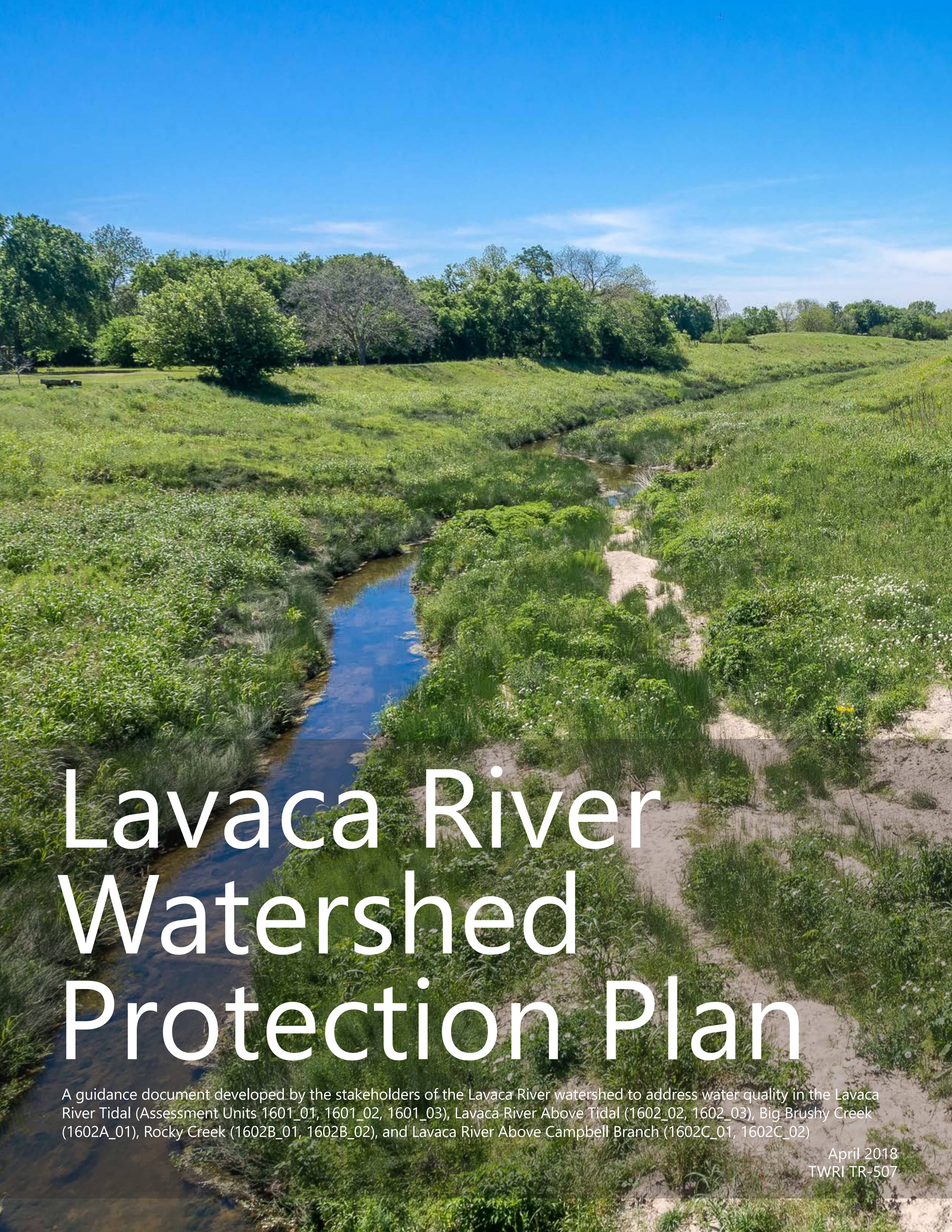


Lavaca River Watershed Protection Plan

A guidance document developed by the stakeholders of the Lavaca River watershed to address water quality in the Lavaca River Tidal (Assessment Units 1601_01, 1601_02, 1601_03), Lavaca River Above Tidal (1602_02, 1602_03), Big Brushy Creek (1602A_01), Rocky Creek (1602B_01, 1602B_02), and Lavaca River Above Campbell Branch (1602C_01, 1602C_02)

April 2018
TWRI TR-507

Lavaca River Watershed Protection Plan

A guidance document developed by the stakeholders of the
Lavaca River watershed to address water quality in the
Lavaca River Tidal (Assessment Units 1601_01, 1601_02, 1601_03),
Lavaca River Above Tidal (1602_02, 1602_03),
Big Brushy Creek (1602A_01), Rocky Creek (1602B_01, 1602B_02), and
Lavaca River Above Campbell Branch (1602C_01, 1602C_02)

Authored and prepared by:
Michael Schramm, Allen Berthold, Clare Entwistle and Kirby Peddicord
Texas Water Resources Institute

Texas Water Resources Institute Technical Report – 507
April 2018

College Station, Texas

Funding support for this project provided by the Texas Commission on Environmental Quality.

Cover photo: Lavaca River in Hallettsville, TX, by Michael Schramm, TWRI

Acknowledgments

The Lavaca River Watershed Protection Plan (WPP) presents the strategy developed by stakeholders of the Lavaca River watershed to restore water quality. Stakeholders dedicated considerable time and effort in discussing the watershed, influences on water quality and potential methods to address water quality concerns, and selecting appropriate strategies to improve water quality. The ultimate success of the Lavaca River WPP achieving its goals depends heavily on the current and continued support from these individuals and agencies.

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

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

- City of Yoakum Public Works
- City of Edna Public Works
- Jackson and Lavaca counties
- Jackson and Lavaca Soil and Water Conservation Districts
- Lavaca-Navidad River Authority

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

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

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Acronym	Meaning
AgriLife Extension	Texas A&M AgriLife Extension Service
AU	Assessment Units
AnU	Animal Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
cfu	Colony Forming Unit
cfs	Cubic Feet per Second
CHOMP	County Hog Out Management Program
CIG	Conservation Innovation Grants
CMP	Coastal Management Program
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DO	Dissolved Oxygen
ECHO	Enforcement and Compliance History Online
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FDC	Flow Duration Curve
FSA	Farm Service Agency
ft	feet
GIS	Geographic Information System
gal	Gallon
HSG	Hydrologic Soil Groups
I&I	Inflow and Infiltration
in	Inch
L	Liter
LDC	Load Duration Curve
LNRA	Lavaca-Navidad River Authority
MGD	Million Gallons per Day
mL	Milliliter
MS4	Municipal Separate Storm Sewer System
NASS	National Agricultural Statistics Service
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NRI	Natural Resources Institute
OSSF	On-Site Sewage Facility
RCPP	Regional Conservation Partnership Program
RMU	Resource Management Unit
RUAA	Recreational Use Attainability Assessment
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Projects
SSO	Sanitary Sewer Overflow
SWCD	Soil and Water Conservation District
SWQM	Surface Water Quality Monitoring Program
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TDS	Total Dissolved Solids
TGLO	Texas General Land Office
TPDES	Texas Pollutant Discharge Elimination Systems
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TWON	Texas Well Owners Network
UAA	Use Attainability Assessment
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility
yr	Year

Executive Summary

A watershed is an area of land that drains to a common water body. John Wesley Powell, early scientist and explorer of the American West, described a watershed as a bounded hydrologic system in which all living things were inextricably linked. Water follows natural boundaries that influence it as it simultaneously influences the landscapes it flows over and through. Both natural and anthropogenic processes that occur within watersheds influence both the quality and quantity of water.

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

Problem Statement

Water quality monitoring conducted by the Texas Commission on Environmental Quality (TCEQ) indicated that sections of the Lavaca River and Rocky Creek exceeded water quality standards for primary contact recreation. The cause of this impairment is excessive *Escherichia coli (E. coli)* bacteria and depressed dissolved oxygen (DO). The Lavaca River was first identified as impaired in the *2008 Texas Integrated Report*, also known as the 303(d) List. Rocky Creek was added in the *2014 Texas Integrated Report*.

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

Action Taken

The WPP process began in fall 2016 with a series of stakeholder meetings to discuss water quality and the WPP process. An extensive review of the watershed's land and water resources was carried out, enabling stakeholders to make decisions based on up-to-date information on watershed characteristics and land uses. Potential sources of bacteria pollution were identified and quantified based on data from the best available data sources and were then integrated into simplistic pollutant load assessment tools. The results of these tools provided information to determine the types and sources of bacteria in the watershed with the highest potential to impact water quality in addition to the sources that could be readily addressed.

Watershed Protection Plan Overview

This document is a culmination of an extensive stakeholder process to identify not only the potential sources of bacteria pollution, but also the methods that are most likely to result in reductions of bacteria loads in the Lavaca River. 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 amounts of information gathered during the development of this WPP, a better understanding of the watershed and the effectiveness of management measures will undoubtedly develop. As such, this plan is a living document that will evolve as needed through the adaptive management process.

Pollutant Reductions

According to the TCEQ *2014 Texas Integrated Report* and 303(d) List, one segment of the Lavaca River and one segment of Rocky Creek did not meet primary contact recreation water quality standards. These segments include two impaired assessment units (AUs): 1602_03 and 1602B_01. Analysis of water quality and flow data collected in both water bodies indicate bacteria load reductions of 77% (Lavaca River) and 78% (Rocky Creek) across all flow conditions are required to meet current water quality standards.

One segment of the Lavaca River above Hallettsville (1602C), includes two AUs listed as impaired due to depressed DO, 1602C_01 and 1602C_02. A change in in the water quality standard is proposed for these AUs. The proposed standards change will lower the criterion for average DO due to the intermittent flows and pools that are characteristic of the segment. Analysis of past water quality data collected in this segment indicates that this portion of the Lavaca River will meet the proposed water quality standard.

Recommended Actions

No specific management measures are proposed to directly address DO in the Lavaca River upstream of Hallettsville. However, further 24-hour monitoring is recommended to ensure sufficient data is available to assess DO and delist the segment once the new DO criterion is accepted.

No single source of bacteria in the watershed is the primary cause of the water quality impairment. A variety of sources, including livestock, wildlife, humans and stormwater, contribute *E. coli* bacteria to the river and its tributaries. Stakeholders identified seven management measures that would reduce and feasibly manage instream bacteria levels. Although the management measures listed below are directed at reducing fecal bacteria loads in the watershed, these management measures also serve to simultaneously reduce other potential pollutant loads reaching water bodies.

Livestock

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

Feral Hogs

Feral hogs not only contribute to crop and property damages, but their behavior also contributes to water quality and riparian habitat degradation. Although many property owners already work hard to remove feral hogs from their property, this WPP recommends continued efforts to remove feral hogs from the watershed. This WPP also recommends all deer feeders be fenced off to reduce the availability of food to feral hogs. Finally, delivery of feral hog management workshops will provide property owners with the knowledge and tools to maximize efforts at controlling and reducing feral hog populations.

Domestic Pets

Unmanaged pet waste, in particular dog waste, can be a significant contributor to bacteria loads in subwatersheds throughout the area. Management of pet waste depends on pet owner behavior, which might be difficult to influence. The WPP recommends installation of pet waste stations in area parks and public areas. Development and delivery of educational material targeted at area pet owners is also recommended to encourage proper management of pet waste.

OSSFs

Although most on-site sewage facilities (OSSFs), sometimes called septic systems, operate properly; failing OSSFs can result in untreated household sewage reaching the soil surface and running off into nearby water bodies. Ensuring these systems function properly and are consistently maintained is crucial for water quality and minimizing potential human health impacts. The Lavaca River WPP recommends all failing systems be repaired or replaced as needed. In some cases, owners may not have the resources to repair or replace a failing system; therefore, the WPP recommends the development of a program to facilitate and provide resources needed to repair or replace non-functioning systems. Furthermore, the plan recommends delivery of education programs and workshops that can equip homeowners with the knowledge of how to properly maintain their OSSFs.

Urban Stormwater

Stormwater from urban and impervious surface runoff is likely a small contributor to bacteria loads in this largely rural watershed. However, opportunities exist to address stormwater loads in the watershed in addition to increasing awareness in areas of denser populations. This plan recommends working with city officials and departments within the watershed to identify potential stormwater best management practice (BMP) demonstration projects and subsequently apply for sources of funding to implement those projects. An education and outreach component is included through the delivery of existing education and workshop programs to area residents.

Sanitary Sewer Overflows and Unauthorized Discharges

Sanitary sewer overflows (SSOs) and unauthorized discharges occur when excess water enters the sewage collection system, resulting in an overload of system capacity. Overloaded systems will discharge untreated or insufficiently treated waste. Although infrequent, these discharges can contribute to bacteria loading, in particular during intense rain events. Inflow and infiltration (I&I) is stormwater that enters the sewage collection systems through faulty sewer pipes, connections, cleanouts and manholes. I&I is a major contributor to SSO and unauthorized discharges. The plan recommends identifying and repairing infrastructure contributing to excessive I&I, developing programs to assist homeowners with replacement of sewage lines, and providing education to homeowners about sewage systems and I&I.

Illicit Dumping

Illicit and illegal dumping was a concern raised by stakeholders. Given the illegal 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 (including increased bacteria). This WPP recommends the development and delivery of educational materials on proper disposal of waste and animal carcasses. Further work on identifying opportunities that can reduce illicit dumping through engagement with law enforcement and game wardens is also needed.

Education and Outreach

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

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

Tracking Progress and Measuring Success

Progress toward achieving success will be measured against quantitative milestones set forth for management measure implementation. Because the overall goal of this WPP is to restore water quality in the Lavaca River and Rocky Creek, progress toward this goal will also be tracked through water quality data collected at two TCEQ water quality monitoring stations. Interim achievable targets have also been set to measure progress over the course of the project period and determine if adaptive management should occur.

Goals of the Plan

The primary goal of the Lavaca River WPP is to restore water quality in the Lavaca River and Rocky Creek to the water quality standards set by the State of Texas through the long-term conservation and stewardship of the watershed's resources.

This plan establishes a 10-year implementation period to achieve this goal. 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). This plan also establishes a number of interim bacteria reductions and programmatic milestones to track progress over the 10-year period.

This plan will also help meet conditions for the state's Coastal Nonpoint Source Pollution Control Program as set forth in Section 6217 of the Coastal Zone Management Act. Since portions of the Lavaca River watershed fall within the Coastal Zone Boundary, the plan will also work to reduce runoff pollutant concentrations and volumes from entering tidal portions of the river and coastal zone.

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

A watershed is composed of an area of land that drains to a common body of water, such as a stream, river, wetland or ocean. All of the land surfaces that surround the water body where runoff drains are considered part of the watershed. Watersheds can be very small features that drain only a few square miles while larger watersheds can encompass numerous smaller watersheds and can drain large portions of states, such as the Colorado River watershed that includes 39,900 square miles of Texas and New Mexico.

The Lavaca River watershed is approximately 909 square miles and is composed of numerous smaller watersheds, such as Rocky Creek, Big Brushy Creek and Dry Creek (Figure 1). The Lavaca River watershed is then part of the larger Matagorda Bay watershed that includes the Navidad River, Tres Palacios River and a number of other creeks and rivers.

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 that 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 (NPS) 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

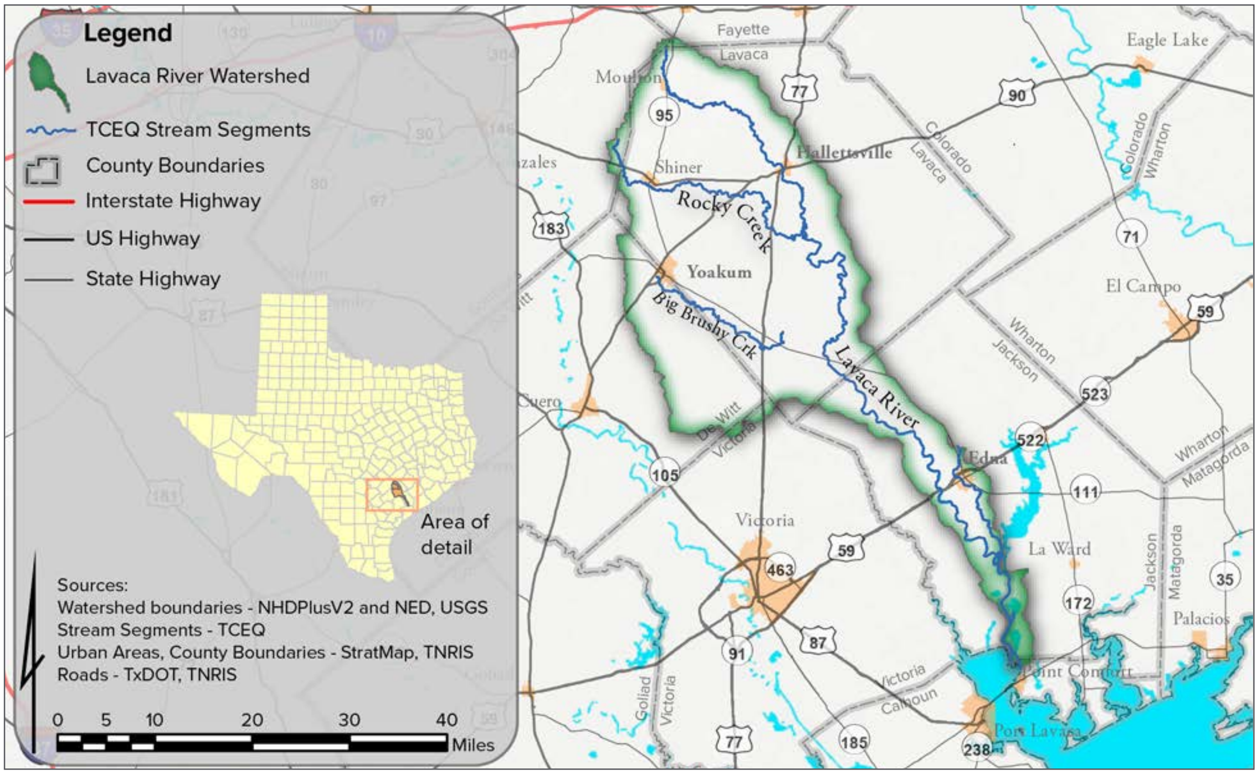


Figure 1. Lavaca River watershed.

pick up natural and anthropogenic pollutants. The concentrations and types of pollutants that are found in a water body will be indicators of both the water quality and suitable uses for the water, 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 NPS.

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" (USEPA 2008). The watershed approach requires engaging stakeholders to make management decisions that are backed by sound science (USEPA 2008). One critical aspect of the watershed approach is that it focuses on hydrologic boundaries rather than political boundaries in order 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 the watershed approach 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 non-governmental organizations.
The Lavaca River WPP follows EPA's nine key elements, which are designed to provide guidance for the development of an effective WPP (USEPA 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):

1. Identification of causes and sources of impairment
2. Expected load reductions from management strategies
3. Proposed management measures
4. Technical and financial assistance needed to implement management measures

5. Information, education and public participation needed to support implementation
6. Schedule for implementing management measures
7. Milestones for progress of WPP implementation
8. Criteria for determining successes of WPP implementation
9. Water quality monitoring

Adaptive Management

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

As management measures recommended in a WPP are put into action, water quality and other measures of success will be monitored to make adjustments 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
Watershed Description

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

Lavaca River and Watershed Description

The Lavaca River watershed is a portion of the larger Lavaca-Navidad River Basin, which is a part of the larger Matagorda Bay watershed located centrally along the Texas Gulf Coast. The Lavaca River watershed is bounded to the west by the Guadalupe River watershed and to the east by the Navidad River watershed. According to the National Hydrography Dataset (NHD), there are approximately 802 miles of perennial and intermittent streams and rivers in the Lavaca River watershed. These water bodies capture runoff from approximately 909 square miles of mostly agricultural land and captures portions of Fayette, Gonzales, Lavaca, DeWitt, Victoria and Jackson counties. However, the majority of the watershed land area lies in Lavaca and Jackson counties. The towns of Moulton, Hallettsville, Shiner, Yoakum and Edna are located within the watershed.

The Lavaca River begins flowing approximately 3.4 miles upstream of State Highway 95 near the intersection of Lavaca, Gonzales and Fayette counties (Figure 2). From there, the river flows generally southeast toward Hallettsville and joins Campbell Branch. The Lavaca River then flows another 26 miles southeast into Jackson County past US Highway 59, meeting with and receiving flows from Rocky, Big Brushy and Clarks creeks along the way. From this point downstream, the Lavaca River is considered a tidal river that is influenced by tides and salinity from Lavaca Bay. The tidal section of the river is approximately 23 miles in length and receives flows from Dry Creek and the Navidad River. Although the Navidad River joins the Lavaca River near

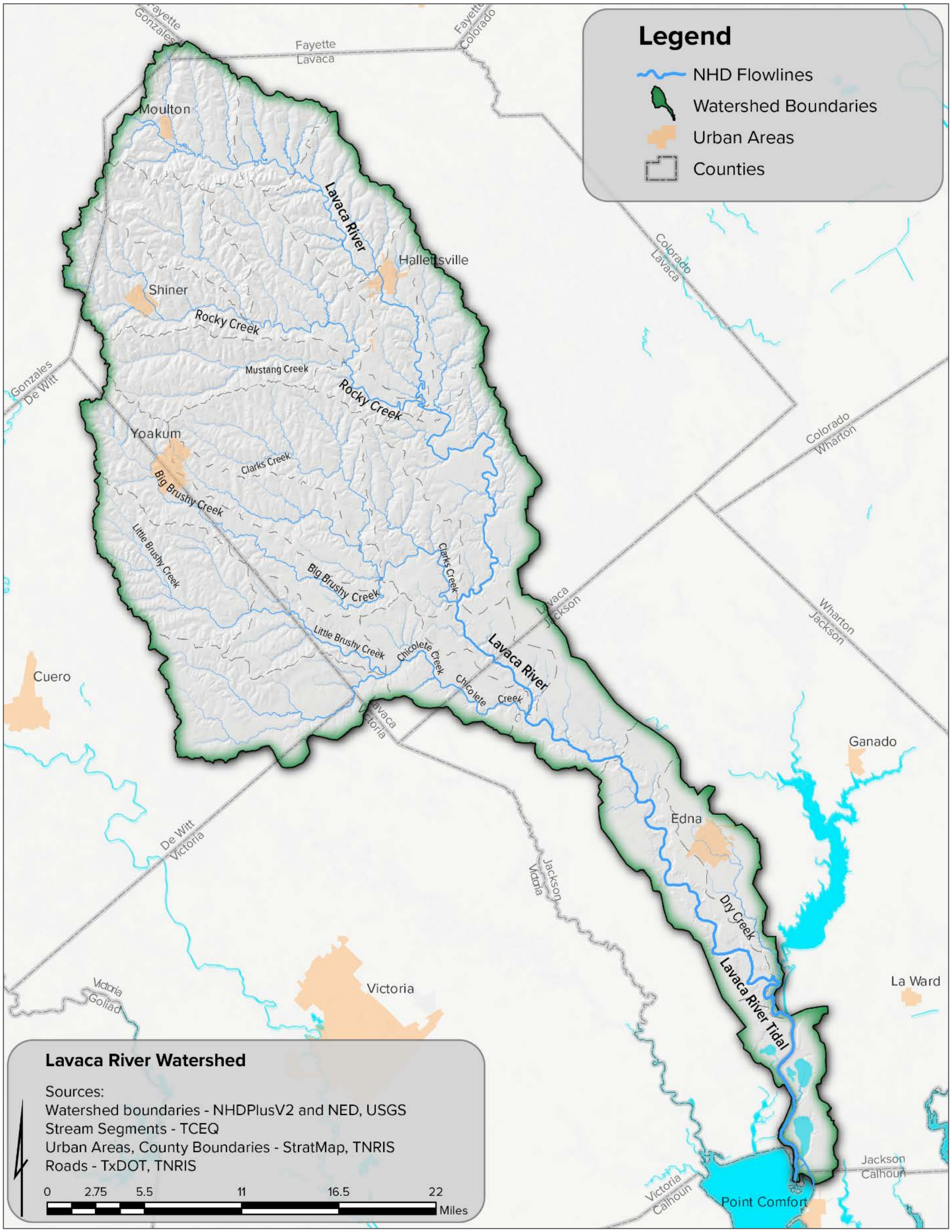


Figure 2. Water bodies of the Lavaca River watershed.

Lavaca Bay, for the purposes of this WPP, the Navidad River is considered a separate watershed and is not included in the WPP. The tidal section of the Lavaca River then drains into Lavaca Bay, a portion of the Matagorda Bay system.

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 limit the types of development and activities that can occur in certain areas.

The Lavaca River watershed can be characterized as a predominantly flat coastal plain watershed. Much of the watershed has poor to moderate drainage. The watershed has a peak elevation of approximately 590 feet (ft) and an average mean elevation of 230 ft (USGS 2013). There is an average of 1-degree slope across the watershed, with more intense slopes restricted to areas such as cut banks near the river system (Figure 3).

