Buck Creek
Watershed Protection Plan

Buck Creek Watershed Protection Plan

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Developed for:

The Buck Creek Watershed Partnership

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List of Acronyms

AC	acre
ac-ft	acre-feet
BMP	best management practice
CAFO	concentrated animal feeding operation
CCA	certified crop advisor
CEA	county Extension Agent
cfu	colony forming unit
EPA	United States Environmental Protection Agency
EQIP	USDA NRCS Environmental Quality Incentives Program
ERIC-PCR	enterobacterial repetitive intergenic consensus sequence polymerase chain reaction
FOTG	USDA NRCS Field Office Technical Guide
FW&DC	Fort Worth and Denver City Railroad
GCD	groundwater conservation district
GPM	gallons per minute
LDC	load duration curve
LULC	land use and land cover
mg/L	milligrams per liter
NPS	nonpoint source
NRCS	USDA Natural Resources Conservation Service
OSSF	on-site sewage facility
PCR	polymerase chain reaction
RRA	Red River Authority of Texas
Riboprinting	automated ribosomal ribonucleic acid genetic fingerprinting
RRC	Texas Railroad Commission
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
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility
USDA	United States Department of Agriculture
WPP	watershed protection plan

Executive Summary

[Executive Summary to be written after text in main document reviewed/approved by stakeholders]

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 all have the potential to influence water quality in the receiving waterbody. As a result, an effective management strategy that addresses water quality issues in a watershed's receiving waterbody 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 and ground water 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 which achieve environmental goals for water resources. Adaptive management is used to modify the WPP based on an on-going science-based process that involves monitoring and evaluating strategies and incorporates new knowledge into decision-making.

The Watershed Coordinator

The role of the Watershed Coordinator is an important one that is at the heart of WPP development and future implementation. The Watershed Coordinator leads efforts to establish and maintain working partnerships 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 AgriLife Research at the Vernon Research and Extension Center has filled this role and will continue to do so in the future.

The future role of the Watershed Coordinator is perhaps the most important as they 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 that keeps WPP implementation on track.

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

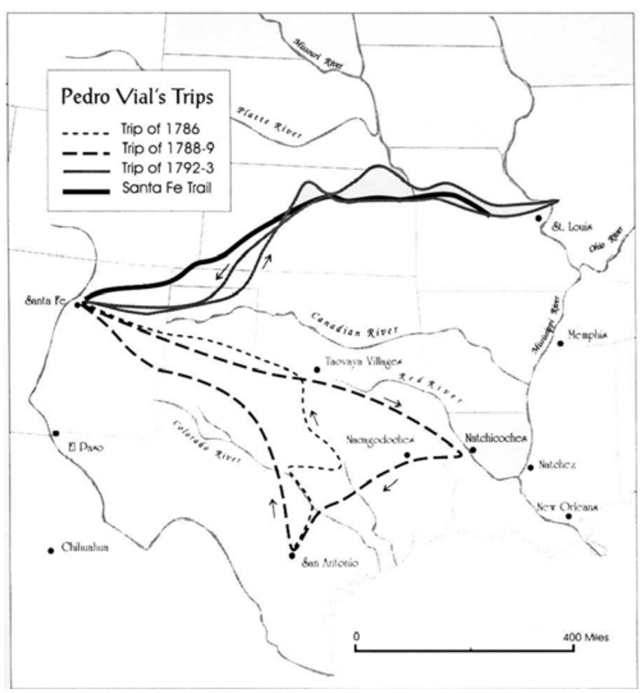
Adaptive management is a defined natural resource management approach that promotes decision making supported by an ongoing science-based process. This approach incorporates results of continual testing, monitoring, evaluation of applied strategies and incorporation of new information into revised management approaches that are modified based on science and societal needs (USEPA 2000). Essentially, adaptive management allows stakeholders to maintain a flexible approach in their decision making process to account for inherent uncertainty and make adjustments that improve the performance of designated management measures over time (Williams et al. 2009). Utilizing this process, members of the 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 & 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 utilized and inhabited many years; the Pueblo Panhandle Culture lived in an 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 where 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 & 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 thru the Buck Creek watershed. Following his initial expedition, he made several other trips through the Panhandle including his trek from Santa Fe, New Mexico



Map of Pedro Vial expeditions (Boyle 1994) to St. Louis, Missouri which led to the establishment of the Santa Fe Trail (Loomis & 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 & 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 animas) 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 coming in to squash the uprising. The Army's campaign became known as the Red River War which consisted of 14 battles scattered across 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 & 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 & Robertson 1981).

Cattle Ranching

The Texas Legislature officially divided the Panhandle into the 26 present counties in 1876; at this point the counties where 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 basin. Charles Goodnight was the pioneering cattle rancher in the Panhandle and 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 & 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 utilize barbed wire (Robertson & Robertson 1981).

The Diamond Tail Ranch established by William. R. Curtis and Thomas J. Atkinson moved into the Panhandle in 1879 and established 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 sell and subsequent move of the bulk of Diamond Tail Ranch operations to Chaves County, New Mexico. About 16,000 acres 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 & Robertson 1981).

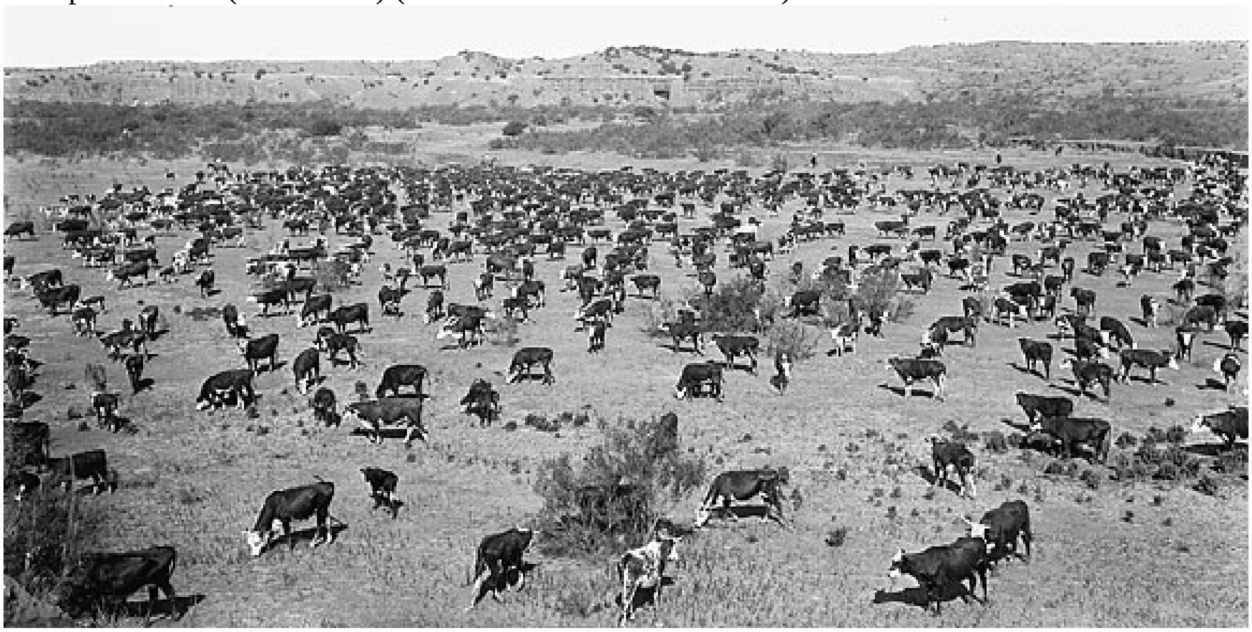
The JA chuck wagon camped on Cotton Wood Creek. JA Ranch, Texas. 1908. Erwin E. Smith. Available at: http://www.cartermuseum.org/collections/smith/collection.php?asn=LC-S59-178&mcat=6&scat=16

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 & Robertson 1981).

The RO Ranch also included portions of the Buck Creek watershed. The ranch was founded by Alfred Rowe, an Englishman, 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 acre 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 acres of the ranch; as of the 1970s it was still in the Lewis family (Robertson & 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 & Robertson 1981).



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?asn=LC-S6-

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 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 stage coaches at a great cost to the 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.

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

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 & Robertson 1981). The late 1880s yielded to harsh growing years with two 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 1890s farming had surpassed ranching as the primary agricultural industry in much of the Panhandle (Ford 1932, Rathjen 1998, Wellington Leader Staff 1925).

“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/

The Dust Bowl

Fueled by the higher than average rainfall on the High Plains of the early 20th century , the U.S. governments push for settling the area and experts’ beliefs that farming would change the climate bringing 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 area was still booming in crop production creating an excess of commodities (Eagan 2006, Worster 2011).

At the same time production was reduced in response the surplus, the rains began to slacken 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 U.S., the fallow fields began losing tons of topsoil to erosion. As the drought continued crop failures continued not only from lack of rain but from the sand blasting 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 that had come there for good farmland and profit now began leaving in droves. The fine dust in the air caused some people that 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 miles 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 which was created in 1934 with limited powers to control this erosion. Championed by Hugh Hammond Bennett, he 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 were authorized in 1937 (Eagan 2006, Worster 2011).

Childress County

Childress County was officially formed and named after George C. Childress, author of the Texas Declaration of Independence (Abbe 2008) in 1876 by the Texas Legislature but 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 to not 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, a total of 1,348 farms and ranches were recorded in the county. At this point, approximately 40 percent 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

Collingsworth County was also established in 1876 by the Texas Legislature and 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 2008). In the late 1870s and early 1880s, three 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 acres. 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 miles to the north. The construction of the Collingsworth County Courthouse began in 1891 and utilized 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 acres 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 2008).

Donley County

Donley County, designated in 1876 and named after Stockton P. Donley, a pioneer lawyer (Abbe & 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 to be 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 miles 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 acres 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 & Anderson 2008).

Chapter 3 ~ The Buck Creek Watershed

Buck Creek originates southwest of Hedley, Texas in Donley County and flows 68 miles 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.

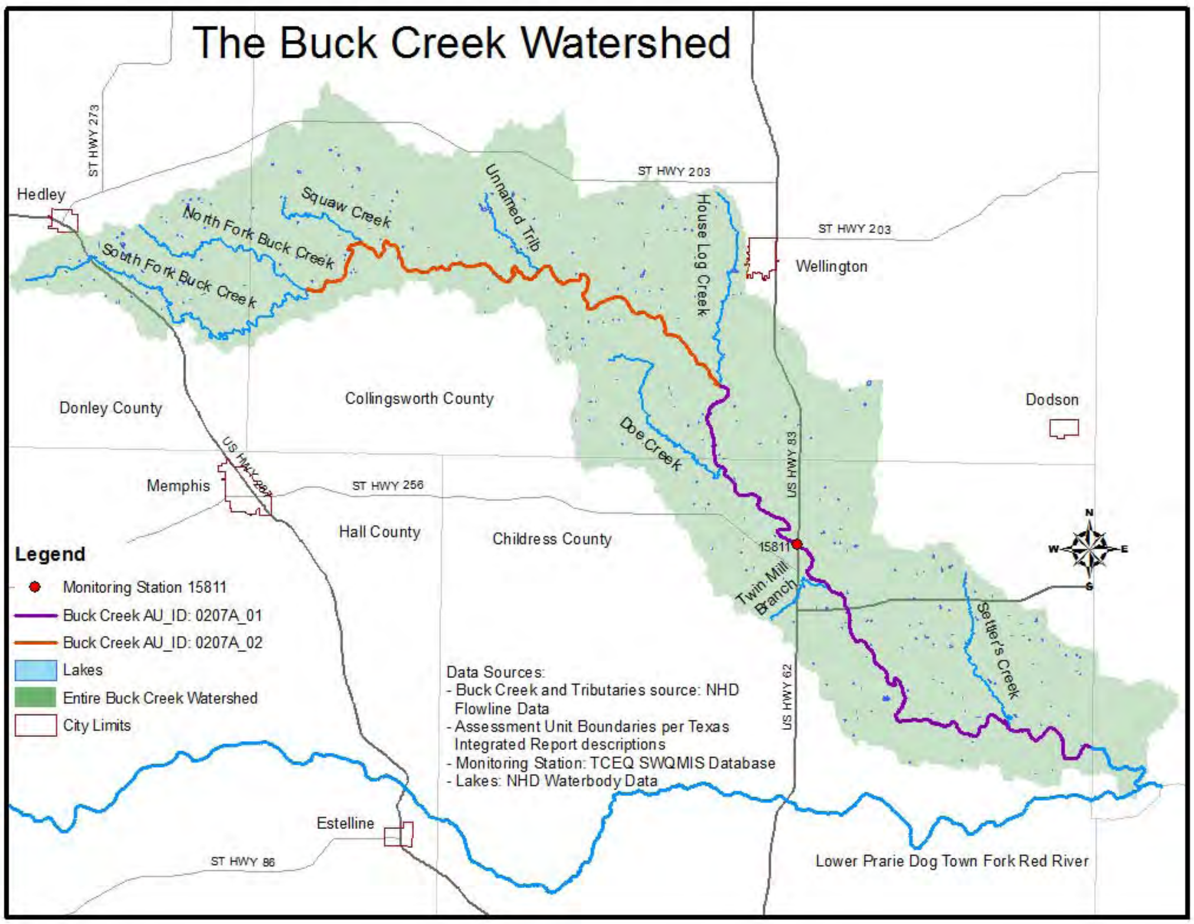


Figure 1. The entire Buck Creek watershed including the portion in Oklahoma

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 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.

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

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 Ecoregion description). 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 above sea level in the headwaters of the watershed to 503 meters 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. In total, the watershed includes 104 individual soil types which are categorized into eight 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. Generally speaking, each of these soils is considered to be 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 2006).

For a complete look at the soils of the Buck Creek watershed, see the USDA-NRCS Soil Surveys developed for Childress, Collingsworth and Donley counties (USDA 1963, USDA 1973 and UDSA 1980 respectively).

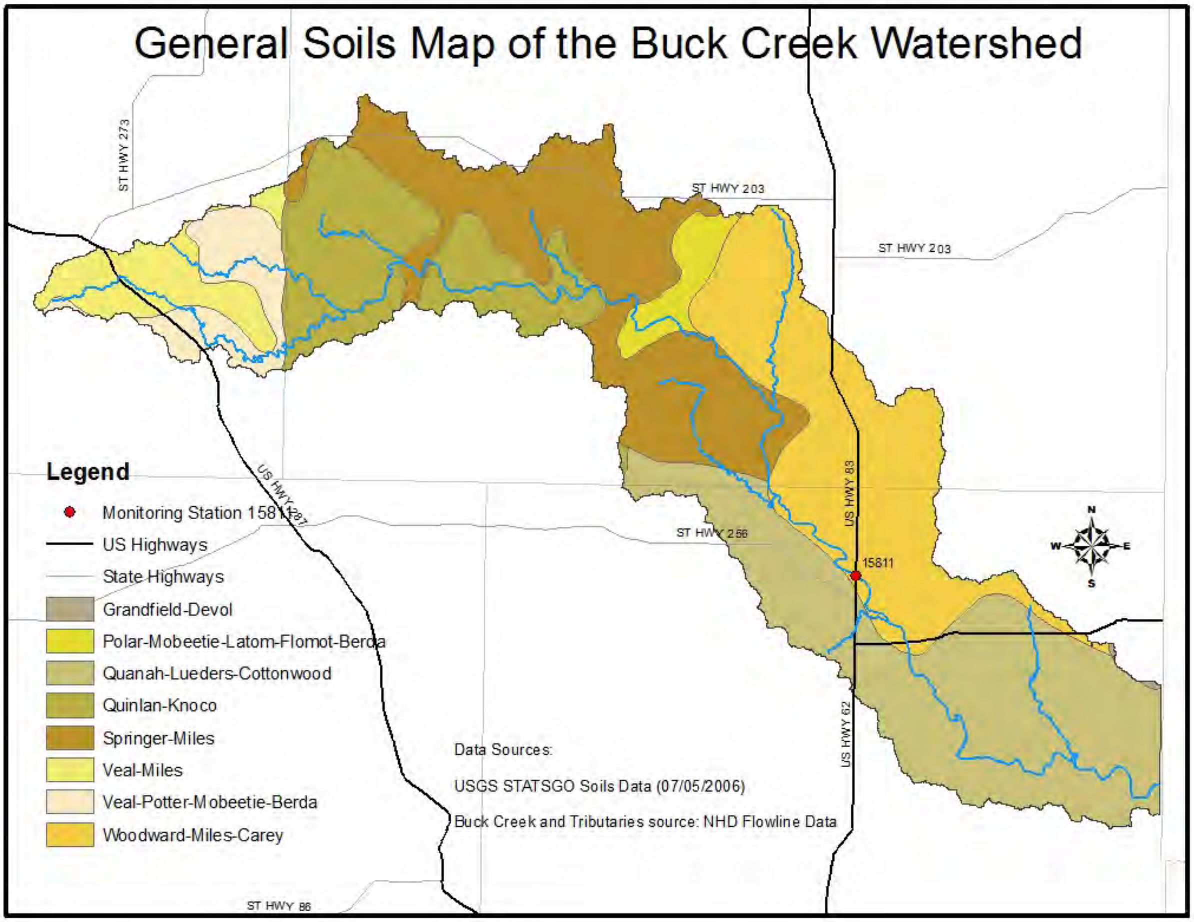


Figure 2. General Soils Map of the Buck Creek Watershed

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 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 was determined using several available datasets. National Agriculture Imagery Program images collected in 2005 were paired with 2003 Landsat Satellite Imagery to develop land use and land cover classifications. Additionally, managed pastures were further delineated utilizing USDA Farm Service Agency data thus enabling a more accurate assessment of watershed land use and land cover. These classifications were verified utilizing 2001 National Land Cover Dataset classifications and ground truthed data thus providing an accurate and up-to-date description of land uses and land covers in the watershed. Further information on the land use and land cover assessment is provided in Appendix B. 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.

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

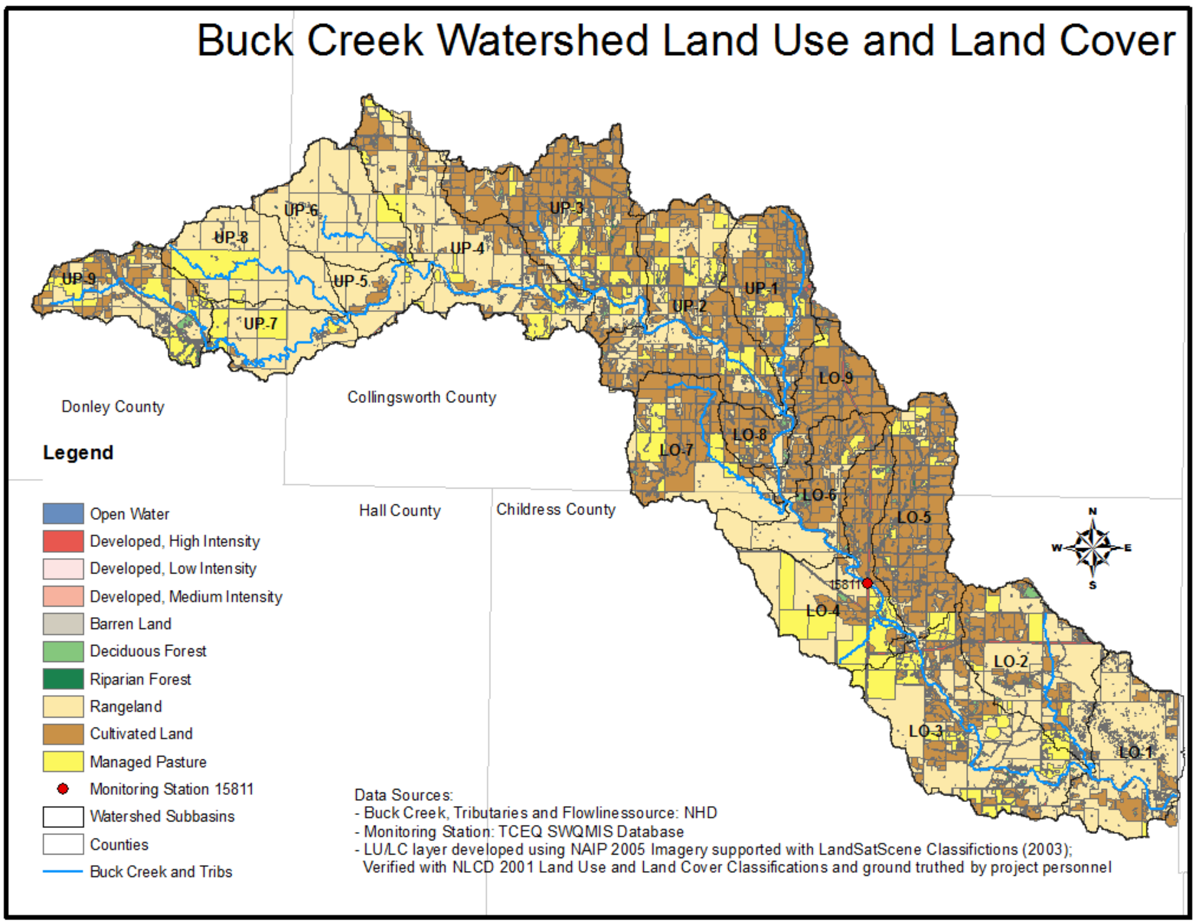


Figure 3. Buck Creek land use and land cover classifications

Ecoregions

Ecoregions describe land areas that contain similar ecosystems and both quality and quantity of natural resources (Griffith, 2004). Ecoregions have been delineated into four 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 be 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 precipitation 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 (http://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.

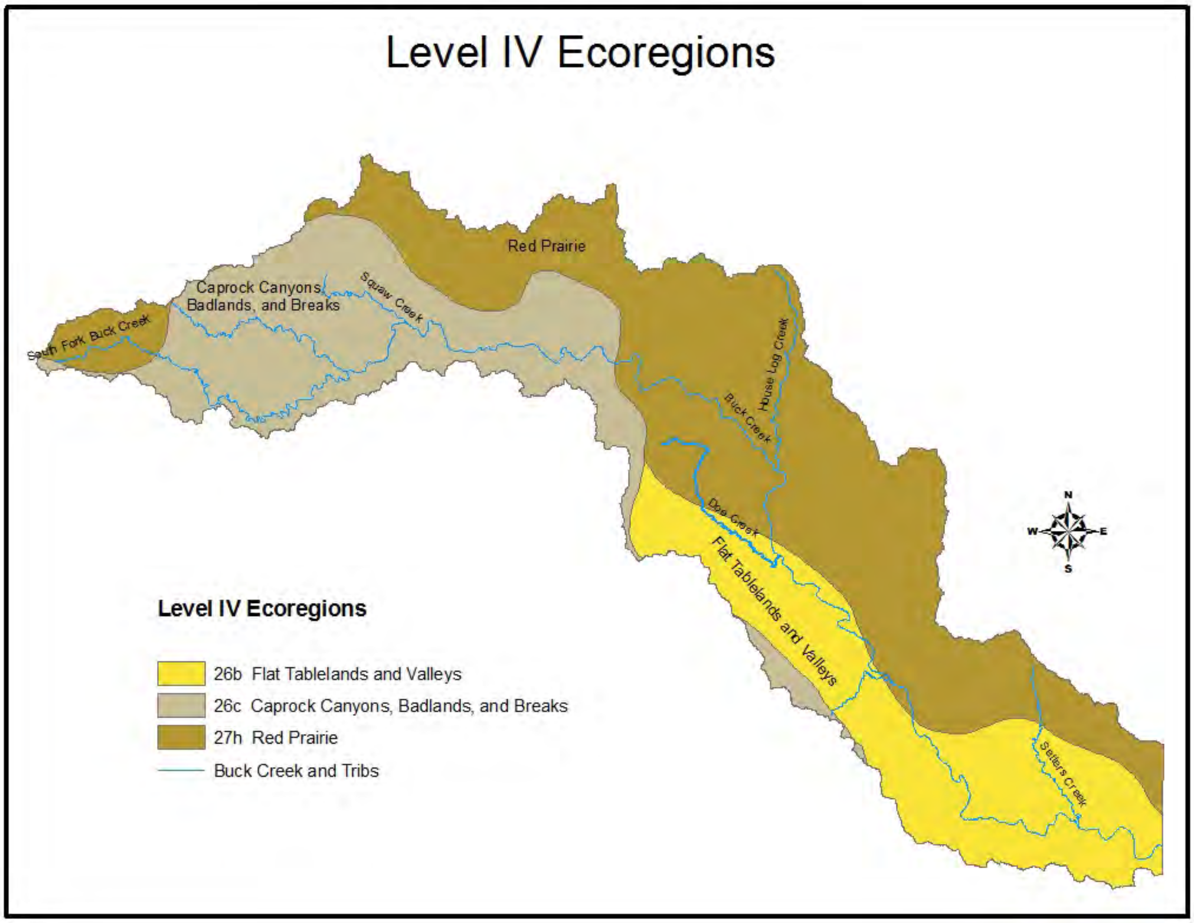


Figure 4. Level IV Ecoregions in the Buck Creek Watershed

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 (http://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 been known to produce 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 (http://hyper20.twdb.state.tx.us/Evaporation/evap.html).

