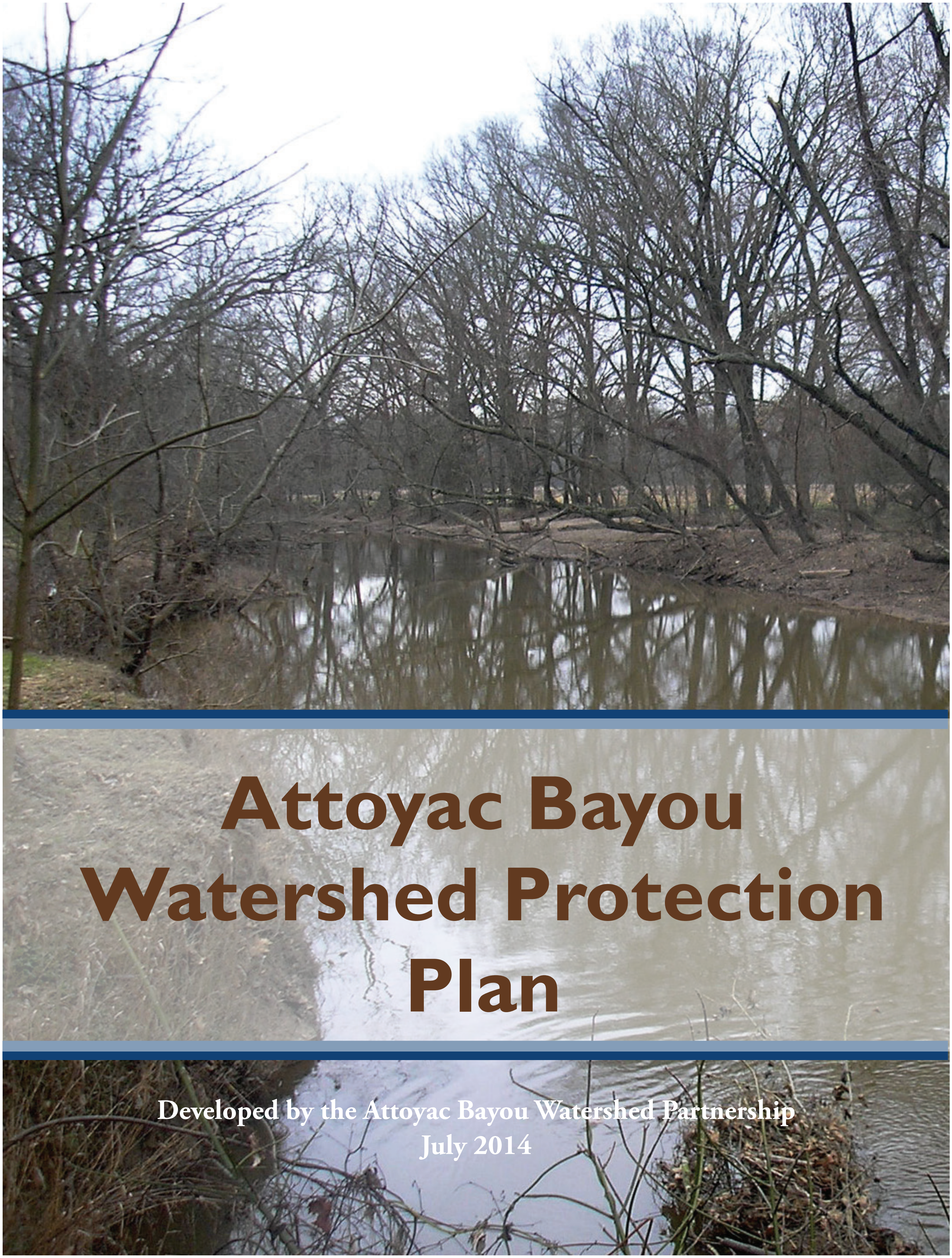

Attoyac Bayou Watershed Protection Plan

Developed by the Attoyac Bayou Watershed Partnership

July 2014

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Attoyac Bayou Watershed Protection Plan

Prepared for the Attoyac Bayou Watershed Partnership

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Attoyac Bayou

WATERSHED PARTNERSHIP

Funding support for this project was provided in part through a Clean Water Act §319(h) Nonpoint Source Grant to the Texas Water Resources Institute from the Texas State Soil and Water Conservation Board and the U.S. Environmental Protection Agency.

Dedication

The members of the Attoyac Bayou Watershed Partnership dedicate this plan to the memory of Mr. Ralph Schwausch. Ralph lived in the community of Concord and was an active member of the watershed partnership, served on its steering committee and was a great advocate for the Attoyac Bayou watershed. He was quite active in the community and served as a board member on the Arlam-Concord Water Supply Corporation and on the Rusk-Smith County Forest Landowners Association. He was also a trustee for the Concord Cemetery Association and a panel member for the Texas A&M AgriLife Extension Service's Forest and Woodland Advisory Panel.

The tree farm that Ralph and his family worked to develop was a testament to his love and respect for the land. Through years of work, consulting experts and completing several Master Tree Farmer courses, Ralph's efforts yielded a well-managed and sustainable tree farm that received the Outstanding Texas Tree Farm award in 2011.

He was truly passionate about the health of natural resources, including the Attoyac Bayou watershed. This translated into advocacy and education as Ralph continually taught his children and grandchildren to be good stewards of the land and was often seen giving impromptu tours of the family farm. These traits were obvious as he contributed considerably to discussions surrounding the development of the Attoyac Bayou Watershed Protection Plan. Many of his thoughts and ideas are reflected in the pages of this plan and we are glad to dedicate this plan to him.

Acknowledgments

The Attoyac Bayou Watershed Protection Plan presents the strategy developed by the Attoyac Bayou Watershed Partnership to restore water quality in the Attoyac Bayou such that it meets applicable water quality standards. Watershed Partnership members dedicated considerable time and effort in discussing the watershed, its influences on water quality, potential means to improve the watershed and water quality and in selecting management strategies appropriate for inclusion in the watershed plan.

With the rural nature of the Attoyac Bayou watershed, continued involvement and input from watershed landowners was all the more important to ensure that the plan encompasses recommendations that not only address the issues facing the watershed, but are also palatable to the landowners themselves. The time and effort of these landowners is greatly appreciated and is reflected in the contents of this plan.

Industry representatives also provided key support for the project. The watershed is a key producer of forestry and poultry products within Texas, and insight from industry representatives and consultants aided in the planning process.

Local governmental organizations also played a key role in plan development. Representatives provided insight regarding their specific focus areas and ensured inclusion of content in the plan that is appropriate for the bayou.

- Angelina & Neches River Authority
- Nacogdoches County Health Department
- Nacogdoches County Judge and Commissioners
- Pineywood Groundwater Conservation District
- Pineywoods RC&D
- Soil and Water Conservation District Board Members
- Texas A&M AgriLife Extension Service

These organizations include:
Agency support for this plan was also critical. Their knowledge and expertise regarding natural resource issues in the watershed were quite valuable in the development and refinement of the plan. Those entities participating throughout the process include:

- Texas A&M Forest Service
- Texas Commission on Environmental Quality
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board
- U.S. Army Corps of Engineers
- U.S. Department of Agriculture – Natural Resources Conservation Service
- U.S. Fish and Wildlife Service
- U.S. Forest Service

Last, but certainly not least, the financial contributions provided by the Texas State Soil and Water Conservation Board and the U.S. Environmental Protection Agency through Federal Clean Water Act §319(h) Program funding are much appreciated. Without these funds, the development of this plan and the work supporting its development would not have been possible.

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List Of Acronyms

ac	acre
AgriLife Extension	Texas A&M AgriLife Extension Service
ANRA	Angelina & Neches River Authority
AU	assessment units
BMP	best management practice
BST	bacterial source tracking
CES	Castilaw Environmental Services, LLC
CFU	colony forming units
cfs	cubic feet per second
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
DO	dissolved oxygen
E. coli	*Escherichia coli*
EQIP	Environmental Quality Incentive Program
ERIC-PCR	enterobacterial repetitive intergenic consensus sequence polymerase chain reaction
gal/min	gallons per minute
ft	feet
HE&WT	Houston East and West Railway
HUC	hydrologic unit code
LDC	load duration curve
LU/LC	land use and land cover
m	meter
µS/cm	micro-Siemens per centimeter
mi	mile
mL	milliliter
MSL	mean sea level
NASS	National Agricultural Statistics Service
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NRCS	National Resource Conservation Service
NPS	nonpoint source
OSSF	on-site sewage facility
RMU	resource management unit
RUAA	Recreational Use Attainability Analysis
RC&D	Resource Conservation & Development
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SFASU	Stephen F. Austin State University
SWCD	Soil and Water Conservation District
TCEQ	Texas Commission on Environmental Quality
TFS	Texas A&M Forest Service
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TST	Texas Stream Team
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TXNDD	Texas Natural Diversity Database
TDS	total dissolved solids
TSS	total suspended solids
SEP	Supplemental Environmental Program
USACE	U.S. Army Corps of Engineers
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WPP	watershed protection plan
WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility
WET	Waters for East Texas Center
yd	yard

Executive Summary

The Attoyac Bayou is a rural East Texas water body that drains a watershed that encompasses many East Texas mainstays: agriculture, natural resource production in the form of forest products, oil and gas, abundant wildlife and the rural residents that call it home. Though practices have changed over time, agriculture and forestry remain dominant in the watershed although oil and natural gas production has certainly arisen in the watershed as a significant economic driver. The Attoyac Bayou provides critical water resources to many users, especially wildlife, livestock and humans and ultimately drains into Sam Rayburn Reservoir, one of the state's largest impoundments.

Problem/Need Statement

Water quality monitoring conducted by the Angelina & Neches River Authority (ANRA) in the late 1990s illustrated that fecal-derived bacteria levels were often elevated above the state's water quality standard for contact recreation. Upon assessment of this data by the Texas Commision on Environmental Quality (TCEQ), the bayou was considered to not support its designated contact recreation uses and was thus listed as an impaired water body for elevated bacteria in the *2004 Texas 303(d) List.* Additionally, TCEQ's 2008 assessment of water quality data indentified ammonia levels that were routinely elevated above the state's screening level in several portions of the water body. As a result, the water body was listed as having a concern for excessive ammonia levels in the *2008 Texas 303(d) List*. With the bacteria impairment and nutrient concerns listed in the *Texas 303(d) List* comes the need to implement corrective actions to restore instream water quality to meet state standards. To meet this need, an assessment and planning project was undertaken to develop the Attoyac Bayou Watershed Protection Plan (WPP).

Action Taken

Through this effort, an extensive review of the watershed's land and water resources was carried out, enabling stakeholders to be provided with the most up-to-date information on watershed characteristics and uses. Potential sources of bacteria pollution in the watershed were also identified and quantified using the best available information. The current and past level of recreational water body use in the watershed was also documented, as were the stream network's physical characteristics and accessibility. Collectively, these tasks established a firm foundation of knowledge on which a WPP could be developed. Watershed stakeholders played an integral role in this effort and ensured that information collected and developed accurately represented the existing conditions in the watershed.

Water quality data collection and assessment also provided critical information regarding the current health of the watershed's resources. Building from an existing network of monitoring stations in the watershed, additional stations were established and monitored through an intensive two-year monitoring program. Water quality and quantity measurements were collected and supplemented the existing data set with additional information. Additionally, advanced pollution source tracking techniques were employed to determine the sources of bacterial contamination actually contributing to the overall bacteria load in the Attoyac Bayou and its tributaries. Collectively, data collected and produced were integrated into several simplistic watershed models and used to aid in determining the types and sources of pollutants identified in the watershed that have the highest potential impact to instream water quality.

Attoyac Bayou WPP Overview

Assessment and monitoring information was then paired with a stakeholder process in which information was provided to local watershed stakeholders and was used to guide the WPP development process. Ultimately, stakeholders' decisions and input regarding needed management and tools to mitigate bacteria loadings and, in time, restore water quality, resulted in the development of this WPP. By comprehensively considering the multitude of potential pollutant sources in the watershed, this plan describes recommended management strategies that, when implemented, will reduce pollutant loading in the most cost-effective manner available at the time of planning. This plan is the culmination of more than three years of intensive assessment, evaluation and planning and presents a logical and judicious approach to restore water quality in the Attoyac Bayou and improve the overall health and function of its watershed. Despite the extensive amounts of information that went into the development of this WPP, a better understanding of the watershed and effectiveness of protective or mitigating actions will undoubtedly develop as the plan is implemented and water quality response is evaluated. As such, this WPP is a living document that will evolve as needed through the adaptive management process.

Addressing Pollutant Sources

Stakeholder feedback supported by sound science was used to identify and prioritize management for potential watershed pollution. Sources of bacteria loading identified in the watershed in decreasing order of their relative estimated contributions include on-site sewage facilities (OSSFs), wildlife, cattle, dogs, feral hogs, poultry litter, hunting camps, horses and wastewater treatment facilities (WWTFs). While each of these are considered contributors to the overall bacteria load, the potential to influence instream water quality was considered greatest from OSSFs, cattle, feral hogs and hunting camps. Other sources were either considered extremely difficult to manage or unlikely to yield much actual bacteria load reduction in the water body.

Recommended Actions

To mitigate loadings from identified pollutant sources, five primary recommended actions were made. Individual recommendations are crafted to deal with specific sources or types of pollution and, in many cases, will have ancillary effects on other pollution sources as well. Briefly, these actions by source or type of source are as follows:

Bacteria

Managing bacteria loading from livestock focuses on the voluntary development of site-specific water quality management plans. These plans provide technical assistance to aid producers in better managing their resources while protecting water quality. In some cases, financial assistance can be provided as well to help defray implementation costs. These plans can include a variety of practices, but will likely focus on providing alternative water for livestock through developing water wells or installing watering facilities, water pumping plants and pipeline. Prescribed grazing and cross fencing to promote prescribed grazing are also critical practices that can be included. Education and outreach in the form of workshops and field days is also recommended to deliver pertinent information on water quality impacts of good resource management practices. Not only will knowledge be imparted in these events, but practice implementation will be promoted and adoption will be enhanced.

Feral hog management in the watershed will consist of both active and passive control. Managing food availability, water and shelter resources can modify hog behavior and encourage them to move elsewhere and is likely to improve trapping effectiveness. Watershed landowners will also continue efforts to trap and kill hogs and these efforts. Education will also provide critical support in efforts to control feral hogs and aid in tracking the number of hogs removed. Tracking the success of feral hog removal efforts via online tools will also be promoted.

Addressing bacteria loading from OSSFs will receive considerable focus as they were identified as having the highest potential bacteria load contribution to the watershed of all pollutant sources. Recommended management focuses on identifying, inspecting and documenting OSSFs within 150 yds of perennial streams and 50 yds of intermittent stream and working to repair or replace those systems noted as failing. Education and outreach delivery regarding proper OSSF function, management and maintenance to homeowners and professionals is also a primary management recommendation.

Potential bacteria loading from hunting camps will also be addressed. Identification, inspection and documentation of these camps are the initially recommended management approaches. This will be followed with an effort to establish functioning OSSFs at each site needing a functioning system.

Ammonia

Recorded ammonia levels indicate that instream ammonia levels are not problematic. Elevated readings occurred sporadically and were sometimes associated with extremely low water levels while in other cases they were associated with higher monitored flows. As such, no management recommendation was made to specifically address ammonia loading. However, practices recommended to address bacteria levels will also provide reductions in the overall ammonia load in the watershed.

Education and Outreach

Providing continued education and outreach to watershed stakeholders is a constant need. These events provide critical platforms for the delivery of new or improved information to watershed stakeholders that will enable them to improve the profitability of their operations while simultaneously enhancing instream water quality. As evidenced by the integration of education into the recommended actions described above, education will be a mainstay of implementing the Attoyac Bayou WPP. Stakeholder meetings, held as needed and supplemented with topically relevant education and outreach events such as workshops and field days, will be critical in maintaining local interest in WPP implementation and providing a needed local platform for conveying and illustrating implementation successes.

Tracking Implementation Progress

Effectively tracking and communicating WPP implementation progress and success is also critical. Water quality monitoring conducted at critical monitoring stations will be incrementally compared to water quality targets outlined in the plan and will serve as a water body report card of sorts. This will illustrate progress made in meeting water quality goals set by watershed stakeholders and will also indicate the need for adjustments to be made to the plan in the future. Documenting the number of practices implemented, events held, people in attendance at events and other measures described in the plan will also serve to document successful implementation of the plan.

Goals of the Plan

The goal of the WPP and drive for implementing practices it recommends is to restore water quality in the Attoyac Bayou through long-term conservation and stewardship of the watershed's resources. Four specific goals were established by the Attoyac Bayou Watershed Partnership to achieve this long-term vision and sustain the watershed for future generations. The first goal is for the Attoyac Bayou to meet water quality standards designated for it by the state. Now, this equates to a geometric mean of 126 colony forming units of *E. coli* per 100 milliliter of water. However, a second goal established by the partnership is to determine and recommend an appropriate recreational use water quality standard. Documented use of the water body suggests that a less restrictive standard would be more appropriate and will reasonably protect the health of those using the water body.

Improving awareness and understanding of water resources in the watershed and threats to those resources is the third goal established by the partnership. Through an improved understanding and appreciation for local water resources, interest in protecting those resources will grow and lead to improved watershed stewardship. This leads to the last partnership goal, which is to encourage the voluntary adoption of practices that improve water quality. Better watershed stewardship produces better watershed services, which reveal themselves as cleaner water, healthier inhabitants, enhanced resource production and improved economic viability.

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

Chapter 1
Watershed Management

Definition of a Watershed

A watershed is the land area that drains to a common waterway such as a stream, lake, estuary, wetland or, ultimately, the ocean. All land surfaces on Earth are included in a watershed; some are very small while others encompass large portions of nations or continents. For example, many smaller watersheds, or sub-watersheds, combine to form the Attoyac Bayou watershed, which is actually a small part of the Neches River Basin.

A Watershed's Impacts on Water Quality

All activities, both human and natural, that occur within the boundaries of a watershed have the potential to influence water quality in the receiving water body. As a result, an effective management strategy that addresses water quality issues in a watershed's receiving water body must examine all human activities and natural processes within that watershed.

The Watershed Approach

The Watershed Approach is "a flexible framework for managing water resource quality and quantity within a specified drainage area or watershed. This approach includes engaging stakeholders to make management decisions supported by sound science and appropriate technology" (USEPA 2008). The Watershed Approach is based on the following principles:

- geographic focus based on hydrology rather than political boundaries;
- water quality objectives based on scientific data;
- coordinated priorities and integrated solutions; and,
- diverse, well-integrated partnerships.

A watershed's boundaries often cross municipal, county and state boundaries, because they are determined by the landscape. Using the Watershed Approach, all potential sources of pollution entering a waterway can be addressed through the process by all potential watershed stakeholders.

A stakeholder is anyone who lives, works or has an interest within the watershed or may be affected by decisions; stakeholders can include individuals, groups, organizations or agencies. Stakeholder involvement is critical for effectively employing a holistic approach to watershed management that adequately addresses all watershed concerns.

Watershed Protection Plan (WPP) Development Process

WPPs are locally driven mechanisms for voluntarily addressing complex water quality problems that cross multiple jurisdictions. WPPs are coordinated frameworks for implementing prioritized water quality protection and restoration strategies driven by environmental objectives. Through the development process, stakeholders are encouraged to holistically address all of the sources and causes of impairments and threats to both surface water and groundwater resources within a watershed. To help ensure that plans developed will effectively address water quality issues when implemented, the U.S. Environmental Protection Agency (USEPA) has established nine key elements that it deems critical for achieving water quality improvements. These elements are listed and defined in Appendix A.

WPPs serve as tools to better leverage the resources of local governments, state and federal agencies and non-governmental organizations. WPPs integrate activities and prioritize implementation projects based upon technical merit and benefits to the watershed, promote a unified approach to seeking funding for implementation and create a coordinated public communication and education program. Developed and implemented through diverse, well-integrated partnerships, a WPP assures the long-term health of the watershed with solutions that are socially acceptable, economically viable and achieve environmental goals for water resources. Adaptive management is used to modify the WPP based on an on-going, science-based process that involves monitoring and evaluating strategies and incorporates new knowledge into decision making.

The Watershed Coordinator

The role of the Watershed Coordinator is an important one that is at the heart of WPP development and future implementation. The Watershed Coordinator leads efforts to establish and maintain working partnerships with watershed stakeholders and serves as a single point of contact for all things related to the development and implementation of the WPP and the WPP itself. Mr. Anthony Castilaw of Castilaw Environmental Services, LLC (CES) has filled this role.

The future role of the Watershed Coordinator is perhaps the most important, as he will be tasked with maintaining stakeholder support in the years to come, identifying and securing needed funding, coordinating and organizing implementation efforts, tracking and reporting the success of WPP implementation and working to effectively implement adaptive management into the long-term WPP implementation process. Simply put, the Watershed Coordinator is the catalyst that keeps WPP implementation on track.

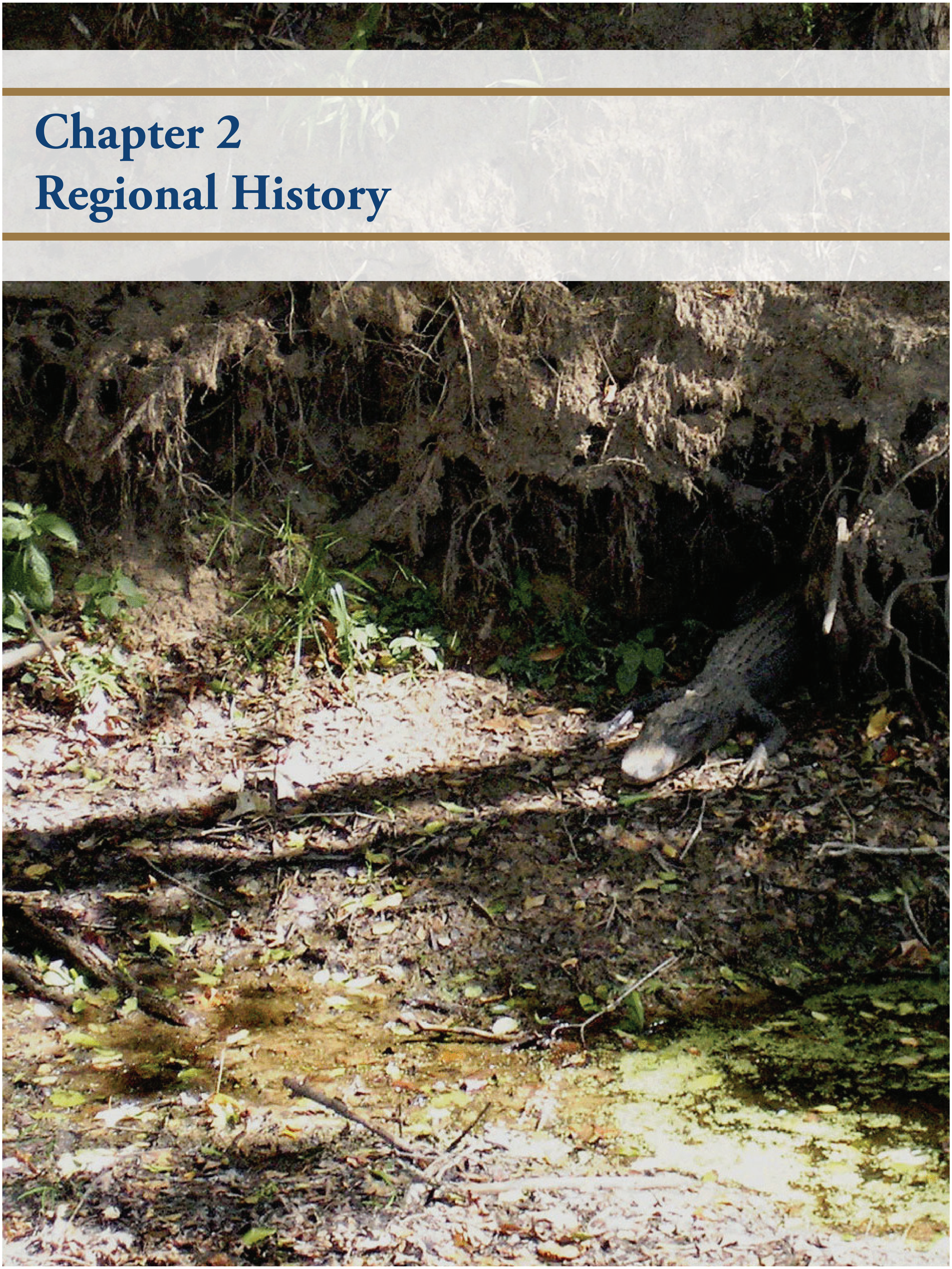
Private Property Rights

Maintaining complete control of privately held land and water rights are primary concerns of landowners across the watershed. This WPP establishes a coordinated plan to voluntarily implement management strategies to restore and protect water quality through partnerships and cooperative efforts. Although this plan is completely voluntary, stakeholders realize that the goals of this plan will not be achieved unless action is taken. As a result, this plan includes implementation activities that can improve water quality without infringing upon the rights of watershed landowners.

Adaptive Management

Adaptive management is a defined natural resource management approach that promotes decision making supported by an ongoing, science-based process. This approach incorporates results of continual testing, monitoring, evaluation of applied strategies and incorporation of new information into revised management approaches that are modified based on science and societal needs (USEPA 2000). Essentially, adaptive management allows stakeholders to maintain a flexible approach in their decision-making process to account for inherent uncertainty and make adjustments that improve the performance of designated management measures over time (Williams et al. 2009). Utilizing this process, members of the Attoyac Bayou Watershed Partnership will implement strategies known to address manageable pollutant loadings within the watershed.

Chapter 2
Regional History



Early History

A variety of cultural remains indicate that early humans occupied portions of Texas at least 11,200 years ago. These remains consist of any evidence that humans have visited an area and took advantage of its plant and animal resources. Research has divided the Texas prehistorical record into four general periods: Paleo-Indian (9200 B.C.–6000 B.C.), Archaic (6000 B.C.–200 B.C.), Ceramic Period (200 B.C.–A.D. 700) and Late Prehistoric (A.D. 700–1600) (Hester and Turner 2012).

Paleo-Indian (9200 B.C.–6000 B.C.)

The earliest evidence of human activity in East Texas is represented by the Paleo-Indian period. There is little evidence of mammoth hunting in East Texas as has been documented elsewhere; rather, a broad-based subsistence pattern appears to have been practiced until the Late Prehistoric period. Paleo-Indian peoples are often thought to have been organized into small groups of a few dozen individuals that practiced a nomadic subsistence and settlement pattern. The distribution of Paleo-Indian artifacts suggests these groups were highly mobile and frequently settled within valleys of major stream basins as well as other resource-rich areas (Hester and Turner 2012).

Archaic (6000 B.C.–200 B.C.)

The beginning of the Archaic period is thought to have been onset by climatic warming and drying trends. These climate changes reduced the amounts of large game animals in much of North America, forcing Archaic peoples to diversify their food sources to include smaller game animals and wild plants. The primary hunting weapon during this period was the atlatl, as the bow and arrow had not been introduced. Life in East Texas does not appear to have been affected by changing climatic trends as much as other parts of North America. Large game animals, such as mammoth, were not used extensively as a food source. As a result, the generalized hunting and gathering pattern continued throughout the Archaic period (Hester and Turner 2012).

The Archaic period is generally subdivided into early, middle and late phases. The Early Archaic (6000 B.C.–2500 B.C.) is characterized by low populations of scattered and highly mobile peoples; although the least is known about this phase. The Middle Archaic (2500 B.C.–1000 B.C.) is characterized by significant population increases, with a large number of sites and numerous artifacts being present. It is thought that this period is when Archaic cultures became more specialized on a regional basis, with different regions having distinctive types of tools and arrow points. Also in the Middle Archaic phase, cemeteries containing large numbers of burial sites began to appear, possibly indicating establishment of territories by some hunting and gathering societies. The Later Archaic (1000 B.C.–200 B.C.) is characterized by the continuing of hunting and gathering societies with additional types of projectile points and stone tools. In East Texas, around 500 B.C., the first pre-Caddo settled villages began to appear (Hester and Turner 2012; Perttula 2005).

The Ceramic Period (200 B.C.–A.D. 700), also known as the Woodland Period, was still characterized by populations of hunter-gatherers, although these peoples lived in increasingly larger groups and in the same place for longer amounts of time. Artifacts from this period generally consist of ceramic bowls, axe heads, smaller and thinner dart points, and later in this period, corner-notched arrow points. The use of ceramics during this period varies depending on location, indicating regional differences in dietary habits and food processing techniques. Some evidence suggests that Early Ceramic groups were practicing some level of horticulture activity, possibly cultivating squash and other native plants. Burial mounds from this period have been documented in the Neches and Sabine river bottoms (Perttula 2005).

Late Prehistoric (A.D. 700–1600)

The Late Prehistoric Period (A.D. 700–1600) is notable for the introduction of the bow and arrow. Although hunting and gathering continues in the Late Prehistoric as in earlier periods, the material culture, hunting patterns, settlement types and other facets of the era mark a distinctive break with the past. In East Texas, the Late Prehistoric period is subdivided into four prehistoric Caddoan periods (Formative, Early, Middle and Late) (Hester and Turner 2012).

Prehistoric Caddoan Culture

Caddoan period groups show increased reliance on cultivated crops such as maize and squash, along with several other native plant species. By roughly 1450 A.D., maize comprised more than half of the Caddo's diet, with food obtained by hunting and gathering constituting the remainder. Artifacts found from this era include distinctive ceramics made for a variety of uses, as well as tools, clothing, baskets and ornaments such as beads, ear-pendants, pipes and figurines. Most of these artifacts were made from locally occurring materials; however, some non-local materials and goods were obtained through the development of long-distance trade networks. The Caddo lived in modest structures most commonly consisting of a framework of log poles with a covering of either thatched grass or earthen material (Perttula 2012).

European Exploration and Historic Caddoan Culture

The first European visitors to travel through East Texas were likely with the Moscoso Expedition in the early 1540s. The Moscoso Expedition was a continuance of Herando DeSoto's expedition that landed in present day Florida in 1539 to explore the southeastern coast of present day United States and to obtain riches from the Native Americans. During their journey west, DeSoto died of a fever at the Mississippi River, and Moscoso took command of the expedition. The goal following DeSoto's death was to find an overland route back to New Spain (now Mexico). Accounts of the route Moscoso and his men took through East Texas vary, although most theories have them traveling through some portion of East Texas, on their way west and stopping at a major river, before turning around and heading back east to the Mississippi River. An account published in 1939 has the expedition entering Texas through Sabine County, traveling south to present day San Augustine and traveling west to the Navasota River before turning around. This account has Moscoso's expedition traveling through the Attoyac Bayou watershed and possibly crossing the Attoyac Bayou in roughly 1542. Other accounts conclude that the expedition entered Texas further north of Shelby County in differing parts of northeast Texas, traveling south to either Nacogdoches or Shelby County before heading west. None of these routes are conclusive; however, it is apparent that Moscoso's expedition came through portions East Texas and was very close, if not within portions of the Attoyac Bayou watershed. Moscoso's expedition through East Texas did encounter Caddo Indians and documented important aspects of their daily life and culture. However, European contact with the Native Americans remained extremely limited until the late 1600s (Bruseth 2012).

The next venture into Texas was made by the French expedition led by La Salle. The goal of La Salle's expedition was "to establish a colony sixty leagues up the river (Mississippi River) as a base for striking Mexico, afflicting Spanish shipping and blocking English expansion, while providing a warm-water port for the Mississippi valley fur trade" (Weddle 2012). La Salle's expedition was riddled with misfortune, including sailing past the Mississippi River and eventually landing on the Texas coastline. In trying to establish a settlement on the Texas coast, many of LaSalle's men succumbed to malnutrition, exhaustion, Indian attacks or were lost in the wilderness. La Salle was killed by one of his own men while on a march east to find the Mississippi River. The settlement was eventually overcome by Indians and was found in ruins by Spaniard Alonso De Leon in 1689. La Salle's expedition was a failure for the French, but it did entice the Spanish to undergo efforts to colonize and establish missions in the area that is now East Texas (Long 2011; Weddle 2012).

In the late 1600s and early 1700s the route that would become the Camino Real or Old San Antonio Road, was carved out of the Texas and Louisiana forestland. Portions of the route were old Indian trails used for trade routes while other portions were new trails blazed by early Spanish explorers. The route was an important artery through East Texas and is now State Highway 21 that passes through the southern portion of the Attoyac Bayou watershed (Long 2011; McCroskey 2011).

Spaniard Domingo Ramon ventured into East Texas in 1716 to find several villages of Caddo Indians in what is now Nacogdoches County. In an effort to convert the Native Americans to Christianity, three missions were established in present day Nacogdoches County, one at the site of present day Nacogdoches (named after the Nacogdoche Indians who resided there). The mission was temporarily abandoned in 1719 due to a French invasion of Texas, but was in operation until 1773 when the French ceded Louisiana to the Spanish. After the cession of Louisiana, all the settlers were ordered to move to San Antonio or the Rio Grande communities. Led by Antonio Gil Ibarvo, the settlers petitioned the government to return to their former homes, and in 1779, began to rebuild the town of Nacogdoches (Long 2011).

The Caddoans up to this time experienced continual pressure from both French and Spanish efforts to control the Native American tribes. The desire of the French and Spanish to control the Native Americans was threefold: gain control of their territory, establish trade and convert them to Christianity. With the cession of Louisiana to the Spanish in 1773, the Caddos became subject to Spanish Indian policy. Initial relations with the Spanish government were unstable at best, but eventually the Caddo became loyal to the Spanish and pledged to maintain peace by not engaging in trading of arms and munitions with hostile Native American tribes (Glover 1935).

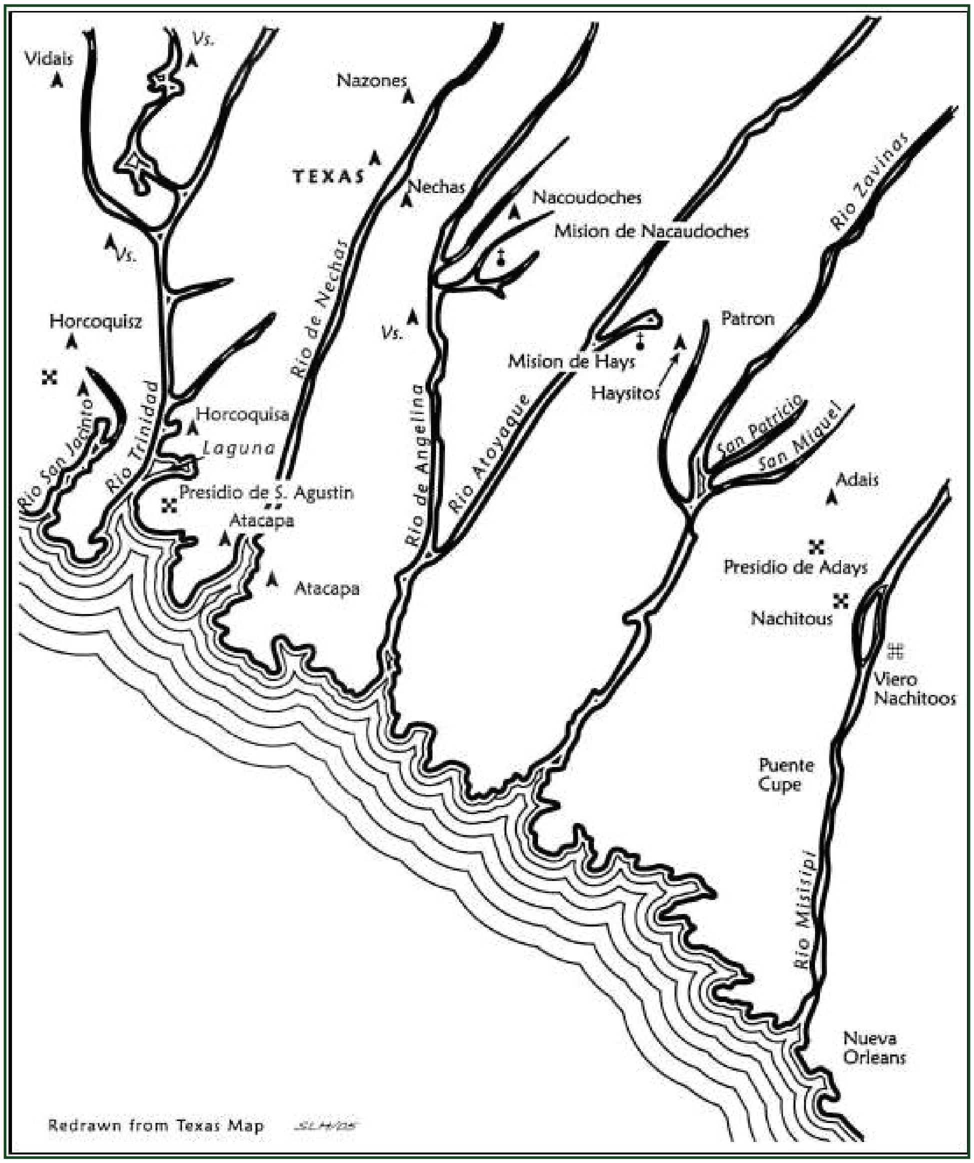


Figure 2.1. Redrawn version of 1757 map by Miranda, "Parte de la Provyncya De Texas." Map shows some of the locations of Spanish missions established in portions of Texas
Source: Perttula and Nelson 2007

Early Texas

The 1800s were a volatile time in East Texas history. Early in the 19th century, much of East Texas was abandoned due to fighting associated with the Mexican Revolution. Many residents of East Texas fled across the Sabine River, and much of the area was deserted by 1818. Mexico gained independence from Spain in 1821, and East Texas began to re-populate once again. Immigrants came pouring in from the United States causing further problems for the Mexican government. It was during this time that Mexican restrictions forbade settlements within 20 leagues (roughly 60 mi) of the Texas boundary. The primary purpose was to avoid military contact with the United States, but this "neutral ground" became a haven for squatters and fugitives further causing unrest in portions of East Texas (Long 2011; Harper 2011).

In 1826, Nacogdoches was home to what is now known as the Fredonian Rebellion. The rebellion occurred because two brothers — the Edwards brothers — received a grant entitling them to settle as many as 800 families in Nacogdoches and the surrounding area. The brothers informed the existing settlers in the area that they would have to show documentation of their land claim or move off the land. The amount of land in question was very small, and there is only one documented case of someone's land being sold to someone else; however, these assertive actions stirred up conflict between the previous settlers and the new. Due to the ongoing conflict between landowners, as well as conflicts that arose in local governmental elections held in that year, the brothers' grant was revoked. This outraged the brothers and with the help of more than thirty of their supporters, they overthrew the local government. When the Mexican authorities heard of the incident, they quickly dispatched more than 100 troops to Nacogdoches to end the rebellion. Edwards decided to meet the Mexican force in the new republic they termed Fredonia and declared independence on December 21, 1826. The Mexican forces reached Nacogdoches on January 31, 1827, and the Fredonian Rebellion ended with most of Edwards' men fleeing across the Sabine River. The Republic of Fredonia lasted a mere 41 days (McDonald 2012a).