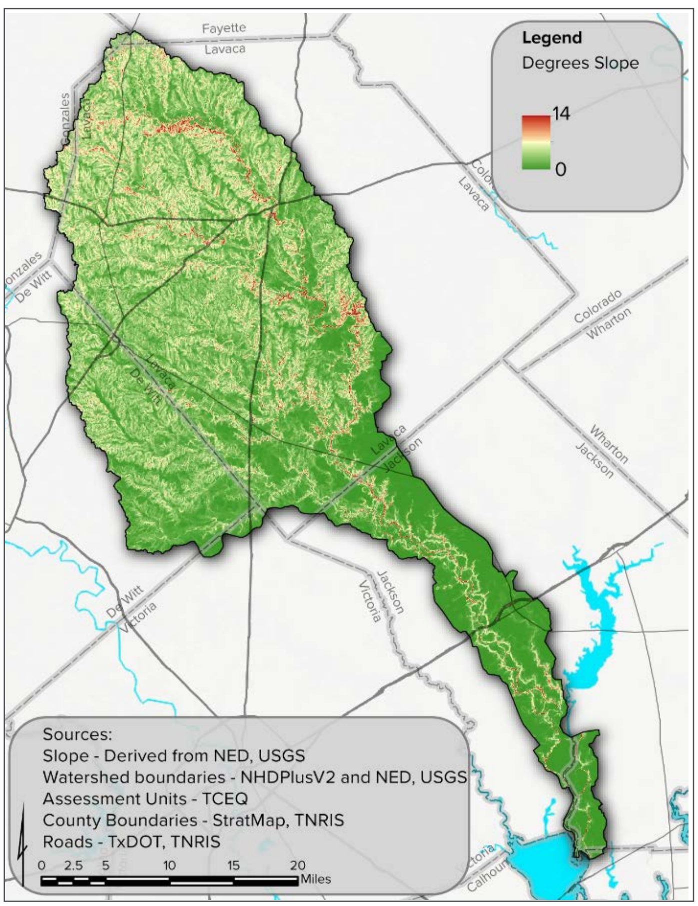


Figure 3. Degrees slope across the Lavaca River watershed.

The soils in the Lavaca River watershed are mostly Alfisols, a relatively fertile soil that is well-suited for agriculture and silviculture (Figure 4). A mix of Vertisols and Mollisols are more common near the northern reaches of the watershed. Vertisols are clay-rich and exhibit a shrinking and swelling action with changes in moisture that can lead to wide cracks forming during dry periods. Mollisols are characterized by a dark surface layer indicative of high amounts of organic material and are very fertile and productive for agricultural uses.

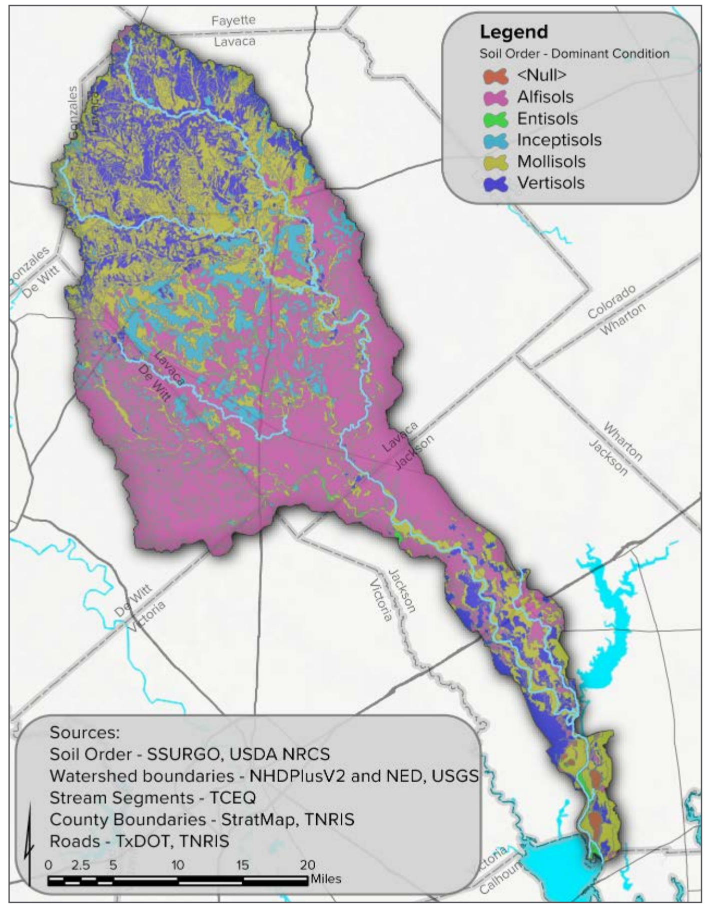


Figure 4. Watershed soil orders.

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 (therefore 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 are defined as having moderate and slow infiltration rates, respectively. The majority of soils in the Lavaca River watershed have an HSG of D (65% of the watershed) or C (12%), with a belt of Group A (14%) soils running across the midsection of the watershed (Figure 5) (USDA 2017).

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) provides suitability ratings for septic tank absorption fields based on soil properties, depth to bedrock or groundwater, hydraulic conductivity and other properties that may affect the absorption of on-site sewage facility effluent, installation and maintenance. A "Not Limited" rating indicates soils with features favorable to on-site sewage facility (OSSF) use. "Somewhat Limited" indicates soils that are moderately favorable, with limitations that can be overcome by design, planning and installation. "Very Limited" indicates soils that are very unfavorable for OSSF use, with expectation of poor performance and high amounts of maintenance. The majority of the soils in the watershed are rated "Very Limited" for OSSF use, with small areas rated "Somewhat Limited" (Figure 6) (USDA 2017).

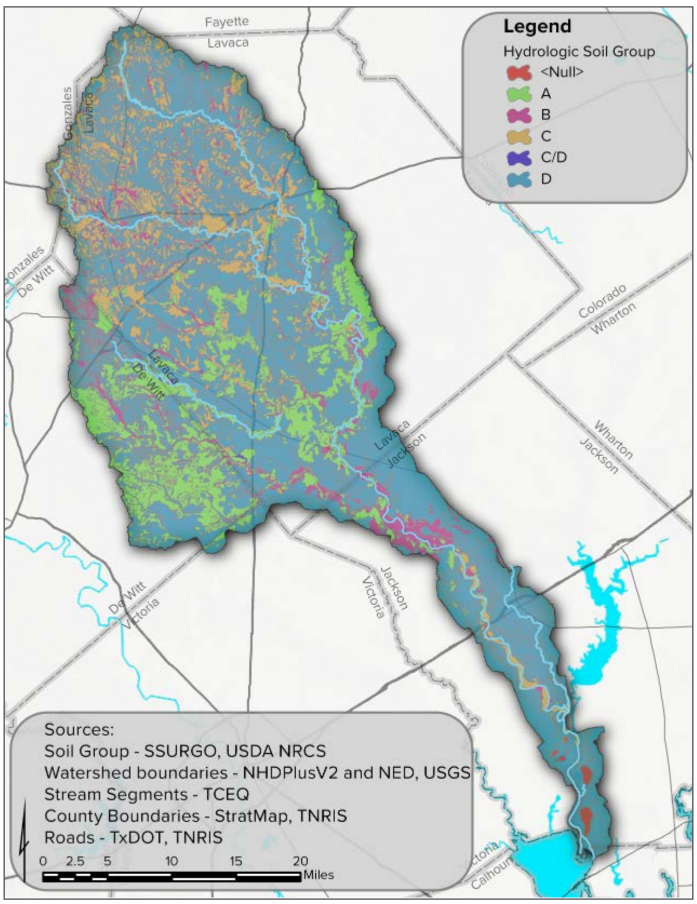


Figure 5. Hydrologic soil groups.

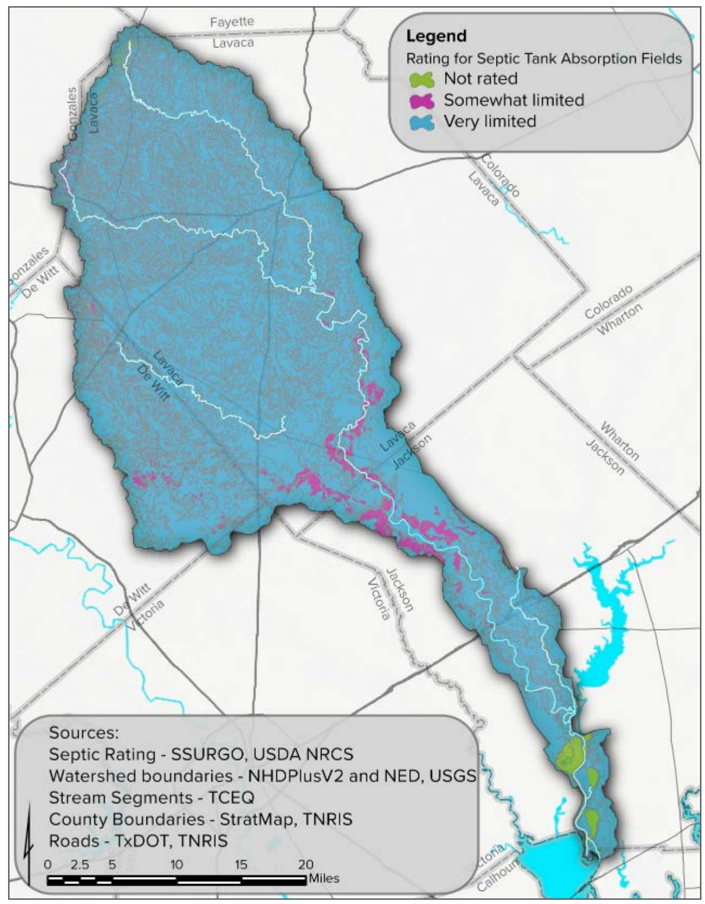


Figure 6. OSSF absorption field ratings.

Land Use and Land Management

The Lavaca River watershed is largely rural, with a landscape dominated by rangelands, pasture and hayfields, with limited row crop production. Urban development has been restricted to the few small towns scattered in the watershed. Based on 2011 National Land Cover Database (NLCD) data, approximately 62% of the land cover in the watershed is hay, pasture, brush or grassland (Figure 7). Only 6% of the watershed is classified as urban development. Finally, approximately 4.5% of the watershed is classified as cultivated cropland.

In Jackson County, common crops are corn, cotton, hay and rice (USDA 2014). In DeWitt and Lavaca counties, significant amounts of acreage are devoted to hay rather than other commodity crops. Fayette, Gonzales and Victoria counties make up very small portions of the watershed and their overall crop production numbers may not be reflective of the land uses contained in the watershed (Figure 8). The average farm size in the watershed is approximately 285 acres based on a weighted average of USDA National Agricultural Statistics Service (NASS) farm operation data (USDA 2014).

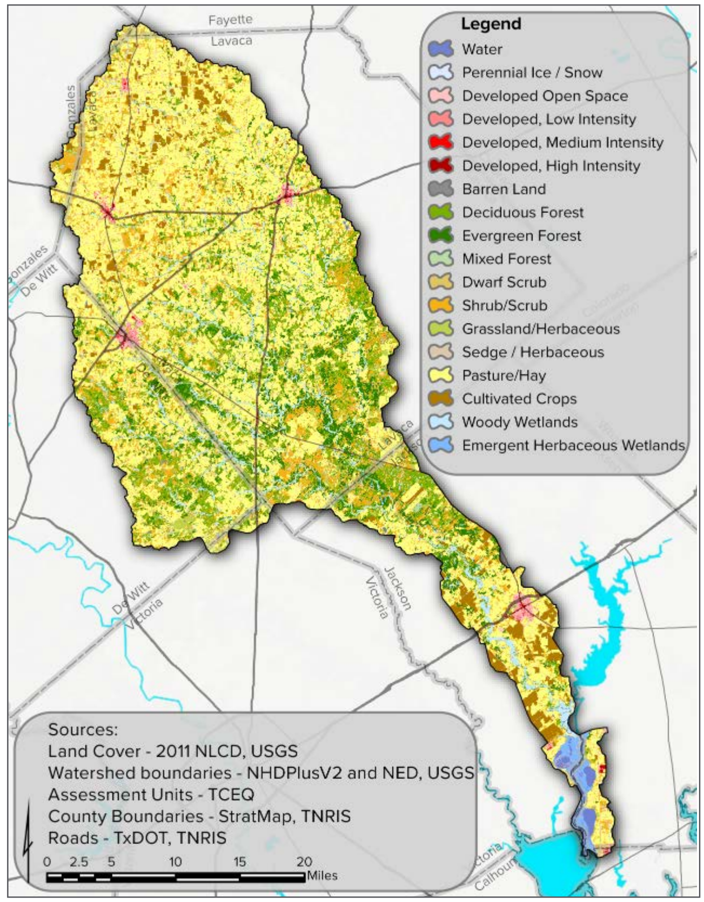


Figure 7. Land cover in the Lavaca River watershed.

Climate

Due to its location along the Central Gulf Coast, the watershed's climate is characterized by warm summer temperatures and moderate winter low temperatures. The Victoria Regional Airport, located adjacent to the watershed, reports

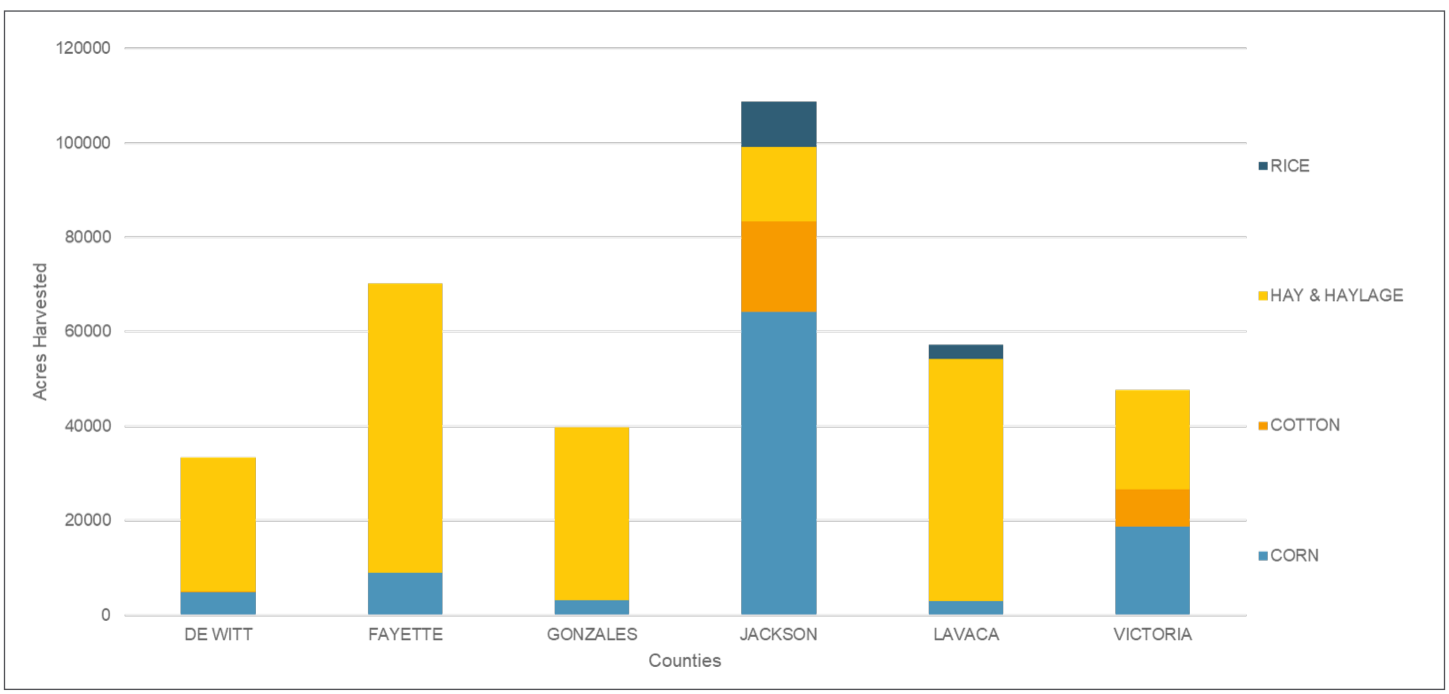


Figure 8. Acres harvested by crop type in 2012 (only includes major crops, not all crop types) (USDA 2014).

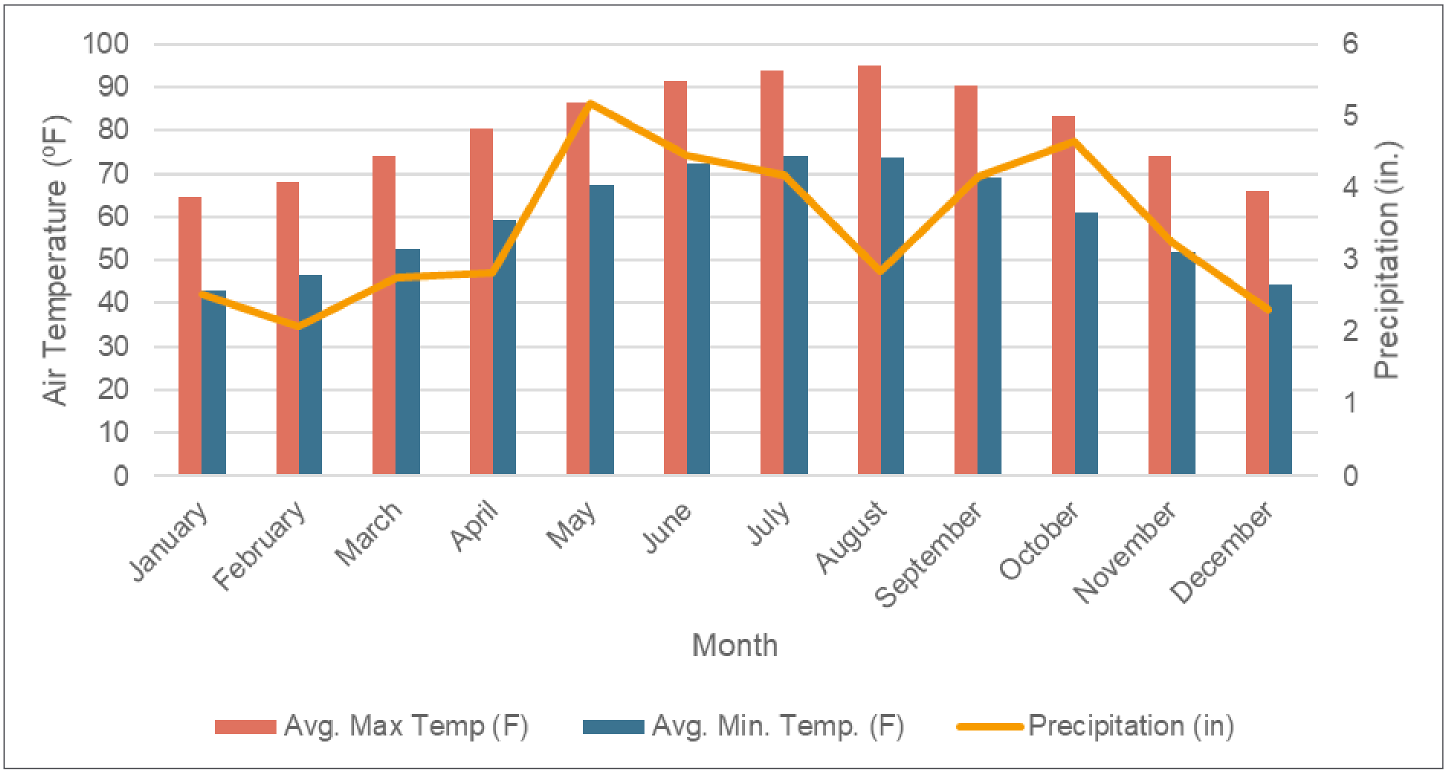


Figure 9. 10-year average watershed temperature and precipitation.

average peak daily highs of 94.5°F occurring in August (Figure 9). Meanwhile, average daily lows reach the lowest temperatures in January at 45°F.

Precipitation peaks in May, with an average of 5.19 inches (in) of rainfall. February sees the lowest average rainfall totals with 2.08 in. Average annual precipitation is around 41 in for the watershed (PRISM 2012). Based on this historic data, steady amounts of precipitation can be expected throughout the year, with slightly drier periods occurring in August and mid-winter.

Demographics

As of 2010, the Lavaca River watershed population was approximately 30,156, with a population density of 33 people/square mile (USCB 2010). Population is most dense within and near the towns of Moulton, Hallettsville, Shiner, Yoakum and Edna (Figure 10). Population projections by the Office of the State Demographer and the Texas Water Development Board (TWDB) for cities in the watershed are provided in Table 1 (TWDB 2016). From 2020 to 2070 the population of Lavaca County is expected to remain stable, Jackson County and DeWitt County are expected to increase by approximately 12% (population increases for Gonzales, Calhoun and Fayette counties are not included due to the very small land area included within the watershed).

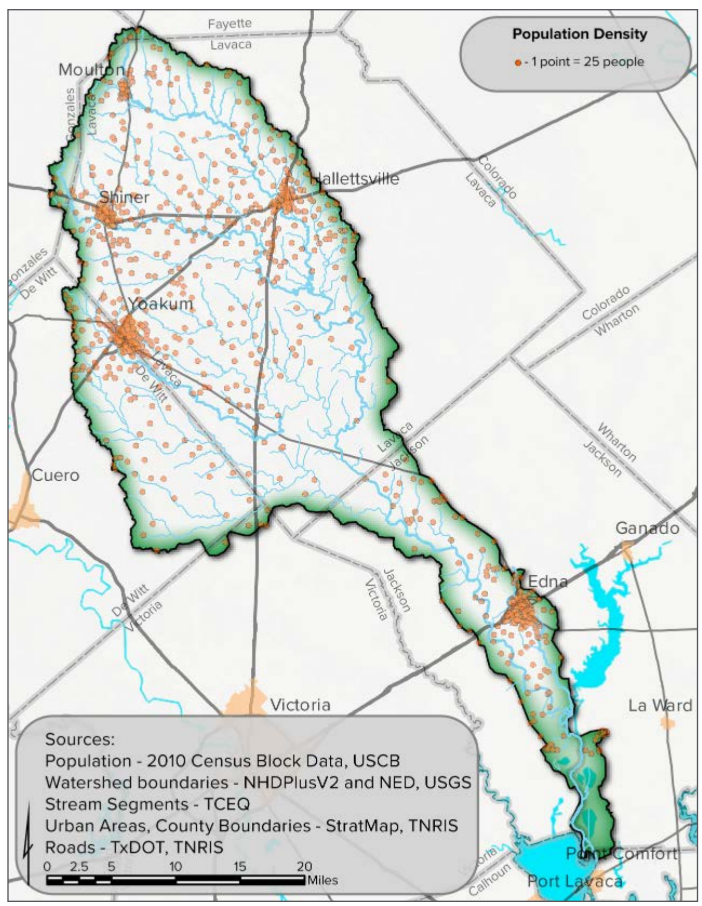


Figure 10. Population density in the Lavaca River watershed (each dot represents 25 people).

Table 1. City population projections (TWDB 2016).

City	Population by Year					
	2020	2030	2040	2050	2060	2070
Edna	5,707	5,907	5,992	6,062	6,106	6,134
Hallettsville	2,550	2,550	2,550	2,550	2,550	2,550
Moulton	886	886	886	886	886	886
Shiner	2,070	2,070	2,070	2,070	2,070	2,070
Yoakum	5,897	5,972	6,008	6,042	6,042	6,080

Table 2. Estimated educational attainment and primary language by county in the Lavaca River watershed in 2014 (USCB 2014).

County	High School Diploma (%)	College Degree (%)	English Primary (%)	Non-English Primary (%)
Lavaca	81.1	15.3	81.9	18.1
Jackson	81.5	16.5	78.6	21.4
DeWitt	76.2	13.3	82.5	17.5
Gonzales	71.1	14.7	61.6	38.4
Victoria	81.1	16.8	75.5	24.5
Calhoun	79.0	15.8	73.6	26.4

The majority of the population in the watershed have at least a high school education, and approximately 13-16% of the population have a college degree (Table 2; USCB 2014). The majority of residents speak English as a primary language. However, between 17% and 38% of the population do not speak English as a primary language. These demographics are highlighted because understanding unique and differing needs of target audiences within the watershed is critical to successful stakeholder engagement for WPP development and subsequent implementation.

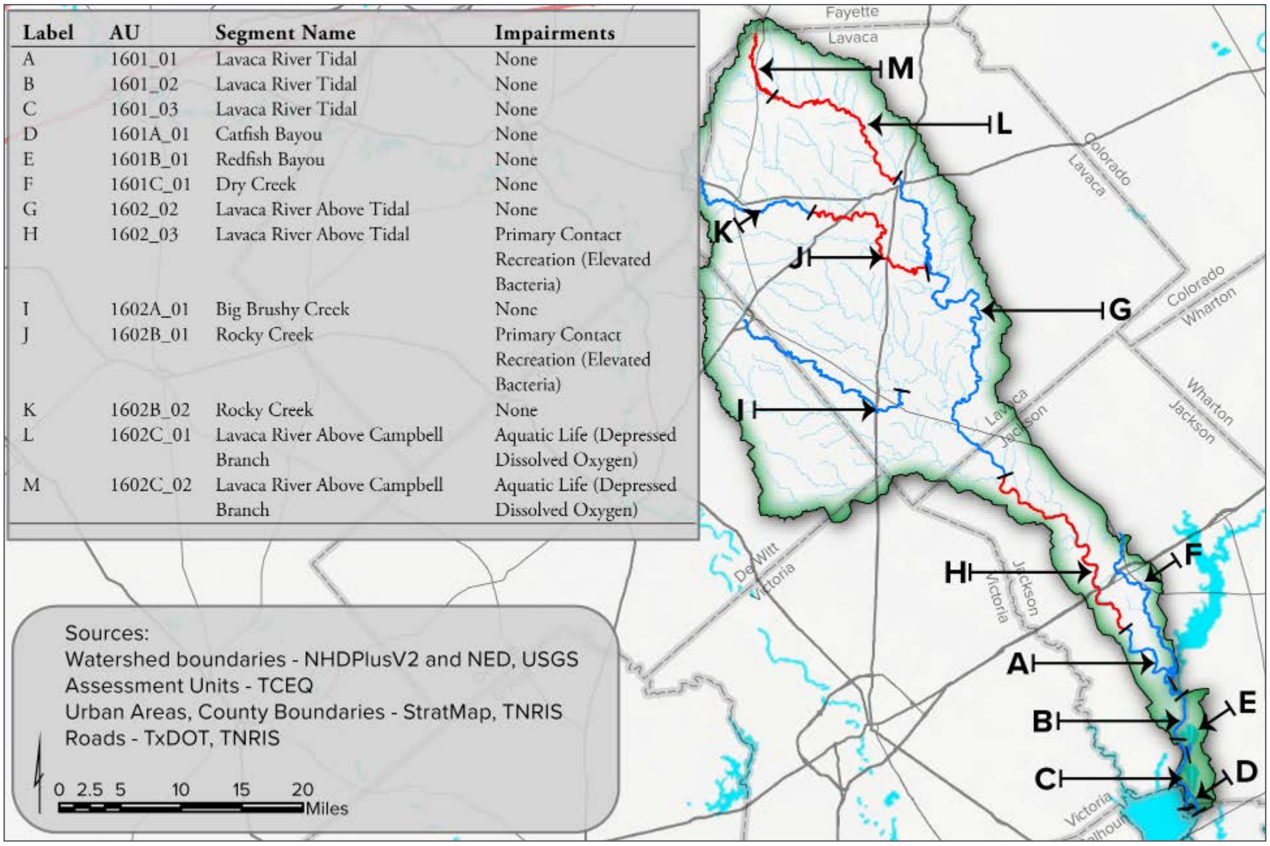
Chapter 3
Water Quality

Introduction

Under the Federal Clean Water Act (CWA) section 303(d) and 305(b), the State of Texas is required to identify water bodies that are unable to meet water quality standards for their designated uses. Texas Commission on Environmental Quality (TCEQ) assigns unique "segment" identifiers to each water body. Locations within a segment are broken up into hydrologically distinct assessment units (AUs). The AUs are evaluated every two years to determine if they meet designated water quality standards, and those that are not meeting requirements are listed on the *Texas Integrated Report for the Texas 303(d) List*: https://www.tceq.texas.gov/waterquality/assessment/14twqi/14txir.