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 percent 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 mg/L in the Southern High Plains. Aquifer recharge typically occurs at about 1 inch per year and has been greatly exceeded by pumping rates since the post-war 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 4). 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 ac-ft of water are available based on 75 percent of the total storage with annual effective recharge to the aquifer of approximately 215,000 ac-ft or 5 percent 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 oil-field activities has resulted in localized contamination of formerly fresh ground 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).

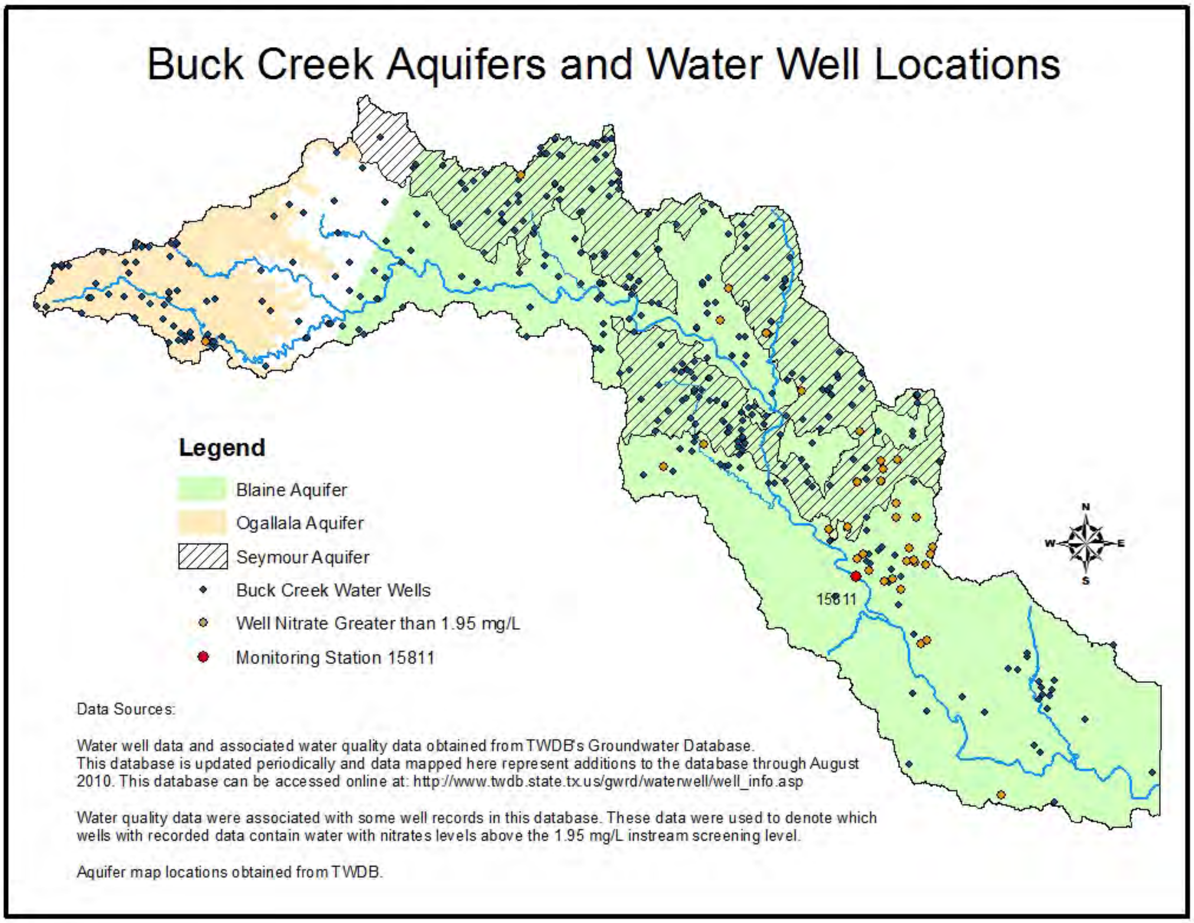


Figure 5. Aquifers and associated wells in the Buck Creek watershed

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.

Numerous shallow groundwater tables also exist within the Buck Creek watershed. Field observations indicate that these water tables are highly connected with the creek and are influenced by irrigation wells located near 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. In the spring, when irrigation begins, groundwater flow into the creek largely ceases and the stream starts to loose water to the depleted water tables. Once irrigation stops, spring flow slowly returns to the stream.

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 stream flow. Named tributaries of Buck Creek include Doe Creek, House Log Creek, Setters 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 & 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 also influence groundwater flow into the creek. Field observations have noted that stream flow 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, stream flow typically returns within 1 or 2 months (TWRI 2008).

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

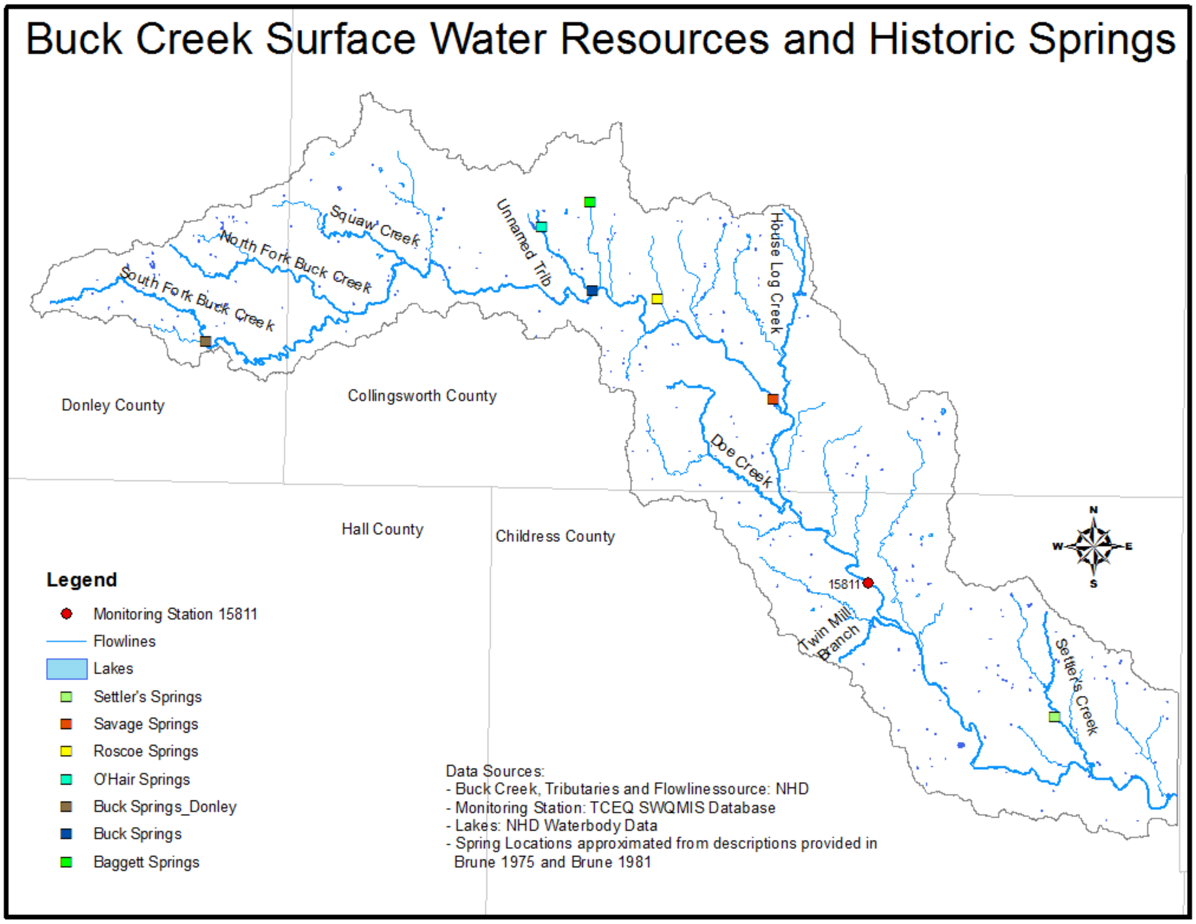


Figure 6. Surface water resources of the Buck Creek watershed

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 waterbodies as either classified or unclassified with the classified segments being individually defined in the *Texas Surface Water Quality Standards* (TCEQ, 2004a). Applicable water quality standards designated for unclassified waterbodies 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.

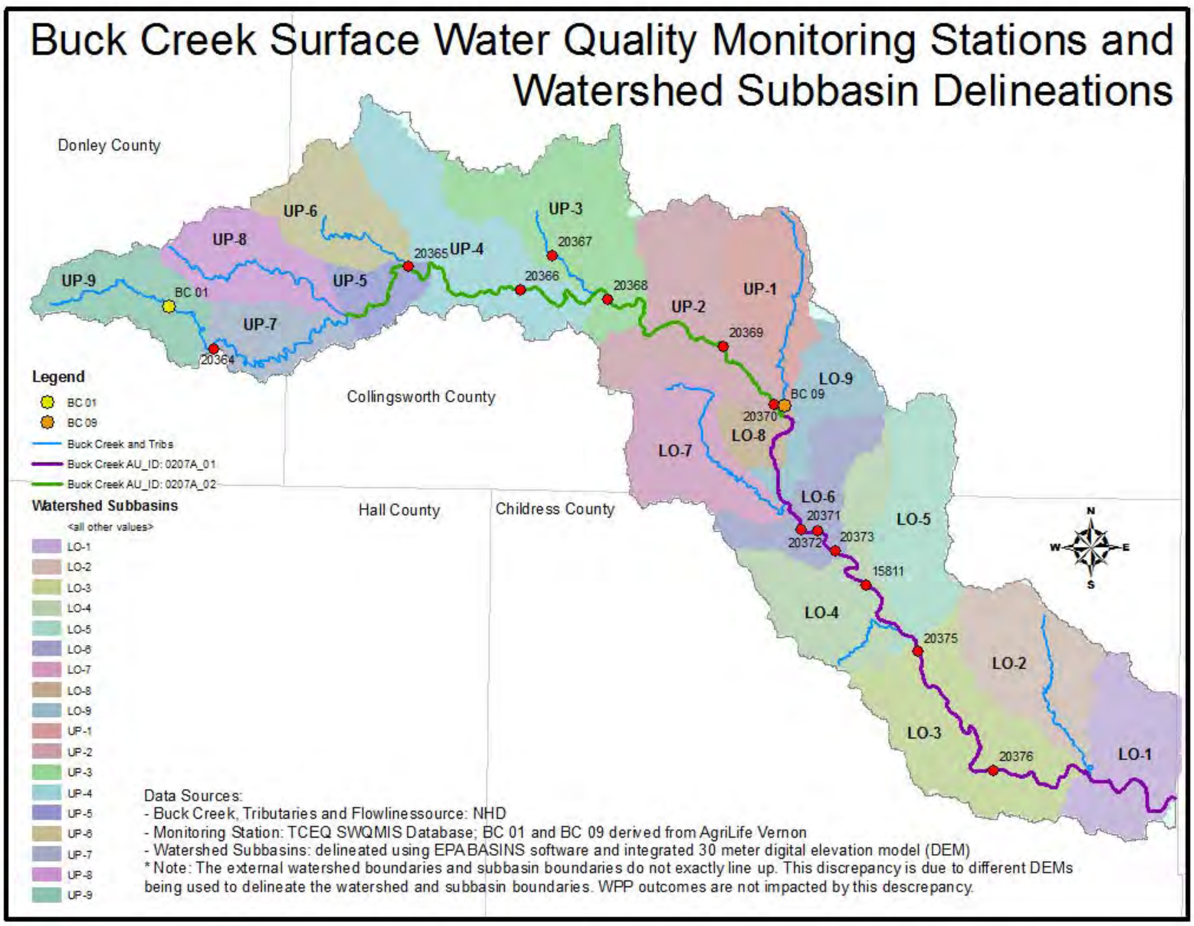


Figure 7. Buck Creek surface water quality monitoring stations and watershed subbasin delineations

Assessment Units

Following designation, waterbodies 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 waterbody 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, 2008). Initially, Buck Creek was defined by one AU, 0207A_01 which extends from “Oklahoma state line to House Log Creek” (TCEQ 2008). In 2010, Buck Creek was further subdivided into two AUs. AU 0207A_01 remained unchanged and AU 0207A_02 was added and described as extending from “House Log Creek to the upper end of the segment” (TCEQ, 2010a). During water body assessments, data collected from with a designated AU are used to assess 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

Designated uses are defined by TCEQ for all classified and unclassified streams in Texas and 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. Buck Creek is required by TCEQ to support 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 contact recreation use, must be supported in all but a few waterbodies 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 mL of water. *Escherichia coli (E. coli)* is the bacterial indicator utilized 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 total dissolved solids (TDS); additionally, concerns for meeting the general use are also quantified with screening levels for nutrients and chlorophyll a (TCEQ, 2010b).

Water Body Assessment

The actual water body assessment is conducted by TCEQ on a biennial basis with the most recent approved assessment being from 2008. 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 utilizes 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 it is available.

Monitoring Station Locations

During the process of developing this WPP, Texas AgriLife Research personnel from the Vernon Research and Extension Center (AgriLife Vernon) established 14 additional monitoring stations within the Buck Creek watershed with primary consideration being ease of access. 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.

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

Index Sites

One monitoring location was chosen within each AU as an index site for that AU. These sites are considered to be 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 and was 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 thus helping to identify what areas of the watershed are contributing to pollutant loading at a specific monitoring station. These watershed subbasins are also utilized in predictive 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, water body specific water quality standards have not been set for Buck Creek. 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 utilized to quantify a waterbody's ability to meet its designated uses are: 1) dissolved oxygen standards for aquatic life use; 2) *E. coli* standards for recreation use and 3) nitrate and chlorophyll-a screening levels for designated general uses.

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

Dissolved Oxygen (DO)

DO is considered the main factor in determining a water body's ability to support existing, designated and attainable aquatic life uses. If DO levels in a waterbody 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 stream flow, maximum temperatures and minimum DO levels typically occur across Texas. At least half of the samples used to assess a stream's DO levels should be collected during the critical period with the remainder of the samples used coming from the index period. DO measurements collected during the cold months of the year are not considered because flow and DO levels are typically highest during the winter months (TAC §307.7 and §307.9).

Bacteria

Bacteria standards set for contact recreation are applied to all freshwater bodies in the state unless otherwise designated in the TSWQS. This standard has been established to gauge the ability of a stream to support its designated contact recreation use. This standard was established 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, tubing among others. As a result, a geometric mean of 126 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 is being phased out; 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, those and all other samples collected within the most recent 7 year time-frame must remain at or below the geometric mean to support contact recreation. Samples utilized in waterbody assessments must not include extreme hydrologic conditions such as very high-flows and flooding. The high-flow exemption 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 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 state-wide use were established to protect waterbodies 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 waterbodies in Texas and designating the 85th percentile as the 'screening level.' If a water body exceeds these established screening levels more than 20 percent of the time, that water body is on average experiencing pollutant concentrations higher than 85 percent of the streams in Texas. Screening levels have been designated for ammonia, nitrate, orthophosphorus, total phosphorus and chlorophyll-a. Of the screening levels presented in Table 4, only those for nitrate and chlorophyll-a are applicable to unclassified, intermittent streams with perennial pools such as Buck Creek.

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

Historic Water Quality

Water quality data was first collected and reported to TCEQ on Buck Creek in December of 1997 by the RRA above the US 83 Hwy crossing in Childress County at Station 15811 (Figure 7). Data were collected periodically at this site by the RRA through 2005 and submitted to TCEQ for water body assessment purposes. Table 5 shows summary statistics of water quality parameters sampled by the 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 presented here resulted in Buck Creek's original listing on the *2000 Texas 303(d) List* as an impaired waterbody and its continual listing through 2008.

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 as well as any concerns or impairments. While there are multiple water quality parameters included in this dataset, only bacteria and dissolved oxygen 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 Red River Authority 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 three 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 three 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.

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

The populations within the counties are employed in a variety of industries/professions. In all three 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 five areas of employment for the tri-county area (Table 7). Median incomes and unemployment rates in the three counties are also reported in the table and are relatively similar.

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

Agricultural Production

Commodities produced in the watershed have remained relatively unchanged since modern settlement began. Cattle, cotton, forage, grain sorghum and wheat are still 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 production numbers reported in the 2007 Census of Agriculture for each of the three counties that Buck Creek crosses.

Table 8. Agricultural production information 1997 - 2007 for all counties in 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

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 above over estimated cattle numbers in the watershed due to cattle in feed lots outside of the watershed but in the three counties being tallied. Using 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. 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 non-existent in the watershed and were thus 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 that 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 acres of farmland. The water right was re-issued September 25, 1987 but has since been inactive; however, the right still exists (http://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 over-estimate 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 made a resurgence 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.

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/

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 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. This information is also available for feral hogs. Using available information supplemented with watershed stakeholder survey data, watershed populations for these three species and associated animal densities were determined and are described below.

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 considered to be 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 to be most appropriate while the 2009 estimate for mule deer was considered the best current representation of existing watershed populations. It is duly noted and agreed upon by TPWD's regional biologist that these numbers are only estimates and many factors actually influence the 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, the estimated watershed population for each species was calculated 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.

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)	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	**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	**7,310**

* white-tailed deer densities were applied to cultivated land, rangeland, mixed forests, riparian forests and managed pastures to calculate a watershed population estimate

* 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.

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 was taken into consideration 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. Taking into consideration, 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 acres/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 their preference to bottomlands, damage caused to pastures, range and cropland has been verified throughout the watershed and partnership members requested that the average hog density rate be applied evenly across the entire watershed. This approach is consistent with the application of the feral hog density described in Wagner and Moench (2009). Computer based modeling utilized this recommendation when identifying critical areas for feral hog management throughout the watershed.

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 the 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 the RRC indicated that the plugging status of these other wells is not known.

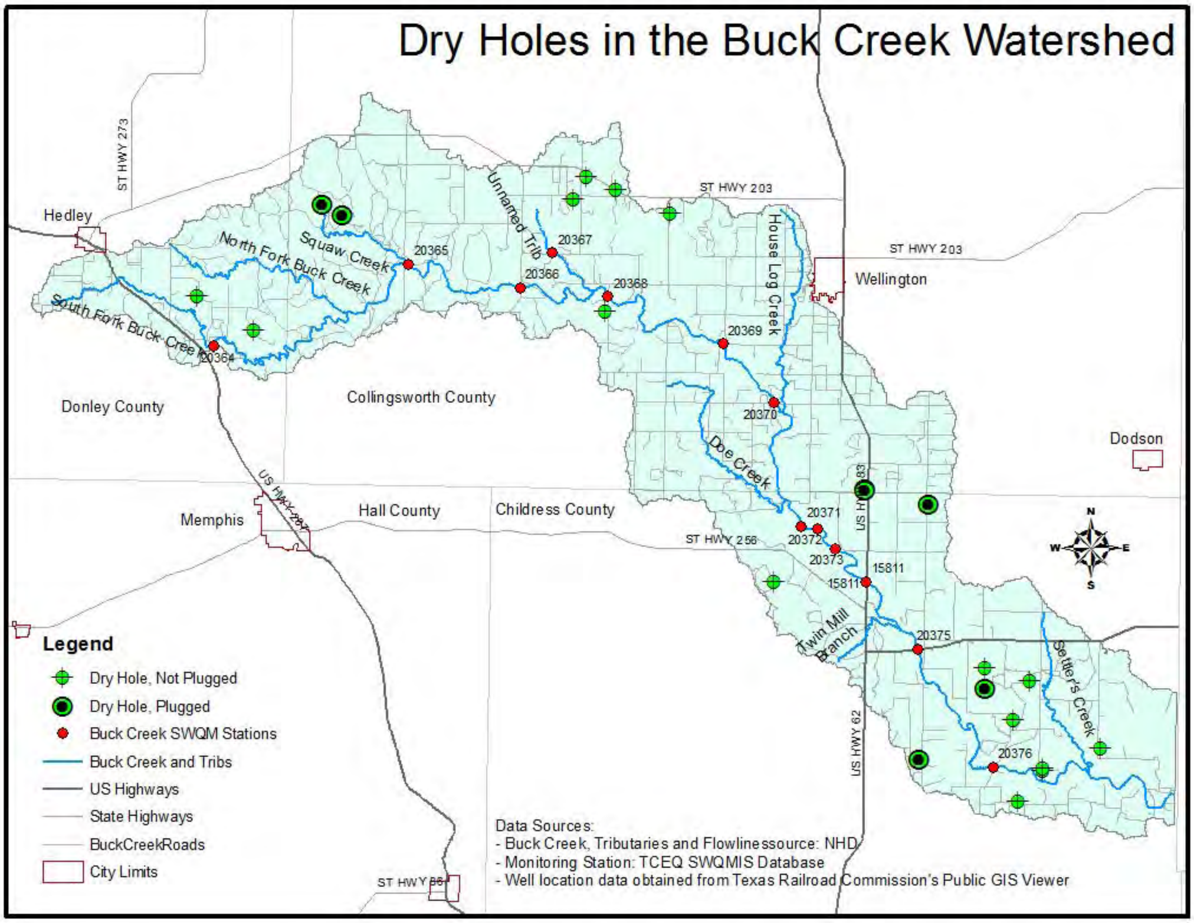


Figure 8. Dry holes from oil and gas activity in the Buck Creek watershed

Current Water Quality

Beginning in May 2004, data collection and monitoring was conducted by Texas AgriLife Research personnel from the Vernon Research and Extension Center (AgriLife Vernon) 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 and 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 and ultimately spawned the *Watershed Protection Plan Development for Buck Creek* project. Findings from these projects are presented below.

Water Quality Findings

Monitoring in Buck Creek was initiated with a primary objective of obtaining sufficient *E. coli* data from multiple locations in order to make a scientifically sound decision about the bacterial impairment of the waterbody. 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, a routine sampling schedule was implemented to collect samples every other week over a three year period (May 2004 – May 2007) at the monitoring sites described in Table 3. This time frame 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.

Waterbody Sampling Procedures

Each site was visited to determine if enough flowing water was present to collect a sample or take water quality measurements. Samples were taken at all sites with flowing water and field observations were recorded 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 stream flow, the number of days since the last significant rainfall event, 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 cm (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 too may contain 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 (stream flow 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. http://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 Vernon AgriLife Research and Extension Center 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, *E. coli* were extracted 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 two 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.

Field blanks and laboratory blanks were also tested using the same sampling and sterilization techniques to insure 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 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 being 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 stream flow, nitrates and bacterial source tracking were added to enhance knowledge of the waterbody 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 11 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. They utilized 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 11. 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

Bacteria

Throughout the course of these studies, data have confirmed that *E. coli* levels in the creek are periodically elevated to levels exceeding state water quality standards. In the majority of cases, these high *E. coli* levels occur 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 *E. coli* level exceedances, the six-year geometric mean (Table 11) is well within current TSWQS; however, the creek will technically remain impaired until the recommendation for delisting by TCEQ in the 2010 water quality assessment is approved by the EPA.

