1 INTRODUCTION

The Cedar Creek Watershed Protection Plan outlines a comprehensive strategy for the reduction of phosphorus pollution within Cedar Creek Lake. The Plan accounts for all pollutant sources and provides a targeted management strategy and outreach program based in science and the implementation of best management practices.

1.1 WATER QUALITY GOALS

Cedar Creek Lake serves as a recreational, environmental, and economic asset to the north central Texas region. However, historical land use and new development in the areas surrounding the lake combine to threaten the water quality and aesthetics of this 34,000 acre reservoir. Beginning in 2002, segments within Cedar Creek Lake have been listed on the Texas Water Quality Inventory, or 303(d), list for excessive acidity as measured on the pH scale. Reservoir managers with the Tarrant Regional Water District and watershed planners have determined a causal connection between the algae indicating photosynthetic chemical Chlorophyll-*a* and high measurements of pH. Because nutrients such a nitrogen and phosphorus exacerbate the growth of algae, the target of the Cedar Creek Watershed Plan is to reduce overall watershed-based phosphorus loadings within the reservoir by 35% below current conditions. Computer modeling via the Soil and Water Assessment Tool (SWAT) and the Water Quality Analysis Simulation Program (WASP) determine that the stakeholder confirmed 35% reduction goal is sufficient to arrest and gradually reverse the rising 3.85% APR trend of Chlorophyll-a within the reservoir.

1.2 THE PURPOSE OF THE WATERSHED PROTECTION PLAN

A watershed protection plan is a formalized, yet flexible working plan developed by stakeholders to address water quality issues within a designated water body. Local landowners, agricultural producers, residents, business persons, civic leaders, and agency officials each participated in the development of the Cedar Creek Watershed Protection Plan. The Cedar Creek Plan outlines management measures for various land uses that contribute to pollutant flows and outlines strategies for educational and outreach programming designed to inform targeted audiences.

The purpose of the Cedar Creek Watershed Protection Plan is to create and implement a scientifically- based management strategy to lower the level of chlorophyll-a in Cedar Creek Lake, reduce existing pH levels resulting in removal of the water body from the Texas Water Quality Inventory, and the creation of a watershed savvy local population to ensure the future water quality of the reservoir.

1.3 ELEMENTS OF AWATERSHED PLAN

Watershed planning, in many instances, has usurped or enhanced the established Total Maximum Daily Load program in which state or federal officials set customized pollutant “budgets” for an impaired water body. In recent years, funding agencies have directed resources toward watershed planning efforts in deference to the benefits of locally driven and holistic watershed planning programs. To provide guidance in the development of watershed plans, the United States Environmental Protection Agency has developed a list of elements that each watershed plan must conform to:

Nine Elements of Watershed Protection Planning

1. Identify the sources and causes of pollution
2. Estimate the necessary load reductions
3. Describe Point and Non Point Source management Measures
4. Assess Technical and Financial Assistance Needed
5. Design an Educational Component
6. Develop a schedule of implementation
7. Set Interim Measurable Goals
8. Establish Criteria to Determine Plan Success
9. Create a Monitoring Program

1.4 UPDATES AND REVISIONS

The Cedar Creek Watershed Protection Plan serves as a living document as it provides a flexible framework for water quality improvements within the watershed and reservoir. Watershed planners have taken extreme care to account to potential changes in climate, human population, and land use. However, the structure of the plan allows for the evaluation and adjustment of management strategies in real time and stakeholders are encouraged to proceed with scientifically based revisions should they see fit to do so.

1.5 SUMMARY OF EXISTING WATER QUALITY CONDITIONS

Continuous water quality monitoring of Cedar Creek Lake has occurred since creation of the reservoir in the 1960's. Perimeters for designated uses of the water body of contact recreation, water supply, fish consumption, and wildlife habitat are assigned by the Texas Commission on Environmental Quality (TCEQ). Cedar Creek Reservoir has always met the designated water quality criteria for each of these designated uses. In addition to usage standards, chemical and biological benchmarks are established and followed as well. Among these are E Coli bacteria, temperature, pH, turbidity, Dissolved Oxygen, and salinity. A statewide biannual reporting water bodies that do not conform to the established standards is known as the Texas Water Quality Inventory or Texas 303(d) list. Cedar Creek Lake has appeared on the 303(d) list beginning in 2002 through the draft 2010 version for excessive pH measurements in several segments throughout the lake.

2008 Texas 303(d) List (March 19, 2008)

SegID: 0818 **Cedar Creek Reservoir**
From Joe B. Hoggsett Dam in Henderson County up to normal pool elevation of 322 feet (impounds Cedar Creek)

Area		Category	Year First Listed
0818_01	*1674*		
	pH	5c	2002
0818_02	*Caney Creek cove*		
	pH	5c	2002
0818_03	*Clear Creek cove*		
	pH	5c	2002
0818_04	*Lower portion of reservoir east of Key Ranch Estates*		
	pH	5c	2002
0818_05	*Cove off lower portion of reservoir adjacent to Clearview Estates*		
	pH	5c	2002
0818_06	*Middle portion of reservoir downstream of Twin Creeks cove*		
	pH	5c	2002
0818_07	*Twin Creeks cove*		
	pH	5c	2002
0818_08	*Prairie Creek cove*		
	pH	5c	2002
0818_09	*Upper portion of reservoir adjacent to Lacy Fork cove*		
	pH	5c	2002
0818_11	*Upper portion of reservoir east of Tolosa*		
	pH	5c	2002
0818_12	*Uppermost portion of reservoir downstream of Kings Creek*		
	pH	5c	2002

SegID: 0819 **East Fork Trinity River**
From the confluence with the Trinity River in Kaufman County to Rockwall-Forney Dam in Kaufman County

Area		Category	Year First Listed
0819_01	*Entire segment*		
	sulfate	5b	2008
	total dissolved solids	5b	2008
	chloride	5b	2008

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Figure 1.1 Cedar Creek Reservoir on the 303(d) List (TCEQ 2008).

Additionally, the state of Texas has recently added a numeric limit to the level of Chlorophyll-a permitted in Texas water bodies of 23.47 micrograms per liter. Current Cedar Creek levels are at 19.87 and are among the highest in the state.

Table 1.1Draft Nutrient Criteria for Texas Reservoirs (TCEQ 2006).

Lake Name	Site ID	Segment No.	Chl criteria (mg/L)	TP criteria (mg/L)
1 Buffalo Springs Lake	11529		83.77	0.33
2 Lake Wichita	10163	219	42.5	0.182
3 Lake Murvaul	10444	509	33	0.073
4 White Rock Lake	11038	827	31.78	0.103
5 Lake Tanglewood	10192	229	30.38	1.468
6 Somerville Lake	11881	1212	30.1	0.061
7 Proctor Lake	11935	1222	29.58	0.063
8 O.C. Fisher Reservoir	12429	1425	27.2	0.089
9 Lake Mexia	14238	1210	26.38	0.221
10 Lake Livingston	10899	803	24.95	0.178
11 Cedar Creek Reservoir	**10982**	**818**	**23.47 (90th)**	**0.068 (70th)**
12 Wright Patman Lake	10213	302	21.4	0.103
13 Benbrook Lake	15151	830	21.19	0.062

Chlorophyll-*a* is a measure of blue-green algae in the water column. Excessive algae growth can impact the health of a water body in a variety of ways. Surface algae growth can block sunlight needed by submerged aquatic vegetation needed by wildlife as a source of food and shelter. Dead and decomposing algae can deplete the water of oxygen content resulting in fish suffocation. Lastly, algae growth can raise pH levels, the listed impairment for Cedar Creek Lake.

1.6 PREVIOUS WATER QUALITY EFFORTS

In 1989, officials with the Tarrant Regional Water District began yearly monitoring and modeling efforts focused on the level and causes of chlorophyll-a within Cedar Creek Lake. The result of the study demonstrated rising levels of chlorophyll-a over a 20 year span with fluctuations accounting for years of higher rainfall and years with drought-like conditions.

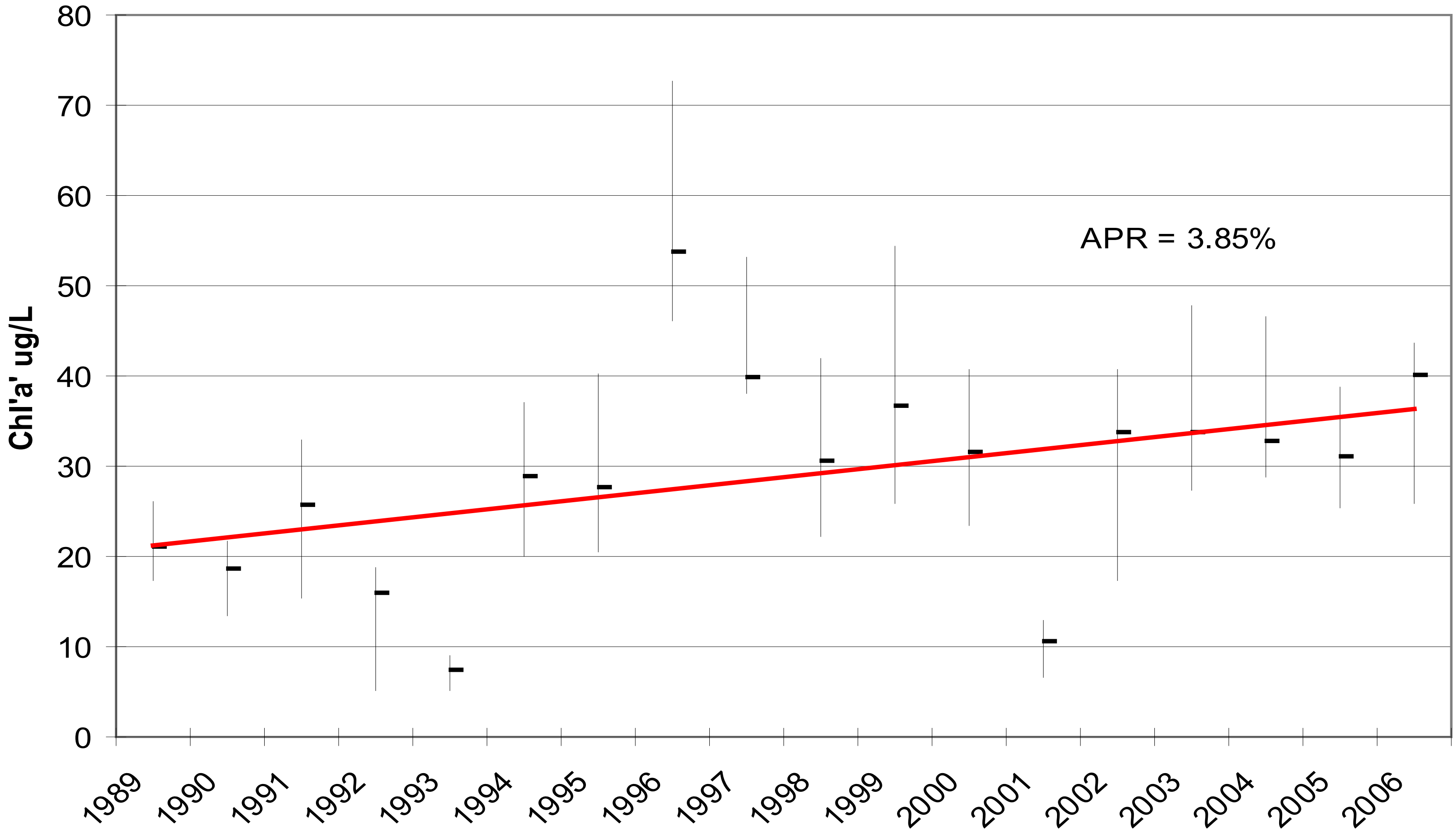


Figure 1.2 The 19-year 3rd quarter lakewide Chlorophyll-*a* trend analysis (TRWD 2007)

With the knowledge of chlorophyll-*a* as targeted constituent, TRWD researchers turned to the Spatial Science Laboratory at Texas A&M University to create a comprehensive computer modeling report utilizing the Soil and Water Assessment Tool (SWAT) as a method to identify the sources of nutrient and sediment loadings within the Cedar Creek reservoir watershed. Based on maps created to account for land use, soils, climate, waste water treatment plant discharges, and channel erosion, modeling efforts determined that the historical farming practices of the watershed combined with highly erodible clay soils are the leading cause of nutrient pollution in the reservoir.
Additionally, TRWD utilized the Water Quality Analysis Simulation Protocol to provide data on the nutrient levels for assigned segments of the water body allowing for a determination of the levels of nutrients and sediment as the constituents flow into and out of the reservoir.

