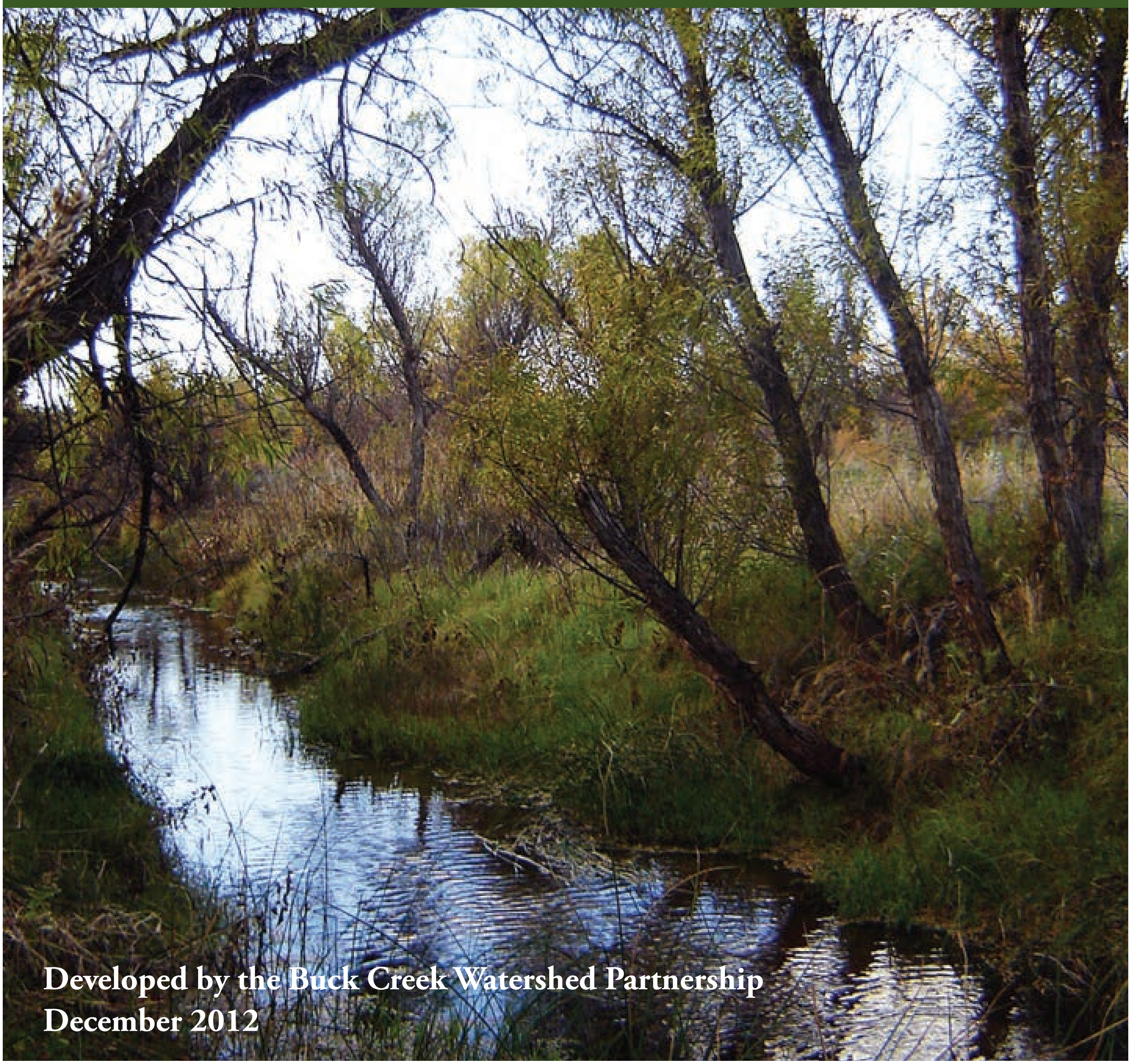
Buck Creek Watershed Protection Plan



Developed by the Buck Creek Watershed Partnership
December 2012

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Texas Water Resources Institute TR-420

Funded By:
Texas State Soil and Water Conservation Board (Project 06-11)
U.S. Environmental Protection Agency

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Funded with Clean Water Act §319(h) nonpoint source grants from the Texas State Soil and Water Conservation Board and U.S. Environmental Protection Agency.

Acknowledgements

The Buck Creek Watershed Protection Plan was developed as the direct result of dedicated time, effort and resources of the Buck Creek Watershed Partnership and its many members. The individuals and agency representatives participating in this group each played a critical role in the development of this plan. Their efforts in developing this plan are much appreciated and we commend them for their contributions.

A special thank you is extended to the many landowners participating in the development of this plan, especially those who diligently attended meetings and events to provide direct inputs to the plan. Buck Creek is a rural watershed dominated by private lands, thus the participation of private landowners in the development of the plan was crucial in drafting a plan that will be implemented in the future. These same landowners also took it upon themselves to immediately begin implementing practices on their properties that protect and restore water quality in Buck Creek while simultaneously improving the productivity of their land prior to the completion of the watershed plan. This led to the removal of Buck Creek from the state's list of impaired waters. Without these individuals taking the initiative to implement practices on their own, this achievement in water quality would not have happened.

Agency support and input was also an integral part of the Buck Creek Watershed Plan development process. The agencies' technical guidance and willingness to provide specialized knowledge on a variety of subjects are much appreciated. Agencies contributing to the watershed protection plan development process include:

- Red River Authority of Texas
- Texas A&M AgriLife Extension Service
- Texas A&M AgriLife Research
- Texas Commission on Environmental Quality
- Texas Department of Agriculture
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board
- USDA-APHIS Wildlife Services
- USDA Farm Service Agency
- USDA Natural Resource Conservation Service
- U.S. Environmental Protection Agency

Local or regional groups and personnel also played an important role in the development of the watershed protection plan and the efforts of these representatives to protect the watershed's resources and its water quality are greatly appreciated; these groups include:

- County Extension Agents
- Donley County SWCD
- Hall-Childress SWCD
- Salt Fork SWCD
- Texas Cattle Feeders Association

Last, but certainly not least, we would like to acknowledge 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. Without these funds, the development of this plan would not have been possible.

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List of Acronyms

ac	acre
ac-ft	acre-feet
AU	assessment units
AgriLife El Paso	Texas A&M AgriLife Research and Extension Center at El Paso
AgriLife Vernon	Texas A&M AgriLife Research and Extension Center at Vernon
BMP	best management practice
BOD	biochemical oxygen demand
BST	bacterial source tracking
CAFO	concentrated animal feeding operation
cfu	colony forming unit
DO	dissolved oxygen
EPA	United States Environmental Protection Agency
EQIP	USDA NRCS Environmental Quality Incentives Program
ESRI	Environmental Systems Research Institute
ERIC-PCR	enterobacterial repetitive intergenic consensus sequence-polymerase chain reaction
ft	feet
FOTG	USDA NRCS Field Office Technical Guide
FDC	flow duration curve
FW&DC	Fort Worth and Denver City Railroad
GCD	groundwater conservation district
gpm	gallons per minute
LDC	load duration curve
LU/LC	land use and land cover
m	meter
mi	mile
mL	milliliter
MOS	margin of safety
mg/L	milligrams per liter
NAIP	National Agriculture Imagery Program
NASS	National Agricultural Statistics Service
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NPS	nonpoint source
NRCS	USDA Natural Resources Conservation Service
OSSF	on-site sewage facility
PCR	polymerase chain reaction
RRA	Red River Authority of Texas
RMU	Resource Management Unit
Riboprinting	automated ribosomal ribonucleic acid genetic fingerprinting
RRC	Railroad Commission of Texas
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SSL	Spatial Sciences Laboratory at Texas A&M University
SWCD	soil and water conservation district
TAMU	Texas A&M University
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
WAF	waste application field
WQMP	water quality management plan
WWTF	wastewater treatment facility
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WPP	watershed protection plan
yds	yards

Executive Summary

The Buck Creek Watershed is a rural watershed in the southeastern corner of the Texas Panhandle that served as a birthplace for many ranching and farming endeavors during the settlement of the southern Great Plains. The watershed remains largely engaged in farming and ranching and also supports a diverse and healthy wildlife population. Once an integral water resource for the area, the creek is now an intermittent stream that no longer sustains flow during the warm months of the year. Despite the creek's decline in flow, it is still a critical water resource for livestock, wildlife and other animals in the watershed.

Problem/Need Statement

Water quality monitoring conducted by the Red River Authority of Texas in the late 1990s illustrated that fecal-derived bacteria levels were often elevated above the state's water quality standard for contact recreation and led to its listing as an impaired water body for elevated bacteria in the *2000 Texas 303(d) List.* Additionally, in 2006 it was determined that nitrate levels were routinely elevated above the state's screening level, thus causing a concern for excessive aquatic vegetation growth. With the bacteria impairment and nutrient concerns comes the need to implement corrective actions to restore instream water quality to meet state standards. To meet this need, a series of 3 projects have been undertaken to collectively assess the need for and develop the Buck Creek watershed protection plan (WPP).

Action Taken

The first project, *"Bacterial Monitoring for the Buck Creek Watershed"* (TSSWCB Project 03-07) began in October 2003 with the goal of collecting an intensive dataset that would better illustrate the extent and variability of bacteria loading in the Buck Creek watershed. Project results did indicate that periodically elevated bacteria levels existed and that proceeding with developing a WPP for Buck Creek would effectively identify the most probable sources of these bacteria and develop a plan for mitigating those sources.

Subsequently, a second project was developed entitled *"Watershed Protection Plan Development for Buck Creek"* (TSSWCB Project 06-11). This project was designed to continue intensive water quality monitoring, to identify bacteria loading sources in the watershed through physical watershed assessment and to identify the types of sources most likely contributing to the bacteria load through bacterial source tracking analysis. Results from this project confirmed the assumptions of watershed partnership members that wildlife and feral animals were primary bacteria contributors followed by livestock and, to a lesser extent, humans. The singling out of human sources by BST analysis is somewhat surprising considering the limited number of people that live in the watershed.

An additional project entitled *"Modeling Support for Buck Creek Watershed Protection Plan Development"* (TSSWCB Project 08-05) was also developed. The work conducted through this project used watershed-specific information developed in the previous projects to develop a predictive model of the Buck Creek watershed. This model evaluates the potential for bacterial loading across the entire watershed and aggregates the potential at the subbasin scale. Land use characteristics, soil types, topography, climate and estimated animal populations are the input parameters that have direct impacts on this model. By evaluating these parameters, the model is able to predict which subbasin within the watershed has the highest potential for contributing bacteria to the creek. This tool provided significant assistance in determining where selected management measures are likely to have the highest potential impacts and was thus useful in determining where specified practices are recommended for implementation in the watershed.

Buck Creek WPP Overview

Using information developed in these 3 projects and, most importantly, input from watershed stakeholders, this document is the culmination of efforts to identify the sources of bacteria pollution in the watershed and develop a plan to mitigate loadings from those sources by voluntarily implementing practices described in the plan. 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. Despite the extensive amounts of information that went into the development of this WPP, a better understanding of the watershed and the effectiveness of protective or mitigating actions will undoubtedly develop. As such, this WPP is a living document that will evolve as needed through the adaptive management process.

Pollutant Sources to Address

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 contributions include wildlife and feral animals, livestock and human sources. Potential nitrate sources in the watershed are underlying groundwater, which actively contributes baseflow to the creek and, to a lesser extent, commercial fertilizers. Evidence strongly suggests that groundwater is the primary nitrate contributor to the creek; however, this cannot be definitively proven.

Recommended Actions

To mitigate loadings from identified pollutant sources, 6 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 and in some cases can provide financial assistance as well. These plans can include a variety of practices that include brush management, critical area planting, range and pasture planting, livestock water wells, livestock watering facility, a water pumping plant for livestock, pipeline for livestock watering, shade structures, prescribed burning and grazing, cross fencing and others. Education and outreach 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.

Bacteria loading reductions from wildlife sources are difficult to achieve; however, habitat management can have direct impacts on the time these animals spend in or near riparian areas. By providing needed resources such as food, water and shelter away from the creek, wildlife can be coaxed to venture farther from the creek, thus minimizing potential bacteria inputs to the creek. Education will be paired with habitat modifications to further illustrate the importance of proper resource management to improve water quality.

Feral hog management in the watershed will consist of both active and passive methods of control. Similar to wildlife, managing the available food, water and shelter resources can modify hog behavior and encourage them to move elsewhere; however, feral hogs are a nuisance species that cause extensive damage watershed-wide. Watershed landowners will continue efforts to trap and kill hogs and their efforts will be supplemented when possible by agency control actions. Education will also provide critical support in efforts to control feral hogs and aid in tracking the number of hogs removed.

Human-derived bacteria management will focus on providing technical support for on-site sewage facility (OSSF) owners, installers and maintenance providers. Concerted efforts will also be undertaken to identify problematic systems and secure needed funds to repair or replace these systems. Education is a cornerstone of this effort and is commonly identified as a significant need in the management, operation and maintenance of septic systems.

Nitrates

The primary action needed to address nitrate loading in the creek is to properly identify the source of nitrates entering the creek. Local watershed knowledge and available data strongly suggest that underlying groundwater is the primary source of nitrate present in Buck Creek. Despite this evidence, a definitive source has not been identified. To accomplish this, an intensive look at instream, spring and groundwater quality and isotope composition is needed and is recommended. In concert with this, it is recommended that a water body-specific assessment be conducted to determine the level of nitrate that Buck Creek can effectively attenuate and that a water body-specific nitrate screening level or water quality standard be established.

In the interim, watershed stakeholders can implement nitrate management. Nitrate is readily available to farmers in their soils and irrigation waters; however, it is often under-utilized or not utilized at all. Pairing a soil and water testing campaign with soil fertility demonstrations and nutrient management education will provide "proof of concept" evidence that farmers need before they are willing to adopt these nutrient conservation practices. Collectively, these practices are expected to reduce nitrate inputs to the watershed by more than 150,000 pounds annually.

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 farmers and ranchers 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 Buck Creek WPP. Stakeholder meetings held as needed and supplemented with topically relevant education and outreach events will be critical in maintaining local interest in WPP implementation and provide a needed local platform for conveying and illustrating implementation successes.

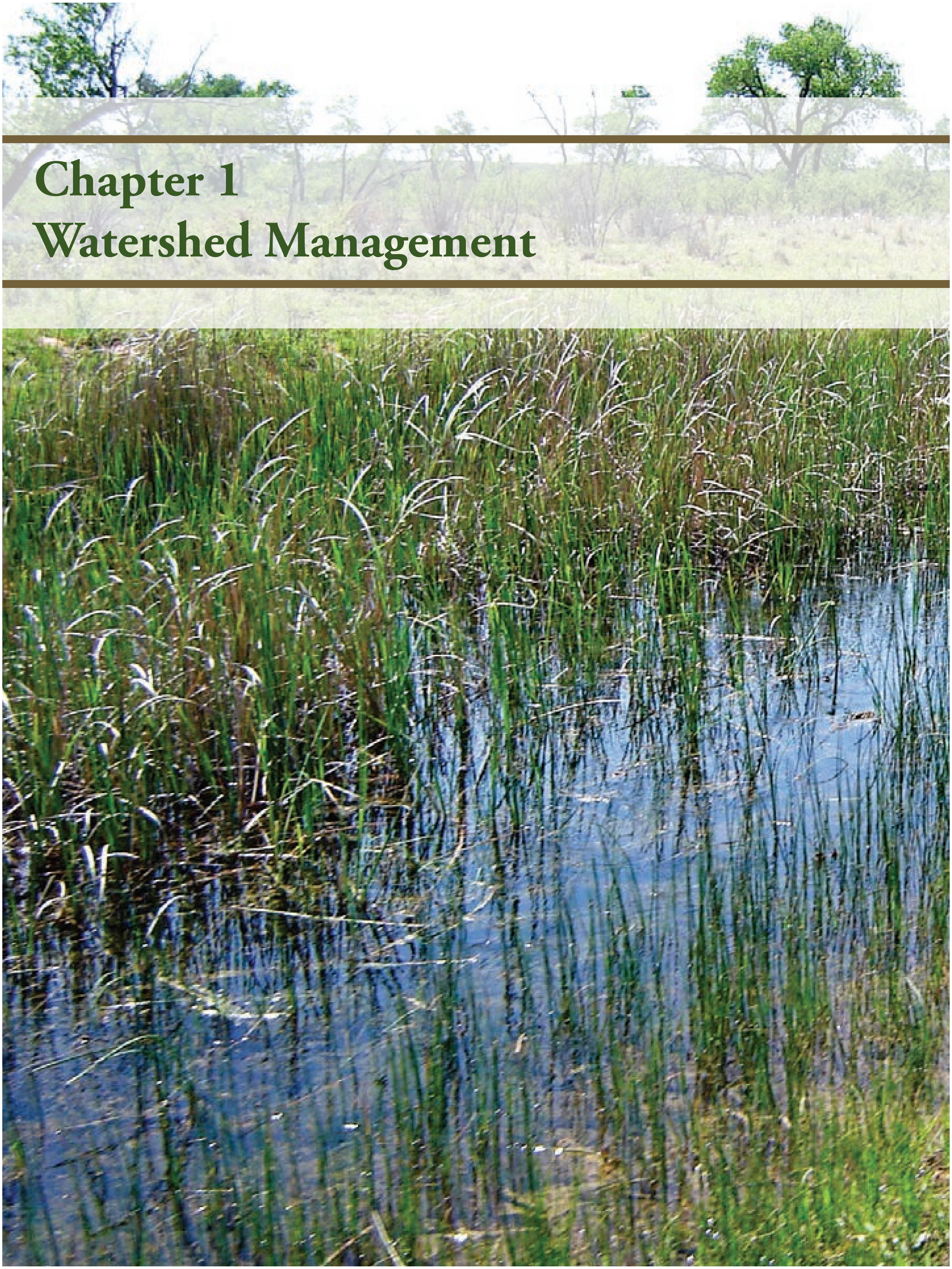
Tracking Progress

Effectively tracking and communicating WPP implementation progress and success is also critical. Periodic water quality monitoring conducted at selected sites will be gaged against water quality benchmarks established in the plan. This monitoring will serve as the primary measure of WPP implementation success. The numbers of practices implemented, events held, people in attendance at events and other measures described in the plan will also document success. Collectively, this information will feed into the adaptive management process and be used to redirect the WPP should implemented practices not produce anticipated water quality improvements.

The Goals

Ultimately, the goal of the WPP and the impetus behind implementing practices it recommends is to protect water quality in Buck Creek as well as its watershed. To achieve this over-arching goal, 3 specific goals were established by the Buck Creek Watershed Partnership. The first goal is to maintain Buck Creek's current unimpaired status. Buck Creek has no impairments listed in the *2010 Texas Integrated Report* and the local desire is to keep impairments from appearing. The second goal is to maintain *E. coli* levels in Buck Creek at or below 95 colony forming unit (cfu)/100 milliliters (mL) of water. This numeric value is a 25% improvement over the state's water quality standard and affords a significant cushion for periodically elevated bacteria levels that are sure to occur. The last goal specified in the plan is to determine an appropriate nitrate screening level for Buck Creek. The current nitrate screening level is based upon statewide nitrate data and is not necessarily appropriate for Buck Creek. Screening levels are designed to protect in-stream aquatic life uses by establishing a level at which excessive plant growth is unlikely to occur. Despite recurring elevated nitrate levels in Buck Creek, excessive plant growth is not often found in the water body. As a result, the Buck Creek Watershed Partnership established a goal of conducting a water body use attainability analysis to establish an appropriate nitrate screening level for Buck Creek.

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 subbasins, combine to form the Buck Creek watershed, which is actually a small part of the Mississippi River watershed.

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 stakeholder involvement and management action supported by sound science and appropriate technology." 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 individual, 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 Development Process

Watershed protection plans (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. 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.

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 community, 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 and economically viable and that achieve environmental goals for water resources. Adaptive management is used to modify the WPP based on an ongoing science-based process that involves monitoring and evaluating strategies and incorporates new knowledge into decision making.

Private Property Rights

Maintaining complete control of privately held land and water rights are primary concerns of many 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 the stakeholders or harming their livelihood and are cost effective through financial and technical resource leveraging.

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 (EPA 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). Using this process, members of the Buck Creek Watershed Partnership will implement strategies known to address pollutant loadings and work to initiate efforts to clarify uncertainties that remain within the watershed.

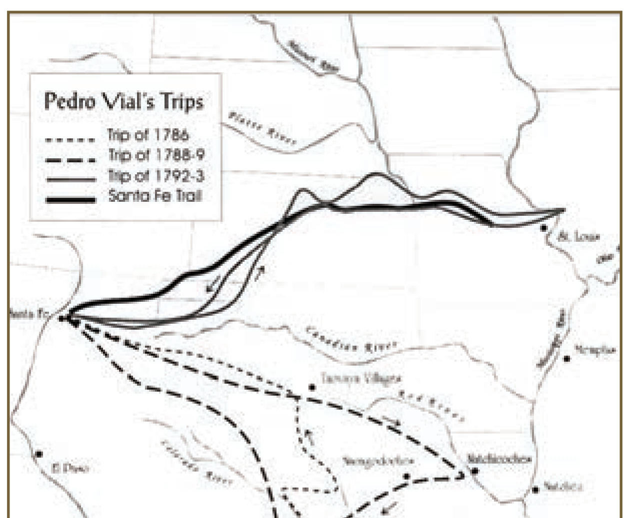
Chapter 2
Regional History

The Texas Panhandle and the Buck Creek watershed have a rich history that spans many years of difficult, yet prosperous times. Artifacts located across the Panhandle indicate that the area was inhabited by early Native Americans as early as 10,000 B.C., according to evidence discovered at the Alibates Flint Quarry located near Lake Meredith (Robertson and Robertson 1981); however, earlier habitation is quite possible. As noted by Rathjen (1998), the first humans arriving in the Texas Panhandle likely found a more humid environment than is present today and a variety of big-game animals such as elephant/mammoths, pre-historic bison, horses, camels and sloths. This was evidenced by the 1933 discovery of Columbian mammoths and associated Clovis fluted points (arrowheads) near Miami in Roberts County.

Following these early inhabitants of the Panhandle, occupying groups came and went as climatic conditions dictated. It was not until about 1000 A.D. that more permanent inhabitants made the Panhandle their home (Rathjen 1998). The Alibates Flint Quarry site near Lake Meredith is one site where these people have been documented. This area was used and inhabited many years; the Pueblo Panhandle Culture lived in and around this area for about 500 years until about 1450 A.D. Francisco Vázquez de Coronado was the first person to document the presence of the Native Americans occupying the Panhandle when he traveled through the region in 1541. He encountered nomadic buffalo hunting “Querechos” or Apaches who inhabited and apparently controlled the area until sometime in the 1700s. At this point, the Comanches (and their allies, the Kiowas) had risen to power upon their mastery of horsemanship and were in complete control of the region by 1800. This remained the case until the 1870s (Rathjen 1998).

Other notable explorations in the Panhandle that are more specific to the Buck Creek watershed include the expedition of Hernando De Soto, Pedro Vial and Captain Randolph B. Marcy and Captain George B. McClellan. According to some accounts (Robertson and Robertson 1981), De Soto is said to have traveled as far as the Texas Panhandle in 1541 and very near the Buck Creek watershed; however, other accounts place him nowhere near the Panhandle. Pedro Vial’s trek in 1786–1787 is better documented as he was attempting to find the shortest route between San Antonio, Texas and Santa Fe, New Mexico (Boyle 1994). This expedition led him very near and possibly through the Buck Creek watershed. Following his initial expedition, he made several other trips through the Panhandle including his trek from Santa Fe, New Mexico to St. Louis, Missouri, which led to the establishment of the Santa Fe Trail (Loomis and Nasatir 1967). Captain Randolph B. Marcy and Captain George B. McClellan led an expedition through the Great Plains to find the headwaters of the Red River and document the area’s natural resources along the way (Robertson and Robertson 1981).

The Comanches and their allies dominated the Southern Great Plains for the first 75 years of the 19th Century and were almost solely dependent upon the southern bison herd (estimated at 4 to 6 million animals) for their livelihood. Their eventual downfall was brought about through their understanding of the Medicine Lodge Treaties of 1867 that gave them sole hunting rights south of the Arkansas River. The arrival of buffalo hunters who slaughtered the animals for their hides in the early and mid-1870s led to increasing attacks against these hunters and their encampments. The attack led by Quanah Parker at the Adobe Walls trading camp (Hutchinson County) on June 27, 1874 was the height of these skirmishes and led to the U.S. Army being sent to quell the uprising. The Army’s campaign became known as the Red River War, which consisted of 14 battles scattered across



Map of Pedro Vial expeditions (Boyle 1994) the Panhandle. This effort ultimately pushed the Indians back to their reservations in southwestern Oklahoma and allowed the slaughter of the southern bison herd, almost to the point of extermination (Rathjen 1998, Robertson and Robertson 1981). The establishment of Fort Elliot in Wheeler County in 1875 provided a constant presence that largely kept the Indians on their reservations and opened the way for modern settlement in the Panhandle (Robertson and Robertson 1981).

Cattle Ranching

The Texas Legislature officially divided the Panhandle into the 26 present counties in 1876; at this point the counties were merely drawn on a map and were not officially organized. At this same time, the grazing potential of the Panhandle was realized. Casimero Romero led this movement by bringing sheep from New Mexico to graze on the High Plains near Tascosa in the Canadian River ba-

The JA chuck wagon camped on Cotton Wood Creek. JA Ranch, Texas. 1908. Erwin E. Smith.
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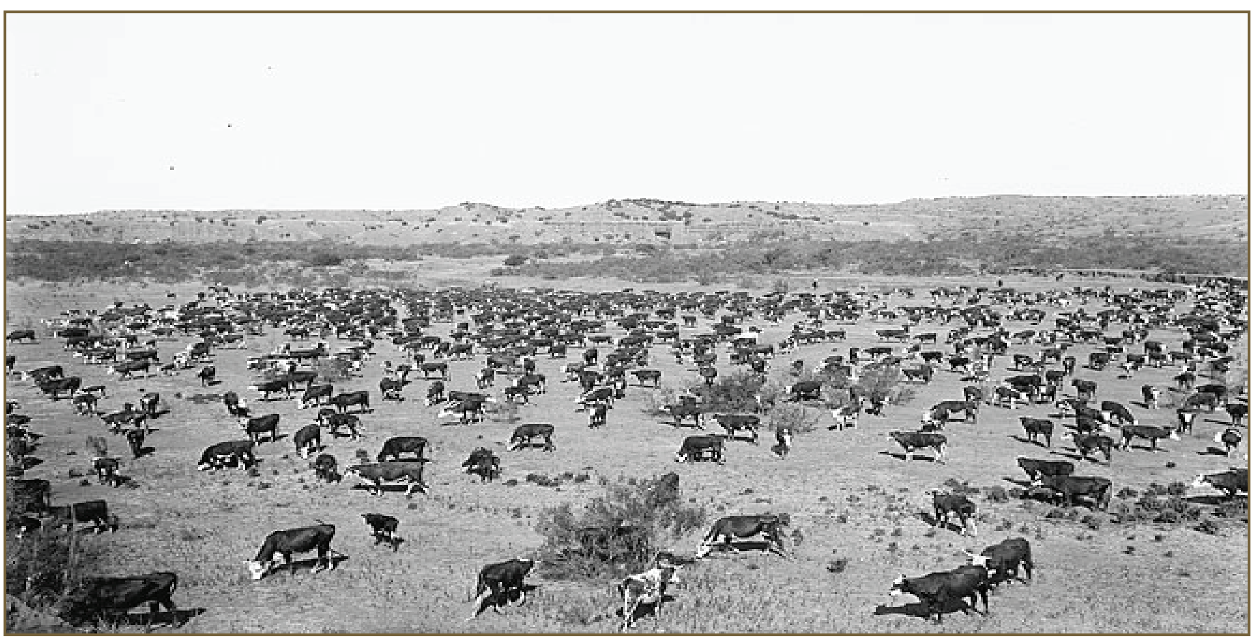


Looking down from a high point on Matador longhorns grazing. Shoe Bar Ranch, Texas. 1912. Erwin E. Smith.
Available at: http://www.cartermuseum.org/collections/smith/collection.php?mcat=6&scat=22

sin. Charles Goodnight was the pioneering cattle rancher in the Panhandle. Goodnight arrived with his herd from Colorado in the spring of 1876 and staked claim to the Palo Duro Canyon and began the storied JA Ranch in partnership with John Adair. This cattle ranch covered portions of Armstrong, Briscoe, Donley, Hall, Randall and Swisher counties and encompassed practically all of the Palo Duro Canyon. Thomas Bugbee arrived shortly after Goodnight and established the Quarter Circle T Ranch in Hutchinson County. These ranches were followed by many more during the Panhandle ranching boom (Rathjen 1998, Robertson and Robertson 1981). Charles Goodnight also was the first to bring many other practices to the Panhandle, including windmill-powered water wells, improved cattle (crossbred with Hereford stock) and was one of the first ranches in the area to use barbed wire (Robertson and Robertson 1981).

William R. Curtis and Thomas J. Atkinson moved into the Panhandle in 1879 and established the Diamond Tail Ranch with their ranch headquarters near the confluence of Doe and Buck Creek in Collingsworth County. This headquarters later served as a stage stop and supply store on the trail between Wichita Falls and Mobeetie. The arrival of the railroad and its path through the ranch in 1887 shifted operations toward the town of Giles nearer the headwaters of Buck Creek. Giles became the local shipping hub for many cattle operations in and around Buck Creek. At the ranch's peak, it covered parts of Childress, Collingsworth, Donley, Greer (now in Oklahoma) and Hall counties and owned more than 60,000 head of cattle. Unlike many other Panhandle ranches, the Diamond Tail was never sold out to foreign investors. In the 1890s, farmers began arriving in the Panhandle and eventually led to the sale and subsequent move of the bulk of Diamond Tail Ranch operations to Chaves County, New Mexico. About 16,000 ac were retained in Donley and Hall counties. These were sold to John M. Browder in 1905, shortly after William Curtis' accidental death. The heirs of John Browder were still using the Diamond Tail brand into the 1970s (Browder 1975, Robertson and Robertson 1981).

The Doll Baby Ranch was established in Childress, Donley and Hall counties by brothers Tom and James Morrison and was headquartered near Giles on Buck Creek. The ranch was short lived as it was founded in 1878 and closed in 1882. The ranch's land was sold to William Curtis of the Diamond Tail Ranch and the cattle were sold to Alfred Rowe of the RO Ranch. Tom Morrison was one of the founding members of the Panhandle Stock Association (a predecessor of the Texas and Southwestern Cattle Raisers Association) and was appointed one of the first Donley County Commissioners alongside Charles Goodnight, Leigh R. Dyer and S.B. Nall when the county was organized in 1882 (Robertson and Robertson 1981).

The RO Ranch also included portions of the Buck Creek watershed. Alfred Rowe, an Englishman, founded the ranch in 1880. At the peak of the enterprise, the ranch included portions of Donley, Collingsworth, Gray and Wheeler counties. Hedley, McClean and Quail all lay within the 300,000-ac spread that was once the RO Ranch. Alfred Rowe was a generous man and donated the land for Rowe Cemetery near Hedley. Rowe owned and oversaw the ranch until his untimely death in the sinking of the *Titanic* on April 15, 1912. Alfred's brother Bernard took over the ranch after his death and began to sell it off. William J. Lewis purchased 77,000 ac of the ranch; as of the 1970s, it was still in the Lewis family (Robertson and Robertson 1981).

Other notable ranches that operated very near, and possibly in, the Buck Creek watershed included the Mill Iron Ranch (1881–1916), the OX Ranch (1880–1930s), the Rocking Chair Ranche (1877–1896), the Shoe Bar Ranch (1883–1910), the Shoe Nail Ranch (1883–1907) and the Spade Ranch (1880–1889) (Robertson and Robertson 1981).

Arrival of the Railroad

The arrival of railroads through the area led to the eventual demise of many of the big ranches in the Panhandle. A common practice among the cattle ranches was to buy every other section of land and lease (from the State of Texas) the grazing rights to the sections in between. Along with the railroads came an influx of farmers who purchased land from the State. The ranches were able to stave off this influx for a while by purchasing the land from the farmers. The Fort Worth & Denver City (FW&DC) Railroad constructed its trunk line from Fort Worth to Denver and the line was built through Childress, Hall and Donley counties in 1887, greatly changing the region. Prior to this, trade and travel was conducted by overland wagons and stagecoaches at a great cost to the

The "Colorado Special" on its way through the Texas Panhandle in 1929 on the Fort Worth and Denver Railway.
Photo courtesy of http://texashistory.unt.edu

consumer. Railways meant that goods and people could be moved much cheaper and faster. The arrival of the rail also caused numerous towns along the line to move and led to the demise of many others. Childress, Clarendon, Hedley and Memphis all relocated to be on the rail line and prospered as a result. Clarendon served as the main rail hub for a while until the rail yard and maintenance shops were moved to Childress in 1902 (Browder 1975, Ford 1932, Ord et al. 1970). Branch lines later extended to areas away from this main line and further modernized the shipment of goods. Wellington was reached by a branch line on the Wichita Falls and Northwestern Railroad in 1910 (Hofsommer 1999) and later by the Fort Worth and Denver Northern Railway in 1931 (Cravens 2008). These branch lines improved the ability of area residents to market their produced commodities as well as purchase goods.

Farming

Riding on the coat tails of the Panhandle ranchers, the first farmers made their arrival in the mid to late 1880s. Most of these farms were small and interspersed amongst the various ranching operations of the area; in fact, many ranches bought out these early farmers in an attempt to keep them out of the Panhandle (Robertson and Robertson 1981). The late 1880s yielded to harsh growing years with 2 dry years and grasshopper plagues. The bulk of early farmers were forced out of the area by these conditions; however, some stayed behind and further cemented farming in the Texas Panhandle. Grains such as wheat and maize were the dominant early crops, but were soon surpassed by cotton as the top commodity. The expansion of roads and railways greatly expanded the ability of farmers to market their crops as well as to purchase goods and supplies at more affordable costs. By the mid to late

“Tractored out,” Power farming displaces tenants from the land in the western dry cotton area. Photo by Dorothea Lange, Farm Security Administration, available from The Library of Congress: http://www.loc.gov/pictures/resource/ppmsc.00232/

1890s, farming had surpassed ranching as the primary agricultural industry in much of the Panhandle (Ford 1932, Rathjen 1998, Wellington Leader Staff 1925).

The Dust Bowl

Fueled by the higher than average rainfall on the High Plains in the early 20th century, the U.S. government's push for settling the area and experts' beliefs that farming would change the climate and bring even more rain to the area, an explosion of farming in the Texas Panhandle— known as the great plow-up—began in earnest in the mid-1920s. Wheat, maze and cotton production exploded and did very well in these wetter years. As the rest of the country was entering the Great Depression, the Panhandle was still booming in crop production, creating an excess of commodities (Eagan 2006, Worster 2011).

At the same time production was reduced in response to the surplus, the rains began to slack by 1931 and almost disappear. Exacerbated by the introduction of the gasoline-powered tractor plowing up the grasslands that had for years protected the soil from the brutal winds of the central United States, the fallow fields began losing tons of topsoil to erosion. As the drought continued, crop failures continued not only from lack of rain but also from the sandblasting effect that the suspended dust particles had on plants, laying even more land fallow and subjecting it to wind erosion. Forages became scarce and livestock starved. The people who had come there for good farmland and profit now began leaving in droves. The fine dust in the air caused some people who stayed to contract “dust pneumonia” and lead to death in extreme cases (Eagan 2006). These “black blizzards” would begin in the High Plains area and sweep across the country, darkening large urban areas such as Chicago, New York, and they would even reach 30 mile (mi) off the Eastern seaboard to coat ships at sea (Worster 2011).

The Dust Bowl was the primary driver behind the establishment of the Soil Erosion Service, created in 1934 with limited powers to control this erosion. Hugh Hammond Bennett, who championed the service, was giving a speech to Congress lauding the need for more proactive programs to combat the erosion he saw as a threat to the United States. As Bennett was finishing his speech, he told Congress, "This is what I am talking about gentlemen," and almost as if on cue, the storm, consisting of tons of soil from the middle of the country, hit the Capitol. As a result the Soil Conservation Act was passed and the Soil Conservation Service in late 1935 (changed in 1994 to Natural Resources Conservation Service) and Soil and Water Conservation Districts in Texas were authorized in 1939 (Eagan 2006, Worster 2011).

Childress County

The Texas Legislature officially formed Childress County, named after George C. Childress, author of the Texas Declaration of Independence (Abbe 2008a) in 1876 but the county remained unorganized until 1887 when the FW&DC Railroad made its way into and through the county. The FW&DC's arrival prompted the citizens of the county to seek organization for the county and to select a county seat. In April 1887, the initial county election was held and Childress City (about 5 mi north of present day Childress) was selected as the Childress County seat. The FW&DC management had lobbied for the town of Henry to be the county seat and upon news of the election threatened not to stop their trains in Childress County. The county residents resisted this threat and the FW&DC eventually promised to give all residents of Childress City equal lots in the town of Henry and change the town's name to Childress if they voted to move the county seat to Henry. In July 1887, another election was held and the county seat was moved to Henry, its name changed to Childress and Childress City subsequently disappeared as all of the town's residents and buildings were moved to Childress. The county and the city of Childress grew rapidly once the railroad was established. Farming, ranching and railroad work were the top industries in the early 1900s. Railroad growth in Childress continued when the FW&DC moved its shops from Clarendon to Childress in 1901–02 and multiple branch lines were constructed from Childress outward (Reeves 1951).

After the turn of the century, farming steadily increased in acres tilled and production levels while ranching declined until it was largely relegated to the non-arable acres of the county. By 1930, 1,348 farms and ranches were recorded in the county. At this point, approximately 40% of the county's land was in production with about 135,000 of these acres devoted to cotton. Cattle production was still thriving with an estimated 18,700 head counted in 1930. The prolific times were greatly affected by the Great Depression and the Dust Bowl of the 1930s. The number of farms and ranches declined to 948 by 1939 and acres under cultivation decreased to 114,467, down from a high of 183,000 in 1930. Mechanization of farm tasks also led to the decline in the number of farms (Reeves 1951).

Collingsworth County

The Texas Legislature also established Collingsworth County in 1876 and the county was originally part of Bexar and Young counties. The county was named after James Collinsworth, the first Chief Justice of the Republic of Texas. In the legislation establishing the county, his name was misspelled (Abbe 2008b). In the late 1870s and early 1880s, 3 large ranches, the Diamond Tail, the RO and the Rocking Chair controlled almost the entire county. Droughts, blizzards and the influx of farmers decimated the large ranches and led to the eventual end of ranching's grip on the county. By 1890, there were 89 recorded farms and ranches in the county with only 2 of them being larger than 500 ac. The county's residents decided to organize in 1890 and held the first election in September. Wellington was selected as the county seat over Pearl City, approximately 2 mi to the north. The construction of the Collingsworth County Courthouse began in 1891 and used bricks made on Buck Creek (Wellington Leader Staff 1925).

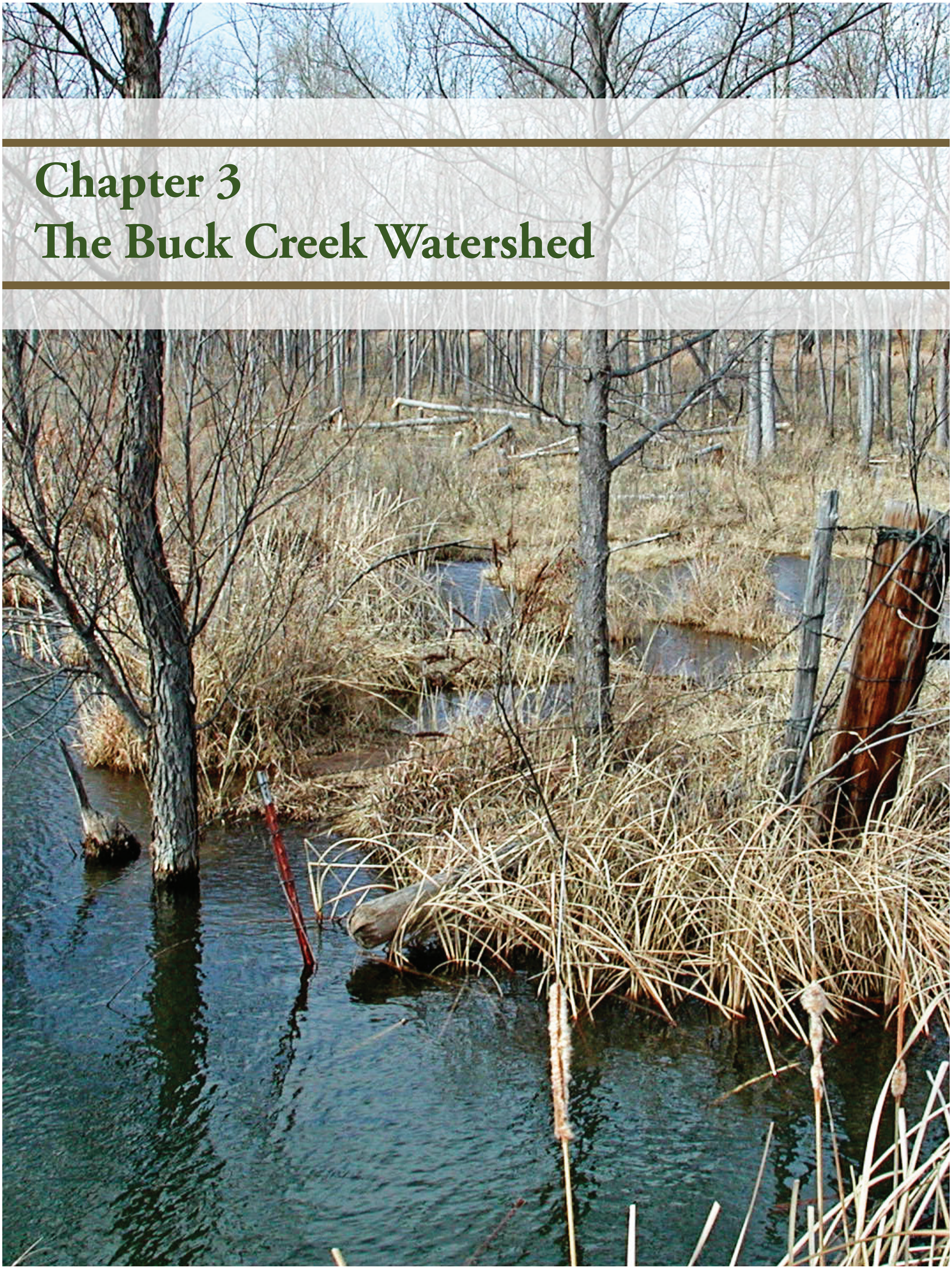
As the 1930s arrived, the agricultural economy of Collingsworth County was booming. Two railways now went to Wellington and made the shipment of agricultural commodities easier than ever. The 1930 Census indicates that there were 2,112 farms and ranches in the county with 246,000 ac under cultivation and about 26,400 head of cattle. The Great Depression and Dust Bowl greatly curtailed the expansion of the county and led to a large decline in the number of farms and the county's population. Since 1929, the county population has declined from 14,461 to 3,206 (2000 Census), which has been further fueled by farm mechanization and reduced labor needs (Abbe 2008b).

Donley County

Donley County, designated in 1876 and named after Stockton P. Donley, a pioneer lawyer (Abbe and Anderson 2008), encompasses the headwaters of Buck Creek and was also home to some of the earliest non-native settlements. In 1876, Charles Goodnight and John Adair established the first large cattle ranch, the JA, in the Panhandle in the southwestern portion of Donley and other counties and opened the way for future settlement. In 1878, Lewis Henry Carhart led a group of settlers to the county and founded Clarendon, the third town established in the Panhandle. The county formally organized in 1882 and selected Clarendon as the Donley County seat. In 1887 the FW&DC Railroad crossed Donley County 5 mi south of Old Clarendon and prompted the town's people to relocate to the railway. The railroad provided an economic boost to the town and county by locating its shops there until 1902 when they were moved to Childress following a major fire. Prior to 1890, ranching and the railroad were the primary industry, but farming rapidly increased following this time and has held a fair share of the local economy ever since (Ford 1932). By 1930, 1,364 farms and ranches were documented in the county with about 77,000 ac in cultivation and 35,500 head of cattle being raised. The county population also peaked during 1930 at 10,262 residents and has declined since to 3,828 during the 2000 Census. Ranching has remained a larger part of the county's economy than in Childress and Collingsworth counties due to the more rugged landscape and non-arable land (Abbe and Anderson 2008).

Fighting sand. Childress County, Texas Panhandle. Cultivating weedless cotton fields in Great Plains to break crust and prevent blowing sand from cutting young cotton plants. Photo by Dorothea Lange, Farm Security Administration, available from The Library of Congress: http://www.loc.gov/pictures/item/fsa2000001791/PP/

Chapter 3
The Buck Creek Watershed



Buck Creek originates southwest of Hedley, Texas in Donley County and flows 68 mi in an east-southeast direction across the Oklahoma border to its confluence with the Prairie Dog Town Fork of the Red River (Figure 1). At its confluence with the Lower Prairie Dog Town Fork of the Red River, the Red River above Pease River is formed. Field observations and information from the Texas Commission on Environmental Quality (TCEQ) indicate that Buck Creek is an intermittent stream, with perennial pools, that typically ceases to flow in places during the summer months. The creek provides critical habitat and supplies of drinking water to livestock and wildlife as it flows through the rural watershed.

Watershed Boundaries

Buck Creek is situated in the southeastern corner of the Texas Panhandle and briefly flows through the southwestern corner of Oklahoma before joining the Lower Prairie Dog Town Fork of the Red River. For the purposes of this WPP, only the Texas portion of the watershed will be discussed. The creek originates in Donley County southwest of Hedley and flows east into Collingsworth County where it turns south to flow into Childress County before entering Harmon County, Oklahoma. The watershed for the Salt Fork of the Red River forms the northern and eastern boundaries of the Buck Creek watershed while

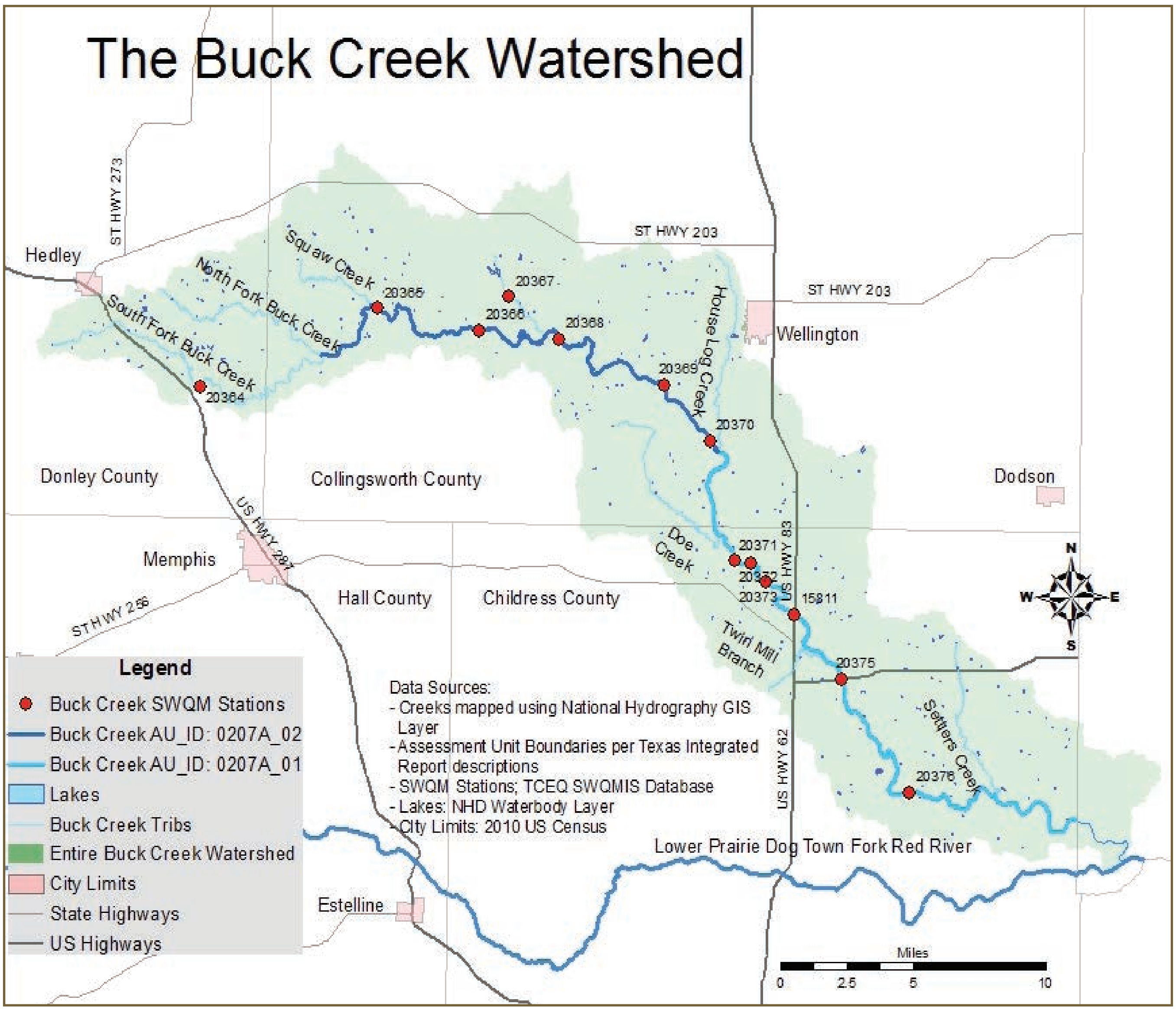


Figure 1. The entire Buck Creek watershed including the portion in Oklahoma

Table 1. Number of acres of each county in the Buck Creek watershed and corresponding percentages of each county in the watershed

County	Total Acres in each County	Acres of County in Watershed	% of County in Watershed	% of Watershed by County
Childress	459,866	65,970	14.35%	35.23%
Collingsworth	592,502	101,500	17.13%	54.20%
Donley	595,693	19,800	3.32%	10.57%
Total	**1,648,061**	**187,270**	**~~~**	**100.00%**

numbers derived from 2008 SSL Land Use data

the Prairie Dog Town Fork of the Red River forms the southern and western boundaries. Table 1 illustrates the distribution of watershed across Childress, Collingsworth and Donley counties.