Flow

Instantaneous flow measurements 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 cubic feet per second (cfs) and has likely been higher than that due to the inability to record flow after each storm event. The lack of a USGS gaging station on the creek severely hampers the available record of flow for the creek. Temporal variations in flow are a constant in Buck Creek. During the dormant season for plant growth (approximately November – early May) the presence of water is almost constant except in the driest years. Once plant growth and subsequent irrigation of nearby cropland returns in the spring and summer, water levels in the creek decline to the point of zero flow for much of this time. Only following runoff producing storm events is there water present in the majority of the creek. There are isolated locations that maintain water year round, but flow in these pools is practically non-existent. This annual fluctuation in flow has been verified during monitoring conducted under *Bacterial Monitoring for the Buck Creek Watershed* (TSSWCB project 03-07) and *Watershed Protection Plan Development for Buck Creek* (TSSWCB project 06-11) projects is often mentioned by local landowners as well. 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, fishing, boating.

Nitrates

Elevated nitrate levels in Buck Creek were first listed as a water quality concern on the *2008 Texas Water Quality Inventory*. The draft of this report was released in the summer of 2007 and led to the inclusion of nitrate in monitoring into the analysis schedule in November 2007. As a result, a limited data set of nitrate concentration data has been obtained from Buck Creek. Although nitrate sampling has been limited, data collected have sufficiently illustrated that the nitrates concern is well founded (Table 11).

Elevated nitrate levels are also a primary concern in local groundwater as well. Both the Blaine and Seymour Aquifers are known to harbor high nitrates across their extents. Nitrate levels 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 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 contributions to the creek from the Blaine and/or Seymour Aquifers (Figure 5 & 9). Average flow rates and nitrate concentrations illustrated in Figure 9 suggest that the influence of groundwater on Buck Creek is significant and strongly correlated; this hypothesis is further supported by field observations. Throughout the course of water quality monitoring on Buck Creek, flow has consistently been observed to mimic the flow regime illustrated in Figure 9 and variations in creek flow appear highly correlated with agricultural irrigation timing. While not clearly portrayed in this graphic, flow most drastically increases just upstream of site 20371. Stations 20369 and 20370 were dry for the vast majority of the six year data collection period. Flow returns to the creek in the form of spring flow or baseflow somewhere between stations 20370 and 20371. The southeastern extent of the Seymour Aquifer within the watershed and the Blaine Aquifer underlie this location and are the suspected contributors of baseflow/spring flow. This site is also down-gradient from the bulk of irrigation wells in the watershed. Assuming that this hypothesis is indeed correct, it is logical to assume that groundwater quality will also directly impact the water quality of Buck Creek; however, adequate data specific to the Buck Creek watershed are not available to definitively support this hypothesis at this time.

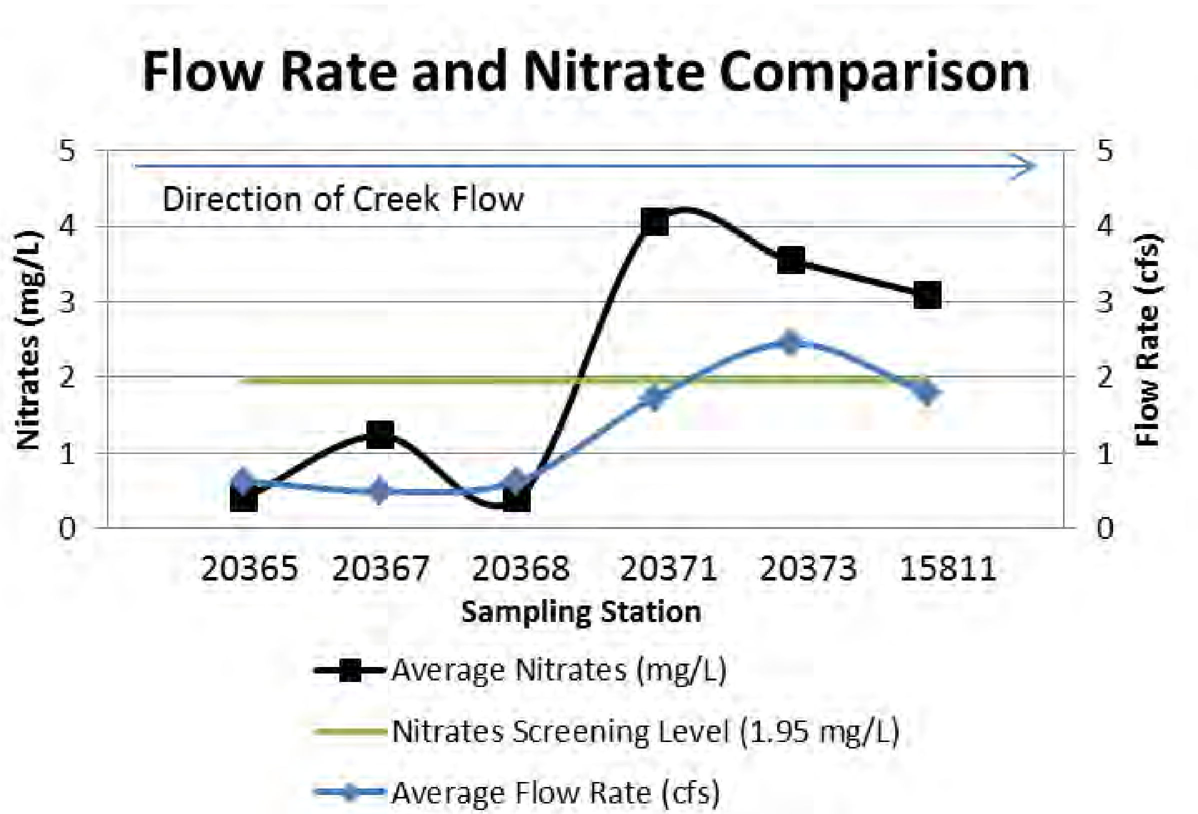


Figure 9. Average nitrate-N concentrations and flow rates for sampling sites in the Buck Creek watershed

Chapter 6 ~ Potential Sources of Pollution

Potential sources of pollution in the Buck Creek watershed were identified through a sanitary source survey conducted by AgriLife Vernon. During many trips throughout the watershed, the Watershed Coordinator documented the many different potential sources of pollution observed. The primary pollutants of concern in the Buck Creek watershed are bacteria, specifically *E. coli*, and nitrates (Figure 10). Specific pollution sources 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 are considered to be zero discharge permitted point sources.

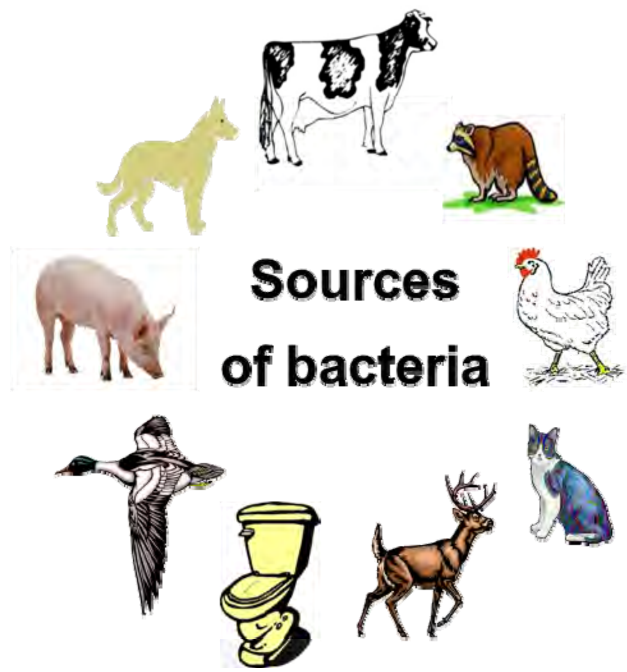


Figure 10. Potential sources of bacteria in all watersheds

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 of 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 functioning 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 non-game species that deposit fecal material as they utilize the land resulting in potential *E. coli* and nutrient loading to the creek.

Wagner (2011) found that 'background' levels of *E. coli* in un-grazed 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.

City of Wellington WWTF

The City of Wellington (Regulated Entity Number RN102185774) 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 acres of non-public access agricultural lands. 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: http://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). 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 but samples were never collected due to the lack of water. Evidence of stream flow was noted on several occasions, but observations confirm that flow only occurs following substantial, runoff producing rain events. As such, the potential for rain induced runoff to wash WWTF effluent applied to the irrigation field into House Log Creek and thence to Buck Creek is minimal.

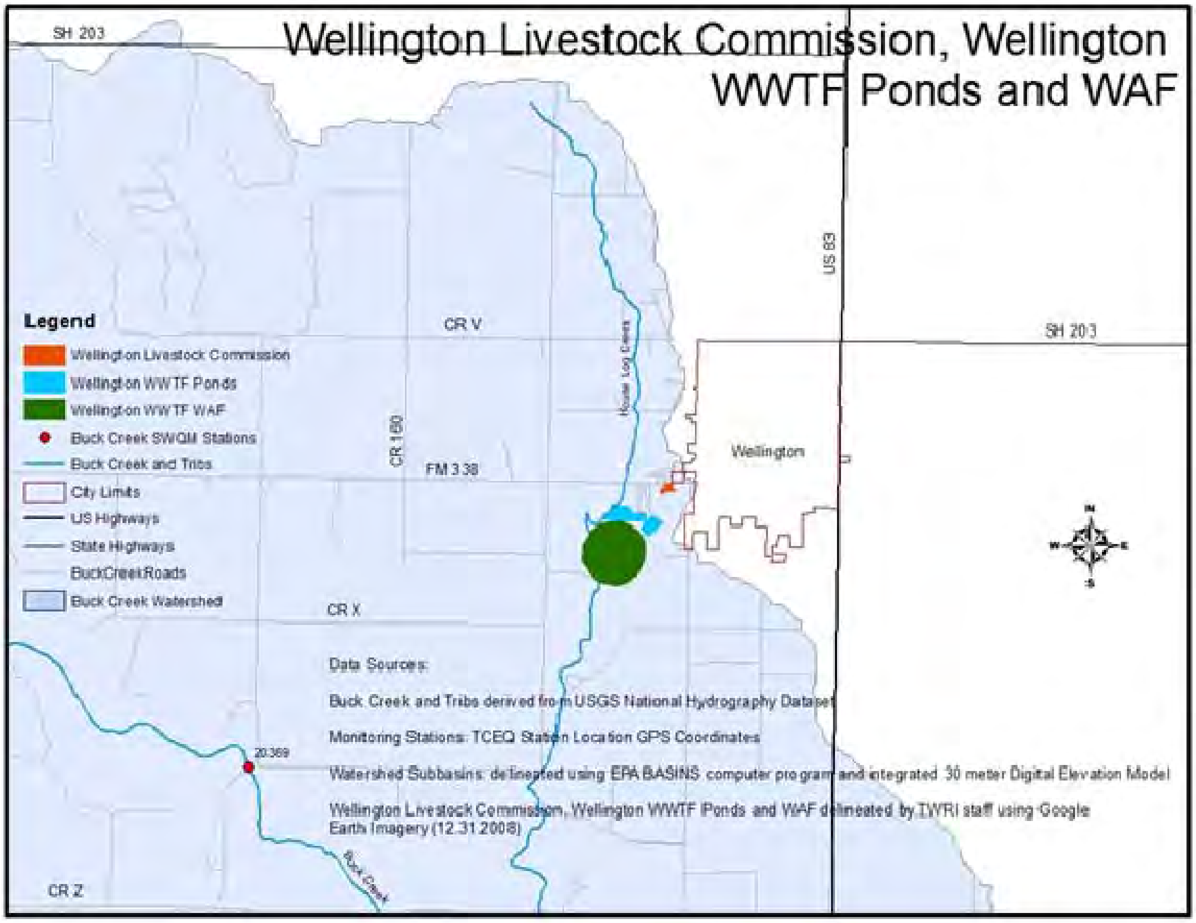


Figure 11. Locations of the Wellington Livestock Commission, Wellington WWTF Ponds and Wellington WWTF WAF in the Buck Creek watershed

Concentrated Animal Feeding Operations

Concentrated animal feeding operations (CAFOs) and their byproducts (animal waste) are another potential nonpoint source of pollution in the watershed. There is only one 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. In general, the CAFO in the Buck Creek watershed utilizes wastewater for irrigation of crops adjacent to and in close proximity to the CAFO facility. Manure is typically sold to farmers locally either as compost or directly collected from pens. Manure has direct as well as indirect benefits such as enhancing the soil water holding capacity, providing nutrients for crops, reducing erosion, and increasing soil organic matter; however, if mismanaged, manure can be a source of water pollutants. A record of acreage that is fertilized with manure from these facilities within the Buck Creek watershed is not readily available.

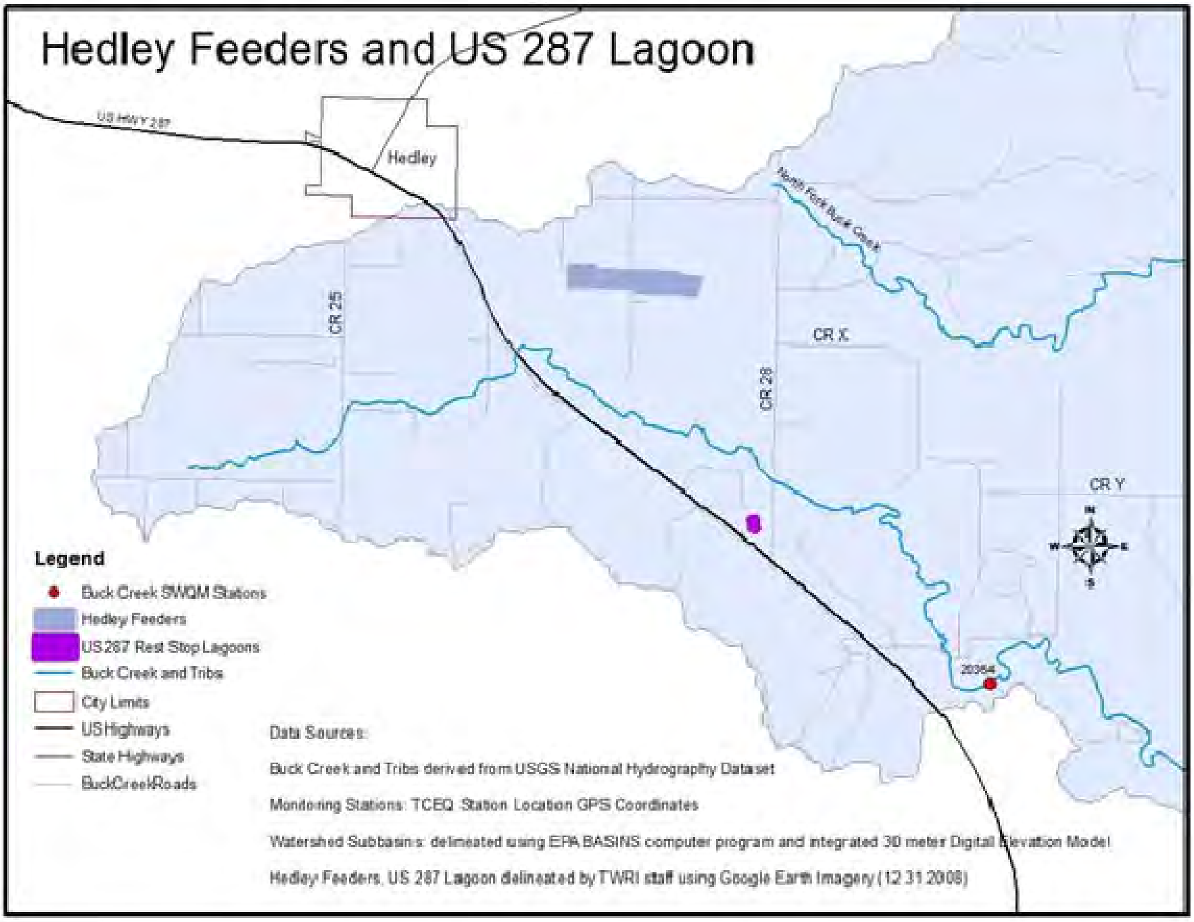


Figure 12. Potential pollutant sources in the Buck Creek watershed

Failing Septic Systems

Homesteads scattered throughout the watershed utilize septic systems, or on-site sewage facilities (OSSFs). Malfunctioning or improperly maintained OSSF 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 three-county area encompassing the watershed was not available. To estimate appropriate OSSF numbers, several methods were utilized and compared. The first method utilized information collected during the 1990 Census. These data indicate that a total of 2,264 housing units in the three county area were equipped with OSSFs (http://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, a percentage based estimate of OSSFs within the Buck Creek watershed was developed. 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 utilized 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 12 illustrates the number of OSSFs estimated to be in the watershed using the two methods described above.

Table 12. Estimated Number of OSSF within the Buck Creek watershed

1990 Cenus Data					2008 Google Earth 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

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 non-riparian areas. Reclusive by nature, feral hogs are somewhat of a nocturnal species and typically remain in thick cover during the day and venture away from this cover at night. This is typically when feral hogs move away from dense cover and venture out 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 waterbodies 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 nonpoint source 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 waterbody.

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 (2008) supports the theory that these high levels of nitrate are a result of natural sources. TCEQ (2008) 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 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 wastewater treatment facility (Figure 11) and could be a potential nonpoint source of pollution from runoff during high rainfall events. 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 there are many factors that influence their behavior, as well as the areas within a watershed that they utilize. Water, food, and shelter are the three most critical factors that dictate where the wildlife can be found throughout a watershed, and since all three are all found within riparian areas, wildlife are likely to utilize 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 utilizes 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 waterbody which in turn further increases the bacterial loading within the creek.

Other Sources

A rest area located on US Hwy 287 south of Hedley has a retention pond for runoff and is a potential source of pollution during high rainfall events. The location of the retention pond is less than 0.3 mi away from Buck Creek and is approximately 2 mi upstream of Station 20364 (Figure 12). Another possible source of bacteria coming from the rest area is unmanaged pet waste.

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.

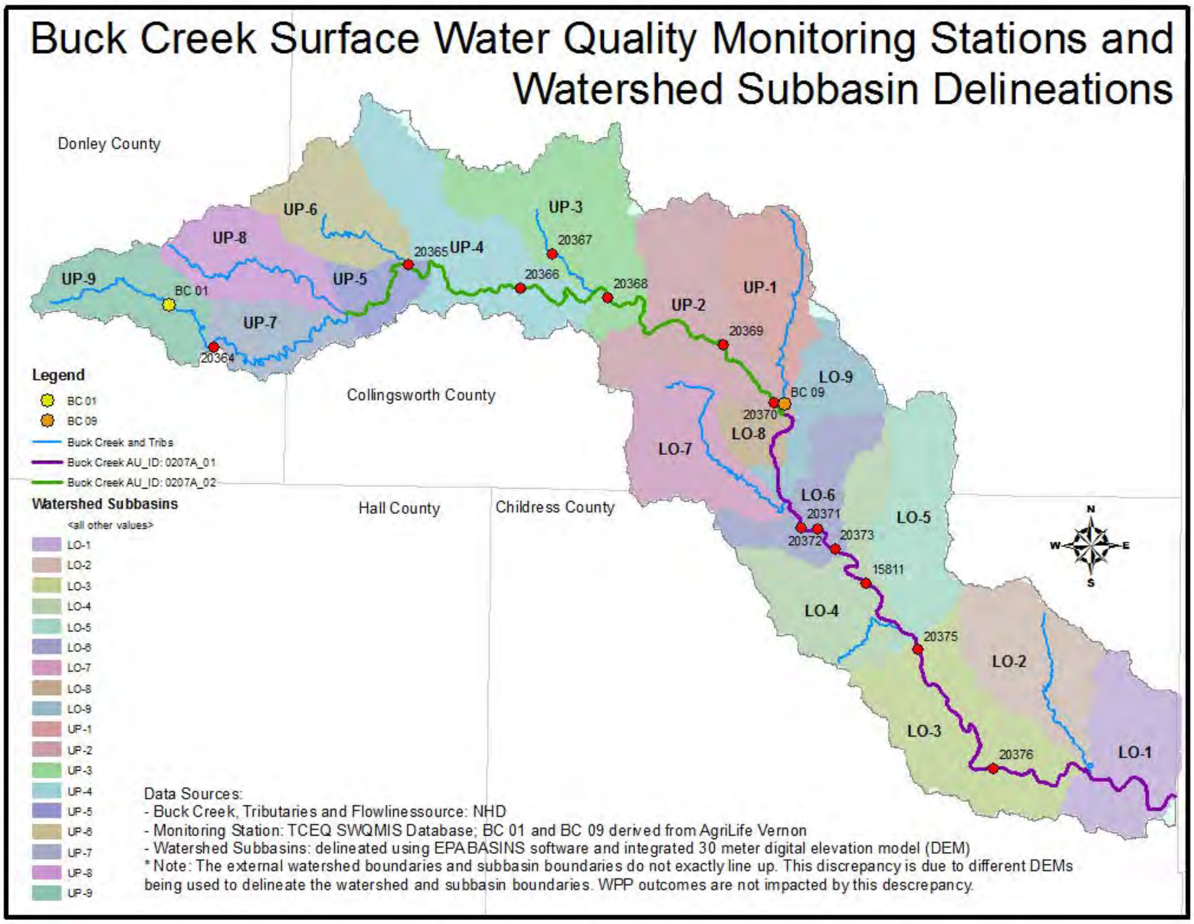


Figure 13. Buck Creek surface water quality monitoring stations, assessment units and watershed subbasin delineations

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 two 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 two 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 out BMP implementation schemes as will be discussed in Chapter 8.

E. coli Data Assessment

Collecting over 5 years of intensive data from 13 sites on Buck Creek has highlighted that the creek is quite dynamic and that *E. coli* loading across the watershed is both spatially and temporally variable. The presence of streamflow strongly influences the measured *E. coli* levels in that sites that typically have sustained flow for much of the year tend to have lower geometric means under routine flow conditions. Inversely, those sites that only have flow for short periods of time exhibit higher *E. coli* geometric means. Table 13 summarizes all available *E. coli* data available through July 30, 2009 and includes historic data from RRA as well. Data are presented in a variety of ways to illustrate the varying impacts of flow conditions on instream 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 Flow" column is utilized and is aggregated at 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.

Table 13. 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 Flow
BC 02	20364	0207A_02	7	5	2	4		258.5	278.3	251.0
BC 03	20365	0207A_02	89	74	15	14		14.9	55.8	12.1
BC 04	20366	0207A_02	70	57	13	6		60.7	186.5	52.2
BC 05	20367	N/A: Tributary	80	60	20	21		88.7	144.6	75.3
BC 06	20368	0207A_02	49	35	14	15		25.6	105.8	14.5
BC 07	20369	0207A_02	14	10	4	4		198.1	429.2	145.4
BC 08	20370	0207A_02	5	4	1	4		167.6	146.0	173.5
***AU 0207A_02 Totals / Geometric Means**			**314**	**245**	**69**	**68**		**34.8**	**118.2**	**25.3**
BC 10A	20371	0207A_01	98	82	16	16		136.7	134.6	137.1
BC 10B	20372	0207A_01	38	34	4	3		110.1	205.9	102.2
BC 10C	20373	0207A_01	66	52	14	18		44.8	56.1	42.2
BC 11	15811	0207A_01	112	90	22	53	46.6	26.0	63.6	18.6
BC 12	20375	0207A_01	20	14	6	1		99.8	167.0	90.4
BC 13	20376	0207A_01	21	11	10	1		77.6	201.1	41.1
AU0207A_01 Totals / Geometric Means			**355**	**283**	**72**	**92**		**66.9**	**100.2**	**59.6**
Entire Creek Totals / Geometric Means			**669**	**528**	**141**	**160**		**55.0**	**107.0**	**46.3**

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 did not have the required 10 data points for a site specific comparison to the water quality standard

* AU 0207A_01 totals do not include Station 20367 data; this station is on a tributary and is not considered a part of the AU

[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 Flow data were collected by Texas AgriLife Research between May 2004 and July 2009 on a regular schedule; usually every other week

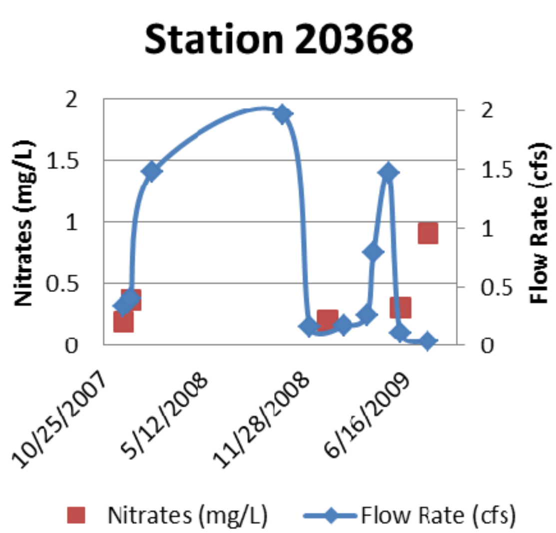
The highest *E. coli* levels occur at the upper end and in the middle section of the watershed, specifically at monitoring station 20364, 20369, 20370, 20371 and 20372 (Table 13). These data suggest that isolated areas of intensive *E. coli* loading could occur in the watershed. Pairing this information with streamflow data, or the lack thereof, further illustrates that direct fecal material deposition is likely the cause of these elevated *E. coli* levels at station 20371 and 20372 while surface runoff is the likely cause of *E. coli* spikes at station 20364, 20369 and 20370. As illustrated by the total number of samples collected at these station, 20364, 20369 and 20370 are often dry while station 20371 and 20372 have always had some water. The spatial distribution of these sites may also play into the periodically elevated *E. coli* levels seen at these sites. As illustrated in Figure 13, there is approximately 4.4 miles between stations 20370 and 20371. During dry conditions, wildlife in this area is likely drawn to these water resources and concentrates around them thus increasing the likelihood of increased direct fecal deposition to the water body.