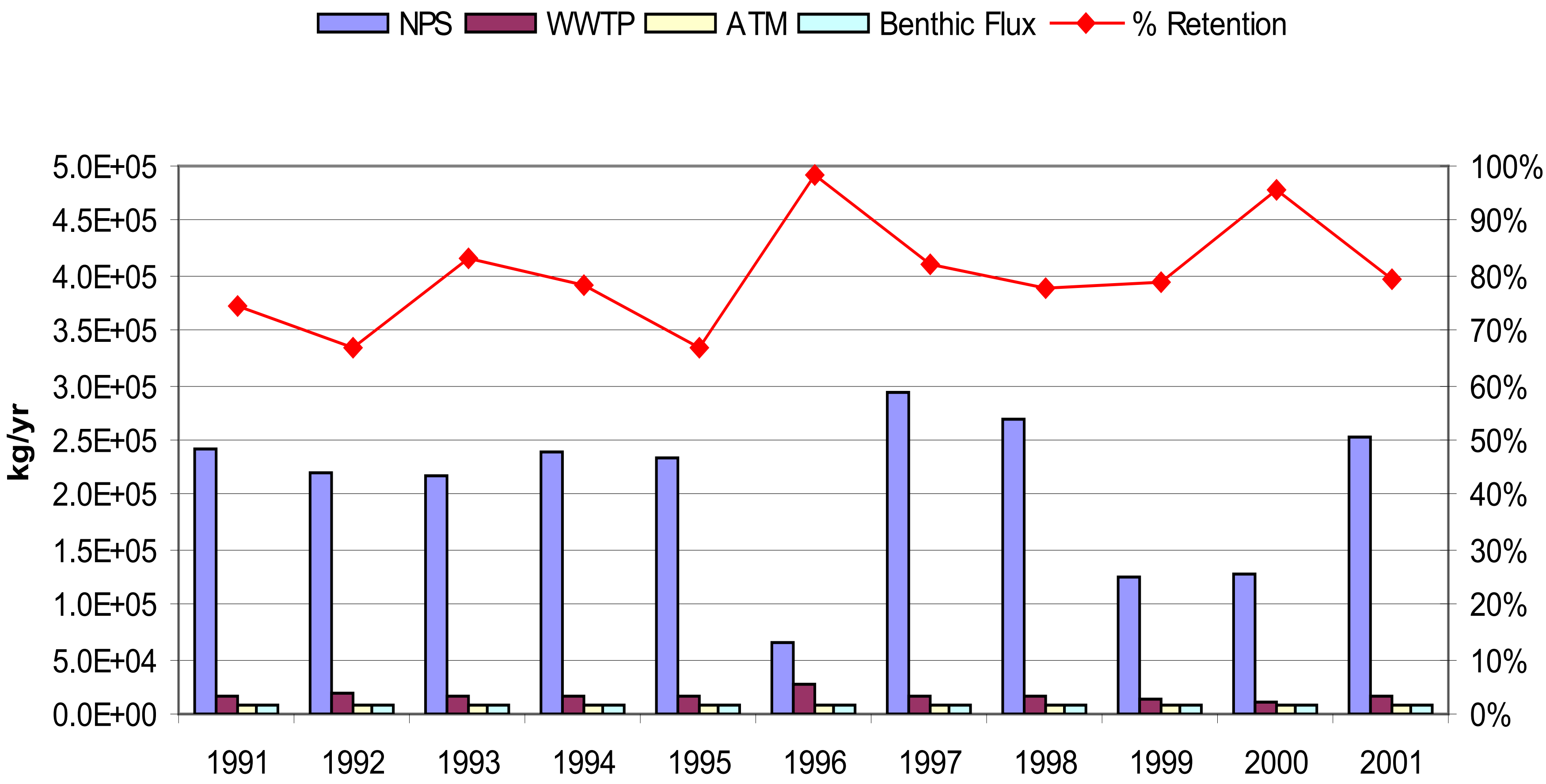


Figure 1.3 WASP Nutrient Budget for Cedar Creek Reservoir (TRWD 2007)

To confirm concerns about channel erosion, modeling and field analysis of tributary streams in the Cedar Creek Watershed were performed by Baylor University researchers along with the environmental engineering firm Espey Consultants. The study and modeling effort confirmed that the tributary streams with the highest levels of erosion matched SWAT results for the areas of the watershed with the highest levels of sediment loss and nutrient loadings.

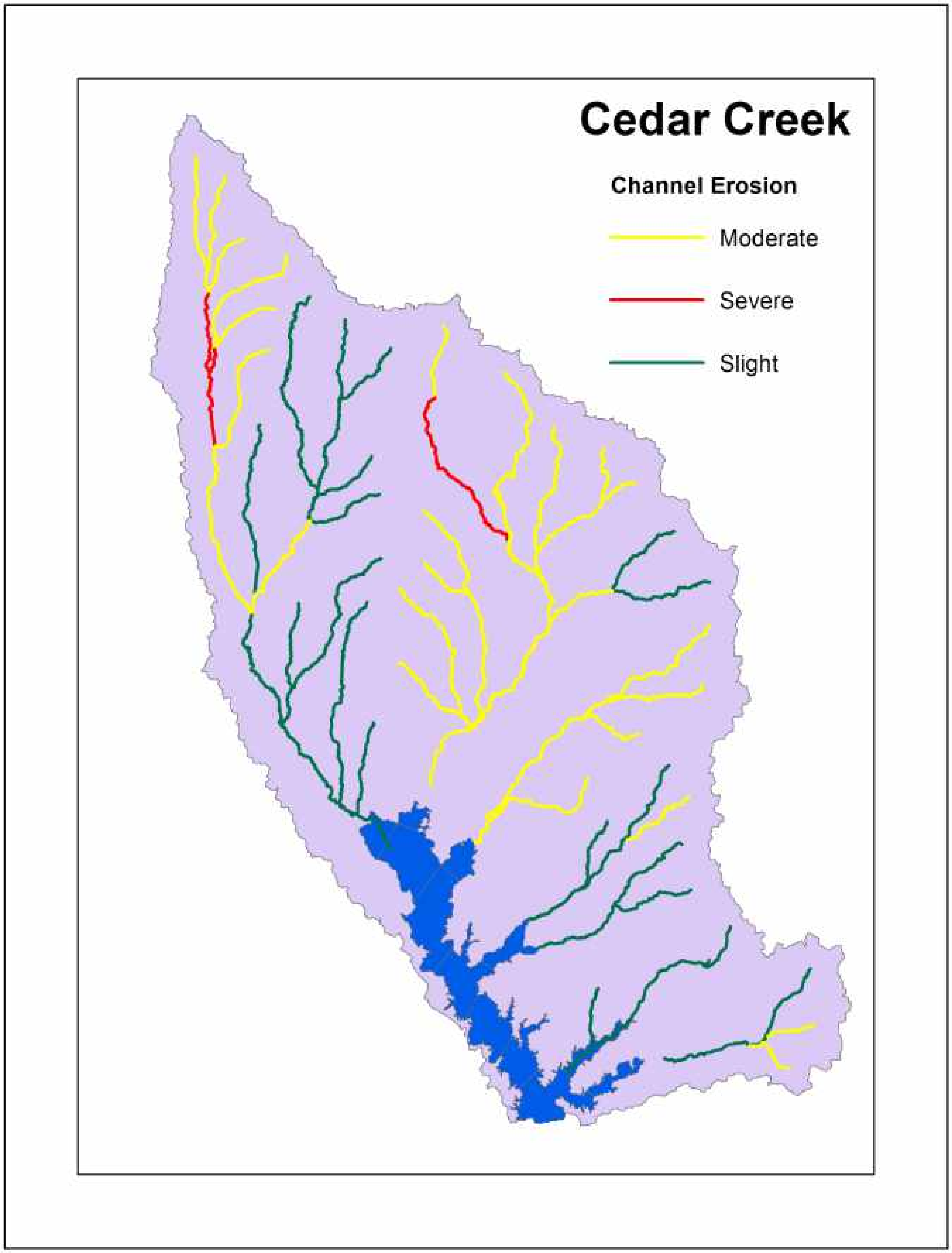


Figure 1.4 Cedar Creek Channel Erosion (TAMU –SSL 2007).

While WASP modeling confirmed that point sources were not the largest contributor of nutrient loadings within the watershed, reducing pollutants from the nine existing wastewater treatment plants represented a management solution that could be coupled with regularly scheduled permitting requirements. The engineering firm Alan Plummer Associates conducted a thorough review of the existing watershed wastewater treatment plants including site visits, infrastructure analysis, permit reviews, and monitoring of discharge for nutrient and sediment levels.

Figure 1.5 Wastewater Treatment Plant Locations in Cedar Creek Watershed (APAI 2008).

The combined results of previous efforts allowed Tarrant Regional Water District to conclude that the development of a stakeholder-based watershed protection plan for Cedar Creek would be a wise strategy for addressing current and future impairments. Reservoir managers viewed the watershed management approach as a method for preempting state establishment of a TMDL for Cedar Creek Reservoir as well as a cost effective alternative to dealing with pollutants via chemical or mechanical treatment. Additionally, it was hoped that the development of a stakeholder-based watershed plan would shift the thinking of local residents toward a view of the resource as not only a water source for regional populations but as the economic engine of the local communities.

1 CEDAR CREEK WATERSHED OVERVIEW

The water quality of Cedar Creek Lake is a directly influenced by the surrounding watershed lands. Watersheds are determined by topography, slope, climate, soils, vegetation, wildlife, and human populations. Natural processes have permitted watersheds to work in balance allowing for streams and other water bodies to provide habitat, transport sediment, and assimilate rainfall. However, human modification of lands and streams have resulted in diminished water quality and resulted in the need for an examination of watershed issues to address these problems.

1.1 General Watershed Concepts

1.1.1 Watershed Definition

A watershed is a land area that drains into a common water body such as Cedar Creek Reservoir. Watersheds also account for the land use, human populations, wildlife, and biological and ecological processes that take place within the basin.