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

According to the 2014 Texas Integrated Report, there are two AUs impaired due to elevated levels of bacteria; AU 1602_03 in the Lavaca River and AU 1602B_01 in Rocky Creek. The report also indicates two AUs listed for depressed DO in the upper segment of the Lavaca River Above Campbell Branch in Hallettsville (AU 1602C_01 and AU 1602C_02) (Figure 11).



Label	AU	Segment Name	Impairments
A	1601_01	Lavaca River Tidal	None
B	1601_02	Lavaca River Tidal	None
C	1601_03	Lavaca River Tidal	None
D	1601A_01	Catfish Bayou	None
E	1601B_01	Redfish Bayou	None
F	1601C_01	Dry Creek	None
G	1602_02	Lavaca River Above Tidal	None
H	1602_03	Lavaca River Above Tidal	Primary Contact Recreation (Elevated Bacteria)
I	1602A_01	Big Brushy Creek	None
J	1602B_01	Rocky Creek	Primary Contact Recreation (Elevated Bacteria)
K	1602B_02	Rocky Creek	None
L	1602C_01	Lavaca River Above Campbell Branch	Aquatic Life (Depressed Dissolved Oxygen)
M	1602C_02	Lavaca River Above Campbell Branch	Aquatic Life (Depressed Dissolved Oxygen)

Figure 11. TCEQ assessment units and watershed impairments.

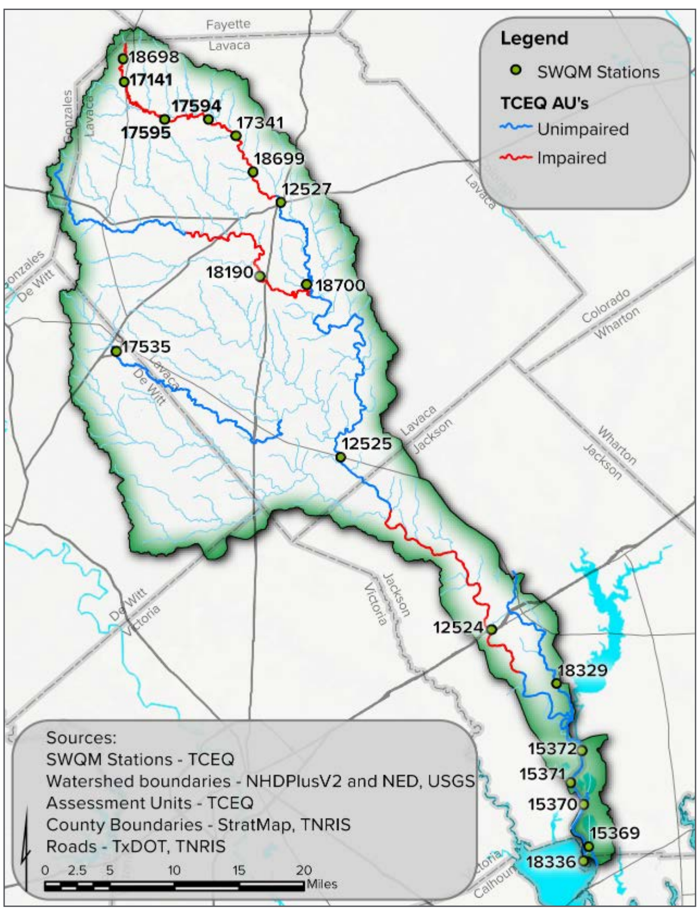


Figure 12. SWQM stations.

Water quality is monitored at designated sampling sites throughout the watershed. The TCEQ Surface Water Quality Monitoring Program (SWQM) coordinates the collection of water quality samples at specified water quality monitoring sites throughout the watershed and the state (Figure 12). Through the TCEQ Clean Rivers Program (CRP), the Lavaca-Navidad River Authority (LNRA) conducts monthly or quarterly monitoring of field parameters (clarity, temperature, DO, specific conductance, pH, salinity and flow), conventional parameters (total suspended solids, sulfate, chloride, ammonia, total hardness, nitrate-nitrogen, total phosphorous, alkalinity, total organic carbon, turbidity and chlorophyll-a), and bacteria. Sampling sites and frequency are detailed in Table 3.

Table 3. Sites currently monitored by LNRA.

Station			Annual Samples			
ID	AU	Description	Conventional	Field	Flow	Bacteria
15372	1601_01	Lavaca River @ Frels Landing		12		
15371	1601_02	Lavaca River @ Mobil Dock		12		
15370	1601B_01	Lavaca River @ Mouth of Redfish Lake		12		
15369	1601A_01	Lavaca River @ Mouth of Swan Lake		12		
18336	1601_03	Lavaca River near Lavaca Bay	4	12		
12525	1602_02	Lavaca River @ SH 111	4	12	12	4
12524	1602_03	Lavaca River @ Hwy 59	4	12	12	4
18190	1602B_01	Rocky Creek @ Lavaca CR 387	4	4		4
12527	1602_02	Lavaca River @ Hwy 90A Hallettsville	4	4	4	4

Bacteria

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

Under the primary contact recreation standards, the geometric mean criterion for bacteria is 126 colony forming units (cfu) of *E. coli*/100mL in freshwater. Currently, all water bodies in the Lavaca River are evaluated under this standard. However, the recreational use category for Rocky Creek is undergoing a study called a Recreational Use Attainability Assessment (RUAA) to determine if a secondary contact 1 (SC1) or secondary contact 2 (SC2) recreation standard is more appropriate. Under SC1, the geometric mean criterion is elevated to 630 cfu/100mL. Under SC2, the geometric mean criterion for *E. coli* is 1,030 cfu/100 mL.

As previously mentioned, currently two AUs [1602_03 (Lavaca River Above Tidal) and 1602B_01 (Rocky Creek)] are listed as impaired due to elevated indicator bacteria according to the *2014 Texas Integrated Report* (Table 4; TCEQ 2016). This listing is based on the geometric mean value from at least 20 bacteria samples collected at stations in each AU between November 2005 and December 2012.

Currently, *E. coli* concentrations are measured at four stations throughout the watershed; one station in Rocky Creek, two stations in the unimpaired Lavaca River Above Tidal AU 1602_02 and one station in the impaired Lavaca River Above Tidal AU 1602_03. All available measurements are shown in Figure 13. The reductions needed to meet water quality standards are further discussed in chapter 4.

Table 4. *2014 Texas Integrated Report* Assessment Results for stream segments in the Lavaca River watershed currently monitored for bacteria (TCEQ 2016).

AU	Description	Current Standard	Geomean	Supporting/Not Supporting
1602_02	Lavaca River Above Tidal – From the confluence of Beard Branch upstream to the upper end of segment at the confluence of Campbell Branch in Hallettsville.	126 cfu/100 mL *E. coli*	114.65	Fully Supporting
1602_03	Lavaca River Above Tidal – Lower portion of segment from confluence with NHD RC 12100101002463 south of Edna upstream to confluence with Beard Branch.	126 cfu/100 mL *E. coli*	294.94	Not Supporting
1602B_01	Rocky Creek – From confluence of Lavaca River upstream to confluence of Ponton Creek	126 cfu/100 mL *E. coli*	222.16	Not Supporting

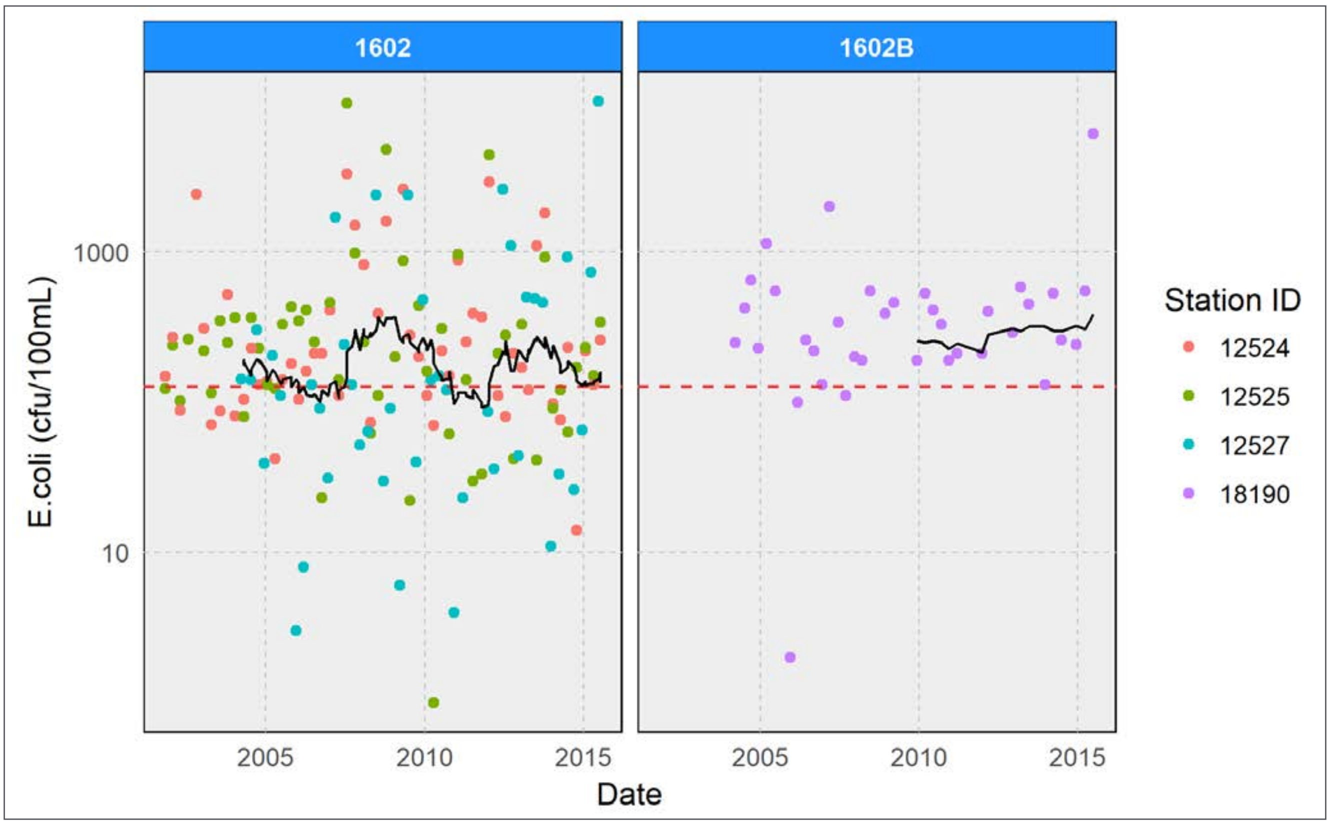


Figure 13. Historical *E. coli* concentrations at monitored segments with bacteria data. Dotted line indicates the 126cfu/100mL criterion and solid black line indicates the mean value of previous 20 measurements.

RUAA

In 2017, the Texas Water Resources Institute (TWRI) collaborated with the Texas Institute for Applied Environmental Research to conduct an RUAA for Rocky Creek. The purpose of the RUAA is to determine and recommend the appropriate recreational use water quality standard for Rocky Creek. This approach uses stakeholder surveys, water body use information, stream surveys and documentation, and public meetings. During this process, potential common recreational uses are documented and compiled into a report that is used to determine the appropriate recreational use standard. The RUAA report is anticipated to be completed in 2018.

Dissolved Oxygen

Aquatic species rely on DO for respiration. Low levels of DO may limit the amount and types of aquatic species found in a water body. When DO levels fall too low, fish and other organisms may begin to die off. Oxygen is dissolved into water through simple diffusion from the atmosphere, aeration of water as it flows over surfaces, and aquatic plant photosynthesis. Typically, DO levels fluctuate throughout the day, with the highest levels of DO occurring in mid to late afternoon, due to plant photosynthesis. DO levels are typically lowest just before dawn as both plants and 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 material 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 then also drive down DO concentrations.

All water bodies in the Lavaca River watershed are under the aquatic life use category “High.” Under this category, the mean criterion is 5.0 mg DO/liter (L) for freshwater bodies and 4.0 mg DO/L for tidal and marine water bodies. Overall, grab samples indicate DO in monitored segments, with adequate data, are generally well above the 5.0 mg/L minimum across the watershed, indicating no issues with DO (Figure 14). Segment 1602C (Lavaca River upstream of Campbell Branch in Hallettsville) is listed impaired for 24-hour average DO on the 2014 Integrated Report. There is currently inadequate data to update the assessment, and it is carried forward from previous assessments. The attainable standards for this segment are discussed below.

UAA

From 2005 to 2006, a Use Attainability Assessment (UAA) was conducted by TCEQ’s Water Quality Standards team, Texas Parks and Wildlife Department (TPWD) and LNRA in Segment 1602C (Lavaca River upstream of Campbell Branch in Hallettsville). UAAs are analysis that determine what the applicable water quality standard should be, based on attainable standards for that water body.

Under the 2014 Integrated Report, AUs 1602C_01 and 1602C_02 were listed as impaired for depressed DO based on the “High” aquatic life use standard. However, the UAA study concluded that portions of Segment 1602C are characterized by intermittent flows and perennial pools, very different from the perennial flow observed downstream. A site-specific seasonal change in the DO criterion of 3.0 mg/L as a 24-hour average and 2.0 mg/L as a 24-hour minimum has been recommended for this segment and is awaiting approval from EPA. Based on the original standard, 30% of 24-hour DO samples were below the 5.0 mg/L 24-hour average criterion. With the site specific seasonal change to 3.0 mg/L, all of the 24-hour samples will meet the proposed criterion. Based on the results of the UAA, the WPP does not recommend any further actions regarding DO in this intermittent segment, despite the listing in the 2014 Integrated Report. Once the Aquatic Life Use standard is approved and finalized, further 24-hour DO monitoring will need to occur in order to delist the segment.

Nutrients

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

Currently, TCEQ does not have approved numeric criteria for these measures of nutrients in water bodies. Screening levels provided by TCEQ are used as a preliminary indication of possible concerns. The current nitrate screening level in freshwater streams for nitrate is 1.95 mg/L and 0.69

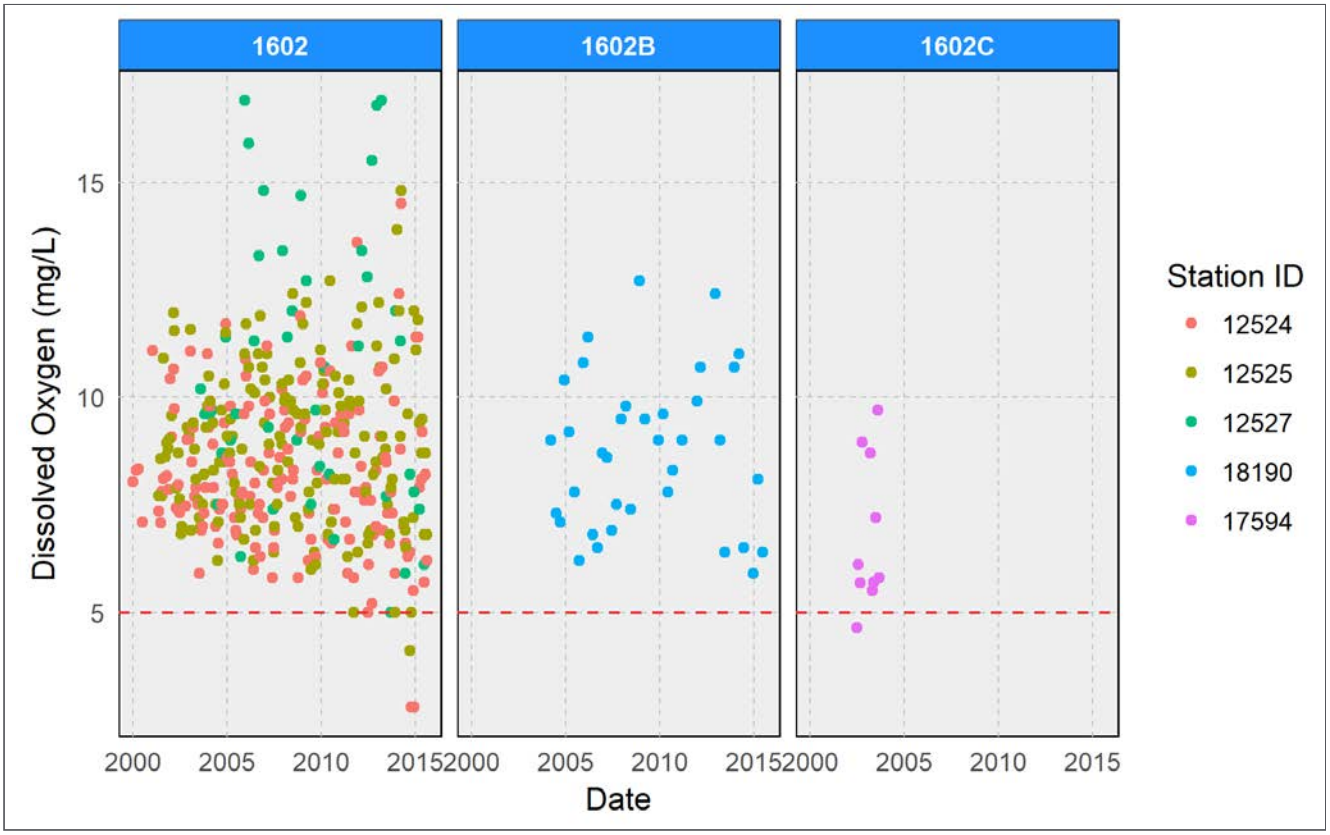


Figure 14. Historical dissolved oxygen concentrations at monitored segments in the Lavaca River watershed. Dotted line indicates the 5.0 mg/L criterion for mean dissolved oxygen concentrations; indicated points are dissolved oxygen grab samples.

mg/L for total phosphorous (Figures 15 and 16). Concerns are indicated when the screening level is exceeded by at least 20% of the measurements during the assessment period.

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. The relationships between water quality and streamflow are further detailed in Chapter 3.

There are two U.S. Geological Survey (USGS) streamflow gages in the watershed. Streamflow gage 08164000 is located at the SWQM Station 12524 (Figure 12) near the outlet of the freshwater segment of the river. Instantaneous streamflow information is available at this station dating back to October 2007 (Figure 17). A second streamflow gage (0816500) is located near SWQM Station 12527 at Hallettsville in the upper portion of the watershed and has instantaneous streamflow records dating back to October 2015 (Figure 17).

Over the last nine years, average streamflows at the lower end of the Lavaca River (USGS gage 08164000) peak in March (Table 5, Figure 18). Average streamflow then decreases through August and remains minimal through November before increasing again.

Table 5. Average (Median) monthly streamflows at Lavaca River (USGS gage 08164000) since October 2007.

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Streamflow (cfs)	20	37	62	42	30	17	11	4	6	9	14	24

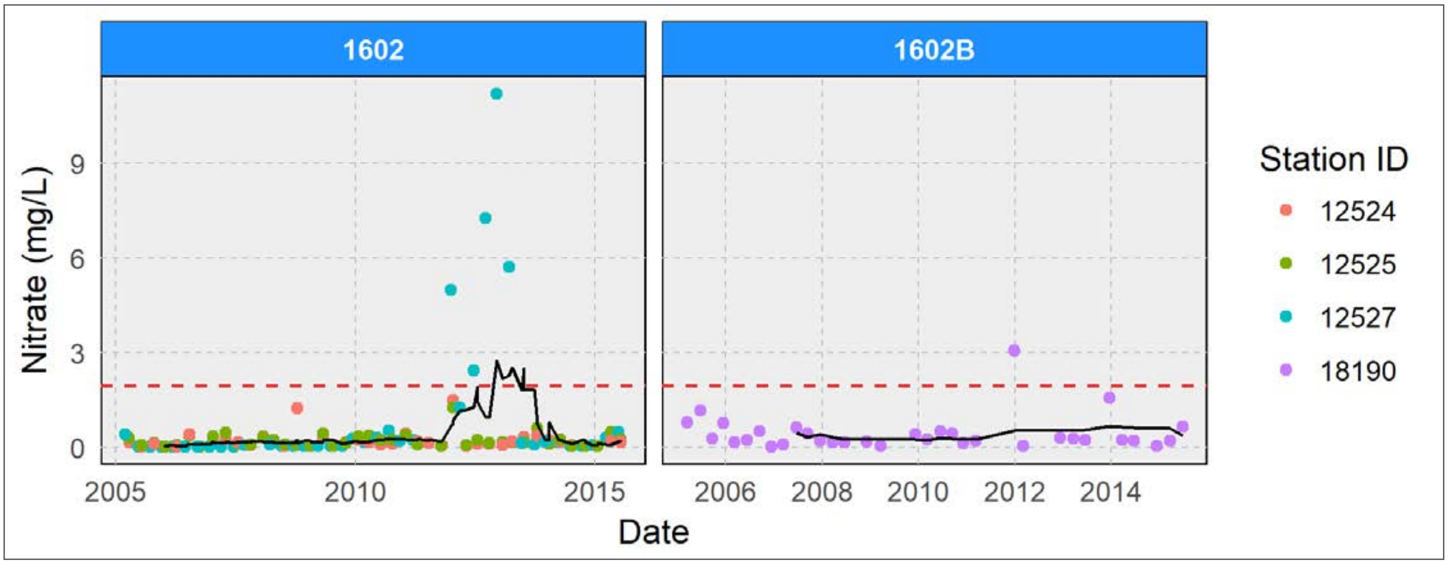


Figure 15. Nitrate concentrations measured since 2005. Dotted line indicates screening level (1.95 mg/L) and solid black line indicates the mean value of previous 10 measurements.

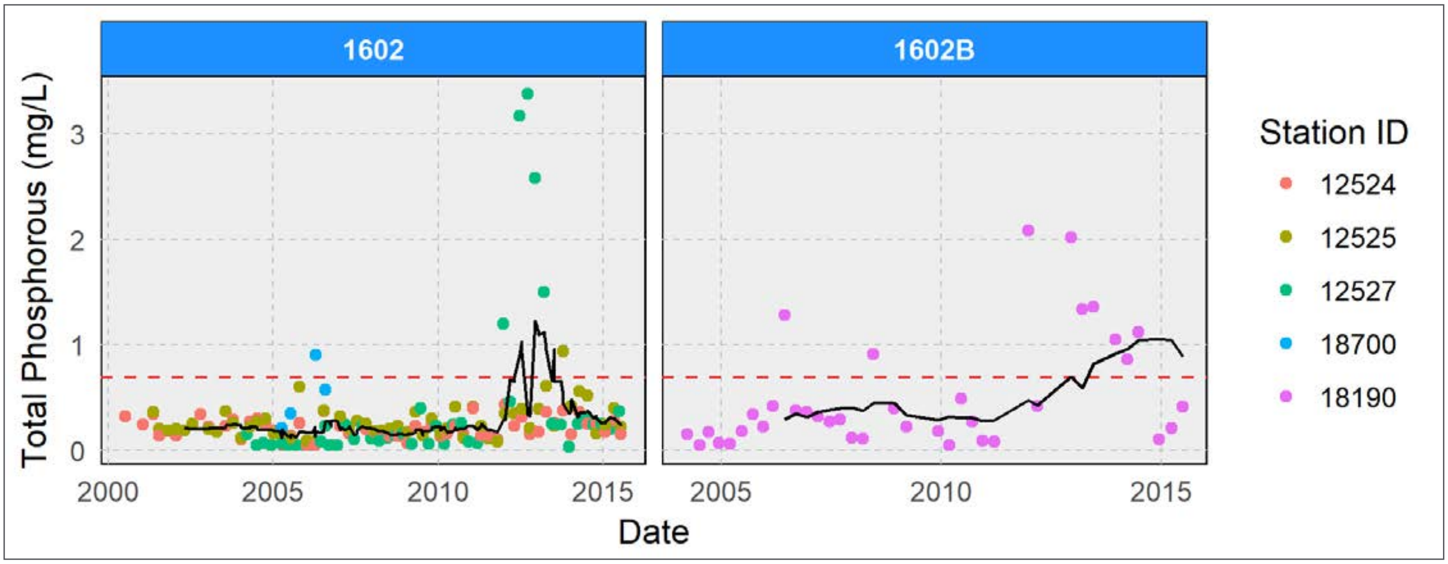


Figure 16. Total phosphorous concentrations measured since 2000. Dotted line indicates screening level (0.69 mg/L) and solid black line indicates the mean value of previous 10 measurements.