Nitrate Data Assessment

Water samples began being analyzed for nitrates in November 2007 shortly after the nitrates concern was listed in the *Draft 2008 Texas Water Quality Inventory*. A limited number of samples were collected; however, they do illustrate that nitrate levels above the designated screening level of 1.95 mg/L do exist. A distinct delineation between the upper and lower watershed was discovered in these data suggesting that there is a primary source of nitrates entering the creek occurring somewhere upstream of monitoring station 20371 (Table 14)

Table 14. 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%



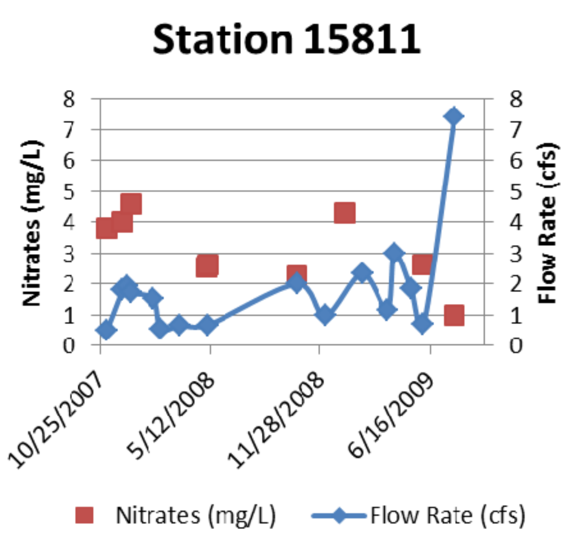


Figure 14. Nitrate concentrations compared to streamflow at Stations 20368 and 15811

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 14 illustrate two features that support this hypothesis. Nitrate levels monitored under baseflow 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 one exceeded the screening level. Moving downstream to sites 20371, 20373 and 15811, the situation is quite different. A total of 27 nitrates samples were collected at these three sites and all but three of them were above the screening level. Figure 14 illustrates that the six of the nine samples were collected under baseflow conditions. The one 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. It is acknowledged that this hypothesis is built from a limited data set.

Irrigation timing also has a clear influence on instream nitrate levels. Figure 15 below illustrates nitrates data collected at the monitoring stations discussed above as well as approximate irrigation timing. It is recognized that the data set is limited; however, the data are quite telling in that as the irrigation season progresses, nitrate levels monitored instream decline and are then elevated again before the next irrigation season. Additional nitrate data are needed to further evaluate this and the previous hypotheses.

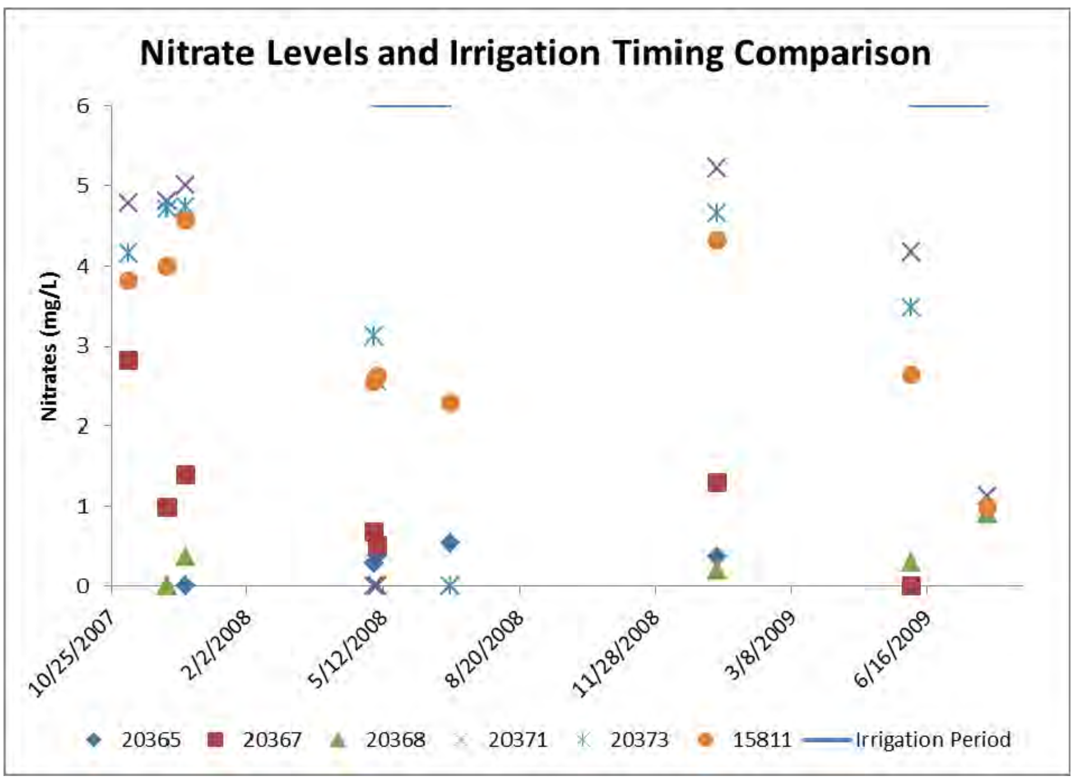


Figure 15. Nitrate levels monitored in Buck Creek paired with irrigation timing.

LDC Analysis

Load duration curve (LDC) analysis was used in Buck Creek to illustrate bacteria and nitrate loadings across the creek's varying levels of flow. This is a commonly utilized approach that provides a simplistic method of illustrating what general source types of pollutant loadings are influencing a waterbody by evaluating when loadings exceed the allowable limit as compared to average daily flow records. In general, a stream's flow regime can be divided into five different flow categories: high flow, moist conditions, mid-range flows, dry conditions and low or no flow as seen in the example LDC in Figure 16.

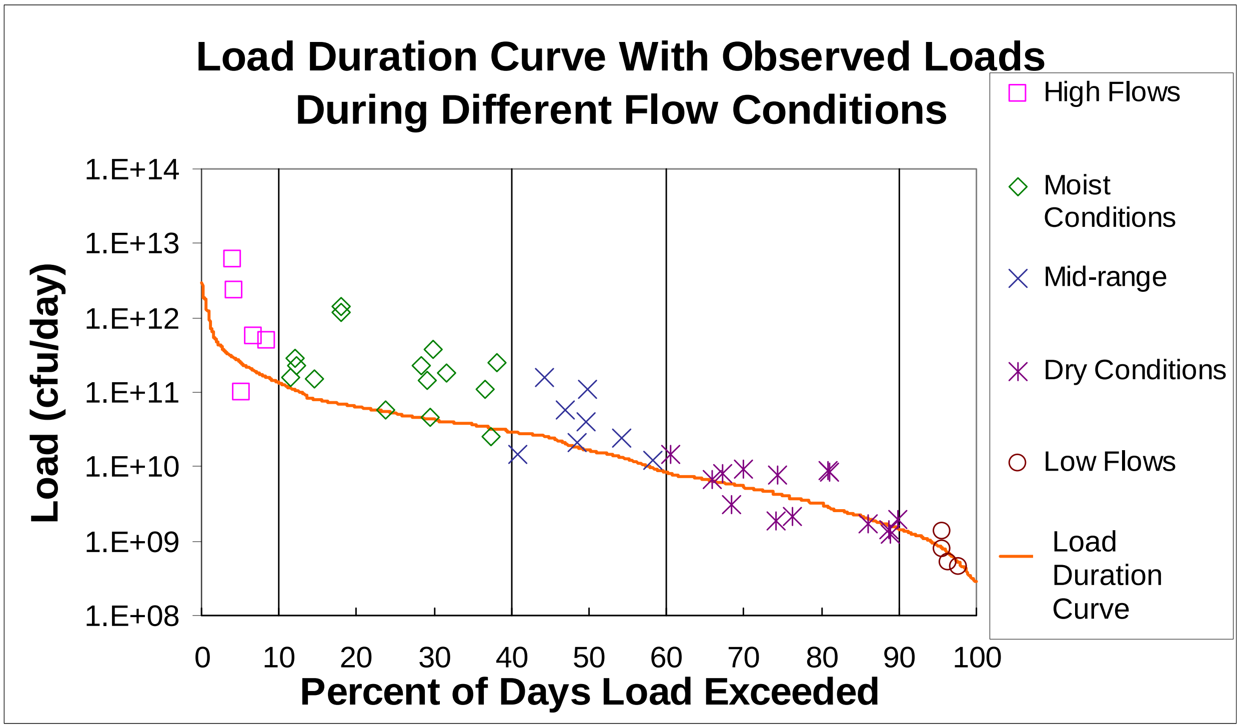


Figure 16. Example load duration curve. Vertical lines separate flow categories, the orange line is the allowable pollutant load and points are water quality paired with associated flow rates

LDCs can then be evaluated under each flow category and load reductions needed to meet water quality goals can be developed for each flow category. In almost all cases, and here in Buck Creek, 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).

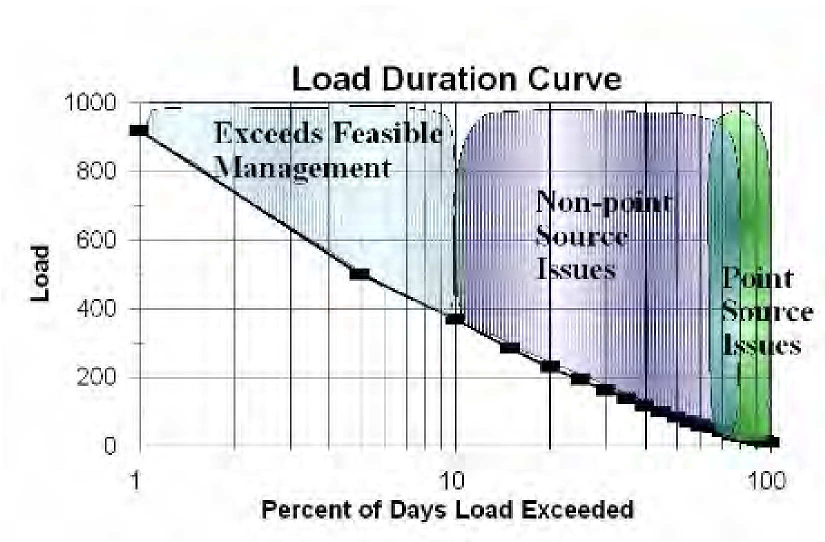


Figure 17. Graphic depiction of the types of sources that can be expected under relative flow conditions illustrated by LDCs. Source: Kansas Dept. of Health and Environment: http://www.kdheks.gov/tmdl/basic.htm

Point sources of pollution, direct fecal deposition and groundwater inflows have the greatest impact on a waterbody's pollutant loading under low flow conditions as surface runoff is not contributing to the pollutant load or streamflow. When runoff occurs, it transports NPS pollutants deposited across the watershed since the last runoff event. Point sources and direct deposition remain as contributors during these times, but are less of a factor due to dilution from runoff. That said, Buck Creek has no identified point sources, so any excessive pollutant loading that occurs during low flow conditions is a result of 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. At each station, available flow data is sorted from largest to smallest and then ranked from 1 to n. 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 stream flow gages on Buck Creek; therefore, instantaneous flow measurements collected at the two watershed index sites (Chapter 4) were relied upon to develop flow duration curves. Station 20368 is the index site for AU 0207A_02 and station 15811 is the index site for AU 0207A_01; these sites had 15 and 53 flow data points respectively.

Multiplying the flow duration curve by the concentration of the water quality criterion for the pollutant produces the LDC (Fig. 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 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 4, 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; however, there is a screening level of 1.95 mg/L. LDCs were developed using these levels as threshold concentrations for each respective pollutant.

To analyze monitored pollutant loads, regression analysis is conducted 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 17) and is compared to the maximum allowable pollutant load. Percent load reductions are calculated by subtracting the regression curve load from the maximum allowable load for each point and then dividing by the regression curve load and multiplying by 100. To calculate the load reductions for a particular flow category, the individual percent load reductions falling within the flow category are averaged together.

Loading estimates presented in these LDCs are calculated on a daily basis and are scaled up to account for an average annual load as well. Daily load calculations best represent conditions seen in Buck Creek due to its intermittent and flashy flow nature. Loadings are calculated and presented both on a daily and annual basis in the section below. These numbers correlate with each other in that the daily loading is 1/365th of the calculated annual load. For a more complete explanation of the LDC approach, see Appendix C.

E. coli LDC Results

Station 15811

The LDC developed at station 15811 utilizes 53 *E. coli* concentration data points collected by RRA and AgriLife Vernon (1997 – 2009) that have corresponding flow measurement data; 34 samples did not have corresponding flow data and were not included in this analysis (Figure 18). Based on regression analysis, the LDC indicates that over the 13 year data collection period, only high flow events produce daily *E. coli* loadings that exceed the water quality standard; however, moist flow conditions also are shown to be above the water quality standard much of the time and illustrate that *E. coli* loadings are periodically problematic during wetter than normal periods. Table 15. shows the percentage based amounts that measured *E. coli* loadings need to be reduced to meet the maximum allowable *E. coli* load as calculated using regression analysis discussed above. Average daily loads and average annual loads are also presented here as well and are vital to calculating estimated load reductions presented in Chapter 8.

Table 15. 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	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	35	1.17 E+11	4.27 E+13
Moist Conditions	10-40%	N/A	1.58 E+10	5.78 E+12
Mid-Range	40-60%	N/A	3.16 E+09	1.15 E+12
Dry Conditions	60-90%	N/A	1.04 E+09	3.78 E+11
Low Flows	90-100%	N/A	6.30 E+07	2.30 E+10

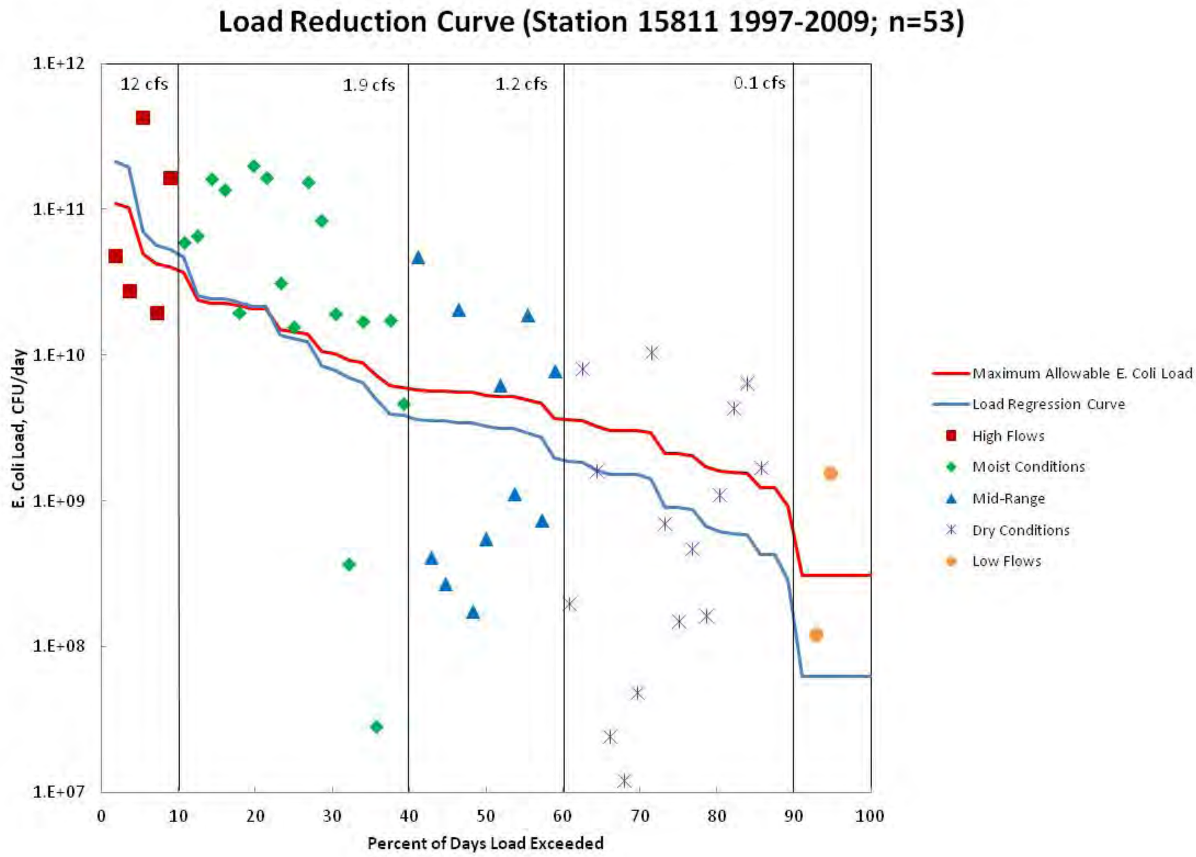


Figure 18. Daily *E. coli* LDC of all data collected by RRA and Texas AgriLife Research between 1997 and 2009 at station 15811

Station 20368

The LDC developed at station 20368 utilizes 15 *E. coli* concentration data points collected by AgriLife Vernon (2007 – 2009) that have corresponding flow measurement data; 20 samples did not have corresponding flow data and were not included in this analysis (Figure 19). Based on regression analysis, the LDC indicates that over the three year data collection period, no flow category produce daily *E. coli* loadings that exceed the water quality standard. Table 16. shows average daily loads and average annual loads calculated for this site. Loadings at this site are much lower than those seen downstream at Station 15811.

Table 16. 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	% Exceedance	Needed % Reduction	Daily Loading (cfu/day)	Annual Loading (cfu/year)
High Flow	0-10%	N/A	3.91 E+08	1.43 E+11
Moist Conditions	10-40%	N/A	2.37 E+08	8.66 E+10
Mid-Range	40-60%	N/A	1.09 E+08	3.98 E+10
Dry Conditions	60-90%	N/A	6.38 E+07	2.33 E+10
Low Flows	90-100%	N/A	2.50 E+07	9.14 E+09

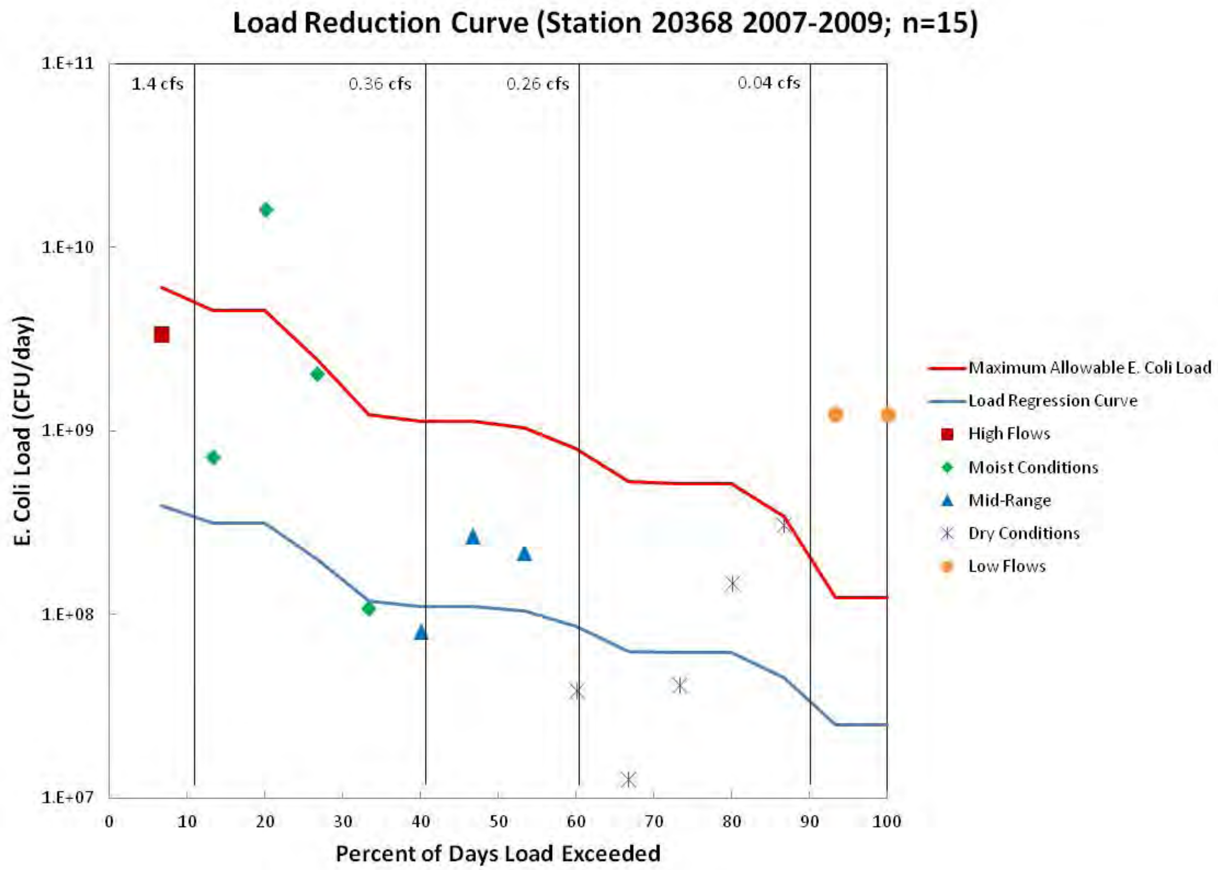


Figure 19. Daily *E. coli* LDC of all data collected by Texas AgriLife Research between 2007 and 2009 at Station 20368

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; however, the lack of nitrates data paired with flow data at all monitoring sites except Station 15811 limited the usability of LDCs in evaluating nitrate loadings. Nitrates data collection at this station was initiated by RRA in 1997 and continued by AgriLife Vernon 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.

This LDC presented in Figure 20 suggests that excessive nitrate loading occurs during three flow regimes: high flow, moist conditions and mid-range flow conditions. Regression analysis indicates that reasonable load reductions are needed in these three flow categories to meet the maximum allowable load based on the current nitrate screening level (Table 17). Daily and annual loading estimates are also presented here as well.