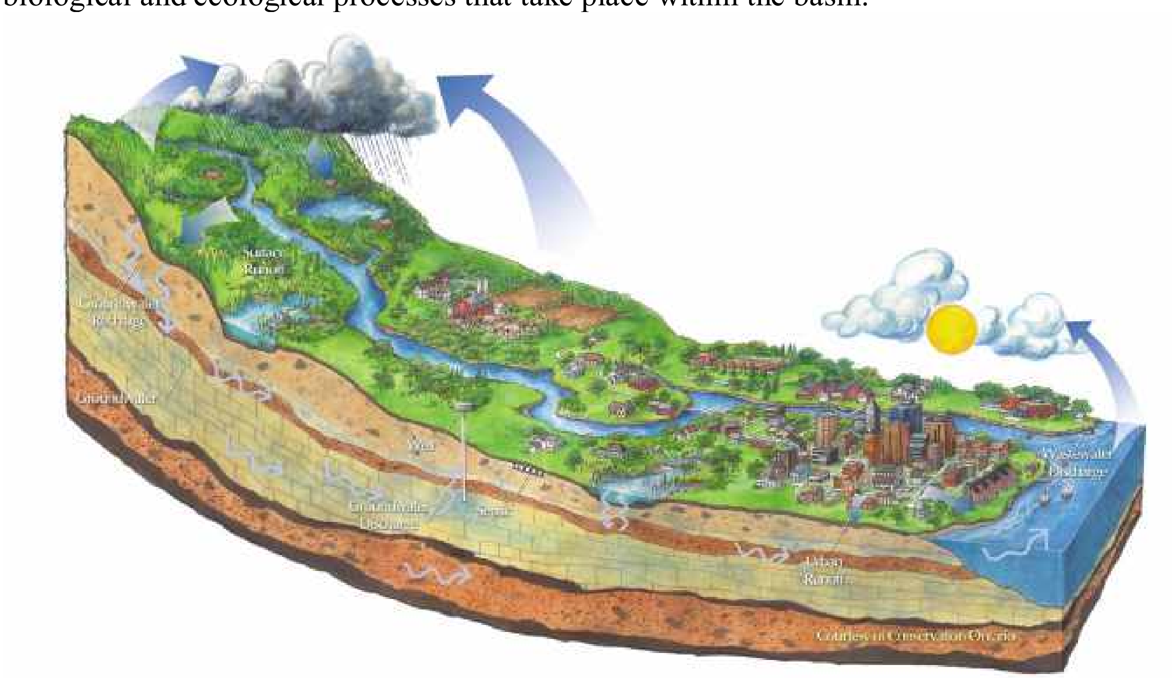


Figure 1.1 Example of a watershed with multiple land uses (Conservation Ontario).

Watersheds do not correspond to political boundaries drawing upon the cooperative interests of nations, states, counties, and cities. Land use decisions and practices taking place under one jurisdiction in one part of a watershed will impact the water quality in another area of the same basin. Watersheds fit into larger river basin systems to drain large areas of land to the ocean. Inversely, watershed can be broken down into smaller sub basins or catchment areas as determined by the hydrology of the landscape.

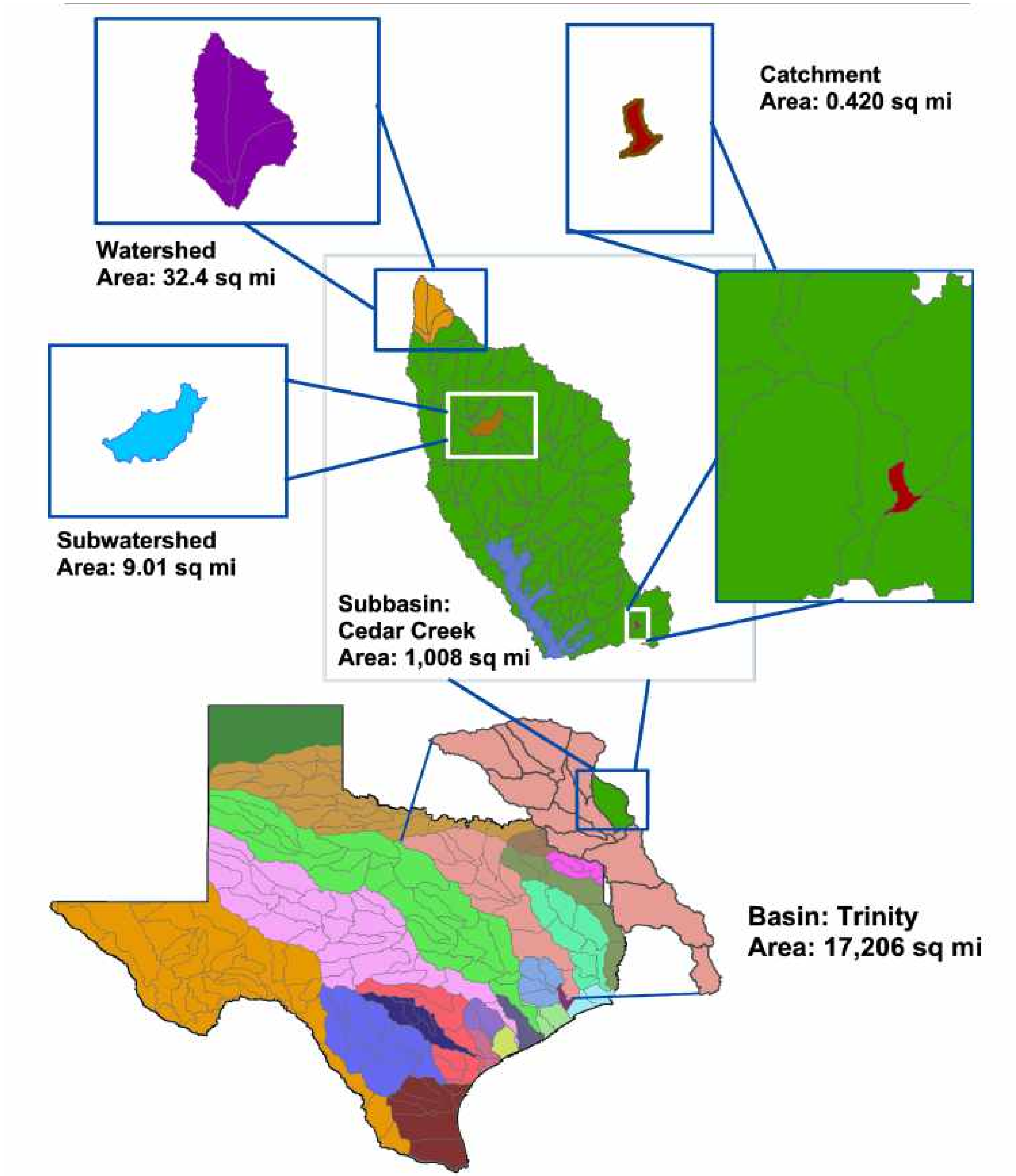


Figure 1.2Watershed Management Planning units for Cedar Creek Lake

1.1.2 Watersheds and Water Quality

Water quality within streams, rivers, lakes, and oceans is dependant upon the land use of the areas that drain into the water body. Watersheds with high areas of crops may have excessive loadings of fertilizers and pesticides. Areas with high urban development may suffer from excessive chemical pollution or stream erosion. Management of the resources and pollutants within a watershed are determined by origin.

Point Source pollutants come from a designated discharge location such as a factory, wastewater treatment plant, feedlot, or dairy. Depending on size and capacity for pollutant production, point sources are regulated and permitted by the state of Texas via the Texas Pollution Discharge Elimination System (TPDES) which requires regular monitoring or discharge quality and system upgrades. Even the storm water drainage systems of medium to large cities are considered to be point source discharges and fall under the regulation of the Municipal Separate Storm Sewer System (MS4).

Management of Non-point source pollutants is typically beyond the scope of regulatory agencies and demands a more innovative approach to mitigate the flow of pollutants over the landscape resulting from rain or snow events. Nonpoint source pollutants such as nutrients or bacteria result from the overland flow of storm water that picks up the pollutants and carries them to a tributary stream and on to the destination water body. Mitigation of non-point source pollutants is typically accomplished through education efforts directed toward agricultural producers and the public as well as the installation of structural best management practices to detain sediment and pollutants before they enter a stream.

1.1.3 Watershed Approach to Improve Water Quality

Cedar Creek Lake mangers with Tarrant Regional Water District opted to develop a stakeholder- based watershed protection plan for a variety of reasons. Among these, watershed planning is a holistic exercise that requires that the sources of pollutants are discovered and managed in a manner that is acceptable to local stakeholders and thus more likely to garner support for implementation. The Cedar Creek Watershed occupies 1008 square miles overlying portions of Kaufman, Rockwall, Henderson, and Van Zandt Counties. Stakeholders who have participated in development of the watershed plan include farmers, ranchers, lakeside residents, agency officials, and developers. Because of the diverse interests among Cedar Creek Stakeholders, watershed planning provides a common thread to foster a sense of ownership among those who impact, enjoy, and manage the resource.

1.2 CEDAR CREEK WATERSHED INVENTORY

The Cedar Creek Watershed is 1,007 square miles in northeast Texas (Figure P.1) located primarily southeast of Dallas. It is located in the northeast portion of the state. The watershed is defined by the drainages of Big Brushy, Lacey, Kings, Caney, Lacey Fork, North and South Twin and Cedar Creeks into Cedar Creek Reservoir. Prior to the construction of Cedar Creek Reservoir, the destination water body was the Trinity River flowing southward toward Galveston Bay and the Gulf of Mexico.

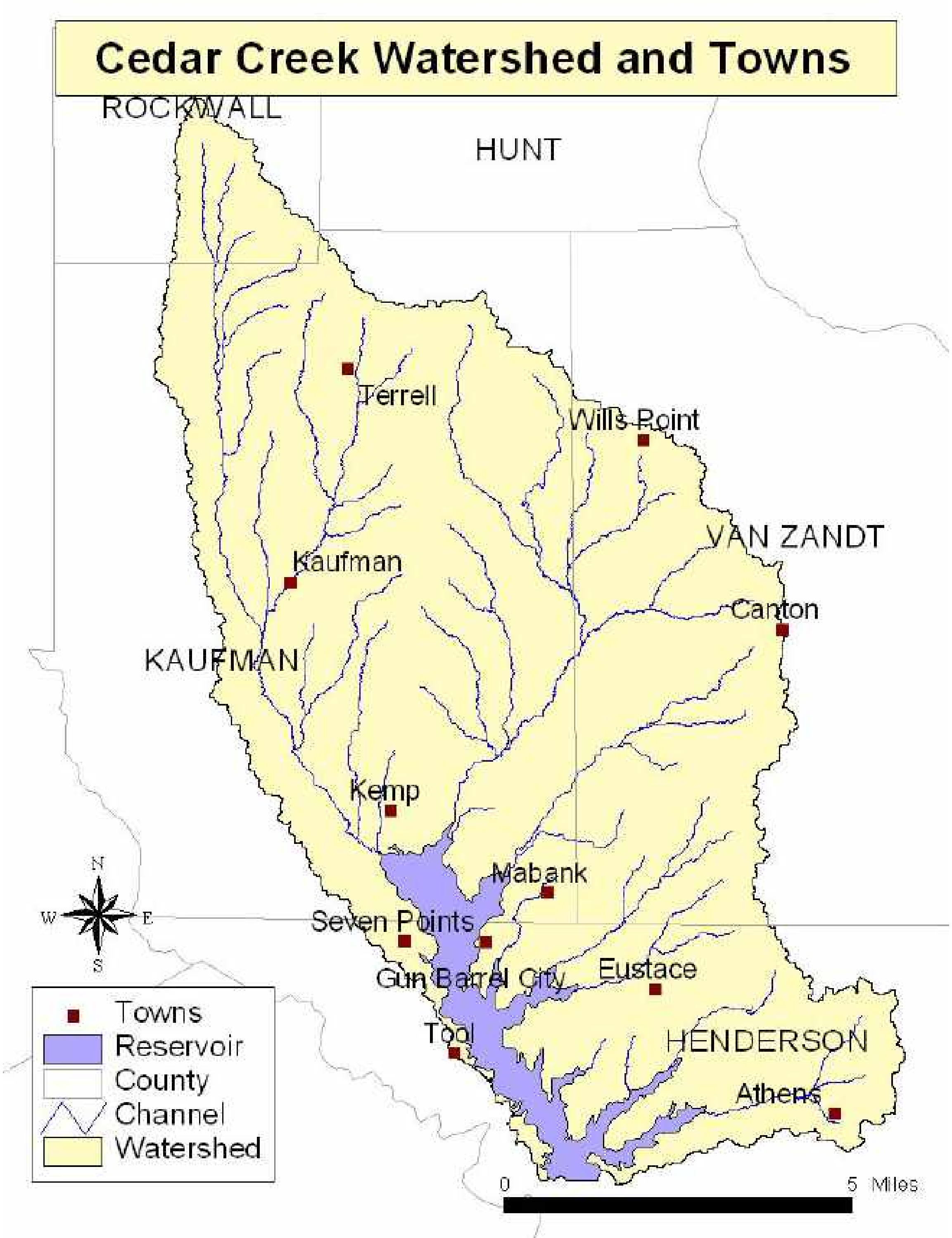


Figure 1.3 Cedar Creek Watershed and Towns

1.2.1 Water Resources

The Cedar Creek Watershed totals 1,007 square miles situated southeast of Dallas (Figure 1.11). As a part of the Trinity River basin, waters from this area drain into the Gulf of Mexico at Galveston Bay. Cedar Creek Reservoir is a 33,873-acre reservoir located in the southwestern portion of the watershed. The reservoir was formed by the 1965 impoundment of Cedar Creek, a tributary of the Trinity River. The storage capacity of the reservoir is 644,785 acre-feet (TWDB 2005) and is designated for public water consumption under TCEQ standards. The watershed is comprised of a network of tributary streams flowing west and southwest into the Reservoir.

