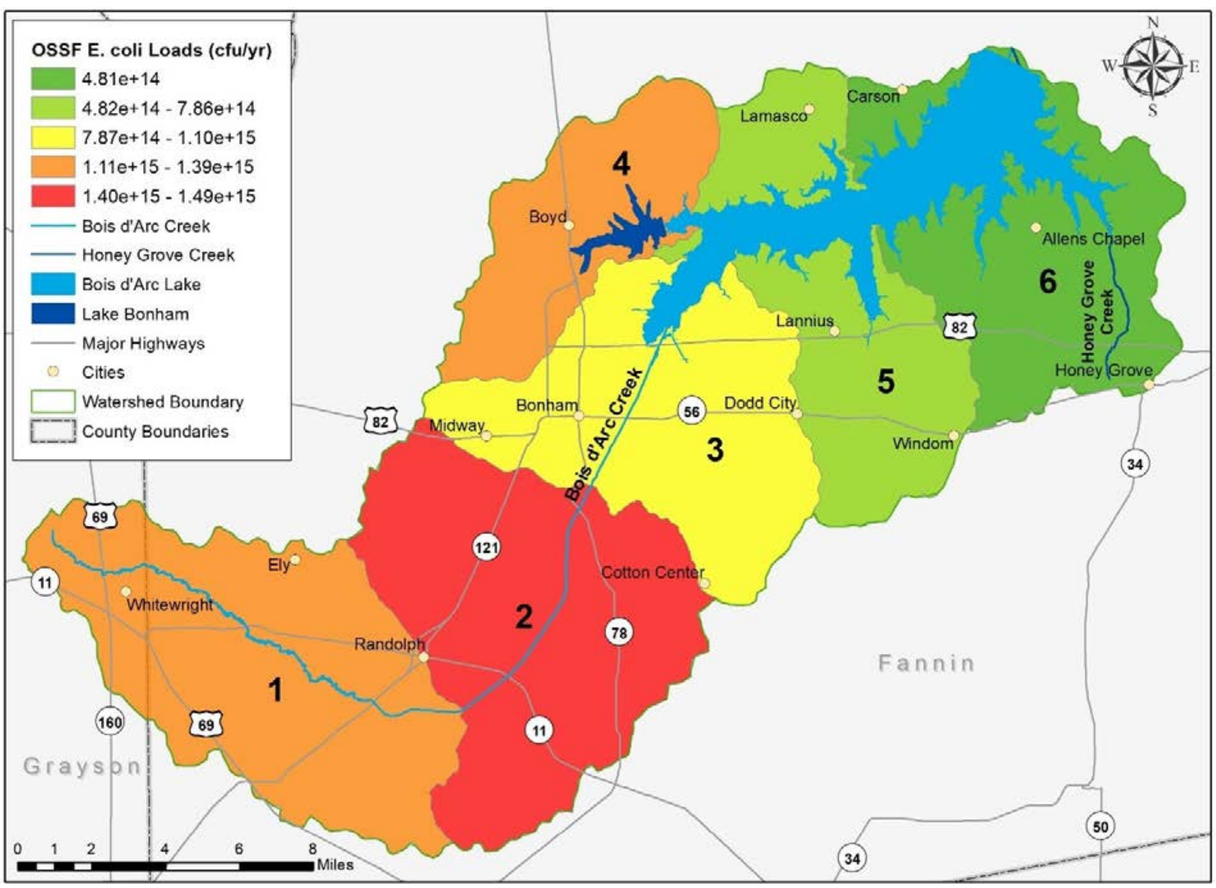


Figure 45. Potential annual bacterial loadings from on-site sewage facilities (OSSFs) in the Bois d’Arc Lake watershed.

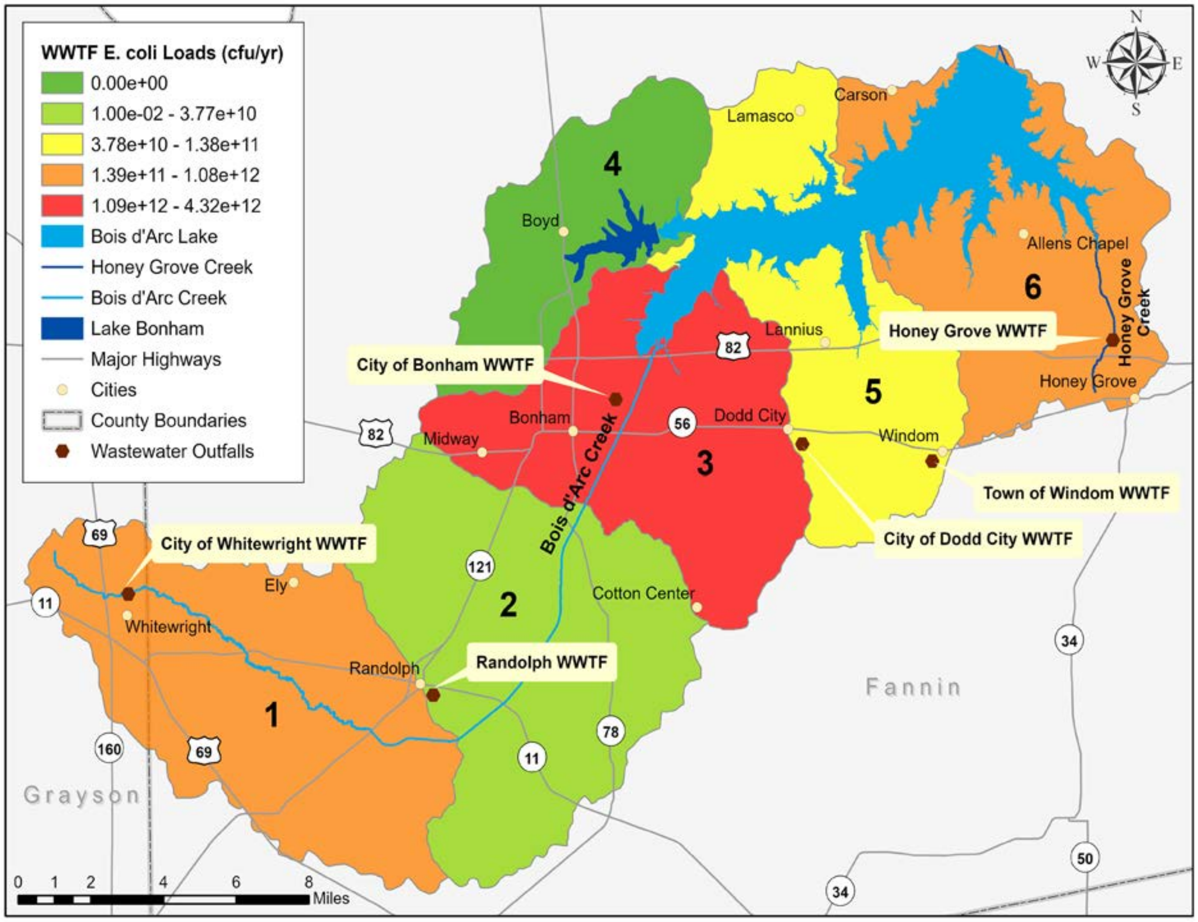


Figure 46. Potential annual bacterial loadings from wastewater treatment facilities (WWTFs) in the Bois d’Arc Lake watershed.

Chapter 6 Strategies for Watershed Protection Plan Implementation

Wheat field near Randolph, TX. Photo by Ed Rhodes, TWRI.

Introduction

Chapters 4 and 5 illustrate the diverse sources of bacterial and nutrient loading in the Bois d'Arc Lake watershed. No single source of *E. coli* in the watershed is the primary cause of current levels in the watershed. According to the GIS analysis, cattle, sheep, OSSFs, and deer have the highest potential to contribute *E. coli* to the waterbodies and their tributaries; however, all potential sources in the watershed contribute at some level. Due to the diverse potential sources, a range of management strategies are recommended to address all potential sources of *E. coli* in the watershed. Recommended management strategies were developed based on stakeholder feedback and management recommendation effectiveness in reducing bacterial loading.

Estimated potential load reductions from each management measure are presented with each recommended action discussed in this chapter. Each loading estimate presented is based on a predicted worst-case scenario loading. As a result, these estimates do not accurately predict real loadings that are occurring or expected load reductions that may be realized in-stream. Actual reductions are dependent on several factors that may trigger the need for adaptive implementation. Potential annual load reductions from management measures are discussed through this chapter and indicate that reducing bacterial loads entering the waterbodies in the watershed to levels that support primary contact recreation use is feasible.

Priority implementation areas for each recommended management strategy were identified based on spatial analysis and stakeholder feedback. While management measures can be implemented throughout the watershed, priority locations were selected based on areas where management strategies could be most effective in removing or reducing potential loading.

Stakeholder input was crucial throughout the decision-making process for these suggested management strategies. Management measures suggested in this chapter are voluntary and will rely on stakeholder adoption for successful

Table 19. Available pasture and rangeland practices to improve water quality.

Practice	NRCS code	Focus area or benefit
Brush management	314	Livestock, water quality, water quantity, wildlife
Fencing	382	Livestock, water quality
Filter strips	393	Livestock, water quality, wildlife
Grade stabilization structures	410	Water quality
Grazing land mechanical treatment	548	Livestock, water quantity, wildlife
Heavy use area protection	562	Livestock, water quantity, water quality
Pond	378	Livestock, water quantity, water quality, wildlife
Prescribed burning	338	Livestock, water quality, wildlife
Prescribed grazing	528	Livestock, water quality, wildlife
Range/pasture planting	550/512	Livestock, water quality, wildlife
Stream crossing	578	Livestock, water quality
Water well	642	Livestock, water quality, wildlife
Watering facility	614	Livestock, water quantity

Natural Resources Conservation Service, NRCS

implementation. Therefore, receiving stakeholder input on willingness to adopt these practices is important throughout this process. All management measures were discussed with and approved by steering committee to ensure community support and successful implementation. A complete list of management measures and goals, responsible parties and estimated costs are included in Table 30.

Management Measure 1 – Developing and Implementing Water Quality Management Plans or Conservation Plans

Potential bacterial loadings in the Bois d'Arc Lake 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, much of the *E. coli* in livestock waste dies before reaching a water body. However, livestock may spend significant amounts of time in and around water bodies, thus resulting in more direct impacts 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 around a property. As a result, it can effectively reduce the potential of *E. coli* concentrations from runoff entering nearby water bodies.

A variety of best management practices (BMPs) are available to achieve goals of improving forage quality, diversifying water resource locations and better distributing livestock across a property. Practices commonly implemented to effectively improve forage and water quality are listed in Table 19. However, the actual appropriate practices will vary by operation and should be determined through technical assistance from NRCS, TSSWCB, and local SWCDs as appropriate. In the last 3 years, over 70 conservation plans (CPs) have been developed in Fannin County. Through implementation of this watershed plan we hope to achieve the adoption of an additional 100 CPs/water quality management plans (WQMPs) over the next 10 years. Load reductions achieved from this measure will vary depending on where and what conservation measures are implemented in various plans. Establishing additional acreage under management practices and additional CPs plans in this watershed is the primary goal of this management measure.

The implementation of CPs and WQMPs is beneficial, regardless of location in the watershed. Although those management measures mainly address and calculate bacteria sources from cattle, the use of CPs and WQMPs can reduce fecal loading from all types of livestock. Research has proven that recommended management measures also reduce nutrient and sediment loading from properties where they are implemented. The overall effectiveness of CPs and WQMPs can be greater on properties with riparian habitat. Therefore, all properties with riparian areas are considered a priority. Meanwhile, properties without riparian habitat are also encouraged to participate in implementation activities. Priority areas will include subwatersheds 1 and 2. Table 20 summarizes management recommendations for cattle and other livestock in the watershed.

Table 20. Management measure 1: Cattle and other livestock.

Pollutant source: cattle and other livestock			
Problem: Livestock derived fecal loading into water bodies			
Objectives: • Work with landowners to develop property-specific conservation plans (CPs) and water quality monitoring plans (WQMPs) to protect water quality • Provide technical and financial assistance to producers • Reduce fecal loading from livestock in riparian areas			
Location: Subwatersheds 1 and 2, with priority given in rural areas near waterbodies			
Critical Areas: Properties with creek and tributary access, especially those using them as a livestock watering source			
Goal: Develop up to 100 plans (CPs and/or WQMPs) focused on minimizing the time spent by livestock in the riparian corridor and better use of available grazing resources across the property.			
Description: CPs and WQMPs will be developed to address direct and indirect fecal deposition from cattle and other livestock. Best management practices to reduce time spent in the creek or riparian corridor, improve grazing distribution, and grass quality, and decrease runoff will be recommended. Likely practices include prescribed grazing, cross-fencing, pasture planting, water wells, and watering facilities. Education program delivery will support and promote implementation adoption.			
Implementation strategy			
Participants	**Recommendations**	**Period**	**Capital costs**
Producers, Natural Resources Conservation Service, Texas State Soil and Water Conservation Board, Soil and Water Conservation Districts	Develop, implement, and provide financial assistance for livestock CPs and WQMPs at $15,000 per plan for 100 plans	2022–2031	$1,500,000
Texas A&M AgriLife Extension Service, Soil and Water Conservation District, North Texas Municipal Water District	Deliver education and outreach programs and workshops to landowners	2022–2031	N/A

Estimated load reduction	
Prescribed management will reduce loadings associated with livestock by reducing runoff from pastures and rangeland as well as reducing direct deposition by livestock. Implementation of 100 WQMPs and CPs is estimated to reduce annual loads from livestock by 1.01×10^{15} colony forming units *E. coli* per year in the Bois d'Arc Lake watershed (Appendix B).	
Effectiveness	High: Decreasing the time that livestock spend in riparian areas and reducing runoff through effectively managing vegetative cover will directly reduce nonpoint source contributions of bacteria and other pollutants to creeks.
Certainty	Moderate: Landowners acknowledge the importance of good land stewardship practices and management plan objectives; however, financial incentives are often needed to promote WQMP and CP implementation.
Commitment	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.
Needs	High: Financial costs are a major barrier to promote implementation. Education and outreach are needed to demonstrate benefits of plan development and implementation to producers.