Topography

The topography of the Buck Creek watershed includes several diverse landscape features. Generally, the watershed south and west of the creek includes the land features that are characterized as the Southwestern Tablelands (see *Ecoregions* section). This is essentially land that is along the eastern boundary of the Great Plains (Llano Estacado) and has eroded over time. This area contains many canyons, mesas and badlands and is generally non-arable land. Most of the land to the north and east of Buck Creek is a part of the Central Great Plains or Rolling Plains. This landscape is predominantly cropland that has received sediment from the continual erosion of the High Plains. This area is much lower in elevation than the High Plains to the west. The elevation of the watershed ranges from about 750 meters (m) above sea level in the headwaters of the watershed to 503 m above sea level where the creek joins the Prairie Dog Town Fork of the Red River.

Soils

The predominate soil in the watershed are loams, silt loams and sandy soils. The watershed includes 104 individual soil types that are categorized into 8 soil associations (Figure 2), which can be further categorized as those suitable for cultivation or not. The Grandfield-Devol, Polar-Mobeetie, Springer-Miles, Veal-Miles and Woodward-Miles-Carey soils are those suitable for cultivation within the watershed. Each of these soils is generally considered deep, gently sloping loamy or sandy soils that typically occupy upland areas of the watershed. The Quanah-Luders-Cottonwood, Quinlan-Knoco and Veal-Potter soil associations can typically be found in areas of the watershed dominated by rangeland. These soils are quite variable in that they are shallow to deep soils in upland areas that are typically underlain by rocky substrates (USDA NRCS 2006).

For a complete look at the soils of the Buck Creek watershed, see the United States Department of Agriculture (USDA)-Natural Resources Conservation Service (NRCS) Soil Surveys developed for Childress, Collingsworth and Donley counties (USDA 1963, USDA 1973 and USDA 1980 respectively).

Land Use and Land Cover

The Spatial Sciences Laboratory (SSL) at Texas A&M University classified land uses of the Buck Creek watershed in 2008 through Texas State Soil and Water Conservation Board (TSSWCB) project 08-52, *Classification of Current Land Use/Land Cover for Certain Watersheds Where Total Maximum Daily Loads or Watershed Protection Plans Are In Development.* For Buck Creek, the land use and land cover (LU/LC) was determined using several available datasets. National Agriculture Imagery Program (NAIP) images collected in 2005 were paired with 2003 Landsat Satellite Imagery to develop LU/LC classifications. Additionally, managed pastures were further delineated using USDA Farm Service Agency data, thus enabling a more accurate assessment of watershed LU/LC. These classifications were verified using 2001 National Land Cover Dataset (NLCD) classifications and ground-truthed data, thus providing an accurate and up-to-date description of land uses and land covers in the

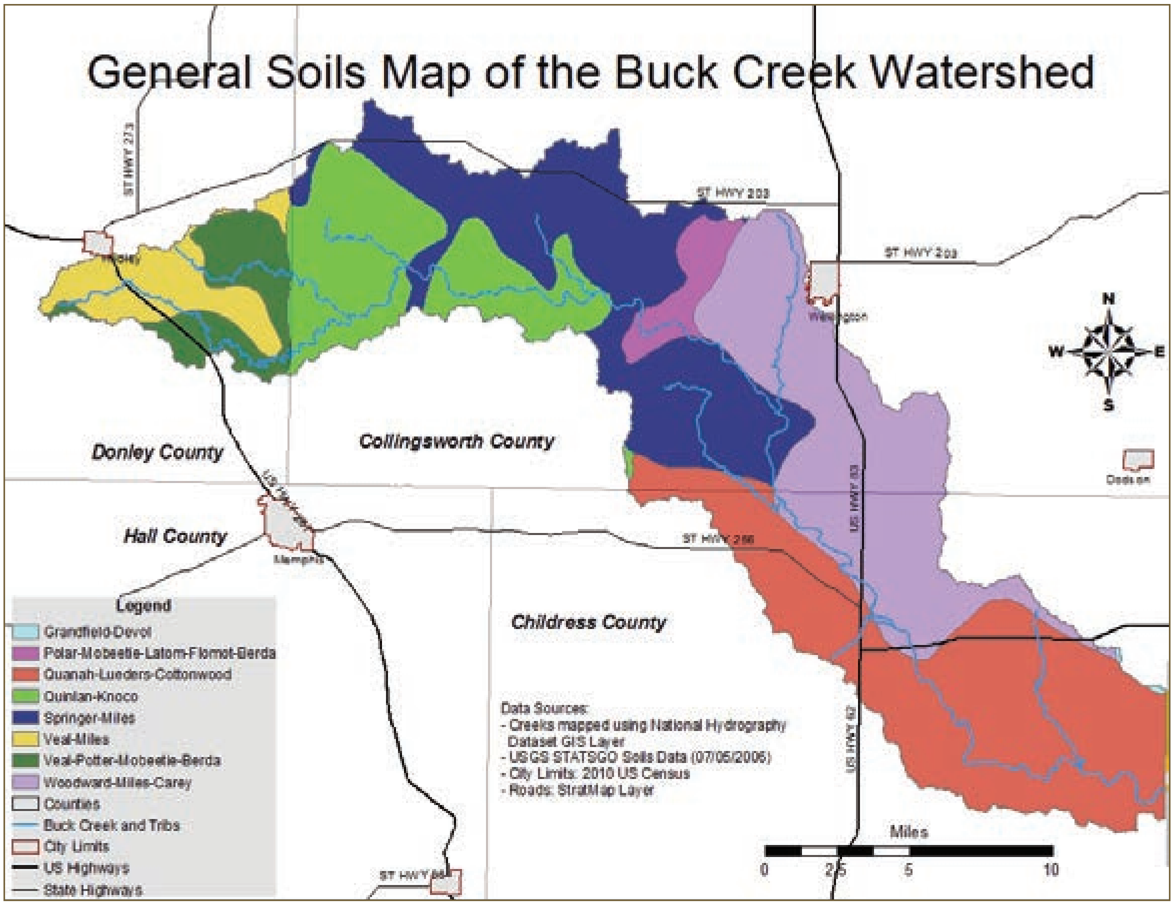


Figure 2. General soils map of the Buck Creek watershed

watershed. Appendix B provides further information on the LU/LC assessment. This assessment verifies that the watershed consists predominantly of cropland and rangeland with little development. Table 2 illustrates the land use types in the watershed and their relative percentage of the watershed that each land use covers. Figure 3 shows the distribution of these land use types.

Ecoregions

Ecoregions describe land areas that contain similar ecosystems and both quality and quantity of natural resources (Griffith 2004). Ecoregions have been delineated into 4 separate levels; level I is the most unrefined classification while level IV is the most refined. The Buck Creek watershed is located in Level III Ecoregions 26 and 27, the Southwestern Tablelands and Central Great Plains and is further subdivided into Level IV Ecoregions 26b, 26c and 27h (Figure 4). Ecoregion 26b is described as the "Flat Tablelands and Valleys" and consists of relatively level land between prominent buttes, badlands and escarpments of the tablelands. Soils in Ecoregion 26b are typically fine sandy loams or silt loams and are typically tilled to produce cotton, sorghum and wheat. Fragments of remaining native prairie exist within these areas and usually consist of mixed mid-grasses if they have not been subjected to heavy grazing pressure. Areas of native prairie that have seen intensive grazing are generally dominated by shorter grasses, cacti and shrubs. This ecoregion can typically be found in the Buck Creek watershed southeast of the creek in parts of Childress and Collingsworth counties. Ecoregion 26c is named the "Caprock Canyons, Badlands and Breaks" and encompasses the broken edges of the eastern fringe of the High Plains. Numerous geological layers are exposed in this region and are easily distinguished by the stark differences in red and white colors. Brush is the dominant vegetation throughout the region, which includes the far western portion of the watershed. Ecoregion 27h, the "Red Prairie," consists of gently rolling prairies that support grassland and cultivated agriculture. This region typically receives more pre-

Table 2. Land use acreages by county, the Buck Creek watershed and as a percentage of the watershed

Acres per Land Use per County					
Land Use Category	Childress	Collingsworth	Donley	Total Acres in Watershed	Percent of Wateshed
Open Water	79	218	45	342.3	0.18%
Developed, High Intensity	1,587	2,212	121	3,919.5	2.09%
Developed, Low Intensity	135	17	110	261.8	0.14%
Developed, Medium Intensity	1	0	1	2.6	0.00%
Barren Land	16	9	49	73.5	0.04%
Mixed Forest	1,245	808	212	2,265.1	1.21%
Riparian Forest	753	1,130	238	2,120.4	1.13%
Rangeland	35,273	40,583	11,284	87,140.2	46.53%
Cultivated Land	18,221	46,435	2,680	67,335.5	35.96%
Managed Pasture	8,660	10,089	5,060	23,809.0	12.71%
Total	**65,970**	**101,500**	**19,800**	**187,270**	**100.00%**

numbers derived from 2008 SSL Land Use data

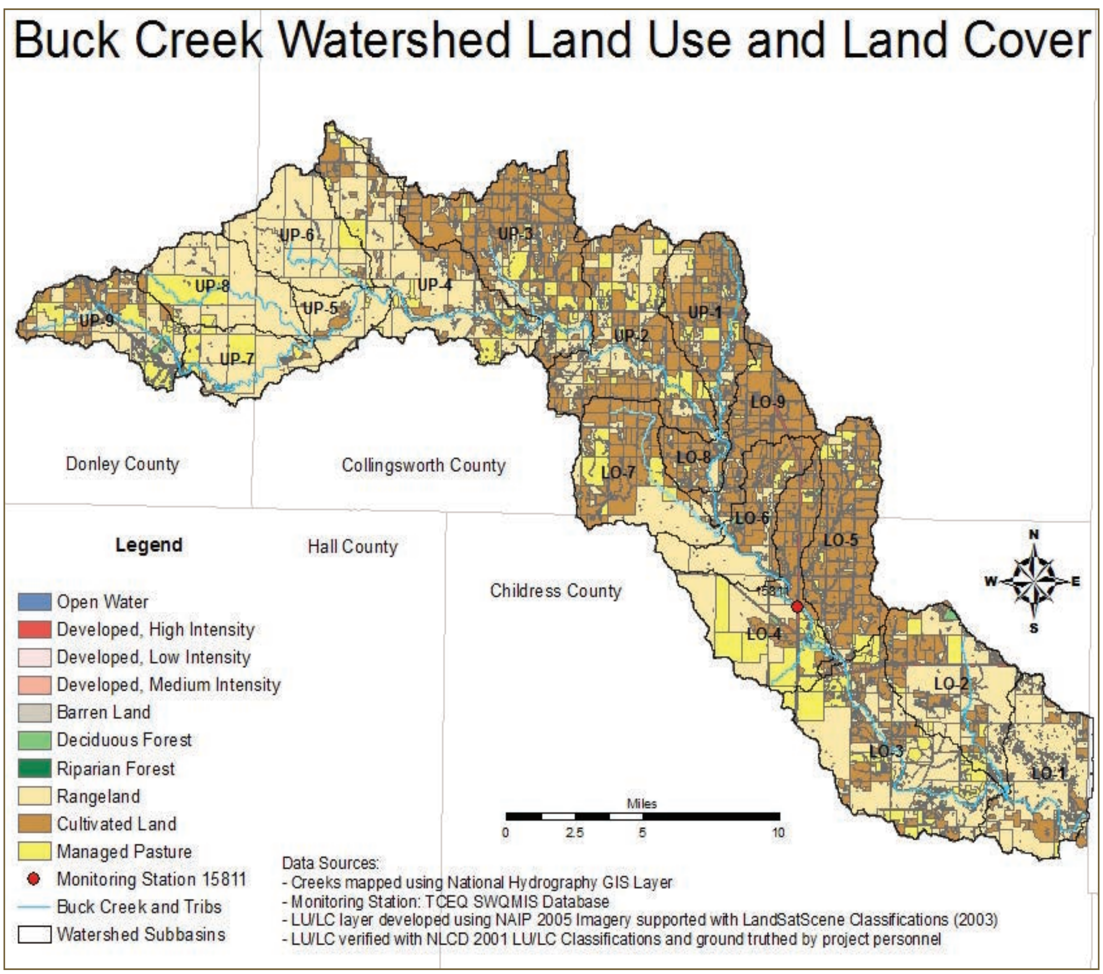


Figure 3. Buck Creek LU/LC classifications

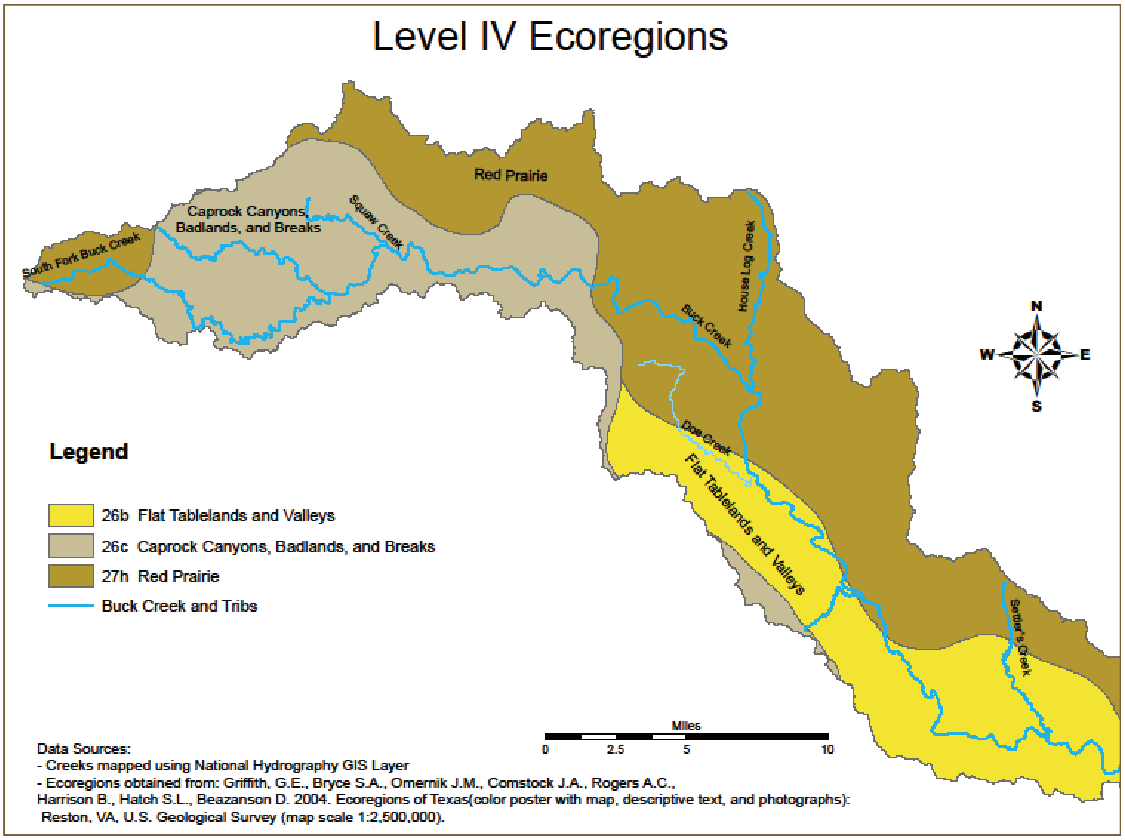


Figure 4. Level IV Ecoregions in the Buck Creek Watershed

cipitation than the High Plains and supports midgrass or shortgrass prairies. In areas that are not cultivated, grasses include little bluestem, Texas wintergrass, white tridens, Texas cupgrass, sideoats grama and curlymesquite (www.epa.gov/wed/pages/ecoregions/tx_eco.htm). The portion of the watershed northeast of the creek and southeast of Wellington is included in this ecoregion.

Climate

The watershed falls within the Continental Steppe sub-climate in Donley and west Collingsworth counties, while the eastern portion of Collingsworth and Childress counties have a subtropical, sub-humid climate. Both sub-climates are characterized by hot, low humidity summers with moderate high daytime temperatures and cool evenings. Winter months are subject to rapid temperature drops from cold fronts moving in from the Rocky Mountains and High Plains. Cold fronts have been known to produce temperature changes of 50 to 60 degrees (°F) within several hours and up to 40-degree differentials in a matter of minutes. Mean annual temperature in the watershed is about 62°F, with average lows and highs of 29°F and 93°F, respectively (www.srh.noaa.gov/lub/). The prevailing wind is south-southwest in summer and is frequented by northwesterly winds moving in from the Rocky Mountains and the High Plains in the late fall to early spring months. The majority of rainfall occurs between April and September, mostly in the form of locally intense thunderstorms. Winter months are typically dry but have produced snowfalls of up to 10 inches. Total annual precipitation averaged 21 inches over the past 65 years. Annual pan evaporation for the watershed averaged about 65.5 inches over the past 50 years (www.twdb.state.tx.us/surfacewater/conditions/evaporation/index.asp).

Groundwater

Three aquifers, the Ogallala, Seymour and Blaine, underlie the Buck Creek watershed and supply the bulk of available groundwater (Figure 5). The Ogallala and Seymour aquifers are considered to be major aquifers and provide major sources of drinking and irrigation water across the High Plains of Texas. The Blaine aquifer is defined as a minor aquifer in Texas and largely provides irrigation water to highly salt-tolerant crops (Ashworth and Hopkins 1995).

Ogallala Aquifer

The Ogallala is the primary source of groundwater for all of the Texas High Plains. In Texas, the aquifer extends to all or part of 46 counties; outside of Texas, it reaches to 6 other states. While the Ogallala does provide considerable amounts of drinking water to communities in the High Plains, approximately 95% of water withdraws are for irrigation purposes. Water flow in the aquifer generally occurs in a southeasterly direction toward the eastern escarpment of the High Plains. The aquifer consists primarily of sand, gravel, clay and silts and can have a saturated thickness up to 600 ft thick. Wells drilled into areas of the aquifer dominated by coarse-grained material can yield up to 2,000 gallons per minute (gpm); average yield across the aquifer is closer to 500 gpm. Water quality is generally fresh with dissolved solids and chlorides increasing in the southern portions of the aquifer; concentrations of these constituents typically exceed 1,000 milligrams per liter (mg/L) in the Southern High Plains (Ashworth and Hopkins 1995). A recent U.S. Geological Survey (USGS) assessment of the aquifer noted that water quality in the Ogallala is generally within United States Environmental Protection Agency (EPA)'s drinking water standards; however, there are isolated locations where elevated levels of both naturally occurring and man-made pollutants such as chloride, fluoride, manganese, dissolved solids, arsenic, nitrate and uranium can exceed these standards (Gurda et al. 2009). Aquifer recharge typically occurs at about 1 inch per year and has been greatly exceeded by pumping rates since the post-World War II expansion of irrigation. Some areas have experienced water level declines of more than 100 ft and water levels continue to decline (Ashworth and Hopkins 1995).

Seymour Aquifer

The Seymour is a major aquifer located primarily in north central Texas and a few Panhandle counties (Figure 5). The aquifer is fresh to slightly saline and typically less than 100 ft thick, although a few isolated locations in Collingsworth County may exceed 300 ft. This aquifer is primarily under water table conditions but artesian conditions may occur where the water-bearing zone is overlain by clay. Approximately 3 million acre-feet (ac-ft) of water are available based on 75% of the total storage with

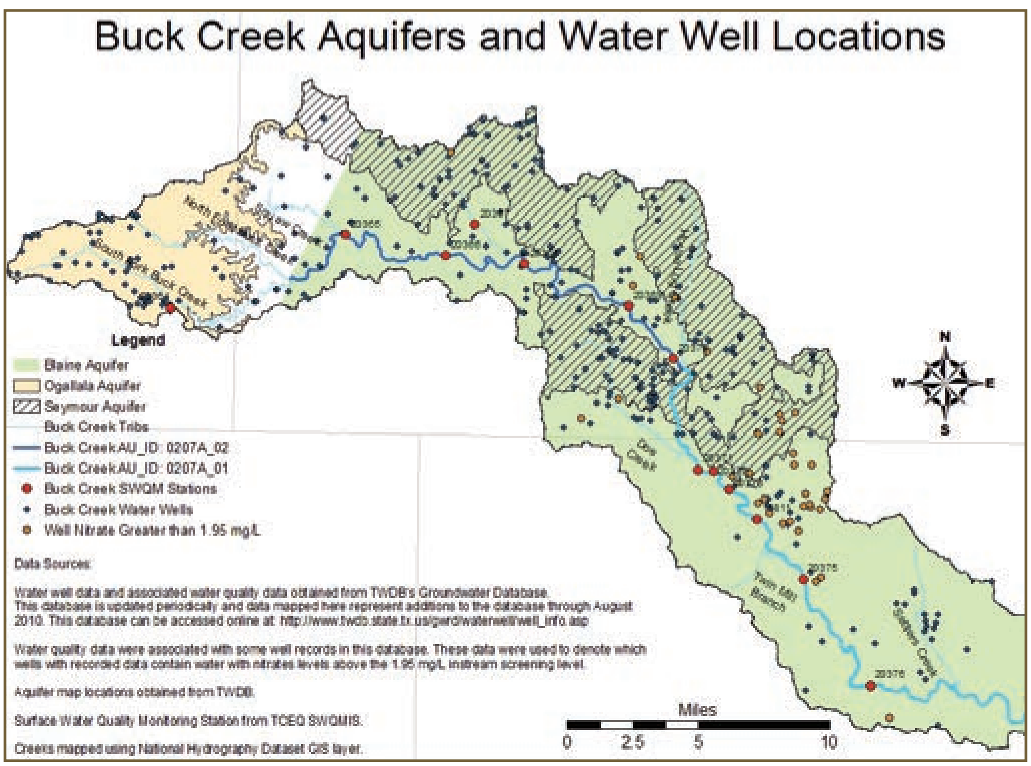


Figure 5. Aquifers and associated wells in the Buck Creek watershed

annual effective recharge to the aquifer of approximately 215,000 ac-ft or 5% of the average annual precipitation that falls on the aquifer outcrop. No significant long-term water-level declines have occurred in irrigated areas supplied by groundwater from the Seymour Aquifer. The lower, more permeable part of the aquifer produces the greatest amount of water with well capacities in the area averaging about 300 gpm. Yields typically range from less than 100 gpm to as much as 1,300 gpm. Salinity has increased in many heavily pumped areas and the aquifer's water is now unsuitable for domestic uses in some cases. In some portions of the Seymour outside of the Buck Creek watershed, brine pollution from oilfield activities has resulted in localized contamination of formerly fresh groundwater and surface water supplies. Due to the lack of oil and gas production in the watershed, this contamination is not directly influential to Buck Creek. Nitrate concentrations in the aquifer are the primary concern for many people. Nitrates in excess of the primary drinking water standard of 10 mg/L are widespread in Seymour groundwater (Ashworth and Hopkins 1995).

Blaine Aquifer

The Blaine is a minor aquifer located in portions of the Panhandle and rolling plains of Texas and Oklahoma. The aquifer varies from approximately 10 to 300 ft thick and is typically poor in quality. Concentration of dissolved solids increases with depth and in natural discharge areas at the surface, but contains water with total dissolved solids (TDS) of less than 10,000 mg/L. The primary uses are for watering livestock and irrigation of highly salt-tolerant crops with well yields varying from about 1 gpm to more than 1,500 gpm (Ashworth and Hopkins 1995). The Blaine Aquifer is also known to have nitrate levels that commonly exceed the drinking water standard of 10 mg/L.

Surface Water

Surface water resources in the watershed can be described as limited at best. Buck Creek is the major water feature in the watershed and it is an intermittent stream, which partly dries up during the summer months or extended dry periods. Buck Creek begins as a North Fork and South Fork of Buck Creek in Eastern Donley County and join in the western portion of Collingsworth County (Figure 6). Tributaries of Buck Creek are ephemeral streams and typically only flow following rainfall events or during prolonged wet periods. Intense spring and summer thunderstorms occurring from April through September provide the majority of runoff for Buck Creek. Runoff from these events produces a rapid rise and subsequent fall in stream levels and rarely results in long-term flooding. Winter storms are generally lower intensity, longer duration storms that do not produce significant runoff and do not cause any major fluctuation in streamflow. Named tributaries of Buck Creek include Doe Creek, House Log Creek, Settlers Creek, Squaw Creek and Twin Mill Branch (TWRI 2008).

Springs located throughout the watershed also provide small amounts of surface water and contribute to the flow in Buck Creek. Named springs documented by Brune (1975 and 1981) include Baggett Springs, Buck Springs in Collingsworth County, Buck Springs in Donley County, O'Hair Springs, Roscoe Springs, Savage Springs and Settler's Springs. Figure 6 illustrates approximate locations of these springs plotted based on Brune's described location of each spring. At the time of Brune's assessments, Buck Springs in Donley County and Savage Springs had ceased flowing. Brune also noted that widespread irrigation had markedly influenced the level of flow present in many of these springs and causes some to periodically cease flowing. Additionally, flow from these springs is noted to be

absorbed into deep sands present along much of Buck Creek's length. The Blaine and Seymour aquifers underlie Buck Creek and the watershed and contribute base flow to the creek. In times of normal rainfall, these aquifers remain at a level that supports return flow into the creek but during periods of drought, spring flow ceases in many locations. Irrigation in the spring and summer months influences groundwater flow into the creek. Field observations have noted that streamflow gradually diminishes and in many places dries up following the onset of irrigation and the development of vegetative growth in the riparian zone. Once irrigation is terminated in the fall and vegetation along the creek becomes dormant, streamflow typically returns within 1 or 2 months (TWRI 2008).

Numerous small stock ponds are located throughout the watershed, but none are very large. No surface water reservoirs in the watershed are used as a municipal water supply. In total, 342 ac of surface water exist in the watershed and account for approximately 0.18% of the total watershed area according to the land use analysis conducted in 2008 by the SSL.

Groundwater Connectivity to Buck Creek

Buck Creek exhibits clear connections to groundwater across the watershed. Texas A&M AgriLife Research and Extension Center at Vernon (AgriLife Vernon) personnel have been in the field routinely since 2004 and have observed numerous and repeated occurrences of Buck Creek's connection to regional groundwater. The influence of nearby irrigation wells on the creek is the most obvious connection. When irrigation begins in the spring, the creek goes dry except in the wettest of years. Similarly, once irrigation ceases in the fall, water slowly reappears in the creek. Several springs have been observed discharging water into the creek channel during wet periods but typically cease in dry periods. Water flowing in the creek has also been observed disappearing underground as it moves down the stream channel. The specific source of the water observed entering Buck Creek is not known and will require specialized evaluation such as an isotope tracer analysis to determine.

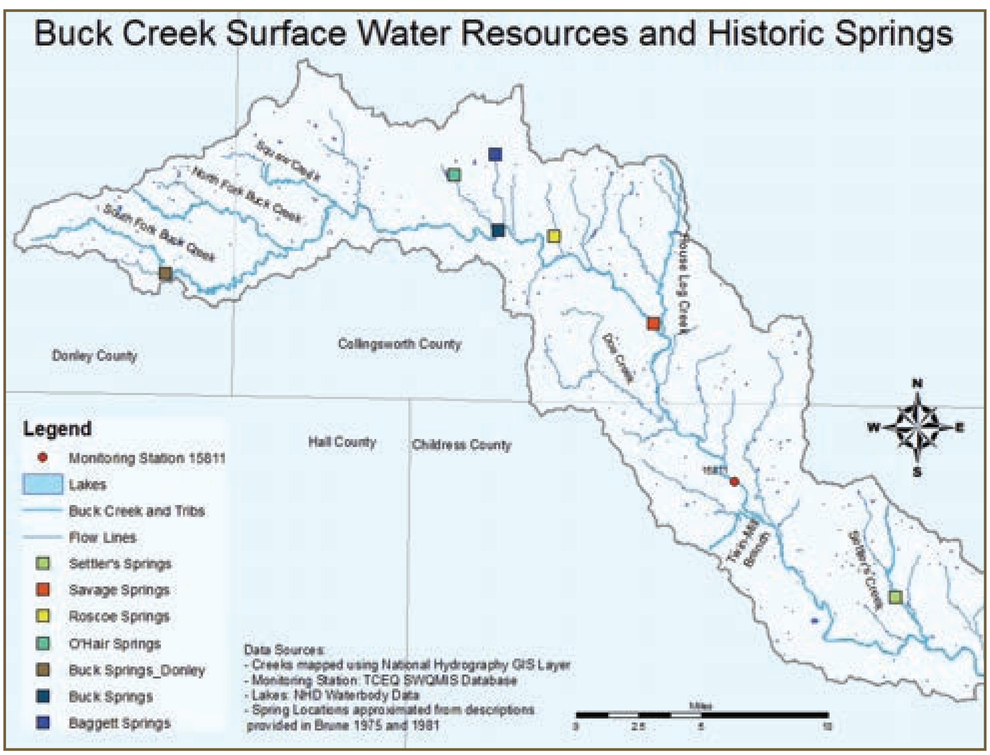
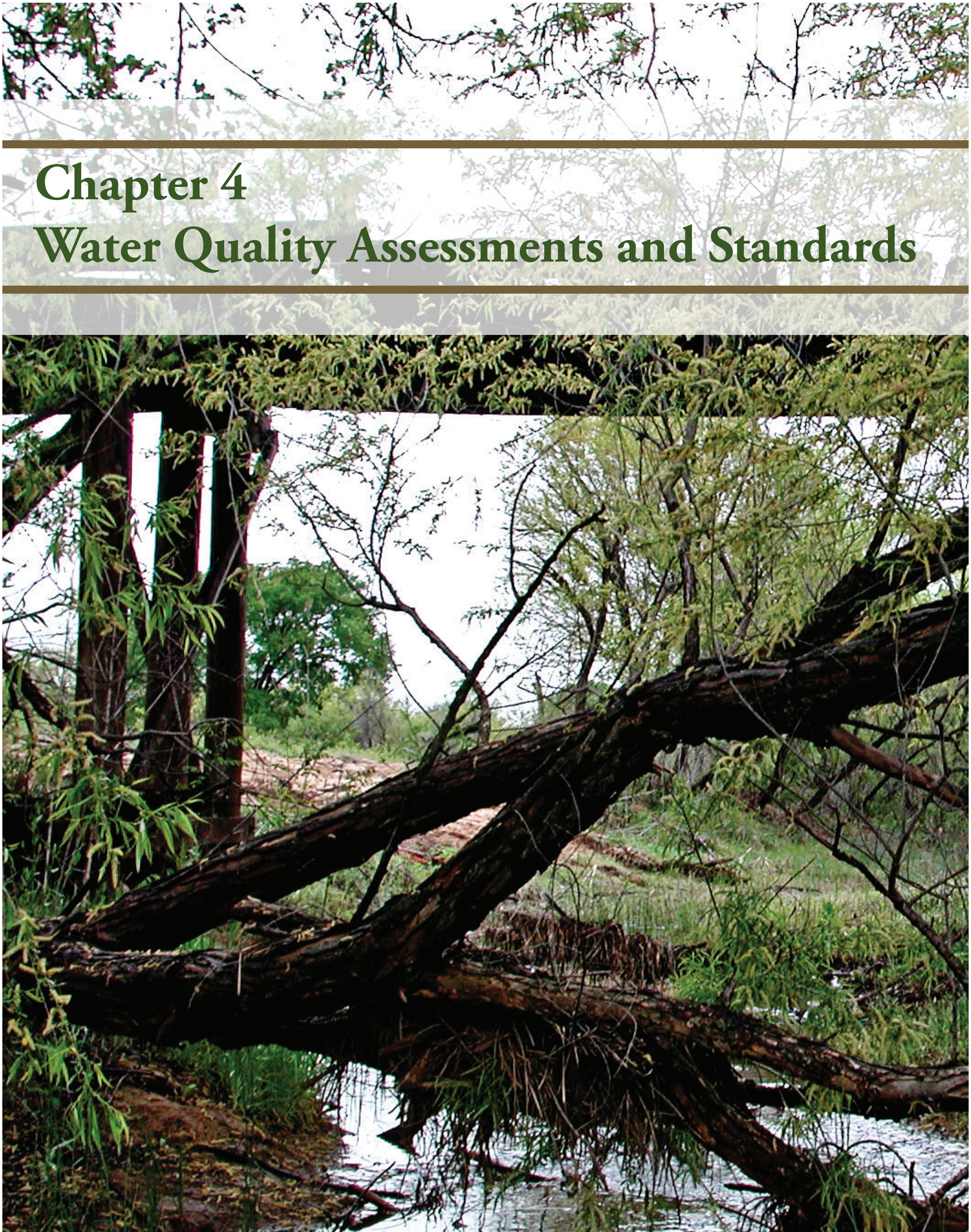


Figure 6. Surface water resources of the Buck Creek watershed

Chapter 4
Water Quality Assessments and Standards



Water Quality Assessments in Buck Creek

Water quality monitoring in the Buck Creek watershed began in December 1997 when the Red River Authority of Texas (RRA) began monitoring the creek at the US 83 road crossing (Figure 7). This monitoring location was designated by TCEQ as Station 15811 and incorporated into TCEQ's water quality monitoring network. For assessment purposes, TCEQ assigned Buck Creek as segment 0207A and designated it an unclassified segment. TCEQ assigns water bodies as either classified or unclassified with the classified segments individually defined in the *Texas Surface Water Quality Standards* (TCEQ 2004a). Applicable water quality standards designated for unclassified water bodies are defined by TCEQ (2010b) according to the flow type exhibited by the given stream. Water quality standards specific to Buck Creek are discussed in detail later in this chapter.

Assessment Units

Following designation, water bodies are provided with a written description of the segment and are further subdivided into assessment units (AU). According to TCEQ (2010b), "AUs are the smallest geographic area of use support reported in the water body assessment." Buck Creek was defined by TCEQ as extending "from the Oklahoma state line east of Childress in Childress County to the upstream perennial portion of the stream west of Wellington in Collingsworth County" (TCEQ 2008a). Initially, Buck Creek was defined by one AU, 0207A_01, which extends from "Oklahoma state line to House Log Creek" (TCEQ 2008a). In 2010, Buck Creek was further subdivided into 2 AUs. AU 0207A_01 remained unchanged and AU 0207A_02 was added encompassing the creek from "House Log Creek to the upper end of the segment" (TCEQ 2010a). During water body assessments, data collected from a designated AU are used to assess

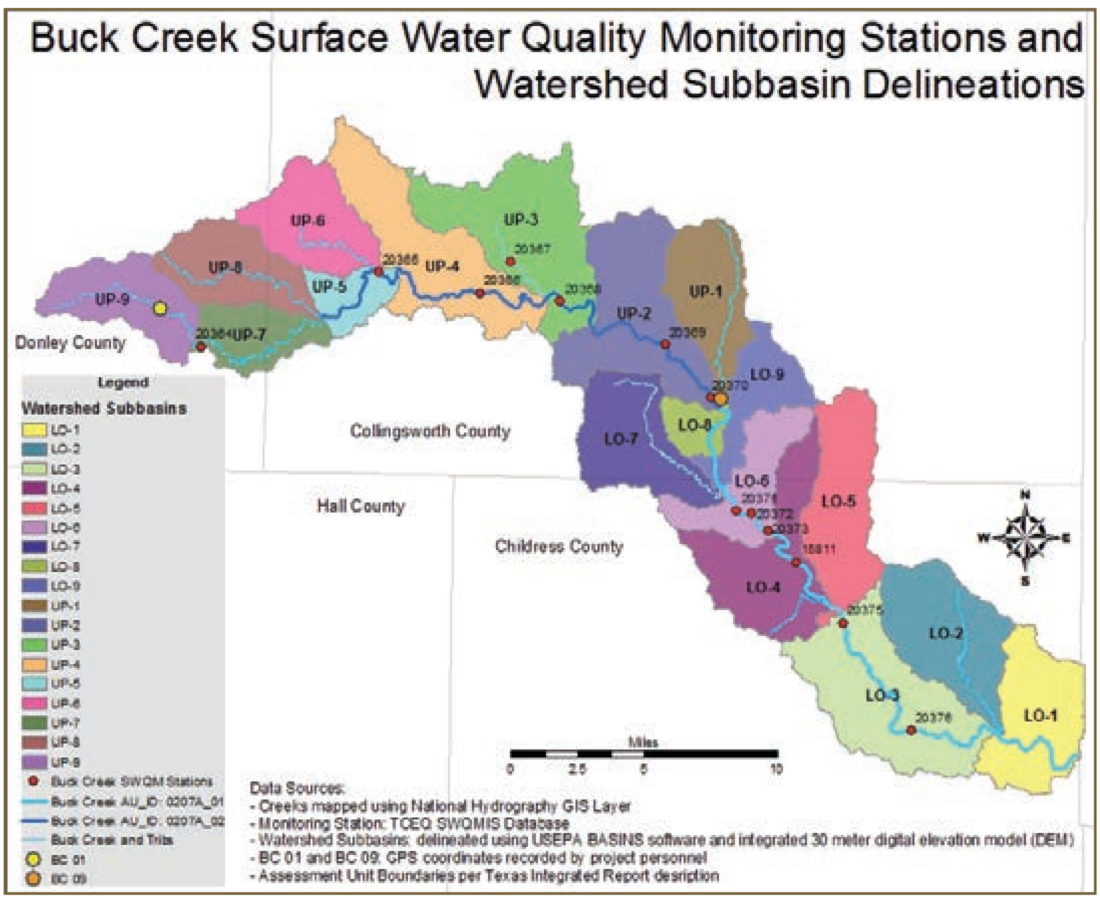


Figure 7. Buck Creek surface water quality monitoring stations and watershed subbasin delineations

each AU independently of other AUs in that segment. Figure 7 illustrates the locations of these AUs as defined by their respective descriptions and the mapped extent of the stream segment.

Designated Uses

TCEQ defines designated uses for all classified and unclassified streams in Texas and these designated uses dictate what 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 requires that Buck Creek supports limited aquatic life use, recreation use and general use. 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, benthic macroinvertebrate and fish community. In Buck Creek, DO is the only parameter evaluated. 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 Buck Creek 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 TDS; additionally, concerns for meeting the general use are also quantified with screening levels for nutrients and chlorophyll-a (TCEQ 2010b).

Water Body Assessment

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

Monitoring Station Locations

During the process of developing this WPP, AgriLife Vernon personnel established 14 additional monitoring stations within the Buck Creek watershed with ease of access the primary consideration. Water was never found at 2 of these sites and as such, they were never fully established as monitoring stations in TCEQ's water quality monitoring network. Table 3 and Figure 7 present descriptive information about each of these monitoring stations and a visualization of where these sites 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 were selected for further pollutant source analysis. In AU 0207A_01, Station 15811 was selected as the index site. This station has been monitored since 1997 and has the longest and most extensive data record of all monitoring stations in the Buck Creek watershed. Station 20368 was selected as the index site in AU 0207A_02. This station is located in the middle portion of the upper AU. Each of these index sites is located at the approximate midpoint of their respective AU. Ideally, these index sites would be situated at the lower end of the AU; however, each of these has the best available data set within that AU, thus chosen as the index site. These locations are denoted in Table 3 and Figure 7.

Watershed Subbasins

Watershed subbasins illustrated in Figure 7 were also delineated within the Buck Creek 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 subbasins as well, helping to identify what areas of the watershed are contributing to pollutant loading at a specific monitoring station. These watershed subbasins are also used in pre-

Table 3. Buck Creek sampling sites

Project Site No.	TCEQ Monitoring Station No.	General Station Location & Description	County	TCEQ Assessment Unit Station is Located In	Watershed Subbasin Station is Located In	Period Monitored	
						May 2004 - May 2007	October 2007 - September 2009
BC 01	*	South Fork Buck Creek Upstream of CR 28	Donley	N/A	UP-9	√	
BC 02	20364	South Fork Buck Creek Upstream of CR 29 & CR Z Intersection	Donley	N/A	UP-7	√	
BC 03	20365	Buck Creek Upstream of CR 40	Collingsworth	0207A_02	UP-5	√	√
BC 04	20366	Buck Creek Upstream of FM 1547	Collingsworth	0207A_02	UP-4	√	
BC 05	20367	Unnamed Tributary of Buck Creek upstream of FM 1056	Collingsworth	N/A	UP-3	√	√
BC 06	20368	Buck Creek Upstream of CR 110	Collingsworth	0207A_02	UP-3	√	√
BC 07	20369	Buck Creek Upstream of FM 338	Collingsworth	0207A_02	UP-2	√	
BC 08	20370	Buck Creek Upstream of CR SA	Collingsworth	0207A_02	UP-2	√	
BC 09	*	House Log Creek Upstream of CR SA	Collingsworth	N/A	UP-1	√	
BC 10A	20371	Buck Creek on Private Property off SH 256	Childress	0207A_01	LO-6	√	√
BC 10B	20372	Buck Creek on Private Property off SH 256	Childress	0207A_01	LO-6	√	
BC 10C	20373	Buck Creek on Private Property off SH 256	Childress	0207A_01	LO-6	√	√
BC 11	15811	Buck Creek Upstream of US 83	Childress	0207A_01	LO-4	√	√
BC 12	20375	Buck Creek Upstream of US 62	Childress	0207A_01	LO-3	√	
BC 13	20376	Buck Creek Upstream of CR 19	Childress	0207A_01	LO-3	√	√

* These sites were never designated a TCEQ Monitoring Station No. AgriLife Vernon personnel did not observe or record streamflow at either site during the course of intensive monitoring

N/A: These sites are located outside of the defined Assessment Unit areas

Monitoring stations highlighted in green are selected index sites in the two designated Aus

dictive computer-based modeling that estimates which subbasins have the highest bacteria loading potential, thus prioritizing them for future management implementation. This modeling will be discussed in detail later in Chapter 7.

Texas Surface Water Quality Standards for Buck Creek

TCEQ designates applicable water quality standards for each water body assessed in the state as outlined in the Texas Surface Water Quality Standards (TSWQS). As an unclassified segment, Buck Creek does not have established water body specific water quality standards. Instead, it must meet applicable surface water quality standards outlined in the *2010 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ 2010b). As an intermittent stream with perennial pools, Buck Creek is required to support aquatic life use, recreation use and general use standards. 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 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 (2010b), 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 15th to October 15th. The critical period of the year is July 1st to September 30th and is the portion of the year when minimum streamflow, 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 as a measure 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 unit (cfu)/100 mL must be maintained (TAC §307.7, TCEQ 2010b); 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 7-year period are required. Once 10 samples have been collected, the geometric mean of all samples collected within the most recent 7-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 exclusion applies for a 24-hour period following the last measured or estimated determination that extreme hydrologic conditions exist (TAC §307.9). Additionally, a low flow exemption applies if flows are recorded below the 7-day, 2-year low flow value, which has been determined to be 0.0 cubic feet per second (cfs) for Buck Creek (TCEQ 2010b). This essentially means that if no flow exists, bacteria samples will not be considered for assessment purposes.

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 85th percentile as the 'screening level' (Table 4). 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.

E. coli on a petri dish. Photo credit: Kay Ledbetter, Texas A&M AgriLife Communications

Historic Water Quality

For the purposes of this report, historic water quality data are considered to be only the data collected by RRA. It first collected and reported water quality data on Buck Creek above the US 83 Hwy crossing in Childress County at Station 15811 (Figure 7) to TCEQ in December 1997. Data were collected periodically at this site by RRA through 2005 and submitted to TCEQ for water body assessment purposes. Table 5 shows summary statistics of water quality parameters sampled by RRA over the 9-year period sampled and indicates if a water quality impairment or concern exists based on this data set. A portion of the *E. coli* data collected by RRA and presented here resulted in Buck Creek's original listing on the *2000 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 4. Nutrient screening levels applicable to fresh water streams

Nutrient	Screening Level
NH3-N (Ammonia)	0.33 mg/L
NO3-N (Nitrate)	1.95 mg/L
OP (Orthophosphorous)	0.37 mg/L
TP (Total Phosphorous)	0.69 mg/L
Chl a (Chlorophyll a)	14.1 µg/L

The data presented in Table 5 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 DO are applicable standards for Buck Creek. Nitrates and chlorophyll-a are also evaluated for identifying concerns. All other parameters are informational in nature and help to illustrate the general water quality of the creek as well as some of its physical characteristics.

Table 5. Historic water quality data collected by the RRA at TCEQ Site 15811 above US 83 from 1997 to 2005**

Parameter	# of Samples	Minimum	Maximum	Average	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired / Concern ††
Water Temp (°C)	32	5.02	31.30			33.9 maximum	
Flow (cfs)	30	0.00	35.34	6.33			
Specific Conductance (µmhos/cm@25°C)	32	2,025.00	3,764.00	3,337.56		30,030 annual average	
Dissolved Oxygen (mg/L)	32	6.53	13.50	10.39		3.0/2.0 (grab avg/min)[x]	
pH (standard units)	32	7.60	8.20			6.5 - 9.0 range	
Ammonia Nitrogen (mg/L)	17	0.02	0.11	0.05		*0.33 (>20% exceedance)*[Y]	
Nitrate Nitrogen (mg/L)	17	0.75	6.33	3.28		*1.95 (>20% exceedance)*[Y]	concern
Total Phosphorus (mg/L)	9	0.02	0.14	0.07		*0.69 (>20% exceedance)*[Y]	
Orthophosphorus(mg/L)	14	0.03	0.21	0.08		*0.37 (>20% exceedance)*[Y]	
Chloride (mg/L)	17	167.90	2,900.00	440.34		37,000 annual average	
Sulfate (mg/L)	17	771.00	2,110.00	1,705.77		5,300 annual average	
Fecal Coliform (colonies/100 mL)	30	38.00	1,600.00		301.54	200 geometric mean	impaired
E. coli (cfu/100 mL)	30	27.00	1,400.00		262.08	126 geometric mean	impaired
Chlorophyll-a (µg/L)	10	3.10	10.00	5.28		*14.1 (>20% exceedance)*[Y]	
Total Dissolved Solids (mg/L)	21	0.01	3,464.00	2,504.22		46,200 annual average	

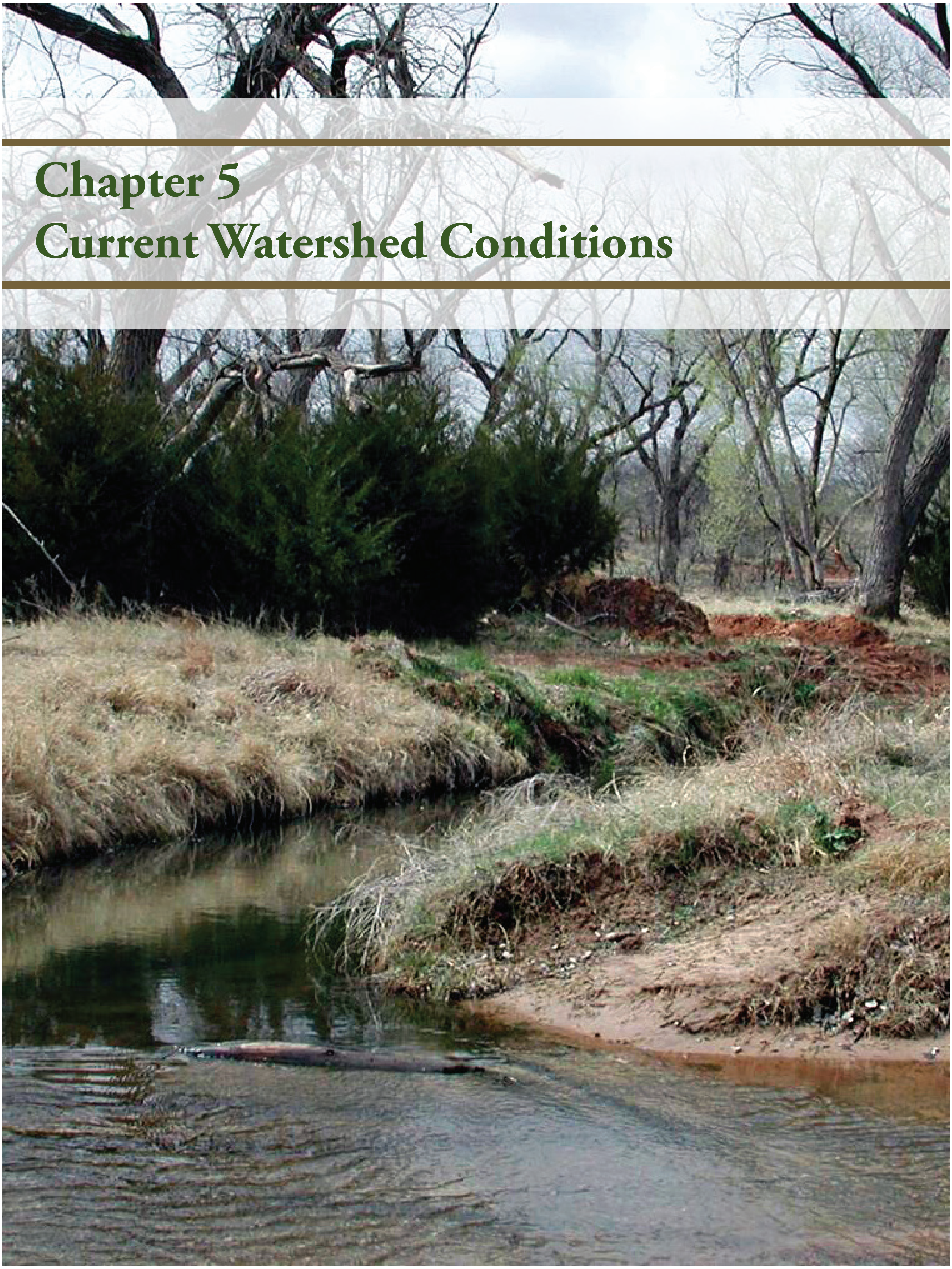
** data as collected and reported for TCEQ Monitoring Site 15811 (BC 11) at the US 83 crossing

†† the listed impairment / concern is according to the *2008 303(d) List*

[x] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards

[Y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

Chapter 5
Current Watershed Conditions



Demographics

The Buck Creek watershed includes parts of 3 towns/communities within its boundaries. The town of Hedley, located in Donley County, lies partially within the watershed near the headwaters of Buck Creek. The town of Wellington and the community of Quail, both in Collingsworth County, are also partially included in the watershed. Table 6 shows the populations of these 3 towns and counties partially within the watershed as reported in the 2000 and 2010 Censuses and the associated population changes. Populations in the watershed mirror a national trend of people migrating toward urban areas.