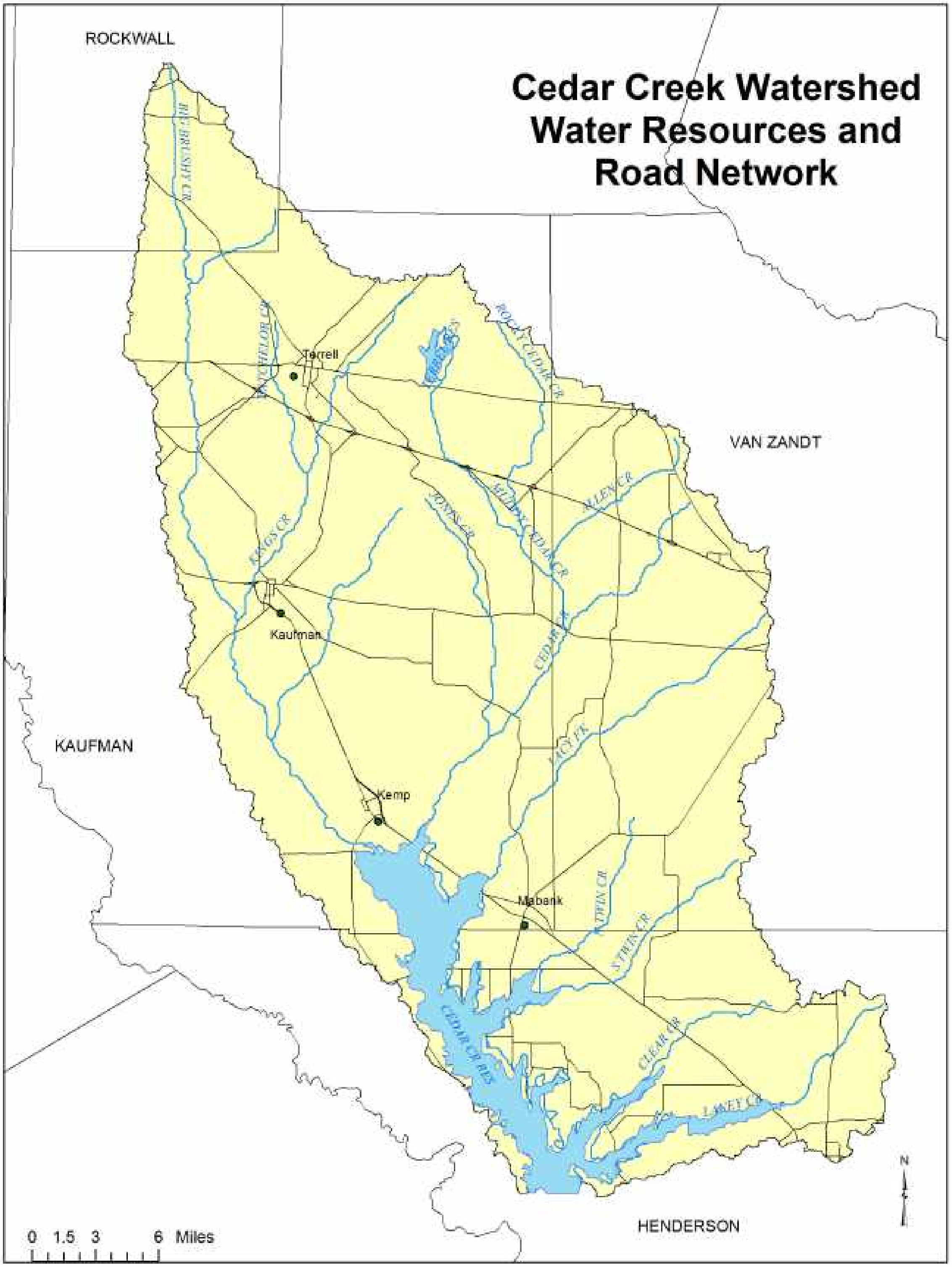


Figure 1.4Cedar Creek Watershed Water Resources and Road Network (TAMU-SSL 2007).

1.2.2 Aquifers

The outcrop of the Carrizo-Wilcox Aquifer lies beneath western portions of Van Zant County in the Cedar Creek Watershed. The Nacatoch Aquifer, runs north to south through central Kaufman County.

1.2.3 Tributaries

The main tributaries of Cedar Creek Reservoir are Kings Creek, flowing from north to south into the northern tip of Cedar Creek Reservoir, and Cedar Creek flowing northeast to southwest into Northeastern flank of the reservoir (Figure 1.12). Flood control efforts conducted in the 1950s by the Army Corps of Engineers resulted in straightening of sections of Kings Creek and its tributary, Big Brushy Creek. Hydologists familiar with the watershed believe that the channelizing of these stream segments may contribute significantly to erosion and sedimentation of downstream areas. Meanwhile, the lower sections of Kings Creek and Cedar Creek have formed wetlands on their respective routes. The southeastern portion of the watershed supports a bottomland hardwood forest in the lower portions of Caney and Clear Creeks.

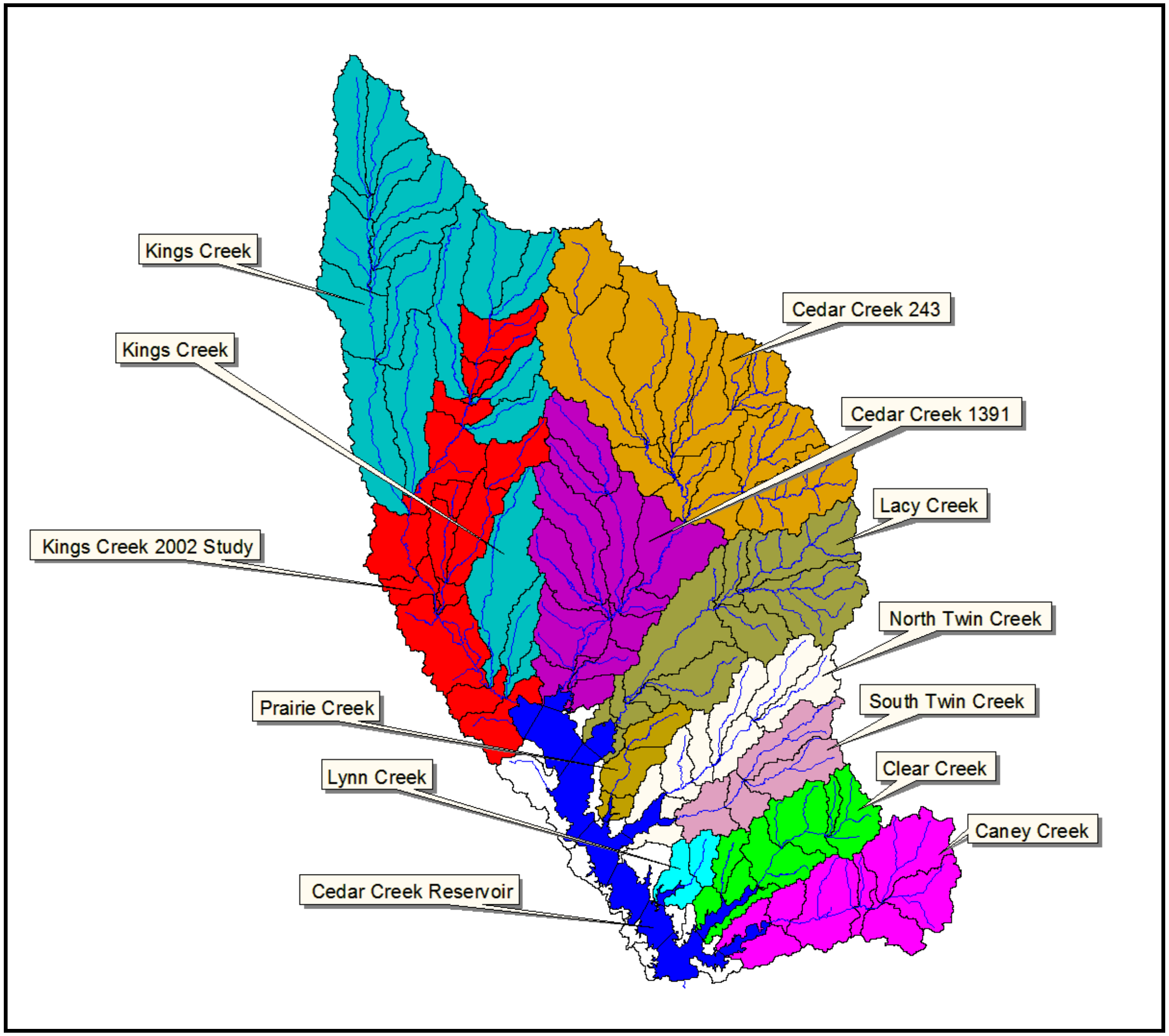


Figure 1.5 Tributary sub-basins of the Cedar Creek Watershed (TAMU-SSL 2007).

1.2.4 Stream Flow

Gauging the flow of water into the reservoir is an important aspect of water quality modeling and analysis. Pollutant fate and transport can differ during periods of high and low flow such as a storm event or periods of extended rainfall. Stream areas with high levels of flow will transport nutrients and sediment quickly and are more prone to channel erosion. Tributaries with lower flow are more likely to take on the effects of nutrient loadings such as algae growth due to potential stagnation. Gathering of accurate stream flow data over extended time periods is necessary to calibrate the models accurately and to understand the impact that nutrients and sediment can have on the reservoir. Flow data is collected through a series of established United States Geological Survey (USGS) tributary monitoring stations (Figure 1.13) that record the movement of water on a continual basis. This data is averaged over a pre-determined time period and then factored into water quality analysis.