Management Measure 2 – Promote Technical and Operational Assistance to Landowners for Feral Hog Control

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

According to statewide feral hog trend data, feral hog populations grow an average of 21% per year (Timmons et al. 2012). For the Bois d'Arc Lake watershed this growth rate applied to the current population indicates the population will potentially increase by six times the current estimate over the next 10 years (Figure 47). Physically removing hogs from the watershed is the best strategy for reducing their impact on water quality. A variety of methods exist to accomplish this goal, and other tactics can also improve the success of removal efforts. In the watershed, trapping animals is the most effective means for removing large numbers of hogs. With proper planning and diligence, trapping can successfully remove large numbers of hogs at once, whereas shooting or catching with dogs typically results in fewer individuals being removed before they move to another part of the watershed. Hunting hogs is already common across the watershed and should certainly continue.

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

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

Trapping hogs may provide a potential source of income or at least a means to recuperate some costs associated with repairing feral hog damage and trapping efforts. The state of Texas allows live feral hogs to be transported to approved feral hog holding facilities where they can be sold to the holding facility. Purchase prices vary by facility and are market driven. There is a facility in nearby Delta County. An online mapping tool and listing of approved facilities is available at: https://tahc.maps.arcgis.com/apps/webappviewer/index.html?id=6406b01b5b284f2398c3117928869808. Other informational resources such as regulations regarding feral hog movement and holding restrictions are also available at this website. Each of these needs, priority management areas, and expected *E. coli* loading reductions are discussed further in Table 21.

Table 21. Management measure 2: Feral hogs.

<table>
<tr><th colspan="4">Pollutant source: feral hogs</th></tr>
<tr><td colspan="4">Problem: Direct and indirect fecal loading, riparian habitat destruction, soil damage, and erosion from rooting</td></tr>
<tr><td colspan="4">Objectives:
• Reduce fecal contaminant loading from feral hogs
• Reduce hog population
• Reduce food supply for feral hogs
• Provide education and outreach to stakeholders</td></tr>
<tr><td colspan="4">Location: Entire watershed, with highest priority in subwatersheds 1 and 2</td></tr>
<tr><td colspan="4">Critical Areas: Riparian areas and travel corridors from cover to feeding areas</td></tr>
<tr><td colspan="4">Goal: Manage the feral hog population through available means to reduce the total number of current hogs in the watershed by 15% and maintain them at this level over 10 years of implementation.</td></tr>
<tr><td colspan="4">Description: Voluntarily implement efforts to reduce feral hog populations throughout the watershed by reducing food supplies, removing hogs, and educating landowners on hog removal techniques.</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, land managers, and lessees</td><td>• Voluntarily construct fencing around deer feeders to prevent feral hog use
• Voluntarily identify travel corridors and employ trapping and hunting in these areas to reduce hog numbers
• Voluntarily shoot hogs on sight; ensure that lessees shoot hogs on sight</td><td>2022–2031</td><td>$200/feeder</td></tr>
<tr><td>Texas A&M AgriLife Extension Service, counties, landowners</td><td>Implement a bounty program for eliminating feral hogs (e.g., $2/tail)</td><td>2022–2031</td><td>Varies</td></tr>
<tr><td>AgriLife Extension, counties</td><td>Provide support for a feral hog extension associate to trap and hunt feral hogs in the watershed as well as provide educational resources to stakeholders</td><td>2022–2031</td><td>$75,000/year</td></tr>
<tr><td>North Texas Municipal Water District, AgriLife Extension</td><td>Deliver feral hog education workshops</td><td>2022–2031</td><td>$7,500 each</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 total feral hog population by 15% of the current population in the Bois d’Arc Lake watershed is estimated to reduce potential annual loads by $6.89x10^{12}$ colony forming units E. coli annually (Appendix B). This 15% reduction considers the necessity of eliminating 66% of the current population annually to keep population numbers from increasing (32,745 hogs eliminated over 10 years; Figure 48).</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Moderate: Reduction in feral hog population will result in a direct decrease in bacterial and nutrient loading to the 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 each year 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 battling feral hog populations and will continue to do so as long as resources remain available. Hogs adversely affect their livelihood.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Funds are needed to provide education and outreach to further inform landowners about feral hog management options, adverse economic impacts.</td></tr>
</table>

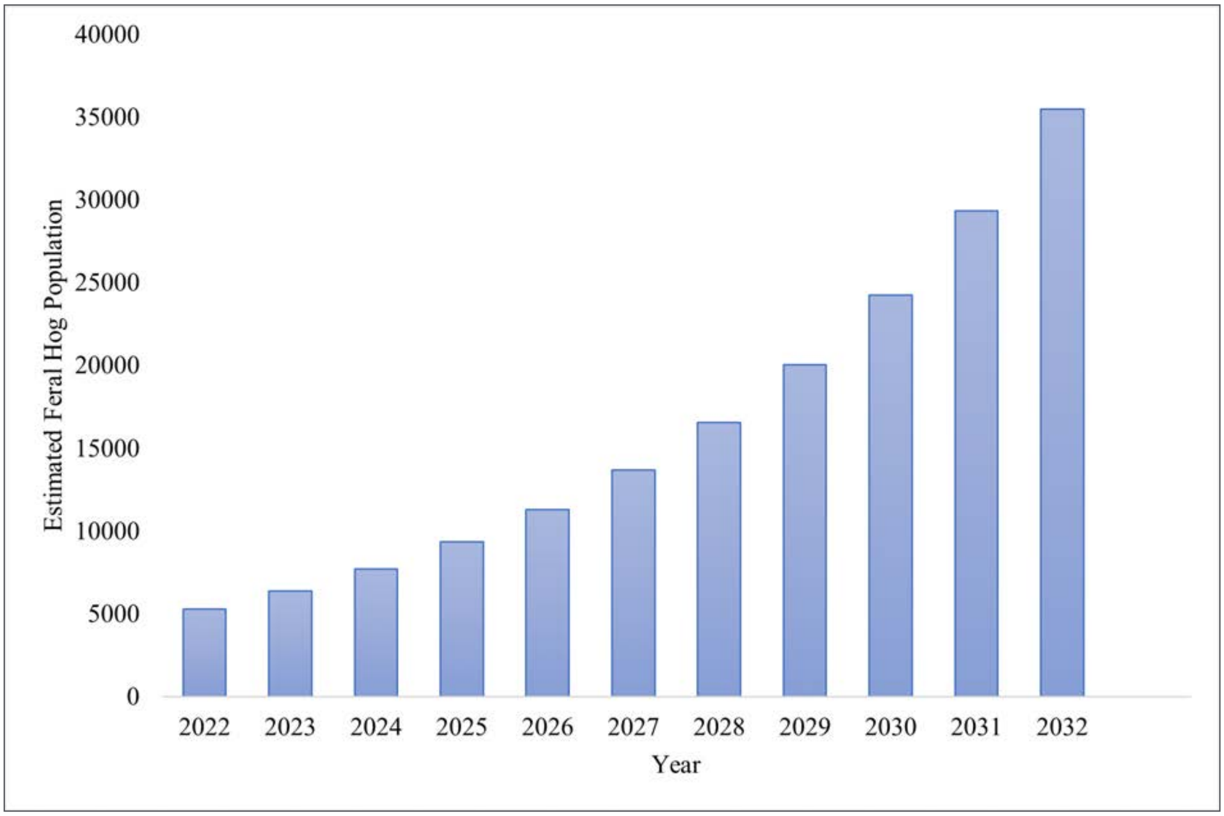


Figure 47. Estimated feral hog population growth in the Bois d’Arc Lake watershed over 10 years assuming 21% growth each year.

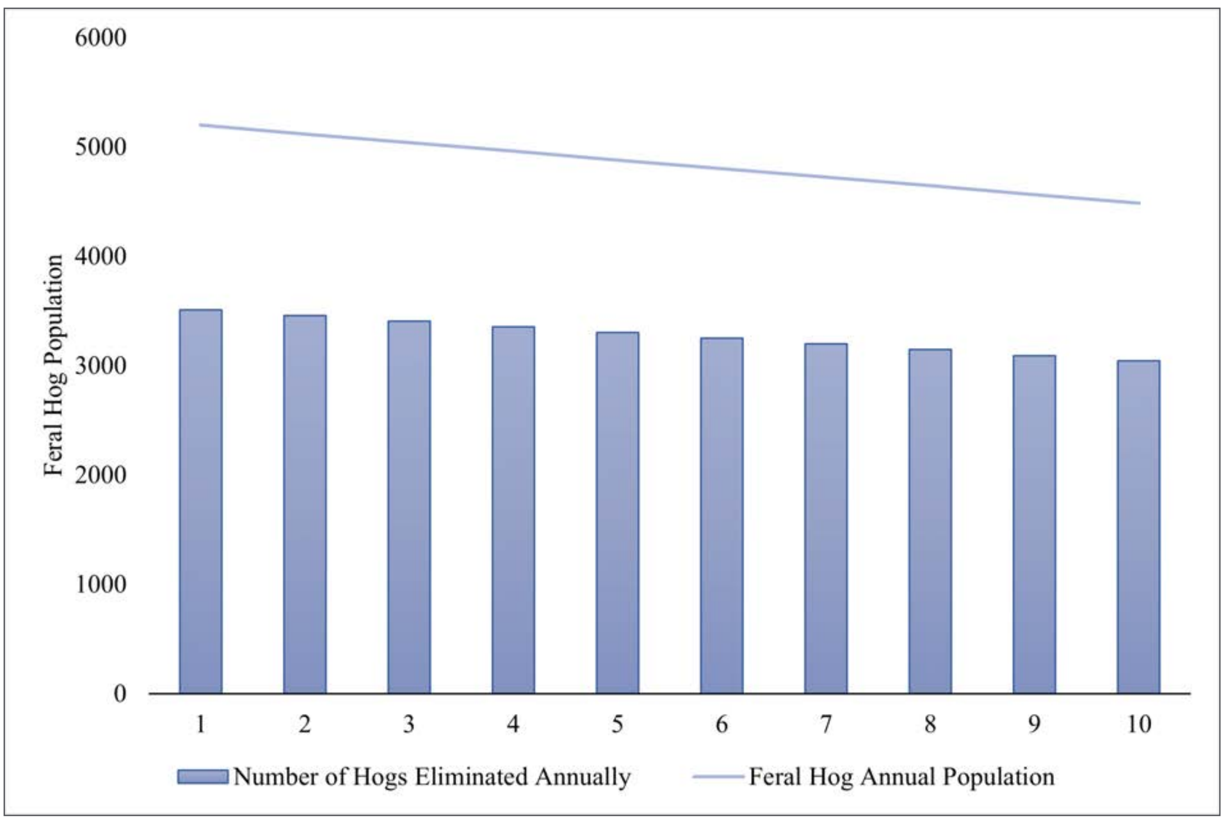


Figure 48. Feral hog annual population and number of hogs eliminated over 10 years to reach an overall 15% reduction from the current population in the Bois d’Arc Lake watershed.

Management Measure 3 – Identify, Inspect, and Repair or Replace Failing On-Site Sewage Systems

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 Bois d'Arc Lake watershed, approximately 49.8% of the watershed's soils are considered very limited, and 41.8% are somewhat limited and generally are not recommended for use with conventional systems.

In these areas, advanced treatment systems—most commonly aerobic treatment units—are recommended for on-site wastewater treatment. While advanced treatment systems are highly effective, the 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 or nonexistent OSSFs can provide significant bacterial and nutrient loading into the watershed. The exact number of failing systems is unknown; however, it is estimated as many as 440 systems may be malfunctioning across the watershed based on a 15% failure rate (Reed, Stowe, & Yanke 2001). A number of reasons contribute to OSSF failure, including improper system design or selection, improper maintenance, and lack of education and financial resources. OSSFs should be replaced as needed across the entire watershed, with the priority placed on subwatershed 2. Additionally, priority will be placed on OSSFs within 500 yards of perennial water bodies or in areas of the watershed where soils are considered very limited for septic suitability.

To address these needs, efforts are required to focus on expanding and providing education and workshops to homeowners (Table 22). Additionally, maintenance providers, installers, and inspectors should be secured to assist homeowners to repair or replace OSSF systems if issues arise.

Management Measure 4 – Reduce the Amount of Pet Waste Mixing into Water Bodies

Given the association between dogs and human activity, addressing the waste and bacterial loads generated by dogs is relatively simple compared to other sources. Properly disposing of pet waste into a trash can is a simple and effective way of reducing *E. coli* loads in the watershed.

Widespread adoption of this practice across the watershed, however, is not very probable and will require effort to encourage pet owners to implement it. First, expanded education and outreach efforts to educate and encourage pet owners to pick up pet waste are needed. Second, pet owners can be encouraged to pick up pet waste when pet waste bags and disposal bins are easier to access in public areas. The priority areas for this management measure are urbanized and public areas located in subwatershed 3. Table 23 summarizes management measures for pet waste.

Management Measure 5 – Implement and Expand Urban and Impervious Surface Stormwater Runoff Management

One of the sources of *E. coli* and nutrients entering water bodies is stormwater generated in urban areas. Compared to other sources, the chances of bacterial loading from urban impervious surface is currently relatively low based on percent total land cover (Table 24). The main objective of this management measure is to organize general stormwater management education and outreach programs and educate residents about stormwater BMPs. The entities involved are AgriLife Extension, cities, property owners, and contractors. The second objective is to work with local municipalities to identify and install demonstration BMPs that manage stormwater runoff as appropriate and as funding permits. BMPs that are commonly known are rain gardens, rain barrels/cisterns, green roofs, permeable pavements, bio retention, swales, and detention ponds. These BMPs can be adopted based on the precipitation amount, pattern, and local preferences. The third objective is to monitor the effectiveness of BMPs and suggest new techniques to manage stormwater. Therefore, multiple processes can be introduced to identify the most effective one.

Table 22. Management measure 3: On-site sewage facilities (OSSFs).

