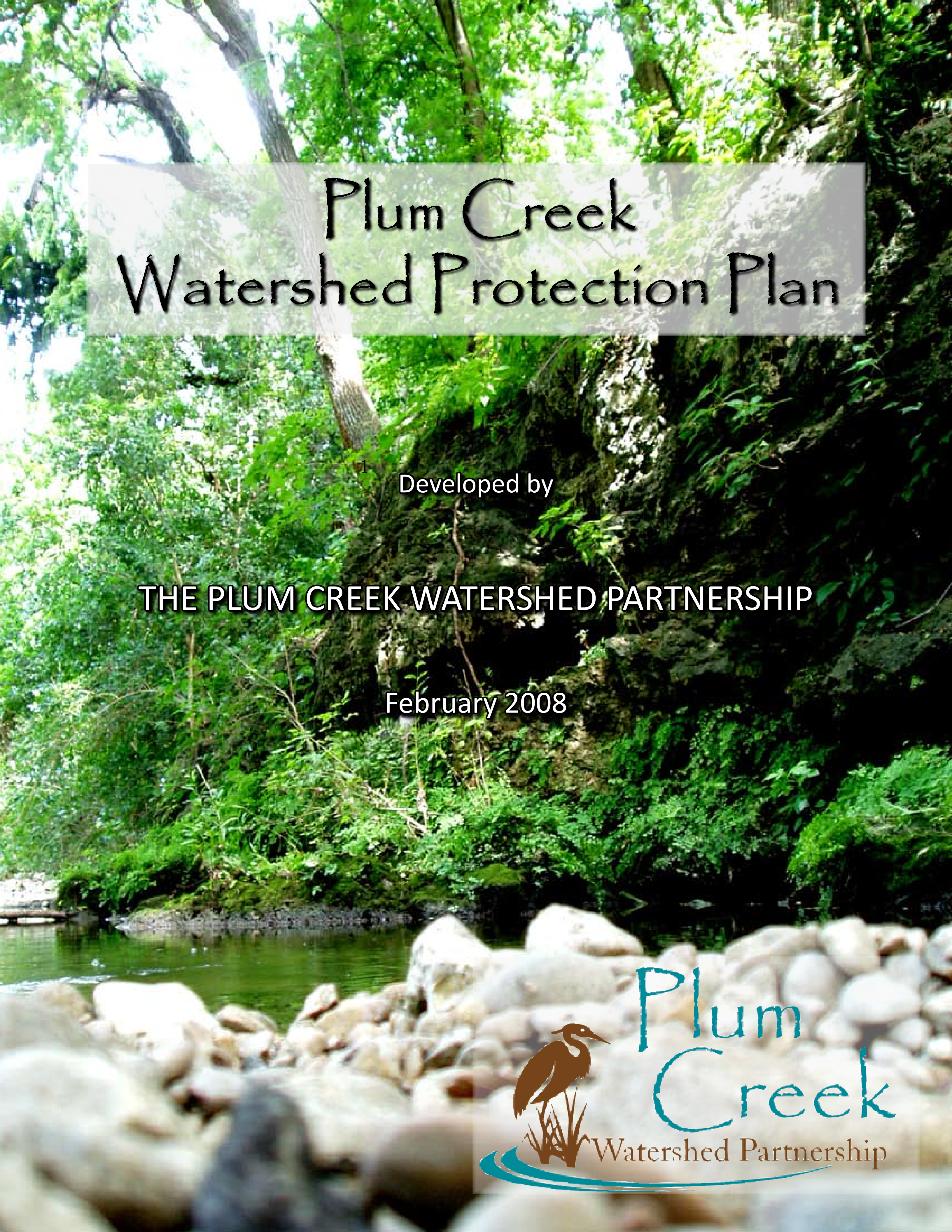


Plum Creek Watershed Protection Plan

Developed by

THE PLUM CREEK WATERSHED PARTNERSHIP

February 2008

Plum Creek Watershed Partnership

Photos courtesy of Nikki Dictson, Texas AgriLife Extension Service
JupiterImages Corporation
USDA-NRCS

All uncredited images courtesy of Matt Berg, Texas AgriLife Extension Service

Plum Creek Watershed Protection Plan

Prepared for the
Plum Creek Watershed Partnership
by

Matt Berg, Mark McFarland, and Nikki Dictson

Texas AgriLife Extension Service, College Station, Texas

Funding for the development of this Watershed Protection Plan was provided through a
federal Clean Water Act §319(h) grant to the Texas AgriLife Extension Service, administered by
the Texas State Soil and Water Conservation Board from the U.S. Environmental Protection Agency

Acknowledgments

This document and the efforts behind its completion are the result of collaboration and cooperation between many different groups and individuals. Each has played an important role in the Plum Creek Watershed Partnership and its activities.

First and foremost, the Partnership wishes to express thanks to members of the Steering Committee for their investments of time and energy in participating throughout the process. Without their direction and support, progress would have been impossible. Through the Plum Creek Watershed Protection Plan, their efforts serve as an example to all watershed stakeholders of the importance of active stewardship of water resources.

The Plum Creek Watershed Partnership also would like to thank the members of the Technical Advisory Group, who provided their expertise and specialized knowledge in dealing with several key issues and offered critical guidance in development and refinement of portions of the Plum Creek Watershed Protection Plan:

-Texas Commission on Environmental Quality
-Texas Department of Agriculture
-Texas Farm Bureau
-The Railroad Commission of Texas
-Texas Water Development Board
-U.S. Environmental Protection Agency
-Texas AgriLife Extension Service
-Texas Department of Transportation
-Texas Parks and Wildlife Department
-Texas State Soil and Water Conservation Board
-USDA Natural Resources Conservation Service
-U.S. Geological Survey

In addition, the Partnership is grateful for cooperation and participation from representatives of key local groups who will play a vital role in protecting water quality:

-Guadalupe-Blanco River Authority
-The City of Lockhart
-The City of Uhland
-The City of Niederwald
-Caldwell County
-Caldwell-Travis SWCD
-Texas Watch
-Lockhart State Park
-San Marcos River Foundation
-The City of Kyle
-The City of Luling
-The City of Buda
-Hays County
-Plum Creek Conservation District
-Hays County SWCD
-First-Lockhart National Bank
-Luling Foundation
-Plum Creek Community

The Partnership expresses thanks to Dr. Meghna Babbar-Sebens, Aarin Teague, and Dr. R. Karthikeyan of the Texas A&M University Biological and Agricultural Engineering Department and Jennifer Jacobs and Dr. Raghavan Srinivasan of the Texas A&M University Spatial Sciences Laboratory for their diligence and tremendous help in analyzing water quality in Plum Creek.

We are especially grateful to the Texas State Soil and Water Conservation Board and the Environmental Protection Agency for their vision of a strong and influential stakeholder-led watershed planning process in the Plum Creek Watershed. Funding provided through these agencies provided support vital for the development of this Watershed Protection Plan and established a solid foundation for watershed stewardship in Plum Creek.

Statement of Purpose

Plum Creek has historically played a critical role in the growth and development of the area, from its appeal as a reliable water source for settlers and livestock to recreation opportunities in the watershed. The landscape around the stream is diverse, ranging from one of the state's most rapidly growing population centers in the north to rural bottomlands dominated by agriculture in the south. However, beginning in 2004, the stream was listed by the State of Texas as having *E. coli* bacteria levels that impaired contact recreation use of the stream, as well as having elevated nutrient concentrations. As a result, the Plum Creek Watershed Protection Plan was developed by the Plum Creek Watershed Partnership using a stakeholder process driven by public participation to provide a foundation for restoring water quality in Plum Creek and its tributary streams. By identifying key water quality issues in the Plum Creek Watershed and determining the factors contributing to these issues, management programs and public outreach efforts will be targeted to restore and protect the vital water resource of this watershed. The Plum Creek Watershed Protection Plan incorporates an analysis of existing water quality data and an investigation into potential pollutant sources based on local knowledge and experience to develop a strategy for addressing concerns related to water quality and watershed health.

Stakeholders are any individual or group that may be directly or indirectly affected by activities implemented to protect water quality, such as citizens, businesses, municipalities, county governments, river authorities, nonprofit organizations, and state agencies. This document is a means by which stakeholders can become more familiar with the Plum Creek Watershed and actively make a difference in the quality and health of their streams through voluntary management practices. It is a starting point to focus restoration efforts and enable financial and technical assistance to facilitate improvements in Plum Creek. This Watershed Protection Plan is intended to be a living document, adjusted to include new data and modified as conditions in the watershed change over time. It will evolve as needs and circumstances dictate and will be guided by the stakeholders themselves as they undertake active stewardship of the watershed.

Table of Contents

List of Figures

List of Tables

Executive Summary

The Plum Creek Watershed is very diverse, ranging from one of the state's most rapidly growing urban areas in the north to rural lands near the confluence with the San Marcos River. The creek itself played an important role in early development in the area and continues to be a valued resource for local citizens and communities. However, based on routine water quality sampling, the Texas Commission on Environmental Quality listed portions of Plum Creek for high nutrient concentrations in 1998, and in 2002, *E. coli* bacteria levels were identified as a concern. By 2004, *E. coli* data indicated that Plum Creek no longer supported the designated use of human contact recreation, and additional sections of the stream were identified as having high nutrient levels. While not all *E. coli* cause disease, their presence can indicate a potential health threat in the water. When nutrients are present at high levels, excessive growth of algae and aquatic plants can occur and result in damage to aquatic habitat, loss of recreation opportunities, and fish kills.

As a result of these issues, a special advisory committee of the Texas State Soil and Water Conservation Board selected Plum Creek in December 2005 for a voluntary effort to improve water quality. The Plum Creek Watershed Partnership, composed of local stakeholders, was formed to guide the planning process and address the bacteria and nutrient concerns in the stream. Led by a Steering Committee, the Partnership works with citizens, businesses, and officials in the watershed to restore the health of Plum Creek, recognizing that success in improving and protecting water resources depends on the people who live and work there. The Plum Creek Watershed Protection Plan created through these efforts and presented here, will serve as a guidance document for restoring and protecting local water quality.

The Steering Committee, along with topical work groups created by the Partnership, dedicated significant time to the identification of potential sources of pollutants in the Plum Creek Watershed (listed below). Many pollutant sources, such as human and animal waste, can contribute both *E. coli* and nutrients. Some land use practices, such as crop production and lawn and landscape fertilization, also affect nutrient levels.

Potential Sources	Bacteria	Nutrients	Other
Urban Runoff	X	X	X
Pets	X	X	
Wastewater			
Septic Systems	X	X	X
Wastewater Treatment Facilities	X	X	X
Agriculture			
Sheep and Goats	X	X	
Horses	X	X	
Cattle	X	X	
Cropland		X	X
Wildlife			
Deer	X	X	
Feral Hogs	X	X	
Oil and Gas Production			X

Through scientific analysis, researchers supporting the Partnership determined how much bacteria and nutrient levels in Plum Creek should be reduced in each monitored region of the watershed (below). The Uhland region contains Kyle and parts of Buda and Mountain City. The Lockhart region contains Lockhart, Niederwald, and most of Uhland and Mendoza. The Luling region contains Luling and several smaller communities. Specific water quality improvement activities will be focused in each of these regions.

Pollutant Reduction Needed			
Region	***E. coli* Bacteria**	**Phosphorus**	**Nitrate**
Uhland	65%	27%	43%
Lockhart	15%	49%	80%
Luling	41%	0%	1%

Based on an evaluation of existing water quality data and watershed characteristics (land use, topography, etc.) and information, the work groups recommended management measures needed to reduce pollutant levels in Plum Creek. Key recommendations adopted by the Steering Committee include the following:

The Urban Stormwater and Nonpoint Source work group has worked with area cities to develop strategies that both meet city needs and help improve water quality. One major goal is to put in place stormwater control measures through city programs and public outreach. These efforts will be guided by stormwater engineering analyses to be completed for each of the major cities. City specific efforts also include enhanced street sweeping programs and public grounds maintenance to reduce runoff and pollutant losses. In addition, city ordinances and collection facilities are proposed to address management of dog waste, which was identified as a significant potential pollutant source.

The Wastewater and Industry work group engaged critical parties to promote signing of the East Hays County Wastewater Compact, an agreement between cities and wastewater treatment facilities to generate cooperation and improve water quality. Larger cities also committed to investigate techniques for phosphorus removal from wastewater before it enters Plum Creek. Cities also will implement and/or continue on-going efforts to replace old sewer pipes and upgrade overflow management systems, where necessary and appropriate. In rural areas of the watershed that rely on septic systems, resources will be directed toward increased inspection and repair capabilities.

The Agricultural Nonpoint Source work group recommends implementation of voluntary site-specific Water Quality Management Plans for individual farms. Enhanced planning and financial assistance will be provided to farmers and ranchers for development of management plans that reduce bacteria and nutrient losses and meet the needs of each farm operation. Activities including prescribed grazing, buffer strips, and nutrient management are highly recommended as pollution control approaches in the Plum Creek Watershed.

To address increasing concerns over feral hogs, the Water Quality and Habitat work group recommends close cooperation with the Texas Wildlife Damage Management Service. A new position will be created to work directly with landowners to remove animals from the watershed by trapping and hunting. This effort will be further supported by development of a reporting website to identify target areas with significant hog activity.

The Outreach and Education work group defined a wide range of supporting education and training programs to encourage public awareness and involvement in implementation of the Plum Creek Watershed Protection Plan. In urban areas, online and direct training programs will be provided for city and county personnel on pollution, stormwater control, nutrient management, and wastewater treatment. At the same time, public education will focus on programs including proper management of septic systems, pet waste, and fertilizer nutrients. Landowners and agricultural producers will receive training in selection and management of practices designed to control bacteria and nutrients, and in strategies for control of feral hogs and illegal dumping.

As the recommended pollution control measures of the Plum Creek Watershed Protection Plan are put into action, it will be necessary to track water quality over time and make any needed adjustments to the strategy. Routine water quality testing programs at the three existing monitoring stations in the watershed will be continued throughout the implementation phase. In addition, the Guadalupe-Blanco River Authority will conduct a special water quality monitoring project that will allow researchers to more closely pinpoint the timing and sources of high pollutant levels. This monitoring project will help focus management activities and track the performance of ongoing restoration efforts.

Finally, the Plum Creek Watershed Partnership will continue to meet on a quarterly, or as needed, basis to receive updates on the progress of implementation efforts and guide the program through adaptive management actions. Ultimately, it is the goal of the Partnership and this plan to improve and protect water quality in Plum Creek so that the stream is restored and preserved for current and future generations.

1. Watershed Management

WATERSHED DEFINITION

A **watershed** is an area of land that water flows across, through, or under on its way to a single common point in a stream, river, lake, or ocean. Watersheds include not only water bodies such as streams and lakes, but also all the surrounding lands that contribute water to the system as runoff during and after rainfall events. Relationships between the quality and quantity of water affect the function and health of a watershed. Thus, significant water removals (such as irrigation) or water additions (such as wastewater discharges) are important. Watersheds can be extremely large, covering many thousands of acres, and often are separated into smaller **subwatersheds** for the purposes of study and management.

WATERSHEDS AND WATER QUALITY

To effectively address water issues, it is important to examine all natural processes and human activities occurring in a watershed that may affect water quality and quantity. Runoff that eventually makes it to a water body begins as surface or subsurface water flow from rainfall on agricultural, residential, industrial, and undeveloped areas. This water can carry with it pollutants washed from the surrounding landscape. In addition, wastewater from various sources containing pollutants may be released directly into a water body. To better enable identification and management, potential pollutants are classified based on their origin as either point source or nonpoint source pollution.

Point source pollution is discharged from a defined location or a single point, such as a pipe, drain, or wastewater treatment plant. It includes any pollution that may be traced back to a single point of origin. Point source pollution is typically discharged directly into a waterway and often contributes flow across all conditions, including both droughts and floods. In Texas, dischargers holding a wastewater permit through the Texas Pollutant Discharge Elimination System (TPDES – see Appendix A for a complete list of acronyms) are considered point sources, and their effluent is permitted with specific pollutant limits to reduce their impact on the receiving stream.

Nonpoint source pollution (NPS), on the other hand, comes from a source that does not have a single point of origin. The pollutants are generally carried off the land by runoff from stormwater following rainfall events. As the runoff moves over the land, it can pick up both natural and human-related pollutants, depositing them into water bodies such as lakes, rivers, and bays. Ultimately, the types and amounts of pollutants entering a water body will determine the quality of water it contains and whether it is suitable for particular uses such as irrigation, fishing, swimming, or drinking.

Figure 1.1. Lowland near confluence with the San Marcos River. A key feature of watershed management is addressing issues across the landscape.

BENEFITS OF A WATERSHED APPROACH

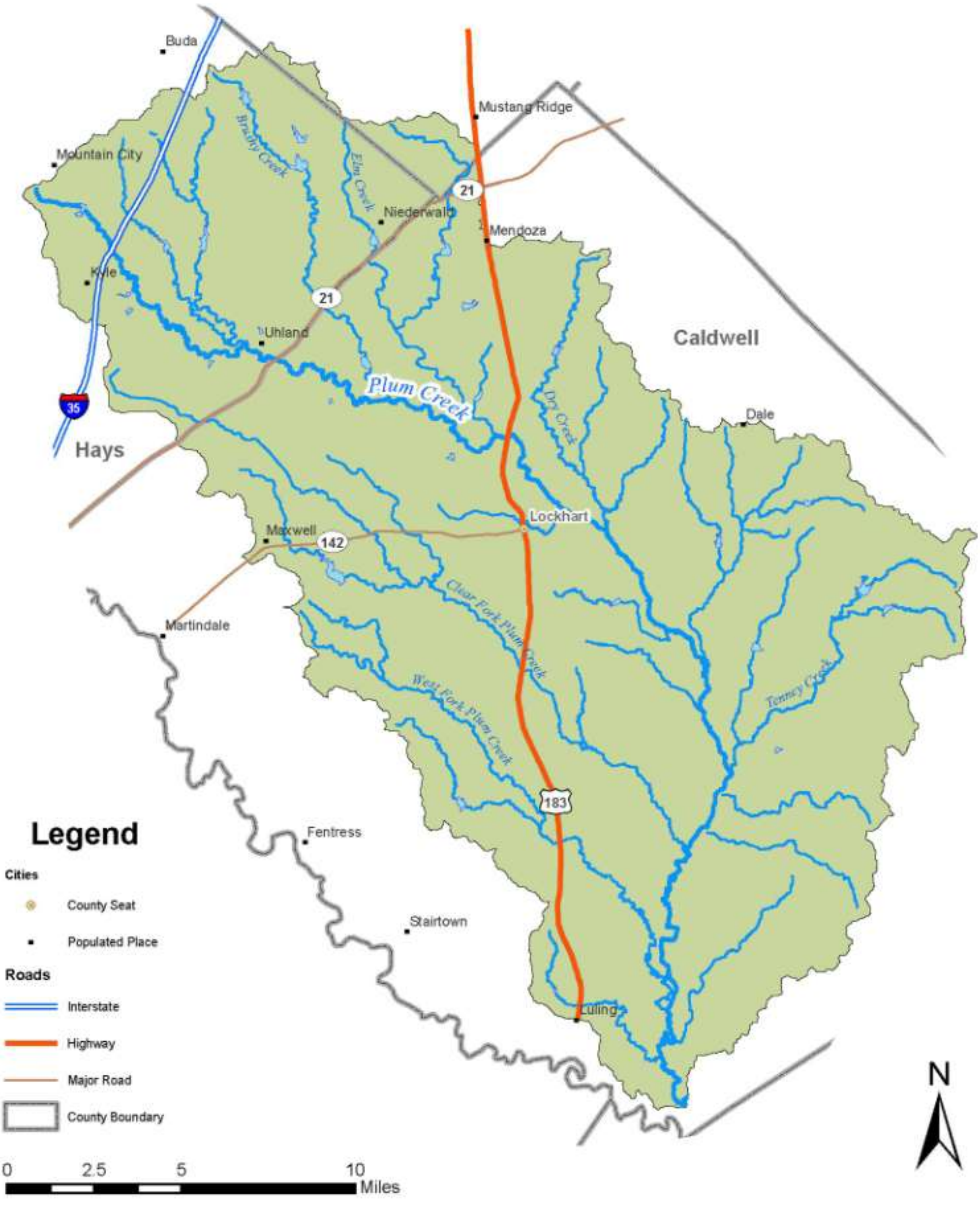
Because watersheds are determined by the landscape and not political borders, watersheds often cross municipal, county, and state boundaries (Figure 1.1). By using a watershed perspective, all potential sources of pollution entering a waterway can be better identified and evaluated. Just as important, all stakeholders in the watershed can be involved in the process. A watershed stakeholder is anyone who lives, works, or engages in recreation in the watershed. They have a direct interest in the quality of the watershed and will be affected by planned efforts to address water quality issues. Individuals, groups, and organizations within a watershed can become involved as stakeholders in initiatives to protect and improve local water quality. Stakeholder involvement is critical for selecting, designing, and implementing management measures to successfully improve water quality.

Figure 1.2. Town Branch runs clear near springs in Lockhart City Park. By engaging diverse interests, the stakeholder process strengthens the ability to protect water resources.

WATERSHED PROTECTION PLANNING

A Watershed Protection Plan is typically developed according to the Elements of Successful Watershed Plans (see Appendix B) by local stakeholders with the primary goal being to restore and/or protect water quality and designated uses of a water body through voluntary, non-regulatory water resource management (Figure 1.2). Public participation is critical throughout plan development and implementation, as ultimate success of any Watershed Protection Plan depends on stewardship of the land and water resources by landowners, businesses, elected officials, and residents of the watershed. The Plum Creek Watershed Protection Plan defines a strategy and identifies opportunities for widespread participation of stakeholders across the watershed to work together and as individuals to implement voluntary practices and programs that restore and protect water quality in Plum Creek.

Plum Creek Watershed



2. State of the Plum Creek Watershed

GEOGRAPHY

Ecology

The Plum Creek Watershed has a drainage area of 397 square miles (1028 km^2) and lies within the Guadalupe River Basin, which drains South Central Texas from the Hill Country to the Gulf of Mexico. The Plum Creek Watershed includes portions of Hays and Travis Counties and much of Caldwell County. Elevations in the area range from 303 feet (92m) near the San Marcos River to 891 feet (272m) in the northern reaches of the watershed (Figure 2.1).

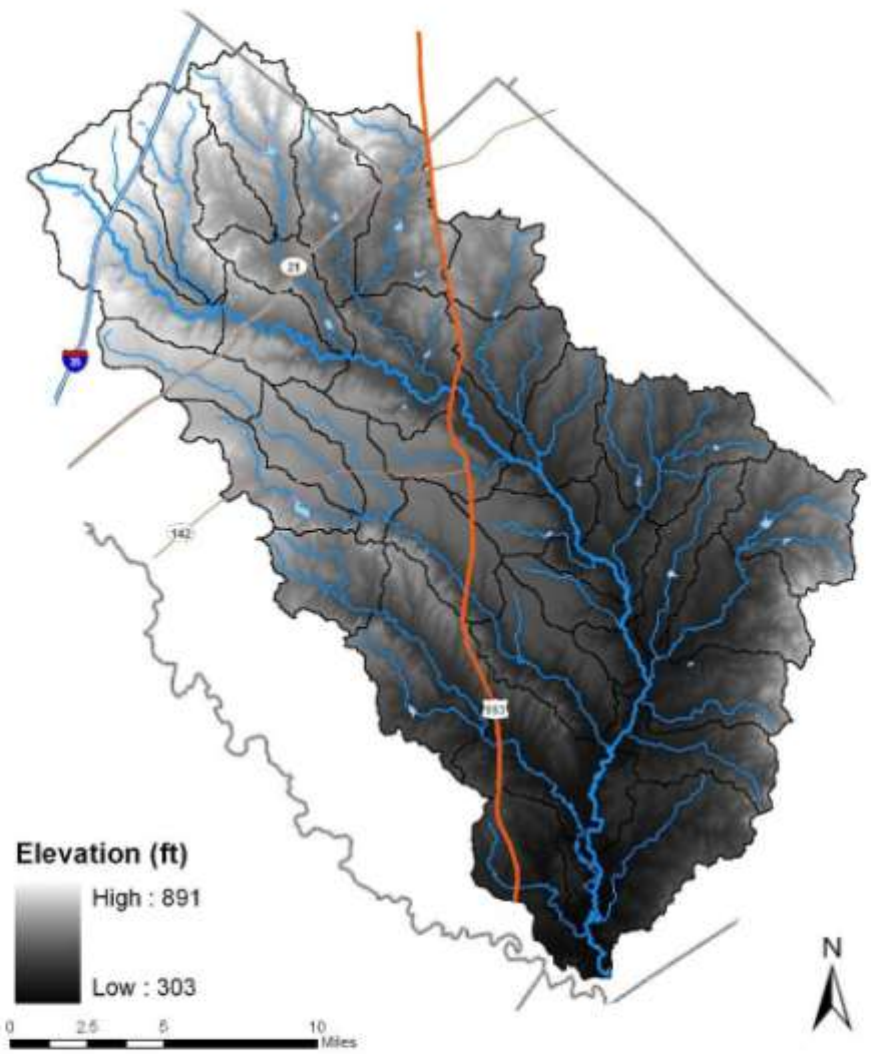


Figure 2.1. Digital elevation model of the Plum Creek Watershed. Elevations near 900 feet are found at the upper end of the watershed, while areas near the confluence with the San Marcos River are approximately 300 feet in elevation.

The upper reaches of Plum Creek fall within the Texas Blackland Prairies ecoregion, which historically was dominated by tallgrass species on uplands and by deciduous woodlands along riparian corridors (Figure 2.2). The downstream landscape is located in the East Central Texas Plains ecoregion, an area originally characterized by post oak savanna, having tallgrasses interspersed with oaks and other hardwoods, as well as juniper. Riparian corridors in the Plum Creek Watershed are characterized by pecan, elm, and oak bottomlands. In the past, open areas in both ecoregions were maintained by natural fires and grazing by large herbivores. Fire suppression has resulted in encroachment of woody plant species in many areas. Animals native to the area include white-tailed deer, javelina, beaver, bobcat, coyote, fox, skunk, raccoon, squirrel, turkey, and a diverse array of small mammals and birds. In addition, feral hog populations in the area are believed to be significant and increasing.

Soils

Soils across both ecological areas are highly varied. Far southeastern portions of the Plum Creek Watershed in Caldwell County contain primarily deep, noncalcareous, sandy soils over clays, sandy clay loams, and fine sandy loams of the Padina-Silstid-Chazos association. Uplands in much of the watershed are characterized by deep, calcareous to noncalcareous, loamy to clayey soils over shaly clay loams and clays of the Houston Black-Heiden-Altoga, Branyon-Lewisville-Barbarosa, and Crockett-Luling-Benchley associations. Bottomland areas along much of Plum Creek and lower portions of West Fork and Clear Fork are mostly deep, calcareous, clayey soils over clays of the Meguin-Trinity-Degola association. Along Interstate 35 near Kyle, there are shallow to deep, gently sloping to sloping soils over chalk or marly clay in the Austin-Houston Black-Stephen association typical of upland Blackland Prairies. Extreme northern areas of the watershed north and west of Kyle have soils that are very shallow to moderately deep, undulating to steep and hilly over hard limestone of the Comfort-Rumple-Rock Outcrop association. This area of the Plum Creek Watershed overlies the southern limit of the Edwards Plateau.

Figure 2.2. Tributary and pasture along State Highway 21. Contrasting landscape of Plum Creek Watershed shown by densely vegetated riparian corridors and more open upland areas dominated by grasses.

Water Resources

The Plum Creek Watershed overlies the Carrizo-Wilcox formation and a small section of the Edwards-Balcones Fault Zone in Hays County, both of which are water-bearing geologic formations. The Carrizo and Wilcox aquifers in the southern and eastern portions of the watershed contain the majority of the usable groundwater storage in the area and are considered to be stable and dependable (Follett 1966). These formations have been the focus of widespread development of groundwater resources. Water quality in the Carrizo Sand and Wilcox group is generally suitable for public municipal supply, irrigation, and industrial purposes, though some areas are affected by high nitrate and chloride concentrations. Local historical observations suggest elevated salinities may be partially explained by leaky oil well casings or seepage of brine from operating oil pads, but the location of faults and nature of circulation patterns within the Carrizo-Wilcox Aquifer likely also contribute to the upward movement of saline groundwater (Follett 1966).

Much of Clear Fork Plum Creek, mostly in Caldwell County, is fed by perennial Leona formation springs arising near State Highway 142. Additional springs located around Lockhart contribute flow to Plum Creek (Figure 2.3), resulting in year-round flow at the southern end of the watershed.

Figure 2.3. Rocky outcrop and springs in Lockhart City Park on Town Fork Plum Creek.

Surface water plays a major role in the watershed and is considered sufficient for agricultural use in most areas. However, surface water is susceptible to heavy siltation during runoff events and may become severely limited in periods of drought. Through the Watershed Protection and Flood Prevention Program, the Plum Creek Conservation District currently operates 28 flood control structures in Hays and Caldwell Counties, which have a total storage of approximately 46,800 acre feet and a flood storage capacity of 36,300 acre feet. The Conservation District also oversees the use and quality of groundwater resources in the area. Though groundwater has been the primary drinking water supply in the past, a significant portion of water supplies in the Plum Creek Watershed now comes from surface water, including reliance on San Marcos River water pumped from lower portions of Caldwell County near Luling. The City of Luling depends on this supply of surface water, as do many other cities in the watershed. Lockhart currently receives 80% of its water from the San Marcos River, following recent completion of a pipeline to the city.

Climate

Plum Creek lies in a semi-humid subtropical climate zone and is heavily influenced by its proximity to the Gulf of Mexico. Prevailing winds are southerly throughout the year, and as a result, only moderate variations in average temperature and precipitation values are observed from month to month. However, actual weather varies widely from year to year. For example, average annual rainfall is 33 inches (838 mm), but has ranged from 7 inches (178 mm) to almost 60 inches (1524 mm) over the last 30 years. On average, slightly more rainfall occurs in late spring and early fall, and summer rains fall as infrequent downpours associated with thunderstorms. Individual rainfall events also result in a variable distribution of rainfall, with adjacent locations often receiving substantially different storm rainfall totals. Torrential rains accompanying tropical systems during summer and fall can be significant but are rare. Winter rain events are often long in duration but usually light in intensity.

Winters are mild, with January mean temperatures of approximately 48°F (9ºC). Summers are generally hot, with July mean temperatures of 85°F (29ºC). Annual average potential evaporation is more than double the average annual rainfall, resulting in significant drawdown of surface water in summer months and during dry periods.

HISTORY OF THE PLUM CREEK WATERSHED

Early Settlement

Following years of limited Spanish settlement in the area, the lands surrounding and including the Plum Creek Watershed experienced increased immigration with the establishment of land grants in the region. To spur settlement after the Mexican War for Independence, numerous colonies were chartered in the 1820s and 1830s. Settlers from Mexico and the United States moved into the region. Plum Creek played a major role in this colonization, as most of the small communities were established along the waterway and its tributaries. The availability of water from freshwater springs fueled ongoing settlement. In the 1830s, the Texas War of Independence slowed settlement and even led to the departure of some pioneering Texans as many settlers fled the conflict. Upon the establishment of the Republic of Texas, the region’s population again underwent significant growth.

The Battle of Plum Creek

This influx of settlers caused friction with Native Americans in the area, and several skirmishes and raids plagued the area. In 1840, bands of Comanche chiefs and warriors passed through the area following a raid in retaliation for the death of many Comanche representatives on an ill-fated peace mission in the Council House Fight in San Antonio a few months earlier. Retracing their steps along the Guadalupe Valley after attacking several settlements including Linnville and Victoria, the raiding party was intercepted along Plum Creek near present-day Lockhart by a combined army of volunteers, Texas Rangers, and Tonkawa Indians. By the end of a running fight covering 15 miles, more than 80 Comanche warriors were reported killed, while only one Texan was killed. Some of the plunder taken in the raids was recovered, and the Battle of Plum Creek proved to be pivotal in ending significant conflict with Comanche bands in the area.

Growth of Agriculture

By the late 1840s, Caldwell, Hays, and Travis Counties were established, and the area population continued to grow along with the cattle industry and again later as traffic increased along the Chisholm Trail. After the Civil War and following widespread economic hardship during the Reconstruction period, farming also became more profitable, drawing more settlers to the area. The expansion of rail lines into the area fueled settlement and offered easy access to markets, causing additional growth in farming and the cattle industry. Cotton farming grew in importance until the early 1900s, but was eventually replaced by livestock as fertile soil in the area was depleted.

Oil Boom

The discovery of oil in Caldwell County in 1922 lessened the dependence on agriculture in the area, and petroleum production began to replace agriculture as the main economic contributor. Oil exploration quickly grew, and the oil industry generated tremendous income for invested partners. Following discovery of the Luling field, Edgar B. Davis funded construction of a golf course, athletic facilities, and other public projects in the vicinity, including the Luling Foundation. Additional exploration resulted in the development and expansion of the oilfields in and around Luling (Figures 2.4 and 2.5), and production quickly rose to 11 million barrels per year beginning in 1924. Oilfield workers poured into the watershed, resulting in rapid development of the land around Luling. The city population jumped from near 500 to over 5,000 as workers arrived and attracted other service industries. Over the following decades, production fluctuated with market demand. Oil production statewide peaked in the early 1970s then slowly declined until the 1980s, when sharp declines in the price of oil drove local economic dependence to other industries. However, recent increases in oil and gas prices have resulted in small numbers of old wells being returned to production beginning in 2004.

Figure 2.4. Oilfield in production between Luling and Lockhart in Caldwell County.

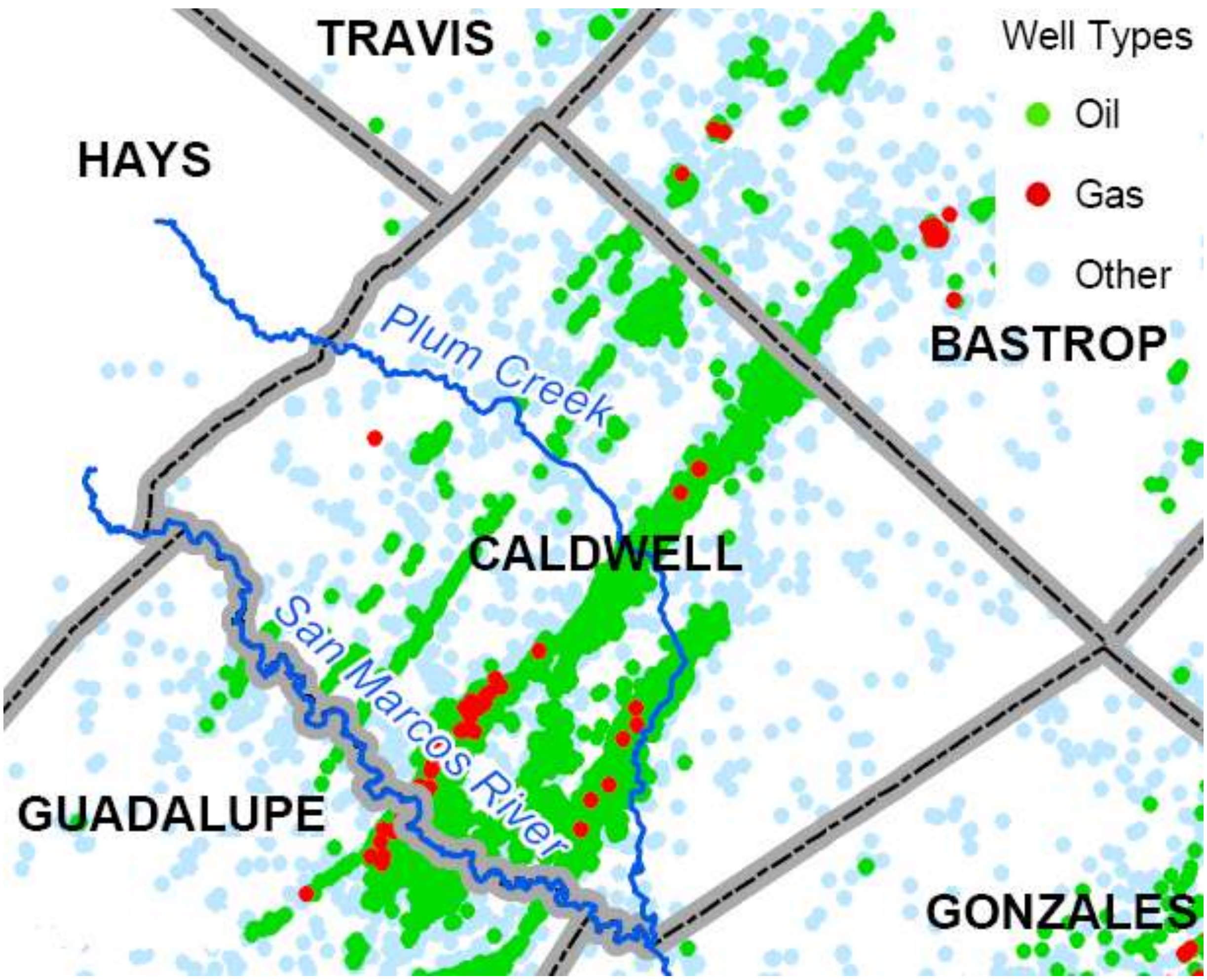


Figure 2.5. Location of documented oil, gas, and other wells in the Plum Creek Watershed and surrounding areas in April 2007. Source: The Railroad Commission of Texas.

CURRENT CONDITIONS

Oil Production

The vast majority of oil wells in the watershed are concentrated in Caldwell County in an area north of Luling. According to the Railroad Commission of Texas (RRC), the number of oil wells in production in Caldwell County has remained relatively stable at around 3,500, with slight fluctuations between years. Of these, most are located in the Plum Creek Watershed, with the remainder found near the San Marcos River. In 2006, high market values of crude oil resulted in a higher number of wells in production than had been seen in several years (Table 2.1).

Table 2.1. Number of oil wells in production and total oil wells in Caldwell County by year. Statistics collected in February of each year. Source: The Railroad Commission of Texas.

Year	Producing Wells	Total Wells
2000	3,178	4,623
2001	2,917	4,541
2002	2,873	4,479
2003	2,739	4,450
2004	3,046	4,357
2005	2,982	4,326
2006	3,126	4,283

Historical monitoring indicates no significant surface water contamination by total petroleum hydrocarbons or benzene, toluene, ethylbenzene, or xylene (chemical compounds found in crude oil) has occurred. However, in 1999, the Texas Commission on Environmental Quality (TCEQ) directed the removal of contaminated soil around a petroleum transmission line near Plum Creek. Though there is no evidence of widespread contamination from petroleum pollutants, the potential for isolated incidents of leaks and pollution transported by rainfall runoff does exist. Locations in southern areas of the Plum Creek Watershed, downstream from the highest concentration of oil wells, face the greatest potential risk of water pollution from oil and gas production. Gas production in Plum Creek is currently minimal, with only a handful of wells in operation in Caldwell County.

Under normal oilfield operations, operators check their wells and tank batteries on a daily basis to gauge production and evaluate well status. However, orphaned wells, as their name implies, no longer have a responsible party and thus are not regularly inspected or maintained. There are a significant number of abandoned wells in the Plum Creek Watershed (Figure 2.6). The RRC must inspect these abandoned wells to determine their condition and evaluate them either for referral for legal enforcement action or for plugging under the state plugging program funded by the agency.

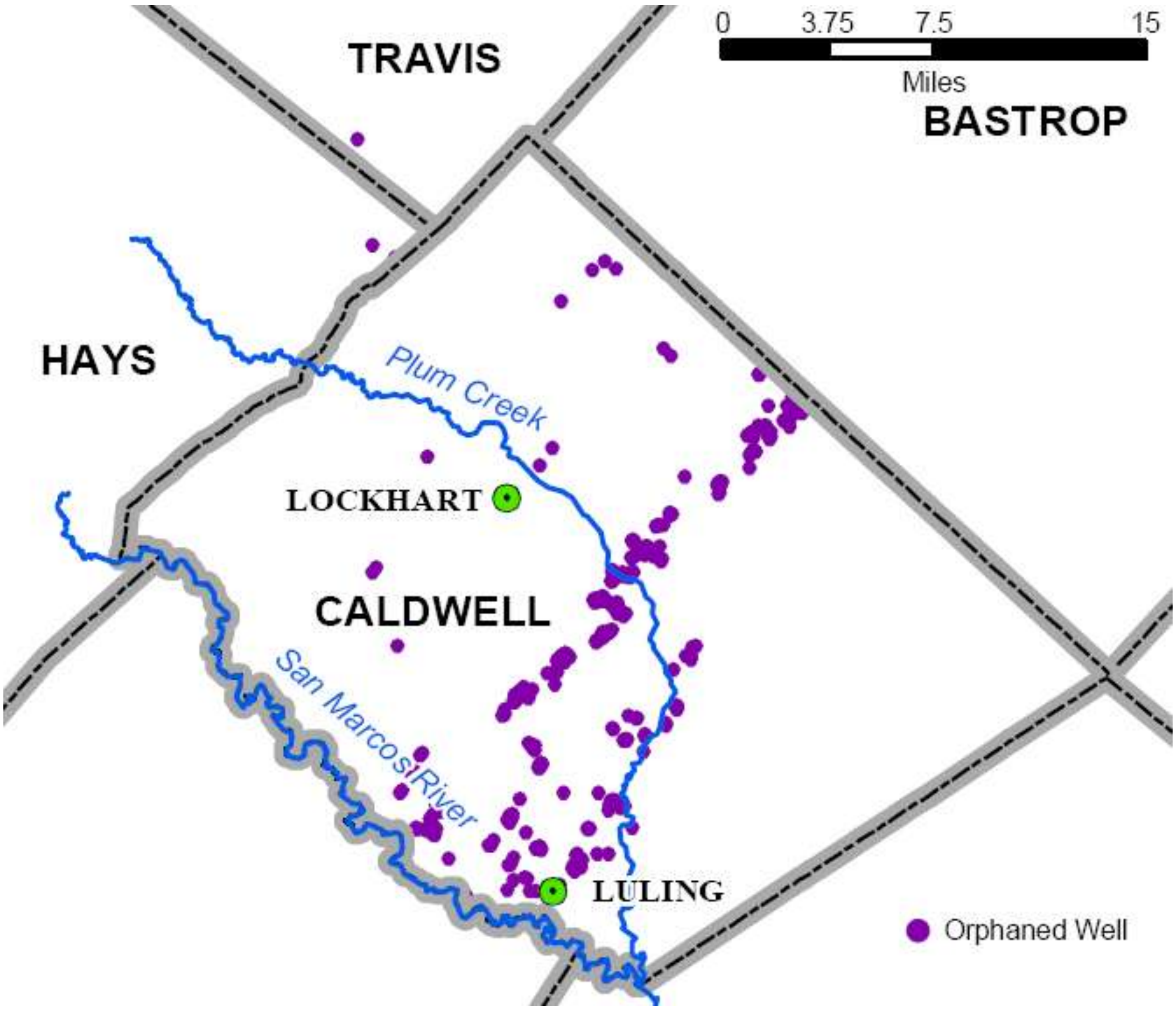


Figure 2.6. Location of documented abandoned wells in the Plum Creek Watershed and surrounding areas in March 2007. Source: The Railroad Commission of Texas.