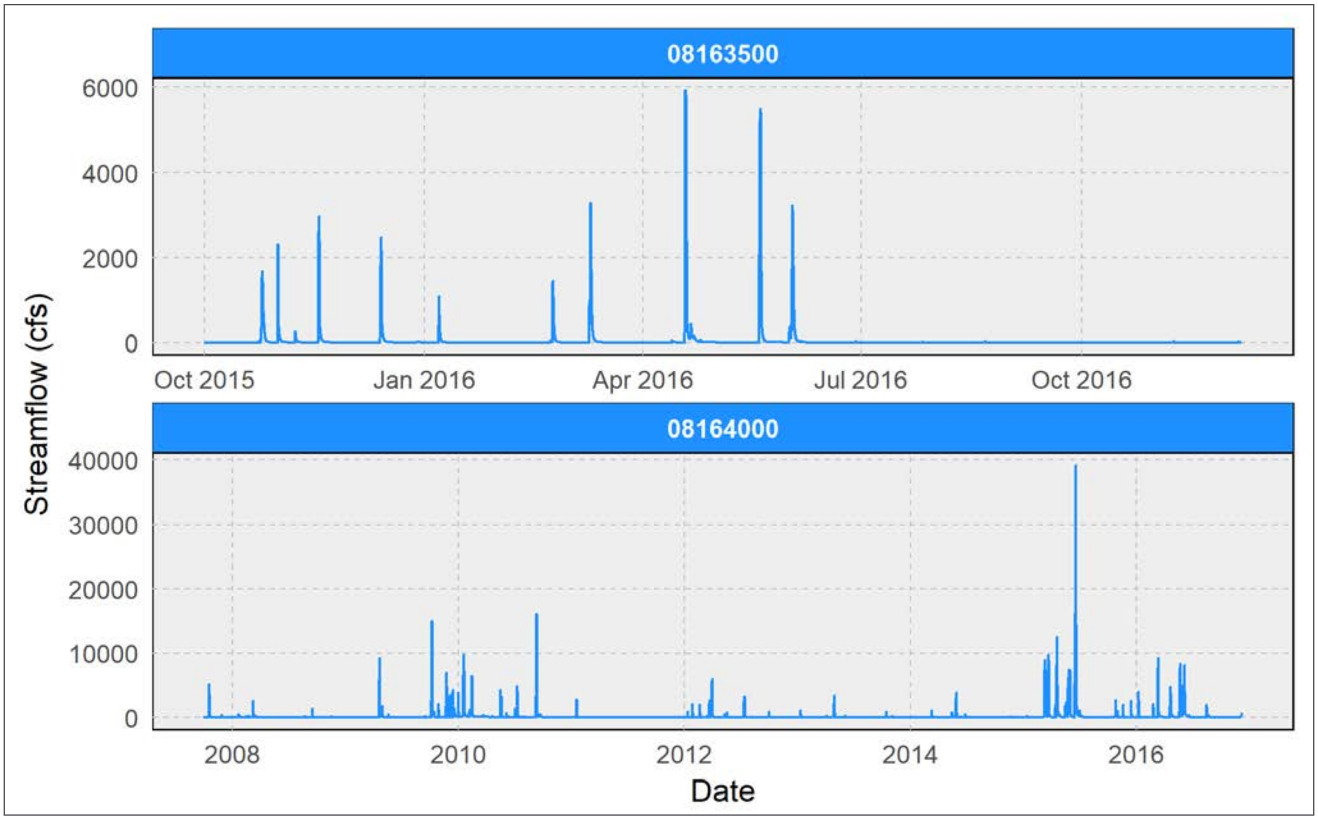


Figure 17. Instantaneous streamflow records at USGS gages 08163500 and 08164000.

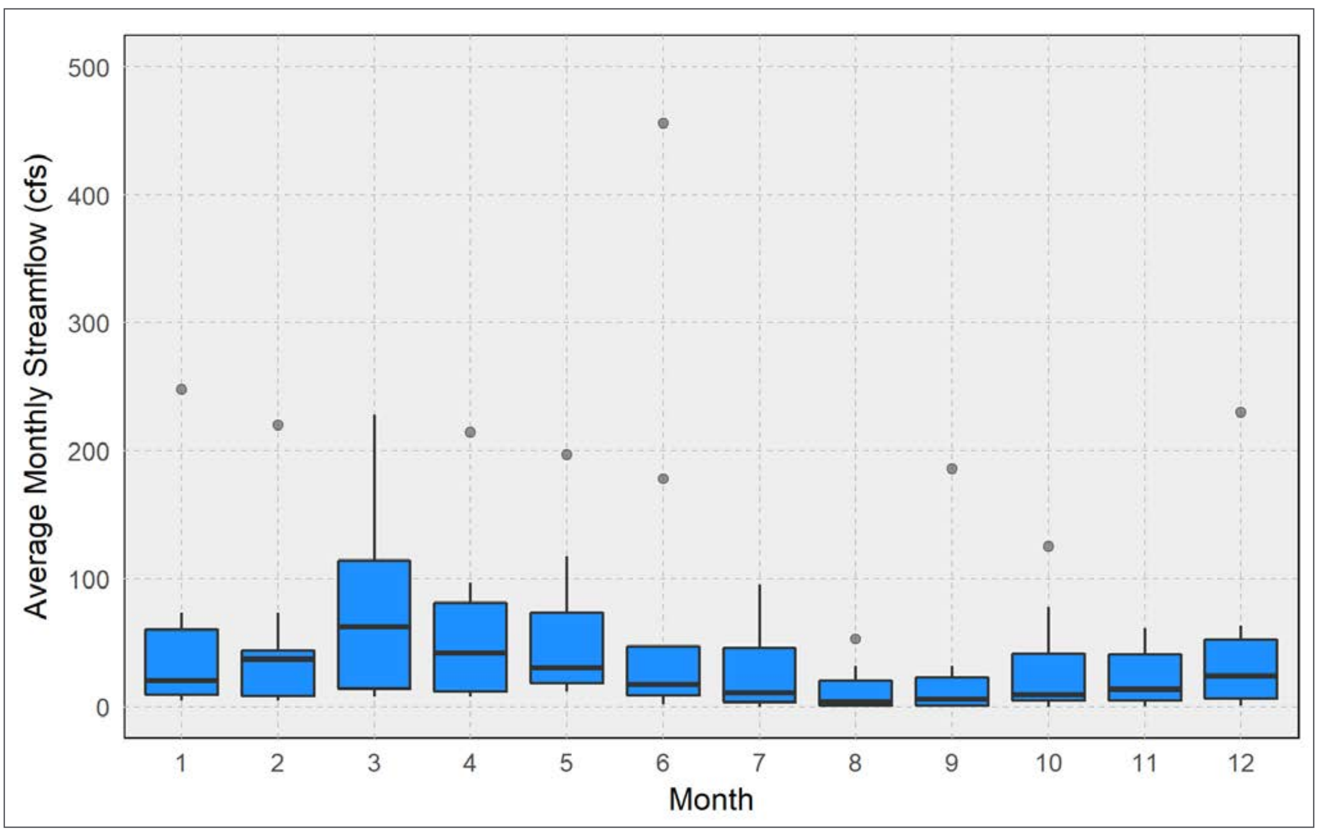


Figure 18. Boxplot of median monthly streamflows at Lavaca River, USGS gage 08164000 (points indicate outlier values).

Potential Sources of Water Quality Issues

Domestic Livestock

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

Because watershed-level livestock numbers are not available, populations were estimated using the USDA NASS and USGS NLCD datasets. Specifically, the livestock population for each county was obtained using the USDA NASS dataset. The county-level data were multiplied by a ratio based on the acres of grazeable land, identified with USGS NLCD data, divided by the total number of acres in the county. Then, the proportion of grazeable acres in the watershed within each county was used to estimate the number of cattle from each county that occur in the watershed. Based on this method, it was estimated that 72,182 cattle and calves are present in the watershed. Furthermore, it was estimated that 937 goats, 803 horses, 494,844 poultry and 632 sheep are also present in the watershed.[1]

According to the Texas State Soil and Water Conservation Board (TSSWCB) database, there are three poultry facilities in the watershed that house approximately 38,800 breeders. Poultry facilities are required to obtain a Water Quality Management Plan (WQMP) before operations begin. WQMPs prescribe proper handling and use of produced litter to ensure adequate water quality protection.

Wildlife and Feral Hogs

Wildlife have the potential to be major contributors to bacteria within a watershed. Animals with the potential to contribute meaningful levels of bacteria include white-tailed deer, feral hogs and birds, such as waterfowl or swallows that can be associated with water bodies, riparian areas or bridge crossings. While wildlife contributions to water quality issues can be difficult to manage, landowners can use various habitat and wildlife management measures to ensure that healthy population levels of deer are maintained on their property. Furthermore, feral hog trapping and feral hog exclusion fences around deer feeders are effective methods of reducing feral hog populations.

[1]Livestock estimates have been reviewed and approved by the SWCDs, NRCS and TSSWCB.

Unfortunately, developing exact quantitative estimates of wildlife can be difficult, and most estimates are restricted to studies of particular areas of interest. Within the Lavaca River watershed, estimates were generated for feral hogs and white-tailed deer based on TPWD and Natural Resources Institute (NRI) data based on studies and estimates from nearby watersheds and the local Resource Management Unit (RMU). Estimates for avian wildlife were not generated; however, a significant portion of the Texas Gulf Coast, including Lavaca and Jackson counties, provides important wetland habitats for wintering waterfowl.

Reports from nearby watersheds (Mission and Aransas rivers) suggest approximate feral hog densities of 1 hog/33 acres, which fluctuate based on habitat conditions (Wagner and Moench 2009). A feral hog population estimate was calculated by applying this density to the acres of suitable habitat in the Lavaca River watershed. Suitable habitat is defined as pasture, scrub, grassland, forest and wetland. There are approximately 541,650 acres of appropriate habitat in the watershed, resulting in an estimate of 16,259 feral hogs in the watershed.

TPWD estimated 1 deer/19 acres for appropriate land cover in RMU 12 from 2005-2011. Based on this density, 30,645 deer are estimated across the entire watershed.

Although wildlife can be a substantial source of fecal bacteria in the watershed, management of all sources of wildlife is not practical and would have low likelihood of success. Based on stakeholder feedback, management efforts will focus on feral hogs due to their invasive nature and propensity to damage crops and pastures.

Domestic Pets

Dogs and cats can contribute to bacteria loads in the watershed when fecal matter is not picked up and disposed of properly. In rural areas, it is common for dogs and cats to spend most or all of their time roaming outdoors. In such cases, picking up pet waste might be impractical. However, in more highly urbanized areas that are more densely populated with both humans and pets, disposing of pet waste in the trash can prevent bacteria loading in stormwater runoff. Furthermore, properly chosen and placed structural stormwater management measures, such as detention ponds or rain gardens, can also mitigate bacteria loads.

The American Veterinary Medical Association (AVMA) estimates there are approximately 0.584 dogs and 0.638 cats/home across the United States (AVMA 2012). Multiplying these ratios with the number of households (13,817) in the watershed suggests there are approximately 8,069 dogs and 8,069 cats across the watershed.

On-Site Sewage Facilities

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

Based on visually validated county 911 data and areas of existing wastewater service, an estimated 5,246 OSSFs may occur in the watershed. Given the extensive occurrence of "Very Limited" soils for OSSF use (Figure 6), the vast majority of these systems occur in areas with expected failure rates of at least 15% (Reed, Stowe & Yanke 2001). The highest densities of OSSFs appear in the upper portions of the watershed just outside of existing service areas (Figure 19). Pockets of high densities also occur in the lower portions of the watershed near Edna and the lower portions of the above tidal segment of the Lavaca River. Figure 19 depicts expected distributions of all OSSFs in the watershed but does not identify failing OSSFs.

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

Permitted Discharges

Permitted discharges are sources regulated by permit under the Texas Pollutant Discharge Elimination Systems (TPDES) and the National Pollutant Discharge Elimination System (NPDES) programs. Examples of permitted discharges include WWTF discharges, industrial or construction site stormwater discharges, and discharges from municipal separate storm sewer systems (MS4) of regulated cities or agencies.

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 permit. Plants that exceed their permitted levels may require infrastructure or process improvements in order to meet the permitted discharge requirements.

As of March 2016, seven facilities with indicator bacteria reporting requirements operate in the Lavaca River watershed under the TPDES and NPDES programs (Figure 20 and Table 6). Three of the seven WWTF dischargers experienced several non-compliance issues during the 12-quarter period (three years) January 1, 2013 through March 31, 2016 (USEPA 2016). The City of Moulton reported one quarter of non-compliance due to high bacteria discharges. The City of Hallettsville reported four quarters of non-compliance due to high bacteria. The City of Edna reported 11 quarters of non-compliance due to high bacteria. According to EPA's Enforcement and Compliance History Online (ECHO) database, none of the bacteria effluent violations were reported as "Significant Noncompliance" effluent violations.

Although stormwater is generally considered a NPS, stormwater is subject to regulation if it originates from a regulated MS4 or is associated with industrial and/or construction activities. MS4 permits refer to the permitting of municipal stormwater systems that are separate from sanitary sewer systems. They are broken down into "large" Phase I and "small" Phase II system permits based on population. Further details on MS4 permitting requirements are available from TCEQ: www.tceq.texas.gov/permitting/stormwater/ms4. TPDES

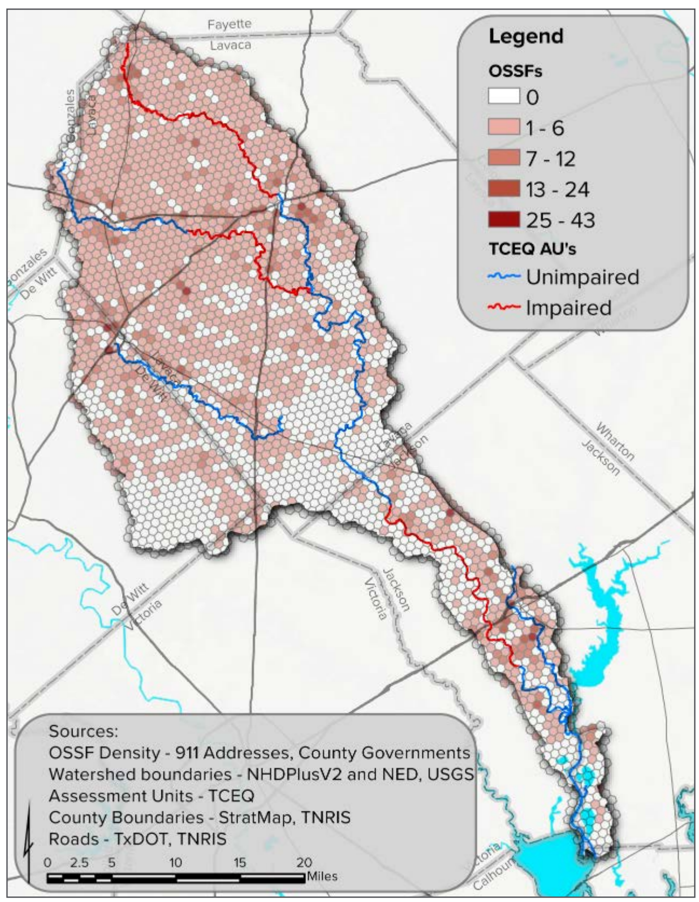


Figure 19. OSSF density.

issues stormwater permits for industrial facilities, construction activities over 1 acre, concrete production facilities and petroleum terminals. These urban and industrial stormwater sources may contain elevated levels of bacteria or nutrients as they wash accumulated materials from roads, parking lots, buildings, parks and other developed areas. Potential pollutants can be managed from these sites through stormwater best management practices, including structures such as detention ponds, riparian buffers, pervious pavement and low impact design.

As of June 2016, there are no Phase I or II MS4 permit holders. However, there are twelve industrial site stormwater permits and seven active construction site stormwater permits in the watershed. Based on the 2011 NLCD, only 54 square miles out of the 909 square mile watershed are urbanized or developed. Therefore, 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.

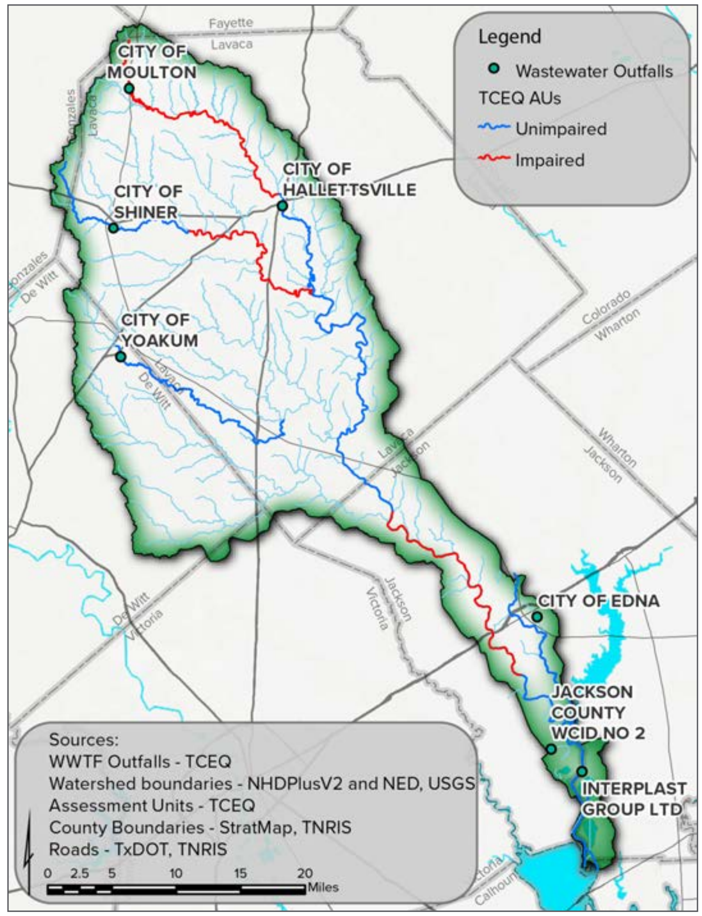


Figure 20. WWTF outfall locations.

Table 6. Permitted wastewater treatment facilities and recent reporting exceedances.

Facility	Receiving AU	Receiving Water body	Discharge Type	Permitted Discharge (MGD)	Recent Discharge (MGD)	% Monthly Exceedances Daily Avg Bacteria	% Monthly Exceedances Single Grab Bacteria
Hallettsville WWTF	1602	Lavaca River Above Tidal	Treated domestic wastewater	0.80	0.78	14.29%[a]	19.05%[a]
Shiner WWTF	1602B	Rocky Creek	Treated domestic wastewater	0.85	0.736	0.00%[b]	0.00%[b]
Moulton WWTF	1602	Lavaca River Above Tidal	Treated domestic wastewater	0.242	0.111	3.57%[c]	3.57%[c]
Jackson County WCID No 2 WWTF	N/A	Drainage ditch to unnamed tributary	Treated domestic wastewater	0.045	0.027	0.00%[d]	0.00%[d]
Yoakum WWTF	1602A	Big Brushy Creek	Treated domestic wastewater	0.95	0.686	0.00%[e]	0.00%[e]
Interplast Group	1601	Lavaca River Tidal	Wastewater (> or = 1 MGD domestic sewage or process water including WTP discharge)	0.045	0.032	0.00%[f]	0.00%[f]
Edna WWTF	Tributary to 1601C	Dry Creek	Wastewater (> or = 1 MGD domestic sewage or process water including WTP discharge)	1.8	0.479	2.70%[g]	69.44%[g]

[a] 28 monthly *E. coli* records (1/2014–4/2016)
[b] 19 monthly *E. coli* records (11/2104–5/2016)
[c] 21 monthly *E. coli* record (9/2014–5/2016)
[d] 6 monthly *E. coli* records (1/2015–4/2016)
[e] 20 monthly *E. coli* records (10/2014–6/2016)
[f] 19 monthly *Enterococci* records (10/2014–4/2016)
[g] 37 monthly *E. coli* records (4/2013–4/2016)

Table 7. SSO events since 2009.

Facility	Date	Gallons	Cause
City of Yoakum	2009-10-04	Unknown	Inflow and Infiltration
City of Yoakum	2010-04-25	3000	Grease blockage
City of Moulton	2013-10-14	1000	Grease blockage
City of Edna	2013-11-11	2000	Sewer line
City of Edna	2013-11-11	200	Rags
City of Yoakum	2014-12-05	3000	Blockage from piece of wood
City of Moulton	2015-01-12	Unknown	Bacteria exceedance in outfall
City of Edna	2015-06-16	93,600	Inflow and infiltration (Tropical Storm Bill)
City of Moulton	2015-12-03	250	Lift station electrical malfunction[1]
City of Moulton	2015-12-03	250	Lift station electrical malfunction[1]

[1] Separate events on the same day

Unauthorized Discharges

SSOs occur when sewer lines lose capacity due to becoming plugged, collapsing because of age or lack of maintenance, or receiving excessive amounts of inflow and infiltration (I&I). Overflows result when the sanitary sewer system backs up and the untreated water flows through manhole covers or other points in the system. These overflows and spills can reach water bodies, resulting in significant bacteria loading. Permit holders are required to report SSOs that occur in their system to TCEQ. According to the TCEQ regional office, ten SSOs have been reported in the watershed since 2009 (Table 7). Many of the events were blockages caused by material that should not be flushed or poured down drainpipes. The largest event was caused by excessive I&I that overwhelmed infrastructure during Tropical Storm Bill, resulting in overflows at 16 manhole covers throughout the City of Edna. The city followed up with smoke testing of collection systems and infrastructure repairs and replacement.

Water Quality Summary

The Lavaca River watershed is a largely rural watershed, characterized by a vital agricultural community. Therefore, a significant portion of the watershed has been used for cropland, pasture or grazing. The population of the watershed is mostly concentrated in the small municipalities of Edna, Hallettsville, Shiner and Yoakum and is projected to increase by small proportions over the next 50 years.

The primary water quality concerns are bacteria impairments in the above tidal segment of the Lavaca River and in Rocky Creek, pending the outcome of the aforementioned RUAA study. Potential contributors to the bacteria impairments likely include some combination of (1) managed livestock/cattle; (2) unmanaged wildlife/feral hogs; (3) failing OSSFs; (4) stormwater runoff from urban areas and impervious surfaces (including contributions from household pets); and (5) permitted discharges and SSOs (Table 8).

Table 8. Summary of potential bacteria sources contributing to Lavaca River impairments.

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

Chapter 4
Pollutant Source Assessment

Introduction

Water quality sampling, described in Chapter 3, established that the primary water quality concern in the Lavaca River watershed is excessive fecal indicator bacteria. The current water quality standard established by TCEQ for primary contact recreation is 126 cfu/100mL for *E. coli*. The *2014 Texas Integrated Report* lists the Lavaca River Above Tidal (AU 1602_03) as impaired with a geometric mean of 294 cfu/100 mL *E. coli.* Rocky Creek (AU 1602B_01) is also listed as impaired with a geometric mean of 222 cfu/100 mL *E. coli.*

In order to calculate the reductions needed to meet primary contact recreation standards, the bacteria load capacity of the Lavaca River and Rocky Creek were calculated. The current bacteria loads for the Lavaca River and Rocky Creek were also calculated using water quality samples and the Load Duration Curve (LDC) method. By taking the difference between the load capacity and the current load, this WPP estimates the needed reductions to meet water quality standards.

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. 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.

Source and Load Determination

Load Duration Curves

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

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

Three LDCs were produced for stations with at least 20 data points. Station 12524 is the furthest downstream station (Figure 21). The Station 12524 LDC indicates the *E. coli* loadings exceed allowable loads (red line) across all flow conditions. Station 12525 is upstream of Station 12524 on the main stem of the Lavaca River (Figure 22). Although this segment is not currently impaired, a number of samples exceed the 126 cfu/100 mL criterion. The LDC indicates that *E. coli* loadings exceed the load capacity primarily under high flow and moist conditions. This is indicative of loadings associated with NPS pollution or from bacteria present within stream sediments that are resuspended under increased flow. The last LDC was developed for SWQM Station 18190 on Rocky Creek (Figure 23). The Rocky Creek LDC indicates loads exceeding capacity under all flow conditions. While elevated loadings under high flows are indicative of NPSs of indicator bacteria due to presumed greater amounts of runoff, exceedances during lower flow conditions are generally more indicative of point sources or direct fecal deposition to streams from wildlife or domestic livestock.

Table 9 presents the estimated daily loads and daily reductions needed under each flow category to achieve primary contact recreation water quality standards in each AU. Table 10 provides the estimated total annual loads and total required load reductions to achieve primary contact recreation standards. To establish this numeric target for total annual load reduction, the needed daily load reduction for each flow category was multiplied by the number of days per year within each respective flow category and then added together to yield a total annual load reduction. Due to the cumulative nature of watershed loadings, the required load reductions identified at station 12524 (Lavaca River) include the required load reduction identified in Rocky Creek.