Table 17. 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	% Exceedance	Needed % Reduction	Daily Loading (mg/day)	Annual Loading (mg/year)
High Flow	0-10%	56	2.58 E+05	9.41 E+07
Moist Conditions	10-40%	32	3.98 E+04	1.45 E+07
Mid-Range	40-60%	10	8.98 E+03	3.28 E+06
Dry Conditions	60-90%	N/A	3.16 E+03	1.15 E+06
Low Flows	90-100%	N/A	1.24 E+02	4.52 E+04

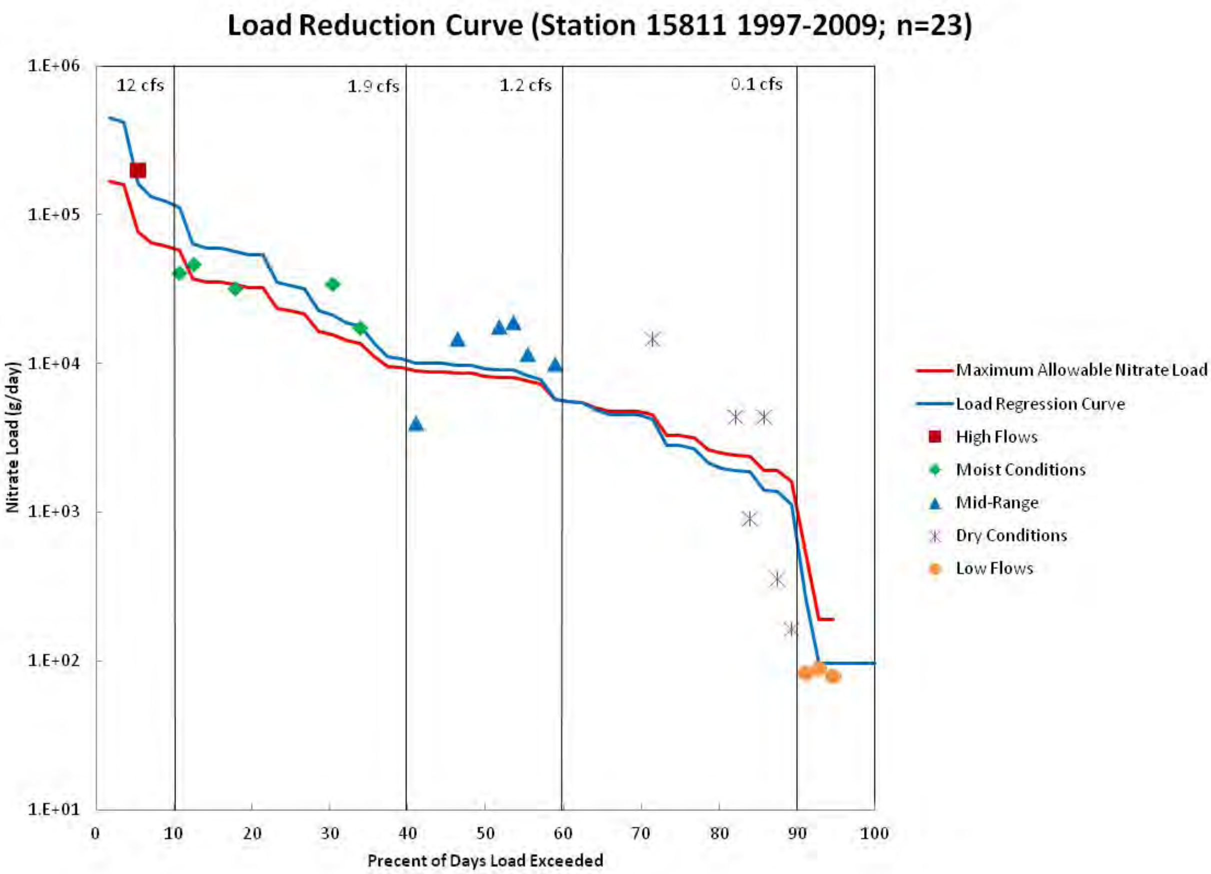


Figure 20. Daily nitrate Load Duration Curve developed using all available data collected by RRA and AgriLife Vernon at Site BC 11 (1997 – 2009) at Station 20368

The needed load reductions based on regression analysis presented in Table 17 are contradictory to the raw data assessment and interpretations presented earlier in this chapter. The earlier data assessment considered limited data sets from six monitoring locations conducted over a three year 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. The differences seen in the LDC can be somewhat explained by the fact that nitrate values in the high flows and low flows category skew the regression line in the moist conditions and dry conditions categories. 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 *E. coli* loadings from potential sources in the evaluated watershed. 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 subbsins, within the Buck Creek watershed contribute the highest potential 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 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. These three sources were identified by watershed stakeholders to be major contributors of bacteria to the watershed and were thus the focus of SELECT. Other wildlife (opossums, raccoons, coyotes, rabbits, squirrels, etc.) is 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, two 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 (R. Karthikeyan, personal communication). 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. It is also recognized that 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 18. 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 18). Figure 21 further illustrates the range of loadings predicted by the SELECT model for each watershed subbasin. SELECT outputs are illustrated using six 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 two or three orders of magnitude lower than cattle (Figure 22, 23 and Table 18). 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 18).

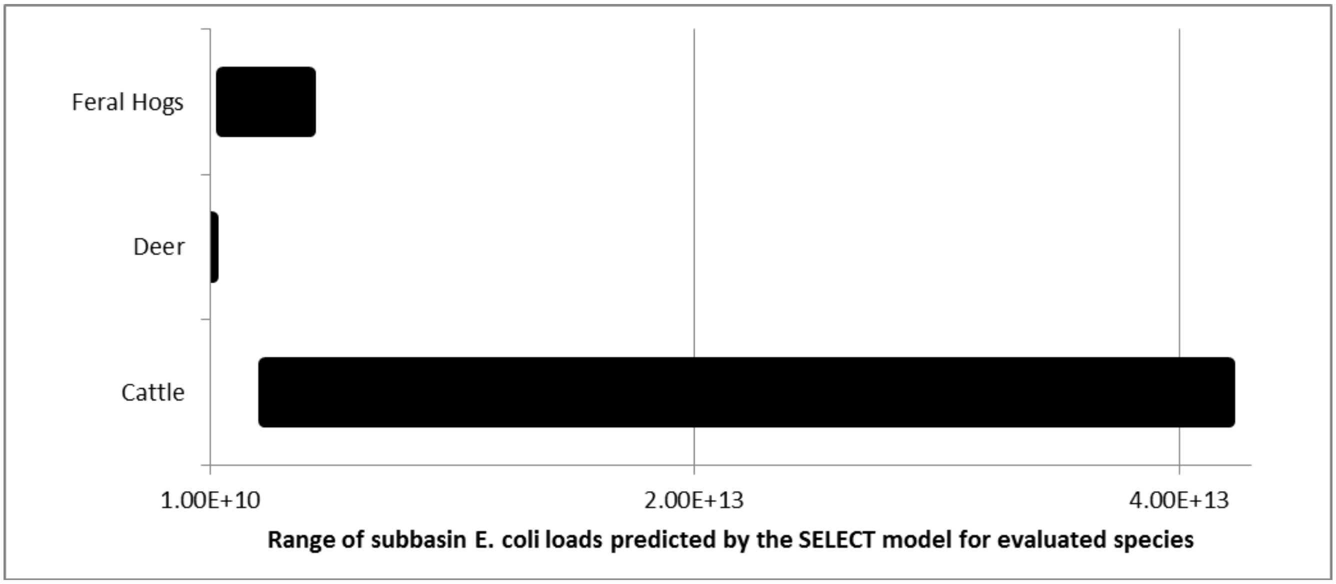


Figure 21. Range of bacteria loadings predicted by the SELECT model for individual subbasins

Cattle
Populations of cattle 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 feedlot near Hedley. For SELECT modeling purposes, only those cattle grazed on rangeland or managed pasture were considered. The watershed stakeholder derived estimate of 6,640 head of cattle was utilized 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 18.

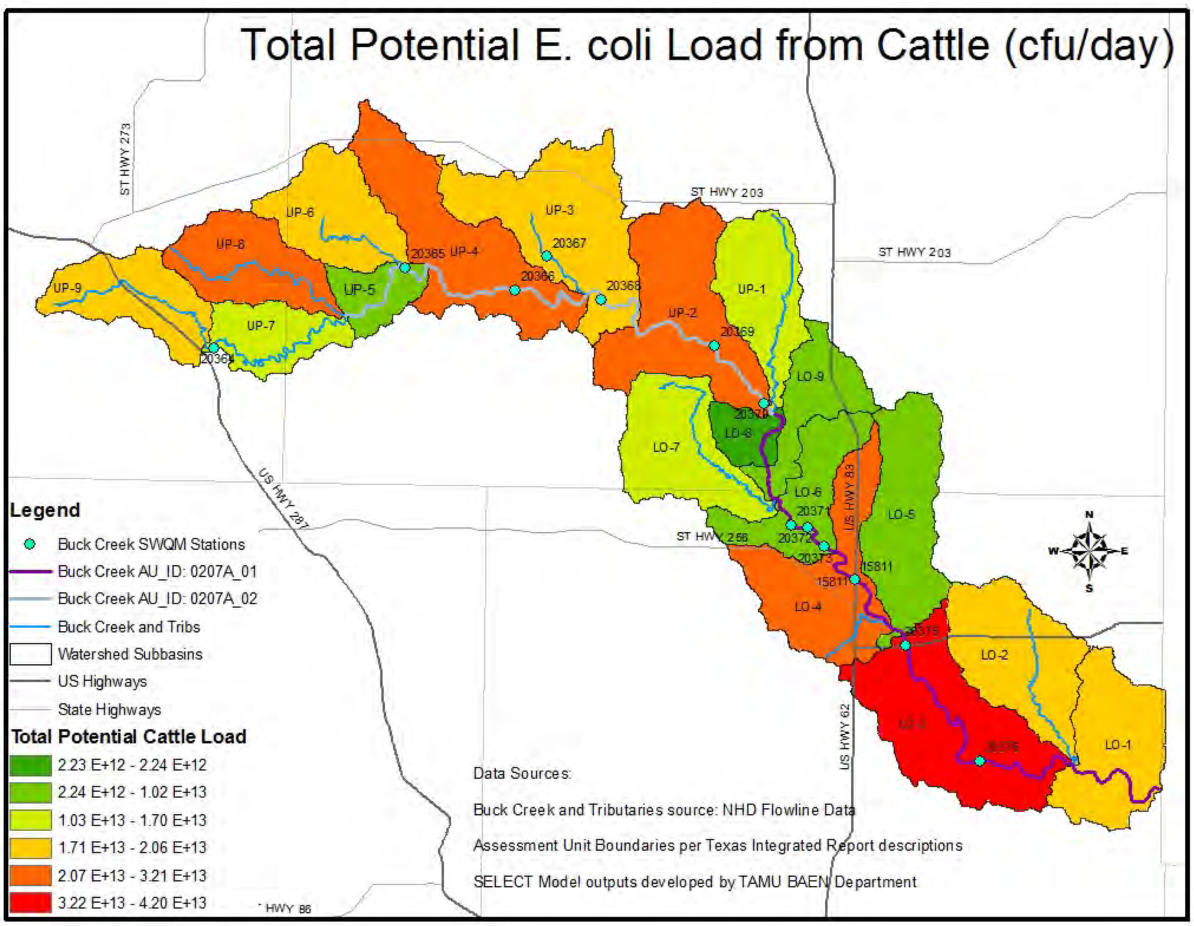


Figure 22. Estimated potential *E. coli* loading from cattle in Buck Creek subbasins

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 to be evenly distributed over the rangeland, managed pasture, deciduous forest, riparian forest and cultivated land uses at an average rate of 36 acres 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 18.

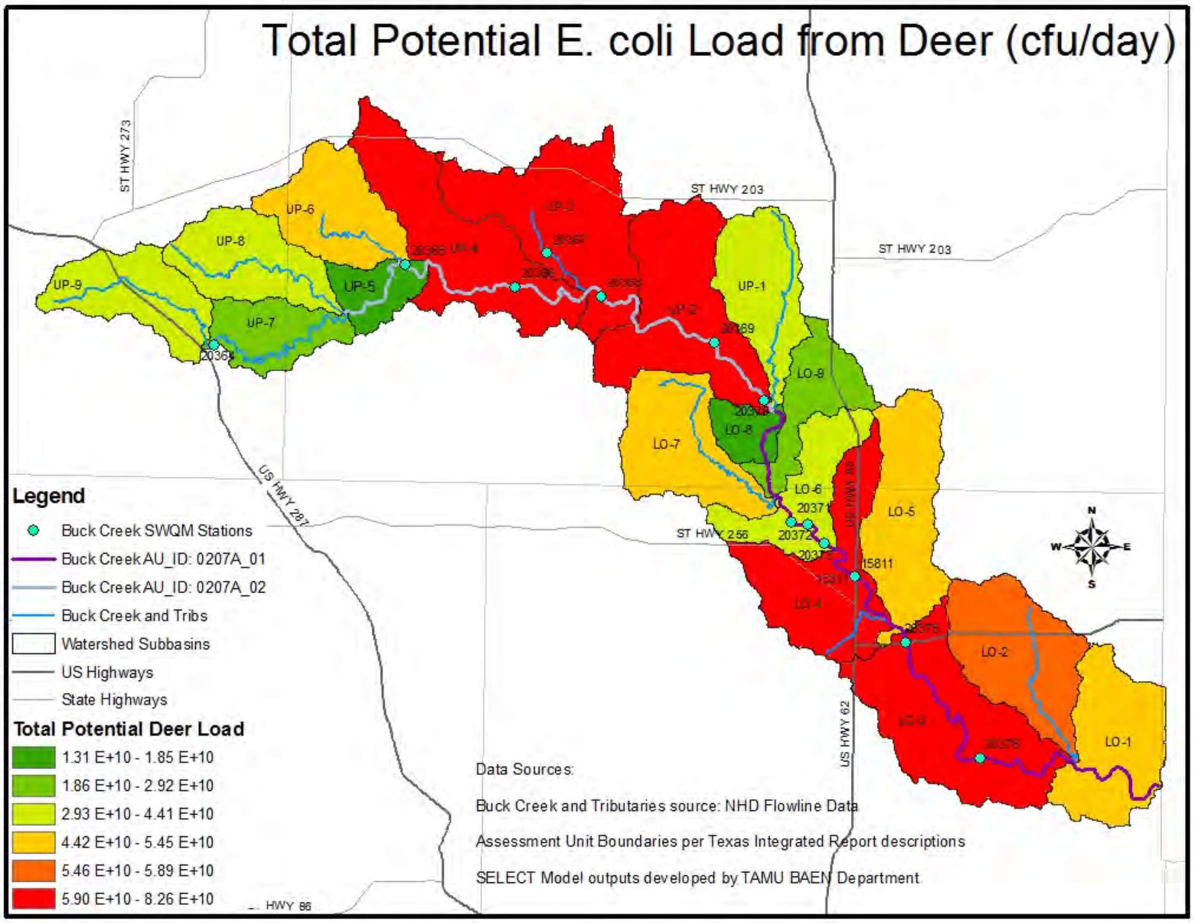


Figure 23. Estimated potential *E. coli* loading from deer in Buck Creek subbasins

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 acres 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, an estimated feral hog population of 7,310 animals was developed for the entire watershed.

In modeling feral hog pollutant contributions, the SELECT model was used to concentrate these hog populations to within 300 feet of all streams or stream beds 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 utilize 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 18 presents predicted *E. coli* loads for each subbasin.

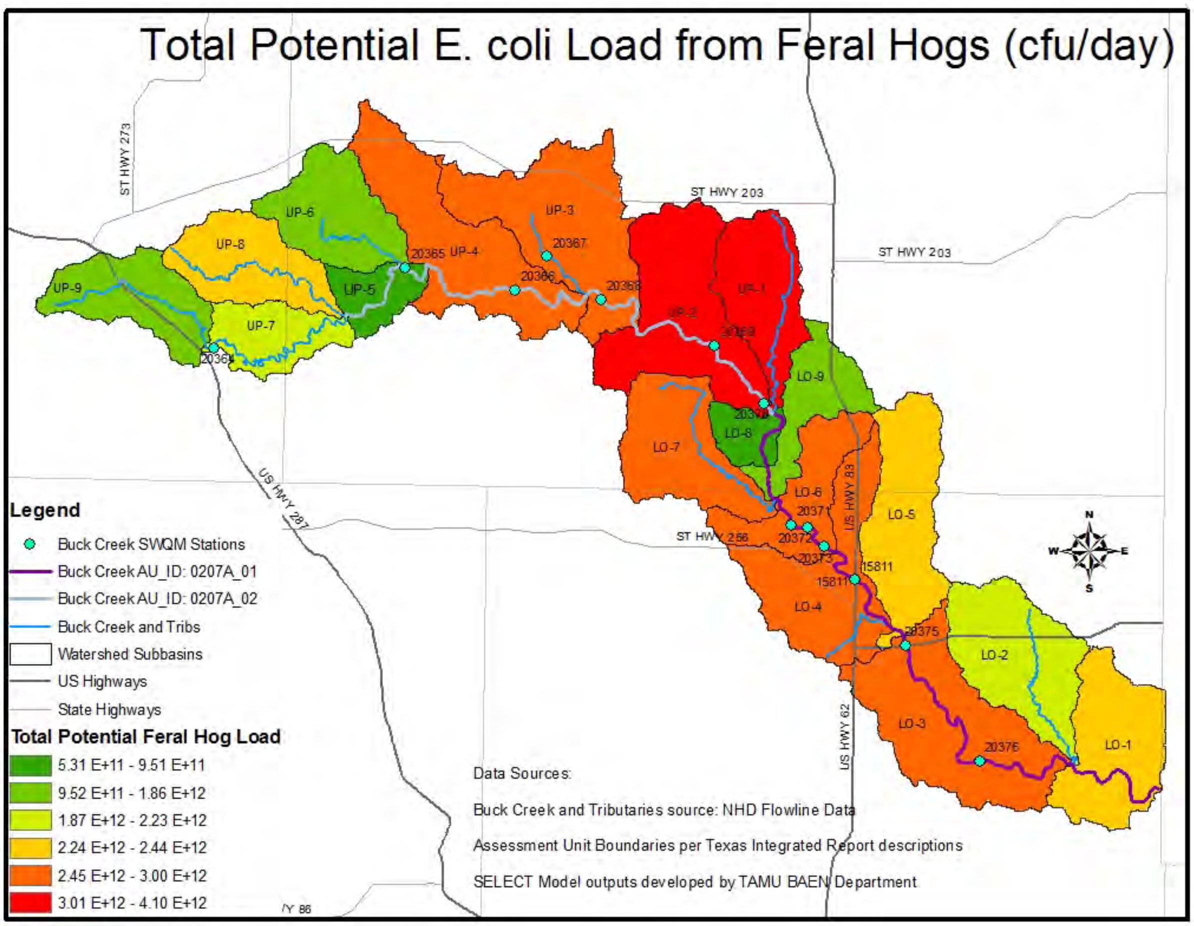


Figure 24. Estimated potential *E. coli* loading from feral hogs in Buck Creek subbasins

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 18 further illustrates the collective potential *E. coli* loadings.

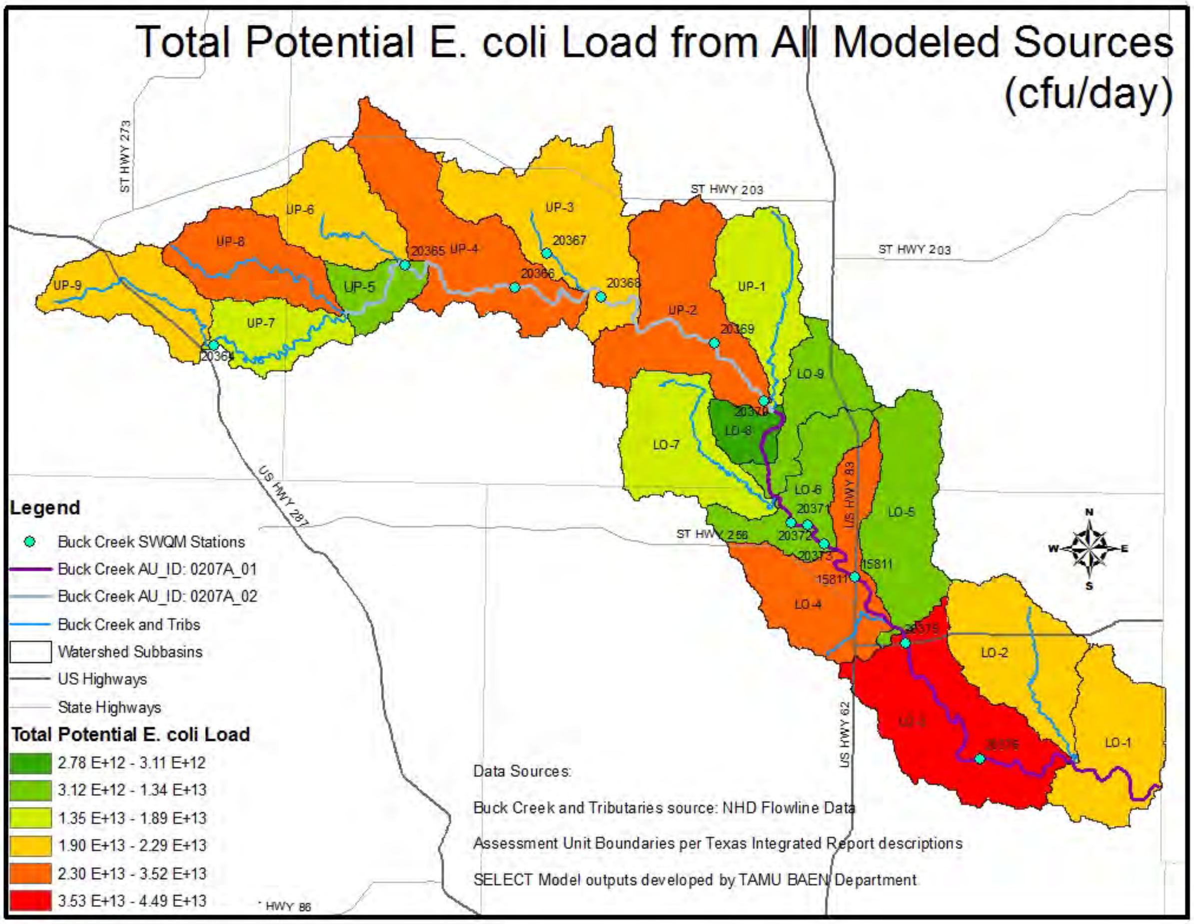


Figure 25. Estimated Total potential *E. coli* production by watershed for all modeled sources

Table 18. Potential *E. coli* loads (cfu/day) per watershed subbasin and per acre predicted by the SELECT model for individual watershed subbasins

Subbasins	Subbasin Acreage	Cattle Load	Cattle Load / acre	Deer Load	Deer Load / acre	Feral Hog Load	Feral Hog Load / acre	Total Load	Total Load / acre
LO 1	10,995.5	1.88E+13	1.71E+09	5.36E+10	4.88E+06	2.32E+12	2.11E+08	2.11E+13	1.92E+09
LO 2	11,977.1	2.06E+13	1.72E+09	5.64E+10	4.71E+06	2.22E+12	1.85E+08	2.29E+13	1.91E+09
LO 3	17,351.2	4.20E+13	2.42E+09	8.26E+10	4.76E+06	2.78E+12	1.60E+08	4.49E+13	2.59E+09
LO 4	12,583.6	3.22E+13	2.56E+09	5.89E+10	4.68E+06	2.96E+12	2.35E+08	3.52E+13	2.80E+09
LO 5	11,574.6	9.22E+12	7.97E+08	5.44E+10	4.70E+06	2.34E+12	2.02E+08	1.16E+13	1.00E+09
LO 6	7,690.0	9.24E+12	1.20E+09	3.71E+10	4.83E+06	2.45E+12	3.18E+08	1.17E+13	1.52E+09
LO 7	10,510.9	1.60E+13	1.52E+09	5.06E+10	4.81E+06	2.75E+12	2.62E+08	1.88E+13	1.79E+09
LO 8	2,815.4	2.23E+12	7.94E+08	1.31E+10	4.67E+06	5.31E+11	1.89E+08	2.78E+12	9.87E+08
LO 9	6,301.6	2.25E+12	3.57E+08	2.92E+10	4.63E+06	9.57E+11	1.52E+08	3.23E+12	5.13E+08
UP 1	8,984.0	1.03E+13	1.15E+09	4.21E+10	4.69E+06	3.01E+12	3.35E+08	1.34E+13	1.49E+09
UP 2	15,434.1	2.53E+13	1.64E+09	7.43E+10	4.81E+06	4.10E+12	2.66E+08	2.95E+13	1.91E+09
UP 3	16,148.3	1.93E+13	1.19E+09	7.71E+10	4.77E+06	2.71E+12	1.68E+08	2.20E+13	1.37E+09
UP 4	15,353.3	3.09E+13	2.01E+09	7.45E+10	4.85E+06	2.76E+12	1.80E+08	3.37E+13	2.19E+09
UP 5	3,821.5	7.20E+12	1.88E+09	1.86E+10	4.86E+06	9.51E+11	2.49E+08	8.17E+12	2.14E+09
UP 6	9,102.0	1.95E+13	2.14E+09	4.42E+10	4.86E+06	1.39E+12	1.52E+08	2.09E+13	2.30E+09
UP 7	5,955.7	1.70E+13	2.86E+09	2.91E+10	4.89E+06	1.87E+12	3.14E+08	1.89E+13	3.18E+09
UP 8	8,950.7	2.62E+13	2.92E+09	4.37E+10	4.89E+06	2.24E+12	2.50E+08	2.85E+13	3.18E+09
UP 9	8,453.0	1.98E+13	2.35E+09	4.00E+10	4.74E+06	1.83E+12	2.16E+08	2.17E+13	2.57E+09
Potential Daily *E. coli* Load for All Subbasins		**3.28E+14**	**N/A**	**8.80E+11**	**N/A**	**4.01E+13**	**N/A**	**3.69E+14**	**N/A**
Potential Annual *E. coli* Load for All Subbasins		**1.20E+17**	**N/A**	**3.21E+14**	**N/A**	**1.47E+16**	**N/A**	**1.35E+17**	**N/A**

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 (DiGiovanni 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 (DiGiovanni 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 PCR. Currently, there are polymerase chain reaction (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 (DiGiovanni et al., 2011).