Flag of the Republic of Fredonia

The Fredonian Rebellion was just the beginning of unrest in Texas, which culminated in the Texas Revolution. The Texas Revolution reportedly began with the Battle of Gonzales in October 1835, but there were many military incidents occurring before 1835, including the battle of Nacogdoches in 1832. The Battle of Nacogdoches occurred when a group of East Texas settlers refused to surrender their arms to the Mexican government. With the help of surrounding communities of Ayish Bayou, Neches, Sabine, Shelby and others, the Texans defeated a small force of Mexican soldiers. Although minor, the Battle of Nacogdoches "cleared East Texas of military rule and allowed the citizens to meet in convention without military intervention" (McDonald 2012b). The Texas Revolution ended with the battle of San Jacinto on April 21, 1836, and the Republic of Texas was established (Barker and Pohl 2012).

The Caddo Indians during this time were experiencing a barrage of changes to their lifestyle, including trading of goods with the Europeans, encroachment of their land by settlers, rampant disease and raids by hostile Indian tribes. In 1836, the Caddo Indians in the United States reached an agreement to sell their land, in present day Louisiana, for $80 thousand. As part of this treaty, the Caddo Indians were to leave the United States, within one year of signing the treaty. Most of the Caddoan tribes living in Louisiana planned to move into Texas to join remaining populations of Caddos. This move was interrupted by the onset of the Texas Revolution and the request that the United States not allow the Caddos to move into Texas. After the Republic of Texas was established, relations with the Caddo Indians continued to degrade. The Caddos engaged in some hostile actions against white settlers resulting in an attempt to drive out or exterminate the Caddos that had migrated to Texas. By the early 1840s most of the Caddo Indians had moved to the Brazos River area in order to avoid repressive measures and colonization efforts. In 1855, the Caddos were placed on the Brazos Indian Reservation where they lived for only four years before being moved to the Washita River in present day western Oklahoma where they reside today (Glover 1935; Perttula 2012).

The Republic of Texas lasted nearly 10 years, but ended on December 29, 1845 when Texas was annexed as the 28th state in the United States. The annexation of Texas and continual westward expansion of United States settlers, were the primary causes of the Mexican war with the United States that lasted from 1846–1848. The United States defeated the Mexican army, and in February of 1848, the Treaty of Guadalupe Hidalgo was signed by the two governments. The treaty recognized Texas' annexation to the United States and established the Rio Grande as the boundary of Texas; the United States also gained California, Arizona, New Mexico, as well as portions of Utah, Nevada and Colorado (Bauer 2012).

In early Texas history, conflict was never far off the horizon. This became increasingly clear as states within the Union began aligning themselves between North and South. Although Texas had strong alignment with the Union that they worked hard to join in 1845, continual attacks on Southern institutions from Northern politicians, as well as opposition to any interference in the practice of slavery, aligned them strongly with the South. The Civil War began in 1861 and lasted until 1865. There were approximately 90,000 Texans that fought in the war (Wooster 2012).

Following the Civil War, the Reconstruction Era in Texas, as in much of the South, represented a time of hardship and turmoil. An economic system that did not use slavery had to be developed, social issues associated with freed slaves had to be dealt with, and broken political systems had to be fixed. Railroads continued to expand during reconstruction, further legitimizing the Texas agriculture economy. Cultivation of corn and wheat increased during this period; however, the main cash crop was cotton. The population in Texas greatly increased during reconstruction, with more than 200,000 people immigrating to the state between 1860 and 1870. These immigrants drove the population of Texas to more than 1 million by the end of reconstruction (Moneyhon 2012).

Engine #28, which came through Nacogdoches County in 1914
Source: East Texas Research Center

Workers on an early East Texas cotton farm
Source: East Texas Research Center

Railroads

The introduction of the railroad into East Texas greatly increased the economic viability of the area, turning subsistence farming into for-profit ventures and allowing widespread timber harvesting by providing an efficient and reliable transportation mechanism. The first railroad to come through East Texas was the Houston East and West Railway (HE&WT). The HE&WT Railway eventually connected Houston Texas with Shreveport, Louisiana and was constructed through Nacogdoches in 1882. The town of Nacogdoches was on the decline before the arrival of the HE&WT Railway, largely due to lack of adequate and reliable transportation, but the arrival of the railway rekindled economic prosperity in the region. The railways changed the face of East Texas by shifting transportation from either river traffic or utilization of poorly constructed and maintained roads to the much more efficient and reliable railways. This caused the decline of river port towns such as Pattiona, which was situated near the Angelina River in southeast Nacogdoches County. Many towns, such as Garrison, sprang up due to the construction of railroads and the associated industry needed for supplies. Other railroads constructed near the Attoyac Bayou watershed during this period included the Caro Northern Railway constructed in 1894 from Nacogdoches County to Mount Enterprise in Rusk County, the Gulf, Beaumont and Great Northern Railroad constructed in 1904 through the central portion of Shelby County, and the Timpson and Northwestern Railway was constructed from Timpson in Shelby County to Henderson in Rusk County in 1909 (Harper 2011; Knapp and Beisele 2011; Long 2011).

Agriculture

Agriculture has always been a critical aspect to life in East Texas. Farming in East Texas began with the Caddo Indians who became increasingly reliant on cultivated crops such as maize and squash. As settlers moved into East Texas, land was cleared and mainly small subsistence

Workers standing beside loads of sawed and stacked logs in East Texas forest
Source: Texasbeyondhistory.net

farms were established. During the mid-1800s, cotton and corn were the most important and widely grown crops, and hogs were the most abundant livestock. Other crops grown during this period were mainly for individual family consumption and consisted of wheat, sugar cane, tobacco and various other vegetables. Although hogs were the most abundant livestock, there were sizeable numbers of cattle and the monetary value of cattle when compared to hogs was generally greater; additional animals consisted of sheep, goats and horses. As with other industries, the arrival of the railroads significantly changed the agriculture economy of East Texas. The trend of subsistence farming declined and cultivation of cash crops, mainly cotton, increased substantially (Harper 2011: Knapp and Beisele 2011; Long 2011).

The end of the Civil War marked a significant change in agricultural practices in the South. With the end of slavery, plantation owners needed a way to ensure they had adequate labor supplies but had very little money due to

Photograph from early 1900s of cutover forest land in East Texas
Source: Texasbeyondhistory.net

the war. As a result, forms of tenant farming developed. Tenants were charged a portion of their harvest in exchange for farming land they did not own. As the practice of tenant farming increased, it became a highly systematic and hierarchical institution. At the top were farmers who supplied all the necessary farming equipment except the land; these share or cash tenants typically paid the landlord a third to a fourth of their harvest. At the bottom, were the sharecroppers who only supplied their labor; they typically paid roughly half of the harvest. Directly after the Civil War, most of the tenant farmers were freed slaves; however, as time went on the number of white tenants steadily increased. The number of tenant farmers continued to rise into the 1930s. The census of 1930 recorded that 61% of all Texas farmers were tenant farmers (Harper and Odom 2012).

During the 1920s, cotton prices dropped; as a result, most Southern farmers increased their production to offset the drop in prices. This decline in price, along with the arrival of the boll weevil, devastated numerous farms, causing many to move to larger cities to find work. During the Great Depression, government programs associated with the New Deal reduced the number of tenant farmers by enacting programs that encouraged tenants to become owners, as well as programs that paid farmers to reduce crop acreage, which reduced the amount of labor that was needed. By the 1950s the number of farms in most East Texas counties dropped by roughly 50% from the 1930s. As cotton production fell, livestock production increased and replaced many other forms of agriculture. By the 1970s, most of the agriculture receipts from Nacogdoches, Shelby and San Augustine and Rusk counties were from livestock production, mostly cattle and poultry. This trend is still evident today, with Shelby and Nacogdoches counties ranking first and second in the state for broiler (meat chicken) production in the 2007 Census of Agriculture produced by the National Agricultural Statistics Service (NASS) (Harper 2011; Knapp and Beisele 2011; Long 2011; McCroskey 2011).

Logging

As with agriculture, logging began in East Texas with the Caddo Indians who felled trees to construct their houses and villages and to clear land for small subsistence farms. The impact the Native Americans had on the land was minimal when compared to what was to come with the onset of European settlement. One of the first sawmills to be constructed in East Texas was built in 1829 in Nacogdoches County on Carrizo Creek. Due to the lack of reliable transportation, these early mills remained small and were only able to sell wood to local markets. Some tried to float logs down major rivers, but rivers were commonly clogged with logs and other debris and flows were sporadic. As a result, the vast forests of East Texas could not be profitably exploited, and lumber was in short supply in Texas (University of Texas at Austin 2004).

The arrival of the railroad spurred what is known as the "bonanza period" in East Texas logging history. At the same time, innovations such as the band saw made milling safer and more efficient. Corporations began to construct larger and larger mills, and mill towns began to pop up all across East Texas and the south. As forest resources were used up in one area, logging operations moved further into remote forests and more towns were built. Trams or logging railroads were constructed deeper and deeper into the virgin forests of East Texas as logging fronts advanced. These trams and cleared routes became the rural transportation system of farm to market and county roads we have now. By the early 1900s, the Attoyac Bayou watershed was home to many towns with sawmills such as Garrison and Mayotown in northeast Nacogdoches County, Smyrna in southeast Nacogdoches County, Waterman in southwest Shelby County and Denning in northwest San Augustine County. Many more mills were likely present within the Attoyac Bayou watershed, and by 1910 there were over 600 mills in Texas (University of Texas at Austin 2004).

By 1920, most of the forest land acquired by the larger mills had been cutover, leaving tangled thickets of hardwood re-growth with little to no pine regeneration. Some companies moved on to other areas of the United States such as out west where large tracts were still available for cut-and-run logging while other companies simply went bankrupt. In 1933, the Texas legislature passed a bill allowing the U.S. Forest Service (USFS) to purchase cutover forest lands in Texas. The USFS began to appraise and buy forest lands that would comprise the National Forests now in Texas. More than 90% of this land was purchased from 11 timber companies. Forestry and timber production continue to play a key role in the economy of East Texas and the Attoyac Bayou watershed (University of Texas at Austin 2004).

Oil and Natural Gas Production

Oil and natural gas production have played an important role in East Texas and the Attoyac Bayou watershed (Figure 2.2). The first oil well to be drilled in Texas was done so in Oil Springs located in southern Nacogdoches County. In 1865 Taliaferro Barret and some friends established the Melrose Petroleum Oil Company, and in 1866, at a depth of 106 ft, they struck oil. Due to lack of financial support, Barret abandoned his venture, and the oil field lay dormant until 1887 when new drilling companies came into the area. By 1889, there were 40 producing wells in the oil field around Oil Springs (Folsom 2012).

In the early 1930s, the largest and most prolific oil field in the continental United States was discovered in Rusk County. The East Texas oilfield is roughly 45 mi north/south and five mi east/west and is situated in portions of Gregg, Rusk, Upshur, Smith and Cherokee counties. Since its discovery, the East Texas Oilfield has produced roughly 5.2 billion barrels of oil from over 30,000 wells. Although situated outside of the Attoyac Bayou watershed, the East Texas Oilfield had a significant impact on the economy, landscape and culture of East Texas (Smith 2012).

As seen in Figure 2.2, most of the drilling in the Attoyac Bayou watershed is for the exploration of natural gas. Natural gas producing formations in and around the Attoyac Bayou watershed include the Haynesville Shale, Bossier Shale, Travis Peak and Cotton Valley formations. Most of the wells in the Attoyac Bayou watershed are associated with the Travis Peak and Cotton Valley formations in the northern portion of the watershed. However, beginning in 2009 drilling activities associated with the Haynesville Shale formation emerged. Most of the drilling associated with the Haynesville Shale was concentrated in the southern portion of the watershed in eastern Nacogdoches County, northern San Augustine County and southern Shelby County (Bartberger et al. 2003; Dyman and Condon 2006).

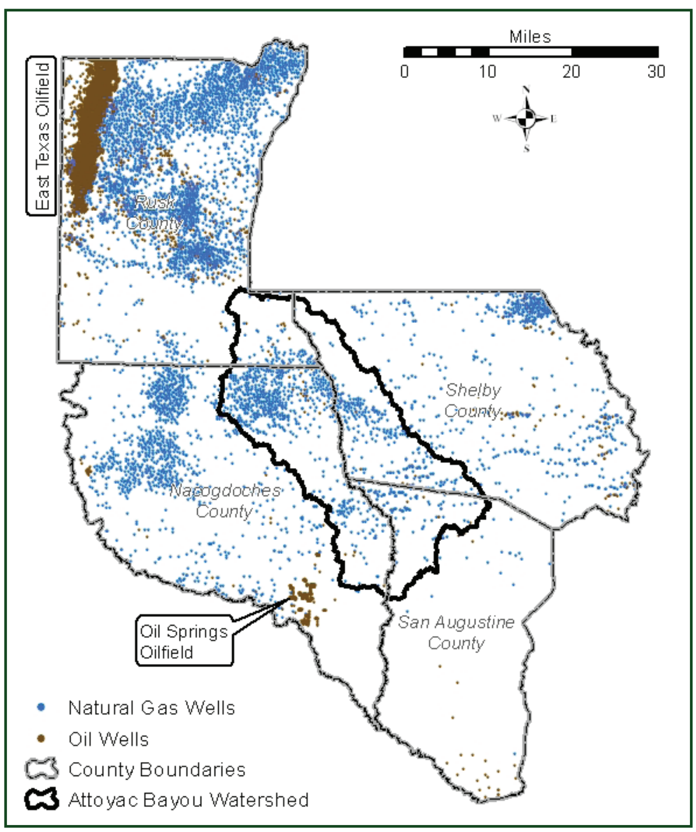
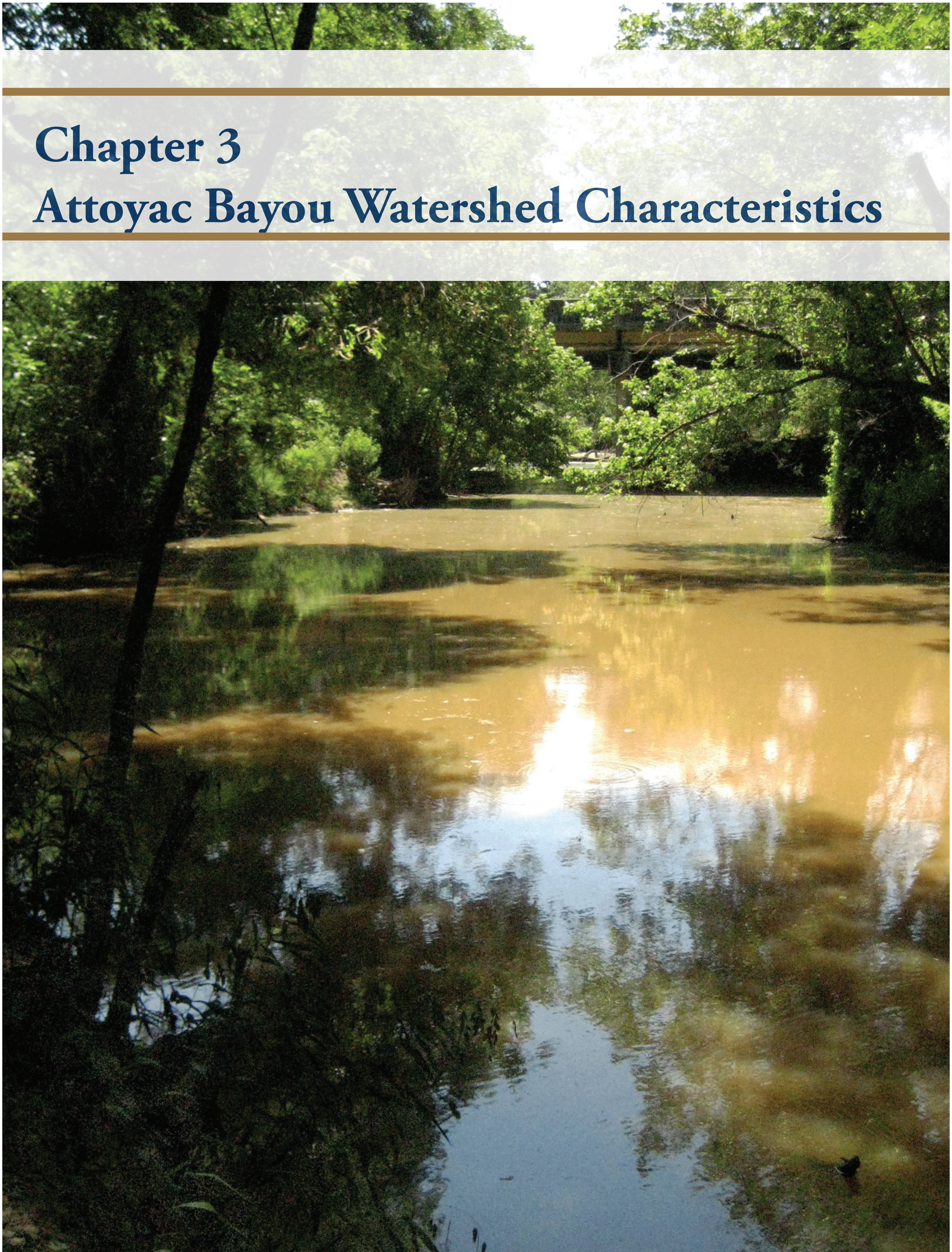


Figure 2.2. Oil and natural gas wells within and around the Attoyac Bayou watershed
Source: The Railroad Commission of Texas

Chapter 3
Attoyac Bayou Watershed Characteristics



Attoyac Bayou Watershed Location

The Attoyac Bayou watershed is a predominantly rural watershed situated in deep East Texas. The watershed is located in portions of Nacogdoches, Rusk, San Augustine and Shelby counties. Local cities and communities within the watershed include Chireno, Garrison, Martinsville and Stockmann. The Attoyac Bayou watershed is situated approximately 180 mi southeast of Dallas and approximately 150 mi northeast of Houston (Figure 3.1). Major roads accessing the watershed include US Highways 59 and 84 in the northern portion of the watershed and State Highways 7 and 21 in the south.

Watershed Boundaries

The Attoyac Bayou watershed has a drainage area of approximately 554 mi^2, or 354,629 ac, and constitutes the northern extent of the Lower Angelina Sub-basin (8-Digit hydrologic unit code (HUC): 12020005). The Lower Angelina Sub-basin is one of seven sub-basins that make up the Neches River Basin (6-Digit HUC: 120200). The headwaters of the Attoyac Bayou begin near the town of Mt. Enterprise in Rusk County. The watershed then extends south and east to the segment boundary near Sam Rayburn Reservoir. The Attoyac Bayou watershed is further subdivided into 55 smaller sub-watersheds. Figure 3.2 depicts the location of the Attoyac Bayou watershed within the Neches River Basin.

Topography

The majority of the watershed consists of gently to moderately sloping terrain, characterized by hills and ridges, which slope down to level floodplains of numerous streams extending throughout the watershed. Slope ranges from 0 to approximately 30%, depending on landform throughout the watershed. Elevation ranges from approximately 705 ft above mean sea level (MSL) in the upper

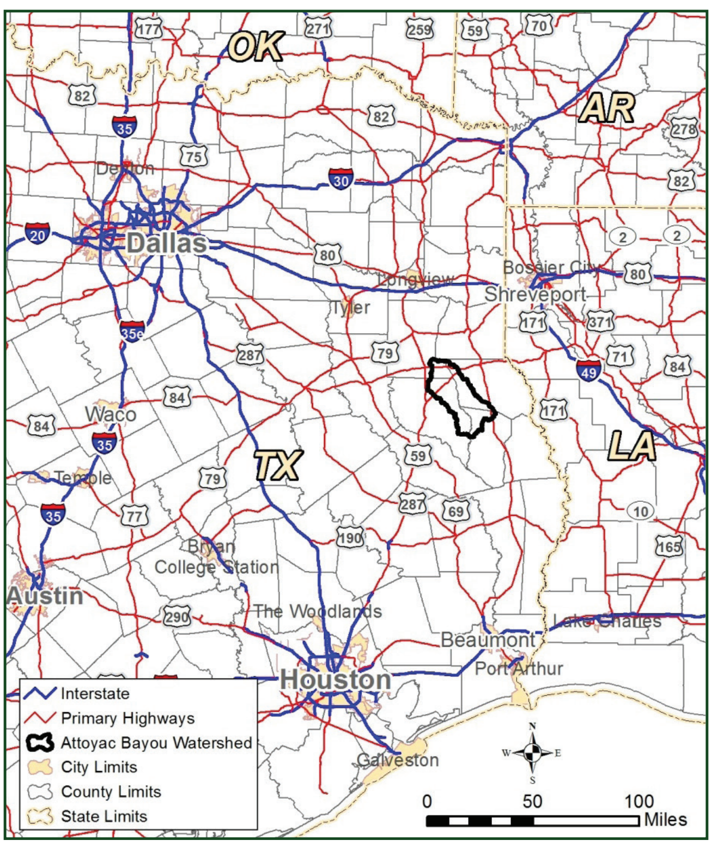


Figure 3.1. Location of the Attoyac Bayou watershed
Source: ESRI

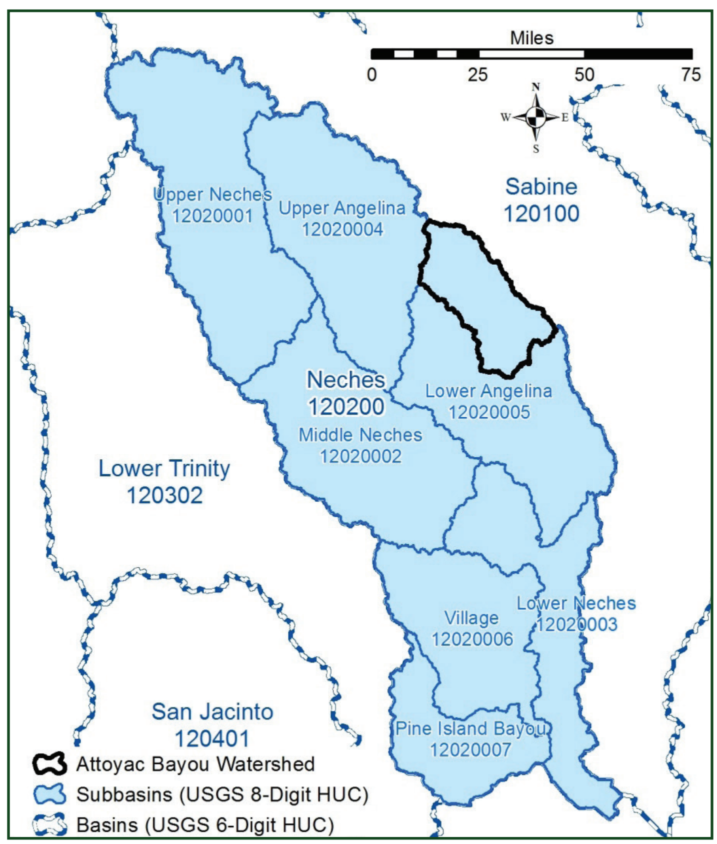


Figure 3.2. Basins of East Texas and sub-basins of the Neches River Basin
Source: TWDB

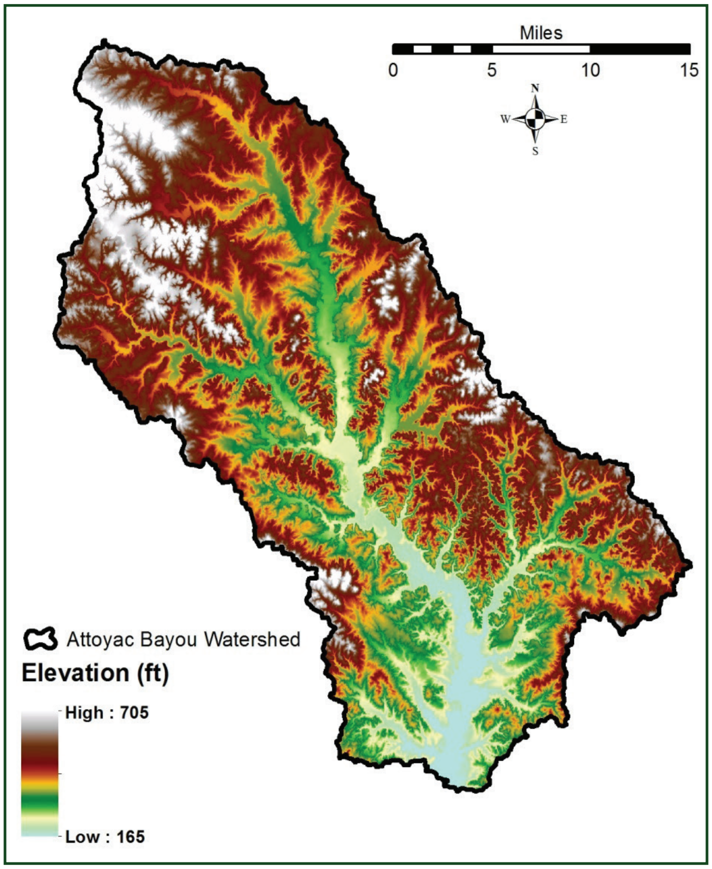


Figure 3.3. Elevation of Attoyac Bayou watershed
Source: Mosaic of U.S. Geologic Survey (USGS) 10-m NED images.

reaches of the watershed to 165 ft above MSL near the watershed outlet point at the segment boundary. Figure 3.3 depicts the elevation of the watershed derived from 10-m national elevation dataset (NED) images.

Soils

Soils throughout the watershed are diverse but generally consist of deep, moderately well-drained to well-drained, loamy to sandy, acidic soils. For a complete look at the soils of the Attoyac Bayou watershed, see the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Soil Surveys developed for Nacogdoches, Rusk, San Augustine and Shelby counties (USDA 1980; USDA 1992; USDA 2006; USDA 2002, respectively).

The Attoyac Bayou watershed is divided into eight soil associations as seen in Figure 3.4. Most of these soil associations generally consist of a variety of well-drained loamy soils situated in various upland landscapes and along minor drainage ways and streams within the watershed. Notable exceptions include the Tonkawa-Osier-Darco (s7691) and Tuscosso-Marietta-Mantachie-Iuka-Hannahatchee (s7453) soil associations. The Tonkawa-Osier-Darco (s7691) soil association is comprised of deep, sandy soils situated on side slopes and narrow drainage ways. The Tankawa and Darco soils consist of excessively drained sandy soils situated on side slopes while the Osier soils consist of poorly drained, wet sandy soils situated on foot slopes and along drainage ways. The Tuscosso-Marietta-Mantachie-Iuka-Hannahatchee (s7453) soils association consists of a variety of frequently flooded bottomland soils situated in floodplains. These soils range from moderately well-drained to somewhat poorly drained have textures ranging from clay loam to sandy loam (USDA 1980; USDA 1992; USDA 2006; USDA 2002).

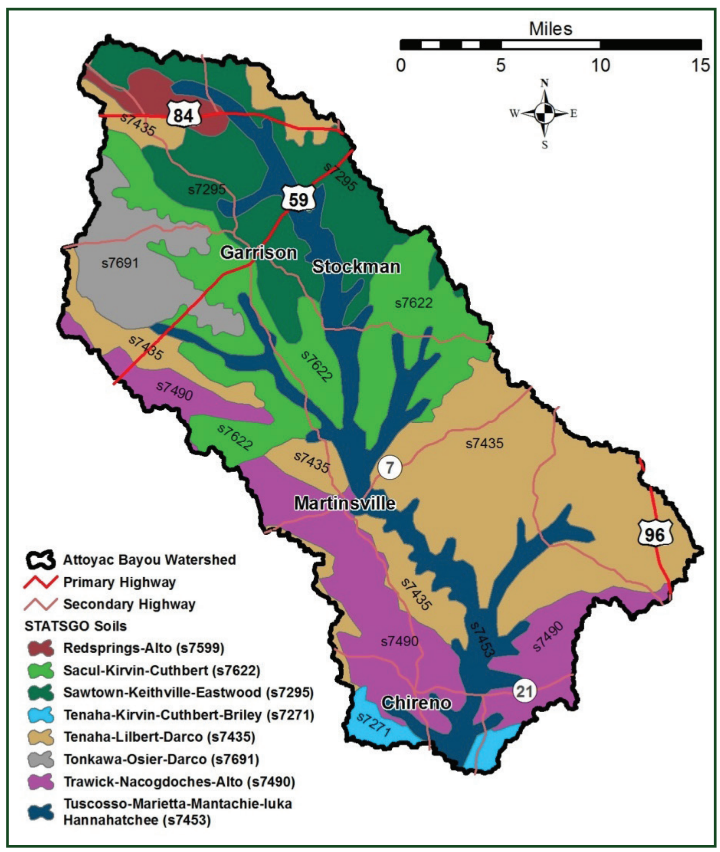


Figure 3.4. Soil associations within the Attoyac Bayou watershed
Source: USGS State Soil Survey Geographic (STATSGO) Soils

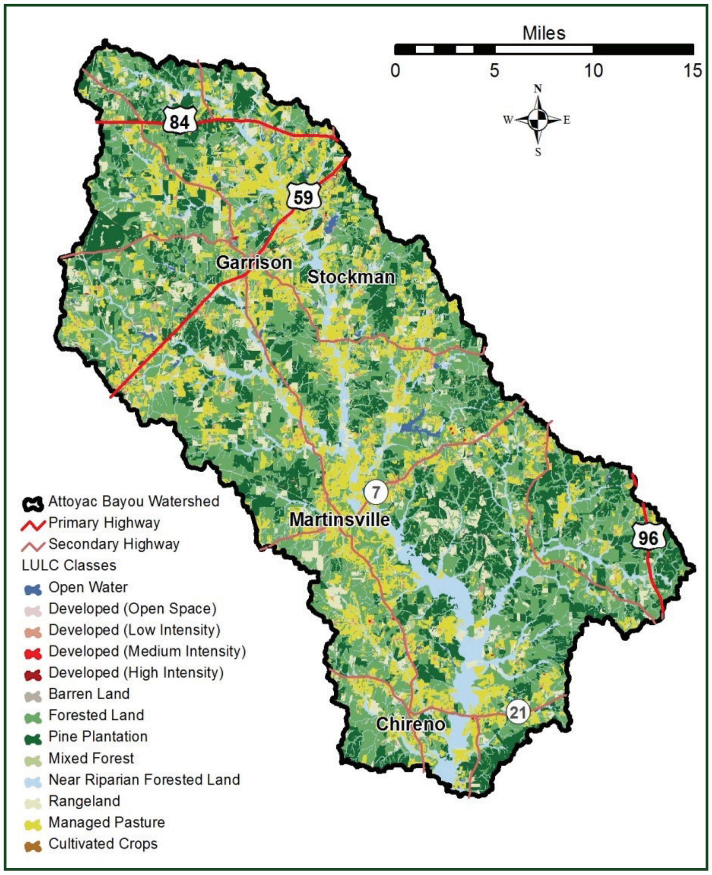


Figure 3.5. LU/LC classes within the Attoyac Bayou watershed
Source: CES

Land Use/Land Cover

CES personnel classified the land use and land cover (LU/LC) types within the Attoyac Bayou watershed in 2009–2010. The watershed was divided into 13 LU/LC classes including barren land, cultivated cropland, developed areas (low, medium and high intensity as well as open spaces), forested land, managed pasture, mixed forest, near riparian forested land, pine plantation and rangeland. A detailed description of these classes, as well as the methods used to classify these features, can be found in Appendix B and in Boitnott et al. (2014).

As seen in Table 3.1, the Attoyac Bayou watershed is a predominantly rural watershed with roughly 70% consisting of forested LU/LC classes, 26% consisting of managed pasture or rangeland and only approximately 3% consisting of classes of developed land. The remaining classes consisted of open water, barren land and cultivated crops.

Ecoregions

The watershed is located in the South Central Plains (35) ecoregion, commonly referred to as the "Piney Woods." Once dominated by a mix of pine and hardwood forest, much of this ecoregion has now been converted to pine plantations. Soils in the South Central Plains ecoregion are generally acidic and sand to sandy loam textures. The Attoyac Bayou watershed is further subdivided into two level IV ecoregions identified as the Tertiary Uplands (35a), which comprises the northern three-fourths of the watershed, and the Southern Tertiary Uplands (35e), comprising the southern one-fourth of the watershed.

The Tertiary Uplands (35a) consists of a large area encompassing portions of East Texas, Southern Arkansas and North Louisiana. The landscape in this area consists of gently to moderately sloping rolling terrain with numerous stream channels that support a wide variety of habitats and species. The soils in this area are mostly well drained with sandy to sandy loam surface horizons. The natural vegetative communities within the Tertiary Uplands exhibit a lower pine component when compared to the Southern Tertiary Uplands (35e). Much of the forested land has been converted to pine plantations for timber production. Additional land uses consist of livestock grazing, poultry production, as well as oil and natural gas production (Griffith et al. 2007).

The Southern Tertiary Uplands (35e) consist of the northern extent of the longleaf pine range in Texas and Louisiana. The landscape in this area is gently sloping, rolling terrain dissected with low to moderate gradient stream channels. In general, this area has less topographic relief than the Tertiary Uplands, but has more relief than the Flatwoods (35f) ecoregion situated to the south. Soils are diverse in this area and range from well-drained sands to poorly drained clays. Historically, the vegetative community within this ecoregion consisted of longleaf pine forest with other forest types containing hardwoods present at a lower frequency. Large portions of the Southern Tertiary Uplands are public national forest land consisting of the Angelina, Davy Crockett, Sabine and Sam Houston National Forests. Other land uses consist of pine plantations for timber production, pastureland for livestock grazing, recreation, wildlife and oil and natural gas production (Griffith et al. 2007).

Table 3.1. Acreage and percent of each LU/LC class within the Attoyac Bayou watershed

LULC Class	Acreage	Percent
Total Watershed	**354,629**	
Forested Land	133,193	37.56%
Managed Pasture	69,662	19.64%
Pine Plantation	67,891	19.14%
Near Riparian Forested Land	43,193	12.18%
Rangeland	23,049	6.50%
Developed (Low Intensity)	6,618	1.87%
Developed (Open Space)	3,394	0.96%
Open Water	2,681	0.76%
Mixed Forest	2,561	0.72%
Barren Land	1,546	0.44%
Developed (Medium Intensity)	771	0.22%
Cultivated Crops	57	0.02%
Developed (High Intensity)	13	0.004%

Climate

The climate within the watershed can be characterized as humid subtropical with warm humid summers and humid, mild winters. Average high temperatures during the summer months range from the low to mid 90s with average low temperatures ranging from the low to mid 70s. Average high temperatures during the winter months range from the mid to high 50s with low temperatures in the upper 30s (Southern Regional Climate Center 2012). Average rainfall within the watershed varies from 45 to 49 inches per year, with an average of 45 inches occurring in the western portion of the watershed and increasing to 49 inches per year in the eastern portion of the watershed. Rainfall is distributed fairly evenly throughout the cooler months of the year. The months of July and August generally receive the least amount of rain in a year. East Texas is characterized as a portion of Texas that experiences a summer drought climatic pattern, with peak precipitation occurring in the spring and fall months. When rainfall is below normal during the cooler months, especially during the peak rainfall periods before and after the typical summer drought conditions, significant drought periods can result (Carr 1967).

Groundwater

The Carrizo-Wilcox, Sparta and Queen City aquifers are present within the Attoyac Bayou watershed. The Carrizo-Wilcox is identified by the Texas Water Development Board (TWDB) as a major aquifer, and the Sparta and Queen City are identified as minor aquifers (Figure 3.6).

Carrizo-Wilcox Aquifer

The Carrizo-Wilcox aquifer is situated in a narrow band that parallels the Gulf Coast and extends from the Rio Grande in South Texas northeast into Arkansas and Louisiana. This aquifer provides water to all or portions of 60 counties in Texas. Municipal pumpage accounts for roughly 35% of total withdraws with the largest metropolitan areas including Bryan-College Station, Lufkin-Nacogdoches and Tyler. Pumpage for irrigation accounts for roughly 51% of total and is the predominant use in the Winter Garden region of South Texas. Well yields are generally around 500 gal/min, although some wells may reach 3,000 gal/min in the downdip (subcrop) areas where the water bearing geologic formation is overlain by another formation creating artesian conditions for the aquifer. The Carrizo-Wilcox Aquifer produces water that is fresh to slightly saline. In the outcrop, the water is usually hard and low in dissolved solids. In the subcrop, water is softer but contains more dissolved solids. Water level declines have occurred in the aquifer, with the Lufkin-Nacogdoches area experiencing declines in excess of 400 ft since the 1940s (Ashworth and Hopkins 1995). Depth to water within the Attoyac Bayou watershed is typically in the range of 150 to 450 ft (TWDB 1970) and aquifer thickness ranges between 1,000 and 1,800 ft deep (TWDB 1991). Water level declines in the aquifer are slowing, largely due to increasing use of surface water instead of groundwater (Ashworth and Hopkins 1995).

Sparta

The Sparta Aquifer is situated in a narrow band that runs from Frio County in South Texas, northeasterly to Sabine County along the Louisiana border. The Sparta Aquifer passes through portions of 26 Texas counties and the southern portion of the Attoyac Bayou watershed. The depth to the aquifer in the watershed is general less than 200 ft, (TWDB 1970), and its thickness ranges from 30 to 100 ft (TWDB 1991). Individual water well yields are generally around 100 gal/min, with some high capacity wells averaging 400 to 500 gal/min. Water quality is generally good within the outcrop and in shallower portions of the subcrop. Water quality deteriorates with depth in the subcrop (Ashworth and Hopkins 1995).

Queen City

The Queen City Aquifer is situated in a narrow band that runs from Frio County in South Texas, northeasterly into Northeast Texas and Louisiana. Yields of individual water wells are generally low, with only a few exceeding 400 gal/min. Water quality deteriorates with depth in the subcrop (Ashworth and Hopkins 1995) and in the Nacogdoches County area is caused by elevated levels of iron (TWDB 1991).

Groundwater Usage

Major groundwater usage does not occur in the watershed; however, municipal usage is the greatest use in the area. The nearby cities of Lufkin and Nacogdoches both use enough water to cause aquifer drawdown in the area, and 12 different rural water suppliers own and operate wells within the watershed. Other groundwater uses in descending order of pumped volume are manufacturing, mining, livestock, irrigation and steam-electric generation (TWDB 1991). This is not necessarily the trend in the Attoyac Bayou watershed, but it illustrates uses area-wide.