The populations within the counties are employed in a variety of industries/professions. In all 3 counties, the education, health and social service industry employs the largest portion of the working population, according to the 2000 Census (2010 Census data for this demographic has not yet been released). Agricultural-related employment ranks 2nd in Collingsworth and Donley counties but drops to 4th in Childress County. Retail trade, public administration and construction-related jobs round out the top 5 areas of employment for the tri-county area (Table 7). Median incomes and unemployment rates in the 3 counties are also reported in the table and are relatively similar.

Agricultural Production

Commodities produced in the watershed have remained relatively unchanged since modern settlement began. Cattle, cotton, forage, grain sorghum and wheat are still

Table 6. Population figures for the cities/communities partially in the Buck Creek watershed

City / Community	2000 Census	2010 Census	% Change	Persons Per Household
Wellington	2,275	2,189	-3.8%	N/A
Quail	33	19	-42.4%	N/A
Hedley	379	329	-13.2%	N/A
County				
Childress	7,688	7,041	-8.4%	2.47
Collingsworth	3,206	3,057	-4.6%	2.41
Donley	3,828	3,677	-3.9%	2.36

Source: U.S. Census Bureau

Table 7. Employment trends as reported in the 2000 Census in counties partially in the Buck Creek watershed

Most Common Industry of Employment	% Employed by County Childress	Collingsworth	Donley
Educational, health and social services	22.1	23.4	23.8
Retail trade	15.1	9.0	13.4
Public administration	13.2	7.1	7.0
Agriculture	12.0	20.3	17.1
Construction	7.7	6.6	5.0
Income Estimates			
Median Household Income	$27,457	$25,437	$29,006
Employment Status			
% of population 16yrs & over in work force unemployed	4.4	3.1	4.4

Source: U.S. Census Bureau

the top commodities produced as they were in the early 20th century. Peanuts have recently become a popular crop in the watershed and many acres have been converted to peanut production. Although production levels have varied significantly throughout the years, agriculture remains the top industry in these areas and is responsible for a significant impact to the local economy in each county. Table 8 illustrates countywide production numbers reported in the 2007 Census of Agriculture for each of the 3 counties that Buck Creek crosses. This countywide data serves as a starting point for landowners to determine appropriate watershed specific agricultural production values.

While numbers show typical production values for the area, they are not watershed specific and will not accurately represent existing conditions in the watershed. Developing appropriate animal population numbers is important because these numbers are critical in estimating pollutant loads in the watershed. Watershed partnership members provided local expertise needed to refine cattle estimates for the watershed as they felt the numbers presented below overestimated cattle numbers in the watershed because cattle that were in feed lots outside of the watershed but in the 3 counties were tallied. Using local knowledge, an average resident cattle population of 6,640 head was estimated for the watershed and this count does not include transient cattle housed at the livestock auction barn in Wellington or the feedlot near Hedley. This estimate is consistent with applying recommended NRCS stocking rates on rangeland and managed pastures. Other livestock populations were considered by watershed stakeholders to be minimal or nonexistent in the watershed, thus were not considered in estimating manageable pollutant loading to the watershed.

Irrigation Water Use

Water used for irrigation in and around Buck Creek is predominantly groundwater. One surface water permit does exist on Buck Creek, which grants the annual use of 38.5 ac-ft and was established with a priority date of April 5, 1954. The water right was originally used to irrigate 40

Table 8. County-wide agricultural production information 1997–2007 for all counties partly within the Buck Creek watershed

	Childress County			Collingsworth County			Donley County		
Farm Statistics and Production Value	**Year**			**Year**			**Year**		
	1997	2002	2007	1997	2002	2007	1997	2002	2007
Number of Farms	315	300	374	626	449	442	456	440	392
Land in Farms (ac.)	399,557	368,782	399,383	489,376	506,942	512,537	661,310	584,340	588,947
Average Farm Size (ac.)	1,268	1,229	1,068	782	1,129	1,160	1,450	1,328	1,502
Market Value of Production ($1,000s)	$20,084	$13,592	$25,899	$30,607	$34,224	$50,309	$93,009	$73,614	$85,815
% of Production Value (crops / livestock)	71 / 29	53 / 47	73 / 27	65 / 35	73 / 27	72/28	8 / 92	12 / 88	15 / 85
Inventory of Livestock (# head) and Crops Planted (acres)	**Year**			**Year**			**Year**		
	1997	2002	2007	1997	2002	2007	1997	2002	2007
Cattle and Calves	19,359	19,757	19,029	40,560	33,818	31,079	84,878	55,586	60,010
Horses and Ponies	280	303	361	698	662	492	741	970	655
Goats	n/a	203	218	345	82	161	n/a	n/a	421
Sheep and Lamb	n/a	n/a	n/a	303	n/a	43	75	n/a	n/a
Laying Hens	n/a	n/a	n/a	215	159	238	190	n/a	224
Hogs and Pigs	n/a	n/a	62	n/a	n/a	n/a	160	108	n/a
Bee Colonies	n/a	195	n/a	n/a	n/a	n/a	n/a	n/a	n/a
All Cotton	44,010	32,300	36,150	27,035	31,798	43,822	15,638	12,765	9,770
All Wheat	35,504	20,792	30,044	17,878	4,984	20,836	8,664	5,822	7,148
Forage/Hay	10,429	9,578	8,517	10,763	13,588	16,460	5,507	9,980	7,425
Grain Sorghum	n/a	1,144	3,452	11,427	1,688	4,534	2,284	1,742	1,209
Peanuts	2,788	1,271	n/a	24,582	39,080	17,120	3,111	5,267	5,085

Source: USDA National Agricultural Statistics Service: Census of Agriculture ac of farmland. The water right was re-issued September 25, 1987, but has since been inactive; however, the right still exists (www.tceq.state.tx.us/permitting/water_supply/water_rights/wr_databases.html).

Groundwater is a more common source of irrigation water used in the watershed. Table 9 shows trends in irrigation use between 1958 and 2000 for Childress, Collingsworth and Donley counties. Because these numbers include the entire county, they overestimate actual acres irrigated, water used and the number of wells that are located within the watershed but give a good view of how irrigation has varied over the last 50 years. Following the drilling of the first water well in the Panhandle during the 1880s, irrigation generally increased until the mid-1970s before slightly declining. Irrigation has resurged over the past 20 years and has eclipsed the mid-1970s irrigation levels in some cases. Satellite imagery from 2005 showed that there were 102 fields under center pivot irrigation within or partially within the Buck Creek watershed: 30 in Childress County, 70 in Collingsworth County and 2 in Donley County. This same satellite imagery also showed numerous other fields that appeared to be irrigated using some other form of irrigation method such as drip or furrow irrigation.

Wildlife and Feral Hogs

There are a variety of wildlife and wildlife habitats within the watershed. The watershed contains suitable habitat for open land, rangeland and riparian wildlife. These areas consist of cropland, pastures, meadows, brush and riparian corridors that provide cover and forage for a variety of species such as: quail, doves, badger, rabbits, pronghorn antelope, mule and white-tailed deer, lesser prairie chicken, wild turkey, coyotes, red fox, bobcats, prairie dogs, skunks, opossums, raccoons, songbirds, ducks, geese, crows, hawks and owls. Each of these species and other wildlife not listed here all contribute *E. coli* and nutrients

A wheat field near Buck Creek

Table 9. Irrigation water use 1958–2000 for the counties partially in the Buck Creek watershed

	Year									
	1958	**1964**	**1969**	**1974**	**1979**	**1984**	**1989**	**1994**	**2000**	**2004***
Childress	Water Source: Blaine and Seymour Aquifer									
Acres Irrigated	7,500	11,356	11,601	12,033	11,746	10,770	6,405	8,136	10,096	
Acre-Feet Used	12,499	17,261	8,903	9,383	9,747	10,002	5,829	6,941	7,890	10,681
# of Water Wells	91	137	142	145	150	130	135	100	210	
Acre-Foot/Acre	1.67	1.52	0.77	0.78	0.83	0.93	0.91	0.85	0.78	
Collingsworth	Water Source: Blaine and Seymour Aquifer									
Acres Irrigated	6,930	7,985	7,750	8,975	6,081	5,314	10,999	19,358	23,241	
Acre-Feet Used	6,803	6,469	5,084	17,640	2,882	5,884	12,934	29,905	24,503	57,475
# of Water Wells	54	100	130	144	143	136	168	220	301	
Acre-Foot/Acre	0.98	0.81	0.66	1.97	0.47	1.11	1.18	1.54	1.05	
Donley	Water Source: Ogallala Aquifer									
Acres Irrigated	3,460	12,600	16,679	18,663	17,128	11,795	23,560	15,864	22,212	
Acre-Feet Used	2,156	21,187	11,786	26,020	8,379	6,715	17,516	12,638	23,873	29,326
# of Water Wells	20	150	235	244	170	160	180	204	195	
Acre-Foot/Acre	0.62	1.68	0.71	1.39	0.49	0.57	0.74	0.80	1.07	

note: all irrigation water used is groundwater

Source: *Surveys of Irrigation in Texas.* Texas Water Developmnent Board Report 347

* data come from TWDB online database: http://www.twdb.state.tx.us/wushistorical/

to the watershed and are thus a source for a part of the overall *E. coli* and nutrient load. Species-specific *E. coli* production, fecal production and population estimates are not available for many of these species, thus making it impossible to quantify pollutant contributions or even reasonable estimates of pollutant contributions from each of these species.

Of wildlife present in the watershed, mule and white-tailed deer are the only species for which population surveys are conducted and for which daily fecal production data are available. Mule deer-specific fecal production rates were not found and were thus assumed to be the same as those of white-tailed deer. This information is also available for feral hogs. Using available information supplemented with watershed stakeholder survey data, project personnel developed watershed population estimates for these 3 species and associated animal densities. These numbers were approved by watershed stakeholders and descriptions of each population are provided in Table 10.

The Texas Parks and Wildlife Department (TPWD) conducts annual evaluations of mule and white-tailed deer within ecologically similar areas defined as resource management units (RMUs). RMUs are areas with similar soils, geology, physiography, vegetation types, climate, precipitation zones and, to a lesser extent, land use practices; TPWD biologist knowledge of the area was also considered in designating RMU boundaries. The Buck Creek watershed is located completely within RMU 30 and deer numbers derived for that RMU are largely applicable to the watershed. These estimates were derived using a spotlight, distance-sampling method for white-tails in the fall, and mule deer are sampled using a helicopter aerial survey method in the winter. Table 10 provides a summary of TPWD deer density estimates for RMU 30. Deer density estimates were discussed with partnership members including the TPWD area biologist, and the decision was made to use a portion of the density estimates rather than the 4-year average density when applying them in computer-based modeling. The modeled acres/animal presented in the table denotes the average density agreed upon by partnership members. In the case of white-tailed deer, the average of the 2007 and 2008 density estimates was considered the most appropriate while the 2009 estimate for mule deer was considered the best current representation of existing watershed populations. TPWD's regional biologist noted and agreed that these numbers are only estimates and many factors actually influence the

Table 10. Estimated densities for selected wild animals in the Buck Creek watershed

TPWD Survey Estimates Year and Acres per Animal					4-Year Average (acres/ animal)	Selected Density Estimate (acres/ animal)	Modeled Density Estimate (acres/ animal)+	Estimated Watershed Population (density applied to selected LU/LC) *
	2006	2007	2008	2009				
White-tailed Deer	74.44	51.02	29.06	22.25	44.19	40.04	36	**4,153**
	2006	2007	2008	2009				
Mule Deer	137.73	125.38	160.97	92.46	129.14	92.46		**990**
Stakeholder Estimate								
Feral Hogs	Hog density estimate is based on watershed stakeholder estimates				25	25	25	**7,310**

* white-tailed deer densities were applied to cultivated land, rangeland, mixed forests, riparian forests and managed pastures to

* Feral Hog habitat is considered to be barren land, cultivated land, rangeland, mixed forests, riparian forests and managed pastures

* Mule deer densities were applied to rangeland to achieve the population estimate.

\+ For modeling purposes, the white-tailed and mule deer populations were combined due to lack of fecal production and fecal bacteria density data for the individual species

true number of animals in a watershed at any given point in time. Using the agreed upon modeled acres per animal listed in the table and applying them evenly across the watershed, project personnel calculated the estimated watershed population for each species by dividing the total number of acres within the watershed expected to be used by wild animals (cultivated, mixed forest, managed pasture, rangeland and riparian forest land covers/ land uses) by the average acres/animal.

Feral hogs, an invasive species and not considered as wildlife, have established a significant population in the watershed. Although the exact number of feral hogs in the watershed is not known, numerous sources of information from watershed stakeholders were considered when estimating a feral hog population for the watershed. Estimated feral hog densities from other portions of Texas (Reidy 2007) were discussed with partnership members; however, reported densities from other areas were thought to be lower than those in Buck Creek. Considering average annual rainfall and habitat resources in Buck Creek and comparing them to those reported by Reidy (2007) as well as Wagner and Moench (2009), partnership members arrived at 25 ac/animal as an appropriate, watershed-specific, feral hog estimate. Feral hogs are known to generally inhabit white-tailed deer ranges, have very few natural predators and prefer bottomlands when available but also do well in drought prone areas (Taylor 2003). Despite feral hogs' preference to bottomlands, damage they have caused to pastures, rangeland and cropland has been verified throughout the watershed. Partnership members requested that the average hog density rate be applied evenly across the entire watershed to produce an appropriate feral hog population estimate across the watershed. This approach is consistent with the application of the feral hog density described in Wagner and Moench (2009). Computer-based modeling used this population estimate but then applied the population within a 300 ft buffer of all flowlines as noted in the USGS's National Hydrography Database (NHD) when prioritizing watershed subbasins for potential bacteria loading from feral hogs.

Oil and Gas Production

According to the Railroad Commission of Texas (RRC), there are no producing or abandoned oil or gas wells within the Buck Creek watershed. Collingsworth County has about 350 producing wells, but they are all north of the Salt Fork of the Red River. Childress and Donley counties have a combined total of 11 producing wells. As reported in RRC's online GIS map viewer, there are 24 recorded "dry holes" (wells drilled that did not produce) within the watershed; only 7 of these are documented as being plugged (Figure 8). Further information from RRC

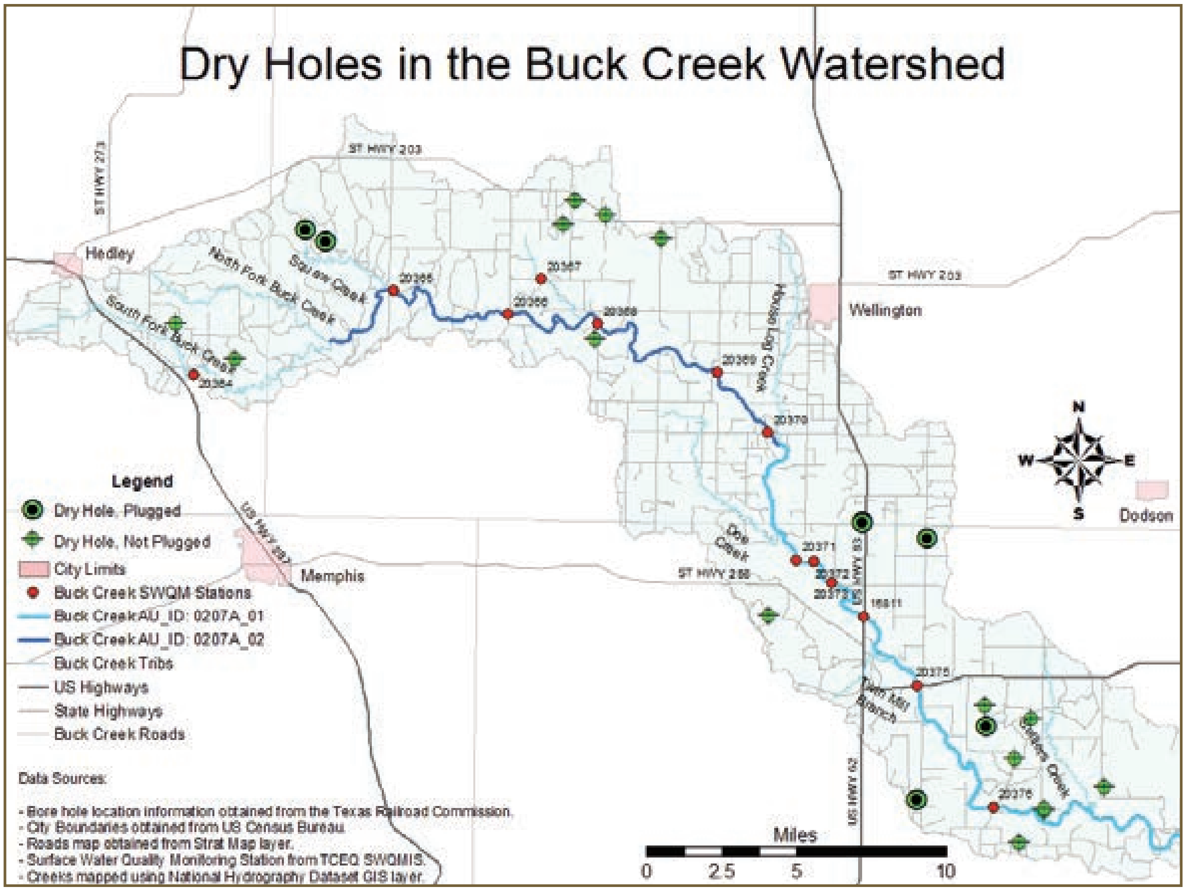


Figure 8. Dry holes from oil and gas activity in the Buck Creek watershed

indicated that the plugging status of these other wells is not known and no information on efforts to plug these known dry holes could be found. Landowners engaged in developing this WPP indicated that these "dry holes" were not problematic; therefore, no action was desired.

Current Water Quality

Beginning in May 2004, data collection and monitoring was conducted by AgriLife Vernon personnel as a part of the *Bacterial Monitoring for the Buck Creek Watershed* (TSSWCB project 03-07) and *Watershed Protection Plan Development for Buck Creek* (TSSWCB project 06-11) projects funded by TSSWCB with EPA Clean Water Act Section 319(h) funding. The *Bacterial Monitoring for the Buck Creek Watershed* project was conducted to initially assess the water quality in Buck Creek and determine the need for additional action. This project ultimately spawned the *Watershed Protection Plan Development for Buck Creek* project. Table 11 illustrates sampling locations, the range of dates that data were collected at each site, parameters monitored and the entity that collected the data. Data described in this table were used in the development of the Buck Creek WPP.

Water Quality Findings

Monitoring in Buck Creek was initiated with a primary objective of obtaining sufficient *E. coli* data from multiple locations to make a scientifically sound decision about the bacteria impairment of the water body. Once it was determined that elevated *E. coli* levels do periodically exist in Buck Creek, the focus of the monitoring shifted to aid in targeting future management efforts. To accomplish these objectives, project personnel implemented a routine sampling schedule to collect samples every other week over a 3-year period (May 2004–May 2007) at the monitoring sites described in Tables 3 and 11. This approach generated representative data during wet and dry conditions and across all seasons. With the shift in monitoring objectives, a more focused sampling regime

was implemented in October 2007. At this point, sampling was reduced to 6 sites (denoted in Table 3) and a monthly sampling frequency was implemented and continued through September 2009. It should be noted that the last samples were collected in July 2009 because of drought conditions. Brief findings from these projects are presented below; a more in-depth water quality analysis is presented later in Chapter 8.

Bacteria

Throughout the course of these studies, data confirmed that monitored *E. coli* levels in the creek are periodically elevated above the designated TSWQS of 126 cfu/100 mL. The majority of these high *E. coli* levels occur in isolated cases during and after runoff producing storm events. There are other instances when under normal flow conditions, *E. coli* levels are elevated as well. Despite the periodic exceedances of the *E. coli* standard, the geometric means of the data collected at these sites (Table 12 and 14) are well within current TSWQS at almost all monitoring sites. Further, when aggregating the data to the AU level and only considering routine sampling data as TCEQ does in its water body assessments, both AUs are well within the state's standards. In fact, in TCEQ's 2010 water body assessment, Buck Creek has been identified as fully supporting its contact recreation standard, and as such the creek has been recommended for removal from the 303(d) List.

Flow

Instantaneous flow measurements and field observations illustrate a wide range of flow rates in Buck Creek as well as the prevalent connections with underlying groundwater reservoirs. Following storm events since 1997, flow has been recorded as high as 158.16 cfs and has likely been higher than that due to the inability to record flow during and immediately after each storm event. The lack of a USGS gaging station on the creek severely hampers the available record of flow for the creek and the ability to know how high flows on the creek can be. Spatial and temporal variations in flow are a constant in Buck Creek and are illustrated clearly in the flow record and through field observations. Spatially, a storm event monitored on May 7, 2007 illustrates the stark variability in flows from along the length of the creek. On that date, a large rain event produced measured flows of 36.54 and 158.16 cfs at Stations 20369 and 20370 respectively. Approximately 5.4 mi downstream at Station 20371, streamflow was measured at 2.31 cfs illustrating the dynamic nature of flows in Buck Creek on relatively small spatial scales. Each of these measurements was taken within 3 hours of each other. This is only one example of drastic decreases in measured streamflows from upstream to downstream sites; however, this general decreasing trend in flow has always been seen in the available flow data.

Additionally, Buck Creek exhibits clear connections to underlying groundwater resources. During the dormant season for plant growth (approximately November–April), the presence of water in the creek is almost constant except in the driest years. Once plant growth and subsequent irrigation of nearby cropland begins in the spring, water levels in the creek decline until the creek completely dries up in many locations. During the irrigation season (May–October), water is usually only observed in the creek following runoff-producing storm events. Isolated locations on the creek do maintain pools of water year round, but flow in these pools is nonexistent. This annual fluctuation in flow has been verified through the extensive monitoring conducted on the creek and countless field observations. Table 12 further illustrates Buck Creek's flow dynamic. Lack of flow during the warmer months of the year drastically reduces the chance that people will use these waters for recreational uses such as swimming and fishing.

Nitrates

Elevated nitrate levels in Buck Creek were first listed as a water quality concern in the *2008 Texas Water Quality Inventory.* The draft of this report was released in the summer of 2007 and prompted the inclusion of nitrate in monitoring into AgriLife Research's analysis schedule in November 2007 conducted through the *Watershed Protection Plan Development for Buck Creek* project (TSSWCB project 06-11). As a result, a limited data set of 46 nitrate concentration measurements was obtained from Buck Creek (Table 12). Although nitrate sampling was limited, data collected have sufficiently illustrated that the nitrates concern is well founded.

Elevated nitrate levels are also a primary concern in local groundwater. Both the Blaine and Seymour aquifers are known to harbor high nitrates across their extents. Nitrate levels in these aquifers have been reported to greatly exceed the 1.95 mg/L surface water screening level. Work conducted in Baylor, Fisher, Hall, Haskell, Knox, Wichita and Wilbarger counties illustrates that median nitrate levels exceed 10 mg/L (Hudak 2000). While these numbers are not specific to the Buck Creek watershed, local water quality data illustrate that elevated nitrate levels do exist in a portion of the watershed (Figure 5).

Evidence of surface water and groundwater connectivity in Buck Creek raises further concern of elevated nitrates instream. Data collection across varying flow regimes support the hypothesis that the primary source of nitrates in the watershed is likely groundwater contribution to the creek from the Blaine or Seymour aquifers (Figure 5). Average flow rate and nitrate concentrations illustrated in Figure 9 suggest that the influence of groundwater, or baseflow, is the primary contributor of nitrates to Buck Creek. Throughout the course of water quality monitoring in Buck Creek, flow has been observed to be disjointed. The creek is usually dry downstream of Station 20368 and does not surface again until just upstream of Station 20371, some 15 mi downstream. Monitoring trips to Stations 20369 and 20370 affirmed this observation as water was only present during 17 of 160 monitoring events during the monitoring period.

Approximately 0.75 mi downstream of Station 20370, the Seymour Aquifer crosses underneath Buck Creek and is potentially the source of groundwater returning to the creek upstream of Station 20371 and could be the source of the high nitrate levels observed. The Blaine Aquifer also underlies all but the upper reaches of the watershed and is a potential contributor of baseflow/spring flow. Station 20371 is also down-gradient from the bulk of irrigation wells in the watershed and often goes dry when irrigation begins. This further supports the hypothesis that groundwater contributions to the creek are a primary contributor of nitrates to the creek. Before this hypothesis can be proven though, additional data are needed.

Table 11. Monitoring record and parameters available at each monitoring site

Project Site No.	TCEQ Monitorin	General Station Location & Description	Date Range for Available Data	Parameters Monitored**	Collecting Entity
BC 01	*	South Fork Buck Creek Upstream of CR 28	N/A	N/A	N/A
BC 02	20364	South Fork Buck Creek Upstream of CR 29 & CR Z Intersection	05/2004 - 05/2007	Field, *E.coli*	AgriLife
BC 03	20365	Buck Creek Upstream of CR 40	05/2004 - 07/2009	Field, *E.coli*, N, Flow rate	AgriLife
BC 04	20366	Buck Creek Upstream of FM 1547	05/2004 - 12/2007	Field, *E.coli*	AgriLife
BC 05	20367	Unnamed Tributary of Buck Creek upstream of FM 1056	05/2004 - 07/2009	Field, *E.coli*, N, Flow rate	AgriLife
BC 06	20368	Buck Creek Upstream of CR 110	05/2004 - 07/2009	Field, *E.coli*, N, Flow rate	AgriLife
BC 07	20369	Buck Creek Upstream of FM 338	05/2004 - 05/2007	Field, *E.coli*	AgriLife
BC 08	20370	Buck Creek Upstream of CR SA	05/2004 - 05/2007	Field, *E.coli*	AgriLife
BC 09	*	House Log Creek Upstream of CR SA	N/A	N/A	N/A
BC 10A	20371	Buck Creek on Private Property off SH 256	05/2004 - 07/2009	Field, *E.coli*, N, Flow rate	AgriLife
BC 10B	20372	Buck Creek on Private Property off SH 256	05/2004 - 05/2007	Field, *E.coli*	AgriLife
BC 10C	20373	Buck Creek on Private Property off SH 256	05/2004 - 07/2009	Field, *E.coli*, N, Flow rate	AgriLife
BC 11	15811	Buck Creek Upstream of US 83	12/1997 - 07/2009	Field, *E.coli*, N, Flow rate	AgriLife, RRA
BC 12	20375	Buck Creek Upstream of US 62	05/2004 - 05/2007	Field, *E.coli*	AgriLife
BC 13	20376	Buck Creek Upstream of CR 19	05/2004 - 07/2009	Field, *E.coli*, N, Flow rate	AgriLife

* These sites were not designated with a TCEQ Monitoring Station ID as water was never present during sampling trips

**Field parameters monitored include: DO, pH, salinity, specific conductance and water temperature

N/A: Water was never present at these sites so no monitoring occurred

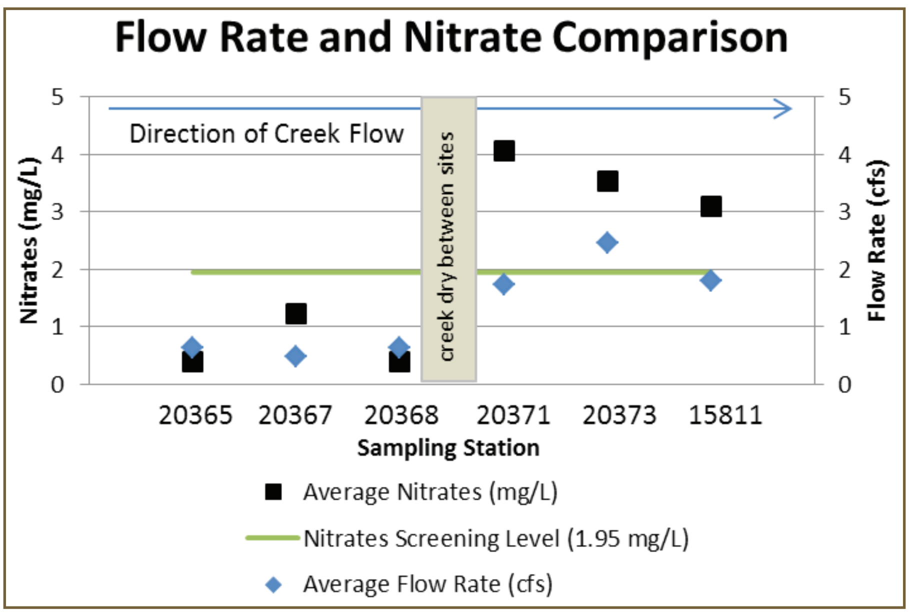


Figure 9. Average nitrate-N concentrations and flow rates for sampling sites in the Buck Creek watershed. All nitrate concentration and corresponding flow rate data available at each site were averaged for the purpose of this graphic.

Table 12. Summary of all data collected on Buck Creek between 05/2004 and 07/2009 by AgriLife Research*

TCEQ Station ID #	Number of Monitoring Events**	Parameters Monitored													
		Water Temp (°C)		Flow (cfs)		Specific Conductance (µmhos/cm)		Dissolved Oxygen (mg/L)		pH (standard units)		Nitrate N (mg/L)ᶲ		*E. coli* (cfu/100 mL)	
		Water Quality Standards (S) or Designated Screening Level (SL)†													
		S: max of 33.9°C		N/A: no standard or sceening level exists for flow		S: max avg. of 30,030 µmhos/cm		S: min avg 3.0 mg/L, min grab 2.0 mg/L		S: within 6.5 - 9.0 range		SL: >20% of samples exceed 1.95 mg/L		S: Geomean ≤ 126 cfu/100 mL	
		# of Readings	Max Reading	# of Readings	Range of Readings	# of Readings	Max Average	# of Readings	Grab avg / min	# of Readings	Range of Readings	# of Samples	% > 1.95	# of Samples	Geometric mean¥
20364	79	6	20.5	4	dry - 0.33	6	782.83	6	10.66 / 8.45	6	7.97 - 8.35	0	N/A	7	258.5
20365	111	77	30	18	0 - 17.40	61	2473.38	53	8.37 / 2.24	60	4.81 - 9.14	5	0	89	16.3
20366	83	64	27.45	6	dry - 17.04	63	2404.51	58	7.41 / 1.26	64	6.85 - 8.51	0	N/A	72	69.3
20367	112	63	25.1	21	dry - 2.88	62	779.83	52	10.56 / 2.33	64	5.98 - 9.07	7	14.28%	79	90.4
20368	112	39	31.56	19	dry - 19.49	39	1857.54	36	11.22 / 2.01	39	6.65 - 8.98	5	0	49	26.9
20369	81	11	26.1	4	dry - 36.54	11	1984.45	9	12.11 / 9.21	11	7.77 - 8.76	0	N/A	14	198.1
20370	79	5	27.37	4	dry - 158.16	5	1845.6	5	10.31 / 10.01	5	8.07 - 8.22	0	N/A	5	167.6
20371	113	84	29.4	19	0.52 - 4.21	84	3360.02	81	10.07 / 4.17	84	6.44 - 9.52	9	88.89%	98	137.5
20372	46	65	28.5	3	0.61 - 7.12	65	3375.12	63	9.88 / 4.15	65	7.22 - 8.26	0	N/A	70	173.2
20373	113	83	28.08	20	1.01 - 9.84	78	3368.88	75	10.57 / 4.49	78	5.04 - 8.93	9	88.89%	98	83.5
15811	115	66	32	22	dry - 10.68	65	3250.57	50	10.84 / 4.2	65	5.13 - 8.99	9	88.89%	82	25.3
20375	82	20	30.64	1	dry - 10.48	18	3307.89	17	9.73 / 4.23	18	6.2 - 8.49	0	N/A	19	99.8
20376	105	19	34.7	1	dry - 6.73	19	4086.42	15	9.49 / 3.62	19	7.6 - 8.31	2	0	25	79.4
Total # of Exceedances			2		N/A		0		0 / 2		3-May		25		5 sites
Total # of Samples		602		142		576		520		578		46		707	

* This table does not include any data collected by the RRA at site 15811

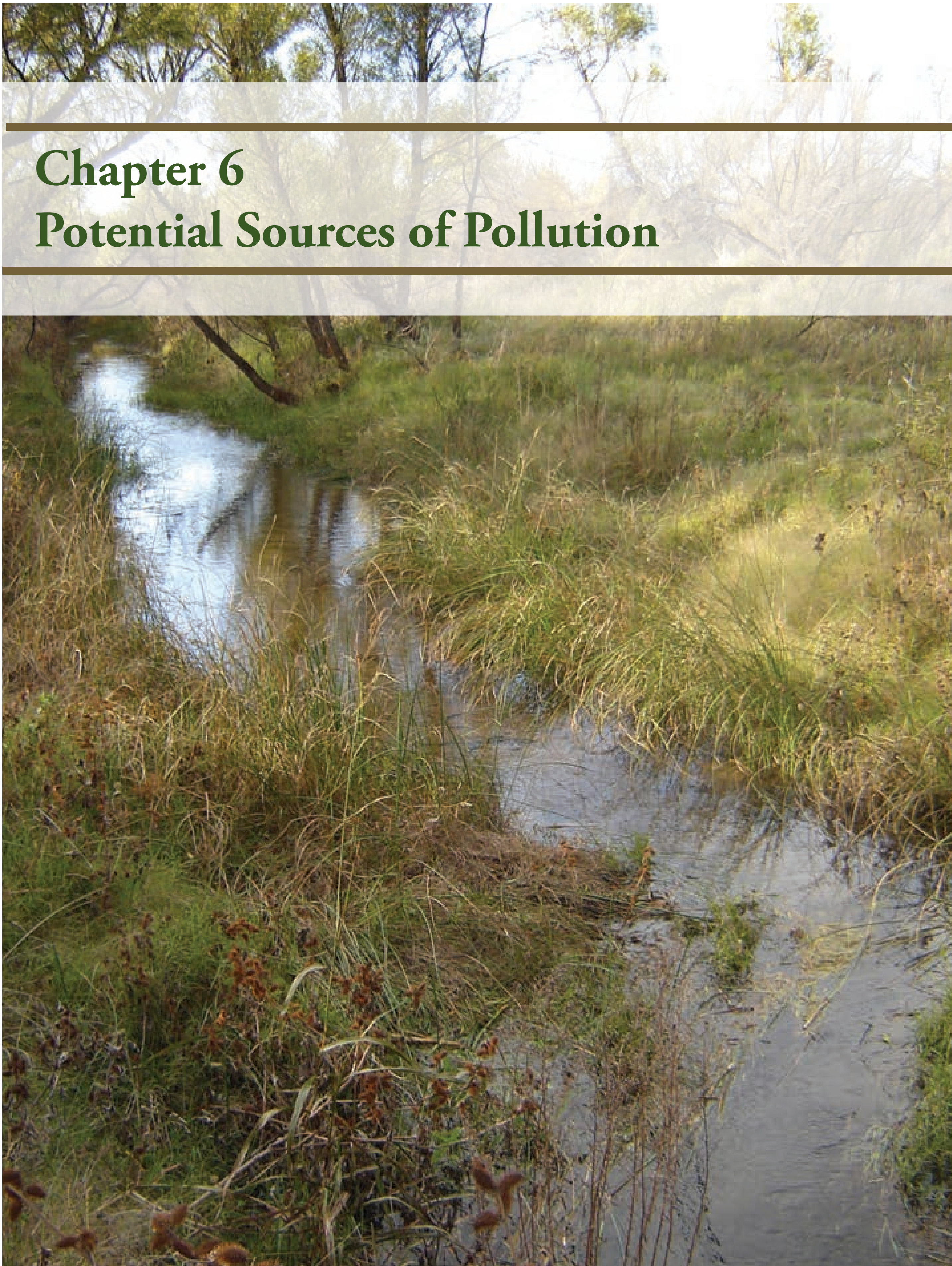
** The number of monitoring events denotes the number of times an attempt was made to monitor each individual sampling station. The variation in number depends on many factors including the sampling period, access to sites due to adverse conditions or other reasons

† Data presented here are raw data that are compared to the Texas Surface Water Quality Standards or Designated Screening Levels for informational purposes only. This data presentation is not equal to the state's bi-annual water quality assessment.

¥ Geometric means were calculated using all data (biased flow and routine) at each site

ᶲ none of the nitrate samples collected exceeded the 10 mg/L maximum contaminant limit established by USEPA for drinking water

Chapter 6
Potential Sources of Pollution



Through a sanitary source survey, AgriLife Vernon identified potential sources of pollution in the Buck Creek watershed. During many trips throughout the watershed, the Watershed Coordinator documented potential sources of pollution observed. The primary pollutants of concern in the Buck Creek watershed are bacteria, specifically *E. coli*, (Figure 10) and nitrates. Potential sources of pollution and source types are discussed in this chapter in further detail.

Point Source Pollution

Point source pollution is any type of pollution that can be traced back to a single point of origin, such as a wastewater treatment facility (WWTF), with a specific discharge point or a leaking underground gasoline storage tank. There are no known point source discharges in the Buck Creek watershed. The cities of Hedley and Wellington each maintain WWTFs but Wellington's WWTF is the only one that lies within the watershed. This WWTF is permitted to apply wastewater as irrigation water to agricultural land and therefore is considered to be zero discharge-permitted source. The WWTF is a permitted source of potential pollution to the Buck Creek watershed and as such will be described within the point source pollution category. It must be noted though that the WWTF is not technically a point source of pollution as it applies treated wastewater via a surface irrigation system to a 120-ac grass field. According to the facility's permit, they are not permitted to discharge any treated effluent to the waterways.

WWTF at Wellington

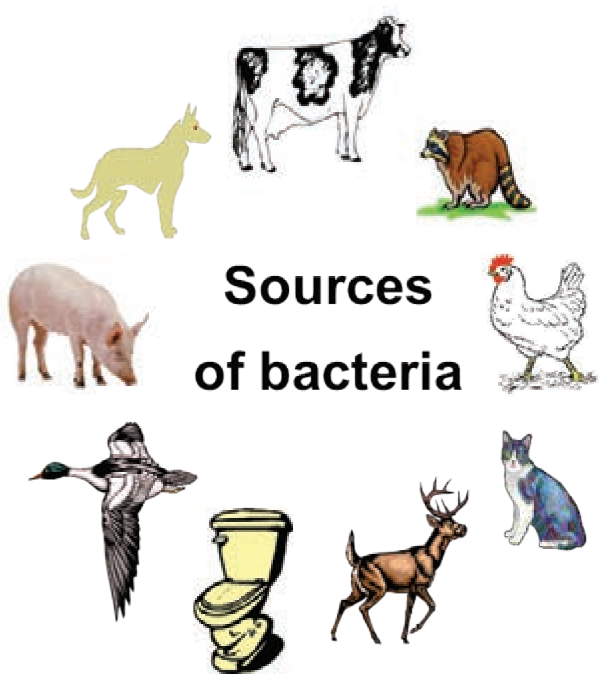


Figure 10. Potential sources of bacteria in all watersheds

City of Wellington WWTF

The City of Wellington operates and maintains a WWTF under permit WQ0010328001 from TCEQ, which permits the disposal of no more than 300,000 gallons of treated effluent per day via surface irrigation on 120 ac of nonpublic access agricultural lands continually cropped in Bermuda grass and Rye grass. This permit explicitly states that the permittee is not authorized to discharge any pollutants to waters of the state. The City of Wellington is the only municipality permitted to dispose of treated effluent into the Buck Creek watershed. This wastewater permit can be downloaded from TCEQ's Commissioners' Integrated Database at: www.tceq.texas.gov/agency/cc/cc_db.html. This permit requires the city to monitor flow of effluent leaving the plant 5 times per week, the 5-day Biochemical Oxygen Demand (BOD) once per month and pH once per month. Effluent limitations for the WWTF are 300,000 gallons daily average flow, 100 mg/L BOD and pH must remain within a range of 6.0 to 10.0 standard units. Bacteria concentration monitoring is not required at this WWTF since its treated effluent is surface applied as irrigation water. No complaints are on file for this facility with TCEQ Region 10 (TCEQ Personnel Communication September 2011).

Although the permit does not allow discharge into the waters of the State, the application fields are located within the watershed of Buck Creek. The treatment facility and the waste application field (WAF) are located in the drainage of House Log Creek, an ephemeral tributary of Buck Creek, about 0.5 mi southwest of the intersection of SH 338 and FM 1035 (Haskell St.) in Collingsworth County (Figure 11). While House Log Creek is a creek by name, in reality it is merely a conveyance that rarely transmits water except under extremely high rainfall events. During the intensive monitoring described in Chapter 5, not once was water observed flowing down House Log Creek. A monitoring station was originally planned for the creek at the County Road SA crossing 4.25 mi downstream of the WWTF WAF but samples were never collected due to the lack of water. Evidence of streamflow was noted on several occasions over the 6-year sampling period, but observations confirm that flow only occurs following substantial, runoff producing rain events.

The limited potential for House Log Creek to have water in it and convey water to Buck Creek combined with the surface application of treated effluent and the rapid degradation of viable bacteria when exposed to ultraviolet radiation produced by the sun minimizes potential for bacteria derived from the Wellington WWTF to reach Buck Creek.

Nonpoint Source Pollution

TCEQ and TSSWCB (2009) define nonpoint source (NPS) pollution as "all water pollution that does not come from point sources." NPS pollution occurs when precipitation flows off the land, roads, buildings and other landscape features and carries pollutants into drainage ditches, lakes, rivers, wetlands, coastal waters and underground water resources. NPS pollution includes but is not limited to polluted water from leaking or improperly

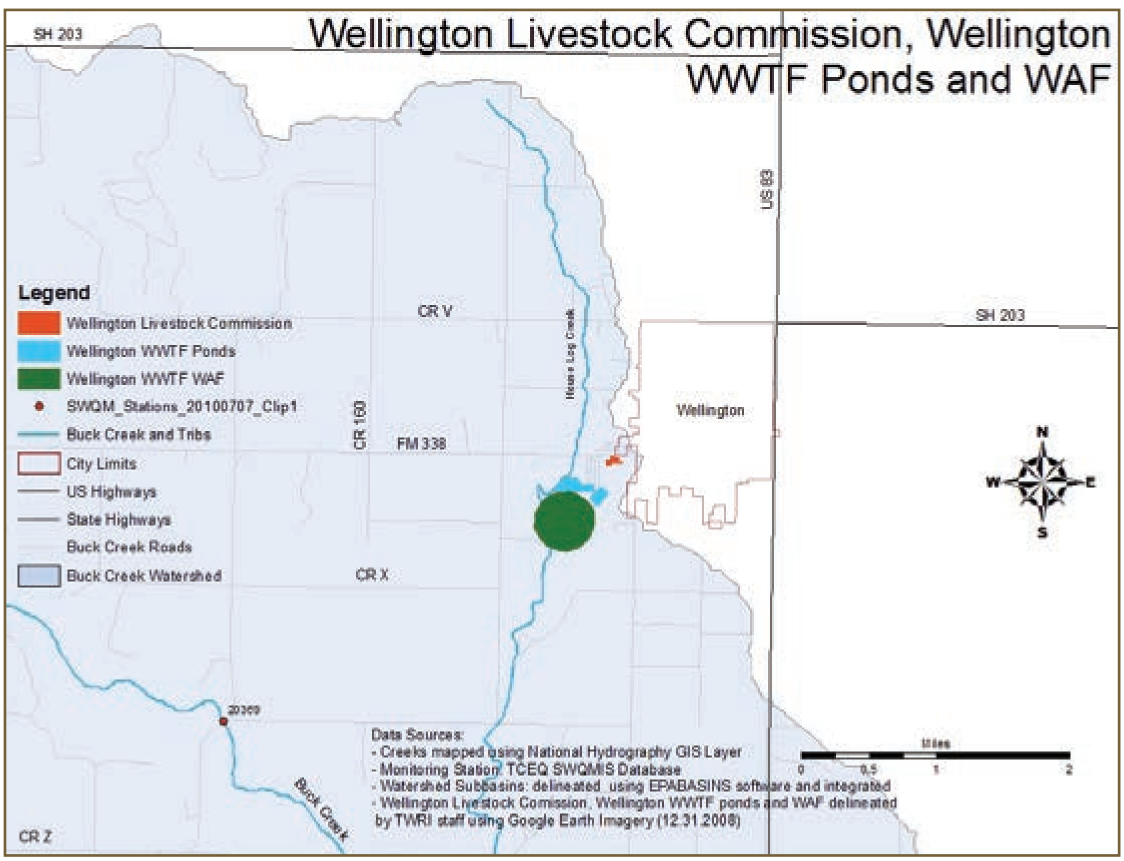


Figure 11. Locations of the Wellington Livestock Commission, Wellington WWTF Ponds and Wellington WWTF WAF in the Buck Creek watershed

functioning on-site sewage facilities (OSSFs), fertilizers, herbicides, pesticides, oil, grease, toxic chemicals, sediment, bacteria, nutrients and many other substances.

Agricultural NPS

Cropland, improved pasture and native rangeland are a potential source of pollution in the watershed. Fertilizers, herbicides and pesticides are commonly applied to cropland and pastures and under certain circumstances may be washed into Buck Creek during runoff events. These managed lands also provide a source of food and cover for livestock, wildlife and other nongame species that deposit fecal material as they use the land, resulting in potential *E. coli* and nutrient loading to the creek.

Wagner (2011) found that 'background' levels of *E. coli* in runoff from ungrazed landscapes such as cropland or rangeland can exceed the current *E. coli* water quality standard of 126 cfu/100 mL by an order of magnitude or more (i.e. 1,260 cfu/100 mL or more) and was typically in the range of 3,500 to 4,500 cfu/100 mL. Potential explanations of these elevated *E. coli* levels could be contributions from transient wildlife or even indigenous populations of *E. coli* in the soil; however, clear evidence to support either of these claims does not exist.

Concentrated Animal Feeding Operations

Concentrated animal feeding operations (CAFOs) and their byproducts (animal waste) are another potential NPS of pollution in the watershed. There is only 1 CAFO located in the watershed southeast of Hedley (Figure 12). TCEQ regulates all CAFOs in Texas and categorizes CAFOs as livestock feeding operations that: 1) feed stabled or confined animals for a total of 45 days or more in any 12-month period and the confinement area does not sustain crops, vegetation, forage growth or post-harvest residues in the normal growing season; and 2) meet certain animal number thresholds, such as maintaining more than 1,000 head of beef cattle or more than 700 head of dairy cattle. When disposed of, manure and wastewater generated from CAFOs must be used in an appropriate and beneficial manner.