Livestock and Crop Production

Due to their natural characteristics and location with respect to topography, soils, and weather patterns, both the Texas Blackland Prairies and East Central Texas Plains ecoregions in this part of the state have undergone widespread conversion for agricultural use, as both cultivated croplands and rangelands (Figure 2.7). Current agricultural land uses in the Plum Creek Watershed include beef cattle and hay production in addition to row cropping of corn, sorghum, wheat, and cotton. Watermelon production is also a locally important industry around the city of Luling. In 2004, approximately 11% of the Plum Creek Watershed was under active cultivation for the production of annual crops. While land in cotton production has remained relatively constant the last 2-3 years, much of the land previously devoted to sorghum and wheat has been converted to corn production in response to rises in market value.

Figure 2.7. Corn and beef cattle in early spring around Plum Creek. Row crops and livestock are important industries in the watershed.

Rangeland for grazing cattle comprises a large percentage of the landscape (approximately 38% in 2004), and is by far the most common land use class in the watershed. As a result, cattle production is a dominant industry in the watershed. While rangeland dominated by grasses is common, much of the rangeland in Caldwell, Hays, and Travis Counties has experienced widespread invasive growth of brush including mesquite, which is particularly problematic in areas without active brush management. Excessive growth by invasive plant species affects the distribution of cattle which cannot move easily through dense brush, and reduces production of desirable forage plants.

Urban Development

While the area has a largely agricultural history and remains heavily influenced by farming and livestock, portions of the watershed are undergoing significant change (Figure 2.8). In 2004, urban land use accounted for 8.4% of the total land area in the Plum Creek Watershed. Northern sections of the watershed, particularly near Kyle and Buda along the Interstate 35 corridor, have been marked by rapid suburban growth, with city populations rising quickly over only a few years (Table 2.2). The 2005 U.S. Census estimated the population of Kyle at 17,770 compared to only 5,314 in 2000. This growth mirrors what is occurring elsewhere in Hays County (Table 2.3), making it the fourth fastest-growing county in Texas between 2000 and 2006.

Figure 2.8 (following). Historic Caldwell County courthouse in Lockhart.

Table 2.2. Population of incorporated cities completely or partially within the Plum Creek Watershed. Cities are listed alphabetically. Source: Texas State Data Center and Office of the State Demographer.

City	2000 Census Population	2006 Population Estimate	Percent Change
Buda	2,404	4,424	84.0
Kyle	5,314	19,335	263.9
Lockhart	11,615	12,978	11.7
Luling	5,080	5,704	12.3
Mountain City	671	773	15.2
Mustang Ridge	785	953	21.4
Niederwald	584	416	-28.8
Uhland	386	425	10.1

Table 2.3. Population of counties partially within the Plum Creek Watershed. Source: Texas State Data Center and Office of the State Demographer.

County	2000 Census Population	2006 Population Estimate	Percent Change
Caldwell	32,194	35,383	9.9
Hays	97,589	129,129	32.3
Travis	812,280	907,922	11.8

Among the numerous smaller towns and unincorporated settlements in the Plum Creek Watershed, Mountain City and Uhland also anticipate rising populations and associated impacts in the future, though population growth in the recent past has been slow. A growing number of watershed citizens are employed in various industries outside the watershed in Austin and nearby San Marcos. These residents commute to urban centers in neighboring counties but live in outlying areas in the watershed (Figure 2.9).

Other cities in the central and southern reaches of the watershed have not experienced rapid growth, but likely will be affected by construction of future segments of State Highway 130, a tollway which will dramatically alter transportation around the Austin metropolitan area. The highway will run very near Lockhart, passing west through the current outskirts of town before joining U.S. Highway 183 to the north. As development and population growth continue, the percentage of urban land use will rise and play an increasingly important role in the hydrology and water quality of Plum Creek and its tributaries. Increases in impervious cover result in flashy and more variable flows, with both higher floods and lower base flows affecting streams in some areas of the watershed.

Figure 2.9. Plum Creek community near Kyle and others demonstrate the rapidly growing population in northern portions of the Plum Creek Watershed.

Demographics

Economic growth in the northern part of the watershed has resulted in increases in median household income with respect to the state average of $39,927 (Table 2.4). The majority of residents in the counties comprising the watershed area have completed high school, and a growing number have received a degree at a college or university (Table 2.5).

Table 2.4. 2000 Median household income for Plum Creek counties. Source: Texas State Data Center and Office of the State Demographer.

County	Median Household Income
Caldwell	$36,573
Hays	$45,006
Travis	$46,761
Texas Average	$39,927

Table 2.5. Residents 25 years or older having completed high school or received a college level or higher degree in Plum Creek counties in 2000. Source: Texas State Data Center and Office of the State Demographer.

County	Education (Percent)	
	High School Diploma	College Diploma
Caldwell	71.3	13.3
Hays	84.7	31.3
Travis	84.7	40.6
Texas Average	75.6	23.2

Most residents speak English as their primary language. However, a significant portion of the population speaks a different language in the home (Table 2.6). A proper understanding of each of these audiences, their perspectives, and how to engage them is critical for successful implementation of management measures to improve water quality in the watershed. It will be the people of these counties who take ownership of the water resources and actively participate in efforts to maintain or restore the quality of the watershed and its waterways.

Table 2.6. Primary language spoken by residents of Plum Creek counties in 2000. Source: Texas State Data Center and Office of the State Demographer.

County	Language Spoken at Home (Percent)	
	English	Non-English
Caldwell	67.7	32.3
Hays	76.9	23.1
Travis	71.3	28.7
Texas Average	68.8	31.2

WATER QUALITY

Stream Segment Description

Beginning near Kyle in eastern Hays County, Plum Creek flows 52 miles (84 km) before its confluence with the San Marcos River south of Luling. Plum Creek is fed by many small streams and tributaries, including Porter Creek, Brushy Creek, Elm Branch, Dry Creek, and the West Fork and Clear Fork of Plum Creek. Slope on Plum Creek is low, falling only 425’ (130m) over its course. Though some downcutting has been observed, no significant alteration to the stream channel has occurred. The stream contains a series of pools in the lower portion of the drainage, resulting in low flow velocities and depressed levels of dissolved oxygen (Texas Water Commission 1991).

Plum Creek proper, the main waterway classified as Segment 1810 by the TCEQ, is documented in the Texas Water Quality Inventory and includes Plum Creek from near FM 2770 in southeastern Hays County to the San Marcos River. It has been designated for high aquatic life, contact recreation, general, and fish consumption uses. The stream currently has 3 water quality monitoring stations. Stations 17406 on Plum Creek Road near Uhland and 12640 on Caldwell County Road 135 near Luling are monitored monthly by the Guadalupe-Blanco River Authority (GBRA). Station 12647 is located one mile south of Caldwell County Road 202 near Lockhart and is monitored quarterly by the TCEQ (Figure 2.10).

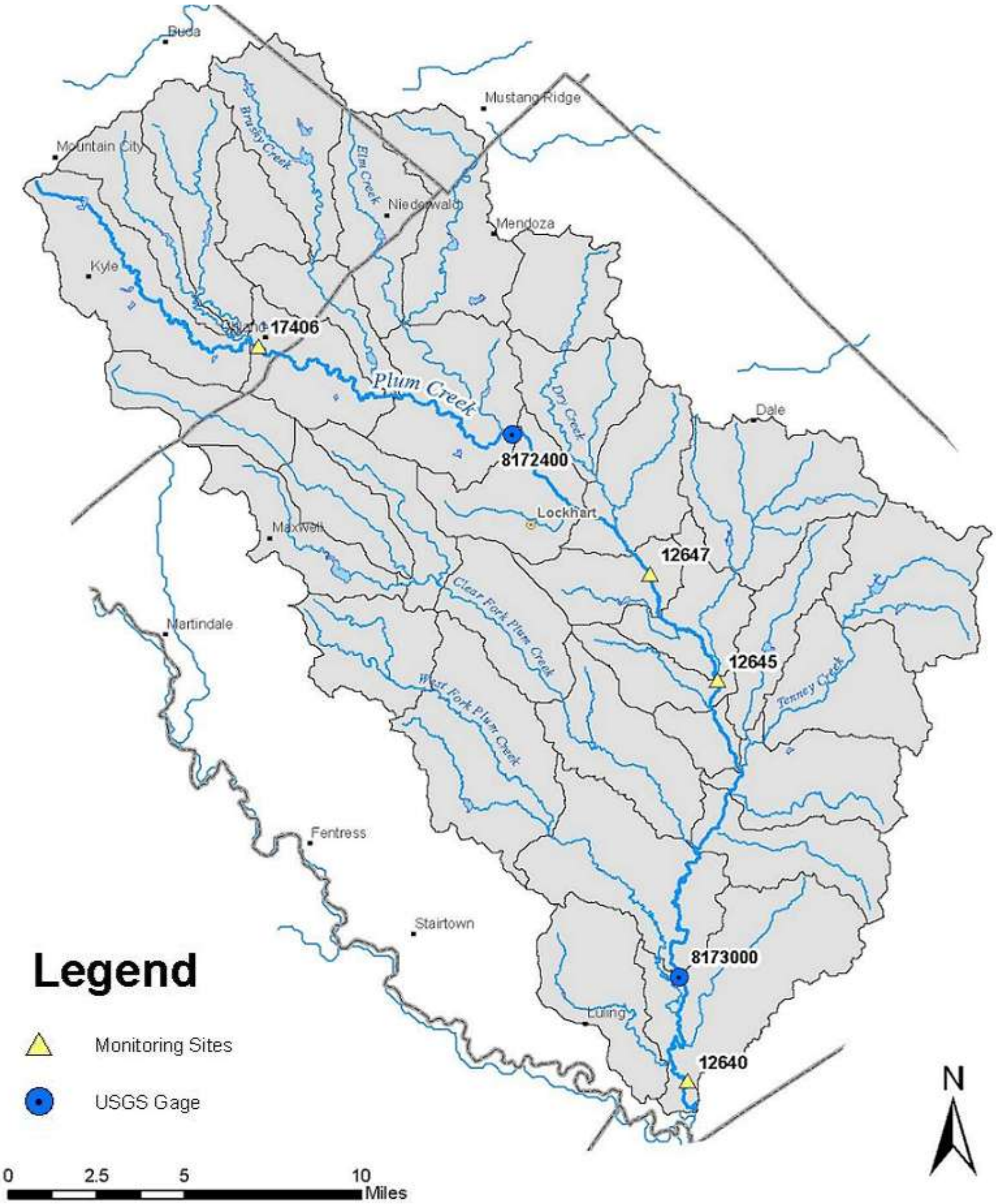


Figure 2.10. Map of the Plum Creek Watershed showing the location of current water quality monitoring stations and USGS flow gages.

Plum Creek is a shallow, intermittent stream that historically ran dry in times of drought and under summer conditions but responded quickly during significant rainfall events. Two US Geological Survey (USGS) gage stations are located on Plum Creek to monitor streamflows: one north of Lockhart (Station 08172400) and one near Luling (Station 8173000). Near Lockhart (Figure 2.11), periods of no flow have occurred almost every year on record. Prior to human development and associated impacts, northern portions of the creek were mostly dependent on runoff and were driven by rainfall events because of lower groundwater contributions. Southern reaches of Plum Creek, particularly south of Lockhart, are fed by a number of small springs and are usually perennial.

Figure 2.11. USGS gage station on Plum Creek north of Lockhart in Caldwell County.

Bacteria Impairment

Based on routine water quality sampling, the TCEQ initially listed portions of Plum Creek for bacteria impairment of the contact recreation use in 2002. By 2004, Plum Creek appeared on the Texas 303(d) List of Impaired Waters. This means that the stream does not support the designated use of contact recreation, which includes wading and swimming. Under the Texas Surface Water Quality Standards, water quality criteria for contact recreation in freshwater streams consist of 2 parts. The first criterion is a geometric mean concentration of 126 *Escherichia* c*oli* (*E. coli*) colony forming units (cfu) per 100 milliliters of stream water (126 cfu/100 mL). The second criterion, based on grab samples, requires that no more than 25% of single samples from a given monitoring station exceed 394 *E. coli* cfu/100 mL. While the *E. coli* bacteria that are analyzed in typical water quality samples are not of the pathogenic strain, their presence can indicate the potential threat of other harmful bacteria found in the feces of warm-blooded animals.

Portions of Plum Creek were again included in the List of Impaired Waters for the 2006 assessment, covering the period of December 1, 1999 to November 30, 2004 (Table 2.7). Of the water samples collected at the Luling monitoring station, 8 of 58 samples (14%) exceeded the single sample criterion, and the geometric mean of all samples was 112 cfu/100 mL. As a result, this portion of Plum Creek was not listed as impaired by *E. coli* (However, analyses of data from the 2008 assessment indicates this monitoring station will soon be listed for bacteria impairment). The Lockhart monitoring station in the central portion of the watershed indicated no impairment by *E. coli* bacteria. The Lockhart station showed 2 of 13 samples (15%) exceeded the single sample criterion, with a geometric mean of 107 cfu/100 mL. In the northern portion of the Plum Creek Watershed, 8 of 37 samples (22%) exceeded the single sample criterion. However, the geometric mean of all samples collected at the Uhland monitoring station over the assessment period was 205 cfu/100 mL. As a result, contact recreation use in the upper portion of Plum Creek in Hays County was listed as impaired by *E. coli* bacteria from monitoring station 17406 near State Highway 21 to the top of the watershed (Figure 2.12). This section of Plum Creek was designated Category 5c on the 2006 303(d) List, meaning additional data and information will be collected before a regulatory Total Maximum Daily Load (TMDL) is conducted. Analyses of samples in the 2006 assessment indicated the downstream section of the segment is not currently impaired by bacteria, though periodically high levels of *E. coli* have been observed. The tributary streams in the Plum Creek Watershed are not individually assessed at this time, but they contribute to the quality of water in the mainstem of Plum Creek that is regularly monitored.

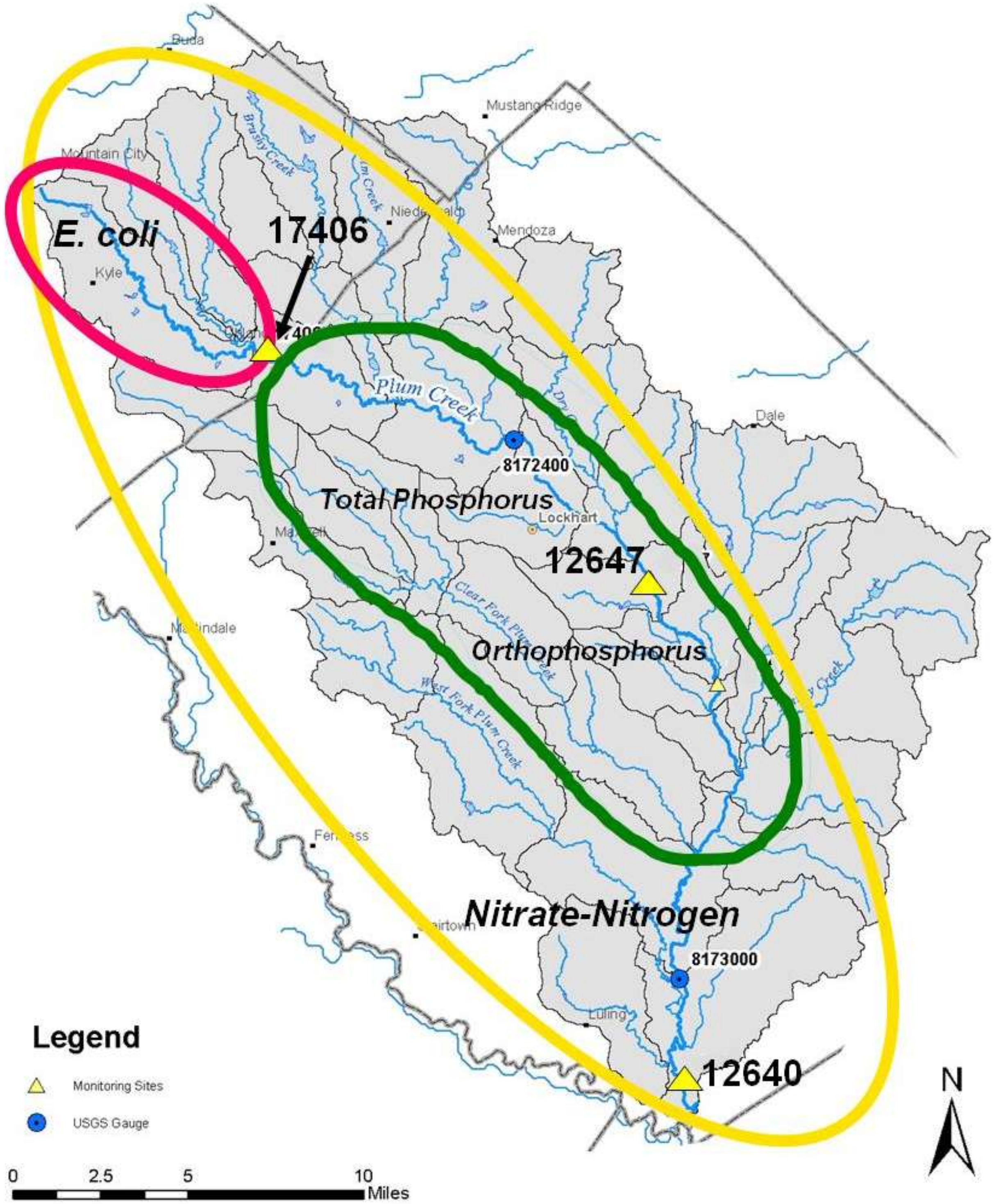


Figure 2.12. Bacteria impairment and nutrient concerns in the Plum Creek Watershed. Red oval indicates *E. coli* bacteria impairment. Green oval represents concern for orthophosphorus and total phosphorus, and yellow oval represents concern for nitrate-nitrogen.

Table 2.7. 2006 Texas Water Quality Inventory listing of bacteria impairment by bacteria and nutrient concerns for Plum Creek.

Assessment Area	Use/Concern	Status	Parameter
From approximately 0.5 miles upstream of State Highway 21 to upper end of the segment	Contact Recreation Impairment	Not Supporting	*E. coli* Bacteria
Confluence with San Marcos River to upper end of the segment	Nutrient Enrichment	Concern	Nitrate-Nitrogen
From approximately 2.5 miles upstream of confluence with Clear Fork Plum Creek to approximately 0.5 miles upstream of State Highway 21	Nutrient Enrichment	Concern	Orthophosphorus
From approximately 2.5 miles upstream of confluence with Clear Fork Plum Creek to approximately 0.5 miles upstream of State Highway 21	Nutrient Enrichment	Concern	Total Phosphorus

Figure 2.13. Plum Creek near Lockhart in Caldwell County has high levels of nitrogen and phosphorus, resulting in nutrient concerns in that portion of the stream.

Nutrient Concerns

Nitrogen and phosphorus compounds are among the most important nutrients affecting water quality. Nitrates are absorbed by aquatic plants and used to build cellular molecules, including proteins and genetic material. Phosphorus is critical in the construction of cell membranes and the transfer of energy within all organisms. When nutrients are present at high levels, excessive growth of algae and undesirable aquatic vegetation can occur, leading to a decreased ability to support designated uses of a stream. Damage to aquatic habitat, loss of recreation opportunities, and fish kills are possible outcomes of high nutrient levels in streams. While there currently are no regulatory criteria for nutrients in Texas, streams with high loads of these pollutants are assessed as having nutrient enrichment **concerns**. Streams are evaluated using screening criteria based on the 85th percentile of nutrient concentrations in all streams monitored in the state during the assessment period. As with the bacteria single sample criteria, exceedence of the screening criteria in 20% of samples collected over a given period results in nutrient concerns for that portion of the water body.

In the Plum Creek Watershed, sections of the stream have been identified as having nutrient enrichment concerns for nitrate (a form of nitrogen), orthophosphorus, and total phosphorus concentrations (Table 2.7). Based on the 2006 assessment covering the years from December 1999 to November 2004, screening criteria for these nutrients are 1.95 mg/L, 0.37 mg/L, and 0.69 mg/L, respectively. Nitrate and total phosphorus are measured at all 3 monitoring stations in the watershed, while orthophosphorus is measured only at the Lockhart station. Plum Creek has nitrate concerns along the entire length of the stream, from the upper portion of the watershed to the confluence with the San Marcos River below Luling. In the central portion of the watershed at the Lockhart monitoring station, concerns for both orthophosphorus and total phosphorus are indicated (Figures 2.12 and 2.13). At that station, 11 of 19 samples (58%) exceeded the orthophosphorus criterion, while the total phosphorus criterion was exceeded in 7 of 18 water quality samples (39%).

3. The Plum Creek Watershed Partnership

Watershed Selection

In December 2005, the Watershed Coordination Steering Committee (WCSC) of the Texas State Soil and Water Conservation Board's (TSSWCB) Wharton Regional Office selected Plum Creek to develop a watershed protection plan as a voluntary, non-regulatory alternative to addressing water quality issues. The WCSC is a cooperative committee of river authorities, local governments, and state and federal agencies with an interest in water quality and was formed to guide the regional process of watershed protection in a 47-county area in Southeast and South Central Texas. From 48 regional watersheds, Plum Creek was chosen based on the following:

- Impairment on Texas 303(d) List and additional nutrient concerns
- No TMDL or Watershed Protection Plan currently present
- Diverse and rapidly changing land use, with agricultural-urban interface
- Size amenable to both manageability and potential effectiveness
- Active Soil and Water Conservation District
- High level of County Extension Agent involvement
- High level of oil and gas production in portions of watershed
- Anticipated stakeholder buy-in and participation

Through this process, funding for development of the Plum Creek Watershed Protection Plan was provided through a federal Clean Water Act §319(h) grant to the Texas AgriLife Extension Service, administered by the TSSWCB through the United States Environmental Protection Agency (EPA).

Partnership Formation and Mission

Local public involvement is critical for successful development and implementation of a Watershed Protection Plan. To inform and educate citizens from across the watershed and engage them in the planning process, an intensive information and education campaign was conducted at the outset. Six press releases were developed and delivered in the watershed in advance of the planning process using key media outlets including local newspapers and newsletters. Over 700 notifications were sent by direct mail to known potential stakeholders throughout the watershed. In addition, presentations were made at meetings of numerous local groups and organizations, including:

- Plum Creek Conservation District Board
- Hays County Soil and Water Conservation District Board
- Caldwell-Travis Soil and Water Conservation District Board
- GBRA Board
- GBRA Clean Rivers Steering Committee
- Hays County Wildlife Management Training
- Luling Kiwanis Club
- Luling Foundation Field Day
- Kyle Citizen Water Advisory Board

Following these efforts, 3 public meetings were announced and held on 3 different dates in April 2006, with one each in the northern (Kyle), central (Lockhart) and southern (Luling) portions of the watershed. Over 100 stakeholders attended the public meetings at which information was provided regarding conditions in Plum Creek and the proposed development of a Watershed Protection Plan. Participants were invited to become members of the Plum Creek Watershed Partnership and asked to help notify other potential stakeholders that should be part of the process.

The goal of the resulting Plum Creek Watershed Partnership is to address the bacteria impairment and nutrient concerns in Plum Creek through the development and implementation of a Watershed Protection Plan designed to restore water quality in the stream. The Partnership works with all stakeholders and citizens in the watershed and with the support of state and federal agency partners to accomplish this goal and restore the health of Plum Creek.

PARTNERSHIP STRUCTURE

To guide the overall watershed protection plan development and implementation, the Partnership adopted the following structure.

Steering Committee

A Steering Committee was formed to represent the key stakeholder interests in the watershed and be the decision-making body for the Plum Creek Watershed Partnership. The process of identifying and inviting stakeholders to serve on the Steering Committee included consultation with County Extension Agents, the Plum Creek Conservation District, the GBRA, Caldwell-Travis and Hays County Soil and Water Conservation Districts, and local and regional governments. In addition, self-nomination and requests by various stakeholder groups also resulted in additional members being named to the Committee. A total of 27 individuals representing the majority of key interests in the watershed served as official members of the Plum Creek Steering Committee and were involved throughout the process.

The Plum Creek Watershed Partnership operates under guidelines approved and signed by the Steering Committee as their first order of business (Appendix C). As part of the Partnership, the Steering Committee is a facilitated group that met approximately bi-monthly during the watershed protection plan development process. The primary objectives of the Steering Committee are to 1) identify desired water quality conditions and measurable goals, 2) prioritize programs and practices to achieve those goals, 3) assist in the development of the watershed protection plan document, 4) lead implementation of the plan at the local level, and 5) communicate implications of the watershed protection plan to other interested groups within the Plum Creek Watershed.

The Steering Committee, working together and with support from topical work groups (described below), led the development of the Plum Creek Watershed Protection Plan and will guide the implementation phase of the plan. While formation of the Steering Committee was coordinated by Extension and the TSSWCB, the Committee functions as an independent group of watershed stakeholders, including both organized entities and individuals, with an interest in restoring and protecting the designated uses and overall health of the Plum Creek Watershed.

Work Groups

Work groups were created by the Steering Committee to focus on specific topical issues and areas of concern and to make recommendations to the Steering Committee. Work groups were composed of Steering Committee members and any other members of the Plum Creek Watershed Partnership with expertise or a vested interest in that topic. Work group meetings were facilitated by Extension and the TSSWCB and held on a bimonthly basis to study specific issues, identify and make recommendations on implementation strategies, and support development of the watershed protection plan. Approximately 50 Partnership members have been active in the various work groups. The 5 work groups established by the Partnership were:

- Outreach and Education
- Urban Stormwater and Nonpoint Source
- Agricultural Nonpoint Source
- Wastewater and Industry
- Water Quality and Habitat

Technical Advisory Group

A Technical Advisory Group (TAG) consisting of state and federal agencies with water quality responsibilities provides guidance to the Steering Committee and work groups, and answers questions related to matters falling under the jurisdiction of each TAG member. The TAG includes representatives from the following agencies and organizations:

- Texas Commission on Environmental Quality (TCEQ)
- Texas AgriLife Extension Service
- Texas Department of Agriculture (TDA)
- Texas Department of Transportation (TxDOT)
- Texas Farm Bureau (TFB)
- Texas Parks and Wildlife Department (TPWD)
- The Railroad Commission of Texas (RRC)
- Texas State Soil and Water Conservation Board (TSSWCB)
- Texas Water Development Board (TWDB)
- USDA Natural Resources Conservation Service (NRCS)
- U.S. Environmental Protection Agency (EPA)
- U.S. Geological Survey (USGS)

In addition, various other state and federal agencies and organizations have participated on the TAG and supported the efforts of the Plum Creek Watershed Partnership.

4. Methods of Analysis

To begin work in the Plum Creek Watershed, the Partnership utilized a variety of approaches to interpret water quality patterns in the watershed, identify pollutant sources, and assist in making decisions regarding necessary management measures.

Land Use Classification

The Plum Creek Watershed was delineated using elevation maps to determine the size and characteristics of lands contributing to the creek along its course (Figure 4.1). Using 2004-2005 National Agriculture Imagery Program (NAIP) aerial photography, land use in the watershed was classified by hand using ESRI ArcGIS 9 software (Figure 4.2). In addition, based on elevation and flows, the watershed was broken down into a total of 35 subwatersheds to enable closer examination of possible pollutant sources and to aid in targeting implementation efforts.

Figure 4.1. Pasture near Mustang Ridge during spring. Much of the Plum Creek Watershed is agricultural land.

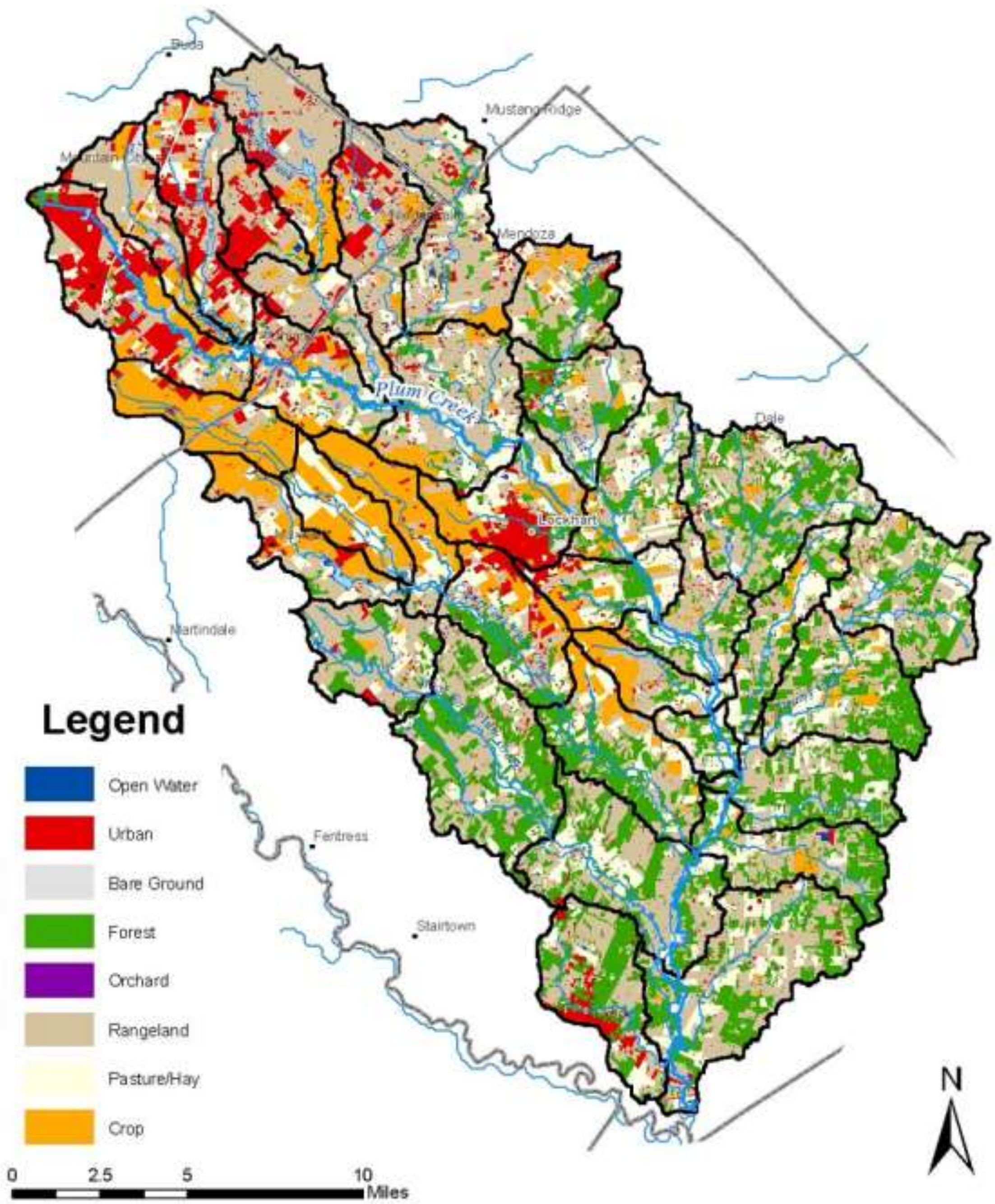


Figure 4.2. Land use classification map of the Plum Creek Watershed based on 2004-2005 NAIP aerial photography. Bold lines represent subwatershed boundaries.

Urban land, open water, bare ground, forest, rangeland, and cultivated land were considered major land use classes (see Appendix D for descriptions). Parcels were assigned classes based on natural and human-impacted attributes including vegetation, hydrology, and level of development (Table 4.1). If land use was distinct, classification was performed on areas to the level of less than one acre in size. Tracts with land use characteristics similar to neighboring areas were combined to form larger areas of a common class. Following digital classification, land use was verified through on-the-ground field sampling within the watershed (Figure 4.3).

Table 4.1. Land use classes in the Plum Creek Watershed.

Land Use Class	Total Acres	Proportion of Watershed (%)
Developed Open Space	1,607	< 1
Developed Low Intensity	12,033	4
Developed Medium Intensity	8,043	3
Developed High Intensity	2,446	< 1
Open Water	3,548	1
Barren Land/Bare Ground	1,362	< 1
Forested Land	27,996	10
Riparian Forested Land	16,371	6
Mixed Forest	22,522	8
Orchard	122	< 1
Rangeland	110,158	38
Pasture / Hay	49,290	17
Cultivated Crop	32,740	11
Total	288,240	100

Figure 4.3. Riparian forest near Luling. Such areas are common in lowland areas, particularly in downstream portions of the watershed.

DETERMINING SOURCES OF POLLUTION

Load Duration Curve

A widely accepted approach for predicting whether pollutants are coming from point and/or nonpoint sources is the use of a Load Duration Curve (LDC). An LDC is developed by first constructing a flow duration curve using historical streamflow data (Figure 4.4). Flow data are then multiplied by a threshold concentration (such as a desired target or an official water quality criterion) of a pollutant, including *E. coli* bacteria or a specific nutrient.

For the purposes of this plan, a 10% margin of safety was applied to the threshold concentrations for both bacteria and nutrient pollutants. Thus, threshold concentrations used in the LDC analysis were 114 cfu/100mL for bacteria and 1.76 mg/L, 0.33 mg/L, and 0.62 mg/L for nitrate, orthophosphorus, and total phosphorus, respectively.

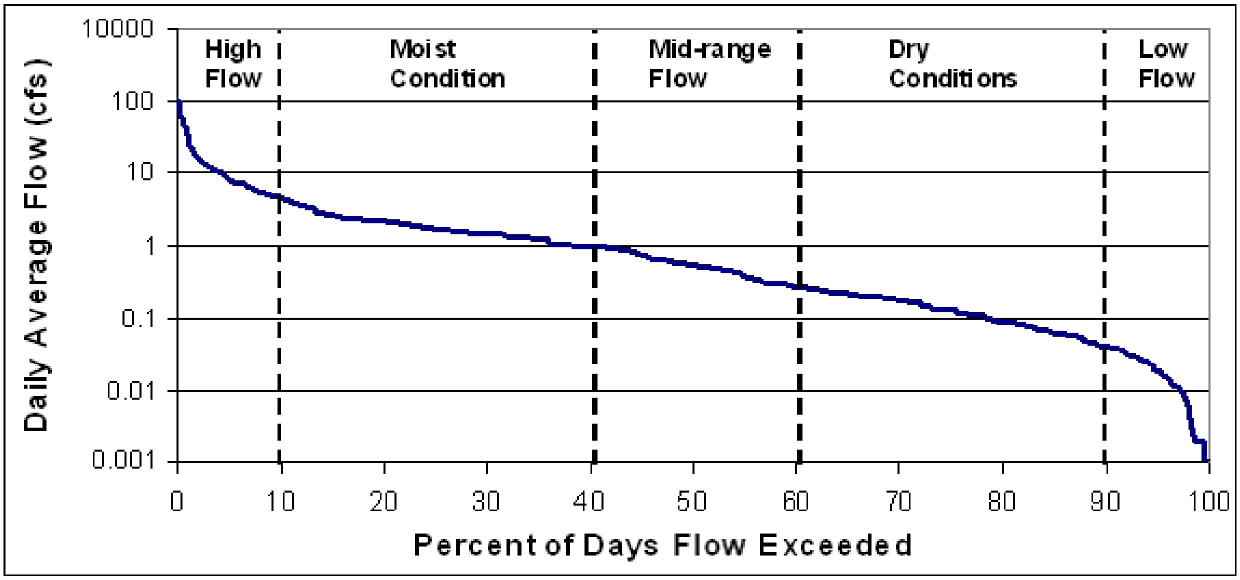


Figure 4.4. Example flow duration curve. Historical streamflow data are used to determine how frequently stream conditions exceed different flows.

When flow and the critical concentration are multiplied together, they produce the estimated pollutant load (Figure 4.5). The resulting load duration curve can then be used to show the maximum load a stream can carry without exceeding regulatory criteria or screening criteria across the range of flow conditions (low flow to high flow). In addition, stream monitoring data for a pollutant can be plotted on the curve to show when and by how much criteria are exceeded. For example, in Figure 4.5, the solid line indicates the maximum acceptable stream load for *E. coli* bacteria and the pink boxes represent monitored loads from water quality sample data. Where the pink boxes are above the solid line, the actual stream load has exceeded the regulatory limit, and a violation of the criterion has occurred.

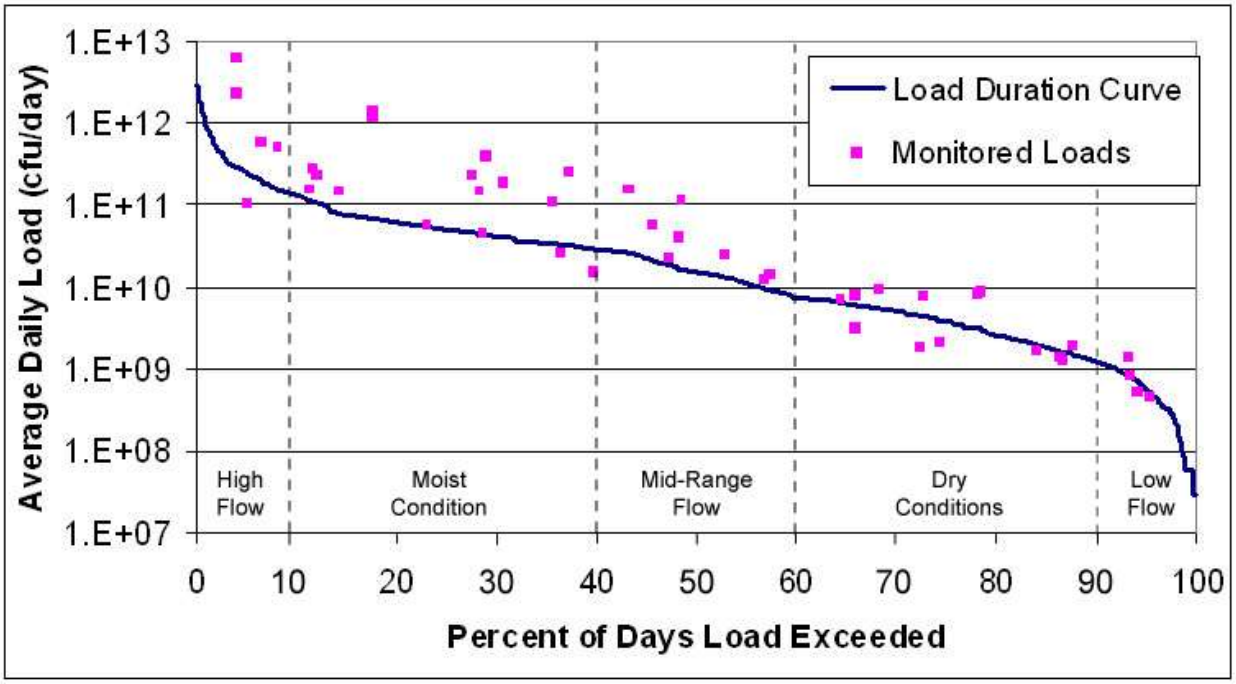


Figure 4.5. Example load duration curve. Multiplying streamflows by pollutant concentration produces an estimate of pollutant load. Regulatory criteria can be compared to monitored data and used to help determine if contributions are dominated by point or nonpoint sources.

By considering the processes at work during high, mid-range, and low flows, it is possible to link pollutant concentrations with potential point or nonpoint sources of pollution. Next, by using a regression analysis of monitored data, estimates of the percent reduction needed to achieve acceptable pollutant loads can be determined. For the Plum Creek Watershed, the highest of predicted load reductions considering all flow conditions at a given monitoring station was used to establish the target reduction for that portion of the watershed. A more complete explanation of the Load Duration Curve approach can be found in Appendix E.

Spatially Explicit Load Enrichment Calculation Tool (SELECT)

To more specifically identify potential pollutant sources and their contributions within a watershed, the SELECT approach was developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University. Using the best available data, a potential pollutant load is estimated for each source based on known pollutant production rates. SELECT utilizes numbers and estimated distributions of developed urban land coverage, pets, septic systems, permitted wastewater facilities, livestock, and wildlife. These sources can then be compared across different subwatersheds and to each other. As a result, areas with the greatest potential for impacting water quality can be identified, and major contributors in those areas can be selected for the implementation process. A more complete explanation of the SELECT approach can be found in Appendix F.

DATA LIMITATIONS

When determining the relationships between in-stream conditions and driving factors in the surrounding landscape, it is important to consider all potential sources of pollution and rely on the most dependable data available. In addition to receiving input from local stakeholders, information used in the analysis of the Plum Creek Watershed was gathered from a number of sources, including local and regional groups, river authorities, and state and federal agencies.

It is important to remember that information collected in the Plum Creek Watershed represents a snapshot in time of the processes at work. Whether associated with human activities (Figure 4.6), weather patterns, animal distributions, or other factors, Plum Creek and other watersheds are very dynamic in nature, and conditions change dramatically between years and even within a given season. Because of this, the actual input of pollutants from different sources in the Plum Creek Watershed varies considerably over time.

Figure 4.6. A boy fishes using a handline in Lockhart’s Town Branch.

5. Estimate of Pollutant Loads and Required Load Reductions

LDC analyses for Plum Creek were performed for the 3 monitoring stations where water quality monitoring data are currently collected. These analyses indicate that *E. coli* bacteria loads exceeding regulatory limits occur across most flow conditions at all 3 of the monitored sites. In addition, some nutrients exceed desirable levels at selected locations. However, there are differences in trends at the individual monitoring stations with regard to the severity and timing of high bacteria and nutrient loads. These differences coincide with variations in flow patterns in the creek and with variations in land use across the Plum Creek Watershed (Figure 5.1). The following sections provide the results of analyses for bacteria and nutrients for each of the 3 monitoring stations in the Plum Creek Watershed.

Figure 5.1. Clear Fork at Lockhart State Park. Analysis by load duration curves indicates patterns and timing of pollutant loads in Plum Creek.

BACTERIA

Uhland Monitoring Station

In upstream portions of the watershed, as indicated by analysis of data from the monitoring station near Uhland (Figure 5.2), high *E. coli* loads occur across streamflows, with greatest loads during high flow and moist conditions. This indicates that both nonpoint and point sources are potential contributors of bacteria in the upper part of Plum Creek. A 65% reduction during moist conditions is required to bring the *E. coli* load in Plum Creek to acceptable levels in this area, while *E. coli* load reductions of about 51% and 26% are needed during mid-range and low flows, respectively. In dry periods, flow may be largely comprised of point source discharges, as there are few perennial stream inputs in this area of the watershed. Utilizing a conservative approach, a 65% *E. coli* load reduction will be the target in this section of the watershed.