<table>
<tr><th colspan="5">Pollutant source: failing OSSFs</th></tr>
<tr><td colspan="5">Problem: Pollutant loading from failing or nonexistent OSSFs</td></tr>
<tr><td colspan="5">Objectives:
• Identify and inspect failing OSSFs in the watershed
• Secure funding to promote OSSF repairs/replacements in low-income areas
• Repair or replace OSSFs as funding allows
• Provide education and outreach to homeowners</td></tr>
<tr><td colspan="5">Location: Entire watershed, increased priority in subwatershed 2 and near water bodies</td></tr>
<tr><td colspan="5">Critical Areas: OSSFs situated on soils that are not suitable for OSSF drain fields and within 500 yards of a perennial waterway</td></tr>
<tr><td colspan="5">Goal: Because they pose a higher human health risk than some of the other potential pollutant sources, stakeholders expressed a desire to identify, inspect, and repair or replace (as appropriate) up to 300 OSSF systems in the watershed. Target load reductions may be met by replacing 30 failing OSSFs located within 500 yards of a waterway.</td></tr>
<tr><td colspan="5">Description: OSSF failures will be addressed by working to identify and inspect failing OSSFs within critical areas. Failing systems will be repaired or replaced as appropriate to bring them into compliance with local requirements.</td></tr>
<tr><th colspan="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">County or cities</td><td>Administer OSSF repair/replacement program to address deficient systems identified during inspections</td><td>2022–2031</td><td>$10,000/year</td></tr>
<tr><td colspan="2">County or cities</td><td>Identify and inspect failing OSSFs within priority areas; increased priority for OSSFs near water body</td><td>2022–2031</td><td>$750/ inspection</td></tr>
<tr><td colspan="2">North Texas Municipal Water District, Texas A&M AgriLife Extension Service</td><td>Deliver education and outreach programs and workshops to homeowners</td><td>2022–2031</td><td>N/A</td></tr>
<tr><td colspan="2">Homeowners</td><td>Repair/replace OSSFs as funding allows</td><td>2022–2031</td><td>~$7,500/ system</td></tr>
<tr><th colspan="5">Estimated load reduction</th></tr>
<tr><td colspan="5">At a minimum, repair or replacement of 30 failing OSSFs in the Bois d’Arc Lake watershed. This would result in a potential load reduction of 4.30×10^{15} colony forming units E. coli/year (See Appendix B).</td></tr>
<tr><td>Effectiveness</td><td colspan="4">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="4">Low: Funding available to identify, inspect, and repair or replace OSSFs is limited; thus, the actual level of implementation attainable is uncertain.</td></tr>
<tr><td>Commitment</td><td colspan="4">Moderate: Depending on funding sources available and stakeholder buy-in on allowing outside assistance, this is a strategy that could potentially have the greatest effect on human health and should be a top priority.</td></tr>
<tr><td>Needs</td><td colspan="4">High: Funding to identify, inspect and repair/replace OSSFs is limited. Costs to administer a program, identify, inspect, and repair/replace OSSFs are considerable. Many homeowners with failing OSSFs may not realize that their OSSF is failing, so delivering educational resources to them is critical. Some homeowners may know that they need a new OSSF but may not have funds available to acquire one.</td></tr>
</table>

Table 23. Management measure 4: Pet waste management.

Pollutant source: dogs			
Problem: Improperly disposed dog waste is left on the surface and washes into streams during rainfall or irrigation runoff			
Objectives: • Educate residents on disposal of pet waste • Install and maintain pet waste stations in public areas			
Location: Entire watershed, with highest priority in subwatershed 3			
Critical Areas: Urban areas, homes with dogs near waterways			
Goal: To reduce the amount of dog waste in the watershed that may wash into water bodies during runoff events by providing educational and physical resources to increase stakeholder awareness of the water quality and potential health issues caused by excessive dog waste.			
Description: Expand distribution of educational messaging regarding the need to properly dispose of pet waste in the watershed. Specifically target homeowners and the general public. Stock and maintain existing dog waste stations in parks and other public areas to facilitate increased collection and proper disposal of dog waste.			
Implementation strategy			
Participants	**Recommendations**	**Period**	**Capital costs**
Cities	Install at least five pet waste stations in area parks and other potentially high dog concentration areas	2022–2031	$500/station
Cities, counties, Texas A&M AgriLife Extension Service, North Texas Municipal Water District	Develop and provide educational resources to residents	2022–2031	N/A
Estimated load reduction			
Load reductions resulting from this management measure are reliant on changes in people's behavior. Assuming 12% of targeted individuals respond by properly disposing of pet waste, an annual load reduction 2.68×10^{13} colony forming units *E. coli*/year (Appendix B).			
Effectiveness	High: Collecting and properly disposing of dog waste is a sure way to prevent *E. coli* and nutrients from entering local waterways. This will directly reduce the quantity of *E. coli* in the watershed.		
Certainty	Low: Some dog owners already collect and properly dispose of dog waste. Those who do not may be a difficult audience to reach or convince that dog waste should be collected and discarded properly despite their respective reasons for not doing so.		
Commitment	Low: There are relatively few parks in the watershed. Adding signage or waste stations may not be a high priority.		
Needs	Moderate: Pet waste stations are relatively inexpensive. Additional work required to maintain stations should be minimal.		

Table 24. Management measure 5: Urban stormwater runoff.

<table>
<tr><th colspan="4">Pollutant source: urban stormwater runoff</th></tr>
<tr><td colspan="4">Problem: Fecal bacterial and nutrient loading from stormwater runoff in developed and urbanized</td></tr>
<tr><td colspan="4">Objectives:
• Organize general stormwater management education and outreach program
• Educate residents about stormwater best management practices (BMPs)
• Monitor the effectiveness of BMPs and suggest new techniques to manage stormwater</td></tr>
<tr><td colspan="4">Critical Areas: Urban areas of the watershed, with priority in subwatershed 3</td></tr>
<tr><td colspan="4">Goal: Reduce E. coli loading associated with urban stormwater runoff through implementation of stormwater BMPs as appropriate and to increase residents’ awareness of stormwater pollution and management.</td></tr>
<tr><td colspan="4">Description: Potential locations and types of stormwater runoff management BMP demonstration projects will be identified in coordination with cities, public works, and property owners.</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>Cities, property owners, contractors</td><td>Identify and install stormwater BMPs as funding becomes available</td><td>2022–2031</td><td>$4,000-$45,000/acre (estimate)</td></tr>
<tr><td>Texas A&M AgriLife Extension Service, North Texas Municipal Water District</td><td>Deliver education and outreach to landowners</td><td>2022–2031</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated load reduction</th></tr>
<tr><td colspan="4">Installation of stormwater BMPs that reduce runoff or treat bacteria will result in direct reductions in bacterial loadings in the watershed. Potential load reductions were not calculated because the location, type, and size of projects installed will dictate the potential load reductions; however, they have not been identified yet.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Moderate to high: The effectiveness of BMPs at reducing bacterial and nutrient loadings is dependent on the design, site selection, and maintenance of the BMP.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Installation of BMPs requires sustained commitment from city officials or property owners.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate to low: Urban stormwater management is not a high priority for local municipalities; financial or other incentives will be needed to encourage and secure long-term commitment.</td></tr>
<tr><td>Needs</td><td colspan="3">High: It is unlikely stormwater BMPs will be installed without financial assistance.</td></tr>
</table>

Management Measure 6 – Identify Potential Wastewater Conveyance System Failure and Prioritize System Repairs or Replacement

Although infrequent, SSOs and unauthorized WWTF discharges can contribute to bacterial loads, particularly during high runoff events. Inflow is surface runoff that enters the sewer collection system through manhole covers, sewer cleanouts, damaged pipes, and faulty connections. Infiltration is groundwater that enters the collection system through compromised infrastructure. As runoff enters the sewer collection system, there is increased potential for overloading the collection system or even the WWTF, resulting in an unauthorized discharge. Furthermore, I&I can have a diluting effect that sometimes decreases treatment efficiency and can increase utility pumping and treatment costs.

The main goal of this management measure is to work with entities operating WWTFs to continue and expand inspection efforts and identify problematic areas within their WWTFs. Once identified, entities will work to repair or replace problematic infrastructure to reduce I&I issues and minimize WWTF overload occurrences. Table 25 summarizes management measures for centralized wastewater systems.

Table 25. Management measure 6: Centralized wastewater.

<table>
<tr><th colspan="4">Pollutant source: centralized wastewater</th></tr>
<tr><td colspan="4">Problem: Fecal bacterial loading from unauthorized discharges when excessive water enters the sanitary sewer system through inflow and infiltration (I&I)</td></tr>
<tr><td colspan="4">Objectives:
• Expand system inspections by working with wastewater treatment facility (WWTF) to identify problem areas
• Increase rate of WWTF conveyance system repairs
• Reduce unauthorized discharges and sanitary sewer overflows (SSOs)</td></tr>
<tr><td colspan="4">Location: WWTF service areas</td></tr>
<tr><td colspan="4">Critical Areas: All WWTFs</td></tr>
<tr><td colspan="4">Goal: Work with WWTF entities to identify problematic areas within their WWTFs. Once problem is identified, work to replace or repair problematic infrastructure. Reduce E. coli loading associated with sewer system failures that occur during high rain events and unauthorized discharge.</td></tr>
<tr><td colspan="4">Description: Smoke tests, camera inspections, etc. can be used to identify connections where I&I problems exist. Prioritize system repairs or replacements based on system impacts (largest impact areas addressed first). Deliver education and outreach to residents.</td></tr>
<tr><th colspan="4">Implementation strategy</th></tr>
<tr><th>Participants</th><th>Recommendations</th><th>Period</th><th>Capital costs</th></tr>
<tr><td>WWTF operating entities</td><td>Perform WWTF conveyance system testing to identify I&I problem areas; prioritize problem areas for repair/replacement</td><td>2022–2031</td><td>$3,000–$10,000/site</td></tr>
<tr><td>WWTF operating entities</td><td>As funds allow, repair or replace WWTF conveyance infrastructure</td><td>2022–2031</td><td>$100–$150/foot total cost to be determined</td></tr>
<tr><td>WWTF operating entities</td><td>Provide educational resources regarding inflow and infiltration (uncapped cleanouts, faulty sewer lines) and effect of malfunctions with utility bill inserts</td><td>2022–2031</td><td>N/A</td></tr>
<tr><td>Cities, Texas A&M AgriLife Extension Service</td><td>Develop and deliver education materials regarding SSOs to residents and property owners</td><td>2022–2031</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated load reduction</th></tr>
<tr><td colspan="4">Reduction of SSOs and discharges associated with I&I will result in direct reductions in bacterial loads. However, because the response to education efforts and the development of resources to compel pipe repairs is uncertain, load reductions were not calculated.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Reducing the number and volume of inflow and infiltration issues will directly reduce E. coli loading to receiving waters.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Each entity operating a WWTF in the watershed already performs inflow and infiltration inspections and makes repairs as needed and as funding allows.
High: Utility bill inserts are common and information on inflow and infiltration can easily be included.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Each entity operating a WWTF will continue to perform inspections and repairs within their respective collection systems.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial assistance needs are great. Operating budgets for entities are small and already strained, making financial assistance to inspect and repair conveyance system necessary.</td></tr>
</table>

Table 26. Management measure 7: Illicit and illegal dumping.

Pollutant source: illicit and illegal dumping			
Problem: Illicit and illegal dumping of trash and animal carcasses in and along waterways			
Objectives: • Promote and expand education and outreach efforts in the watershed • Support cleanups and other efforts to reduce illegal dumping			
Critical Areas: Entire watershed with focus at bridge crossing and public access areas			
Goal: Increase awareness of proper disposal techniques and reduce illicit dumping of waste and animal carcasses in water bodies throughout the watershed.			
Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on the proper disposal of carcasses and waste materials. Also work with responsible parties to lessen the impact of illicit dumping and improper animal carcass disposal.			
Implementation strategy			
Participants	**Recommendations**	**Period**	**Capital costs**
Texas A&M AgriLife Extension Service, counties, North Texas Municipal Water District	Develop and deliver educational and outreach materials to residents	2022–2031	N/A
Counties	Support efforts to reduce illegal dumping	2022–2031	N/A
Estimated load reduction			
Load reductions are likely minimal from this management measure and were not quantified.			
Effectiveness	Low: Preventing illicit dumping, especially animal carcasses, is likely to reduce bacterial loads by some amount, although this loading is likely limited to areas with public access.		
Certainty	Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that illegally dump is likely difficult.		
Commitment	Moderate: Many stakeholders indicate illicit dumping occurs; however, enforcement is difficult in rural areas. The issue is not a high priority and commitment of limited resources will likely remain low.		
Needs	Moderate: Some financial resources will be required to develop educational materials. Information could be incorporated into ongoing watershed related educational and outreach efforts.		

Management Measure 7 – Reduce Illicit and Illegal Dumping

Stakeholders indicate that illicit dumping, particularly of animal carcasses, can be problematic. These issues typically occur at or near bridge crossings where individuals may dispose of deer, hog, or small livestock carcasses in addition to other trash. The scope of the problem is not entirely known or quantified but anticipated to be a relatively minor contributor to bacterial loadings in the watershed compared to other sources. However, development and delivery of educational and outreach materials to local residents on proper disposal of carcasses and other trash could help reduce illicit dumping and associated potential bacterial loadings. Table 26 summarizes management measures for illicit dumping.

Table 27. Management measure 8: Volunteer monitoring on the other streams in the watershed.