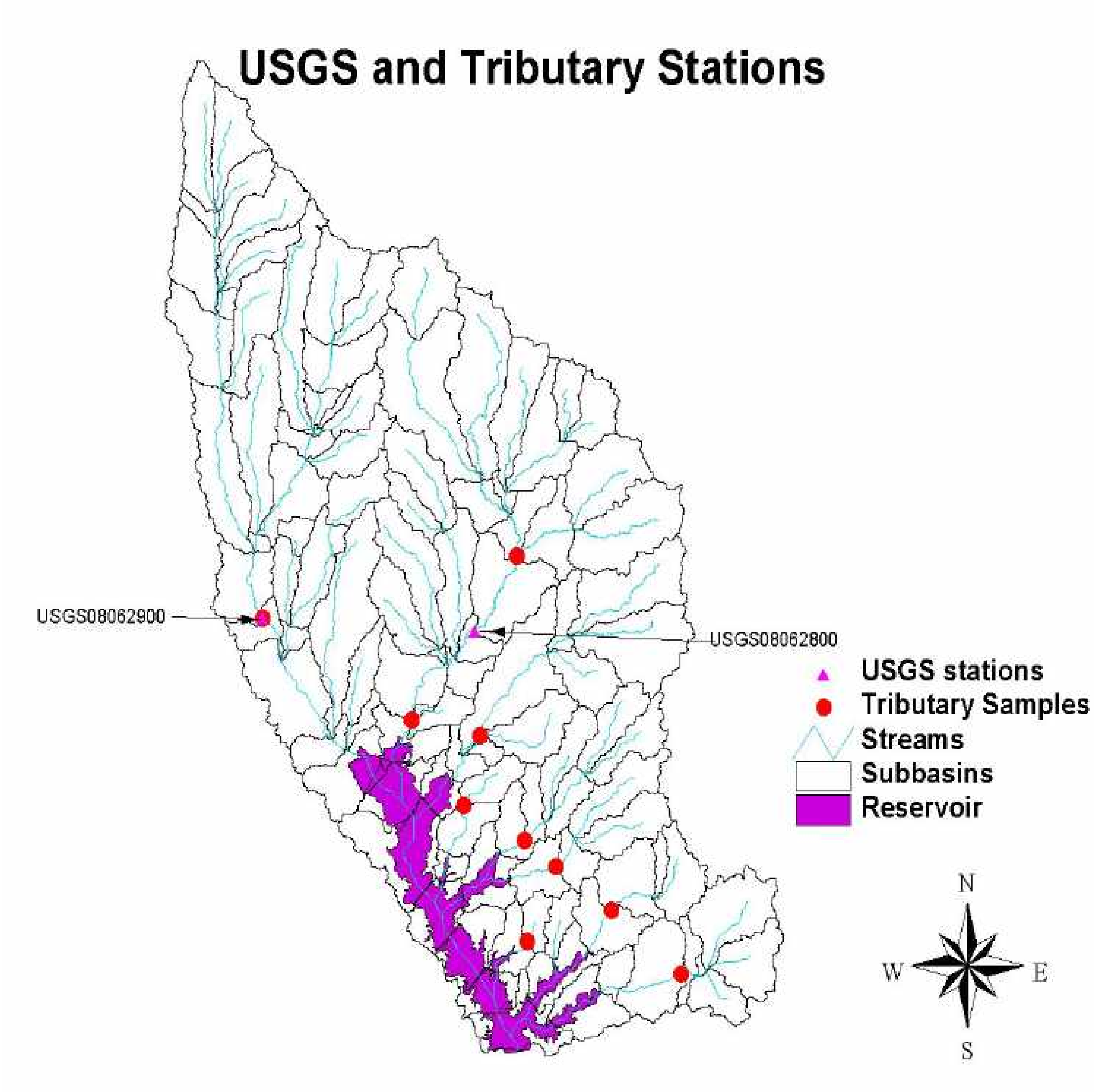
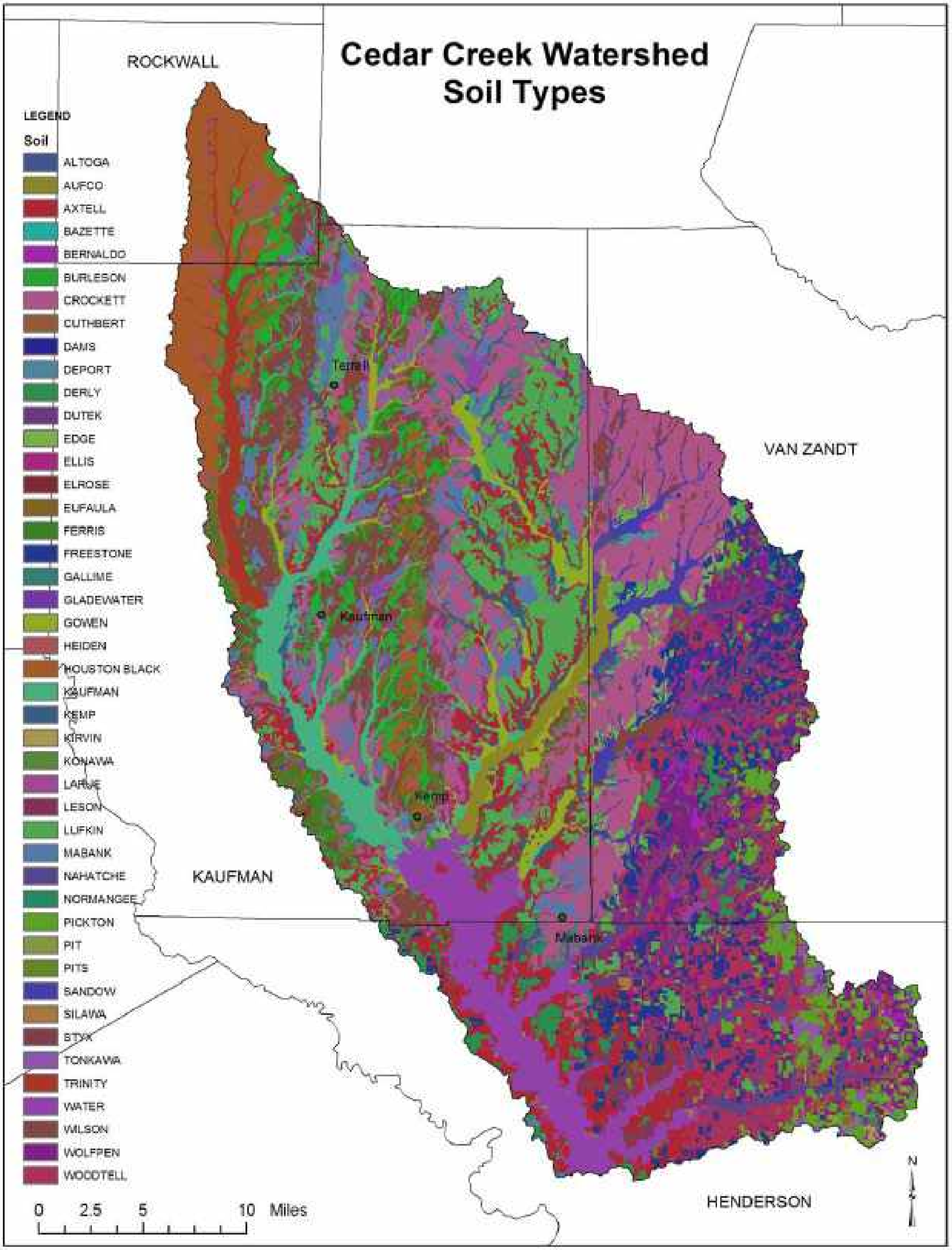


Figure 1.6 Stream flow gauge stations within the Cedar Creek Watershed (TAMU-SSL 2007).

1.2.5 Soils

Typical Cedar Creek Watershed soils are slightly acidic with dark and light loamy surfaces and clayey sub soils (Baylor University Study 2005). The quality of soils in this region has allowed it to be termed the "Blackland Prairie" due to the fertility and versatility of the soil. This also means that certain portions of the watershed are highly susceptible to erosion and sedimentation during a heavy rain event due to the clay content of the soil. General classification demonstrates that the western portions of the watershed are predominantly clay soils and the eastern portions favor sandy soils.


Cedar Creek Watershed
Soil Types
ROCKWALL
VAN ZANDT
KAUFMAN
HENDERSON
Terrell
Kaufman
Kemp
Mabank
LEGEND
Soil
ALTOGA
AUFCO
AXTELL
BAZETTE
BERNALDO
BURLESON
CROCKETT
CUTHBERT
DAMS
DEPORT
DERLY
DUTEK
EDGE
ELLIS
ELROSE
EUFAULA
FERRIS
FREESTONE
GALLIME
GLADEWATER
GOWEN
HEIDEN
HOUSTON BLACK
KAUFMAN
KEMP
KIRVIN
KONAWA
LARUE
LESON
LUFKIN
MABANK
NAHATCHE
NORMANGEE
PICKTON
PIT
PITS
SANDOW
SILAWA
STYX
TONKAWA
TRINITY
WATER
WILSON
WOLFPEN
WOODTELL
0 2.5 5 10 Miles
N

1.2.6 Topography

The Cedar Creek Watershed is part of the Upper Trinity River Watershed Region. The eastern boundary of the watershed represents an elevation change, resulting in drainage of rainfall to the Sabine River while the western boundary represents a split of the drainage between Cedar Creek and the main stem of the Trinity River. The topography results from flow of the Cedar Creek, Kings Creek, Clear Creek, and Big Brushy Creek tributaries into Cedar Creek Reservoir at the southwest corner of the watershed (Figure 1.8). Prior to the construction of the reservoir, Cedar Creek flowed into the Trinity River at a point to the southwest of the current reservoir site.

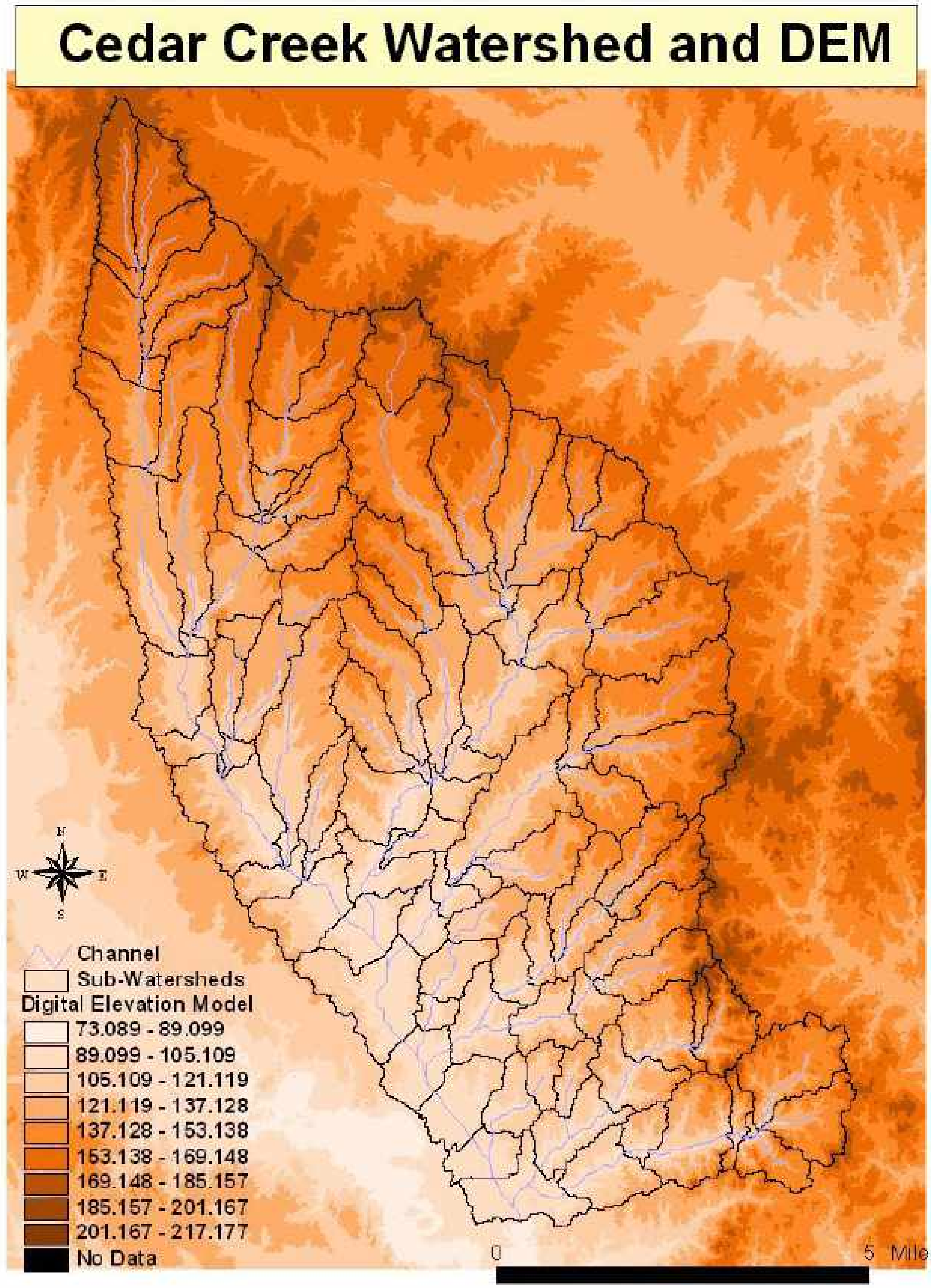


Figure 1.7 Cedar Creek Watershed Topography (TAMU-SSL 2007).