TWDB has record of 148 water wells drilled in the watershed, which range in depth from 10 to 995 ft deep. Of these, 25 are noted as public water supply wells, 53 are domestic use wells, two are irrigation wells; the remainder are used for stock water or have no noted use. The Carrizo-Wilcox Aquifer has 137 of these wells completed within its boundaries while only two are completed within the Sparta Aquifer. No aquifer is noted for the remaining wells. Individual households in the watershed are also reliant upon the watershed's groundwater resources for water. Numerous other non-permitted water wells are likely to exist in the watershed as well. Irrigated

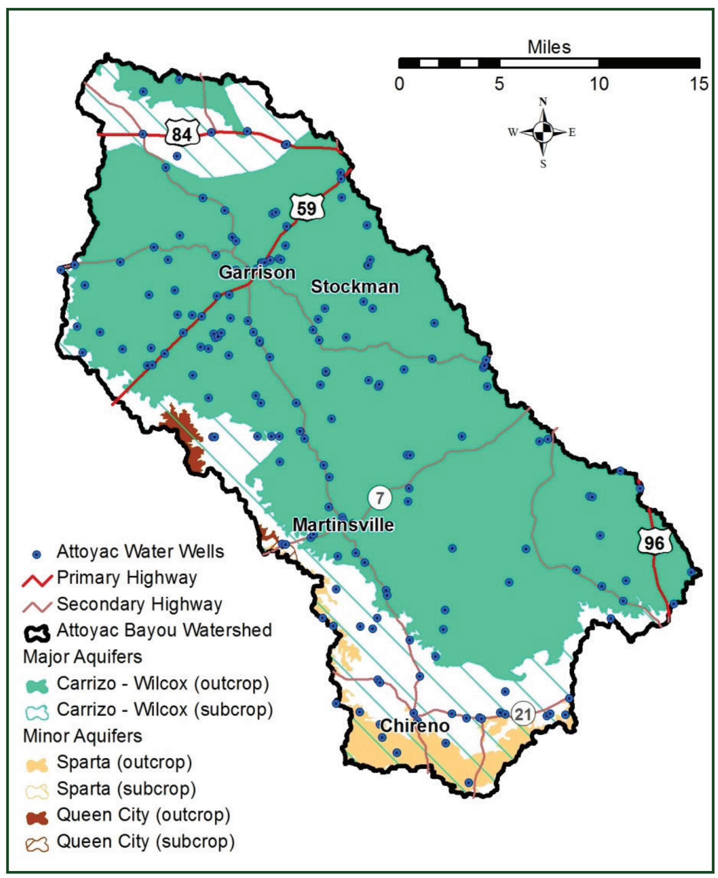


Figure 3.6. Aquifers and permitted water wells within the Attoyac Bayou watershed
Source: TWDB

agriculture is not a significant water user in the region. In total, 2,097 ac of irrigated cropland were documented in Nacogdoches, Rusk, San Augustine and Shelby counties combined (USDA 2007).

Surface Water

Surface water in the Attoyac Bayou watershed is abundant. As delineated by the USGS National Hydrography Dataset (NHD), there are over 1,930 stream mi within the Attoyac Bayou watershed. The majority of these streams consist of unnamed ephemeral and intermittent tributaries of the Attoyac Bayou; however, there are approximately 584 stream mi of named streams, generally intermittent or perennial, within the Attoyac Bayou watershed. The Attoyac Bayou begins in Rusk County in the northern portion of the watershed and flows in a southerly direction, meandering approximately 97 mi to the segment boundary near Sam Rayburn Reservoir. Major tributaries of the Attoyac Bayou include Big Iron Ore, Naconiche, Terrapin, Waffelow and West creeks.

Man-made reservoirs and stock ponds of various sizes are numerous throughout the watershed. Open-water habitats account for 2,680 ac or 0.76% of the land surface within the watershed. Smaller ponds and lakes within the watershed appear to have been built for agriculture or recreational uses by private individuals. There are 13 impoundments within the watershed that were built with assistance from NRCS for flood control. Lake Naconiche is the largest of these impoundments; however, most range in size from 20 to 50 ac (NRCS 2011). There are three larger reservoirs in the watershed: Lake Naconiche, Lake Pinkston and Lake Timpson (Figure 3.7).

Lake Naconiche

Lake Naconiche is a recently constructed impoundment of Naconiche Creek located in Nacogdoches County. Construction of the dam was completed in 2006; however, recreational facilities are in various stages of engineering and construction. Funding for the approximately $6.5 million project was provided by Nacogdoches County and NRCS (Anderson 2008). The primary function of Lake Naconiche is for flood control with recreation as a secondary use. Future utilization of the lake as a municipal water supply was also mentioned in the 2011

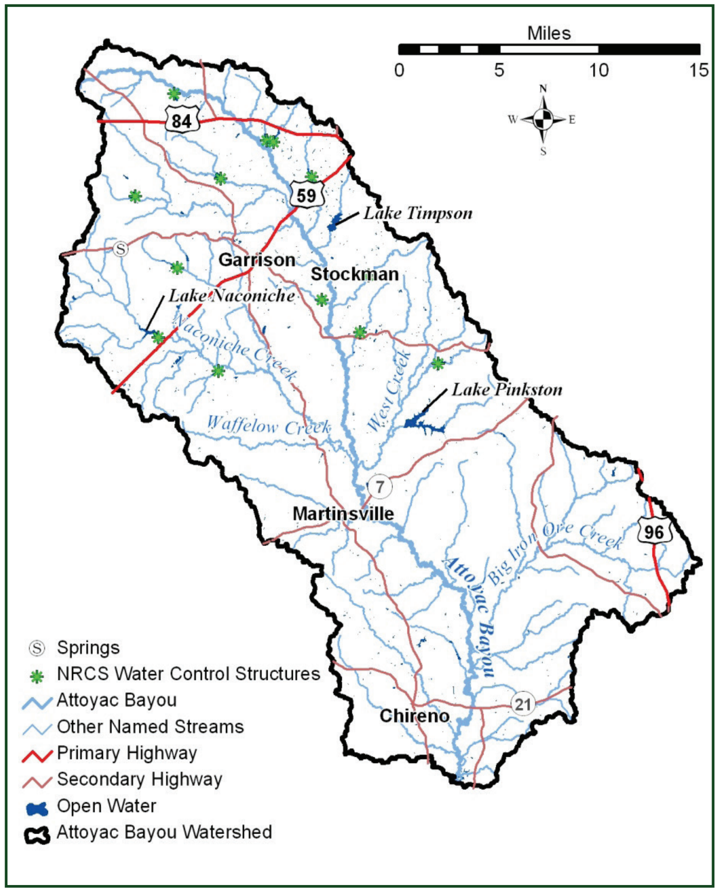


Figure 3.7. Surface water resources within the Attoyac Bayou watershed
Sources: NHD (Streams), LU/LC (Open-Water)

East Texas Water Plan; however, a primary sponsor for a new water supply system has not been confirmed. The lake has a conservation pool surface area of 692 ac and a total project area of 1,254 ac, a planned storage capacity of 9,074 acre-feet (ac-ft) and a maximum depth of 40 ft (ETRWPG 2010). The lake can be accessed from Farm to Market Road 2435, off U.S. Highway 59, approximately 13 mi north of Nacogdoches (ANRA 2011).

Lake Pinkston

Lake Pinkston is located in southwest Shelby County and is an impoundment of Spring Creek. The lake is owned and operated by the city of Center and construction of the lake was completed in 1978. The primary purpose of Lake Pinkston is for municipal water supply for Center with recreation as a secondary use. The lake has a conservation pool area of 447 ac , roughly four mi of shoreline and an average depth of approximately 20 ft From State

Highway 7, County Road 1510 accesses the dam and western portion of the lake and County Road 1211 accesses the eastern portion of the lake (ANRA 2011).

Lake Timpson

Lake Timpson is located in northwest Shelby County and is an impoundment of Blackwater Creek. Lake Timpson was constructed in 1956 and the controlling authority is the Shelby County Freshwater Supply District. The primary purposes of this lake are water supply for the city of Timpson and recreation. This lake has a surface area of approximately 223 ac, roughly eight mi. of shoreline and an average depth of eight ft. The lake can be accessed from Farm to Market Road 2667, off U.S. Highway 59, approximately five mi southwest of Timpson (ANRA 2011).

Population

2010 census data was obtained for individual census tracts present within the Attoyac Bayou watershed. Census tracts are areas within a county that generally have between 2500 and 8000 people and relatively homogenous population characteristics. These tracts were clipped to only include the area within the watershed, and the population was adjusted based on the amount of land area still present from the original tract. According to 2010 census data, the population for the Attoyac Bayou watershed is approximately 13,275 people. These people are spread throughout the watershed, but are generally concentrated around towns, communities and along major road corridors. Based on 911 address data, there are approximately 6,670 structures within the watershed. The majority of these structures are housing units; however, this does include churches, businesses, shops and other large structures. Figure 3.8 depicts the density (structure per square mile) within the watershed.

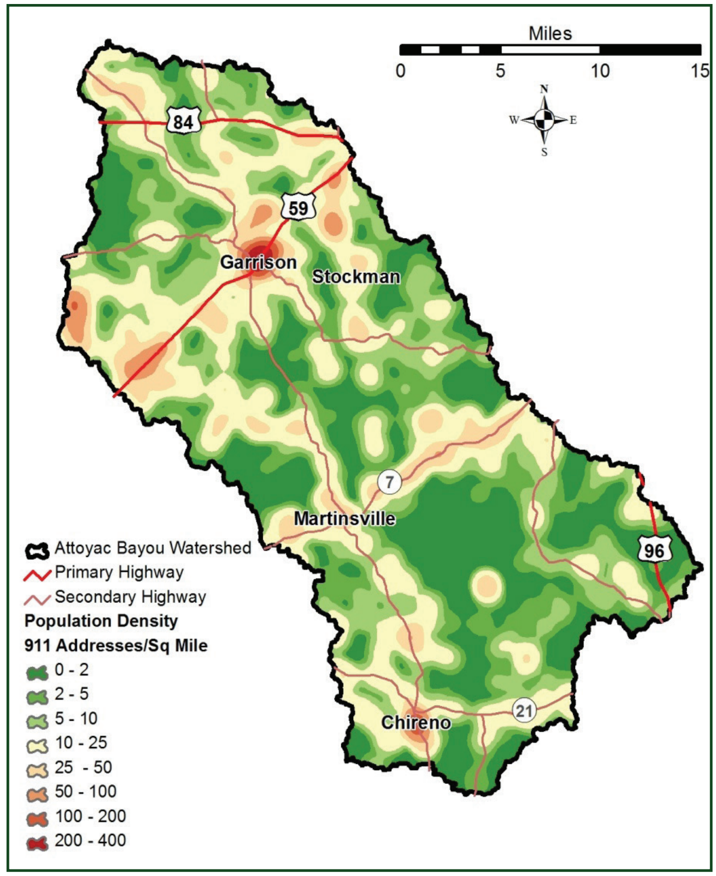
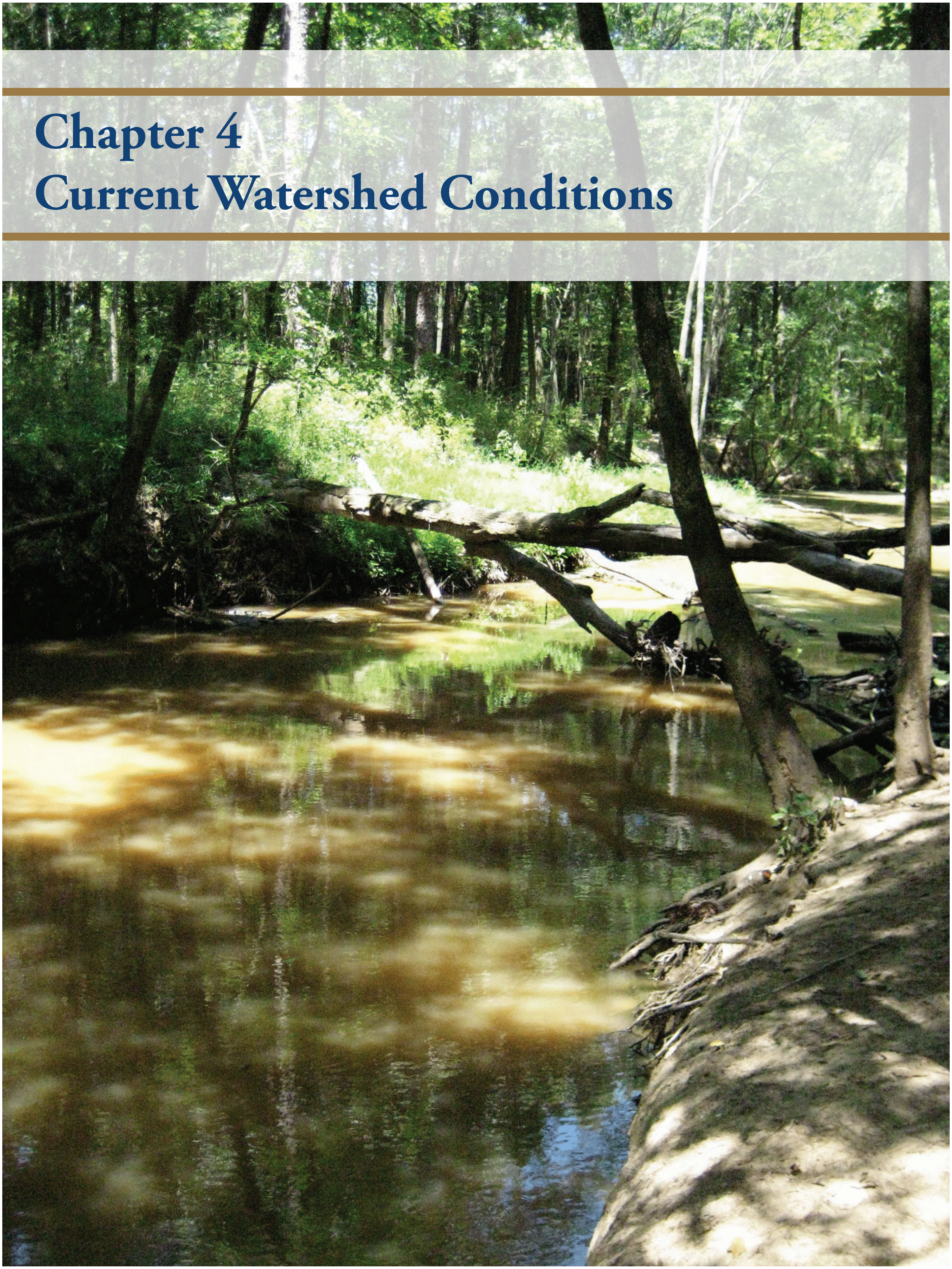


Figure 3.8. Structure Point Density for Attoyac Bayou watershed
Source: East Texas Council Of Governments and Deep East Texas Council Of Governments

To accurately quantify the number of actual households within the watershed, the 911 address data was compared to the number of households provided by the 2010 census data. The 2010 census tracts were clipped in the same way as previously noted to extrapolate an approximate number of households present in the watershed. The results of the 2010 census data indicated there were 6,255 households (occupied and unoccupied) present in the watershed. To reconcile the differences in the 911 address data and the 2010 census data, the 911 address data was reviewed to determine the number of address that do not represent an actual residence or other structure that typically has an OSSF such as a church or restaurant. The 911 address data provided for Rusk County had physical descriptions of the structure occupying the 911 address. Anything that did not represent a structure likely having an OSSF was not counted. After this review, it was determined that roughly 6.2% of the 911 address in Rusk County represent obscure structures such as barns, shops and other non-residential buildings. A reduction in the number of 911 addresses across the entire watershed by 6.2% results in 6,258 residences in the watershed, very similar to the 2010 census data. To quantify the number of residences in the watershed, the 2010 census data of 6,255 will be used; however, the 911 address data will be used to identify spatial patterns and distribution of residences and potential OSSFs.

Chapter 4
Current Watershed Conditions



Demographics

The Attoyac Bayou watershed incorporates two cities and two towns/communities within its boundaries. The cities of Garrison and Chireno as well as the community of Martinsville lie in Nacogdoches County while the community of Stockman, located in Shelby County, is near the headwaters of Attoyac Bayou. Table 4.1 shows the populations of the Shelby, Rusk, San Augustine and Nacogdoches counties, the four counties partially within the watershed, as reported in the 2000 and 2010 censuses, and their associated population changes. Populations in the watershed mirror a national trend of people migrating toward urban areas.

Table 4.1. Population in counties making up the Attoyac Bayou watershed

County	2000 Census	2010 Census	% Change	Persons per Household
Shelby	25,224	25,448	+1.0%	2.56
Nacogdoches	59,203	64,524	+9.0%	2.52
San Augustine	8946	8865	-0.9%	2.43
Rusk	47,372	53330	+2.6%	2.66

Source: U.S Census Bureau

The populations within the counties are employed in a variety of industries and professions. In all four counties, the education, health and social service industry employs the largest portion of the working population, according to the 2010 Census. Manufacturing-related employment ranks 2nd in Nacogdoches, Shelby and Rusk counties but drops to 6th in San Augustine County. Retail trade, agriculture and construction-related jobs round out the top five areas of employment for the area (Table 4.2). Median incomes and unemployment rates in the four counties are also reported in the table and are relatively similar except Nacogdoches Country displaying lower median income and higher rates of unemployment.

Agricultural Production

Commodities produced in the watershed have remained relatively unchanged since modern settlement began. Poultry, cattle and forage are the top commodities produced. Poultry operations especially are numerous throughout the Attoyac Bayou watershed. Estimated production numbers are available from the NASS and the NRCS. See sections on livestock and poultry in Chapter 6 for further details. Much acreage is also dominated by short-rotation woody crops. Although production levels have varied significantly throughout the years, agriculture remains an important industry and is responsible for a significant impact to the local economy in each county. Table 4.3 illustrates county-wide production numbers reported in the 2007 Census of Agriculture for each of the four counties that the Attoyac Bayou crosses. This county-wide data serves as a starting point for landowners to determine appropriate watershed specific agricultural production values.

Table 4.2. Employment trends as reported in the 2010 Census in counties partially in the Attoyac Bayou watershed

Most Common Industry of Employment	% Employed by County			
	Nacogdoches	Shelby	Rusk	San Augustine
Agriculture, forestry, fishing and hunting, and mining	5.7	15.5	10.4	9.3
Construction	8.6	7.3	8.7	12.0
Manufacturing	12.3	15.9	10.7	6.8
Retail trade	10.3	11.2	10.2	12.8
Transportation and Utilities	3.8	6.1	6.9	9.7
Education, health and social services	29.8	19.4	22.7	27.0
Entertainment and Recreation	8.5	3.7	6.5	4.1
Income Estimates				
Median Household Income	35,378	41,824	46,438	41,398

Table 4.3. 2007 Census of Agricultural production statistics for the four-county area encompassing the Attoyac Bayou

	Shelby			Nacogdoches			Rusk			San Augustine		
Farm Statistics and Production Value	**Year**			**Year**			**Year**			**Year**		
	1997	**2002**	**2007**	**1997**	**2002**	**2007**	**1997**	**2002**	**2007**	**1997**	**2002**	**2007**
Number of Farms	1,187	1,100	1,123	1,367	1,290	1,277	1,532	1,391	1,521	332	308	346
Land in Farms (ac)	201,427	192,036	197,791	372,446	273,880	265,131	282,848	272,436	300,900	65,867	58,723	72,640
Average Farm Size (ac)	192	175	176	272	212	208	185	196	198	198	191	210
Total Market Value of Products Sold ($1000s)	185,397	240,639	403,115	170,041	197,972	317,287	29,796	39,348	56,120	27,302	24,980	55,639
Market Value of Production ($1000s) avg/farm	156	219	359	124	153	248	19	28	37	82	81	161
Inventory of Livestock (# head) and Crops Planted (acres)	**Year**			**Year**			**Year**			**Year**		
	1997	**2002**	**2007**	**1997**	**2002**	**2007**	**1997**	**2002**	**2007**	**1997**	**2002**	**2007**
Cattle and Calves	46,895	45,966	42,722	59,460	54,026	46,328	57,513	52,745	48,924	11,135	11,981	13,232
Horses and Ponies	N/A	1,453	N/A	N/A	2,006	1,928	976	2,125	N/A	253	296	529
Broilers/Fryers (in 1,000s)	12,769	148,676	24,186	11,456	15,449	19,372	827	1,102	1,537	2,087	1,507	5,710
Layers (in 1,000s)	1,469	1,810	1,371	688	589	514	N/A	N/A	N/A	83	N/A	218
Forage/Hay	20,637	19,678	25,404	26,210	28,784	29,386	29,336	31,873	35,299	6,083	6,774	7,056
Short-rotation woody crops	N/A	446	238	53	360	517	179	645	740	52	N/A	271

Forestry

Roughly 70% of the rural watershed is covered by forest, accounting for an estimated 447,922 ac. For much of its course, Attoyac Bayou flows through forested hardwood bottomlands; however, numerous pine plantations also occur in the watershed. The forestry industry is a key source of income in the watershed and highly significant to the local economy (Table 4.4), contributing an estimated $9.4 billion annually.

Drought

During the course of the project to develop the Attoyac Bayou WPP, Texas' worst single year drought gripped the state. The project started on November 1, 2009, and water quality monitoring began on July 26, 2010. At this point, the watershed was already experiencing moderate drought conditions. Good rains in September eased these conditions slightly, but the year spanning October 2010 through September 2011 proved to be one of the driest one-year periods on record. The watershed area typically receives 45 to 49 in of rainfall annually, but during this year only 24.5 in of rainfall was recorded at Nacogdoches. While conditions began to improve after this, the watershed remained in moderate drought conditions through March 2012. Despite the improved moisture conditions, the watershed remains impacted by this drought several years later due to the death of vegetation and reduction in livestock numbers.

Table 4.4. Estimated economic impacts of local forestry industry in 2009

County	Industry Output (in millions of $)		Employment (# of jobs)		Labor Income (in millions of $)		Indirect Business Tax (million $)
	Direct Impacts	Total Impacts	Direct Impacts	Total Impacts	Direct Impacts	Total Impacts	
Nacogdoches	135.32	197.48	678	1,166	28.72	46.82	1.24
Rusk	87.50	123.69	562	861	20.62	31.65	0.53
San Augustine	24.58	32.66	163	231	5.03	7.43	0.13
Shelby	115.90	171.11	698	1,141	36.05	53.56	1.45
Totals	**363.30**	**524.94**	**2,101**	**3,399**	**90.42**	**139.46**	**3.35**

Source: Texas A&M Forest Service County Summary Tool

Chapter 5
Water Quality Assessments

The Attoyac Bayou, a sub-watershed (Segment 0612) within the Upper Neches River Basin (Figure 5.1), extends approximately 82 mi through Rusk, Nacogdoches, San Augustine and Shelby counties before emptying into Sam Rayburn Reservoir. It is a freshwater stream measuring 81.7 mi in length from a point 3.9 km (2.4 mi) downstream of Curry Creek in Nacogdoches/San Augustine County to FM 95 in Rusk County. The watershed is a rural area managed for agricultural (cattle and poultry), silvicultural, recreational and wildlife uses. It is one of many rural watersheds in the state listed as an impaired water body on the Texas Water Quality Inventory.

Three monitoring stations (Table 5.1) monitored by the Angelina & Neches River Authority (ANRA) and previously by the USGS and the Texas Commission on Environmental Quality (TCEQ) has provided water quality data on the bayou for a number of years. Beginning in 2000, data collected for *E. coli* have consistently shown elevated *E. coli* levels that exceed the applicable TCEQ standards.

Water Body Assessments

TCEQ conducts a water body assessment on a biennial basis with the most recent approved assessment from 2010. In years past, this assessment was called the "Texas Water Quality Inventory and 303(d) List," but was renamed to the "Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)," in 2010. TCEQ uses the most recent seven years of water quality data available on a given water body to assess that water body's ability to support its designated uses. For example, the 2010 Integrated Report takes into consideration data collected

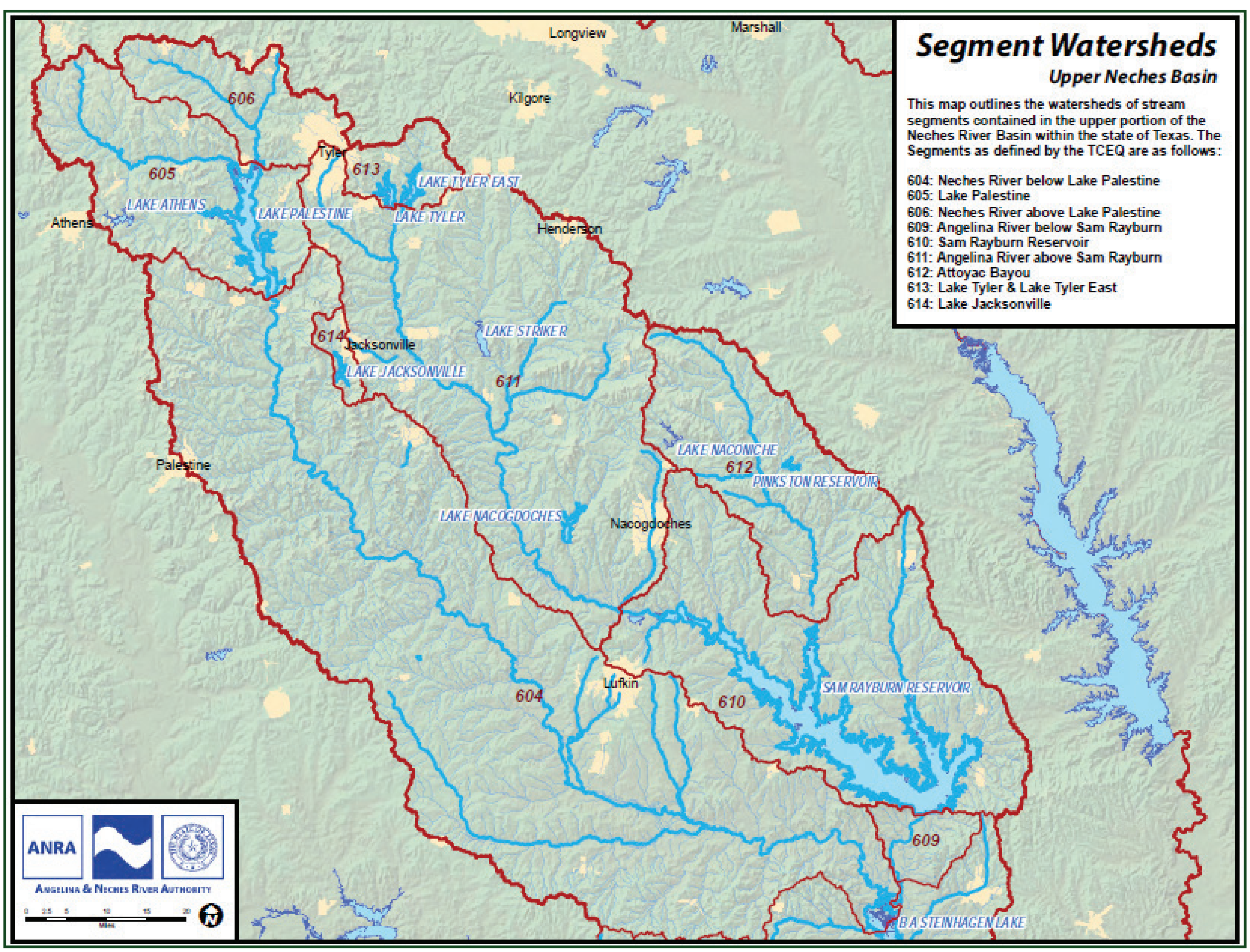


Figure 5.1. The Upper Neches River Basin
(ANRA website)

Table 5.1. ANRA monitoring stations

Station ID	Station Name	Collecting Agency	Frequency	Parameters*
10636	Attoyac Bayou at SH 21	ANRA	Quarterly	Field, Conventionals, Bacteria, Flow
15253	Attoyac Bayou at SH 7	ANRA	Quarterly	Field, Conventionals, Bacteria, Flow
16076	Attoyac Bayou at US 59	ANRA	Quarterly	Field, Conventionals, Bacteria, Flow

* Field: includes pH, dissolved oxygen, specific conductance, temperature and flow
Conventional: includes nutrients, minerals and particulate matter
Bacteria: refers to *Escherichia coli* in this case

between December 1, 2001 and November 30, 2008. TCEQ data assessors have the option of including data that are more recent if they are available or older data collected up to 10 years prior to the assessment date.

Designated Uses

TCEQ assigns water bodies as either classified or unclassified with the classified segments individually defined in the *Texas Surface Water Quality Standards* (TCEQ 2004). Applicable water quality standards designated for unclassified water bodies are defined by TCEQ (2010) according to the stream's flow type. Three flow types have water quality standards applied according to Texas' standards: perennial streams, intermittent streams with pools and intermittent streams. Perennial streams are those that maintain continuous flow year round in normal precipitation years; intermittent streams are those with a period of zero flow for at least one year, and intermittent streams with perennial pools are intermittent streams that maintain persistent pools even when stream flow is less than 0.1 cfs (cubic feet per second). Ephemeral streams are those that only flow for a short time following a runoff event; however, these streams do not have water quality standards applied in Texas.

Designated uses dictate which water quality assessment criteria a water body must adhere to. Unclassified segments are usually assigned the same designated uses as the classified segment that they are associated with, but this is not always the case. TCEQ considers all portions of the Attoyac Bayou to be perennial and thus requires it to support high aquatic life, general use, contact recreation and public water supply water quality standards. Aquatic life use is simply defined as a water body's ability to support a healthy aquatic ecosystem; the ability to support this use is evaluated based on assessment of dissolved oxygen (DO) criteria, toxic substances in water criteria, ambient water and sediment toxicity test results and indices for habitat for benthic macroinvertebrate and fish community. Recreation use, more specifically primary contact recreation use, must be supported in all but a few water bodies in Texas and is designed to evaluate the ability of a water body to support designated levels of recreation. This use is assessed by quantifying levels of bacterial indicator organisms in 100 milliliter (mL) of water. *Escherichia coli (E. coli)* is the bacterial indicator used in the Attoyac Bayou to assess this use. General use is a set of water quality criteria that are monitored to assess general water quality. These criteria include water temperature, pH, chloride, sulfate and total dissolved solids (TDS); additionally, concerns for meeting the general use are also quantified with screening levels for nutrients and chlorophyll a (TCEQ 2010).

Assessment Units

Water bodies are provided with a written description of the segment and are further subdivided into assessment units (AU). According to TCEQ (2010), "AUs are the smallest geographic area of use support reported in the water body assessment." The Attoyac Bayou is defined by three AUs, 0612_01, 0612_02 and 0612_03, which extend from "a point 3.9 km (2.4 mi) downstream of Curry Creek in Nacogdoches/San Augustine County to FM 95 in Rusk County."

During water body assessments, data collected from a designated AU are used to assess each AU independently of other AUs in that segment. Figure 5.2 illustrates the locations of these AUs as defined by their respective descriptions and the mapped extent of the stream segment.

Monitoring Station Locations

During the process of developing this WPP, 14 monitoring stations; 10 routine stations and four wastewater treatment facilities (WWTFs), were established within the Attoyac Bayou watershed with ease of access as the primary consideration. Table 5.2 presents descriptive information about each of these monitoring stations and Figures 5.2 and 5.3 illustrate where these stations are located in the watershed.

Index Sites

One monitoring location was chosen within each AU as an index site for that AU. These sites are considered most representative of the specific AU and will be used for future pollutant source analysis following WPP implementation. In AU 0612_01, Station 10636 was selected as the index site. This station has been monitored since 1972 and has the longest and most extensive data record of all monitoring stations in the Attoyac Bayou watershed. Stations 15253 and 16076 were selected as the index site in AU 0612_02 and 0612_03 respectively and have the most extensive data record for any site within these AUs. Each of these index sites is located at the approximate midpoint of their respective AU. These locations are denoted in Table 5.1 and Figure 5.2.

Table 5.2. Location of monitoring stations for the Attoyac Bayou WPP

Segment	Station ID	Station Name	Collected by	Frequency	Parameters*
0612	10636	Attoyac Bayou at SH 21	SFASU	Biweekly	F, C, B, BST
0612	15253	Attoyac Bayou at SH 7	SFASU	Biweekly, Stormwater	F, C, B, BST
0612	20841	Attoyac Bayou at FM 138	SFASU	Biweekly	F, C, B, BST
0612	16073	Attoyac Bayou at US 59	SFASU	Biweekly	F, C, B, BST
0612	20842	Attoyac Bayou at US 84	SFASU	Biweekly	F, C, B, BST
0612B	16083	Waffelow Creek at FM 95	SFASU	Biweekly	F, C, B, BST
0612A	16084	Terrapin Creek at FM 95	SFASU	Biweekly	F, C, B, BST
0612	20843	Naconiche Creek at FM 95	SFASU	Biweekly	F, C, B, BST
0612	20844	Big Iron Ore Creek at FM 354	SFASU	Biweekly, Stormwater	F, C, B, BST
0612	20845	West Creek at FM 2319	SFASU	Biweekly	F, C, B, BST
0612	WWTF1	City of Garrison WWTF Effluent	SFASU	Quarterly	F, C, B, BST
0612	WWTF2	Chireno ISD WWTF Effluent	SFASU	Quarterly	F, C, B, BST
0612	WWTF3	Martinsville ISD WWTF Effluent	SFASU	Quarterly	F, C, B, BST
0612	WWTF4	City of Center Water Treatment Filter Backwash	SFASU	Quarterly	F, C, B, BST

* F=field: includes pH, DO, specific conductance, temperature and flow
C=conventional: includes nutrients, minerals and particulate matter
B=bacteria: refers to *E. coli* in this case
BST=bacterial source tracking of *E. coli* in water samples

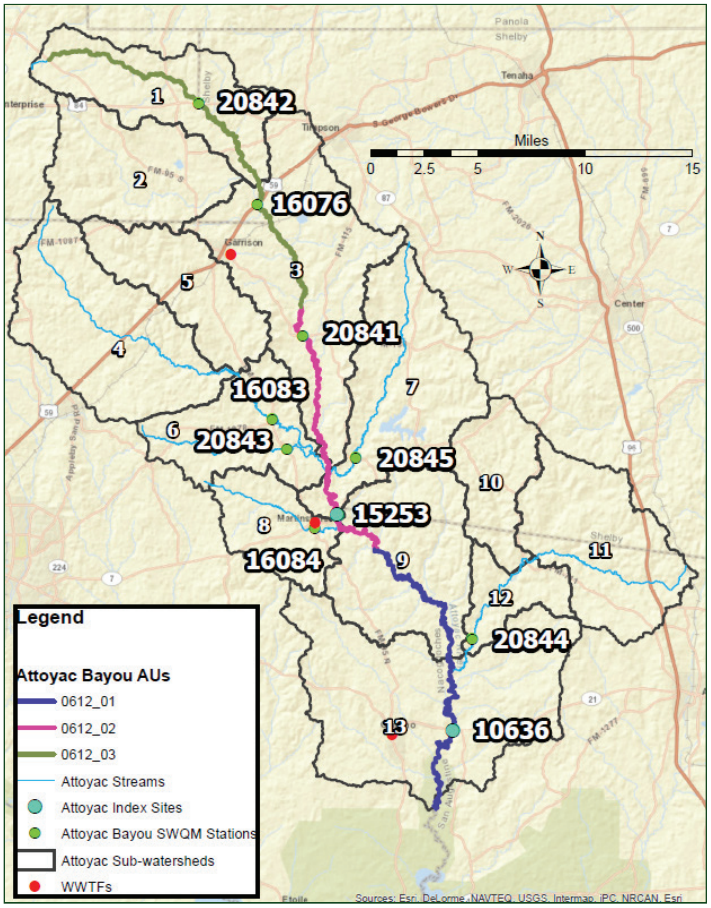


Figure 5.2. Location of monitoring stations and water body AU

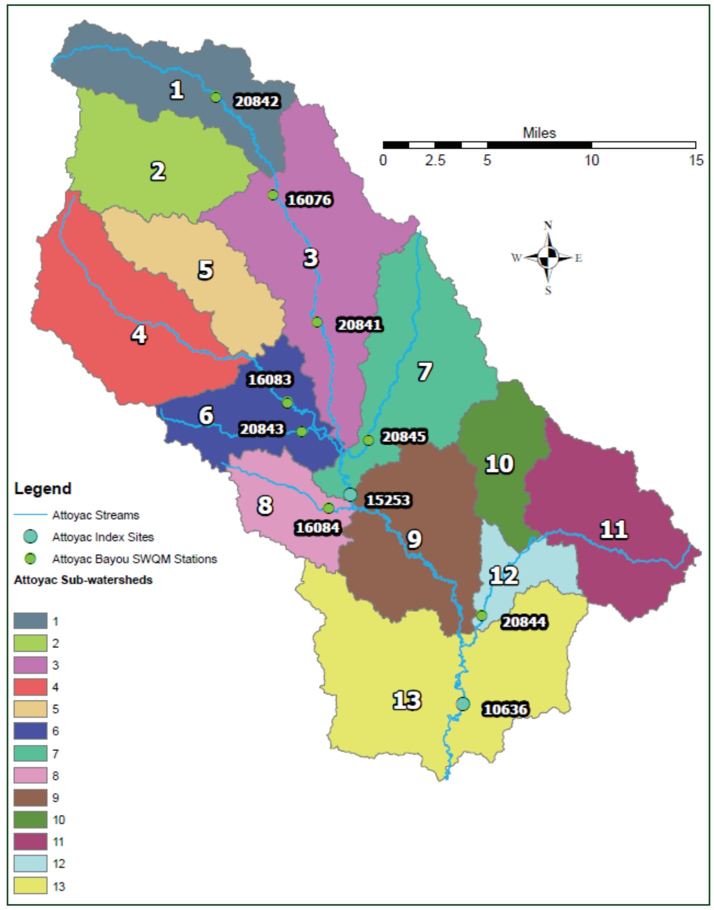


Figure 5.3. Attoyac Bayou sub-watersheds delineated to aid management recommendation prioritizing

Sub-watersheds

Sub-watersheds illustrated in Figure 5.3 were also delineated within the Attoyac Bayou watershed. This was done as a means to subdivide the watershed into hydrologically connected areas that can be targeted during WPP implementation efforts. Water quality data collected throughout the watershed can be tied back to the sub-watersheds as well, thus helping to identify what areas of the watershed are contributing to pollutant loading at a specific monitoring station. These watershed sub-watersheds are also used in predictive computer-based modeling that estimates which sub-watersheds have the highest bacteria loading potential, thus prioritizing them for future management implementation. This modeling will be discussed in detail later in Chapter 7.

The EPA Better Assessment Science Integrating Point and Non-point Sources or BASINS model was used to delineate 13 watershed sub-watersheds. Boundaries of each sub-watershed are derived from watershed topography while its outlet is often determined by the location of stream confluences. Figure 5.3 depicts the sub-watersheds delineated for the watershed.

Texas Surface Water Quality Standards (TSWQS) for the Attoyac Bayou

Primary concerns to water quality in the Attoyac Bayou are nutrient enrichment and elevated bacteria levels. Ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total phosphorus, dissolved orthophosphorus, total suspended solids (TSS) and *E. coli* have been evaluated in stream water since July 2010 by Stephen F. Austin State University (SFASU) field personnel.

TCEQ designates applicable water quality standards for each water body assessed in the state as outlined in the TSWQS. Measures used to quantify a water body's ability to meet its designated uses are: 1) DO standards for aquatic life use, 2) *E. coli* standards for recreation use and 3) nitrate and chlorophyll-a screening levels for designated general uses.

It must be noted that the nutrient screening levels are not a water quality standard, but instead a measure used to determine if a concern exists or not for that specific water quality constituent. Each of the above listed water quality standards/concerns are described in detail below.