<table>
<tr><th colspan="4">Pollutant source: other streams in the watershed that drain into Bois d'Arc Lake</th></tr>
<tr><td colspan="4">Problem: Lack of historical water quality data for additional creeks in the watershed that drain into Bois d'Arc Lake</td></tr>
<tr><td colspan="4">Objectives:
• Establish a volunteer monitoring program in the watershed
• Coordinate with Clean Rivers Program and Texas Commission on Environmental Quality about monitoring in the watershed to share information and ensure efficient use of monitoring resources</td></tr>
<tr><td colspan="4">Critical Areas: Bullard Creek, Cottonwood Creek, and Sloans Creek</td></tr>
<tr><td colspan="4">Goal: Collect preliminary water quality monitoring data on additional creeks in the watershed to determine whether they need routine monitoring due to excess nutrients and bacteria.</td></tr>
<tr><td colspan="4">Description: A Texas Stream Team (TST) chapter will be established in the watershed to train citizen scientists to conduct volunteer monitoring on Bullard Creek, Cottonwood Creek, and Sloans Creek.</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>TST, Meadows Center for Water and the Environment</td><td>Help train, equip, manage, and offer general support to the citizen scientists in the watershed</td><td>2022–2031</td><td>~$550 initial cost for streamflow and nutrient kit
~$650 initial cost for E. coli bacteria monitoring supplies kit</td></tr>
<tr><td>North Texas Municipal Water District</td><td>Partner with TST to help facilitate the volunteer monitoring program</td><td>2022–2031</td><td>N/A</td></tr>
<tr><td>Citizens in the watershed</td><td>Conduct the water quality monitoring on the creeks</td><td>2022–2031</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated load reduction</th></tr>
<tr><td colspan="4">Load reductions from this management measure and were not quantified.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">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="3">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="3">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="3">Moderate: Some financial resources will be required to purchase the initial kits and replace and replenish supplies.</td></tr>
</table>

Management Measure 8 – Water Quality Monitoring in the Watershed

Stakeholders recommended establishing monitoring locations in Bois d'Arc Lake to determine baseline water quality conditions. During the planning process, it was noted that there are some tributaries to the lake that are not routinely monitored. Stakeholders recommended adding monitoring locations on Bullard Creek, Cottonwood Creek, and Sloans Creek and at Bois d'Arc Creek at Hwy 82. These and other creeks should be considered for future monitoring as funding and resources allow. Monitoring locations and frequencies should be coordinated with stakeholders, TCEQ, and CRP partners.

It was suggested that a volunteer monitoring program be established in the watershed to gather preliminary data and determine whether additional routine monitoring on these waterbodies is necessary (Table 27). The Texas Stream Team (TST) coordinates and trains volunteers, or citizen scientists, to conduct water quality monitoring on local rivers, lakes, streams, and estuaries throughout Texas. In the North Texas region, TST already has trained citizen scientists to monitor over 100 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 28. Management measure 9: Conduct soil tests for both agricultural and urban areas.

Pollutant source: soils in the agricultural and urban areas			
Problem: Excessive soil nutrients in agricultural and urban areas due to over-fertilization could runoff into surface water during high 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 application of proper fertilization rates.			
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**
Texas A&M AgriLife Extension Service, counties, North Texas Municipal Water District	Develop and deliver educational and outreach materials to residents	2022–2031	~$25,000
Healthy Lawns and Healthy Waters	Conduct workshops on soil testing and ways to determine nutrient application amounts	2022–2031	N/A
Local stakeholders, landowners, land managers	Conduct soil tests before applying fertilizer	2022–2031	$12/soil test
Estimated load reduction			
N/A: No available nutrient load standards, though a reduction will be beneficial to water quality overall			
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 commitment 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.		

Management Measure 9 – Conduct Soil Tests for Both Agricultural and Urban Areas

Stakeholders indicated that conducting soil tests in both agricultural and urban areas can also be part of management measures to reduce nutrient loadings due to high runoff events. The composition of soil can vary from place to place within the watershed. Soil compositions in agricultural areas tend to be high in nutrients due to application of fertilizers. Similarly, lawns and parks in urban areas can be high in fertilizer as well. Therefore, soil testing in both agricultural and urban areas is included to prevent nutrient runoff into nearby water bodies by ensuring the proper rates and timing of fertilizer applications. Table 28 summarizes management measures for soil tests in agricultural and urban areas.

Table 29. Management measure 10: Conduct new and small landowner educational workshops.

<table>
<tr><th colspan="4">Pollutant source: landowners without education resources</th></tr>
<tr><td colspan="4">Problem: Due to a lack of knowledge about stormwater, pet waste, on-site sewage facilities (OSSFs), grazing lands, and water resource management, landowners might adopt incorrect methods to manage them.</td></tr>
<tr><td colspan="4">Objectives: Promote and expand education and outreach efforts in the watershed.</td></tr>
<tr><td colspan="4">Critical Areas: Entire watershed</td></tr>
<tr><td colspan="4">Goal: Educate landowners about sources of E. coli and other pollutants in the watershed and various ways to manage them.</td></tr>
<tr><td colspan="4">Description: Education delivery will mainly focus on landscape and water resource management, OSSF operation and maintenance, and OSSF design and installation.</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>Texas A&M AgriLife Extension Service, counties, North Texas Municipal Water District</td><td>Develop and deliver educational and outreach materials to residents</td><td>2022–2031</td><td>~25,000</td></tr>
<tr><th colspan="4">Estimated load reduction</th></tr>
<tr><td colspan="4">Load reductions from this management measure were not quantified.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Educating landowners to effectively manage stormwater, pet waste, and OSSFs prevents E. coli and nutrients from contaminating streams.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that need assistance will be beneficial.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Stakeholders indicate that they would like to attend educational workshops.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Some financial resources will be required to develop educational materials. Information could be incorporated into ongoing watershed related educational and outreach efforts.</td></tr>
</table>

Management Measure 10 – Conduct New or Small Landowner Education Workshop Program

As discussed in previous chapters, land use in the Bois d'Arc Lake watershed is going to change with the development of the lake. There may be an influx of newer landowners or small acreage landowners to the area due to this development. It is important that those landowners are provided with educational resources regarding the impacts of land stewardship on water quality. Therefore, the main objective of this workshop will be educating landowners to identify sources of *E. coli,* nutrients, and other pollutants in the watershed. Often, new and/or small acreage landowners may be unaware of BMPs and resources available for implementation. Educating landowners to manage stormwater, pet waste, OSSFs, feral hogs, and water resource management is very important to prevent *E. coli* and nutrients from getting into nearby water bodies. Stakeholders indicated that workshops like this will be helpful and should be conducted in different parts of the watershed. These education workshops will further protect and improve local water resources by ensuring that appropriate persons are informed by new techniques, requirements, and resources (Table 29).

Expected Loading Reductions

Implementation of the management measures in the WPP will reduce *E. coli* loads across the watershed. Many of the management measures will provide direct *E. coli* load reductions. Other management measures, such as education and outreach programs, will result in reductions but are not easily quantified. The bulk of expected load reductions come from management measures recommended for livestock, pet waste, OSSFs, and feral hogs (Table 31). Improvements in urban stormwater and illicit dumping can also be expected to contribute to improved water quality.

Table 30. Bois d'Arc Lake watershed management measures, participants, goals, and estimated costs.

Management measure	Participants	Unit cost	Implementation goals (years after implementation begins) 1–2	3–4	5–6	7–8	9–10	Total cost
Livestock								
Develop 100 water quality monitoring plans (WQMPs)/ conservation plans (CPs)	Texas State Soil and Water Conservation Board, soil and water conservation districts (SWCDs), Natural Resources Conservation Service	$15,000 per plan	20	20	20	20	20	$1,500,000
Education events and outreach	Texas A&M AgriLife Extension Service, SWCDs, North Texas Municipal Water District (NTMWD)	N/A	Approximately once every 3 years					N/A
Feral hogs								
Install feral hog enclosures	Landowners	$200 per feeder	As many as possible					Varies
Feral hog removal	Landowners	Varies	15% reduction					Varies
Bounty program	AgriLife Extension, counties, landowners	Varies	As many as possible					Varies
Feral hog removal workshop	AgriLife Extension, NTMWD	$7,500 each	3					$22,500
Provide resources to support a county feral hog trapper	AgriLife Extension, counties	~$75,000/year	1					~$750,000*
On-site sewage facilities (OSSFs)								
Develop OSSF repair/ replacement education program	Counties	N/A	1					N/A
Repair or replace at least 30 failing OSSFs	Homeowner, county designated representative, or contractor	$7,500 per system	6	6	6	6	6	Varies
NTMWD, AgriLife Extension	Deliver education and outreach programs and workshops to homeowners	N/A	1					N/A
Pet Waste								
Install and maintain five pet waste stations	Cities	$500 per station	1	1	1	1	1	$2,500
Develop and deliver educational and outreach materials	Cities, AgriLife Extension, NTMWD	N/A	1	1	1	1	1	N/A
Urban stormwater								
Identify and install potential stormwater best management practice projects	Cities, property owners, contractors	$4,000 to $45,000/acre treated	As many as possible					Varies

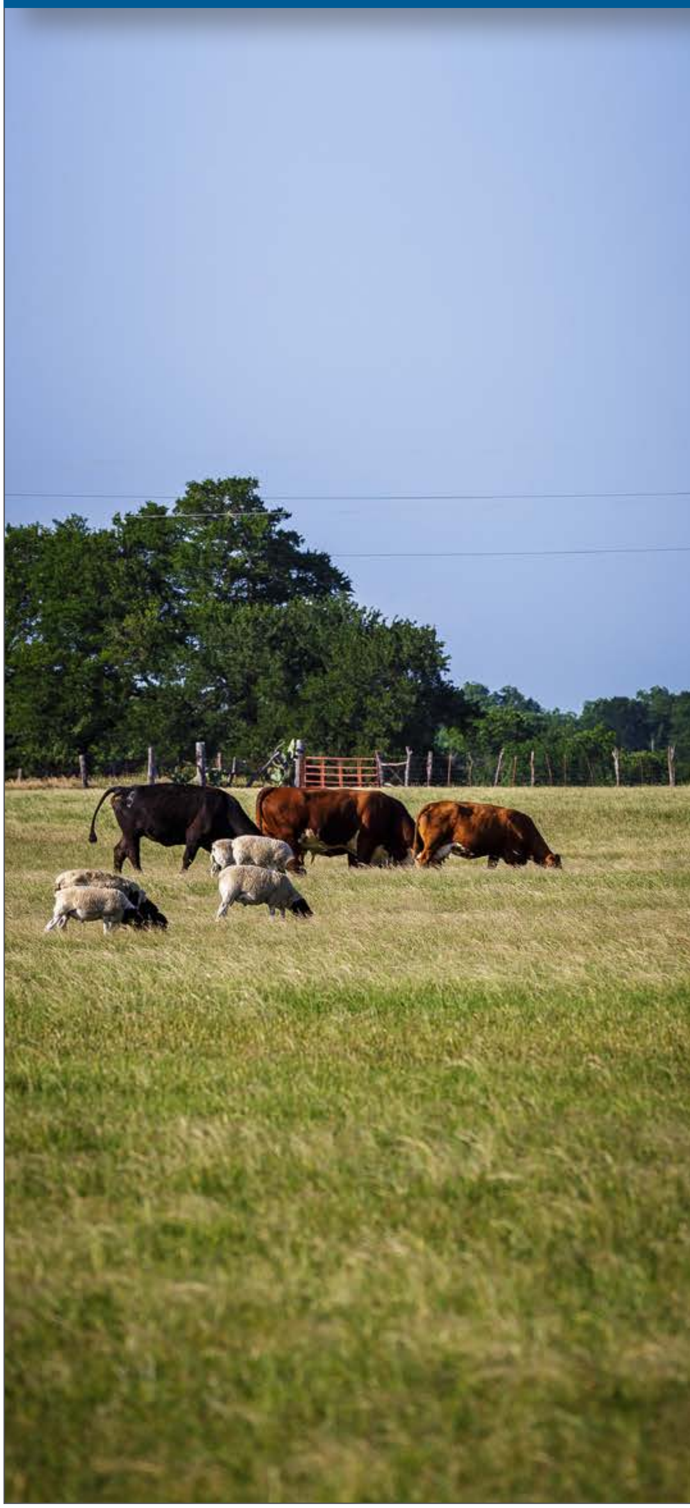
Management measure	Participants	Unit cost	Implementation goals (years after implementation begins)					Total cost
			1 2	3 4	5 6	7 8	9 10	
Centralized wastewater								
Wastewater treatment facility (WWTF) conveyance system testing to identify inflow and infiltration problem areas	WWTF operating entities	$3,000–$10,000/site	As many as possible					Varies
Repair or replace WWTF conveyance infrastructure	WWTF operating entities	N/A	As many as possible					Varies
Cities, AgriLife Extension	Develop and deliver education materials regarding sanitary sewer overflows to residents and property owners	N/A	1					N/A
Illicit dumping								
Develop educational and outreach materials	Counties, AgriLife Extension, NTMWD	N/A	Develop and deliver annually					TBD
County	Support efforts to reduce illegal dumping	N/A	1					N/A
Volunteer monitoring								
Establish a volunteer monitoring program in the watershed	Texas Stream Team, NTWMD, citizens in the watershed	~$550 initial cost for streamflow and nutrient kit ~$650 initial cost for *E. coli* bacteria monitoring supplies kit	1					~1,200 startup cost plus additional costs for replacing and replenishing supplies
Soil testing								
Develop and deliver educational and outreach materials	AgriLife Extension, NTMWD, counties	~5,000	1	1	1	1	1	~25,000
Soil testing	AgriLife Extension	$12/test						TBD
Landowner education								
Develop and deliver educational and outreach materials to landowners	AgriLife Extension, NTMWD, counties	~5,000	1					~25,000
General watershed management								
Provide resources in support of a watershed coordinator	NTMWD, AgriLife Extension, counties	~75,000/year	1					~750,000*
Semi-annual meetings	NTMWD, watershed coordinator	$300/meeting	Semi-annually					$6,000

*Includes salary and fringe over 10 years

Table 31.Total estimated loading reduction.

Management measure	Expected *E. coli* load reduction (from previous section)
Agricultural management measures	
Water quality management plans (Texas State Soil and Water Conservation Board/Natural Resources Conservation Service [NRCS])	1.01×10^{15} colony forming units (cfu)/year
Conservation Plans (NRCS)	
Livestock management education and outreach	
Feral hog management	
Feral hog removal	6.89×10^{12} cfu/year
Supplemental feeding exclosures	
Feral hog education and outreach programming	
On-site sewage facility (OSSF) management	
OSSF repair and replacement	4.30×10^{15} cfu/year
OSSF owner education and outreach	
OSSF installer and service provider education and outreach	
Dog management	
Dispose of dog waste into trash receptacles	2.68×10^{13} cfu/year
Total reduction	5.34×10^{15} cfu/year
Total reduction needed	8.84×10^{14} cfu/year

Chapter 7
Education and Outreach



Cattle and Sheep grazing south of Bonham, TX. Photo by Ed Rhodes, TWRI.