1.2.7 Climate

Climate of the Cedar Creek Watershed is classified by the National Oceanic and Atmospheric Administration as subtropical-humid with temperatures ranging from an average July high of 97 degrees to a January average low of 33 degrees. Rainfall averages 39 inches with an agricultural growing season of 245 days (Handbook of Texas). In recent years, substantial rainfall has led to erosion issues on tributary creeks and flooding of areas adjacent to the reservoir. Weather monitoring stations throughout the watershed provide ongoing reports of conditions to researchers and officials (Figure 1.10).

Figure 1.8 Cedar Creek Watershed Weather Station Locations

1.2.8 Land Use

Utilizing land surveys, satellite imagery (Figure 1.5), and ground truthing, the Spatial Sciences Laboratory at Texas A&M University produced a map of the various land uses within the Cedar Creek Watershed. Linking land use to pollutant loadings is a vital part of watershed protection planning as it allows for the creation of pollutant reduction strategies catered to areas and activities of the watershed.
As of April 2007, the majority (63 percent) land use (Figure 1.6) for the watershed consists of pastureland. Forest cover occupies 15.48 percent of the watershed, primarily in the southeastern portion near Athens, Texas. Urban uses such as cities and housing developments take up 6.39 percent of the watershed. Cropland utilizes 6.17 percent of the land mass, mostly in the northwestern portion of the watershed. Lastly, water cover and wetlands located in proximity of the reservoir and tributaries account for 7.38 percent of the land use (Figure 1.7).

Agriculture

Although the economy and demographics of the Cedar Creek Watershed are changing quickly, the area still operates primarily as an agriculturally-based region. Soil conditions have allowed for farming of hay, wheat, corn, cotton, and sorghum and cattle ranching. However, the accumulative effect of 150 years of agriculture has impacted water quality through traditional practices that were once deemed acceptable but have been found to adversely impact water quality.

Farming

Current surveys and spatial sciences data indicate that a small portion of the watershed is still designated crop lands. These areas are located primarily in the northern portion of the watershed governed by Rockwall County. The excessive use of nutrient laden fertilizers, herbicides, and pesticides combined with tilling practices and planting practices, designed to maximize land productivity, have resulted in high sediment and nutrient loadings from these areas. Many of these lands are quickly transitioning to suburban housing developments that support the Dallas work force, presenting another set of water quality issues.

Ranching

Cattle ranching now accounts for the main agricultural usage of watershed lands. While there are currently no Confined Animal Feeding Operations located in the watershed, livestock operations can still threaten water quality due to the concentration of nutrients resulting from manure that flows into watershed creeks and streams. Furthermore, grazing operations if not managed correctly can create conditions in which vegetative cover is degraded, increasing the flow of sediment and nutrients.

Urban Development

Development of lands previously used for agricultural purposes poses a significant threat to water quality in the Cedar Creek Watershed. Areas within southern Rockwall County and near the Kaufman and Terrell areas are projected to grow significantly in the next 20 years (NCTCOG 2006).New residential and commercial construction disturb the soil and require a specialized set of best management practices to limit the amount of sediment lost to stormwater runoff. Additionally, new construction results in the installation of more impervious surfaces such as parking lots and roadways that impair the infiltration of rainwater into the ground. Lastly, the increase in human population associated with development exacerbates the construction and associated discharges of wastewater treatment plants.

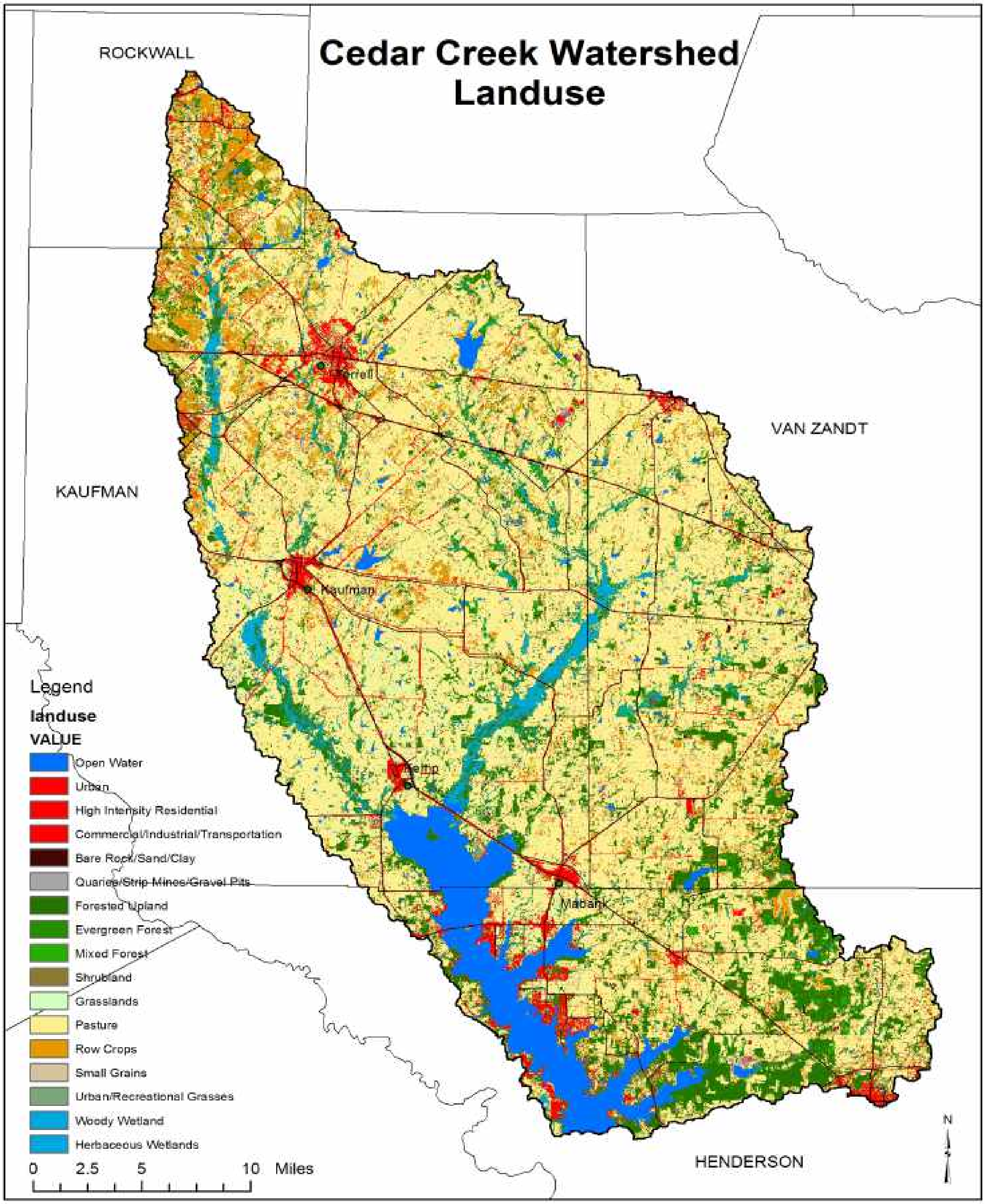


Figure 1.9 Cedar Creek Watershed Land Use

1.2.9 Ecology

Vegetation within the watershed consists primarily of prairie grasses including little and big bluestem, Indian grass, switch grass, grama, and Virginia wild rye. In the northern portion of the watershed, pastureland has replaced native grasses with Bermuda, Johnson grass, and clover. Woody undergrowth consists of American Beautyberry, Hawthorn, and greenbriar. Trees include mesquite, oak, hackberry, pecan, and elm trees (Handbook of Texas).

Because the majority of the watershed has yet to be urbanized, the land supports a wide swath of wildlife. Large mammals such as coyotes, bobcats, and whitetail deer still thrive within the pasturelands and forested areas. Feral hogs present a considerable nuisance in the north east corner of the watershed. Cedar Creek Reservoir supports a fishery of largemouth and palmetto bass as well as sunfish, catfish and crappie species. The Reservoir is actively stocked with largemouth and palmetto bass. According to a 2003 Texas Parks & Wildlife Survey Report, the Reservoir contained less than one percent aquatic vegetation. (TPWD 2003). TPWD operates a wildlife management area on a series of small islands in the Reservoir that serve as rookeries for migratory bird species.

1.2.10 History

The high plains region of northeast Texas, home to the Cedar Creek watershed, was originally home to the native Caddo and Cherokee peoples prior to European settlement. In 1840, a band of pioneers from Holly Springs, Mississippi led by William P. King settled the area, utilizing the readily-available land grants issued by the Republic of Texas. Word of the quality farming conditions spread and the area attracted farmers primarily from the states of Arkansas, Tennessee, and Missouri. By 1930, over 5,100 farms operated in Kaufman County alone. Primary crops were corn, cotton, and wheat, with the area also showing a steady increase in beef and dairy cattle operations. The eastward spread of Dallas combined with changing economic forces gradually reduced the crop and livestock production of the area. As commercial and industrial opportunities grew, so did the population with the most significant increases in the northern portion of the watershed in the cities of Terrell and Rockwall (Handbook of Texas 2003).