Lockhart Monitoring Station

Although quarterly sampling at the Lockhart water quality monitoring station has resulted in fewer data points than the other 2 locations, results indicate that significant exceedences do occur, but these are mostly during dry conditions and low flow periods (Figure 5.3). As there is little surface runoff to carry pollutants from nonpoint sources under these conditions, these load values are likely due to direct deposition and point discharges. A 15% reduction in *E. coli* loads during dry conditions is needed to improve bacteria levels in the middle section of the watershed and will be utilized as the reduction target.

Luling Monitoring Station

The Luling monitoring station showed high bacteria loads during all flow conditions (high flows, moist conditions, mid-range flows, and dry conditions) in southern portions of Plum Creek (Figure 5.4). This trend is similar to what is shown by the Uhland monitoring station. While this segment of the stream is not currently listed as being impaired by either geometric mean or the grab sample method of water quality data analysis, high levels of bacteria inputs especially during runoff events should be addressed to prevent future increases and impairment of designated stream uses. Results of the LDC analysis indicate that a 41% reduction is needed during moist conditions, an 11% reduction during median flows, and an 8% reduction during dry conditions. Again, using a conservative approach to address current and potential future problems across all flow regimes, a 41% reduction in bacteria loading will be the target in this section of the watershed. A summary of the bacteria load reduction target for this and other monitoring stations can be found in Table 5.1.

Annual Loads and Load Reductions

The mean annual bacteria load (cfu/year) for each of the 3 monitoring stations and associated 95% confidence intervals are presented in Table 5.1. In addition, recommended load reductions and target loads for each station based on LDC analysis are given.

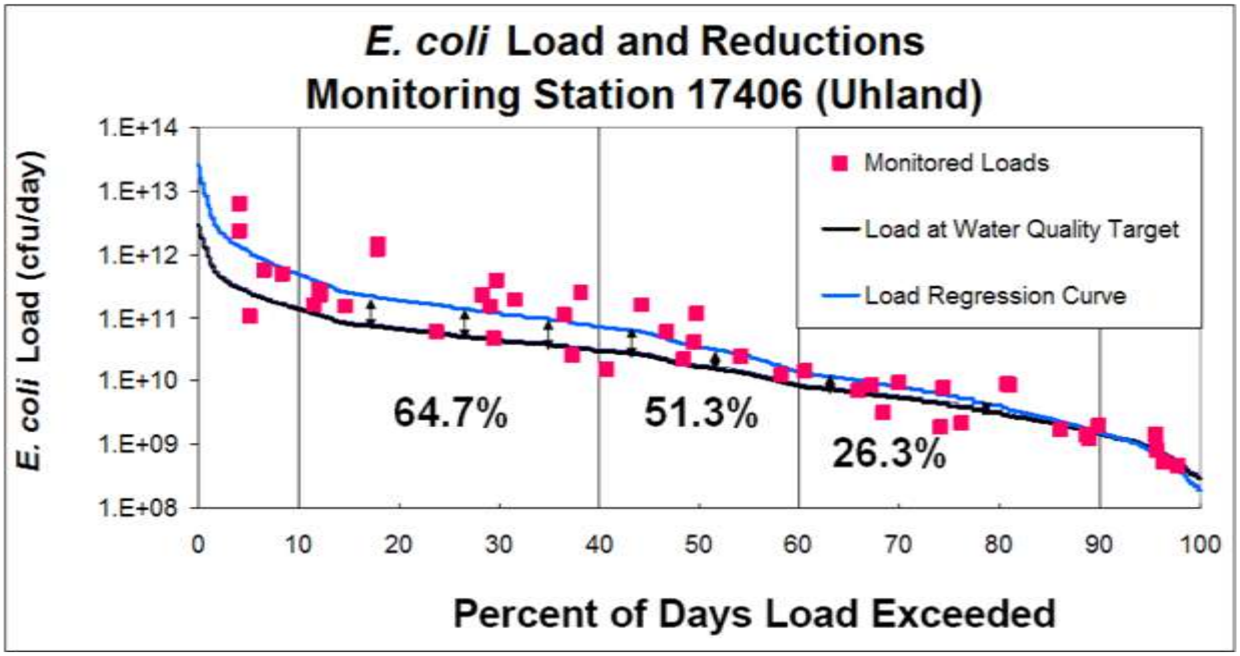


Figure 5.2. *E. coli* load duration curve for station 17406 near Uhland in Hays County.

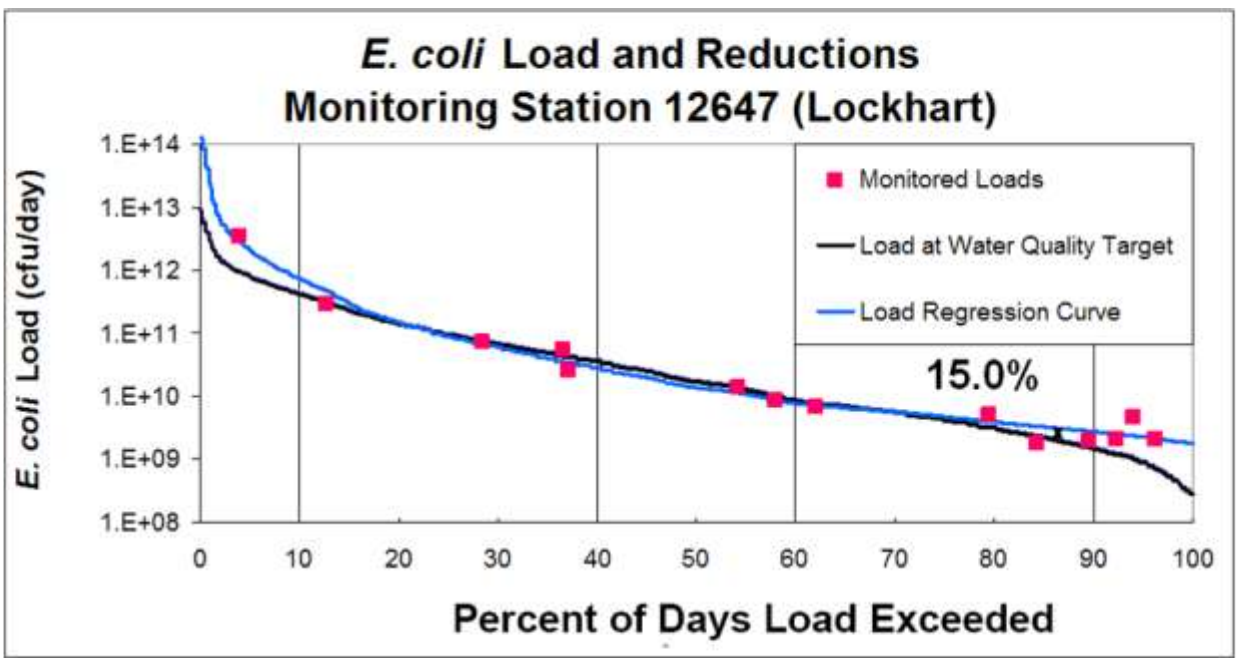


Figure 5.3. *E. coli* load duration curve for station 12647 near Lockhart in Caldwell County.

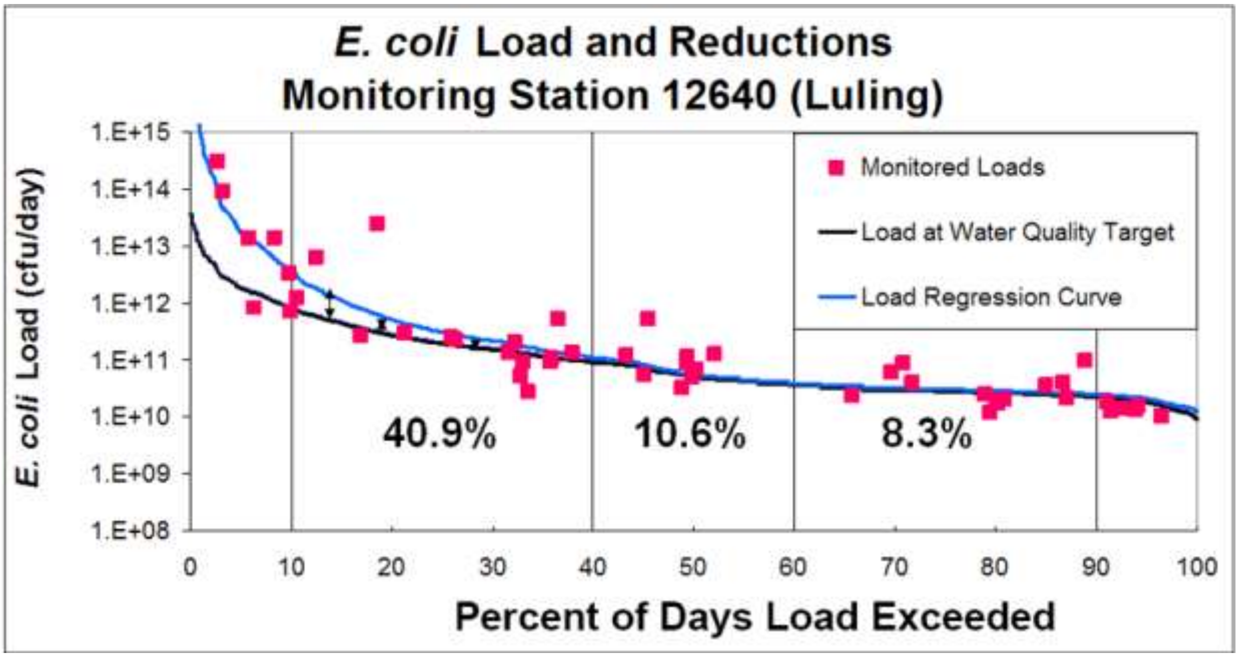


Figure 5.4. *E. coli* load duration curve for station 12640 near Luling in Caldwell County.

Table 5.1. Annual load characteristics and *E. coli* reductions for each station (in billions of cfu).

Monitoring Station	Mean Annual *E. coli* Load (cfu/year)	Minimum 95% CI[1]	Maximum 95% CI[1]	Load Reduction (cfu/year)	Target Load (cfu/year)
Uhland (17406)	1.12E+05	8.74E+04	1.36E+05	7.28E+04	3.92E+04
Lockhart (12647)	4.26E+05	2.46E+05	6.06E+05	6.39E+04	3.62E+05
Luling (12640)	3.02E+07	1.04E+07	5.01E+07	1.24E+07	1.78E+07

[1] The 95% confidence interval for minimum and maximum nutrient loads.

Bacteria Load Trends and Processes at Work

Table 5.2 presents a summary of the estimated average annual bacteria load categorized by flow condition for the 3 monitoring stations. The highest *E. coli* loads occur during periods of higher flow in Plum Creek, which include bankfull stages and floods (Figure 5.5). However, these events occur on average only 10% of the time. High flows occur in association with runoff events which carry high concentrations of bacteria, nutrients, and other pollutants from the surrounding landscape. Additionally, bacteria that are associated with sediments in Plum Creek may be stirred up and resuspended in the water column, contributing to the pollutant load during high flows. As a result, bacteria loads in Plum Creek may be elevated both by the increased concentrations of *E. coli* bacteria in surface runoff and the potential resuspension of bacteria in stream sediments. As flows and contributions from nonpoint sources decrease, point sources and direct deposition become dominant contributors in dry periods.

Table 5.2. Estimated average annual *E. coli* loads (in billions of cfu) under different flow conditions at each water quality station in Plum Creek.

Monitoring Station	Loading by Streamflow Condition				
	High Flows (cfu/year)	Moist Conditions (cfu/year)	Mid-Range Flows (cfu/year)	Dry Conditions (cfu/year)	Low Flows (cfu/year)
Uhland (17406)	8.83E+04	6.31E+03	1.39E+03	2.19E+02	3.65E+01
Lockhart (12647)	4.02E+05	5.77E+03	5.48E+02	5.48E+02	7.30E+01
Luling (12640)	2.93E+07	2.07E+04	2.26E+03	1.10E+03	7.30E+02

Figure 5.5. Plum Creek at bankfull stage. The highest loads of *E. coli* bacteria in Plum Creek typically occur during high flow conditions.

NUTRIENTS

Uhland Monitoring Station

The Uhland monitoring station reflects high nutrient levels that consistently exceed the TCEQ screening criteria during dry conditions (Figure 5.6). This may indicate a high level of background nitrates, contributions from point sources, or a combination of both factors. Optimally, nitrate concentrations should be reduced by 43% in this northern portion of the watershed. However, as described in the Management Measures section, contributions from natural sources of nitrate will affect implementation efforts. This portion of the watershed is not listed as having nutrient concerns for total phosphorus, and the majority of water quality samples collected at this location were below the target concentration for phosphorus (Figure 5.7). However, during dry conditions, many samples exceeded the target. As a result, a 27% reduction in the total phosphorus load at this site is necessary to be proactive in preventing the area from being listed in the future. Table 5.3 provides a summary of loading and reductions for nutrients at the Uhland monitoring station.

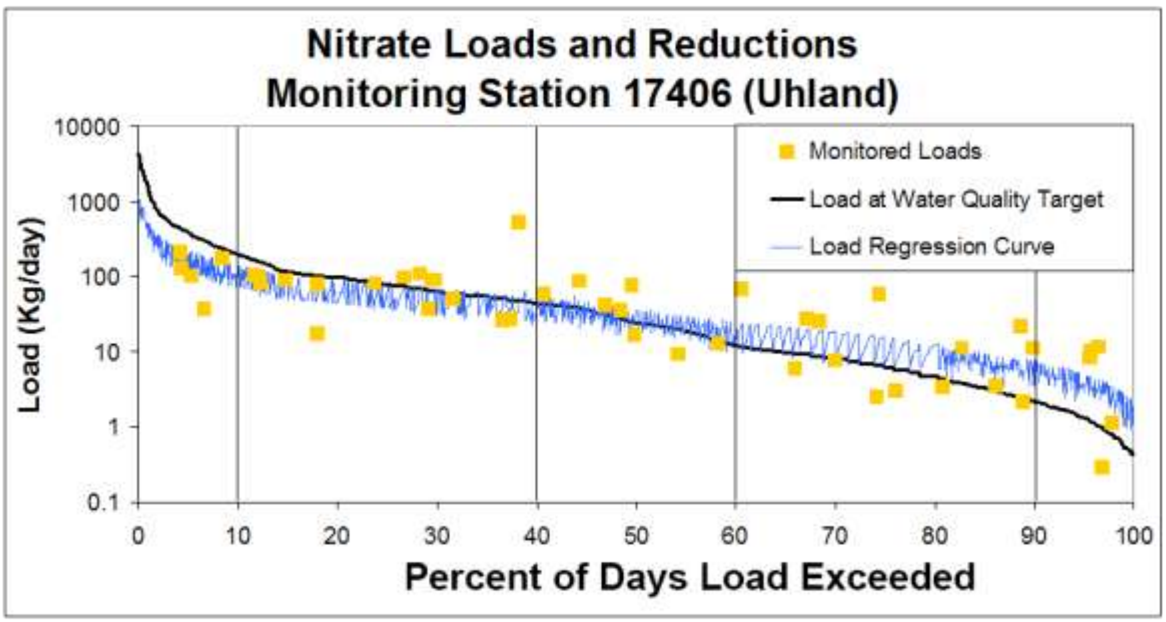


Figure 5.6. Nitrate load duration curve for station 17406 near Uhland in Hays County.

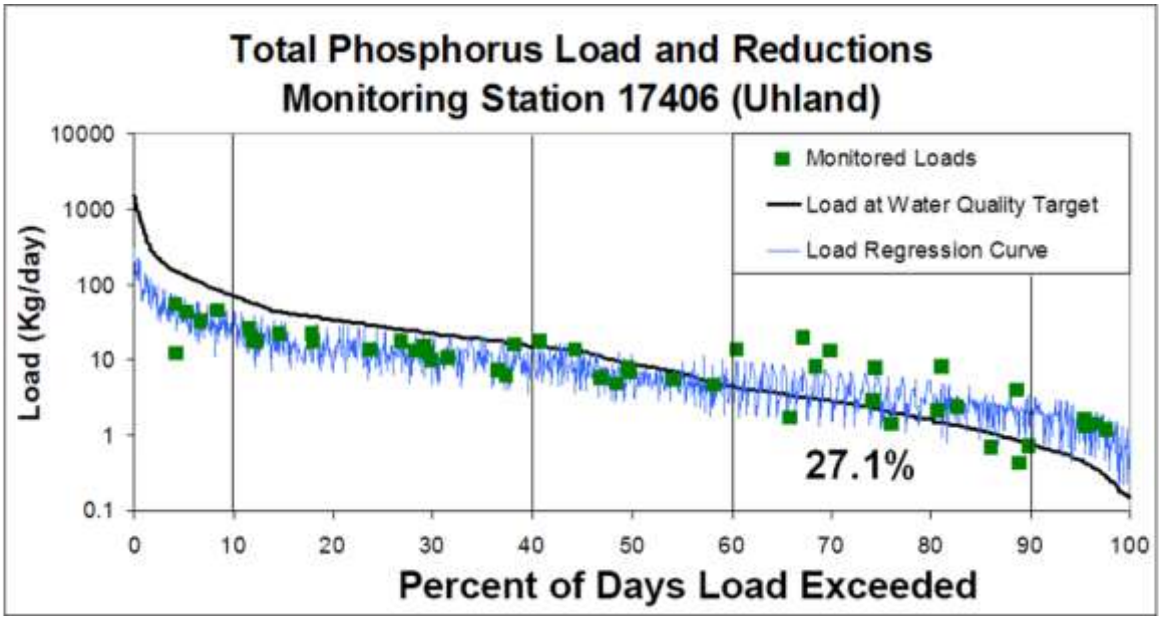


Figure 5.7. Total phosphorus load duration curve for station 17406 near Uhland in Hays County.

Table 5.3. Annual load characteristics and needed reductions for nutrients at the Uhland monitoring station.

Nutrient	Mean Annual Nutrient Load (kg/year)	Minimum 95% CI	Maximum 95% CI	Load Reduction (kg/year)	Target Load (kg/year)
Nitrate	18,062	16,581	19,543	7,767	10,295
Total P	4,425	4,082	4,768	1,195	3,230
Ortho P[1]	-	-	-	-	-

[1] Not monitored at this location.

Lockhart Monitoring Station

Based on sampling at the Lockhart monitoring station, the central portion of Plum Creek was listed as having nutrient concerns for nitrates. Nitrates exceed the screening criteria during all but highest flows, with significant exceedences under dry conditions (Figure 5.8). An 18% reduction in nitrate loads is necessary during moist conditions to bring these nutrients to acceptable levels, and reductions of 66% and 80% are required for nitrates in mid-range flows and dry conditions, respectively. As a conservative measure, 80% will be the reduction target for nitrates in the central portion of the Plum Creek Watershed.

Water quality samples from the Lockhart monitoring station also resulted in nutrient concerns for both measures of phosphorus in that region. High levels of orthophosphorus and total phosphorus are most common during dry conditions, potentially indicating contributions from point sources and/or direct deposition. A 49% decrease in orthophosphorus and a 5% decrease in total phosphorus are necessary under dry conditions in order to meet water quality targets based on the nutrient screening criteria (Figures 5.9 and 5.10). Table 5.4 provides a summary of loading and reductions for nutrients at the Lockhart monitoring station.

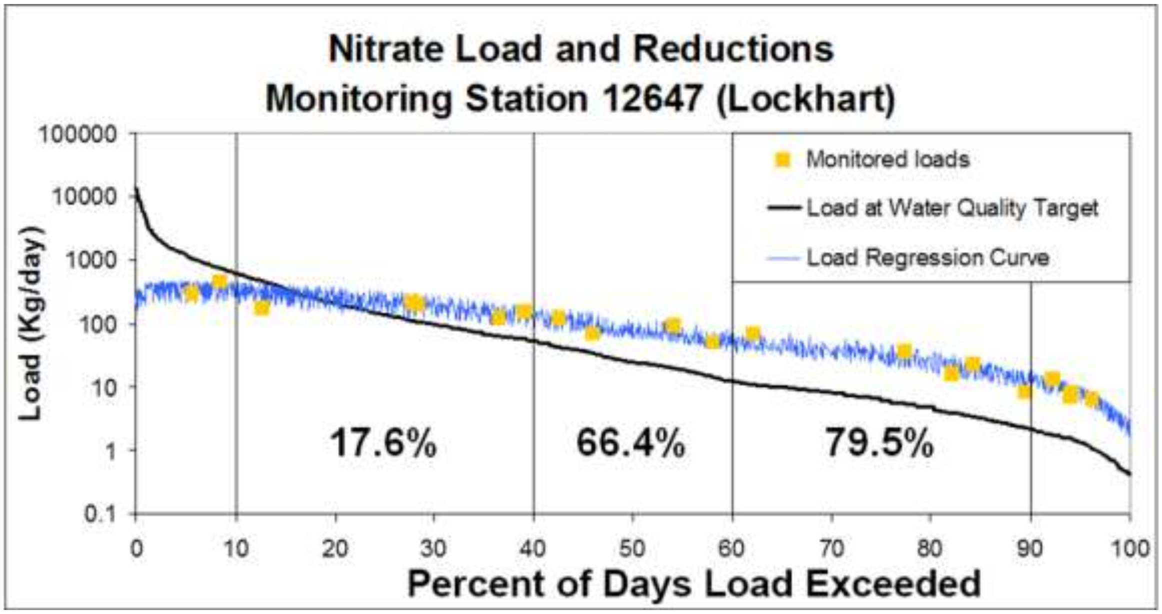


Figure 5.8. Nitrate load duration curve for station 12647 near Lockhart in Caldwell County.

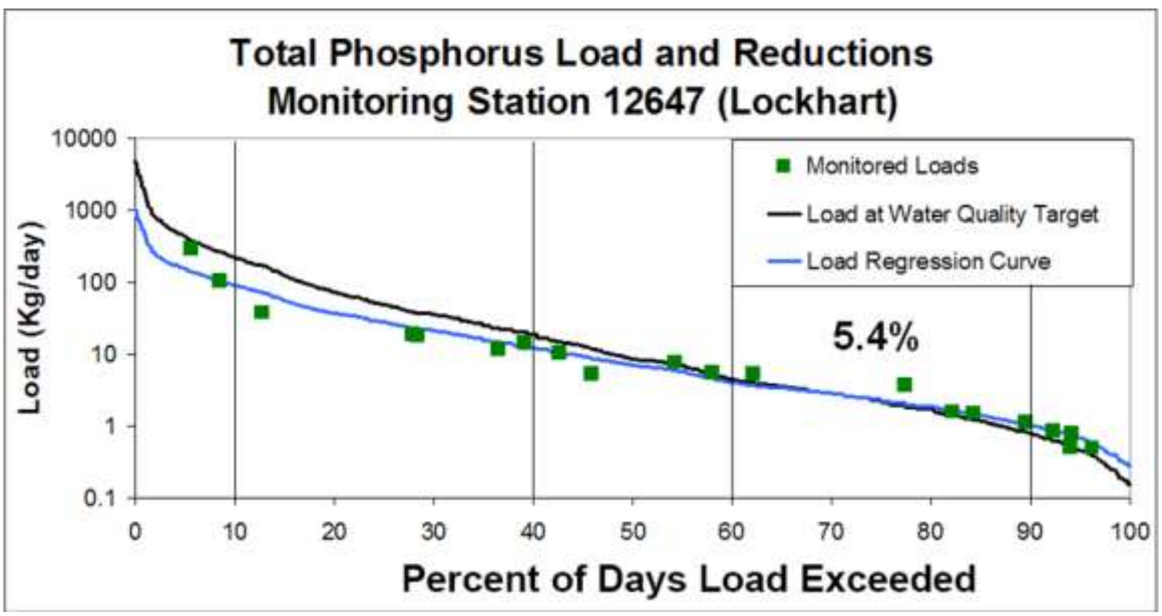


Figure 5.9. Total phosphorus load duration curve for station 12647 near Lockhart in Caldwell County.

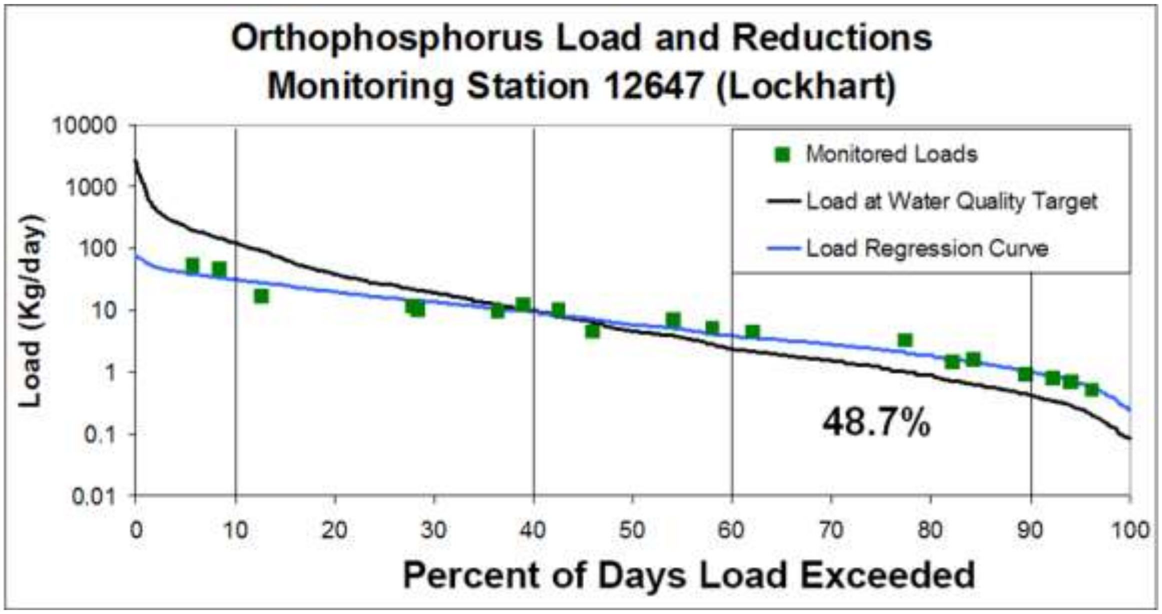


Figure 5.10. Orthophosphorus load duration curve for station 12647 near Lockhart in Caldwell County.

Table 5.4. Annual load characteristics and needed reductions for nutrients at the Lockhart monitoring station.

Nutrient	Mean Annual Nutrient Load (kg/year)	Minimum 95% CI	Maximum 95% CI	Load Reduction (kg/year)	Target Load (kg/year)
Nitrate	47,295	45,174	49,416	37,836	9,459
Total P	12,275	10,853	13,697	614	11,661
Ortho P	4,238	4,007	4,470	2,077	2,162

Luling Monitoring Station

As in other sections of Plum Creek, nitrate concerns exist in the southern portion of the watershed, based on water quality data from the Luling monitoring station. Though a number of individual samples exceed the state screening criteria at this site, the mean of all samples lies very near the target level for nitrate (Figure 5.11). As a result, only a 1% reduction in nitrate loads is required to meet water quality targets during dry conditions. Total phosphorus samples rarely exceed the nutrient screening criteria at this location, and the mean level of phosphorus is well below the target (Figure 5.12). As a result, no load reduction is required for phosphorus in the southern portion of the watershed. Table 5.5 provides a summary of loading and reductions for nutrients at the Luling monitoring station.

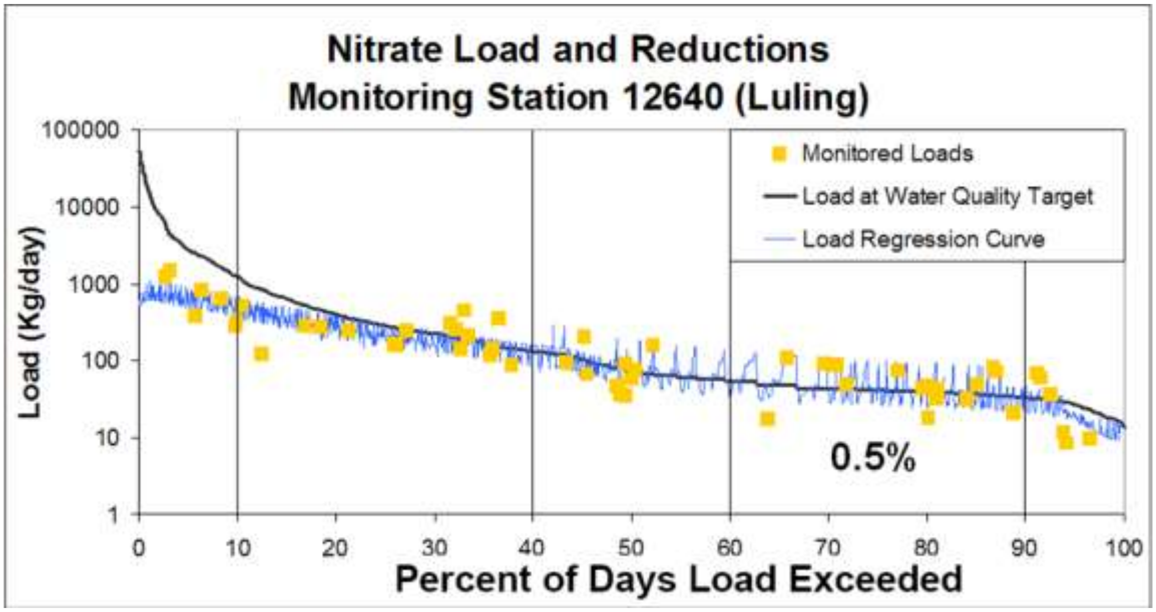


Figure 5.11. Nitrate load duration curve for station 12640 near Luling in Caldwell County.

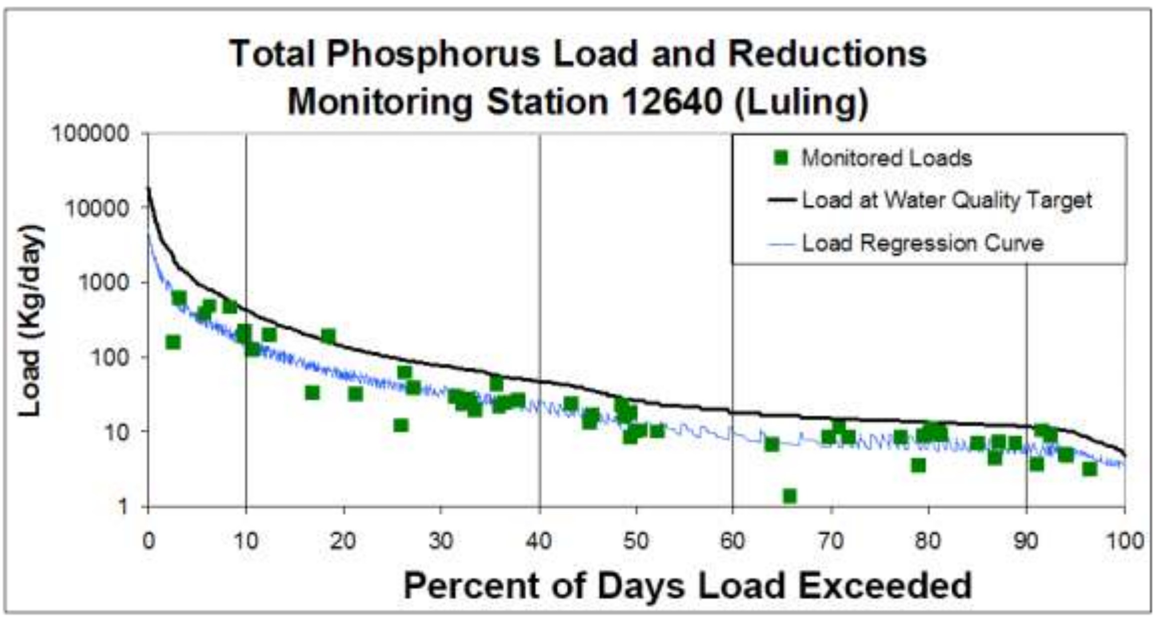


Figure 5.12. Total phosphorus load duration curve for station 12640 near Luling in Caldwell County.

Table 5.5. Annual load characteristics and needed reductions for nutrients at the Luling monitoring station.

Nutrient	Mean Annual Nutrient Load (kg/year)	Minimum 95% CI	Maximum 95% CI	Load Reduction (kg/year)	Target Load (kg/year)
Nitrate	63,738	60,290	67,185	637	63,100
Total P	32,000	26,485	37,516	0	32,000
Ortho P[1]	-	-	-	-	-

[1] Not monitored at this location.

6. Pollutant Sources in the Plum Creek Watershed

The LDC analysis for Plum Creek indicates that both point and nonpoint sources contribute pollutants in the watershed. Identifying sources is a key step in determining and implementing management practices to reduce or eliminate pollution and restore water quality in Plum Creek.

Topical work groups of the Plum Creek Watershed Partnership dedicated significant time to the identification of potential point and nonpoint sources of pollutants in the watershed. Available information and statistics for the Plum Creek Watershed were gathered from stakeholders and independent sources and used to support this process. Based on those discussions, the likely potential sources of pollutants were determined and are presented in Table 6.1.

Table 6.1. Potential pollutant sources in the Plum Creek Watershed.

Potential Sources	Bacteria	Nutrients	Other
Urban			
Urban Runoff	X	X	X
Pets	X	X	
Wastewater			
Septic Systems	X	X	X
Wastewater Treatment Facilities	X	X	X
Agriculture			
Sheep and Goats	X	X	
Horses	X	X	
Cattle	X	X	
Cropland		X	X
Wildlife			
Deer	X	X	
Feral Hogs	X	X	X
Oil and Gas Production			X

Many pollutant sources can contribute both *E. coli* and nutrients. In most cases, identification and management of bacteria sources also will reduce nutrient contributions, particularly when sources include human and animal waste. However, some land use and management practices, such as crop production and lawn and landscape fertilization, only affect nutrient loading and will need to be managed separately from control measures intended to reduce bacteria pollution.

SELECT RESULTS

The Plum Creek Steering Committee and work groups utilized the SELECT approach to evaluate each pollutant source and identify which subwatersheds have the greatest potential to contribute to *E. coli* loads based on both the average bacteria production rate and the concentration of a source within a subwatershed. It is important to note that SELECT evaluates the **potential** for pollution from the possible sources and subwatersheds, resulting in a relative approximation for each area. Sources with high potential are then evaluated to determine if necessary controls are already in place or if action should be taken to reduce pollutant contributions. The following sections of the Watershed Protection Plan present and discuss results of the SELECT analysis for each of the potential sources.

Figure 6.1 presents the total estimated daily *E. coli* load summed for all potential sources in the different subwatersheds in Plum Creek. In this and following figures, red areas indicate a higher potential daily load in that area, and yellow areas indicate a lower potential daily bacteria load, and oranges depicting intermediate levels of potential loads. The northern portion of the Plum Creek Watershed is listed as impaired by *E. coli* and shows a greater potential for bacteria loading than other regions of the watershed. However, high bacteria loads also have been observed in southern reaches of the watershed. Urban runoff, domestic dogs, wastewater, livestock, and wildlife are all key potential nonpoint source pollution contributors in the watershed.

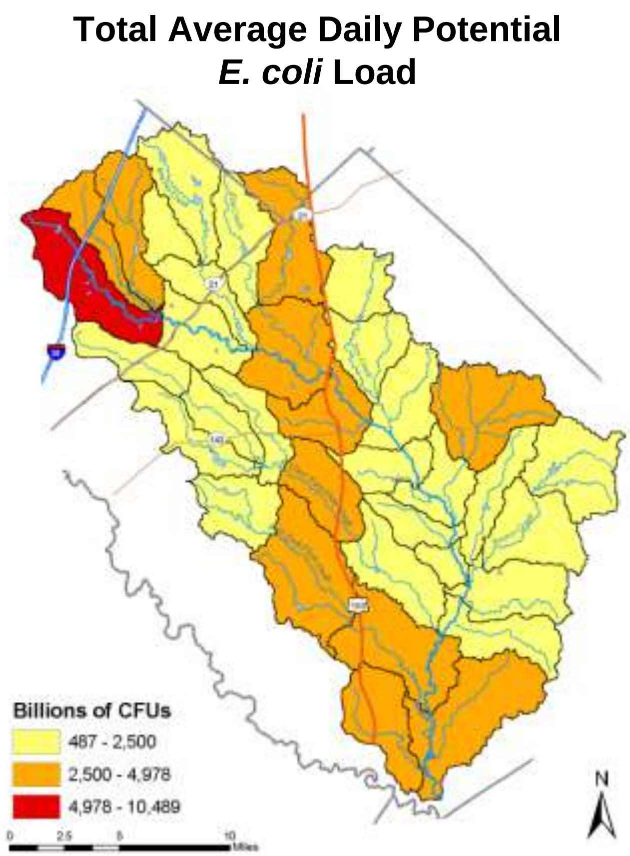


Figure 6.1. Estimate of total potential bacteria contribution by all sources by subwatershed.

URBAN RUNOFF

Because of the range of activities that occur there, runoff from urban areas can contain a variety of pollutants, including both bacteria and nutrients. Increased impervious cover (rooftops, roads, and other hard surfaces) causes more surface runoff and less water infiltration into the soil (Figure 6.2). This greater runoff increases the potential for pollutants from household pets, leaky wastewater pipes, sanitary system overflows, and urban wildlife to eventually reach Plum Creek. Identifying the original source of pollution is extremely difficult, since pollutants in runoff from urban areas may potentially come from any one source or a combination of several sources.

Figure 6.2. Development in Hays County. Impervious cover causes increased runoff, which can carry pollutants.

A study conducted by the City of Austin (1997) showed that bacteria concentrations in urban runoff can be extremely high, particularly in areas with a high degree of impervious surface cover. Similar conditions and potentials for significant bacteria contributions exist for established and growing cities in the Plum Creek Watershed, including Kyle, Lockhart, and Luling. Based on the land use analysis, each of these urban areas contains substantially higher densities of impervious cover than the Plum Creek Watershed as a whole (Table 6.2).

Table 6.2. Approximate city limit area and corresponding impervious cover estimates for cities having a majority of their city area within the Plum Creek Watershed based on 2004 land use classification.

City	City Area (Acres)	Impervious Cover (Percent)
Kyle	5,597	38
Lockhart	7,212	27
Luling	2,123	38
Plum Creek Watershed	288,240 (total)	9

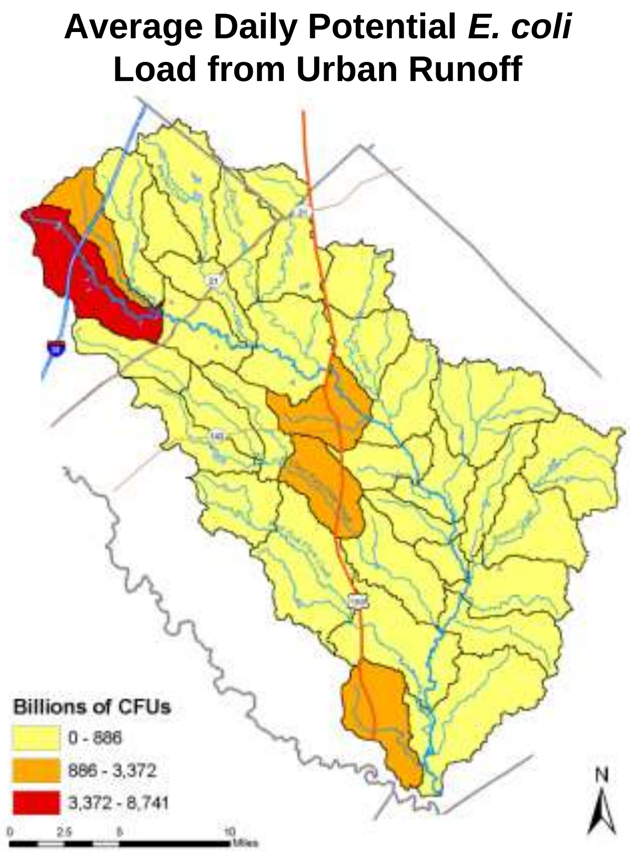


Figure 6.3. Potential bacteria contributions from urban runoff.

The Urban Stormwater and Nonpoint Source work group utilized estimates of impervious surface cover from the land use analysis and bacteria loading estimates from the study conducted by the City of Austin (1997) to complete SELECT analysis for urban runoff. Results confirm a significant potential for urban bacteria and nutrient loading in Plum Creek from the subwatersheds containing the majority of urban development, including Kyle along Interstate 35, Lockhart, and Luling (Figure 6.3).

Considerable variation exists in the level of urbanization among municipalities in the Plum Creek Watershed. The city of Buda, a small area of which falls in the far northern portion of the watershed, is now under municipal separate storm sewer system (MS4) regulations as a part of federal Clean Water Act legislation. These regulations are discussed in more depth later in the document. The city of Kyle most likely will fall under the same regulations following the next census due to its rapid population growth, and the cities of Lockhart and Luling eventually may face similar regulations. Future changes in population and potential for pollutant contributions from these urbanizing areas will need to be considered as plan implementation proceeds.

PETS

According to the American Veterinary Medical Association (AVMA 2002), the average Texas household owns 0.8 dogs. The Urban Stormwater and Nonpoint Source work group recommended using this information to estimate dog numbers in the watershed. Pets are sources of *E. coli*. Especially in urban areas, improper disposal of dog waste can affect water quality. Pollution concerns arise when animals deposit their waste outdoors and it is not collected. Waste and the bacteria it contains are transported to the stream during rainfall events or as a result of over-irrigation, especially when it is deposited directly in drainage ditches or streets and sidewalks. The closer these pets are to a waterway, the greater the likelihood they will be a major source of *E. coli*. The same potential for pollution applies to nutrients in pet waste, if the waste itself or soluble nutrients within it are transported to local streams. Thus, pet waste represents a significant potential source of both bacteria and nutrients in the watershed. Because the majority of cat waste is collected in litter boxes, these animals were not included in the SELECT analysis.

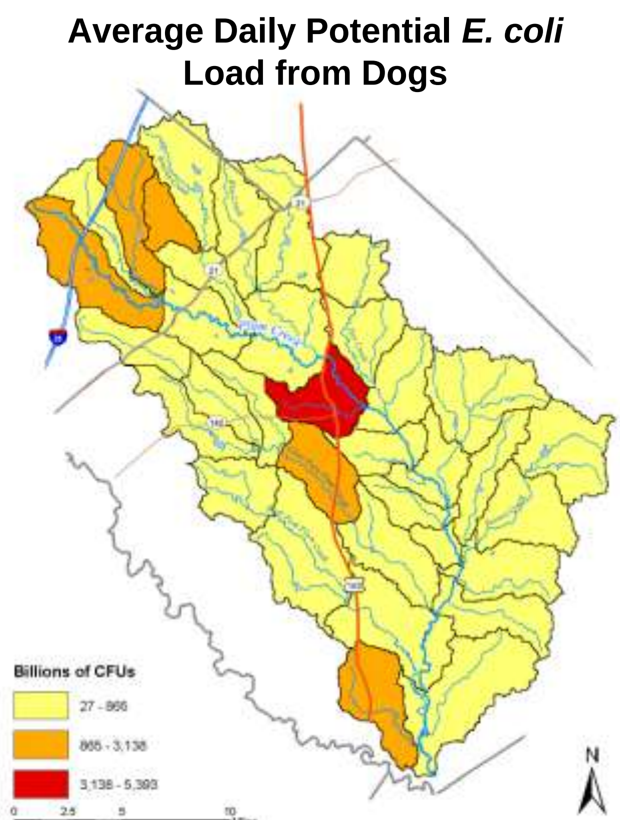


Figure 6.4. Dog in the Plum Creek Watershed. Animal densities and potential bacteria loads are highest in urban areas.