Dissolved Oxygen (DO)

DO is considered the main factor in determining a water body's ability to support existing, designated and attainable aquatic life uses. If DO levels in a water body drop too low, fish and other aquatic species will not survive. According to TCEQ (2010), an intermittent stream with perennial pools should maintain a 24-hour average for DO of 3.0 mg/L with a minimum of 2.0 mg/L. When evaluating DO levels in a water body, TCEQ considers an index period and a critical period. The index period represents the warm-weather season of the year and spans from March 15 to October 15. The critical period of the year is July 1 to September 30 and is the portion of the year when minimum stream flow, maximum temperatures and minimum DO levels typically occur across Texas. At least half of the samples used to assess a stream's DO levels should be collected during the critical period with the remainder of the samples used coming from the index period. DO measurements collected during the cold months of the year are not considered, because flow and DO levels are typically highest during the winter months (TAC §307.7 and §307.9).

Bacteria

Bacteria standards set for contact recreation are applied to all freshwater bodies in the state unless otherwise designated in the TSWQS. This standard has been established to gauge the ability of a stream to support its designated contact recreation use. This standard was established to gauge the level of risk that someone engaged in primary contact recreation will have of contracting a fecal contamination derived ailment. Primary contact recreation can be defined as activities that are presumed to have a significant risk of water ingestion such as wading by children, swimming and tubing among others. As a result, a geometric mean of 126 colony forming units (cfu)/100 mL of *E. coli* must be maintained (TAC §307.7, TCEQ 2010); otherwise, there is considered to be an elevated risk of ingesting pathogenic organisms associated with fecal material during contact recreation. A single sample criterion was also used in the past but has been removed from the TSWQS in the 2010 revisions; as such, it will not be discussed in this WPP. In order for the bacteria standard to apply, a minimum of 10 samples collected within a seven-year period are required. Once 10 samples have been collected, the geometric mean of all samples collected within the most recent seven-year time frame must remain at or below the geometric mean to support contact recreation. Samples used in water body assessments must not include extreme hydrologic conditions such as very high-flows and flooding. This applies for a 24-hour period following the last measured or estimated determination that extreme hydrologic conditions exist (TAC §307.9).

Nutrients

Nutrient screening levels developed for statewide use were established to protect water bodies from excessive nutrient loadings and support their primary, secondary and noncontact recreation, aquatic life and public water supply uses by assessing statewide data collected from similar water bodies in Texas and designating the 85^{th} percentile as the 'screening level.' If a water body exceeds these established screening levels more than 20% of the time, that water body is on average experiencing pollutant concentrations higher than 85% of the streams in Texas. Screening levels have been designated for ammonia, nitrate, orthophosphorus, total phosphorus and chlorophyll-a (Table 5.3).

Table 5.3. Nutrient screening levels applicable to fresh water streams

Nutrient	Screening Level
NH3-N (Ammonia)	0.33 mgl/L
NO3-N (Nitrate)	1.95 mg/L
OP (Orthophosphorus)	0.37 mg/L
TP (Total Phosphorus)	0.69 mg/L

Other Water Quality Measurements

Several other water quality parameters are often recorded including pH, TDS, TSS and water temperature. These measures are evaluated to assess the general quality of water measured. Acidity of water is measured by pH. Waters with a pH less than 7 are considered acidic and those greater than 7 are basic, or alkaline. Measuring pH is important, because it indicates the suitability of water to support aquatic life and also determines how fast some contaminants dissolve or degrade in water. In the Attoyac Bayou, pH should range between 6.0 and 8.5. TDS is a measure of the dissolved ions in water such as salts and nutrients. These are often referred to as dissolved solids. Higher levels indicate higher levels of dissolved ions and, thus, poorer water quality. The established maximum limit for TDS is 200 mg/L. TDS can also be converted to specific conductance, which is a measure of water's ability to conduct electricity. Specific conductance should not exceed 307.7 microsiemens per centimeter (µS/cm) more than 25% of the time.

Water temperature measurements are used to assess a water body's ability to support aquatic life. Too high temperatures can be harmful or deadly to aquatic species. TCEQ established a temperature maximum of 32.2°C for the Attoyac Bayou. TSS is a measure of particulate matter suspended in water that will not pass through a filter. These solids are primarily sediment and organic matter, which cause water bodies to loose clarity and retain heat. As a result, DO levels decline and photosynthesis slows. Texas has not established TSS standards for instream water quality.

Historic Water Quality

For the purposes of this report, historic water quality data are considered the data collected by ANRA and TCEQ prior to the start of the project. Table 5.4 illustrates the range of historic record reported for the Attoyac Bayou. Data were collected periodically at all five stations by the ANRA through 2008 and submitted to TCEQ for water body assessment purposes. Table 5.5 shows summary statistics of water quality parameters sampled by ANRA and indicates if a water quality impairment or concern exists based on this data set. A portion of the *E. coli* data collected by ANRA and presented here resulted in Attoyac Bayou's original listing on the *2004 Texas 303(d) List* as an impaired water body and its continual listing through 2008. It should be noted that fecal coliform was used as the indicator organism for assessing a water body's ability to support its primary contact recreation standard in freshwater; however, the TSWQS now requires *E. coli* to be used for assessing this water body use.

Table 5.4. Range of historical water quality data records

Station ID#	Start Date	End Date
10636	11/15/2000	3/24/2008
15253	10/23/2003	7/28/2008
16076	11/15/2000	7/28/2008
16083	11/19/1997	5/27/1998
16084	11/19/1997	5/27/1998

The data presented in Tables 5.5 – 5.7 illustrate the number of samples collected or recorded for each water quality parameter; the minimum, maximum and appropriate average of the recorded values; and any concerns or impairments. While multiple water quality parameters are included in this dataset, only bacteria and ammonia nitrogen are of concern in the Attoyac Bayou. All other parameters are informational in nature and help to illustrate the general water quality of the water body as well as some of its physical characteristics

In general, historic water quality in the Attoyac Bayou has been good and is meeting the state's applicable water quality standards with the exception of *E. coli.* Ammonia nitrogen has also been noted to be periodically elevated above the applicable screening level. TDS levels were well within the allowable maximum levels as were pH, nitrate+nitrite nitrogen, total phosphorus and orthophosphorus. Several instances of pH being slightly lower than it should be did occur, but not at problematic levels. DO levels were also noted as being above allowable low level with the exception of one measurement.

Table 5.5. Historical water quality data collected by the ANRA at TCEQ station #10636 at Attoyac Bayou at SH21 from 2000 to 2008

Parameter	# of Samples	Minimum	Maximum	Average	Geometric Mean	TCEQ Standard or Screening Criteria
Water Temp (°C)	157	5	29			32.2 maximum
Flow (cfs)	103	22	2500	482.95		
Total Dissolved Solids (mg/L)	113	30	261	123.45		200
Dissolved Oxygen (mg/L)	158	2.9	11.8	7.78		5.0/3.0 (grab avg/min)
pH (standard units)	152	5.7	8.9			6.0- 8.5 range
Ammonia Nitrogen (mg/L)	103	0.01	1.01	0.08		0.33 (> 20% exceedance)
Nitrate-Nitrite Nitrogen (mg/L)	28	0.3	5.4	1.27		1.95 (> 20% exceedance)
Total Phosphorus (mg/L)	98	0.026	1.622	0.14		0.69 (> 20% exceedance)
Orthophosphorus (mg/L)	37	0.01	0.712	0.03		0.37 (> 20% exceedance)
E. Coli (cfu/100mL)	38	32.4	5000	559.51	249.83	126 geometric mean

Impaired: does not meet the applied water quality standard

Table 5.6. Historical water quality data collected by the ANRA at TCEQ station #15253 at Attoyac Bayou at SH7 from 2003 to 2008

Parameter	# of Samples	Minimum	Maximum	Average	Geometric Mean	TCEQ Standard Screening Criteria
Water Temp (°C)	24	9.4	27.8			32.2 maximum
Flow (cfs)	2	0	0	0		
Total Dissolved Solids (mg/L)	24	75	193	134.125		200
Dissolved Oxygen (mg/L)	24	3.6	10.9	7.177		5.0/3.0 (grab avg/min)
pH (standard units)	22	5.95	8.1			6.0- 8.5 range
Ammonia Nitrogen (mg/L)	24	0.02	1.31	0.431		0.33 (> 20% exceedance)
Nitrate-Nitrite Nitrogen (mg/L)	20	0.04	2.1	0.44		1.95 (> 20% exceedance)
Total Phosphorus (mg/L)	24	0.06	0.427	0.205		0.69 (> 20% exceedance)
Orthophosphorus (mg/L)	20	0.04	0.121	0.058		0.37 (> 20% exceedance)
E. Coli (cfu/100mL)	20	75	820	278.22	231	126 geometric mean

Concern: greater than 20% of recorded values exceed applied screening level
Impaired: does not meet the applied water quality standard

Table 5.7. Historical water quality data collected by the ANRA at TCEQ station #16076 at Attoyac Bayou at US59 from 2000 to 2008

Parameter	# of Samples	Minimum	Maximum	Average	Geometric Mean	TCEQ Standard Screening Criteria
Water Temp (°C)	43	2.2	26.4			32.2 maximum
Flow (cfs)	17	0	16	7.78		
Total Dissolved Solids (mg/L)	42	40	312	105.57		200
Dissolved Oxygen (mg/L)	41	3.2	13.2	8.33		5.0/3.0 (grab avg/min)
pH (standard units)	40	5.8	8.5			6.0- 8.5 range
Ammonia Nitrogen (mg/L)	43	0.01	1.4	0.291		0.33 (> 20% exceedance)
Nitrate-Nitrite Nitrogen (mg/L)	43	0.04	3.87	0.7		1.95 (> 20% exceedance)
Total Phosphorus (mg/L)	36	0.024	0.863	0.1967		0.69 (> 20% exceedance)
Orthophosphorus (mg/L)	21	0.04	0.152	0.069		0.37 (> 20% exceedance)
E. Coli (cfu/100mL)	55	45	2400	499.03	321.88	126 geometric mean

Impaired: does not meet the applied water quality standard

Chapter 6
Potential Sources of Pollution

Potential sources contributing bacteria in the Attoyac Bayou watershed were identified through a variety of avenues including stakeholder input, local experience in the watershed from project partners and conducting watershed reconnaissance surveys. These sources are summarized in Table 6.1 below.

Residential On-Site Sewage Facilities (OSSFs)

The Attoyac Bayou watershed is a predominantly rural watershed. As a result, the majority of the residences present in the watershed use an OSSF. Using 911 address data validated with 2010 Census data as described in Gregory et al. (2013), it is estimated that there are approximately 6,085 residences within the Attoyac Bayou watershed and outside of the incorporated city of Garrison. Garrison has a WWTF, and any residences within the city limits are assumed to be connected to the WWTF and therefore do not need an OSSF. The remaining residences within the watershed are assumed to use an OSSF.

The majority of older OSSFs in the watershed use a conventional septic tank and subsurface soil absorption to treat discharged wastewater. In these systems, wastewater is first passed through a septic tank, which separates solids and liquid before dispersing effluent into a soil absorption field where wastewater is further treated by percolating through the soil (USEPA 1980). Many newer residences are now equipped with aerobic treatment systems largely due to the soil's inability to properly support a conventional soil absorption field. The majority of these systems use above-ground dispersion of treated wastewater effluent.

Many factors can affect the efficiency of these treatment systems including the soil properties of the soil absorption field. It is estimated that only 32% of the land area in the United States has soils suitable to adequately treat

Table 6.1. Summary of potential sources of bacteria occurring within the Attoyac Bayou watershed

Category	Cause	Deposition Into Water Body
Residential OSSFs	Improperly functioning or non-existent onsite septic systems releasing improperly treated wastewater into water bodies.	Direct and Indirect
Pets	Pets deposit fecal matter to the land surface, which is washed into water bodies during runoff events.	Indirect
Livestock	Livestock manure directly deposited into water body and/or washed into water body during runoff events.	Direct and Indirect
Poultry	Poultry litter deposited on land application fields and washed into water body during runoff events.	Indirect
WWTFs	Potential maintenance issues and flow exceedances during runoff events causing improperly treated wastewater to be discharged into water body.	Direct
Oil and Gas OSSFs	Improperly functioning or non-existent onsite septic systems releasing improperly treated wastewater into water bodies. Potential for issues is generally most common during construction and drilling activities only.	Direct and Indirect
Wildlife and Feral Animals	Both wildlife and feral animals depositing fecal matter directly into water bodies or washed into water body during runoff events.	Direct and Indirect
Illegal Dumping	Illegal dumping of household waste as well as animal carcasses releasing *E. coli* directly into water bodies, and washed into a water body during runoff events.	Direct and Indirect

wastewater by percolation. As seen in Figure 6.1, the Attoyac Bayou watershed has approximately equal areas of 'very limited' and 'not limited' soils with a much smaller portion of the watershed in the 'somewhat limited' category for use as a soil absorption field. Comparing soil suitability rankings to the LU/LC (Figure 3.5) illustrates that the bulk of 'not limited' soils are associated with the watershed's extensive forested areas.

Other factors that can also impact OSSF function include lack of maintenance or damaged systems. Sludge should be removed from the tank every three to five years, and annual inspections should be conducted at a minimum. If routine maintenance is neglected, the system may malfunction and discharge improperly treated wastewater. Leaking and ruptured pipes or tanks may also lead to these discharges.

Lack of maintenance is the major limiting factor for aerobic OSSFs as well. If the effluent is not properly disinfected, it could result in improperly treated wastewater being applied to the land surface. Additionally, as in traditional OSSF, accumulated solids, oils and greases need to be periodically removed in order for the system to function properly.

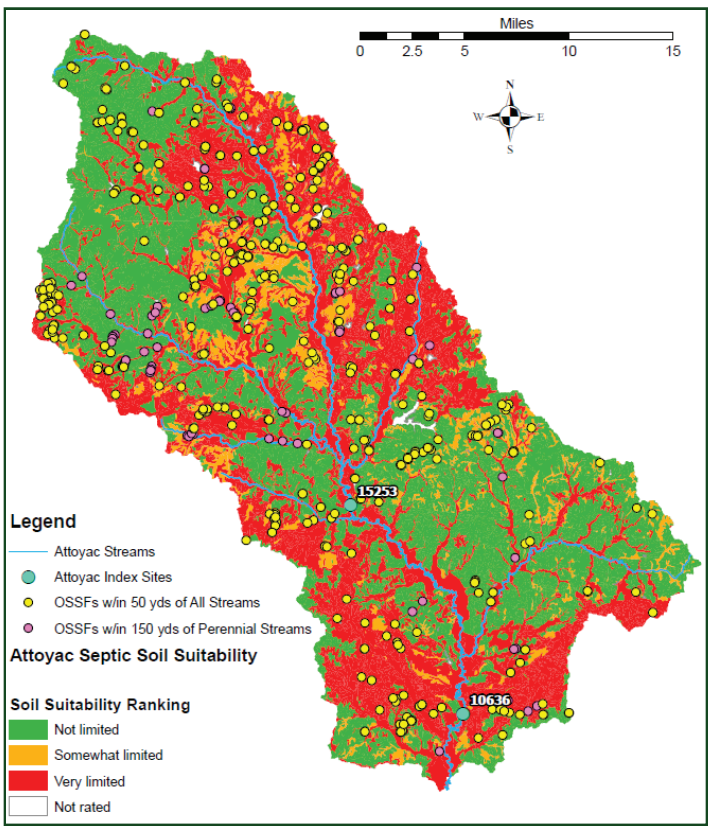


Figure 6.1. Septic tank soil absorption field properties
Source: USDA NRCS soil data viewer

Of the estimated 6,085 OSSFs identified within the watershed, approximately 50% or 3,043 were estimated as not functioning properly or are non-existent. This estimate was derived from stakeholder input and is based largely on the assumption and local knowledge of the majority of homes in the watershed being built before Texas law required a permit to install an OSSF. As a result, most OSSFs in the watershed are not documented and their functional status is unknown. Older systems can still function properly: however, they do have a higher likely hood of malfunctioning.

An OSSFs proximity to the stream is also important when considering whether or not it can impact instream water quality. All OSSFs have the potential to have adverse environmental impact if they are improperly functioning, but those closer to the stream present an elevated risk. In the Attoyac Bayou, 452 OSSFs are suspected to lie within 50 yds of a water way and an additional 127 OSSFs are likely to be within 150 yds of perennial streams (Figure 6.1).

Pets

According to the American Veterinary Medical Association, the average household in the United States is home to 1.7 dogs. Applying this average to the Attoyac Bayou watershed results in 11,285 dogs spread across the watershed. These dogs are concentrated in areas of higher human population densities such as in Garrison, Martinsville and Chireno. The majority of dog owners probably do not collect their dog's waste in rural areas, and as a result, this waste represents a likely contributor to *E. coli* in the Attoyac Bayou watershed. As with other animal waste, proximity to water bodies plays an important role on how much *E. coli* and other bacteria enter the water.

Livestock

The grazing of livestock, primarily cattle and to a lesser extent horses, occurs throughout the Attoyac Bayou watershed on managed pastures, rangeland and in the case of horses, developed open spaces (Figure 3.5). These animals deposit urine and fecal matter to the land surface as well as directly to water bodies if accessible. Exact numbers of these animals within the watershed are difficult to quantify at one time: however, estimates are available from the NASS. Stocking rate recommendations are also made by NRCS based on land cover type, thus allowing estimates to be made. Using these resources, as well as stakeholder input, there are an estimated 23,646 head of cattle and 587 horses in the watershed. Populations of livestock are generally concentrated on managed pasture, with lesser densities occurring on rangeland. Based on the updated land use/land cover dataset, 19.64%, or 69,662 ac, of the watershed consists of managed pasture and 6.50%, or 23,049 ac, consists of rangeland. Horses were determined to be present in these same areas as well as developed open spaces. Sub-watersheds 3, 4, 7 and 13 contain the most suitable livestock habitat and are priority areas for water quality management plan (WQMP) implementation; however, each sub-watershed has suitable habitat for livestock grazing and will benefit from WQMP implementation.

Poultry

Poultry operations are numerous throughout the Attoyac Bayou watershed and according to Texas State Soil and Water Conservation Board (TSSWCB) WQMP data, 111 poultry facilities existed in the watershed in 2011. Table 6.2 presents poultry numbers for the watershed from TSSWCB's WQMP data.

Litter produced from these houses is the source of primary concern regarding potential water quality issues since the litter removed is typically land applied as a fertilizer.

Table 6.2. Attoyac Bayou watershed poultry numbers from 2011 TSSWCB WQMP data

Bird Type	Count
Broilers	11,392,960
Breeder	842,180
Total	**12,235,140**

As such, developed WQMPs place considerable focus on litter management. Guidance provided by TSSWCB on WQMP development states that land application fields must have the soils tested yearly to determine the appropriate application rate of manure and should have a buffer of at least 100 ft of well-vegetated ground between water bodies and applied manure. WQMPs also note the amount of litter planned for both on- and off-farm use. Litter should be stored in a roofed litter storage facility, but can be stored for up to 30 days outdoors if the litter is covered by an impermeable layer, protected from external rainwater or surrounded by an earthen berm to prevent runoff (TSSWCB 2010). TSSWCB estimated that 76,164 tons of litter is produced from poultry facilities in the watershed in 2011. Of this, only 63,340 tons was estimated to be land applied within the watershed with the remander considered to be shipped outside of the watershed.

Nutrient and bacteria loading to the water body is the potential water quality concern arising from litter application. The use of proper land application techniques planned in WQMPs greatly reduces the chance of adverse water quality impacts. Poor practices such as over application of manure can lead to excessive manure runoff, which may cause *E. coli* and nutrient loading in nearby waterways. When land applied, poultry litter has usually been stored for a period since being removed from the house. During this time, litter usually dries out and leads to reduced bacteria levels within the stored litter.

Wastewater Treatment Facilities (WWTFs)

Two types of WWTFs exist in the Attoyac Bayou watershed. The Garrison WWTF uses an aeration and settling basin system with chlorination to reduce pathogens and bacteria concentrations to acceptable levels while the Chireno Independent School District and Martinsville Independent School District WWTFs use a lagoon-type system with a 21-day residence time to achieve sufficient disinfection. These facilities and their associated permit requirements are outlined in Table 6.3. Measured levels of *E. coli* in effluent are generally far below the state standard; however, significant exceedances of the standards have been observed. According to TCEQ records, four individual permit violations have occurred for elevated

Table 6.3 Permitted WWTFs within Attoyac Bayou watershed

Facility Name	County	Receiving Stream	Permitted Flow (MGD)	Reported Flow (3-yr avg.) (MGD)	Bacteria Limitations (CFU or MPN/ 100 mL)	Number of Quarters in Violation from 01/2011 – 12/2013 (violation type)
Chireno ISD	Nacogdoches	Ditch to Attoyac Bayou	0.01	.00048	126 Daily Avg, or 394 Single Grab	7 (6 reporting; 1 ammonia exceedance)
City of Garrison	Nacogdoches	Tributary of Jenks Creek	0.12	.7983	126 Daily Avg, or 394 Single Grab	10 (7 reporting; 2 *E. coli* exceedance; 1 low chlorine)
Martinsville ISD	Nacogdoches	Tributary of Terrapin Creek	0.008	.0032	126 Daily Avg, or 394 Single Grab	10 (3 reporting; 2 *E. coli* exceedance; 5 total suspended solids exceedance)

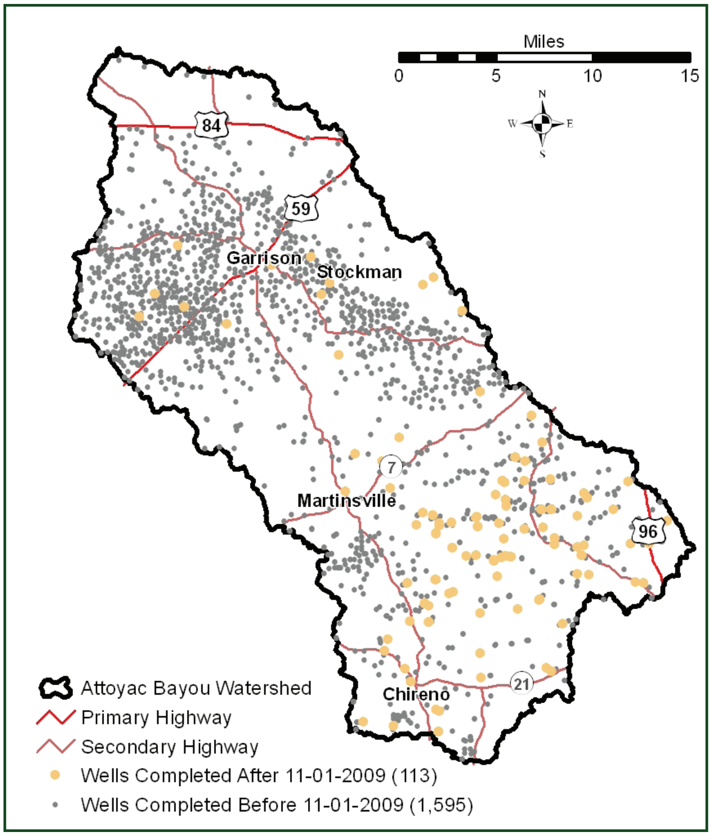


Figure 6.2. Oil and gas wells within the Attoyac Bayou watershed
Source: Railroad Commission of Texas

bacteria in the last three-year reporting period (Jan. 2011 to Dec. 2013); however, no formal permit enforcement actions resulted from these violations.

Oil and Natural Gas Drilling

Oil and natural gas production activities were identified as a potential concern as a response to the increased drilling activities in the Haynesville Shale formation. During temporary construction of oil and natural gas infrastructure such as pipelines and well pad locations, workers use portable sewage disposal facilities, commonly referred to as portable toilets. Waste is discharged and held in the portable facilities and disposed of at an off-site location. During the drilling and fracturing processes, workers use temporary, OSSFs for the disposal of waste. Even though multiple workers are present on a drilling location for up to four months, if these on-site septic facilities are not working properly, these locations could cause increases in bacteria concentrations in nearby water bodies. Spatial data obtained from the Texas Rail Road Commission on July 7, 2011 indicate there were approximately 1,708 oil & natural gas wells within the watershed at that time (Figure 6.2). Of these, approximately 201 wells have been plugged, and 113 have been drilled, primarily in the southern portion of the watershed, since this project began on September 1, 2009. Since that point, oil and natural gas exploration in the watershed has slowed considerably as production has increased in other areas of the state. With this decline in activity comes a decline in the potential for illicit discharges from the portable OSSFs used.

Wildlife and Feral Animals

Numerous species of wildlife occur throughout the Attoyac Bayou watershed. In most watersheds wildlife and feral animals contribute a significant amount of bacteria to the watershed and in some cases wildlife alone can cause impairment to a water body. Population estimates of individual wildlife species present in the watershed are not available, so the Attoyac Bayou Watershed Partnership focused on identifying the most significant potential sources.

Deer

Whitetail deer are numerous in the watershed and represent a significant potential contributor of *E. coli* the Attoyac Bayou. The Texas Parks and Wildlife Department (TPWD) conducts deer population surveys within the state of Texas at the resource management unit (RMU) level. RMUs are developed based on similar ecological characteristics within a defined area. The Attoyac Bayou watershed is situated in the southern portion of RMU 15. The estimated deer population within RMU 15 is 45.2 acres per deer. This population estimate was applied to every LU/LC classes within the watershed except for open water, barren land and developed land. When applied across the remaining land use/land cover classes, the Attoyac Bayou watershed is home to an estimated 7,547 deer. Attoyac Bayou Watershed Partnership members concurred that this number is an appropriate estimate of the total deer population in the watershed.

Feral Hogs

Hogs were introduced into the United States by settlers as early as the 1500s for use as a food source due to their adaptability to a variety of environments and their prolific reproduction. Over time, hogs were released or escaped into the environment, which led to the populations we have today (Taylor 2003). In the Attoyac Bayou watershed, feral hog populations are growing and causing increasing amounts of damage to private property and to the native environment. Using a variety of information sources as well as stakeholder input, the Attoyac Bayou Watershed Partnership members determined that an appropriate feral hog population estimate for the watershed is 10,155 hogs. Distributing this number of hogs across suitable habitat in the watershed yields an estimated density of 33.4 acres per hog. This estimation is very similar to the 33.3 acres per hog reported in Wagner and Moench 2009.

Waterfowl and Other Birds

Waterfowl and other birds were identified as a potential source for elevated levels of *E. coli* in the Attoyac Bayou watershed, especially in areas of high population density. Areas of high bird population density can occur in or near large open water areas, in rookeries where large numbers of birds nest and roost, as well as under bridges where potentially large numbers of birds roost. According to data obtained from the Texas Natural Diversity Database (TXNDD), received on October 16, 2011, one rookery is noted in the watershed and is located approximately 3.5 mi. north of Chireno in the southern portion of the watershed. The TXNDD data indicates this rookery consisted of a nesting colony of little blue heron, and the last field observation was 1974. During the watershed reconnaissance surveys, CES personnel did not observe a rookery within this area. It is likely that this rookery has moved.

Data obtained from the U.S. Department of Transportation for the National Bridge Inventory indicates there are 119 bridges in the watershed. Most of these consist of smaller bridges crossing minor stream channels; however, some larger bridges are present within the watershed. During the watershed reconnaissance surveys, project partners did not observe any sizable concentrations of cliff swallow nests under the larger bridges within the watershed.

Illegal Dumping

Illegal dumping was identified as a potential source of *E. coli* in the watershed by stakeholders and project team members. Since this project began, numerous discarded deer carcasses have been reported near bridges and water quality monitoring stations during the fall and winter months. These carcasses can be a direct source of *E. coli* when improperly discarded in water bodies. Illegal dumping of residential waste can also represent a source of *E. coli* within the watershed. Residential waste can contain items such as used diapers that can contribute bacteria, as well as other pathogens, to a water body; however, none of these sites have been identified or documented in the watershed.

Chapter 7
Watershed Pollutant Source Assessment

Pollutant loading to the Attoyac Bayou and its tributaries was assessed using four separate, yet complementary, assessment methods. A multi-tooled approach was used to develop an improved understanding of both observed and potential loadings, specifically for bacteria and ammonia and their sources. No single method provides a perfect result or definitive answer, thus multiple methods were warranted. This chapter briefly describes each method and the results obtained.

Water Quality Monitoring Data and Results

In an effort to expand the distribution of monitoring locations and frequency across the watershed, bi-weekly (twice per month) grab samples were taken the 10 established water quality monitoring stations (Figure 5.2) when water was flowing between July 26, 2010 and August 20, 2012. Sampling occurred on a routine schedule throughout the course of the study and was conducted by the SFASU Department of Forestry and Agriculture and the Waters for East Texas (WET) Center. This data collection added to historical water quality data collected by ANRA through the Clean Rivers Program (CRP) program and the TCEQ Regional office. Storm sampling was also conducted at two locations (Stations 10636 and 20844) and targeted elevated flow conditions occurring as a result of rainfall runoff. Table 7.1 contains the average (geometric mean for *E. coli*) of collected water quality data at each station. More information on water quality at each station can be found in the *Attoyac Bayou Surface Water Quality Monitoring Report* (Schwab et al. 2013).

E. coli

Data collection illustrated that *E. coli* counts vary widely with recorded numbers ranging from 4 to more than 3,900 cfu/100 mL. Table 7.2 and Figure 7.1 illustrate the range and variation in recorded *E. coli* counts observed at each sampling location. The box plots demonstrate that many of the individual data points collected are above the current recreational standard of 126 cfu/100 mL. Using this approach, none of the TCEQ assessed water bodies (either individually or by assessment unit) of the Attoyac Bayou currently meet the applied water quality standard, thus signifying the need to reduce *E. coli* loading across the watershed. The *E. coli* geometric means at each station showed no significant differences (Kruskal-Wallis test: $p = 0.437$; $\alpha = 0.05$) further suggesting that *E. coli* loading is occurring watershed-wide.

Ammonia

Similar to *E. coli*, ammonia levels recorded across the watershed showed some variations from station to station. The vast majority of data points (94.5%) recorded were either at or below the 0.33 mg/L screening level and only

Table 7.1. Two-year averages of monitored water quality parameters in the Attoyac Bayou watershed

Station	# of Samples	Ammonia Nitrogen (mg/L)	Nitrate Nitrite Nitrogen (mg/L)	Dissolved Ortho-phosphorus (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)	Specific Conductance (µS/cm)	pH	Water Temp °C	Dissolved Oxygen (mg/L)	*E. coli* (geometric mean: cfu/100 mL)
Attoyac Bayou											
10636	64	0.11	0.32	0.06	0.16	45.0	151.6	8.05	18.7	7.7	241.1
15253	50	0.13	0.26	0.07	0.18	40.4	164.1	7.83	18.4	6.2	173.4
20841	40	0.12	0.18	0.09	0.21	30.1	170.3	7.80	17.3	6.6	376.5
16076	38	0.24	0.10	0.06	0.28	53.1	140.7	7.94	17.4	5.6	208.5
20842	14	0.29	0.04	0.05	0.22	34.4	162.9	7.68	19.4	3.0	82.1
Tributaries											
16083	25	0.24	0.11	0.05	0.13	29.7	147.3	7.73	15.1	5.8	201.9
16084	43	0.17	0.53	0.04	0.09	34.6	115.4	7.92	18.4	6.0	194.3
20843	46	0.12	0.39	0.07	0.14	11.8	148.7	7.83	17.1	7.2	189.4
20844	56	0.12	0.61	0.04	0.10	27.2	127.5	8.23	17.6	7.9	454.3
20845	43	0.11	0.20	0.05	0.11	18.9	168.1	7.89	18.0	6.6	346.6

Table 7.2. *E. coli* summary statistics from each sampling station in the Attoyac Bayou watershed

Station	Number of Samples	Minimum	Maximum	Geometric Mean	Assessment Unit (AU)	AU Geometric Mean
10636	64	13	2400	241.1	0612_01	241.1
15253	50	13	2400	173.4	0612_02	244.7
20841	40	75	2400	376.5	0612_02	
16076	38	12	2400	208.6	0612_03	162.3
20842	14	4	820	82.1	0612_03	
20844	56	49	3900	454.3	N/A	N/A
16084	43	9	2400	194.3	N/A	N/A
20845	43	38	2400	346.6	N/A	N/A
16083	25	40	2400	201.9	N/A	N/A
20843	46	15	2400	189.5	N/A	N/A

two stations (20842 and 16083) had more than 20% of their respective samples above the screening level; however, these stations were limited to only 14 and 25 samples, respectively due to drought conditions. Additionally, each of these stations were plagued with beaver activity that often caused flow to cease. The box and whisker plots shown in Figure 7.2. illustrate that bulk of the ammonia readings were well below the screening level and are not problematic watershed-wide. This contradicts TCEQ's earlier findings but is more represntative of recent conditions

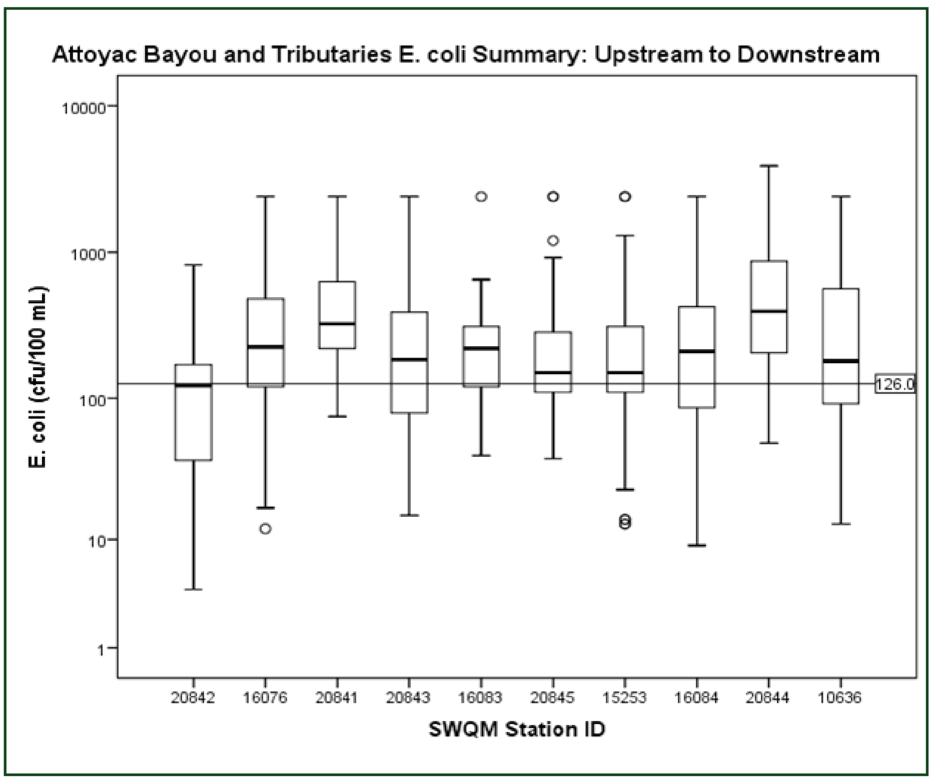


Figure 7.1. *E. coli* data summary for the Attoyac Bayou and tributaries by station: upstream to downstream
Tributary stations are situated relative to the location that they join the Attoyac Bayou; for a description of the information that box plots present, see Appendix C

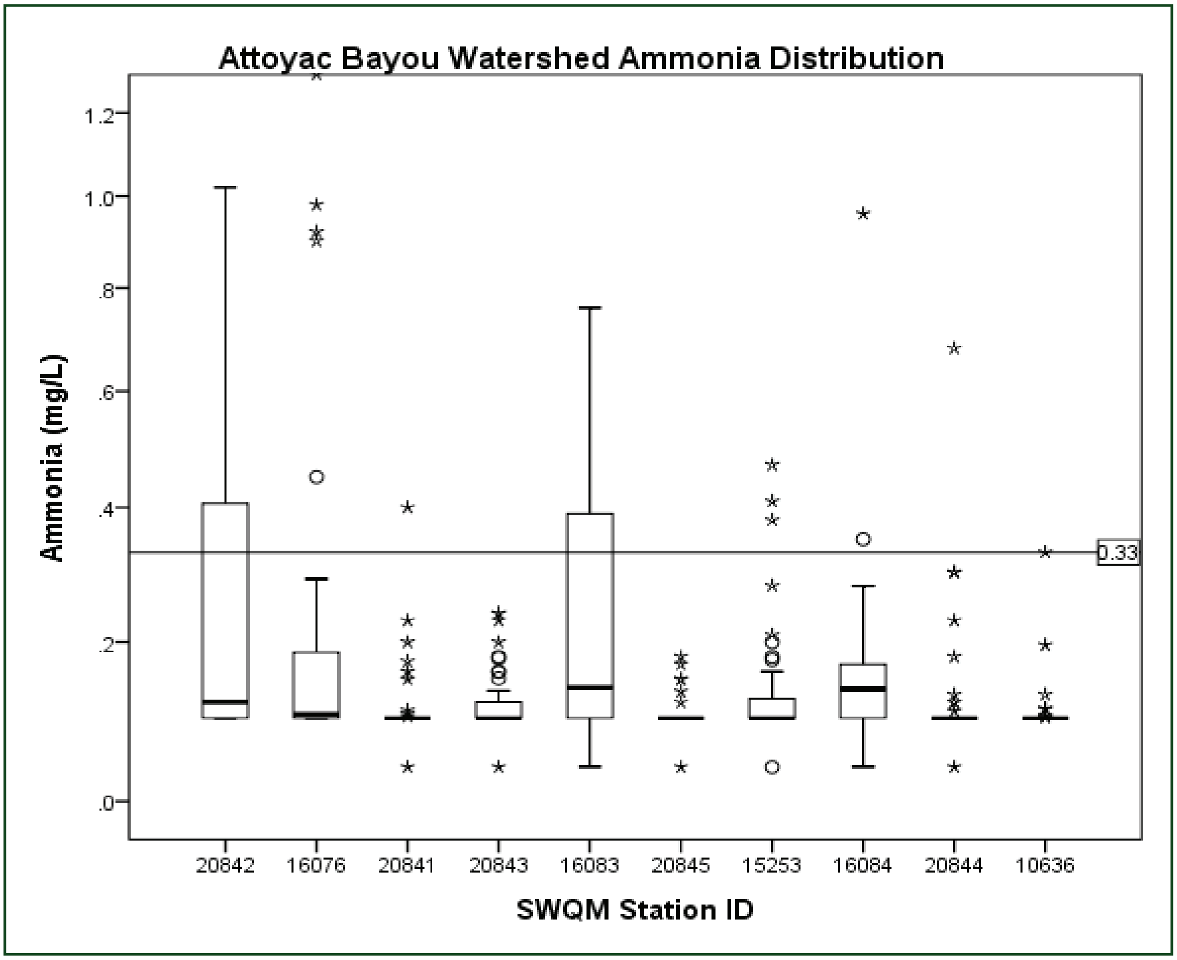


Figure 7.2. Ammonia data summary for the Attoyac Bayou and its tributaries: upstream to downstream (tributary stations are situated relative to the location that they join the Attoyac Bayou)

Other Nutrients

Nitrate-nitrite nitrogen, ortho-phosphorus and total phosphorus levels were also monitored during this assessment. At no point in the data collection effort were nitrate-nitrite nitrogen, or ortho-phosphorus found at levels above the state's established screening level. Total phosphorus was only found to exceed its screening level on a single occasion in what appears to be an isolated event. As a result, elevated nutrients are currently not concerning in the Attoyac Bayou watershed.