In 1957, completion of a long-range water supply strategy by the Tarrant County Water Improvement District (changed to Tarrant Regional Water District in 1996) coincided with a seven-year drought that had affected the region. In response to a growing population, drought conditions, and uncertainty of the future of water availability, the plan called for the construction of two separate reservoirs southeast of Dallas. By 1959, Tarrant County voters had approved $55 million in a combination of revenue and general obligation bonds to fund the construction of Cedar Creek Reservoir (funding for the second reservoir, Richland-Chambers, would not be approved until 1979). Areas east of Dallas were targeted for reservoir construction due to the higher rainfall amounts and lower population of such areas. Construction of the 91 foot tall Joe Hogsett Dam began in 1960. Due to a heavy rainfall trend in the late 1960's, the new reservoir was filled to conservation capacity by 1967. Construction of a 72-inch diameter pipeline through

Ellis County, with pumping stations in Ennis and Waxahachie was completed in 1973 to transport raw water back to Tarrant County. Following the construction of Richland-Chambers Reservoir in the early 1980s, an additional pipeline was added to parallel the Cedar Creek water line. Portions of this water are delivered in route to the cities of Arlington and Mansfield. The remaining supply is either fed into balancing ponds southeast of Fort Worth to allow for uninterrupted flow during peak usage times or delivered for terminal storage in into Eagle Mountain or Benbrook Lakes (Tarrant Regional Water District 2008)

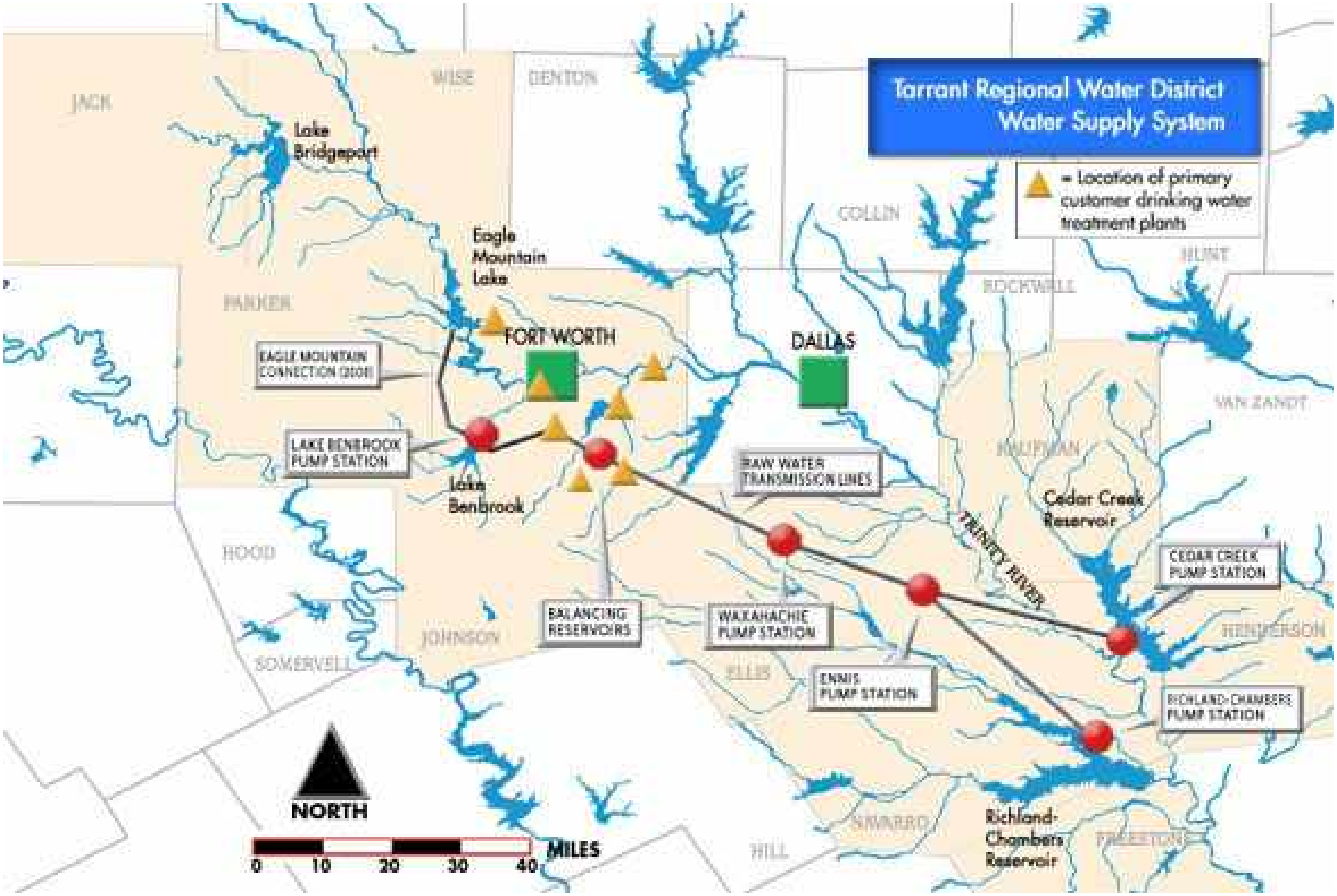


Figure 1.10 Tarrant Regional Water District Water Supply System (TRWD 2007).

1. The Cedar Creek Watershed Partnership

The Cedar Creek Watershed Protection Plan is an outgrowth of a partnership formed in 2004 between the Tarrant Regional Water District and Texas Water Resources Institute as an effort to rectify impaired water quality conditions in several of the north Texas reservoirs operated by Tarrant Regional Water District. Ambient water quality analysis and modeling of the Cedar Creek watershed was finalized in the spring of 2007. This proactive strategy is a collaborative effort of land owners, agricultural producers, agency personnel, urbanites, and elected officials. These participants, herein known as stakeholders, are the focus of the EPA's new approach for Watershed Protection Planning. By developing strategies for the reduction of pollutants by consulting with and advising stakeholders, it is anticipated that acceptance and participation among local communities will be enhanced.

1.1 Formation and Mission

The Cedar Creek Partnership was formed in the summer of 2007 at the request of the Tarrant Regional Water District to address the concerns raised by reservoir managers over nutrient and sediment levels in the Cedar Creek Watershed. New members were added by invitation of the North Central Texas Water Quality Project in July of 2006 drawing from representative land owners, agricultural producers, elected officials, municipal and county leaders, and agency personnel heretofore referred to as "stakeholders." Meetings of the group were held regularly to review the concepts behind and issues of water quality facing the Cedar Creek Watershed as well as to review and discuss possible best management practices

As stated in the Ground Rules signed by each participating stakeholder (see appendix A):

"*the goal of the Cedar Creek Partnership is to develop and implement a watershed protection plan to improve and protect the water quality of Cedar Creek Reservoir and Watershed.*"

1.2 Public Partnerships

Open discussion among stakeholders and project technical advisory group was encouraged. Project organizers promoted a template in which the opinions and concerns of stakeholders would weigh heavily into the final decisions regarding nutrient reduction goals and the selection of best management practices to achieve them. Stakeholders representing the various constituencies of Cedar Creek Watershed were able to advise project leaders on the feasibility and acceptance of various aspects of the Watershed Protection Plan.

1.3 Agencies

Crucial to the success of the Cedar Creek Partnership was the involvement of local, state and Federal Agencies. Such groups were able to provide advice, technical support, and financial backing of the project. Agency officials worked collaboratively with stakeholders by attending meetings and offering guidance through the process of best management practice selection.

Table 6.1 Agency Roles in Cedar Creek Watershed Protection Planning Efforts.

Agency	**Description of support for Watershed Protection Planning**
United States Department of Agriculture – Natural Resources Conservation Service	Consultation on BMPs, funding for projects
Texas Parks & Wildlife Department	Advisory on wildlife and land management impacts
Texas Commission on Environmental Quality	Permitting of Wastewater Treatment Plant's, water quality testing, assembly of 303(d) list
Texas State Soil and Water Conservation Board	Funding, consultation on land management
Texas AgriLife Extension Service	Liaison between project organizers and agricultural producers; Development, organization, and implementation of educational programming
Spatial Sciences Laboratory, Texas A&M University	Modeling of BMPs, Modeling of watershed conditions, mapping of watershed boundaries and features
Texas AgriLife Research and Extension Urban Solutions Center	Organization of stakeholders, assembly of grant funding, writing and submittal of WPP
Environmental Protection Agency	Funding of WPP efforts through 319 grant program; Template and consultation for WPP efforts
Tarrant Regional Water District	Funding, scientific and management support for project leadership
Department of	Advisory on cost-benefit

Agricultural Economics, Texas A&M University	data of BMPs
North Central Texas Council of Governments	Demographic and urban data forecasting and support

1.4 Work Groups

Project leadership determined that an efficient use of stakeholder time and effort would be to subdivide the group into two separate work groups to focus on the individual issues and best management practices targeted for urban, rural, and educational areas of concern. Rosters for each work group ensured adequate representation of stakeholder interests but were small enough to produce effective consultation to project leaders. Work groups were created for rural and agricultural, urban and wastewater treatment plant, and informational and outreach issues.

1.5 Technical Advisory Group

Certain Members of the technical advisory group also served in the role as project leaders. The group consisted primarily of representatives of the Tarrant Regional Water District and Texas AgriLife Research and Texas AgriLife Extension Service. Assisting with technical guidance were engineers from Espey Consultants of Austin, Texas and Alan Plummer Associates, Inc. of Fort Worth, Texas. Logistical and organizational support was provided by the Texas A&M AgriLife Texas Water Resources Institute.

1.5.1 Cedar Creek Watershed Protection Plan Technical Advisory Team

Woody Frossard, Tarrant Regional Water District
Darrel Andrews, Tarrant Regional Water District
Mark Ernst, Tarrant Regional Water District
Jennifer Owens, Tarrant Regional Water District
Clint Wolfe, Texas AgriLife Research
David Waidler, Texas AgriLife Research
Dr. Bruce Lesikar, Texas AgriLife Extension Service
Justin Mechell, Texas AgriLife Extension Service
Molly Griffin, Texas AgriLife Extension Service
Brent Clayton, Texas AgriLife Extensions Service
Ryan Gerlach, Texas AgriLife Extension Service
Dr. Balaji Narashim, Spatial Science Laboratory, Texas A&M University
Dr. Raghavan Srinivasan, Spatial Science Laboratory, Texas A&M University
Dr. Taesoo Lee, Spatial Science Laboratory, Texas A&M University
Bill Espey, Espey Consultants, Inc.
David Harkins, Espey Consultants, Inc.
Margarethe Berge, Espey Consultants, Inc.
Dr. Allan Jones, Texas A&M AgriLife Texas Water Resources Institute
Lucas Gregory, Texas A&M AgriLife Texas Water Resources Institute
Alan Plummer, Alan Plummer Associates, Inc.

Dr. Robert Adams, Alan Plummer Associates, Inc.
Betty Jordan, Alan Plummer Associates, Inc.
Bill Ratlif, Alan Plummer Associates, Inc.
Ken Lawrence, Alan Plummer Associates, Inc.
Dr. Ed Rister, Texas AgriLife Research
Dr. Ron Lacewell, Texas AgriLife Research
Allen Sturdivant, Texas AgriLife Research

1.6 Stakeholder Meetings

Beginning in July of 2007, stakeholder workshops were conducted on a regular basis to inform local citizens, agricultural producers, and civic leaders of reservoir and watershed conditions. Each of the preliminary reports informing the watershed protection effort were presented. Among these were the SWAT Modeling Report, WASP Modeling Report, and Point-Source Evaluation.

Figure 1.1 Cedar Creek Watershed Stakeholder Discussion

Stakeholders were educated in watershed concepts, water quality policy, water quality analysis, and best management practices for water quality improvement. As the project progressed, stakeholders were asked to vote on technical advisory group recommendations for watershed management measures including pollutant reduction goals. All meetings were held at the Kaufman County Library in the City of Kaufman providing a central, accessible location within the watershed. Stakeholder meeting dates and agendas can be found in the appendices.