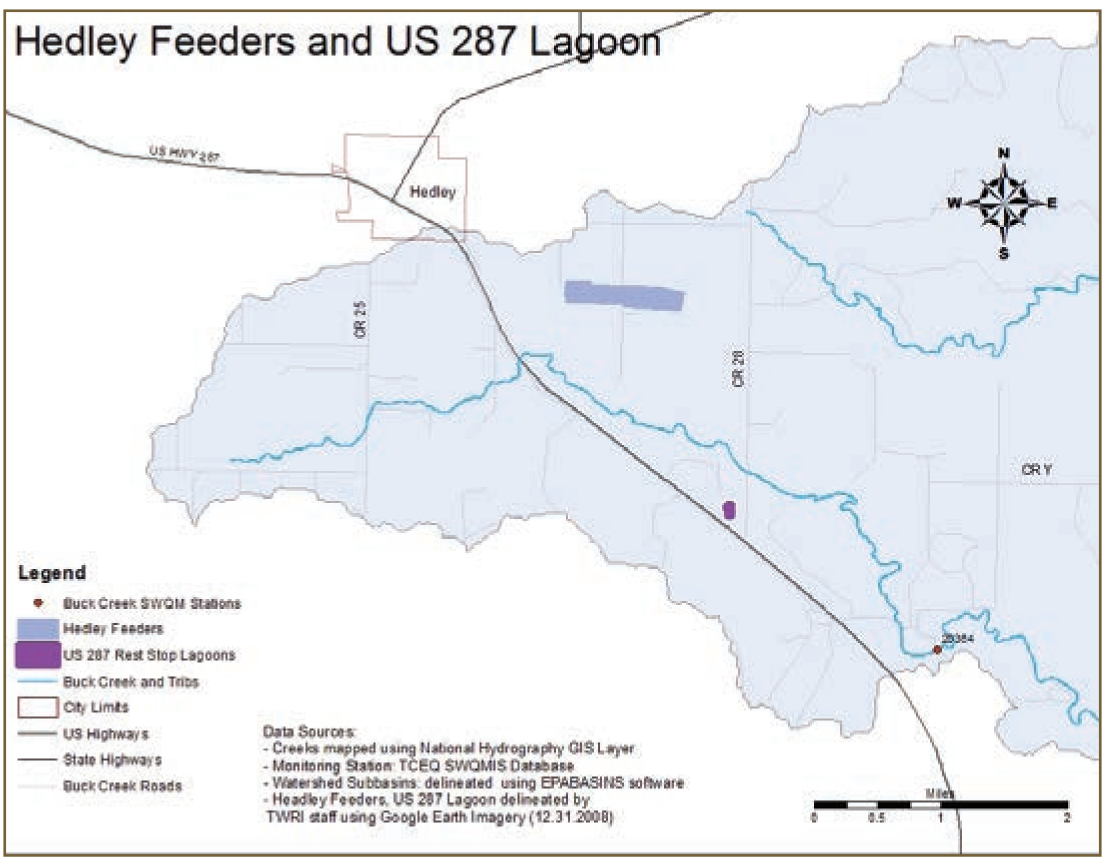


Figure 12. Potential pollutant sources in the Buck Creek watershed

Hedley Cattle Feedlot located southeast of Hedley is the only permitted CAFO in the Buck Creek watershed. This facility is permitted to house up to 14,900 head of cattle and operates on a total land management unit area of 330 ac. Of these, 98 ac are used to house cattle and drain into waste storage ponds. As described in the permit, the facility is estimated to produce 24,147 tons of solid waste annually and 47.07 ac-ft of liquid waste. This liquid waste is used onsite as irrigation water for crops and manure is typically sold to farmers locally either as compost or directly collected from pens.

Failing Septic Systems

Homesteads scattered throughout the watershed use septic systems, or OSSFs. Malfunctioning or improperly maintained OSSFs can be a potential source of bacteria and nutrients that enter Buck Creek. Failures can occur in many different ways including insufficient drain fields, broken pipes or overloading of the drain field resulting in surfacing and ponding of septage.

Local information on the number of OSSFs in watershed or 3-county area encompassing the watershed was not available. To estimate appropriate OSSF numbers, several methods were used and compared. The first method used information collected during the 1990 Census. These data indicate that 2,264 housing units in the 3-county area were equipped with OSSFs (www.factfinder.census.gov/). Using a calculation that multiplies the amount of each county within the watershed by the total number of OSSFs in each county, project personnel developed a percentage-based estimate of OSSFs within the Buck Creek watershed. The 2000 and 2010 Censuses did not collect OSSF data.

The second approach used was initially employed to verify the estimated number of OSSFs from 1990 Census, but was found to be more appropriate. In this approach, aerial photography from March 2008 available through Google Earth™ was used to physically count the number of potential OSSFs in the Buck Creek watershed. To accomplish this, project personnel visually identified buildings throughout the watershed and documented them with a place mark. These place marks were incorporated into a GIS (Figure 12) of the watershed for further analysis. Not all buildings in the watershed were considered to have OSSFs, as many of the outbuildings are barns or sheds providing shelter for animals. Assumptions made by project personnel when identifying potential OSSF locations included:

- Clusters of buildings were counted as 1 potential OSSF unless there were multiple structures that were clearly identifiable as dwellings
- Only buildings with well-defined roads or driveways were considered to have an OSSF
- Buildings located within the city limits of Hedley and Wellington AND in the watershed were not identified as having potential OSSFs as they are connected to the Hedley or Wellington WWTFs

Though this method is still an estimation, it provides additional insight into the location of potential OSSFs specifically in the Buck Creek watershed. Table 13 illustrates the number of OSSFs estimated to be in the watershed using the 2 methods described above. The method using the 2008 satellite imagery was chosen by the stakeholders to represent potential OSSFs in the Buck Creek watershed.

Table 13. Estimated number of OSSFs within the Buck Creek watershed

1990 Cenus Data					2008 Satellite Imagery*
County	Total # of households in Co.	# of OSSFs in Co.	% of Co. in watershed	Estimated # of OSSFs in the watershed	Potential OSSF Locations in the Watershed
Childress	3,046	554	14.35%	79	36
Collingsworth	1,952	608	17.13%	104	118
Donley	2,304	1,102	3.32%	37	34
Total	7,302	2,264		220	188

* This method was used to estimate the potential number of OSSFs in the Buck Creek watershed

Feral Hogs

Feral hogs are a non-native, invasive species rapidly expanding throughout Texas, inhabiting similar areas as white-tailed deer. They are especially fond of places where there is dense cover and food and water are readily available. They are also known to wallow in available water and mud holes. It is obvious that riparian corridors are prime habitat for feral hogs; therefore, they spend much of their time in or near the creek. This preference for riparian areas does not preclude their use of nonriparian areas. Reclusive by nature, feral hogs are somewhat of a nocturnal species. They typically remain in thick cover during the day and venture away from this cover at night into more open areas of the watershed such as cropland, pastures or rangeland. Feral hogs are significant contributors of pollutants to creeks and rivers across the state. Although feral hogs are known to eat their own feces, when they congregate in riparian areas and around water sources to drink and wallow, their fecal matter is deposited directly in streams polluting the State's water bodies with bacteria and nutrients. In addition, extensive rooting by feral hogs causes extreme erosion and soil loss. See Table 10 for the estimated feral hog population in the Buck Creek watershed.

Grazing Livestock

Free ranging livestock (predominantly cattle in Buck Creek) also serve as another potential source of NPS pollution. These animals range over large tracts of land, rather than being confined, and distribute their waste to a larger area. Availability of food and water is one of the influencing factors of how livestock as well as other animals will use their respective habitats and where their waste is distributed. Since Buck Creek serves as a water source for many animals within the watershed, it will cause many of the animals to spend at least some of their time within close proximity of the creek. The animals that use the creek as a water source are very likely to deposit fecal matter directly into or near the creek. Recent research in Central Texas has illustrated that cattle provided with no other water source spend an average of 25 minutes/animal unit/day within 4.6 m of the creek (Wagner 2011) and deposit fecal matter during this time. Fecal matter that is deposited within the watershed is likely to be transported to the creek during runoff events, which contributes to the total bacterial load in the water body.

Natural Nitrates

Natural sources of nitrate are also thought to be a major source of overall nitrate levels in the watershed. While not a major influence on the surface, nitrate stores in the soil and groundwater are substantial and could contribute to elevated nitrate levels seen in the creek. Work conducted near Buck Creek by Scanlon et al. (2008) and TCEQ (2008b) supports the theory that these high levels of nitrate are a result of natural sources. TCEQ (2008b) states that "High groundwater nitrate contamination prior to fertilization and irrigation in the Seymour aquifer, low to moderate fertilizer application rates, and low to moderate unsaturated zone nitrate accumulations indicate that high groundwater contamination may be related to natural nitrate sources prior to irrigation and to irrigation recycling." With the hypothesized interconnectivity of surface water and groundwater in the Buck Creek watershed, these natural sources of nitrate could be quite influential in monitored surface water nitrate levels.

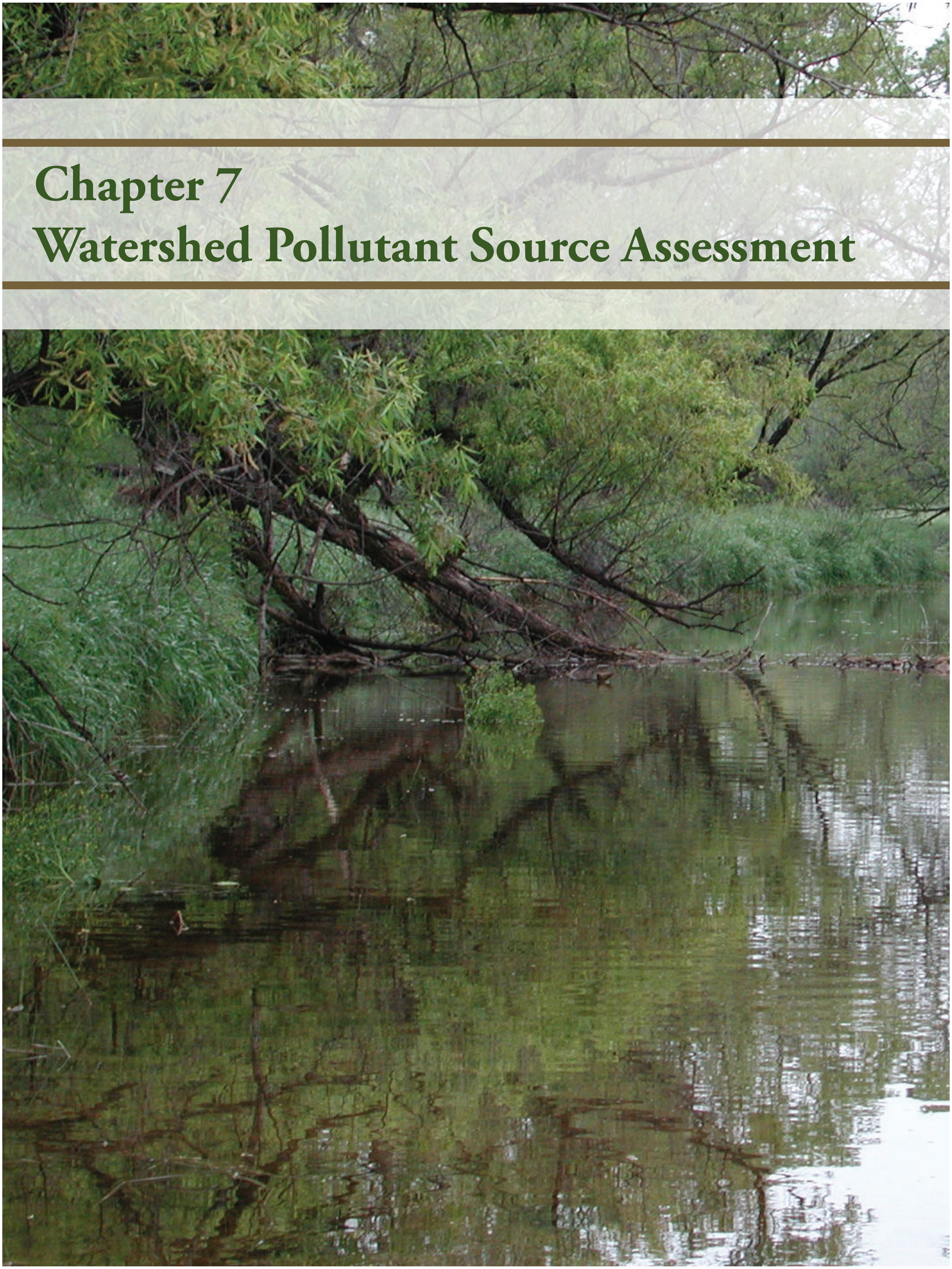
Wellington Livestock Commission Company

A cattle auction facility is located west of Wellington near the city's WWTF (Figure 11). Given the previous information about runoff potential from the WWTF and surrounding areas, this potential source of pollution is considered to have a low potential to contribute pollutants to Buck Creek. This facility is not considered a CAFO nor does it have or need a water quality permit from TCEQ to operate. Weekly sales average about 900 head as reported in the *Mesquite Country Bargains,* a free classified ads newspaper.

Wildlife

Wildlife, including birds, are also contributors to NPS pollution in a watershed, and many factors influence their behavior as well as the areas within a watershed that they use. Water, food, and shelter are the 3 most critical factors that dictate where the wildlife can be found throughout a watershed, and since all 3 are all found within riparian areas, wildlife are likely to use these areas. Often, creeks are the only reliable source of water and therefore, riparian areas are prime suspects for fecal depositions by wildlife. See Table 10 for the estimated white-tailed and mule deer populations in the Buck Creek Watershed.

Wildlife also use upland areas of a watershed and deposit fecal material randomly throughout their habitat. Regardless of the source, runoff can then carry this material to the water body, which in turn further increases the bacterial loading within the creek.



Chapter 7
Watershed Pollutant Source Assessment

Water Quality Monitoring

As discussed in Chapter 4 and 5, AgriLife Vernon conducted extensive water quality monitoring at the monitoring stations illustrated below in Figure 13 beginning in May 2004 to bolster the historic data set. This data collection continued through July 2009 on a monthly basis and following runoff events. Only data collected through July 2009 are considered in this WPP.

For the purposes of assessing the overall water quality of the Buck Creek watershed, water quality data assessment and load duration curve (LDC) analysis will be restricted to the 2 index sites selected. Station 15811 located above the US 83 Buck Creek crossing in Childress County represents AU 0207A_01 and Station 20368 at CR 110 in Collingsworth County represents AU 0207A_02. This approach is used to take advantage of the data available at these 2 sites. Pairing the RRA's historical data with data collected by AgriLife Vernon provided a substantial data set that produced defensible LDCs that show long-term pollutant loading and provide a reasonable long-term pollutant reduction needed. Data collected from other Buck Creek sampling sites has been incorporated into other portions of the WPP development process and has played a critical role in planning best management practice (BMP) implementation schemes as will be discussed in Chapter 8.

E. coli Data Assessment

Collecting more than 5 years of intensive data from 13 sites on Buck Creek has highlighted that the creek is quite dynamic and that *E. coli* concentrations across the watershed are both spatially and temporally variable. No obvious problem areas for excessive *E. coli* concentrations were identified; however, some interesting observations were made. The general presence or absence of streamflow appears to influence measured *E. coli* levels at respective monitoring stations. Sites that typically have sustained water present for much of the year tend to have lower geometric means under routine monitoring and biased flow conditions. Inversely, those sites that only have flow for short periods typically exhibit higher *E. coli* geomet-

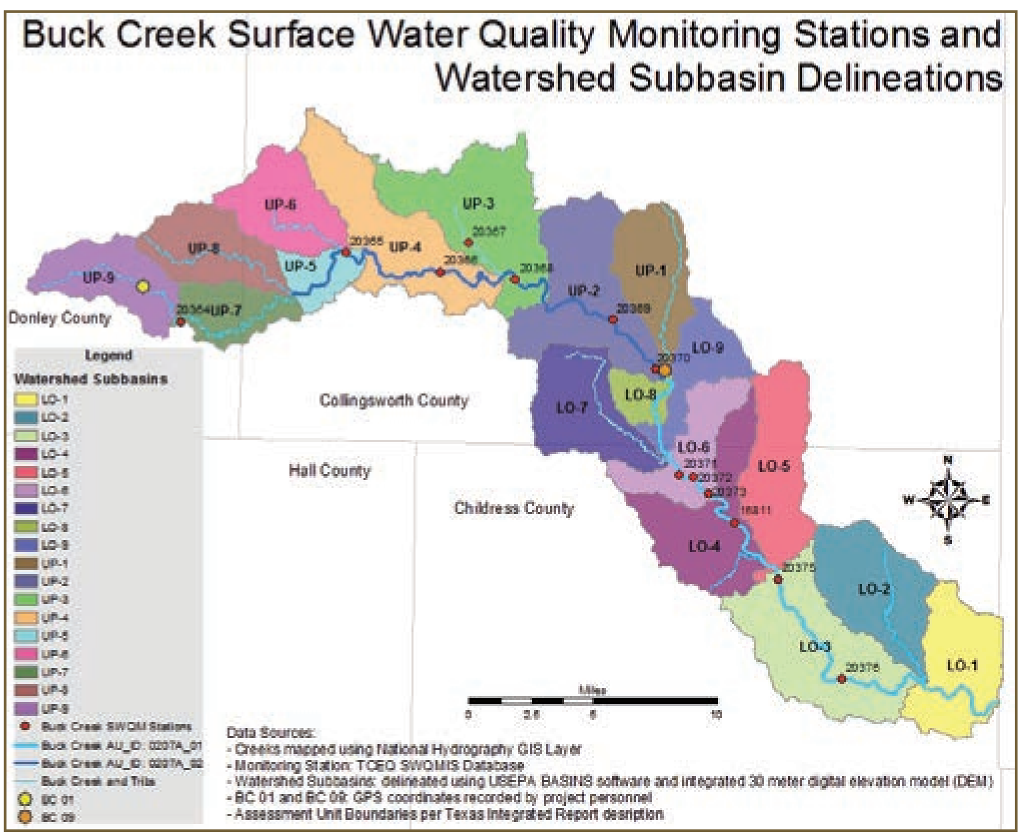


Figure 13. Buck Creek surface water quality monitoring stations, assessment units and watershed subbasin delineations

ric means under both flow conditions. This suggests that the creek is able to better attenuate *E. coli* where water is commonly present. Table 14 summarizes all *E. coli* data collected by AgriLife Research through July 30, 2009 and includes historic data from RRA as well.

Data in this table are presented in a variety of ways to illustrate the varying impacts of flow conditions on in-stream water quality and aid in developing appropriate management strategies to address *E. coli* loading in the watershed. For the state's water body assessment purposes, data presented in the "Routine Data" column are used and aggregated to the AU level. Based on these data, Buck Creek is not impaired for elevated *E. coli* levels and is well within the state's water quality standard. Supporting this statement in the *2010 Texas Integrated Report* is the removal of Buck Creek from the 303(d) List as being impaired for elevated *E. coli* levels.

Looking at individual *E. coli* concentrations across all sites, several interesting observations were noted. Over the course of the 5 plus years of monitoring by AgriLife Research, the following observations were made:

- During each sampling event and when sampled, stations 20364, 20369, 20370 and 20375 always produced *E. coli;* all other sites yielded 0 culturable *E. coli* on at least one occasion.
- Station 20367, the unnamed tributary to Buck Creek, produced the highest single *E. coli* concentration reading of 8,100 cfu/100 mL.
- Of the highest single *E. coli* concentration readings at each site, 6 of them occurred during biased flow sampling events. One other occurred during a routine sampling event that happened to be rain influenced.

Table 14. Summary of *E. coli* data collected on Buck Creek

Project Site #	TCEQ Station ID #	Assessment Unit (AU)	Total Number of Samples	Number of Routine Flow Samples	Number of Biased Flow Samples	Number of Flow Data Points	~~~~~~~ *E. coli* Geometric Means ~~~~~~~			
							[1] Historic & All Project Data	[2] All Project Data	[3] Biased Flow	[4] Routine Data
BC 02	20364	N/A: Above AU	7	5	2	4		258.5	278.3	251.0
BC 03	20365	0207A_02	89	75	14	18		16.3	45.8	13.3
BC 04	20366	0207A_02	72	58	14	6		69.3	243.4	52.2
BC 05	20367	N/A: Tributary	79	60	19	21		90.4	161.4	76.8
BC 06	20368**	0207A_02	49	34	15	22		26.9	97.6	15.2
BC 07	20369	0207A_02	14	9	5	4		198.1	498.0	118.7
BC 08	20370	0207A_02	5	3	2	4		167.6	376.0	97.8
AU 0207A_02 Totals / Geometric Means*			**224**	**176**	**48**	**50**		**35.1**	**126.7**	**24.5**
BC 10A	20371	0207A_01	98	82	16	19		137.5	142.4	136.5
BC 10B	20372	0207A_01	41	37	4	3		122.7	205.9	116.0
BC 10C	20373	0207A_01	69	55	14	20		50.1	58.5	48.2
BC 11	15811**	0207A_01	113	92	21	53	45.4	25.8	64.9	18.3
BC 12	20375	0207A_01	19	11	8	1		99.8	116.4	91.3
BC 13	20376	0207A_01	25	15	10	1		79.4	201.1	37.0
AU0207A_01 Totals / Geometric Means			**365**	**292**	**73**	**97**		**68.8**	**101.3**	**61.8**
Entire Creek Totals / Geometric Means***			**589**	**468**	**121**	**147**		**52.3**	**110.9**	**42.4**

Rows highlighted in Orange indicate that if assessed independently, this site would not meet current water quality standards

Rows highlighted in Gray indicate that the indivudial site does not have the required 10 data points for a valid site specific comparison to the water quality standard

* AU 0207A_02 totals do not include data from Stations 20364 or 20367: Staion 20364 is located upstream of the AU boundary and Station 20367 is located on a tributary to the AU

** Sites 15811 and 20368 were chose as index sites for AU 01 and AU 02 respectively due to their relatively robust data sets

***Total sample numbers and geometric means calculated for the entire creek only include data within the two designated assessment

[1] Historic & All Project Data are only available for Station 15811 and include all data (routine and biased flow) collected by RRA and Texas AgriLife Research between December 1997 and July 2009

[2] All Project Data include all data (routine and biased flow) collected by Texas AgriLife Research between May 2004 and July 2009

[3] Biased Flow data were collected by Texas AgriLife Research between May 2004 and July 2009 and occurred shortly following a rain event

[4] Routine Data were collected by Texas AgriLife Research between May 2004 and July 2009 on a regular schedule; usually every other

- Beaver activity and a large number of Cliff swallows were noted at 2 sites when their respective highest single *E. coli* concentration readings occurred.
- The 11/16/2004 biased flow monitoring event yielded 2 of the highest single *E. coli* concentration readings: 2,510 and 4,030 at stations 20366 and 15811 respectively.
- The 4/24/2007 routine flow monitoring event yielded 2 of the highest single *E. coli* concentration readings: 1,206 and 780 at stations 20364 and 20372 respectively (this event was rain influenced as a significant rain fell 2 days prior to sample collection).

These observations along with the summary data presented in Table 14 suggest that isolated areas of intensive *E. coli* loading can occur in the watershed. Elevated instream *E. coli* are often associated with runoff-producing rain events that either wash pollutants into the stream or agitate stream sediments releasing *E. coli* harbored within. These elevated *E. coli* levels are also short lived. Following these high concentration events, the next routine sampling events commonly produce *E. coli* levels approximately an order of magnitude or more smaller, illustrating the rapid reduction in instream *E. coli* levels. Routine data collection also yielded some individually elevated *E. coli* concentrations. While generally not as high as those seen during storm events, some were significantly higher than the 126 cfu/100 mL water quality standard, suggesting the occurrence of recent direct fecal contamination or a recent disturbance of the streambed. Each of these scenarios is likely given that the creek is used as a primary water source for numerous feral hogs, livestock and wildlife. Essentially, the data collected illustrate that both direct deposition and runoff are contributors to the *E. coli* load observed in Buck Creek.

Nitrate Data Assessment

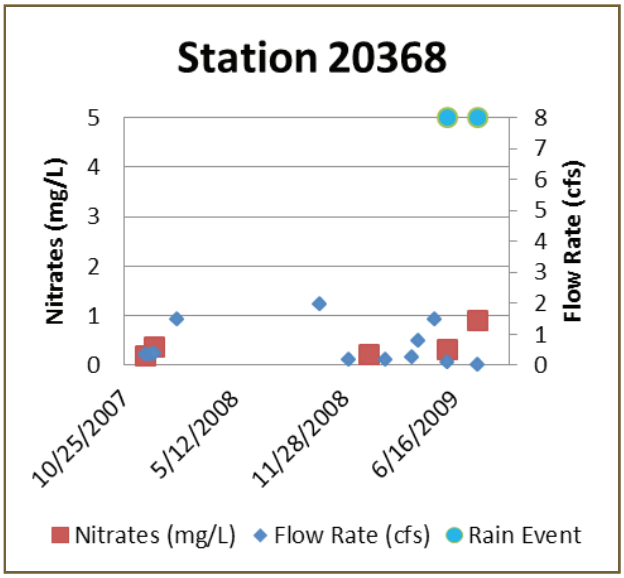
Project personnel began analyzing water samples for nitrates in November 2007 shortly after nitrates were listed as a concern in the *Draft 2008 Texas Water Quality Inventory.* A limited number of samples were collected; however, they do illustrate that nitrate levels above the screening level of 1.95 mg/L do exist. A distinct delineation between the upper and lower part of the watershed was discovered in these data, suggesting that there is a primary source of nitrates entering the creek somewhere upstream of monitoring Station 20371 (Table 15).

Further evaluation suggests that baseflow entering the lower half of the creek may be the primary driver behind these elevated nitrate levels. Figure 14 and Table 15 illustrate 2 features that support this hypothesis. Nitrate levels monitored under all flow conditions at Station 20368 remain consistently below the nitrate screening level and thus are not a concern. Further, of the 17 nitrates samples collected in the upper part of the watershed, only 1 exceeded the screening level. Moving downstream to sites 20371, 20373 and 15811, the situation is quite different. In total, 27 nitrates samples were collected at these 3 sites and all but 3 of them were above the screening level. Figure 14 illustrates that the 6 of the 9 samples were collected under baseflow conditions (not influenced by rainfall runoff). The 1 sample that did not exceed the screening level occurred shortly following a significant rain event, which produced considerable streamflow. If NPS pollution washing into the creek during rain events is the primary source of nitrate in the creek, this sampling event should yield higher nitrate levels. The data illustrate that this is not necessarily the case though as nitrate levels are considerably higher when rainfall runoff is not impacting streamflow, suggesting that groundwater contributions to the creek are the primary source of instream nitrates.

Table 15. Monitored nitrate (mg/L) levels in Buck Creek (2007–2009)*

Station ID	# of Samples	Minimum	Maximum	Average	% above 1.95 mg/L
20365	5	0.2	0.55	0.403	0%
20367	7	0.52	2.82	1.283	14%
20368	5	0.2	0.91	0.450	0%
20371	9	1.13	5.22	4.183	89%
20373	9	0.92	4.73	3.539	89%
15811	9	0.98	4.57	3.086	89%

* data represented here include both routine and biased flow data



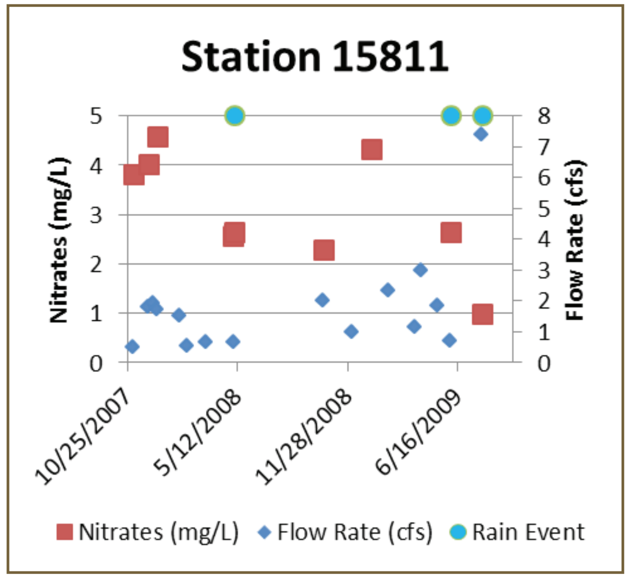


Figure 14. Nitrate concentrations compared to streamflow at Stations 20368 and 15811

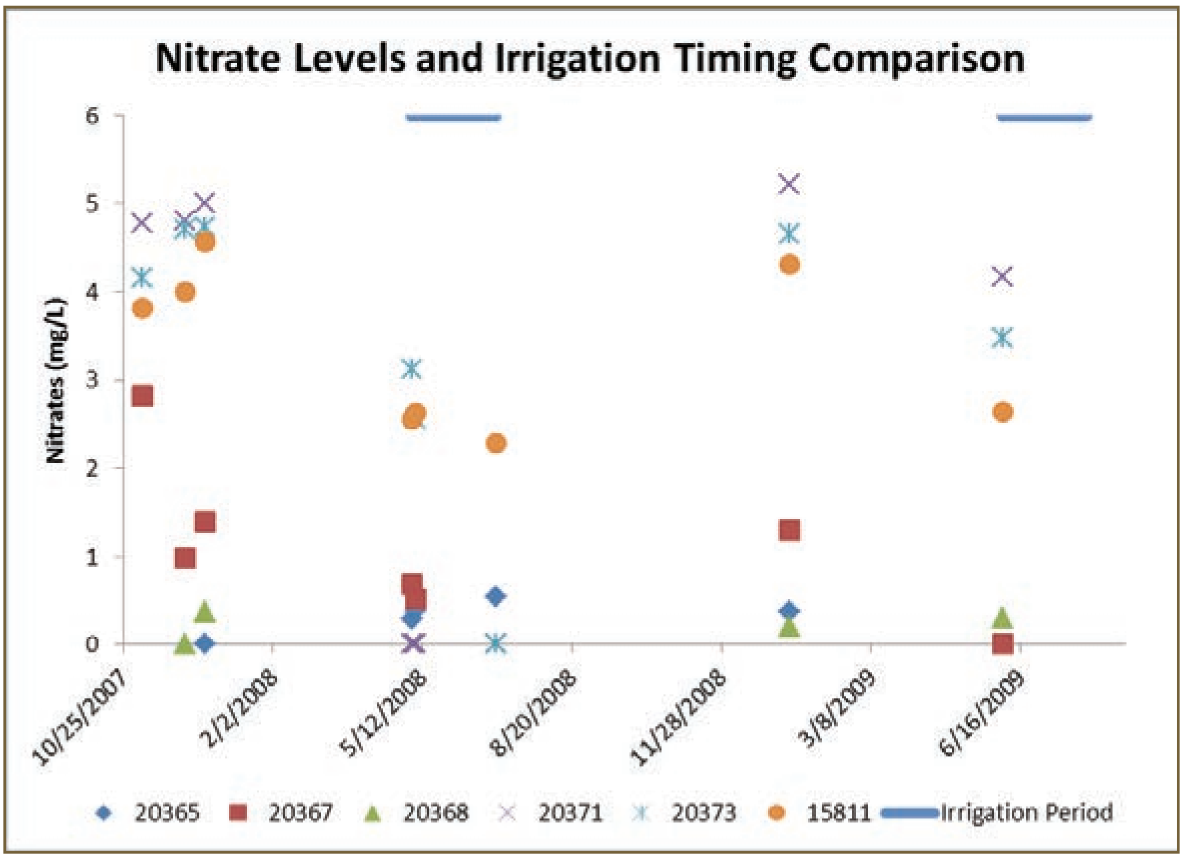


Figure 15. Nitrate levels monitored in Buck Creek paired with irrigation timing. (All data were collected under routine sampling conditions when flow conditions were normal or low.)

Irrigation timing also has a clear influence on instream nitrate levels. Figure 15 below illustrates nitrates data collected at the monitoring stations discussed under normal, or non-runoff impacted conditions, and its relationship to irrigation timing. Despite the limited data set, the influence of irrigation on nitrate levels monitored instream is obvious. When irrigation occurs, decreasing instream nitrate concentrations are observed. These are presumably a result of decreasing contributions of groundwater to the creek. Nitrate data are needed to further evaluate this and the previous hypotheses.

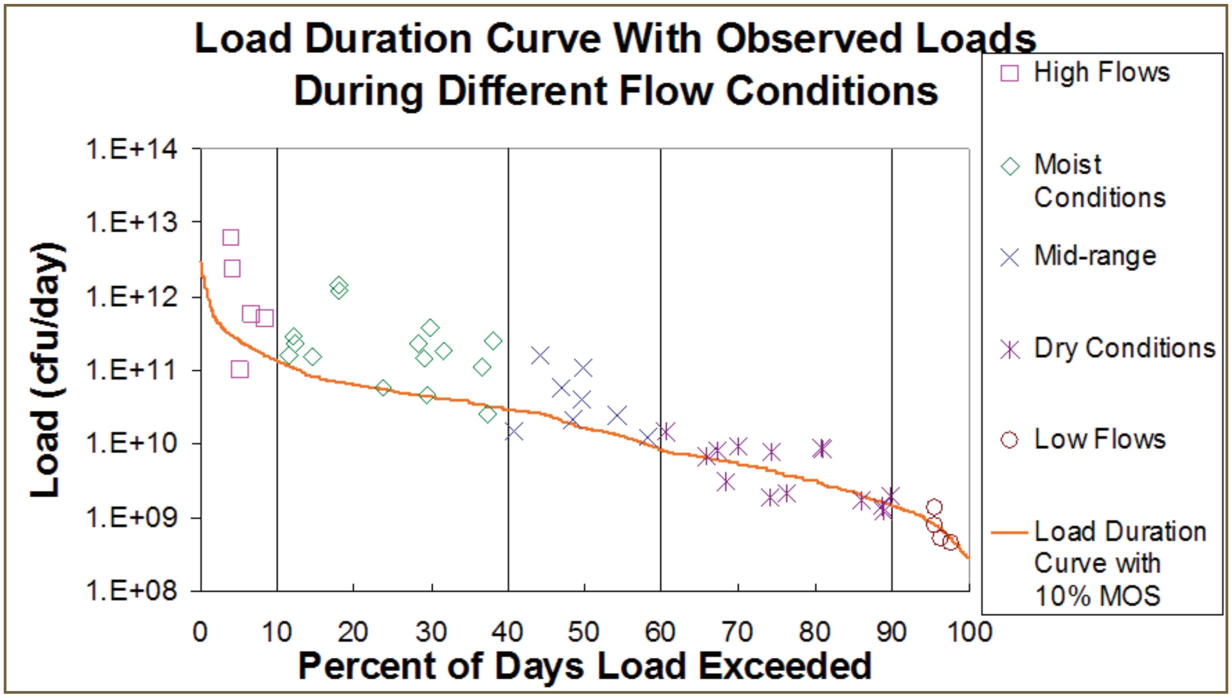


Figure 16. Example LDC. Vertical lines separate flow categories, the orange line is the allowable pollutant load and points are water quality paired with associated flow rates

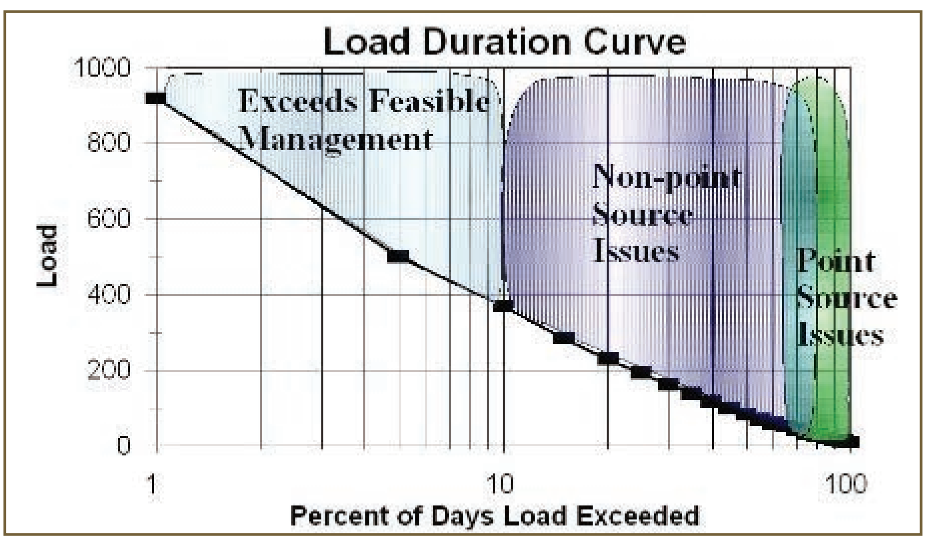


Figure 17. Graphic depiction of the types of sources that can be expected under relative flow conditions illustrated by LDCs. Source: Kansas Department of Health and Environment: http://www.kdheks.gov/tmdl/basic.htm

LDC Analysis

LDC analysis was used in Buck Creek to illustrate bacteria and nitrate loadings across the creek's varying levels of flow. This commonly used approach provides a simplistic method of illustrating what general source types (direct or indirect deposition) of pollutant loadings are influencing a water body by evaluating when loadings exceed the allowable limit as compared to average daily flow records. A stream's flow regime can be divided into as many flow categories as needed to accurately depict the variety of flows observed. For Buck Creek, 4 different flow categories were used: high flow, moist conditions, normal conditions and low flow. A 5th category, creek dry, was also added to illustrate the time that the creek is dry in a given year. This deviates slightly from the LDC illustration presented in Figure 16.

Once developed, LDCs are evaluated by flow category, and load reductions needed to meet water quality goals can be developed for each respective flow category. In almost all cases, high flow events are considered to 'exceed feasible management' due to the inability to prevent large volumes of runoff from occurring during large storm events (Figure 17); however, defining what level of flows actually "exceed feasible management" is difficult due to variability in rainfall events. Additionally, the lack of a continuous flow record also makes it difficult to define what flow levels are manageable and what flow levels are not. As a result, a specific flow level has not been defined for Buck Creek that qualifies as "exceeding feasible management."

Permitted discharges, direct fecal deposition and groundwater inflows have the greatest impact on a water body's pollutant loading under low flow conditions, as surface runoff is not contributing to the pollutant load or streamflow. When runoff occurs, it can transport NPS pollutants deposited across the watershed since the last runoff event. Permitted discharges and direct deposition remain as contributors during these times, but are less of a factor due to dilution from runoff. Buck Creek has no permitted discharges, so any excessive pollutant loading that occurs during low flow conditions is from direct deposition of pollutants into the stream.

To develop a LDC, a flow duration curve (FDC) is first developed for each individual monitoring station located along a stream with continuously measured or instantaneous flow data. Typically, rural streams do not have continuously measured flow data available so routine or historical instantaneous flow data is used to develop the FDC (this results in a variable FDC that is not smooth like the example in Figure 16). At each station, available flow data is sorted from largest to smallest and then ranked from 1 to n (n is the number of total flow values). The percent flow exceedance is calculated by dividing the flow's rank by n and then multiplying by 100. The FDC is created by plotting the flow against the percent flow exceedance. There are no streamflow gages on Buck Creek; therefore, instantaneous flow measurements collected at the 2 watershed index sites (Chapter 4) were relied upon to develop FDCs. As a result, the true range of flows is likely not illustrated in these FDCs. Station 20368 is the index site for AU 0207A_02 and Station 15811 is the index site for AU 0207A_01; these sites had 22 and 53 flow data points, respectively.

The next step in developing a LDC is to establish the maximum allowable load. To do this, the FDC is multiplied by the water quality criterion for the pollutant of concern (Figure 16). This curve shows the maximum pollutant load (amount per unit time; e.g., for bacteria, cfu/day) a stream can receive across the range of flow conditions (low flow to high flow) without exceeding the water quality standard. Typically, a margin of safety (MOS) is also applied to the threshold pollutant concentration to account for possible variations in loading due to sources, streamflow, effectiveness of management measures and other sources of uncertainty. The Buck Creek Watershed Partnership chose not to incorporate an explicit MOS for bacteria or nitrate LDCs because the goal of further reducing *E. coli* loadings by 2% from their existing levels provides an implicit MOS.

Last in the LDC development process is conducting regression analysis using monitored pollutant data to determine the 'best fit line,' or a load regression curve. The load regression curve is then plotted on the graph (blue line in Figure 18) and is compared to the maximum allowable pollutant load; or in the case of Buck Creek, the water quality target. The water quality target was plotted by subtracting 2% from the load regression curve. To calculate the load reductions in Tables 15, 16 and 17, for a particular flow category, individual loads are averaged together within that flow category and compared to the midpoint of the maximum allowable loading curve within that flow category.

Loading estimates presented in these LDCs illustrate individual loadings at a specific point in time and are aggregated by flow regimes then scaled up to account for an average annual load across all flow regimes. Presenting data in this way illustrates the intermittent variability in loadings seen in Buck Creek caused by its intermittent and flashy flow nature. Loadings are calculated and presented both as average loads across a flow condition and an aggregated annual loading across all flow conditions. For a more complete explanation of the LDC approach, see Appendix C.

E. coli LDC Results

Station 15811

The LDC developed at Station 15811 uses 53 *E. coli* concentration data points collected by RRA and AgriLife Vernon (1997–2009) that have corresponding flow measurement data; 60 water quality samples collected at this site did not have corresponding flow data and were not included in this analysis (Figure 18). Applying the 2% load reduction goal established by the Buck Creek Watershed Partnership, Table 16 illustrates the needed daily *E. coli* load reductions to meet this goal. Also shown are estimated daily *E. coli* loadings as well as estimated annual loadings.

Table 16. Daily and annual *E. coli* loading estimates and daily load reductions needed based on regression analysis of all data collected by RRA and AgriLife Vernon (1997–2009) at Station 15811

Flow Condition	% of Time Flow Exceeds	% Reduction Goal	Estimated Daily Loading (cfu/day)	Estimated Annual Loading (cfu/year)*	Needed Daily Load Reduction to Meet Goal (cfu/day)
High Flow	0-10%	2	1.10 E+11	4.02E+12	2.20E+09
Moist Conditions	10-25%	2	1.97 E+10	1.08E+12	3.94E+08
Normal Conditions	25-40%	2	4.61 E+09	2.52E+11	9.22E+07
Low Flows	40-77%	2	1.55 E+09	2.09E+11	3.10E+07
Creek Dry	77-100%	N/A	N/A	N/A	N/A

* annual loading is calculated by multiplying the dailiy load estimate within a flow category by the number of days within a year that the respective flow category is exceeded

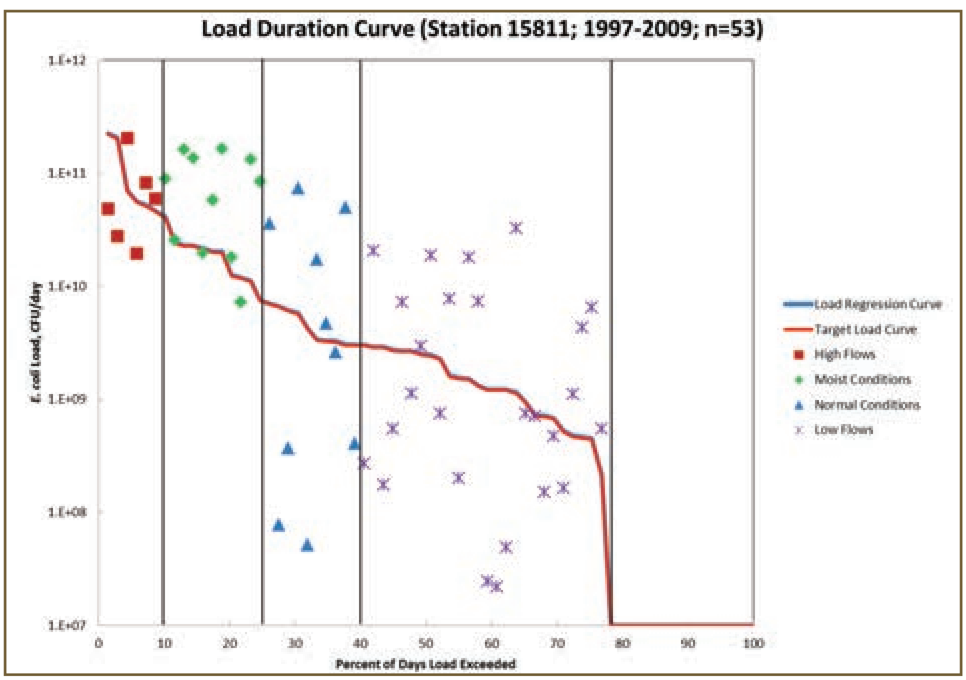


Figure 18. Daily *E. coli* LDC of all data collected by RRA and AgriLife Research between 1997–2009 at Station 15811

To establish a numeric target for total load reductions needed to meet the 2% load reduction goal at Station 15811, the 'needed daily load reduction to meet the goal' numbers from Table 16 were aggregated. Since each flow condition has its own respective daily load reduction needed to meet the goal, each daily load reduction needed to meet the goal was multiplied by the number of days within each respective flow category. These products were added together to yield an annual load reduction needed to meet the 2% reduction goal. This annual reduction needed equates to 1.11E+11 cfu of *E. coli* per year.

Station 20368

The LDC developed at Station 20368 uses 22 *E. coli* concentration data points collected by AgriLife Vernon (2007–2009) that have corresponding flow measurement data; 27 water quality samples collected did not have corresponding flow data and were not included in this analysis (Figure 19). Applying the 2% load reduction goal established by the Buck Creek Watershed Partnership, Table 17 illustrates the needed daily *E. coli* load reductions to meet this goal. Also shown are estimated daily *E. coli* loadings as well as estimated annual loadings. As expected, loadings at this upstream site are lower than those seen further downstream at Station 15811 because of the cumulative nature of bacteria loads in stream.

Using the same approach as described for Station 15811, the annual load reduction needed to meet the 2% load reduction goal at this location is 1.58 E+10 cfu of *E. coli.*

Table 17. Daily and annual *E. coli* loading estimates and daily load reductions needed based on regression analysis of all data collected by AgriLife Vernon (2007–2009) at Station 20368

Flow Condition	% of Time Flow Exceeds	% Reduction Goal	Estimated Daily Loading (cfu/day)	Estimated Annual Loading (cfu/year)*	Needed Daily Load Reduction to Meet Goal (cfu/day)
High Flow	0-5%	2	1.39 E+10	2.54E+11	2.78E+08
Moist Conditions	5-20%	2	4.12 E+09	2.26E+11	8.24E+07
Normal Conditions	20-30%	2	5.43 E+08	1.98E+10	1.09E+07
Low Flows	30-46%	2	2.08 E+08	1.21E+10	4.16E+06
Creek Dry	46-100%	N/A	N/A	N/A	N/A

* annual loading is calculated by multiplying the dailiy load estimate within a flow category by the number of days within a year that the respective flow category is exceeded

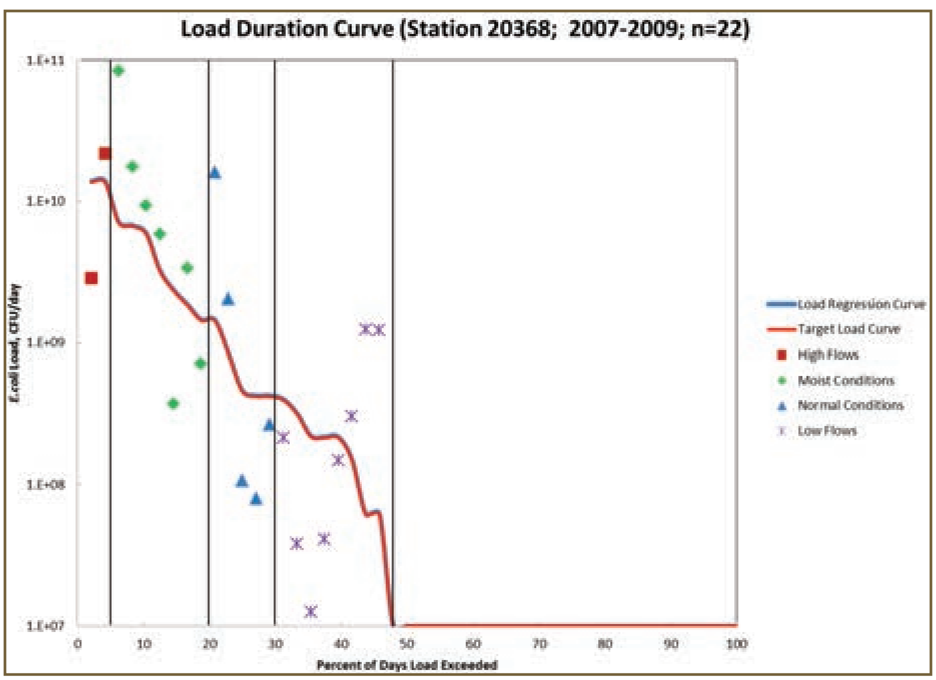


Figure 19. Daily *E. coli* LDC of all data collected by AgriLife Vernon between 2007–2009 at Station 20368

Nitrate LDC Results

Station 15811

An LDC was also developed for Buck Creek to evaluate nitrate loadings and aid in evaluating potential sources of pollution contributing to the overall nitrate load. The Buck Creek Watershed Partnership did not establish a water quality goal for nitrates as it believes that identifying the source of nitrates is the first step needed in dealing with instream nitrate levels. As a result, in developing the LDC for nitrates, the maximum allowable load was calculated using the current 1.95 mg/L screening level established for nitrates. This is not the water quality goal established; rather, this is used to illustrate the relative load reductions needed to meet the current nitrate screening level.

The lack of nitrates and paired flow data at all monitoring sites except Station 15811 precluded the ability to develop meaningful LDCs at other monitoring sties. The dataset at Station 15811 was not much better, but was bolstered by RRA's nitrate data collection at this station, which began in 1997. AgriLife Vernon continued the collection through 2009. The nitrate LDC developed used all available data (1997–2009) that had corresponding flow data. In total, 23 samples were used in this analysis.