Buck Creek Approach

Using the *E. coli* and *Bacteroidales* BST methods described above, the sources of fecal pollution impacting Buck Creek were identified. 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 program. 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 USEPA Method 1603 with modified mTEC medium. Once cultured and enumeration was complete, five representative *E. coli* colonies from modified mTEC plates were isolated, purified, and confirmed. Once confirmed, these isolated colonies were submerged in liquid nitrogen, 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 one sample per site was prepared for the *Bacteroidales* test. *E. coli* isolates and *Bacteroidales* samples were periodically sent on dry ice to AgriLife Research at El Paso for BST analysis (DiGiovanni et al., 2011).

Known Source Fecal Samples

Known sources of fecal material were also obtained by AgriLife Vernon for use in the ‘library-dependent’ ERIC-RP analysis. Fecal samples were collected from 78 animals and processed to isolate individual *E. coli* strains. In total, 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 the identification of Buck Creek *E. coli* water isolates. Following the inclusion of the samples, the Texas *E. coli* BST library consisted of fingerprint patterns from 1172 *E. coli* isolates from 1044 different human and animal samples collected throughout the state of Texas from four previous BST studies (DiGiovanni et al., 2011).

ERIC-RP

Using the process describe earlier, processed samples were analyzed 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 percent similarity cutoff was used (Casarez and Pillai, 2007). Water isolate that were not at least 80 percent 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 three groups, 1) human; 2) wildlife (including deer and feral hogs) and; 3) domestic animals (including livestock and pets) (DiGiovanni 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 which 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 utilized 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 (DiGiovanni et al., 2011).

BST Results

Findings from the BST verified that a variety of sources are 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 wildlife, while the *Bacteroidales* PCR method combines portions of those two groups into one 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 index sites 15811 and 20368 are presented here. Complete BST results can be found in Appendix E.

BST results from the ERIC-RP method are relatively similar for both index sites. 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.

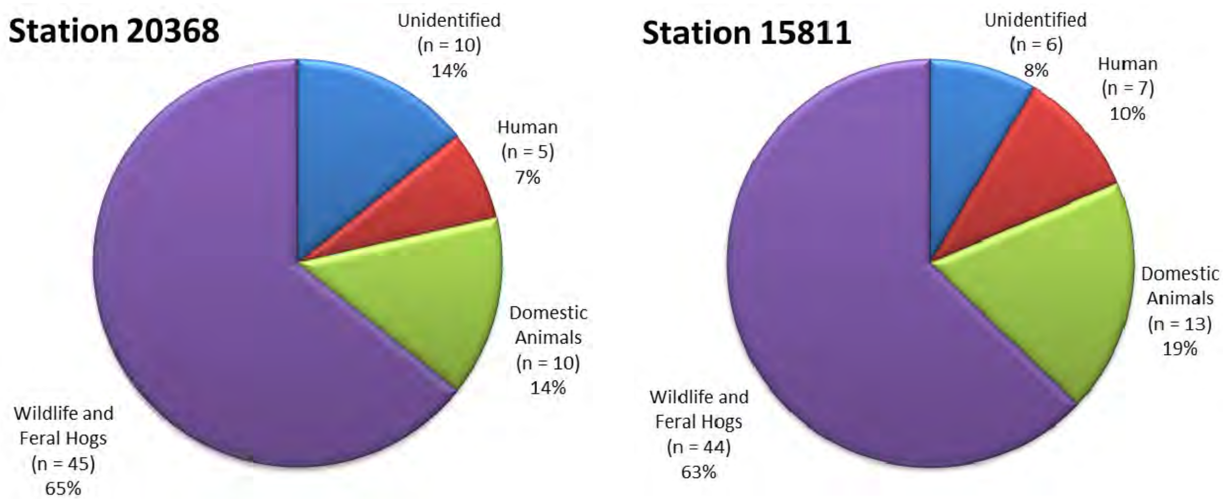


Figure 26. ERIC-RP BST results for Stations 20368 and 15811

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.

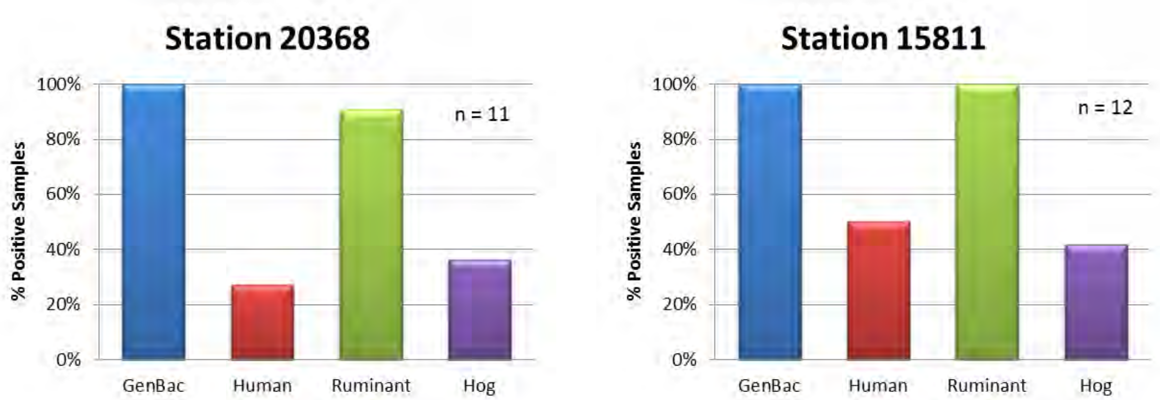


Figure 27. *Bacteroidales* PCR results for Stations 20368 and 15811. Markers abbreviations: GenBac = General *Bacteroidales*; Human = all human sources; Ruminant = all ruminants (i.e. cattle, deer, etc.); Hog = domestic and feral hogs

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 two possible explanations for the elevated level of human sources being 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 two 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, the risk still exists thus prompting an assessment of this potential source. Utilizing GIS, two spatial analyses were conducted 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, a GIS layer of potential OSSF locations was developed. Next, a multiple ring buffer was applied to Buck Creek and its tributaries to determine the number of potential OSSFs that were within 100, 500 and 1,000 yards of these waterbodies.

Table 19 summarizes these findings and illustrates that 10 potential OSSFs are within 100 yds of Buck Creek or one of its tributaries and another 70 are between 100 and 500 yds away. If any systems are contributing pollution directly to the creek, they are likely in these two categories. An interesting fact highlighted through this analysis is that 65 percent 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. Utilizing NRCS Soil Survey Geographic (SSURGO) data and their Soil Data Viewer extension in ArcGIS, a map layer was generated 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 three septic suitability categories. Potential OSSFs were found in ‘very limited’ soils in 26 locations and ‘somewhat limited’ soils in 17 locations. Additionally, 5 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.

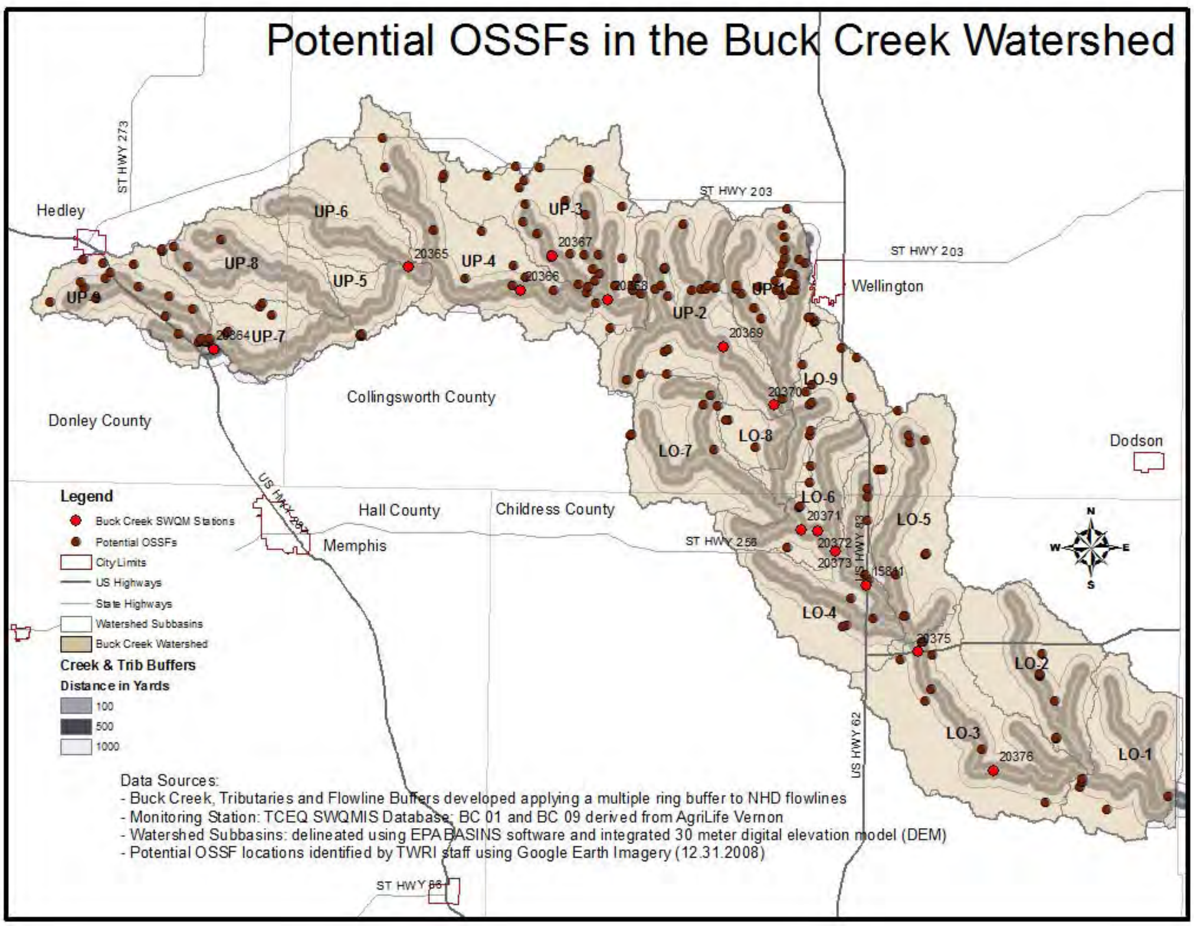


Figure 28. Potential OSSFs in the Buck Creek watershed and multiple distance buffers around Buck Creek illustrating approximate distance of OSSFs from Buck Creek

Table 19. 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 100 yds
					100 yds	500 yds	1,000 yds	
UP 9	23	3	0	20	3	8	4	2
UP 8	3	0	0	3	2	0	1	0
UP 7	8	0	0	8	1	3	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	0	3	3	0
UP 3	34	3	2	29	2	12	5	2
UP 2	16	5	3	8	0	9	3	0
UP 1	26	1	7	18	1	12	5	1
Upper Watershed Totals	123	16	13	94	9	47	22	5
LO 9	10	0	0	10	0	1	1	0
LO 8	3	1	1	1	0	0	0	0
LO 7	6	0	1	5	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	0
LO 3	8	0	0	8	0	4	2	0
LO 2	6	2	0	4	0	4	1	0
LO 1	5	0	0	5	1	1	2	0
Lower Watershed Totals	65	10	4	51	1	23	16	0
Entire Watershed Totals	188	26	17	145	10	70	38	5

* The number of OSSFs within a given distance does not include the count from the closer distance 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 utilized 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 percent but could be higher based on system age Assuming this failure rate for potential OSSFs in the watershed, it is anticipated that 15 of the 188 OSSFs are likely failing. Table 20 shows where these failing OSSFs could be using a uniform distribution of likely failing OSSFs across the watershed.

Table 20. Potential Number of Failing OSSFs in the Buck Creek Watershed by Estimated Location

Septic Limitations		
'Very Limited' Soil	'Somewhat Limited' Soil	'Not Limited' Soil
2	1	12
Distance from Buck Creek or a Tributary		
100 yds	500 yds	1,000 yds
1	6	3

* Assume 8% failure rate reported in Reed, Stowe and Yanke 2001.

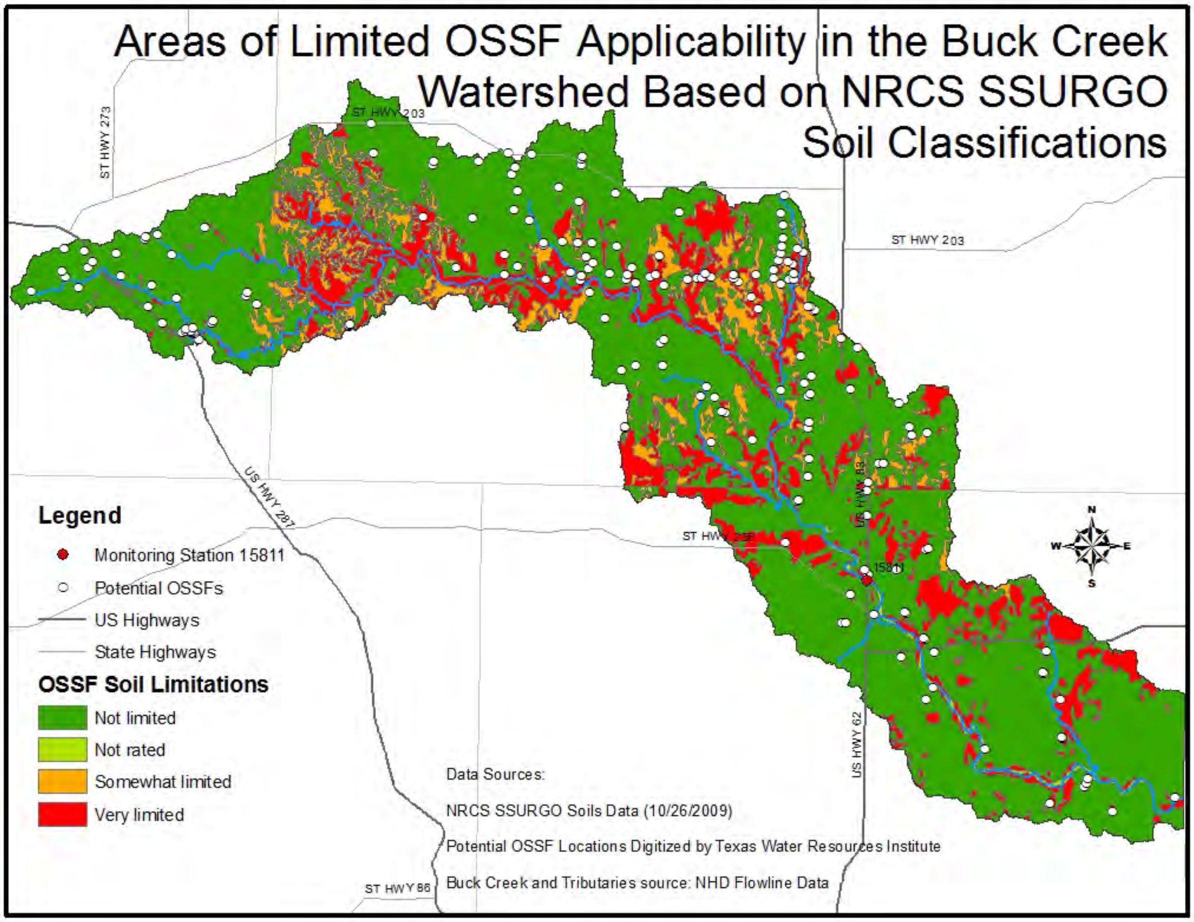


Figure 29. Areas of OSSF soil limitation and potential OSSF distribution in the Buck Creek watershed

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 percent of potential OSSFs in the watershed are situation on soils that are 'not limited' for OSSF use further support the anticipated minimal influence of OSSFs to pollutant loading in the watershed. That said; 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.

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 measured at station 15811. 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. Also occurring during the process of developing this WPP was the listing of Buck Creek as having a screening level concern for elevated nitrate levels as monitored at station 15811.

Understanding that water quality goals establish the need to effectively implement the Buck Creek WPP in the future and establish a basis for providing funds to implement this plan, watershed stakeholders have established an over-arching goal and two sub-goals as targets to achieve in the near and long-term.

Maintain Unimpaired Status

The over-arching 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 of 126 cfu/100 mL of water to prevent a relisting as impaired for elevated bacteria levels and preventing the creek from becoming impaired for elevated nitrate levels when nitrate standards are developed for the state. Nitrate standards are likely several years away; however, current water quality data suggest that Buck Creek would not meet the presumed nitrate criterion of 1.95 mg/L.

Further Reduce E. coli Levels

To ensure that Buck Creek remains unimpaired, watershed stakeholders have decided to set 95 cfu/100 mL as a benchmark goal for *E. coli* in both AUs of the creek. This goal equates to an additional 2 percent reduction in *E. coli* levels in AU 0207A_01 as reported in the *2010 Texas Integrated Report* and maintenance of *E. coli* levels at 25 percent below the current water quality standard. Maintaining *E. coli* levels in the creek at least 25 percent below the water quality standard will ensure that the creek maintains assimilative capacity to receive infrequent loads of *E. coli* above the water quality standard yet still meet mandated water quality standards.

Using the LDC developed for station 15811 and discussed earlier in Chapter 7, this load reduction goal can be illustrated in terms of fecal loading per day. Several assumptions made in calculating this numerical load reduction are that high flow conditions are not readily manageable due to their unpredictable nature; managing fecal loading during moist flow conditions is more achievable and presents a worst-case-scenario for manageable loadings. As a result, the total annual load as calculated through LDC analysis of station 15811 is used as the 'current' level of *E. coli* loading in the watershed. This load is estimated at 5.78 E+12 cfu/year of

E. coli. A numerical load reduction goal can be calculated by multiplying this annual load by 2 percent and yields a numeric load reduction of 1.16 E+11 cfu/year. This numerical reduction needed will be used to determine the number of management practices recommended for implementation to achieve this overall annual goal.

The annual load reduction goal 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 as a means to gauge the ability of all freshwater streams to meet their designated general use requirements. All streams are not created equal and thus respond differently to water quality variations on an individual basis. In light of this, watershed stakeholders have established a goal of collecting needed data to support the development of a Buck Creek specific nitrate screening level.

To achieve this goal, a special study will be conducted to collect surface and groundwater quality data to illustrate the connectivity of surface and groundwater resources in the Buck Creek watershed. These data will supply needed surface 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 needed management to address that source was not economical or desired. Economic viability, benefits to the landowner and anticipated loading reductions received from the practice strongly influence the adoption of these practices. A landowner survey was completed by partnership members asking for their opinions of practice feasibility in the watershed and the individual's willingness to implement the give 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 percent of surveyed landowners.

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%

Using this information and pollutant source analysis (BST results, LDC analysis, SELECT outputs, water quality data) information presented in Chapter 7, a staggered approach that incrementally focuses management measures in subbasins with the highest likelihood for contributing from a specific source first followed by lower priority areas until planned implementation levels and load reduction goals have been achieved will be utilized. 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

There are many sources that 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 two 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 for 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 Management Recommendation discussed in this chapter.

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 two here and there, their behavior can be managed by fencing and providing their three critical needs in order of importance: water, food and shelter. Resource utilization by cattle and other livestock is highly dependent upon where these three 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 and thus reducing or properly timing utilization of 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

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

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 percent. 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).

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 also open the door for financial assistance to pay for a portion of these practices. A WQMP is a site-specific plan developed through and approved by soil and water conservation districts (SWCDs) for agricultural or silvicultural lands. The plan includes appropriate land treatment practices, production practices, management measures, technologies or combinations thereof. The purpose of WQMPs is to achieve a level of pollution prevention or abatement determined by the TSSWCB, in consultation with local soil and water conservation districts, to be consistent with state water quality standards (TSSWCB 2011).

The TSSWCB selected requirements for WQMPs based on criteria outlined in the *Field Office Technical Guide* (FOTG), a publication of the USDA NRCS. The FOTG represents the best available technology and is tailored to meet the needs of individual SWCDs (TSSWCB 2011).

A WQMP covers the entire farm or ranch unit, and includes required practices applicable to the planned land use. Conservation cropping and residue management should be considered for cropland. Proper grazing use is a vital consideration for a good WQMP on rangeland. Various grazing systems will be examined and a sustainable system will be implemented. A WQMP on pastureland/hayland will have livestock water facility considerations. Forestland and wildlife areas are not to be excluded from the WQMP operating unit (TSSWCB 2011).

WQMPs also include technical requirements. Nutrient management must be outlined if nutrients are applied and pesticide management must also be considered. An owner/operator will have to know how to properly apply these components to their land. If an animal feeding operation is involved (such as a dairy or poultry operation), an animal waste management system will be a component of the WQMP. Waste utilization will be considered when agricultural wastes are applied to the land. WQMPs also have components for irrigation waters, erosion control, and are flexible enough to cater to a wide range of operating systems (TSSWCB 2011).

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 Management Recommendation 1.

Management Recommendation 1

<table>
<tr><td>Pollutant Source: Cattle and Other Livestock</td><td rowspan="5">Insert Cattle grazing photo</td></tr>
<tr><td>Problem: Direct and indirect fecal loading, riparian degradation, overgrazing</td></tr>
<tr><td>Objectives:
• Work with ranchers, property owners to develop WQMPs
• Customize whole-farm plans
• Provide financial assistance
• Implement WQMPs</td></tr>
<tr><td>Location: Priority Subbasins Identified Below</td></tr>
<tr><td>Critical Areas: Properties with Creek access and tributary access</td></tr>
<tr><td colspan="2">Goal: To develop WQMPs focused on minimizing/planning the time spent by livestock in the riparian corridor</td></tr>
<tr><td colspan="2">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.</td></tr>
</table>

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	2012-2022	$150,000
Other subbasins UP- 6, & 8	Develop, cost share, and implement livestock WQMPs $15,000 per plan with 5 plans	2012-2022	$75,000
Texas AgriLife Extension Service	Deliver *Lone Star Healthy Streams* programming to watershed landowners	2014, 2020	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.

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 utilized 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 Management Recommendation 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 Management Recommendation 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 owner of the OSSF is responsible for maintaining their system such that it is properly functioning. Permitting for new OSSFs and inspections of existing systems in the Buck Creek watershed are conducted by TCEQ Region 10 personnel from Amarillo. This person inspects new OSSFs as they are planned and installed and also 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 potential OSSFs pollutant contributions in the Buck Creek watershed, efforts will need to start from scratch. The first step will be to identify OSSF locations, sites where OSSFs should be in use (hunting camps), and OSSF owners as well as sludge haulers and maintenance providers who operate in the watershed. Once identified, education and outreach to these targeted parties is needed and should be followed by inspections. Following OSSF inspections, failing or non-compliant systems will be prioritized with the most problematic systems being dealt with first. Providing technical and financial assistance to needed parties will round out the efforts needed in the watershed. These efforts are described in detail in Management Recommendation 4.