According to 2000 US Census population data for the watershed, there are an estimated 9,000 dogs in the watershed. These animals are concentrated in urban areas, particularly near Lockhart, Kyle, and Luling, which have more households and a greater human population. There has been a significant influx of residents since 2000, and this number will rise as development continues in the watershed. Based on this information, the SELECT analysis indicates the greatest potential for pollutant loads from pets occurs in these urbanized subwatersheds (Figure 6.4).

SEPTIC SYSTEMS

Rural areas across Texas rely on on-site sewage facilities (also referred to as OSSFs), or septic systems, for disposal of household wastewater. Thousands of new systems are installed statewide each year when homes and businesses are constructed outside city limits or where centralized municipal sewer service is unavailable. While municipal wastewater facilities must be operated by trained personnel, septic systems are the responsibility of the homeowner. If regular and essential maintenance are not conducted, major problems can occur. Lack of septic system training has been a major issue in some areas and has been acknowledged by homeowners themselves.

When septic systems fail, wastewater does not receive adequate treatment. This sewage can be a source of bacteria, other pathogens, and nutrients. While inadequate septic system maintenance is a factor in system failure, other concerns are system design, inappropriate soils, and age. Pre-regulatory systems installed before requirements issued in 1989 are often not as efficient as new systems and are more prone to failure. Degradation of construction materials can lead to a drop in performance and eventual failure. Alteration or compaction of the drainfield can also dramatically affect septic system function and may completely eliminate treatment in worst-case scenarios. Some soils also limit system function, because they inhibit leaching and increase the likelihood of surfacing. Selection of a system should be determined by soil type, a practice which has not always been followed. Additionally, a lack of enforcement of septic system regulations can contribute to system failure. In some cases, governing bodies do not have adequate resources to inspect and regulate septic systems throughout their jurisdictions. This allows potential problem systems to go undetected and unaddressed. A combination of these factors makes septic systems a potential major contributor of both bacteria and nutrients to Plum Creek.

As with most types of nonpoint source pollution, failing septic systems are found across the landscape. Those located nearest streams or drainage areas are most likely to impact water quality in Plum Creek. A study funded by the Texas On-Site Wastewater Treatment Research Council (Reed, Stowe, & Yanke 2001) determined that in the counties within and around the Plum Creek Watershed, approximately 12% of reported septic systems are chronically malfunctioning. However, older unregulated systems have been shown to fail at a much higher rate. Because records of the location, age, and failure rate for septic systems in the watershed are not available, the Wastewater and Industry work group recommended utilization of a conservative failure rate for unregulated septic systems of 50% for the SELECT analysis. Based on the location of current centralized sewer utilities in Plum Creek, the highest potential densities of septic systems are located in Hays County in the northern portion of the watershed (Figure 6.5).

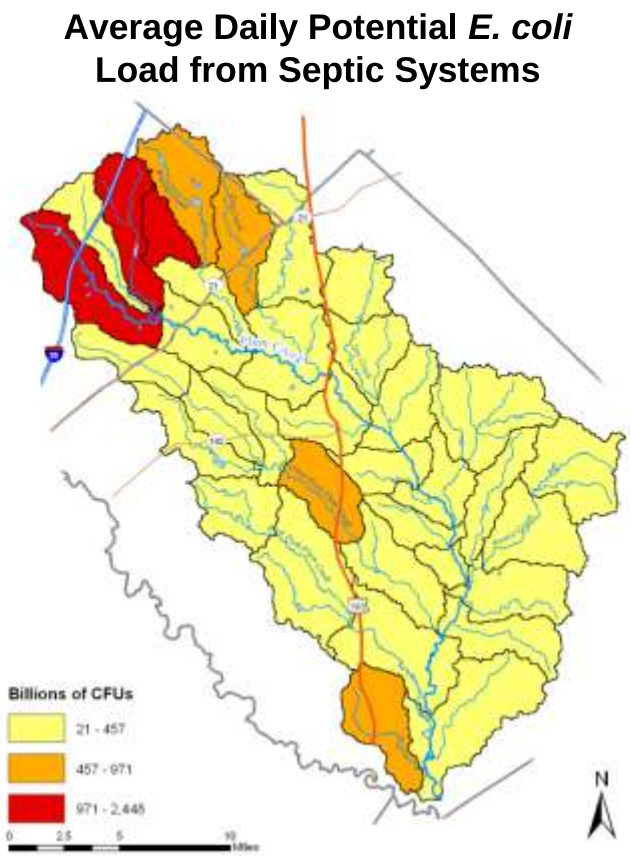


Figure 6.5. Distribution of potential *E. coli* loads from failing septic systems by subwatershed.

WASTEWATER TREATMENT FACILITIES

Permitted point sources in the Plum Creek Watershed are comprised of 12 wastewater treatment facilities (WWTFs), 2 water treatment facilities, and one industrial facility (Figure 6.7). With the exception of the industrial operation, which has no discharge, daily permitted flow in the watershed totals over 12 million gallons per day (MGD). While current discharge rates are well below this level, discharge rates will continue to increase toward the permitted total as existing facilities increase capacity. Further urban development and expansion of WWTF coverage area will also increase total effluent discharge in the watershed. Several additional permits exist for future facilities in conjunction with planned residential and commercial development, particularly in Hays County and western Caldwell County. Many of these facilities will become operational in the near future.

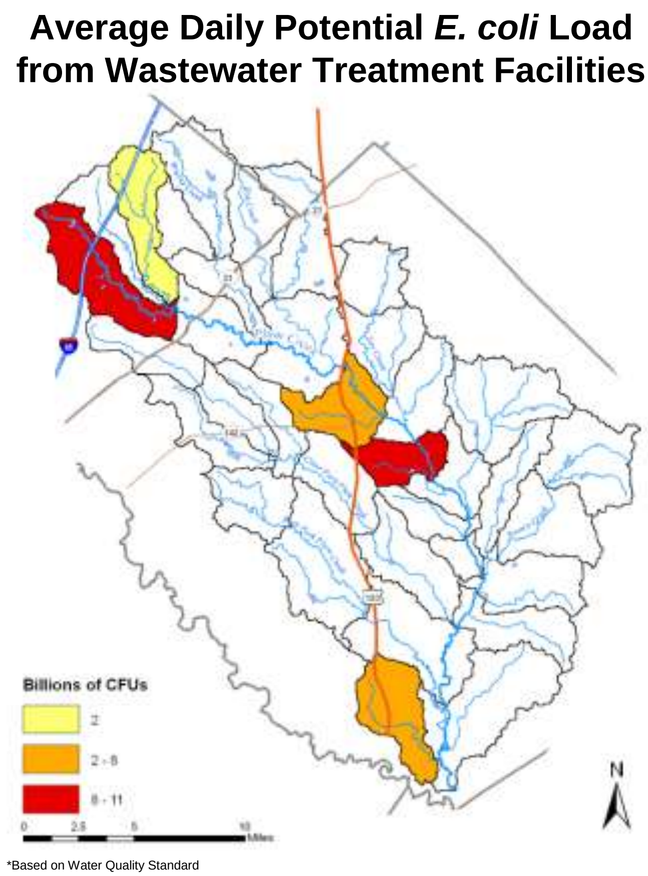


Figure 6.6. Potential *E. coli* contributions from wastewater treatment facilities are concentrated in areas with actively discharging permits in developed areas of the Plum Creek Watershed.

Because exact locations and permitted discharge volumes exist for WWTFs (though precise water quality data do not), these pollutant sources were addressed by the Wastewater and Industry work group somewhat differently in the SELECT analysis. Rather than being contributed from nonpoint sources across the landscape, these point sources of pollutants are introduced at the point where they are discharged to Plum Creek (Figure 6.6). A discussion of the methodology is provided in Appendix F.

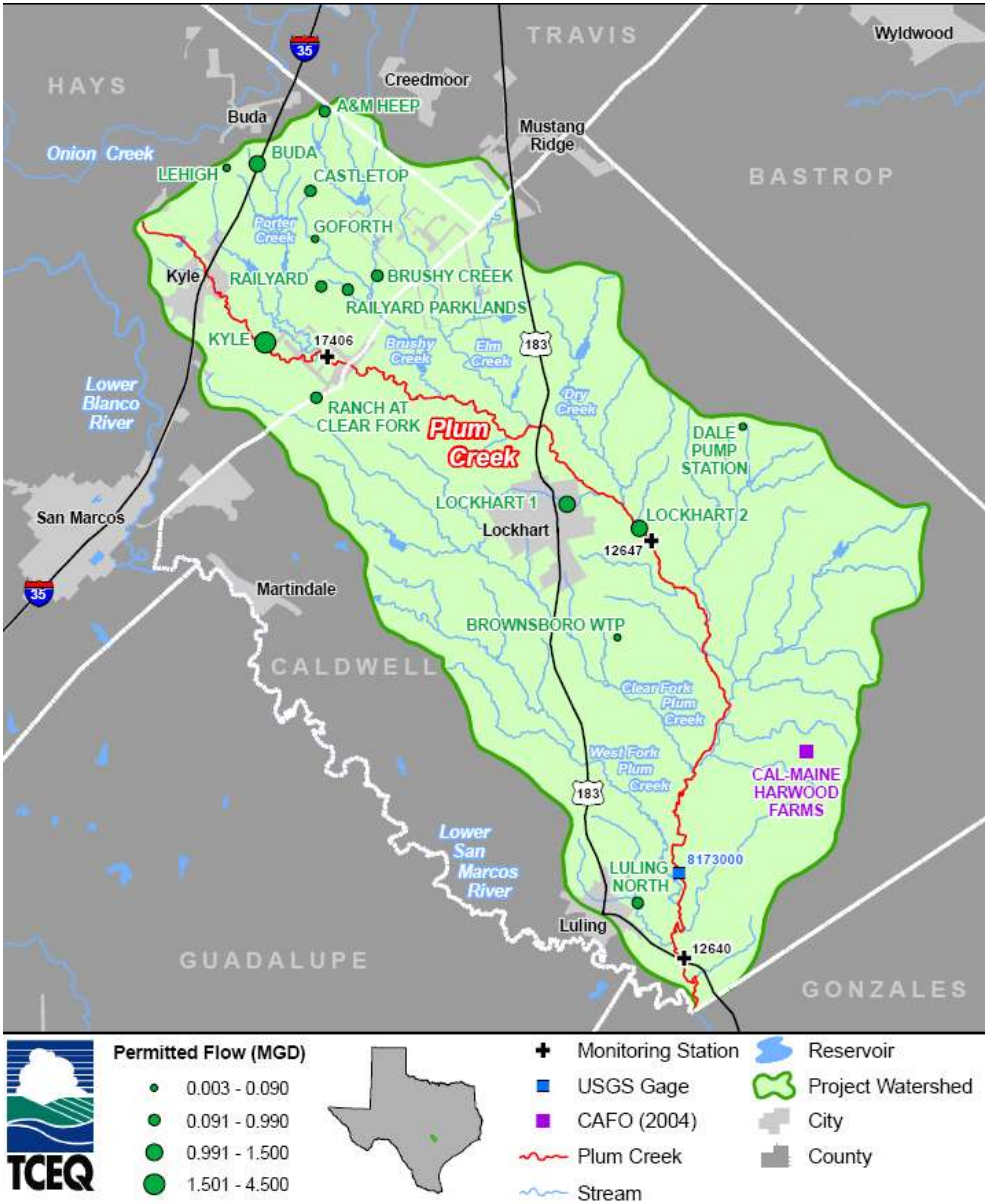


Figure 6.7. Location of wastewater permits and relative discharge volumes in the watershed. Source: TCEQ.

With some exceptions, most permits are written with requirements of 10/15/2 or 10/15/3 (see Appendix G Plum Creek facility permits). This refers to monthly average levels of 10 mg/L biochemical oxygen demand (BOD), 15 mg/L total suspended solids (TSS), and ammonia levels of 2 or 3 mg/L, respectively. Some of the newer permits contain more stringent effluent requirements, maintaining lower concentrations of both BOD (5 mg/L) and TSS (5 mg/L). Certain existing permits transition to include more rigorous limits as facilities expand and increase discharge flows in the future.

Currently, no WWTFs in the Plum Creek Watershed have effluent *E. coli* limits and only two (Lockhart No. 2 and Railyards-Parklands) have fecal coliform bacteria limits in place (not to exceed 200 cfu/100 mL). These two facilities utilize ultraviolet (UV) light to treat bacteria and other pathogens in the effluent. The other facilities use chlorine treatment and are only required to monitor chlorine residuals. While neither process provides complete eradication, both reduce the concentrations of pathogenic viruses and bacteria in effluent to levels which are considered safe for discharge under normal operating conditions (Figure 6.8).

Figure 6.8. City of Lockhart Wastewater Facility No. 2 is managed by the Guadalupe-Blanco River Authority and utilizes UV sterilization to treat bacteria in wastewater.

In dry periods, flow in portions of Plum Creek is dominated by wastewater effluent (Figure 6.9). Particularly in areas where the stream was historically intermittent, increases in wastewater discharge have resulted in a greater percentage of the streamflow coming from these facilities. Some northern sections of Plum Creek that generally had flow only during and shortly after rainfall events now flow perennially due to the addition of effluent from WWTFs.

There have been a number of documented WWTF malfunctions in the Plum Creek Watershed. Violation reports from the TCEQ indicate effluent quality requirements were not met on at least one occasion at several permitted facilities, and some locations had recurring effluent violations. While major failures are rare, there have been a number of treatment bypasses at WWTFs that have resulted in untreated waste being transported to Plum Creek. A major spill on the Porter Creek tributary in 2000-2001 was attributed to the Buda WWTF. Sewage bypass occurred as a result of excessive sludge buildup, which was eventually released to the stream causing extremely high bacteria concentrations directly downstream of the discharge point. A massive cleanup operation was undertaken to remove much of the waste and improve stream health in response to this incident.

Figure 6.9. Parts of the watershed are dominated by effluent during periods of low flow. Photo courtesy of Nikki Dictson, Texas AgriLife Extension Service.

AGRICULTURE

Farm and ranch operations have played an important role in the Plum Creek Watershed (Figures 6.10 and 6.11). Although urbanization has drastically changed upstream reaches of the landscape, much of the watershed remains dominated by agricultural land use, particularly in those parts of Caldwell County not affected by the growth of Lockhart. Production of various classes of livestock, as well as row and forage crops is significant.

Figure 6.10. Orchard in southern Caldwell County. Crop production remains a common activity in the watershed.

Livestock

Plum Creek Watershed residents have long relied on livestock production for food and income. Land use analysis indicated that rangeland and pasture make up more than half of the land use in the watershed. Most of this area is devoted to grazing by domestic animals, including sheep, goats, horses, and cattle.

Figure 6.11. Cattle graze in western central Caldwell County.

Sheep and Goats

While overall numbers in the watershed are not large, goats and sheep are often found in high concentrations in areas where they are present. The waste from these animals represents a source of both bacteria and nutrients. Proper grazing management is necessary to reduce the loss of plant cover, which can increase runoff and erosion of topsoil. In addition, direct access to riparian areas and streams increases potential contributions of both pollutants.

The USDA National Agricultural Statistics Service estimated that there were 1,100 sheep and goats in the Plum Creek Watershed in 2002. Although these numbers most certainly change among and even within years, the overall trend has been stable in the last several years. As a result, the Agricultural Nonpoint Source work group determined to use the 2002 estimate in the SELECT analysis. Results of the analysis indicate that these animals are most likely located primarily in the northern reaches of Plum Creek, on and near the base of the Edwards Plateau (Figure 6.12).

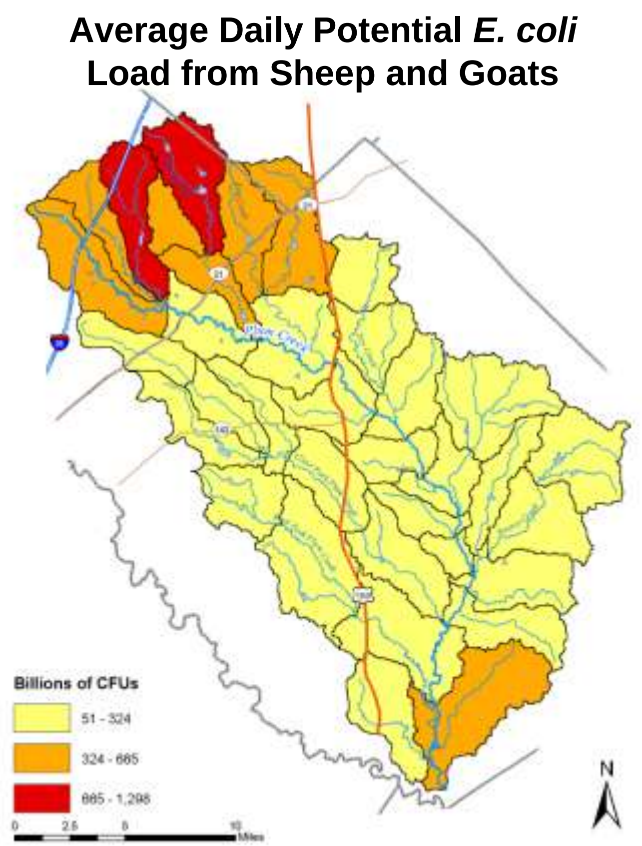


Figure 6.12. Sheep and goat production occur throughout the Plum Creek Watershed but are mostly concentrated in the northern area.

Horses

Horses are grazed in the Plum Creek Watershed, though at much lower densities than other livestock. Most horse owners in the watershed have small numbers of animals, as compared to other types of livestock operations. Nevertheless, the waste from these animals has the potential to contribute both bacteria and nutrients, particularly if pastures or confinement areas are located near drainage areas or the animals are allowed direct access to stream and riparian zones. The Agricultural Nonpoint Source work group recommended utilizing the Texas Agricultural Statistics Service county estimates for 2002 in the SELECT analysis. From the portion of Caldwell, Hays, and Travis Counties lying in the watershed, there are approximately 900 horses in the watershed. Based on land use and census data, these animals are likely more dispersed across undeveloped areas of the entire watershed as opposed to being concentrated in only a few subwatersheds (Figure 6.13).

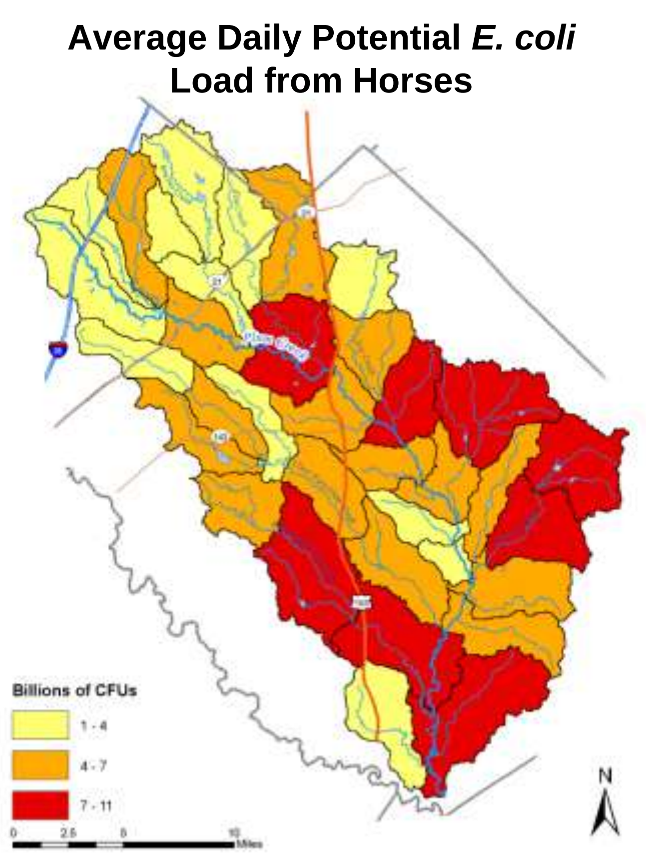


Figure 6.13. Horses are not found in numbers as high as other livestock in the watershed but are scattered throughout pastures and rangelands in southern portions of the watershed.

Cattle

Like other animals, urine and feces from cattle represent sources of both nutrients and bacteria. These pollutants can be transported to streams during runoff events following rainfall. The potential for impact increases where animals are grazed or confined near streams or drainage areas, or when they are permitted direct access to stream and riparian corridors.

The Agricultural Nonpoint Source work group utilized the 2002 Texas Agricultural Statistics Service estimate for cattle in Hays and Caldwell Counties in the SELECT analysis. Although periodic dry weather conditions have resulted in significant fluctuations in animal numbers in the watershed, average total head estimates have remained relatively constant over the last several years. Based on the portions of Caldwell and Hays Counties within the Plum Creek Watershed, there are an estimated 33,000 cattle in the watershed. There are no concentrated cattle feeding operations, such as feedlots or dairies, in the watershed. Most animals are grazed on pasture and rangelands in both upland and bottomland areas. The SELECT analysis indicated that cattle are most likely distributed primarily in the eastern and southern portions of the Plum Creek Watershed (Figure 6.14), outside of areas that have experienced significant urbanization.

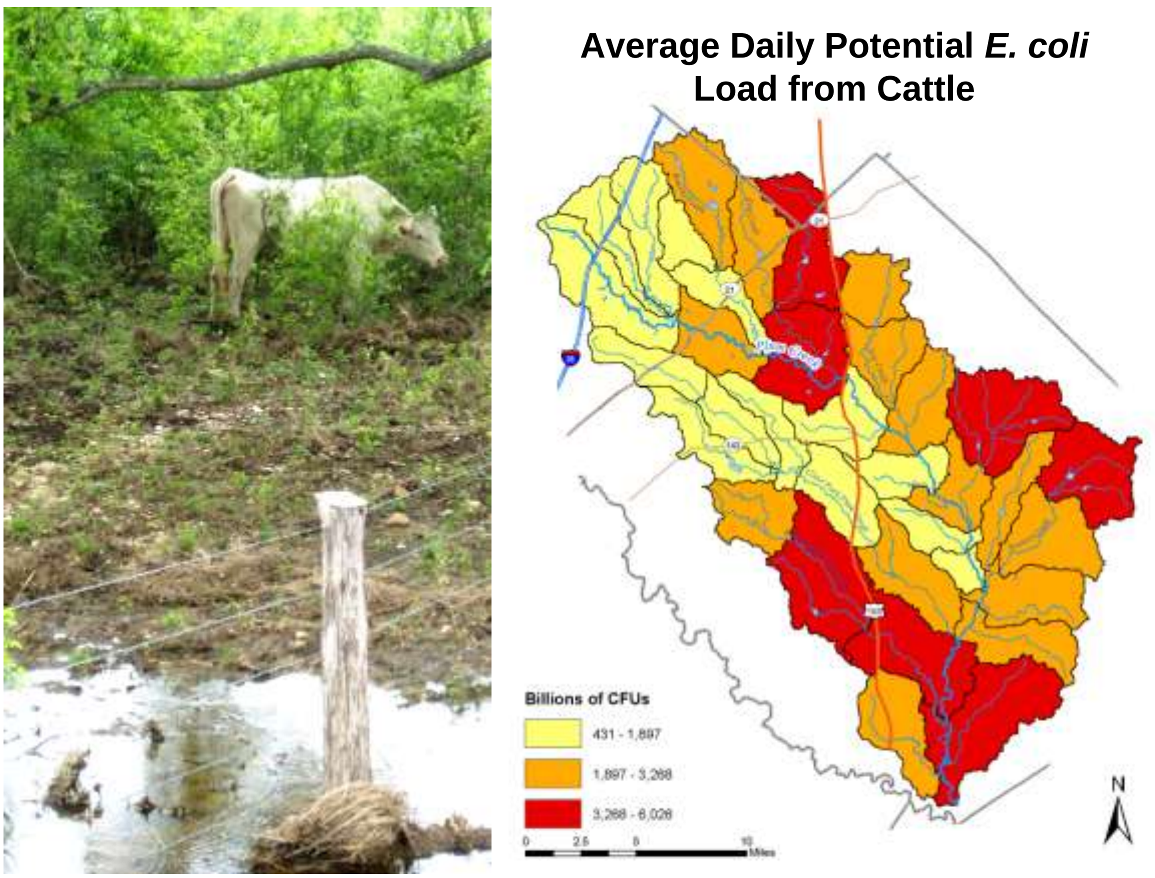


Figure 6.14. Beef cattle represent the primary class of livestock in the watershed and are common throughout rural areas on a variety of land use types. Estimated numbers and potential *E. coli* contributions are highest in southern and eastern areas of the watershed.

Other Livestock

There is one concentrated animal feeding operation in the southeastern portion of the Plum Creek Watershed. Harwood Farm is located in the Copperas Creek drainage northeast of Luling (Figure 6.15). This facility is an egg laying operation with approximately 1 million chickens and is managed by Cal-Maine Foods, Inc. under a general permit with the TCEQ through the TPDES. As part of the permit, the facility must operate according to a nutrient management plan filed with the TCEQ. Flush water used in production is retained on site, and solids are removed from the facility every 2 months. Currently, the facility does not apply manure on site. However, a portion of liquid waste is offered to landowners for application as fertilizer on nearby pasturelands.

Figure 6.15. Harwood Farm in the eastern portion of the watershed.

Row Crops

Row crops do not typically represent a significant source of bacteria to a watershed but may have the potential to contribute high levels of nutrients. Fertilizers used in crop production can be carried downstream in runoff generated by rainfall events and irrigation. This overland flow can potentially allow high concentrations of nutrients to reach a stream and affect water quality if effective management practices are not used.

Areas in the western and central part of the Plum Creek Watershed along the Clear Fork drainage are largely devoted to production of row crops, including corn, sorghum, wheat, and cotton. Some row crop production still occurs in Hays County, but this is slowly declining as agricultural land undergoes development. In the 2006 assessment, nutrient concerns for orthophosphorus and total phosphorus existed from near State Highway 21 to 2.5 miles upstream of the confluence of Clear Fork Plum Creek with the mainstem of Plum Creek. As previously mentioned, the stream was also listed as having nitrate concerns for the entire length of the segment to the San Marcos River. Nutrients from crop production, among other sources, may contribute to high levels of these nutrients.

WILDLIFE

In many watersheds across the country, *E. coli* input from wildlife contributes a large portion of the total stream bacteria load. Wildlife also can be a significant source of nutrients. This is particularly true where populations of riparian animals (raccoon, beaver, and waterfowl) are high. In some cases, bacteria from wildlife alone cause violations of water quality standards.

An assessment of watersheds within central Texas by the TCEQ included examination of bacteria sources in Peach Creek, a watershed adjacent to Plum Creek. Non-avian wildlife (wildlife other than birds) was responsible for almost 30% of the bacteria loading in that watershed (Di Giovanni and Casarez 2006). The non-avian wildlife component includes animals such as raccoons, coyotes, deer, and other mammals. However, information on the abundance and contribution of most animal species is very limited. It is hoped that future studies will shed light on the impacts different species have on water quality in different habitats. In some watersheds, large lakes or reservoirs attract large populations of waterfowl, which can contribute to bacteria loads. However, there are no large reservoirs to attract permanent waterfowl populations in the Plum Creek Watershed and no known large bird colonies in the area contributing to bacteria loads.

Deer

Due to their numbers, white-tailed deer are a significant potential contributor to wildlife bacteria loads in some portions of central Texas. In addition, urine and feces from deer also contribute to nutrient loading. While deer densities are particularly high in areas of the Edwards Plateau to the north and west, much of the potential deer habitat near the Plum Creek headwaters has experienced rapid urban development, and southern portions of the watershed are less suitable for deer habitat. This lack of habitat results in low deer populations in the Plum Creek Watershed. Until recently, TPWD conducted deer surveys in this region, but the predominant habitat type yielded such low counts that resources were shifted elsewhere in the state. The Water Quality and Habitat work group used current density data derived from a 2005 TPWD study (Lockwood 2005) for individual resource management units to estimate that there are approximately 2,000 deer in the Plum Creek Watershed. Because most of these animals are located in the rural and more heavily wooded southern portions of the watershed, the SELECT analysis indicates that these areas have the greatest potential for contributions of bacteria and nutrients by deer (Figure 6.16).

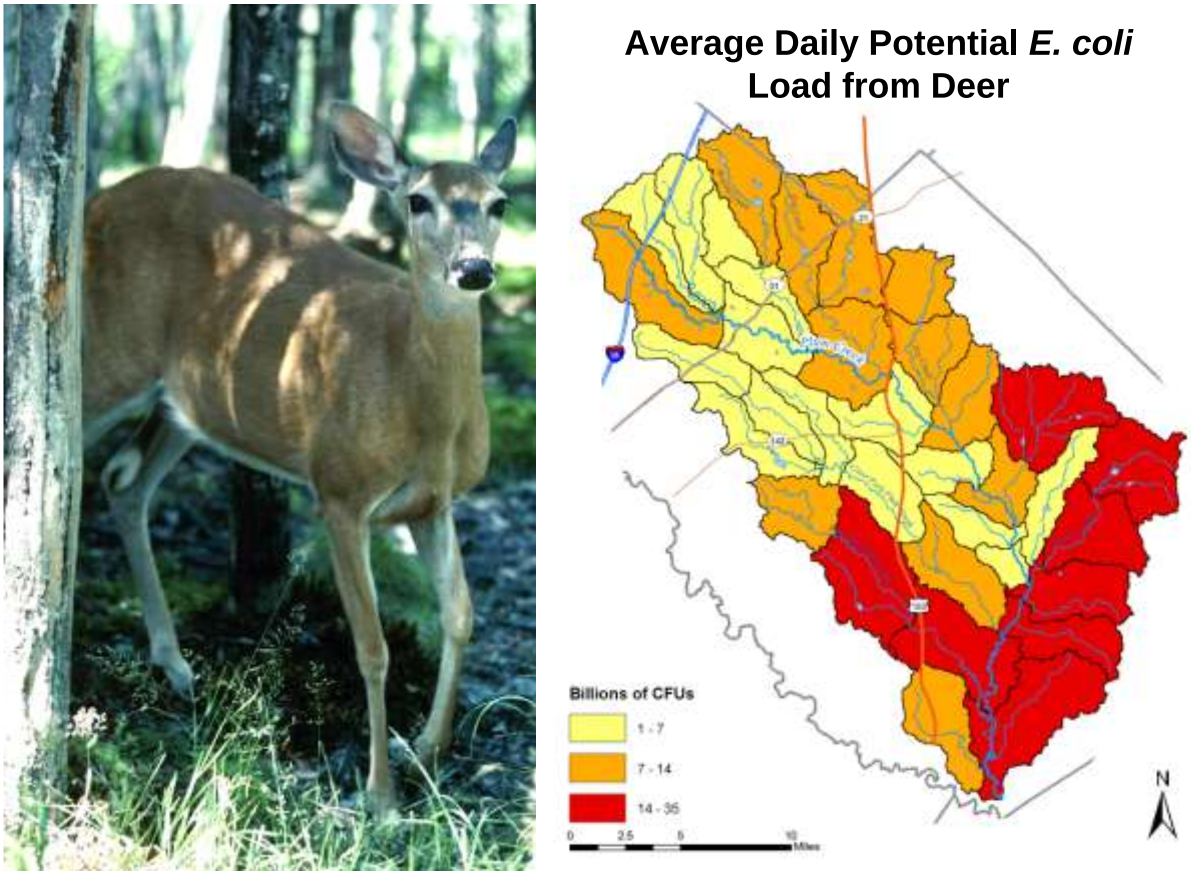


Figure 6.16. White-tailed deer densities and potential *E. coli* loads are highest in rural areas with ideal habitat, including abundant vegetation and water sources. Photo courtesy of © 2007 JupiterImages Corporation.

Feral Hogs

In many watersheds across the state and much of the southern United States, feral hogs are a growing concern. A high rate of reproduction and preference for secluded habitats along streams make high numbers of hogs concentrated in small riparian areas a potential threat to water quality. In addition, extensive rooting activities of groups of feral hogs can cause extreme erosion and soil loss, and herbivory of planted crops can cause significant economic impacts in areas with high numbers of animals. Hogs are often quite secretive, and little solid data exists on their abundance and distribution, which is compounded by their high rate of reproduction and tendency to move in groups along waterways over large areas of a watershed in search of food.

Though density and distribution data are scarce, studies in comparable habitats indicate hogs typically occur in various bottomland habitats at densities of 0.8 to 4 hogs/mile^2 (Tate 1984 and Hone 1990). Particularly in periods of low flow and drought, hogs will congregate around water sources to drink and wallow, and in the process deposit a portion of their waste directly in the stream. As a result, feral hogs can contribute both bacteria and nutrients as a nonpoint source and also through direct deposition, depending on their location and stream conditions.

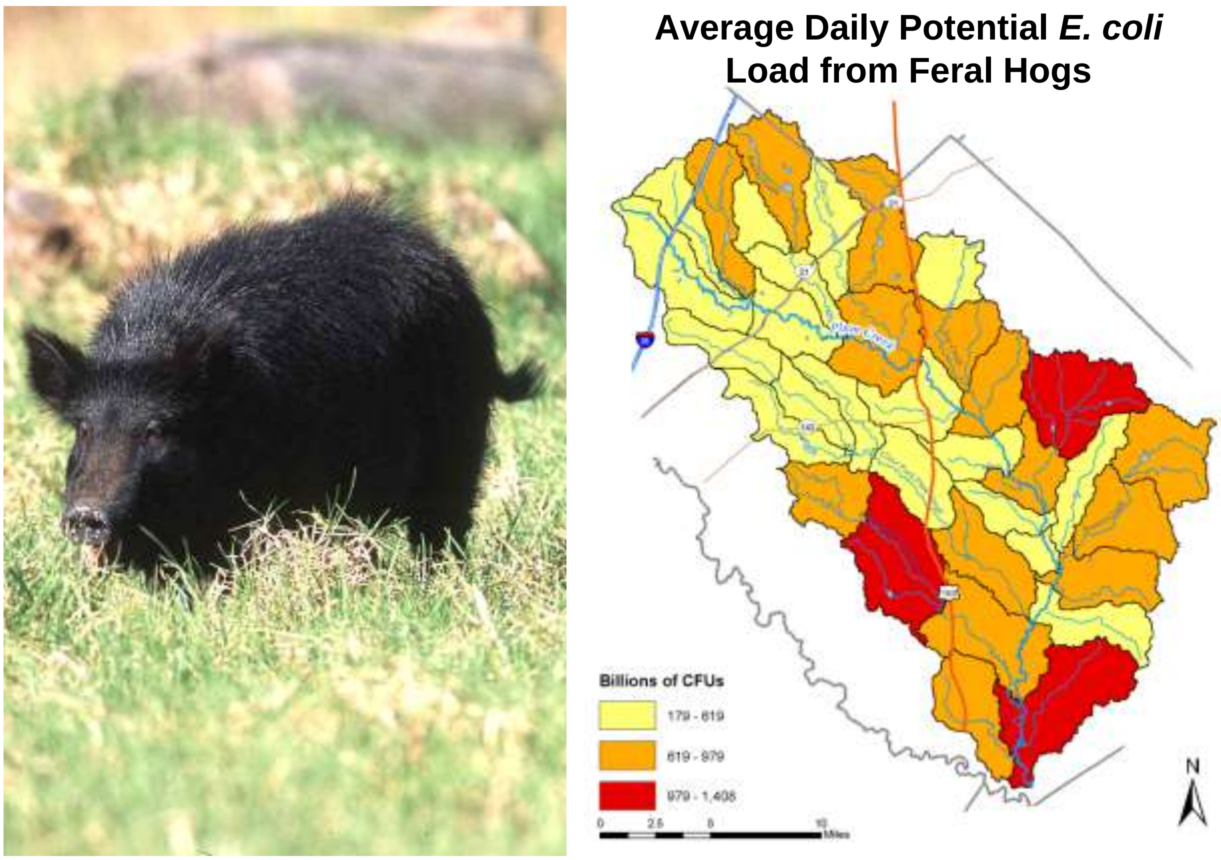


Figure 6.17. Feral hogs are concentrated in areas with perennial water sources and dense vegetation types, and numbers appear to be increasing in the Plum Creek Watershed. Photo courtesy of USDA-NRCS.

As with all other animals, urine and feces from feral hogs contribute to potential loadings of both bacteria and nutrients in the watershed. Landowner observations and general road surveys indicate significant hog activity in the watershed, particularly along Plum Creek and its tributaries. However, because no specific data exist for Plum Creek, the Water Quality and Habitat work group estimated hog numbers using the mean of the reported range, or approximately 2 hogs/mile^2. Based on this estimate, there are as many as 5,000 feral hogs in the Plum Creek Watershed. Because hogs tend to prefer riparian corridors, their distribution was focused in those areas by limiting the land use to zones in closer proximity to creeks and water impoundments for the SELECT analysis. As a result, analysis indicates that while feral hogs are located throughout the watershed, the primary areas of potential impact are in central and southern portions of the Plum Creek Watershed which have numerous water sources and large areas of undeveloped land (Figure 6.17).

Oil and Gas Production

Production of natural gas and petroleum continues in the Plum Creek Watershed. While some cases of hydrocarbon and saltwater release have been reported in the past, there are currently no known pollution problems associated with these activities (GBRA and UGRA 2003). However, continued monitoring for leakage of brine and other waste products is warranted, as the potential exists for some small-scale contamination by old and abandoned wells in the area. Though oil activities were not assessed in SELECT since these wells do not contribute to the *E. coli* load, they may be a source of nitrogen compounds, salts, and hydrocarbons (petroleum byproducts).

Other Issues

Though not regulated as a water quality **pollutant**, trash and solid waste are major problems in portions of the watershed (Figure 6.19). Home appliances, large quantities of old tires, and other items are found at many stream crossings, particularly along less frequently used rural roads. Smaller pieces of trash are swept downstream, and even large objects can be moved during floods. This is a significant issue in some areas, where much of the stream channel is filled with debris. Accumulation of trash can alter streamflow, adding to flood concerns, and contributing to further pollution of the stream. In areas where illegal dumping is a problem, a great deal of effort is necessary to clean up existing trash and prevent further dumping. Sites with trash often receive additional dumping when there appear to be no consequences or control measures in place.

Figure 6.19. Debris at a stream crossing in Caldwell County. Trash is a major issue along stream crossings in rural areas of the watershed.

7. Management Measures

Based on thorough evaluation of water quality data and supporting information characterizing the watershed, the work groups identified management measures that will be necessary to achieve recommended pollutant reductions in Plum Creek. Load duration curves provided the basis for defining needed load reductions within each monitoring zone, and SELECT analysis supported focusing on specific sources and target locations within the watershed to most efficiently achieve reduction goals. Figure 7.1 presents a map which establishes specific subwatershed designations (UH-1-3, LO-1-11, and LU-1-21) within each monitoring region. Management measures are proposed to address both bacteria and nutrient concerns. In most cases, steps taken to reduce bacteria loads in the watershed also will result in reductions in nutrient loading. However, because a portion of the nutrient load likely comes from sources not associated with bacteria production (e.g., urban landscaping and cropland), specific measures addressing these sources also have been recommended.

As noted previously, the entire length of Plum Creek has been listed as having concerns for nitrate concentrations. While a portion of the nitrate load in the Plum Creek Watershed likely is due to point and nonpoint source pollution, an examination of groundwater conditions and streamflow data in the area indicates that a significant percentage of the nitrate load originates from natural sources. Data from the TWDB's Water Information Integration and Dissemination database show that groundwater samples in the area have high nitrate levels. For example:

- 106 of 245 well water samples in the watershed exceeded the screening criterion (1.95 mg/L) with an average nitrate concentration of 45 mg/L.
    - 27 of these samples were collected before 1945, 12 of which exceeded the criterion, and the average concentration for all pre-1945 samples was 25 mg/L.
- All 62 samples from Plum Creek Watershed wells sampled within the Leona formation exceeded the standard, with an average concentration of 56 mg/L.
    - 10 of these were collected before 1945, and the average concentration was 47 mg/L.

Because a significant proportion of the water samples tested prior to 1945 (when nitrogen fertilizer use became widespread) had high nitrate concentrations, it can be assumed that the cause is not related to human activity. Instead, historical and current high nitrate levels in the groundwater are likely due to natural geological characteristics. Further, elevated nitrate concentrations measured within Plum Creek are predominantly influenced by this natural occurrence. This conclusion is supported by the fact that the greatest stream nitrate concentrations are found at the Lockhart monitoring station, where groundwater reaches the surface through countless Leona formation springs in the area. The station is located below the springs and exhibits relatively constant elevated nitrate concentrations across streamflow conditions.

As a result, recommended measures for nutrient management focus on the reduction of phosphorus loads. However, because most nutrient management practices also have a simultaneous effect in reducing nitrogen loads (e.g., fertilizer management, removal of animal waste), potential nitrate contributions from anthropogenic sources also will be minimized.