According to the regression analysis of this LDC presented in Figure 20, it suggests that excessive nitrate loading occurs during 3 flow regimes: high flow, moist conditions and normal flow conditions. However, if individual data points are observed and compared to the allowable load (red line), data in the high flow category indicates that the observed load is less than the allowable load. Granted, only one data point falls in this flow category, but it contradicts the needed 55% reduction calculated based on the regression analysis (blue line). In this case, the regression analysis line does not fit the data well and is quite misleading. The same can be said about the regression analysis line in the moist condition category as well; however, the observed data points are scattered above and below the allowable load.

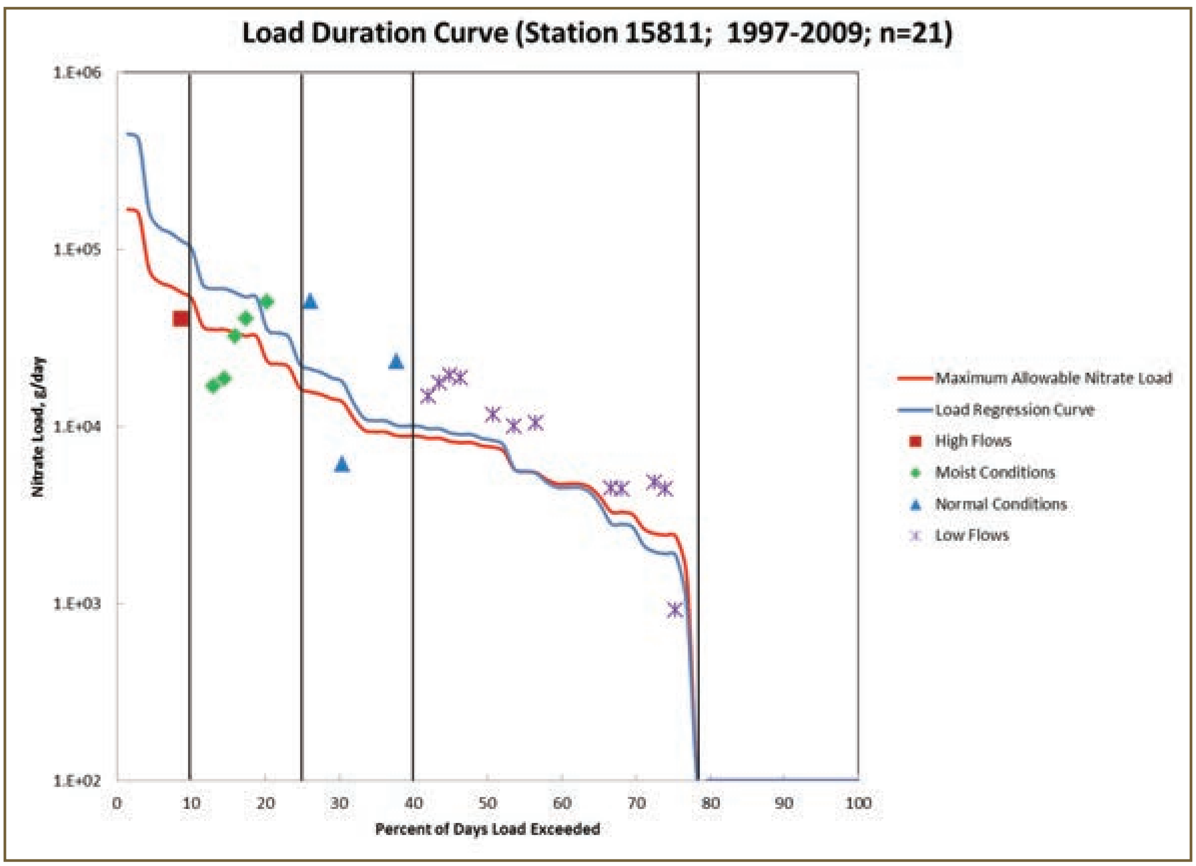


Figure 20. Daily nitrate LDC developed using all available data collected by RRA and AgriLife Vernon between 1997–2009 at Station 20368

Table 18. Daily and annual nitrate loading estimates and daily load reductions needed based on regression analysis of all data collected by RRA and AgriLife Vernon (1997–2009) at Station 15811

Flow Condition	% of Time Flow Exceeds	Needed % Reduction	Estimated Daily Loading (mg/day)	Estimated Annual Loading (mg/year)*	Needed Daily Load Reduction to Meet 1.95 mg/L Screening Level
High Flow	0-10%	55	2.33 E+05	8.50E+06	1.28E+05
Moist Conditions	10-25%	38	5.20 E+04	2.85E+06	1.98E+04
Normal Conditions	25-40%	18	1.44 E+04	7.88E+05	2.59E+03
Low Flows	40-77%	N/A	5.44 E+03	7.35E+05	N/A
Creek Dry	77-100%	N/A	N/A	N/A	N/A

* annual loading is calculated by multiplying the dailiy load estimate within a flow category by the number of days within a year that the respective flow category is exceeded

Regardless of correctness, what the regression analysis and LDC indicates is that observed data in the normal and low flow categories comprise the bulk of nitrate loading above allowable levels observed at this site. This suggests that groundwater inflows to the stream are the source of elevated nitrate levels.

The needed load reductions based on regression analysis presented in Table 18 are contradictory to the raw data assessment and interpretations presented earlier in this chapter. The earlier data assessment considered limited data sets from 6 monitoring locations conducted during the 2007–2009 assessment period and concluded that the bulk of nitrate loading was occurring under dry conditions and low flows when groundwater contributions to the stream dominate flow. Ultimately, the total nitrates data set is limited and conclusions drawn at this point are largely hypothetical that need additional data to prove or disprove.

SELECT Analysis

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is a computer-based model that predicts potential *E. coli* loadings from modeled sources in the evaluated watershed. These estimates are a worst-case scenario that does not factor in any form of bacteria die-off. As a result, the loading estimates produced by the model are not loads that are expected to enter the creek.

The model distributes these potential loads across the watershed based on land use characteristics and the geographical location within the watershed. To accomplish this, land use classification data updated in 2008 was used along with stakeholder verified estimates of cattle, deer and feral hogs as well as other watershed characteristics such as the watershed boundaries, topography, the stream network and watershed soils data.

SELECT was used to predict what areas, or subbasins, within the Buck Creek watershed have the highest potential for bacterial loading. To accomplish this, the watershed was divided into subbasins as shown in Figures 7 and 13 (presented earlier in this chapter and Chapter 4) based on watershed topography and surface hydrology characteristics. Each of the subbasins was given an arbitrary label for identification purposes and will be used when targeting needed management measures throughout the watershed.

SELECT Results

Buck Creek SELECT results presented here were developed using watershed specific information (animal populations, land use data, topography, etc.) and assumed fecal bacteria production rates to develop potential pollutant loadings for each species modeled from each watershed subbasin. This analysis highlights which subbasins have the highest potential *E. coli* loading in the watershed based on land use characteristics and pollutant contributor populations.

SELECT was used to develop loading estimates for cattle, deer and feral hogs. Watershed stakeholders identified these 3 sources to be major contributors of bacteria to the watershed; therefore, they were the focus of SELECT. Other wildlife (opossums, raccoons, coyotes, rabbits, squirrels, etc.) are thought to be problematic in Buck Creek as well, but information needed to model potential loads from these sources is not available (animal densities, fecal production rates, etc.). Opossums and raccoons—2 species known to inhabit riparian areas—have been found to produce average *E. coli* counts per gram of fecal material much higher than cattle, deer or feral hogs (Karthikeyan et al. 2012). While these species are considerably smaller and produce less fecal material per day, they do congregate in riparian areas and are known to contribute pollutants to the watershed. Other sources of potential pollution exist in the watershed (a CAFO, OSSFs, a WWTF, etc.); however, they were considered miniscule by watershed stakeholders and not modeled. A complete explanation of the SELECT model, including assumed fecal production and *E. coli* content in fecal material, can be found in Appendix D.

Modeling results and potential *E. coli* loads for evaluated pollutant sources are presented below in Figures 22, 23, 24 and 25 as well as in Table 19. Individual subbasin potential loads are also aggregated by species and subbasin to show total potential loads from each species and total potential loads for each subbasin (Table 19). Figure 21 further illustrates the range of loadings predicted by the SELECT model for each watershed subbasin for each evaluated species. SELECT outputs are illustrated using 6 different colors ranging from green to red with green showing the lowest potential for *E. coli* loading from a given source and red showing the highest *E. coli* loading potential from the same source. SELECT outputs cannot be compared directly between species as the potential loading from each species varies. For example, potential *E. coli* loadings from deer are generally 2 or 3 orders of magnitude lower than cattle (Figures 22, 23 and Table 19). Potential loads predicted for all modeled species can be aggregated by subbasin to show total potential *E. coli* load production for each subbasin (Figure 24 and Table 19).

Cattle

Cattle populations in the Buck Creek watershed consist of those grazed on rangeland and managed pasture and those temporarily housed at the auction barn at Wellington and a feedlot near Hedley. For SELECT modeling purposes, only those cattle grazed on rangeland or managed pasture were considered (this also includes mixed and riparian forests, which only account for 2.34% of the entire watershed). The watershed stakeholder-derived estimate of 6,640 head of cattle was used and applied to the watershed at recommended NRCS stocking rate for rangeland (25 ac/animal) and managed pasture (8 ac/animal). This rate was calculated using recommended stocking rates for Childress, Collingsworth and Donley counties. These cattle numbers and distributions were verified with watershed stakeholders and determined to be representative of the Buck Creek watershed.

Figure 22 illustrates the daily potential *E. coli* production across the watershed as a result of cattle. Red and orange subbasins exhibit the highest potentials daily *E. coli* production from cattle relative to other subbasins in the watershed. These subbasins are ranked highest due to the relatively greater portion of those subbasins being rangeland or managed pasture. Potential loads from individual subbasins and all subbasins combined are presented in Table 19.

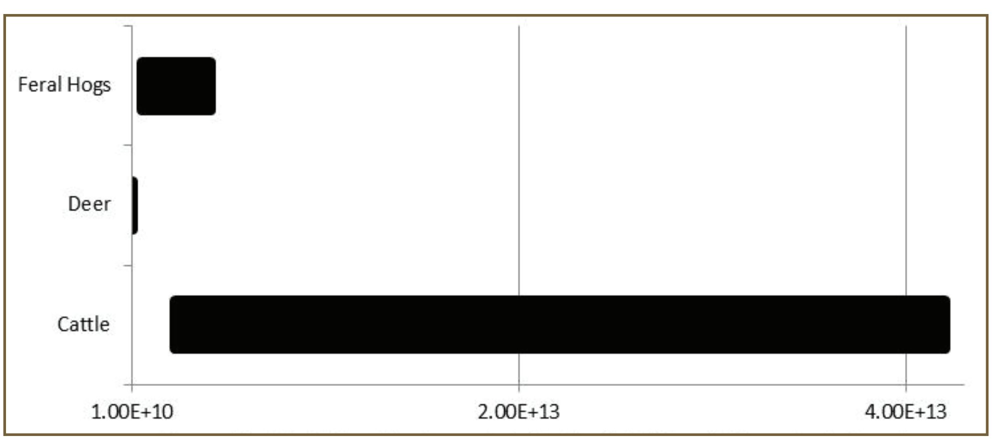


Figure 21. Range of bacteria loadings predicted by the SELECT model for individual subbasins

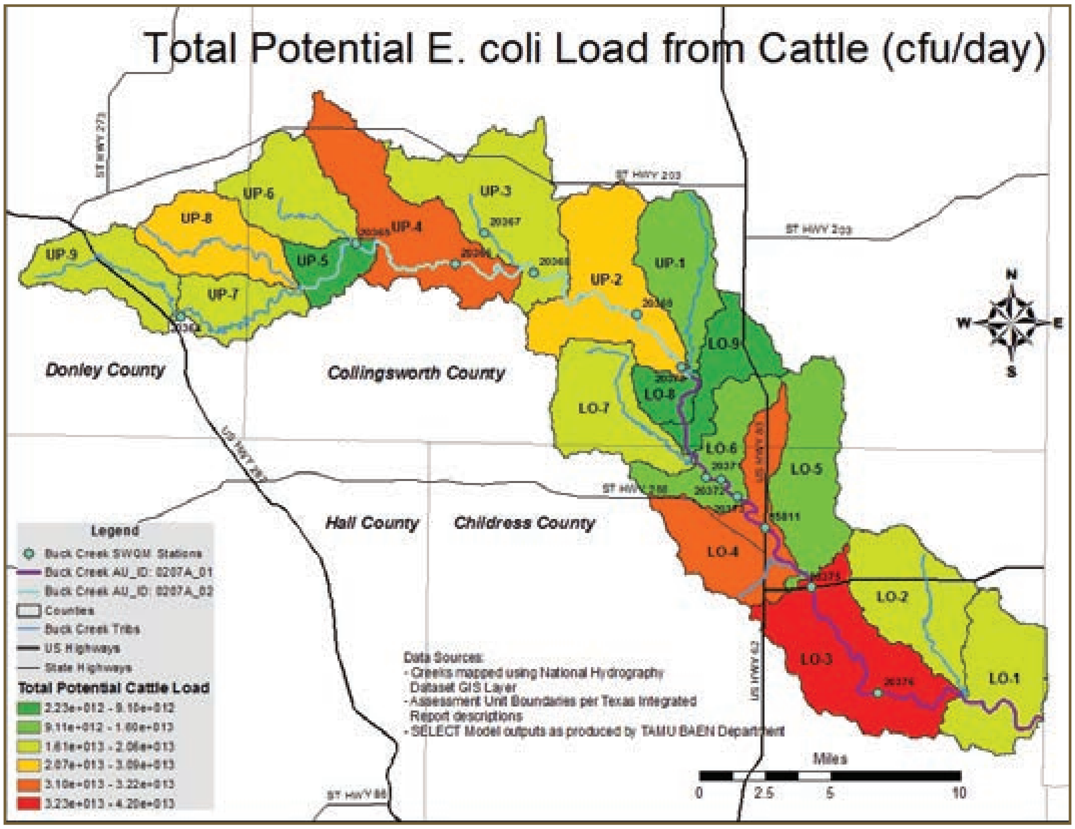


Figure 22. Estimated potential *E. coli* loading from cattle in Buck Creek subbasins

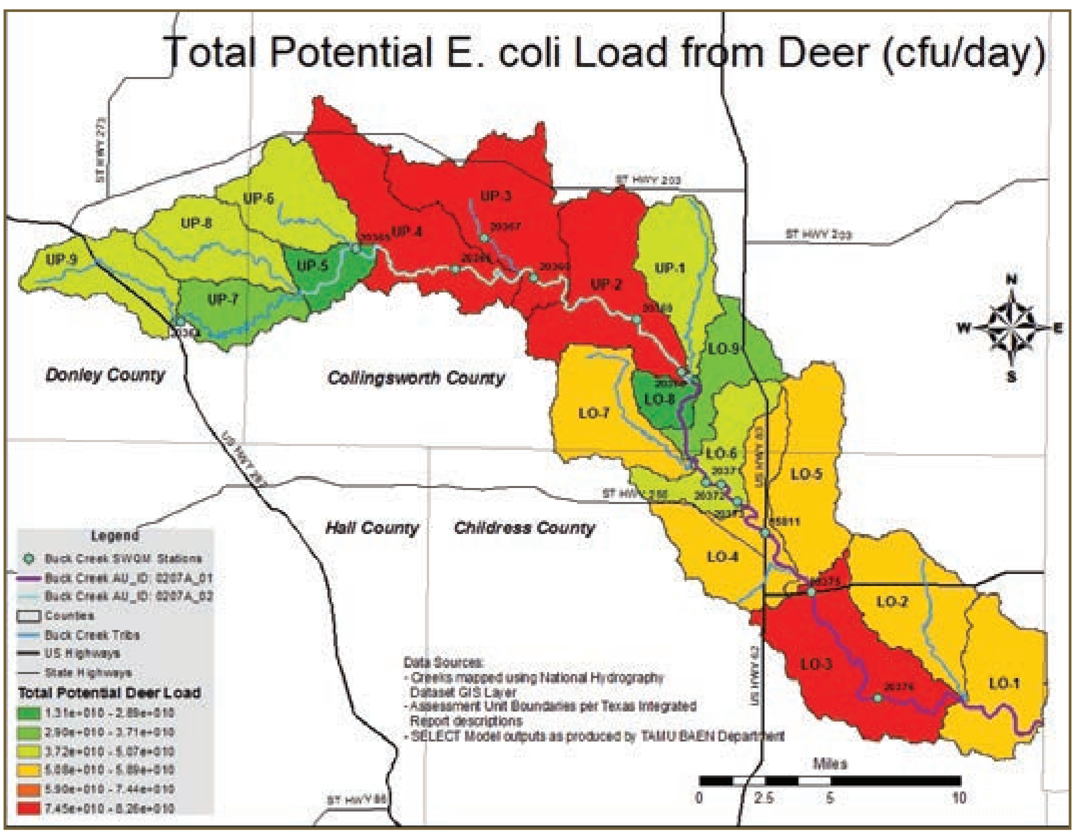


Figure 23. Estimated potential *E. coli* loading from deer in Buck Creek subbasins

Deer

Estimations of the deer population used in developing the SELECT model for Buck Creek are a combination of white-tailed and mule deer. TPWD provided initial population estimates and associated animal densities for areas as near to Buck Creek as possible. Using this information as a starting point, stakeholders were asked to provide input on the size and distribution of the deer herds in the watershed. In total, 5,143 deer (990 mule deer and 4,153 white-tailed deer) are assumed to reside in the watershed and are assumed evenly distributed over the rangeland, managed pasture, deciduous forest, riparian forest and cultivated land uses at an average rate of 36 ac per animal. Mule deer are assumed to have the same fecal production and *E. coli* levels per gram of fecal material as white-tailed deer since no data were found quantifying these numbers. Figure 23 shows the daily potential *E. coli* loadings from deer in the Buck Creek watershed and indicates potential for pollutant contributions for each subbasin. Numerical pollutant load estimates for individual subbasins are presented in Table 19.

Feral Hogs

As is the case statewide, no accurate estimate of feral hog numbers in the Buck Creek watershed exists. Stakeholders were asked to provide input regarding feral hog numbers in Buck Creek; using this feedback, an acceptable population density estimate of 25 ac per animal was determined. Stakeholders also indicated that the feral hog population should be evenly distributed across rangeland, barren land, managed pasture, cultivated land, mixed forest and riparian forest land uses to attain an appropriate number of animals. Using this information, project personnel developed an estimated feral hog population of 7,310 animals for the entire watershed.

In modeling feral hog pollutant contributions, the SELECT model was used to concentrate these hog populations to within 300 ft of all streams or streambeds in the watershed. This area provides the most suitable habitat for these animals and they likely spend a bulk of their time in these areas. It is understood that feral hogs use

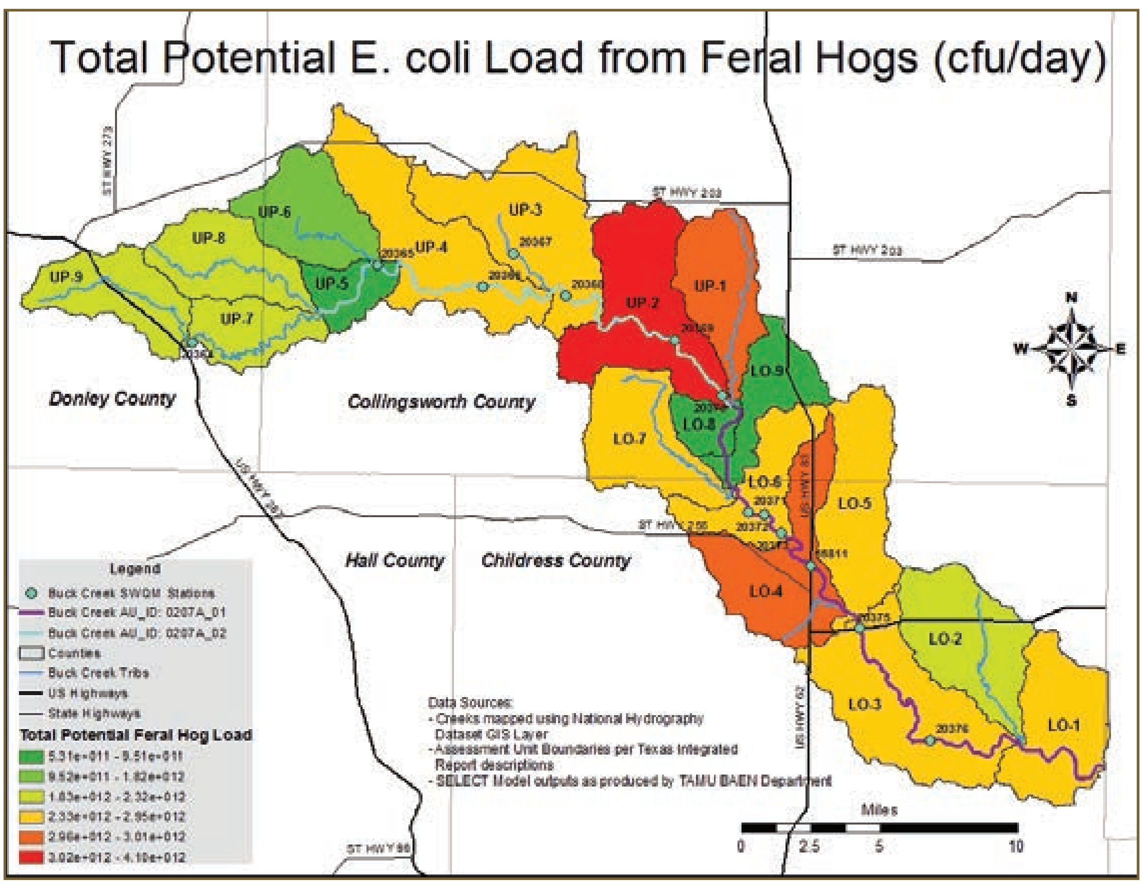


Figure 24. Estimated potential *E. coli* loading from feral hogs in Buck Creek subbasins

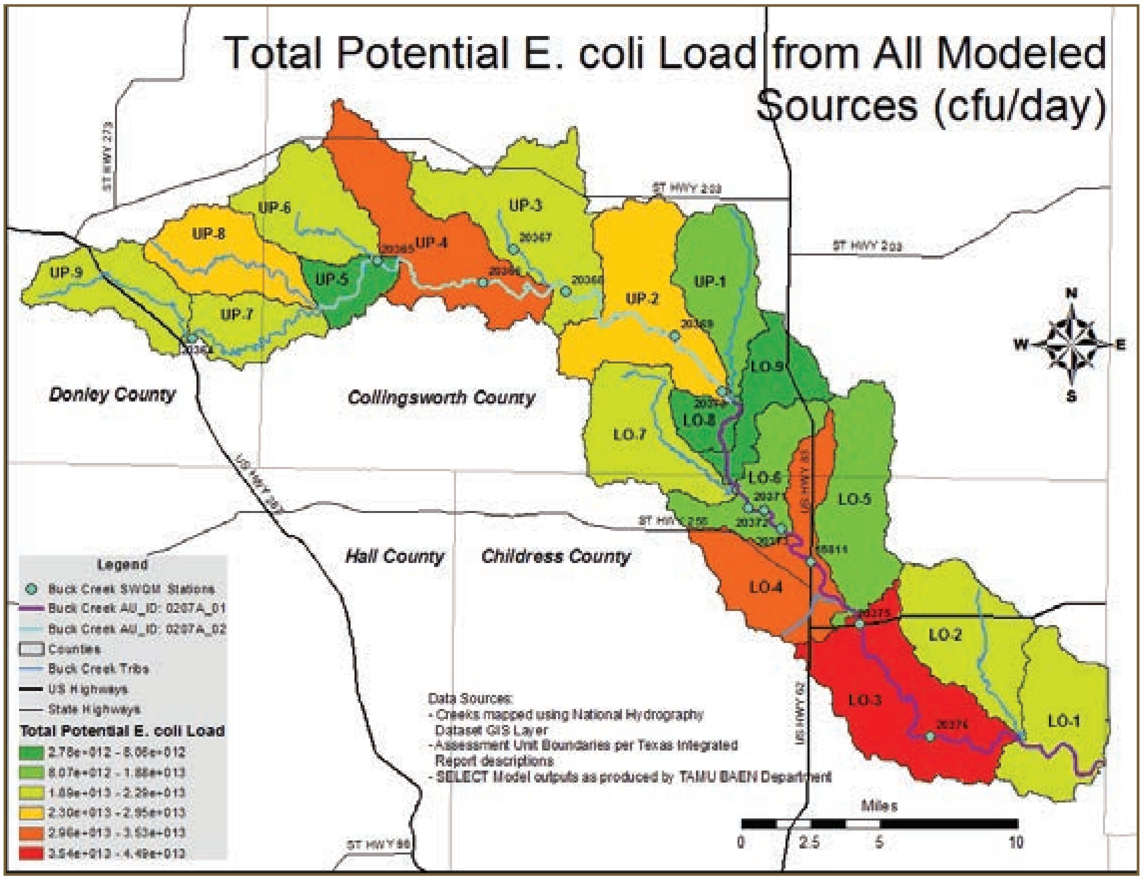


Figure 25. Estimated total potential *E. coli* production by watershed for all modeled sources

Table 19. Potential *E. coli* loads (cfu/day) per watershed subbasin

Subbasins	Subbasin Acreage	Cattle Load	Deer Load	Feral Hog Load	Total Load
LO 1	10,995.5	1.88E+13	5.36E+10	2.32E+12	2.11E+13
LO 2	11,977.1	2.06E+13	5.64E+10	2.22E+12	2.29E+13
LO 3	17,351.2	4.20E+13	8.26E+10	2.78E+12	4.49E+13
LO 4	12,583.6	3.22E+13	5.89E+10	2.96E+12	3.52E+13
LO 5	11,574.6	9.22E+12	5.44E+10	2.34E+12	1.16E+13
LO 6	7,690.0	9.24E+12	3.71E+10	2.45E+12	1.17E+13
LO 7	10,510.9	1.60E+13	5.06E+10	2.75E+12	1.88E+13
LO 8	2,815.4	2.23E+12	1.31E+10	5.31E+11	2.78E+12
LO 9	6,301.6	2.25E+12	2.92E+10	9.57E+11	3.23E+12
UP 1	8,984.0	1.03E+13	4.21E+10	3.01E+12	1.34E+13
UP 2	15,434.1	2.53E+13	7.43E+10	4.10E+12	2.95E+13
UP 3	16,148.3	1.93E+13	7.71E+10	2.71E+12	2.20E+13
UP 4	15,353.3	3.09E+13	7.45E+10	2.76E+12	3.37E+13
UP 5	3,821.5	7.20E+12	1.86E+10	9.51E+11	8.17E+12
UP 6	9,102.0	1.95E+13	4.42E+10	1.39E+12	2.09E+13
UP 7	5,955.7	1.70E+13	2.91E+10	1.87E+12	1.89E+13
UP 8	8,950.7	2.62E+13	4.37E+10	2.24E+12	2.85E+13
UP 9	8,453.0	1.98E+13	4.00E+10	1.83E+12	2.17E+13
Potential Daily *E. coli* Load for All Subbasins		**3.28E+14**	**8.80E+11**	**4.01E+13**	**3.69E+14**
Potential Annual *E. coli* Load for All Subbasins		**1.20E+17**	**3.21E+14**	**1.47E+16**	**1.35E+17**

the entire watershed; however, the bulk of their influence likely occurs in the riparian areas. Figure 24 illustrates the potential daily *E. coli* loading from feral hogs as predicted by the SELECT model while Table 19 presents predicted *E. coli* loads for each subbasin.

Total Potential Load

Figure 25 illustrates the "Total Potential Load" or the combined load, which includes loading potentials from cattle, deer and feral hogs. These predictions are simply aggregate potential pollutant load estimates from cattle, deer and feral hogs combined for each subbasin. As in other SELECT outputs, red subbasins have the highest potential for collective *E. coli* loading to the watershed while the darkest green areas represent areas with the lowest potential. Table 19 further illustrates the collective potential *E. coli* loadings.

Bacterial Source Tracking

In water bodies that exceed fecal indicator bacteria standards, a common approach to reducing monitored bacteria levels is to study the watershed and identify sources of fecal pollution. Laboratory tests are used to identify sources of fecal pollution in a process referred to as bacterial source tracking (BST). This process can identify different strains of *E. coli* and *Bacteroidales* that have adapted to conditions in the guts of their specific animal hosts, resulting in strains that are specifically associated with that species or closely related species. BST allows the original host animal of *E. coli* and *Bacteroidales* isolated from water to be identified. As a result, the likely human and animal sources of fecal pollution impacting a water body can be identified (Di Giovanni et al. 2011).

BST tests commonly used on *E. coli* are automated ribosomal ribonucleic acid genetic fingerprinting (RiboPrinting) and enterobacterial repetitive intergenic consensus sequence polymerase chain reaction (ERIC-PCR). These tests generate DNA fingerprints that resemble bar codes. The RiboPrinting and ERIC-PCR techniques are known as 'library-dependent' methods that require reference libraries of DNA fingerprints for *E. coli* isolated from known human, livestock and wildlife fecal samples. The fingerprints of *E. coli* isolated from water samples are matched with the fingerprints in the identification library to identify the likely sources of fecal pollution using computer software that can accurately assess the similarity between *E. coli* DNA fingerprints. When used in combination, these methods are collectively referred to as ERIC-RP (Di Giovanni et al. 2011).

The *Bacteroidales* BST method differs from the *E. coli* BST methods since the bacteria are not grown in the laboratory. This makes it a culture-independent technique. This method is known as a 'library-independent' method that does not need an identification library like *E. coli*. Instead, water samples are concentrated by filtration and DNA is extracted from the concentrated sample. The DNA sample derived from a water sample is then tested for the presence of specific *Bacteroidales* DNA markers using polymerase chain reaction (PCR). Currently, there are PCR markers for *Bacteroidales* specific to humans, pigs (including feral hogs) and ruminants (including cattle, deer, llamas and sheep). When these DNA markers are detected, the group of animals the *Bacteroidales* came from can be determined, allowing identification of broad sources of fecal pollution (Di Giovanni et al. 2011).

Buck Creek Approach

Using the *E. coli* and *Bacteroidales* BST methods described above, project personnel identified the sources of fecal pollution impacting Buck Creek. This analysis was conducted at monitoring stations sampled between October 2007 and September 2009 (Table 3), and samples were collected as a duplicate set of the routinely scheduled water quality monitoring. While runoff-influenced flows were not specifically targeted, several routine sampling events did occur following runoff-producing events. This sampling regime included Stations 20365, 20367, 20368, 20371, 20373, 15811 and 20376 (Figures 7 and 13).

Sample Collection and Processing

Briefly, the approach for sample collection consisted of two 125 mL water samples being collected from each station during each sampling trip. One sample was used to enumerate *E. coli* levels and obtain *E. coli* cultures for the ERIC-RP analysis while the other was processed for *Bacteriodales* analysis. 100 mL water samples were processed using 45-micron filters and EPA Method 1603 with modified mTEC medium. Once cultured and enumeration was complete, 5 representative *E. coli* colonies from modified mTEC plates were isolated, purified and confirmed. Once confirmed, these isolated colonies were submerged in liquid nitrogen and then stored at -80°C for future ERIC-RP analysis. Water samples for *Bacteroidales* analysis were filtered using 100 mL of sample and a 0.2 micron Supor filter, then folded, and placed in centrifuge tubes with 3 mL GITC lysis buffer, completely wetted with buffer, and kept frozen at -80°C. Additionally, ambient water samples (set of 5 water samples of 125 mL, collected 1-3 minutes apart, waiting each time for the sediment to clear and water to return to the normal condition before obtaining another sample) were also collected during 8 sampling events. At least 3 of the 5 samples collected at each site were filtered using EPA method 1603 and at least 1 sample per site was prepared for the *Bacteroidales* test. *E. coli* isolates and *Bacteroidales* samples were periodically sent on dry ice to Texas A&M AgriLife Research and Extension Center at El Paso (AgriLife El Paso) for BST analysis (Di Giovanni et al. 2011).

Known Source Fecal Samples

AgriLife Vernon staff obtained known sources of fecal material for use in the 'library-dependent' ERIC-RP analysis. The staff collected fecal samples from 78 animals and processed them to isolate individual *E. coli* strains. In total, they successfully isolated 53 *E. coli* isolates from 28 different animals from the local Buck Creek watershed. Some fecal samples collected from animals did not produce viable *E. coli* colonies, possibly due to the age of the fecal material or the general absence of *E. coli* from a specific species. Samples that produced viable *E. coli* isolates were obtained from swallows, cattle, coyotes, feral hogs, mule deer, prairie dogs and porcupines. Other samples collected from armadillos, badger, beaver, bobcat, cattle, opossum, rabbit, raccoon and turkey did not produce viable *E. coli* colonies. Although these samples did not produce *E. coli* isolates, they were able to be screened through the *Bacteroidales* analysis. Isolates were screened to remove identical isolates (clones) from the same fecal sample. The resulting 31 isolates from the 28 source animals from Buck Creek were then added to the October 2009 version of the Texas *E. coli* BST library and used for identifying Buck Creek *E. coli* water isolates. Following the inclusion of the samples, the Texas *E. coli* BST library consisted of fingerprint patterns from 1,172 *E. coli* isolates from 1,044 different human and animal samples collected throughout the state of Texas from 4 previous BST studies (Di Giovanni et al. 2011).

ERIC-RP

Using the process describe earlier, project personnel analyzed processed samples using the ERIC-RP BST approach. Composite DNA fingerprints produced through this process were analyzed with the Applied Maths BioNumerics software and compared to fingerprints of known source *E. coli* isolates in the Texas *E. coli* BST library. Likely sources of these bacteria were identified using this method and an 80% similarity cutoff was used (Casarez and Pillai 2007). Water isolate that were not at least 80% similar to a library isolate were considered unidentified. Although fingerprint profiles are considered a match to a single entry, identification is to the host source class and not to the individual animal represented by the best match. Host sources were divided into 3 groups: 1) human, 2) wildlife (including deer and feral hogs) and 3) domestic animals (including livestock and pets) (Di Giovanni et al. 2011). A more complete description of this methodology and how it was applied in Buck Creek is provided in Appendix E.

Bacteriodales PCR

The *Bacteroidales* PCR method is a culture- and library-independent molecular method that targets genetic markers of *Bacteroides* and *Prevotella* spp. fecal bacteria that are specific to humans, ruminants (including cattle, deer, llamas and sheep) and pigs (including feral hogs); there is also a general *Bacteroidales* marker (GenBac) that is used as a general indicator of fecal pollution. This method and the markers used here have proven to be highly specific to detecting fecal pollution from animals within a particular source category. As applied in Buck Creek, *Bacteroidales* PCR was used to quantify the presence/absence of the host-specific genetic markers meaning that there was or was not bacteria from that specific source type present in the sample (Di Giovanni et al. 2011).

BST Results

Findings from the BST verified that a variety of sources is contributing fecal bacteria to Buck Creek. In total, 426 *E. coli* isolates from water samples were analyzed using the ERIC-RP method and 79 water samples were analyzed using the *Bacteroidales* PCR method. While these methods complement each other, they do not report the exact same sources of pollution. For example, the ERIC-RP method discriminates between domestic animals and

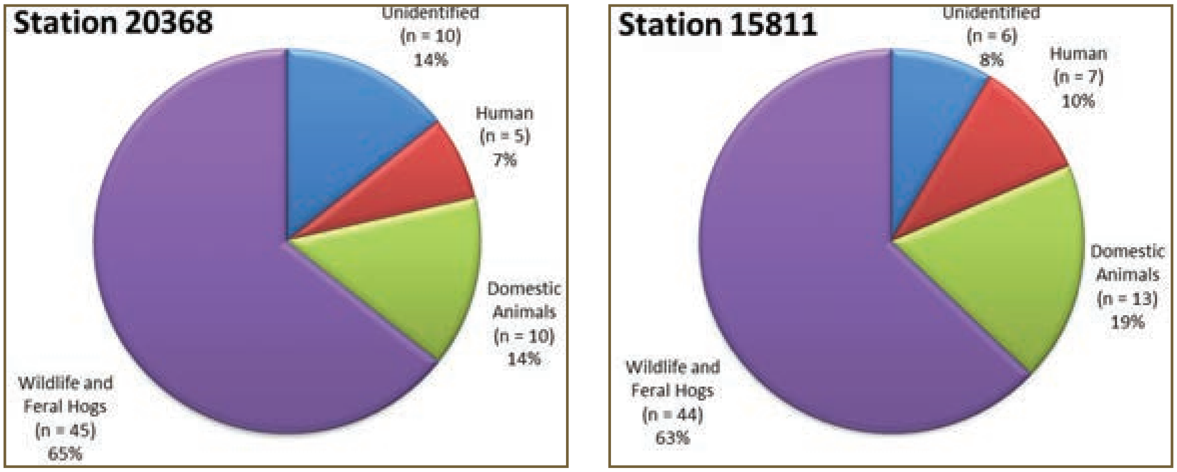


Figure 26. ERIC-RP BST results for Stations 20368 and 15811

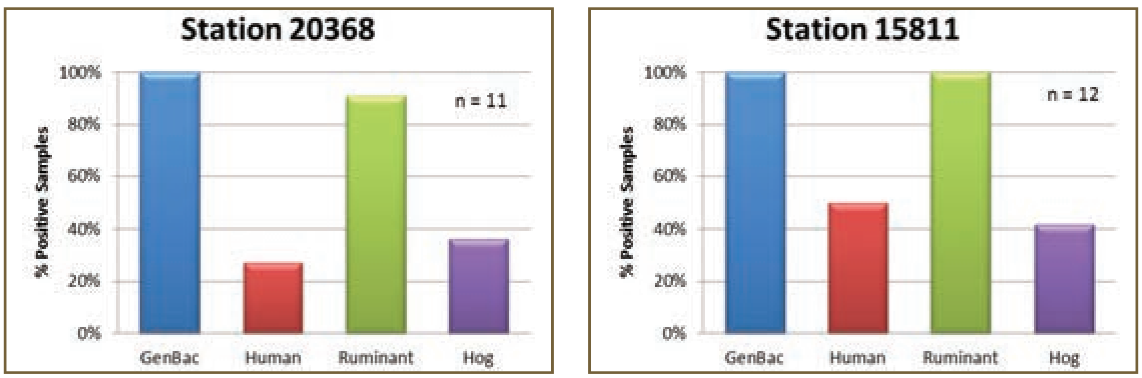


Figure 27. *Bacteroidales* PCR results for Stations 20368 and 15811. Markers abbreviations: GenBac = General *Bacteroidales*; Human = all human sources; Ruminant = all ruminants (i.e. cattle, deer, etc.); Hog = domestic and feral hogs

wildlife, while the *Bacteroidales* PCR method combines portions of those 2 groups into 1 group classified as ruminants. ERIC-RP results are presented in pie charts (Figure 26) and *Bacteroidales* PCR results are presented as bar graphs (Figure 27). BST results from Stations 15811 and 20368 (chosen index sites) are presented here. Complete BST results can be found in Appendix E.

BST results from the ERIC-RP method are relatively similar for both Stations. As illustrated below in Figure 26, wildlife and feral hogs dominate the source contributions at these sites followed by domestic animals, humans and unidentified sources. The observed levels of domestic animals, wildlife and feral hogs was expected and thought to be representative of current watershed conditions. Human sources were higher than anticipated, especially at Station 15811. Station 20368 has a relatively dense cluster of potential OSSFs in the proximity of the monitoring station while Station 15811 does not.

Results from the *Bacteroidales* PCR analysis conducted at these same monitoring locations (Figure 27) showed that of the samples evaluated, all samples tested positive for the general *Bacteroidales* marker, meaning that fecal material pollution was present. Ruminant sources of fecal material were found in all samples at Station 15811 and all but one sample at Station 20368. Fecal contamination from hogs was somewhat lower than expected while human sources were surprisingly high, especially at Station 15811, considering the small number of potential OSSFs in that area of the watershed.

Generally speaking, the bulk of bacteria present in Buck Creek are derived from wildlife sources (including feral hogs) with livestock and humans also identified as significant sources. Wildlife, feral hog and livestock contributions were found at expected levels; however, the occurrence of human sources is somewhat puzzling. Given the small number of OSSFs in the watershed, there are 2 possible explanations for the elevated level of human sources identified. The first possible reason for this finding is direct discharges of human waste into Buck Creek or a tributary. This could stem from a failing OSSF very near the creek or a direct discharge of sewage to the creek from someone without an OSSF or improper disposal of waste from a septic pump truck. In 2004, a septic pump truck was observed parked near a bridge over Buck Creek by the Watershed Coordinator. As the truck was approached, it drove away before any identification could be made. The second potential reason could be false positives for the human marker. The occurrence of false positives for the human *Bacteroidales* marker has been observed in other studies, although it is quite infrequent. This human marker was identified in one badger and 2 porcupine samples from the Buck Creek watershed and has been identified in a small number of coyotes, raccoons, deer and rabbits in other areas of the state. This likely does not explain all of the human markers identified but could contribute to the overall total.

Potential OSSF Failure Analysis

Although the total number of OSSFs in the Buck Creek watershed is quite small and thought to contribute little pollution to the watershed, a slight risk still exists, thus prompting an assessment of this potential source. Using GIS, project personnel conducted 2 spatial analyses to assess the potential for OSSF-derived pollution contributions to Buck Creek; assessing the distance of each potential OSSF from Buck Creek or one of its tributaries and the proximity of each OSSF to septic limited soils.

Using approximate locations of potential OSSFs (Figure 28) identified using the counting methodology described in Chapter 6, project personnel developed a GIS layer of potential OSSF locations. Next, a multiple ring buffer was applied to Buck Creek and its tributaries to determine the number of potential OSSFs that were within

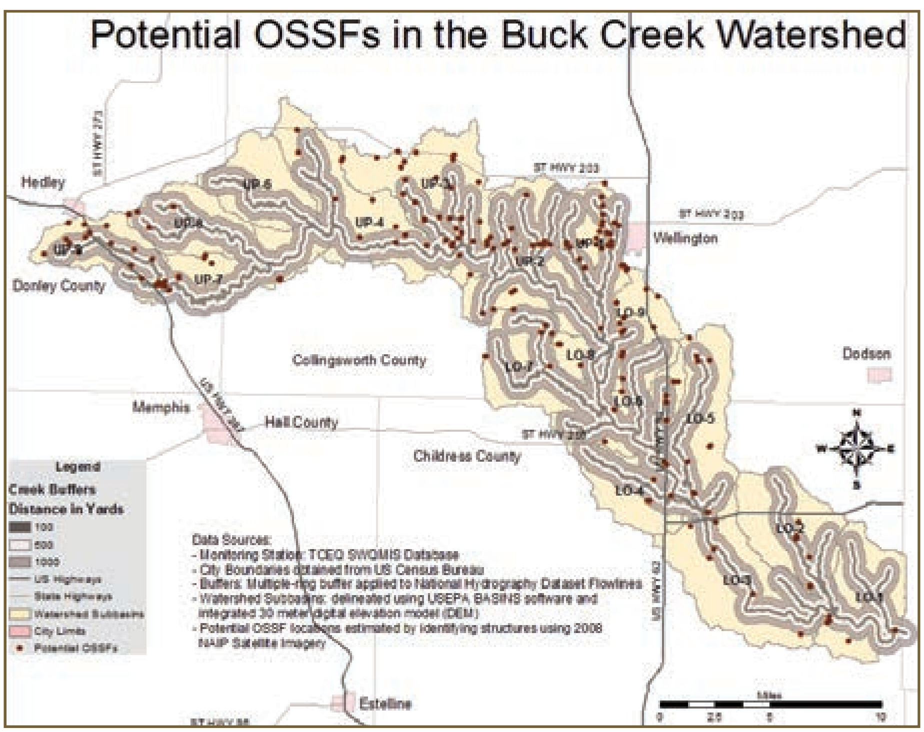


Figure 28. Potential OSSFs in the Buck Creek watershed and multiple distance buffers around Buck Creek illustrating approximate distance of OSSFs from Buck Creek

100, 500 and 1,000 yards (yds) of these water bodies. Table 20 summarizes these findings and illustrates that 9 potential OSSFs are within 100 yds of Buck Creek or one of its tributaries and are the most likely to contribute pollutants to the creek due to this proximity. An interesting fact highlighted through this analysis is that 65% of all potential OSSFs are in the upper part of the watershed.

OSSF proximity to soils considered 'very limited,' 'somewhat limited' and 'not limited' was also assessed. Using NRCS Soil Survey Geographic (SSURGO) data and its Soil Data Viewer extension in ArcGIS, project personnel generated a map layer that illustrated the distribution of soils and their respective septic suitability for the watershed (Figure 29). This enabled potential OSSF locations to be depicted over this layer allowing the number of potential OSSFs in each of the 3 septic suitability categories. Potential OSSFs were found in 'very limited' soils in 27 locations and 'somewhat limited' soils in 18 locations. Additionally, 3 potential OSSFs in the upper part of the watershed were located within 100 yds of the creek and in 'very limited' soils and pose the greatest risk of pollutant contribution to the creek.

Failure rates are the other major factor potentially influencing the contributions of OSSFs to bacteria and nutrient loading to a watershed. County and watershed specific data that illustrate these rates are not available; therefore, regional information was attained and used as representative for the watershed. In this report, Reed, Stowe and Yanke (2001) report that OSSF failure rates in the region inclusive of Buck Creek were found to be approximately 8% but could be higher based on system age, site-specific soils and lack of maintenance. Assuming

Table 20. Distribution of potential OSSFs in the Buck Creek watershed

Watershed Subbasin	# OSSFs in Subbasin	# OSSFs in Very Limited Soils	# OSSFs in Somewhat Limited	# OSSFs in Non-Limited Soils	# OSSFs Within a Given Distance of Buck Creek or Tributary*			# OSSFs in Very Limited Soils and within 1,000
					100 yds	500 yds	1,000 yds	
UP 9	19	3	0	20	2	9	4	3
UP 8	5	0	0	3	2	0	1	0
UP 7	9	0	0	8	1	4	1	0
UP 6	0	0	0	0	0	0	0	0
UP 5	3	0	1	2	0	0	0	0
UP 4	10	4	0	6	1	2	3	4
UP 3	34	3	2	29	1	13	5	3
UP 2	15	5	3	7	0	9	3	5
UP 1	27	1	8	18	1	13	5	1
Upper Watershed Totals	122	16	14	93	8	50	22	16
LO 9	9	0	0	9	0	1	1	0
LO 8	3	1	1	1	0	0	0	0
LO 7	7	0	1	6	0	3	2	0
LO 6	7	1	0	6	0	0	3	0
LO 5	9	3	1	5	0	5	1	0
LO 4	11	3	1	7	0	5	4	1
LO 3	8	0	0	8	0	4	2	3
LO 2	7	3	0	4	0	4	2	0
LO 1	5	0	0	5	1	1	2	0
Lower Watershed Totals	66	11	4	51	1	23	17	4
Entire Watershed Totals	188	27	18	144	9	73	39	20

* The number of OSSFs within a given distance does not include the count from the closer distance to the creek

this failure rate for potential OSSFs in the watershed, it is anticipated that 15 of the 188 OSSFs are likely failing. Assuming that these failures are evenly distributed across all OSSFs, it is estimated that 1.6 of the failing systems are situated in "very limited soils and within 1,000 yds of the creek. That said, the exact number and location of failing OSSFs in the watershed cannot be determined without a physical inspection of each system.

As a result of these analyses, it is expected that there is minimal influence on bacterial or nutrient loading in Buck Creek from OSSFs. The estimated number of OSSFs in the Buck Creek watershed, their proximity to the creek and the fact that 77% of potential OSSFs in the watershed are situated on soils that are 'not limited' for OSSF use further support the anticipated minimal influence of OSSFs on pollutant loading in the watershed. This does not eliminate the potential for bacteria and/or nutrient contributions to the creek from OSSFs nor the need to provide management strategies for addressing potential OSSF loadings.