Management Recommendation 2

Pollutant Source: Deer and Other Wildlife	
Problem: Direct fecal loading in riparian areas	**Wildlife habitat photo here**
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	2012-2022	N/A
	Implement habitat management practices as appropriate	2012-2022	TBD
	Work with lessees to locate supplemental feeding locations away from riparian areas	2012-2022	N/A
TWRI	Provide Riparian and Stream Ecosystem Management	2015	N/A
Texas AgriLife Extension Service; Texas Parks & Wildlife	Deliver wildlife and habitat management workshop highlighting watershed specific needs and assistance opportunities	2015, 2018, 2021	$7,500

Estimated Load Reduction

Reductions in the amount of time that wildlife utilizes the riparian corridor will reduce bacteria loading in these areas and direct deposition to waterbodies. 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
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.

Management Recommendation 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 number
- Reduce non-growing season food supply
- Provide education & outreach to watershed landowners

Location: All subbasins

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

Insert feral hog photo here

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	Construct fencing around deer feeders to prevent feral hog utilization	2012-2015	$200 ea.
	Identify travel corridors and employ trapping and hunting in these areas	2012-2022	N/A
	Shoot all hogs on site; ensure that lessees shoot all hogs on site	2012-2022	N/A
Landowners	Aerial gunning of feral hogs	As needed	~$2,000 ea.
Texas AgriLife Extension Service	Deliver Feral Hog Education workshop	2013, 2017, 2021	$7,500 ea.
Local officials	Coordinate with Texas Wildlife Services to conduct supplemental aerial gunning	2013-2015	N/A

Estimated Load Reduction

Reductions in feral hog populations will reduce bacteria loading to the landscape and direct deposition to waterbodies. This effort will be most effective in reducing 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 estimated annual load of 1.47 E+16 cfu of *E. coli* to the watershed. Reducing the population by 10% yields an annual load reduction of 1.47 E+15 and reduces the annual feral hog 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:	High: 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

Management Recommendation 4

Pollutant Source: Failing OSSFs

Insert OSSF photo here

Problem: Fecal loading from failing or non-existent OSSFs

Objectives:

- Identify OSSFs and sites where OSSFs should be used
- Provide E&O for owners, installers and maintenance providers
- Prioritize identified OSSFs for inspection
- Inspect priority OSSFs and identify failing systems
- Provide technical and financial assistance to address failing an non-compliant OSSFs

Location: All subbasins

Critical Areas: Identified OSSFs within 1,000 yds feet of Buck Creek or its tributaries

Goal: To identify OSSFs near the creek, inspect and repair or replace failing or non-compliant systems

Description: OSSF failures will be addressed by identifying OSSF locations, sites where OSSFs should be in use (hunting camps), and OSSF owners as well as sludge haulers and maintenance providers who operate in the watershed. Once identified, education and outreach to these targeted parties will be delivered. This will provide a better idea of the general scope and need for OSSF remediation. Once identified, OSSFs will be prioritized for inspection and failing or non-compliant systems will be prioritized for remediation or replacement. Technical and financial assistance will be sought to round out the efforts needed in the watershed.

Implementation Strategies

Participation	Recommended Strategies	Period	Capital Costs
Texas AgriLife Research	Identify potential OSSFs	2010	complete
	Update potential OSSF locations using refined spatial analysis; prioritize for inspection	2012	$15,000
	Determine property ownership through contacting county Appraisal Districts	2012-2013	$10,000
Texas AgriLife Extension Service	Deliver two education and outreach events: 1) homeowners and landowners 2) installers, maintenance providers, sludge haulers	2015 & 2020	$30,000
Landowners	Provide/require OSSF facilities for hunting leases	2013-2022	Up to $2,500 ea.
Watershed Coordinator	Coordinate with TCEQ Region 1 to conduct OSSF inspections on prioritized systems	2013-2015	TBD
Watershed Coordinator	Coordinate with Local Counties to secure and provide needed assistance to replace/repair failing OSSFs	2016-2022	TBD

Estimated Load Reduction

Replacing/repairing failing OSSFs identified will reduce bacteria loading to the subsurface and potential direct deposition to waterbodies. Using the conservative assumed failure rates presented by Reed et al. (2001), an estimated 8 OSSFs are failing within 1,000 yds of the creek. Using the load reduction calculations presented in Appendix F, an expected reduction of 1.49 E+13 cfu can be seen annually.

Effectiveness:	High: Replacement and repair of failing OSSF will yield direct fecal reductions to the creek
Certainty:	Low: It is not known how many OSSFs in the watershed are currently failing
Commitment:	Moderate: The lack of information on OSSF owners near the creek and their financial means is unclear. Possible enforcement of fines for failing systems may increase desire to implement.
Needs:	Moderate: Financial assistance to identify OSSFs, OSSF owners and deliver educational programming are reasonable; however, until inspections are performed, needed financial assistance to replace failing systems is unknown.

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 Texas AgriLife Research – 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 thus suggesting that ground water 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 are needed to verify the source of elevated nitrates in the creek. Other, potential sources that are 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 5, 6 and 7 illustrate that natural sources of nitrate present in underlying groundwater could be the primary source of nitrates in the watershed and nitrate contributions to Buck Creek. Research conducted by Scanlon et al. (2008) provide 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 that is specific to Buck Creek is inconclusive in determining if this is the case here in Buck Creek as well.

While these sources are natural and not caused by anyone in the watershed, there are several management strategies that can be employed that will benefit the environment and landowners alike. Addressing this issue has two main 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) reported that providing education and outreach supplemented with soil and water testing was a critical need for most producers and will enhance 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. Table 23 illustrates nitrate availability in lbs/acre for irrigation waters of given quality applied at designated rates. 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. This could result in a more appropriate nitrate screening level being applied in Buck Creek. These management measures are described in detail in Management Recommendations 5 and 6.

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

lbs NO_3/acre = $N0_3$ (ppm) x 0.23 x inches of water applied/acre					
Well Water NO_3 (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

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 and the dual benefit of nutrient reductions will be realized when implementing these same management measures. Rather than re-create management measure tables again, load reduction estimates for nitrates will be included in those tables as well.

Management Recommendation 5

Pollutant Source: Natural Nitrates	
Problem: Groundwater contributions causing nitrate levels in the creek to be in excess of the designated screening level	Insert Nitrates photo?
Objectives: • Collect nitrates data to verify source of nitrate in creek • Conduct a waterbody 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 verify 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 AgriLife Research, Creek Owners and Water well Owners	Conduct water quality monitoring to assess nitrate levels and sources in Buck Creek, identified springs entering the creek and nearby irrigation and water wells	2012-2015	$40,000
TCEQ	Conduct nitrate screening level appropriateness assessment	2014-2015	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:	Low: 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.

Management Recommendation 6

Pollutant Source: Natural Nitrates	
Problem: Groundwater contributions causing nitrate levels in the creek to be in excess of the designated screening level	Insert Nitrates photo?
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 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 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.	2012-2015	$50,000
Texas AgriLife Extension Service; Texas 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 acres 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. 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 for free to the landowner soil and irrigation water testing 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

Technical assistance needs in the watershed vary substantially depending on the source of pollution being addressed and the specific management recommendation being utilized. 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. Additionally, the successful implementation of the Buck Creek WPP, tracking of WPP Implementation activities and moving efforts to secure funding and technical assistance needs forward will require a coordinated effort. A Watershed Coordinator will fill this role and serve as a consistent point of contact for the Buck Creek WPP and WPP implementation efforts. Texas AgriLife Research personnel from the Vernon Research and Extension Center have fulfilled this role to date and will likely do so for the foreseeable future. Should this situation change, other options can be explored. For now, efforts will be undertaken by TWRI, Texas AgriLife Research – Vernon and TSSWCB to explore funding options and secure needed funds to fund this position.

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

Table 24. Technical assitance 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 Field Technicians; NRCS District Conservationists
WQMP Implementation Tracking	Coordinated tracking of WQMP practices implemented and assessment of expected water quality improvements	TSSWCB/SWCD Field 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 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 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 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
Feral Hog Abatement Outreach	Technology transfer of improved tactics and methods for controlling feral hogs	Texas 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		
OSSF and OSSF Owner Identification	Applicaton of proven techniques for identifying OSSFs in rural areas and man-power to identify specific OSSF owners	Texas AgriLife Research; TCEQ
OSSF Inspections	Inspections completed by authorized and appropriately trained personnel in a timely fashion	TCEQ
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 AgriLife Extension Service; Watershed Coordinator
OSSF Management Tracking	Coordinated tracking of OSSF inspections, repairs, replacements as well as assessing expected water quality improvements	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 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 AgriLife Extension Service; Texas 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 AgriLife Extension Service; Texas AgriLife Research

Chapter 10 ~ Sources of Financial Assistance

Funding the implementation of a WPP can be carried out in many ways using numerous sources of financial assistance. 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 (AWEP)

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 and ground water conditions on their agricultural land. AWEP is a part of the Environmental Quality Incentives Program (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 crop, range, pasture and other farm or ranch lands.

http://www.tx.nrcs.usda.gov/programs/awep/index.html

Conservation Reserve Program (CRP)

The **USDA – Farm Service Agency** (FSA) operates the Conservation Reserve Program. This is a voluntary program for agricultural landowners that 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 percent of landowner costs in establishing approved conservation practices. CRP contracts vary between 10 and 15 years in length.

http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp

Conservation Stewardship Program (CSP)

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.

http://www.nrcs.usda.gov/wps/portal/nrcs/main?ss=16&navid=100120300000000&pnavid=100120000000000&position=SUBNAVIGATION&ttype=main&navtype=SUBNAVIGATION&pname=Conservation%20Stewardship%20Program%20|%20NRCS

Environmental Quality Incentives Program (EQIP)

The **USDA-NRCS** operates this program to provide a voluntary conservation program for farmers and ranchers to address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land. EQIP offers contracts with a maximum term of ten 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.

http://www.nrcs.usda.gov/wps/portal/nrcs/main/?ss=16&navid=100120310000000&pnavid=100120000000000&position=SUBNAVIGATION&ttype=main&navtype=SUBNAVIGATION&pname=Environmental%20Quality%20Incentives%20Program

Grassland Reserve Program

The Grassland Reserve Program (GRP) is a voluntary conservation program that is 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.

http://www.tx.nrcs.usda.gov/programs/GRP/index.html

Wildlife Habitat Incentives Program (WHIP)

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 percent 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.

http://www.nrcs.usda.gov/wps/portal/nrcs/main/?ss=16&navid=100120340000000&pnavid=100120000000000&position=SUBNAVIGATION&ttype=main&navtype=SUBNAVIGATION&pname=Wildlife%20Habitat%20Incentives%20Program

USDA-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.

http://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, USEPA 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.

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

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.

http://www.twdb.state.tx.us/assistance/financial/fin_infrastructure/awcfund.asp

Clean Rivers Program (CRP)

The Texas Clean Rivers Program (CRP) is administered by **TCEQ** and is a state fee-funded program for surface water quality monitoring, assessment, and public outreach. The program provides the opportunity to identify and evaluate water quality issues within each Texas river basin at the local and regional level. Allocations are made to 15 partner agencies (mostly river authorities) across the state for routine monitoring efforts, special studies, and outreach efforts. In Buck Creek, the Red River Authority of Texas (RRA) is the designated CRP 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.

http://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 nonpoint source pollution controls.

http://www.twdb.state.tx.us/financial/programs/cwsrf.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.

http://www.tpwd.state.tx.us/landwater/land/private/lip/

Supplemental Environmental Projects (SEP)

The SEP program is administered by **TCEQ** and 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, http://www.texasrcd.org/) with pre-approved "umbrella" projects.

http://www.tceq.state.tx.us/legal/sep/

Texas Farm & Ranch Lands Conservation Program

This program was established by Senate Bill 1273 in 2005 and 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.

http://www.glo.state.tx.us/res_mgmt/farmranch/apply.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 acres and NRCS has developed conservation plans that include prescribed grazing on another 4,520 acres. 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.

http://www.tsswcb.state.tx.us/wqmp

Other Sources

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

Directory of Watershed Resources

Utilizing 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.

http://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 general 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.

Current Efforts

Project Website

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

http://buckcreek.tamu.edu/

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, nine news releases have been made 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 WPP development, 12 newsletters were distributed to a total of 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. These meetings provided attendees with information about the findings of the monitoring project. Utilizing stakeholder feedback and data collected led to the continuation of monitoring and the application of additional planning tools with a watershed protection plan as an end goal. This watershed protection plan 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 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.

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

In addition to the meetings listed above, constant contact was made with each of the three 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 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 Watershed Steward program was delivered by the Texas AgriLife Extension Service January 24, 2008 in Wellington. This program is a partnership between Texas AgriLife Extension Service 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 USEPA to Texas AgriLife Extension Service 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 nonpoint source 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 percent of participants indicated that they do plan to implement improved management practices that will promote better water quality. A follow up survey 6 months later indicated that 80 percent 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, meeting with focused groups of stakeholders to seek out and secure implementation funds, providing content to maintain and updating the project website, tracking WPP implementation progress and participating 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 periodically update readers 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 26 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. The focus of this work shop will be to educate landowners on the negative impacts of feral hogs, effective control methods and resources to help them engage control these pests. Workshop frequency will be approximately every five years unless there are significant changes in available means and methods to control feral hogs. It is anticipated that feral hog management education will be incorporated into the *Lone Star Healthy Streams* program in the future and as such will likely be the appropriate delivery mechanism for this programming. If not, AgriLife Extension personnel in the Wildlife and Fisheries Science department will be relied upon to deliver this needed programming.

Lone Star Healthy Streams Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver the *Lone Star Healthy Streams* curriculum. This program is geared to expand knowledge of how to improve grazing lands by beef cattle producers to reduce NPS pollution. This state-wide 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 five years or as needed.

Nutrient Management Workshops

Delivery of nutrient management material will aid producers in better utilizing 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 a septic system, 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: http://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 three 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 utilizing 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 Texas AgriLife Extension Service personnel to deliver this program in the Buck Creek watershed in the spring of 2012. 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.

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 utilized 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 late 2012 or early 2013. 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 engaged 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 that is inherent in watershed planning. Figure 30 illustrates the three primary measures that will be utilized to gauge the success of WPP implementation.

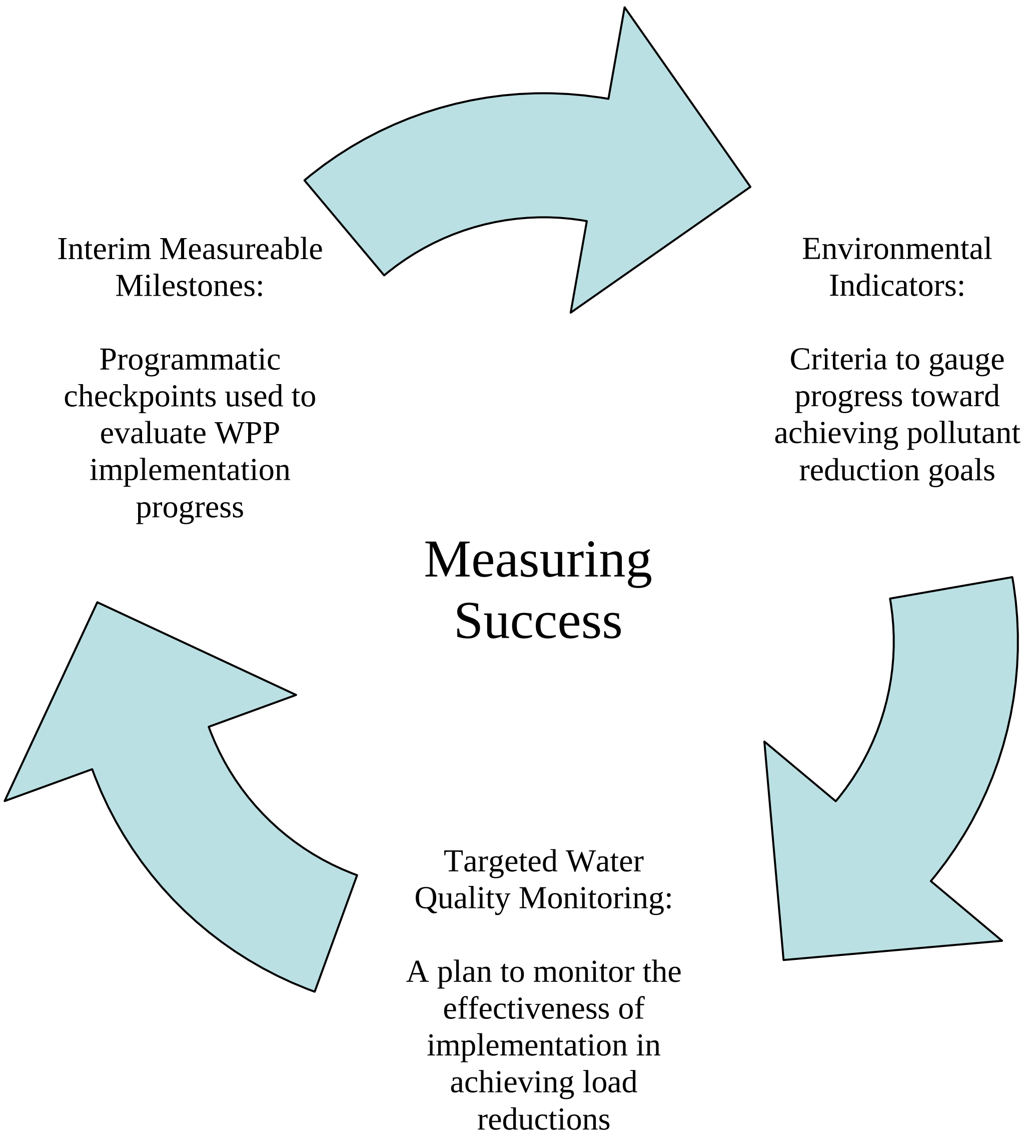


Figure 30. Integrated approach to successfully measuring progress toward achieving WPP goals

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 being implemented as scheduled.

Milestones are separated into short, mid, and long-term milestone. Short-term milestones are those that can be quickly accomplished utilizing existing or easily attainable resources. These milestones can be accomplished during the first three years of WPP implementation. Mid-term milestones are those that 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 four to six 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 implemented seven 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. In the event that milestones are completed ahead of schedule, there 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 be made 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. *E. coli* levels are expected to be reduced over time as a result of management measures prescribed in the WPP. Reductions are best quantified by collecting a spatially and temporally representative data set and evaluating long-term water quality trends. Establishing target *E. coli* levels at selected monitoring sites will provide water quality thresholds that signify successful WPP implementation. Benchmark water quality targets (Table 26) and reflect expected water quality improvements as a result of implementing the WPP as scheduled. 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 will provide the quantitative measures needed to evaluate WPP implementation and gauge the water body's ability to meet designated benchmarks. The most

Table 26. *E. coli* and nitrate concentration reduction milestones

Implementation Year	*E. coli* cfu/100 mL
Initial Conditions	
2010 Integrated Report	97.6
Reduction Goals	
Yr 3 (Sep 2015)	<95
Yr 6 (Sep 2018)	<95
Yr 10 (Sep 2022)	<95

recent seven years of water quality data will be used as the primary measure in evaluating these trends and progress toward designated benchmarks. The seven year data window is the method utilized by TCEQ in their biennial waterbody 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.

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 as a result of 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 five 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. It could be determined that the benchmark goals are unrealistic and should be modified or it might be found that management measures recommended were not adequate to meet prescribed benchmark goals.

Targeted Water Quality Monitoring

Water quality monitoring will provide benchmark information that verifies that the successful implementation of the Buck Creek WPP is resulting in the water quality goals being achieved 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, Texas AgriLife Research personnel from the Vernon Research and Extension Center will continue routine monitoring on a monthly basis at stations 20365, 20367, 20368, 15811 and 20376. In the event that funding is not secured for this monitoring, RRA will be contacted by the Watershed Coordinator to discuss continued monitoring of these sites through their clean rivers program.

Monitoring will be conducted at two 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 one upstream and one downstream location in each AU as well as in one tributary location. Additionally, 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. Index sites 20368 and 15811 will continue to be monitored as 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. These samples will provide the most useful information in that they can be used for both WPP implementation effectiveness monitoring and in future waterbody 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. Participants in the TWON program will be asked for their permission to access water quality data from their well screenings; these data should be available in the spring of 2012. 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. It is anticipated that funding will be received in the fall of 2012 and sampling will begin shortly thereafter. 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 two 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 between 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 have led to these recommended measures and the areas where implementation has been 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 implementation milestones that may need to be adjusted through the adaptive management process if it is found that the milestones are unrealistic or the management practice is 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 included 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 identifying failing OSSFs in the watershed and developing 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.

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	$5,000	$50,000
Fencing around deer feeders	Landowners/Lessees /Lessors	unknown number of feeders			$200	TBD
Trapping and Shoot-On-Site	Landowners/Lessees	20	20	20	$500	$30,000
OSSF Management						
OSSF ID and Inspection Prioritization	Research	1	0	0	$10,000	$10,000
OSSF Ownership Determination	Research	1	0	0	$15,000	$15,000
Priority OSSF Inspections	TCEQ		1	1	N/A	N/A
Hunting Camp OSSFs	Landowners	as needed			up to $2,500	TBD
Nitrate Source Assessment						
Targeted Nitrate Monitoring	Research	1	0	0	$40,000	$40,000
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	N/A	N/A
Water Quality Montioring						
Routine Montioring	Research	1			$25,000	$250,000
Watershed Coordinator						
Extension Assistant @ 1 FTE plus travel, supplies, etc.	Extension	1			$75,000	$750,000
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			N/A	N/A
Work with lessees to improve wildlife habitat management	Landowners/Lessors	as needed			N/A	N/A
Total Management Implementation Costs						***$1,403,000***

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, management strategies that can be used to address specific pollutants as well as information 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**

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Appendix A: Elements of Successful Watershed Plans

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 which 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 whe3ther 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 results, rather, indicates the overall water quality from other programs can be used. 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. A total of five watershed LU/LCs 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 meters tall, and greater than 50% of total vegetation cover.

Riparian Forested Land - Areas dominated by trees generally greater than 5 meters tall, and greater than 50% of total vegetation cover. These areas are found following in near proximity to streams, creeks and/or rivers.

Mixed Forest - Areas dominated by trees generally greater than 5 meters 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 being actively tilled.

Data and Materials

National Agriculture Imagery Program (NAIP) Digital Ortho Imagery: NAIP Ortho photos are collected and compiled each year by the United States Department of Agriculture (USDA) Farm Service Agency (FSA) during a portion of the agricultural growing season at a one or two meter resolution. The 2005 images for Texas were provided in county mosaics at a spatial resolution of two meters. 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 meter 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 High and Medium Resolution Data: The National Hydrography Dataset (NHD) is a combination of the United States Geological Survey (USGS) Digital Line Graph Hydrography files and the United States Environmental Protection Agency (USEPA) 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: 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 which 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 meters. 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 utilize 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 ESRI grid file and projected using ArcMap software.

Data Processing

The Environmental Systems Research Institute's (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 (NAD) 1983 Universal Transverse Mercator (UTM) 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 utilized which involved numerous processing steps that 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 were extracted and manually compared against more recent NAIP imagery to test that the areas were still in a barren state. As the NAIP imagery was viewed any additional bare areas that were manually digitized. The barren categories from the Landsat classification were also implemented into the dataset.

A data layer was created for all bodies of water with the use of NHD data. NAIP imagery was then viewed to find additional water areas that 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 one mile buffer of the watersheds and buffered to 225 feet. 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 feet 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 waterbodies, 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 acres. 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 meters 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 two 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 Load Duration Curve (LDC). An LDC allows for a visual determination of how stream flow 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. These results are used to create a graph of flow volume versus frequency, which produces the flow duration curve.