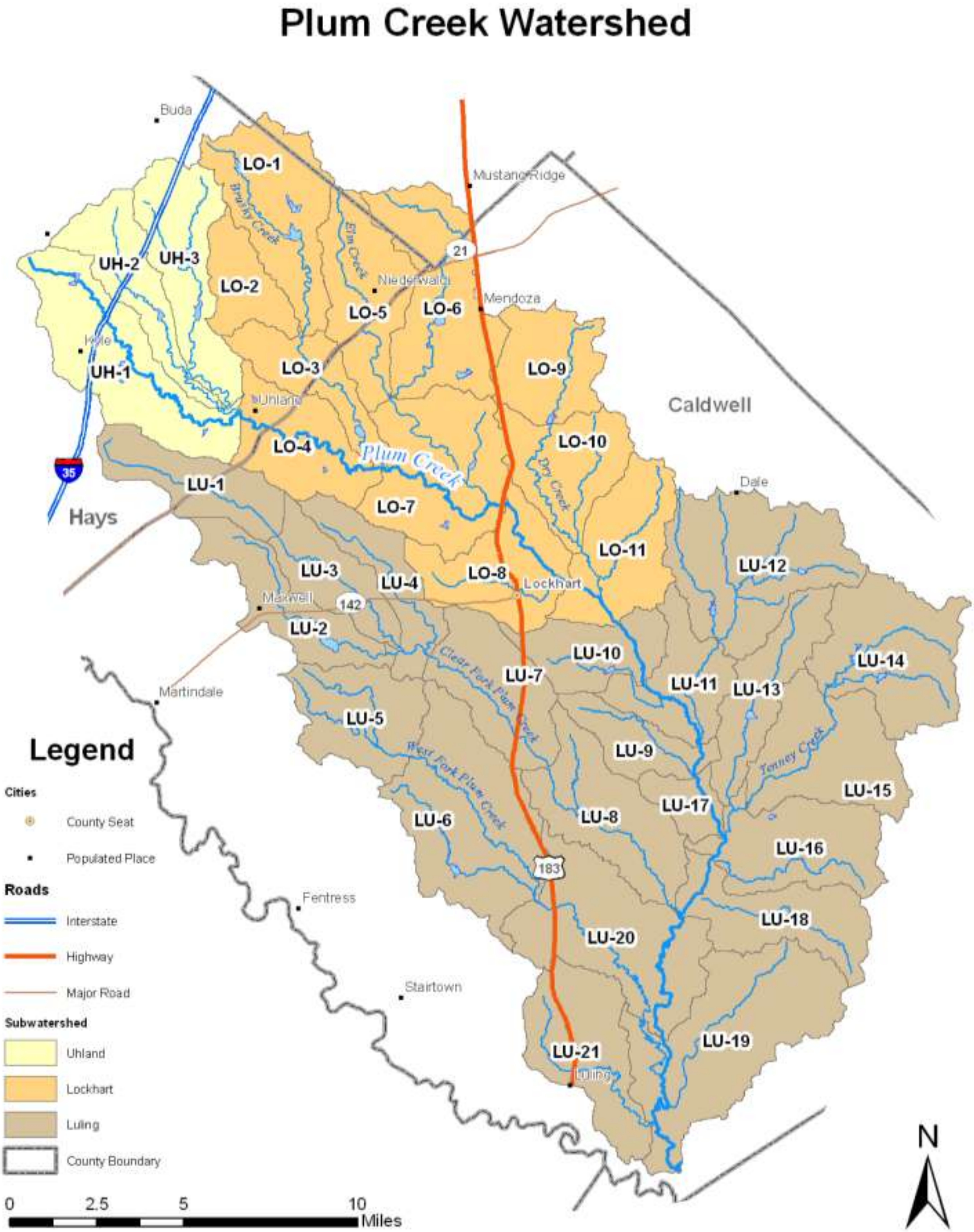


Figure 7.1. Subwatershed map used to target management measures in appropriate areas.

URBAN NONPOINT SOURCE MANAGEMENT MEASURES

The Urban Stormwater and Nonpoint Source work group engaged each of the 4 larger cities with a portion of their city limits in the Plum Creek Watershed to develop strategies that 1) meet city needs and 2) support the overall goals of the Plum Creek Watershed Partnership. Both common and city-specific implementation goals were defined through this process; a summary of these measures is presented in Table 7.1. Emphasis was placed on implementation of programs and practices consistent with MS4 requirements. In addition, because dog waste was identified by SELECT analysis as a significant potential pollutant source in urban areas, measures were defined to address its management. Public outreach components associated with urban management are discussed in the Outreach and Education section.

MS4 Management Strategies

MS4 permits granted by the TCEQ for municipal separate storm sewer systems require several components including public outreach and participation, illicit discharge elimination, runoff control, and general housekeeping measures (see Appendix H for MS4 requirements and Urban Runoff section of Pollutant Sources in the Plum Creek Watershed). While Kyle and Lockhart likely will soon surpass the threshold based on TCEQ guidelines, Buda is currently the only city in the watershed that must satisfy MS4 permit requirements because of its proximity to the Austin metropolitan area. Nevertheless, any municipality can voluntarily implement required measures in whole or part to prevent deterioration of water quality and protect against pollutant loading from urban areas. An important outcome of planning meetings with cities in the watershed was consensus that early implementation of appropriate MS4 programs and practices should be undertaken to the greatest extent possible given available funding.

A fundamental limiting factor for implementation of both non-structural and structural practices is funding. Accordingly, cities agreed to work in concert with the Partnership to identify potential funding sources to support both public education programs on stormwater quality and management, and the installation of structural controls. However, it was determined that to effectively define and guide structural control implementation efforts, detailed engineering analyses are needed for each city to properly locate and design these stormwater management practices. Thus, an initial goal of the implementation plan will be to seek funding to support the needed engineering analyses (Figure 7.2). Results of these analyses will be used by the cities to ensure selection and installation of the most effective structural control measures.

Table 7.1. Summary of recommended common and city-specific stormwater management practices.

Urban Stormwater Management Measures

Common Goals
- Implement non-structural components of MS4 permits on a voluntary basis in advance of program requirements
- Conduct stormwater engineering analyses and city-wide assessments to determine placement of structural management measures in individual cities
- Pet waste management, including passage or modification of ordinances and installation and management of pet waste stations

Kyle
- Continue to enforce existing stormwater management provision of the Subdivision Ordinance
- Conduct a comprehensive stormwater mapping project of drainage, detention facilities, and the storm sewer system
- Retrofit selected detention basins to provide water quality benefits
- Initiate city-wide street sweeping program
- Install 10 pet waste stations and signage in parks
- Nutrient/irrigation water management in park areas

Lockhart
- Enact a pet waste ordinance
- Install 10 pet waste stations and signage
- Nutrient/irrigation water management in park areas
- Manage/periodically relocate duck population at City Park
- Continue/expand existing street sweeping program

Luling
- Reconstruct Cottonwood Creek stormwater retention pond
- Enact a pet waste ordinance
- Install 6 pet waste stations and signage
- Continue/expand existing street sweeping program

Buda
- Enact a pet waste ordinance
- Install 10 pet waste stations and signage
- Enforce the Water Quality Protection requirements of the Unified Development Code
- Complete comprehensive stormwater mapping
- Initiate a city-wide street sweeping program

Dog Waste Management

SELECT analysis was used to determine the total number of dogs in each urbanizing subwatershed. These numbers were then multiplied by the necessary bacteria load reduction for each monitoring station zone to estimate the number of dogs that should be managed within that area. Results for each of the 3 monitoring station regions are presented in Table 7.2. Based on these estimates, emphasis and resources will be directed primarily into the most urbanized subwatersheds around Kyle, Lockhart, and Luling. A significant number of dogs is already under management, but reducing pollutant input depends upon increasing efforts in city parks and in watershed neighborhoods. Management strategies should include waste bag dispensers and collection stations, code enforcement, and intensive public outreach.

Table 7.2. Recommended number of dogs under pet waste management practices.

Region	Subwatershed	Total Dogs	Dogs Managed
Uhland	UH-1	1,255	816
	UH-2	127	83
	UH-3	815	530
	Region Total	2,197	1,429
Lockhart	LO-1	346	52
	LO-2	520	78
	LO-8	2,157	324
	Region Total	3,023	454
Luling	LU-7	615	252
	LU-21	769	315
	Region Total	1,384	567
	Total	6,604	2,450

Figure 7.2. Storm drain in Kyle adjacent to Steeplechase Park. Stormwater engineering analyses are an important initial part of the urban management strategy.

City-Specific Management Measures

City representatives worked with the Partnership to identify current and ongoing urban stormwater management measures, as well as additional measures that cities plan to implement as a part of their commitment to the Plum Creek Watershed Partnership. In many cases, proactive efforts on the part of cities already are reducing pollutant loading. Below are descriptions of existing and planned management measures for each of the individual cities. In most cases, focus on the management of pet waste and stormwater are critical parts of individual cities' strategies (Figure 7.3).

Figure 7.3. Pet waste station in Plum Creek community and storm drain outlet in Lockhart City Park. Management of pet waste and stormwater are important activities in urbanized areas of the watershed.

Kyle

Based on 2004 land use and city boundary information, the city of Kyle covered approximately 6,000 acres, of which 38% was impervious cover. However, commercial and residential development are occurring at a rapid pace, and this is expected to continue into the future. Article V Section 7 (Watershed and Flood Prevention) of Kyle City Subdivision Ordinance 296 is in place to address impacts from stormwater. Activities associated with new development are required to minimize sediment transport and protect environmental quality during construction, and developers must submit plans for stormwater management.

A large percentage of the current stormwater conveyance system in Kyle, particularly in older areas of town, is comprised of open, vegetated ditches. These ditches have some stormwater pollution mitigation effects as a result of plants slowing water and trapping and assimilating pollutants. However, the city plans to complete a comprehensive stormwater map including storm sewer, detention, and drainage infrastructure. The mapping initiative will be used to coordinate stormwater management between developments and across different areas of the city. The city also has begun efforts to secure funding from the TCEQ to retrofit detention basins to improve water quality. The Plum Creek and Steeplechase neighborhoods have been selected for initial efforts. As an additional management measure, the city has purchased a street sweeper and has implemented a regular sweeping program. Initially, residential streets will be swept twice annually, and a 6 block radius around downtown will be swept monthly to reduce the buildup and runoff of pollutants.

The City of Kyle has enacted a pet waste ordinance under Section 14 of Park Ordinance 461, which requires pet owners to pick up and dispose of pet waste in park areas. Although there are currently no signs in parks, the city is prepared to install both signs and pet waste stations in park areas to facilitate proper pet waste management. Upon funding, the city has made arrangements to install 14 pet waste stations in city parks, with additional stations to be installed by neighborhoods in the future. Common areas in some of the larger neighborhoods, such as the Plum Creek community, already have small numbers of pet waste stations to encourage proper management, but additional stations in this and other participating neighborhoods are needed to reduce pollutant loading to the stream.

To further minimize nutrient inputs and water consumption in parks, park staff currently implement a policy to not irrigate or apply pesticide or fertilizer treatments. If more intensive management is initiated, park staff will recommend management practices including irrigation scheduling, integrated pest management methods, soil testing, and proper application methods for nutrient management.

Lockhart

In 2004, the City of Lockhart covered approximately 7,210 acres. Based on land use analysis, approximately 27% of the city area is comprised of impervious cover. The city currently relies on established stormwater rules under the statewide general TPDES permit, which governs stormwater discharge from construction activities.

As an initial step, the city plans to enact a comprehensive pet waste ordinance requiring collection and proper disposal of waste on private property. Waste collected at parks is currently treated with lime before being disposed of with routine trash collection. The city supports the installation of signage informing the public of the need to dispose of their pet waste. In addition, the city requires waste on private property, especially near stream areas, to be picked up and treated with lime for trash collection or reapplication to the lawn. Contingent upon funding, the city also supports the installation of pet waste stations in city parks.

To reduce nutrient loading, it is recommended that city staff implement a routine soil testing program to guide fertilizer application as part of standard park maintenance. In addition, it is recommended that park staff monitor any irrigation systems to minimize system leaks and over-application, which can result in increased runoff. In addition, approximately 60% of the resident duck population at the city park has recently been relocated outside city limits, and the city has indicated the number of animals will be maintained at this reduced level to minimize potential pollutant inputs (Figure 7.4).

The city currently conducts street sweeping every 45-90 days using a vacuum sweeper. The city anticipates continuing these efforts in support of plan objectives, with the primary focus being residential and commercial streets.

Figure 7.4. Muscovy duck at City Park. Lockhart plans to manage the resident duck population.

Luling

As of 2004, Luling covered approximately 2,120 acres, with an estimated 38% of this area being impervious surface. To control stormwater within the city limits, a recent subdivision policy was established requiring that detention ponds be constructed with new development. A site detention plan must be submitted for approval with the development plan in these areas.

Cottonwood Creek, a tributary to Plum Creek, receives stormwater from the area of Luling that drains into the Plum Creek Watershed. A retention pond which previously existed on this tributary captured and provided some level of treatment of stormwater runoff. However, the structure was functionally destroyed in a 1998 flood. Contingent upon funding, the city supports the redesign and reconstruction of the pond to provide flood control and water quality benefits.

The city has approximately 60 acres of city parks. However, only 2 of these parks, representing 25 acres, are within the Plum Creek Watershed. Contingent upon funding, the city supports the installation of a total of 6 pet waste stations and associated signage in these parks. Currently, the city does not have a pet waste removal ordinance, but through an addendum to the current animal control ordinance, Luling has agreed to require that owners pick up and properly dispose of pet waste deposited in public areas. To reduce nutrient loading, it is recommended that city staff implement a routine soil testing program to guide fertilizer application as part of standard park maintenance. Park staff also intend to monitor irrigation systems to minimize system leaks and over application which could contribute to surface runoff. As an additional measure, city maintenance crews plan to maintain an existing program in which all city streets are swept at least monthly (and as frequently as once per week).

Buda

As noted previously, only a small portion of the Buda city limits, just north and west of Interstate 35, lies within the watershed and contributes urban stormwater flow and potential pollutant loading to Plum Creek. Because it is considered part of the Austin metropolitan area, Buda falls under MS4 regulations and is required to file a stormwater management permit with the TCEQ. This permit is in the initial stages of development, but will include several key components that will mitigate stormwater impacts in the Plum Creek Watershed.

Buda currently has 7 parks representing approximately 210 acres. Two of these facilities, Stoneridge Park and Green Meadows Park, lie within the Plum Creek Watershed. No leash or pet waste collection ordinances for public areas are currently in place. However, the city supports installation of pet waste collection stations in city and neighborhood parks to encourage proper disposal of waste from dogs. Contingent upon funding, the city has agreed to install 10 pet waste stations in the parks that contribute stormwater to Plum Creek.

Under Chapter 8 of Buda's Unified Development Code, development within the city and its extraterritorial jurisdiction (ETJ) must comply with requirements of the City of Austin's Environmental Criteria Manual. As part of the requirements of Section 8.4 Water Quality Protection, structural controls must be installed and designed to reduce stormwater concentrations of total phosphorus and total suspended solids by 75%. In addition, developers inspect and maintain these controls after installation, depending on the nature of the development. As a part of the Plum Creek plan, Buda will continue to ensure compliance with the ordinance. To complement these efforts, the city anticipates mapping its stormwater system to complete a comprehensive plan which integrates the requirements of the Unified Development Code. This will improve the ability to track and manage stormwater impacts within the city.

The city has budgeted funds to purchase a street sweeping vehicle to maintain city streets and to mitigate the first-flush effect of stormwater pollutant loading. Specific locations and frequencies have not yet been outlined but will be designed both to meet city needs and to support attainment of water quality goals in the watershed.

WASTEWATER MANAGEMENT MEASURES

Wastewater management in both centralized treatment facilities and private septic systems is and will continue to be important in the Plum Creek Watershed, particularly as the population of the area increases. Planning for this future growth, as well as addressing existing infrastructure issues, is a priority for the Plum Creek Watershed Partnership. WWTFs in the watershed are operated by a combination of municipalities and/or private entities (Table 7.3). All WWTFs must comply with site-specific regulations contained in a TPDES permit issued by the TCEQ. Municipalities manage the means of conveyance to WWTFs and are charged with the upkeep and maintenance of these collection systems. There also are some septic systems still present within the city limits or extraterritorial jurisdictions of several of the cities in the Plum Creek Watershed.

In areas where no public sewer services are available, county and local governments serve as authorized agents and are responsible for the inspection and permitting of septic systems. Inspections are typically conducted when new systems are installed and in association with complaints filed with the authorized agent.

The Wastewater and Industry work group developed a suite of management goals common to all entities in the watershed in addition to city- and county-specific management measures to minimize wastewater contributions to pollutant loads in Plum Creek.

Common Goals

The Plum Creek Watershed Partnership worked in cooperation with key city, county, and private wastewater treatment corporations in the watershed to identify strategies for reducing pollutant loading. Common implementation goals identified and supported by all entities include:

Wastewater Treatment Facilities:

- Promote signing of the East Hays County Wastewater Compact, a key interlocal agreement between multiple entities in the region.
- All WWTFs agree to work toward treatment levels of 5-5-2-1 (BOD/TSS/NH_3/TP) by way of permits for new facilities and voluntary action by existing plants.
- All WWTFs will begin monthly self-monitoring of effluent for bacteria and nutrients.
- All WWTF operators will demonstrate the appropriate licenses and certifications and be current on continuing education opportunities.
- The cities of Kyle, Lockhart, and Luling will evaluate costs and feasibility in an effort to implement phosphorus removal techniques for all effluent entering Plum Creek.

Wastewater Infrastructure:

- Cities will continue or initiate daily inspections of lift stations and equip all stations with dialers and/or Supervisory Control and Data Acquisition (SCADA) systems.
- Cities will continue to apply for grants to replace old clay pipe sewer lines, and clean and maintain existing sewer lines.
- Cities will work to locate any septic systems that may still be within the city limits and connect those residences to central wastewater treatment.

Table 7.3. Current permitted and proposed future permitted or voluntarily achieved wastewater treatment levels in the Plum Creek Watershed. Bacteria limits indicate the use of UV treatment.

Facility (Operator) Permit Number		**Flow (MGD)**	**BOD (mg/L)**	**TSS (mg/L)**	**NH_3 (mg/L)**	**TP (mg/L)**	**Fecal Coliform Bacteria (cfu/100mL)**
Kyle (AquaTexas) 11041-002	C[a]	4.5	10	15	3	-	-
	PF[b]	4.5	5	5	2	1	-
Lockhart No. 2 (GBRA) 10210-002	C	1.5	10	15	3	-	200
	PF	1.5	5	5	2	1	<200
Buda (GBRA) 11060-001	C	1.5	5	12	2	0.8	-
	PF	1.5	5	5	2	0.8	-
Lockhart No. 1 (GBRA) 10210-001	C	1.1	10	15	3	-	-
	PF	1.1	5	5	2	1	-
Luling North (City of Luling) 10582-002	C	0.9	10	15	3	-	-
	F	0.9	5	5	2	1	-
Ranch at Clear Fork 14439-001 (construction 2008)	C	0.7	10	15	2	-	-
	PF	0.7	5	5	2	1	-
Niederwald 14672-001 (construction 2008)	C	0.125	5	12	2	1	-
	PF	0.125	5	5	2	1	-
Railyards-Parkland 14165-001 (construction 2008)	C	0.35	10	15	-	-	200
	PF	0.35	5	5	2	1	<200
Railyard (Village Homes) 14060-001	C	0.124	10	15	-	-	-
	PF	0.124	5	5	2	1	-
Goforth (AquaTexas) 13293-001	C	0.042	10	15	3	-	-
	PF	0.042	5	5	2	1	-
Sunfield (GBRA) 14377-001	C	0.99	5	5	2	1	-
	PF	0.99	5	5	2	1	-
Castletop (GBRA) 14431-001	C	0.486	5	5	2	1	-
	PF	0.486	5	5	2	1	-

[a]Current permitted wastewater treatment level.
[b]Proposed future permitted or voluntarily achieved wastewater treatment level.

One of the key recommendations in common for WWTFs is for an increased level of effluent treatment in order to further reduce bacteria concentrations and introduce phosphorus removal measures where they are not already in place. More stringent effluent limits should effect a reduction in both bacteria and nutrient inputs to Plum Creek. In conjunction with the East Hays County Wastewater compact, the Plum Creek Watershed Partnership strongly recommends that wastewater facilities strive to achieve 5-5-2-1 treatment levels. In many situations, effluent quality consistently meets or exceeds current permit requirements for some water quality parameters. The Plum Creek Watershed Partnership recommends new facilities apply for permits with these requirements, possibly including bacteria limits. At existing WWTFs, operators have agreed to continue efforts to improve effluent quality without permit revisions on a good-faith basis. With available funding, facilities agree to expand and/or retrofit operations to facilitate the increased level of treatment. The Partnership also recommends that the TCEQ implement an unannounced inspection program for WWTFs to encourage and ensure compliance with permit requirements.

City-Specific Management Measures

Kyle

The city has begun to pursue funds to facilitate replacement of old and/or damaged sewer pipes. There is a significant portion of the downtown area that has a clay pipe collection system. Four recent and current projects totaling over $1 million have been initiated to replace these clay pipes and to rehabilitate newer pipes in need of repairs. In addition, the city is now performing smoke testing on the sanitary sewer system to detect and then eliminate problem areas with high rates of infiltration and inflow. Lift stations are currently on dialer notification systems, and the city plans to continue daily inspections. The city also plans to pursue funding for installation of a SCADA system to continuously monitor these stations.

The city currently pumps a portion of its treated effluent to a holding pond which is used to irrigate the Plum Creek Golf Course. Up to 50% of the current discharge volume is now reused for this purpose and requires a fecal bacteria geometric mean of less than 200 cfu/100 mL. If additional reuse occurs in the future, the reduction in discharge volume contributed to Plum Creek may affect both water quality and quantity. In the interim, and contingent upon funding, the city has agreed to initiate voluntary monthly monitoring of bacteria and nutrients in effluent that is to be discharged to Plum Creek.

Within the city limits, there is a limited area of development that relies on private septic systems for household wastewater treatment. The city is investigating the incorporation of this area into existing infrastructure in the future.

Uhland

The city of Uhland does not have a centralized wastewater treatment facility, and there are currently no sanitary sewer lines. As a result, all residents rely on septic systems, and the city is responsible for permitting and inspecting these systems within the city limits. Many of these systems are quite old and may be prone to failure. In some sections of town, properties with systems requiring major repair or replacement have been abandoned. The City Manager currently serves as the septic system inspector, but problem systems typically are identified only as a result of complaints or when properties known to be without proper permits are found to have residents. To address the issue of aerobic spray system maintenance, the city recently has adopted an ordinance requiring aerobic septic system inspection and maintenance to be conducted by trained professionals. In addition, the city continues to investigate the construction of a centralized wastewater facility to service the area under its jurisdiction. County Line Water Supply holds a Certificate of Convenience and Necessity (CCN) to supply water to the city and is applying for the wastewater CCN for the area. In addition to obtaining funding and a proper permit, efforts to identify a suitable location are underway.

Lockhart

There are approximately 60 miles of sanitary sewer lines in Lockhart, and smoke tests indicate roughly 22 miles are currently in need of repair or replacement. All known areas of clay pipe are being systematically replaced through ongoing infrastructure upgrades. The city continues to routinely inspect all sewer lines every 3 to 4 years using a camera system to identify problem areas. The city also continues to prioritize and seek funding assistance for replacement and repair programs for the wastewater collection system, with a goal of at least 600 feet per year. The city plans to maintain a cleanout cap inspection process which occurs after all significant rain events. In addition, city personnel continue daily inspection of lift stations and maintain the SCADA system utilized for monitoring.

The city and the GBRA have agreed to begin voluntary monthly sampling of phosphorus at both facilities and weekly bacteria sampling at the Lockhart No. 1 facility. In addition, the GBRA and the city have proposed evaluating the feasibility of installing flow-triggered phosphorus removal. With this system, effluent would be treated to remove phosphorus when flow in the creek drops below a specific level in order to enhance the stream’s ability to assimilate existing nutrient loads.

Luling

Most of the old sewer mains in the city are composed of clay pipe and in need of replacement. Through a proactive 10-year project with the TWDB, the city already has replaced 2 miles of old pipe, representing approximately one-third of existing problem pipes. Additional critical areas will be addressed annually. To support these efforts, the city is in the process of purchasing a camera to inspect pipes and locate critical areas. The city of Luling currently operates 8 lift stations and soon will be adding 2 additional stations. Lift stations continue to be inspected daily by public works personnel. In addition, to help prevent overflows, the city plans to seek funding to install dialers or a SCADA system to monitor all lift stations.

The City of Luling has 2 WWTFs, one of which discharges into Plum Creek (Luling North) while the other discharges into the San Marcos River. Contingent upon funding, the city has agreed to conduct monthly sampling for bacteria and nutrients at the Luling North facility.

There are currently no septic systems within the city limits of Luling. However, as a result of planned annexation, nearly two dozen residential systems as well as several commercial systems will be brought under city jurisdiction. When complete, a new sewer line to Carter Memorial Airport will connect these properties to city utilities.

Buda

Within the City of Buda's ETJ and in the Plum Creek Watershed, there are multiple neighborhoods representing approximately 500 homes on septic systems. The city anticipates the incorporation of these areas and their connection to municipal sewer services as the annexation plan progresses. These connections will contribute wastewater to the city facility, which discharges to the Plum Creek Watershed.

There are currently 6.4 miles of sewer lines within the city. Multiple locations have been identified as problem areas mostly due to blockage by tree roots. The city desires to pursue funding to upgrade areas relying on older clay pipe to minimize infiltration/inflow and leakage issues in the future. In addition, the city will continue a program to inspect and replace cleanout caps within the city in order to minimize the likelihood of sanitary sewer overflows. The 6 lift stations operated by the city are equipped with emergency dialers and undergo daily inspections.

The Buda wastewater facility conducts monthly sampling for bacteria in addition to monthly phosphorus monitoring already directed by permit requirements. The city currently does not reuse treated wastewater effluent, but will investigate the potential for municipal irrigation or sale/release to potential industrial users (e.g., Texas Lehigh Cement Company).

Counties

Most septic systems in the watershed lie outside city limits and are within county jurisdictions. Thus, active programs in both Caldwell and Hays Counties will be critical in locating and addressing failing systems and to ensure appropriate preventative management of all systems. Both counties plan to continue requirements of the inspection of new systems when new utilities are connected or when properties change ownership. In addition, Hays County and the City of Uhland have drafted and plan to implement an ordinance requiring aerobic septic systems to be routinely inspected and maintained by trained professionals, rather than by homeowners. Caldwell County also has adopted an ordinance addressing routine inspection and maintenance of aerobic systems by properly trained professionals. Hays County will continue to maintain 8 total sanitarians to implement the program. Caldwell County currently has only 1 sanitarian, thus funding will be sought to add 2 additional staff to implement and assist the inspection and enforcement program.

To target the inspection programs, SELECT analysis was utilized to locate and quantify potentially failing septic systems in the watershed and to estimate the number of systems in close proximity (within 330 ft) to Plum Creek and its tributaries. These systems will be targeted for repair or replacement due to their greater potential to impact water quality. Analysis included a 12% failure rate for systems constructed after state regulations (Reed, Stowe, and Yankee 2001) and a higher estimated failure rate of 50% for older pre-regulatory systems. These failure rates were applied to the total number of systems within each subwatershed to predict the number of systems that may require management, repair, or replacement (Table 7.4).

Table 7.4. Estimated total number of septic systems, failing systems, and failing systems within 330 ft. of a stream.

Region	Subwatershed	Total Systems	Potential Failing Systems	Near-Stream Failing Systems
Uhland	UH-1	739	367	43
	UH-2	130	65	9
	UH-3	1,009	501	52
	Region Total	1,878	933	104
Lockhart	LO-1	435	217	11
	LO-2	649	311	31
	LO-3	171	82	10
	LO-4	195	82	5
	LO-5	392	195	10
	LO-6	191	92	8
	LO-7	113	56	6
	LO-8	268	126	1
	LO-9	118	49	4
	LO-10	165	66	5
	LO-11	121	53	5
	Region Total	2,818	1,329	96
Luling	LU-1	155	66	10
	LU-2	153	76	4
	LU-3	29	14	1
	LU-4	44	22	3
	LU-5	60	30	3
	LU-6	145	72	11
	LU-7	438	208	17
	LU-8	56	28	2
	LU-9	50	25	3
	LU-10	111	54	4
	LU-11	69	33	5
	LU-12	233	96	12
	LU-13	52	26	3
	LU-14	81	31	2
	LU-15	81	40	5
	LU-16	28	15	2
	LU-17	14	7	0
	LU-18	42	21	1
	LU-19	95	48	4
	LU-20	95	48	3
	LU-21	313	149	12
	Region Total	2,346	1,110	107
	Total	7,040	3,369	307

Using this approach of focusing on potentially failing systems near waterways, the greatest concentration of systems requiring repair or replacement is in the upper portion of the watershed in Hays County (subwatersheds UH-1, UH-3, and LO-2). Additional target areas will include LU-7 south of Lockhart and LU-12 near Dale. Inspection programs will initially focus on these areas, but over time will work to address all subwatersheds.

To assist in the repair and replacement of failing septic systems, high risk areas within targeted subwatersheds will be identified through coordination with authorized agents and inspectors in both Hays and Caldwell Counties. In cooperation with these counties, critical areas that would benefit from more intense monitoring and inspection will be located based on GIS mapping, county data, and local knowledge of residents and inspectors. These initial efforts will enable effective septic system remediation.

Counties continue to update septic system permits, compiling data on system age, location, and condition in electronic format for quick access. With incorporation of new information, this central database will allow patterns of system installation and failure to be monitored in order to predict, prevent, and respond to problems in the future.

Regional Compact

The East Hays County Wastewater Compact (Appendix I) represents a key interlocal agreement, which if adopted, will serve to mitigate the effects of failing septic systems as well as provide the benefits of regional wastewater treatment services. As a partnership between the cities of Buda, Niederwald, Uhland, and Kyle, as well as Hays County and the GBRA, the Compact would serve to elevate the standard of wastewater treatment in the area, provide opportunities for reuse, and protect water quality in Plum Creek. Once signed, the agreement will act as a reasonable assurance that commitments to components of the Compact will be implemented by local entities. Some of the key components of the Compact are:

- While not all developments are practical candidates for connection to centralized wastewater services, where possible, developments of 10 or more homes should be connected to a wastewater facility.
- To ensure proper operation over the long-term, WWTFs should be operated by public entities, and centralized facilities associated with new developments should be jointly permitted (as between a private developer and a public entity).
- By utilizing the best available technology, new facilities will move toward adopting a 5-5-2-1 effluent set (BOD/TSS/NH_3/TP) to protect water quality.
- Reuse of treated wastewater utilizing a “purple pipe” system for irrigation and other applications will be encouraged to reduce pressure on the drinking water supply.
- The parties will jointly participate in the review of proposed wastewater projects, plans, and in special studies.
- The parties will agree to participate in supporting the core provisions of the Compact.

The Compact has been signed by several local entities, including the GBRA, the City of Niederwald, and Hays County. As a part of the Plum Creek Watershed Protection Plan, the remaining parties commit to review and move forward with an effort to finalize the Compact.

To assist in the activities outlined in the Compact, professional engineering analysis will be sought to determine the constraints and costs for upgrading wastewater infrastructure throughout the Plum Creek Watershed. Increased levels of treatment will require additional equipment at most facilities, and selection of additional treatment options will be guided by the findings of the analysis.

AGRICULTURAL NONPOINT SOURCE MANAGEMENT MEASURES

To achieve bacteria and nutrient load reduction goals established for Plum Creek, specific management practices and combinations of practices will be implemented on agricultural land (Figure 7.5). Guided by the Agricultural Nonpoint Source work group, it was determined that this would best be achieved by developing voluntary, site-specific management plans for individual operations. Both the NRCS and the TSSWCB offer planning assistance for agricultural producers. Water Quality Management Plans (WQMPs) are developed by local Soil and Water Conservation Districts (SWCDs) under the statewide TSSWCB program and are tailored to meet the needs of each operation. The NRCS offers options for development and implementation of both individual practices and whole farm conservation plans. Cost-share assistance is available through associated programs to offset implementation costs. To facilitate development and implementation of these management plans, the Plum Creek Watershed Partnership will pursue funds to support a cost-share program and the creation of a new position at the SWCD level to be housed in the watershed.

Based on USDA-NASS data, the average farm in Caldwell and Hays Counties is estimated to be approximately 230 acres, and local knowledge from NRCS, Extension, and agricultural producers indicates that livestock operations maintain an average of approximately 50 animal units (cumulative cattle, sheep, goats, and horses). Utilizing this information, along with results from the SELECT and LDC analyses, the number of comprehensive management plans necessary for livestock and cropland operations within each subwatershed and monitoring station region was estimated and is presented below.

Livestock Operations

The estimated number of animal units in each subwatershed, was divided by the average number of animal units per operation to estimate the number of livestock operations within each subwatershed. Next, the bacteria reduction percentage for the corresponding monitoring station region (Uhland 65%, Lockhart 15%, Luling 41%) was applied to the total number of livestock operations within each subwatershed to determine the number of operations that should undergo plan development. Based on these estimates, the number of livestock operation management plans required for individual subwatersheds ranges from 1 to 19. A total of 235management plans are necessary for the entire Plum Creek Watershed (Table 7.5).

Table 7.5. Recommended number of management plans for livestock operations by subwatershed.

Region	Subwatershed	Animal Units	Number of Farms	Recommended # of Conservation Plans
Uhland	UH-1	493	10	6
	UH-2	403	8	5
	UH-3	731	15	10
	Region Total	1,627	33	21
Lockhart	LO-1	1,024	20	3
	LO-2	327	7	1
	LO-3	717	14	2
	LO-4	852	17	3
	LO-5	882	18	3
	LO-6	1,751	35	5
	LO-7	2,019	40	6
	LO-8	506	10	2
	LO-9	828	17	2
	LO-10	1,117	22	3
	LO-11	1,308	26	4
	Region Total	11,331	226	34
Luling	LU-1	168	3	1
	LU-2	748	15	6
	LU-3	498	10	4
	LU-4	322	6	3
	LU-5	1,257	25	10
	LU-6	1,879	38	15
	LU-7	694	14	6
	LU-8	1,027	21	8
	LU-9	542	11	4
	LU-10	600	12	5
	LU-11	1,020	20	8
	LU-12	1,787	36	15
	LU-13	999	20	8
	LU-14	1,662	33	14
	LU-15	1,173	23	10
	LU-16	1,124	22	9
	LU-17	344	7	3
	LU-18	986	20	8
	LU-19	2,348	47	19
	LU-20	1,981	40	16
	LU-21	989	20	8
	Region Total	22,148	443	180
Total		35,101	702	235

Focus Areas

Cost-share and technical assistance programs will be directed to subwatersheds with the greatest number of operations. However, recognizing that livestock numbers within individual subwatersheds vary due to weather conditions and market economics, programs provided in the watershed will require flexibility. In addition, preference will be given to operations with the greatest number of animal units, and particularly to those located closest to streams and drainage areas.

In the Uhland region, livestock operation plans will be targeted along Porter Creek (UH-3). Management plans in the Lockhart region will be focused along U.S. Highway 183 (LO-6 and LO-7), along Cowpen Creek south of Mustang Ridge, and Elm Creek in the vicinity of Niederwald (Table 7.6). Operations near the Dry Creek drainage west of Dale in Caldwell County (LO-11) will receive secondary focus for plan implementation. In the Luling region, management plans primarily will be focused along West Fork and along McNeil Creek east of Luling (LU-6, LU-19, LU-20). Operations near Tenney Creek (LU-14) and south of Dale (LU-12) also will receive priority consideration.

Table 7.6. Critical areas for livestock management plan development.

Region	Primary Focus	Secondary Focus
Uhland	Porter Creek drainage	Upper reaches of Plum Creek mainstem
Lockhart	Along U.S. Highway 183 Cowpen Creek near Mustang Ridge Elm Creek near Niederwald	Brushy Creek east of Buda Dry Creek and tributaries west of Dale
Luling	West Fork Drainage McNeil Creek east of Luling	Tenney Creek drainage Dry Creek and tributaries south of Dale

Cropland Operations

The number of cropland management plans required to achieve estimated nutrient load reductions was determined using an approach similar to that for livestock operations (Table 7.7). The total cropland acreage in each subwatershed was divided by the average watershed farm size (230 acres) to estimate the number of cropland operations. Next, the required phosphorus reduction for each monitoring station was used to determine the number of cropland operations within each subwatershed and monitoring station region needing plan development.

Table 7.7. Recommended number of management plans for cropland operations by subwatershed.

Region	Subwatershed	Cropland Acres	Number of Farms	Recommended # of Conservation Plans
Uhland	UH-1	1,374	6	2
	UH-2	930	4	1
	UH-3	569	2	1
	Region Total	2,873	12	4
Lockhart	LO-1	1,138	5	2
	LO-2	149	1	0
	LO-3	433	2	1
	LO-4	1,163	5	2
	LO-5	1,374	6	3
	LO-6	742	3	2
	LO-7	1,117	5	2
	LO-8	1,890	8	4
	LO-9	742	3	2
	LO-10	222	1	0
	LO-11	1,117	5	2
	Region Total	10,087	44	20
Luling	LU-1	4,059	18	0
	LU-2	2,171	9	0
	LU-3	2,623	11	0
	LU-4	3,143	14	0
	LU-5	148	1	0
	LU-6	72	1	0
	LU-7	1,106	5	0
	LU-8	1,890	8	0
	LU-9	742	3	0
	LU-10	88	1	0
	LU-11	500	2	0
	LU-12	240	1	0
	LU-13	289	1	0
	LU-14	88	1	0
	LU-15	506	2	0
	LU-16	24	1	0
	LU-17	70	1	0
	LU-18	351	2	0
	LU-19	72	1	0
	LU-20	30	1	0
	LU-21	351	2	0
	Region Total	18,563	86	0
Total		31,523	142	24

Focus Areas

To optimize the potential for nutrient load reductions, cropland management plans in the Uhland region primarily will be focused between Plum Creek and the southern portions of Bunton Branch in Hays County (Table 7.8). Additional plans will be implemented along the upper reaches of Porter Creek near Buda. In the Lockhart region, plans will be targeted on agricultural lands along Town Branch immediately west of Lockhart and bordering central portions of Brushy Creek near Niederwald. Upper portions of Dry Creek near Mendoza will receive secondary priority. Similar to livestock operations, planning efforts for cropland systems will give preference to those operations closest to streams and those with characteristics (including soil type and slope) which have the greatest potential to contribute pollutants to Plum Creek.

Table 7.8. Critical areas for cropland management plan development.

Region	Primary Focus	Secondary Focus
Uhland	Between Plum Creek and southern Bunton Branch	Upper Porter Creek south of Buda
Lockhart	Upper Town Branch west of Lockhart Brushy Creek near Niederwald	Upper Dry Creek near Mendoza
Luling	(none)	(none)

Management Measures

To focus management plan development and implementation, management measures addressing bacteria and nutrient issues will be encouraged and given top priority. Based on site-specific characteristics, plans should include one or more of the following management practices to reduce pollutant loads from agricultural lands:

- Prescribed Grazing: Manages the controlled harvest of vegetation with grazing animals to improve or maintain the desired species composition and vigor of plant communities, which improves surface and subsurface water quality and quantity.
- Riparian Herbaceous Buffers: Establishes an area of grasses, grasslike plants, and forbs along water courses to improve and protect water quality by reducing sediment and other pollutants in runoff as well as nutrients and chemicals in shallow groundwater.
- Grassed Waterways: Natural or constructed channel-shaped or graded and established with suitable vegetation to protect and improve water quality.
- Riparian Forest Buffers: Establishes area dominated by trees and shrubs located adjacent to and up-gradient from watercourses to reduce excess amounts of sediment, organic material, nutrients, and pesticides in surface runoff and excess nutrients and other chemicals in shallow groundwater flow.
- Watering Facilities: Places a device (tank, trough, or other watertight container) that provides animal access to water and protects streams, ponds, and water supplies from contamination through alternative access to water.

- Field Borders: Establishes a strip of permanent vegetation at the edge or around the perimeter of a field to protect soil and water quality.
- Filter Strips: Establishes a strip or area of herbaceous vegetation between agricultural lands and environmentally sensitive areas to reduce pollutant loading in runoff.
- Nutrient Management: Manages the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize agricultural nonpoint source pollution of surface and groundwater resources.
- Conservation Cover: Establishes permanent vegetative cover to protect soil and water.
- Stream Crossings: Creates a stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles, improving water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream.
- Alternative Shade: Although not currently an approved cost-share practice, creation of shade reduces time spent loafing in streams and riparian areas, thus reducing pollutant loading. Efforts will be made to include this practice as a component of livestock management plans.

Figure 7.5. Clear Fork runs through grazing land in Caldwell County. Management plans will be used to protect water quality in agricultural areas.

WILDLIFE AND NON-DOMESTIC ANIMAL MANAGEMENT MEASURES

Feral Hog Control

Based on SELECT analysis, non-domestic animals are a significant potential contributor of pollutants to Plum Creek. TPWD manages native wildlife and oversees harvest of game species across the state. However, the feral hog, a nonnative species, appears to be growing in numbers in the watershed. The Water Quality and Habitat work group recommends that efforts to control feral hogs be undertaken to reduce the population, limit the spread of these animals, and minimize their effects on water quality and the surrounding environment. Other non-domestic animals, including feral dogs and cats also are likely contributors, although to a much lesser extent and at levels and locations that cannot be predicted at this time. In addition, native wildlife such as deer, raccoons, opossums, and bird species, are also contributing pollutants. However, this is considered background nonpoint source pollution. Active management of native wildlife for water quality purposes is generally not promoted in the state of Texas and will not be included in the Plum Creek Watershed Protection Plan.

To address the feral hog issue, the Plum Creek Watershed Partnership will rely heavily on the expertise and resources of the Texas Wildlife Damage Management Service (TWDMS), a division of the Texas AgriLife Extension Service. This agency protects the resources, property, and well-being of Texans from damages related to wildlife. TWDMS serves rural and urban areas with technical assistance, education, and direct control in wildlife damage management of both native wildlife and non-domestic animals. Pursuant to funding, a full-time position will be established through TWDMS to focus specifically on feral hog management in Plum Creek. The position will work directly with landowners to remove animals from the watershed by trapping and hunting.

To determine the approximate number of feral hogs that should be removed, the estimated number of hogs in each subwatershed was multiplied by the necessary load reduction for the corresponding water quality monitoring station region (Table 7.9). Because the SELECT analysis used to determine total hog numbers also identified the most likely habitat zones based on land cover, TWDMS personnel will target initial management efforts in those areas. These hog numbers represent initial goals over the course of the project, and as more information is gathered or if populations increase rapidly, these targets will be adjusted accordingly.

To further enhance program targeting and success, a website will be established to enable reporting of the date, time, location, and approximate number of hogs observed (Figure 7.6). In addition, a landowner survey also will be conducted through local Extension offices to identify specific properties for participation and to better quantify feral hog populations. This will be supported by an annual or biennial feral hog management seminar sponsored by Extension to address feral hog control issues.

Table 7.9. Recommended number of feral hogs to be removed by subwatershed.

Region	Subwatershed	Total Hogs	Hogs to Be Removed
Uhland	UH-1	127	83
	UH-2	89	58
	UH-3	192	125
	Region Total	408	266
Lockhart	LO-1	167	25
	LO-2	67	10
	LO-3	122	18
	LO-4	90	14
	LO-5	96	14
	LO-6	184	28
	LO-7	207	31
	LO-8	53	8
	LO-9	114	17
	LO-10	159	24
	LO-11	177	27
	Region Total	1,436	216
Luling	LU-1	98	40
	LU-2	111	46
	LU-3	87	36
	LU-4	119	49
	LU-5	146	60
	LU-6	316	130
	LU-7	130	53
	LU-8	146	60
	LU-9	90	37
	LU-10	93	38
	LU-11	173	71
	LU-12	280	115
	LU-13	131	54
	LU-14	177	73
	LU-15	206	84
	LU-16	220	90
	LU-17	40	16
	LU-18	139	57
	LU-19	239	98
	LU-20	194	80
	LU-21	160	66
	Region Total	3,295	1,353
Total		5,139	1,835

Administered by the Texas Association of Community Action Agencies (TACAA), the Texas Hunters for the Hungry Program is a statewide wild game donation program that provides a healthy source of protein to Texans who need assistance obtaining well-balanced, nutritious meals. Through participating meat processors, game is processed for a nominal fee and then distributed to food banks and similar entities. Statewide, venison has been the staple for the Hunters for the Hungry Program, but other game such as feral hogs are accepted. Current regulations stipulate that feral hogs must be trapped live and transported to an approved facility for inspection prior to slaughter. This has historically limited the quantity of feral hogs processed for distribution through this program. The Plum Creek Watershed Partnership will work with TACAA, TDA, and other partnering groups to explore the feasibility of integrating management of nuisance animal populations with the generation of low-cost food products for community groups and low-income families. If successful, this will serve as a model for a statewide coordinated feral hog management and food assistance program.