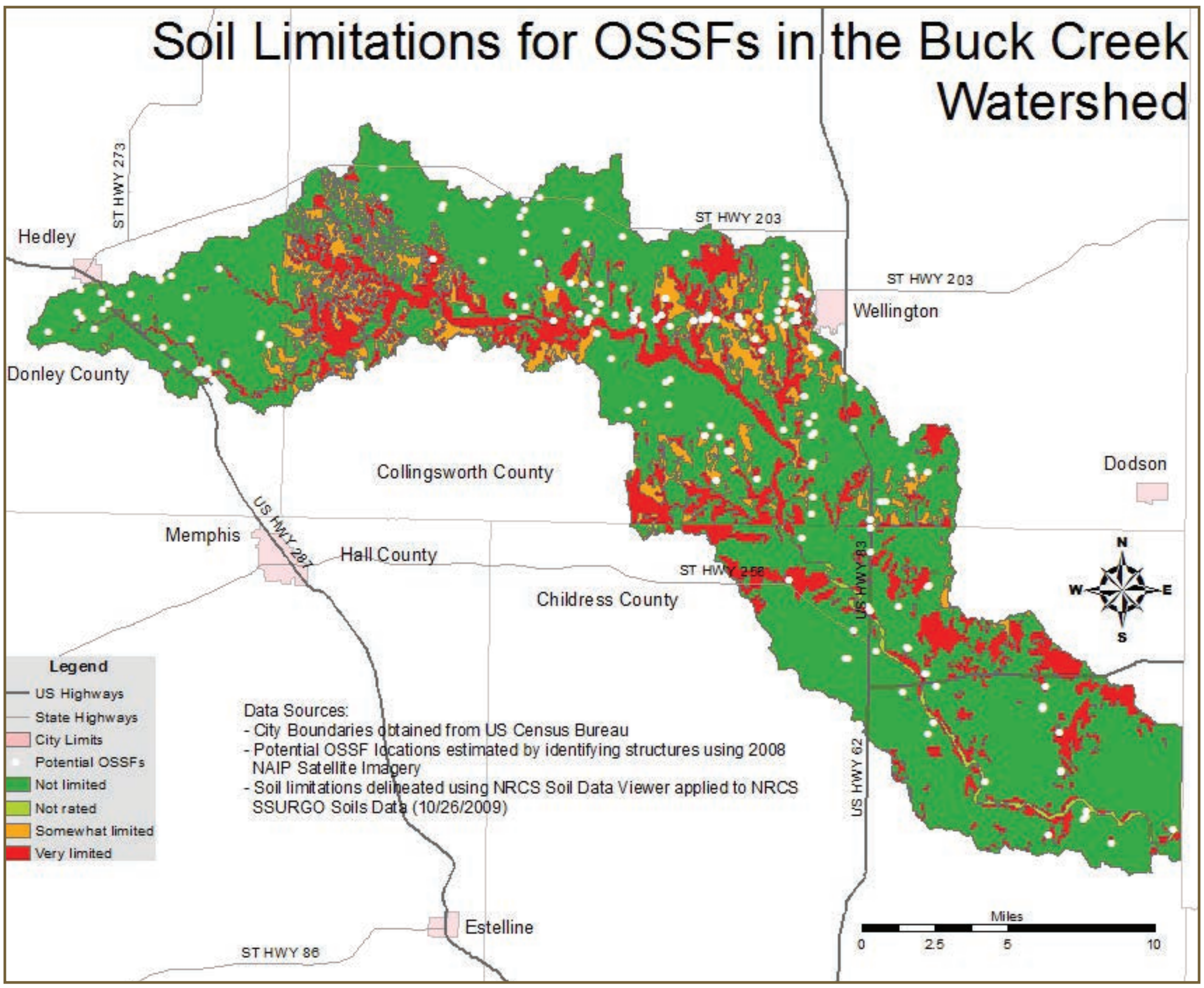


Figure 29. Areas of OSSF soil limitation and potential OSSF distribution in the Buck Creek watershed

Chapter 8
Watershed Goals

When the development of the Buck Creek WPP was initiated, the desired water quality goal expressed by watershed stakeholders was the removal of Buck Creek 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 as calculated by TCEQ. Water quality data collected during the development of the WPP and submitted to TCEQ for water quality assessments resulted in the attainment of this original goal. As reported in the data assessment report in the *2010 Texas Integrated Report,* the calculated *E. coli* geometric means for AUs 0207A_01 and 0207A_02 were 97.6 and 44.2 cfu/100 mL of water respectively. However, also occurring during the process of developing this WPP was the identification of Buck Creek as having a concern for elevated nitrate levels above the established screening level of 1.95 mg/L.

Understanding that water quality goals establish the need to effectively implement the Buck Creek WPP in the future and establish a basis for acquiring resources to implement this plan, watershed stakeholders have established an overarching goal and a pair of secondary goals as targets to achieve through WPP implementation.

Maintain Unimpaired Status

The overarching goal decided upon by watershed stakeholders is to maintain the current unimpaired status that Buck Creek has achieved. This includes maintaining *E. coli* levels in the creek below the current water quality standard for bacteria and preventing the creek from becoming impaired for elevated nitrate levels when numeric nutrient standards are developed for the state. Nitrate standards are likely several years away; however, current water quality data suggest that Buck Creek is higher than the current nitrate screening criterion of 1.95 mg/L.

Further Reduce *E. coli* Levels

To ensure that Buck Creek remains unimpaired, watershed stakeholders set a goal to maintain current *E. coli* levels (*2010 Texas Integrated Report* numbers), but also decided to pursue a 2% load reduction from existing bacteria loads. Using available *E. coli* and flow data, LDCs were developed illustrating the existing bacteria load in the creek. To illustrate this goal, 2% was subtracted from the current load to produce a needed load reduction to meet this goal. Load reductions are discussed at length in Chapter 8 and Appendix C. Once this goal is achieved, *E. coli* levels in the creek will be at least 25% below the water quality standard, ensuring that the creek maintains assimilative capacity to receive infrequent loads of *E. coli* above the water quality standard.

Using the LDCs developed for Stations 15811 and 20368, average daily load reduction goals were established at 2% less than the currently calculated loading. The average daily load reductions needed to meet this 2% goal as calculated for Stations 15811 and 20368 are 6.79 E+08 and 9.39 E+07 cfu respectively. The manner in which these

goals were derived is discussed in detail in Chapter 8 and Appendix C.

These load reduction goals will be achieved and maintained through the voluntary implementation and long-term maintenance of BMPs described in Chapter 9 that mitigate direct bacteria loading to the creek and indirect bacteria loading in riparian areas and the watershed.

Determine an Appropriate Nitrate Screening Level

Water quality data indicate that nitrate levels in Buck Creek are considerably above the current nitrate screening level established by the state. Realizing that numeric nutrient standards are being developed for the state, watershed stakeholders were compelled to recommend developing an appropriate, site-specific nitrate standard for Buck Creek. The screening level currently in use by the state was established at the 85^{th} percentile of all nitrate concentrations recorded statewide. This assumes that all water bodies have similar flow conditions and aquatic life, are used similarly and have comparable abilities to assimilate nitrates. Buck Creek is an intermittent stream that typically maintains pools throughout the year and is thus quite different than many other streams in Texas. In light of this, watershed stakeholders have established a goal of collecting needed data to support the development of an appropriate nitrate screening level and numeric nitrate standard specific to Buck Creek.

To achieve this goal, a special study will be conducted to collect surface water and groundwater quality data to illustrate the connectivity of surface water and groundwater resources in the Buck Creek watershed. These data will supply needed surface water and groundwater data to the RRA and TCEQ, justifying the need for an assessment of Buck Creek's ability to support its designated general use requirements under elevated nitrate conditions.

Chapter 9
Watershed Management Strategies

Strategies for managing sources of pollution identified in the Buck Creek watershed included in this WPP focus on strategies suggested by watershed landowners that have the highest likelihood of being voluntarily implemented and effectively reducing targeted pollutant loads. Not all potential sources of pollution are addressed as they do not require additional management or the needed management to address that source was not economical or desired. Economic viability, benefits to the landowner and anticipated loading reductions received from any particular practice strongly influence the adoption of these practices. Partnership members completed a survey that asked landowners for their opinions on practice feasibility in the watershed and the individual's willingness to implement the given practice. This feedback was incorporated into planning efforts and selection of recommended management measures included in the WPP. Table 21 shows practices that were deemed feasible and had a high likelihood of being implemented by at least 60% of landowners surveyed at the October 23, 2008 watershed partnership meeting.

Using this information, pollutant source analysis (BST results, LDC analysis, SELECT outputs, water quality data), information presented in Chapter 8, and the spatial distribution of each subbasin, management measures were recommended for subbasins with the highest likelihood for contributing from a specific source. Subbasins with subsequently lower likelihoods of pollutant contribution were then identified along with relevant management measures until planned implementation levels were estimated to meet load reduction goals. Depending on the specific source of bacteria addressed, priority subbasins vary across the watershed both in location and in time. Implementation plans are based on need for management within each subbasin and planned accordingly. Subbasin delineations can be seen in Figures 3, 7 and 13.

Bacteria

Many sources contribute to bacteria loading in Buck Creek. As illustrated in Chapter 7, the sources of pollutant loading to Buck Creek are diverse and occur at indiscriminant levels across the entire watershed. Water quality monitoring data illustrate that *E. coli* levels are currently within the state's water quality standard, yet periodic spikes are seen at all monitoring locations. LDC analysis indicates that the bulk of *E. coli* loading in the watershed occurs under the 2 highest flow categories. BST analysis results largely point to wildlife and feral hogs as primary contributors of fecal contamination yet surprisingly illustrates that humans may be bigger contributors than initially thought. The SELECT model predicts that cattle have a higher potential to contribute fecal contamination and *E. coli* loading across the watershed than do deer or feral hogs. Prompted by BST results, analysis of OSSFs illustrates that there is some isolated potential for *E. coli* loading to the stream as well.

Load reduction calculation and the assumptions used for each recommended management measure are presented in detail in Appendix F. Estimated potential load reductions from each management strategy are presented within each Recommended Action discussed in this chapter.

Table 21. Landowner BMP implementation priorities

NRCS Approved Practice and Practice Code (number) or Other Desired BMP	% of Landowners Responding Positively on Practice Feasibility and Willingness to Implement
Brush Management (314) Grassed Waterways (412)	100%
Critical Area Planting (342) Range/Pasture Planting (550/512) Water Well for Livestock (642) Watering Facility for Livestock (614) Pumping Plant for Livestock (533 A, B, C) Pipeline for Livestock Watering (516)	92%
Conservation Cover (327) or CRP Soil Testing Shade Structures	85%
Nutrient Management (590) Ponds (378) Prescribed Burning (338) Prescribed Grazing (528) Residue Management (345, 329, 344) Riparian Herbaceous Cover (390) Terraces (600)	77%
Fencing (Cross Fencing) (382) Filter Strips (393) OSSF Repair/Upgrade Restoration and Management of Declining Habitats (643) Upland Wildlife Habitat Management (645) Wetland Habitat Management (644)	69%
Contour Farming (330) Riparian Forest Buffer (391) Stream Crossing (578) Strip Cropping (585)	61%

Each loading estimate presented is based on predicted 'worst case scenario' loadings and, as a result, do not accurately predict real loadings that are occurring or expected load reductions that may be realized in stream. The dynamics of bacteria's life and death in the environment are poorly understood; therefore it is impossible to accurately predict what load reductions can realistically be expected. Further, ambient weather conditions (e.g. solar radiation, humidity, rainfall, temperature, etc.) strongly influence the survival and persistence of fecal-derived bacteria in the environment.

Cattle and Other Livestock

Fecal loading from cattle and other livestock throughout the watershed is one of the more readily manageable pollutant sources. With the exception of a crazy cow or 2 here and there, their behavior can be managed by fencing and providing their 3 critical needs in order of importance: water, food and shelter. Resource utilization by cattle and other livestock is highly dependent upon where these 3 needs can be met. Fecal loading is directly tied to the amount of time that a particular animal spends in a given area of the watershed, thus, reducing or properly timing use near riparian areas can directly impact potential fecal loading to the creek. Utilization of an area can be modified in many ways including the implementation of fencing, filter strips, prescribed grazing, stream crossing, alternative watering facilities and many others. In areas of the watershed where the creek is relied upon as a primary source of water for cattle and other livestock, providing other sources of water can have a great impact on the amount of time they spend near the creek. Providing food and shelter in locations away from riparian areas can further reduce the time cattle and other livestock spend near creeks (Redmon et al. 2011).

In work conducted in south central Texas, Wagner (2011) found that time spent in or near the creek can be directly tied to the availability of alternative water resources. With a creek as the only source of water, monitored cattle spent an average of 3 min/day directly in the creek. Making an alternative source of water available to the same herd of cattle reduced the average time spent directly in the creek to 1.7 min/day; this is a reduction of 43%. This estimate is conservative compared to other literature values reported outside of Texas. Other practices such as exclusionary fencing, filter strips, prescribed grazing and stream crossings can also be quite effective in reducing fecal contamination (Table 22).

Table 22. Livestock BMP Fecal Coliform Removal Efficiencies

Management Practice	Effectiveness: Low Rate	Effectiveness: High Rate	Median
Exclusionary Fencing [1]	30%	94%	62%
Filter Strips [2]	30%	100%	65%
Prescribed Grazing [3]	42%	66%	54%
Stream Crossing [4]	44%	52%	48%
Watering Facility [5]	51%	94%	72.5%

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

[2] Casteel et al. 2005, 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, Roodsari et al. 2005, Stuntebeck & Bannerman 1998, Sullivan 2007, Tate 2006, Young 1980

[3] Tate et al. 2004, USEPA 2010

[4] Inamdar et al. 2002, Meals 2001

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

As described, these practices will be most effective in grazing systems where cattle and other livestock rely on the creek as a source of water and have unrestricted access. Further increasing their effectiveness will be complementary implementation of selected practices. To aid producers in identifying which practices will be most effective, water quality management plans (WQMPs) can be developed. This is the preferred mechanism to prescribe BMPs targeted to improve instream water quality and can open the door for financial assistance to pay for a portion of these practices. A WQMP is a site-specific plan for agricultural or silvicultural lands that includes appropriate and essential land treatment practices, production practices, management measures and technologies, which when implemented will achieve a level of pollution prevention or abatement determined by the TSSWCB in consultation with the local soil and water conservation district (SWCD) and TCEQ to be consistent with Texas surface water quality standards (TAC §523.3(b)(16)). These plans are designed to assist landowners in managing NPS pollution from agricultural and silvicultural activities. WQMPs are traditional conservation plans based on the criteria outlined in the NRCS Field Office Technical Guide (FOTG). The FOTG is the best available technology and is tailored to meet local needs. WQMPs are developed in cooperation with the landowner with assistance from NRCS and approved by the local SWCD and are certified by TSSWCB. This approach to preventing and abating NPS pollution uses a voluntary approach while affording the landowner a mechanism for compliance with the state's water quality standards (TAC §523.3).

A WQMP covers the entire farm or ranch unit and includes required practices applicable to the planned land use. WQMPs also include technical requirements that the producer must become familiar with and be able to implement. The first step in obtaining a WQMP is to visit the local SWCD. NRCS or SWCD staff can take a request for a WQMP, obtain necessary information from the producer and start the plan development process. There is no charge for development of a WQMP; however, there may be costs for implementing certain practices required in a WQMP, for which financial assistance may be available (TSSWCB 2011).

WQMP needs are described in Recommended Action 1.

Recommended Action 1

Pollutant Source: Cattle and Other Livestock

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

Objectives:
- Work with ranchers, property owners to develop WQMPs
- Customize whole-farm plans
- Provide financial assistance
- Implement WQMPs

Location: Priority subbasins identified below

Critical Areas: Properties with creek access and tributary access

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

Description: WQMPs will be developed in designated 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 and watering facilities.

Implementation Strategies

Participation	Recommendations	Period	Capital Costs
Riparian Areas in subbasins LO-3 & 4, UP-2, 3, & 4	Develop and implement livestock WQMPs $15,000 per plan with 10 plans	2013–2023	$150,000
Other subbasins UP- 6, & 8	Develop, cost share, and implement livestock WQMPs $15,000 per plan with 5 plans	2013–2023	$75,000
Texas A&M AgriLife Extension Service	Deliver *Lone Star Healthy Streams* programming to watershed landowners	2015, 2021	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 and watering facilities on 20% of the estimated ranches in the above listed subbasins, potential annual load reductions from cattle are estimated to be 7.69 E+15 cfu/year for prescribed grazing and 1.03 E+16 cfu/year for watering facilities. Compared to the annual potential load estimated by the SELECT model for the entire watershed of 1.20 E+17, these reductions combined equal 1.80 E+16 cfu/year or a 15% reduction in total *E. coli* loading from cattle. This estimate is further explained in Appendix F. This estimated loading reduction far exceeds the needed load reductions described at Stations 15811 and 20368 to meet the 2% load reduction goal.

Effectiveness:	High: Decreasing the time that livestock spend in the riparian corridor and reducing surface runoff through effectively managing upland vegetative cover will significantly reduce NPS contributions of bacteria and nutrients to the creek.
Certainty:	Medium: 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:	Medium: Landowners are largely willing to implement land stewardship practices that will benefit both the land and their operations; however, costs are often prohibitive 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 needed to illustrate the production and water quality benefits of WQMP development and implementation

Deer and Other Wildlife

Wildlife species were found to be the largest contributor of *E. coli* to Buck Creek by BST analysis. This is not a surprising finding given that the creek and its associated riparian area typically provide the best and most used habitat for the wide variety of wildlife species in the watershed. Many species rely on cover typically associated with riparian areas for daytime loafing/seclusion, foraging, nesting and roosting among other needs. Managing deer and wildlife in the watershed will focus on the voluntary implementation of management practices that will modify their use of the riparian area. This includes items such as the establishment of food and water resources away from the riparian area, removal of excess cover near riparian areas and establishment of preferred habitat away from these areas. Many landowners in the watershed do rely on wildlife species such as deer, quail and turkey as a revenue stream and want to be careful to preserve this resource. Recommended management practices that can be implemented to modify wildlife behavior are outline in Recommended Action 2.

Feral Hogs

Managing feral hog populations was expressed as a primary concern by many, if not all, watershed partnership members. Active efforts undertaken by watershed landowners currently stem the growth of the feral hog herd; however, additional efforts are needed to further reduce these numbers. Without a significant number of hogs removed from the watershed and sustained efforts to keep their numbers down, water quality improvements will not be realized. Trapping, shooting and aerial gunning are currently employed in the watershed, and more of the same are needed as well as general education and awareness about feral hogs, their biology, control options, economic impacts, habitat use characteristics and other feral hog-related issues. Recommended strategies to control feral hogs are described in Recommended Action 3.

OSSFs

Requirements for permitting, establishment, operation, maintenance inspection and repair of OSSFs have been set forth in Title 30, Texas Administrative Code, Chapter 285 and regulate the overall management of OSSFs. Generally speaking, the owners of the OSSF are responsible for maintaining their system so that it is properly functioning. TCEQ Region 10 personnel from Amarillo issue permits for new OSSFs and inspect existing systems in the Buck Creek watershed. This person inspects new OSSFs as they are planned and installed and responds to complaints of failing OSSFs when received. Given the sparse population of the watershed, complaints about failing OSSFs are likely rare as are installations of new systems.

To address the limited potential OSSF pollutant contributions in the Buck Creek watershed, efforts will focus on education and outreach. These efforts will be targeted to OSSF owners as well as sludge haulers and maintenance providers who operate in the watershed. This education will provide information on the proper operation and maintenance of OSSFs as well as information needed to identify a failing system and guidance on how to repair or replace that system. These efforts are described in detail in Recommended Action 4.

Recommended Action 2

Pollutant Source: Deer and Other Wildlife

Problem: Direct fecal loading in riparian areas

Objectives:

- Reduce fecal contaminant loadings in riparian areas
- Reduce time spent in riparian areas
- Provide education and outreach to landowners on proper/improved wildlife management

Location: All riparian areas

Critical Areas: Riparian areas and priority subbasins

Goal: To reduce the amount of wildlife-derived fecal contributions in the riparian area by modifying the time spent in these areas through habitat management

Description: Voluntarily implement efforts to establish more desirable wildlife habitat away from the riparian corridor and/or making riparian habitat less desirable.

Implementation Strategies

Participation	Recommended Strategies	Period	Capital Costs
Landowners, land managers, lessors (Subbasins LO 3 & 4, UP 2, 3, & 4)	Voluntarily work with TPWD and biologists as appropriate to develop property-specific habitat management plans	2013–023	N/A
	Implement habitat management practices as appropriate	2013–2023	TBD
	Work with lessees to locate supplemental feeding locations away from riparian areas	2013–2023	N/A
TWRI	Provide Riparian and Stream Ecosystem Management Workshop	2016	N/A
Texas A&M AgriLife Extension Service; Texas Parks & Wildlife	Deliver wildlife and habitat management workshop highlighting watershed specific needs and assistance opportunities	2016, 2019, 2022	$7,500

Estimated Load Reduction

Reductions in the time that wildlife uses the riparian corridor will reduce bacteria loading in these areas and direct deposition to water bodies. Given the uncertainty of inputs that go into estimating a load reduction from recommended practices, a good-faith load reduction estimate cannot be made for expected reductions as a result of wildlife habitat management. Further discussion on this subject can be found in Appendix F.

Effectiveness:	Low: Wildlife relies on ample water, food and shelter, which is usually most available in and near the riparian corridor. Significant implementation of prescribed practices will be needed to increase their time spent away from riparian areas.
Certainty:	Low: Financial incentives will most likely be needed to garner decent adoption of prescribed practices.
Commitment:	Moderate: Many landowners receive supplemental income from wildlife and are interested in conducting habitat management practices that will maximize income opportunities. TPWD is prepared to coordinate and assist with workshop organization.
Needs:	Moderate: Technical and financial assistance are primary needs for the adoption of habitat management practices most likely to reduce animal time spent in riparian areas. Financial assistance is also needed to facilitate the delivery of wildlife and habitat management workshops.

Recommended Action 3

Pollutant Source: Feral Hogs

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

Objectives:

- Reduce fecal contaminant loading from feral hogs
- Reduce hog numbers
- Reduce nongrowing season food supply
- Provide education and outreach to watershed landowners

Location: All subbasins

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% (731 hogs) and maintain that level of reduction annually.

Description: Voluntarily implement efforts to reduce feral hog populations throughout the watershed

Implementation Strategies

Participation	Recommended Strategies	Period	Capital Costs
Landowners, land managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog utilization	2013–2016	$200 per feeder exclusion
	Voluntarily identify travel corridors and employ trapping and hunting in these areas	2013–2023	N/A
	Voluntarily shoot all hogs on site; ensure that lessees shoot all hogs on site	2013–2023	N/A
Landowners	Voluntarily conduct aerial gunning events	As needed	~$2,000 ea.
Texas Wildlife Services	Aerial gunning	As funding can be secured	~$650/hr
Texas A&M AgriLife Extension Service	Deliver Feral Hog Education workshop	2014, 2018, 2022	$7,500 ea.
Local officials	Coordinate with Texas Wildlife Services to conduct supplemental aerial gunning	2014–2016	N/A

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 by the SELECT model, feral hogs contribute an as much as 1.47 E+16 cfu of *E. coli* to the watershed annually. Using this number, reducing the population by 10% yields a maximum annual load reduction of 1.47 E+15 and reduces the annual load to 1.32 E+16. See Appendix F 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 a transient species that adapts to its environment and will migrate due to hunting and trapping pressure; as such, the ability to remove 25% of the population and prevent a population rebound 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 for aerial gunning are needed to get the upper hand on current feral hog populations; Education and outreach deliver is needed to further inform landowners about feral hog management options

Recommended Action 4

Pollutant Source: Failing OSSFs

Problem: Pollutant loading from failing or nonexistent OSSFs

Objectives:

- Provide education and outreach for owners, installers and maintenance providers

Location: All subbasins

Critical Areas: Entire watershed, but specifically OSSFs situated on soils that are not suitable for OSSF drain fields and within 1,000 yds of the creek or a tributary.

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: Potential OSSF failures will be addressed by providing education and outreach to OSSF owners as well as pumping services and maintenance providers who operate in the watershed. 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
Texas A&M AgriLife Extension Service	Deliver 2 education and outreach events: 1) homeowners and landowners 2) installers, maintenance providers, sludge haulers	2015 & 2021	$30,000

Estimated Load Reduction

Since funding is not being provided to repair or replace failing OSSFs, it is not expected that a high number of systems will be improved. In the event that a failing OSSF is repaired or replaced, an *E. coli* load reduction of 1.86 E+12 cfu can be realized annually for each OSSF replaced.

Effectiveness:	High: Replacement and repair of failing OSSF will yield direct fecal reductions to the creek
Certainty:	Low: It is not known how many OSSF owners, pumping services or maintenance providers would be interested in attending these trainings and how many attendees will apply information learned in the events.
Commitment:	Moderate: Texas A&M AgriLife Extension Service currently operates an OSSF education, outreach and training program and with funding provided, can deliver this program in the Buck Creek watershed.
Needs:	Moderate: Funding to deliver the educational programming in the watershed is needed. Financial assistance may also be needed to encourage OSSF owners to repair or replace failing OSSFs.

Nitrates

Similar to bacteria, nitrates come from a variety of sources throughout the watershed that can cause nutrient loading in streams. Nitrates in the watershed were not monitored as extensively as *E. coli* were due to the late arrival of the nitrates concern. Historic surface water quality data and data collected in the monitoring effort described in Chapter 6 paired with groundwater data assessments and data from underlying aquifers do shed some insight into the locally elevated nitrates. Despite the limited dataset, water quality monitoring data collected by AgriLife Vernon illustrate that nitrate levels are consistently higher in the lower portion of the stream than they are in the upper part of the stream. Data further illustrate that elevated nitrates levels are typical during baseflow conditions and decrease during runoff events, suggesting that groundwater is a significant source of nitrate loadings. LDC analysis further supports this hypothesis. Additional stream and groundwater data are needed to evaluate this hypothesis and to verify the source of elevated nitrates in the creek. Other potential sources likely less influential than groundwater are infrequent runoff from the landscape, failing OSSFs and direct or near-riparian deposition from animal sources.

Natural Nitrates

The discussion and data presented in Chapters 6, 7 and 8 illustrate that natural sources of nitrate present in underlying groundwater could be the primary source of nitrates in Buck Creek. Research conducted by Scanlon et al. (2008) provides compelling evidence that elevated nitrates in the Seymour Aquifer south of the Buck Creek watershed are naturally occurring and present before farming-related nitrate application began in the late 1940s. The limited data set currently available specific to Buck Creek is inconclusive in determining if this is actually the case in Buck Creek as well; however, both baseflow and runoff dominated samples illustrate the highly variable nature of nitrate concentrations in the creek.

While these sources are natural and not caused by anyone in the watershed, several management strategies can be employed that will benefit the environment and landowners alike. Addressing this issue has 2 focuses: 1) collecting and assessing additional water quality data to identify the source of nitrates entering Buck Creek and 2) expanding education and outreach to farmers across the watershed, enabling them to capitalize on available nitrogen resources. Sij et al. (2008), in their work conducted under the *Seymour Aquifer Water Quality Improvement* project (TSSWCB Project #01-08) found that providing education and outreach supplemented with soil and water testing was a critical need for most producers and enhances the likelihood that they will adopt nitrate-mining practices. Nitrates in irrigation water are plant available and should be accounted for when planning to meet crop nutrient needs. In work conducted by Dr. Paul DeLaune through the *Groundwater Nitrogen Source Identification and Remediation* project funded by TSSWCB (Project #09-03), he has been demonstrated that deficit-applying nitrogen to crops to account for the plant-available nitrates in the soil and irrigation water does not adversely impact crop yields or quality. Table 23 illustrates nitrate availability in lbs/ac for irrigation waters of given quality applied at designated rates. The crop planted is used to "mine" nitrates from both the soil and water. Once extracted by the plant, nitrate is stored in the plant tissue and is subsequently exported from the watershed when the crop is harvested and sold. Combined, the results of these 2 projects need to be delivered widely throughout the farming community to broaden the base of farmers that actually implement this nitrate-mining practice.

Additionally, a request to TCEQ will be made to assess the appropriateness of the 1.95 mg/L nitrate screening level in Buck Creek since it is a groundwater-dominated, intermittent stream. A use attainability analysis will be conducted to evaluate the appropriateness of the nitrate screening level or future water quality standard and the ability of the creek to support its designated uses and assimilate existing nitrate loads. This could result in a more appropriate nitrate screening level applied in Buck Creek. These management measures are described in detail in Recommended Actions 5 and 6.

Other Nitrates

Nitrate contributions from other sources in the watershed could also be contributing to elevated nitrate levels seen in the creek and include livestock, feral hogs and failing OSSFs among others. Nitrate deposition from these sources is contributed to the watershed in the same way that *E. coli* from these sources are deposited: through fecal material. As a result, efforts to manage these sources overlap with those discussed earlier in this chapter addressing *E. coli* loading. Ancillary benefits of nutrient reductions will likely be realized when implementing these same management measures; however, nutrient loading from these sources is highly variable for a variety of reasons. Estimated nitrate load reductions from these sources were not calculated.

Table 23. Nitrate availability in irrigation waters at designated application rates and nitrate concentrations

lbs NO_3-N/acre = $N0_3$-N (ppm) x 0.23 x inches of water applied/acre					
Well Water NO_3-N (ppm)	Inches of Water Applied				
	6	12	18	24	30
5	7	14	21	28	35
10	14	28	41	55	69
15	21	41	62	83	103
20	28	55	83	110	138
25	34	69	104	138	173

Recommended Action 5

Pollutant Source: Natural Nitrates

Problem: Groundwater contributions causing nitrate levels in the creek to be in excess of the designated screening level

Objectives:
- Collect nitrates data to verify source of nitrate in creek
- Conduct a water body specific assessment of the appropriateness of the nitrate screening level

Location: In the creek and nearby water wells

Critical Areas: AU 0207A_01

Goal: To conduct additional data assessment to gain additional data on the source of nitrate in the creek and determine the appropriateness of the nitrate screening level.

Description: Additional water quality data will be collected instream, in springs identified in the creek and from nearby irrigation wells to verify the source of nitrate in Buck Creek. Coordinate with TCEQ to evaluate the appropriateness of the nitrate screening level in Buck Creek.

Implementation Strategies

Participation	Recommendations	Period	Capital Costs
Texas A&M AgriLife Research or contractor, creek owners and water well owners	Conduct water quality monitoring and isotope analysis to assess nitrate levels and sources in Buck Creek, identified springs entering the creek and nearby irrigation and water wells	2014–2017	$240,000
TCEQ	Conduct nitrate screening level appropriateness assessment	2015–2017	N/A

Estimated Load Reduction

N/A. This measure will provide information that will aid in quantifying nitrate loading to the stream and identifying the source of nitrate loading. The screening level appropriateness assessment will assess the creek's ability to assimilate nitrates received and determine if a nitrate pollution issue actually exists

Effectiveness:	High: Instream and groundwater quality monitoring will provide needed information to support a variance in the applicable nitrate screening level for Buck Creek
Certainty:	High: Field observations and anecdotal evidence by watershed landowners strongly supports hypotheses that groundwater is the driving factor behind elevated nitrate levels
Commitment:	Moderate: Financial assistance will be sought to conduct instream and well water testing; TCEQ has not yet been approached about a nitrate screening level assessment
Needs:	Moderate: Financial assistance needs are minimal to conduct water quality assessments instream and in nearby water wells. TCEQ should have needed staff and resources to conduct the nitrate screening level assessment. Funds needed to conduct water quality monitoring and isotope analysis are substantial and are crucial for being able to conduct this analysis.

Recommended Action 6

Pollutant Source: Natural Nitrates

Problem: Groundwater contributions causing nitrate levels in the creek to be in excess of the designated screening level

Objectives:
- Provide soil and water testing in targeted subbasins
- Provide education and outreach to farmers on available nitrate resource

Location: Priority subbasins identified below

Critical Areas: Subbasins dominated by irrigated cropland

Goal: To provide education and outreach promoting nitrate mining supported by no-cost soil and water testing

Description: Soil and water testing in designated subbasins will be conducted to highlight available nitrate resources. Education and outreach on proper nutrient management will be delivered to all farmers in the watershed to further promote adoption of groundwater and soil nitrate mining in the watershed and will be supported by soil fertility demonstrations.

Implementation Strategies

Participation	Recommendations	Period	Capital Costs
Texas A&M AgriLife Research; target farmers in Subbasins LO-4, 5, 6, 7, 8 & 9; UP-1, 2, & 3	Conduct soil fertility demonstrations and provide soil and irrigation water testing in the watershed in support of education and outreach efforts.	2013–2016	$50,000
Texas A&M AgriLife Extension Service; Texas A&M AgriLife Research	Deliver nutrient management education and outreach program in the watershed and soil fertility demonstration	2013, 2016, 2020	$7,500
Farmers in Subbasins LO-4, 5, 6, 7, 8 & 9; UP-1, 2, & 3	Implement nitrate-mining practices on irrigated cropland	2012–2022	N/A

Estimated Load Reduction

The Buck Creek watershed contains an estimated 67,335 ac of cultivated land of which approximately 20% is irrigated. Assuming a 50% adoption rate of nitrate mining and a conservative estimate of 25 lbs of nitrate being applied per acre annually, a load reduction of 168,337 lbs of nitrate will be removed from the watershed through harvested crops. Once soil and irrigation water testing are implemented and supported by soil fertility demonstrations and nutrient management education, a better estimate of nitrate load reductions can be made.

Effectiveness:	Low: The volume of nitrate-stored groundwater resources and hydrogeological processes responsible for the dissolution of nitrates into underlying aquifers is not well understood; as a result nitrate mined from the aquifer may pale in comparison to existing stores.
	Moderate: Education and outreach paired with soil and water testing and fertility demonstrations are critical needs to effectively change cropping practices.
Certainty:	High: Nitrate mining is a cost-advantaged practice for farmers and will yield substantial nitrate reductions when implemented.
	High: Education and outreach paired with nutrient testing and fertility demonstrations is the primary hurdle preventing widespread adoption of the practice. Once farmers see the economic implications of implementing this practice, it will be adopted.
Commitment:	Moderate: Financial assistance will be sought to provide soil and irrigation water testing free to the landowner as well as to conduct soil fertility demonstrations.
	Moderate: Farmers are leery of under-applying nutrient and risking production in the event that rainfall is above average and irrigation is below average.
Needs:	Low: Financial assistance to conduct soil and irrigation water testing, fertility demonstrations and education and outreach efforts are reasonable given potential loading reductions from implementing nutrient mining.

Technical Assistance Needs and Sources

To successfully implement the Buck Creek WPP, track WPP implementation activities and move forward efforts to secure funding and technical assistance needs, a coordinated effort is required. The logical choice to meet these needs is to establish a Watershed Coordinator position to fill this role. Ideally, this person will serve as a consistent point of contact for the Buck Creek Watershed Partnership and WPP implementation efforts and work to keep watershed stakeholders engaged and actively implementing the WPP. AgriLife Research personnel from AgriLife Vernon have fulfilled this role to date and will likely do so for the near future; however, other options can be explored should the need arise. This position is, of course, dependent upon funding availability and efforts will be made to secure sources of funds needed.

Technical assistance needs in the watershed vary substantially depending on the source of pollution being addressed and the specific management recommendation being used. Many watershed stakeholders participating in the development of this WPP have extensive knowledge in specific subject areas; however, some of the recommended management measures will require technical expertise that is not readily available.

The needs and sources of technical assistance to provide guidance on planning and implementing management practices described in the 6 Recommended Actions outlined earlier are quite diverse and specific to each individual practice. Table 24 summarizes these needs and the available sources that will be relied upon to provide this needed assistance.

Table 24. Technical assistance needs and sources to support WPP implementation

Management Practice	Technical Assistance Needs	Sources of Technical Assistance
Management Recommendation 1		
WQMP Development	Planning assistance to develop property specific WQMP that supports producer and water quality mangement goals	TSSWCB/SWCD Technicians; NRCS District Conservationists
WQMP Implementation Tracking	Coordinated tracking of WQMP practices implemented and assessment of expected water quality improvements	TSSWCB/SWCD Technicians; Watershed Coordinator
Lone Star Healthy Streams Program Delivery	Delivery of technically sound information on land stewardship and livestock management practices that promote improve water quality	Texas A&M AgriLife Extension Service
Management Recommendation 2		
Wildlife Habitat Planning	Planning assistance to develop property specific wildlife habitat management plans to reduce wildlife time spent in riparian areas	TPWD Regional Biologist; Texas A&M AgriLife Extension Wildlife Specialist; NRCS District Conservationist
Habitat Management Workshop	Delivery of technically sound wildlife habitat management informaiton to watershed landowners	TPWD Regional Biologist; Texas A&M AgriLife Extension Wildlife Specialist
Wildlife Habitat Management Practice Implementation Tracking	Coordinated tracking of wildlife habitat management practices implemented and assessment of expected water quality improvements	TPWD Regional Biologist; Watershed Coordinator
Management Recommendation 3		
Feral Hog Aerial Gunning	Skilled expertise in the use of helicopter based feral hog control measures	Texas Wildlife Services; Contractor
Feral Hog Abatement Outreach	Technology transfer of improved tactics and methods for controlling feral hogs	Texas A&M AgriLife Extension Service; Watershed Coordinator
Feral Hog Control Tracking	Coordinated tracking of Feral Hog control efforts implemented and estimated numbers removed and an assessment of expected water quality improvements	Watershed Coordinator
Management Recommendation 4		
Education and Outreach on Proper OSSF Operation, Maintenance, Rules and Regs	Delivery of applicable and accurate information on the state's rules and regulations regarding OSSFs and the role of the OSSF owner in properly operating and maintaing these systems	Texas A&M AgriLife Extension Service; Watershed Coordinator
Management Recommendation 5		
Surface and Groundwater Testing	Assistance to monitor and collect water samples; perform analysis and evaluations of sources of nitrate in surface and groundwater	Texas A&M AgriLife Research
Nitrate Screening Level Assessment	Technical expertise to conduct a waterbody assessment to determine the appropriateness of the nitrate screening level	TCEQ
Management Recommendation 6		
Soil and Water Testing Paired with Fertility Demonstrations	Assistance to monitor and collect water samples; perform analysis and evaluations of sources of nitrate in surface and groundwater resources	Texas A&M AgriLife Extension Service; Texas A&M AgriLife Research; Watershed Coordinator
Nutrient Management E&O	Delivery of nutrient management education and outreach program that illustrates ability to mine nitrate from the watershed	Texas A&M AgriLife Extension Service; Texas A&M AgriLife Research

Chapter 10
Sources of Financial Assistance

Successful implementation of the Buck Creek WPP, as written, will require substantial fiscal resources. Due to the extremely 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 Buck Creek is viewed locally. Buck Creek is a small intermittent stream that is dry or pooled for the bulk of the year and generally exhibits good water quality. Local landowners generally feel that the creek is as healthy as it can be but recall a more vibrant creek that maintained flow almost year round. As a result, monetary support from local watershed residents is largely limited to landowners that are investing their dollars to support management needs on their respective properties.

To implement WPP implementation items such as OSSF management, nitrate source assessments, continued water quality monitoring and support for a watershed coordinator, grant funds will be solely relied upon. While it is noted that grant funds are not sustainable, they are the only source of money identified at this point that can be contributed to these WPP implementation areas. Some specific sources of funding that are applicable and available for use in implementing this WPP are briefly described below.

Federal Sources

Farm Bill Programs

The *Food, Conservation and Energy Act of 2008,* 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. Programs geared toward conservation continue to promote land conservation and environmental practice implementation (USDA-ERS 2008). Individual programs falling under the provisions of The Farm Bill are discussed below. It should be noted that The Farm Bill is currently undergoing a revision and the level and certainty of funding sources that will be available in the future is unclear.

Agricultural Water Enhancement Program

The Agricultural Water Enhancement Program (AWEP) is a voluntary conservation initiative operated by USDA-NRCS that provides financial and technical assistance to farmers and ranchers to improve surface water and groundwater conditions on their agricultural land. AWEP is a part of the EQIP (see below) that operates through program contracts with producers to plan and implement conservation practices in project areas established through partnership agreements. Producers engaged in livestock or agricultural production may be eligible for the program and eligible land includes cropland, rangeland, pasture and other farm or ranch lands. http://www.nrcs.usda.gov/wps/portal/nrcs/main/tx/programs/financial/awep/

Conservation Reserve Program

The **USDA–Farm Service Agency** (FSA) operates the Conservation Reserve Program. This is a voluntary program for agricultural landowners, which enables producers to receive annual rental payments and financial assistance to establish long-term, resource conserving covers on eligible farmland. The program also provides up to 50% of landowner costs in establishing approved conservation practices. The Conservation Reserve Program contracts vary between 10 and 15 years in length. www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp

Conservation Stewardship Program

The Conservation Stewardship Program (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. www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/financial/csp/?cid=nrcs143_008316

Environmental Quality Incentives Program

The **USDA-NRCS** operates the Environmental Quality Incentives Program (EQIP) is 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. These contracts 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. www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Grassland Reserve Program

The Grassland Reserve Program (GRP) is a voluntary conservation program jointly administered by USDA-FSA and USDA-NRCS that supports grazing operations, plant and animal biodiversity and protection of grasslands under threat of conversion to other uses. Program participants can enroll land permanently or under rental contract periods ranging from 10 to 20 years. Applications for GRP are accepted on a continual basis at your local USDA Service Center. www.tx.nrcs.usda.gov/programs/GRP/index.html

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program administered by **USDA-NRCS** for conservation-minded landowners who want to develop and improve wildlife habitat on private lands. It provides both technical assistance and cost sharing up to 75% to help establish and improve fish and wildlife habitat. Participants work with USDA-NRCS to prepare a wildlife habitat development plan in consultation with a local conservation district. National priorities for the WHIP program include restoration of declining native fish and wildlife habitat, reduce the impacts of invasive species on fish and wildlife habitats; protect, restore, develop, or enhance important migration and other movement corridors for wildlife. www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/whip/

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

State Sources

Agricultural Water Conservation Program

The Texas Water Development Board (TWDB) provides grants and low-interest loans to political subdivision and private individuals for agricultural water conservation and/or improvement projects. The program also provides a linked deposit loan program for individuals to access TWDB funds through participating local and state depository banks and farm credit institutions. www.twdb.state.tx.us/financial/programs/AWCG/index.asp

Clean Rivers Program

The Texas Clean Rivers Program 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 Buck Creek, the RRA is the designated Clean Rivers Program partner and might be able to provide limited resources for the continued monitoring of Buck Creek to aid in assessing water quality conditions and implementation impacts. www.rra.dst.tx.us/

Clean Water State Revolving Fund

The **TWDB** provides loans at lower than market rates to entities the authority to own and operate a WWTF. These loans can have flexible terms and principal forgiveness for planning, designing and constructing wastewater infrastructure improvements and NPS pollution controls. www.twdb.state.tx.us/financial/programs/CWSRF/index.asp

Landowner Incentive Program

The **TPWD** Landowner Incentive Program (LIP) is designed to meet the needs of private landowners wishing to enact good conservation practices on their land. LIP program efforts are focused on projects aimed at creating, restoring, protecting and enhancing habitat for rare or at-risk-species throughout the State. The proposed conservation practices must contribute to the enhancement of at least one rare or at-risk species or its habitat as identified by the Texas State Wildlife Action Plan or the LIP Priority Plant Species List. www.tpwd.state.tx.us/landwater/land/private/lip/

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, www.texasrcd.org/) with pre-approved "umbrella" projects. www.tceq.state.tx.us/legal/sep/

Texas Farm & Ranch Lands Conservation Program

This program, established by Senate Bill 1273 in 2005, is administered through the **General Land Office of Texas**. This program provides grants to landowners for the sale of conservation easements that create a voluntary free-market alternative to selling land for development, which stems the fragmentation or loss of agricultural lands. www.glo.texas.gov/what-we-do/caring-for-the-coast/grants-funding/projects/texas-farm-ranch-conservation.html

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 your 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 9

WQMP that implement prescribed grazing on 29,630 ac and NRCS has developed conservation plans that include prescribed grazing on another 4,520 ac. To support these grazing management systems, landowners have installed cross-fencing and alternative watering sources, among other management practices. In fiscal year 2011 alone, Hall-Childress SWCD received $19,557.77 and Salt-Fork SWCD received $21,532.10 in financial assistance through TSSWCB's WQMP program. www.tsswcb.state.tx.us/wqmp

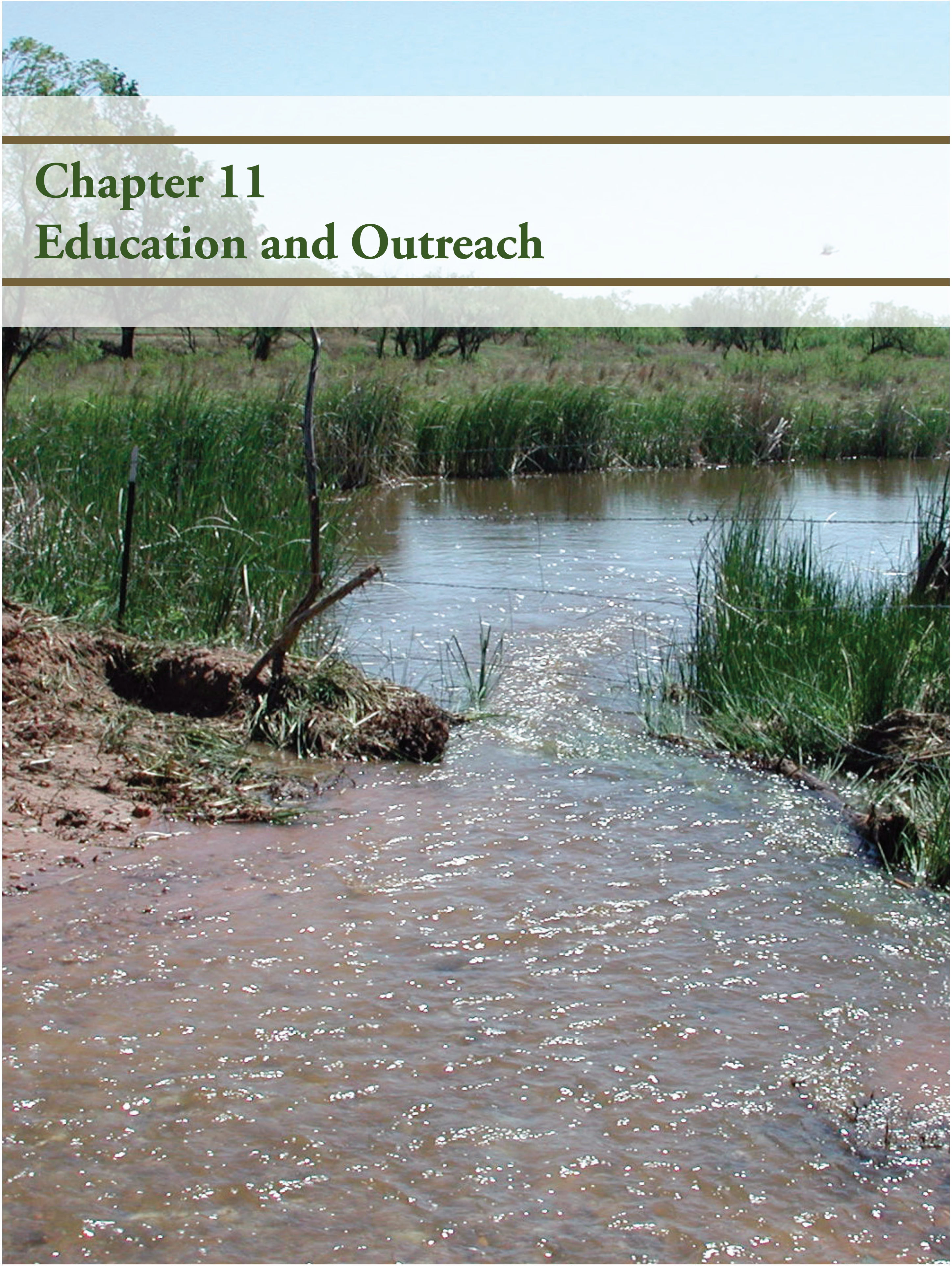
Other Sources

Numerous private foundations, nonprofit organizations, land trusts and individuals also represent potential sources of funding that can be used for implementing WPPs. Each group will have its own set criteria that must be met to receive funding and these criteria should be explored before applying.

Directory of Watershed Resources

Using funds from TCEQ, TWRI worked with the Environmental Finance Center at Boise State University to update the Directory of Watershed Resources to include Texas-specific funding programs. The Directory of Watershed Resources is an online, searchable database for watershed restoration funding. The database includes information on federal, state, private, and other funding sources and assistance and allows Texas users to query information in a variety of ways including by agency sponsor, or keyword, or by a detailed search. www.efc.boisestate.edu/efc/watershed/SearchOurDatabase/TargetedSearch/tabid/199/stype/3/Default.aspx

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 will be needed to accomplish comprehensive improvements in the Buck Creek watershed of Texas. 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 with 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. Ms. Phyllis Dyer of Texas A&M AgriLife Research at the AgriLife Vernon has filled this role and will continue to do so.

The future role of the Watershed Coordinator is perhaps the most important as she 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.

Current Efforts

Project Website www.buckcreek.tamu.edu

TWRI developed and hosts a website for the Buck Creek watershed. This site is home to information about the projects, the watershed, publications and presentations about the project, upcoming meeting notices and news releases. The WPP can also be downloaded from the Buck Creek website and links to project partners are provided on the website as well.

News Releases and Newsletters

AgriLife Vernon and TWRI have developed and distributed news releases to local media outlets during the development of this WPP. Newspapers regularly picking up and running the stories about upcoming meetings are the *Amarillo Globe-News, Childress Index* and *Wellington Leader* among others. Additionally, the release is delivered electronically via AgriLife Today. To date, 9 news releases were distributed and were picked up by various local and regional media outlets.

Newsletters and meeting announcements were also e-mailed and/or mailed directly to stakeholders to keep them informed of upcoming project activities. During

Stakeholders at Buck Creek Field Day, June 24, 2008

Stakeholders at the Texas Watershed Steward program, January 24, 2008

WPP development, 12 newsletters were distributed to 2,069 individuals to keep watershed stakeholders informed of project happenings and upcoming events. Newsletter distribution was timed such that they were sent at approximate midpoints between planned meetings. This allowed for continued engagement of the stakeholder group without hosting a physical meeting.