An essential element to the implementation of this WPP is an effective education and outreach campaign. Long-term commitments from citizens and landowners will be necessary for achieving comprehensive improvements in the Bois d'Arc Lake watershed. The education and outreach component of implementation must focus on keeping the public, landowners, and agency personnel informed of project activities, providing information about appropriate management practices, and assisting in identifying and forming partnerships to lead the effort.

Watershed Coordinator

The role of the watershed coordinator is to lead efforts to establish and maintain the working partnerships with stakeholders. The watershed coordinator also serves as a point of contact for all things related to WPP development and implementation and the WPP itself. During the planning effort, NTMWD has taken the lead on this role. A dedicated position is recommended to support WPP implementation.

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

Future Stakeholder Engagement

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

Education Programs

Educational programming will be a critical part of the WPP implementation process. Multiple programs geared toward providing information on various sources of potential pollutants and feasible management strategies will be delivered in and near the Bois d'Arc Lake watershed and advertised to watershed stakeholders. An approximate schedule for planned programming is provided in Chapter 6. This schedule will be used as a starting point, and efforts will be made to abide by this schedule as much as possible. As implementation and data collection continues, the adaptive management process will be used to modify this schedule and respective educational needs as appropriate.

Feral Hog Management Workshop

The watershed coordinator will coordinate with AgriLife Extension personnel to deliver periodic workshops focusing on feral hog management. This workshop will educate landowners on the negative impacts of feral hogs, effective control methods, and resources to help them control these pests. Workshop frequency will be approximately every 3–5 years, unless there are significant changes in available means and methods to control feral hogs.

Lone Star Healthy Streams Workshop

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

OSSF Operation and Maintenance Workshop

Once OSSFs in the watershed and their owners have been identified, an OSSF rules, regulations, operation, and maintenance training will be delivered in the watershed. This training will consist of education and outreach practices to promote the proper management of existing OSSFs and to garner support for efforts to further identify and address failing OSSFs through inspections and remedial actions. AgriLife Extension provides the needed expertise to deliver this training. Trainings will be based on needs identified early during WPP planning. Additionally, an online training module that provides an overview of septic systems, how they operate, and what maintenance is required to sustain proper functionality and extend system life will be made available to anyone interested through the partnership website. This training module was developed by the Guadalupe-Blanco River Authority in cooperation with AgriLife Extension and is currently available online at: https://www.gbra.org/presentations/septic/index.html. AgriLife also now provides an online training for homeowners regarding proper operation, maintenance, and monitoring service of OSSFs: (https://ossf.tamu.edu/event/homeowner-maintenance-of-atu-online/).

Healthy Lawns Healthy Waters Workshop

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

Texas Well Owners Network Training

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network program 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. Well screenings are conducted through this program. The program provides useful information to well owners that will assist them in better managing their water supplies. The watershed coordinator is currently coordinating with AgriLife Extension personnel to deliver this program in the Bois d'Arc Lake watershed. Information on this program can be found at: https://twon.tamu.edu/.

Riparian and Stream Ecosystem Education Program

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

Stream Trailer Facilitator Training

To promote and amplify water and landscape conservation practices in North Texas, NTMWD received funding for a stream hydrology trailer from TSSWCB. The trailer serves as a traveling classroom that demonstrates the influence of water quantity, sediment, and vegetation on waterbodies. This program provides classroom and hands-on facilitator training whereby participants who successfully complete the training may use the stream trailer as a teaching tool for their events. Information for this program can be found at: https://www.ntmwd.com/watershed-planning/.

Land Management and Wildlife Management Workshops

Wildlife has numerous significant impacts on the Bois d'Arc Lake watershed and as a result, periodic wildlife management workshops are warranted to provide information on management strategies and available resources to landowners and others interested in protecting wildlife habitat. The watershed coordinator will work with AgriLife Extension wildlife specialists and TPWD as appropriate to plan and secure funding to deliver workshops in and near the Bois d'Arc Lake watershed.

Defend Your Drain Program

In an attempt to reduce SSOs, the Defend Your Drain program was developed by the city of Dallas to inform citizens about the detrimental effects of certain products and substances on their plumbing, wastewater system, and the environment. The program was largely successful and has since been adopted by a number of entities in the North Texas region. NTMWD has collaborated with its wastewater system member and customer communities to explore opportunities for outreach and education relating to proper disposal of personal care products, household chemicals, and fats, oils, and grease. Support for implementation of the Defend Your Drain program and other outreach and education efforts aimed at reducing SSOs and unauthorized wastewater discharges in the Bois d'Arc Lake watershed is recommended.

Public Meetings

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

Newsletters and News Releases

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

Chapter 8
Resources to Implement the Watershed Protection Plan

Fannin County Courthouse. Photo by Ed Rhodes, TWRI.

The Bois d'Arc Lake watershed is a largely rural watershed with limited resources available for the implementation of the management measures identified by stakeholders. This chapter identifies the potential sources of technical and financial assistance available to maximize the implementation of management measures. Grant funding will likely be a substantial source of implementation funding given the availability of resources identified thus far. In addition to funding management measures, it is recommended that funds be identified and developed to support a local watershed coordinator to guide WPP implementation and facilitate long-term success of the plan.

Technical Assistance

Designing, planning, and implementing some of the management recommendations in the plan will require technical expertise. In these cases, appropriate support will be sought to provide needed technical guidance. Funds required to secure needed expertise will be included in requests for specific projects and may come from a variety of sources. Table 32 provides a summary of the potential sources of technical assistance for each management measure.

Livestock Management

Developing and implementing practices to improve livestock management will require significant technical assistance from TSSWCB, local SWCDs, AgriLife Extension, and local NRCS personnel. Producers requesting planning assistance in the watershed will work with these entities to define operation-specific management goals and objectives and develop a management plan that prescribes effective practices that will achieve stated goals while also improving water quality.

Feral Hog Management

Watershed stakeholders will benefit from technical assistance regarding feral hog control approaches, options, best practices, and regulations. AgriLife Extension and TPWD provide educational resources through local programs and public events. Technical resources regarding trap and transport regulations, trap construction and design, exclusion

Table 32. Summary of potential sources of technical assistance.

Management Measure (MM)	Technical Assistance
MM 1: Promote and implement water quality management plans or conservation plans	Texas A&M AgriLife Extension Service; Natural Resources Conservation Service (NRCS); Texas State Soil and Water Conservation Board (TSSWCB); local soil and water conservation districts (SWCDs)
MM 2: Promote technical and operational assistance to landowners for feral hog control	AgriLife Extension; NRCS; Texas Parks and Wildlife Department (TPWD); TSSWCB; local SWCDs
MM 3: Identify, inspect, and repair or replace failing on-site sewage systems	AgriLife Extension; Fannin County Environmental Development Department – Septic Systems and designated representative
MM 4: Reduce the amount of pet waste mixing into water bodies	City public works departments; AgriLife Extension
MM 5: Implement and expand urban and impervious surface stormwater runoff management	City public works departments; engineering firms; AgriLife Extension
MM 6: Identify potential wastewater conveyance system failure and prioritize system repairs or replacement	Wastewater treatment facility operating entities; city public works departments; contractors; consulting engineers
MM 7: Reduce illicit and illegal dumping	AgriLife Extension; county law enforcement; TPWD game wardens
MM 8: Volunteer monitoring on other streams in the watershed	Texas Stream Team, North Texas Municipal Water District (NTMWD)
MM 9: Conduct soil testing for both agriculture and urban areas	AgriLife Extension, NTMWD, counties
MM 10: Conduct old and new landowner education workshop	AgriLife Extension, NTMWD, counties

fencing construction, and other related feral hog resources are available through AgriLife Extension as publications and videos for homeowners: https://feralhogs.tamu.edu/.

OSSF Management

Technical support is needed to address failing OSSFs throughout Fannin County. Technical assistance will be sought from respective county-designated representatives and permitting offices in prospective OSSF program design, funding acquisition, identification of potential participants, and publicizing of program availability as funds become available. Technical assistance for education and outreach will be provided through AgriLife Extension.

Pet Waste

Limited technical assistance is available to directly address pet waste. City public works and parks departments will be relied upon to identify appropriate sites for pet waste stations. Technical assistance for educational materials will be provided through AgriLife Extension.

Urban Stormwater

Limited technical assistance is available to address urban stormwater in these largely rural watersheds. City public works staff will be relied upon to identify potential projects and sites. For structural projects, engineering designs may be needed and will be integrated into the costs of the projects or potentially through grants. Technical assistance with education and outreach is available through AgriLife Extension.

Centralized Wastewater

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

Illicit Dumping

Efforts to reduce illicit dumping will focus on education and outreach and volunteer cleanups. AgriLife Extension will provide technical assistance with education and outreach efforts. Keep Texas Beautiful and its local affiliates offer technical resources toward working with cities and counties to facilitate cleanups. County law enforcement and TPWD game wardens are the primary source of enforcement and monitoring activities associated with illicit dumping.

Volunteer Monitoring

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

Soil Testing

Soil testing efforts will focus on education and outreach. AgriLife Extension will provide technical assistance with developing and delivering educational and outreach materials to landowners in the watershed.

Small Landowner Education

AgriLife Extension will provide technical assistance with developing and delivering educational and outreach materials to new or small landowners in the watershed.

Technical Resource Descriptions

AgriLife Extension

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

Engineering Firms

Private firms provide consulting, engineering, and design services. The technical expertise provided by firms may be required for urban BMP design. Funding for services will be identified and written into project budgets as required.

Fannin County Designated Representative

OSSF construction or replacement in Fannin County requires a permit to be filed with Fannin County. Permits must be applied for through a TCEQ-licensed professional installer. The county designated representative is responsible for approving or denying permits. Site evaluations in Fannin County must be done by a TCEQ-licensed site and soil evaluator, licensed maintenance provider, or licensed professional installer.

Fannin County Environmental Development Department -Septic Permits

As an authorized agent of TCEQ, Fannin County is responsible for implementing and enforcing rules pertaining to OSSFs under the Texas Health and Safety Code and Texas Administrative Code. These codes establish minimum standards for the planning, permitting, construction, and maintenance of OSSFs.

Municipal Public Works Departments

The respective public works departments of the cities of Bonham and Honey Grove are responsible for the management of city street, utility, and open space infrastructure. Implementation of stormwater BMPs and dog waste stations will require coordination and assistance from public works departments from each city.

Natural Resources Conservation Service

NRCS provides conservation planning and technical assistance to private landowners. For decades, private landowners have voluntarily worked with NRCS specialists to prevent erosion, improve water quality, and promote sustainable agriculture. Technical and financial 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. The local NRCS center is in Bonham.

Soil and Water Conservation Districts

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 conservation plan to meet each land unit's specific capabilities and needs. The local SWCD is Fannin County SWCD #520.

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 also consistent with other land use goals to ensure plant and animal diversity, provide aesthetic and economic benefits, and conserve soil, water, and related natural resources. To participate, landowners may request assistance by contacting TPWD district serving their county.

Texas State Soil and Water Conservation Board

The TSSWCB WQMP program provides technical assistance for developing management and conservation plans at no charge to agricultural producers. A visit with the local NRCS office is the first step for operators to begin the plan development process.

Texas Stream Team

The Texas Stream Team program provides training and information on necessary equipment to citizen scientists to develop volunteer water quality monitoring programs in their local area. Texas Stream Team is housed at the Meadows Center for Water and the Environment at Texas State University. To partner with TST, citizens or entities can fill out the following form on their website: https://www.meadowscenter.txstate.edu/Leadership/TexasStreamTeam/Partners/PartnerForm.html.

Financial Resource Descriptions

Successful implementation of the Bois d'Arc Lake WPP, as written, will require substantial fiscal resources. Diverse funding will be sought to meet these needs. Resources will be leveraged where possible to extend the impacts of acquired and contributed implementation funds.

Many landowners are already engaged in implementing the WPP through the development and implementation of WQMPs and installation of other conservation practices through Farm Bill-funded programs such as NRCS' Environmental Quality Incentive Program (EQIP). The continued funding support from federal and state governments will provide a large portion of funds needed to implement this WPP.

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

Federal Funding Sources

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

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

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

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

Environmental Education Grants

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

Environmental Quality Incentives Program (EQIP)

NRCS operates a voluntary conservation program, EQIP, which provides assistance to farmers and ranchers to address natural resource concerns by implementing activities to improve soil, water, plant, animal, air, and other resources associated with agricultural land. An EQIP contract extends up to 10 years and provides financial and technical assistance for planning and implementing prescribed conservation practices. EQIP participants include individuals engaged in livestock or agricultural production on eligible land. Selected practices address natural resource concerns and are subject to NRCS technical standards adapted for local conditions. They also must be approved by the local SWCD. Local work groups are formed to provide recommendations to 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/detail/tx/programs/financial/eqip/?cid=nrcs144p2_002597.

Conservation Stewardship Program (CSP)

NRCS administers a voluntary conservation program known as the Conservation Stewardship Program (CSP) that encourages producers to address resource concerns in a comprehensive manner by adding, maintaining, improving, and managing conservation activities. The program is available for private agricultural lands including cropland, grassland, prairie land, improved pasture, and rangeland. CSP encourages landowners and stewards to improve conservation activities on their land by installing and adopting additional conservation practices. Practices may include, but are not limited to, prescribed grazing, nutrient management planning, precision nutrient application, manure application, and integrated pest management.

Program information can be found at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/.

Conservation Reserve Program

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

Information on the program is available at: http://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index.

Contact the Fannin County FSA office for more information on this and other programs or to enroll: (903) 583-9513 ext. 2.