Figure 7.6. A feral hog in open brush. Control of hogs is a major strategy to reduce nonpoint source pollution and will be guided by an online reporting system.

Wildlife Surveys

To identify other potential sources among local wildlife populations, the Water Quality and Habitat work group recommends employing additional surveys to further quantify wildlife contributions. Bacterial Source Tracking may be utilized to determine which types of animals have the greatest *E. coli* contribution and is discussed later in this plan. Though formal TPWD deer surveys have been discontinued in the ecoregion comprising the watershed, the Plum Creek Watershed Partnership also recommends that periodic small-scale surveys be conducted every 5 years in the watershed to determine the extent of deer populations in the area. These may be conducted by personnel from the wildlife departments at state universities. In addition to these surveys, a complement of periodic avian and small mammal surveys will be conducted to yield additional information on the distribution of wildlife species in the area to guide future implementation of additional wildlife management strategies. Specific focus will be given to bird rookeries near Plum Creek and its major tributaries and to quantifying bird and bat populations utilizing bridges spanning Plum Creek waterways if sizable concentrations are noted.

8. Outreach and Education Strategy

INITIAL OUTREACH AND EDUCATION EFFORTS

To engage stakeholders and to support development of the watershed protection plan, a suite of outreach strategies was used to inform participants in early stages of the Plum Creek Watershed Partnership. Ongoing outreach and education efforts have maintained public involvement in the process and continue to increase awareness of the program and its goals throughout the watershed. Resources and activities that have and will be utilized in this effort include the following:

Project Website

The Plum Creek Watershed Partnership website (http://pcwp.tamu.edu) is maintained by Extension and hosted by the Texas Water Resources Institute. The site includes information on the watershed and Partnership, a regional watershed coordination newsletter, press releases, an online discussion forum, links to project partners, access to the Watershed Protection Plan, water quality data, a meeting schedule, and information presented at previous meetings.

Fact Sheet

The Plum Creek Watershed Partnership fact sheet was developed as a 2-page information marketing tool to support and facilitate participation in the planning process (Figure 8.1). It has been distributed in the watershed via direct and electronic mail, at stakeholder meetings, and at other area events. The fact sheet also is available at the Hays County and Caldwell County Extension offices, the Plum Creek Conservation District office, and on the Partnership website. Updated versions have been and will continue to be created as needed to provide new information about programs and accomplishments resulting from project implementation.

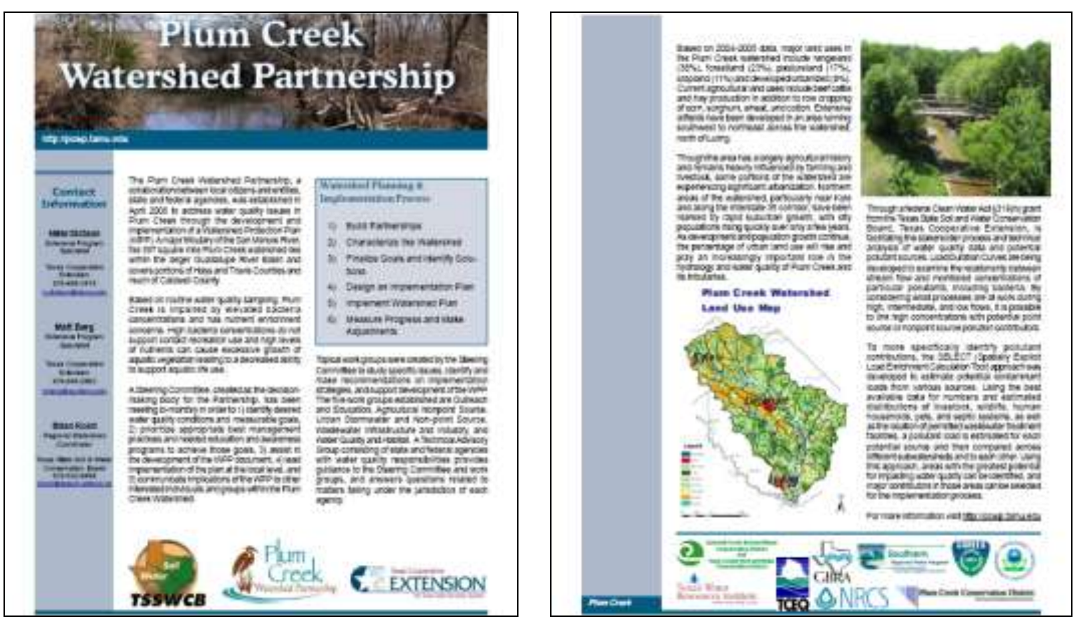


Figure 8.1. Plum Creek Watershed Partnership fact sheet.

News Releases

The Texas AgriLife Extension Service worked with Texas A&M University (TAMU) AgriLife Communications and Marketing to create and submit news releases to numerous media outlets through AgNews, including 5 local newspapers and approximately 100 additional local and regional newspapers and magazines. Additional public information articles will be developed and submitted to key outlets to announce completion of the watershed plan and to encourage stakeholder involvement in the implementation process.

- January 2006: "Texas Cooperative Extension Partnering in Plum Creek Watershed Pilot Program" via AgNews and an additional 5 local newspaper outlets.
- March 2006: "Public Invited to Join Plum Creek Watershed Project" via AgNews and an additional 5 local newspaper outlets.
- April 2006: "Plum Creek Watershed Partnership Under Way; Meetings Set for Kyle and Luling" via AgNews and an additional 5 local newspaper outlets.
- April 2006: "Media Advisory: Watershed Meetings Set for Kyle, Luling" via AgNews and an additional 5 local newspaper outlets.
- June 2006: "Public Invited to Plum Creek Watershed Project Meeting" via AgNews and an additional 5 local newspaper outlets.
- June 2006: "Preventive Measures Can Help Protect Plum Creek Watershed" via AgNews and an additional 5 local newspaper outlets.
- November 2006: "The Wave of the Future: Plans use local involvement to enhance water quality" in tx H_2O
- January 2007: "Group wants to keep creek beautiful and safe", in Hays Free Press.
- January 2007: "Elementary Students Join Plum Creek Water Monitoring Effort" via GBRA to local newspaper outlets.
- December 2007: "Public Invited to Comment on Draft Plum Creek Watershed Protection Plan," via 4 local newspaper outlets and Partnership email.

Newsletter Articles

Plum Creek Watershed updates have been written for the "Coordinated Watershed Protection in Southeast and South Central Texas" newsletter which is prepared and disseminated by the TSSWCB. The newsletter is distributed bimonthly by email and is available on the TSSWCB, Texas Watershed Steward, and Plum Creek Watershed Partnership websites. These updates also provide information to a broader regional audience about activities, approaches, and progress in the Plum Creek Watershed and serve as an important component of partnerships with similar groups in the state.

Newsletter articles about the watershed and project also have been disseminated through County Extension, Master Naturalist, Master Gardener, and local homeowners' associations. Below are specific examples. Additional information/education pieces announcing plan completion and project activities and successes, and encouraging public involvement will be developed by the Partnership for distribution utilizing these established outlets.

- August 2007: "Update on the Plum Creek Watershed Protection Plan and the Texas Watershed Steward Program" in Alliance of Natural Resource Outreach & Service Programs bi-monthly newsletter.
- September 2007: "Make a Splash with Texas Watershed Steward Program" in Hays, Caldwell, Blanco, and Bastrop County Agriculture newsletters.
- September 2007: "Make a Splash with Texas Watershed Steward Program" in Preserve Our Water newsletter, a local non-profit organization in Blanco, Texas.
- September 2007: Plum Creek article in Texas Master Naturalist website and county newsletters.
- September 2007: Plum Creek article on Texas Master Gardeners website and in county newsletters.
- September 2007: Plum Creek article on Texas Education Agency website and teacher course catalog.
- October 2007: "The Plum Creek Watershed Needs You!" in Plum Creek Community Homeowner's Association newsletter.
- October 2007: "The Plum Creek Watershed Needs You!" in Hays, Caldwell, Blanco, and Bastrop County Agriculture newsletters.
- October 2007: "The Plum Creek Watershed Needs You!" in Hometown Kyle Homeowner's Association newsletter.
- October 2007: "The Plum Creek Watershed Needs You!" in Onion Creek Homeowner's Association newsletter.

Watershed Tour

A watershed tour was organized upon request of the Plum Creek Watershed Partnership Steering Committee to provide an overview of the current characteristics and conditions across the watershed. The full-day tour was conducted on July 27, 2006 and attended by 64 participants. Presentations and information were provided on urban, agricultural, and industrial activities and issues and water quality monitoring efforts in the watershed.

Outreach and Education Work Group

The Outreach and Education work group was charged with the task of defining methods to 1) increase public awareness about water quality issues and planning and implementation efforts in the watershed, and 2) motivate individual actions to improve water quality in Plum Creek. Key audiences identified by the work group include rural and urban residents including youth; homebuilders and developers; septic system owners, installers, and inspectors; agricultural producers; elected officials; business and community leaders; news media; and community service organizations. To achieve these goals, the work group developed a strategy that includes both broad-based programs directed at the general public and targeted programs intended to reach specific audiences within the watershed.

As an initial step, the work group developed and used a stakeholder survey to obtain public feedback in creating a logo and branding campaign. The logo is intended to increase public awareness about the watershed and to stimulate a sense of organization, purpose and ownership. The logo is used by the Partnership and its partners on all project-related materials to enhance name and program recognition (Figure 8.2).

Figure 8.2. Plum Creek Watershed Partnership logo.

A major success for the Outreach and Education work group, working closely with Partnership partners at the TCEQ, has been the acquisition of a Taking Charge of Water Quality project funded through Section 106 of the Clean Water Act. The grant funds a significant portion of the educational activities that have been planned for Plum Creek. In addition, many of the resources developed through this project may be adapted and utilized in other watersheds across the state.

BROAD-BASED PROGRAMS AND TRAINING RESOURCES

Texas Watershed Stewards

Texas Watershed Stewards is a science-based watershed education program designed to help citizens identify and take action to address local water quality impairments. The Partnership Steering Committee is the inaugural Texas Watershed Steward group, having received training through presentations and discussions at work group and steering committee meetings. To support the implementation process, 3 additional public training events have been and will be conducted in the watershed. The first event was held on December 4, 2007 in Kyle with 42 participants, and further trainings will be scheduled in Lockhart and Luling in 2008. The goal will be to engage as many citizens as possible in the implementation process.

Advertisements for Plum Creek and Texas Watershed Stewards

- July 2007, Bluebonnet Electrical Coop “Market Square” in Texas Coop Magazine.
- July 2007: “Make a Splash with the Texas Watershed Steward Program” in Hays, Caldwell, Guadalupe, Gonzales, Comal, Blanco, and Bastrop Counties weekly Extension news columns.
- August 2007: Bluebonnet Electrical Coop “Market Square” in Texas Coop Magazine.
- September 2007: Bluebonnet Electrical Coop “Market Square” in Texas Coop Magazine.
- October 2007: Bluebonnet Electrical Coop “Market Square” in Texas Coop Magazine.
- October 2007: “The Plum Creek Watershed Needs You!” in Hays, Caldwell, Guadalupe, Gonzales, Comal, Blanco, and Bastrop Counties weekly Extension news columns.
- October 2007: “The Plum Creek Watershed Needs You!” on City of Kyle website and calendar.

Elementary School Water Quality Project

To promote youth education and involvement in the Plum Creek Watershed Partnership, a water quality monitoring program is being continued during the 2007-2008 school year. The program was initiated and is led by the GBRA. In October 2006, meetings were held with curriculum directors and principals from local elementary schools to obtain approval for the program. Current partner schools include Negley Elementary, Tobias Elementary, Hemphill Elementary, Science Hall Elementary, Plum Creek Elementary, Clear Fork Elementary, and Luling Shanklin Elementary. Science teachers at each school are trained in basic water quality monitoring techniques. In addition, classroom instruction is delivered to students covering watersheds, nonpoint source pollution, and the Plum Creek project. Water monitoring test kits, supplies, poster-sized watershed maps, and student workbooks are donated to the schools by the GBRA.

During the 2006-2007 school year, a total of 760 fourth and fifth grade students and 18 teachers have completed 3 rounds of water quality testing in their classrooms (November 2006, February and May 2007). Students use the Texas Watch model to test and monitor water from Plum Creek for temperature, dissolved oxygen, pH, turbidity, nitrates, and phosphates. In addition, packets of educational information about the watershed and water quality issues were sent home with the students to be shared with their parents. This project will be repeated in the 2008-2009 school year and subsequent years, if possible.

Watershed Protection Campaign Brochure

A watershed protection brochure titled “Don’t Be Clueless About Water” was developed by the GBRA to educate individuals about the impacts of individual activities on water quality and how to reduce those impacts (Figure 8.3). The brochure, which was originally created for the entire Guadalupe-Blanco River Basin, has been adapted specifically for the Plum Creek Watershed. The brochure was initially distributed to students involved in the Plum Creek water quality project in the 2006-2007 school year. Additional copies will be distributed in information packets for future participating students as well as at educational meetings, training programs, public events, and in selected mailouts from the Partnership and the GBRA.

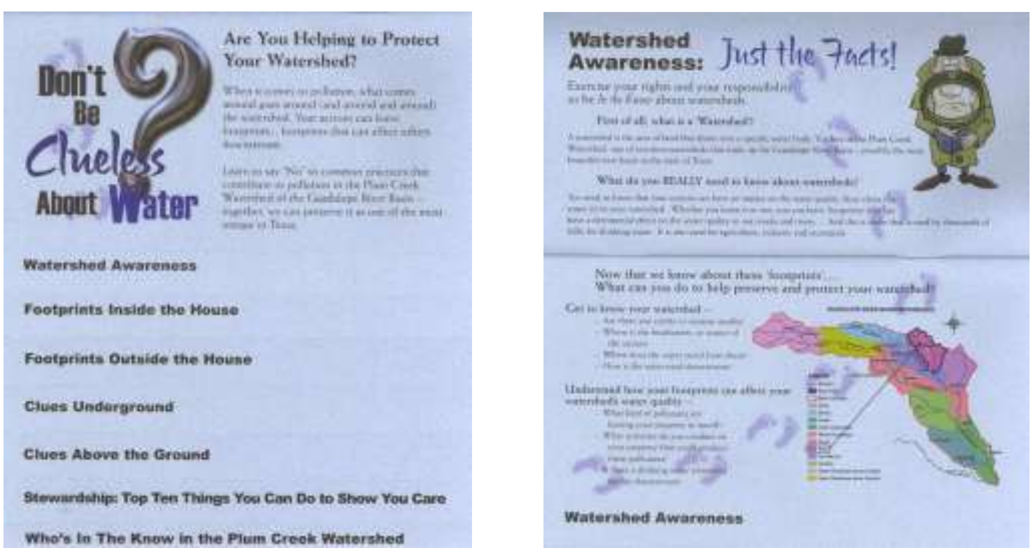


Figure 8.3. GBRA Don’t Be Clueless About Water brochure adapted for use in Plum Creek.

Tributary and Watershed Roadway Signage

Contingent upon funding, signs will be developed and posted along major roads notifying travelers that they are entering the watershed or when they are crossing Plum Creek or a significant tributary. In addition, ad space will be purchased for existing large billboards at key locations in the watershed encouraging residents and travelers to take positive action to protect water quality in their area.

Outreach at Local Events

Local public events such as the Luling Foundation Field Day, Luling Watermelon Thump, Lockhart Chisholm Trail Days, Kyle Stream Cleanup, and Lockhart Rites of Spring will be used as venues for presentations and/or distribution of education and information resources. Plum Creek Watershed posters, map displays, fact sheets, and handouts addressing plan implementation will be disseminated. The TSSWCB and Extension already have participated in the 2006 and 2007 Luling Foundation Field Days to promote the Plum Creek Watershed Partnership.

Rainwater Harvesting Education

Extension personnel will organize and conduct a rainwater harvesting educational program to provide information on the benefits, methods and costs of installation. To supplement an existing demonstration at the Luling Foundation and contingent upon funding, home and/or business rainfall harvesting demonstrations will be established in Kyle and Lockhart.

TARGETED POLLUTANT SOURCE OUTREACH EFFORTS

Urban Runoff

NEMO workshops

Two Nonpoint Education for Municipal Officials (NEMO) workshops for city and county employees and elected officials will be conducted in the watershed by Extension, Texas Sea Grant, and the GBRA. NEMO is a national program that is a confederation of 32 educational programs in 31 states dedicated to protecting natural resources through better land use planning. To maximize participation, one workshop will be held in the Kyle/Buda area and the other in the Lockhart/Luling area. Workshops will include topics such as smart growth, low impact design, stormwater management, and reducing impervious surfaces. Following the training, participants will be surveyed to evaluate changes in knowledge and intentions to implement recommended practices. Follow-up trainings will be conducted as necessary and appropriate.

Online Stormwater Management Training

The GBRA will develop an online stormwater training tool for municipal operations employees that will be made available on the Plum Creek and GBRA websites. Key personnel from each city will be invited to the training, which will address management practices for the control of stormwater and include information on the requirements for entities that must satisfy MS4 regulations.

Stormwater BMP Demonstrations

Ina areas where preferred urban stormwater BMPs are to be implemented, cities in cooperation with Extension and the TCEQ have and will sponsor field demonstrations. Invitations will be sent to builders and developers, city staff, and engineers, and notices will be placed in local newspapers. Two mulch tube stormwater BMP field demonstrations already have been conducted in Kyle and Lockhart (June and July 2007, respectively). Additional events will be held as appropriate.

Site Assessment Visits

The TCEQ will conduct at least 4 site assessment visits to municipal operations in the Plum Creek Watershed. Assessments will focus on enhancing stormwater and wastewater infrastructure and operation efficiency.

Urban Nutrient Management Education

Programs such as Grow Green and Yard Wise will be engaged to provide workshops and materials to educate the general public regarding proper rates and timing of fertilizer and pesticide application for lawns and landscapes. City, county, and private landscape maintenance providers will be solicited to participate in these training workshops. In addition, similar trainings will be provided through Master Gardener programs and by working with local homeowners' associations.

Golf Courses, Sports Athletic Fields, and Schools

The Partnership will work with Extension's Sports and Athletic Field Education (SAFE) program to educate golf course and other sports and athletic field managers and personnel on nutrient and pesticide management practices. The SAFE program is a multidisciplinary approach for turfgrass management based on comprehensive evaluation and monitoring of individual fields. This program addresses fertilizer and pesticide selection and use, irrigation management, aerification, and cultural practices such as mowing height and frequency.

Household Hazardous Waste Collection Days

The Partnership will provide publicity support to cities in the watershed conducting annual or biennial hazardous waste collection events to increase public participation in these activities. The Partnership will send out email notification of events in the watershed, print and distribute fliers, and post information on the project website.

Pet Waste Programs

A public information and outreach program will be used to educate pet owners about the importance of properly disposing of pet waste, both at home and in public areas. Contingent upon funding, signs will be placed in city parks and other areas frequented by pets. Mass mailings will be sent in conjunction with utility billing, public service announcements will be made on local radio stations, and brochures will be placed at veterinary clinics, County Extension offices, county courthouses, and other suitable locations.

Septic Systems

Online Training for Septic System Owners

An online training program will be developed by the GBRA to illustrate proper septic system function and maintenance to ensure efficiency and to extend the life of the system. The training will be made available on both the Partnership and GBRA websites.

Septic System Workshops

Extension personnel will conduct 2 workshops for homeowners and 2 workshops for inspectors, installers, and maintenance providers of septic systems in 2008. These trainings will target subwatersheds identified by SELECT and will focus on key aspects of operation, maintenance, and repair that are important for each audience. Future training events will be conducted in other areas as needed and where additional funding is available.

Wastewater

Online Wastewater Treatment Facility Training

An informational wastewater treatment module will be developed by the GBRA and made available online to watershed residents. The module will address treatment methods and processes and will explain the importance of proper wastewater management within the home to protect the quality of receiving waters.

Online Fats, Oils, and Grease Training

Online training addressing management practices for handling fats, oils, grease, and household chemical use and disposal will be developed by the GBRA. The training will be geared toward both businesses and homeowners and will be available through GBRA, Partnership, and city web linkages.

Fats, Oils, and Grease Workshops

The TCEQ will conduct at least 2 workshops for restaurants in the watershed on fats, oils and grease in 2008. The Partnership will support these trainings through direct and web-based marketing.

Agriculture

Soil and Water Testing Campaigns

Soil and water testing campaigns will be conducted annually or biennially by County Extension personnel to encourage proper nutrient management in both agricultural and urban areas. Funding will be sought to provide free or reduced-rate testing when possible.

Nutrient Management Education

Training events will be organized and conducted by County Extension personnel to educate agricultural producers regarding sound nutrient management practices in row and forage crop production systems. These events will be held annually in conjunction with soil testing campaigns in the fall or spring.

Crop Management Seminars

Annual or biennial crop management and production seminars will be organized and conducted by County Extension personnel and will include training to promote the use of recommended management practices for reducing pesticide and sediment loss.

Livestock Grazing Management Education

Livestock grazing workshops and training events will be organized and conducted by County Extension personnel annually or biennially to educate producers on proper grazing management techniques.

Agricultural Waste Pesticide Collection Days

Contingent upon funding, agricultural waste pesticide collection days will be conducted annually or biennially and will be rotated between Caldwell, Hays, and surrounding Counties. The Partnership will support these efforts through web-based and direct marketing programs. In coordination with the TCEQ and the Caldwell County AgriLife Extension Service, one collection event was held in Luling on June 5, 2007. Over 31,400 pounds of waste were collected. This included approximately 8,800 pounds of solid and liquid organic pesticides and 10,365 pounds of lead-acid batteries. Other wastes collected included solvent-based and latex paints, petroleum products, mercury bulbs, a variety of chemicals, and empty containers.

Wildlife and Non-Domestic Animals

Feral Hog Management Workshops

Feral hog management workshops will be conducted to educate landowners regarding the negative impacts of feral hogs and the most effective methods for their control. In response to immediate needs, County Extension personnel conducted the first such workshop in February 2007 in Luling with an attendance of over 180. Additional area events will be conducted annually or biennially, as appropriate.

Stream and Riparian Workshops

County Extension personnel, in cooperation with local NRCS and SWCD personnel, will coordinate annual workshops to educate the public on stream and riparian area management. Trainings will focus on the importance of these areas as wildlife habitat and their effects on water quality and overall watershed health.

Abandoned Oil and Gas Wells

The large number of abandoned wells in the Plum Creek Watershed demonstrates the need for continued monitoring of all oil and gas wells, both those currently in production as well as those that are no longer in use. The Partnership will continue to work with the RRC to maintain inspection programs and to identify and plug abandoned wells.

Illegal Dumping/Litter Campaign

Identification of Priority Clean-up Sites

Over 35 road crossings and accessible areas were identified while planning the targeted water quality monitoring project. These sites will be assessed and prioritized for cleanup by GBRA contractors based on the extent of the problem and the potential for environmental impacts (Figure 8.4). Site descriptions, photographs, and indications of challenges (traffic, slope, brush and fencing hazards) that could affect cleanup efforts will be obtained. Private landowners associated with priority sites will be identified to obtain permission for access. Based on site prioritization, the following activities will be developed:

- Site Cleanup Projects: Cleanups will be conducted at the most critical sites utilizing a contractor with heavy equipment to remove large debris and trash. Proper disposal of debris, post-cleanup photographs, and a report on each event, including the amount and type of debris removed, will be developed.
- Signs: The GBRA will coordinate with Caldwell and Hays Counties to post signs at cleanup sites and at other identified watershed dumping sites to discourage future activity.
- Community Cleanup Events: At least 2 community cleanup events sponsored by the GBRA will be conducted in cooperation with Keep Texas Beautiful to remove smaller debris from watershed streams and also capitalize on public involvement to improve awareness of the overall Plum Creek project. Educational materials will be distributed at these events and provided to cities and counties for other community-sponsored events in the watershed.

Figure 8.4. Dumping site adjacent to Plum Creek. A special project will clean up key dumping sites and discourage future activity at such areas.

9. Measures of Success

MONITORING AND WATER QUALITY CRITERIA

Due to the dynamic nature of watersheds and the countless variables governing landscape processes across scales of time and space, some uncertainty is to be expected when a Watershed Protection Plan is developed and implemented. As the recommended restoration measures of the Plum Creek Watershed Protection Plan are put into action, it will be necessary to track the water quality response over time and make any needed adjustments to the implementation strategy.

As efforts continue, incorporation of new data will improve the understanding of watershed conditions and will drive a more efficient implementation process. Adaptive management will allow initial results to guide future restoration strategies as stakeholders learn through experience. By tracking stream trends, stakeholders will be able to evaluate whether plan execution is successful and will determine the need for new action or refocusing of existing programs. This adaptive approach relies on constant input of watershed information and the establishment of intermediate and final water quality targets.

Pollutant concentration targets were developed based on complete implementation of the Watershed Protection Plan and assume full accomplishment of pollutant load reductions by the end of the 10-year project period (Tables 9.1 and 9.2). While some of the less complex management measures recommended here will be relatively simple to implement early in the process, implementation of other measures will require more time, energy, and funding. For this reason, reductions in pollutant loads and associated concentrations initially may be gradual. However, it can be assumed that reductions in the loading of bacteria and nutrients will be tied to the implementation of management measures throughout the watershed. Thus, these projected pollutant targets will serve as benchmarks of progress, indicating the need to maintain or adjust planned activities. While water quality conditions likely will change and may not precisely follow the projections indicated here, these estimates serve as a tool to facilitate stakeholder evaluation and decision-making based on adaptive management.

Table 9.1. *E. coli* bacteria targets at selected intervals through implementation.

Month	*E. coli* Concentration (cfu/100mL)		
	Uhland (17406)	Lockhart (12647)	Luling (12640)
Feb-2008	205	107	112
Aug-2009	192	105	107
Feb-2011	165	102	98
Aug-2012	131	98	87
Feb-2014	98	94	75
Feb-2016	84	93	71
Feb-2018	71	91	66

Table 9.2. Orthophosphorus and total phosphorus targets at selected intervals through implementation.

Month	OP Concentration (mg/L)	TP Concentration (mg/L)		
	Lockhart[1] (12647)	Uhland (17406)	Lockhart (12647)	Luling (12640)
Feb-2008	0.39	0.53	0.52	0.35
Aug-2009	0.38	0.51	0.52	0.35
Feb-2011	0.34	0.48	0.51	0.35
Aug-2012	0.29	0.45	0.50	0.35
Feb-2014	0.24	0.41	0.50	0.35
Feb-2016	0.22	0.40	0.49	0.35
Feb-2018	0.20	0.38	0.49	0.35

1 Orthophosphorus data are not collected at the Uhland and Luling sites.

For bacteria and nutrients of concern, water quality data will be compiled and a 5-year geometric mean for *E. coli* bacteria, total phosphorus, and orthophosphorus (where applicable) will be computed every 6 months to examine trends in Plum Creek. These values will be compared to the incremental reductions outlined in Tables 9.1 and 9.2 to determine the need to adjust implementation. Though a geometric mean generally is not calculated for nutrients, these indicators will enable ongoing assessment of the effects of implementation efforts on pollutant concentrations. In addition, from single grab samples will be compiled and analyzed every 6 months to determine compliance with the water quality criteria. If water quality samples continue to exceed the single sample criteria more than 20% of the time for nutrient concerns and 25% for bacterial impairment, implementation approaches will be adjusted accordingly.

Current water quality monitoring efforts in the Plum Creek Watershed rely on the existing routine monitoring stations at Uhland, and those near Lockhart and Luling. These locations form the assessment units for regulatory purposes and will be an integral part of continued efforts to track the success of plan implementation. To monitor water quality progress over the course of the project, these sites will continue to collect ambient in-stream data including:

- *E. coli*
- Nitrate
- Total Dissolved Solids
- High pH
- Low pH
- Ammonia
- Chlorophyll-a
- Sulfate
- Orthophosphorus (Lockhart)
- Total Phosphorus
- Temperature
- Chloride
- Dissolved Oxygen Grab-Minimum
- Dissolved Oxygen Grab-Screening Level (at Uhland and Luling)

Though not all of these measures coincide with current impairments or concerns, continued monitoring for a wide array of parameters will detect the development of additional water quality problems, in addition to measuring progress toward goals to address current issues. Continued routine monthly sampling at the Uhland and Luling stations is considered necessary and sufficient for these locations. In addition, the Steering Committee and work groups recommend continued and more frequent sampling be conducted at monitoring station 12647 near Lockhart. Given that *E. coli* data have been collected at this station only since 2001, current quarterly sampling is deemed inadequate. Further, to more effectively define the magnitude and timing of pollutant loads in this middle reach of the stream, the Plum Creek Watershed Partnership strongly recommends that the frequency of sampling for the same suite of pollutants be increased from quarterly to monthly at the Lockhart monitoring station.

TARGETED WATER QUALITY MONITORING

To supplement this routine sampling, a special Surface Water Quality Monitoring project funded by the TSSWCB and conducted by the GBRA will increase the temporal and spatial resolution of sampling efforts to more effectively pinpoint the timing and sources of high pollutant loads. A combination of additional routine stations, multiple targeted locations, urban stormflow monitoring, wastewater effluent sampling, and springflow sampling will be utilized (Figure 9.1). A summary of the water quality monitoring components of this project are as follows:

- Increase routine sampling sites from 2 monthly, and1 quarterly to 8 monthly (duration of 15 months)
- Conduct 24-hour dissolved oxygen monitoring monthly at 8 routine sites (8 months)
- Targeted sampling twice per season at 35 sites (12 months)
- Automated stormflow sampling of 4 events at one urban/residential site in Hays County (over 12 months)
- WWTP effluent sampling once per season at 5 sites (12 months)
- Springflow sampling once per season at 3 springs in central portion of watershed (12 months)

This short-term intensive monitoring effort will refine the focus of management efforts as well as track the performance of ongoing implementation activities during the study.

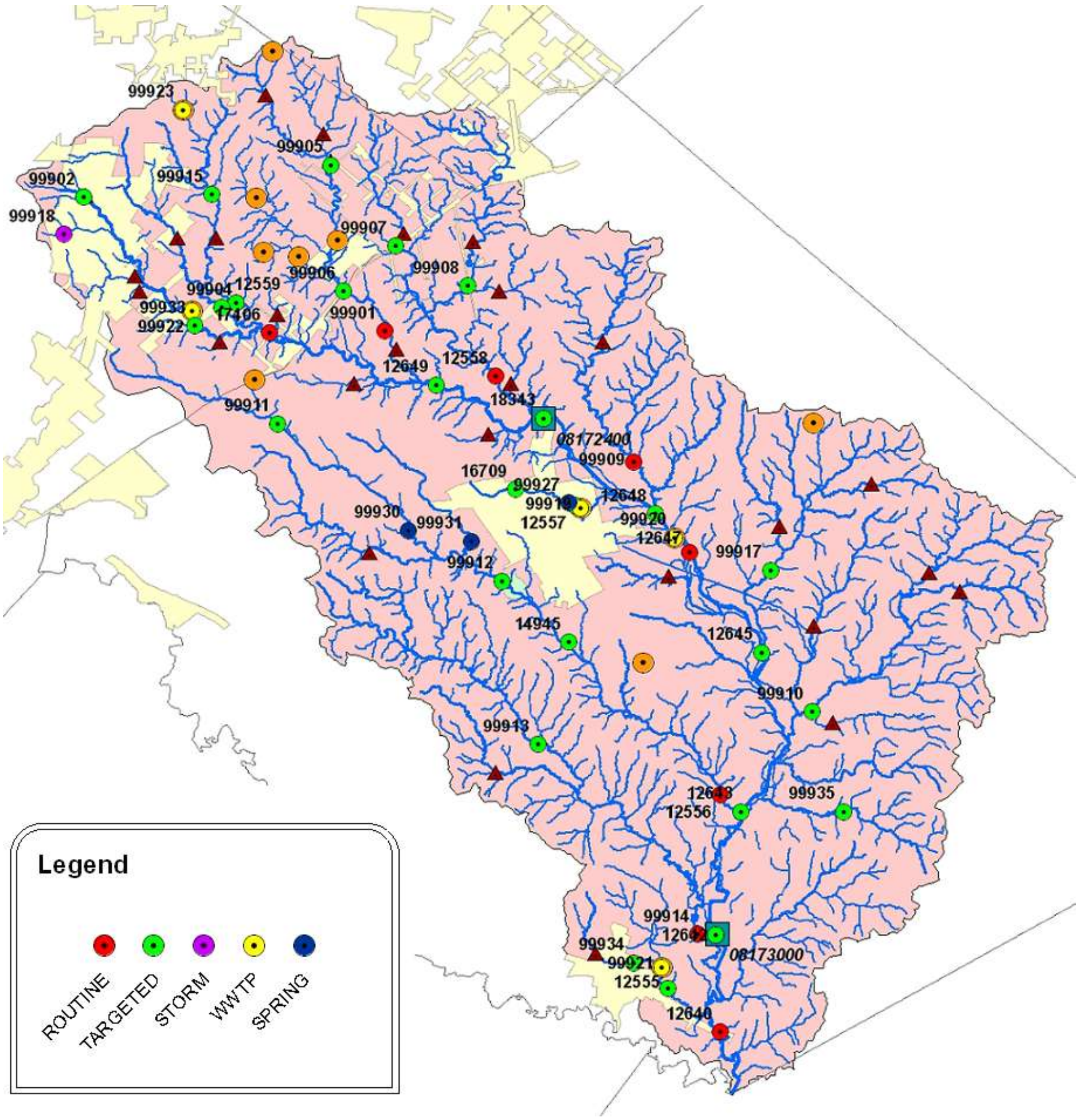


Figure 9.1. Map of locations for Plum Creek Surface Water Quality Monitoring project.

STREAM BIOLOGICAL ASSESSMENTS

In addition to these water quality analyses, the GBRA annually conducts biological and habitat assessments near the Uhland and Luling water quality monitoring stations (Figure 9.2). Surveys of the fish and macroinvertebrate communities in the stream as well as the plant communities and physical characteristics of the environment adjacent to the stream serve as indicators of positive or negative responses to changes in stream conditions. These surveys will be continued to determine if water quality trends result in measurable changes in the biological communities in Plum Creek. Reports will be developed after each survey and compared with results from previous years to determine differences between sites and over time.

Figure 9.2. GBRA technician conducts biological assessment demonstration. Such assessments will play an important role in tracking the health of the Plum Creek Watershed.

SWAT

To support adaptive management during implementation, the Soil and Water Assessment Tool (SWAT) will be used to model hydrologic processes, nutrient loading, and fate and transport of *E. coli* within the watershed. The SWAT model is a basin-scale model that simulates daily flows and events in the watershed. This tool allows prediction of management impacts on water volume and loads of nutrients, bacteria, and other pollutants over long periods of time. Initial stages of SWAT have been developed in tandem with the Plum Creek Watershed Protection Plan, and further iterations will support adaptive management in the watershed. Integration of SWAT with both long-term monitoring and the targeted sampling efforts will allow additional focusing of management measures in the watershed. As water quality monitoring data, information on animal numbers and wastewater discharges, and other inputs are collected, they will be included to adjust key management areas and further project which actions should be taken. The Spatial Sciences Laboratory at Texas A&M University will conduct the SWAT analysis for the Plum Creek Watershed Partnership to assist in adaptive management. If selected management practices are found to be insufficient, they will be adjusted accordingly during implementation (Figure 9.3).

BACTERIAL SOURCE TRACKING

The Plum Creek Watershed Partnership Steering Committee and work groups also have recommended employing Bacterial Source Tracking techniques as an additional management tool. Bacterial Source Tracking is a relatively new approach in which a bacteria DNA library is prepared using known sources from within the watershed. Water quality monitoring samples are then compared to the library to determine the most significant contributors. These data would enhance and refine results from the SELECT analysis and also could be used to confirm and/or adjust ongoing and planned implementation efforts. Funding for targeted Bacterial Source Tracking analysis within Plum Creek will be pursued as a part of the implementation strategy.

Figure 9.3. Springflow on Town Branch. A number of ongoing monitoring and assessment programs, including springflow water quality monitoring and SWAT analysis, will assist in adjusting the implementation of the Plum Creek Watershed Protection Plan.

10. Project Implementation

This section outlines needed technical assistance, a schedule for implementation of the recommended management measures, an estimate of the associated costs, potential sources of funding, and an estimate of load reductions expected as a result of program implementation.

Technical Assistance

Successful implementation of the Plum Creek Watershed Protection Plan relies on active engagement of local stakeholders, but also will require support and assistance from a variety of other sources. The technical expertise, equipment, and manpower required for many management measures are beyond the capacity of Plum Creek stakeholders alone. As a result, direct support from one or a combination of several entities will be essential to achieve water quality goals in the watershed. Focused and continued implementation of key restoration measures will require the creation of multiple full-time equivalent positions in the watershed to coordinate and provide technical assistance to stakeholders.

Urban Stormwater and Wastewater Management Measures

Structural and programmatic urban stormwater controls are the responsibility of individual cities in the watershed. However, identification and design of specific improvements to stormwater conveyances and wastewater treatment facilities are beyond the scope of many smaller municipal operations. Professional engineering analysis will be essential to assess construction of new structural controls and upgrades to existing components of both stormwater and wastewater facilities. Funding will be sought to support these engineering evaluations for Kyle, Lockhart and Luling. Installation of pet waste collection stations in each of the major communities, in combination with street sweeping programs, construction of recommended structural stormwater controls, and construction of wastewater facility upgrades along with enhanced monitoring and management procedures will enable the achievement of target pollutant load reductions. Throughout this process, the continued assistance and commitment of city officials, staff, and facility permittees and operators will be critically important to the implementation of recommended management measures.

Septic System Management Measures

Site-specific evaluations will be necessary to determine whether existing septic systems are operating effectively, or whether they require maintenance, repair, or complete replacement. To support and facilitate this effort, particularly in Caldwell County where staff is limited, a new position will be created to focus on septic system inspection and enforcement in the watershed. The position will work in cooperation with independent contractors and in support of existing programs in Caldwell and Hays Counties. Based on preliminary cost estimates, performing needed repairs, replacement or connection of failed septic systems to centralized wastewater treatment facilities will be a multimillion dollar effort. These estimates of needed funding will be adjusted, as appropriate, as the inspection program is implemented and a more complete understanding of potential contributions and needed management measures for these systems is developed. In addition, management targets will be adjusted over time based on field assessments by staff and results of ongoing water quality monitoring efforts in the watershed.

Agricultural Management Measures

Technical support from SWCD and NRCS personnel is critical to selection and placement of appropriate management measures on individual agricultural properties. However, due to the number of management plans that will be needed a new position dedicated specifically to WQMP development in the watershed will be necessary. Targets for the number of livestock and cropland WQMPs to be developed will be adjusted as the plan implementation process moves forward. Assistance from local Extension agents, other agency representatives, and landowners already participating will be relied upon to identify and engage key potential agricultural producers. The duration of the position will be dictated by demand for enhanced technical assistance, assuming water quality monitoring results indicate the need for continued improvement.

Non-Domestic Animal and Wildlife Management Measures

Management of the feral hog control program will be coordinated through TWDMS, with a new staff position housed in the watershed. Animal number targets will be used as an initial measure of program effectiveness. In addition, hog surveys and supplemental wildlife assessments will be utilized to better define the extent and distribution of the problem and to direct control efforts.

SCHEDULE, MILESTONES, AND ESTIMATED COSTS

The implementation schedule, milestones, and estimated costs of implementation, presented in Table 10.1, are the result of planning efforts of the Steering Committee and work groups, in coordination with county and city officials, and other watershed stakeholders. A 10-year project timeline has been constructed for implementation of the Plum Creek Watershed Protection Plan. Increments of years 1-3, 4-6, and 7-10 post-approval and implementation of the plan have been defined. In addition, for most management measures, estimated quantitative targets have been established. This allows key milestones to be tracked over time so that stakeholders can more effectively gauge implementation progress and success. In the event that insufficient progress is being made toward achievement of a particular milestone, efforts will be intensified or adjusted as necessary. Multi-year increments also take into account the fact that many management practices will require the acquisition of funding, hiring of staff, and the implementation of new programs, all of which will have initial time demands. In addition, changes in water quality often are delayed following initial implementation of management measures, and substantive changes generally require several years to be discernable. Thus, while annual assessments of implementation progress will be made, broader evaluations will be used to direct overall program management.

Table 10.1. Responsible party, implementation milestones, and estimated financial cost for management measures.