Dissolved Oxygen (DO)

Levels of DO recorded in the watershed were generally good, especially considering that the monitoring regime encompassed the worst single drought year on record for the area. In total, 15 individual measurements were recorded below the 3.0 mg/L minimum standard; however, the average DO concentration remained above the 5.0 mg/L average standard at 6.35 mg/L. While the low oxygen levels were recorded, oxygen levels rebounded when more normal rainfall and flow conditions returned. As such, DO levels are not concerning in the watershed.

Total Suspended Solids (TSS) and Water Temperature

Water temperatures recorded in the watershed ranged between 5.13 and 29.46 ^{0}C and were well within the maximum allowable temperature of 32 ^{0}C. TSS levels recorded varied between 2.5 and 790 mg/L; however, values were typically below 200 mg/L, which is typical in river systems. Only two individual samples were higher than 200 mg/L, and both were recorded following recent large rain events. Neither of these water quality measures revealed problematic trends in water quality.

Specific Conductance and pH

Recorded specific conductance levels in the Attoyac Bayou and its tributaries ranged from 64 to 289 μS/cm and remained below the allowable level of 307.7 μS/cm. Alternatively, pH data indicated that both the minimum and maximum allowable levels of 6.0 and 8.5 were exceeded. A single event in Terrapin Creek fell below the allowable range while 29 samples were recorded above 8.5. With the exception of three of these, each elevated level was associated with higher stream flow levels seen following intense drought conditions.

Load Duration Curve (LDC) Analysis

Load duration curve (LDC) analysis was conducted for water quality stations across the Attoyac Bayou watershed to illustrate relative *E. coli* and ammonia loadings as they relate to measured stream flow levels. While LDCs can help in determining what flow regimes are responsible for the bulk of pollutant loading, they are limited in their ability to accurately illustrate what is happening on a collective basis because they must have chronologically paired pollutant concentration and stream flow volume data. Using available data, regression analysis is used to estimate pollutant loads based on available data. The difference between the predicted load and the allowable load (flow rate multiplied by the water quality standard minus a 10% margin of safety) is the estimated load reduction needed to achieve the water quality goal.

For planning purposes, the LDCs developed at stations 10636 and 15253 were used as index sites to represent the rest of the watershed. The distributions of loads across flow regimes as well as the needed loading reductions at these stations were representative of the entire watershed. Additionally, these stations will be monitored into the future through the CRP program, which will provide additional data to calculate future loadings at these stations. LDCs were developed for other sampling station except 16076, which did not have sufficient data collected. They are presented and discussed in the *Modeling Support for the Attoyac Bayou Assessment using Load Duration Curves* (Borel et al. 2012a).

E. coli

LDCs produced at stations 10636 and 15253 (Figures 7.3 and 7.4) to evaluate *E. coli* loading to the stream illustrate that loadings exceeding the water quality standard

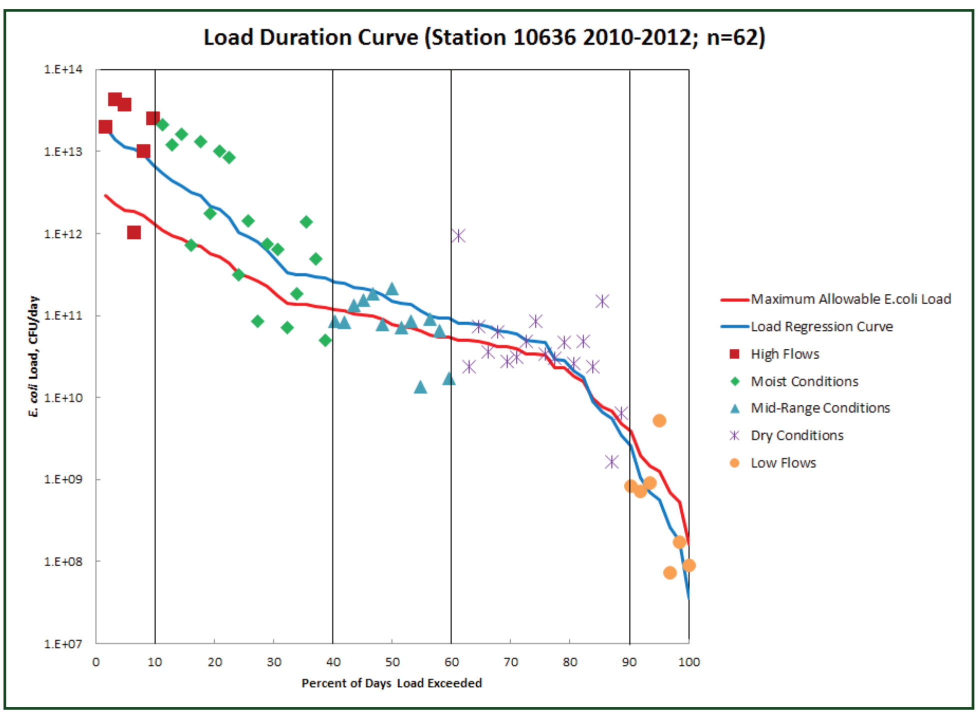


Figure 7.3. Load duration curve for station 10636 showing *E. coli* loading across monitored flow regimes

can occur under all flow regimes monitored. These graphs also illustrate that *E. coli* loads are more often elevated under higher flow conditions suggesting that the sources of *E. coli* are from the watershed (nonpoint source [NPS] pollution) or are *E. coli* present in stream sediments that are resuspended under increased flow rates. Resuspended *E. coli* are very likely to represent a large portion of the overall bacteria load monitored because rainfall events that produce runoff and carry NPS pollutants to the water body occur rather infrequently. Tables 7.3 and 7.4 presents load reduction goals under each flow category as well as the numerical load reduction needed to achieve the water quality goal.

Table 7.3. *E. coli* loadings and reductions needed to meet the water quality goal at station 10636 (Hwy 21) as determined by LDC analysis

Flow Condition	**% Exceedance**	**% Reduction Needed to Meet Goal**	**Daily Loading**	**Estimated Annual Load**	**Daily Loading Reduction Needed**	**Annual Loading Reduction Needed**
			(cfu/day)	(cfu/yr.)	(cfu/day)	(cfu/yr.)
High Flows	0–10	85	1.20E+13	4.38E+14	1.02E+13	3.73E+14
Moist Conditions	10–40	71	1.70E+12	1.86E+14	1.31E+12	1.43E+14
Mid-Range Flows	40–60	53	1.65E+11	1.21E+13	9.07E+10	6.62E+12
Dry Conditions	60–90	27	4.25E+10	4.66E+12	1.63E+10	1.78E+12
Low Flows	90–100	N/A*	7.68E+08	2.80E+10	N/A	N/A

*N/A denotes values that are currently within the water quality goal thus no reduction is needed under those conditions

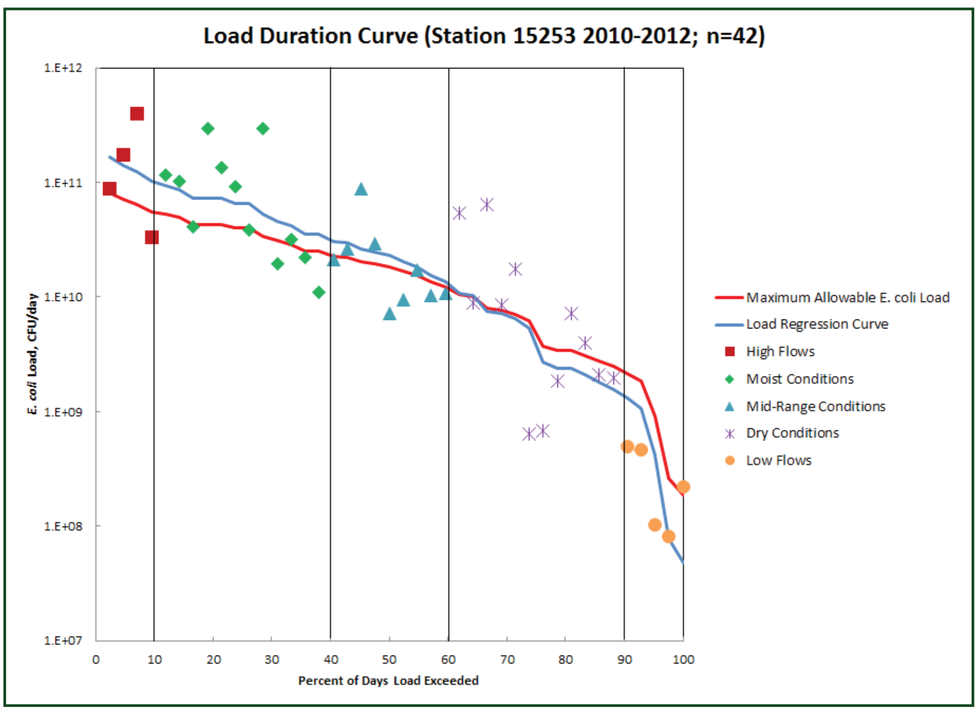


Figure 7.4. Load duration curve for station 15253 showing *E. coli* loading across monitored flow regimes

Table 7.4. *E. coli* loadings and reductions needed to meet the water quality goal at station 15253 (Hwy 7) as determined by LDC analysis

Flow Condition	% Exceedance	% Reduction Needed to Meet Goal	Daily Loading (cfu/day)	Estimated Annual Load (cfu/yr.)	Daily Loading Reduction Needed (cfu/day)	Annual Loading Reduction Needed (cfu/yr.)
High Flows	0–10	54	1.33E+11	4.86E+12	7.22E+10	2.64E+12
Moist Conditions	10–40	43	6.16E+10	6.75E+12	2.75E+10	3.01E+12
Mid-Range Flows	40–60	27	2.24E+10	1.64E+12	6.31E+09	4.61E+11
Dry Conditions	60–90	N/A	5.06E+09	5.54E+11	N/A*	N/A
Low Flows	90–100	N/A	5.82E+08	2.12E+10	N/A	N/A

*N/A denotes values that are currently within the water quality goal thus no reduction is needed under those conditions

Ammonia

LDCs were also developed to aid in determining potential sources of ammonia present in the Attoyac Bayou. Analysis revealed that loading at stations 10636 and 15253 (Figures 7.5 and 7.6) rarely exceed or even approach the applicable ammonia screening level under monitored flow conditions. Two of the individual ammonia loading exceedances that were observed occurred during the mid-range flow condition, which is typical of normal flow conditions while the two other exceedances occurred under low flow conditions suggesting that ammonia loading to the water body is likely not from the watershed. Additionally, these elevated readings also occurred during the summer of 2011 during the height of drought conditions

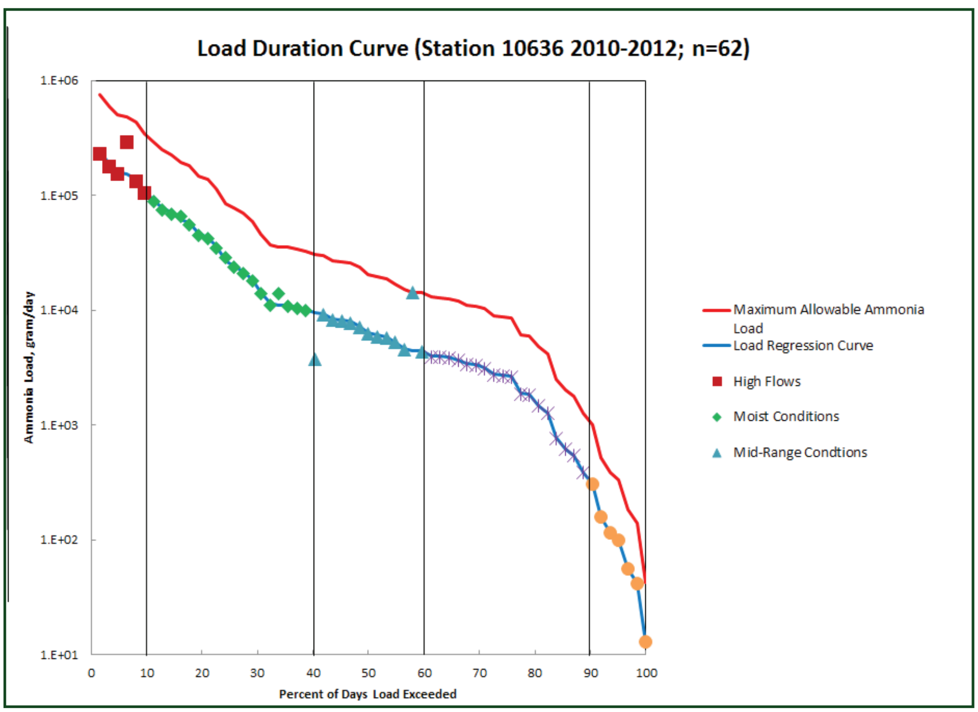


Figure 7.5. Load duration curve for station 10636 showing ammonia loading across monitored flow regimes

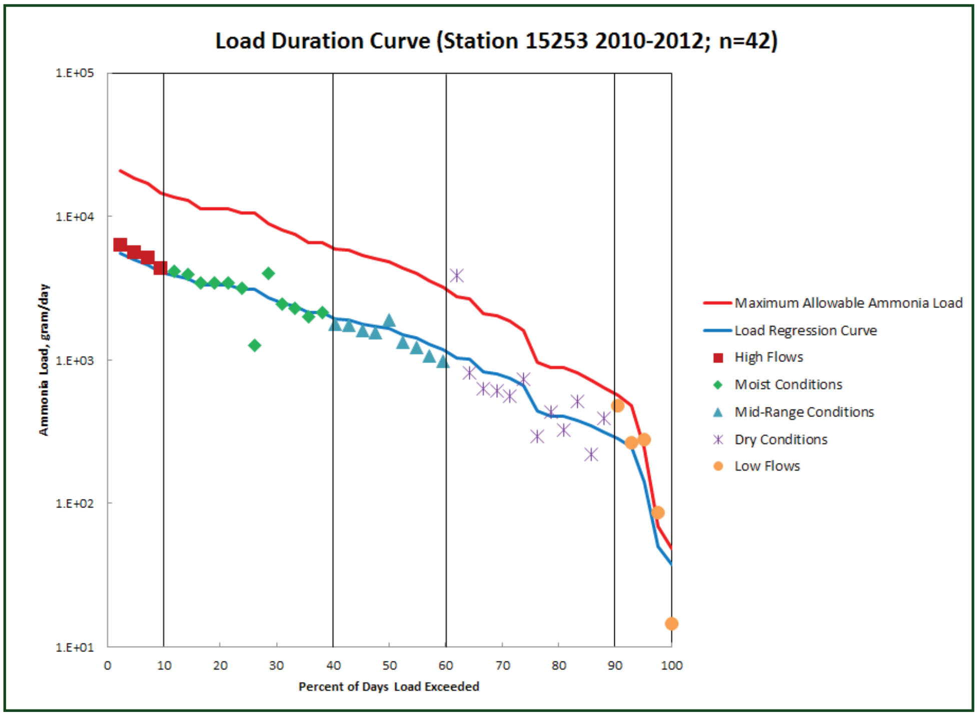


Figure 7.6. Load duration curve for station 15253 showing ammonia loading across monitored flow regimes

experienced in the watershed. Collectively, this indicates that ammonia loading to the Attoyac Bayou is not problematic under any of the monitored flow conditions.

As a result, no management measures will be focused specifically to address ammonia loads. Management practices designed and implemented to address bacteria loading will likely provide ancillary benefits and result in reduced ammonia loads entering the water body.

SELECT Analysis

To aid in determining potential areas of *E. coli* contribution within the watershed, the Spatially Explicit Load Enrichment Calculation Tool (SELECT) was applied. This model uses best available information and stakeholder input to estimate potential pollutant loading from the modeled source. SELECT was used to evaluate potential *E. coli* loadings from cattle, deer, dogs, feral hogs, horses, hunting camps, poultry litter, septic systems and WWTFs. Other potential sources of *E. coli* certainly exist in the watershed such as rodents and small mammals but they were not modeled at this time due to lack of population and fecal production information. Using outputs generated by the model, the relative potential for *E. coli* loading from each evaluated source across the watershed can be compared and aids in prioritizing future management. A complete discussion on the development of the SELECT model, its inputs and results can be found in Borel et al. (2012b).

Loading estimates produced by the SELECT model are potential loading estimates that do not account for bacteria fate and transport processes that occur between the points in the watershed where they originate and where they enter the water body if at all. As such, this model presents a worst cases scenario that does not represent actual *E. coli* loadings expected to enter the creek. Predicted loads are estimated at the sub-watershed level to show the relative potential loading in each of the 13 sub-watersheds (Figures 7.7 through 7.9).

Results of this assessment suggest that sub-watersheds 3, 4 and 13 have the highest potential *E. coli* production load; sub-watersheds 7 and 9 were also noted as having considerable *E. coli* production potential. Figures 7.7 through

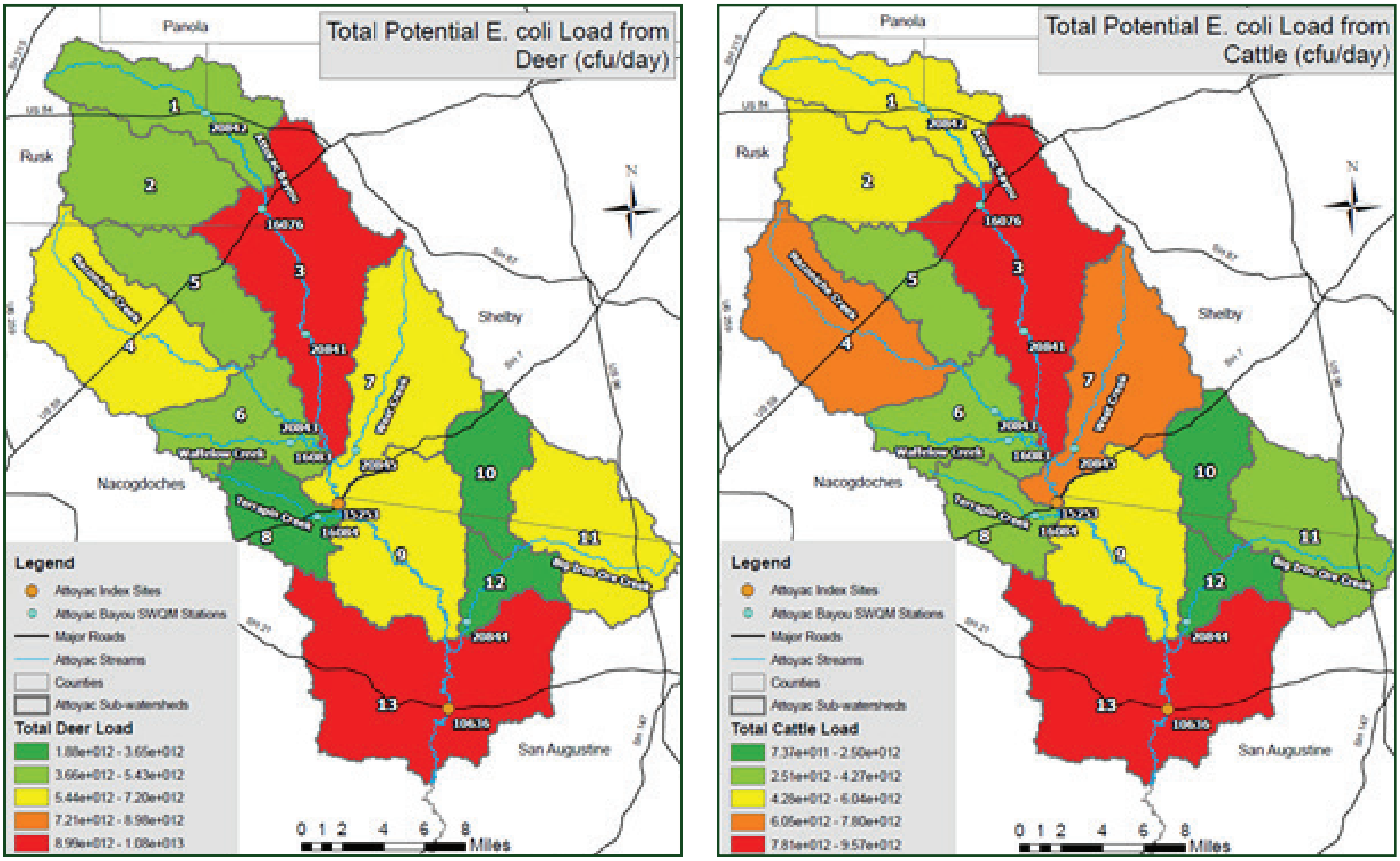


Figure 7.7. Distribution of total potential *E. coli* loads from cattle and deer across the Attoyac Bayou watershed

7.9 illustrate the relative distribution of potential *E. coli* production between sub-watersheds within each source type while Figure 7.10 demonstrates how the ranges of potential *E. coli* production for each source compare to each other. This suggests that OSSFs have the highest potential *E. coli* loading across the watershed followed by deer, cattle, dogs and feral hogs, in order respectively.

Bacterial Source Tracking (BST) Analysis

Bacterial source tracking (BST) is a process that can detect differences in the genetic make-up of bacterial strains that are specific to their host thus enabling the source of the evaluated bacteria to be identified (Di Giovanni et al. 2013). A variety of BST methods exist; however, two are commonly used in Texas.

A combined test used on *E. coli* is automated ribosomal deoxyribonucleic acid genetic fingerprinting (RiboPrinting) paired with enterobacterial repetitive intergenic consensus sequence polymerase chain reaction (ERIC-PCR). When used in conjunction, the method is referred to as ERIC-RP. *E. coli* from a water sample is first grown in a laboratory before DNA is extracted and scanned. This test produces a DNA fingerprint that resembles a bar code, which can be compared to DNA fingerprints stored in a reference library that were produced from known sources of fecal matter. A second method used is called the Bacteroidales BST. This method differs from *E. coli* BST methods as water samples are concentrated by filtration and DNA is extracted from the concentrated sample. DNA extracted from the water screened for the presence of specific Bacteroidales DNA markers. This approach uses currently available markers for Bacteroidales specific to humans, pigs (including feral hogs) and ruminants (including cattle, deer, llamas and sheep). Detection of these DNA markers indicates the group of animals that the Bacteroidales came from thus allowing identification of the broad sources of fecal pollution (Di Giovanni et al. 2011).

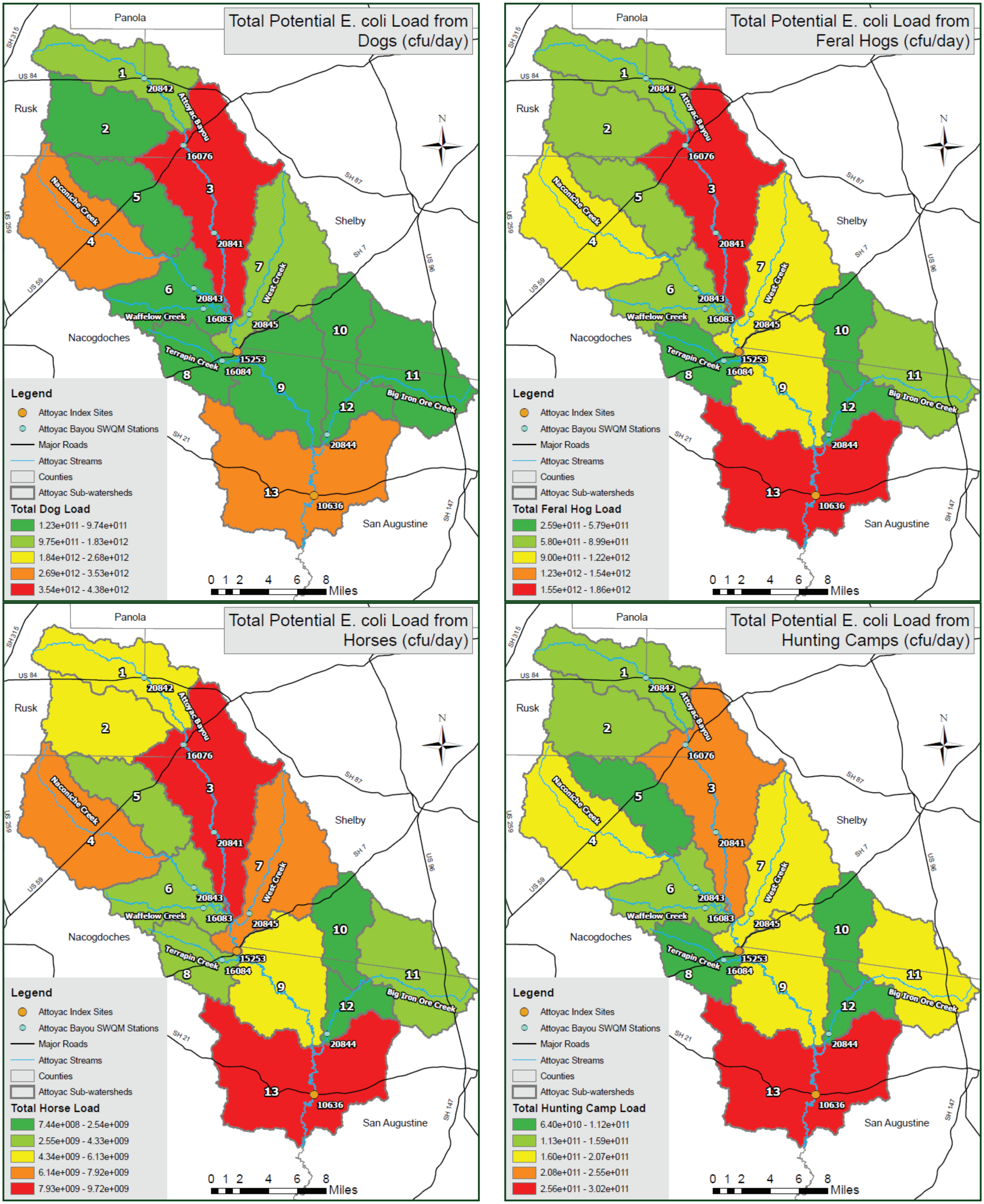


Figure 7.8. Distribution of total potential *E. coli* loads from dogs, feral hogs, horses and hunting camps across the Attoyac Bayou watershed

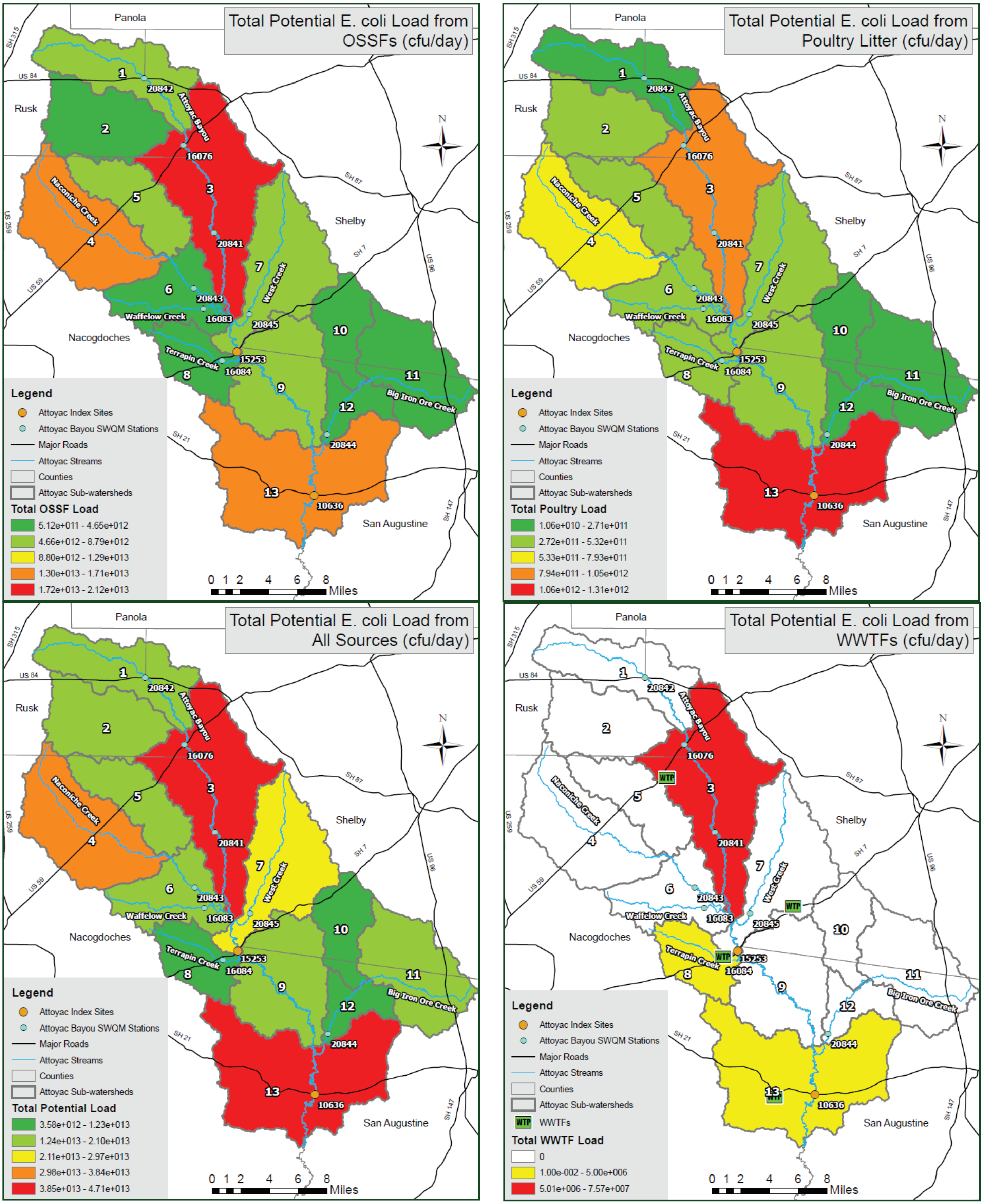


Figure 7.9. Distribution of total potential *E. coli* loads from OSSFs, poultry litter and WWTFs across the Attoyac Bayou watershed as well as total potential loading from all sources

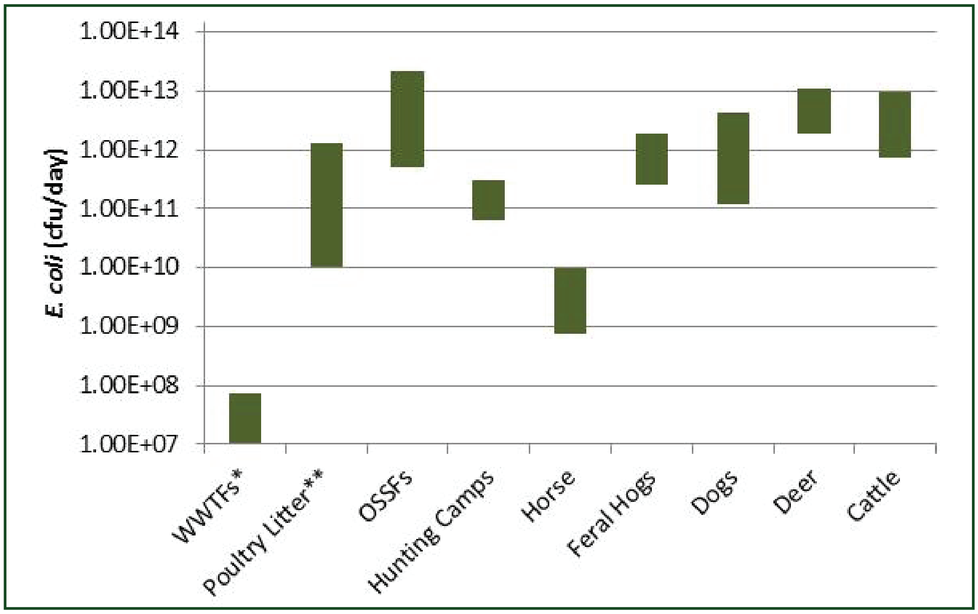


Figure 7.10. Relative potential differences in *E. coli* loading by source as predicted using the SELECT model
(*The lower limit of WWTF *E. coli* loads predicted per day is actually 0 cfu/day; numerous sub-watersheds do not contain WWTFs; ** poultry loads were estimated using the minimum detection limit of 100 cfu/gram for *E. coli* in feces; the expected load is less than is graphically represented)

Using these methods, in conjunction with the collection of 156 known sources of fecal material, BST was applied in the Attoyac Bayou watershed. A total of 267 water samples (base flow, storm flow and WWTF samples) were processed using Bacteriodales PCR and 108 (base flow, storm flow and WWTF samples) were processed with ERIC-RP. An in-depth review of these methods as well as the water and known source fecal sample collection, processing and analysis is available in the Bacterial Source Tracking Assessment for the Attoyac Bayou (Martin et al. 2014). It should be noted that all BST analysis represents the bacteria load in a very small volume of water (100 mL usually) at a specific point in time. As such, results are merely a representation of bacterial loading occurring in the watershed and should not be considered as an exact indication of bacterial load distribution.

Results from the BST analysis indicate that a variety of sources contribute to the overall bacteria load in the Attoyac Bayou. Bacteriodales PCR analysis was conducted confirmed the presence of bacteria in more than 96% of samples processed and bacteria originating from humans, ruminants (including cattle, deer, llamas and sheep) and hogs (including feral hogs) in 5%, 47% and 28% of samples processed respectively. This indicates that ruminants are likely the most common contributor of bacteria to the watershed from the sources tested and are followed by hogs and then humans. No horse bacteria were found in the any water samples processed indicating that they are not a substantial source contributing bacteria in the watershed (Figure 7.11).

When evaluating Bacteriodales PCR results by sampling station (Figure 7.12), several key observations can be made. The ruminant marker is identified more than human or hog markers at all stations suggesting that ruminant derived bacterial loading is most common. This is not unexpected as the ruminant marker identifies multiple species such as cattle and deer. Hog markers, which include feral hogs, were found at increasing levels in areas of the watershed with more forested land. Human markers were identified at the lowest rate, suggesting that their loading is less frequent than other potential sources. The Terrapin Creek sampling station (16084) did indicate an increased presence of human-derived bacteria. This is also not a surprise as the Martinsville Independent School

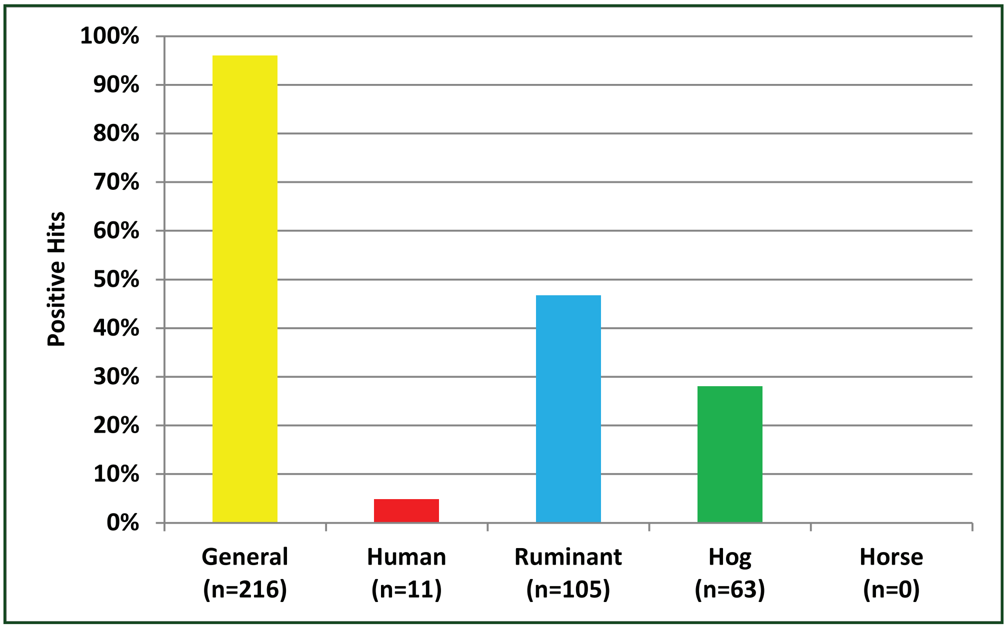


Figure 7.11. Bacteriodales PCR results from water samples collected under base flow conditions
(n = 225)

District WWTF periodically contributes treated wastewater to the creek a short distance upstream of the sampling station.

ERIC-PCR, which is a more refined test that can identify a more diverse number of source categories, produced results that corroborated Bacteroidales PCR findings. Due to a small number of water samples processed with this method, results were aggregated at the watershed level. Results indicated that wildlife (avian and non-avian; inclusive of feral hogs) were the largest source of bacteria found in the water body (Figure 7.13). Unidentified sources of bacteria make up the next largest portion of the contributions identified and are subsequently followed by cattle, humans, pets and other livestock.

Collectively, these BST results further the understanding of the most likely sources of bacteria contributions seen in the watershed. These findings are similar to results found in other rural Texas watersheds where BST has been conducted.

Recreational Use Attainability Analysis (RUAA) Findings

A recreational use attainability analysis (RUAA) was also conducted by SFASU and CES in the watershed and provided insight into the presence of potential sources of fecal material near the water body (Fuller et al. 2012). The intent of this survey was to determine the level of human use of the water body by conducting historical surveys, landowner interviews and field observations. Collectively, human uses noted in the watershed dating back to 1975 in descending order of occurrence include fishing, hunting, boating, wading, swimming and noodling. Additionally, observations made in riparian areas are also useful in noting the occurrence of potential bacteria loading events and sources.