Public Meetings and Field Days

Throughout the course of this effort, stakeholder engagement has been critical, and since early 2004, 21 meetings and educational events have been held (Table 25). These meetings provided attendees with information about the findings of the monitoring project. Using stakeholder feedback and data collected led to the continuation of monitoring and the application of additional planning tools with a WPP as an end goal. This WPP integrates science and stakeholder input described above to develop a comprehensive watershed specific plan for restoring and protecting water quality in Buck Creek. Public meetings engaging watershed stakeholders and local officials have been integral to this effort. 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

Table 25. Project meeting list and number in attendance

Meeting Type	Date	Meeting Audience	# in Attendance
Educational	2/8/2005	Hall Co. Farm & Ranch Meeting	80
Educational	9/27/2006	TAMU Soil & Crop Science Dept.	12
Educational	5/6/2007	Quail Appreciation Day	40
Field Day	6/12/2007	Educational Field Day	35
Field Day	6/24/2008	Educational Field Day	32
Informational	3/30/2004	Red River Authority	10
Informational	10/28/2004	Red River Authority	10
Informational	3/30/2005	Red River Authority	15
Informational	3/14/2006	Red River Authority	25
Informational	3/15/2007	Red River Authority	23
Informational	3/21 & 28/2006	Red River Authority Basin Advisory Committee	86
Informational	3/20 & 27/2007	Red River Authority Basin Advisory Committee	82
Informational	3/25 & 4/1/2008	Red River Authority Basin Advisory Committee	75
Informational	3/24 & 31/2009	Red River Authority Basin Advisory Committee	69
Informational	3/23 & 30/2010	Red River Authority Basin Advisory Committee	64
Informational	3/22 & 29/2011	Red River Authority Basin Advisory Committee	61
Public	5/5/2005	Stakeholder Meeting	18
Public	5/9/2006	Stakeholder Meeting	22
Public	6/12/2007	Stakeholder Meeting	40
Public	9/11/2007	Stakeholder Meeting	55
Public	1/24/2008	Texas Watershed Steward	37
Public	6/24/2008	Stakeholder Meeting	43
Public	10/23/2008	Stakeholder Meeting	17
Public	4/30/2009	Stakeholder Meeting	28
Public	7/21/2009	Stakeholder Meeting	18
Public	10/27/2009	Stakeholder Meeting	20
Public	8/25/2011	Stakeholder Meeting	17
Total People in Attendance:			1,034

was conveyed as well. Field days further illustrated management practices discussed and gave those interested in implementing a particular practice a chance to speak with landowners that had already implemented these practices.

In addition to the meetings listed above, constant contact was made with each of the 3 SWCDs in the watershed. In total, 14 SWCD meetings were attended in person and the Watershed Coordinator participated in an additional 47 SWCD meetings by phone. Each SWCD meets monthly and the Watershed Coordinator initially attended meetings in person. After several rounds of SWCD meetings, the SWCD board members and Watershed Coordinator determined that participating in the bulk of these meetings by phone was most appropriate and the best use of financial resources. In each of these instances, the Watershed Coordinator provided a brief update on respective Buck Creek projects and answered any questions from attending board members.

Texas Watershed Steward Program

The Texas A&M AgriLife Extension Service delivered the Texas Watershed Steward program January 24, 2008 in Wellington. 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. At the one-day workshop there were 37 participants learning about the nature and function of watersheds, water quality impairments and watershed protection strategies to minimize NPS pollution.

Additionally, this educational platform allowed the collection of vital information on willingness to adopt management practices that will aid in protecting the watershed. At the time of the Texas Watershed Steward event, 61% of participants indicated that they do plan to implement improved management practices that will promote better water quality. A follow-up survey conducted 6 months later indicated that 80% of respondents indicated that they had already implemented beneficial practices.

Future Stakeholder Engagement

Watershed stakeholders will continue to be engaged throughout and following the transition of efforts from development to implementation of the WPP. The Watershed Coordinator will play a critical role in this transition by continuing to organize and host periodic public meetings and needed educational events 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 and the project website will be primary tools used to communicate with watershed stakeholders on a regular basis and will be developed to update readers periodically on implementation progress; provide information on new implementation opportunities, available technical or financial assistance; and other items of interest related to the WPP effort.

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

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 Buck Creek watershed and advertised to watershed stakeholders. An approximate schedule of when specific programs will be held in the watershed is presented in Table 27 later in Chapter 13. This schedule will be used as a starting point for planned programming, and efforts will be made to abide by this schedule to the extent possible. As implementation and data collection continues, the adaptive management process will be used to modify this schedule and respective educational needs as appropriate.

Feral Hog Management Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver periodic workshops focusing on feral hog management. This workshop will educate landowners on the negative impacts of feral hogs, effective control methods and resources to help them control these pests. Workshop frequency will be approximately every 5 years unless there are significant changes in available means and methods to control feral hogs. Feral hog management education is incorporated into the *Lone Star Healthy Streams* program and, as such, is the appropriate delivery mechanism for this programming. Information on this program can be found online at: lshs.tamu.edu.

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 by beef cattle producers to reduce NPS pollution. This statewide program promotes the adoption of BMPs that have proven to effectively reduce bacterial contamination of streams. This program provides educational support for the development of WQMPs by illustrating to program participants the benefits of many practices available for inclusion in a WQMP. This program will likely be delivered in the watershed once every 5 years or as needed. 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 Buck Creek will be held in the first year of WPP implementation and will be followed by subsequent workshops held in and around the watershed on a near annual basis. Crop production is critical to the local economy in the Rolling Plains and Panhandle and nutrient management workshops are often held near the watershed a locations such as the Chillicothe Research Station. 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.

Additionally, an online training module that provides an overview of septic systems, how they operate and what maintenance is required to sustain proper functionality and extend system life will be made available to anyone interested through the partnership website. This training module was developed by the Guadalupe-Blanco River Authority in cooperation with AgriLife Extension and is currently available online at: www.gbra.org/septic.swf.

Soil and Water Testing Campaign

Given the importance of crop production and irrigation in the Buck Creek watershed, a soil and water testing campaign will greatly improve local producer's knowledge about nutrient levels applied to specific fields. Funding is currently being sought to fully fund sample analysis costs for 1,000 soil samples and 150 water samples. If funded, this testing campaign will be done in conjunction with the initial nutrient management workshop delivered in the watershed. Pairing these events will enhance participation in both activities and further the educational outcomes by providing property-specific information to the producer that clearly illustrates the economic and environmental impacts of proper nutrient application. It is recommended that soil testing be done every 3 years at a minimum. Through the combined efforts of this testing campaign and the nutrient management workshop, it is expected that producers will realize the value in conducting soil and water testing at least this often and undertake these efforts on their own in the future. The Watershed Coordinator, AgriLife Research and Extension personnel and others as appropriate (NRCS, SWCDs, others) will promote participation in these programs and stress the benefits of conducting soil and water tests.

Texas Well Owners Network Training

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network (TWON) program provides needed education and outreach regarding private drinking water wells and the impacts on human health and the environment that can be mitigated by using proper management practices is the focus of this training event. 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 Buck Creek watershed. Additionally, permission will be sought from program participants to obtain nitrates data from well screenings conducted in the watershed and will be useful in illustrating spatial trends in nitrate variability across the 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 Buck Creek watershed in the near future. The Watershed Coordinator will work to plan an associated field day to coincide with this event.

Wildlife Management Workshops

Wildlife have a significant impact on the Buck Creek 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 Buck Creek watershed. With the variety of wildlife species prevalent in the Buck Creek watershed, it is anticipated that workshops focused on at least one game species will be delivered regionally every other year. Wildlife management workshops will be advertised through newsletters, news releases, the project website and other avenues as appropriate.

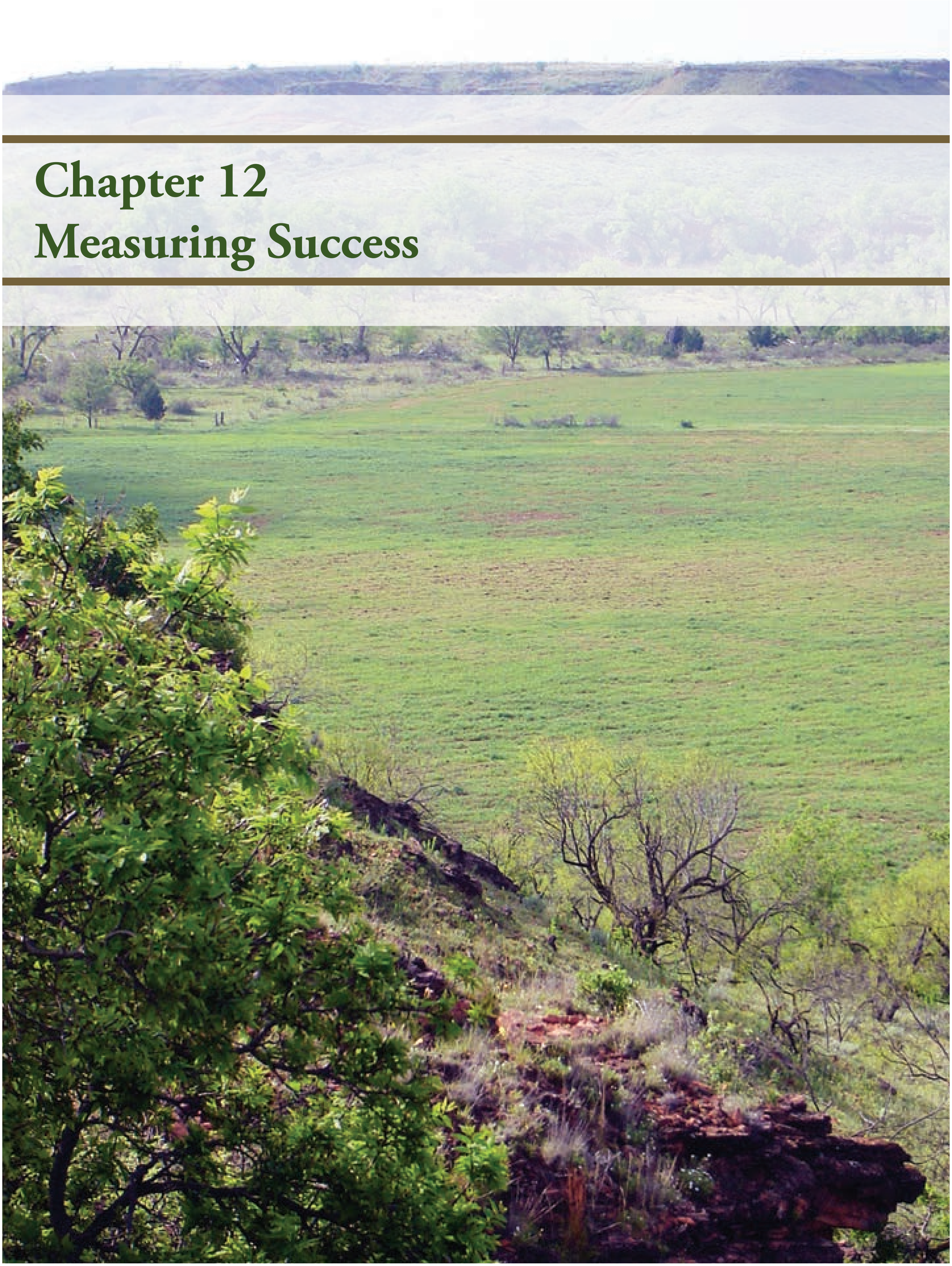
Public Meetings

Continuing to periodically conduct public stakeholder meetings will be employed to 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 addendums 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

Buck Creek Watershed Partnership newsletters will continue to be developed and will be sent directly to actively engage stakeholders. Newsletters will be sent approximately semi-annually and will be staged such that they come out between project meetings. News releases will also be developed and distributed as needed through the mass media outlets in the area and will be used to highlight significant happenings related to WPP implementation and to continue to raise public awareness and support for watershed protection. These means will be used to inform stakeholders of 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.

Chapter 12
Measuring Success



Measuring WPP implementation success is an inherently complex process that requires evaluation of multiple measures including incrementally measurable milestones, environmental indicators and water quality assessments. Adequately and appropriately quantifying each of these measures provides critical information that will be integrated into the adaptive management process inherent in watershed planning. Figure 30 illustrates the 3 primary measures that will be used to gauge the success of WPP implementation.

Interim Measurable Milestones

Milestones are used as a measure to evaluate progress in implementing specific management measures recommended in the WPP. These milestones outline a simple tracking method that clearly illustrates if management measures are implemented as scheduled.

Milestones are separated into short-, mid- and long-term milestones. Short-term milestones can be quickly accomplished using existing or easily attainable resources and during the first 3 years of WPP implementation. Mid-term milestones will take more time to complete and will likely need additional funds secured before they can be undertaken. These milestones will likely be completed within 4 to 6 years of beginning to implement the WPP. Long-term milestones include those management measures that will take the longest time to organize, prepare for 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

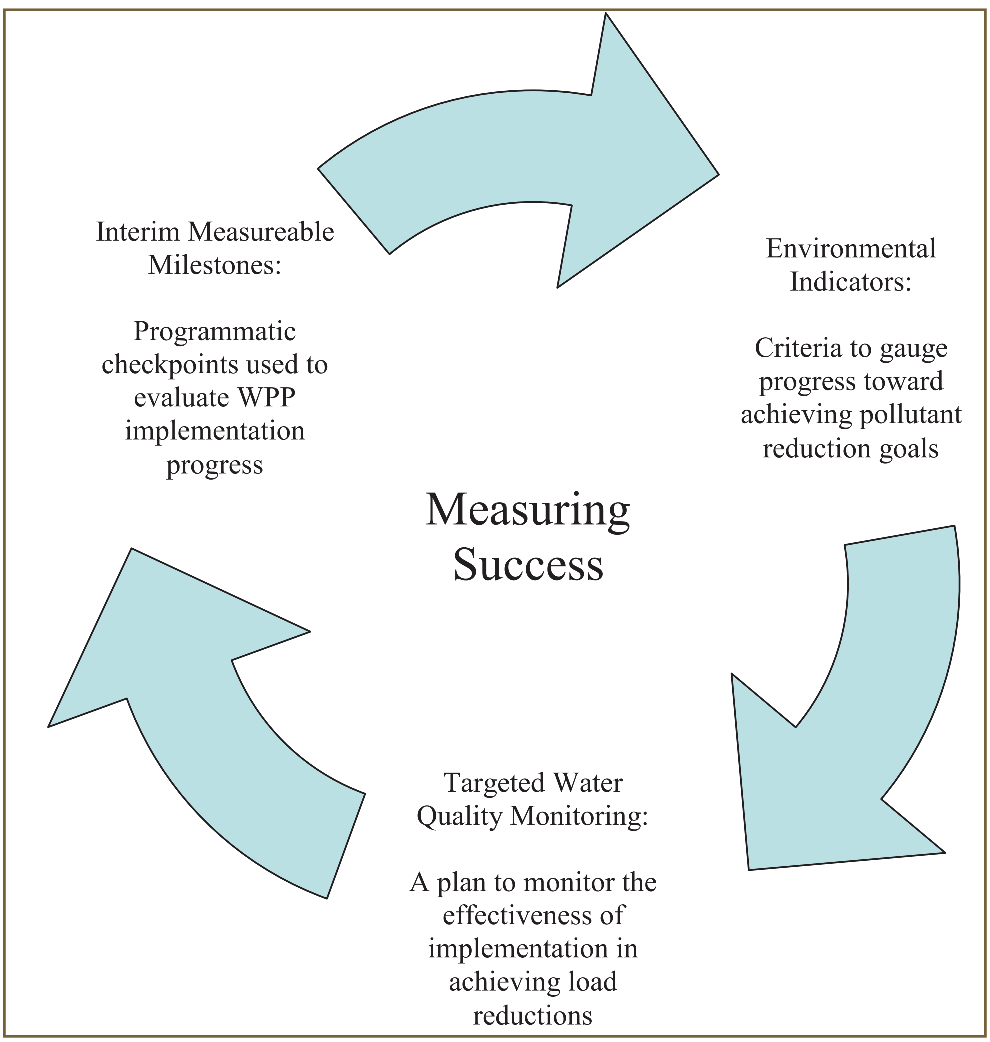


Figure 30. Integrated approach to successfully measuring progress toward achieving WPP goals

implemented 7 years after WPP implementation has begun.

Interim measureable milestones are identified in the implementation schedule outlined Tables 27 and 28 presented in Chapter 13.

Milestones are simply goals of when a specific practice or measure is targeted for implementation. It is quite likely that some milestones will be accomplished sooner than anticipated while others will be completed slower than expected. If milestones are completed ahead of schedule, their completion will be documented and implementation efforts will be shifted to the next implementation milestone as appropriate given resource availability. Should a milestone not be reached during the anticipated implementation period, efforts will continue to implement them until the milestone is accomplished. If it is determined that the milestone is not achievable, the milestone will be addressed during the adaptive management process.

Environmental Indicators

WPP implementation success will also be gauged by evaluating improvements in water quality. As explained in Chapter 2, the Buck Creek Watershed Partnership established a goal of reducing *E. coli* loads by an additional 2% from the current levels reported in the Buck Creek WPP. In similar terms, this reduction can be illustrated as a 2% reduction from monitored *E. coli* levels reported in the *2010 Texas Integrated Report* (Table 26). To achieve this goal, implementing the WPP is expected to reduce *E. coli* levels and loadings over time and maintain them within the established goal. Water quality data collected across the watershed at reasonable temporal scales will produce a representative data set that can be used to evaluate long-term water quality trends. It is important to note that established benchmarks are not set in stone; rather they are targets that can be adjusted if it is found that they are unrealistic or overly ambitious. Data collected at Stations 20365, 20367 20368, 15811 and 20376 (see *Targeted Water Quality Monitoring* section below) will provide the quantitative measures needed to evaluate WPP implementation and gauge the water body's ability to meet designated benchmarks. The most recent 7 years of water quality data will be used as the primary measure in evaluating these trends and progress toward designated benchmarks. The 7-year data window is the method used by TCEQ in its biennial water body assessment and will be used here. Long-term trends will also be assessed to illustrate collective changes in water quality as monitored in the creek.

Table 26. *E. coli* reduction milestones

Implementation Year	*E. coli* Geometric Mean cfu/100 mL
Initial Conditions	
2010 Integrated Report	97.6
Reduction Goals	
Yr 3 (Sep 2016)	≤ 97
Yr 6 (Sep 2019)	≤ 96
Yr 10 (Sep 2023)	< 95

Nitrate levels will also be evaluated in a similar manner; however, data collection and source identification are primary needs identified for dealing with locally elevated nitrate issues. As a result, direct instream nitrate reductions after implementing these items are not expected. Until the nitrate source assessment is completed, numerical benchmarks for instream nitrate levels will not be established. In the interim, data collection at the 5 stations listed above will illustrate the spatial and temporal variability of instream nitrates levels.

An evaluation of progress made toward achieving *E. coli* benchmarks (and nitrate once established) will serve as catalysts for triggering need adaptive management. If benchmarks are not met in a timely fashion, an evaluation will be conducted to determine why these benchmarks are not being met. These benchmark goals may be unrealistic and should be as appropriate. Similarly, management measures implemented up to the point of this evaluation may be insufficient to meet prescribed benchmark goals, thus triggering changes to recommended number of practices implemented or a change in the types of practices implemented.

Targeted Water Quality Monitoring

Water quality monitoring will provide benchmark information that verifies that the successful implementation of the Buck Creek WPP is achieving the water quality goals as prescribed. Collecting water quality data on a routine basis will allow for a quantitative assessment of water quality trends that illustrate continued improvements in the creek over time. Additional data collection is essential to assessing the impacts of future WPP implementation.

Pending funding availability, AgriLife Research personnel from the AgriLife Vernon will continue routine monitoring on a monthly basis at Stations 20365, 20367, 20368, 15811 and 20376. If funding is not secured for this monitoring, the Watershed Coordinator will contact RRA to discuss continued monitoring of these sites through the Clean Rivers Program.

Monitoring will be conducted at 2 stations in each AU (Stations 15811 and 20376 in AU 0207A_01 and Stations 20365 and 20368 in AU 0207A_02). These stations were selected to yield a spatially representative water quality dataset that includes 1 upstream and 1 downstream location in each AU. One other station (20367) located in a tributary is also suggested to be monitored as well. The selection of these sites allows for the upper and lower extents of the creek to be monitored, thus providing the most extensive look at implementation effectiveness. Stations 20368 and 15811 (the chosen index sites) will continue to be monitored as funding allows because they provide the most extensive data records for each of the AUs. Continuing monitoring at these sites will allow for the most comprehensive look at water quality changes over time.

Data collection will focus on collecting routine water quality samples once per month. These samples will provide the most useful information in that they can be used for both WPP implementation effectiveness monitoring and in future water body assessments. Parameters monitored will include temperature, pH, DO, specific conductance, salinity, flow, *E. coli*, nitrates as well as observational data such as days since last rainfall, appearance of water, odor of water, biological activity and any other information of importance such as illegal dumping activity or animal activity in the creek.

All applicable surface water quality data collected in future monitoring efforts will be submitted to TCEQ for use in biennial assessments of water quality for Clean Water Act purposes (i.e., 303(d) List).

Groundwater quality will also be evaluated through several avenues in the near future. TWON program participants will be asked for their permission to access water quality data from their well screenings. Funds are also being sought to conduct an intensive surface water, spring and irrigation well monitoring effort with a primary focus on obtaining needed nitrates data. These data will provide needed insight into the current state of groundwater quality across the watershed as well as information on its connectivity with Buck Creek. The need for long-term groundwater quality monitoring plans will be assessed based on information gleaned during these special studies and will be planned as appropriate at the conclusion of these targeted groundwater monitoring efforts, most likely in the summer of 2015.

Chapter 13
Implementation Schedule

Implementation of the Buck Creek WPP can be broken down into 2 major implementation sections: management measures and education and outreach programming. The management measures and education and outreach programs listed in Tables 27 and 28 are the result of planning efforts and discussions among the many watershed stakeholders involved in the Buck Creek WPP development process. Data collected throughout the course of developing this WPP, analysis of this data, computer-based modeling and input from local stakeholders are the determining factors that led to these recommended measures and the areas where implementation is planned.

Implementing the Buck Creek WPP is planned to take place over a 10-year timeframe. Tables 27 and 28 illustrate the timelines, implementation schedules and milestones, unit costs and total costs for effectively implementing the management measures, educational programming and continued monitoring efforts that will illustrate successful WPP implementation. This schedule and milestones allow for the implementation of individual practices or programs within a window of time, thus allowing proper acquisition of needed funds, personnel and time to develop and carry out these tasks. It should be remembered that implementation milestones are milestones that may need to be adjusted through the adaptive management process if the milestones are found to be unrealistic or the management practice is determined to be ineffective.

E. coli Management

Management measures needed to address *E. coli* loading in the Buck Creek will collectively reduce the overall *E. coli* load to the creek and meet water quality goals and objectives. Management measures include focus on decreasing the influences of *E. coli* loadings from cattle and other livestock, wildlife, feral hogs and failing OSSFs. Generally speaking, livestock- and wildlife-focused practices will strive to reduce *E. coli* loads by decreasing the amount of time livestock and wildlife spend in the riparian corridor. Feral hog management will focus on completely removing hogs from the watershed and keeping them removed while OSSF management will identify failing OSSFs in the watershed and develop a plan to replace or repair failing systems.

Nitrates Management

Nitrates management will focus primarily on identifying the source of nitrates in Buck Creek and working with TCEQ to conduct a use assessment to evaluate the appropriateness of a separate nitrate screening level for Buck Creek. With the exception of nutrient management education supported by a soil and water testing campaign, no true management measures are proposed to directly reduce nitrate loading to the creek. Without a firm understanding of the sources of nitrate in Buck Creek, management is premature. Rather, efforts will be made to implement reasonable items such as education while determining the source of pollution.

Education

In addition to physical management practice implementation, delivering educational programming in the watershed will be critical to effectively restoring water quality in Buck Creek. Workshops will provide topical information to watershed stakeholders to foster an improved understanding of potential pollutant sources, their significance in watershed health and management strategies that can be used to address specific pollutants as well as informa-

Table 27. Bacteria and nutrient management measures, implementation schedules and milestones, timeline and costs

Management Activity	Responsible Party	Implementation Milestones Year 1 to 3	4 to 6	7+	Unit Cost	Total Cost
		number of planned practices				
Agricultural Management						
Grazing WQMPs	SWCD	5	5	5	$15,000	$225,000
Feral Hog Management						
Aerial Gunning	USDA-Wildlife Services	3	3	4	650/hr @ 5 hr/event	$32,500
Fencing around deer feeders	Landowners/Lessees /Lessors	unknown number of feeders			$200	TBD
Trapping and Shoot-On-Site	Landowners/Lessees	unknown number of landowners participating			TBD	TBD
Nitrate Source Assessment						
Targeted Nitrate Monitoring	Research	1	0	0	$40,000	$40,000
Nitrate Isotope Analysis	Research/USGS	1	0	0	$200,000	$200,000
Soil Testing	Research/Extension/ Landowners	1,000	500	250	$10 + shipping	$17,500 + shipping
Water Testing	Research/Extension/ Landowners	150	75	50	$20 + shipping	$5,500 + shipping
Soil Fertility Demonstrations	Research	2	0	0	$5,000	$10,000
Screening Level Applicability Assessment	TCEQ	1	0	0	TBD	TBD
Water Quality Montioring						
Routine Montioring = 0.25 FTE inclusive of travel, supplies, etc.	Research/Extension	1			$25,000	$250,000
Watershed Coordinator						
Extension Assistant @ 0.25 FTE inclusive of travel, supplies, etc.	Research/Extension	1			$25,000	$250,000
Wildlife Management						
Develop wildlife habitat management plans	TPWD	as needed/desired			N/A	N/A
Implement wildlife habitat management plans as appropriate	Landowners	as needed/desired			TBD	TBD
Work with lessees to improve wildlife habitat management	Landowners/Lessors	as needed			TBD	TBD
Total Management Implementation Costs						***$1,030,500***

tion on technical and financial assistance available to help landowners deal with localized pollutant loads.

Continuing to keep watershed stakeholders informed of project happenings and engaging them in the active implementation of the WPP is also critical to the long-term success of the WPP. The Watershed Coordinator will lead the effort to coordinate and host public meetings and develop and disseminate newsletters and news releases. The Watershed Coordinator will use these as platforms for conveying the successful implementation of the WPP and promoting additional implementation activities.

Education will further the development of WPP improvements in the future. As more information is learned about the watershed and effectiveness of planned management measures, modifications to the plan can be made through the adaptive management process. Education and outreach efforts will foster adaptive management by providing pertinent information to watershed stakeholders on management measures that might not be in the current version of the WPP.

Table 28. Education and outreach programming, implementation schedules and milestones, timeline, and costs

Education & Outreach Activity	Responsible Party	Implementation Milestones Year 1 to 3	4 to 6	7+	Unit Cost	Total Cost
		number of planned programs				
Agricultural Programming						
Lone Star Healthy Streams Workshop	Extension	1	0	1	N/A*	N/A*
Nutrient Management Workshops	Extension & Research	1	1	1	$2,500	$7,500
Domestic Needs						
OSSF O&M Workshops	Extension	1	0	1	$7,500	$15,000
OSSF Installer & Maintenance Provider Workshop	Extension	1	0	1	$7,500	$15,000
Texas Well Owner Network	Extension	1	0	0	N/A*	N/A*
Habitat Management						
Riparian and Stream Ecosystem Management	TWRI/IRNR	1	0	0	N/A*	N/A*
Newsletters/News Releases						
2 Newsletters Annually and News Releases Developed and Delivered as Needed	Watershed Coordinator/ TWRI	10	10	10	$1,500	$45,000
Public Meetings						
2 Public Meetings per Year	Watershed Coordinator	6	6	6	$500	$9,000
Wildlife and Invasive Animal Programming						
Feral Hog Management Workshop	Extension	1	1	1	$7,500	$22,500
Wildlife Management Workshops	Extension, Research & TPWD	1	1	1	$7,500	$22,500
Total Educational Programming Costs						**$136,500**

* no additional costs will be required to deliver these programs as their costs are currently included in existing funds to deliver these programs statewide in priority watersheds

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Appendix A: Elements of Successful Watershed Plans

The description of each 'Element of Successful Watershed Plans' provided below is taken from EPA's "Handbook for Developing Watershed Plans to Restore and Protect Our Waters" (2008). While these elements do not encompass everything that is included in a WPP, they are considered minimum elements that must be included for EPA to provide funding from Clean Water Act Section 319 funds.

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 subbasin inventory, aerial photos, GIs data and other sources.

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.

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.

D. Technical and Financial Assistance Needs

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

E. Information, Education and Public Participation Component

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

F. Schedule

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

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.

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.

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.

Appendix B: Land Use and Land Cover Assessment Methods

The land use and land cover (LU/LC) assessment for the Buck Creek watershed was conducted by the Spatial Sciences Laboratory at Texas A&M University through TSSWCB project 08-52 funded by state General Revenue funding. LU/LCs for 5 watersheds were updated through this project and as such, a small portion of the information presented here may not apply to Buck Creek but was critical to the overall methodology applied.

Initially, a standardized set of land cover types and descriptions were established and used as thresholds in LU/LC classifications. These land cover descriptions are presented in detail below.

Open Water — All areas of open water, generally with less than 25% cover of vegetation or soil.

Developed Open Space — 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 — Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49% of total cover. These areas most commonly include single-family housing units.

Developed Medium Intensity — 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 — 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 (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 — Areas dominated by trees generally greater than 5 m tall, and greater than 50% of total vegetation cover.

Riparian Forested Land — Areas dominated by trees generally greater than 5 m tall, and greater than 50% of total vegetation cover. These areas are found near streams, creeks and/or rivers.

Mixed Forest — Areas dominated by trees generally greater than 5 m tall, and greater than 20% but less than 50% of total vegetation cover.

Rangeland — Areas of unmanaged shrubs, grasses or shrub-grass mixtures.

Managed Pasture — 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 — 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 actively tilled.

Data and Materials

National Agriculture Imagery Program (NAIP) Digital Ortho Imagery: NAIP Ortho photos are collected and compiled each year by the USDA FSA during a portion of the agricultural growing season at a 1- or 2-m resolution. The 2005 images for Texas were provided in county mosaics at a spatial resolution of 2 m. The NAIP imagery was processed and projected using a Nearest Neighbor Triangulation method to match the study area.

Landsat Satellite Imagery: Landsat imagery is acquired from Earth-orbiting sensors collecting imagery of the globe. The imagery has a moderate spatial-resolution of 30-m pixels. Individual houses on a Landsat image cannot be seen, but large man-made objects such as highways can be. The Landsat Program is managed by NASA; data from Landsat is collected and distributed by the USGS.

National Hydrography Dataset (NHD) High and Medium Resolution Data: The NHD is a combination of the USGS Digital Line Graph Hydrography files and the EPA Reach Files version 3.0 (rf3) and provides nationwide coverage of hydrologic features. The ArcGIS software was used to subset the NHD lines for the watershed that were studied.

National Land Cover Dataset (NLCD): The NLCD was developed using a decision-tree classification approach for multi-temporal Landsat imagery and several ancillary datasets. The categories of developed and barren were extracted from the dataset using the ArcGIS Spatial Analyst extension to compare and compliment the Landsat classification.

Ground Truth Data: Samples for each LU/LC class within the study were gathered using Trimble GeoXT GPS units, as well as digital sampling of high resolution aerial photography. The primary focus of the field collection process was to collect ground control points across the entire area, particularly in classes that were difficult to distinguish. Where access was limited, sample points were offset from the road using distance and bearing. The horizontal accuracy of the points ranged from 0.4 to approximately 4 m. Additional samples points were collected in the ArcGIS software for under-sampled classes and areas after a baseline of knowledge was established about the appearance of each class based on field samples.

Methods

Two pixel-based classification approaches were investigated on the Landsat images, supervised and unsupervised. Pixel-based classifications are widely used to classify these types of images; however, the specific approaches, algorithms and inputs vary. Supervised classification approaches use training pixels of known land cover types to define the properties of each class based on the spectral, and sometimes ancillary, properties at each training pixel. All other pixels are then classified based on these properties. Training pixels for each class are identified from ground truth data. A common algorithm used for supervised classification is the Maximum Likelihood Classifier. This method determines the probabilities that a pixel belongs to a specific class by using the location of training pixels in the feature space. Another common algorithm is Mahalanobis Distance. This method identifies patterns and takes into account the correlations of the data set. It is not dependent on the scale of measurements. The unsupervised approach differs from the supervised approach, in that it does not use training data to define the properties of desired classes. Rather, clustering techniques are used to create a specified number of classes based on the properties of the input data. These classes are then interactively grouped to fit the needs of the user. These methods were experimented with on all Landsat scenes covering the study areas using ENVI geospatial imagery processing and analysis software. The supervised methods of Maximum Likelihood and Mahalanobis Distance resulted in the most accurate results.

The Buck Creek watershed was classified using Landsat scene 2936 from the year 2003. This scene was resized to a buffer around the watershed boundary. The subset of the image reduced the processing time required to classify the scene. Regions of interest, in the form of points, were selected across the study region. These regions of interest were used to train the Mahalanobis Distance supervised classification of the scene. The classification process was run multiple times while the inputs and regions of interest were adjusted to result in the most accurate outcome. The variability in some of the classes led to the need for them to be split into several smaller subclasses. Urban, Water, Cultivated Crops, Rangeland, Pasture/Hay and Barren Land were the classes derived from the scene in the watershed. After applying several variations of classification, the top outcomes were tested for accuracy by comparing the classification to the known regions of interest gathered during ground sampling. NAIP imagery was also used in comparing the classifications to ground truth. Once the most accurate classification was selected, the final version was converted to an Environmental Systems Research Institute (ESRI) grid file and projected using ArcMap software.

Data Processing

The ESRI ArcGIS 9.x software and ArcInfo Workstation were used in all data processing for this project. All of the data used was projected to North American Datum 1983 Universal Transverse Mercator coordinate system zone 14 north. The data was clipped to the buffered study area watershed boundaries delivered to the Spatial Sciences Laboratory.

Several additional data sources were used that involved numerous processing steps, which were necessary before the data was merged into a single final classification layer. A dataset was created composed of developed land areas by extracting the developed areas out of the NLCD 2001 dataset. It was inferred that any land developed in this dataset would still be classified as developed at the current. NAIP imagery was then viewed to find additional developed areas that were manually digitized. These areas, in most situations, were construction that occurred after the NLCD was completed.

Barren land categories were classified using several different methods. The barren land category of the NLCD 2001 was extracted and manually compared against more recent NAIP imagery to test if the areas were still in a barren state. As the NAIP imagery was viewed, any additional bare areas were manually digitized. The barren categories from the Landsat classification were also implemented into the dataset.

A data layer was created for all water bodies with the use of NHD data. NAIP imagery was then viewed to find additional water areas, which were manually digitized. The NHD 'area' and 'water body' files were merged using the ET MergeLayers Tool, an extension to the ArcMap software. The merged data was then clipped to a buffer of the watershed boundaries and dissolved. The resulting file was exploded to break all separate water bodies into individual features. The derived water file was viewed against the NAIP imagery to validate the outlines. Any additional water bodies were manually digitized into the water data layer.

The near riparian-forested class was derived with the use of both NHD files and the Landsat classification. NHD High Resolution data, except in the Brazos watershed, which is a merge of high and medium resolution, was gathered and prepared for use. The NHDflowline and NHDflowlineVAA were merged for each study area and overlaid onto the 2004 NAIP photos. The lines were clipped to a 1-mi buffer of the watersheds and buffered to 225 ft. The Landsat classifications were converted to ERDASA IMAGINE files and brought into ArcMap. The Spatial Analyst extension's Reclass tool was used to export out all forested regions. All forested regions falling within the 225 ft water buffer were deemed to the near riparian-forested regions.

Next, overlapping areas were removed from all data layers using the ArcInfo erase tool. These layers were then merged together in the following order of importance: NHD water bodies, near riparian forests, developed and finally the Landsat classification. The eliminate tool was then used to remove all polygons with an area of less than 0.5 ac. These areas were combined with the neighboring areas with the largest shared border.

The newly created layer was next converted to a Personal Geodatabase. In this format, topology was created for the layer. Topology is a spatial data structure used primarily to ensure that the associated data forms a consistent and clean topological fabric. A cluster tolerance of 5 m was used in validating this topology. Cluster tolerance is the minimum distance between vertices in the topology. Vertices that fall within the cluster tolerance will be snapped together during the validation.

The rules set in the creation of the topology included 'must not overlap' and 'must not have gaps'. The 'must not overlap' rule requires that the interior of polygons in the feature class not overlap. The polygons can share edges or vertices. This rule is used when an area cannot belong to 2 or more polygons. The 'must not have gaps rule requires that polygons not have voids within themselves or between adjacent polygons. Polygons can share edges, vertices or interior areas. Polygons can also be completely disconnected. This rule is used when polygons or blocks of contiguous polygons should not have empty spaces within them. All errors found using the topology function were removed accordingly, and verified with the use of the 2004 and 2005 NAIP imagery.

Appendix C: The Load Duration Curve Approach

A widely accepted approach for analyzing water quality is the use of a LDC. An LDC allows for a visual determination of how streamflow may or may not impact water quality, in regard to a specific parameter.

The first step in developing an LDC is the construction of a Flow Duration Curve. Flow data for a particular sampling location are sorted in order and then ranked from highest to lowest to determine the frequency of a particular flow in the stream (Figure C-1). These results are used to create a graph of flow volume versus frequency, which produces the flow duration curve (FDC).

Next, data from the FDC are multiplied by the concentration of the water quality criterion for the pollutant to produce the LDC (Figure C-2). This curve shows the maximum pollutant load (amount per unit time; e.g., for bacteria, cfu/day) a stream can assimilate across the range of flow conditions (low flow to high flow) without exceeding the water quality standard. Typically, a MOS is applied to the threshold pollutant concentration to account for possible variations in loading due to sources, streamflow, effectiveness of management measures and other sources of uncertainty. The Buck Creek Watershed Partnership chose not to incorporate a MOS for bacteria or nitrate in this plan. As previously discussed in Chapter 1, for primary contact recreation in Texas, the geometric mean of *E. coli* must be below 126 cfu/100 mL. Currently, there are no numeric criteria for nitrate-nitrogen; however, there is a screening level of 1.95 mg/L. LDCs were developed using these level as threshold concentrations.

Stream monitoring data for a pollutant also can be plotted on the curve to show frequency and magnitude of exceedances. A regression line following the trend of the stream is plotted through the stream monitoring data using the USGS program LOAD ESTimator (LOADEST). LOADEST is used to determine load reductions for different flow regimes using the load reduction percentage (Babbar-Sebens and Karthikeyan 2009). Load reduction percentage was calculated as (Loadest-Water Quality Goal/Loadest) × 100.

LOAD ESTimator (LOADEST) is a FORTRAN program for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables and constituent concentration, LOADEST assists the user in developing a regression model for the estimation of constituent load (calibration). Explanatory variables within the regression model include various functions of streamflow, decimal time and additional user-specified data variables.

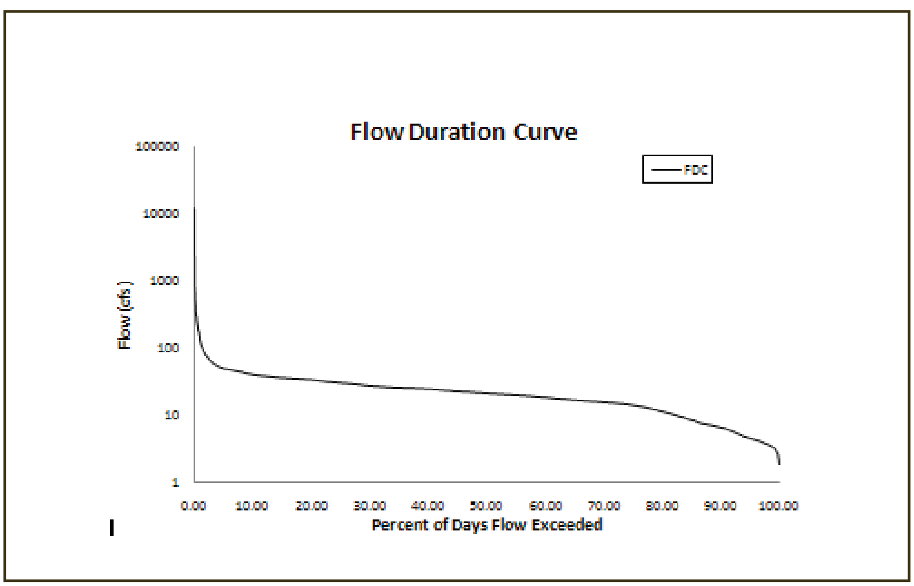


Figure C-1. Example FDC

The formulated regression model then is used to estimate loads over a user-specified time interval (estimation).

The calibration and estimation procedures within LOADEST are based on 3 statistical estimation methods. The first 2 methods, Adjusted Maximum Likelihood Estimation (AMLE) and Maximum Likelihood Estimation (MLE), are appropriate when the calibration model errors (residuals) are normally distributed. Of the 2, AMLE is the method of choice when the calibration data set (time series of streamflow, additional data variables and concentration) contains censored data. The third method, Least Absolute Deviation (LAD), is an alternative to maximum likelihood estimation when the residuals are not normally distributed. LOADEST output includes diagnostic tests and warnings to assist the user in determining the appropriate estimation method and in interpreting the estimated loads.

In the example, the red line indicates the maximum acceptable stream load for *E. coli* bacteria and the squares, triangles and circles represent water quality monitoring data collected under high, mid-range and low flow conditions, respectively. Where the monitoring samples are above the red line, the actual stream load has exceeded the water quality standard, and a violation of the standard has occurred. Points located on or below the red line comply with the water quality standard.

To analyze the entire range of monitoring data, regression analysis is conducted using the monitored samples to calculate the "line of best fit" (blue line). Where the blue line is on or below the red line, monitoring data at that flow percentile comply with the water quality standard. Where the blue line is above the red line, monitoring data indicate that the water quality standard is not being met at that flow percentile. Regression analysis also enables calculation of the estimated percent reduction needed to achieve acceptable pollutant loads.

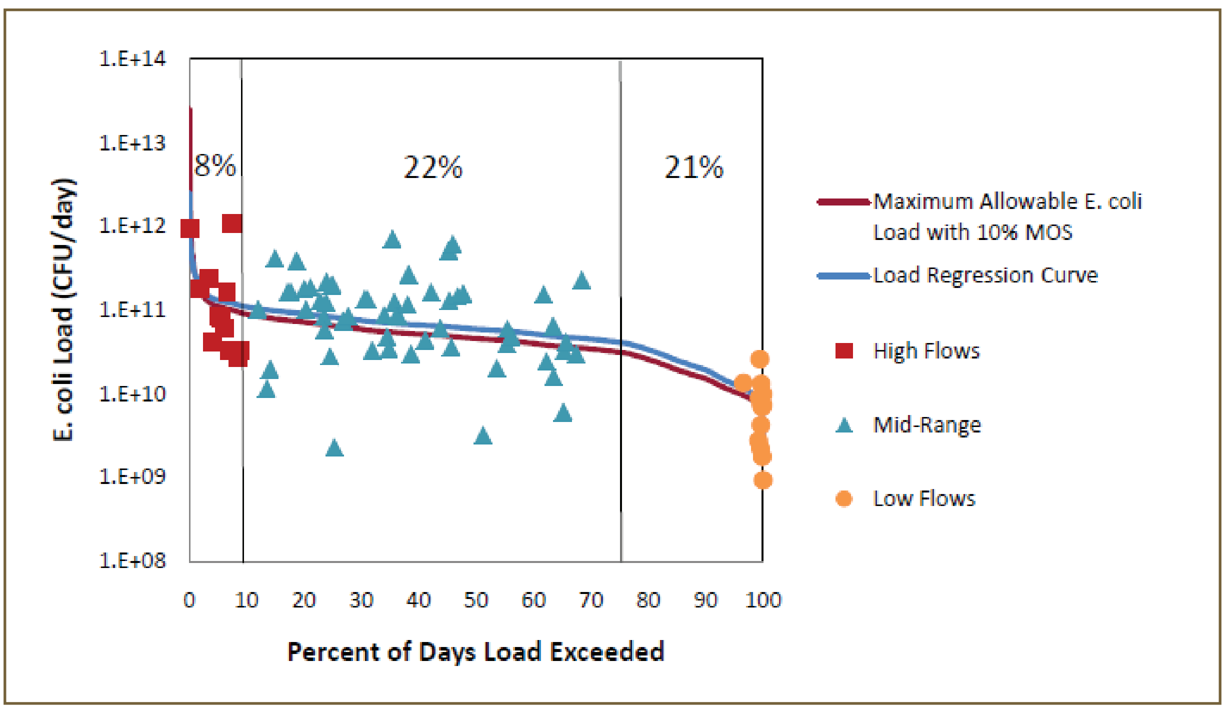


Figure C-2. Example LDC and calculated load reductions needed to meet water set water quality goal

Appendix D: SELECT Model Description and Approach

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is an analytical approach for developing an inventory of potential pollutant sources, particularly NPS contributors, and distributing their potential loads based on land use and geographical location. The LU/LC classification described in Appendix B was used as the basis for SELECT calculations. The watershed was divided into 18 smaller subbasins based on elevation changes along tributaries and the main segment of the water body (Figure 3). Animal densities/populations for cattle, deer and feral hogs were used as inputs and were applied to designated LU/LC categories within the watershed to calculate subbasin pollutant load potentials.

The SELECT model loading estimates are a worst-case scenario that does not factor in any form of bacteria die-off. As a result, the loading estimates produced by the model are not loads that are expected to enter the creek.

Cattle

The average potential daily *E. coli* load from cattle for each subbasin was estimated using the following calculation:

$$\text{Cattle Load} = \#\ \text{Cattle}*10*10^{10}*0.5$$

Where $10*10^{10}$cfu/day *0.5 is the average daily *E. coli* production per head of cattle (EPA 2001).

Watershed stakeholders developed cattle population estimates for cattle across the watershed. USDA National Agricultural Statistics Service (NASS) data for the 3 counties partially within Buck Creek included numerous feedlots and as such were thought to be an overestimate of actual cattle numbers in the watershed. Using a 3-county average of NRCS recommended stocking rates of 25 ac/AU for rangeland, mixed forest and riparian forest and a rate of 8 ac/AU on managed pasture supplemented with local knowledge, an average resident cattle population of 6,640 head was estimated for the watershed and does not include transient cattle housed at the livestock auction barn in Wellington or the feedlot near Hedley. Subbasin populations are presented in Table F-1 located in Appendix F.

Deer

The average potential daily *E. coli* load from deer for each subbasin was estimated using the following calculation:

$$\text{Deer Load} = \#\ \text{Deer}*3.5*10^{8}\ \text{cfu/day}*\ 0.5$$

Where $3.5*10^{8}$ cfu/day* 0.5 is the average daily *E. coli* production per deer (EPA 2001).

The potential bacteria concentration of white-tailed deer in the Buck Creek watershed was estimated using TPWD deer census estimates supplemented with landowner feedback. Average densities of the white-tailed deer within resource management units for 2005 through 2008 were obtained for the SELECT analysis. Based on the average number of deer per 1,000 ac, deer were distributed on contiguous areas of rangeland, cultivated land, managed pasture, mixed forest and riparian forest and the total number of deer in each subbasin was calculated.

Feral Hog

The daily potential *E. coli* load from feral hogs was estimated for each subbasin using the following calculation:

$$\text{Feral Hog Load} = \# \text{ hogs}*1.1*10^{10} \text{ cfu/day}*0.5$$

Where $1.1*10^{10}$ cfu/day*0.5 is the average daily *E. coli* production rate per hog (EPA 2001).

The feral hog population is estimated to be 7,310 animals for the entire watershed and was determined by watershed stakeholders (Table 10). This estimate assumed a density of 25 ac per animal applied to mixed forest, 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. See Chapter 5 for additional discussion on population estimation.

The most suitable habitat for feral hogs was determined to be the 300-ft area surrounding all streams in the Buck Creek watershed including all types of land use/cover except for urban. It is understood that feral hogs are located outside of these areas.

Appendix E: Bacterial Source Tracking Methods and Results

Water Sample Collection and Processing

Water samples analyzed using BST analysis were collected between 2007 and 2009, mostly representing routine, normal to low flow conditions. Field data points were recorded at each sample site including pH, water temperature, DO, specific conductance and flow measurements (cfs) for each site sampled. Other data notes included water depth for samples, recent rainfall, ambient air temperature, current weather condition and time of day samples were collected. Field notations included presence of animal tracks along the creek bed, signs of feral hogs, hunting and beaver activity. Any cropping activity was also noted as was any disturbances in creek flow including waterway maintenance, road improvements, recent flooding, erosion, fires, storm damage and other information pertinent to the health of the watershed. Personnel from AgriLife Vernon collected two 125-mL-water-grab samples known as a duplicate set from the selected sites and transported them back to Vernon at 4°C for processing. At the lab, 100 mL of each sample was filtered using a .45 micron filter for *E. coli* enumeration using EPA Method 1603 with modified mTEC medium (EPA 2006) and *Bacteroidales* analysis.

After growing the *E. coli* on mTEC media and colony enumeration, all data results were recorded on field and laboratory reports and included on site data reports generated in Excel files. Since values of zero (none present) colonies are unable to be used to calculate the geometric mean of *E. coli* levels, sites with no *E. coli* growth were listed as 0.5 colonies per TCEQ data assessment staff guidance.