National Integrated Water Quality Program (NIWQP)

The NIWQP, administered by USDA, provides funding for research, education, and extension projects aimed at improving water quality in agricultural and rural watershed and has identified eight themes that are being promoted: (1) animal manure and waste management, (2) drinking water and human health, (3) environmental restoration, (4) nutrient and pesticide management, (5) pollution assessment and prevention, (6) watershed management, (7) water conservation and agricultural water management, and (8) water policy and economics. Awards are made in three program areas: national projects, regional coordination projects, and extension education projects. It is important to note that funding from this program is only available to universities.

More information is available at: https://nifa.usda.gov/national-integrated-water-quality-program-frequently-asked-questions.

National Water Quality Initiative (NWQI)

NWQI is administered by NRCS and is a partnership between NRCS, state water quality agencies, and EPA to identify and address impaired water bodies through voluntary conservation. Conservation systems include practices to promote soil health, reduce erosion and nutrient runoff.

Further information is available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/initiatives/?cid=stelprdb1047761.

State Funding Sources

Clean Rivers Program

TCEQ administers the Texas CRP, a state fee-funded program that provides surface water quality monitoring, assessment, and public outreach. Allocations are made to 15 partner agencies (primarily river authorities) throughout the state to assist in routine monitoring efforts, special studies, and outreach efforts. RRA is CRP partner for the Bois d'Arc Lake watershed. The program supports water quality monitoring and annual water quality assessments and engages stakeholders in addressing water quality concerns in the Red River Basin.

More information about the Clean Rivers Program is available at: http://www.rra.texas.gov/.

Clean Water State Revolving Fund (CWSRF)

TWDB provides low-cost financing for a variety of wastewater, stormwater, reuse, and other pollution control projects. Political subdivisions and private entities are eligible to apply for loans at lower than market rates to plan, design, acquire, or construct projects. The loans can spread project costs over a repayment period of up to 20 years. Repayments are cycled back into the fund and used to pay for additional projects.

More information on CWSRF is available at: http://www.twdb.texas.gov/financial/programs/CWSRF/.

Landowner Incentive Program

The Landowner Incentive Program, administered by TPWD, works with private landowners to implement conservation practices that benefit healthy aquatic and terrestrial ecosystem. The program provides financial assistance but does not require the landowner to contribute through labor, materials, or other means.

Further information about this program is available at: http://tpwd.texas.gov/landwater/land/private/lip.

Supplemental Environmental Projects (SEP)

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

Further information about SEPs and how to apply can be found at: https://www.tceq.texas.gov/compliance/enforcement/sep.

Texas Wildlife Services Program

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

Water Quality Management Plan Program (WQMP)

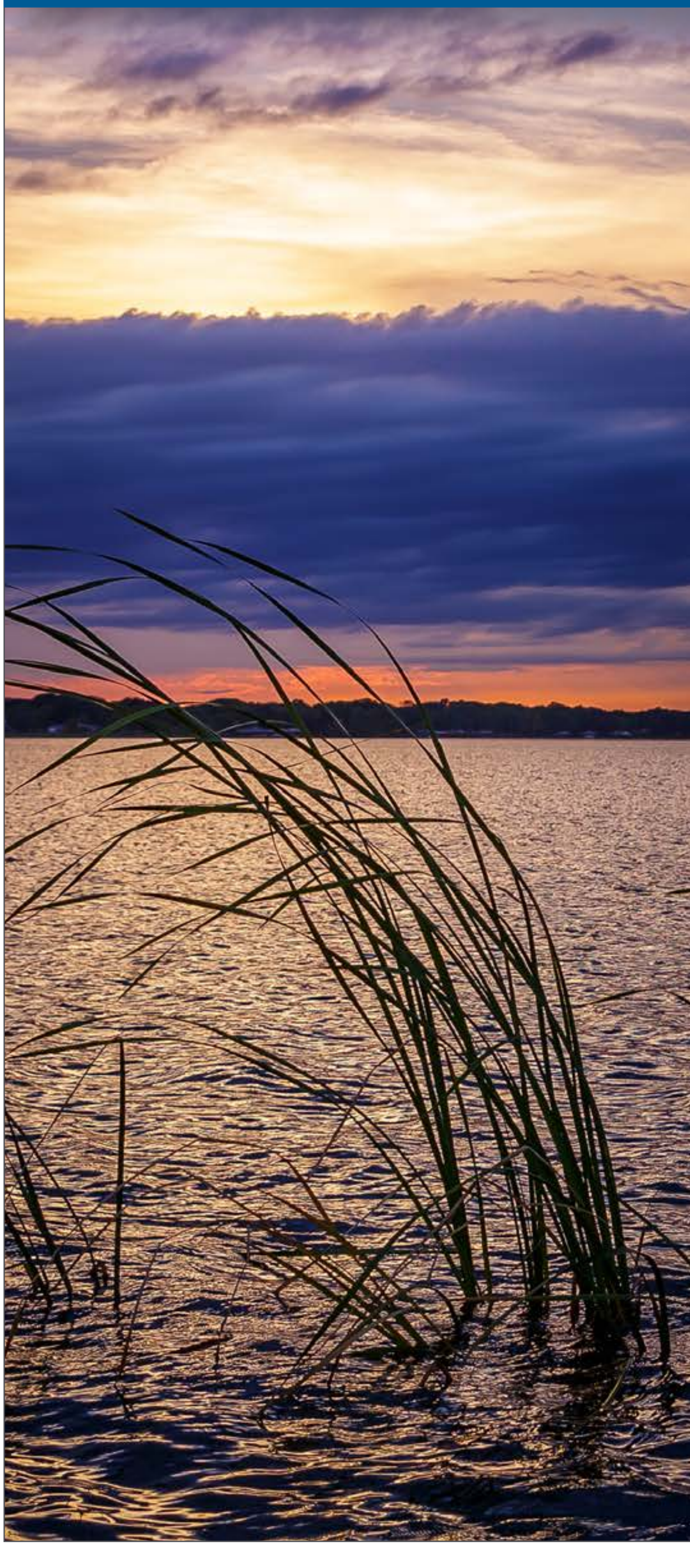
WQMPs are management plans developed and implemented to improve land and water quality. TSSWCB and local NRCS provide necessary technical assistance to develop plans that meet producer and state goals. Once the plan is developed, TSSWCB may financially assist implementing a portion of prescribed BMPs. As of 2021, TSSWCB has developed and certified three WQMPs in the watershed. These plans can include practices such as conservation cover, prescribed grazing, fencing, heavy-use area protection, water facilities, wells, and upland wildlife management.

Other Sources

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

- Cynthia and George Mitchell Foundation: provides grants for water and land conservation programs to support sustainable protection and conservation of Texas' land and water resources.
- Dixon Water Foundation: provides grants to 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: provides funding to assist in establishing conservation easements for enrolled lands.
- Texan by Nature – Texas Water Action Collaborative (TxWAC) matches organizations, companies, and funders with conservation projects to positively benefit Texas' water resources. TxWAC is piloting in the Upper Trinity River Basin but has plans to expand throughout the state.

Chapter 9 Measuring Success



Lake Bonham at sunset. Photo by Ed Rhodes, TWRI.

Over the next 10 years, implementation of this WPP will require the coordination of many dedicated stakeholders. The goal is to achieve water quality targets by addressing the most readily manageable sources of *E. coli* in the watershed. To achieve these targets, this plan has identified the needed substantial financial commitments, technical assistance, and education and outreach programs. The management measures identified in this WPP are voluntary but supported at the recommended levels by watershed stakeholders.

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

Water Quality Targets

An established water quality goal defines the target for future water quality and allows the needed bacterial load reductions to be defined. The appropriate goal for water quality in Bois d'Arc Creek is the existing primary contact recreation standard for *E. coli* of 126 cfu/100 mL. The target for Honey Grove Creek is currently established at the same standard. However, the Bois d'Arc Creek water quality target may change to SCR1 if the RUAA is approved by EPA. The ongoing Honey Grove Creek RUAA study may also determine that a different water quality standard is appropriate for the water body once it is complete. If the water quality standards do change, the targets will be addressed during a WPP update. Table 33 outlines water quality targets identified by stakeholders. These targets are based on a geometric mean of water quality samples taken in each segment. The Data Review section further discusses how water quality data will be reviewed.

Table 33. Water quality targets.

Station(s)	Segment	Current concentration	5 years after implementation*	10 years after implementation*
15036	0202A_03 Bois d'Arc Creek	178	152	126
21030	0202L_01 Honey Grove Creek	444	285	126

*In units of colony forming units *E. coli*/100 milliliters

Additional Data Collection Needs

Continued monitoring of water quality in the Bois d'Arc Lake watershed is necessary to track progress toward the goal of improved water quality. Monitoring data is needed to track changes in water quality resulting from WPP implementation. Currently, water quality monitoring is conducted by RRA on a quarterly basis at one site through CRP and monthly by NTMWD at five sites (Table 6).

Increasing the frequency of currently employed CRP data collection at the upstream Bois d'Arc Creek site would improve data availability and better illustrate water quality variations within a year and in response to implementation of the WPP. The WPP recommends increasing frequency of data collection from quarterly to monthly or bimonthly at this index site with anticipation that the data will enhance trend analysis and better illustrate improvements in water quality.

Through the adaptive management process and WPP updates, future water quality monitoring recommendations may include targeted water quality monitoring efforts to better track the effects of specific implementation projects. Targeted water quality monitoring may include studies on multiple subwatersheds, paired watershed studies, or multiple watershed studies. Targeted monitoring can also include more intensive monitoring along identified stream segments to better identify potential pollutant sources.

Data Review

Watershed stakeholders will use two methods to evaluate WPP implementation impacts on instream water quality. First will be TCEQ's statewide biennial water quality assessment approach, which uses a moving 7-year geometric mean of *E. coli* data collected through the state's CRP program. This assessment is published in the *Texas Integrated Report* and 303(d) List, which is available online at: https://www.tceq.texas.gov/waterquality/assessment/305_303.html. It is noted that a 2-year lag occurs in data reporting and assessment; therefore, the 2024 report will likely be the first to include water quality data collected during implementation of the WPP.

Water quality improvements are often harder to identify using the 7-year data window used for the *Texas Integrated Report.* Therefore, progress toward achieving the established target of 126 cfu/100 mL will also be evaluated using the geometric mean of the most recent 3 years of water quality data identified within TCEQ's Surface Water Quality Monitoring Information System. Trend analysis and other appropriate statistical analyses will also be used to support data assessment as needed.

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

Interim Measurable Milestones

Implementing the Bois d'Arc Creek WPP will occur over a 10-year period. Milestones are useful for incrementally evaluating the implementation progress of specific management measures recommended in the WPP. Milestones outline a clear tracking method that illustrates progress toward implementation of management measures as scheduled. Interim measurable milestones are identified in the implementation schedule (Table 30). Participants and estimated costs are also included in the schedule. In some cases, funding acquisition, personnel hiring, or program initiation may delay the start of implementation. This approach provides incremental targets that can be used to measure progress. If sufficient progress is not made, adjustments will ensue to increase implementation and meet established goals. Adaptive management may also be used to adjust the planned approach if the original strategy is no longer feasible or effective.

Adaptive Management

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

Adaptive management is often referred to as "learning by doing" (Franklin et al. 2007). It is the ongoing process of accumulating knowledge of the causes of impairment as implementation efforts progress, which results in reduced uncertainty associated with modeled loads. As implementation activities are instituted, water quality is tracked to assess impacts and guide adjustments, if necessary, to future implementation activities. This ongoing, cyclical implementation and evaluation process serves to focus project efforts and optimize impacts. Watersheds in which the impairment is dominated by nonpoint source pollutants, such as Honey Grove Creek, are good candidates for adaptive management.

Progress toward achieving the established water quality target will also be used to evaluate the need for adaptive management. A periodic review of implementation progress and water quality trends will be discussed with stakeholders during semiannual meetings. Due to the numerous factors that can influence water quality and the time lag that often appears between implementation efforts and resulting water quality improvements, sufficient time should be allowed for implementation to occur fully before triggering adaptive management. In addition to water quality targets, if satisfactory progress toward achieving milestones is determined to be infeasible due to funding, scope of implementation or other reasons that would prevent implementation, adaptive management provides an opportunity to revisit and revise the implementation strategy. If stakeholders determine inadequate progress toward water quality improvement or milestones is being made, efforts will be made to increase adoption of BMPs and adjust strategies or focus area if and when necessary.

References

Asquith, W. H., Roussel, M. C., Vrabel, J. 2006. Statewide Analysis of the Drainage-Area Ratio Method for 34 Streamflow Percentile Ranges in Texas, Reston, VA: U.S. Geological Survey. Scientific Investigations Report 2006-5286. https://pubs.er.usgs.gov/publication/sir20065286.

AVMA (American Veterinary Medical Association). 2018. 2017–2018 U.S. Pet Ownership & Demographics Sourcebook, Schaumberg, IL: American Veterinary Medical Association. https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx.

Borel, K., Gregory, L., Karthikeyan, R. 2012. Modeling Support for the Attoyac Bayou Bacteria Assessment using SELECT. College Station, TX: Texas Water Resources Institute. TR-454. https://twri.tamu.edu/publications/technical-reports/2012-technical-reports/tr-454/.

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.

EPA (United States Environmental Protection Agency). 2000. EPA Office of Water. Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management. Federal Register, October 18, 2000, pp. 62565-62572. https://www.govinfo.gov/content/pkg/FR-2000-10-18/pdf/00-26566.pdf.

EPA. 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. Washington, DC: U.S. Environmental Protection Agency. EPA 841-B-07-006. https://www.epa.gov/tmdl/approach-using-load-duration-curves-development-tmdls.

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Washington, DC: EPA 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.

FNI (Freese and Nichols, Inc.). 2010. Instream Flow Study for Proposed Lower Bois d'Arc Creek River Reservoir. http://cdm16021.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/5519.

FNI. 2017. Proposed Lower Bois d'Arc Creek Reservoir, Appendix C: Revised Mitigation Plan. Tulsa, OK: U.S. Army Corps of Engineers. http://cdm16021.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/5501.