Items noted during the survey included both the presence of fecal material as well as evidence of recent use by animals and humans (tracks, litter, wallows, etc.). Animal activity and other items noted in the survey that are potential sources of fecal bacteria to the watershed included a variety of animals and trash. Table 7.5. documents the

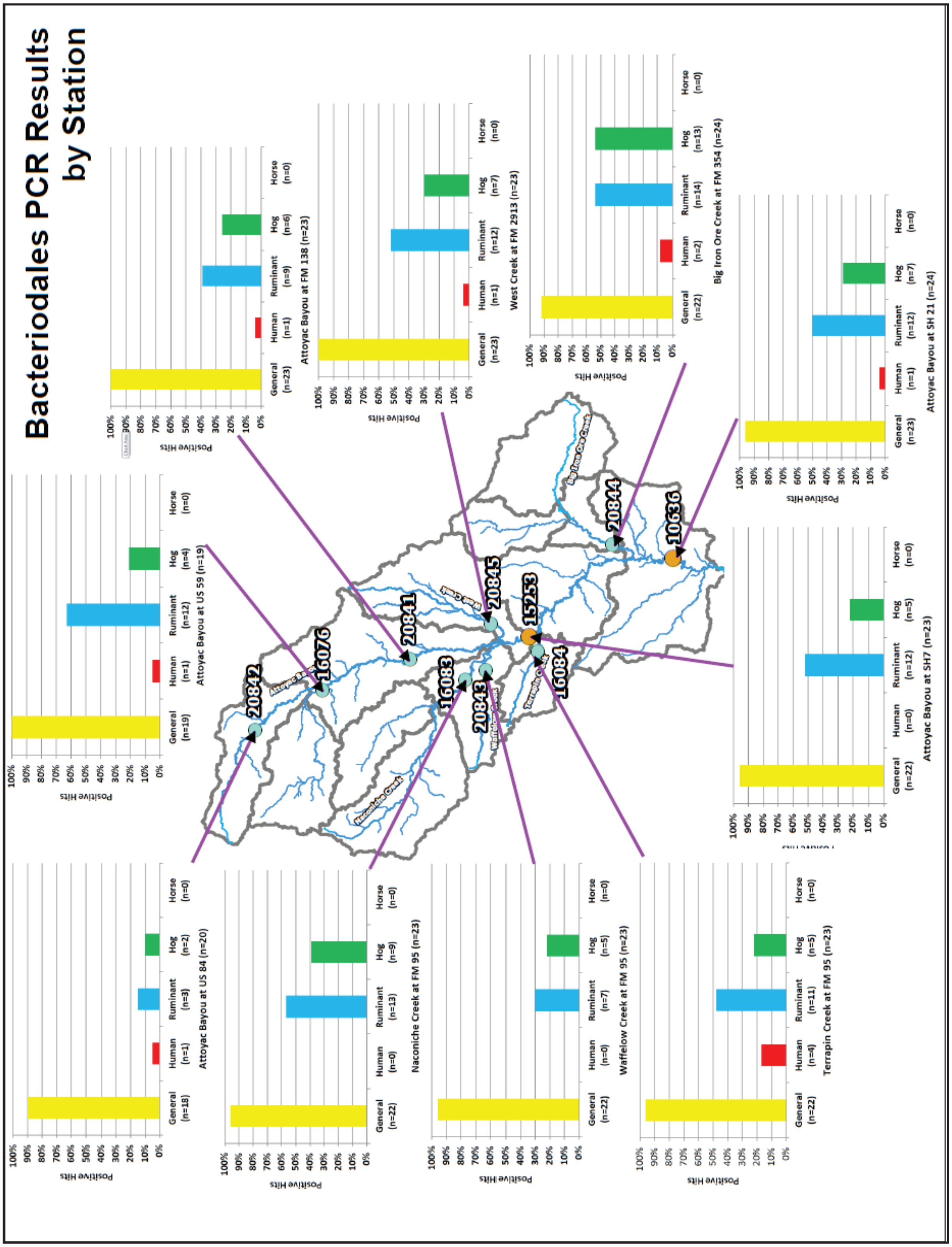


Figure 7.12. Bacteriodales PCR results at each water quality monitoring station in the Attoyac Bayou watershed

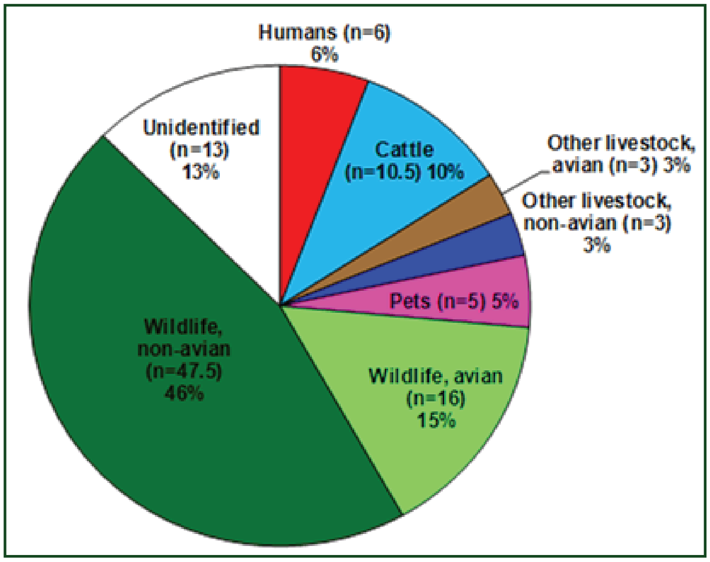


Figure 7.13. *E. coli* BST results for the Attoyac Bayou watershed

number of observations made as well as the evidence observed along 300-yd reaches of surveyed sites. Additionally, trash in the water body and on its banks was also documented. In the Attoyac Bayou, trash was noted as being rare in the downstream portion, but it was considered common in upstream areas. Naconiche and West creeks were commonly found to have trash while trash was rare in Big Iron Ore, Terrapin and West creeks. The type of trash most commonly observed was household trash, old tires, discarded fishing bait and tackle as well as discarded animal carcasses.

Watershed Stakeholder Input

Local watershed landowners also provided valuable information that enabled a better understanding of the potential sources of bacteria and their relative impacts to the watershed. Landowner knowledge was critical in providing watershed-specific information that is often lost in information aggregated at the county or state level. This was especially the case for OSSFs. Local knowledge of common system age and presence of failing systems was much higher than anticipated. Thus an improved estimate of potential impacts from OSSFs was developed.

Input regarding appropriate numbers of feral hogs, livestock and wildlife to consider as well as their distribution across the watershed was also quite valuable.

Table 7.5 Animal evidence observed during the RUAA

Potential Source	# of Observations	Evidence Observed
Alligators	13	Presence
Beaver	5	Dams, Tree Damage
Cattle	19	Feces, Presence, Tracks
Deer	1	Tracks
Feral Hogs	34	Feces, Tracks, Wallow
Other Wildlife	26	Feces, Tracks
Pets	3	Tracks
Raccoon	5	Tracks
Snakes	14	Presence
Water Birds	14	Presence, Tracks

Reconciliation of Assessment Results

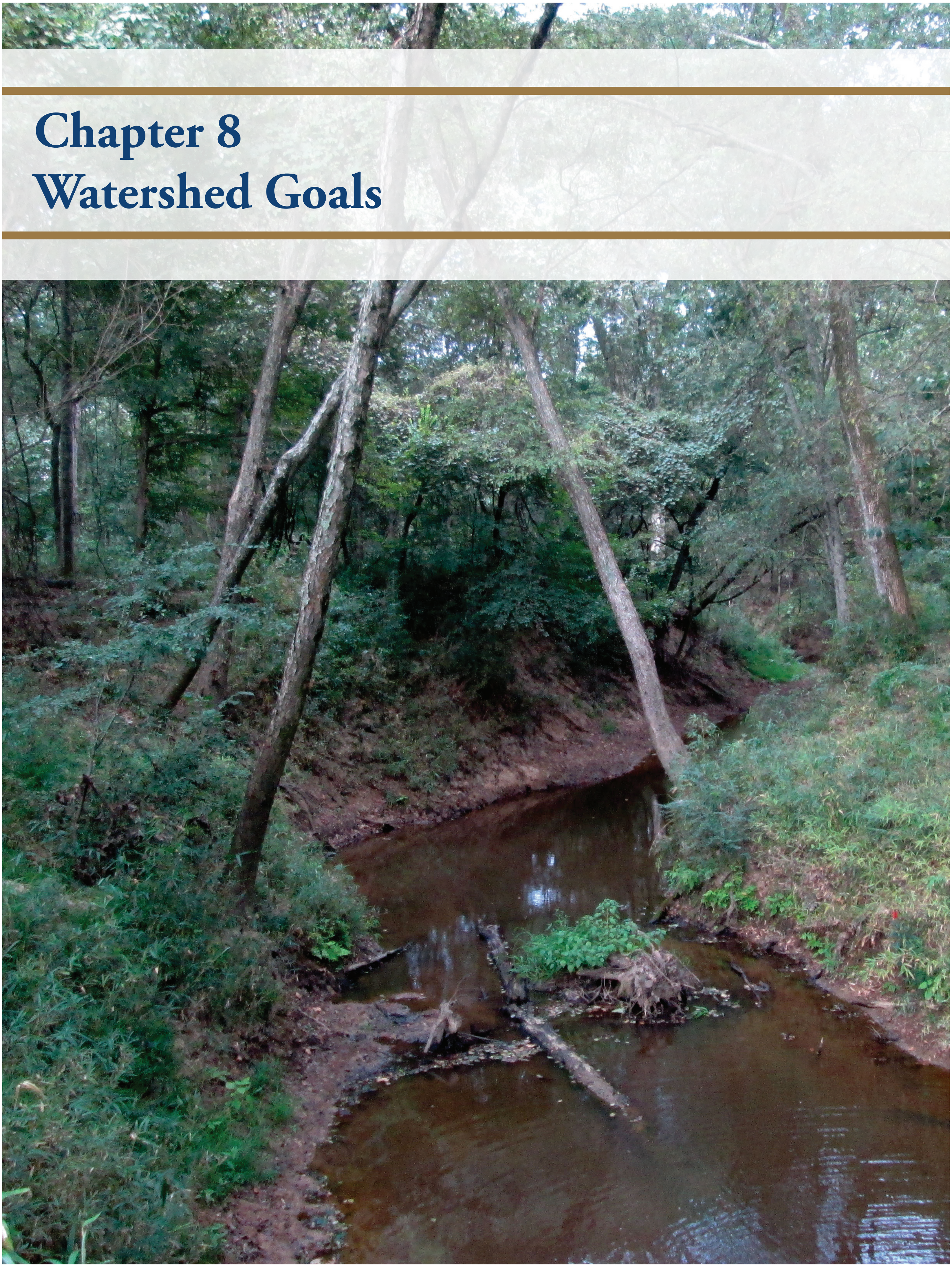
The variety of tools and information used to assess the presence and potential contributions of bacteria contributors in the watershed do not always yield results that directly agree with each other. BST and the SELECT model commonly produce conflicting results, which should not be compared. BST results are actual findings from evaluated discreet water samples while models, such as SELECT, are predictive tools that use best available information to estimate potential bacteria contributions to a watershed. Thus, BST detemines which *E. coli* are in the water while SELECT predicts what might be there.

Similarly, water quality monitoring results may indicate that a certain portion of the assessed watershed has a larger bacteria loading issue than is predicted by the SELECT model. The Big Iron Ore Creek sub-watersheds (10, 11 and 12) provide a perfect example of this disconnect between model results and measured water quality. As seen in Figures 7.7 through 7.9, the Big Iron Ore Creek sub-watersheds had predicted *E. coli* production rates less than other sub-watershed for all modeled sources except deer and hunting camps yet it had the highest measured *E. coli* levels in the watershed. However, when field observations made during the RUAA are considered, the higher *E. coli* numbers are not surprising. Beaver activity was noted at two survey sites, water dependent birds were found at four while feral hogs and wildlife evidence (small and large) was noted at all locations within the banks of the creek indicating its frequent use by wildlife and feral animals. The LDC developed at this location supports this claim as a considerable *E. coli* loading reduction is needed under low flow and dry conditions for Big Iron Ore Creek to meet water quality standards. This suggests the presence of point source discharges or direct fecal deposition to the stream as runoff is not and likely has not occurred for some time under these flow conditions. Since the Big Iron Ore Creek sub-watersheds do not have any permitted point source discharges, direct fecal deposition and resuspension of stream sediments are the only viable sources of *E. coli* in the stream.

Despite individual assessments not agreeing with each other perfectly, individual assessments were evaluated collectively to determine the most likely sources of bacterial contributions to the water body and watershed. In this case, those sources contributing bacteria in or near riparian areas are thought to have the largest impact on instream bacteria levels. Stakeholders used this information along with local knowledge to recommended management strategies. Proposed strategies are discussed in Chapter 9 and focus on addressing reasonably manageable sources of bacteria across the watershed the will provide ample benefits to instream water quality. These include feral hogs, livestock and OSSFs.

Several manageable sources of bacteria in the watershed were not the focus of management measures recommended by partnership members. These included pets, poultry (litter), oil- and gas-related OSSFs and WWTFs. While it is noted that these sources do contribute to the overall bacteria load in the watershed, the cost to manage them versus the expected bacteria reduction did not justify management measure development. Oil- and gas-related loads for example are transient and the local decline in activity minimized their potential for pollutant loading. Alternatively, pets and poultry are mainstays in the watershed; however, BST results indicate that their contributions are miniscule compared to other watershed sources. WWTFs were viewed similarly as the SELECT model predicted their bacteria loading potential to be lower than all other sources if they maintain operation within the limits of their discharge permit issued by TCEQ.

Chapter 8
Watershed Goals



Attoyac Bayou Watershed Partnership Mission Statement

"To promote the long-term conservation and stewardship of the Attoyac Bayou watershed in a manner that improves and sustains instream water quality, protects its ecologically diverse natural resources and maintains the economic viability of the watershed while simultaneously supporting the needs of watershed stakeholders."

Watershed Goals

When the development of the Attoyac WPP was initiated, the desired water quality goal expressed by watershed stakeholders was the removal of the Attoyac Bayou from the 303(d) List. This goal, translated to numeric terms, is a goal of an *E. coli* geometric mean less than 126 cfu/100 mL. Understanding that water quality goals establish the need to effectively implement the Attoyac Bayou WPP in the future and establish a basis for providing funds to implement this plan, watershed stakeholders have established an over-arching goal and four sub-goals as targets to achieve in the near and long term.

Meet Designated Water Quality Standards

The over-arching goal decided upon by watershed stakeholders is to meet designated water quality standards set by the State of Texas for the Attoyac Bayou. The current *E. coli* standard within the Attoyac Bayou is set at 126 cfu/100 mL of water, based on the water body's classification as a primary contact recreation water body. The majority stakeholder and steering committee members did not agree with the primary contact recreation designation for the Attoyac Bayou. This sentiment led to the establishment of another goal for the Watershed Partnership, which was to determine and recommend to the state an appropriate water quality standard for the Attoyac Bayou.

Determine and Recommend an Appropriate Water Quality Standard

As previously stated, most stakeholders and steering committee members do not think the Attoyac Bayou should be held to primary contact recreation standards. Stakeholders and steering committee members within the watershed and Attoyac Bayou did not indicate the Attoyac Bayou to be a primary contact recreation water body. The results of the RUAA performed on the Attoyac Bayou in 2012 further supported the sentiment that the Attoyac Bayou should be classified as a secondary contact recreation water body. While the RUAA is being reviewed by the TCEQ, the Attoyac Bayou Watershed Partnership has continued to progress with the development of the WPP with a focus on increasing awareness, understanding local water quality concerns and encouraging voluntary adoption of practices that improve water quality through better watershed stewardship.

Improve Awareness and Understanding of Local Water Quality Concerns

The Attoyac Bayou Watershed Partnership expressed a desire to improve awareness and understanding of local water quality concerns. This awareness will be achieved by continuing and increasing public outreach and education through additional stakeholder meetings, public workshops focused on improving local water quality, the dissemination of project-related materials through multiple vectors including e-mail and traditional mail distribution lists, the project website, telephone and/or face-to-face correspondence with local community members. Public workshops held in the future may consist of, but are not limited to, feral hog management, septic system operation and maintenance, importance of soil testing, as well as numerous other riparian and water quality-related issues.

Encourage Voluntary Adoption of Practices that Improve Water Quality through Better Watershed Stewardship

The Attoyac Bayou Watershed Partnership stressed personal responsibility in improvements in water quality and better watershed stewardship. The Partnership felt that individual landowners, when given adequate amounts of information regarding water quality issues and watershed stewardship, is quite likely to make the best decisions on what actions to take on their land that meets both their personal needs as well as watershed partnership's goals. The Partnership stressed the need to employ completely voluntary adoption of any management practices to be implemented, and those management measures should be implemented with private funds when possible.

Chapter 9
Voluntary Management Strategies

Using watershed pollutant source assessment information, local stakeholder knowledge and management practice effectiveness information, watershed partnership members identified the voluntary management strategies recommended in this chapter to address bacteria loading in the watershed. Through implementation of these practices at the noted levels, bacteria loads entering the Attoyac Bayou will be reduced to levels that support the current primary contact recreation use. Actual reductions are, of course, dependent upon a number of factors, which may trigger the need for adaptive implementation in the future.

Information presented in Chapter 7 indicates that no single source contributing bacteria to the watershed is the primary contributor of bacteria to the bayou. LDC analysis suggested NPS pollution as a larger bacteria contributor than point source pollution; however, the infrequent nature of runoff producing rain events suggests that the bayou itself could also be a considerable source of *E. coli.* This source is practically unmanageable though. In addition, wildlife was considered unmanageable as well. Habitat management is essentially the best tool to influence wildlife behavior; however, partnership members viewed managing this natural source of bacteria as futile. As such, no management measure is recommended to directly address wildlife bacteria loading.

Evaluated sources contribute bacteria to the bayou at varying rates and volumes that are dependent upon many factors. The distance from the stream that bacteria are deposited into the environment is thought to be the factor that has the most influence on the amount of bacteria entering a stream. As a result, recommended management measures are focused in and near riparian areas in an effort to produce the largest bacteria load reductions for the implementation dollar spent. Additionally, recommended management measures are prioritized by sub-watersheds and are focused in areas with highest potential for loading. Figure 3-3 illustrates sub-watershed locations within the watershed as do Figures 7.7, 7.8 and 7.9.

Another factor considered by the steering committee was the feasibility of effectively managing a source of bacteria. Management recommendations were only developed for sources that are known to be more effectively managed or were deemed significantly problematic. Sources that are known contributors to the overall bacteria load, but are extremely difficult to manage (e.g. wildlife) were not directly addressed through a recommended management measure.

To aid in prioritizing management strategy selection, watershed partnership members were polled to determine the feasibility and acceptability of a number of potential management practices regardless of their use or effectiveness. Practices included in the survey came from published best management practice (BMP) manuals such as the NRCS Field Office Technical Guide, Texas A&M Forest Service's (TFS) Texas Forestry BMPs manual or were gleaned from other existing WPPs. Within the survey, BMPs were grouped according to the relevant sources of potential pollution managed (forests, livestock, wildlife, human) and a brief description of the practice as well as its expected benefits were provided. Partnership members were asked to respond to two questions regarding each measure: 1) Do you think this practice is feasible to implement in the Attoyac Bayou watershed, and 2) Would you be willing to implement this practice on your property? Responses were given numerically (0 = no, 1 = maybe, 2 = yes) and were summed for all responses received. Table 9.1 presents the survey's results in order of combined highest scores to lowest combined score.

Survey results were used to help determine which management practices are most likely to be implemented and as such, appropriate to include in the WPP. Other management measures such as feral hog control and focused education delivery were not included in the survey, but were also found to be desirable and feasible. Ultimately, this information was considered in the final selection of management strategies along with the results of the watershed pollutant source assessment and stakeholder feedback.

Livestock

Bacteria loadings to the bayou from cattle and other livestock were estimated to have a potentially high relative contribution of bacteria to the watershed as compared to other evaluated sources. These sources are also considered more easily managed as the behavior of cattle and the areas where they spend their time can be easily modified through changes to food, shelter and water availability and access. Cattle resource utilization is highly dependent

Table 9.1. BMP feasibility and implementation acceptance levels

BMP Name and NRCS Practice Code (number) as Appropriate		% Combined Practice Feasibility Score
- Soil Testing - Farm Ponds (378) - Prescribed Burning (338)	- Streamside Management Zones - Forest Roads	90% or Greater
- Nutrient Management (590) - Cross Fencing (382) - Brush Management (314) - Moving Supplemental Feeding Locations	- Stream Crossings (578) - Watering Facilities (614) - Prescribed Grazing (528)	80% to 90%
- Grazing Land Aeration (548) - Pasture Planting (512) - Critical Area Planting (342) - Water Well (642) - Vegetated Barrier (601) - Habitat Management (643, 644, 645, 647)	- Heavy Use Protected Area (562) - Riparian Forest Buffer (391) - Pipeline (516) - Conservation Reserve Program (327) - Stream Crossings (578)	70% to 79%
- Septic System Maintenance/Upgrade - Grassed Waterways (412) - Wildlife Watering Facility (648)	- Filter Strips (393) - Pumping Plant (533)	60% to 69%
- Grade Stabilization Structure (410) - Hunting Camp Septic Systems	- Shade Structures - Roof Runoff Structure (558)	45% to 59%

upon the proximity to these resources, especially water. Their fecal loading is also strongly tied to resource utilization as it is directly related to the amount of time an animal spends in an area. Therefore, reducing the amount of time livestock spend in riparian pastures through rotational grazing, adding alternative watering facilities or moving supplemental feeding locations can directly reduce the potential for bacteria from livestock to enter the bayou. Actual practices needed or appropriate will vary by operation and will be determined through technical assistance from NRCS, TSSWCB or local soil and water conservation districts (SWCDs) as appropriate.

Rotational grazing system paired with alternative water

Research has shown that the amount of time livestock spend in and very near water bodies as well as the time since grazing occurred can have direct impacts on the amount of instream and edge-of-field bacteria observed. For example, Wagner et al. (2012) reported that *E. coli* loads were reduced from 88 to 99% when runoff occurred two weeks or more following grazing and thus recommended grazing in creek pastures when runoff is less likely to occur. Additionally, Wagner et al. demonstrated that the time cattle spent near a small stream in south central Texas was reduced by 43% when an alternative water source was provided (2013). Other research summarized by Wagner et al. (2013) indicates that *E. coli* load reductions seen in-stream are well correlated to the amount of time animals spend near the water body and that increasing the distance from the stream where fecal matter is deposited reduces the amount of bacteria that actually make it to the stream. As a result, management recommended for grazing livestock is focused on properties with riparian access. Properties that have a direct hydrologic connection to the water body should also be a priority as well. Figure 9.1 illustrates watersheds with the highest potential for bacteria loading from livestock and the watershed's perennial stream network. This information and proximity to the Attoyac Bayou was used to prioritize watershed areas where loadings should be addressed.

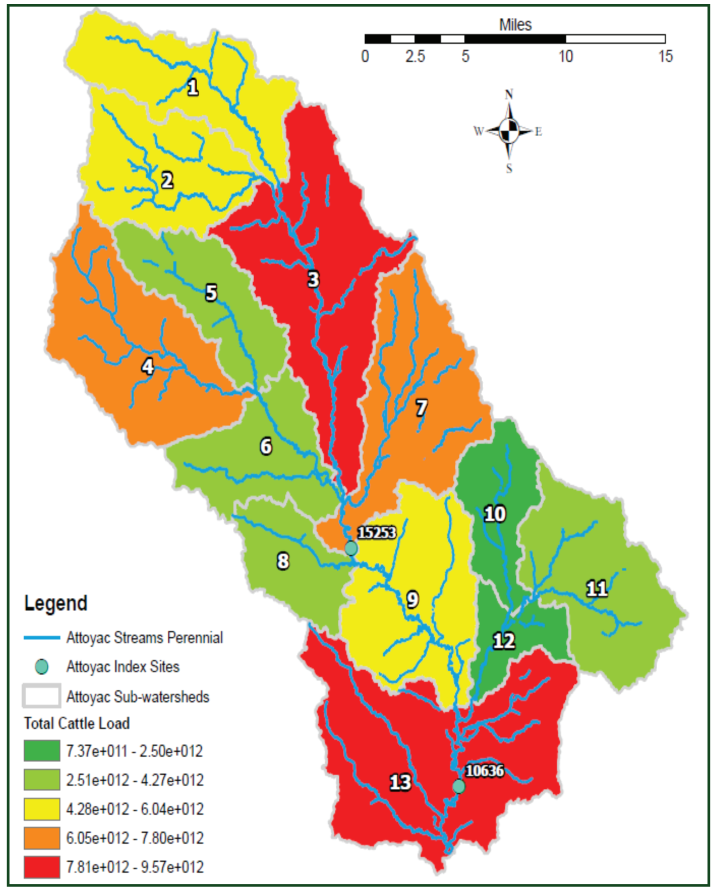


Figure 9.1. Livestock management priority reference map with SELECT model bacteria loading potential from cattle and perennial stream network shown

WQMPs, developed by local SWCDs, are an effective, yet adaptable means for planning for the enhanced resource utilization on farms, forestry and ranching operations. Each WQMP is an operation-specific plan requested by the landowner to meet both the landowner's goals for that operation while improving the quality of water produced from that property. During plan development, TSSWCB and the local SWCD will determine appropriate practices that will achieve a level of pollution abatement consistent with Texas' surface water quality standards. A WQMP covers the entire operating unit and includes required practices appropriate for the planned land use. They include technical requirements that the producer must be able to implement and maintain.

To obtain a WQMP, the producer must contact the local SWCD office and request a plan. NRCS or SWCD staff will take the request and begin the planning process. WQMP development is done free of charge; however, there may be costs for implementing practices required in a WQMP. Financial assistance may also be available to volunteering producers to aid in implementing prescribed management practices through TSSWCB or NRCS programs.

Specific management recommendations for livestock are described in Management Recommendation 1.

Management Recommendation 1

Pollutant Source: Cattle and Other Livestock

Problem: Direct and indirect riparian fecal loading, riparian degradation, overgrazing

Objectives:

- Work with ranchers, property owners with riparian/creek access to develop WQMPs
- Develop customized whole-farm plans
- Provide producers technical and financial assistance
- Implement WQMPs
- Reduce fecal loading in riparian areas from grazing livestock

Location: Priority sub-watersheds identified below

Critical Areas: Properties with livestock grazing, creek and tributary access, especially those used as a water source

Goal: To develop WQMPs focused on minimizing/planning the time spent by livestock in the riparian corridor

Description: WQMPs will be developed in areas to most appropriately address direct and indirect fecal deposition from cattle and other livestock and prescribe BMPs that will reduce time spent in the creek or riparian corridor, likely focusing on prescribed grazing, cross-fencing and watering facilities.

Implementation Strategies

Participation	Recommendations	Period	Capital Costs
Riparian areas in sub-watersheds 13, 3, 9	Develop, implement and provide financial assistance for livestock WQMPs @ $15,000 per plan for 45 plans	2015–2025	$675,000
Riparian areas in sub-watersheds 7, 4, 6, 1	Develop, implement and provide financial assistance for livestock WQMPs @ $15,000 per plan for 55 plans	2015–2025	$825,000
Texas A&M AgriLife Extension Service	Deliver *Lone Star Healthy Streams* programming to watershed landowners	2015, 2018	N/A

Estimated Load Reduction

Prescribed management will most effectively reduce direct deposition but will also reduce bacteria loads from the landscape as well. By implementing prescribed grazing, cross fencing and watering facilities on 33% of the estimated total number of ranches in the above listed sub-watersheds, potential annual load reductions from cattle are estimated to be 6.97 E+14 cfu/year. This assumes that each WQMP will include prescribed grazing, cross-fencing and alternative watering facilities in creek pastures to collectively minimize the amount of time livestock spend in riparian areas. This estimate is further explained in Appendix D.

Effectiveness:	High: Decreasing the time that livestock spend in the riparian corridor and reducing surface runoff through effectively managing vegetative cover will significantly reduce NPS contributions of bacteria and other associated pollutants to the creek.
Certainty:	Moderate: Landowners acknowledge the importance of good land stewardship practices and WQMP objectives; however, financial incentives are needed in many cases to increase WQMP implementation
Commitment:	Moderate: Landowners are largely willing to implement land stewardship practices that will benefit both the land and their operations; however, costs are often prohibitive and financial incentives will be needed to increase WQMP implementation
Needs:	High: Financial assistance is the primary need, and WQMP implementation will likely not occur without it; education and outreach are needed to illustrate animal production, economic and water quality benefits of WQMP development and implementation to producers
*** Potential Funding Sources:**	WQMPs: TSSWCB WQMP program, CWA §319(h) grant program, NRCS EQIP program, landowners Education: CWA §319(h) grant program

* Funding available from listed programs varies yearly so potential contributions are unknown

With properly designed and installed feeder enclosures, adult and yearling deer can access feeders while feral hogs cannot. Excluding them from this food source may increase trapping success nearby as they look for available food.

Feral Hogs

Bacteria loading from feral hogs was determined to be among the largest contributors to the water body and is considered a source that is marginally manageable. Feral hogs have an affinity for riparian areas as they provide ideal food, habitat and water for this largely nocturnal species. Wallowing is a primary way that hogs cool themselves, thus water bodies are more frequently used in the summer months. Wallowing disturbs stream sediment and degrades bank stability and their presence in riparian areas equates to deposited fecal matter either in or near the water body. In addition to riparian areas, feral hogs also use almost all land use types across the Attoyac Bayou watershed. Feral hogs are responsible for extensive damage to other natural resources and cause subsequent economic losses, thus making their management desirable on multiple levels.

Feral hog management will focus primarily on removal of animals from the watershed but will include a considerable education component as well. Through a program offered by the AgriLife Extension, information will be periodically provided to landowners on feral hog biology, behavior, trapping techniques, exclusion and more. Additionally, Extension hosts the http://feralhogs.tamu.edu website that provides excellent resources on hog management and provides access to the growing Feral Hog Community of Practice (http://extension.org/feral_hogs), which also serves as great resource to landowners.

Landowners and lessees are at the forefront of efforts to remove feral hogs from any watershed. Their vigilance in the effort to remove feral hogs will be required to effectively manage feral hog populations and impacts across the watershed. Two techniques that work well together are exclusionary fencing and trapping. Food is a major resource requirement of hogs and in times of limited food, deer feeders become an important source of food for the feral hog population. Constructing properly designed fences around feeders can be a quite effective means to limit food resources available to hogs. Timmons et al. (2011) report that a 28-in high fence constructed using utility panels and T-posts is effective at completely excluding feral hogs from accessing the feeder. A description and plans for this fence can be found online at http://feralhogs.tamu.edu/files/2011/11/exclusion.pdf.

Excluding feral hogs from feeders may also increase trapping success. With less available food, hogs may be more likely to use baits at trapping locations as a primary food source. Feral hogs are a wary species and extreme care should be used in the trapping process. The use of pre-baiting and game cameras prior to trap placement and setting are highly recommended. Pre-baiting an area will provide evidence of the size and number of hogs coming to the baited area as well as the pattern of their use. This information can help in selecting the proper size and type of trap to catch most if not all of the hogs. Baiting an unset trap for a period to train hogs to enter the trap is also highly recommended. This will maximize the likelihood of trapping most or all of the hogs at once as they have become accustomed to entering and exiting the trap with no prior effect. This information along with other publications on trap design, baiting techniques, trap door designs and triggers, game camera use and more is available at: http://feralhogs.tamu.edu/publications/.

Feral hog populations can also be reduced by shooting and removing as many hogs as possible. This is already done in many cases; however, feral hogs are viewed as an extra hunting opportunity for lessees and are not actively removed year round. This should be avoided as it provides a refuge for hogs. Landowners can encourage or require lessees to actively remove hogs at all times. Hunting pressure may reduce trapping effectiveness by pushing hogs off a property. Again, the use of game cameras can aid in determining if shooting is the most appropriate strategy based on the size and number of hogs present.

Documenting hog removal is also important when quantifying removal impacts. AgriLife Extension hosts an online feral hog reporting tool (http://feralhogreports.tamu.edu/) that can aid in tracking feral hog movements and documenting number of hogs removed. This tool should be used to document both evidence of hog activity and removal of hogs.

Management Recommendation 2 describes specific feral hog management measures.

On-Site Sewage Facilities (OSSFs)

According to watershed stakeholders, OSSFs are considered extremely problematic regarding potential bacteria loading to the watershed. As discussed earlier in Chapters 6 and 7, the number of OSSFs (6,085) in the watershed, their ages and the general inability of soils present in the watershed to adequately treat domestic sewage make OSSF failures likely in the watershed. Information provided by stakeholders concurred with these findings as they indicate that at least 50% of all systems in the watershed are likely failing. The system's age as well as improper maintenance was pointed to as likely causes for failure. The SELECT model also predicted that of all evaluated bacteria sources OSSFs have the highest potential to contribute bacteria to the watershed. Since the majority of the systems present in the watershed were installed prior to statewide regulations requiring registration, data on the location, size, type and age of these systems do not exist in many cases, making it extremely difficult to know exactly what potential impact these systems may be having on water quality.

The number of OSSFs in the watershed and the high expected failure rate make prioritizing planned management to address these issues important. To accomplish this, the expected proximity to perennial and intermittent

A variety of trap designs have proven effective for trapping feral hogs. Scouting, planning and patience will improve trapping success. Technology can also help. Using game cameras to document when and how many hogs are coming to bait or remote triggers like that used in the coral trap on the right have shown the ability to improve trapping success.

Management Recommendation 2

Pollutant Source: Feral Hogs

Problem: Direct and indirect fecal loading, riparian habitat destruction, forest and pasture damage, wildlife predation and competition

Objectives:

- Reduce fecal contaminant loading from feral hogs
- Reduce hog numbers
- Reduce food supply for feral hogs
- Provide landowner education and outreach

Location: All sub-watersheds

Critical Areas: Riparian areas and travel corridors from cover to feeding areas

Goal: To manage the feral hog population through available means in efforts to reduce the total number of hogs in the watershed by 10% (1,015 hogs) and maintain that level of reduction annually.

Description:Voluntarily implement efforts to reduce feral hog populations throughout the watershed by reducing food supplies, removing hogs as practical and educating landowners on BMPs for hog removal.

Implementation Strategies

Participation	Recommended Strategies	Period	Capital Costs
Landowners, land managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog utilization	2015–2018	$200 per feeder exclusion
	Voluntarily identify travel corridors and employ trapping and hunting in these areas to reduce hog numbers	2015–2025	N/A
	Voluntarily shoot all hogs on site; ensure that lessees shoot all hogs on site	2015– 2025	N/A
AgriLife Extension	Deliver Feral Hog Education workshop	2015, 2018, 2025	$7,500 ea.
County/AgriLife Extension	Promote use of Extension's online tracking tool to report hog harvest data	2015–2025	$10,000

Estimated Load Reduction

Reducing the feral hog population will reduce bacteria loading to the landscape and direct deposition to the creek. This effort will primarily reduce direct deposition as these animals spend the majority of their time in the riparian corridor. As estimated and used in the SELECT model, each feral hog can contribute as much as 1.16 E+09 cfu of *E. coli* to the watershed daily. Using this number plus a reasonable attenuation factor that assumes 25% of the fecal bacteria deposited by feral hogs reaches the water body, reducing the population by 10% yields a maximum annual load reduction of 1.07 E+14 cfu of *E. coli*. See Appendix D for calculations.

Effectiveness:	High: Reduction in feral hog population will result in a direct decrease in bacteria and nutrient loading to the streams.
Certainty:	Low: Feral hogs are transient and adapt to their environment and will migrate due to hunting and trapping pressure; as such, the ability to remove 10% of the population each year will be difficult and is highly dependent upon the diligence of watershed landowners.
Commitment:	Moderate: Landowners are actively battling feral hog populations and will continue to do so as long as resources remain available.
Needs:	Moderate: Additional funds are needed to provide an additional incentive to landowners to actively remove feral hogs. Education and outreach delivery is needed to further inform landowners about feral hog management options, adverse economic impacts of feral hogs and what their options for dealing with feral hogs are.
*** Potential Funding Sources:**	Control: private funds, State-level feral hog control grants Education: CWA §319(h) grant program (these monies cannot be used for control or removal)

* Funding available from listed programs varies yearly so potential contributions are unknown

streams was calculated. The distance away from a water body that an OSSF is located and dispersing treated or untreated wastewater has a great influence on the likelihood that pollutants from that system will make it into that water body. Essentially, the shorter this distance is to the stream, the higher the chance for pollution transmission to the water body is. The type of water body may also influence bacteria transport as well. Perennial streams maintain flow year round and are more likely to have shallow groundwater tables nearby that are connected to the stream. If OSSFs discharge within or near this water table, bacteria transmission may be accelerated. Therefore, it is important to ensure that OSSFs within close proximity are functioning properly. For perennial streams, a 150-yd proximity to the stream was used and found that 127 OSSFs fell within this area. Intermittent streams were also evaluated as they do provide a direct hydrologic connection to the bayou in times of rainfall runoff. Since these water bodies are often dry, a 50-yd buffer was used to estimate the presence of 452 OSSFs. Figure 9.2 illustrates the distribution of these OSSFs relative to the watershed sub-watersheds and corresponding SELECT model results.

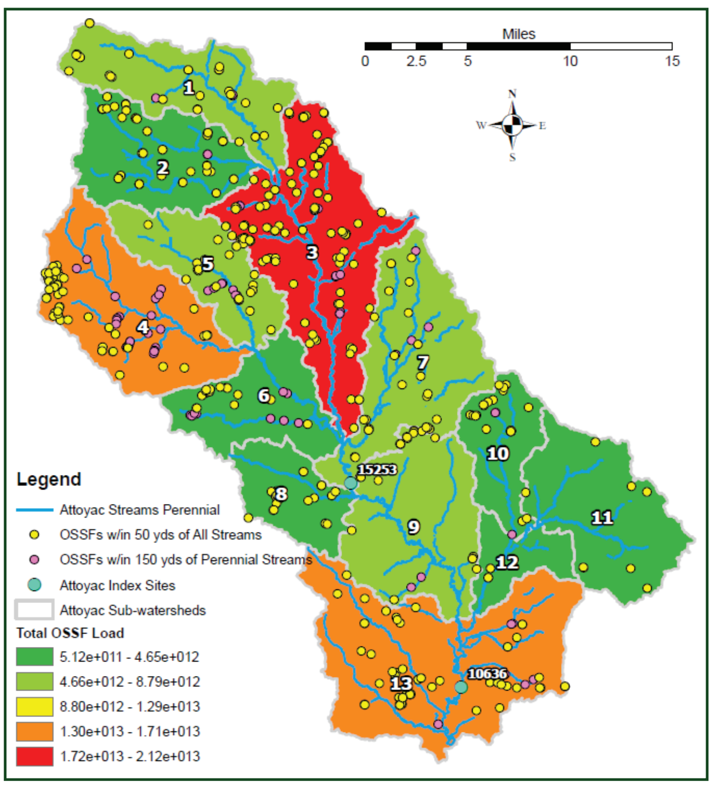


Figure 9.2. OSSFs within 150 yds of perennial streams or 50 yds of all streams, potential OSSF loads from the SELECT Model and sub-watershed used to prioritize OSSFs for inspection and possible repair or replacement

Management recommendations for addressing bacteria loading from OSSFs take several approaches to reduce bacteria loading from this source. Initially, identifying and inspecting OSSFs in within the perennial and intermittent stream buffers to determine their functional status is a priority need. Developing a watershed-wide OSSF database that documents system location, type, functional status, proximity to streams, age and general maintenance information is also needed. This will enable improved OSSF maintenance in the future and can be paired with the limited existing OSSF information to develop a better understanding of OSSF status across the watershed. Management will also focus on repairing or replacing failing OSSFs of volunteering homeowners as funding allows. Each of these items capitalize on ANRA's efforts to initiate these tasks in the watershed through Clean Water Act Section 319(h) grant "Lake Sam Rayburn OSSF Program Support and Attoyac Bayou OSSF Remediation" funded by TCEQ. Lastly, OSSF management will consist of both broad-based and targeted education and outreach to OSSF owners. This will focus on providing information on system operation and maintenance as well as proper installation, inspection and repair procedures. Education and outreach events will also discuss financial assistance options available to OSSF owners.

Management Recommendations 3 and 4 discuss management measures for OSSFs in detail.

Management Recommendation 3

Pollutant Source: Address Failing OSSFs

Problem: Pollutant loading from failing or nonexistent OSSFs

Objectives:

- Identify and inspect failing OSSFs in the watershed
- Determine priority areas for OSSF repair and replacement
- Develop watershed-wide OSSF database
- Repair or replace OSSFs as funding allows

Location: All sub-watersheds with proximity to Attoyac Bayou considered

Critical Areas: Entire watershed, but specifically OSSFs situated on soils that are not suitable for OSSF drain fields and within 150 yds of a perennial waterway or within 50 yds of an intermittent waterway.