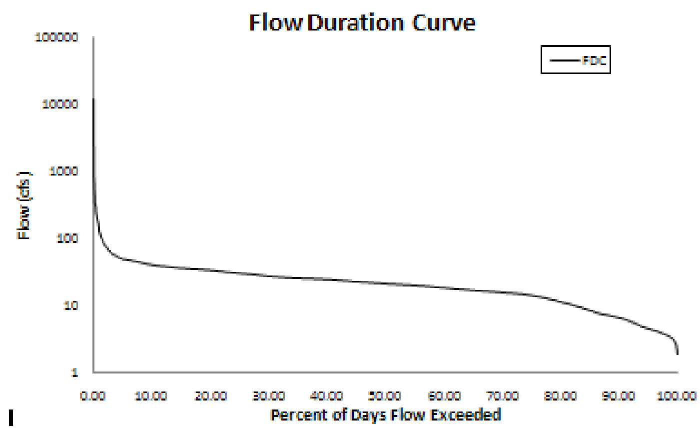

Figure C-1. Example flow duration curve

Next, data from the flow duration curve are multiplied by the concentration of the water quality criterion for the pollutant to produce the LDC (Fig. X). 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 margin of safety (MOS) is applied to the threshold pollutant concentration to account for possible variations in loading due to sources, stream flow, 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-TMDL/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. 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 three statistical estimation methods. The first two methods, Adjusted Maximum Likelihood Estimation (AMLE) and Maximum Likelihood Estimation (MLE), are appropriate when the calibration model errors (residuals) are normally distributed. Of the two, 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 are in compliance with the water quality standard.

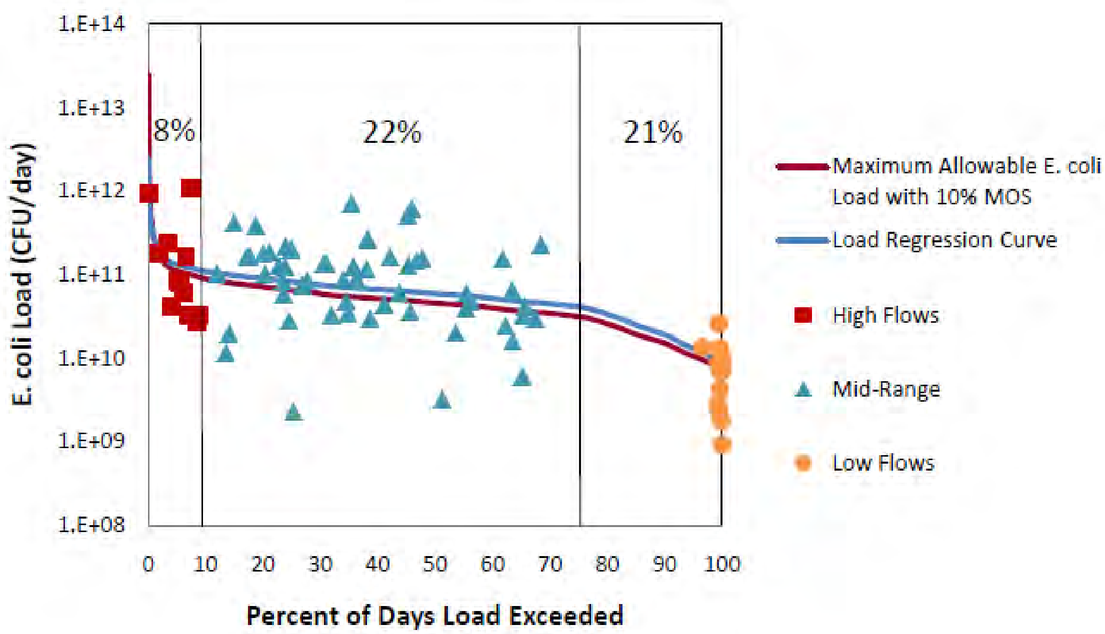

Figure C-2. Example load duration curve and calculated load reductions needed to meet water set water quality goal

In order 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 is in compliance 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.

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 nonpoint source contributors, and distributing their potential loads based on land use and geographical location. The LU/LC classification described in Appendix B was utilized 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.

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).

Cattle Population estimates for cattle across the watershed were developed by watershed stakeholders. USDA NASS data for the three counties partially within Buck Creek included numerous feedlots and as such were thought to be an over estimate of actual cattle numbers in the watershed. Using a three county average of NRCS recommended stocking rates of 25 acres/AU for rangeland, mixed forest and riparian forest and a rate of 8 acres/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 deer census estimates from TPWD 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 acres, 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:

$$\text{Feral Hog Load} = \#\ \text{hogs}*1.1*10^9\ \text{cfu/day}*0.5$$

Where $1.1*10^9$ 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 acres 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 utilize 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 utilize 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 foot 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, dissolved oxygen, specific conductance, and flow measurements (cubic feet per second) 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 Research at 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 USEPA Method 1603 with modified mTEC medium (USEPA 2005) 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 Texas Commission on Environmental Quality data assessment staff guidance.

After *E. coli* enumeration, five 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 one purified colony in 1.5ml 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 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 Research at El Paso for BST analysis.

Ambient water samples were also collected on a minimum of five 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 one sample per site was prepared for the *Bacteroidales* test. *E. coli* enumeration was recorded for all samples. Three to five colonies per sample were isolated, purified for testing, and sent to AgriLife Research at 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 the identification of 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, providing 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 three 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 1044 different human and animal samples collected throughout the state of Texas from four 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 1. Jackknife analysis revealed an 87 percent average rate of correct classification using a three-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 which 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 ml 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 our 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%) non-target 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%) non-target 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%) non-target 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 three-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 two different methods. For example, one 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, ten out of ten water samples tested positive for the GenBac general and ruminant *Bacteroidales* markers, followed by a lower frequency of hog and ruminant marker detection (Fig. E-1).

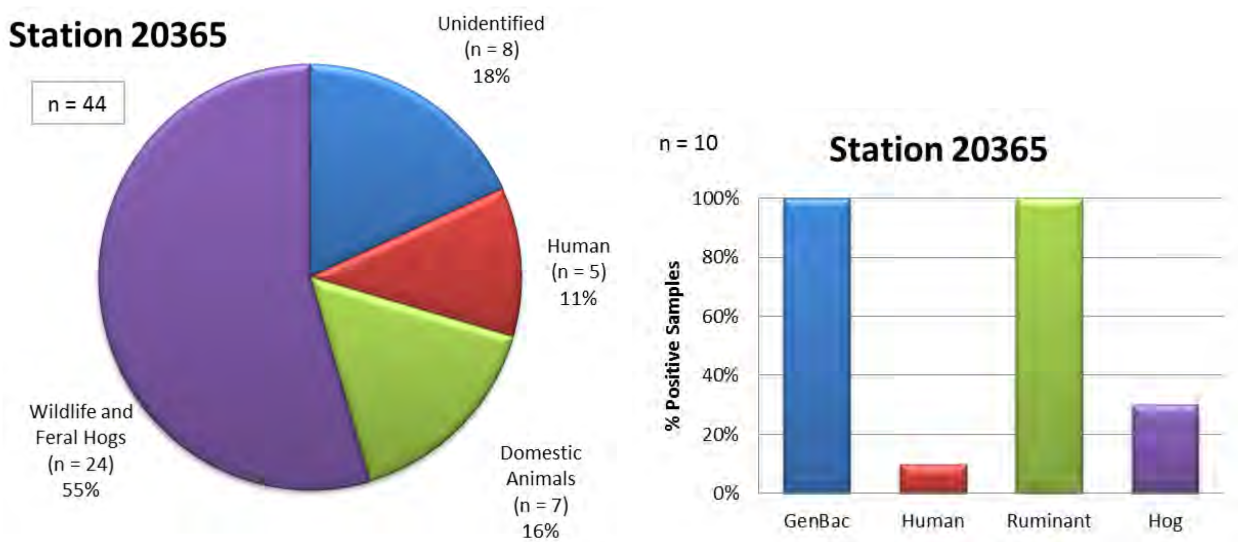

Figure E-1. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20365. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. Cattle, deer, etc.); Human. = all human sources

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 twelve 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 (Fig. 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.

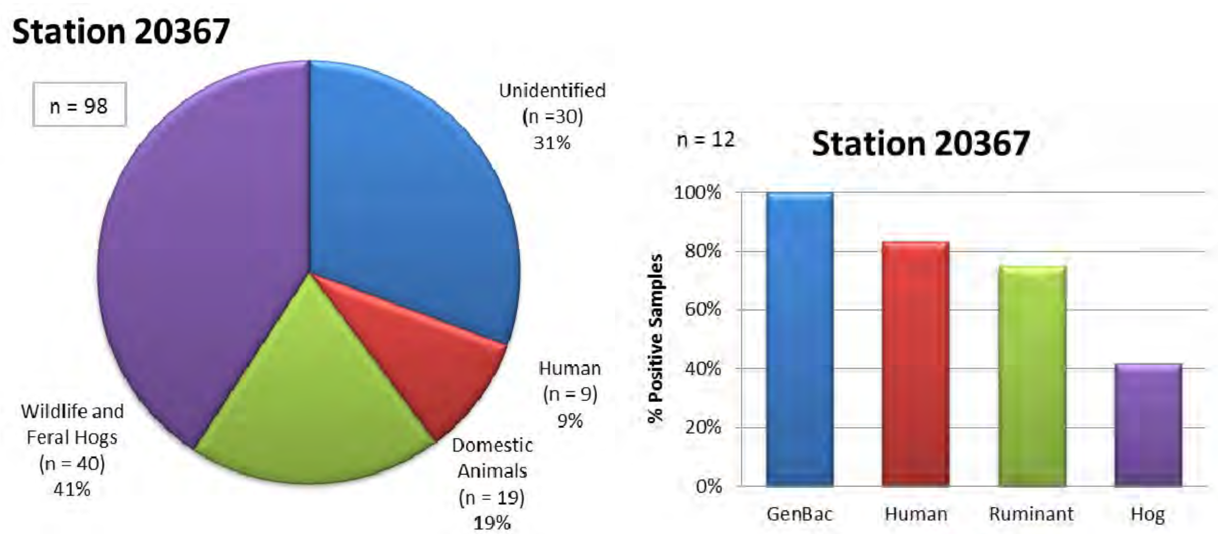

Figure E-2. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20367. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. Cattle, deer, etc.); Human. = all human sources

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 eleven 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 (Fig. E-3).

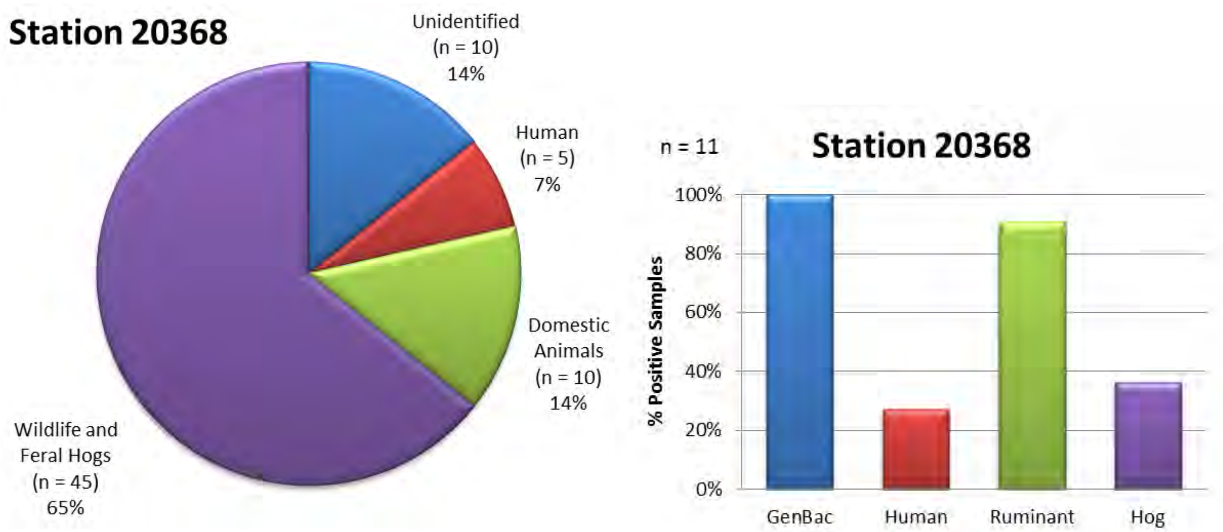

Figure E-3. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20368. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. Cattle, deer, etc.); Human. = all human sources

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. A total of 14 water samples were collected for *Bacteroidales* analysis. All water samples tested positive for the GenBac general and ruminant markers, followed by moderately high occurrence of the hog marker and a low occurrence of human marker (Fig. E-4).

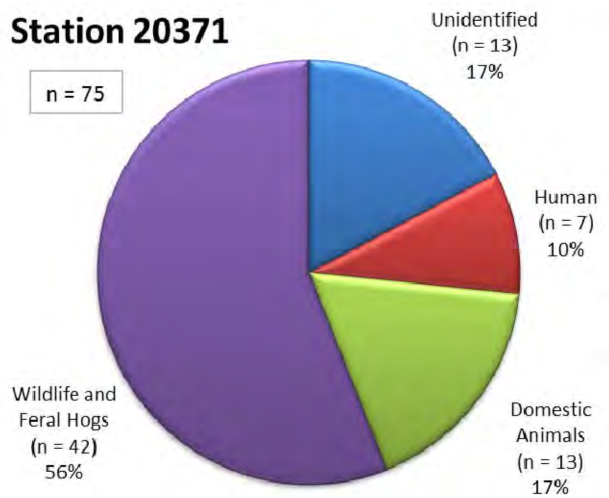

Figure E-4. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20371. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. Cattle, deer, etc.); Human. = all human sources

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. A total of 20 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 (Fig. 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.

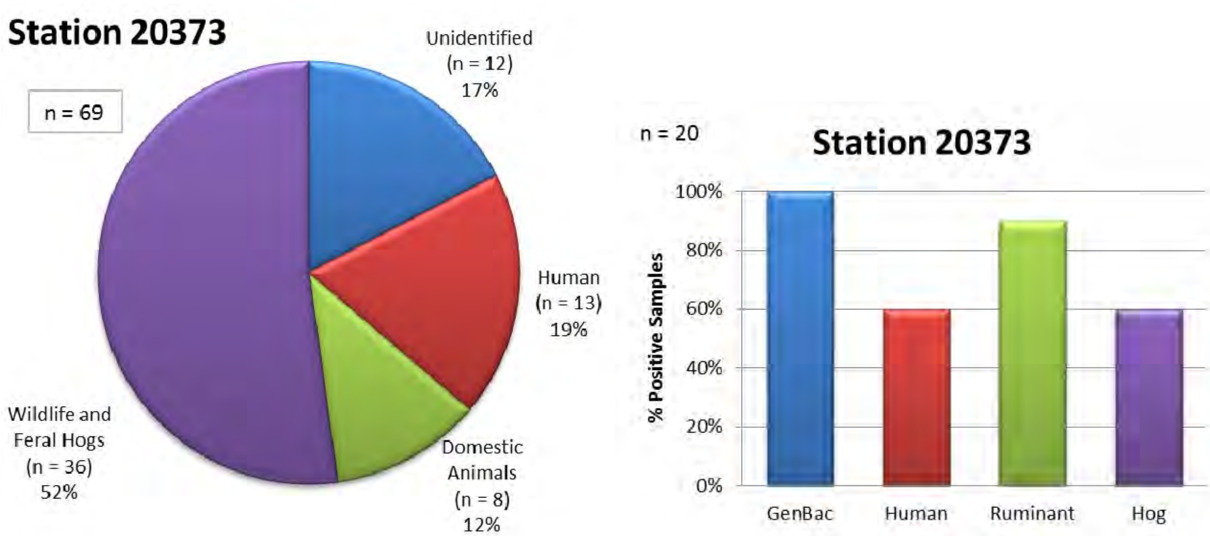

Figure E-5. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 20373. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. Cattle, deer, etc.); Human. = all human sources

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. A total of 12 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 (Fig. E-6).

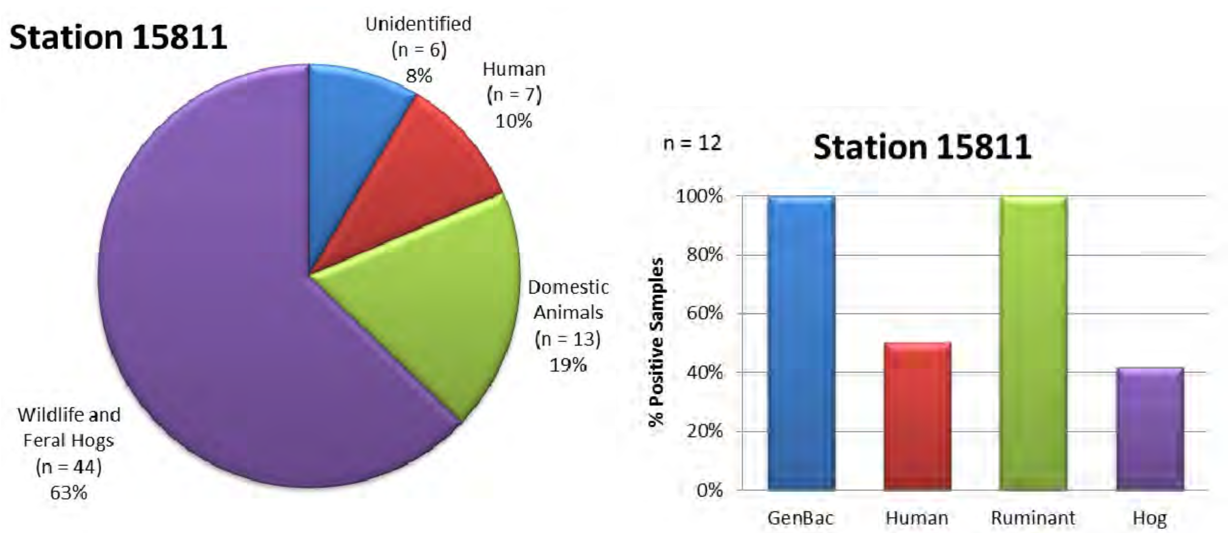

Figure E-6. Identification of water isolates (pie chart) and *Bacteroidales* PCR marker occurrence (bar chart) at Station 15811. Marker abbreviations: GenBac = General *Bacteroidales*; Hog = feral and domestic hog; Ruminant = all ruminants (ie. Cattle, deer, etc.); Human. = all human sources

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 landuse/landcover make up, total acres, animal population estimates and potential number of OSSFs in each designated subbasin. Information in this table will be referenced in estimated load reductions described below.

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

	ACRES											Species Population Estimates by Subbasin			
Subbasin	Open Water	Roads	Developed, Low Intensity	Developed, 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	379	313	438	5
LO-2	19.6	426.0	15.0		0.2	337.4	18.5	6,901.7	3,280.6	978.1	11,977.1	417	330	476	6
LO-3	25.3	445.4	27.4	1.3	0.1	284.7	239.8	9,487.3	3,337.5	3,502.6	17,351.2	846	482	690	8
LO-4	7.7	460.7	86.7		0.5	204.2	116.6	4,224.3	3,774.9	3,708.0	12,583.6	650	345	498	11
LO-5	26.9	427.4	2.1			139.2	184.0	1,001.5	8,748.1	1,045.5	11,574.6	188	319	460	9
LO-6	3.8	100.7	7.8			124.9	148.9	3,615.4	3,447.0	241.4	7,690.0	190	217	306	7
LO-7	4.0	183.6				50.9	25.7	3,477.6	5,334.8	1,434.4	10,510.9	326	296	419	6
LO-8	4.2	136.5			0.0	123.0	57.3	667.3	1,740.2	86.7	2,815.4	49	76	111	3
LO-9	2.3	325.8	1.3			72.2	106.9	544.9	5,116.7	131.6	6,301.6	50	171	250	10
UP-1	23.7	343.3	4.8		1.1	35.6	157.2	1,774.3	5,628.9	1,015.1	8,984.0	210	247	357	26
UP-2	23.3	264.9			0.4	83.5	218.5	5,401.1	7,228.5	2,214.0	15,434.1	509	434	615	16
UP-3	36.7	366.1	0.2		4.6	197.7	341.0	3,449.8	9,951.9	1,800.4	16,148.3	389	451	643	34
UP-4	26.0	124.8			0.0	114.2	117.2	10,017.5	3,298.1	1,655.6	15,353.3	621	435	612	10
UP-5	4.5	25.6				1.3	29.5	3,355.0	340.9	64.6	3,821.5	148	108	151	3
UP-6	73.4	5.7			0.6	21.8	12.8	8,389.2	181.1	417.4	9,102.0	394	259	360	0
UP-7	12.7	3.1	1.0		3.0	2.8	35.6	4,414.6	181.9	1,300.9	5,955.7	345	170	236	8
UP-8	12.9				4.2	0.2	33.7	6,681.4	174.0	2,044.4	8,950.7	529	256	356	3
UP-9	20.9	115.8	105.8	1.3	41.8	191.8	172.2	3,723.3	2,226.0	1,854.1	8,453.0	400	234	332	23
Totals	341.7	3,807.5	252.0	2.6	56.6	2,178.1	2,110.7	85,964.6	65,720.7	23,568.0	184,002.5	6,640	5,143	7,310	188

Cattle

Population estimates for cattle across the watershed were developed by watershed stakeholders. USDA NASS data for the three counties partially within Buck Creek included numerous feedlots and as such were thought to be an over estimate of actual cattle numbers in the watershed. Using a three county average of NRCS recommended stocking rates of 25 acres/AU for rangeland, mixed forest and riparian forest and a rate of 8 acres/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.

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:

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

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, that have been documented to measurably reduce the amount of fecal bacteria loading from cattle, and that 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 three most likely practices to be implemented.

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 nor 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 estimate of practice efficiency and appropriate for predicting potential load reductions that could be realized through voluntary BMP implementation; however, using the lowest effectiveness rate will likely give a more dependable 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 five 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.

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

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.
- $5.0\text{x}10^{10}$ = 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 acres. Using the average farm size from 2007 of 1,243 acres (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 sub-species, 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 acres/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. Utilizing 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 $3.5*10^8$ cfu per animal was utilized (EPA 2001).

Expected load reductions from deer and other wildlife will be realized by a reduction in the amount of time these species spend in the riparian corridor through habitat management. This practice is a non-descript 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 acres 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 utilize 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 utilize 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:

$$\text{Feral Hog Load} = \#\text{ hogs}*1.1*10^9 \text{ cfu/day}*0.5$$

Where $1.1*10^9$ 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 percent 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 percent.

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. Utilizing findings from Reed et al. (2001), a very conservative estimate of 8 percent of all OSSFs in the watershed being failing was utilized 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 10 of these systems would be failing based on the failure rate assumption of 8 percent of all systems.

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

Assumptions:

- 8 OSSFs are failing in the critical area of the watershed
- $10^6 \frac{cfu}{100mL} =$ fecal coliform concentration in OSSF effluent as reported by Metcalf & Eddy 1991, Canter & Knox 1985, Cogger & 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 & Witten 1996.
- 2.41 persons per household average from Childress, Collingsworth and Donley Counties (Table 10.)

Calculation:

Potential OSSF Load: =

$$8\ failing\ septic\ systems * 10^6 \frac{fecal\ coliforms}{100\ mL} * .8 * \frac{70 \frac{gallons}{person}}{day} * 3785.2 \frac{mL}{gallon} * 2.41 \frac{persons}{household} * \frac{365\ days}{year} = 1.49x10^{13} \frac{cfu}{day}$$

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. Cropland is a dominant land use/land cover in the Buck Creek watershed and is estimated to encompass 67,335 acres. Of this, approximately 20 percent, or 13,467 acres are irrigated. Further, it is anticipated that 50 percent of farmers will actually implement nitrate mining on their farms.

Utilizing 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/acre = $N0_3$ (ppm) x 0.23 x inches of water applied/acre					
	Inches of Water Applied				
Well Water NO_3 (ppm)	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/acre is assumed to be realistic. Utilizing this assumption and the watershed statistics presented earlier, the following potential load reduction can be calculated.

Assumptions:

- 67,335 acres of cultivated land in watershed
- 20% of cultivated land is irrigated
- 50% of farmers will implement nitrate mining
- 25 lbs/acre 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/acre NO_3

Annual Potential Load Reduction = 168,337 lbs NO_3 annually