Franklin, T. M., Helinski, R., Manale, A. 2007. Using Adaptive Management to Meet Conservation Goals. Prepared in response to Farm Bill Conservation Practices, Bethesda, MD: The Wildlife Society. Technical Review 07–1. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013594.pdf.

Griffith, G. E., Bryce, S. B., Omernik, J. M., Rogers, A. 2007. Ecoregions of Texas, Austin, TX: Texas Commission on Environmental Quality. http://ecologicalregions.info/htm/pubs/TXeco_Jan08_v8_Cmprsd.pdf.

Mapston, M. E. 2007. Feral Hogs in Texas. Texas Cooperative Extension. Texas Wildlife Services. B-6149 03-07. https://hdl.handle.net/1969.1/87218.

Mayer, J. J. 2009. Biology of wild pigs: taxonomy and history of wild pigs in the United States. In Wild pigs: biology, damage, control techniques and management, edited by J. J. Mayer and I. L. Brisbin Jr., 5-23. Aiken, SC: Savannah River National Laboratory. http://sti.srs.gov/fulltext/SRNL-RP-2009-00869.pdf.

MRLC (Multi-Resolution Land Characteristics Consortium). 2019. NLCD 2019 Land Cover (CONUS). https://www.mrlc.gov/data/nlcd-2019-land-cover-conus.

NOAA (National Oceanic and Atmospheric Administration). 2016. Climate Data Online. http://www.ncdc.noaa.gov/cdo-web/.

PRISM Climate Group, Oregon State University. 2012. 30-Year Normals. 30-Year Normal Precipitation Spatial Data. http://www.prism.oregonstate.edu/normals/.

Rattan J.M., Higginbotham B.J., Long D.B., Campbell T.A. 2010. Exclusion fencing for feral hogs at White-tail deer feeders. Texas Journal of Agriculture and Natural Resource. 23:83-89. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2272&context=icwdm_usdanwrc.

TAC §307. 2014. Texas Administrative Code: Chapter 307 – Texas Surface Water Quality Standards, Austin, TX: Texas Commission on Environmental Quality. https://www.tceq.texas.gov/assets/public/waterquality/standards/tswqs_2014/TSWQ2014Rule.pdf.

TCEQ (Texas Commission on Environmental Quality). 2019. 2020 Draft Guidance for Assessing and Reporting Surface Water Quality in Texas, Austin, TX: Texas Commission on Environmental Quality. https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/gawg/2020/2020_guidance.pdf.

TCEQ. 2020. 2020 Texas Integrated Report - Texas 303(d) List (Category 5), Austin, TX: Texas Commission on Environmental Quality. https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/20txir/2020_303d.pdf.

Timmons, J. B., Higginbotham, B., Lopez, R., Cathey, J. C., Mellish, J., Griffin, J., Sumrall, A., 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.

TWDB (Texas Water Development Board). 2016. Population and Water Demand Projections. https://www.twdb.texas.gov/waterplanning/data/projections/.

TWDB. 2020a. Trinity Aquifer. https://www.twdb.texas.gov/groundwater/aquifer/majors/trinity.asp.

TWDB. 2020b. Woodbine Aquifer. https://www.twdb.texas.gov/groundwater/aquifer/minors/woodbine.asp.

USCB (U.S. Census Bureau). 2010. Explore Census Data. https://data.census.gov/cedsci/.

USCB. 2019. City and Town Population Totals: 2010–2019. https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-cities-and-towns.html.

USDA NASS (U.S. Department of Agriculture National Agricultural Statistics Service). 2017. Census of Agriculture. https://www.nass.usda.gov/Publications/AgCensus/2017/index.php.

USDA NRCS (USDA Natural Resources Conservation Services). 2020. Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx.

USGS (U.S. Geological Survey). 2013. National Elevation Database. https://apps.nationalmap.gov/viewer/.

Wagner, K. L., 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.

Wagner, K. L., Redmon, L. A., Gentry, T. J., Harmel, R. D., Knight, R., Jones, C. A., Foster, J. L. 2013. Effects of an off-stream watering facility on cattle behavior and instream *E. coli* levels. Texas Water Journal. 4 (2): 1-13. https://doi.org/10.21423/twj.v4i2.6460.

Appendix A: GIS Analysis and Potential Load Calculations

A GIS analysis was used to estimate potential bacterial loads in the watershed and subwatersheds. This approach estimates potential loads by subwatershed and allows stakeholders to consider results for prioritizing management implementation. This geospatial approach provides an easy method to understand relative contributions and spatial distribution across the watershed without relying on data-intensive (and expensive) modelling approaches. The GIS analysis distributes inputs across the watershed based on land use and land cover attributes using GIS. The bacterial loadings are calculated from published bacteria production data. The loadings are then spatially distributed across the watershed based on appropriate land cover.

Agriculture Bacterial Loading Estimates

The first step to calculate potential bacterial loads from cattle is to develop cattle population estimates. Stakeholder input was critical to develop livestock population estimates across the watershed. Because watershed-level livestock numbers are not available, livestock populations were estimated using the USDA NASS (2017) census counts and the ratio of nonurban county land in the watershed to the ratio of nonurban land in the county.

The assumptions used in this method are documented in Wagner and Moench (2009) and Borel et al. (2015; Table 34).

Table 34. Bacterial loading assumptions for livestock.

Assumptions	
Total cattle in the watershed	26,572
Total number of goats in the watershed	1,294
Total number of sheep in the watershed	1,054
Total number of horses in the watershed	1,053
Animal unit conversion factor for cattle	1
Animal unit conversion factor for goats	0.17
Animal unit conversion factor for sheep	0.2
Animal unit conversion factor for horses	1.25
Fecal coliform production rate for cattle	8.55×10^{9} colony forming units (cfu)/animal-day (Wagner and Moench 2009)
Fecal coliform production rate for goats	2.54×10^{10} cfu/animal-day (Wagner and Moench 2009)
Fecal coliform production rate for sheep	2.90×10^{11} cfu/animal-day (Wagner and Moench 2009)
Fecal coliform production rate for horses	2.91×10^{8} cfu/animal-day (Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Using cattle population estimates, we estimate potential loading across the watershed and for individual subwatersheds. The annual load from cattle was calculated as:

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

Where:

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

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

FC_{cattle} = Fecal coliform rate of cattle

$Conversion$ = Estimated fecal coliform to *E. coli* conversion rate

The estimated potential annual loading across all subwatersheds due to cattle is 5.22×10^{16} cfu *E. coli*/year.

Using population estimates of other livestock in the watershed, the annual load from goats, sheep, and horses were individually calculated as:

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

Where:

$PAL_{livestock}$ = Potential annual *E. coli* loading

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

$FC_{livestock}$ = Fecal coliform rate

$Conversion$ = Estimated fecal coliform to *E. coli* conversion rate

The estimated potential annual loading across all subwatersheds due to all other livestock is 1.54×10^{16} cfu *E. coli*/year.

Collectively, we estimated the potential loading across the watershed from livestock as 6.77×10^{16} cfu *E. coli*/year.

Dog Bacterial Loading Estimates

The dog population in the watershed was estimated using AVMA (2018) statistics for average number of dogs per household and an estimate of number of households derived from U.S. Census block data (Table 35).

Table 35. Bacterial loading assumptions for dogs.

Assumptions	
Average dogs per home	0.614 (AVMA 2018)
Number of homes	8,427
Estimated number of dogs	5,174
Fecal coliform production rate for dogs	5.0×10^9 colony forming units (cfu)/animal-day (EPA 2001)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Using the assumptions listed in Table 35, the annual potential bacterial load from dogs is estimated as:

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

Where:

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

N_d = Number of dogs

FC_d = Fecal coliform loading rate of dogs

$Conversion$ = Estimated fecal coliform to *E. coli* conversion rate

Therefore, the estimated potential annual loading attributed to dogs is 5.95×10^{15} cfu *E. coli*/year.

OSSF Bacterial Loading Estimates

Using the OSSF estimates, potential *E. coli* loading across the watershed and for individual subwatersheds was estimated (Table 36). Methods to estimate OSSF locations and numbers are described in Chapter 4 of this WPP.

Table 36. Bacterial loading assumptions for on-site sewage facilities (OSSFs).

Assumptions	
Subwatershed 1 number of OSSFs	616
Subwatershed 2 number of OSSFs	659
Subwatershed 3 number of OSSFs	487
Subwatershed 4 number of OSSFs	609
Subwatershed 5 number of OSSFs	348
Subwatershed 6 number of OSSFs	213
Failure rate	15% (Reed, Stowe, & Yanke 2001)
Average number of people per household	2.49 (USCB 2010)
Assumed sewage production rate	70 gallons per person per day (Borel et al. 2015)
Fecal coliform concentration in sewage	1.0×10^6 colony forming units (cfu)/100 milliliters (EPA 2001)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Using the assumptions listed in Table 36, the annual potential bacterial load from OSSFs is estimated as:

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

Where:

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

N_{ossfs} = Number of OSSFs

N_{hh} = Average number of people per household

Production = Assumed sewage discharge rate

Fail Rate = Assumed failure rate

FC_s = Fecal coliform concentration in sewage

Conversion = Estimated fecal coliform to *E. coli* conversion rate

Therefore, the estimated potential annual loading attributed to OSSFs is 6.62×10^{15} cfu *E. coli*/year.

Feral Hog and Wildlife Bacterial Loading Estimates

Feral hog populations were estimated based on an assumed population density of 33.3 acres/hog. This number was chosen based on stakeholder input and 175,705 acres of available habitat identified in the NLCD. Potential bacterial loadings from feral hogs were estimated using GIS analysis and the assumptions in Table 37.

Table 37. Bacterial loading assumptions for feral hogs.

Assumptions	
Number of feral hogs in the watershed	5,276
Animal Unit conversion factor for feral hogs	0.125 (Wagner and Moench 2009)
Fecal coliform production rate for feral hogs	1.21×10^9 cfu fecal coliform per animal (Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Using the assumptions listed in Table 42, the annual potential bacterial load from feral hogs is estimated as:

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

Where:

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

N_{fh} = Number of feral hogs

$AnUC$ = Animal Unit Conversion

FC_{fh} = Fecal coliform loading rate of feral hogs

Conversion = Estimated fecal coliform to *E. coli* conversion rate

Therefore, the estimated potential annual loading attributed to feral hogs is 1.84×10^{14} cfu *E. coli*/year.

White-tailed deer estimates for the watershed are not available; therefore estimates from the TPWD RMU 21 were used. The estimated deer density for RMU 21 from 2005 to 2015 is 26.69 acres per deer. Applying this density to pasture, cultivated crops, rangeland, and forest resulted in an estimated 6,583 deer in the watershed. Potential bacterial loadings were estimated using a GIS analysis and the assumptions in Table 38.

Table 38. Bacterial loading assumptions for white-tailed deer.

Assumptions	
Number of white-tailed deer in the watershed	6,583
Animal Unit conversion factor for white-tailed deer	0.112 (Wagner and Moench 2009)
Fecal coliform production rate for white-tailed deer	1.5×10^{10} colony forming units (cfu) fecal coliform per animal (Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Using the assumptions listed in Table 38, the annual potential bacterial load from white-tailed deer is estimated as:

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

Where:

PAL_{wtd} = Potential annual *E. coli* loading attributed to white-tailed deer

N_{wtd} = Number of white-tailed deer

$AnUC$ = Animal Unit Conversion

FC_{wtd} = Fecal coliform loading rate of white-tailed deer

Conversion = Estimated fecal coliform to *E. coli* conversion rate

Therefore, the estimated potential annual loading attributed to white-tailed deer is 2.54×10^{15} cfu *E. coli*/year.

WWTF Bacterial loading Estimates

Potential loadings from WWTFs were calculated for all permitted dischargers with a bacteria monitoring requirement (Table 39). Potential loads were calculated as the sum of the maximum permitted discharges of all WWTFs in each subwatershed multiplied by the maximum permitted *E. coli* concentration:

Table 39. Bacterial loading assumptions for wastewater treatment facilities.

Assumptions	
Maximum permitted daily discharge in subwatershed 1	0.627 million gallons per day (MGD; EPA 2021)
Maximum permitted daily discharge in subwatershed 2	0.0218 MGD (EPA 2021)
Maximum permitted daily discharge in subwatershed 3	2.5 MGD (EPA 2021)
Maximum permitted daily discharge in subwatershed 5	0.08 MGD (EPA 2021)
Maximum permitted daily discharge in subwatershed 6	0.5 MGD (EPA 2021)
Fecal coliform concentration in sewage	1.0 x 10^6 colony forming units (cfu)/100 milliliters (EPA 2001)
E. coli concentration of effluent	1.26 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Using the assumptions listed in Table 39, the annual potential bacterial load from WWTFs is estimated as:

$$PAL_{wwtf} = Discharge \times FC_s \times Concentration_{effluent} \times 3{,}785.2\ \frac{mL}{gallon} \times 365\ \frac{days}{year}$$

Where:

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

Discharge = Maximum permitted daily discharge from each WWTF

FC_s = Fecal coliform concentration in sewage

$Concentration_{effluent}$ = *E. coli* concentration of effluent

Therefore, the estimated potential annual loading attributed to WWTFs is 6.44×10^{12} cfu *E. coli*/year.

Appendix A. References

AVMA (American Veterinary Medical Association). 2018. 2017–2018 U.S. Pet Ownership & Demographics Sourcebook, Schaumberg, IL: American Veterinary Medical Association. https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx.

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.

EPA (U.S. Environmental Protection Agency). 2001. Protocol for Developing Pathogen TMDLs: Source Assessment. 1st Edition. Washington, DC: U.S. Environmental Protection Agency. EPA 841-R-00-002. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt.

EPA. 2021. Enforcement and Compliance History Online (ECHO). http://echo.epa.gov/.

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: Texas Commission on Environmental Quality. http://www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/ossf/StudyToDetermine.pdf.

USCB (U.S. Census Bureau). 2010. Explore Census Data. https://data.census.gov/cedsci/.

USDA NASS (U.S. Department of Agriculture National Agricultural Statistics Service). 2017. Census of Agriculture. https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/.