Goal: To identify, inspect and repair or replace as appropriate 50 failing OSSFs in the watershed within 150 yds of a perennial waterway and an additional 50 failing OSSFs within 50 yds of an intermittent waterway.

Description: Potential OSSF failures will be addressed by working with homeowners to identify and inspect all OSSFs within critical areas. Deficient systems will be repaired or replaced as appropriate to bring them into compliance with local requirements.

Implementation Strategies

Participation	Recommended Strategies	Period	Capital Costs
Designated representative and/or contractor	Identify and inspect all OSSFs within 150 yds of a perennial waterway or 50 yds of an intermittent waterway	2015– 2018	$40,000/yr.
Designated representative and/or contractor	Develop a watershed OSSF database that documents individual OSSF information gleaned during inspections	2015–2018	$50,000
Designated representative	Administer OSSF repair/replacement program to address deficient systems identified during inspections	2015–2025	$15,000/yr.
Contractor	Repair/replace 100 OSSFs as funding allows	2015–2025	$5,000–$10,000 ea.

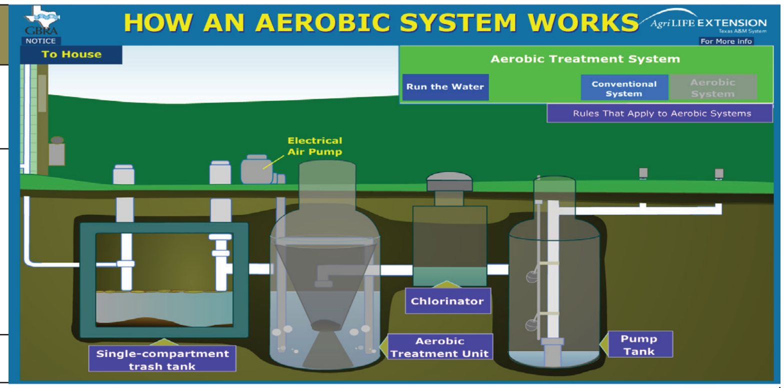
Estimated Load Reduction

As planned, 100 OSSFs will be repaired or replaced throughout the watershed. For those systems that are addressed within 150 yds of a perennial waterway, an annual *E. coli* loading reduction of 5.13 E+14 is expected to be realized instream per system. Systems addressed within 50 yds of an intermittent waterway are expected to yield an annual *E. coli* loading reduction of 2.05 E+14 instream. Collectively, if all 100 planned OSSFs are addressed, the expected annual loading reduction is 3.59 E+16. See Appendix D for calculations.

Effectiveness:	High: Replacement and repair of failing OSSF will yield direct fecal reductions to the waterways and near waterway areas of the watershed
Certainty:	Moderate: The level of funding available to identify, inspect and repair or replace OSSFs is uncertain; however, ANRA is currently undertaking a project to initiate this process and plans to repair or replace up to 31 OSSFs. Actual level of implementation attainable is also uncertain.
Commitment:	Moderate: Watershed stakeholders identified OSSFs as the most likely cause of bacteria impairment to the Attoyac Bayou watershed and noted that this issue should receive implementation priority.
Needs:	High: Funding to identify, inspect and repair/replace OSSFs as well as to develop a watershed database is limited; however, with the expected 50% failure rate of OSSFs in the watershed due to their age and the large number of systems that are within a short distance of the Attoyac Bayou or a flow path leading to it, the need to address this source is great.
*** Potential Funding Sources:**	Inspections, Database, Administration: CWA §319(h) grant program, Texas SEP fund, Local funds Repair/Replacements: CWA §319(h) grant program, Texas SEP fund, OSSF owners

* Funding available from listed programs varies yearly so potential contributions are unknown

Management Recommendation 4



Pollutant Source: OSSFs Education

Problem: Pollutant loading from failing or nonexistent OSSFs

Objectives:

- Provide education and outreach to OSSF owners, installers and maintenance providers on the proper selection, design, installation, operation and maintenance of OSSFs

Location: Entire watershed

Critical Areas: Entire watershed

Goal: To provide needed education and outreach to watershed landowners who own and operate OSSFs, pumping services and maintenance providers enabling them to better manage, repair or replace OSSFs as needed.

Description: The delivery of education and outreach to OSSF owners as well as pumping services and maintenance providers who operate in the watershed will be provided. Through these efforts, information will be provided to these groups that outlines proper OSSF installation, operation, inspection, maintenance and repair procedures. Additionally, information will be provided to interested parties outlining available resources to assist them with OSSF repair or replacements.

Implementation Strategies

Participation	Recommended Strategies	Period	Capital Costs
AgriLife Extension	Deliver two education and outreach events: 1) homeowners and landowners 2) installers, maintenance providers, sludge haulers	2015 & 2021	$30,000

Estimated Load Reduction

It is inherently difficult to determine an expected loading reduction based on delivery of an education and outreach program due to uncertainty in the number of program participants and the number of participants that actually implement practices discussed during that program. Therefore, a total expected loading reduction has not been established; however, with the repair or replacement of each OSSF in the watershed, an annual *E. coli* load reduction to the watershed ranging from 2.05 E+14 to 5.13 E+14 is expected for systems within 50 yds of intermittent streams and 150 yds of perennial streams. See Appendix D for calculations.

Effectiveness:	Moderate: Education is the first and most critical step toward ensuring that OSSFs in the watershed are functioning properly.
Certainty:	Low: It is not known how many OSSF owners, pumping services or maintenance providers will attend trainings and how many attendees will apply information learned in the events.
Commitment:	Moderate: AgriLife Extension currently operates an OSSF education, outreach and training program and, with funding provided, can deliver this program in the Attoyac Bayou watershed. Statewide funding for this program has also been sought. ANRA is also providing educational materials to OSSF owners in the watershed through an existing grant.
Needs:	Moderate: Funding to deliver the educational programming in the watershed is needed.
*** Potential Funding Sources:**	Education & Outreach: CWA §319(h) grant program, local funds

* Funding available from listed programs varies yearly so potential contributions are unknown

Related to household OSSF management is OSSFs for hunting camps. Watershed stakeholders estimated that 125 hunting camps exist across the watershed and that most, if not all, of these camps have inadequate or even non-existent OSSFs. While it is understood that hunting camps are only used a small number of days each year, it was considered highly likely that any sewage discharged was not treated at all. Additionally, hunting camps are typically used in the cooler months of the year when moisture conditions in the watershed are typically higher along with the likelihood of discharged bacteria being transported to a nearby water body; however, their use is also intermittent at best and was estimated at 20 days per year. It was also noted that identifying hunting camps will be difficult due to their typically remote nature and that implementation of appropriate OSSFs would benefit from financial assistance availability.

Management Recommendation 5 discusses a recommended management strategy for addressing hunting camps with non-existing OSSFs.

Management Recommendation 5

Pollutant Source: Hunting Camps without OSSFs

Problem: Hunting camps are usually an older building or congregation of travel trailers that are used several days a year. In most cases, these camps do not have proper sewage treatment and disposal devices. As a result, raw sewage is directly discharged to the surface or a nearby drainage.

Objectives:
- Work with landowners and lessors of lands with hunting camps to educate them on proper disposal methods
- Work with landowners to install appropriate sewage treatment facilities at hunting camps

Location: Entire watershed

Critical Areas: Near riparian areas

Goal: To work with landowners with hunting camps on their properties to install sufficient sewage treatment facilities to prevent future discharge of raw sewage to the watershed.

Description: Identify potential locations in the watershed where hunting camps are and where potential direct discharges of untreated effluent are likely. Work with landowners to establish proper wastewater treatment or disposal means.

Implementation Strategies

Participation	Recommendations	Period	Capital Costs
Designated representative	Identify hunting camps throughout the watershed as opportunities present themselves and inspect sewage disposal methods	2015–2025	Included in ID costs from Management Recommendation 3
Designated representative	As needed, work with volunteering landowners to establish appropriate sewage disposal methods for each inspected hunting camp	2015–2025	$5,000 ea.

Estimated Load Reduction

As planned, 10 hunting camps will be identified and have their sewage disposal methods inspected. Should repairs, replacements or installations of new systems be needed, an expected annual *E. coli* loading reduction of 3.03 E+12 will be realized per hunting camp addressed. If 10 hunting camps with non-existent/failing sewage disposal systems are addressed, a collective *E. coli* load reduction of 3.03 E+13 is expected annually. See Appendix D for calculations.

Effectiveness:	High: Establishing a functioning OSSF for hunting camps will reduce *E. coli* loading to the watershed considerably.
Certainty:	Low: Hunting camps are often in very remote locations and identifying them may prove difficult.
Commitment:	Moderate: Similar to repairing and replacing failing OSSFs, this was viewed as a sizable source of *E. coli* loading in the watershed.
Needs:	Moderate: Financial assistance needs are not trivial as costs for installing an appropriate treatment system will likely be several thousand dollars per system. Financial assistance will be needed to defray costs associated with this practice.
*** Potential Funding Sources:**	Inspections: CWA §319(h) grant program, Texas SEP fund, Local funds Repair/Replacements: CWA §319(h) grant program, Texas SEP fund, OSSF owners

* Funding available from listed programs varies yearly so potential contributions are unknown

Chapter 10
Financial Assistance

Successful implementation of the Attoyac WPP, as written, will require substantial fiscal resources. Due to the rural nature of the watershed, substantial local sources of funding do not exist in the watershed. As a result, grant and other external sources of funding will be needed to support implementation efforts. 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 Incentives Program (EQIP). The continued funding support from federal and state governments will provide a large portion of funds needed to implement the WPP. Aside from these programs, other sources of funding do not currently exist to implement the WPP.

Local sources of funds are extremely limited, especially due to the rural nature of the watershed and will consist largely of matching fund required to secure other financial assistance. This lack of local funding support is also partly due to the way the Attoyac Bayou is viewed locally. The water level within some portions of the Attoyac Bayou is generally low and even pools for portions of the year. Also, due to the physical characteristics and water quality of the majority of the Attoyac Bayou, it is generally only used for recreational activities such as hunting and fishing, as well as for watering livestock. As a result, monetary support from local watershed residents is largely limited to landowners who are investing their dollars to support management needs on their respective properties. For the most part, local landowners believe that the Attoyac Bayou is as healthy as it can be; however, many of them do recall a time when the water body maintained a more consistent flow and was perceived to have better water quality.

To implement WPP implementation, grant funds will be solely relied upon for the development of WQMPs and to manage feral hog populations, address failing OSSFs and provide needed education and outreach to landowners and the general public. While grant funds are not sustainable, they are the only source of money identified at this point that can contribute to these WPP implementation areas. Some specific sources of funding that are applicable and available for use in implementing this WPP are briefly described here.

Federal Sources

Farm Bill Programs

The *Agriculture Act of 2014,* also known as the Farm Bill, governs most Federal agriculture-related programs and includes provisions for administrative and funding authorities for programs including but not limited to conservation through land retirement, stewardship of land and water resources and farmland protection. Individual programs falling under the provisions of the Farm Bill are discussed below.

The NRCS administers a number of programs through the Farm Bill that either are, or could be, applicable in the Attoyac Bayou. The NRCS is a federal agency that works hand-in-hand with Texans to improve and protect their soil, water and other natural resources. For decades, private landowners have voluntarily worked with NRCS specialists to prevent erosion, improve water quality and promote sustainable agriculture. The NRCS provides conservation planning and technical assistance to landowners, groups and units of government to develop and implement conservation plans that protect, conserve and enhance their natural resources. When providing assistance, NRCS focuses on the sound use and management of soil, water, air, plant and animal resources. NRCS ensures sustainability, allows for productivity and respects the customers' needs. Conservation planning can make improvements to livestock operations, crop production, soil quality, water quality and pastureland, forestland and wildlife habitats. The NRCS also integrates ecological and economic considerations in order to address private and public concerns.

The NRCS administers numerous Farm Bill Programs authorized by the U.S. Congress that provide financial assistance for many conservation activities:

- Conservation Innovation Grants
- Conservation Stewardship Program
- Environmental Quality Incentives Program
- Regional Conservation Partnership Program
- Agricultural Conservation Easement Program
- Conservation Reserve Program administered by USDA Farm Service Agency

Two of these programs especially applicable in the Attoyac Bayou watershed are the Conservation Stewardship

(CSP) and Environmental Quality Incentives Programs (EQIP). They are described below.

Conservation Stewardship Program (CSP)

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 and improving, maintaining and managing existing conservation activities. CSP is available to private agricultural lands including cropland, grassland, prairie land, improved pasture, rangeland among others and provides equitable access to all producers regardless of operation size, crops produced or geographic location. CSP encourages land stewards to improve their conservation performance by installing and adopting additional activities and improving, maintaining and managing existing activities on agricultural lands. Specific practices may include but are not limited to:

- prescribed grazing
- nutrient management planning
- precision nutrient application
- manure application
- integrated pest management

http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/

Environmental Quality Incentives Program (EQIP)

The **USDA-NRCS** operates this program to provide a voluntary conservation program for farmers and ranchers to address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land. EQIP offers contracts with a maximum term of 10 years, which provide financial and technical assistance to plan and implement prescribed conservation practices. Persons who are engaged in livestock or agricultural production on eligible land may participate in the EQIP program. EQIP activities are carried out according to a plan of operations developed in conjunction with the producer that identifies the appropriate conservation practice or practices to address the resource concerns. The practices are subject to NRCS technical standards adapted for local conditions and are approved by the local SWCD. Table 10.1 includes a list of practices recently implemented in the Attoyac Bayou watershed area during 2009-2013 as well as the amount of funding paid to enrolling producers during the same period.

Local Work Groups provide recommendations to USDA-NRCS on allocating EQIP county base funds and on resource concerns for other USDA Farm Bill programs. Attoyac Bayou stakeholders are encouraged to participate in the Local Work Group to promote the goals of this WPP as compatible with the resource concerns and conservation priorities for EQIP.

www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Table 10.1. NRCS EQIP implementation summary for Nacogdoches, San Augustine and Shelby counties 2009-2013

NRCS EQIP Implementation		Practices Implemented	Units Implemented
		Poultry Incinerator	3 ea.
Year	**Funding Payments**	Poultry Composter	11 ea.
		Poultry Waste Storage Barn	16 ea.
2009	$36,000.00	Poultry Waste Utilization	463 ac
2010	$116,810.00	Grass Planting	640 ac
2011	$349,895.00	Nutrient Management	5,324 ac
2012	$425,299.00	Prescribed Grazing	6,430 ac
2013	$168,058.41	Tree Planting	5,294 ac
		Timber Stand Improvement	30,179 ac
Total	**$1,096,062.41**	Riparian Forest Buffers	143 ac
		Brush Control	1,937 ac
		Fencing	47,852 ft

For information on these and other NRCS programs, contact your local NRCS Service Centers at:

Nacogdoches County: 936-564-5891
Rusk County: 903-657-8221
San Augustine County: 936-275-2374
Shelby County: 936-598-7050

USDA-Rural Development Program

The Rural Development Program offers grants and low interest loans to rural communities under a variety of circumstances to construction, repair or rehabilitation of potable and wastewater systems. Septic system repairs are one possible implementation activity that can be funded under this grant opportunity. Several options for funding include:

- Rural Repair and Rehabilitation Loans and Grants: for making repairs to low income homeowner's dwellings to improve or remove health and safety hazards such as ineffective sewage disposal systems
- Technical Assistance and Training Grants for Rural Waste Systems: grants to non-profit organizations to provide technical assistance and training related to water delivery and waste disposal
- Water and Waste Disposal Direct Loans and Grants: for developing water and waste disposal systems in rural areas and towns with populations less than 10,000

www.rurdev.usda.gov/RD_Grants.html

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

Through its Clean Water Act §319(h) Nonpoint Source Grant Program, EPA provides grant funding to the state to implement NPS pollution reduction projects. In Texas, these funds are administered by TSSWCB and TCEQ. Funds administered by TSSWCB are targeted toward agricultural and silvicultural NPS pollution while TCEQ funds can address all other areas of NPS pollution.

As determined by USEPA, eligible components of WPPs that adequately address the nine key elements of successful watershed based plans (Appendix A) are eligible for implementation funding through this program (USEPA 2008). The types of implementation items that can be implemented through this program include but are not limited to:

- development and delivery of needed educational programs
- implementation of needed water quality monitoring
- providing financial assistance to implement needed management practices such as OSSF repairs or replacements, improved land management practices, water body clean-up events, and others
- development and dissemination of education and outreach materials

tceq.state.tx.us/compliance/monitoring/nps/grants/grant-pgm.html
www.tsswcb.state.tx.us/managementprogram

State Sources

Clean Rivers Program (CRP)

The Texas CRP is administered by **TCEQ** and is a state fee-funded program for surface water quality monitoring, assessment and public outreach. The program provides the opportunity to identify and evaluate water quality issues within each Texas river basin at the local and regional level. Allocations are made to 15 partner agencies (mostly river authorities) across the state for routine monitoring efforts, special studies and outreach efforts. In Attoyac Bayou, ANRA is the designated CRP partner and is committed to continued monitoring of Attoyac Bayou for the near future to aid in assessing water quality conditions and implementation impacts.

www.anra.org/divisions/water_quality/crp/index.html

Clean Water State Revolving Fund

The **TWDB** provides loans at lower than market rates to entities and authorities on projects related to WWTF infrastructure, wastewater recycling and reuse, and NPS pollution control, which could include OSSFs repairs or replacements These loans can have flexible terms and principal forgiveness for qualifying parties. Planning, designing and construction projects are all eligible.

www.twdb.state.tx.us/financial/programs/CWSRF/index.asp

Supplemental Environmental Projects (SEP)

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 to entities (such as Resource Conservation and Development Councils, texasrcd.org/) with pre-approved “umbrella” projects.

tceq.state.tx.us/legal/sep/

Several types of SEP projects exist and include:

Compliance SEPs: local governments (school district, county, municipality, junior college district, river authority, water district or other special district) may be able to offset up to 100% of an assessed penalty by performing an approved SEP project.

www.tceq.texas.gov/legal/sep/local-govt-comp-seps

Custom SEPs: non-profits and governments in a TCEQ enforcement action may be able to develop and perform a custom SEP. These projects focus on environmental remediation and can include: pollution prevention/reduction, environmental or habitat restoration, illegal dump clean up, household hazardous waste collection.

http://www.tceq.texas.gov/legal/sep/custom-seps

Pre-Approved SEPs: contributions to existing statewide programs can be made in lieu of fines or penalties. Statewide programs relative to water quality that could be contributed to and potentially held locally include:

> The Texas Association of Resource Conservation & Development (RC&D) Areas has four pre-approved statewide projects that will improve watershed health by removing or preventing pollutants from entering the watershed. These are tire collections and clean-ups, illegal dump site clean-ups, household hazardous waste collection events and OSSF repair or replacements for low-income households. Pineywoods RC&D is based in Nacogdoches and has administered SEP programs.
> www.pineywoodsrcd.org/

Water Quality Management Plan Program (WQMP)

WQMPs are property-specific plans that prescribe management practices that, when implemented, will improve the quality of land and water on the property. Through **TSSWCB** and the local **SWCD**, technical assistance is provided to develop plans to meet both producer and state goals. Once developed, TSSWCB may be able to provide financial assistance for implementing a portion of these practices. To date, TSSWCB has certified 112 WQMPs in the watershed that are focused primarily on poultry production operations; however, these plans also implement prescribed grazing (7,104 ac), filter strips (1,336 ac) and upland wildlife habitat (5,111 ac) that improve grazing and wildlife habitat resource utilization.

In fiscal year 2013, the Nacogdoches County SWCD received $45,000 in financial assistance funds and Shelby County SWCD received $50,000. Rusk County and Piney Woods SWCD (San Augustine and Sabine counties) did not receive any funds from the state. In fiscal year 2014, the financial assistance allocations from the state to individual SWCDs changed. Now state resources can be allocated to priority areas such as the Attoyac Bayou watershed or can be allocated to individual districts. Additionally, requests for financial assistance through WQMPs now go through a ranking process to determine which plans receive financial assistance priority. More details can be found at the web address below or by contacting your local SWCD office.

www.tsswcb.texas.gov/en/wqmp

Other Sources

Numerous private foundations, non-profit organizations, land trusts and individuals also represent potential sources of funding that can be used for implementing some aspects of WPPs. Each entity has its own criteria that must be met to receive funding, and these criteria should be explored before applying. Entities that may have funding available for use in the Attoyac Bayou watershed include but are not limited to:

- Dixon Water Foundation: provides grants to non-profit organizations that support watershed health through sustainable land management
- Meadows Foundation: provides grants to non-profit organizations engaged in promoting land conservation practices to maintain water quality and conserve water on private lands
- Texas Agricultural Land Trust: provides funding to establish conservation easements that protect enrolled lands from future development

In-kind Services

In-kind services are not grant dollars or other monies received directly but are instead local resources that can be used to meet a 'matching funds requirement' of some funding programs. In-kind services or monies can be anything from an employee's time to equipment usage, facility uses or event other available funds. These can be provided by individuals, local entities and governments, non-profit organizations, universities or businesses. Use of these resources is a great way to leverage additional resources for the betterment of the watershed.

Watershed Central Wiki

EPA hosts a website where watershed managers can post information about their efforts called the "Watershed Central Wiki." This site is filled with information about watershed planning efforts around the United States and includes information on some available funding sources.

https://wiki.epa.gov/watershed2/index.php/Category:Tools_for_Identifying_Technical_and_Financial_Assistance

Chapter 11
Education and Outreach

An essential element in implementation of this WPP is an effective education and outreach campaign. Long-term commitments from citizens and landowners are needed to accomplish comprehensive improvements in the Attoyac Bayou 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.

The Watershed Coordinator

The role of the Watershed Coordinator is an important one that is at the heart of WPP development and implementation. The Watershed Coordinator leads efforts to establish and maintain working partnerships watershed stakeholders and serves as a single point of contact for all things related to the development of the WPP, WPP implementation and the WPP itself. Mr. Anthony Castilaw of CES in Nacogdoches, Texas has filled this role.

The future role of the Watershed Coordinator is perhaps the most important as he will be tasked with maintaining stakeholder support in the years to come; identifying and securing needed funds to implement pieces of the WPP; coordinating and organizing efforts to implement portions of the WPP; tracking the success of WPP information; reporting implementation outcomes; and working to effectively implement adaptive management into the long-term WPP implementation process. Simply put, the Watershed Coordinator is the catalyst who keeps WPP implementation on track.

Initial Efforts

Partnership Website

The Texas Water Resources Institute (TWRI) developed and hosts a website for the Attoyac Bayou Watershed Partnership. This site is home to information about the project, the watershed, publications and presentations about the project, upcoming meeting notices and news releases. The WPP can also be downloaded from the Attoyac Bayou website and links to project partners are provided on the website as well.

http://attoyac.tamu.edu/

News Releases

AgriLife Extension, TFS and TWRI have developed and distributed news releases to local media outlets during the development of this WPP. Also, the *Daily Sentinel* in Nacogdoches has regularly ran the stories about upcoming meetings. Additionally, the release is delivered electronically via AgriLife Today. Meeting announcements were also e-mailed and/or mailed directly to stakeholders to keep them informed of upcoming project activities.

Public Meetings

Throughout the course of the WPP development process, stakeholder engagement has been critical. Since July 2010, 12 meetings and educational events have been held. In total, 386 watershed stakeholders attended these meetings. These meetings provided attendees with information about the findings of the monitoring project and ushered them through the WPP development process. Through these meetings, educational information on practices that landowners could begin implementing to improve watershed health and water quality while enhancing the operation of their ranch was conveyed as well.

In addition to the meetings mentioned above, contact was made with each of the SWCDs in the watershed. SWCD board members attended many of stakeholder meetings and were updated throughout the development of the Attoyac Bayou WPP.

Texas Watershed Steward Program

AgriLife Extension delivered *Texas Watershed Steward* programs in September 2010 and February 2014 at SFASU and the Nacogdoches County AgriLife Extension office in Nacogdoches with 39 and 55 attendees, respectively. This program is a partnership between AgriLife Extension and TSSWCB to provide science-based, watershed education to help citizens identify and take action to address local water quality impairments. CWA §319(h) grants from TSSWCB and EPA to AgriLife Extension support the statewide implementation of the Texas Watershed Steward Program. These one-day workshops allowed participants to learn about the nature and function of watersheds, water quality impairments and watershed protection strategies to minimize NPS pollution. In general, participants' knowledge is increased by 38% through this course, roughly 15 to 25% intend to increase their involvement in water resource management, planning and restoration, and greater than 72% indicate that they intend to implement improved management practices so that they can be better stewards of their watersheds.

Stakeholders Engaged

Throughout the development of the WPP, a diverse group of watershed stakeholders were actively engaged. Partnership members included individuals, industry representatives, local government and agency personnel. Table 11.1 lists the stakeholder groups or industries/entities represented in the partnership and actively engaged in WPP development. Collectively, stakeholders were continually engaged through the project website, news releases, direct e-mails and personal conversations throughout the course of the project.

Table 11.1. Attoyac Bayou Watershed Partnership stakeholder group representation

Stakeholder Group/Entity/Industry
Private Landowners/Agricultural Producers
Forestry Industry
Oil & Gas Industry
Recreational Users
Poultry Industry
Local Government (Commissioners, Judges, Health Department, River Authority, Groundwater Conservation District, SWCD Board Members)
State Agencies (Extension, TFS, TCEQ, TSSWCB)
Federal Agencies (NRCS, USACE, USFWS, USFS)

Future Stakeholder Engagement

Watershed stakeholders will continue to be engaged throughout and following the transition of efforts from plan development to implementation. The Watershed Coordinator will play a critical role in this transition by continuing to organize and host periodic public meetings and needed educational events and by meeting with focused groups of stakeholders to seek out 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, direct e-mails and the project website will be primary tools used to communicate with watershed stakeholders and keep them engaged in the implementation process. These resources will be developed to update readers periodically on implementation progress; provide information on new implementation opportunities, available technical or financial assistance; and other items of interest related to the WPP effort. Water quality and the continued need to meet water quality standards will also remain a constant in materials developed.

Specific items that are needed and will be delivered in or near the watershed in the near future are described in brief detail below.

Educational Programs and Field Days

Educational programming will be a critical part of the WPP implementation process. Multiple programs geared to provide information on various sources of potential pollutants and feasible management strategies will be delivered in and near the Attoyac Bayou watershed and advertised to watershed stakeholders. Each program is focused on describing the connection between the particular pollutant source or source category and water quality, includes information on how the source can be managed, how implementing actions discussed will help improve and ultimately achieve water quality standards as well as long-term management and maintenance requirements. As implementation and data collection continues, the adaptive management process will be used to modify this schedule and respective educational needs as appropriate. Delivery of all programs will be coordinated with local AgriLife Extension county agents.

Practice Implementation Field Days

Watershed partnership members stressed the importance of holding field days to enhance adoption of watershed management practices. Field days provide an excellent teaching atmosphere as they allow participants to observe installed practices first hand and visit with producers about their experiences with the practice and the impacts it has had on their operation. This hands-on experience greatly enhances the likelihood for practice adoption. Field days also showcase implementation measures and their relation to water quality. Likely field days will cover topics such as grazing management, feral hog management and various forestry management topics.

Lone Star Healthy Streams Workshop (Grazing Cattle component)

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver the *Lone Star Healthy Streams* curriculum. This program is geared to expand knowledge of how to improve grazing lands while reducing NPS pollution. This statewide program promotes the adoption of BMPs that are proven to effectively reduce bacterial contamination of streams and provides educational support for the development of WQMPs by illustrating to program participants the benefits of many practices available for inclusion in a WQMP. The goal is to deliver this program in the watershed once every five years or as needed. Information on this program can be found online at: lshs.tamu.edu.

Feral Hog Management Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver periodic feral hog management workshops. Workshops will discuss the negative impacts of feral hogs, effective control methods and resources to help them control these pests. Workshop frequency will be approximately every three years unless there are significant changes in available means and methods to control feral hogs. Feral hog management education is also incorporated into the *Lone Star Healthy Streams* program and, as such, is an appropriate delivery mechanism for this programming. Information on this program can be found online at: lshs.tamu.edu.

Nutrient Management Workshops

Delivery of nutrient management material will aid producers in better using available nutrients, maximizing their profit margins and promoting improved water quality. The Watershed Coordinator will coordinate with appropriate AgriLife Extension and Research personnel to schedule and deliver this information to watershed stakeholders. An initial workshop focused specifically to Attoyac Bayou watershed will be held in the first few years of WPP implementation and will be followed by subsequent workshops held in and around the watershed on an as needed basis. These events will be advertised to watershed stakeholders through newsletters, news releases meetings and the project website as appropriate.

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 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 and will likely deliver this training for the first time in 2015 or 2016 pending funding availability. Based on needs identified early during WPP implementation and during the first OSSF training, additional trainings will be scheduled accordingly.

Online training modules that provide an overview of OSSFs, how they operate and required maintenance to sustain proper function and extend system life will be made available 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. AgriLife Extension also hosts the ossf.tamu.edu website, which contains numerous educational resources that are available free of charge

OSSF Installer and Maintenance Provider Workshop

Similar to workshops for OSSF owners, workshops focusing on more technical content for OSSF installers or maintenance providers will be provided as well. This workshop will provide them with continuing education units they need to maintain their licenses and will inform them of changes to OSSF laws, rules and regulations. Proper inspection, planning, sizing, installation and maintenance techniques are covered. Online resources available at AgriLife Extension's ossf.tamu.edu website cover this information as well.

Texas Well Owner Network Training

Private water wells provide a source of water to many Texas residents. The *Texas Well Owner Network* program provides needed education and outreach regarding 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 and provide useful information to well owners that will benefit them in better managing their water supplies. The Watershed Coordinator is currently coordinating with AgriLife Extension personnel to deliver this program in the Attoyac Bayou 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, their benefits and BMPs that can be used 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. TWRI will deliver this program in the Attoyac Bayou watershed in the near future and is currently working to schedule an event for the spring/summer of 2014.

Wildlife Management Workshops

Wildlife have a significant impact on the Attoyac Bayou watershed in numerous ways, 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 Attoyac Bayou watershed. With the variety of wildlife species prevalent in the Attoyac Bayou watershed, workshops focused on at least one game species are anticipated to be delivered regionally every other year. Wildlife management workshops will be advertised through newsletters, news releases, the project website and other avenues as appropriate.

Additionally, AgriLife Extension Wildlife and Fisheries Department and the Texas Wildlife Association maintain collections of wildlife management webinars for numerous species available for free online at http://wildlife.tamu.edu/publications/webinars/ and http://www.texas-wildlife.org/resources/webcasts/category/webinars/

Public Meetings

Continuing periodic public stakeholder meetings will serve several major roles of WPP implementation. Public meetings will provide a platform for the Watershed Coordinator and project personnel as appropriate to provide pertinent 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 effectively 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 largely be accomplished by reviewing 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 updates as appropriate. It is anticipated that public meetings will be held on a semi-annual basis but will largely be scheduled based on need.

Newsletters and New Releases

Newsletters for the Attoyac Bayou Watershed Partnership will be developed and will be sent as needed (likely semi-annually) directly to actively engaged stakeholders. 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 practice 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.

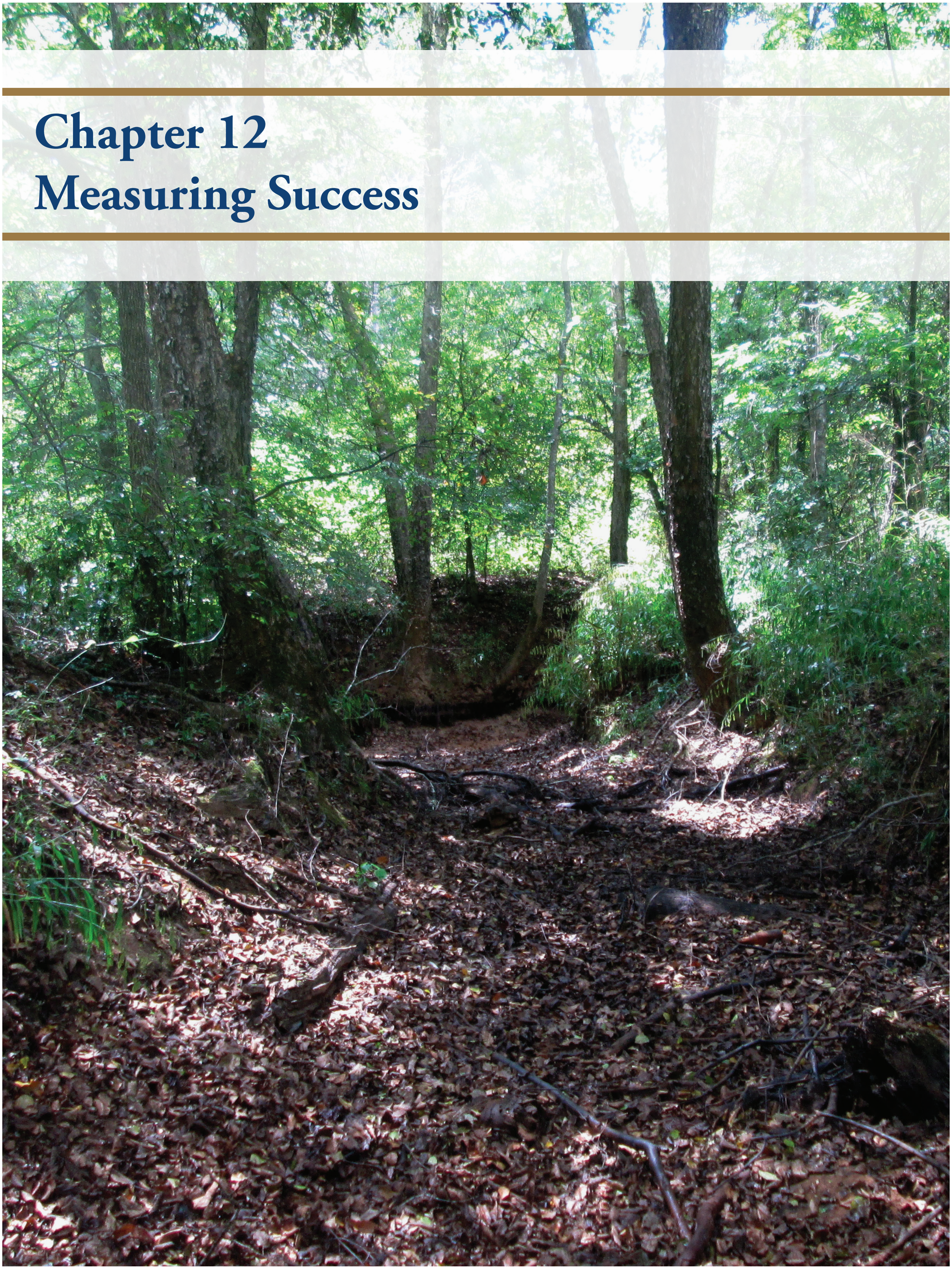
Volunteer Water Quality Monitoring Program

The Texas Stream Team (TST) is a volunteer water quality monitoring program that partners with local entities to train citizens as certified water quality monitors. Volunteers are provided needed training and assisted in identifying monitoring sites. Local entities can partner with TST to train, equip and provide support to citizen monitors across the state. ANRA has partnered with TST and provides monitoring support throughout the Neches River Basin. Through this effort, volunteers not only learn more about water quality and its impacts, but are also able to collect useful data to support WPP implementation. TST also has several educational curricula for grades 3 through 12 that meet a number of the Texas Essential Knowledge and Skills in aquatic science, biology, chemistry, environmental systems and math.

Roadway Signage

Signs on roadways are commonly used to inform drivers of pertinent information regarding their surroundings. From a watershed management perspective, signs have been installed denoting watershed boundaries, environmentally sensitive areas or laws regarding environmental protection. In the Attoyac Bayou watershed, the illegal dumping of household waste was not found to be a major problem, but it has been mentioned as a problem of concern by local stakeholders. Not only does this dumping create an eye sore, it encourages additional dumping, disturbs the natural stream environment, can cause adverse water quality conditions and is illegal. In 2011, House Bill 451 created the Don't Mess with Texas Water program, administered by TCEQ. This program enables local governments to work with TCEQ to place roadway signage on major highway water crossings, which displays a toll-free hotline to report illegal dumping. Calls to this hotline are routed to the proper authorities where illegal activities can be addressed. These signs will help to inform the public that dumping into the water body is a punishable offense and also has adverse effects on instream water quality.

Chapter 12
Measuring Success



Measuring the impacts of implementing a WPP on instream water quality is a critical, yet inherently complicated, process due to ever changing conditions in the watershed. Planned water quality monitoring at critical locations will provide needed data to document water quality changes over time and provide data needed to document progress toward achieving water quality goals for the watershed. While improvements in water quality are the preferred measure of success, documenting implementation accomplishments can also be used to measure implementation success. Combined, data on water quality collected over time and implementation accomplishments will facilitate adaptive management by illustrating what recommended measures are working and which measures need modifications.

Water Quality Targets

The primary goal of the Attoyac Bayou Watershed Partnership and the WPP is to restore measured instream *E. coli* levels to a point where they are meeting the state's designated water quality standards. Consistent with this goal, Table 12.1 outlines incremental *E. coli* targets that should be realized if WPP implementation proceeds according to schedule. The ultimate water quality goals also include a 10% margin of safety to account for variability in water quality measurements; however, water quality meeting the state's designated *E. coli* standard will be considered as successful restoration.

As discussed in Chapter 5, monitoring stations 10636, 15253 and 16076 were chosen as index sites for the watershed due to their historic data sets and plans to continue monitoring these stations in the future through ANRA's CRP monitoring. Through this program, these stations will be sampled four times per year and will collect conventional and bacterial data as well as stream flow. While more data would be great, this data serves as a good basis for assessing long-term changes in water quality. Additionally, this data is what TCEQ uses to determine if the water body is meeting its designated water quality standards.

Additional Data Collection Needs

Additional water quality data collection in the watershed is really needed to properly evaluate WPP implementation impacts. The first approach that would provide useful data is increasing the frequency of currently employed CRP data collection at watershed index sites to monthly or bi-weekly. This would improve data availability and better illustrate variations in water quality within the year. This data would also enhance trend analyses done on the collected data and make their results more representative of what is actually occurring in the water body. ANRA's current monitoring capabilities are at their maximum now and additional resources are needed to expand their monitoring program beyond its current levels.

Table 12.1. *E. coli* targets for water quality index stations on the Attoyac Bayou

Implementation Year*	*E. coli* Concentration (cfu/100 mL)		
	Attoyac Bayou at SH 21 (Station 10636)	Attoyac Bayou at SH 7 (Station 15253)	Attoyac Bayou at US 59 (Station 16076)
2012 303(d) List	236	234	288
Year 3	195	194	230
Year 6	154	153	171
Year 10	113	113	113

* For implementation purposes, the implementation year calculator begins upon USEPA approval of the WPP (anticipated by the start of calendar year 2015)

A second enhanced monitoring approach that would produce useful data is one that is focused in areas of high WPP implementation. Changes in water quality measured instream are difficult to identify regardless of the number of samples collected. A more focused sampling approach that documents pollutant loading reductions at smaller scales will illustrate incremental water quality improvements produced by WPP implementation. Potential monitoring approaches that could be used to capture this data include edge of field, edge of farm, small watershed (pre/post implementation or upstream/downstream of implementation) or paired watershed sampling approaches. Regardless of the specific sampling regime, monitoring should focus on collecting storm runoff samples where perennial flowing waters are not present. Where perennial flowing waters are monitored, near-continuous automated sampling is preferred as it will allow long-term loading estimates to be calculated. If that is not feasible, an intensive grab-sampling approach can also be used. While this data will not directly translate to measured water quality in the Attoyac Bayou, it will illustrate differences in the *E. coli* load being delivered from small catchments to the Attoyac Bayou. The most appropriate approach depends on the specific sampling goal and will be determined as needed. Both ANRA and SFAU WET Center have experience conducting this type of monitoring and can conduct needed monitoring if funding is available.