Management Measure	Responsible Party	Unit Cost	Number Implemented Year 1-3	4-6	7-10	Total Cost
Urban Stormwater Management Measures						
Pet Waste Collection Stations	City of Kyle	$620/station installation $85 annual/station	10	4	4	$22,040[1]
Pet Waste Collection Stations	City of Lockhart	$620/station installation $85 annual/station	10	4	4	$22,040
Pet Waste Collection Stations	City of Luling	$620/station installation $85 annual/station	6	2	2	$12,475
Pet Waste Collection Stations	City of Buda	$620/station installation $85 annual/station	10	4	4	$22,040
Comprehensive Urban Stormwater Assessment	City of Kyle	$30,000/survey	1	---	---	$30,000[1]
Retrofit Stormwater Detention Basins	City of Kyle	$35,000 engineering $50,000/basin	2	---	---	$135,000[1]
Initiate Street Sweeping Program	City of Kyle	$110,000/sweeper	---	---	---	$110,000[2]
Comprehensive Urban Stormwater Assessment	City of Lockhart	$25,000/survey	1	---	---	$25,000
Manage Urban Waterfowl Populations	City of Lockhart	---	---	---	---	N/A
Comprehensive Urban Stormwater Assessment	City of Luling	$20,000/survey	1	---	---	$20,000
Rehabilitate Stormwater Retention Pond	City of Luling	$500,000/pond	1		---	$500,000
Initiate Street Sweeping Program	City of Buda	$150,000/sweeper	1	---	---	$150,000[2]
Wastewater Management Measures						
Wastewater Upgrade (TSS Reduction)	WWTF Operators	$500,000/ 1 MGD facility		3	7	$6,000,000
Wastewater Upgrade (Phosphorus Removal)	WWTF Operators	$60,000/facility (includes material costs)		3	7	$600,000
Voluntary Monthly *E. coli* Monitoring	WWTF Operators	$22/month/facility	---	---	---	$31,000
Voluntary Monthly Phosphorus Monitoring	WWTF Operators	$25/month/facility	---	---	---	$35,000
Sanitary Sewer Pipe Replacement	City of Kyle	$1,000,000/year	2,400 ft	2,400 ft	3,200 ft	$10,000,000[3]
Lift Station SCADA Installation	City of Kyle	$12,000/station	3	4	---	$84,000
Sanitary Sewer Pipe Replacement	City of Lockhart	$320,000/year	1,800 ft	1,800 ft	2,400 ft	$3,200,000[3]
Initiate Sanitary Sewer Inspection Program	City of Luling	$17,000/camera	1	---	---	$17,000[2]

Management Measure	Responsible Party	Unit Cost	Number Implemented			Total Cost
			Year			
			1-3	4-6	7-10	
Wastewater Management Measures (continued)						
Sanitary Sewer Pipe Replacement	City of Luling	$1,000,000/year	2,400 ft	2,400 ft	3,200 ft	$10,000,000[3]
Lift Station SCADA Installation	City of Luling	$12,000/station	4	1		$60,000
Septic System Inspection/Enforcement (New Position)	Caldwell County	$50,000/year	2			$1,000,000
Septic System Repair	Caldwell/ Hays Cos.	$5,000/system	300	300	400	$5,000,000
Septic System Replacement	Caldwell/ Hays Cos.	$10,000/system	150	150	200	$5,000,000
Septic System Connection to Sewer	City of Uhland	$2,000/system	100	100	150	$700,000
Agricultural Management Measures						
WQMP Technician (New Position)	SWCD	$75,000/year	1			$750,000
Livestock Water Quality Management Plans	SWCD	$10,000/plan	65	70	100	$2,350,000
Cropland Water Quality Management Plans	SWCD	$10,000/plan	6	9	9	$240,000
Non-Domestic Animal and Wildlife Management Measures						
Feral Hog Control (New Position)	TWDMS	$90,000/year	1			$900,000
Feral Hog Control (Equipment)	TWDMS	---	---	---	---	$5,000
Monitoring Component						
Targeted Water Quality Monitoring	GBRA	---	1	---	---	$142,000[4]
Comprehensive Stream Assessment	GBRA	$1,500/assessment	12	12	16	$60,000
Bacterial Source Tracking	TAMU	---	1	---	---	$200,000

[1] Activities already funded by the TCEQ 319(h).
[2] Already purchased with city funds.
[3] Estimated necessary total. Partial funds already secured.
[4] Already funded by the TSSWCB 319(h).

Outreach and Education

In addition to the implementation of management measures, some financial and technical assistance will be required to conduct the outreach and education measures designed to improve public awareness and participation throughout the process. As outlined in Table 10.2, cooperation among personnel from Extension, TSSWCB, TCEQ, and GBRA will be vital to successful engagement of watershed stakeholders. In addition, city and county staff will play an important role in the dissemination of important information released through the Plum Creek Watershed Partnership. Development of educational materials will be done by these organizations and others, though some assistance will likely be required in the design and construction of larger visuals, such as billboards or watershed signs. Funding for some of these activities will be supported through routine outreach efforts by these groups. However, additional funding will be required to enhance and sustain these efforts and will be sought from outside sources. Clean Water Act (CWA) Section 106 funds will support a number of these strategies and represent an important step in informing the public about Partnership efforts.

Table 10.2. Responsible party, implementation milestones, and estimated financial costs for outreach and education efforts.

<table>
<tr><th rowspan="2">Outreach Activity</th><th rowspan="2">Responsible Party</th><th colspan="3">Year</th><th rowspan="2">Total Cost</th></tr>
<tr><th>1-3</th><th>4-6</th><th>7-10</th></tr>
<tr><td colspan="6">Broad-Based Programs</td></tr>
<tr><td>Texas Watershed Steward Training Sessions</td><td>Extension</td><td>3</td><td>2</td><td>1</td><td>N/A</td></tr>
<tr><td>Elementary School Water Quality Project</td><td>GBRA</td><td>---</td><td>---</td><td>---</td><td>$25,000</td></tr>
<tr><td>Plum Creek Watershed Protection Brochure</td><td>GBRA</td><td>---</td><td>---</td><td>---</td><td>$15,000[1]</td></tr>
<tr><td>Tributary and Watershed Roadway Signage</td><td>PCW Partnership</td><td>60</td><td>---</td><td>---</td><td>$6,000</td></tr>
<tr><td>Displays at Local Events</td><td>Extension/TSSWCB</td><td>9</td><td>9</td><td>9</td><td>$5,400</td></tr>
<tr><td>Watershed Billboards</td><td>PCW Partnership</td><td colspan="3">1 sign biennially</td><td>$30,000</td></tr>
<tr><td colspan="6">Urban Programs</td></tr>
<tr><td>Pet Waste Programs</td><td>Cities/TCEQ/ Extension</td><td>---</td><td>---</td><td>---</td><td>$35,000</td></tr>
<tr><td>NEMO Workshops</td><td rowspan="3">GBRA/TCEQ/ Extension</td><td>2</td><td>---</td><td>---</td><td rowspan="3">$20,000[1]</td></tr>
<tr><td>Fats, Oils, and Grease Workshop</td><td>2</td><td>---</td><td>---</td></tr>
<tr><td>Municipal Site Assessment Visits</td><td>4</td><td>---</td><td>---</td></tr>
<tr><td>Urban Sector Nutrient Education</td><td>Extension</td><td>3</td><td>3</td><td>3</td><td>N/A</td></tr>
<tr><td>Sports and Athletic Field Education (SAFE)</td><td>Extension</td><td>3</td><td>3</td><td>3</td><td>N/A</td></tr>
</table>

Outreach Activity	Responsible Party	Year			Total Cost
		1-3	4-6	7-10	
Wastewater Programs					
Develop Septic System Online Training Modules	GBRA	4	---	---	$30,000[1]
Septic System Workshops and Assistance	Extension /GBRA	4	3	3	$25,000[1]
Agricultural Programs					
Soil and Water Testing Campaigns	Extension	3	3	3	N/A
Agriculture Nutrient Management Education	Extension	3	3	3	N/A
Crop Management Seminars	Extension	3	3	3	N/A
Agricultural Waste Pesticide Collection Days	TCEQ	1	1	1	$75,000
Livestock Grazing Management Education	Extension	3	3	3	N/A
Non-Domestic Animal and Wildlife Programs					
Feral Hog Management Workshop	Extension	2	1	2	N/A
Stream and Riparian Workshops	Extension	2	1	2	N/A
Additional Programs					
Illegal Dumping Site Targeted Cleanup	GBRA	3	3	3	$40,000[1]
Community Stream Cleanup Events		2	3	3	
Rainwater Harvesting Education/ Demonstration	Extension	2	1	2	$25,000

[1] Estimated necessary total. Funding in years 1-3 is already supported by TCEQ CWA 106; additional funding necessary for subsequent years.

PROGRAM COORDINATION

In addition to technical and financial assistance required for implementation of management measures and outreach programs, it is recommended that a full-time Program Coordinator be employed to facilitate continued progress. This position will oversee project activities, seek additional funding, organize and coordinate regular updates for the Plum Creek Watershed Partnership, maintain the website, and coordinate outreach and education efforts in the watershed. An estimated $85,000 per year including travel expenses will be necessary for this position.

SOURCES OF FUNDING

Successful acquisition of funding to support implementation of management measures will be critical for the success of the Plum Creek Watershed Protection Plan. While some management measures require only minor adjustments to current activities, some of the most important measures require significant funding for both initial and sustained implementation. Discussions with the steering committee and work groups, city officials, agency representatives, and other professionals were used to estimate financial needs. In some cases, funding for key activities already has been secured, either in part or full. Other activities will require funding to conduct preliminary assessments to guide implementation, such as in the case of urban stormwater control. Traditional funding sources will be utilized where available, and creative new approaches to funding will be sought. Some of the key potential funding sources that will be explored include:

Clean Water Act State Revolving Fund

The State Revolving Fund (SRF) administered by the TWDB provides loans at interest rates below the market to entities with the authority to own and operate wastewater treatment facilities. Funds are used in the planning, design, and construction of facilities, collection systems, stormwater pollution control projects, and nonpoint source pollution control projects. Wastewater operators and permittees in the Plum Creek Watershed will pursue these funds to assist in treatment upgrades and to improve treatment efficiency in rural portions of the watershed.

Economically Distressed Area Program (EDAP)

The Economically Distressed Area Program is administered by the TWDB and provides grants, loans, or a combination of financial assistance for wastewater projects in economically distressed areas where present facilities are inadequate to meet residents' minimal needs. While the majority of the watershed does not meet these requirements, small pockets within the area may qualify based on economic requirements of the program. Groups representing these areas may pursue funds to improve wastewater infrastructure.

Environmental Quality Incentives Program (EQIP)

The Environmental Quality Incentives Program is administered by the NRCS. This voluntary conservation program promotes agricultural production and environmental quality as compatible national goals. Through cost-sharing, EQIP offers financial and technical assistance to eligible participants for the installation or implementation of structural controls and management practices on eligible agricultural land. This program will be engaged to assist in the implementation of agricultural management measures in the watershed.

Regional Water Supply and Wastewater Facility Planning Program

The TWDB offers grants for assessments to determine the most feasible alternatives to meet regional water supply and wastewater facility needs, estimate costs associated with implementing feasible wastewater facility alternatives, and identify institutional arrangements to provide wastewater services for areas across the state. This source will be pursued to support wastewater elements of the Plum Creek plan, particularly those pertaining to the implementation of the East Hays County Wastewater Compact.

Section 106 State Water Pollution Control Grants

Through the Clean Water Act, federal funds are allocated along with matching state funds to support state water quality programs, including water quality assessment and monitoring, water quality planning and standard setting, TMDL development, point source permitting, training, and public information. The goal of these programs is the prevention, reduction, and elimination of water pollution. Through a special project from the TCEQ, Section 106 funds have already been allocated to assist in a number of activities, particularly outreach and public education components, in the Plum Creek Watershed.

Section 319(h) Federal Clean Water Act

The USEPA provides funding to states to support projects and activities that meet federal requirements of reducing and eliminating nonpoint source pollution. In Texas, both the TSSWCB and the TCEQ receive 319(h) funds to support nonpoint source projects, with TSSWCB funds going to agricultural and silvicultural issues and TCEQ funds going to urban and other non-agricultural issues. 319(h) funds from the TSSWCB supported the development of the Plum Creek Watershed Protection Plan, and TCEQ funds have already been appropriated to implement some of the management measures recommended in the plan. For instance, a pilot project in the City of Kyle will achieve many of the urban goals for that part of the watershed (Table 10.1). Additional support will be sought from these sources, as appropriate.

Supplemental Environmental Project Program (SEP)

The Supplemental Environmental Projects program administered by the TCEQ aims to direct 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. In addition to other projects, funds may be directed to septic system repair and wildlife habitat improvement opportunities.

Targeted Watersheds Grants Program

The Targeted Watersheds Grants Program is administered by the EPA as a competitive grant program designed to promote community-driven watershed projects. Federal, state, and local programs are brought together to assist in the restoration and preservation of water resources through strategic planning and coordinated project management by drawing in both public and private interests.

Texas Clean Rivers Program (CRP)

The CRP is a statewide water quality monitoring, assessment, and public outreach program funded by state fees. The TCEQ partners with 15 regional river authorities to work toward achieving the goal of improving water quality in river basins across the state. CRP funds are used to promote watershed planning and provide quality-assured water quality data. The Partnership will continue to engage this source to support and enhance surface water quality monitoring in the watershed.

Water Quality Management Plan Program

The WQMP program is administered by the TSSWCB. Also known as the 503 program, the WQMP program is a voluntary mechanism by which site-specific plans are developed and implemented on agricultural and silvicultural lands to prevent or reduce nonpoint source pollution from these operations. Plans include appropriate treatment practices, production practices, management measures, technologies, or combinations thereof. Plans are developed in cooperation with local SWCDs, cover an entire operating unit, and allow financial incentives to augment participation. Funding from the 503 program will be sought to support implementation of agricultural management measures in the watershed.

EXPECTED REDUCTIONS

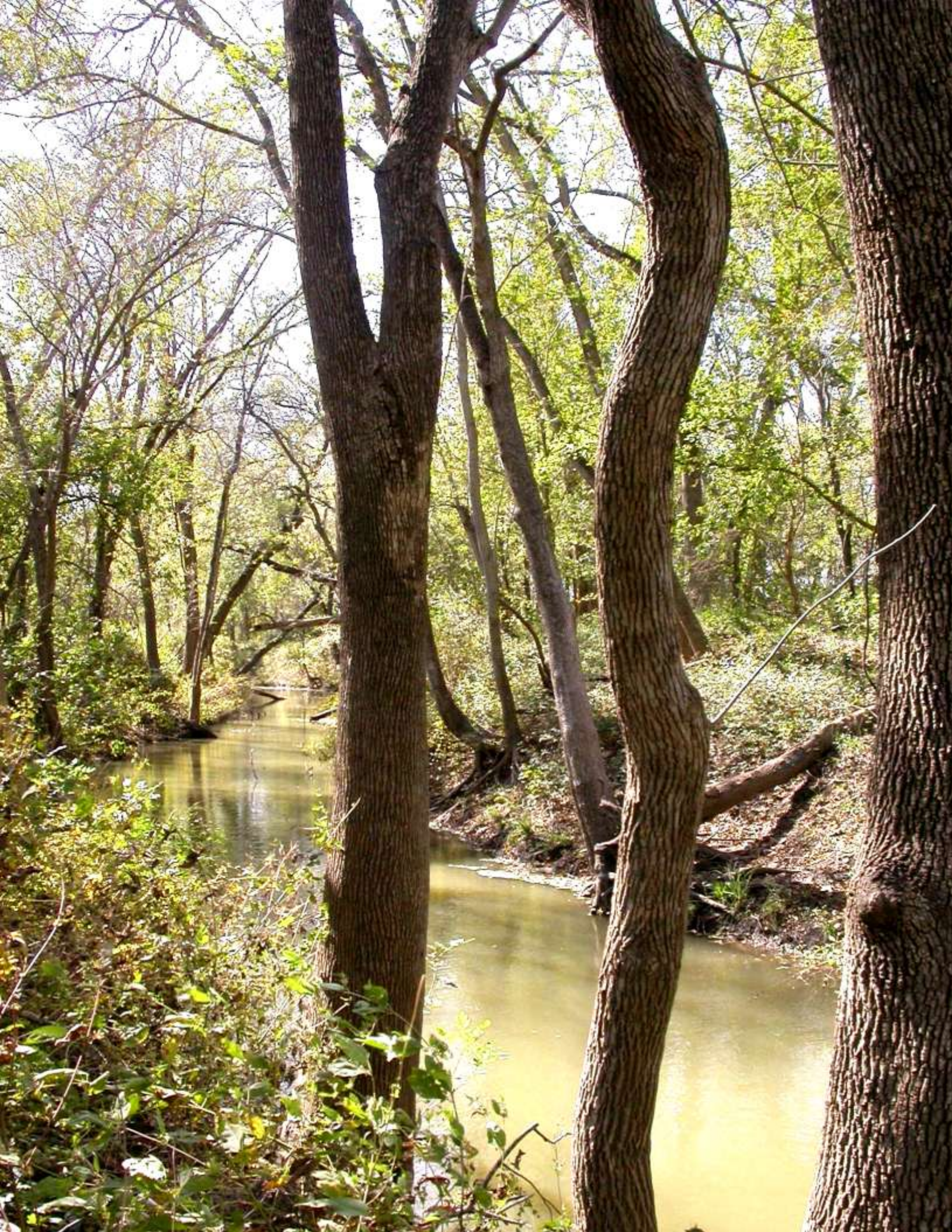
Expected load reductions of *E. coli* bacteria, nitrate, and total phosphorus at each monitoring station as a result of full implementation of the Plum Creek Watershed Protection Plan are presented in Table 10.3. Certainly, precise estimates of attainable load reductions are difficult to determine, and may change over time due to significant changes in land use and pollutant sources. However, these estimates will be used to demonstrate expected improvement toward target water quality goals for the watershed. With active local stakeholder engagement and participation in plan implementation and continued support from cooperating groups and agencies, the activities outlined here will make significant progress toward improving and protecting water quality in the Plum Creek Watershed.

Table 10.3. Estimated regional pollutant load reductions expected upon full implementation of the Plum Creek Watershed Protection Plan.

Management Measure	Expected Load Reduction								
	Uhland			Lockhart			Luling		
	Ec[1]	N[2]	P[3]	Ec	N	P	Ec	N	P
Urban Stormwater Management Measures									
Pet Waste Collection Stations	7.2E+12	70.6	8.2	7.3E+12	158.5	17.9	3.1E+14	1.4	N/A
Comprehensive Urban Stormwater Assessment; Retrofit Stormwater Detention Basins; Initiate Street Sweeping Program; Manage Urban Waterfowl Populations; Rehabilitate Stormwater Retention Pond	4.3E+13	531.7	19.1	1.9E+13	929.6	32.5	9.1E+14	7.8	N/A
Wastewater Management Measures									
Wastewater Upgrade (TSS Reduction); Wastewater Upgrade (Phosphorus Removal); Voluntary Monthly *E. coli* Monitoring; Voluntary Monthly Phosphorus Monitoring; Sanitary Sewer Pipe Replacement; Lift Station SCADA Installation; Initiate Sanitary Sewer Inspection Program	3.5E+10	N/A	N/A	2.1E+10	N/A	N/A	1.6E+12	N/A	N/A
Septic System Inspection/Enforcement (New Position); Septic System Repair; Septic System Replacement; Septic System Connection to Sewer	6.1E+12	22.7	13.3	5.0E+12	42.2	24.2	2.0E+14	0.4	N/A

Management Measure	Expected Load Reduction								
	Uhland			Lockhart			Luling		
	Ec[1]	N[2]	P[3]	Ec	N	P	Ec	N	P
Agricultural Management Measures									
WQMP Technician (New Position)	9.6E+12	5,472	827	2.1E+13	30,427	4,772	2.9E+15	542	N/A
Livestock Water Quality Management Plans									
Cropland Water Quality Management Plans									
Non-Domestic Animal and Wildlife Management Measures									
Feral Hog Control (New Position)	7.3E+12	1,615	327	1.2E+13	5,902	1,163	2.1E+15	105	N/A
Feral Hog Control (Equipment)									

[1] Ec: *E. coli* reduction indicated in cfu/year
[2] N: Nitrogen reduction in kg/year
[3] P: Phosphorus reduction in kg/year



Appendix A: List of Acronyms

7Q2	Minimum 7-Day, 2-Year Discharge
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
cfu	Colony Forming Units
CI	Confidence Interval
CRP	Clean Rivers Program
CWA	Clean Water Act
EDAP	Economically Distressed Area Program
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESRI	Environmental Systems Research Institute
ETJ	Extraterritorial Jurisdiction
GBRA	Guadalupe-Blanco River Authority
GIS	Geographic Information System
LDC	Load Duration Curve
LO	Lockhart Region Subwatershed Designation
LU	Luling Region Subwatershed Designation
MGD	Million Gallons per Day
MS4	Municipal Separate Storm Sewer System
NAIP	National Agriculture Imagery Program
NEMO	Nonpoint Source Education for Municipal Officials
NH_3	Ammonia
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source Pollution
NRCS	National Resources Conservation Service
OSSF	On-Site Sewage Facility
RRC	The Railroad Commission of Texas
SAFE	Sports Athletic Field Education

SCADA	Supervisory Control and Data Acquisition
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Project
SRF	State Revolving Fund
SWAT	Soil and Water Assessment Tool
SWCD	Soil and Water Conservation District
TACAA	Texas Association of Community Action Agencies
TAG	Technical Advisory Group
TAMU	Texas A&M University
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TFB	Texas Farm Bureau
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSS	Total Suspended Solids
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWDMS	Texas Wildlife Damage Management Service
TxDOT	Texas Department of Transportation
UGRA	Upper Guadalupe River Authority
UH	Uhland Region Subwatershed Designation
USDA	United States Department of Agriculture
USGS	Unites States Geological Survey
UV	Ultraviolet
WCSC	Watershed Coordination Steering Committee
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Appendix B: Elements of Successful Watershed Plans

A. Identification of Causes 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 watershed-based plan (and to achieve any other watershed goals identified in the watershed protection plan). Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed. Information can be based on a watershed inventory, extrapolated from a subwatershed 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 and 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 reasonably expeditious. Specific dates are generally not required.

G. Milestones

A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented. Milestones should be tied to the progress of the plan to determine if it is moving in the right direction.

H. LOAD REDUCTION EVALUATION CRITERIA

A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether the watershed-based plan needs to be revised. The criteria for loading reductions do not have to be based on analytical water quality monitoring results. Rather, indicators of 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 C: Partnership Ground Rules

The following are the Ground Rules for the Plum Creek Watershed Partnership agreed to and signed by the members of the Plum Creek Watershed Partnership Steering Committee (hereafter referred to as the Steering Committee) in an effort to develop and implement a watershed protection plan.

The signatories to these Ground Rules agree as follows:

GOALS

The goal of the Partnership is to develop and implement a Watershed Protection Plan to improve and protect the water quality of Plum Creek (Segment 1810). According to the draft *2004 Texas Water Quality Inventory and 303(d) List*, Plum Creek exhibits elevated nutrient levels and is impaired by elevated bacteria concentrations making it unsuitable for contact recreation use.

The Steering Committee will consider and attempt to incorporate the following into the development and implementation of the watershed protection plan:

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

POWERS

The Steering Committee is the decision making body for the Partnership. As such, the Steering Committee will formulate recommendations to be used in drafting the watershed protection plan and will guide the implementation of the watershed protection plan to success. Formal Steering Committee recommendations will be identified as such in the planning documents and meeting summaries.

Although formation of the Steering Committee was facilitated by the Texas AgriLife Extension Service and the Texas State Soil and Water Conservation Board (TSSWCB), the Steering Committee is an independent group of watershed stakeholders and individuals with an interest in restoring and protecting the designated uses and the overall health of the Plum Creek Watershed.

The Steering Committee provides the method for public participation in the planning process and will be instrumental in obtaining local support for actions aimed at restoring surface water quality in Plum Creek.

TIME FRAME

Development of a Plum Creek Watershed Protection Plan will require at least a 15-month period. The Steering Committee will function under a June 2007 target date to complete the initial development of the watershed protection plan. Achieving water quality improvement in Plum Creek may require significant time as implementation is an iterative process of executing programs and practices followed by achievement of interim milestones and reassessment of strategies and recommendations. The Steering Committee will function throughout the 15-month initial development period and may continue to function thereafter as a recommendation of the watershed protection plan.

STEERING COMMITTEE MEMBERSHIP SELECTION

The Steering Committee is composed of stakeholders from the Plum Creek Watershed. Initial solicitation of members for equitable geographic and topical representation was conducted using three methods: 1) consultation with the County Extension Agents, Plum Creek Conservation District, Guadalupe-Blanco River Authority, Caldwell-Travis and Hays County Soil and Water Conservation Districts and local and regional governments, 2) meetings with the various stakeholder interest groups and individuals, and 3) self-nomination or requests by the various stakeholder groups or individuals.

Stakeholders are defined as either those who make and implement decisions or those who are affected by the decisions made or those who have the ability to assist with implementation of the decisions.

STEERING COMMITTEE

Members include both individuals and representatives of organizations and agencies. A variety of members serve on the Steering Committee to reflect the diversity of interests within the Plum Creek Watershed and to incorporate the viewpoints of those who will be affected by the watershed protection plan.

Size of the Steering Committee is not strictly limited by number but rather by practicality. To effectively function as a decision-making body, the membership shall achieve geographic and topical representation. If the Steering Committee becomes so large that it becomes impossible or impractical to function, the Committee will institute a consensus-based system for limiting membership.

Steering Committee members are expected to participate fully in Committee deliberations. Members will identify and present insights, suggestions, and concerns from a community, environmental, or public interest perspective. Committee members are expected to work constructively and collaboratively with other members toward reaching consensus.

Committee members will be expected to assist with the following:

- Identify the desired water quality conditions and measurable goals;
- Prioritization of programs and practices to achieve goals;
- Help develop a watershed protection plan document;
- Lead the effort to implement this plan at the local level; and
- Communicate implications of the watershed protection plan to other affected parties in the watershed.

Steering Committee members will be asked to sign the final watershed protection plan. The Steering Committee will not elect a chair, but rather remain a facilitated group. Extension and/or the TSSWCB will serve as the facilitator. In order to carry out its responsibilities, the Steering Committee has discretion to form standing and ad hoc work groups to carry out specific assignments from the Committee. Steering Committee members will serve on a work group and represent that work group at Steering Committee meetings to bring forth information and recommendations.

WORK GROUPS

Topical work groups formed by the Steering Committee will carry out specific assignments from the Steering Committee. Initially formed standing work groups are:

- Agricultural Nonpoint Source Work Group
- Outreach and Education Work Group
- Urban Stormwater and Nonpoint Source Work Group
- Waste Water and Industry Work Group
- Water Quality and Habitat Work Group

Each work group will be composed of a minimum of 5 Steering Committee members and any other members of the Partnership with a vested interest in that topic. There is no limit to the number of members on a work group. Each work group will elect a chair.

Tasks such as research or plan drafting will be better performed by these topical work groups. Work Group members will discuss specific issues and assist in developing that portion of the watershed protection plan, including implementation recommendations.

Work Groups and individual Work Group members are not authorized to make decisions or speak for the Steering Committee.

TECHNICAL ADVISORY GROUP

A Technical Advisory Group (TAG) consisting of state and federal agencies with water quality responsibilities will provide guidance to the Steering Committee and Work Groups. The TAG will assist the Steering Committee and Work Groups in watershed protection plan development by answering questions related to the jurisdiction of each TAG member. The TAG includes, but is not limited to, representatives from the following agencies:

- Texas Commission on Environmental Quality
- Texas AgriLife Extension Service
- Texas Department of Agriculture
- Texas Parks and Wildlife Department
- Texas Railroad Commission
- Texas State Soil and Water Conservation Board
- Texas Farm Bureau
- Texas Water Development Board
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- USDA Natural Resources Conservation Service

Replacements and Additions

The Steering Committee may add new members if (1) a member is unable to continue serving and a vacancy is created or (2) important stakeholder interests are identified that are not represented by the existing membership. A new member must be approved by a majority of existing members. In either event, the Steering Committee will, when practical, accept additional members.

Alternates

Members unable to attend a Steering Committee meeting (an absentee) may send an alternate. An absentee should provide advance notification to the facilitator of the desire to send an alternate. An alternate attending with prior notification from an absentee will serve as a proxy for that absent Steering Committee member and will have voting privileges. An alternate attending without advance notification will not be able to participate in Steering Committee votes. Absentees may also provide input via another Committee member or send input via the facilitator. The facilitator will present such information to the Committee.

Absences

All Steering Committee members agree to make a good faith effort to attend all Steering Committee meetings, however, the members recognize that situations may arise necessitating the absence of a member. Three absences in a row of which the facilitator was not informed of beforehand or without designation of an alternate constitute a resignation from the Steering Committee.

Decision-Making Process

The Steering Committee will strive for consensus when making decisions and recommendations. Consensus is defined as everyone being able to live with the decisions made. Consensus inherently requires compromise and negotiation. If consensus cannot be achieved, the Steering Committee will make decisions by a simple majority vote. If members develop formal recommendations, they will do so by two-thirds majority vote. Steering Committee members may submit recommendations as individuals or on behalf of their affiliated organization.

QUORUM

In order to conduct business, the Steering Committee will have a quorum. Quorum is defined as at least 51% of the Steering Committee (and/or alternates) present and a representative of either Extension or the TSSWCB present.

FACILITATOR

The TSSWCB Regional Watershed Coordinator and the Extension Coordinator are independent positions, financed by the State of Texas through federal grant funds. Each has specific roles to perform in facilitating the Partnership and Steering Committee.

TSSWCB Regional Watershed Coordinator

The TSSWCB Regional Watershed Coordinator provides technical assistance to the stakeholders in developing the Plum Creek Watershed Protection Plan. The TSSWCB Regional Watershed Coordinator will 1) ensure the planning process culminates in a watershed protection plan for Plum Creek, 2) facilitate discussions in Steering Committee and Work Group meetings necessary to formulate the watershed protection plan, 3) draft text and prepare the watershed protection plan such that it incorporates Steering Committee recommendations, 4) collaborate with the Extension Coordinator to facilitate the development and implementation of the watershed protection plan through the Steering Committee and work groups, and 5) ensure the Plum Creek Watershed Protection Plan satisfies the 9 elements fundamental to a watershed protection plan as promulgated by the U.S. Environmental Protection Agency.

Extension Coordinator

The Extension Coordinator will serve as an educator and facilitator to help the Steering Committee organize its work, run meetings, coordinate educational trainings and draft notes and other materials if requested, and work with the TSSWCB to facilitate the development and implementation of the plan. The Extension Coordinator will co-lead the meetings and work with all of the members to ensure that the process runs smoothly. The role of the Extension Coordinator includes working with the Steering Committee to prepare meeting summaries, assisting in the location and/or preparation of background materials, distributing documents the Steering Committee develops, conducting public outreach, moderating public workshops, providing assistance to Steering Committee members regarding Committee business between meetings, and other functions as the Steering Committee requests.

MEETINGS

All meetings (Partnership, Steering Committee, and Work Group) are open and all interested stakeholders are encouraged and welcomed to participate.

Over the 15-month development period, regular meetings of either the Steering Committee or work groups will occur each month. The Steering Committee may determine the need for additional meetings. Steering Committee and work group meetings will be scheduled to accomplish specific milestones in the planning process.

Meetings will start and end on time. Meeting times will be set in an effort to accommodate the attendance of all Steering Committee members. The Extension Coordinator will notify members of the Partnership, Steering Committee, and work groups of respective meetings.

Open Discussion

Participants may express their views candidly, but without personal attacks. Time is shared because all participants are of equal importance.

Agenda

Extension and the TSSWCB, in consultation with Steering Committee members are charged with developing the agenda. The anticipated topics are determined at the previous meeting and through correspondence. A draft agenda will be sent to the Steering Committee with the notice of the meeting. Agendas will be posted on the project website. Agenda items may be added by members at the time that the draft agenda is provided. The Extension Coordinator will review the agenda at the start of each meeting and the agenda will be amended if needed and the Committee agrees. The Committee will then follow the approved agenda unless they agree to revise it.

Meeting Summaries

Extension will take notes during the meetings and may provide audio recording. Meeting summaries will be based on notes and/or the recording. Extension and the TSSWCB will draft meeting notes and distribute them to the committee for their review and approval. All meeting summaries will be posted on the project website.

Distribution of Materials

Extension and the TSSWCB will prepare and distribute the agenda and other needed items to members. Distribution will occur via email and websites, unless expressly asked to use U.S. Mail (i.e. member has no email access). To encourage equal sharing of information, materials will be made available to all. Those who wish to distribute materials to the Steering Committee or a Work Group may ask Extension or the TSSWCB to do so on their behalf.

Speaking in the Name of the Committee

Individuals do not speak for the Steering Committee as a whole unless authorized by the Committee to do so. Members do not speak for Extension or the TSSWCB and neither the Extension nor the TSSWCB speak for Steering Committee members. If Committee spokespersons are needed, they will be selected by the Steering Committee.

Development and Revision of Ground Rules

These ground rules were drafted by Extension and the TSSWCB and presented to the Steering Committee for their review, possible revision, and adoption. Once adopted, ground rules may be changed by two-thirds majority vote provided a quorum is present.

Appendix D: Land Use Classification Definitions

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 buildings. Impervious surfaces account for 80 to100% of the total cover.

OPEN WATER

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

BARREN LAND

Barren areas of bedrock, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

FORESTED LAND

Areas dominated by trees generally greater than 5 meters tall, and greater than 50% of total vegetation cover.

NEAR 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 20-50% of total vegetation cover.

ORCHARD

Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

RANGELAND

Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25%, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

PASTURE/HAY

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, sorghum, wheat, and cotton. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Appendix E: Load Duration Curve Explanation

The load duration curve (LDC) is an initial tool that can be used to help identify potential pollutant sources in a watershed. As the first step in this process, a flow duration curve is developed. Flow duration curves are constructed using historical hydrograph data of actual observed streamflows at a given location. In Plum Creek, these flows are obtained from USGS Stations 08172400 (Plum Creek at Lockhart) and 08173000 north of Luling (Plum Creek upstream from confluence of West Fork). The streamflow data for the Uhland monitoring station was based on the nearest downstream USGS station (08172400). Observed streamflow data collected at the Uhland monitoring station were compared to USGS station data for the same dates. During high flows, the USGS station had much higher deviations from the observed streamflows at the Uhland site. However, at lower flows (possibly due to point source flows) the deviation was negligible. A systematic procedure was used to obtain the cutoff for streamflow beyond which the deviation between the USGS station and the GBRA station increased considerably. All USGS streamflow data above this threshold streamflow were adjusted using the land area contributing to this location, and USGS flows lower than the threshold were used without adjustment for the Uhland monitoring station.

For a given period of record, daily average flow data are ordered from highest to lowest and plotted to construct a flow duration curve line. Data are then separated into different flow ranges. Flow duration curves are commonly split into high flows, moist conditions, mid-range flows, dry conditions, and low flows based on observations as indicated in Figure E.1. Here, highest flows occur less than 10% of the time, and over 90% of the time, streamflow is greater than low flow conditions. Extreme low flow conditions, known as 7Q2 data (minimum 7-day flow conditions over a 2-year period) are not included in the analysis, as they are not included in TCEQ water quality assessments. For this reason, they are not utilized for load reduction calculations.

By examining flow conditions at different sampling locations, overall flow patterns within the watershed can be characterized. However, flow duration curves are not based on time and do not show when flows occur, only their frequency.

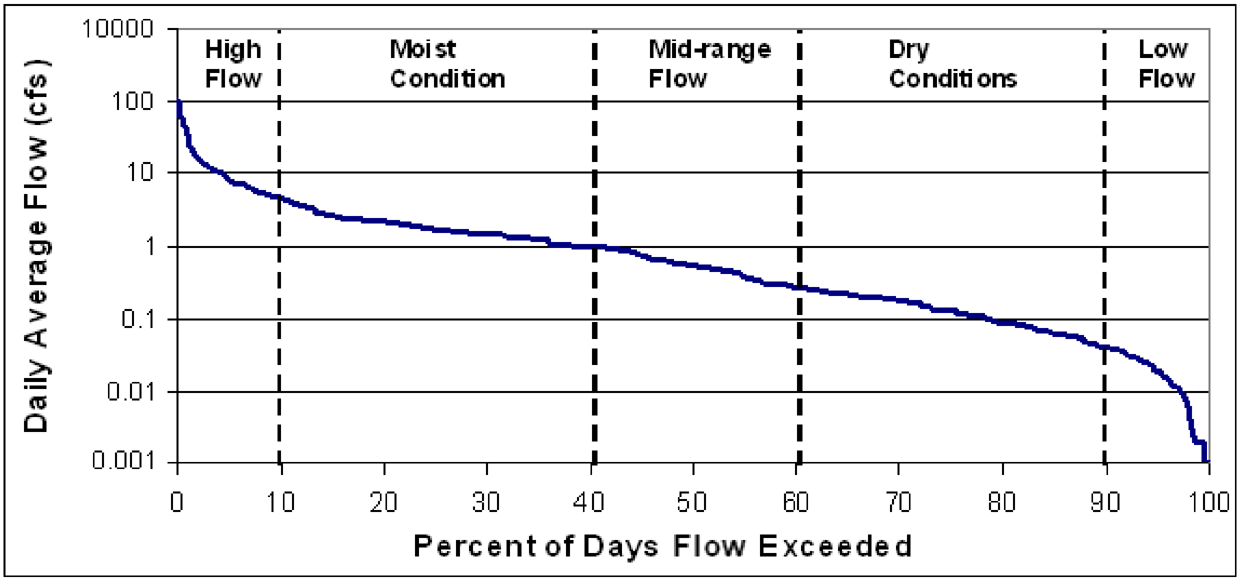


Figure E.1. Example flow duration curve. Vertical axis is flow rate and horizontal axis is percent exceedence. Curve shows percentage of time during a year, on average, a stream exhibits different flow conditions from very high flows during floods to low flow during summer or in long periods of time between rainfall events.

Next, it is necessary to determine if and under which flow conditions water quality standards are not met. The daily streamflow rate at all points along the flow duration curve is multiplied by a water quality criterion or target (EPA 2006). For example, to support contact recreation in Texas freshwater streams, the Texas Surface Water Quality Standard for *E. coli* is a geometric mean of 126 cfu/100 mL. By using the geometric mean rather than the single sample criterion of 394 cfu/ 100 mL, bacteria loads after implementation efforts, if successful, will be below both geometric mean and single sample criteria. If the single sample criterion were used as a water quality target, stream loads after reductions might still exceed the geometric mean.

In addition to a water quality criterion, a 10% margin of safety is typically included in load reduction calculations. The margin of safety allows for possible variability in streamflow and pollutant loads resulting from potential contributions from tributaries, variation in the effectiveness of control measures, and other sources of uncertainty over time and space. As a result, the target stream *E. coli* concentration for Plum Creek is 114 cfu/100 mL, which is the Texas Standard geometric mean of 126 cfu/100 mL minus the 10% margin of safety. Multiplying this value by streamflow at all points along the flow curve produces the maximum acceptable pollutant load (in this example *E. coli*), or the load duration curve (dark blue line in Figure E.2 and blue line in Figures E.3 and E.4) for that specific monitoring location on the stream. Actual monitored data for pollutants (pink boxes in Figure E.2) can then be evaluated based on how they compare to regulatory limits under different streamflow conditions. To do this, the total pollutant load for the stream at a given place and time is calculated by multiplying the measured streamflow by the measured pollutant concentration.

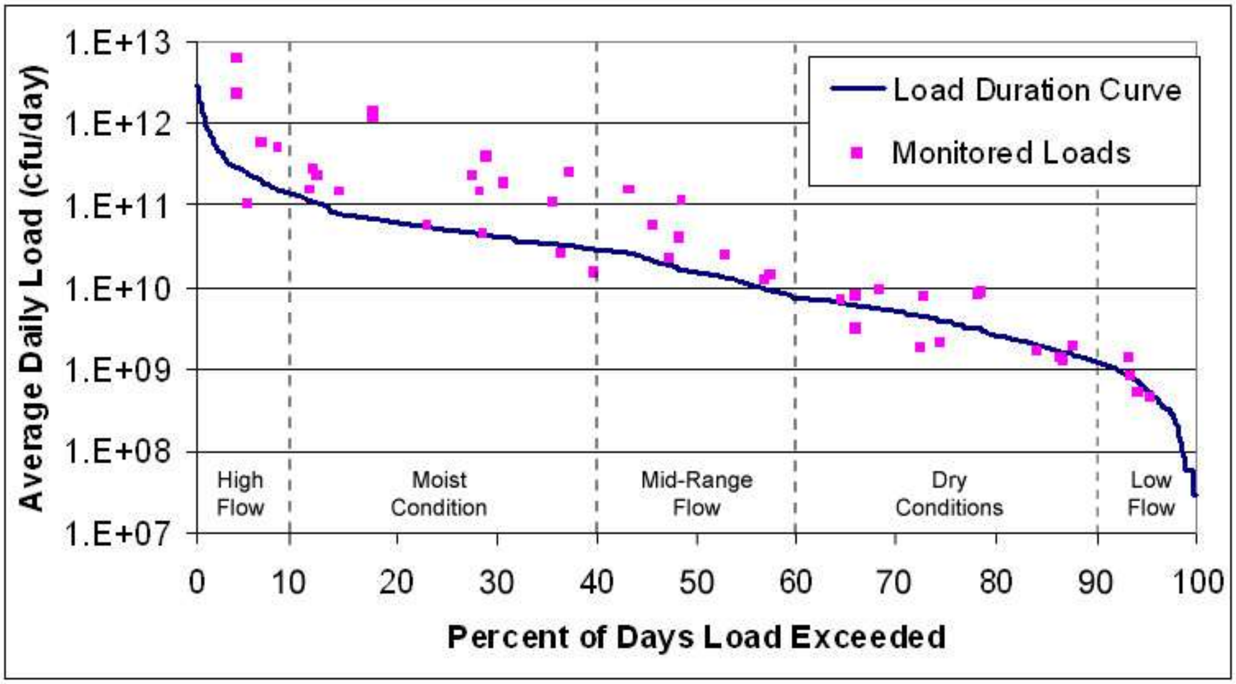


Figure E.2. Example load duration curve. Flow duration curve is multiplied by the *E. coli* bacteria criterion of 126cfu/100 mL to yield a maximum allowable bacterial load for a stream, varying with streamflow conditions.

Once individual monitoring station data points are plotted, patterns of observed exceedences provide basic information on the nature of pollutant sources. Exceedences on the left side of the curve, when flows are highest, typically indicate nonpoint sources. Moderate to high streamflows are correlated with significant rainfall events, which typically generate runoff. As it moves overland, runoff can transport various materials, including sediment, bacteria, and nutrients. Because many pollutants that would not otherwise reach the stream under drier conditions are moved to the stream by runoff, greater pollutant loads are generally observed at high flows.

In contrast, exceedences that occur during low flows in relatively dry conditions (on the right side of the curve) typically indicate point source contributions or discharges directly into the stream, since runoff is not occurring. These may include piped wastewater effluent, sewer bypasses and overflows, urban stormwater outlets, or industrial discharges, and also can be an indication of direct deposition by wildlife, non-domestic animals, and livestock. This separation of timing of exceedences is helpful in identifying both categories of potential pollutant sources and the processes that may be affecting how pollutants are entering the stream. However, load duration curves cannot separate individual sources (septic systems and urban runoff, for example) and cannot determine the exact points in time that all high pollutant levels occur.

Using the LDC and monitored data, it is then possible to calculate the load reduction that will be needed to meet water quality goals. To do this, a statistical regression analysis is performed using the actual monitored data for that location. The regression trendline, or load regression curve in Figures E.3 and E.4, is plotted on the graph and is compared to the load duration curve. The difference between the load estimated by the regression curve and the target load at the water quality criterion (with the 10% margin of safety) determines the percent reduction required for each flow condition. The highest load reduction percent for any one flow condition determines the necessary reduction for that site. For instance, the highest reduction at Uhland is the 64.7% under moist conditions. This value is used as the target load reduction for the site.