After *E. coli* enumeration, 5 representative *E. coli* colonies from modified mTEC plates were isolated on Nutrient Agar with mug, purified, and confirmed using Long Wave UV light, and archived by placing 1 purified colony in 1.5 mL lysis buffer containing 20% glycerol and 80% tryptic soy broth, vortexed, and submerged in liquid nitrogen, then stored at -80°C. Water samples for *Bacteroidales* analysis were filtered using 100 mL of sample and a 0.2-micron Supor filter, then folded, and placed in centrifuge tubes with 3 mL of GITC lysis buffer, completely wetted with buffer, and kept frozen at -80°C. *E. coli* isolates and *Bacteroidales* samples were periodically sent on dry ice to AgriLife El Paso for BST analysis.

Ambient water samples were also collected on a minimum of 5 different dates, which consisted of collecting 5 water samples of 125 mL, collected 1-3 minutes apart, waiting each time for the sediment to clear and water to return to the normal condition before obtaining another sample. These samples were transported at 4°C and treated as all other site samples upon arrival at the lab in Vernon. At least 3 of the 5 samples collected at each site were filtered using EPA method 1603 and at least 1 sample per site was prepared for the *Bacteroidales* test. *E. coli* enumeration was recorded for all samples. Three to 5 colonies per sample were isolated, purified for testing and sent to AgriLife El Paso. Field data described above was also collected during these sample collections.

Known Source Fecal Samples

Although more samples were collected, 53 *E. coli* isolates were successfully isolated from 28 different animals from the local Buck Creek watershed. Some fecal samples collected from animals did not produce viable *E. coli* colonies, possibly due to the age of the fecal material or the general absence of *E. coli* from a specific species. Samples that produced viable *E. coli* isolates were obtained from swallows, cattle, coyotes, feral hogs, mule deer, prairie dogs and porcupines. Other samples collected from armadillos, badger, beaver, bobcat, cattle, opossum, rabbit, raccoon and turkey did not produce viable *E. coli* colonies. Although these samples did not produce *E. coli* isolates, they were able to be screened through the *Bacteroidales* analysis. Isolates were screened to remove identical isolates (clones) from the same fecal sample. The resulting 31 isolates from the 28 source animals from Buck Creek were then added to the October 2009 version of the Texas *E. coli* BST library and used for identifying Buck Creek *E. coli* water isolates.

ERIC-PCR and RiboPrinting of *E. coli*

E. coli isolates from water samples and source samples were DNA-fingerprinted, using a repetitive sequence polymerase chain reaction (rep-PCR) method known as enterobacterial repetitive intergenic consensus sequence PCR (ERIC-PCR) (Versalovic, Schneider et al. 1994). Following ERIC-PCR analysis, *E. coli* water isolates and selected source isolates were RiboPrinted, using the automated DuPont Qualicon RiboPrinter and the restriction enzyme *Hin*d III ("RiboPrinting"). For RiboPrinting all bacterial isolate sample processing was automated, using standardized reagents and a robotic workstation, which provided a high level of reproducibility. ERIC-PCR and RiboPrinting was performed as previously described (Casarez, Pillai et al. 2007).

Analysis of composite ERIC-RP DNA fingerprints was performed, using Applied Maths BioNumerics software. Genetic fingerprints of *E. coli* from ambient water samples were compared to fingerprints of known source *E. coli* isolates in the Texas *E. coli* BST library and the likely sources were identified using this method. To identify potential sources of the unknown water isolates, their ERIC-RP composite patterns were compared to the library using a best match approach and an 80% similarity cutoff (Casarez, Pillai et al. 2007). If a water isolate was not at least 80% similar to a library isolate, it was considered unidentified. Although fingerprint profiles are considered a match to a single entry, identification is to the host source class and not to the individual animal represented by the best match. Host sources were divided into 3 groups: 1) human, 2) wildlife (including deer and feral hogs) and 3) domestic animals (including livestock and pets).

As of October 2009, the Texas *E. coli* BST library consisted of fingerprint patterns from 1172 *E. coli* isolates from 1,044 different human and animal samples collected throughout the state of Texas from 4 previous BST studies. Jackknife analysis is a commonly used approach for evaluating the accuracy of a BST library. Jackknife analysis involves pulling each library isolate one-at-a-time from the library and treating each as an unknown to determine the percentage of isolates correctly identified to the true host source. This is referred to as the rate of correct classification. Composition and rates of correct classification for the October 2009 version of the Texas *E. coli* BST library used in this study are included in Table E-1. Jackknife analysis revealed an 875 average rate of correct classification using a 3-way split of source classes.

Table E-1. October 2009 version of the Texas *E. coli* BST library composition and rates of correct classification

Source Class (number of isolates/samples)	Library Composition and Expected Random Rate of Correct Classification	Calculated Rate of Correct Classification	Left Unidentified (unique patterns)
Human (376/326)	32%	91%	22%
Domestic Animals (383/344)	33%	81%	25%
Wildlife (413/374)	35%	85%	21%

Bacteroidales PCR

The *Bacteroidales* PCR method is a culture- and library-independent molecular method that targets genetic markers of *Bacteroides* and *Prevotella* spp. fecal bacteria that are specific to humans, ruminants (including cattle, deer, llamas and sheep) and pigs (including feral hogs) (Bernhard and Field 2000; Dick, Bernhard et al. 2005). There is also a general *Bacteroidales* marker (GenBac) that is used as a general indicator of fecal pollution (Bernhard and Field 2000). For this method, 100-m-water-grab samples were concentrated by filtration, DNA extracted from the concentrate and purified, and aliquots (dilutions) of the purified DNA analyzed by PCR.

The specificity for the *Bacteroidales* PCR human, ruminant and hog markers is very high based on studies by others (Field, Chern et al. 2003; Gawler, Beecher et al. 2007; Gourmelon, Caprais et al. 2007; Lamendella, Domingo et al. 2007; Lamendella, Santo Domingo et al. 2009) and results from AgriLife El Paso laboratory (Di Giovanni, Truesdale et al. 2009). Collective results from these studies revealed the human HF183 marker was detected in 149/174 (86%) of the human fecal samples tested, and cross-reactivity was reported for only 16/513 (3%) nontarget fecal samples from livestock, wildlife and pets. The ruminant CF128 marker was detected in 253/257 (98%) of the ruminant fecal samples tested, and cross-reactivity was reported for 46/434 (11%) nontarget fecal samples from humans and other animals. The pig/hog PF163 marker was detected in 128/141 (91%) of the pig/feral hog fecal samples, and cross-reactivity was reported for 37/311 (12%) nontarget fecal samples humans and other animals.

For this study, qualitative presence/absence of the host-specific genetic markers was determined; this effectively means that there either was or was not bacteria of a specific type present in the water sample. Of particular interest was the use of *Bacteroidales* PCR to determine whether feral hog populations were impacting Buck Creek. A modification of the pig PF163 *Bacteroidales* PCR marker protocol of Dick, Bernhard et al. (2005) was used for the detection of feral hog fecal pollution. We recently demonstrated that the pig PF163 marker yielded the highest probability of detecting pig fecal contamination in a given water sample compared to several other developed pig markers (Lamendella, Santo Domingo et al. 2009). Current research in our laboratory also indicates that the PF163 assay has high detection rates for feral hog feces collected from different regions of Texas (Truesdale, Barrella et al., manuscript in preparation).

Results

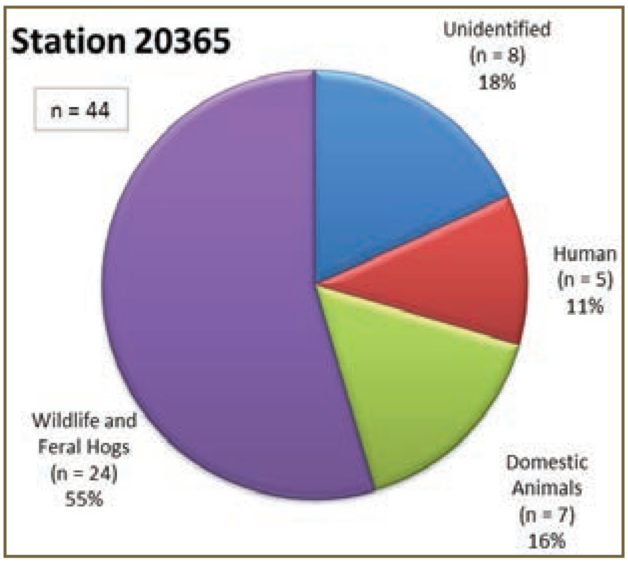
A total of 426 *E. coli* isolates from water samples (44 to 98 individual samples per station) were analyzed using BST. The source identifications of *E. coli* water isolates at each station are presented as pie charts in the following pages. This provides an estimate of pollution source contribution using a 3-way split of sources. A total of 79 water samples (10 to 20 individual samples per station) were analyzed for the presence or absence of *Bacteroidales.* The percentage of positive samples for each of the *Bacteroidales* markers at each station is reported.

Comparisons between *E. coli* and *Bacteroidales* BST results can be made, as they are complementary techniques; however, it is important to note that identified pollution source classes are not identical. They are derived utilizing 2 different methods. For example, 1 of the *E. coli* source classes is domestic animals, which includes cattle but not deer, while the *Bacteroidales* ruminant marker includes both of these animal sources.

It is also important to note that the water samples used for BST were collected under mostly routine, low flow conditions. The geometric mean *E. coli* levels for the BST water samples were low, and ranged from 8.4 to 48.0 cfu/100 mL, well below Texas' current water quality standard of 126 cfu/100 mL.

Station 20365

E. coli counts from water samples collected at Station 20365 ranged from 0.5 CFU/100 mL to 750 CFU/100 mL, with a geometric mean of 8.4 CFU/100 mL. Only 1 of 21 (5%) samples exceeded the single sample maximum limit of 394 CFU/100 mL. BST identification of *E. coli* water isolates (n = 44) for this sampling location are presented in Figure E-1. Overall, 55% of the water isolates were identified as originating from wildlife, followed by 16% from domestic animals and 11% from human sources. A total of 18% of the water isolates at this station were unidentified. For *Bacteroidales* analysis, 10 out of 10 water samples tested positive for the GenBac general and ruminant *Bacteroidales* markers, followed by a lower frequency of hog and ruminant marker detection (Figure E-1).



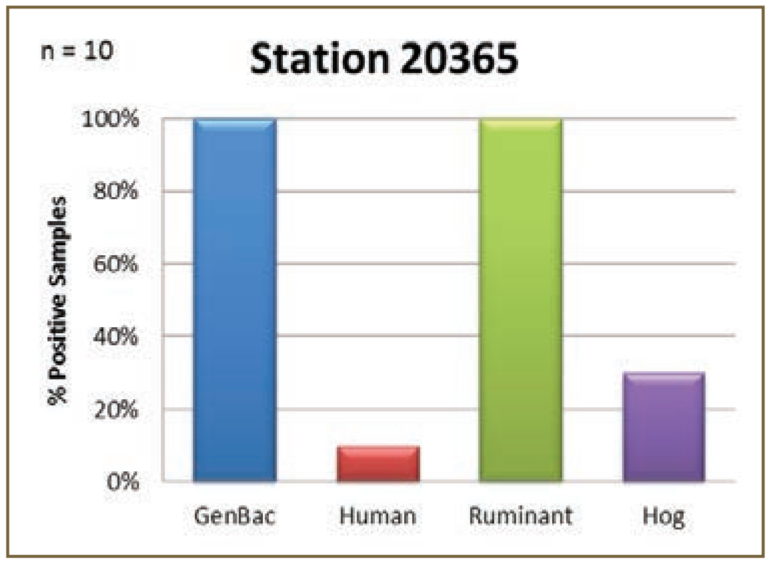


Figure E-1. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20365. Marker abbreviations: GenBac = General Bacteroidales; Hog = feral and domestic hog; Ruminant = all ruminants (ie. cattle, deer, etc.); Human = all human sources

Station 20367

E. coli counts for samples collected at Station 20367 ranged from 0.5 CFU/100 mL to 346 CFU/100 mL, with a geometric mean of 48.0 CFU/100 mL. None of the 24 samples analyzed exceeded the single sample maximum limit of 394 CFU/100 mL. BST identification of *E. coli* water isolates (n = 98) for Station 20367 are presented in Figure E-2. Overall, 41% of the water isolates were identified as originating from wildlife, followed by 19% from domestic animals and 9% from human sources. This station had the highest percentage of unidentified *E. coli* isolates, with 31% of the water isolates left unidentified. A larger Buck Creek *E. coli* local library, especially for wildlife sources, would likely be needed to increase the identification rates and reduce the number of unidentified *E. coli* isolates. For *Bacteroidales* analysis, all 12 water samples tested positive for the GenBac general marker, followed by a high occurrence of human and ruminant *Bacteroidales* markers and a moderate occurrence of hog marker (Figure E-2). Frequent human *Bacteroidales* marker detection with concurrent moderate to average human *E. coli* occurrence suggests human fecal pollution from a distance source or significant but infrequent pollution events such as illegal dumping of wastewater.

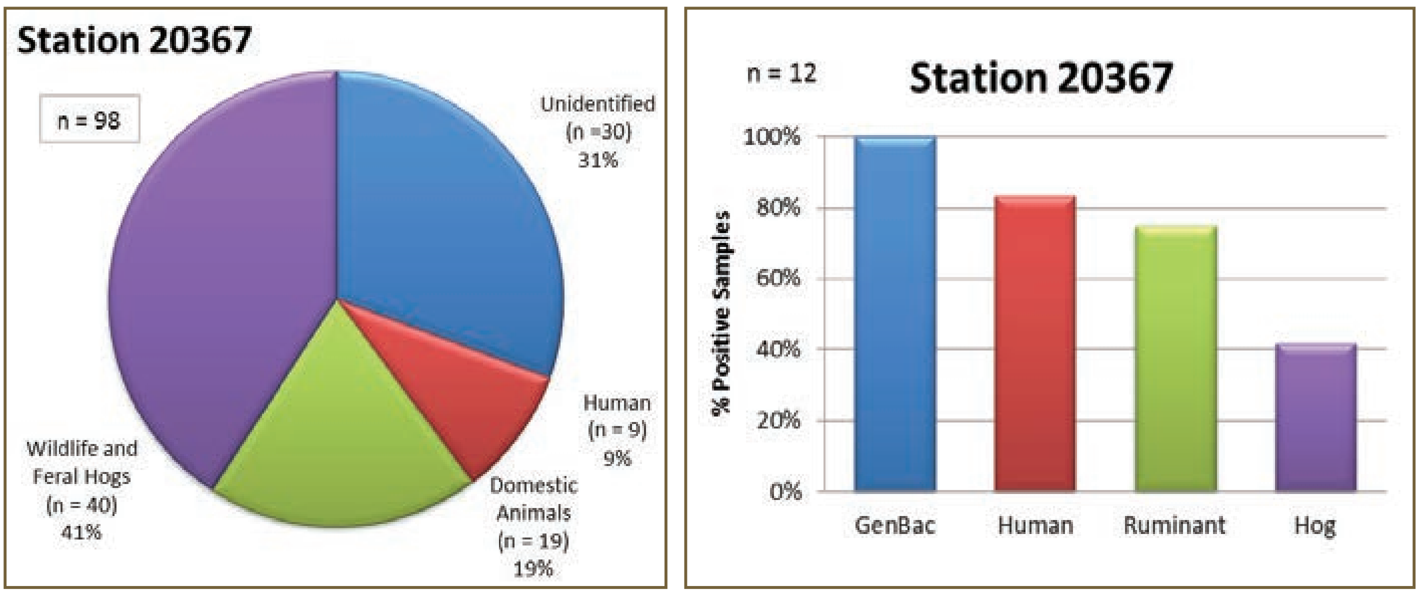
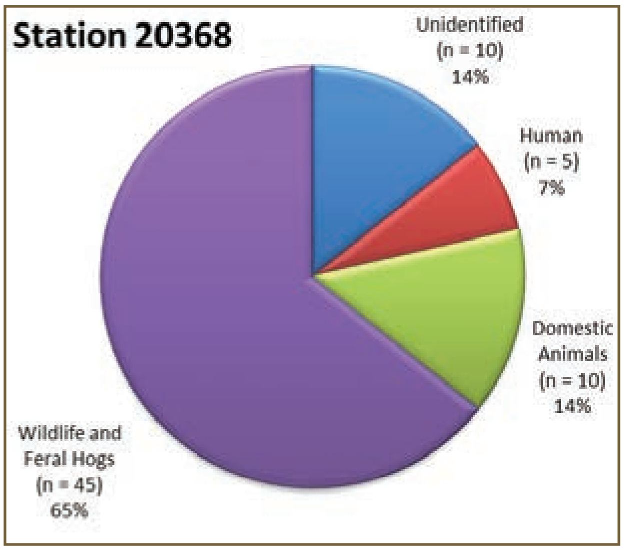


Figure E-2. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20367. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. cattle, deer, etc.); Human = all human sources

Station 20368

E. coli counts for Station 20368 ranged from 0.5 CFU/100 mL to 1260 CFU/100 mL, with a geometric mean of 24.8 CFU/100 mL. Two of 20 samples (10%) exceeded the single sample maximum limit of 394 CFU/100 mL. BST identification of *E. coli* water isolates (n = 70) for Station 20368 is presented in Figure E-3. Overall, 65% of the water isolates were identified as originating from wildlife, followed by 14% from domestic animals and 7% from human sources. For *Bacteroidales* analysis, all 11 water samples tested positive for the GenBac general marker, followed by a high occurrence of the ruminant marker and moderate to low occurrence of hog and human markers (Figure E-3).



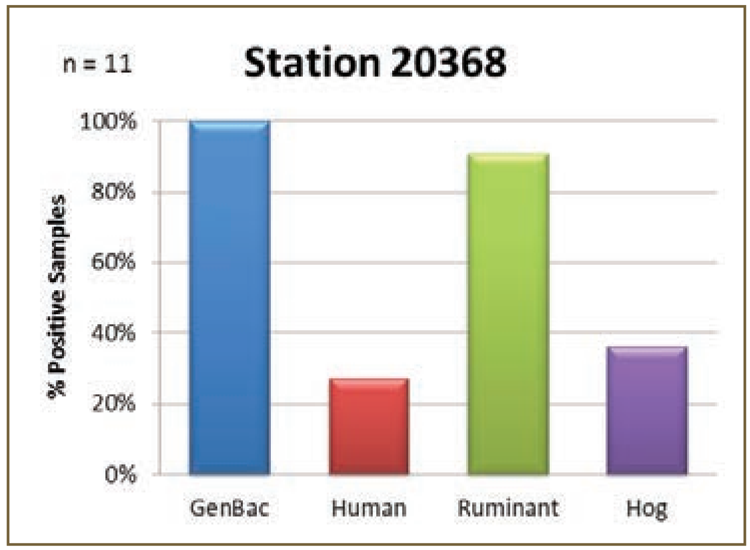
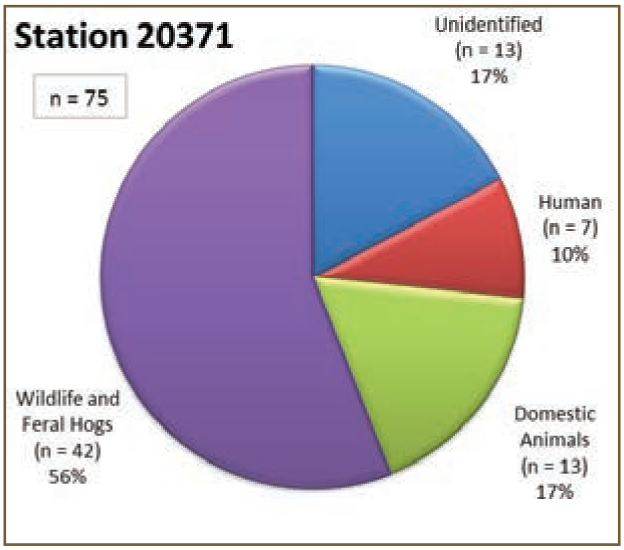


Figure E-3. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20368. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. cattle, deer, etc.); Human = all human sources

Station 20371

E. coli counts for Station 20371 ranged from 0.5 CFU/100 mL to 556 CFU/100 mL, with a geometric mean of 40.8 CFU/100 mL. The single sample maximum of 394 CFU/100 mL was exceeded for only 1 of 25 samples (4%). BST identification of *E. coli* water isolates (n = 75) for Station 20371 is presented in Figure E-4. Overall, 55% of the water isolates were identified as originating from wildlife, followed by 17% from domestic animals and 11% from human sources. Fourteen water samples were collected for *Bacteroidales* analysis. All water samples tested positive for the Gen-Bac general and ruminant markers, followed by moderately high occurrence of the hog marker and a low occurrence of human marker (Figure E-4).



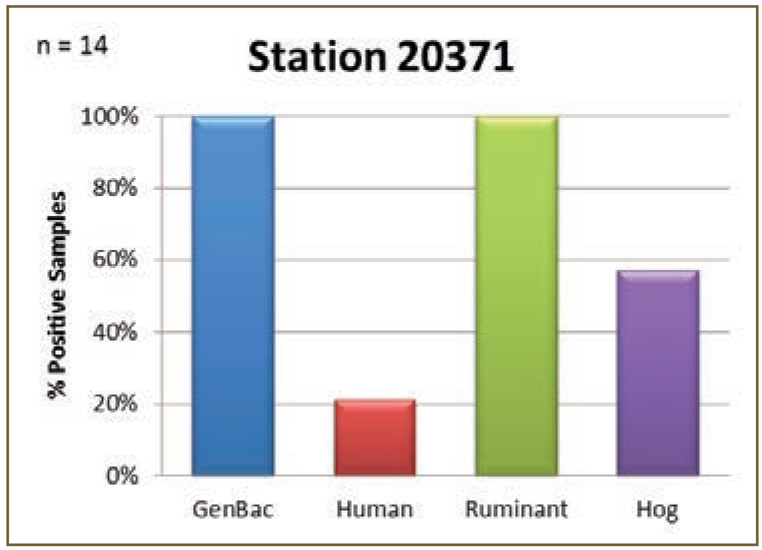
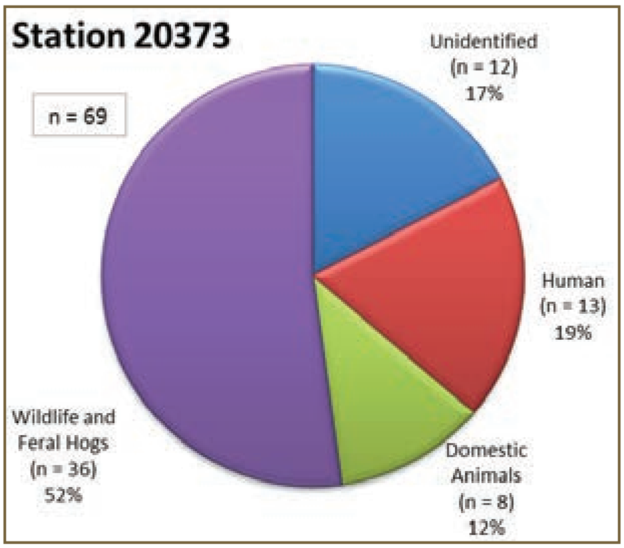


Figure E-4. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20371. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. cattle, deer, etc.); Human = all human sources

Station 20373

E. coli counts for Station 20373 ranged from 0.5 CFU/100 mL to 610 CFU/100 mL, with a geometric mean of 18.9 CFU/100 mL, and only 1 out of 25 (4%) samples exceeded the single sample maximum. BST identification of *E. coli* water isolates (n = 69) for Station 20373 is presented in Figure E-5. Overall, 52% of the water isolates were identified as originating from wildlife, followed by 19% from human and 12% from domestic animals sources. Twenty water samples were collected for *Bacteroidales* analysis (the most from any station). All water samples tested positive for the GenBac general marker, and 18 out of 20 tested positive for the ruminant marker. The human marker and hog markers were detected in 60% of the samples (Figure E-5). The high occurrence of human *E. coli* and frequent human *Bacteroidales* marker detection were unexpected, as this is one of the more remote stretches of Buck Creek.



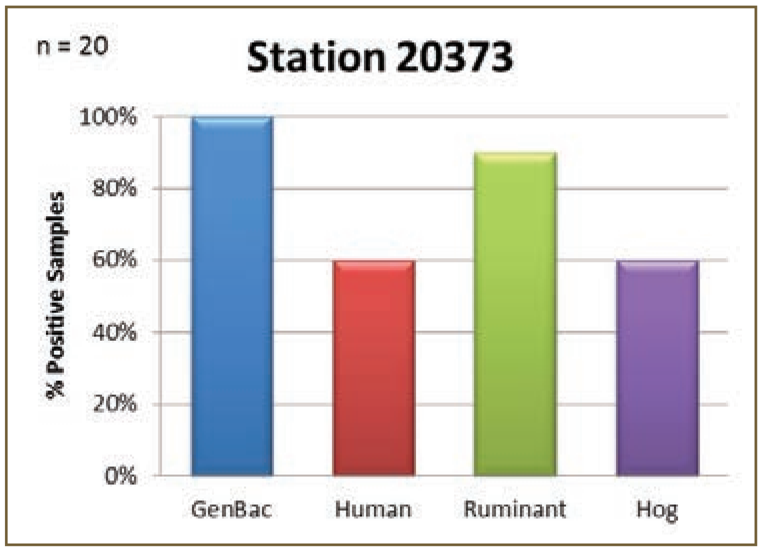
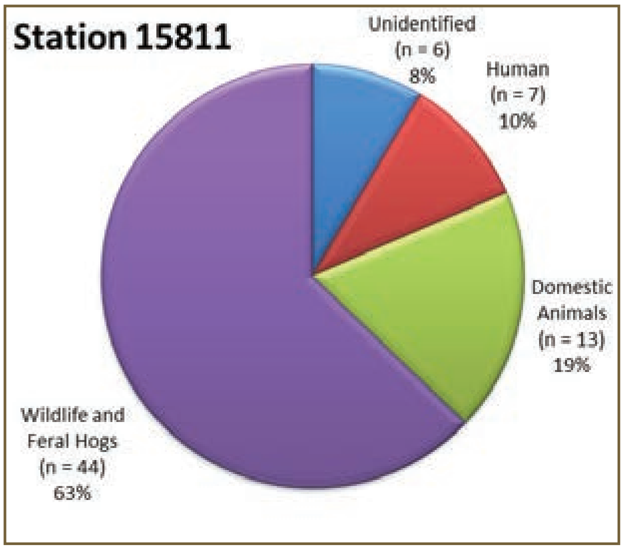


Figure E-5. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20373. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. cattle, deer, etc.); Human = all human sources

Station 15811

E. coli counts for Station 15811 ranged from 0.5 CFU/100 mL to 900 CFU/100 mL, with a geometric mean of only 14.1 CFU/100 mL. Only 1 of 26 (4%) samples exceeded the single sample maximum of 394 CFU/100 mL. BST identification of *E. coli* water isolates (n = 70) for Station 15811 is presented in Figure E-6. Overall, 62% of the water isolates were identified as originating from wildlife, followed by 19% from domestic animals and 10% from human sources. Twelve water samples were collected for *Bacteroidales* analysis, and all tested positive for the GenBac general and ruminant markers followed by moderately high occurrence of the hog and human markers (Figure E-6).



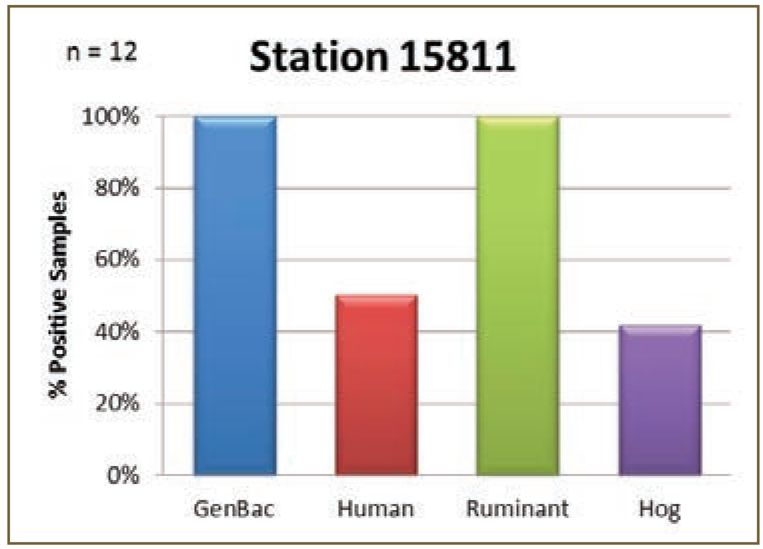


Figure E-6. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 15811. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. cattle, deer, etc.); Human = all human sources

Appendix F: Load Reduction Calculations

Estimates for load reductions are based largely on the characteristics of individual subbasins such as the expected number of cattle, deer or feral hogs or even the number of OSSFs within a subbasin. Table F-1 presented below illustrates the land use/land cover make up, total acres, animal population estimates and potential number of OSSFs in each designated subbasin. It should be noted that the species population estimates presented here represent best estimates and inherently contain uncertainty that cannot be quantified. Information in this table will be referenced in estimated load reductions described below.

Table F-1 Respective land use in each subwatershed of the Buck Creek watershed and population estimates for primary pollutant producers

	ACRES												Species Population Estimates by Subbasin			
			Developed Land													
Subbasin	Open Water	Roads	Low Intensity	Medium Intensity	Barren Land	Mixed Forest	Riparian Forest	Rangeland	Cultivated Land	Managed Pasture	Total Subbasin Acres		Cattle	Deer	Feral Hogs	OSSFs
LO-1	14.1	52.3			0.2	192.7	95.4	8,838.4	1,729.4	73.2	10,995.5		374	306	438	5
LO-2	19.6	426.8	15.0		0.2	342.0	18.5	7,114.3	3,280.6	978.1	12,195.1		421	329	476	6
LO-3	25.3	445.9	27.4	1.3	0.1	290.1	239.8	9,618.8	3,361.5	3,539.7	17,549.7		847	479	690	8
LO-4	7.7	460.7	86.7		0.5	204.2	116.6	4,224.3	3,892.8	3,820.1	12,813.6		659	346	498	11
LO-5	26.9	427.4	2.1			143.8	184.1	1,001.5	9,003.4	1,060.5	11,849.6		185	320	460	9
LO-6	3.8	100.7	7.8			124.9	148.9	3,720.4	3,447.0	241.4	7,794.9		189	216	306	7
LO-7	4.0	183.6				50.9	25.7	3,627.6	5,404.8	1,434.4	10,730.9		327	297	419	6
LO-8	4.2	136.5			0.0	123.9	57.3	667.3	1,740.2	86.7	2,816.2		45	74	111	3
LO-9	2.3	332.8	1.3			99.4	106.9	544.9	5,370.6	133.5	6,591.6		47	177	250	10
UP-1	23.7	343.3	8.4		1.1	36.8	157.2	1,774.3	5,774.1	1,015.1	9,134.0		205	247	357	26
UP-2	23.3	266.1			0.4	83.5	223.1	5,430.1	7,338.6	2,214.0	15,579.1		506	432	615	16
UP-3	36.7	366.1	0.2		4.6	197.7	341.0	3,460.8	10,242.9	1,823.4	16,473.3		387	452	643	34
UP-4	26.0	127.8			0.0	117.0	117.2	10,200.1	3,342.5	1,672.8	15,603.3		626	436	612	10
UP-5	4.5	28.1				1.3	29.5	3,463.3	345.2	64.6	3,936.5		148	109	151	3
UP-6	73.4	6.6			0.6	25.7	12.8	8,524.9	195.6	417.4	9,257.0		394	258	360	0
UP-7	12.7	3.1	1.0		3.0	2.8	35.6	4,538.5	183.2	1,330.8	6,110.8		350	171	236	8
UP-8	12.9				4.2	0.2	33.7	6,820.4	180.2	2,044.4	9,096.0		529	255	356	3
UP-9	20.9	115.8	105.8	1.3	41.8	199.8	175.0	3,791.0	2,416.1	1,875.2	8,742.7		401	238	332	23
Totals	341.7	3,823.5	255.6	2.6	56.6	2,236.7	2,118.3	87,360.9	67,248.7	23,825.3	187,270.0		6,640	5,143	7,310	188

Cattle

Watershed stakeholders developed population estimates for cattle across the watershed. USDA NASS data for the 3 counties partially within Buck Creek included numerous feedlots and as such were thought to be an overestimate of actual cattle numbers in the watershed. Using a 3-county average of NRCS-recommended stocking rates of 25 ac/AU for rangeland, mixed forest and riparian forest and a rate of 8 ac/AU on managed pasture supplemented with local knowledge, an average resident cattle population of 6,640 head was estimated for the watershed and does not include transient cattle housed at the livestock auction barn in Wellington or the feedlot near Hedley. Subbasin population estimates are presented in Table F-1 and were derived by evenly distributing these animals across appropriate land uses.

Utilizing the SELECT model, potential fecal loading from cattle throughout the watershed was estimated for each subbasin as well as the entire watershed. The total daily *E. coli* loading potential from cattle across the entire watershed was estimated to be 3.28 E+14 cfu while the annual potential load is estimated at 1.20 E+17 cfu. These estimates were made using *E. coli* loading rates presented in EPA (2001) where $5.0*10^{10}$ is the daily *E. coli* production rate per head of cattle:

$$\text{Cattle Load} = \#\ \text{Cattle} * 5.0 * 10^{10}$$

This is an absolute worst-case scenario and does not account for any bacteria die-off.

Potential load reductions that can be achieved by implementing practices through WQMP programs will depend specifically on the particular BMP implemented by each individual landowner and the number of livestock in each landowner's operation. BMPs that have been included in WQMP programs, have been documented to measurably reduce the amount of fecal bacteria loading from cattle and can be employed in the Buck Creek watershed include exclusionary fencing, filter strips, prescribed grazing, stream crossings and watering facilities, Fencing, prescribed grazing and water development are the 3 most likely practices to be implemented in the Buck Creek watershed, but that decision is up to the individual landowner.

These BMPs have been the subject of various research efforts and estimated bacteria reduction efficiencies have been established for these practices through these studies. Table F-2 lists the individual practice, the range of bacteria removal efficiency and the midpoint of the efficiency range as described in the literature. While research conducted in these works was not conducted in the Buck Creek 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, using the midpoint of the effectiveness ranges is assumed to be a reasonable and was used to estimate practice efficiency and predict potential load reductions that may be realized through voluntary BMP implementation in Buck Creek. It should be noted that using the lowest effectiveness rate will yield a more conservative prediction for load reductions.

Table F-2. Livestock BMP fecal coliform removal efficiencies

Management Practice	Effectiveness: Low Rate	Effectiveness: High Rate	Median
Exclusionary Fencing [1]	30%	94%	62%
Filter Strips [2]	30%	100%	65%
Prescribed Grazing [3]	42%	66%	54%
Stream Crossing [4]	44%	52%	48%
Watering Facility [5]	51%	94%	72.5%

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

[2] Casteel et al. 2005, 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, Roodsari et al. 2005, Stuntebeck & Bannerman 1998, Sullivan 2007, Tate 2006, Young 1980

[3] Tate et al. 2004, USEPA 2010

[4] Inamdar et al. 2002, Meals 2001

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

To calculate potential load reductions for each of these 5 BMPs, a generic equation has been developed based upon the number of animal units, average fecal material production rates of beef cattle, the average *E. coli* content of beef cattle manure and the selected BMP effectiveness rate as listed above in Table F-2. This generic form of equation based on animal units was chosen because an accurate estimation of BMP implementation cannot be clearly defined. Since BMP implementation is strictly voluntary, no firm number of BMPs that will be installed can be established. The number of cattle or animal units in an operation that voluntarily implements some of these BMPs 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.

$$Daily\ Potential\ Load\ Reduction = \#\ of\ WQMPs * \#\ of\ \frac{cattle}{WQMP} * \frac{5.0x10^{10}cfu}{day} * BMP\ Effectivness\ Rate$$

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.
- $5.0x10^{10}$ = the average *E. coli* production in cfu/day per cattle AU as reported in EPA 2001
- BMP Effectiveness rate = midpoint of BMP efficiencies as illustrated in Table F-2.

Specific load reduction estimates are merely best guesses, as they 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. Subbasins LO 3 and 4 as well as UP 2, 3, 4, 6 and 8 are targeted for WQMPs that will be geared toward improving cattle management in these subbasins. In total, these subbasins are home to an estimated 3,938 head of cattle and encompass 92,924 ac. Using the average farm size from 2007 of 1,243 ac (Table 8), it is estimated that there are 75 farms in these subbasins with approximately 52 head of cattle per farm. A recommendation of developing and implementing 15 WQMPs across these subbasins has been made. Watering facilities and prescribed grazing are the likely practices that will be implemented through these WQMPs and loading reduction estimations will be made with the assumption that each WQMP will include these practices.

Prescribed Grazing Estimate:

$$Annual\ Prescribed\ Grazing\ Load\ Reduction = 15\ WQMPs * 52\ Cattle * \frac{5.0x10^{10}cfu}{day} * .54\ BMP\ Efficiency * \frac{365\ days}{year}$$

$$Annual\ Prescribed\ Grazing\ WQMP\ Load\ Reduction = 7.69x10^{15}$$

Watering Facility Estimate:

$$Annual\ Watering\ Facility\ Load\ Reduction = 15\ WQMPs * 52\ Cattle * \frac{5.0x10^{10}cfu}{day} * .725\ BMP\ Efficiency * \frac{365\ days}{year}$$

$$Annual\ Watering\ Facility\ Load\ Reduction = 1.03x10^{16}$$

Deer

Deer populations in the watershed were estimated based on TPWD estimates modified with watershed stakeholder input. An average of the 2007 and 2008 white-tailed deer density estimates from TPWD was chosen as the most appropriate population for the watershed while TPWD's 2009 mule deer estimate was deemed most appropriate.

Although estimates were calculated for each deer subspecies, they were treated as the same in estimating the potential *E. coli* load that they contribute to the watershed. As such, a modified density estimate was used to estimate populations in the SELECT model. To accomplish this, a uniform density of 36 ac/animal was applied evenly to cultivated land, rangeland, riparian forests, mixed forests and managed pasture to get the total population estimate of 5,143 deer.

Using the SELECT model, potential *E. coli* loadings from deer were estimated to be as much as 8.80 E+11 cfu/day or 3.21 E+14 annually. To estimate these potential loads, the daily *E. coli* production rate for deer of $3.5*10^8*0.5$ cfu per animal was used (EPA 2001).

Expected load reductions from deer and other wildlife will be realized by reducing the amount of time these species spend in the riparian corridor through habitat management. This practice is a nondescript practice that will vary from location to location. Adding further uncertainty to the mix is the inability to force deer and other wildlife away from riparian areas and the lack of an estimate of actual time reduced in riparian areas that can be expected. Lastly, effective *E. coli* removal efficiencies are not available for this practice. As such, a good faith estimate of an expected load reduction from wildlife habitat management cannot be made.

Feral Hogs

The feral hog population is estimated to be 7,310 animals for the entire watershed and was determined by watershed stakeholders (Table F-1). This estimate assumed a density of 25 ac per animal applied to mixed forest, 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. See Chapter 5 for additional discussion on population estimation.

The SELECT model predicted that feral hogs have the potential to contribute 4.01 E+13 cfu/day of *E. coli* to the watershed and the potential to contribute 1.47 E+16 cfu annually. The daily potential *E. coli* load from feral hogs was estimated using:

$$\text{Feral Hog Load} = \#\ \text{hogs}*1.1*10^{10}\ \text{cfu/day}*0.5$$

Where $1.1*10^{10}$ cfu/day*0.5 is the average daily *E. coli* production rate per hog (EPA 2001).

Management reduction goals for feral hogs focus on removing animals from the watershed and keeping populations at a static level. The goal established is to remove 10% of the total hog population from the entire watershed. By removing the hogs from the watershed completely, the potential *E. coli* load from feral hogs will be removed by an equal amount. In this case, the target population reduction is 10%.

Assumptions:

- feral hogs evenly distributed across entire watershed
- 10% population reduction results in an equal 10% reduction in potential load

Calculation:
Annual Potential Load Reduction = Annual Potential Load – (Annual Potential Load * 0.1)

Annual Potential Load Reduction = $1.47x10^{16} - (1.47x10^{16} * 0.1)$

Annual Potential Load Reduction = $1.47x10^{15}/year$

OSSFs

Using the geospatial assessment described in Chapter 6, the number of OSSFs in the watershed is estimated to be 188 systems. Using findings from Reed et al. (2001), a very conservative estimate of 8% of all OSSFs in the watershed being failing was used to assess potential impacts of OSSFs in overall *E. coli* loading. Further analysis described in Chapter 7 indicated that of the OSSFs in the watershed considered to be most likely to influence instream water quality (i.e. within 1,000 yds of the creek or tributary), only 3 of these systems would be failing based on the failure rate assumption of 8% of all systems.

Potential loading from these failing OSSFs was estimated using the methodology presented in EPA (2001) and used in many other watersheds in Texas as well as watershed specific population estimates and other assumptions.

Assumptions:

- 1 failing OSSF in the critical area of the watershed may be replaced
- $10^6 \frac{cfu}{100mL}$ = fecal coliform concentration in OSSF effluent as reported by Metcalf & Eddy 1991, Canter and Knox 1985, Cogger and Carlile 1984.
- 0.8 = conversion factor to convert between fecal coliforms and *E. coli* (TCEQ 2011)
- $3785.2 \frac{ml}{gallon}$ = number of milliliters in a gallon
- 70 gallons per person per day is estimated discharge in OSSFs as reported by Horsley and Witten 1996.
- 2.41 persons per household average from Childress, Collingsworth and Donley counties (Table 10.)

Potential OSSF Load: =

$$1\ failing\ septic\ systems * 10^6 \frac{fecal\ coliforms}{100\ mL} * .8 * \frac{70 \frac{gallons}{person}}{day} * 3785.2 \frac{mL}{gallon} * 2.41 \frac{persons}{household} * \frac{365\ days}{year} = 1.86x10^{13} \frac{cfu}{day}$$

Nitrate Crediting

High nitrate levels in regional groundwater resources are commonly found and can be mined by accounting for these nitrates when planning nutrient applications in irrigated cropland. Plants consume nitrate and stores in plant tissue. When the crop is harvested, it is removed from the watershed, thus reducing the volume of nitrate in the watershed. Cropland is a dominant land use/land cover in the Buck Creek watershed and is estimated to encompass 67,335 ac. Of this, approximately 20%, or 13,467 ac are irrigated. Further, it is anticipated that 50% of farmers will actually implement nitrate mining on their farms.

Using information presented in Table F-3, an estimation of the pounds of nitrate applied per acre can be made. The concentration of nitrate in the irrigation water applied and the inches of water applied per acre annually are multiplied by a conversion factor to yield an annual pounds/acre of nitrate applied. The actual load reduction realized will depend on field-level variables and will fluctuate annually as irrigation quantities are increased or decreased with rainfall.

Table F-3. Nitrate availability in irrigation waters at designated application rates and nitrate concentrations

lbs NO_3-N/acre = $N0_3$-N (ppm) x 0.23 x inches of water applied/acre					
Well Water NO_3-N (ppm)	Inches of Water Applied				
	6	12	18	24	30
5	7	14	21	28	35
10	14	28	41	55	69
15	21	41	62	83	103
20	28	55	83	110	138
25	34	69	104	138	173

In the case of Buck Creek, calculating an expected load reduction for nitrates by implementing this practice is highly uncertain, given limited irrigation water nitrate concentration data and the speculation on the number of inches of water that will be applied annually. However, given the potential pounds of nitrate that can be mined from the watershed, an estimate of 25 lbs/ac is assumed realistic. Using this assumption and the watershed statistics presented earlier, the following potential load reduction can be calculated.

Assumptions:

- 67,335 ac of cultivated land in watershed
- 20% of cultivated land is irrigated
- 50% of farmers will implement nitrate mining
- 25 lbs/ac of nitrate will be mined annually

Calculation:

Annual Potential Load Reduction = Total Cultivated Acres * % irrigated * % of farmers implementing * estimated nitrate-mining rate

Annual Potential Load Reduction = 67,335 ac * 0.2 * 0.5 * 25 lbs/ac NO_3

Annual Potential Load Reduction = 168,337 lbs NO_3 annually

Appendix G: Experimental and Water body Sampling Procedures

Water Body Sampling Procedures

Each site was visited to determine if enough flowing water was present to collect a sample or take water quality measurements. Project personnel took samples at all sites with flowing water and recorded field observations to document the status of the creek and other environmental conditions at the time of the sampling event. A field data report was generated for each site even if a water sample was not collected. These reports recorded the sampling site, time, date, sample ID number, the chain of custody number, the collector's name and the collecting agency. The field data report also contains information on streamflow, the number of days since the last significant rainfall event and current weather conditions and served as a back-up recording of measured water quality parameters. In addition, air temperature, the appearance of the water, presence of any odor and biological activity were noted.

A typical sample was collected directly from the center of the stream between 15 and 30 centimeters (6 to 12 in) below the water surface using a sterile, 125 mL wide-mouthed bag. All samples were labeled with the collection date and time, sampling location, and the sampler's initials. The surface layer of water, known as the micro layer, was avoided for sampling purposes because of possible bacteria enrichment. Care was taken not to disturb the sediment at the bottom of the creek bed because it may have contained higher *E. coli* numbers. If the person collecting the sample actually entered the stream, samples were always collected upstream of the person sampling and water was allowed to clear up before the sample was taken. Once samples were taken, they were placed on ice to lower their temperature to 4°C before being taken to the lab.

Safety of the technicians was a major concern for the project. Lightning, flooding and impassable roads were primary concerns. When technicians felt that it was unsafe to sample at a location, observations were made about the site and a sample was not taken.

In addition to sample collection, field measurements (streamflow severity, water depth, water temperature, pH, specific conductivity and DO) were recorded. Water depth was measured using a meter stick and flow severity was determined through field observation. A YSI multi-probe (YSI Environmental. Yellow Springs, Ohio. www.ysi.com) was used to measure DO, pH, specific conductance, salinity, and water temperature in accordance with the TSSWCB- and EPA-approved Quality Assurance Project Plan (QAPP).

Experimental Procedures

Once samples were returned to the AgriLife Vernon lab, 100 mL of the water sample (or a diluted portion of the sample) was filtered to evaluate the presence of *E. coli* and fecal coliforms. Using a vacuum-powered filtering apparatus, project personnel extracted *E. coli* by passing the collected water sample through a funnel with a sterile filter membrane. The membrane is subsequently placed on prepared modified mTEC agar petri dishes (selective for *E. coli*) and incubated at 35.2° C for 2 hours to resuscitate the bacteria. The petri dishes are then moved to a water-jacketed incubator and kept at 44.5°C for 20 to 22 hours allowing sufficient time for bacterial colonies to develop. *E. coli* colonies are recognized by their magenta color.

Fecal coliform samples are treated similarly, but a different culture medium (m-FC) is used for colony development. This media is selective for fecal coliform and is recognized by its cobalt blue color. Fecal coliform testing was performed only at site 15811.

Project personnel also tested field blanks and laboratory blanks by using the same sampling and sterilization techniques to ensure that materials and methods used were effective and not contaminated by other sources of bacteria. A lab positive using live *E. coli* bacteria was also plated with each set of samples to confirm that the medium used would support bacteria growth. Following the incubation period, colonies were counted by project personnel using a mini light box, magnifier and a counting pen. Colony counts were recorded based on 100 mL of the original water sample. In some cases, colonies were too numerous to count using this method. If this was the case, an aliquot or dilution yielded a number of colonies that could easily be counted. Typically, 10 mL rather than 100 mL of the original sample was filtered on the plates and allowed to form colonies. These colonies were then counted and multiplied by 10 to account for the lesser volume of water used in the sample.

During the *Watershed Protection Plan Development for Buck Creek* project, the same sampling and analysis methods were employed to ensure consistency within the data collected. Instantaneous streamflow, nitrates and BST were added to enhance knowledge of the water body and its characteristics. These added measurements provided additional information about water quality in the watershed and support the implementation of management measures presented later in the WPP. Table G-1 presents a data summary of water quality parameters routinely monitored from 2004–2009 by AgriLife Vernon at 15811, upstream of US 83.

Nitrates analysis was conducted by the RRA lab in Wichita Falls. It used an automated ion chromatograph to quantify nitrate levels in 125 mL water sample delivered to the lab. Samples were collected, labeled, stored and transported similar to *E. coli* water samples.

Table G-1. Water quality data collected by AgriLife Research Vernon at TCEQ Site 15811 above US 83 from 2004 to 2009**

Parameter	# of Samples	Minimum	Maximum	Average / *Geomean*	TCEQ Standard / *Screening Criteria*	Impaired / Concern ††
Water Temp (°C)	64	3.00	32.00	17.50	33.9 maximum	
Flow (cfs)	16	0.00	7.41	1.80	no standard	
Specific Conductance (µmhos/cm@25°C)	64	433.00	3,729.00	3,152.00	30,030 max annual avg	
Dissolved Oxygen (mg/L)	61	4.20	21.23	12.04	3.0/2.0 (grab avg/min)[x]	
pH (standard units)	64	5.10	8.20	8.21	6.5 - 9.0 range	
Nitrate Nitrogen (mg/L)	9	0.98	4.57	3.09	*1.95 (>20% exceedance)[Y]*	concern
E. coli (cfu/100 mL)	82	1.00	4,030.00	*27.56*	126 geometric mean	

** data as collected and reported for TCEQ Site 15811 at the US 83 crossing

†† the listed concern is according to the *Draft 2010 303(d) List*

[x] a grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are both minimum standards

[Y] if the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists

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Texas Water Resources Institute TR-420