Based on LDCs, a total reduction of 9.29×10^{14} cfu/year (yr) is required at Lavaca River SWQM Station 12524 to reach primary contact recreation standards. The LDCs also indicate that NPS pollution is an important contributor to elevated bacteria levels, while direct deposition or point source may also be contributing to elevated bacteria at lower flows.

A total reduction of 1.39×10^{14} cfu/yr is required at the Rocky Creek SWQM Station 18190. The largest reductions are needed during higher flows and under wet conditions where NPSs of bacteria are a primary concern. Elevated loads at low flows indicate a continued need to address potential sources of direct deposition or other sources that may contribute loadings under low flow conditions.

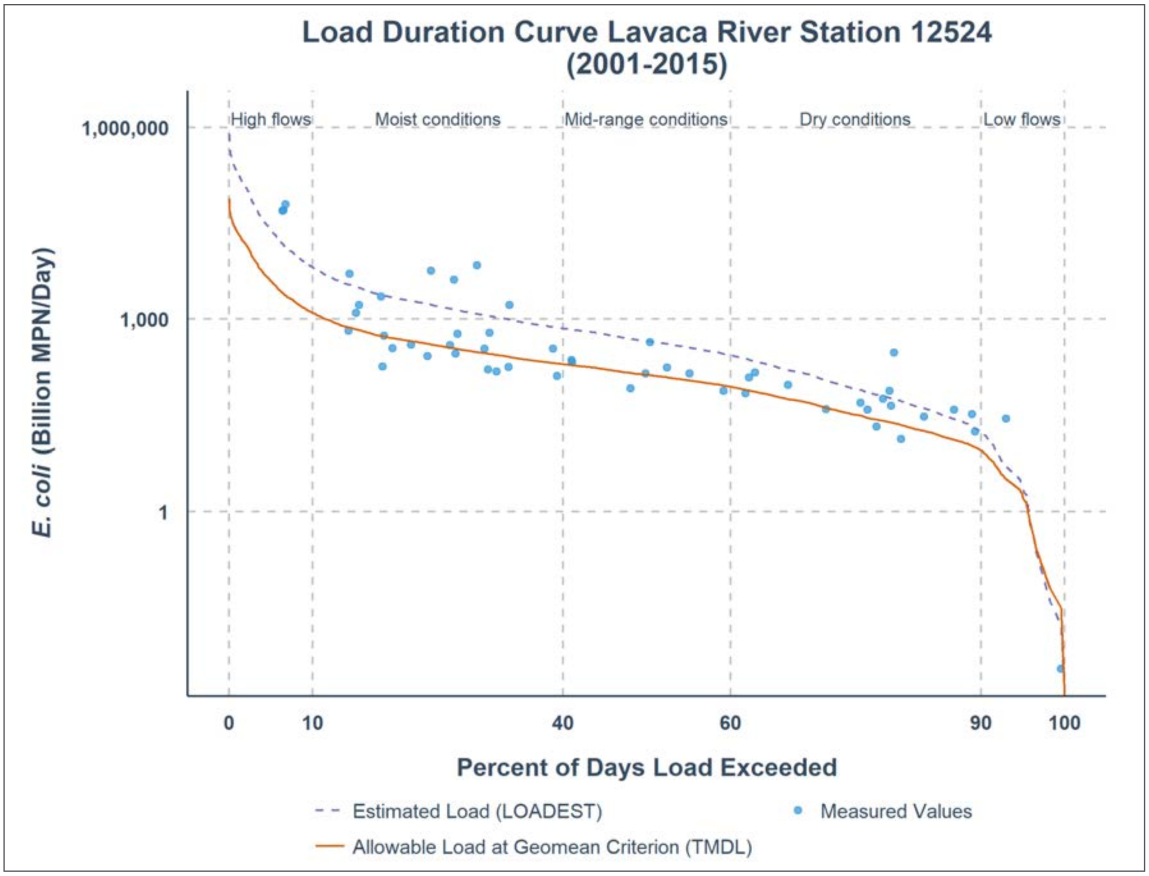


Figure 21. Load duration curve for Lavaca River SWQM Station 12524.

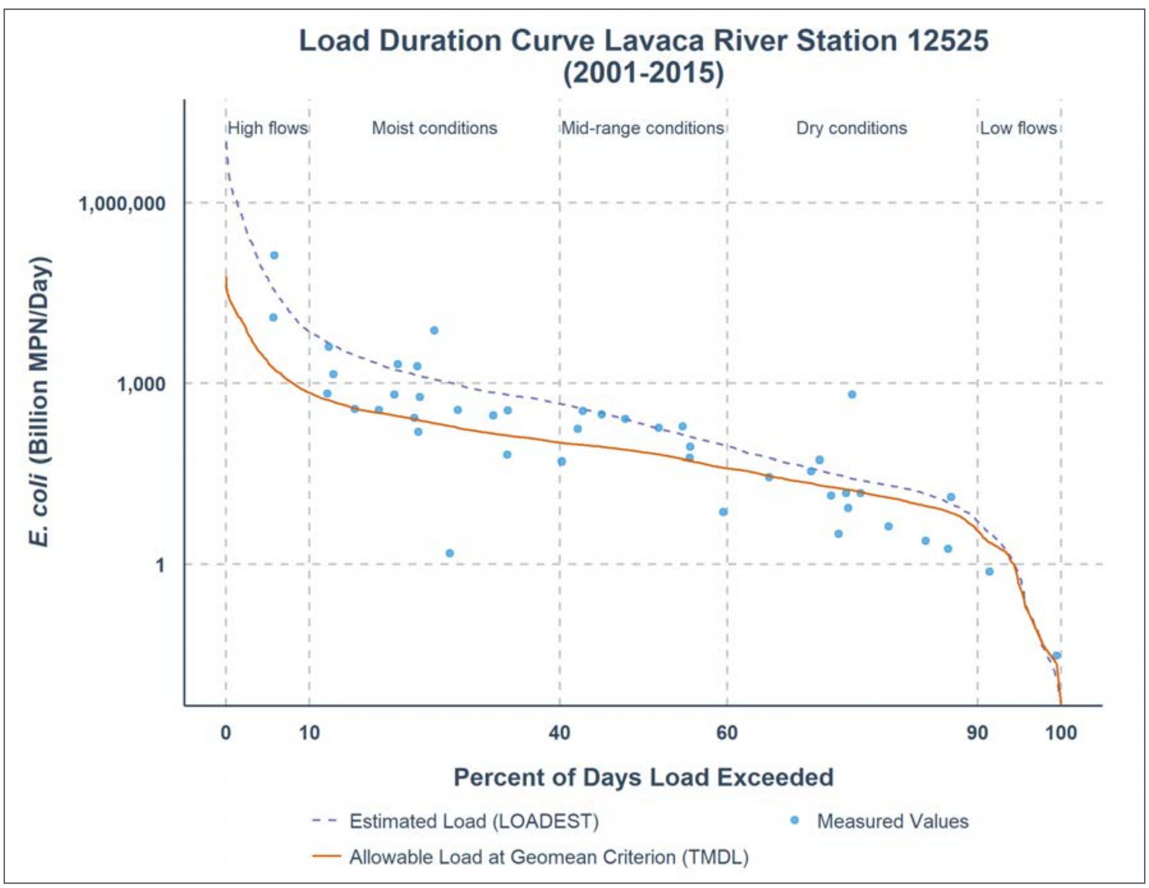


Figure 22. Load duration curve for Lavaca River SWQM Station 12525.

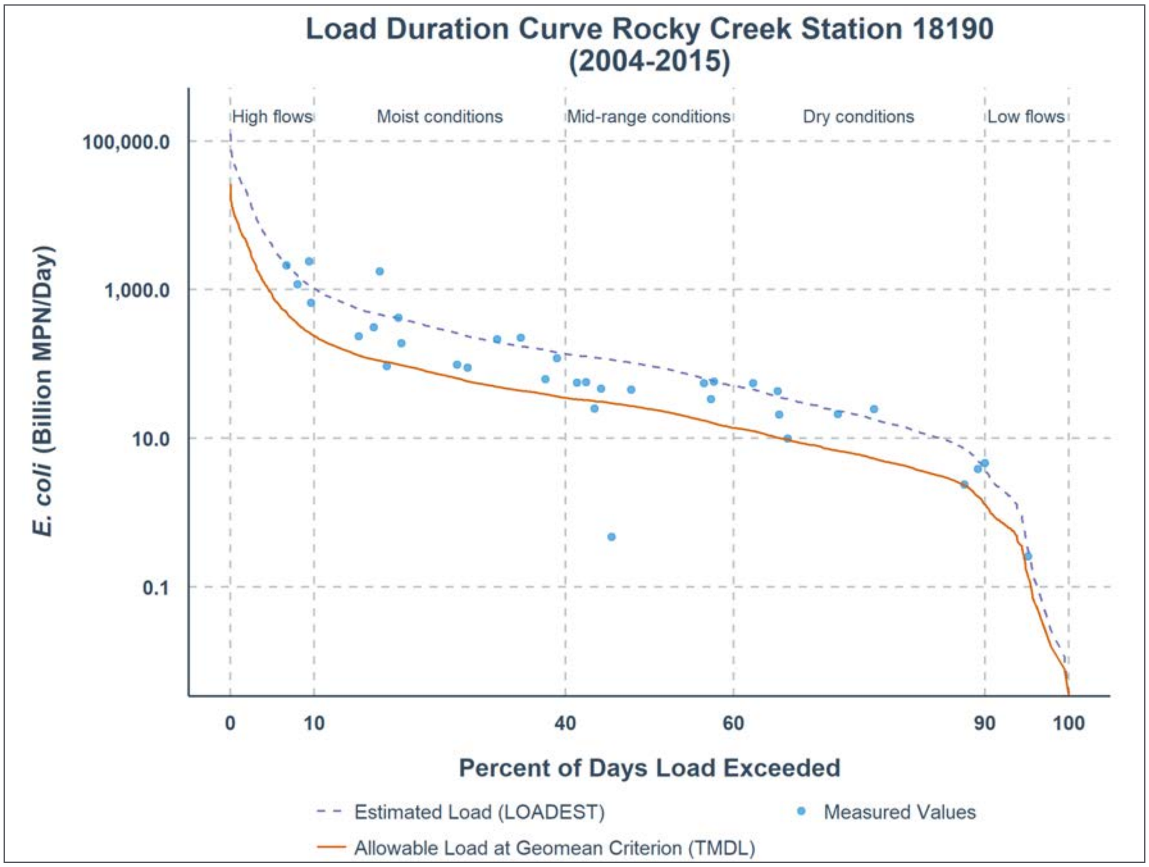


Figure 23. Load duration curve for Rocky Creek SWQM Station 18190.

Table 9. Estimated daily loads and daily reductions required to meet primary contact water quality criteria as determined by LDC analysis.

Flow Condition	Percent Days Flow Exceeded	Existing Daily Load (cfu/day)	Allowable Daily Load (cfu/day)	Reduction Needed (%)	Daily Load Reduction Required
Station 12524 (Lavaca River)					
High flows	0-10	2.51×10^{13}	3.98×10^{12}	84%	2.11×10^{13}
Moist conditions	10-40	1.58×10^{12}	3.82×10^{11}	76%	1.20×10^{12}
Mid-range flows	40-60	4.49×10^{11}	1.33×10^{11}	70%	3.17×10^{11}
Dry conditions	60-90	7.99×10^{11}	3.14×10^{10}	61%	4.84×10^{10}
Low flows	90-100	2.29×10^{9}	1.68×10^{9}	26%	6.11×10^{8}
Station 18190 (Rocky Creek)					
High flows	0-10	3.77×10^{12}	8.28×10^{11}	78%	2.95×10^{12}
Moist conditions	10-40	2.95×10^{11}	7.22×10^{10}	75%	2.22×10^{11}
Mid-range flows	40-60	9.33×10^{10}	2.45×10^{10}	74%	6.88×10^{10}
Dry conditions	60-90	2.05×10^{10}	6.04×10^{9}	71%	1.45×10^{10}
Low flows	90-100	3.44×10^{8}	1.51×10^{8}	56%	1.93×10^{8}

Table 10. Estimated annual load reductions required to meet primary contact water quality criteria.

Flow Condition	Percent Days Flow Exceeded	Existing Annual Load (cfu/yr)	Reduction Needed (%)	Annual Load Reduction Required
Station 12524 (Lavaca River)				
High flows	0-10	2.51×10^{13}	84%	7.70×10^{14}
Moist conditions	10-40	1.58×10^{12}	76%	1.31×10^{14}
Mid-range flows	40-60	4.49×10^{11}	70%	2.31×10^{13}
Dry conditions	60-90	7.99×10^{11}	61%	5.30×10^{12}
Low flows	90-100	2.29×10^{9}	26%	2.23×10^{10}
Total	N/A	1.21×10^{15}	77%	9.29×10^{14}
Station 18190 (Rocky Creek)				
High flows	0-10	3.77×10^{12}	78%	1.08×10^{14}
Moist conditions	10-40	2.95×10^{11}	75%	2.43×10^{13}
Mid-range flows	40-60	9.33×10^{10}	74%	5.02×10^{12}
Dry conditions	60-90	2.05×10^{10}	71%	1.59×10^{12}
Low flows	90-100	3.44×10^{8}	56%	7.05×10^{9}
Total	N/A	1.79×10^{14}	78%	1.39×10^{14}

Table 11. Lavaca River subwatersheds based on NHD HUC12 descriptions (USGS 2012).

Subwatershed ID	Name (NHD HUC12)	Acres
1	Youngs Branch-Lavaca River	27,992
2	Long Branch-Lavaca River	14,118
3	West Campbell Branch-Lavaca River	25,581
4†	Ponton Creek	22,807
5†	Boggy Creek-Rocky Creek	27,623
6†	Smothers Creek-Rocky Creek	35,620
7	Rickaway Branch-Lavaca River	16,985
8	Grafe Branch-Lavaca River	13,886
9†	North Fork Mustang Creek	27,657
10	Kelley Creek-Clarks Creek	34,665
11	Spring Branch-Lavaca River	39,037
12	Big Brushy Creek	34,380
13	Supplejack Creek-Clarks Creek	21,778
14	Waterhole Creek-Clarks Creek	22,525
15	Upper Little Brushy Creek	32,749
16	Lower Little Brushy Creek	17,321
17	Beard Branch-Lavaca River	13,817
18	Chicolete Creek	20,509
19	Knopp Branch-Lavaca River	22,674
20	South Chicolete Creek-Chicolete Creek	38,738
21	Post Oak Branch-Dry Creek	17,671
22	Milby Branch-Lavaca River	34,148
23	Swan Lake-Lavaca River	19,974

† Subwatersheds within both the Rocky Creek and the Lavaca River watersheds

Pollutant Source Load Estimates

GIS Analysis

To aid in identifying potential areas of *E. coli* contributions within the watershed, a GIS analysis was applied using the methodology employed by the Spatially Explicit Load Enrichment Calculation Tool (SELECT) (Borel et al. 2012). The best available information and stakeholder input were used to identify likely NPSs of bacteria and calculate potential loadings.

Using this GIS analysis approach, the relative potential for *E. coli* loading from each source can be compared and used to prioritize management. The loading estimates for each source are potential loading estimates that do not account for bacteria fate and transport processes that occur between the points where they originate and where they enter the water body, if at all. As such, these analyses represent worst-case scenarios that do not represent the actual *E. coli* loadings expected to enter the creek. Potential loads for identified sources are summarized for each of the 23 subwatersheds (Table 11, Figure 24) found in the Lavaca River watershed. This approach allows prioritization of management measures (found in Chapter 5) in subwatersheds with the highest potential for bacteria loadings.

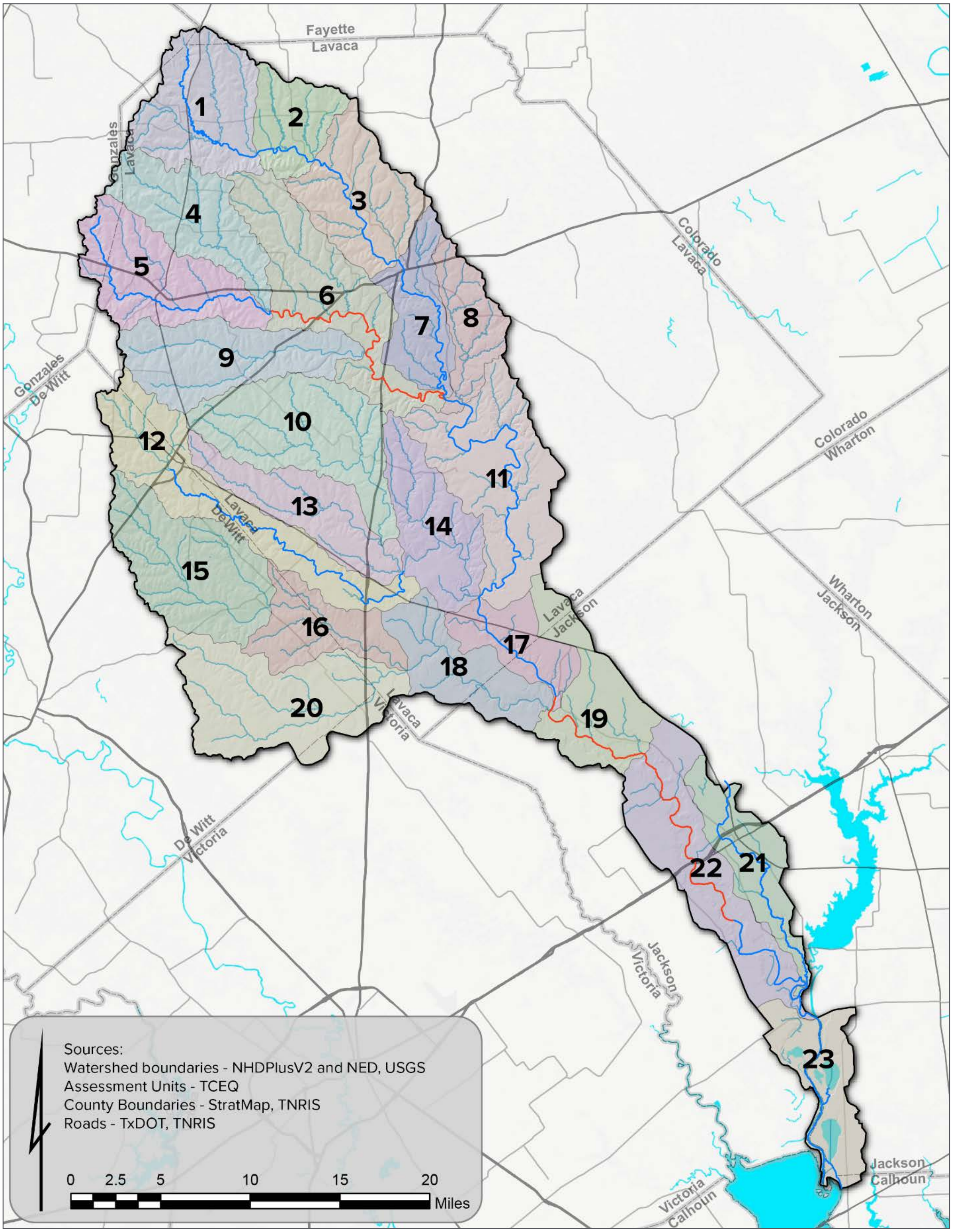


Figure 24. Lavaca River subwatersheds (See Table 11 for descriptions).

Cattle

Cattle can contribute to *E. coli* bacteria 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 bacteria loads in the stream. Improved grazing practices and land stewardship can dramatically reduce runoff and bacteria loadings. For example, recent 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).

The potential loads from cattle were developed based on recommendations from the Agricultural Work Group. Members of the Agricultural Work Group were critical in identifying commonly used stocking rates and the amount of grazed lands in the area. Based on stakeholder input and the best available data, this plan estimated approximately 73,948 cattle animal units across the entire watershed. Appendix A describes the assumptions and equations used to estimate potential bacteria loading in the Lavaca River watershed. Figure 25 shows the total potential loading from grazing cattle by subwatershed. The highest totals are in the northern areas of the watershed. Across the watershed, GIS analysis estimated the potential annual load due to livestock as 1.45×10^{17} cfu/yr.

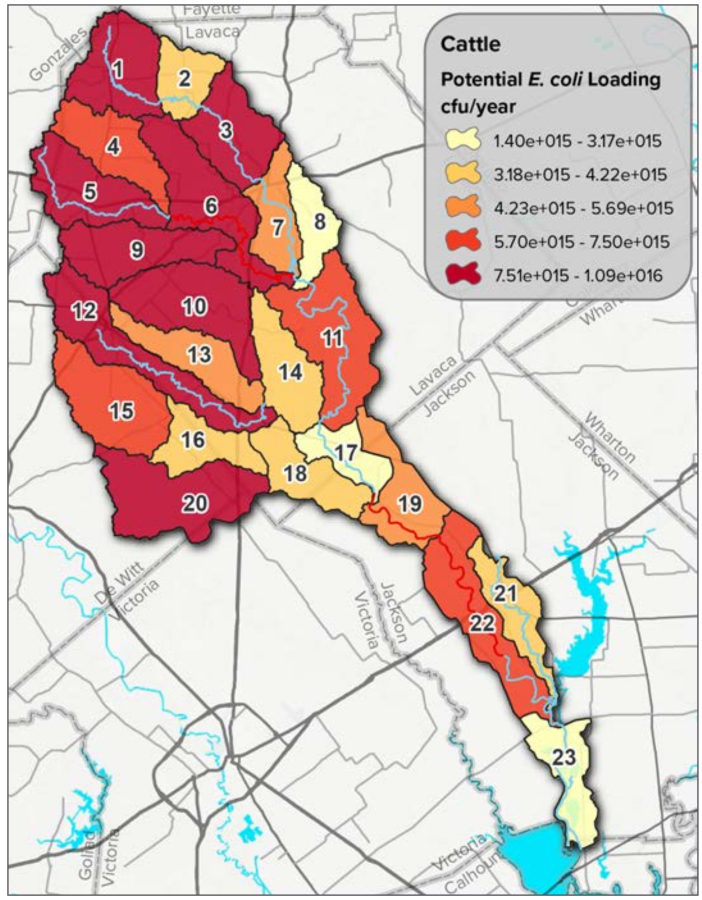


Figure 25. Potential annual bacteria loadings from cattle.

Feral Hogs

Feral hogs (*Sus scrofa*) are an introduced, non-native and invasive species. Early settlers released some of the first domestic hogs in the Texas landscape as early as the 1680s, with many of these hogs becoming feral over time as animals were left to fend for themselves (Mayer 2009; Mapston 2010). Documented introductions of Eurasian wild boar occurred in the early 1920s through the 1940s along the Texas Central Coast, including at the St. Charles Ranch in what is now the nearby Aransas National Wildlife Refuge (Mayer 2009). Current population estimates of feral hogs in Texas alone range from 1 to 3 million individuals (Mayer 2009; Mapston 2010).

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

GIS analysis indicated the highest potential annual loadings occur in subwatersheds 11 and 20 (Figure 26). Across the watershed, GIS analysis estimated the potential annual load due to feral hogs as 6.03×10^{14} cfu/yr. Appendix A describes the equations and assumptions used to generate potential annual loads.

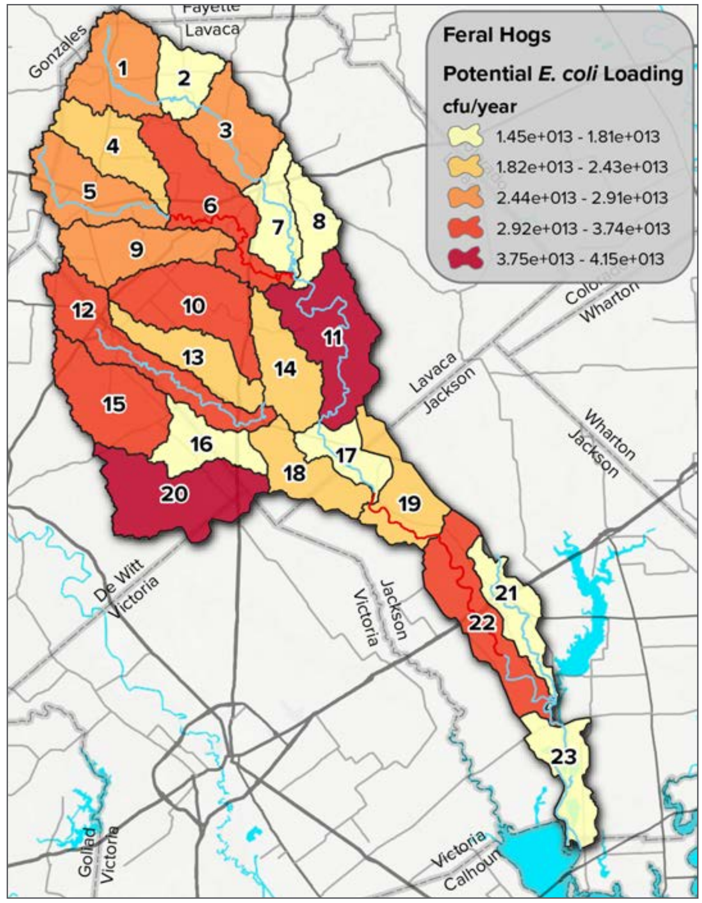


Figure 26. Potential annual bacteria loadings from feral hogs.

Domestic Pets

Domestic pets, with a particular emphasis on dogs, can contribute to bacteria loadings when pet waste is not disposed of and subsequently washes into nearby water bodies during rain and storm events. The highest potential loads from domestic pets are anticipated to occur in developed and urbanized areas. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 5, 7, 12 and 21 (Figure 27). Across the watershed, GIS analysis estimated the potential annual load due to dogs as 3.71×10^{15} cfu/yr. Appendix A describes the equations and assumptions used to generate potential annual loads.