Along these lines, ANRA will begin a special monitoring project in September 2014 as part of the Clean Water Act Section 319(h) grant project entitled "Lake Sam Rayburn OSSF Program Support and Attoyac Bayou OSSF Remediation" and funded by TCEQ. The goal of this project is to evaluate the impacts of repairing or replacing OSSFs on instream water quality. Monthly water quality monitoring will be conducted at Stations 16083, 16084, 20841, 20843 and 20844 (Figures 5.2 & 5.3) for a two-year time frame. Data collected will include all parameters discussed and described in the 'Water Quality Monitoring Data and Results' section of Chapter 7 as well as chlorides, sulfates and TDS. These three additional parameters are commonly associated with human wastewater effluent, thus are pertinent to include.

Volunteer monitoring through the TST program with help of local partners such as ANRA can also provide useful water quality information. Although not used for regulatory purposes, these data are quite informative and can illustrate changes in water quality over time or even WPP implementation effectiveness. Individuals, science classes at local schools such as Chireo, Garrison or Martinsville ISDs, Master Gardeners, Master Naturalists and others can all collect and analyze samples to provide valuable information to support the implementation effort. Funding will be sought to purchase kits and place throughout the watershed.

Data Review

The partnership will use two methods to evaluate WPP implementation's impacts on instream water quality. The first is to use TCEQ's statewide biennial water quality assessment approach, which uses a moving seven-year geometric mean of *E. coli* data collected through the state's CRP program. This assessment is published in the *Texas Integrated Report and 303(d) List,* which is made readily available online at www.tceq.texas.gov. It should be noted that this list incorporates a two-year lag in data reporting. For example, the 2012 303(d) List considers water quality data collected between November 1, 2003 and October 31, 2010. As a result, the 2018 303(d) List is likely to be the first list inclusive of water quality data collected during WPP implementation. ANRA is the CRP partner for the watershed and collects, manages and delivers this data to TCEQ, and it may be able to provide more recent data than is available in TCEQ's biennial assessments when needed.

The second approach will be to participate in ANRA's annual CRP meeting held in or near the watershed. During this meeting, water quality data collected in the Attoyac Bayou is presented and discussed. This data will be compared to established water quality targets and will be useful in gauging implementation success and the need for adaptive management within the WPP.

Should water quality data not meet the target values presented in Table 12.1 or considerable progress be made in meeting those values, the partnership will discuss the deficiency and the potential need to adjust the WPP and its management recommendations. This discussion should include changes in water quality as compared to implementation completed at a minimum. Other factors that may have influenced water quality should also be discussed.

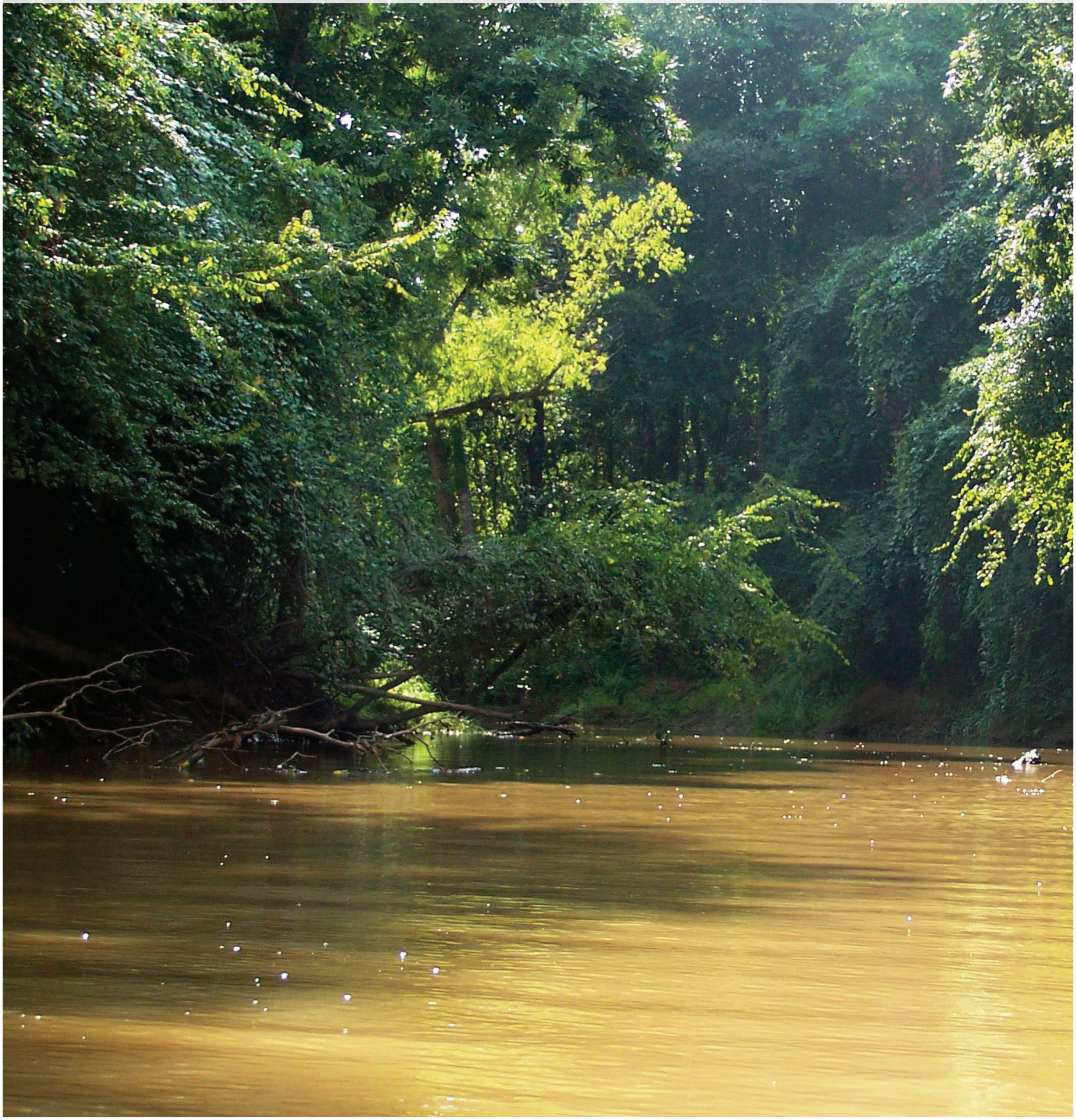
Interim Measurable Milestones

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 implementing management measures as scheduled. They are simply goals of when a specific practice or measure is targeted for implementation and may be completed sooner or slower than planned in some cases. As needed, adaptive management will be employed to reevaluate the goal and modify plans as needed. At a minimum, implementation progress should be evaluated five years following the start of implementation to document progress and make adjustments to the plan as needed. This will allow ample time for funding to be secured, implementation to progress and data to be collected that will support needed adaptations to the recommended management implementation strategy.

Milestones are separated into short-, mid- and long-term increments. Short-term milestones should be accomplished quickly using existing or available resources during the first three years of WPP implementation. Mid-term milestones take more time to complete and will likely need additional funds secured before they can be undertaken and completed. This is likely to occur within four to six years of beginning to implement the WPP. Long-term milestones are management measures that will take longer to plan, acquire funds and implement. Significant time will be needed to secure funding and begin the implementation process of these measures. This group of milestones will begin to be implemented seven years after WPP implementation has begun.

Interim measurable milestones are identified in the implementation schedule presented in Tables 13.1, 13.2 and 13.3 in Chapter 13.

Chapter 13
Plan Implementation



WPP implementation focuses on two key areas: actual management measure implementation and education and outreach programming. Each of these areas has been discussed previously in detail. This chapter provides further scheduling, financial needs, technical assistance needs and implementation goals. The implementation schedule presented spans 10 years and includes a brief description of the practice, interim implementation milestones, expected funding needs to implement the practice and the party responsible of implementing the described practice.

Technical Assistance Needs

Successful WPP implementation will require technical assistance and support from a number of sources. Many of the management recommendations will require expertise in the form of planning or designing a specific practice, delivering education on selected topics, organizing implementation efforts, tracking implementation progress and securing financial resources to carry out planned implementation.

Agricultural Management Measures

Managing agricultural activities to reduce potential bacteria loading will be done primarily through the TSSWCB's WQMP program and will focus on developing property-specific management plans that aim to improve the quality of water produced from that property. Local SWCDs and NRCS personnel provide critical support and lead the development of each WQMP. These same personnel can also assist in identifying and securing financial assistance for volunteering producers as well.

AgriLife Extension can and will also provide technical assistance to watershed landowners regarding agricultural management. Local county Extension agents maintain close connections to watershed landowners and often deliver needed educational programming. Extension specialists can also be brought in as needed to provide additional education to watershed residents. Similarly, the TFS provides educational information related to forest product production.

Feral Hog and Wildlife Management Measures

Education delivery regarding feral hogs is viewed as a critical tool for managing this invasive species. Information regarding feral hog biology, habits, control techniques and options for disposal are useful to anyone attempting to remove feral hogs from their land. AgriLife Extension commonly delivers programs highlighting these topics around the state and will be a critical source of technical expertise for the Attoyac Bayou as well.

Wildlife management is also of interest to watershed landowners. Animal behavior, biology, habitat management and harvest techniques are subjects that will benefit landowners. AgriLife Extension as well as TPWD personnel have technical expertise in these areas on a number of wildlife species and can deliver educational programming as needed.

OSSF Management Measures

Managing OSSFs can be a complicated process that actually starts before a system is installed. Often, owners and operators of these systems do not clearly understand the functional principles of OSSFs, and this lack of understanding could lead to system malfunction or failure. Routinely making information available to watershed residents and delivering focused programs locally is one effective way to improve knowledge about OSSFs. AgriLife Extension routinely delivers this information and will provide this critical source of technical expertise.

Identifying and inspecting existing OSSFs in the watershed and creating database of those systems will be a large undertaking. At a minimum, this will require one full time person and could possibly require more. Existing personnel in the counties or at ANRA tasked with OSSF management have a full workload now and would require assistance to complete these tasks.

Table 13.1. Management recommendations, implementation schedule, responsible party and cost estimates

Management Measure	Responsible Party	Planned Implementation Goal			Unit Cost	Total Cost
		Year 0–3	Year 4–6	Year 7–10		
Agricultural Management Measures						
Water Quality Management Plans	SWCDs/ Landowner	20	30	50	$15,000 ea.	$1,500,000
Feral Hog Management Measures						
Fencing Deer Feeders	Landowners/ Lessees	As Many As Possible			$200 ea.	N/A*
Voluntary Feral Hog Removal	Landowners/ Lessees	1,015 hogs/yr.			N/A*	N/A*
Promote Online Tracking Tool Use	County/ Extension	Continually			$1,000/yr.	$10,000
OSSF Management Measures						
Existing OSSF ID and Inspection	County/ ANRA	236	300	---	$40,000/yr.	$240,000
Develop Watershed OSSF Database	County/ ANRA	1		---	$50,000	$50,000
Administer OSSF Repair/Replace Program	County/ ANRA	3	3	4	$15,000/yr.	$150,000
Repair/Replace OSSFs as funding allows	OSSF Owners	20	30	50	$5,000 – $10,000 ea.	$500,000 – $1,000,000
ID and Inspect Hunting Camp OSSFs	County/ ANRA	As Many As Possible			Included in Existing OSSF ID Costs Above	
Install/Repair Hunting Camp OSSFs	Hunting Camp Owners	3	3	4	$5,000	$50,000
Total Management Recommendation Cost						**$3,000,000**

* Costs will be incurred by the landowner and will vary depending on specific methods and actual number implemented

Table 13.2. Education and outreach implementation schedule, responsible party and cost estimates

Education & Outreach Activity	Responsible Party	Planned Delivery Goal			Unit Cost	Total Cost
		Year 0–3	Year 4–6	Year 7–10		
Agricultural Programming						
Lone Star Healthy Streams Workshops	WS Coord./ Extension	1	---	1	N/A*	N/A*
Management Practice Field Days	WS Coord./ Extension/ SWCDs	3	3	4	$1,000 ea.	$10,000
Nutrient Management Workshop	WS Coord./ Extension/ NRCS	1	---	1	N/A*	N/A*
Wildlife and Feral Animal Programming						
Feral Hog Management	WS Coord./ Extension	1	1	1	$7,500 ea.	$22,500
Wildlife Management	WS Coord./ Extension/ TPWD	1	1	1	$7,500 ea.	$22,500
Habitat Management Programming						
Riparian and Stream Ecosystem Management	WS Coord./ TWRI	1	1	1	N/A*	N/A*
Domestic Management Programming						
OSSF O&M Workshops	WS Coord./ Extension	1	0	1	$7,500 ea.	$15,000
OSSF Installer & Maintenance Provider Workshop	WS Coord./ Extension	1	0	1	$7,500 ea.	$15,000
Texas Well Owner Network	WS Coord./ Extension	1	0	0	N/A*	N/A*
General Education & Outreach						
Partnership Meetings	WS Coord.	Annually or As Needed			$250 ea.	$2,500
Partnership Newsletter	WS Coord.	Annually or As Needed			$250 ea.	$2,500
Don't Mess with Texas Water Signs	County/ ANRA	---	5	---	TBD	TBD
Total Education and Outreach Programming Cost						**$90,000**

* Funding currently provided through existing programs

Table 13.3. Coordination and monitoring implementation schedule, responsible party and cost estimates

Education & Outreach Activity	Responsible Party	Planned Delivery Goal			Unit Cost	Total Cost
		Year 0–3	Year 4–6	Year 7–10		
Watershed Coordination						
Watershed Coordinator*		3	3	4	$75,000/yr.	$750,000
Water Quality Monitoring						
CRP Monitoring: 3 stations, quarterly	ANRA	3	3	4	N/A**	N/A**
Volunteer Monitoring Kits	TBD	5	0	0	$750	$3,750
Implementation Effectiveness Monitoring	ANRA, SFAU WET, TCEQ?	As Needed and Appropriate			Variable $15,000 – $100,000/yr.	Variable $15,000 – $100,000/yr.
Total Coordination and Monitoring Cost* **						**$753,750**

* Cost estimate includes all resources needed by the watershed coordinator (e.g.: compensation, travel, supplies, etc.)
** Funding currently provided through existing programs
***Total costs do not include effectiveness monitoring costs as they will vary widely depending upon the specific monitoring approach needed

Implementation Coordination

WPP implementation has many moving parts and is best served by a central driving force, typically a Watershed Coordinator. The Watershed Coordinator is tasked with ensuring that efforts to implement the WPP as written are underway and are being accomplished. This includes working with responsible parties to secure implementation funds, schedule implementation, document implementation and report on implementation progress. The Watershed Coordinator is also a critical driving force in the delivery of education and outreach throughout the watershed and in relating WPP implementation to water quality. Simply put, the Watershed Coordinator is at the helm of WPP implementation and is absolutely critical to a WPP's success.

If adaptive management is needed, the Watershed Coordinator facilitates needed interactions with watershed stakeholder to complete the process.

Water Quality Monitoring

Continued water quality monitoring is a must for documenting water quality changes in relation to WPP implementation. Effective monitoring requires experience and proper equipment to ensure that data collection is of sufficient quality for assessment purposes. ANRA currently operates the CRP program in the watershed and has this needed expertise and equipment. This effort is also funded through TCEQ but has been faced with budget cuts in recent years.

Any supplemental monitoring needed such as monitoring that occurs at a higher frequency, at more locations or targeted implementation effectiveness monitoring will require additional resources. Depending on monitoring specifics, ANRA, SFASU WET Center or TCEQ personnel may be able to perform this monitoring if sufficient funding is available.

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APPENDIX A: ELEMENTS OF SUCCESSFUL WPPs

USEPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* describes the 'Element of Successful Watershed Plans' that must be sufficiently included in the WPP for it to be eligible for implementation funding through the Clean Water Act Section 319(h) grant funding program (2008). These elements do not preclude additional information from being included in a plan.

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 the water-based plan (and to achieve any other watershed goals identified in the WPP). 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 and other sources.

See Chapter 6; Chapter 7 pages 42-49; Chapter 9

B. Expected Load Reductions

An estimate of the load reductions expected for the management measures proposed as part of the watershed plan. Percent reductions can be used in conjunction with a current or known load.

See Chapter 9; Appendix D

C. Proposed Management Measures

A description of the management measures that will need to be implemented to achieve the estimated load reductions and an identification (using a map or description) of the critical areas in which those measures will be needed to implement the plan. These 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 9

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 9, 10 & 13

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 Chapter 11

F. Schedule

A schedule for implementing the NPS management measures identified in the plan that is reasonable expeditious. Specific dates are generally not required.

See Chapter 13

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 13

H. Load Reduction Evaluation Criteria

A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether 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 12

I. Monitoring Component

A monitoring component to evaluate the effectiveness of the implementation efforts over time, 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 12

APPENDIX B: LAND USE AND LAND COVER ASSESSMENT

The LU/LC assessment for the Attoyac Bayou watershed was created and analyzed by CES using Environmental Systems Research Institute's ArcGIS 9.3 & 10.0 with Spatial Analyst Extension. CES used a variety of sources in order to delineate the individual LU/LC classes found throughout the watershed. The primary method used to delineate these classes was to hand-digitize, often referred to as "heads-up digitizing," individual areas within the watershed exhibiting a significantly different cover types or land use from the surrounding areas. Each area was classified according to the different LU/LC classes presented in Table 3.1. Delineated areas were generally two ac in size and larger. Areas exhibiting a separate LU/LC class but smaller than two ac in size were considered a minor component to a larger LU/LC class and not delineated. Imagery used for the delineation of LU/LC classes consisted of 2008, leaf-off, one-m, National Agricultural Imagery Program county mosaics for each county within the watershed. To ensure the accuracy and completeness of the LU/LC data, CES personnel conducted initial field surveys to characterize dominant LU/LC types within the watershed and to relate on-the-ground observations with aerial photographic signatures associated with different LU/LC classes. These classifications were verified utilizing 2001 National Land Cover Dataset classifications and ground truthed data thus providing an accurate and up-to-date description of LU/LC in the watershed.

The cover types used were adapted from the National Land Cover Dataset standard land cover definitions that were modified to provide more project specific definitions. The cover type's project specific definitions are listed below.

Open Water (11) – All areas of open water, generally with less than 25% cover of vegetation or soil.

Developed (Open Space) (21) – Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control or aesthetic purposes.

Developed (Low Intensity) (22) – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20–49% of the total cover. These areas most commonly include single-family housing units.

Developed (Medium Intensity) (23) – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50–79% of the total cover. These areas most commonly include single-family housing units.

Developed (High Intensity) (24) – Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80–100% of the total cover.

Barren Land (31) – (Rock/Sand/Clay) – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover and includes transitional areas.

Forested Land (41) – Areas dominated by trees generally greater than 5 m tall and greater than 50% of total vegetation cover.

Pine Plantation (42) – Areas of land dominated by pine trees that have been planted to artificially reforest an area for the purpose of timber production; trees are generally planted in an evenly spaced, systematic manner that is easily distinguishable from native tree stands.

Mixed Forest (43) – Areas dominated by trees generally greater than 5 m tall and greater than 20% but less than 50% of total vegetation cover.

Near Riparian Forested (44) – Areas dominated by trees generally greater than 5 m tall and greater than 50% of total vegetation cover. These areas are found following in near proximity (within 30–60 m) to streams, creeks, and/or rivers.

Rangeland (71) – Areas of unmanaged shrubs, grasses or shrub-grass mixtures.

Pasture/Hay (81) – Areas of grasses, legumes or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

Cultivated Crops (82) – Areas used for the production of annual crops, such as corn, soybeans, vegetables and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

APPENDIX C: BOX PLOT DESCRIPTION

Box and whisker plots were used in Chapter 7 to illustrate the range and distribution of *E. coli* and ammonia data collected from the Attoyac Bayou during this project. Box plots are a simple and effective way to illustrate several key aspects of a complete data set while also allowing visual comparisons to be made between stations. The figure below illustrates what data and summary statistics of the data set are shown in the presented box plots.

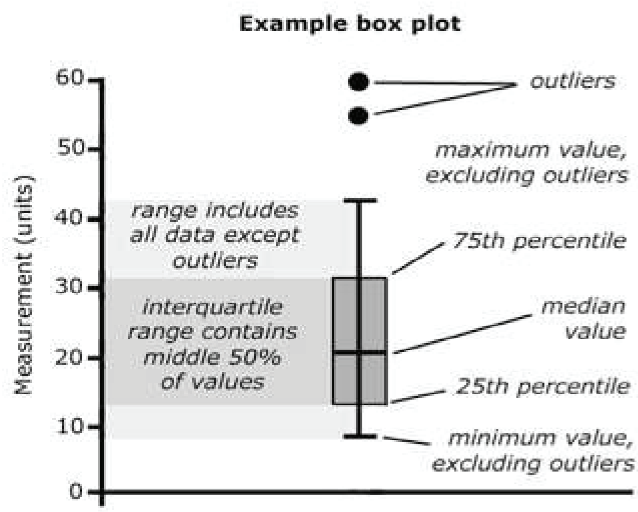

Figure C.1. Example box plot illustrating what components of the plot represent

Outliers: A data point that lies outside of the general pattern of the data set's distribution

75th Percentile: The point in the data set where exactly ¾ of the data lie below that value

Median Value: The midpoint in the data where exactly ½ of the data values lie above and ½ lie below that value

25th Percentile: The point in the data set where exactly ¼ of the data lie below that value

APPENDIX D: MANAGEMENT LOAD REDUCTION CALCULATIONS

Estimates for load reductions are based on the best available information regarding the effectiveness of recommended management as well as the expected number of treatments and expected amount of loading to be addressed by each treatment. Specifics of each location where implementation is completed will ultimately determine the real level of loading reduction achieved once implementation is complete. For estimating expected loading reductions from implementing the WPP, a logical estimation based on generalized characteristics of the watershed and its many uses was employed. These reductions were calculated on a per unit basis and then scaled up to reflect the planned level of implementation included in the plan. This approach allows for simple loading reduction adjustments to occur in the future, should they be needed.

Livestock Management

Watershed stakeholders developed population estimates for cattle across specific to the watershed. USDA NASS data for the four counties partially within the Attoyac Bayou watershed included large areas outside of the watershed and were thought to be an overestimate of actual cattle numbers in the watershed when scaled to the watershed area. The four-county average of NRCS-recommended stocking rates of 10 ac/AU for unmanaged pastures (rangeland), mixed forest and riparian forest and a rate of 3 ac/AU on managed pasture was also considered to be a slight overestimate of cattle in the watershed, especially in light of ongoing drought conditions. Using this information and supplementing it with local knowledge, an average resident cattle population of 23,646 head was estimated for the watershed. Sub-watershed basin population estimates are presented for livestock in Table D.1 and were derived by evenly distributing these animals across appropriate land uses within that sub-watershed. For this project, only managed pasture/hay and rangeland/unmanaged pasture was considered suitable habitat for cattle. Horses were the same except that developed open space was also considered suitable habitat.

Using the SELECT model, potential fecal loading from cattle throughout the watershed was estimated for each sub-basin as well as the entire watershed. The total daily *E. coli* loading potential from cattle across the entire watershed was estimated to be 6.08 E+13 cfu while the annual potential load is estimated at 2.22 E+16 cfu (Borel et al. 2012b). These estimates were made using a daily, per animal *E. coli* loading rate of $2.63*10^9$ cfu; therefore, the daily total *E. coli* production is calculated as:

$$\text{Cattle Load} = \#\ \text{Cattle} *2.3*10^9$$

The daily *E. coli* loading rate used here is somewhat lower that the rate used in other WPPs (Gregory et al. 2012, Prcin et al. 2013). A lower loading rate was chosen as several experts in the beef industry were watershed stakeholders and did not agree with the assumption that average daily manure production rates should be used as the basis for calculating *E. coli* production. Urine and feces make up manure and have starkly different microbial composition. As such, stakeholders felt that the combined weight of feces and urine should not be considered to contain a uniform amount of *E. coli* thus resulting in a lower daily *E. coli* production rate than in other watersheds.

Potential load reductions that can be achieved by implementing practices through the WQMP program will depend specifically on the particular BMP implemented by each individual landowner and the number of livestock in each landowner's operation. BMPs included in previous WQMP programs have been documented to measurably reduce the amount of fecal bacteria loading from cattle and can be employed in the Attoyac Bayou watershed include fencing, filter strips, heavy use area protection, prescribed grazing, shade structures, stream crossings and watering facilities. Fencing, prescribed grazing and water development are the three most likely practices to be implemented in the watershed, but that decision is the individual landowner's.

Table D.1. Sub-watershed land use/land cover acres and population estimates for the Attoyac Bayou watershed

	ACRES														Species Population Estimates by Sub-watershed					
		Developed Land																		
Sub-watershed	Open Water	Open Space	Low Intensity	Medium Intensity	High Intensity	Barren Land	Forest Land	Pine Plantation	Mixed Forest Land	Near Riparian Forest Land	Range / Unmanaged Pasture	Managed Pasture / Hay	Cultivated Cropland	Total Sub-watershed Acres	Cattle	Horses	Deer	Feral Hogs	Hunting Camps	OSSFs
1	686	223	561	60	0	261	11510	4920	207	5198	1881	7569	8	33,084	2518	60	698	939	11	457
2	225	630	319	13	0	54	8257	5831	95	3534	1953	4900	4	25,816	1690	45	545	733	9	328
3	178	475	361	2	0	80	8972	4828	230	2915	1286	5685	0	25,011	1881	45	531	714	9	1086
4	611	485	1232	294	0	175	12734	6409	224	8442	2399	11921	0	44,926	3921	91	936	1259	14	1080
5	352	365	1189	116	4	204	12036	6946	279	4087	3479	6521	0	35,578	2321	64	742	999	12	293
6	147	98	480	61	0	108	6596	3828	60	2089	1769	3480	0	18,717	1231	32	397	534	6	280
7	52	83	258	0	0	27	8590	3533	121	2769	1307	4274	0	21,013	1442	34	456	614	8	459
8	32	132	304	53	0	131	4684	3152	95	2067	1025	2325	14	14,014	809	21	298	402	5	271
9	68	172	341	57	0	168	10880	8457	482	4176	1081	2755	16	28,654	949	24	620	834	12	313
10	77	115	403	16	0	226	8087	6831	183	7294	2442	4965	0	30,638	1750	47	664	894	11	260
11	30	89	323	65	9	48	4889	2479	77	1925	920	3195	0	14,049	1073	25	299	403	5	269
12	13	30	62	0	0	19	3741	1959	169	1795	792	307	0	8,886	160	7	194	261	4	37
13	209	497	785	33	0	46	18294	8718	339	10825	2717	11765	14	54,243	3898	92	1166	1569	19	952
Totals	2,681	3,394	6,618	771	13	1,546	119,270	67,891	2,561	57,116	23,049	69,662	57	354,629	23,643	587	7,547	10,155	125	6,085

These BMPs have been the subject of various research efforts and their estimated bacteria reduction efficiencies have been documented. Table D.2 lists the individual practice, the range of bacteria removal efficiency and the median of the efficiency range as described in the literature. While research conducted in these works was not conducted in the Attoyac Bayou watershed or in Texas in most cases, these studies do illustrate the abilities of these practices to reduce bacteria contributions from livestock. Without watershed-specific BMP efficiency evaluations, the median effectiveness value was assumed to be reasonable and was used to estimate potential load reductions that may be realized through voluntary BMP implementation of each practice.

Table D.2. Livestock BMP bacteria removal efficiencies

Management Practice	*E. coli* Effectiveness			Fecal coliform Effectivness		
	Low	High	Median	Low	High	Median
Fencing [1]	37%	46%	42%	30%	94%	62%
Filter Strips [2]	58%	100%	79%	30%	100%	65%
Heavy Use Area Protection [3]	N/A	N/A	N/A	92%	99%	96%
Prescribed Grazing [4]	66%	72%	69%	42%	96%	69%
Livestock Shade Structures [5]	85%	85%	85%	N/A	N/A	N/A
Stream Crossing [6]	46%	46%	46%	44%	52%	48%
Watering Facility [7]	85%	85%	85%	51%	94%	73%

Cells highlighted in green denote values utilized in loading reduction estimation calculations

[1] Brenner 1996, Cook 1998, Hagedorn et al. 1999, Line 2002, Line 2003, Lombardo et al. 2000, Meals 2001, Meals 2004, Peterson 2011

[2] Cook 1998, Coyne et al. 1995, Fajardo et al. 2001, Goel et al. 2004, Larsen et al. 1994, Lewis et al. 2010, Mankin & Okoren 2003, Peterson 2011, Roodsari et al. 2005, Stuntebeck & Bannerman 1998, Sullivan 2007, Tate 2006, Young 1980

[3] Peterson et al. 2011

[4] Tate et al. 2004, USEPA 2010

[5] Franklin et al. 2009

[6] Inamdar et al. 2002, Meals 2001

[7] Byers et al. 2005, Hagedorn et al. 1999, Sheffield et al. 1997

To calculate potential load reductions for each of the three BMPs most likely to be implemented, a generic equation was developed based upon the number of animal units, average fecal material production rates of cattle, the average *E. coli* content of cattle manure and the selected BMPs' median effectiveness value listed above in Table D.2. This generic form of equation based on animal units was chosen because an accurate estimation of BMP implementation cannot be clearly defined. BMP implementation is strictly voluntary and will vary between properties so no firm number for expected BMP implementation could be established. The number of animal units per operation can also not be determined prior to the actual implementation. As a result, basing the equation on the number of animal units can serve as a starting point for making estimations of potential load reductions that could be realized by implementing each practice.

Daily Potential Load Reduction Expected from Cattle

=# of WQMPs*# of cattle/WQMP*2.63E+9 cfu/day*BMP Effectiveness Rate*Proximity Factor

In this equation, inputs are as follows:

- WQMPs are water quality management plans and are a planning mechanism that incorporates management measure such as prescribed grazing and alternative water sources to address water quality issues.
- 2.63 E+9 = the *E. coli* production in cfu/day per cattle AU used in the SELECT Model
- BMP Effectiveness rate = median of BMP efficiencies as illustrated in Table D.2.
- Proximity Factor = a percentage-based impact factor that accounts for an assumed stream impact factor to be applied based on the location of the management practice (riparian areas = 25% and upland areas = 5%)

Specific load reduction estimates will depend strongly on the number of participating ranchers, specific practices implemented and the number of cattle that will be impacted by a specific management practice. Sub-watersheds 1, 3, 4, 6, 7, 9 and 13 are primarily targeted for WQMPs that will improve cattle management. In total, these sub-watersheds are home to an estimated 15,840 head of cattle and encompass 225,648 ac. Using the average farm size from 2007 of 198 ac (Table 4.3), it is estimated that there are 300 cattle operations in these sub-watersheds with approximately 51 head of cattle per farm. A recommendation of developing and implementing 100 WQMPs across these sub-watersheds on properties with riparian access has been made. It is assumed that each WQMP will include watering facilities, prescribed grazing and fencing.

Annual load reduction calculations also assume a number of days per year that the practice will be used by the management target. For the Attoyac Bayou, these were assumed to be:

<u>Prescribed Grazing:</u>	Riparian Pastures:	73 days per year
	Upland Pastures:	292 days per year
<u>Watering Facility:</u>	Riparian Pastures only:	73 days per year
<u>Cross Fencing:</u>	Riparian Pastures:	73 days per year
	Upland Pastures:	292 days per year

Prescribed Grazing Load Reduction Estimate:

<u>Annual Riparian Pasture Grazing Load Reduction</u>

=100 WQMPs* 51 cattle/WQMP*2.63E+9 cfu/day*.69 BMP Effectiveness Rate*0.25 Proximity Factor*73 days/year

Annual Riparian Pasture Prescribed Grazing Load Reduction = 1.69E+14 cfu

<u>Annual Upland Pasture Grazing Load Reduction</u>

=100 WQMPs* 51 cattle/WQMP*2.63E+9 cfu/day*.69 BMP Effectiveness Rate*0.05 Proximity Factor*292 days/year

Annual Riparian Pasture Prescribed Grazing Load Reduction = 1.35E+14 cfu

<u>Total Prescribed Grazing (Riparian + Upland) Load Reduction= 3.04E+14 cfu</u>

Watering Facility Load Reduction Estimate:

<u>*Annual Watering Facility Load Reduction*</u>

=100 WQMPs* 51 cattle/WQMP*2.63E+9 cfu/day*.85 BMP Effectiveness Rate*0.25 Proximity Factor*73 days/year

<u>*Annual Riparian Pasture Prescribed Grazing WQMP Load Reduction = 2.08E+14 cfu*</u>

Cross Fencing Load Reduction Estimate:

<u>*Annual Riparian Area Cross Fencing Load Reduction*</u>
=100 WQMPs* 51 cattle/WQMP*2.63E+9 cfu/day*.42 BMP Effectiveness Rate*0.25 Proximity Factor*73 days/year

Annual Riparian Area Cross Fencing Load Reduction = 1.03E+14 cfu

<u>*Annual Upland Area Cross Fencing Load Reduction*</u>
=100 WQMPs* 51 cattle/WQMP*2.63E+9 cfu/day*.42 BMP Effectiveness Rate*0.25 Proximity Factor *292 days/year

Annual Riparian Area Cross Fencing Load Reduction = 8.22E+13 cfu

<u>***Total Cross Fencing (Riparian + Upland) Load Reduction= 1.85E+14 cfu***</u>

Feral Hog Management

The feral hog population is estimated to be 10,155 animals for the entire watershed and was determined by watershed stakeholders (Table D.1). This estimate assumed a density of 33.4 acre per animal applied to barren land, forested land, pine plantation, mixed forest, near riparian forest, rangeland, cultivated land and managed pasture. This estimate is similar to other densities reported for other portions of Texas (Reidy 2007; Wagner and Moench 2009). It was also noted that feral hogs are commonly known to use dense cover such as that found in forests or riparian areas during the day but venture out from those areas at night to forage. As such, this feral hog population was modeled to primarily use near riparian habitats.

The SELECT model predicted that feral hogs have the potential to contribute 1.18 E+13 cfu/day of *E. coli* to the watershed and the potential to contribute 4.30 E+15 cfu annually (Borel et al. 2012). The daily potential *E. coli* load from feral hogs was estimated using:

$$\text{Feral Hog Load} = \#\ \text{hogs} * 1.16 * 10^9\ \text{cfu/day}$$

To calculate an estimated loading reduction expected from feral hog management, the daily fecal loading rate per hog, the estimated number of hogs removed, and the number of days per year that this practice will be implemented were considered. Due to the nature of feral hogs and their affinity for dense riparian cover, the 25% riparian stream impact factor discussed earlier is also incorporated into the loading reduction calculation. The goal established is to remove

10% of the total feral hog population annually. By removing the hogs from the watershed completely, the potential *E. coli* load from feral hogs is assumed to decrease by 10% as well.

Daily Potential Load Reduction Expected from Cattle

=# feral hogs removed*1.16E+9 cfu/day*Proximity Factor*365 days/year

In this equation inputs are as follows:

- 1.16 E+9 = the *E. coli* production in cfu/day per feral hog used in the SELECT Model
- Proximity Factor = a percentage based impact factor that accounts for an assumed stream impact factor to be applied based on feral hogs affinity for riparian habitats = 25%

Feral Hog Removal Load Reduction Estimate:

Annual Load Reduction

=1015 hogs removed*1.16E+9 cfu/day*0.25 Proximity Factor*365 days/year

Total Annual Feral Hog Removal Load Reduction = 1.08E+14 cfu

OSSF Management

The number of OSSFs in the Attoyac Bayou watershed was estimated to be 6,085 systems as discussed in Chapters 6 and 9. Of these, 50% were considered failing by watershed partnership stakeholders based on their local knowledge of system age, lack of proper maintenance and direct observations. This percentage is higher than that used in other watersheds, but stakeholders were adamant about the 50% failure rate and this rate was confirmed as reasonable by the Nacogdoches County Health Department.

Due to the high number of estimated OSSFs failing in the watershed, proximity to the Attoyac Bayou and its tributaries and the type of stream was used as a prioritizing factor. For OSSFs within 150 yds of a perennial stream the 25% proximity factor was applied where a 10% proximity factor was applied to OSSFs within 50 yds of an intermittent stream.

Daily Potential Load Reduction Expected from OSSF Repair or Replacement

=# of OSSFs addressed*1.00E+7 cfu/100mL*70 (gallons/person)/day*3785.2 mL/gallon*2.12 persons/household*Proximity Factor

Assumptions:

- 1.00E+7 cfu/100mL = E. *coli* concentration in OSSF effluent as reported by Horsley and Witten 1996
- 3785.2 mL/gallon = number of milliliters in a gallon
- 70 gallons per person per day is estimated discharge in OSSFs as reported by Horsley and Witten 1996.
- 2.12 persons per household average from Nacogdoches, Rusk, San Augustine, Shelby counties (Table 10.)
- Proximity Factor = a percentage based impact factor that accounts for an assumed stream impact factor to be applied based on the location of a waterway (perennial streams = 25% and intermittent streams = 10%)

OSSF Load Reduction Estimate:

<u>*Annual Near-Perennial Stream Load Reduction*</u>

=50 OSSFs addressed*1.00E+7 cfu/100mL*70 (gallons/person)/day*3785.2 mL/gallon*2.12 persons/house hold*365 (days used)/year*.25

Annual Near-Perennial Stream OSSF Load Reduction = 2.56E+16 cfu

<u>*Annual Near-Intermittent Stream Load Reduction*</u>

=50 OSSFs addressed*1.00E+7 cfu/100mL*70 (gallons/person)/day*3785.2 mL/gallon*2.12 persons/house hold*365 (days used)/year*.10

Annual Near-Perennial Stream OSSF Load Reduction = 1.03 E+16 cfu

<u>***Total Annual Near-Stream OSSF Load Reduction = 3.59 E+16 cfu***</u>

Hunting Camp OSSFs

Installation or repair of OSSFs for hunting camps uses the same loading reduction calculation as other OSSFs except that the amount of effluent produced per person per day is considered to be less, the persons per camp is considered higher, days used per year is less and the proximity factor used was 10%. The *E. coli* concentration was considered to be the same.

<u>*Annual Hunting Camp OSSF Load Reduction*</u>

=10 OSSFs addressed*1.00E+7 cfu/100mL*20 (gallons/person)/day*3785.2 mL/gallon*4 persons/camp*10 (days used)/year*.10

<u>***Annual Hunting Camp OSSF Load Reduction = 3.03E+13 cfu***</u>

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