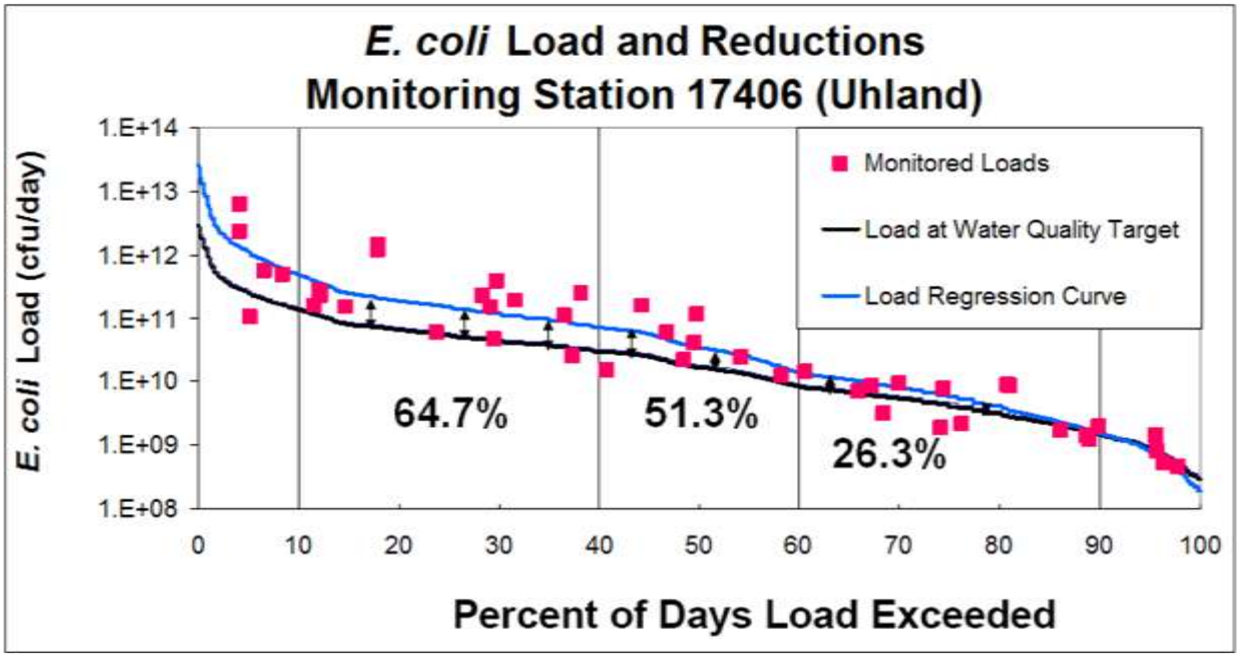


Figure E.3. Example load reduction determination for Uhland monitoring station.

In some situations, the highest load reduction occurs during low flow conditions. For instance, at Lockhart, the highest indicated load reduction is 15% during dry conditions (Figure E.4). Since this is the highest required reduction at the site (other flow conditions show no necessary load reductions), this value is used for the target load reduction at the Lockhart monitoring station.

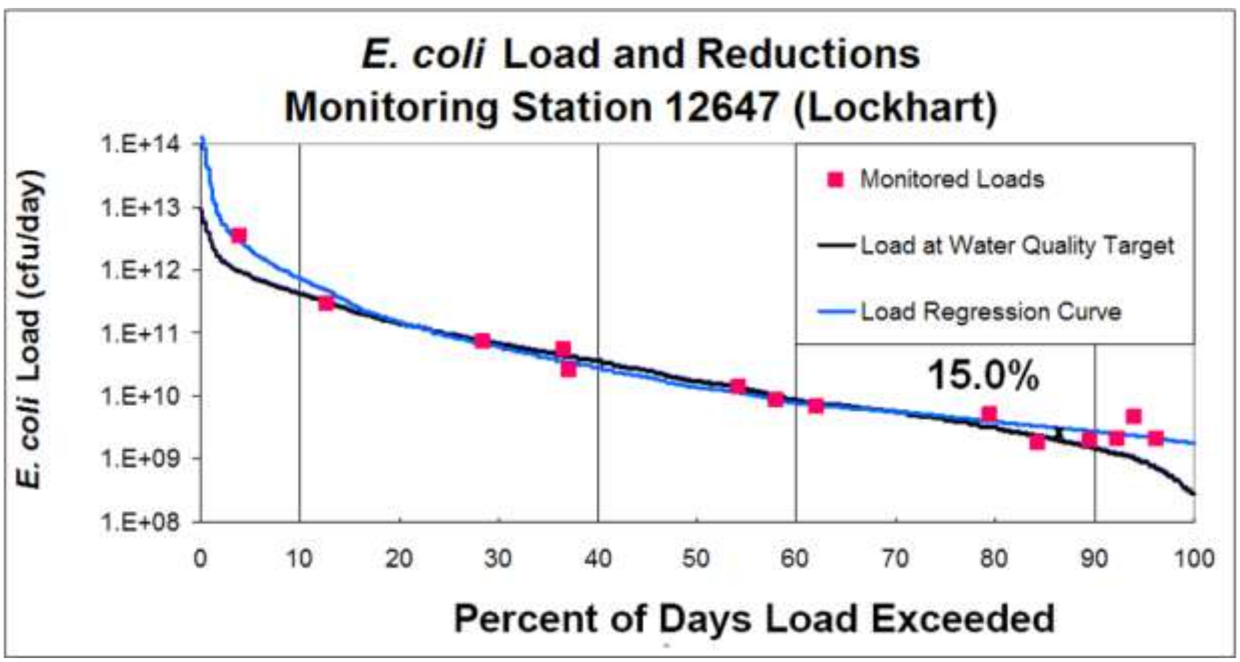


Figure E.4. Example load reduction for Lockhart monitoring station.

For each additional pollutant, the same approach of utilizing flow data, actual monitored water quality data, Texas standards or screening criteria, and margin of safety is used. In this way, estimated loads and load reductions can be determined for any particular pollutant of interest, and this information can serve as a starting point to guide selection of management strategies to achieve watershed planning goals.

Appendix F: SELECT Approach Explanation

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is an analytical approach for developing an inventory of potential bacterial sources, particularly nonpoint source contributors, and distributing their potential bacterial loads based on land use and geographical location. A thorough understanding of the watershed and potential contributors that exist is necessary to estimate and assess bacterial load inputs. Land use classification data and data from state agencies, municipal sources, and local stakeholders on the number and distribution of pollution sources are used as inputs in a Geographical Information Systems (GIS) software format. The watershed is divided into multiple smaller subwatersheds based on elevation changes along tributaries and the main segment of the water body. Pollutant sources in the landscape can then be identified and targeted where they are most likely to have significant effects on water quality, rather than looking at contributions on a whole-watershed basis. The SELECT approach was utilized by the Plum Creek Steering Committee as one of their decision-making tools.

Septic Systems

Using 2000 census block data from the U.S. Census Bureau, the number and location of households in the Plum Creek Watershed were determined. Homes within city limits were determined to be on city sewer facilities, and those outside cities were assumed to rely on septic systems. Using home and subdivision records obtained from the counties in the Plum Creek Watershed, the age of homes, and thus septic systems, was determined. Based on the findings of Reed, Stowe, and Yanke (2001), regulated septic systems installed since 1989 were conservatively estimated to have a 12% failure rate. Systems installed prior to 1989 regulation were assumed to be unregulated and have a 50% failure rate. The total potential daily *E. coli* bacteria load generated by septic systems in individual subwatersheds in the Plum Creek Watershed was estimated as:

$$Septic-Load = \#FailingSystems * \frac{10^6 cfu}{100mL} * \frac{70gal}{person/day} * \frac{\#Persons}{Household} * \frac{3758.2mL}{gal} * 0.5$$

where #FailingSystems is the estimated number of failing septic systems within a subwatershed, 10^6 cfu is bacteria production, 70 gallons per person per day is assumed to be daily discharge, and #Persons is the average number of individuals within a household (EPA 2001).

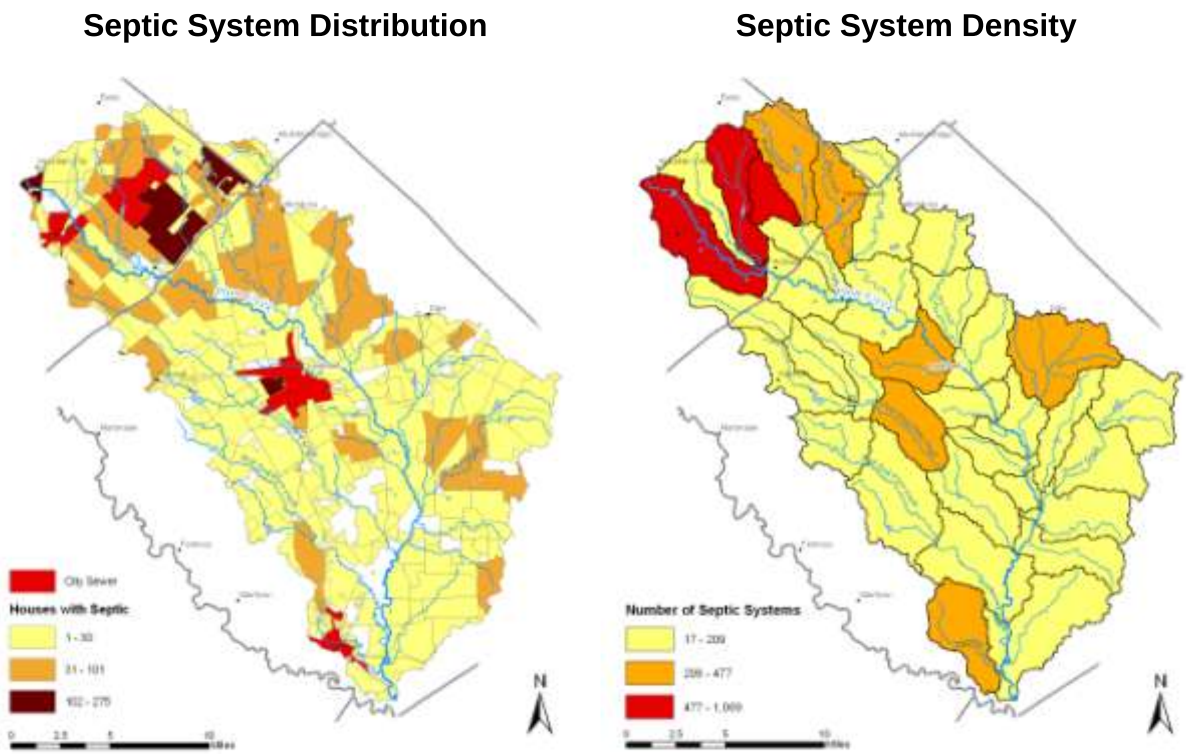


Figure F.1. Septic system distribution and relative density in the Plum Creek Watershed.

PETS

Using 2000 census block data from the U.S. Census Bureau, the number of households was determined for each subwatershed in the Plum Creek Watershed. Based on a survey by the AVMA (2002), the average Texas household has 0.8 dogs. By multiplying the average number of dogs by the number of households in each subwatershed, dog density can be estimated and total potential daily bacterial load approximated using:

$$Dog - Load = \# Households * \frac{0.8 dogs}{Household} * 5 * 10^{9} cfu / day * 0.5$$

where $5*10^9$ cfu/day*0.5 is the average daily *E. coli* bacteria production per dog (EPA 2001).

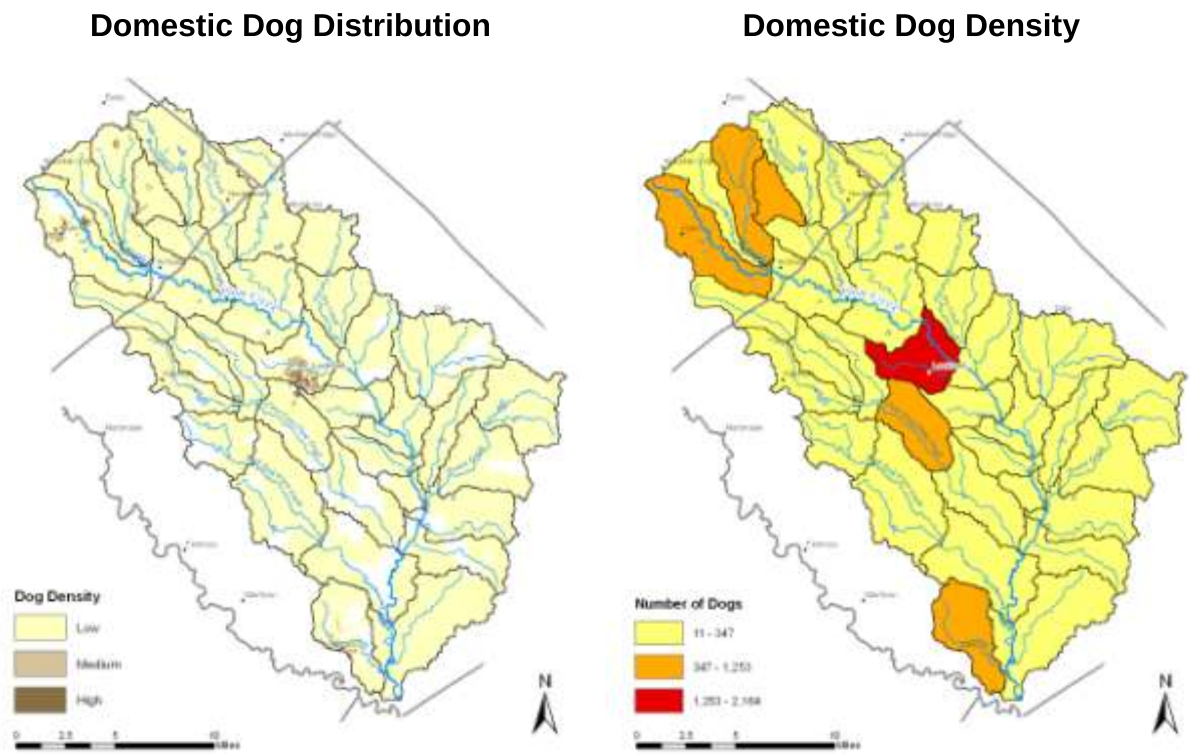


Figure F.2. Estimated dog distribution and relative density in the Plum Creek Watershed.

WILDLIFE

The potential bacteria contribution of white-tailed deer in the Plum Creek Watershed was estimated using deer census estimates from TPWD (Lockwood 2005). Average regional densities of white-tailed deer within resource management units were obtained for the SELECT analysis. Based on the average number of deer per square mile for each resource management unit, the number of deer was calculated within each resource management unit in the Plum Creek Watershed. Deer were then distributed across rangeland and forest land areas 20 acres or larger in size and the total number of white-tailed deer in each subwatershed calculated. The total potential daily bacteria load for each subwatershed was then estimated using the *E. coli* production rate of Zeckoski et al. (2005).

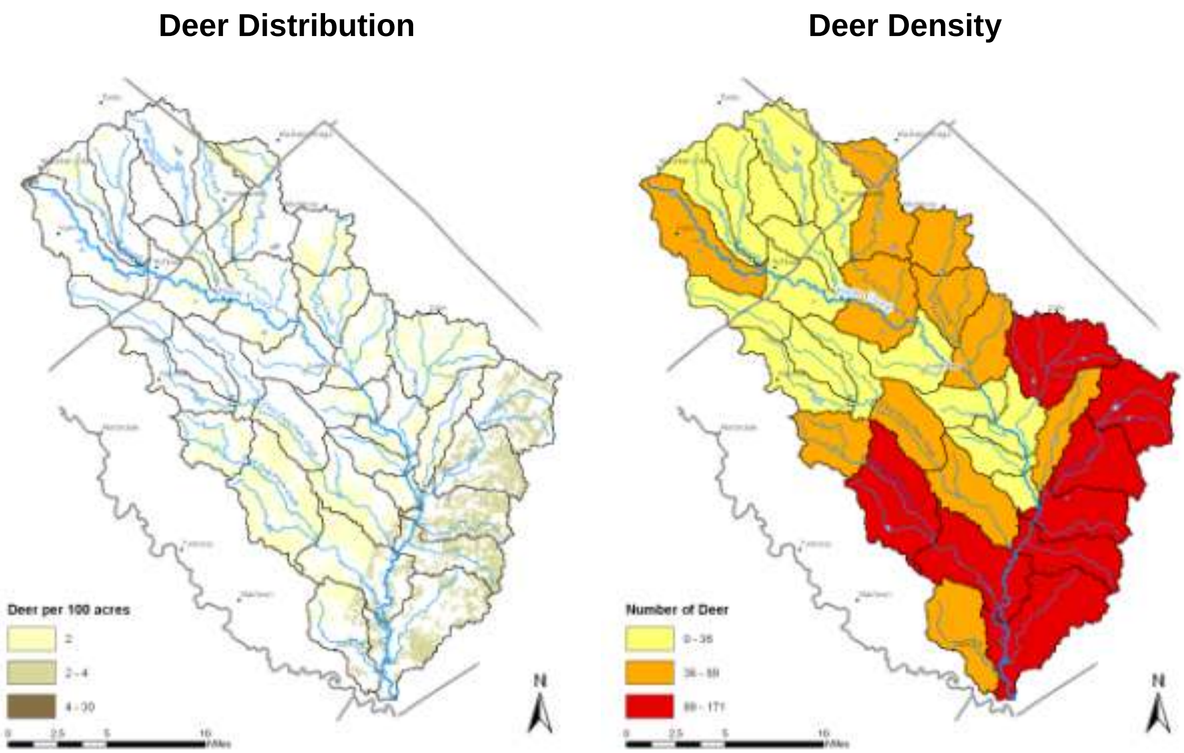


Figure F.3. Estimated white-tailed deer distribution and relative density in the Plum Creek Watershed.

Based on research information from Hellgren (1997), a population density of 2 animals/mile^2 was used to estimate the number of feral hogs in the Plum Creek Watershed. Habitat preferences and behavior characteristics reported by Hellgren (1997) also were used as the basis for distributing hogs to non-developed land use classes (forested land, near riparian forested land, mixed forest, rangeland, pasture/hay, and cultivated crops). In addition, for SELECT analysis, animals were restricted to areas within 100 m of perennial water sources, including ponds, flood control structures, and wastewater outfalls. Total potential daily *E. coli* loads from feral hogs were estimated using:

$$FeralHog-Load = \#Hogs * 8.9*10^9 cfu/day * 0.5$$

where $8.9*10^9$ cfu/day*0.5 is the average daily *E. col*i bacteria production per hog (EPA 2001).

*L*IVESTOCK

E. coli contributions from sheep and goats in the watershed were based on 2002 USDA census data for Caldwell, Hays, and Travis Counties. Using county totals for these animals, goats and sheep were distributed across rangeland and pasture land uses for the SELECT analysis. The average density of sheep and goats was determined for each county, and then the total population within the watershed was estimated by considering only the portions of these counties within the Plum Creek Watershed. Based on these numbers, the total potential daily *E. coli* load for sheep and goats was estimated using:

$$Sheep/Goat-Load = \#SheepGoats * 18 * 10^{9} cfu/day * 0.5$$

Where $18*10^9$ cfu/day*0.5 is the average daily *E. coli* production per animal (EPA 2001).

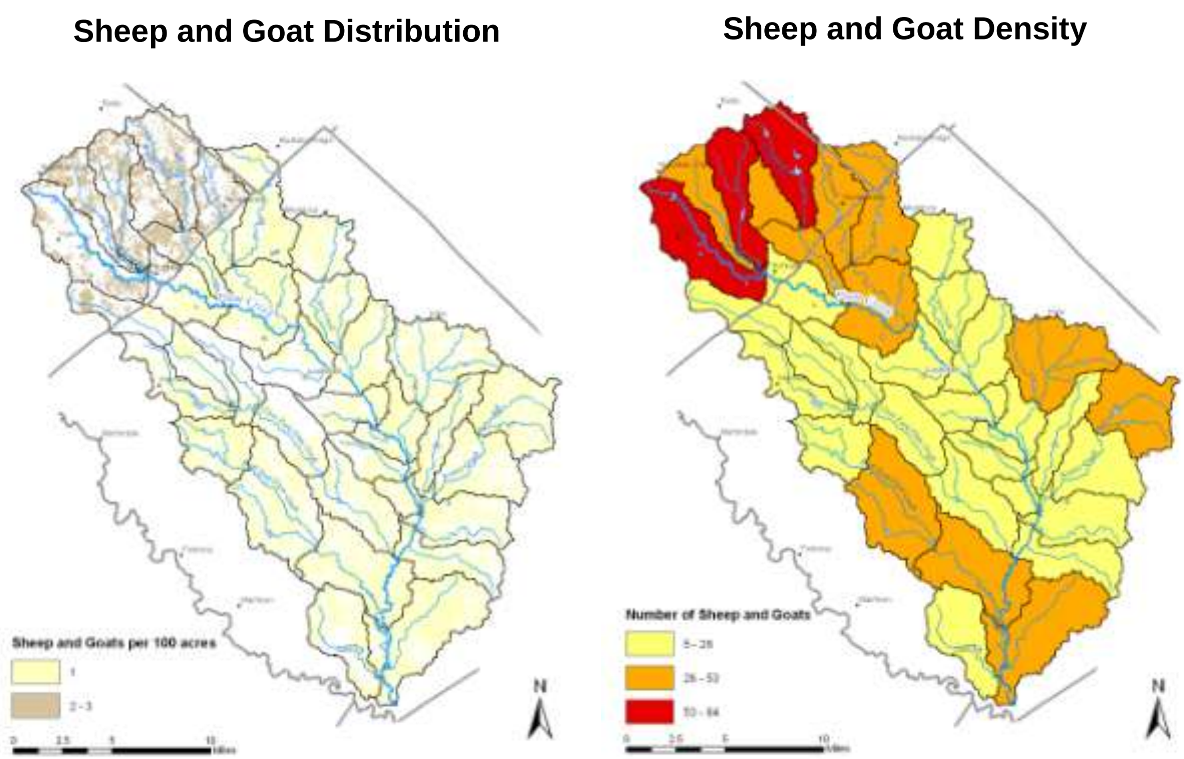


Figure F.4. Estimated sheep and goat distribution and relative density in the Plum Creek Watershed.

In the same way, bacteria load contributions from horses in the Plum Creek Watershed were estimated using 2002 USDA census totals for the counties that make up the watershed. Horses were distributed only across pasture/hay land uses in the watershed. An average density of horses was determined for each county, and the total population of horses within the watershed was estimated by summing the average density across the areas of Caldwell, Hays, and Travis Counties that lie within the Plum Creek Watershed. Based on the total population of horses in the watershed, the total potential daily *E. coli* load produced by horses was estimated using:

$$Horse-Load = \#Horses * 4.2 * 10^{8} cfu/day * 0.5$$

where $4.2*10^8$ cfu/day*0.5 is the average daily *E. coli* production per horse (EPA 2001).

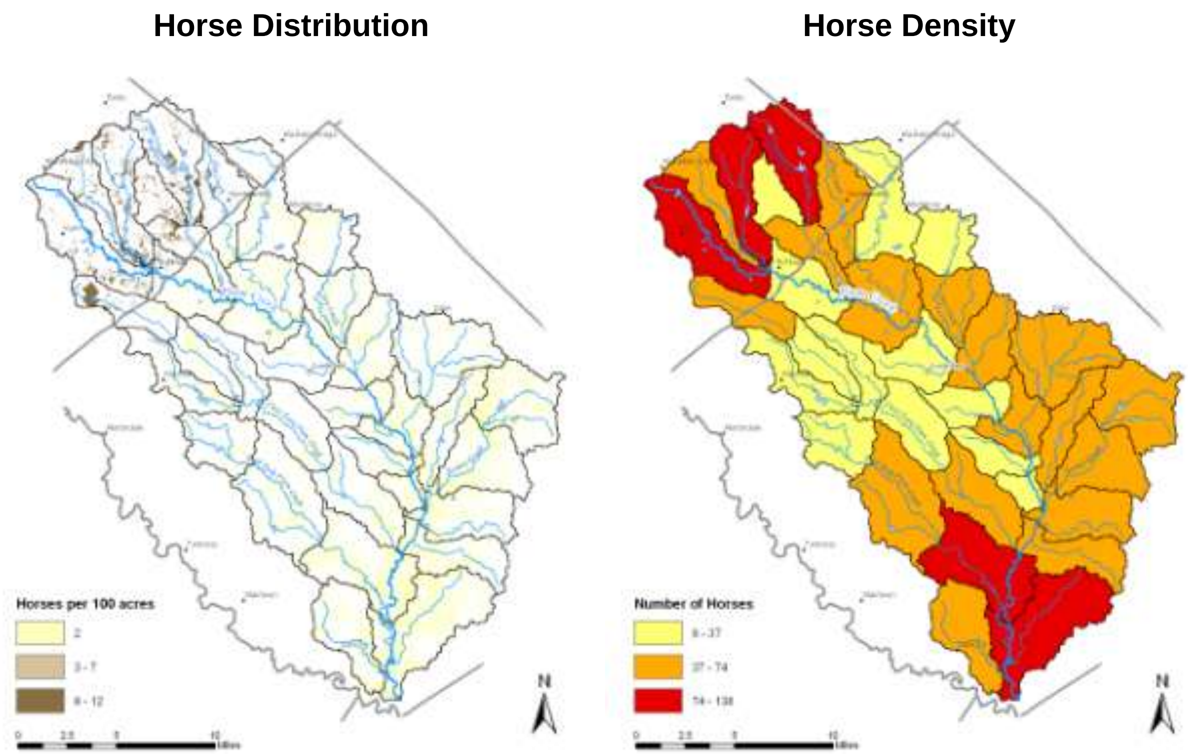


Figure F.5. Estimated horse distribution and relative density in the Plum Creek Watershed.

Cattle *E. coli* contributions were estimated in the same way as those for sheep and goats and horses. Using 2002 USDA census data for Caldwell, Hays, and Travis Counties, the total number of cattle in these areas was distributed across rangeland and pasture/hay land uses. The average density of cattle in each county was estimated and the portions of these counties within the Plum Creek Watershed yielded the estimated total number of cattle within the watershed. Based on this population density, the total potential daily *E. coli* bacteria load for each subwatershed was estimated using:

$$Cattle-Load = \#Cattle * 5.4 * 10^9 cfu/day * 0.5$$

where $5.4*10^9$ cfu/day*0.5 is the average daily *E. coli* production per head of cattle (EPA 2001).

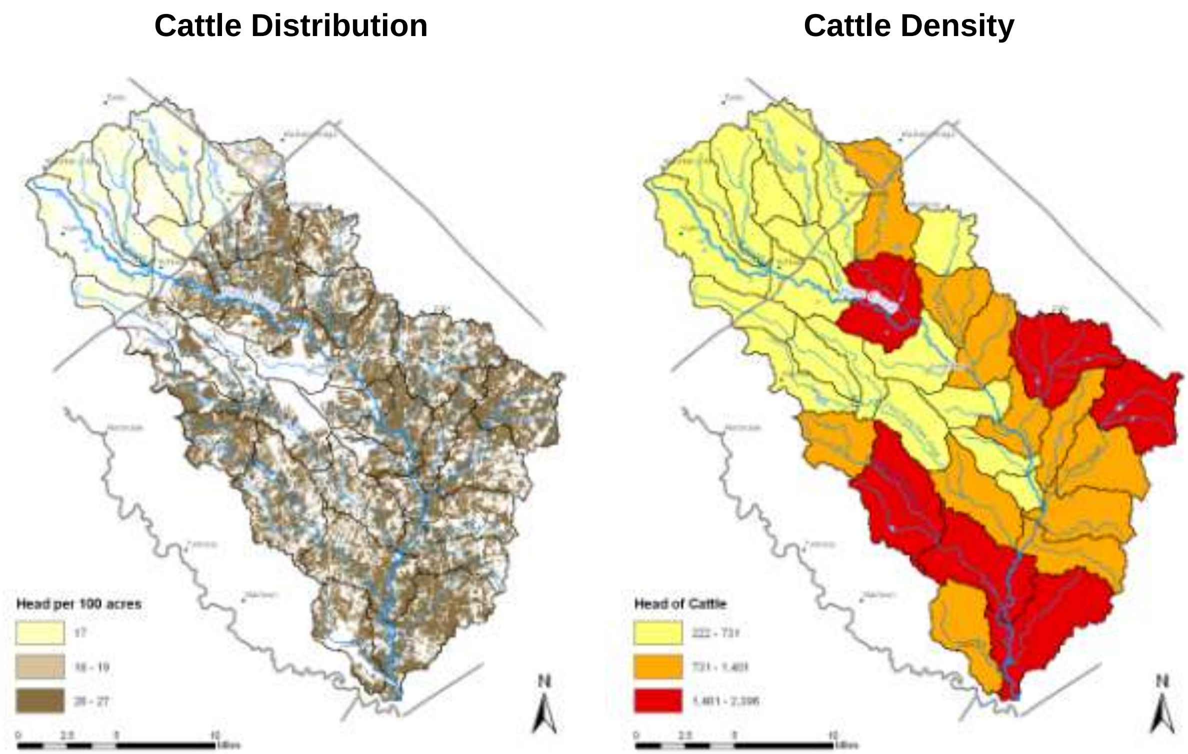


Figure F.6. Estimate cattle distribution and relative density in the Plum Creek Watershed.

URBAN RUNOFF

Results of a study commissioned by the City of Austin (1997) demonstrated a relationship between the amount of impervious surface cover and runoff bacteria concentration. This relationship was used to evaluate urban runoff potential in the Plum Creek Watershed. For each of the watershed's "major" cities (Kyle, Lockhart, and Luling), percent impervious cover within the city limits was determined based on land use classification. Percent cover was then correlated with a corresponding runoff bacteria concentration at that level of urban development based on the City of Austin study. Using 2004 total annual rainfall data from the nearby NOAA Austin Station and an assumed runoff coefficient of 1, the average daily potential rainfall depth was calculated. Using the resulting rainfall depth, potential runoff volume was calculated. Using this volume and the bacteria concentration corresponding to the appropriate level of impervious cover, the total potential daily *E. coli* load in urban runoff for each subwatershed was calculated.

WASTEWATER

SELECT was used to evaluate WWTFs based on their permitted discharge rates. Only actively discharging WWTFs in the Plum Creek Watershed (City of Lockhart #1, City of Lockhart #2, City of Luling North, City of Buda, and City of Kyle) were included in the SELECT analysis. Average maximum daily potential *E. coli* loads were calculated by assuming that each facility was discharging effluent in their subwatersheds at the 2004 permitted volume and with bacteria concentrations equal to the Texas Surface Water Quality Standard criterion (126 cfu/100 mL).

Wastewater Treatment Facility	Flow (MGD)
City of Lockhart No. 1	1.1
City of Lockhart No. 2	1.5
City of Luling North	0.9
City of Buda	0.3
City of Kyle	1.5

100%-25% Buffer Approach

For SELECT analysis of the Plum Creek Watershed and consistent with EPA (2001) TMDL guidelines, a buffer was placed around streams to account for the reduced likelihood of contamination by sources located farther away from the creek and its tributaries. Within 100m of waterways, 100% transmission to the mainstem of the creek was assumed. Virtually all of the bacteria from a source within that distance from water would be expected to reach the stream alive. Beyond 100m, a 25% transmission of bacteria was assumed, since only in conditions of high rainfall would sufficient runoff occur to carry bacteria to the creek from surrounding upland areas. This reduces the estimated effects of potential inputs that are in fact far removed from the stream and less likely to add to bacterial and/or nutrient loads within Plum Creek under most circumstances. The buffer was applied to all potential pollutant sources in the watershed and affected total load contributions from each.

Appendix G: Plum Creek Permit History

Facility	Effluent Set	Begin Date	End Date	Flow (MGD)	BOD (mg/L)	TSS (mg/L)	NH3 (mg/L)	TP (mg/L)	Fecal Bacteria (colonies/100mL)
Kyle	1	5/26/2000	3/11/2003	1.5	10	15	3	-	-
11041-002	2	3/12/2003	6/25/2006	1.5	10	15	3	-	-
	3	6/26/2006	-	1.5	10	15	3	-	-
	4	-	-	3	10	15	3	-	-
	5	-	-	4.5	10	15	3	-	-
Lockhart No. 2	1	2/9/1999	7/18/2001	1.5	10	15	3	-	
10210-002	2	7/19/2001	3/8/2005	1.5	10	15	3	-	
	3	3/9/2005	-	1.5	10	15	3	-	200
Buda	6	4/1/1996	2/15/2005	0.3	10	15	3	2	-
11060-001	8	2/16/2005	-	0.6	10	15	3	2	-
	9	-	-	0.95	7	12	2	1.2	-
	10	-	-	1.5	5	12	2	0.8	-
Lockhart No. 1	9	9/14/1998	12/21/1999	1.1	10	15	3	-	-
10210-001	10	12/22/1999	3/13/2005	1.1	10	15	3	-	-
	11	3/14/2005	-	1.1	10	15	3	-	-
A & M Heep	1	6/29/2004	-	0.25	5	5	2	1	-
14377-001	2	-	-	0.5	5	5	2	1	-
	3	-	-	0.99	5	5	2	1	-
Luling North	5	11/1/1997	1/10/2005	0.9	10	15	3	-	-
10582-002	6	1/11/2005	-	0.9	10	15	3	-	-
Ranch at Clear Fork	1	9/13/2005	-	0.33	10	15	3	-	-
14439-001	2	-	-	0.7	10	15	2	-	-
Castletop 14431-001	1	3/1/2006	-	0.486	5	5	2	1	-
Railyards-Parkland	1	8/13/2001	7/27/2005	0.08	10	15	-	-	
14165-001	2	7/28/2005	-	0.08	10	15	-	-	200
	3	-	-	0.175	10	15	-	-	
	4	-	-	0.35	10	15	-	-	
Railyard	1	5/28/1999	6/13/2005	0.023	10	15	-	-	-
14060-001	2	6/14/2005	-	0.075	10	15	-	-	-
	3	-	-	0.124	10	15	-	-	-
Goforth	3	4/1/1996	5/24/2005	0.042	10	15	3	-	-
13293-001	4	5/25/2005	-	0.042	10	15	3	-	-

Appendix H: Small MS4 Stormwater Program Overview
Minimal Control Measures & Compliance Strategies

Control Measure	What is Required	Best Management Practices
Public Education and Outreach	Implement a public education program to distribute educational materials to the community about the impacts of stormwater discharges on local water bodies and the steps that can be taken to reduce stormwater pollution	Brochures or fact sheets
		Recreational guides
		Alternative information sources
		A library of educational materials
		Volunteer citizen educators
		Event participation
		Educational programs
		Storm drain stenciling
		Storm water hotlines
		Economic incentives
		Public Service Announcements
		Tributary signage
Public Participation/Involvement	Provide opportunities for citizens to participate in program development and implementation	Public meetings/citizen panels
		Volunteer water quality monitoring
		Volunteer educators/speakers
		Storm drain stenciling
		Community clean-ups
		Citizen watch groups
		"Adopt A Storm Drain" programs
Illicit Discharge Detection and Elimination	Develop, implement and enforce an illicit discharge detection and elimination program	A storm sewer system map showing outfalls and receiving waters
		Legally prohibit non-storm water discharges into the MS4
		Implement a plan to detect and address non-storm water discharges into the MS4
		Educate public employees, businesses, and the general public about the hazards of illegal discharges and improper disposal of waste

<table>
<tr><th>Control Measure</th><th>What is Required</th><th colspan="2">Best Management Practices</th></tr>
<tr><td rowspan="5">Construction Site Runoff Control</td><td rowspan="5">Develop, implement, and enforce an erosion and sediment control program for construction activities that disturb 1 or more acres of land</td><td colspan="2">Have an ordinance or other regulatory mechanism requiring the implementation of proper erosion and sediment controls on applicable construction sites</td></tr>
<tr><td colspan="2">Have procedures for site plan review of construction plans that include requirements for the implementation of BMPs to control erosion and sediment and other waste at the site</td></tr>
<tr><td colspan="2">Have procedures for site inspection and enforcement of control measures</td></tr>
<tr><td colspan="2">Have sanctions to ensure compliance (established in the ordinance or other regulatory mechanism)</td></tr>
<tr><td colspan="2">Establish procedures for the receipt and consideration of information submitted by the public</td></tr>
<tr><td rowspan="5">Post-Construction Runoff Control</td><td rowspan="5">Develop, implement, and enforce a program to reduce pollutants in post-construction runoff to their MS4 from new development and redevelopment projects that result in the land disturbance of greater than or equal to 1 acre</td><td rowspan="2">Non-Structural BMPs</td><td>Planning Procedures</td></tr>
<tr><td>Site-Based BMPs</td></tr>
<tr><td rowspan="3">Structural BMPs</td><td>Stormwater Retention/Detention BMPs</td></tr>
<tr><td>Infiltration BMPs</td></tr>
<tr><td>Vegetative BMPs</td></tr>
<tr><td rowspan="5">Pollution Prevention/Good Housekeeping</td><td rowspan="5">Develop and implement an operation and maintenance program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations into the storm sewer system</td><td colspan="2">Employee training on how to incorporate pollution prevention/good housekeeping techniques into municipal operations</td></tr>
<tr><td colspan="2">Maintenance procedures for structural and non-structural controls</td></tr>
<tr><td colspan="2">Controls for reducing or eliminating the discharge of pollutants from areas such as roads and parking lots, maintenance and storage yards</td></tr>
<tr><td colspan="2">Procedures for the proper disposal of waste removed from separate storm sewer systems</td></tr>
<tr><td colspan="2">Ensure that new flood management projects assess the impacts on water quality and examine existing projects for incorporation of additional water quality protection devices or practices</td></tr>
</table>

Appendix I: Draft East Hays County Wastewater Compact

Whereas the parties to this compact, the cities of Buda, Niederwald, Uhland and Kyle, Hays County and the Guadalupe-Blanco River Authority (GBRA) all function in East Hays County (EHC), and

Whereas all parties share common interests in:

- the protection of water quality,
- the beneficial reuse of water to the extent practical,
- minimizing reliance on On-Site Sewage Facilities (OSSFs),
- the provision of high quality and cost-effective water and wastewater services,

and whereas all parties recognize that much of the future water and wastewater infrastructure in EHC will have to be provided initially by the private sector in new developments, and whereas all parties understand that the common interests will be served by adopting a uniform approach, the parties jointly enter into this compact. The key elements to the compact are:

1. The parties recognize that in low-density or remote locations, OSSFs are the most practical and cost-effective means of meeting home wastewater needs. However, OSSFs provide no opportunity for effective wastewater reuse, and raises the potential for water quality impacts as systems age, the parties agree to encourage larger private developments to install centralized wastewater systems. The parties recognize that specific conditions will determine the number of housing units needed for a central wastewater system, but as an initial target agree that OSSFs would not be appropriate for developments of 10 or more homes.

2. The parties believe that domestic wastewater treatment is an important public service, with the potential to affect citizens outside of the immediate project area. The parties also recognize that proper operation and maintenance of wastewater infrastructure is essential to the public welfare. Because it is important to the public, the parties agree that central wastewater facility operations should be a public function, and that future wastewater facilities in the EHC area should be operated by a public rather than a private entity. The parties recognize that the private sector must be involved in the design, permitting and construction of wastewater facilities to serve new developments, but the parties anticipate that these new developments will at some future time become a part of a municipality. As such, the parties agree that central wastewater facilities associated with new developments should be jointly permitted (e.g. private developer and public entity) and operated by the public entity.

3. An important aspect of wastewater operations is the quality of the water produced. The parties agree that a high quality effluent that is discharged to surface waters is important and will encourage the level represented by the Texas Commission on Environmental

Quality's (TCEQ) 5-5-2-1 effluent set will be the goal for all new facilities. That is operating at full flow with a monthly average effluent quality of BOD5 of 5 mg/L, TSS of 5 mg/L, ammonia-Nitrogen of 2 mg/L and total Phosphorus of 1 mg/L. The parties recognize that this goal can be met in several ways including direct treatment, treating to a different level, and meeting the goal by use of an offsetting amount of effluent for irrigation, or through wetland polishing.

4. The parties recognize that EHC has limited water supplies and that providing good quality water to serve future growth will be a challenge. To conserve water supplies to the extent practical, the parties jointly desire new development to include provisions to minimize potable water use in irrigation. This can include a purple pipe system for irrigation and/or cisterns for providing water for toilet flushing and lawn irrigation.

5. Parties agree to jointly participate, to the extent desired, in the review of new proposed projects and plans, and in special studies involving rates or other issues.

6. All parties agree to participate in supporting the core provisions of the Compact. For example, this could include opposing a private permit applicant in the TCEQ hearing process that refuses to follow the central treatment, effluent quality, or reuse provisions of the Compact.

Agreed to on this _____ day of ____

__________________ for the City of Kyle

__________________ for the City of Buda

__________________ for the City of Niederwald

__________________ for the City of Uhland

__________________ for Hays County

__________________ for GBRA

References

American Veterinary Medical Association. 2002. U.S. Pet Ownership and Demographics Source Book. Schaumberg, Ill. Center for Information Management, American Veterinary Medical Association.

City of Austin. 1997. Evaluation of Non-point Source Controls, Volumes 1-2. COA-ERM/WQM & WRE. 1997-04.

Di Giovanni, G.D. and E. Casarez. 2006. Final Report: Upper and Lower San Antonio River, Salado Creek, Peach Creek and Leon River Below Proctor Lake Bacterial Source Tracking Project. Prepared for the Total Maximum Daily Load Program, Environmental Planning and Implementation Division, Texas Commission on Environmental Quality.

EPA. 2001. Protocol for Developing Pathogen TMDLs. Office of Water, United States Environmental Protection Agency.

EPA. 2006. An Approach for Using Load Duration Curves in Developing TMDLs. Office of Wetlands, Oceans, and Watersheds, United States Environmental Protection Agency.

Follett, C.R. 1966. Texas Water Development Board Report 12: Ground-Water Resources of Caldwell County, Texas. Prepared by the U.S. Geological Survey in cooperation with the Texas Water Development Board, Caldwell County Commissioner's Court, and the Guadalupe-Blanco River Authority.

GBRA and UGRA. 2003. Investigation of Impacts of Oil Field Activities on the San Marcos River and Plum Creek in Caldwell County. Prepared in cooperation with the Guadalupe-Blanco River Authority and the Texas Commission on Environmental Quality under the Authorization of the Texas Clean Rivers Act.

Hellgren, E.C. 1997. Biology of feral hogs (*Sus scrofa*) in Texas. Feral Swine Symposium, Texas Cooperative Extension Service.

Hone, J. 1990. Notes on Seasonal Changes in Population Density of Feral Pigs in Three Tropical Habitats. Australian Wildlife Research 17:131-134.

Lockwood, M. 2005. White-Tailed Deer Population Trends. Federal Aid in Fish and Wildlife Restoration. Project W-127-R-14. Texas Parks and Wildlife Department.

Reed, Stowe, and Yanke. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas, Prepared in Cooperation with the Texas On-Site Wastewater Treatment Council.

Tate, J. 1984. Techniques for Controlling Wild Hogs in Great Smoky Mountains National Park: Proceedings of a Workshop. U.S.D.I. National Park Service Southeast Region, Research/Resources Manage. Rep. Ser-72. 87pp.

Texas Water Commission. 1991. Waste Load Evaluation for Plum Creek in the Guadalupe River Basin Segment 1810.

USDA. 2002. 2002 Census of Agriculture – County Data. National Agricultural Statistics Service: 560-634, 716-718, 719-729, 730-732, 733-734.

Zeckoski, R. W., B. L. Benham et al. 2005. BLSC: A Tool for Bacteria Source Characterization for Watershed Management. Applied Engineering in Agriculture 21(5):879-889.