On-Site Sewage Facilities

Failing or unmaintained OSSFs can contribute bacteria loads to water bodies, in particular those where effluent is released near the water bodies. Within the Lavaca River watershed, approximately 15% of OSSFs are assumed to fail on a given year. It was estimated that there are approximately 5,246 OSSFs within the watershed based on the most recently available 911 address data. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 6 and 12 (Figure 28). Across the watershed, GIS analysis estimated the potential annual load due to failing OSSFs as 9.29×10^{14} cfu *E. coli*/yr. Appendix A describes the equations and assumptions used to generate potential annual loads.

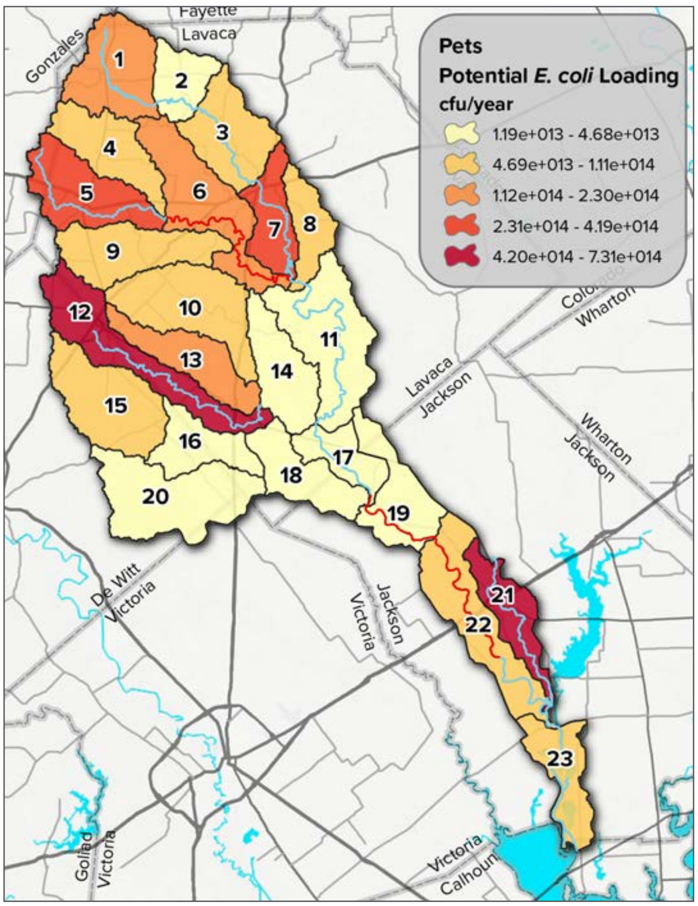


Figure 27. Potential annual bacteria loadings from domestic pets.

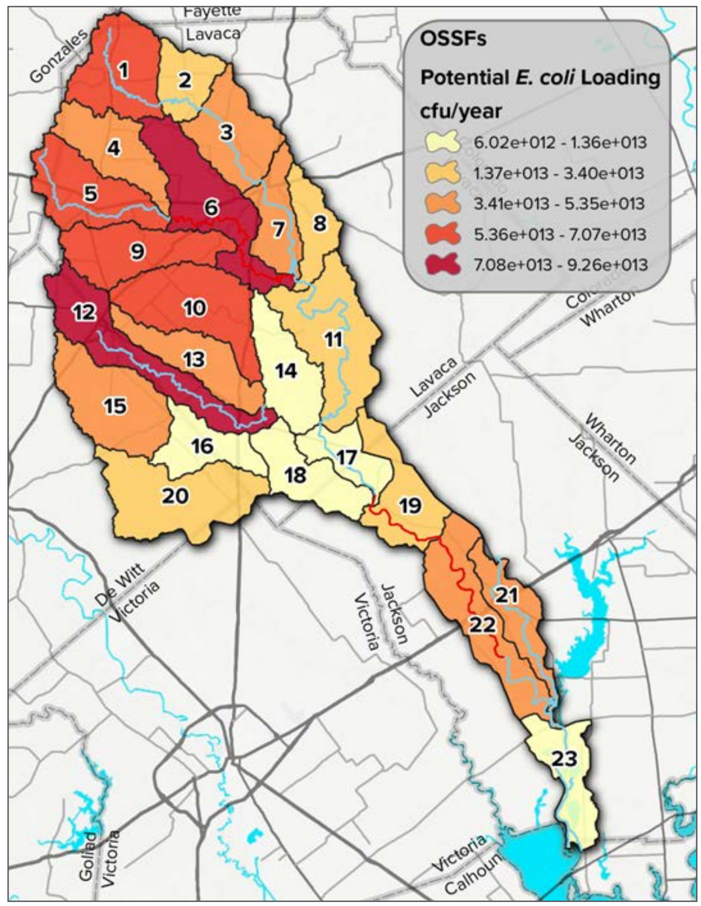


Figure 28. Potential annual bacteria loadings from OSSFs.

Urban Stormwater Runoff

Based on 2011 NLCD data, there are approximately 35,607 acres of developed, impervious surfaces across the watershed. The impervious surfaces in developed and urbanized areas increase the amount of rainfall that becomes runoff. This increased overland flow has the potential to pick up and carry pollutants to nearby water bodies, even during small rainfall events. Numerous stormwater BMPs are available to reduce the volume of stormwater that runs off of developed sites, potentially decreasing the amount of pollutants entering the stream.

GIS analysis estimated a total potential annual load of 4.27×10^7 cfu *E. coli*/yr (Figure 29). The highest potential loads occur in subwatersheds 5, 7, 12 and 21. Appendix A describes the equations and assumptions used to generate potential annual loads.

Wastewater Treatment Plants

According to TCEQ and EPA NPDES data, there are seven permitted wastewater dischargers in the 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. Total potential bacteria loads based on maximum permitted discharges across the watershed is 1.62×10^{10} cfu *E. coli*/yr (Figure 30), and the highest potential loads occur in subwatershed 12. Appendix A describes the equations and assumptions used to generate potential annual loads.

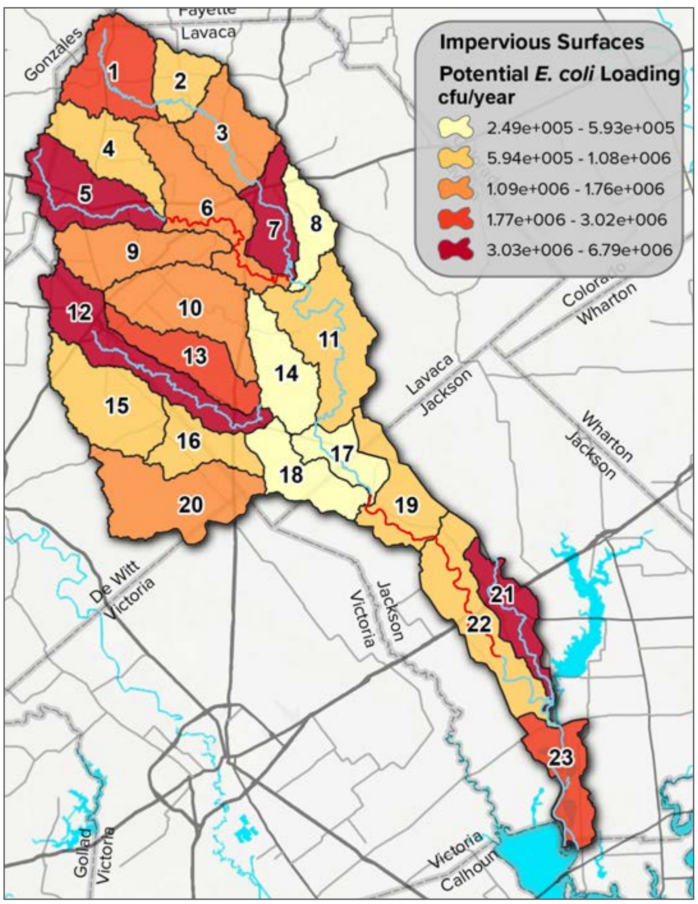


Figure 29. Potential annual bacteria loadings from urban stormwater runoff and impervious surfaces.

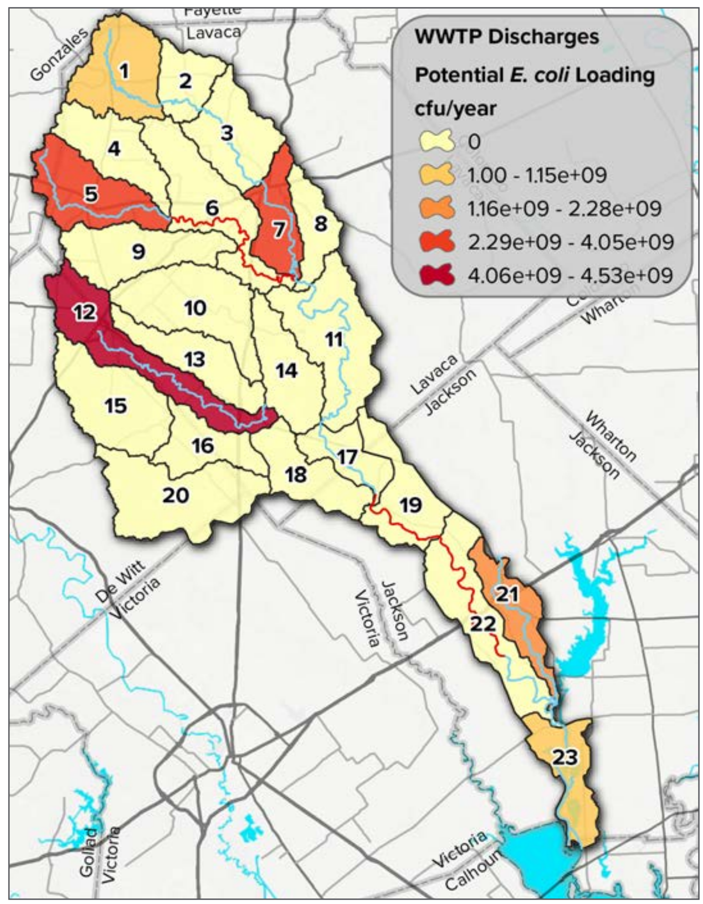


Figure 30. Potential annual loadings from wastewater treatment plants.

Table 12. Summary of potential source loads.

Source	Lavaca		Rocky Creek	
	Potential Load†	Highest Priority Subwatersheds	Potential Load†	Highest Priority Subwatersheds
Cattle	1.45×10^{17}	1, 3, 5, 6, 9, 10, 12, 20	3.53×10^{16}	5, 6, 9
Feral hogs	6.03×10^{14}	11, 20	1.18×10^{14}	6
Dogs	3.71×10^{15}	5, 7, 12, 21	7.34×10^{14}	5
OSSFs	9.29×10^{14}	6, 12	2.67×10^{14}	6
Urban stormwater	4.27×10^{7}	5, 7, 12, 21	8.48×10^{6}	5
WWTFs	1.62×10^{10}	12	4.05×10^{9}	5
Totals	1.50×10^{17}		3.64×10^{16}	

† in units of cfu *E. coli*/yr

Load Reduction and Sources Summary

The LDCs provided in the first half of this chapter indicate that the amount of *E. coli* bacteria entering the Lavaca River and Rocky Creek exceeds the capacities of those water bodies under all flow conditions. Based on these curves, it can be assumed that *E. coli* is entering water bodies under both high flow and low flow conditions. Using the LDC approach, a total reduction of 9.29×10^{14} cfu *E. coli*/yr was estimated as needed to meet primary contact recreation standards at the Lavaca River SWQM Station 12524. A reduction of 1.39×10^{14} cfu *E. coli*/yr was also estimated to meet primary contact recreation standards at Rocky Creek SWQM Station 18190.

Given the relatively good compliance of permitted dischargers in the watershed, bacteria loading exceedances during low flow conditions are likely attributable to direct deposition from livestock and wildlife in addition to discharges from unregulated failing and faulty OSSFs in riparian zones. Bacteria in runoff are likely to contribute to exceedances during higher flow conditions. Sources of bacteria-laden runoff might include runoff from rangeland and pastures, unregulated stormwater runoff in urbanized areas and drainage fields of faulty OSSFs. Although reported SSO events are relatively uncommon in the watershed, I&I during heavy rainfall events and resulting SSOs or unauthorized discharges may also contribute to elevated loads during some high flow events.

Based on the GIS analysis, bacteria loadings from cattle and livestock are likely to be relatively high compared to other sources (Table 12). Estimated total potential loads are likely conservative because most wildlife sources of fecal bacteria are not included in the analysis. However, the recommended management measures in Chapter 5 will still result in load reductions adequate to reach water quality goals without directly targeting wildlife.

Grazed pasture and rangeland are more concentrated in the upper sections of the watershed, which helps to highlight important areas to address and implement potential improvements in pasture and rangeland runoff. GIS analysis suggests relatively high potential for loadings from domestic pets in subwatersheds that encompass the cities of Yoakum, Edna, Hallettsville and Shiner; it will be important to address pet waste and stormwater runoff from impervious surfaces in these areas. Both OSSFs and feral hogs have moderate potential for *E. coli* loading as compared to other sources. WWTFs and urban stormwater indicated the lowest relative potential for loadings amongst sources assessed.

Chapter 5 Watershed Protection Plan Implementation Strategies

Introduction

Local and regional stakeholders identified and recommended management strategies to achieve *E. coli* reductions. Stakeholders identified strategies based on current understanding and knowledge of management effectiveness, feasibility and local acceptance. Analysis to identify major sources of *E. coli* (Chapter 3), actual *E. coli* loads (Chapter 4) and potential loading distribution (Chapter 4) provided the information necessary for stakeholders to make informed decisions.

A variety of sources contribute *E. coli* to the river. Therefore, an approach that addresses the diversity of sources is recommended to address *E. coli* loads. The approach outlined in this WPP focuses on contributions that are most feasibly managed and have the highest chances of reducing instream *E. coli*.

The management measures detailed in this chapter address the following sources: livestock, feral hogs, OSSFs, pet waste, urban stormwater, SSOs and illicit dumping. These sources do not represent all prospective bacteria sources in the watershed but are the most manageable. For example, bacteria source tracking in similar watersheds nearby has identified wildlife as a significant contributor to *E. coli*; however, managing wildlife fecal deposition from all sources of wildlife in the watershed is not practical and does not have a high likelihood of success.

Priority areas in the watershed were identified for each management recommendation using results from the GIS analysis (Chapter 4) and stakeholder feedback. These priority locations are areas that will maximize the effectiveness of the management recommendations. Finally, stakeholder feedback was critical in developing and selecting management strategies. Stakeholders are responsible for the implementation of these voluntary management strategies. Therefore, their recommendations to include particular management measures indicate a greater degree of feasibility and willingness and an increased likelihood that they will implement those recommendations. Only measures that are both sug-

Table 13. 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 quality, 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
Shade structure	N/A	Livestock, water quality, wildlife
Stream crossing	578	Livestock, water quality
Supplemental feed location	N/A	Livestock, water quality
Water well	642	Livestock, water quantity, wildlife
Watering facility	614	Livestock, water quantity

gested and agreed upon by stakeholders are included.
Load reductions resulting from the implementation of management measures were calculated for both Rocky Creek and the Lavaca River. Load reduction calculations are detailed in Appendix B.

Management Measures

Management Measure 1 – Promote and implement Water Quality Management Plans (WQMP) or conservation plans

Bacteria loadings in the Lavaca River watershed from grazed lands are likely to be relatively high compared to other evaluated sources. The fate and transport of fecal bacteria in livestock waste is less certain than with other sources. Livestock waste is often deposited in upland areas and transported to water bodies during runoff events. In between deposition and transport, much of the *E. coli* bacteria in livestock waste dies; however, livestock may spend significant time in and around water bodies, thus resulting in more direct impacts on water quality.

Importantly, livestock behavior and where livestock spend time can be modified through changes to their food, shelter and water availability. Cattle grazing is highly dependent upon proximity to these resources, especially water. Fecal loading is subsequently also strongly tied to resource use, as it is directly related to the amount of time an animal spends in an area. Therefore, reducing the amount of time that livestock spend in riparian pastures through rotational grazing, alternative water supplies, shade structures and supplemental feeding locations can directly reduce the potential for bacteria to enter the creek.

A variety of BMPs are available to achieve goals of improving forage quality, distributing livestock across a property and making water resources available to livestock. Table 13 provides a list of identified practices available to producers. However, the list of practices available to producers is not limited to those in the table. The actual appropriate practices will vary by operation and should be determined through technical assistance from NRCS, TSSWCB and local soil and water conservation districts (SWCDs) as appropriate.

A variety of BMPs are available to achieve goals of improving forage quality, distributing livestock across a property and making water resources available to livestock. Table 13 provides a list of identified practices available to producers. However, the list of practices available to producers is not limited to those in the table. The actual appropriate practices will vary by operation and should be determined through technical assistance from NRCS, TSSWCB and local soil and water conservation districts (SWCDs) as appropriate.

NRCS and TSSWCB provide technical and financial assistance to producers to plan and implement BMPs. NRCS offers a variety of programs to implement operation-specific conservation plans. TSSWCB, through local SWCDs, provides technical and financial assistance to develop and implement WQMPs through planning, implementation and maintenance of each practice.

Table 14. Management measure 1: Promote and implement Water Quality Management Plans or conservation plans.

<table>
<tr><th colspan="4">Source: Cattle and Other Livestock</th></tr>
<tr><td colspan="4">Problem: Direct and indirect fecal bacteria loading due to livestock in streams, riparian degradation and overgrazing</td></tr>
<tr><td colspan="4">Objectives:
• Work with producers to develop conservation plans and WQMPs that improve grazing practices and water quality.
• Provide technical and financial support to producers.
• Reduce fecal loadings attributed to livestock.</td></tr>
<tr><td colspan="4">Critical Areas: All properties with riparian habitat throughout the watershed and all properties in subwatersheds: 1, 3, 5, 6, 9, 10, 12 and 20</td></tr>
<tr><td colspan="4">Goal: Develop and implement conservation plans and WQMPs that minimize time spent by livestock in riparian areas and better use available grazing resource across the property.</td></tr>
<tr><td colspan="4">Description: Conservation plans and WQMPs will be developed with producers to implement BMPs that reduce water quality impacts from overgrazing, time spent by livestock in and near streams, and runoff from grazed lands. Practices will be identified and developed in consultation with NRCS, TSSWCB and local SWCDs as appropriate. Education programs and workshops will support and promote the adoption of these practices.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participation</th><th>Recommendations</th><th>Period</th><th>Capital Costs</th></tr>
<tr><td>TSSWCB, SWCDs</td><td>Develop funding to hire WQMP technician.</td><td>2019-2029</td><td>Estimated $75,000/yr</td></tr>
<tr><td>Producers, NRCS, TSSWCB, SWCDs</td><td>Develop, implement and provide financial assistance for 100 livestock conservation plans and WQMPs (including 30 in Rocky Creek subwatersheds).</td><td>2019-2029</td><td>$1,500,000 (est. $15,000/plan)</td></tr>
<tr><td>AgriLife Extension, TWRI</td><td>Deliver education and outreach programs and workshops (Lone Star Healthy Streams) to landowners.</td><td>2019, 2023, 2027</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">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 conservation plans is estimated to reduce annual loads from livestock by 1.00×10^{15} cfu E. coli/yr in the Lavaca River. Of these 100 plans, at least 30 should be targeted toward the Rocky Creek watershed, which is estimated to reduce loads by 2.25×10^{14} cfu E. coli/yr.†</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High – Decreasing the amount of time livestock spend in riparian areas and reducing runoff from pastures will directly reduce NPS contributions of bacteria in creeks.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate – Landowners acknowledge the importance of good land stewardship practices and management plan objectives; however, financial incentives are often needed to promote the WQMP and conservation plan implementation.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate – Landowners are willing to implement stewardship practices shown to improve productivity; however, because costs are often prohibitive, financial incentives are needed to increase implementation rates.</td></tr>
<tr><td>Needs</td><td colspan="3">High – Financial costs are a major barrier to implementation, education and outreach are also needed to demonstrate benefits to producers and their operations.</td></tr>
<tr><td>Potential Funding Sources</td><td colspan="3">Coastal Zone Management Program/Coastal Management Program (CZM program and CMP); EPA CWA §319(h) grant program; NRCS Environmental Quality Incentives Program (EQIP); Conservation Innovation Grants (CIG); Conservation Stewardship Program (CSP); Regional Conservation Partnership Program (RCPP)‡</td></tr>
</table>

†Load reduction calculations described in Appendix B
‡Funding sources described in Section 7.4

Although this management measure mainly addresses and calculates bacteria sources from cattle, the use of conservation planning and WQMPs can reduce fecal loading from all types of livestock. The implementation of conservation plans and WQMPs is beneficial, regardless of location in the watershed; however, effectiveness is likely greater on properties with riparian habitat. Therefore, all properties with riparian areas are considered a priority; however, properties without riparian habitat are also encouraged to participate in implementation activities. Priority areas will include subwa tersheds 1, 3, 5, 6, 9, 10, 12 and 20. Table 14 summarizes management recommendations for cattle and other livestock.

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

Spatial analysis indicated that potential bacteria loadings from feral hogs were moderate compared to other sources. While other sources of potential *E. coli* loadings were higher, feral hogs demonstrate a preference for the dense habitat, water and shade provided by riparian areas. Feral hog behavior and habitat preferences suggest a high likelihood for negative impacts on riparian habitat and water quality.

While the complete eradication of feral hogs from the watershed is not feasible, a variety of methods are available to manage or reduce populations. Trapping animals is likely the most effective method available to landowners for removing large numbers of feral hogs. Shooting feral hogs removes comparatively fewer individuals before they begin to move to other parts of the watershed. Trapping requires some amount of effort and proper planning to maximize effectiveness, but it also provides landowners a means to recoup costs associated with trapping efforts through the sale of live hogs. Specifically, the State of Texas allows transport of live feral hogs to approved holding facilities for sale. The purchase price will vary by facility and comparative market prices. Furthermore, costs of purchasing or building live traps can also be split among landowners.

Additionally, given the opportunistic feeding nature of feral hogs, minimizing available food from deer feeders is important. Feeders can help support the survival of local feral hog populations while also lowering trapping success by reducing the likelihood of feral hogs entering traps. Feeders located in or near riparian zones may also help maintain populations in areas that maximize their potential impact on water quality. Therefore, constructing exclusion fences around feeders and locating feeders away from riparian areas are other important strategies for minimizing feral hog impacts on water quality.

Education programs and workshops will be used to improve feral hog removal effectiveness. Currently, Texas A&M AgriLife Extension Service (AgriLife Extension) provides a variety of educational resources for landowners: http://feralhogs.tamu.edu. Delivering up-to-date information and resources to landowners through workshops and demonstrations is critical to maximizing landowner success in removing feral hogs.

Based on spatial analysis, the highest potentials for loadings from feral hogs are in subwatersheds 6, 10, 11, 12, 15, 20 and 22. However, given feral hogs' propensity to travel great distances along riparian corridors in search of suitable food and habitat, priority areas will include all subwatersheds with high importance placed on properties with riparian habitat. Tabel 15 summarizes management measures for feral hog control.

Table 15. Management measure 2: Promote technical and direct operational assistance to landowners for feral hog control.

Source: Feral Hogs			
Problem: Direct and indirect fecal bacteria loading due to invasive feral hog populations			
Objectives: • Work with landowners to reduce feral hog populations. • Reduce food availability for feral hogs. • Reduce fecal contamination from feral hogs.			
Critical Areas: All subwatersheds, with high importance placed on riparian properties.			
Goal: Reduce and maintain the feral hog population by 15% in the Lavaca River (2,439) and Rocky Creek (478) watersheds by all available means.			
Description: Voluntary implementation of feral hog population management practices including trapping, reduction of food supplies and educating landowners.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Landowners, managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog use	2019-2029	$200/feeder
Landowners, managers, lessees	Voluntarily trap/remove/shoot feral hogs to reduce numbers	2019-2029	N/A
Landowners, producers, TPWD, NRCS, TSSWCB	Develop and implement wildlife habitat management plans and wildlife management practices in conservation plans and WQMPs	2019-2029	N/A
AgriLife Extension, Texas Wildlife Services, TPWD	Deliver Feral Hog Education Workshop	2020, 2023, 2026	$7,500 each
Estimated Load Reduction			
Removing and maintaining feral hog populations directly reduces fecal loading potential to water bodies in the watershed. Reducing the population by 15% in the Lavaca River watershed is estimated to reduce potential annual loads by 8.48×10^{13} cfu *E. coli* annually. Reducing the population by 15% in the Rocky Creek watershed is estimated to reduce potential annual loads by 1.66×10^{13} cfu *E. coli* annually. †			
Effectiveness	Moderate: Feral hogs are a relatively moderate source of potential loads in the watershed. Removing enough feral hogs to decrease the population is difficult.		
Certainty	Low: Feral hogs are transient, intelligent and adapt to changes in environmental conditions. Population reductions require diligence on the part of landowners to reduce food availability and maintain trapping pressure.		
Commitment	Moderate: Many landowners already engage in feral hog control to reduce damage to pastures and crops.		
Needs	Moderate: Landowners benefit from technical and educational resources to inform them about feral hog management options. Funds are needed to deliver these workshops.		
Potential Funding Sources	CWA §319(h) grant program; Texas Department of Agriculture (TDA) Feral Hog Grant Program; TDA County Hog Out Management Program (CHOMP) ‡		

†Load reduction calculations described in Appendix B
‡Funding sources described in Section 7.4

Management Measure 3 – Identify and repair or replace failing on-site sewage systems

GIS analysis indicated OSSFs are a relatively moderate contributor to potential bacterial loadings across the watershed. Nearly all the soils in the watershed are classified as "Somewhat Limited" or "Very Limited" for OSSF drain fields (Figure 6). This indicates that conventional septic tank systems are not suitable for the proper treatment of household wastewater. In these areas, advanced treatment systems, most commonly aerobic treatment units, are suitable alternative options for wastewater treatment. While advanced treatment systems are highly effective, 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 non-existent OSSFs were a concern raised by stakeholders. The exact number of failing systems is unknown. Based on stakeholder feedback and literature failure rates, as many as 780 systems may be malfunctioning across the watershed. Improper system design or selection, improper maintenance and lack of education are likely reasons contributing to OSSF failure. In some cases, systems can be treated and repaired while in other cases, systems need to be redesigned and replaced; however, homeowners must have the awareness and resources to address OSSF problems when they arise.