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

Appendix B: Land Use/Land Cover Definitions and Methods

Estimates for bacterial load reductions in the Bois d'Arc Lake 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 will 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 10-year period based on perceived local acceptability, effectiveness, and available resources.

Agricultural Nonpoint Source Load Reductions

The potential load reductions that are achieved through conservation planning will depend on the specific management practices implemented by landowners. The load reduction will vary based on the type of practice, existing land condition, number of cattle in each operation and proximity to water bodies. Substantial research has been conducted on bacteria reduction efficiencies of practices. We reviewed literature to assess the median effectiveness of practices likely to be used in the watershed (Table 40) and used a mean 62.8% load reduction effectiveness rate for conservation planning. Assumptions used in bacterial load reduction calculations are provided in Table 41.

Table 40. Conservation practice effectiveness in reducing bacterial 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] Includes the following sources: Brenner et al. 1996; Cook 1998; Hagedorn et al. 1999; Line 2002, 2003; Lombardo et al. 2000; Meals 2001; Peterson et al. 2011

[2] Includes the following sources: Tate et al. 2004

[3] Includes the following sources: Byers et al. 2005; Hagedorn et al. 1999; Sheffield et al. 1997

Table 41. Bacterial load reduction assumptions for livestock.

Assumptions	
Number of operations in the watershed	816
Head of cattle per operation	32.56
Fecal coliform production rate for cattle	8.55×10^9 colony forming units (cfu) per animal unit per day (Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)
Conservation practice effectiveness rate	62.8%
Proximity factor	25%

Potential bacterial load reductions for livestock management measures were calculated based on the assumed average number of cattle per operation, average fecal coliform production rates, standard conversions, conservation practice effectiveness, and proximity factor of practice to water body. The proximity factor estimates the effectiveness of a practice to prevent bacteria from entering surface water based on its proximity to a stream. Practices located closer to a stream are assumed to have a higher potential load reduction. Because actual practices and locations are unknown, a proximity factor of 25% was used. This value assumes that 25% of operations in the watershed will be implementing BMPs that are close enough to the waterbodies to contribute to a potential load reduction.

Using the above assumptions, the potential annual load reduction was estimated by:

$$LR_{cattle} = N_{plans} \times \frac{AnU}{Plan} \times FC_{cattle} \times Conversion \times 365\frac{days}{year} \times Efficacy \times Proximaty\ Factor$$

Where:

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

N_{plans} = Number of WQMPs and conservation plans, 100 are proposed in this WPP

AnU/Plan = Animal Units of cattle (~1,000 lbs of cattle) per management plan, 32.56

FC_{cattle} = Fecal coliform loading rate of cattle

Conversion = Estimated fecal coliform to *E. coli* conversion rate

Efficacy = Median BMP efficacy value

Proximity Factor = Percentage based factor based on the assumed proximity of the management measure to the water body

The WPP recommends implementing 100 WQMPs or CPs across the entire Bois d'Arc Lake watershed, resulting in a total potential reduction of 1.01×10^{15} cfu *E. coli* per year. Additionally, nutrient reductions can be anticipated with each WQMP or CP. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions ranging from 733 to 983 pounds of nitrogen and 276 to 511 pounds of phosphorus per WQMP or CP depending on presumed size and type of agricultural operation (Schramm et al. 2017; Schramm et al. 2019).

Feral Hog Load Reductions

Loading reductions for feral hogs assume that existing feral hog populations can be reduced and maintained by a certain amount on an annual basis. Removal of a feral hog from the watershed is assumed to also completely remove the potential bacterial load generated by that feral hog. Therefore, the total potential load reduction is calculated as the population reduction in feral hogs achieved in the watershed. Based on GIS analysis, 5,276 feral hogs were estimated to currently exist across the Bois d'Arc Lake watershed (see Appendix A for details). The established goal is to reduce and maintain the feral hog population 15% below current population estimates, thus resulting in a 15% reduction in potential loading that is attributable to feral hogs. The 15% reduction of the current population takes into consideration a necessary 66% reduction in the annual population prevent it from increasing over time (Timmons et al. 2012). Assumptions used in bacterial load reduction calculations are provided in Table 42.

Table 42. Bacterial load reduction assumptions for livestock.

Assumptions	
Number of feral hogs removed to achieve a 15% reduction from the current population	792
Animal unit conversion factor	0.125 (Wagner and Moench 2009)
Fecal coliform production rate for feral hogs	1.21×10^9 colony forming units (cfu) per animal unit per day (Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)
Proximity factor	25%

Using the above assumptions, the potential annual load reduction was estimated by:

$$LR_{fh} = N_{fh} \times AnUC \times FC_{fh} \times Conversion \times 365\frac{days}{year} \times Proximaty\ Factor$$

Where:

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

N_{fh} = Number of feral hogs removed

AnUC = Animal Unit conversion factor (~1,000 lbs of cattle)

FC_{fh} = Fecal coliform loading rate of feral hogs

Conversion = Estimated fecal coliform to *E. coli* conversion rate

Proximity Factor = Percentage based factor based on the assumed proximity of the management measure to the water body

The estimated potential annual loading across the Bois d'Arc Lake watershed based on reducing the current population by 15% and maintaining that reduction (792 feral hogs) is 6.89×10^{12} cfu *E. coli* annually. Additionally, nutrient reductions can be anticipated for each feral hog removed. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions 6 pounds of nitrogen and 2 pounds of phosphorus per hog removed (Schramm et al. 2017; Schramm et al. 2019).

Dog Load Reductions

Potential load reductions for pet waste depend on the number of pets that contribute loading and the amount of pet waste that is picked up and disposed of properly. Assessing the number of dog owners who do not pick up waste or who would change behavior based on education or availability of pet waste stations is inherently difficult. It is estimated that 12% of dogs in the watershed will have their waste picked up and disposed of (Swan 1999). Assumptions used in bacterial load reduction calculations are provided in Table 43.

Table 43. Bacterial load reduction assumptions for dogs.

Assumptions	
Number of dogs in the watershed	5,174
Percent of dogs managed	12% (Swan 1999)
Fecal coliform production rate for dogs	5.0×10^9 colony forming units (cfu) per animal per day (EPA 2001)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)
Practice efficiency	75%
Proximity factor	5%

Using the above assumptions, the potential annual load reduction was estimated by:

$$LR_d = N_d \times DM\% \times FC_d \times Conversion \times 365\frac{days}{year} \times Practice\ efficiency \times Proximity\ Factor$$

Where:

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

N_d = Number of dogs

DM% = Percent of dogs managed

FC_d = Fecal coliform loading rate of dogs

Conversion = Estimated fecal coliform to *E. coli* conversion rate

Practice Efficiency = Estimated efficiency of proper dog waste disposal

Proximity Factor = Percentage based factor based on the assumed proximity of the management measure to the water body

The estimated potential load reduction attributed to this management measure in Bois d'Arc Lake watershed is 2.68×10^{13} cfu *E. coli* annually. Additionally, nutrient reductions can be anticipated for every additional dog managed. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions between 0.8 and 1.0 pounds of nitrogen and 0.2 pounds of phosphorus per additional dog managed (Schramm et al. 2017; Schramm et al. 2019).

OSSF Load Reductions

OSSFs are common in the Bois d'Arc Lake watershed, with an estimated 2,932 OSSFs. OSSF failures are factors of system age, soil suitability, system design, and maintenance. For this area of the state, a 15% failure rate is typically assumed (Reed, Stowe, & Yanke 2001). Stakeholders recommend repair and/or replacement of as many as 300 systems if they are identified as failing because they pose a greater risk to human health than some of the other potential pollutant sources. Replacing or repairing 30 failing systems within close proximity of creeks will meet target load reductions. Assumptions used in bacterial load reduction calculations are provided in Table 44.

Table 44. Bacterial load reduction assumptions for on-site sewage facilities (OSSFs).

Assumptions	
Number of OSSFs repaired/replaced	30
Average number of people per household	2.49 (USCB 2010)
Assumed sewage production rate	70 gallons per person per day (Borel et al. 2015)
Fecal coliform concentration in sewage	1.0 x 10^6 colony forming units (cfu)/100 milliliters (EPA 2001)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Using the above assumptions, the potential annual load reduction was estimated by:

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

Where:

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

N_{ossf} = Number of OSSFs repaired/replaced

N_{hh} = Average number of people per household

Production = Assumed sewage production rate

FC_s = Fecal coliform concentration in sewage

Conversion = Estimated fecal coliform to *E. coli* conversion rate

In the Bois d'Arc Creek watershed, it is assumed that at least 30 OSSFs will be repaired or replaced. Replacing these OSSFs results in a potential reduction of 4.30×10^{15} cfu *E. coli* annually. Additionally, nutrient reductions can be anticipated for every OSSF replaced. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions between 11.6 and 20.5 pounds of nitrogen and 2.9 and 4.8 pounds of phosphorus per additional OSSF repaired or replaced (Schramm et al. 2017; Schramm et al. 2019).

Appendix B. 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. 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 *Escherichia coli* loads in unfenced streams of the Georgia Piedmont, USA. Journal of Environmental Quality. 34 (6): 2293-2300. https://doi.org/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 (U.S. Environmental Protection Agency). 2001. Protocol for Developing Pathogen TMDLs: Source Assessment, Washington, DC: EPA Office of Water. 841-R-00-002. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt.

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 (12): 5522-5531. https://doi.org/10.1128/aem.65.12.5522-5531.1999.

Line, D. E. 2002. Changes in land use/management and water quality in the Long Creek watershed. Journal of the American Water Resource Association. 38 (6): 1691-1701. https://doi.org/10.1111/j.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://doi.org/10.13031/2013.12979.

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: North Carolina State University Water Quality Group, Biological and Agricultural Engineering Department, North Carolina 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.

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: Texas Commission on Environmental Quality. http://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. College Station, TX: Texas Water Resources Institute. TR-500. https://twri.tamu.edu/publications/technical-reports/2017-technical-reports/tr-500/.

Schramm, M., Ruff, S., Jain, S., Berthold, A., Mohandass, U. 2019. Carancahua Bay Watershed Protection Plan. College Station, TX: Texas Water Resources Institute. TR-514. 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://doi.org/10.13031/2013.21318.

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.

Timmons, J. B., Higginbotham, B., Lopez, R., Cathey, J. C., Mellish, J., Griffin, J., Sumrall, A., 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.

USCB (U.S. Census Bureau). 2010. Explore Census Data. https://data.census.gov/cedsci/.

Wagner, K. L., 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.

Appendix C: Load Duration Curve Development

EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA 2008) describes the nine elements critical for achieving improvements in water quality that must by sufficiently included in a WPP for it to be eligible for implementation funding through CWA 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 (Table 45).

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	Bois d'Arc Creek and Honey Grove Creek
Assessment units	0202A_02, 0202A_03, 0202L_01
Impairments addressed	Bacteria
Concerns addressed	Nitrate, total phosphorus, and chlorophyll-a

Element	Report Section(s) and Page Number(s)
Element A: Identification of causes and sources of impairment	
1. Sources identified, described, and mapped	Chapter 4 pp. 28-33, Appendix A
2. Subwatershed sources	Chapter 5 pp. 46-52
3. Data sources are accurate and verifiable	Chapter 4 pp. 30-33, Appendix A
4. Data gaps identified	Appendix A
Element B: Expected load reductions	
1. Load reductions achieve environmental goal	Chapter 5, Appendix B
2. Load reductions linked to sources	Chapter 6 Table 31
3. Model complexity is appropriate	Appendix B
4. Basis of effectiveness estimates explained	Chapter 6 tables 20-29, Appendix B
5. Methods and data cited and verifiable	Appendix B
Element C: Proposed management measures	
1. Specific management measures are identified	Chapter 6 pp. 54-64
2. Priority areas	Chapter 6 Tables 20-29
3. Measure selection rationale documented	Chapter 6 pp. 54-64
4. Technically sound	Chapter 6
Element D: Technical and financial assistance needs	
1. Estimate of technical assistance	Chapter 8 pp. 75-79
2. Estimate of financial assistance	Chapter 8 pp. 77-79
Element E: Information, education, and public participation component	
1. Public education/information	Chapter 7 pp. 71-73
2. All relevant stakeholders are identified in outreach process	Chapter 2
3. Stakeholder outreach	Chapter 7
4. Public participation in plan development	Chapter 2
5. Emphasis on achieving water quality standards	Chapter 2
6. Operation and maintenance of best management practices	Chapter 6 Table 30

Element	Report Section(s) and Page Number(s)
Element F: Implementation schedule	
1. Includes completion dates	Chapter 6 Table 30
2. Schedule as appropriate	Chapter 6 Table 30

Element	Report Section(s) and Page Number(s)
Element G: Milestones	
1. Milestones are measurable and attainable	Chapter 6 Table 30, Chapter 9
2. Milestones include completion dates	Chapter 6 Table 30, Chapter 9
3. Progress evaluation and course correction	Chapter 6 Table 30, Chapter 9
4. Milestones linked to schedule	Chapter 6 Table 30, Chapter 9
Element H: Load reduction evaluation criteria	
1. Criteria are measurable and quantifiable	Chapter 6 Tables 20-29
2. Criteria measure progress toward load reduction goal	Chapter 6 Tables 20-29
3. Data and models identified	Chapter 6 Tables 20-29, Appendix B
4. Target achievement dates for reduction	Chapter 9
5. Review of progress towards goals	Chapter 9 pp. 81
6. Criteria for revision	Chapter 9 pp. 81
7. Adaptive management	Chapter 9 p. 81-82
Element I: Monitoring component	
1. Description of how monitoring is used to evaluate implementation	Chapter 9 pp. 81
2. Monitoring measures evaluation criteria	Chapter 9 pp. 81
3. Routine reporting of progress methods	Chapter 9 pp. 81
4. Parameters are appropriate	Chapter 9 pp. 81
5. Number of sites is adequate	Chapter 9 pp. 81
6. Frequency of sampling is adequate	Chapter 9 pp. 81
7. Monitoring tied to quality assurance project plan	Chapter 9 pp. 81
8. Can link implementation to improved water quality	Chapter 9 pp. 81

Appendix C. References

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Washington, DC: EPA 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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