To address these needs, efforts will focus on expanding and providing education and workshops to homeowners. Additionally, resources should be secured to assist homeowners who do not have access to resources to repair or replace OSSF systems should issues arise. The feasibility of replacing 15% of OSSFs within the watershed is very low. Therefore, stakeholders decided to target 5% of failing OSSFs within the watershed. This equates to approximately 40 OSSFs in the Lavaca River watershed and 11 within the Rocky Creek watershed. While OSSFs should be replaced as needed across the entire watershed, priority will be placed on subwatersheds 1, 5, 6, 9, 10 and 12. Additionally, priority will be placed on OSSFs within 150 yards of perennial water bodies. Table 16 summarizes management measures for on-site sewage systems.

Table 16. Management measure 3: Identify and repair or replace failing on-site sewage systems.

<table>
<tr><th colspan="4">Source: Failing or Non-Existent OSSFs</th></tr>
<tr><td colspan="4">Problem: Fecal bacteria reaching streams from untreated or insufficiently treated household sewage</td></tr>
<tr><td colspan="4">Objectives:
• Reduce the number of failing OSSFs.
• Work with counties and communities to replace failing OSSFs as funding allows.
• Educate homeowners on system operations and maintenance.</td></tr>
<tr><td colspan="4">Critical Areas: Subwatersheds 1, 5, 6, 9, 10 and 12 and systems within any subwatershed and within 150 yards of a perennial water body</td></tr>
<tr><td colspan="4">Goal: Repair or replace 40 failing OSSFs in the Lavaca River watershed, including at least 11 in the Rocky Creek watershed.</td></tr>
<tr><td colspan="4">Description: Expanded education programs and workshops will be delivered to homeowners on proper maintenance and operation of OSSFs. Failing or non-existent systems will be repaired or replaced as appropriate and as funding allows.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>TWRI, counties, AgriLife Extension</td><td>Identify and secure funding sources to administer OSSF replacement/repair program</td><td>2019-2029</td><td>N/A</td></tr>
<tr><td>Homeowners, contractor, AgriLife Extension, TWRI, counties</td><td>Identify, repair/replace OSSFs as funding allows</td><td>2019-2029</td><td>$8,000-$10,000/system (estimate)</td></tr>
<tr><td>AgriLife Extension, TWRI</td><td>Deliver OSSF operations and maintenance workshop</td><td>2020, 2024, 2028</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">As planned, repair or replacement of 40 failing systems in the Lavaca River watershed would result in a potential load reduction of 4.72×10^{13} cfu E. coli/yr. Of these 40 systems, at least 11 should be targeted toward Rocky Creek subwatersheds, which would result in a potential load reduction of 1.30×10^{13} cfu E. coli annually in Rocky Creek.†</td></tr>
<tr><td>Effectiveness</td><td colspan="3">High: Replacement or repair of failing OSSFs yields direct E. coli reductions.</td></tr>
<tr><td>Certainty</td><td colspan="3">Low: The level of funding available to identify, inspect and repair or replace OSSFs is uncertain; however, funding sources are available for assistance.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Watershed stakeholders acknowledge failing OSSFs as a potential source of bacteria loading. However, lack of resources to address the issue prevents high levels of commitment.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial resources are the primary need to repair and replace systems as many homeowners do not have the resources to fund replacement themselves. Financial resources are also needed to fund programs to identify systems in need of repair and replacement. Finally, many homeowners with failing systems may not even realize their systems are failing; therefore, education is critical.</td></tr>
<tr><td>Potential Funding Sources</td><td colspan="3">CZM Program and CMP*, CWA §319(h) grant program; Texas Supplemental Environmental Projects (SEP); local funds, property owners‡</td></tr>
</table>

†Load reduction calculations described in Appendix B
‡Funding sources described in Section 7.4
*CMP funding cannot be used on private property or outside of the coastal zone.

Management Measure 4 – Increase proper pet waste management

Dog waste was identified as the second largest potential bacteria source in the watershed. Given the association between dogs and human activity, addressing the waste and bacteria 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.

Adoption of this practice across the watershed, however, is likely 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 subwatersheds 5, 7, 12 and 21. Table 17 summarizes management measures for pet waste.

Table 17. Management measure 4: Increase proper pet waste management.

Source: Dog Waste			
Problem: Direct and indirect fecal bacteria loading from household pets			
Objectives: • Educate residents on disposal of pet waste. • Install and maintain pet waste stations in public areas.			
Critical Areas: High dog concentration areas, subwatersheds 5, 7, 12 and 21			
Goal: Reduce the amount of dog waste that may wash into water bodies during rainfall and irrigation runoff by providing educational and physical resources to increase stakeholder awareness of water quality and health issues caused by excessive pet waste. Specifically, install two pet waste stations in Yoakum, one in Hallettsville, one in Shiner and one in Moulton.			
Description: Expand education and outreach to local residents and pet owners on the need to properly dispose of pet waste and its critical link to water quality. Install and maintain pet waste stations and signage in public areas to facilitate increased disposal of pet waste.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Cities	Install at least 5 pet waste stations in area parks and other potentially high dog concentration areas	2019-2029	$500/station
Cities, counties, AgriLife Extension, TWRI	Develop and provide educational resources to residents	2019-2029	N/A
Estimated Load Reduction			
Load reductions resulting from this management measure are reliant on changes in people's behavior, and therefore uncertain. Assuming 20% of targeted individuals respond by properly disposing of pet waste, an annual load reduction of 3.71×10^{13} cfu *E. coli*/yr is expected in the Lavaca River and 7.36×10^{12} cfu *E. coli*/yr in Rocky Creek.†			
Effectiveness	High: Collecting and properly disposing of dog waste is a direct method of preventing *E. coli* from entering water bodies, directly reducing potential loading in water bodies.		
Certainty	Low: Some pet owners in the watershed likely already collect and properly dispose of dog waste. Those who do not properly dispose of pet waste are likely difficult to reach or convince. The number of additional people who will properly dispose of waste is difficult to anticipate.		
Commitment	Low: There are relatively few public parks in the watershed and/or city staff indicate that relatively few dog owners use these parks. Adding signage or waste stations is not a high priority.		
Needs	Moderate: Pet waste stations are relatively inexpensive. Additional work required to maintain stations should be minimal.		
Potential Funding Sources	CWA §319(h) grant program, local funds‡		

†Load reduction calculations described in Appendix B
‡Funding sources described in Section 7.4

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

Potential bacteria loading from urban and impervious surface runoff is likely relatively low compared to other sources based on GIS analysis. Implementing stormwater BMPs on municipality-owned property is subject to political and economic feasibility and may result in relatively low load reductions compared to other management options, given the rural nature of the watershed. However, strategically placed demonstration projects provide valuable educational opportunities for residents on the water quality impacts of stormwater runoff.

The objective of this management measure is to work with local municipalities to identify and install demonstration BMPs that manage stormwater runoff as appropriate and as funding permits. Potential BMPs include, but are not limited to, rain gardens, rain barrels/cisterns, green roofs, permeable pavement, bioretention, swales and detention ponds. These BMPs can help reduce stormwater runoff quantity and directly or indirectly improve runoff quality. Furthermore, volume reductions from BMPs can reduce stormwater entering local sewage collection systems through inflow and infiltration. The second objective is to deliver education programs in the watershed that educate residents about the impacts of stormwater on riparian areas and water quality. Table 18 summarizes management measures for stormwater runoff.

Table 18. Management measure 5: Implement and expand urban and impervious surface stormwater runoff management.

Source: Urban Stormwater Runoff			
Problem: Fecal bacteria loading from stormwater runoff in developed and urbanized areas			
Objectives: • Educate residents about stormwater BMPs. • Identify and install stormwater BMP demonstration projects, including identification of appropriate sites and costs.			
Critical Areas: Urbanized areas in subwatersheds 5, 7, 12 and 21			
Goal: Reduce *E. coli* loading associated with urban stormwater runoff through implementation of stormwater BMPs as appropriate and to increase local residents' awareness of stormwater pollution and management.			
Description: Potential locations and types of stormwater management BMP demonstration projects will be identified in coordination with cities, public works and property owners.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Cities, property, owners, contractors	Identify and install stormwater BMPs as funding becomes available	2019-2029	$4,000-$45,000/acre (estimate)
AgriLife Extension, TWRI	Deliver education and outreach (Riparian and Stream Ecosystem Education workshop or others as appropriate) to landowners	2020, 2025	N/A
Estimated Load Reduction			
Installation of stormwater BMPs that reduce runoff or treat bacteria will result in direct reductions in bacteria loadings in the watershed. Potential load reductions were not calculated because the location, type and sizes of projects installed will dictate the potential load reductions; however, they have not been identified yet.			
Effectiveness	Moderate to High: The effectiveness of BMPs at reducing bacteria loadings is dependent on the design, site selection and maintenance of the BMP.		
Certainty	Moderate: Installation of BMPs requires sustained commitment from city officials or property owners.		
Commitment	Moderate to Low: Urban stormwater management is not a high priority for local municipalities; financial or other incentives will be needed to encourage and secure long-term commitment.		
Needs	High: It is unlikely stormwater BMPs will be installed without financial assistance.		
Potential Funding Sources	CZM Program and CMP, CWA §319(h) grant program, local funds†		

†Funding sources described in Section 7.4

Management Measure 6 – Address inflow and infiltration

Although infrequent, SSOs and unauthorized WWTF discharges can contribute to bacteria loads, particularly during high runoff events. I&I is surface runoff that enters the sewer collection system through manhole covers, sewer cleanouts, damaged pipes and faulty connections. 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.

Some utilities in the watershed have conducted smoke testing of collection systems to identify connections and infrastructure contributing to increased I&I. Smoke testing is recommended for utilities that have not conducted it yet. I&I that occurs due to damaged pipes or cleanouts beyond the municipal utility connection is the responsibility of the property owner. Although the utility will inform customers of issues and their responsibility to repair the connection, homeowners might not be compelled to repair the issue. This could be attributed to capital costs, lack of concern or the perception that it is the city's responsibility to fix the problem. Therefore, utilities are interested in developing programs to encourage the repair of damaged sewage piping or cleanouts. In addition to repairing and replacing connections contributing to I&I, providing education to customers is critical. It is recommended to develop and deliver materials that educate and inform about I&I, discourage draining land with sewer cleanouts and educate utility users about proper materials that can go in the drain. Table 19 summarizes management measures addressing inflow and infiltration.

Management Measure 7 – Reduce illicit 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, hogs 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 bacteria 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 bacteria loadings. Table 20 summarizes management measures for illicit dumping.

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 21). Improvements in urban stormwater and illicit dumping can also be expected to contribute to improved water quality.

Table 19. Management measure 6: Address inflow and infiltration.

<table>
<tr><th colspan="4">Source: Municipal Sanitary Sewer Overflow (SSO) or Unauthorized Discharges</th></tr>
<tr><td colspan="4">Problem: Fecal bacteria loading from unauthorized discharges when excessive water enters the sanitary sewer system through I&I</td></tr>
<tr><td colspan="4">Objectives:
Reduce unauthorized discharges and SSOs.
Replace and repair sewage infrastructure where I&I problems have been identified.
Educate residents and home owners about the impacts of I&I, the need for infrastructure maintenance and what types of waste can be put in the sewer system.</td></tr>
<tr><td colspan="4">Critical Areas: Urbanized areas in subwatersheds 5, 7, 12 and 21</td></tr>
<tr><td colspan="4">Goal: Reduce periodic E. coli loading associated with municipal sewer system failures that occur during high rain events and unauthorized discharges.</td></tr>
<tr><td colspan="4">Description: Smoke testing will be used to identify and prioritize connections where I&I problems exist. Sewage pipes and connections contributing to I&I will be replaced as funding allows. Education and outreach will be delivered to local residents.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participation</th><th>Recommendations</th><th>Period</th><th>Capital Costs</th></tr>
<tr><td>TWRI, AgriLife Extension, cities</td><td>Identify potential resources and develop programs to assist homeowners with sewage pipe replacement</td><td>2019-2029</td><td>N/A</td></tr>
<tr><td>Cities, property owners, contractors</td><td>Identify and replace pipes contributing to I&I problems as funding permits</td><td>2019-2029</td><td>$3,000-$20,000/site</td></tr>
<tr><td>Cities, AgriLife Extension, TWRI</td><td>Develop and deliver education material to residents and property owners</td><td>2019-2029</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 bacteria 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">Moderate to High: Although infrequent, reduction in SSOs and unauthorized discharges will result in direct reductions to bacteria loading during the highest flow events.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate to Low: Costs associated with sewer pipe replacement can be expensive to homeowners; homeowners often perceive the issue as a problem for the municipality to resolve.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Municipal public works have an incentive to resolve I&I issues to meet discharge requirements. However, lack of funding precludes replacement of sewage pipe.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial needs are likely significant.</td></tr>
<tr><td>Potential Funding Sources</td><td colspan="3">CZM Program and CMP, CWA §319(h) grant program, Clean Water State Revolving Fund, local funds†</td></tr>
</table>

†Funding sources described in Section 7.4

Table 20. Management measure 7: Reduce illicit dumping.

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.			
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.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
AgriLife Extension, TWRI, counties	Develop and deliver educational and outreach materials to residents	2019-2029	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 bacteria 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.		
Potential Funding Sources	CWA §319(h) grant program, local funds, SEP†		

†Funding sources described in Section 7.4

Table 21. Estimated potential load reductions expected from full WPP implementation.

Source	Management Measures	Potential *E. coli* Load Reduction – Lavaca River†	Potential *E. coli* Load Reduction – Rocky Creek†
Livestock	• Hire WQMP technician • Implement WQMPs • Implement conservation plans • Education and outreach	1.00×10^{15}	2.25×10^{14}
Wildlife/feral hogs	• Construct feed exclosures • Feral hog removal • Implement wildlife management plans and practices • Education and outreach	8.48×10^{13}	1.66×10^{13}
OSSFs	• Develop OSSF repair/replacement program • Repair/replace faulty OSSFs • Education and outreach	4.72×10^{13}	1.30×10^{13}
Household pets/dogs	• Install pet waste stations • Develop and deliver education material	3.71×10^{13}	7.36×10^{12}
Urban stormwater	• Identify/install stormwater BMP projects • Develop and deliver education materials	N/A	N/A
SSOs/unauthorized discharges	• Identify infrastructure replacement needs • Develop repair program • Develop and deliver education materials	N/A	N/A
Illicit dumping	• Develop and deliver education materials	N/A	N/A
	Total Potential Reduction	1.17×10^{15}	2.62×10^{14}
	Reduction Required	9.29×10^{14}	1.39×10^{14}

† in units of cfu/yr

Chapter 6 Education and Outreach

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 Lavaca River watershed. The education and outreach component of implementation must focus on keeping the public, landowners and agency personnel informed of project activities, provide information about appropriate management practices and assist in identifying and forming partnerships to 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, implementation and the WPP itself. Currently, TWRI has taken the lead on this role. However, a full-time position is recommended to support WPP implementation.

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

Public Meetings

Throughout the course of developing the WPP, stakeholder engagement has been critical. Public meetings held to develop the WPP with local stakeholders began in October 2016. Throughout the process, numerous local stakeholders have participated in the many public meetings, one-on-one meetings and workshops associated with WPP development.

Table 22. Watershed stakeholders that will need to be engaged throughout the implementation of the WPP.

Lavaca River WPP Stakeholders
Local residents, landowners, businesses
Local governments – Edna, Hallettsville, Moulton, Shiner, Yoakum, Jackson County, Lavaca County
State Agencies – TCEQ, TSSWCB, TPWD, AgriLife Extension
Federal Agencies – USDA NRCS
Regional Entities – LNRA staff and board members, SWCD boards

Future Stakeholder Engagement

Watershed stakeholders (Table 22) will be continually engaged throughout the entire process and following the transition of efforts from development to implementation of the WPP. The Watershed Coordinator will play a critical role in this transition by continuing to organize and host periodic public meetings and needed educational events in addition to seeking out and meeting with focused groups of stakeholders to find and secure implementation funds. The coordinator will also provide content to maintain and update the project website, track WPP implementation progress and participate in local events to promote watershed awareness and stewardship. News articles, newsletters and the project website will be primary tools used to communicate with watershed stakeholders on a regular basis and will be developed to update readers periodically on implementation progress, provide information on new implementation opportunities, inform them on available technical or financial assistance, and other items of interest related to the WPP effort.

Education Programs

Educational programming will be a critical part of the WPP implementation process. Multiple programs geared toward providing information on various sources of potential pollutants and feasible management strategies will be delivered in and near the Lavaca River watershed and advertised to watershed stakeholders. An approximate schedule for planned programming is provided in Chapter 8. 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 NPS pollution. This statewide program promotes the adoption of BMPs that have been proven to effectively reduce bacterial contamination of streams. This program provides educational support for the development of conservation plans by illustrating the benefits of many practices available for inclusion in a conservation plan to program participants. This program will likely be delivered in the watershed once every 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. Based on needs identified early during WPP planning, trainings will be scheduled for every third year. 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: www.gbra.org/septic.swf.

Figure 31. Local stakeholders at the Texas Watershed Stewards Workshop in Edna, TX. Photo courtesy of Michael Kuitu, AgriLife Extension.

Texas Well Owners Network Training

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network (TWON) Program provides 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 Lavaca River watershed. Information on this program can be found at: 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 NPS 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 Lavaca River watershed.

Wildlife Management Workshops

Wildlife have numerous significant impacts on the Lavaca River watershed and as a result, periodic wildlife management workshops are warranted to provide information on management strategies and available resources to those interested. The Watershed Coordinator will work with AgriLife Extension wildlife specialists and TPWD as appropriate to plan and secure funding to deliver workshops in and near the Lavaca River watershed. Wildlife management workshops will be advertised through newsletters, news releases, the project website and other avenues as appropriate.

Figure 32. Lavaca River field trip during a Riparian and Stream Ecosystem workshop. Photo courtesy of Millie Stevens, USDA NRCS.

Public Meetings

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

Newsletters and News Releases

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

Chapter 7
Resources to Implement the Watershed Protection Plan

Introduction

The Lavaca River 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 hire 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 23 provides a summary of the potential sources of technical assistance for each management measure.

Table 23. Summary of potential sources of technical assistance.

Technical Assistance	
Management Measure	**Potential Sources**
MM1 : Promote and implement WQMPs or conservation plans	TSSWCB; local SWCDs; NRCS; AgriLife Extension
MM2: Promote technical and direct operational assistance to landowners for feral hog control	AgriLife Extension; TPWD; NRCS; TSSWCB
MM3: Identify and repair or replace failing on-site sewage systems	Lavaca County designated representative, Jackson County Office of Permitting; AgriLife Extension
MM4: Increase proper pet waste management	City public works departments; AgriLife Extension
MM5: Implement and expand urban and impervious surface stormwater runoff management	City public works departments; engineering firms; AgriLife Extension
MM6: Address inflow and infiltration	City public works departments; engineering firms, TCEQ
MM7: Reduce illicit dumping	AgriLife Extension; county law enforcement; TPWD game wardens

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 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 Lavaca and Jackson counties. 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. 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. Technical assistance with education and outreach is available through AgriLife Extension.

Inflow and Infiltration

City public works staff will be relied upon to provide technical expertise on local systems, identify problem areas and work with firms as needed to smoke test or provide other infrastructure assessments. The repair and/or replacement of pipes will require engineering design and assistance from contractors and outside firms. TCEQ also provides technical assistance for municipalities to address SSO issues through the SSO Initiative.

Illicit Dumping

Efforts to reduce illicit dumping will focus on education and outreach. AgriLife Extension will provide technical assistance with education and outreach efforts. County law enforcement and TPWD game wardens are the primary source of enforcement and monitoring activities associated with illicit dumping.

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.

Lavaca County Designated Representative

OSSF construction or replacement in Lavaca County requires a permit to be filed with Lavaca 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 Lavaca County must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider or licensed professional installer.

Jackson County Office of Septic and Development Permitting

As an authorized agent of TCEQ, Jackson 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 Edna, Hallettsville, Moulton, Shiner and Yoakum 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

The USDA 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. Assistance is available to help landowners (1) maintain and improve private lands, (2) implement improved land management technologies, (3) protect water quality and quantity, (4) improve wildlife and fish habitat, and (5) enhance recreational opportunities. Local NRCS service centers are located in Hallettsville and Edna.

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 are able to 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 SWCDs include Lavaca SWCD #334 and Jackson SWCD #336.

Texas Commission on Environmental Quality

The TCEQ Sanitary Sewer Overflow (SSO) Initiative is a voluntary program for permitted facilities and municipalities. Through the initiative, an SSO Plan is developed outlining the causes of SSOs, mitigation and corrective actions, as well as a timeline for implementation. Assistance for SSO planning and participation in the SSO Initiative is available through the TCEQ Regional Office (Region 14, Corpus Christi) and the TCEQ Small Business and Environmental Assistance Division.

Texas Parks and Wildlife Department

The 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 the 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 Jackson or Lavaca SWCD offices is the first step for operators to begin the plan development process. The Wharton Regional Office administers the TSSWCB WQMP program in Lavaca and Jackson counties.

Financial Resource Descriptions

Successful implementation of the Lavaca River 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 USDA 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 Sources

Coastal Zone Management Program and Coastal Management Program

The CZM Program, administered by the National Oceanographic and Atmospheric Administration (NOAA) and the Texas General Land Office (TGLO), is a voluntary partnership between the federal government and U.S. coastal and Great Lake states and territories and is authorized by the Coastal Zone Management Act (CZMA) of 1972 to address national coastal issues. The act provides funding for protecting, restoring and responsibly developing our nation's diverse coastal communities and resources. To meet the goals of the CZMA, the National CZM Program takes a comprehensive approach to coastal resource management; balancing the often competing, and occasionally conflicting, demands of coastal resource use, economic development and resource conservation. Some of the key elements of the National CZM Program include:

- Protecting natural resources
- Managing development in high hazard areas
- Giving development priority to coastal-dependent uses
- Providing public access for recreation
- Coordinating state and federal actions

The CZM Program provides pass-through funding to TGLO, which, in turn, uses the funding to finance coastal restoration, conservation and protection projects under TGLO's CMP.

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

The EPA provides grant funding to the State of Texas to implement projects that reduce NPS 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/grant-pgm-html and http://www.tsswcb.texas.gov/managementprogram.

Conservation Innovation Grants

The USDA administers the CIG Program, which is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, EQIP funds are used to award competitive grants to non-federal governmental or non-governmental organizations, Tribes or individuals.

Conservation Stewardship Program

The CSP is a voluntary conservation program administered by USDA NRCS that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities as well as improving, maintaining and managing existing 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.

Environmental Quality Incentives Program

Operated by USDA NRCS, the EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns in addition to opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland. Individuals engaged in livestock or agricultural production on eligible land are permitted to participate in EQIP. Practices selected address natural resource concerns and are subject to the NRCS technical standards adapted for local conditions. They also must be approved by the local SWCD. Local work groups are formed to provide recommendations to the USDA NRCS that advise the agency on allocations of EQIP county-based funds and identify local resource concerns. Watershed stakeholders are strongly encouraged to participate in their local work group to promote the objectives of this WPP with the resource concerns and conservation priorities of EQIP. Information regarding EQIP can be found at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.

Regional Conservation Partnership Program

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

Rural Development Water and Environmental Programs

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

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

More information about the Rural Development Program can be found at: http://www.rd.usda.gov/programs-services/all-programs/water-environmental-programs.

Urban Water Small Grants Program

The objective of the Urban Waters Small Grants Program, administered by the EPA, is to fund projects that will foster a comprehensive understanding of local urban water issues, identify and address these issues at the local level, and educate and empower the community. In particular, the Urban Waters Small Grants Program seeks to help restore and protect urban water quality and revitalize adjacent neighborhoods by engaging communities in activities that increase their connection to, understanding of and stewardship of local urban waterways.
More information about the Urban Waters Small Grants Program can be found at: https://www.epa.gov/urbanwaters/urban-waters-small-grants.

State 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. The LNRA is the CRP partner for the Lavaca River watershed. The program supports water quality monitoring and annual water quality assessments, and engages stakeholders in addressing water quality concerns in the Lavaca-Navidad River Basin.
More information about the Clean Rivers Program is available at: http://www.lnra.org/programs/clean-rivers/.

Clean Water State Revolving Fund

The CWSRF, authorized through the CWA and administered by the TWDB, provides low-interest loans to local governments and service providers for infrastructure projects that include stormwater BMPs, WWTFs and collection systems. The loans can spread project costs over a repayment period of up to 20 years. Repayments are cycled back into the fund and used to pay for additional projects. Through 2016, the program committed over $9.8 billion for projects across Texas. More information on CWSRF is available at: http://www.twdb.texas.gov/financial/programs/CWSRF/.

Feral Hog Abatement Grant Program

The Texas Department of Agriculture (TDA) provides grant funding to governmental agencies (counties, cities, etc.) and Texas higher education institutions for practical and effective projects to develop and implement long-term feral hog abatement strategies. AgriLife Extension and TPWD currently receive funding through this program. In the past, individual and groups of counties have applied to receive funds for programs to control feral hogs including providing community traps or bounty payments. More information is available at: https://www.texasagriculture.gov/GrantsServices/TradeandBusinessDevelopment/FeralHogGrantProgram.

Landowner Incentive Program

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

Supplemental Environmental Projects

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

Texas Farm and Ranch Lands Conservation Program

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

Water Quality Management Plan Program

WQMPs are management plans developed and implemented to improve land and water quality. Technical assistance to develop plans that meet producer and state goals is provided by TSSWCB and local SWCDs. Once the plan is developed, TSSWCB may financially assist implementing a portion of prescribed BMPs. As of 2017, TSSWCB has developed and certified 32 WQMPs in the watershed. Through these plans, over 5,800 acres are currently enrolled in the Lavaca River watershed area and include practices such as conservation cover, prescribed grazing, fencing, heavy-use area protection, water facilities, wells and upland wildlife management.

Other Sources

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

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

Chapter 8 Measuring Success

Introduction

Implementing this WPP requires coordination of many stakeholders over the next 10 years. Implementation will focus on addressing the most readily manageable sources of *E. coli* in the watershed to achieve water quality targets. This plan has identified the substantial financial commitments, technical assistance and education required to achieve these targets. The management measures identified in this WPP are voluntary but supported at the recommended levels by watershed stakeholders.

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

Water Quality Targets

An established water quality goal defines the target for future water quality and allows the needed bacteria load reductions to be defined. The appropriate goal for water quality in the Lavaca River is the existing primary contact recreation standard for *E. coli* of 126 cfu/100mL. The target for Rocky Creek is currently established at the same standard. However, this target may change if the ongoing RUAA study determines that a different water quality standard is appropriate for the water body. If the water quality standard does change, the target will be addressed during a WPP update. Table 24 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 24. Water quality targets.

Station(s)	Segment	Current Concentration†	5 yrs After Implementation†	10 yrs After Implementation†
12424	1602_03 Lavaca River Above Tidal	295	211	126
18190	1602B_01 Rocky Creek	222	174	126

† in units of MPN *E. coli*/100mL

Additional Data Collection Needs

Continued monitoring of water quality in the Lavaca River 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 LNRA on a quarterly basis at four different sites in the above-tidal segments of the Lavaca River and Rocky Creek (Table 3) through the CRP.

Increasing the frequency of currently employed CRP data collection at these watershed index sites 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 at these index sites with anticipation that the data will enhance trend analysis and better illustrate improvements in water quality. Furthermore, additional 24-hour DO monitoring will be recommended as needed in Segment 1602C to facilitate delisting of the water body once the 24-hr criterion is finalized.

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

Water quality improvements are often harder to identify using the seven-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 three 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 Lavaca River 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 25 and Table 26). Responsible parties 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 Lavaca River 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 NPS pollutants, such as the Lavaca River, 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. An annual 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.

Table 25. Lavaca River watershed management measures, responsible party, goals and estimated costs.

Management Measure	Responsible Party	Unit Cost	Implementation Goals (years after implementation begins)†										Total Cost
			1	2	3	4	5	6	7	8	9	10	
Livestock													
Hire WQMP field technician.	TSSWCB, SWCDs	$75,000/yr	1										
Develop 100 WQMPs/conservations plans.	TSSWCB, SWCDs, NRCS	$15,000	20		40		60		80		100		$1,500,000
Feral Hogs													
Install feral hog enclosures.	Landowners	$200	As many as possible										N/A
Feral hog removal	Landowners	N/A	15% reduction or > 2,439 hogs/yr										N/A
Develop and implement Wildlife Management Plans and Practices.	Landowners, TPWD, TSSWCB, NRCS	N/A	As many as possible										N/A
OSSFs													
Develop OSSF repair/replacement program.	Watershed Coordinator, counties, AgriLife Extension	N/A	1										N/A
Repair/replace faulty OSSFs.	Homeowner	$8,000			10		20		30		40		$320,000
Pet Waste													
Install and maintain pet waste stations.	Cities	$500 for stations plus $100/yr/station			2		3		4		5		$4,400
Develop educational and outreach materials.	Cities, AgriLife Extension, Watershed Coordinator	N/A	Develop and deliver annually										N/A
Urban Stormwater													
Identify and install potential stormwater BMP projects.	Cities	$4,000 to $45,000/acre treated	As many as possible										N/A
SSOs and Unauthorized Discharges													
Develop program to repair private connections contributing to I&I.	Cities, AgriLife Extension, property owners	N/A	1										N/A
Smoke testing and repair of faulty pipes and connections	Cities, contractors	$2,000-$2,500/mile; $3,000-$20,000/repair	As funding allows										N/A
Develop and deliver educational materials.	Cities, AgriLife Extension, TWRI	N/A	Develop and deliver annually										N/A

Table 25 continued.

Management Measure	Responsible Party	Unit Cost	Implementation Goals (years after implementation begins)†										Total Cost
			1	2	3	4	5	6	7	8	9	10	
Illicit Dumping													
Develop educational and outreach materials.	Counties, AgriLife Extension, Water-shed Coordinator	N/A	Develop and deliver annually										N/A
General Watershed Management													
Hire Watershed Coordinator.	TWRI	$75,000/yr	1										
Semi-annual meetings	TWRI, Watershed Coordinator	$300/meeting	Semi-annually										$6,000

† number of measures are cumulative

Table 26. Lavaca River watershed education and outreach implementation schedule, responsible parties and estimated costs.

Education and Outreach Programs and Activities	Responsible Party	Unit Cost	Planned Delivery (years after implementation begins)†										Total Cost
			1	2	3	4	5	6	7	8	9	10	
Livestock													
Lone Star Healthy Streams (Cattle) ‡	AgriLife Extension, Watershed Coordinator	N/A		1		1		1		1		1	N/A‡
Management practice field days	AgriLife Extension, Watershed Coordinator, NRCS	$1,000			1		1		1		1		$4,000
Feral Hogs													
Lone Star Healthy Streams (feral hog) ‡ or feral hog management workshop	AgriLife Extension, Watershed Coordinator, Texas Wildlife Services, TPWD	N/A or $3,000/ feral hog workshop	1		1		1		1		1		$15,000
OSSFs													
OSSF owner O&M training	AgriLife Extension	$3,000	1		1		1		1		1		$15,000
General Watershed Management													
Texas Watershed Stewards	AgriLife Extension	N/A		1		1		1		1		1	N/A‡
Texas Well Owners Network	AgriLife Extension	N/A		1		1		1		1		1	N/A‡
Texas Riparian and Ecosystem Training	AgriLife Extension	N/A	1		1		1		1		1		N/A‡
Watershed newsletter	Watershed Coordinator	$500	1	1	1	1	1	1	1	1	1	1	$5,000

† number of programs delivered per period, not cumulative

‡ additional funding not required; currently funded through existing resources

References

AVMA (American Veterinary Medical Association). 2012. U.S. Pet Ownership & Demographics Sourcebook (2012 Edition). 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. http://twri.tamu.edu/reports/2012/tr454.pdf

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

Franklin, T. M., Helinski, R., Manale A. 2007. Using adaptive management to meet conservation goals. U.S. Environmental Protection Agency Papers. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013594.pdf

Mapston, M. E. 2010. Feral Hogs in Texas. Texas Cooperative Extension. Texas Wildlife Services. B-6149 03-07. http://feralhogs.tamu.edu/files/2010/05/B-6149-Feral-Hogs-in-Texas.pdf

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. Savannah River National Laboratory, Aiken, South Carolina. http://sti.srs.gov/fulltext/SRNL-RP-2009-00869.pdf

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

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

TCEQ (Texas Commission on Environmental Quality). 2016. 2014 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d). https://www.tceq.texas.gov/waterquality/assessment/14twqi/14txir

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

USCB (United States Census Bureau). 2010. American Fact Finder General Demographic Characteristics. 2010 Census. https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

USCB. 2014. American Fact Finder Selected Social Characteristics in the United States. 2014 American Community Survey 5-yr Estimates. https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

USDA (United States Department of Agriculture). 2017. Web Soil Survey. https://websoilsurvey.nrcs.usda.gov/

USDA. 2014. 2014 Quick Stats (2012 Census). National Agricultural Statistics Service. https://quickstats.nass.usda.gov/?source_desc=CENSUS

USEPA (United States Environmental Protection Agency). 2016. Enforcement & Compliance History Online (ECHO). http://echo.epa.gov/

USEPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. EPA 841-B-08-002. https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

USEPA. 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. https://www.epa.gov/sites/production/files/2015-07/documents/2007_08_23_tmdl_duration_curve_guide_aug2007.pdf

USEPA. 2000. Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management. EPA Office of Water. Federal Register, October 18, 2000, pp. 62565-62572. https://www.federalregister.gov/documents/2000/10/18/00-26566/unified-federal-policy-for-a-watershed-approach-to-federal-land-and-resource-management

USGS (United States Geological Survey). 2012. National Hydrography Dataset (NHD). http://nhd.usgs.gov/data.html

USGS. 2013. National Elevation Database (NED). http://nationalmap.gov/viewer.html

USGS. 2014. National Land Cover Database 2011 (NLCD 2011). Multi-resolution Land Characteristics Consortium (MRLC). https://www.mrlc.gov/nlcd2011.php

Wagner, K. L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, TX: Texas Water Resources Institute. TR-347. http://twri.tamu.edu/reports/2009/tr347.pdf

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.

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 in-stream E. coli levels.” Texas Water Journal. 4(2): 1-13.

Appendix A: Potential Load Calculations

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

Livestock

The first step to calculate potential bacteria loads from cattle is to develop cattle population estimates. Stakeholder input was critical to develop livestock population estimates across the watershed. Based on input from the agricultural work group, we estimated stocking rates of 1 animal unit (AnU)/4 acres of improved pasture and 1 AnU/11 acres of rangeland. This stocking rate likely fluctuates annually based on local conditions but provides a baseline to estimate potential loadings that can be adjusted and fine-tuned if new data becomes available. Other difficulties in developing cattle population estimates include the reliance on the NLCD to identify pasture and rangeland. From this dataset, it is impossible to parse out land that is used for hay production versus grazed pasture. Furthermore, identifying the actual stocking rate used by a particular landowner is not possible with this dataset. Therefore, reliance on local stakeholders was critical to properly estimating cattle populations. Finally, estimates were compared to NASS cattle population estimates for watershed counties to evaluate if the generated estimates compared to USDA census figures. Based on these inputs, there are an estimated 73,948 cattle AnU across the entire watershed.

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

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

Where:

PAL_{cattle} = Potential annual *E. coli* loading attributed to cattle
AnU = Animal Units of cattle (~1,000 lbs of cattle)
FC_{cattle} = Fecal coliform loading rate of cattle, 8.55×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to cattle is: 1.45×10^{17} cfu *E. coli*/yr.

Feral Hogs

Feral hog populations were estimated using an estimated population density of 1 feral hog/33.3 acres of suitable habitat. The density estimate was based on estimates developed for the nearby Mission and Aransas watersheds as well as TPWD and NRI biologist input (Wagner and Moench 2009). GIS analysis was used to estimate watershed-wide and subwatershed feral hog populations. Based on this analysis, an estimated 16,259 feral hogs exist across the watershed. Like cattle, these numbers provide general estimates that likely change based on annual conditions. Furthermore, feral hogs likely roam across large areas that might be larger than individual subwatersheds; however, these estimates provide initial guidance on where to focus control efforts based on suitable habitats.

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

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

Where:

PAL_{fh} = Potential annual *E. coli* loading attributed to feral hogs
N_{fh} = Number of feral hogs
AnUC = Animal Unit Conversion; 0.125 animal units/feral hog (Wagner and Moench 2009)
FC_{fh} = Fecal coliform loading rate of feral hogs, 1.21×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to feral hogs is: 6.03×10^{14} cfu *E. coli*/yr.

Domestic Pets

Dog estimates were generated using an estimated population density of 0.584 dogs/household that was applied to weighted census block household data (AVMA 2012). It was assumed that approximately 40% of dog owners do not pick up dog waste (Swann 1999). Based on these assumptions, there are an estimated 8,069 dogs across the watershed, with about 3,228 dogs whose owners do not pick up after them. Using the resulting dog population estimate, the annual load due to dogs was 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 that owners do not pick up after
FC_d = Fecal coliform loading rate of dogs, 5.00×10^9 cfu fecal coliform/dog/day (USEPA 2001)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

Therefore, the estimated potential annual loading attributed to dogs is: 3.71×10^{15} cfu *E. coli*/yr.

OSSFs

Methods to estimate OSSF locations and numbers are described in Section 3.5 of this WPP. Using the OSSF estimates, potential *E. coli* loading across the watershed and for individual subwatersheds was estimated. The annual load from OSSFs was calculated as:

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

Where:

PAL_{ossf} = Potential annual *E. coli* loading attributed to OSSFs
N_{ossf} = Number of OSSFs
N_{hh} = Average number of people/household (2.05)
Production = Assumed sewage discharge rate; 70 gallons (gal)/person/day (Borel et al. 2015)
Fail Rate = Assumed failure rate; 15% (Reed, Stowe & Yanke 2001)
FC_s = Fecal coliform concentration in sewage; 1.0×10^6 cfu/100mL (USEPA 2001)
Conversion = Conversion rate from fecal coliform to *E. coli* (Wagner and Moench 2009)
and mL to gal (3578.4 mL/gal)

The estimated potential annual loading across all subwatersheds due to OSSFs is: 9.29×10^{14} cfu *E. coli*/yr.

Urban Stormwater Runoff

GIS analysis was used to calculate potential loadings from impervious or urbanized stormwater runoff. Using NLCD data, the acres of developed land cover (assumed impervious) were identified in each subwatershed. Annual runoff and potential annual loading were calculated for each subwatershed using the Simple Method outlined by the Center for Watershed Protection (Collins et al. 2008). Annual runoff is calculated as:

$$R = P \times P_j \times R_v$$

Where:

R = Runoff (in)
P = Average annual precipitation
P_j = Fraction of annual rain events that produce runoff. Assumed to be 0.9 (Collins et al. 2008)
R_v = Runoff coefficient

Rv is the runoff coefficient derived from empirical data and is calculated as:

$$R_v = 0.05 + 0.9 \times I_a$$

Where:

I_a = the fraction of impervious area in the subwatershed

Potential annual load is then calculated as:

$$PAL_{urban} = C \times R \times A \times Conversion$$

Where:

PAL_{urban} = Potential annual *E. coli* loading due to urban and impervious runoff
C = Average *E. coli* concentration for urbanized runoff, assumed to be 4.73×10^3 cfu/100mL (Makepeace et al. 1995)
R = Runoff as calculated above
A = Acres of developed/impervious surface
$Conversion$ = Unit conversion (1.03×10^{-3})

The estimated potential annual loading across all subwatersheds due to urbanized/impervious runoff is:
4.27×10^7 cfu *E. coli*/yr.

WWTFs

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

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

Where:

PAL_{wwtf} = Potential annual *E. coli* loading due to wastewater treatment plant discharges
$Discharge$ = Maximum permitted daily discharge (MGD)
$Concentration_{max}$ = Maximum average permitted concentration of *E. coli* in wastewater discharge (126 cfu/100 mL)
$Conversion$ = Unit conversion (3785.2 mL/gal)

The estimated potential annual loading across all subwatersheds due to WWTF discharges is: 1.62×10^{10} cfu *E. coli*/yr.

Appendix A. References

AVMA. 2012. U.S. Pet Ownership & Demographics Sourcebook (2012 Edition). 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. http://twri.tamu.edu/reports/2012/tr454.pdf

Collins, K., Hirschman, D., Schueler, T. 2008. Technical Memorandum: The Runoff Reduction Method. Ellicott City, MD: Center for Watershed Protection. http://owl.cwp.org/mdocs-posts/collinsk-_runoff_reduction_method/

Makepeace, D., Smith, D., Stanley, S. 1995. "Urban stormwater quality: Summary of contaminant data." Critical Reviews in Environmental Science and Technology. 25(2): 93-139. http://dx.doi.org/10.1080/10643389509388476

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

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

USEPA. 2001. Protocol for Developing Pathogen TMDLs: Source Assessment. 1st Edition. EPA Office of Water. 841-R-00-002. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt

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://twri.tamu.edu/reports/2009/tr347.pdf

Appendix B: Load Reduction Calculations

Livestock

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

According to USDA NASS data, there are approximately 1,262 producers and an estimated 73,948 AnU of cattle in the Lavaca River watershed (see Appendix A). As a result, a broad estimate of 58.5 AnU of cattle/producer was made. This can also be interpreted at 58.5 AnU of cattle addressed by each conservation plan or WQMP. Within the Rocky Creek watershed, there are approximately 408 producers and 17,944 AnU of cattle. This results in approximately 43.9 AnU cattle/plan. In reality, each WQMP or conservation plan will vary in size and number of animal units addressed. Actual potential load reductions will vary by actual existing land conditions, proximity to water bodies, number of animal units addressed by the management measure and the types of BMPs implemented by the plan.

To estimate expected *E. coli* reductions, efficacy values of likely BMPs were calculated from median literature reported values (Table 27). These BMPs were determined based on feedback from members of the Agriculture Work Group. Because the actual BMPs implemented per WQMP or conservation plan are unknown, an overall median efficacy value of 0.58 (58%) was used to calculate load reductions. Finally, the proximity of implemented BMPs to water bodies will influence the effectiveness at reducing loads. Typically, a proximity factor of 0.05 (5%) is used for BMPs in upland areas and 0.25 used in riparian areas. Since there is uncertainty in both the specific BMPs and the locations where plans are implemented, an average proximity factor of 0.15 was used.

Table 27. BMP effectiveness.

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

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

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

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

Where:

LR_{cattle} = Potential annual load reduction of *E. coli*
N_{plans} = Number of WQMPs and conservation plans
AnU/Plan = Animal Units of cattle (~1,000 lbs of cattle) per management plan, 81.6 AnU
FC_{cattle} = Fecal coliform loading rate of cattle, 8.55×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)
Efficacy = Median BMP efficacy value, 0.58
Proximity Factor = Percentage based factor based on the assumed proximity of the management measure to the water body, 0.15

The Agriculture Work Group estimated that on average, approximately 20% of producers across the watershed would be willing to implement some type of management measure through WQMPs and conservation plans if assistance was provided.

Based on this estimate, the WPP recommends the implementation of 100 WQMPs or conservation plans across the entire Lavaca River watershed, resulting in a total potential reduction of 1.00×10^{15} cfu *E. coli*/yr. This WPP also recommends implementation of 30 WQMPs or conservation plans in the Rocky Creek subwatersheds, resulting in total potential reductions of 2.25×10^{14} cfu *E. coli*/yr in Rocky Creek. Because Rocky Creek ultimately drains into the Lavaca River and we assume benefits accrue downstream, the 100 recommended plans for the Lavaca River include the 30 plans for Rocky Creek.

Feral Hogs

Loading reductions for feral hogs assume that existing feral hog populations can be reduced and maintained by a certain amount on an annual basis. Removal of a feral hog from the watershed is assumed to also completely remove the potential bacteria 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, 16,259 feral hogs were estimated to exist across the Lavaca River watershed (see Appendix A for details). Using the same method, 3,186 feral hogs were estimated to exist in the Rocky Creek watershed. The established goal is to reduce and maintain the feral hog population 15% below current population estimates, thus resulting in a 15% reduction in potential loading that is attributable to feral hogs. Load reductions were calculated based on the following:

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

Where:

LR_{fh} = Potential annual load reduction of *E. coli* attributed to feral hog removal
N_{fh} = Number of feral hogs removed
AnUC = Animal Unit Conversion; 0.125 animal units/feral hog (Wagner and Moench 2009)
FC_{fh} = Fecal coliform loading rate of feral hogs, 1.21×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across the Lavaca River watershed based on reducing and maintaining the population by 15% (2,439 feral hogs) is 8.48×10^{13} cfu *E. coli* annually. For the Rocky Creek watershed, reducing and maintaining the population by 15% (478 feral hogs) results in a reduction of 1.66×10^{13} cfu *E. coli* annually.

Domestic Pets

The Lavaca River watershed contains approximately 8,069 dogs, and the Rocky Creek watershed contains approximately 1,595 dogs. *E. coli* loading from dogs is based on the assumption that 40% of dog owners do not properly dispose of dog waste. Load reductions are based on the assumption that approximately 20% of pet owners that do not currently dispose of pet waste will respond to the management measure efforts (Swann 1999). Therefore, the goal is to increase the number of pet owners that dispose of pet waste by 646 pet owners in the entire Lavaca River watershed and 128 pet owners in the Rocky Creek watershed. Since these management measures will be most effective in public areas and places with higher concentrations of dogs, a proximity factor of 0.05 was included to account for the fact that the majority of these areas are upland or further away from riparian areas. The resulting reductions are calculated by:

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

Where:

LR_d = Potential annual load reduction of *E. coli* attributed to proper dog waste disposal
N_d = Number of additional dog owners disposing of pet waste
FC_d = Fecal coliform loading rate of dogs, 5.00×10^9 cfu fecal coliform/dog/day (USEPA 2001)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)
Proximity Factor = Percentage based factor based on the assumed proximity of the management measure to the water body, 0.05

The estimated potential load reduction attributed to this management measure in the Lavaca River is 3.71×10^{13} cfu *E. coli* annually. The estimated potential load reduction attributed to this management measure in Rocky Creek is 7.36×10^{12} cfu *E. coli* annually.

OSSFs

OSSFs are common in the Lavaca River and Rocky Creek watersheds with an estimated 5,246 and 1,507 OSSFs in each watershed, respectively. OSSF failures are factors of system age, soil suitability, system design and maintenance. For this area of the state, a 15% failure rate is typically assumed (Reed, Stowe & Yanke 2001). Given the feasibility of replacing 15% of systems in the watershed, stakeholders decided to target 5% of failing systems for repair or replacement. Load reductions can be calculated as the number of assumed failing OSSFs replaced. The following equation was used to calculate potential load reductions:

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

Where:

LR_{ossf} = Potential annual load reduction of *E. coli* attributed to OSSF repair/replacement
N_{ossf} = Number of OSSFs repaired/replaced
N_{hh} = Average number of people per household (2.05)
Production = Assumed sewage discharge rate; 70 gal/person/day (Borel et al. 2015)
FC_s = Fecal coliform concentration in sewage; 1.0×10^6 cfu/100mL (USEPA, 2001)
Conversion = Conversion rate from fecal coliform to *E. coli* (Wagner and Moench 2009) and mL to gal (3578.4 mL/gallon)

Five percent of assumed failing OSSFs in the Lavaca River watershed equates to approximately 40 OSSFs. Repair or replacement of 40 systems results in a potential reduction of 4.72×10^{13} cfu *E. coli* annually. Five percent of assumed failing OSSFs in the Rocky Creek watershed is approximately 11 systems. Repair or replacement of 11 systems results in a potential reduction of 1.30×10^{13} cfu *E. coli* annually in Rocky Creek.

Appendix B. References

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. http://twri.tamu.edu/reports/2012/tr454.pdf

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

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

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.

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

Inamdar, S.P., Mostaghimi, S., Cook, M.N., Brannan, K.M., McClellen, P.W. 2002. “A long-term, watershed scale, evaluation of the impacts of animal waste BMPs on indicator bacteria concentrations.” Journal of the American Water Resources Associa¬tion. 38: 15.

Line, D.E. 2002. “Changes in land use/management and water quality in the Long Creek watershed.” Journal of the American Society of Agronomy. 38: 1691-1701.

Line, D.E. 2003. “Changes in a stream’s physical and biological conditions following livestock exclusion.” Transactions of the ASAE. 46: 287-293.

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. NCSU Water Quality Group, Biological and Agricultural Engineering Department, NC State University, Raleigh, North Carolina.

Meals, D.W. 2001. “Water quality response to riparian restoration in an agricultural watershed in Vermont, USA.” Water Science Technology 43: 175-182.

Meals, D.W. 2004. “Water quality improvements following riparian restoration in two Vermont agricultural watersheds.” In Lake Champlain: Partnerships and Research in the New Millennium, edited by Manley, T.O., Manley, P.L., and Mihuc, T.B. New York: Kluwer Academic/Plenum Publishers.

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.

Reed, Stowe & Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas. www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/ossf/StudyToDetermine.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: 595-604.

Swann, C. 1999. A Survey of Residential Nutrient Behaviors in the Chesapeake Bay. Widener-Burroes, Inc. 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: 2243-2251.

USEPA. 2001. Protocol for Developing Pathogen TMDLs: Source Assessment. 1st Edition. EPA Office of Water. 841-R-00-002. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt

USEPA. 2010. Implementing Best Management Practices Improves Water Quality. Washington D.C.: EPA Office of Water. 841-F-10-001F.

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://twri.tamu.edu/reports/2009/tr347.pdf

Appendix C: Elements of Successful Watershed Protection Plans

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

A: Identification of Cases and Sources of Impairment

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

See Chapters 2, 3, 4 and Appendix A

B: Estimated Load Reductions

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

See Chapter 5 and Appendix B

C: Proposed Management Measures

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

See Chapter 5

D: Technical and Financial Assistance Needs

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

See Chapters 5 and 7

E: Information, Education and Public Participation Component

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

See Chapters 5 and 6

F: Schedule

A schedule for implementing the NPS management measures identified in the plan that is reasonably expeditious.

See Chapter 8

G: Milestones

A description of interim, measurable milestones for determining whether NPS 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.

See Chapter 8

H: Load Reduction Evaluation Criteria

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

See Chapter 8

I: Monitoring Component

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

See Chapter 8

Appendix C. References

USEPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. EPA 841-B-08-002. https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

April 2018
TWRI TR-507