North Central Texas Water Quality Project

Cedar Creek Reservoir Watershed Protection Plan
Steering Committee Meeting

AGENDA

November 20, 2008

1:30 Welcome and Introductions
Clint Wolfe, Project Coordinator, North Central Texas Water Quality Project

1:40 Water Quality Modeling Activity Report – Sub Watershed Scale BMP Analysis
Taesoo Lee, Spatial Sciences Laboratory, Texas A&M University

2:10 Economic Performance Cost Analysis for Best Management Practices
Ed Rister, Agricultural Economist, Texas AgriLife Extension Service

2:40 Break

2:50 Update on Agricultural Water Quality Management Plan Development
Zack Kinsey, Technician, Kaufman-Van Zandt SWCD

3:00 Progress on Watershed Protection Plan
David Waidler, Watershed Coordinator, North Central Texas Water Quality Project

3:15 Discussion on Funding Sources for WPP/BMP Implementation
Clint Wolfe, Project Coordinator, North Central Texas Water Quality Project

3:30 Workgroup Breakout Sessions

Urban and Wastewater Treatment (*Adams and Ernst*)
Agricultural and Rural (*Munz and Andrews*)
Educational and Outreach (*Lesikar and Mechell*)

4:00 Adjourn

Figure 1.2 Agenda from November 20, 2008 Stakeholder Meeting

1.7 Project Website

A project website for the North Central Texas Water Quality Project was established at the beginning of the watershed planning effort to serve as a clearinghouse of information for stakeholders and other interested parties for both the Cedar Creek Watershed Protection Plan and Eagle Mountain Lake Watershed Protection Plan. The site was managed through an arrangement with the Texas Water Resources Institute and featured background watershed information, workshop presentations, quarterly reports, and draft versions of the watershed protection plan. The project website is located at http://nctx-water.tamu.edu.

INSERT SCREEN CAPTURE OF NCTWQP WEBSITE

1. Nutrient Source Identification

Proper watershed planning requires that the source of pollutants within the watershed are identified and confirmed. Officials with Tarrant Regional Water District and Texas AgriLife Research turned to continuing water quality monitoring efforts as well as state of the art computer models to assist in the location of the sources of high phosphorus and sediment loadings that would impact Cedar Creek Reservoir. New technologies such as the Soil and Water Assessment Tool and Water quality Analysis Simulation Program work to account for the soil erosion, land use, and in-lake pollutant loadings providing an overall picture of past, present, and future watershed conditions.

1.1 Water Quality Monitoring

Tarrant Regional Water District in cooperation with the cooperation of the Trinity River Authority performed regular quarterly water quality monitoring within Cedar Creek Reservoir and the Cedar Creek Watershed at the designated location shown in Figure 1.1. Reports are submitted to the Texas Commission on Environmental Quality for annual reporting and inclusion in the biannual Texas Water Quality Inventory. State standards for each pollutant are determined by the determined use for each water body.

Figure 1.1 Cedar Creek Watershed monitoring sites

1.2 19-year TRWD Study

The impetus for development of a Watershed Protection Plan is a 19-year water quality analysis project performed by Tarrant Regional Water District. Reservoir managers were charged with producing a long-term trend analysis of water quality within the reservoir and watershed and in doing so were able to establish trend analysis of the Chlorophyll-*a*, sediment, nitrogen, and phosphorus levels. The study was performed by combining ambient water quality testing and reservoir computer modeling. As the scope of the resulting watershed planning efforts grew, other computer models analyzing overland and channel processes were employed as well.

Figure 1.2 provides an examination of 19 years of Chlorophyll-*a* data from the third quarter of each year demonstrated a rising trend of Chlorophyll-*a* in Cedar Creek Reservoir at an annual percentage rate of 3.85 percent with an overall median concentration of 27.4 ug/L). A similar analysis including all four quarters of each year, has a rate of 4.94 percent with a median concentration of 19.5 ug/L. Both of these rates suggest that chlorophyll-*a* rates will double in less than 20 years. When compared to other Texas reservoirs, Cedar Creek places among the top bodies in the state for levels of chlorophyll- *a* (TCEQ 2006).

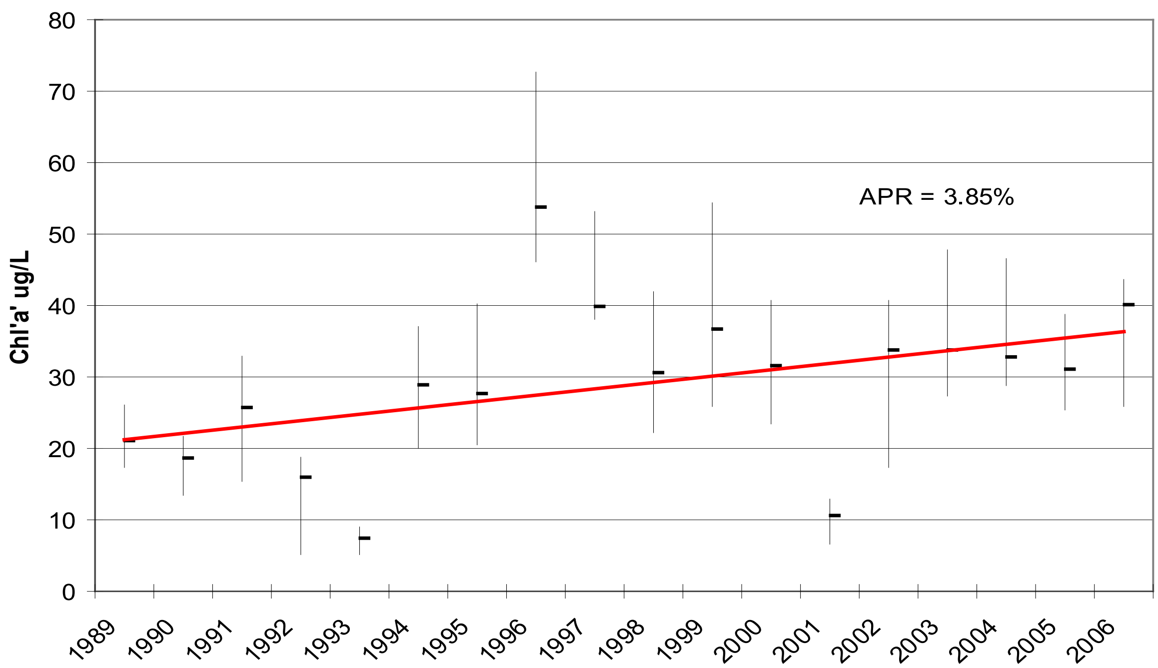


Figure 1.2 19-year 3rd quarter lakewide Chlorophyll-*a* trend analysis (TRWD 2007).

With the knowledge of chlorophyll-*a* as targeted constituent, TRWD researchers turned to the Spatial Science Laboratory at Texas A&M University to create a comprehensive computer modeling report utilizing the Soil and Water Assessment Tool (SWAT) as a method to identify the sources of nutrient and sediment loadings within the Cedar Creek reservoir watershed. Based on maps created to account for land use, soils, climate, waste water treatment plant discharges, and channel erosion, modeling efforts determined that the historical farming practices of the watershed combined with highly erodible clay soils are the leading cause of nutrient pollution in the reservoir.

Additionally, TRWD utilized the Water Quality Analysis Simulation Protocol to provide data on the nutrient levels for assigned segments of the water body allowing for a determination of the levels of nutrients and sediment as the constituents flow into and out of the reservoir.

1.3 Point Source Pollutant Discharges

Modeling of wastewater treatment plant discharges and recommended upgrades for the watershed plan are based on the nine plants in operation evaluated in a 2007 Alan Plummer Associates, Inc. report (Figure 1.3). Discharge of treated wastewater from these plants present a significant source of tributary flow, especially during periods of little rainfall. The level of these flows can be impacted by seasonal factors and population growth. All nine wastewater treatment plants are permitted by the Texas Commission on Environmental Quality and allow for discharge of varying levels of pollutants such as phosphorus. A summary of current wastewater treatment discharge conditions is provided in Table 1.1.

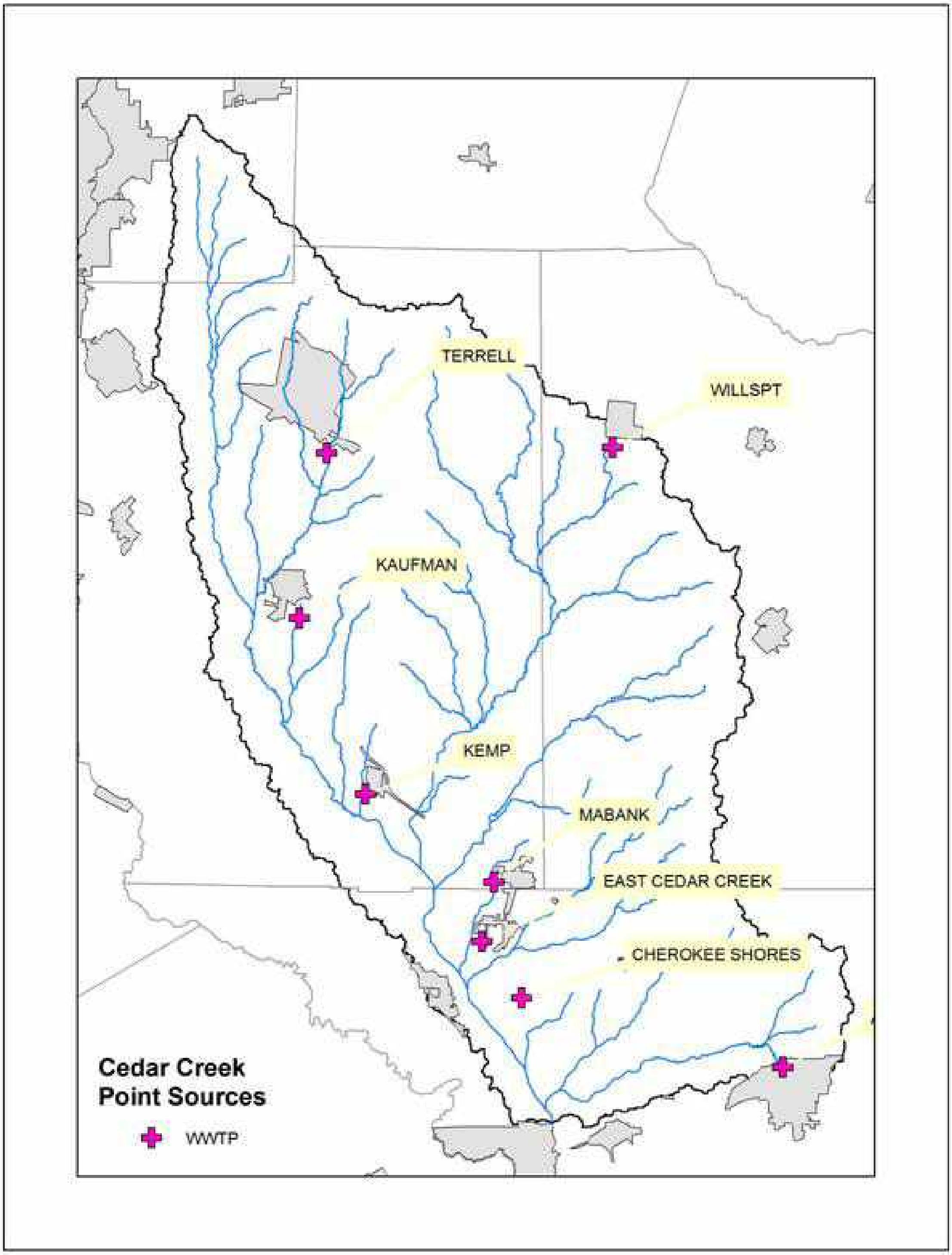


Figure 1.3 Wastewater treatment facilities within the Cedar Creek Watershed (TAMU-SSL 2007).

Table 1.1 Current flow and pollutant concentrations for Cedar Creek Watershed Wastewater Treatment Plants (APAI 2007)

Plant	Population Served (2005)	Average Daily Flow (MGD) (2003)	Average TSS (Mg/L)	Average TP (Mg/L)	Average TN (Mg/L)
Athens North	12390*	.42	8.7	2.85	13.53
Cherokee Shores	1730	.09	*18.3*	*4.3*	*37.8*
East Cedar Creek	7150	ND	ND	2.17	23.38
Eustace	839	.06	73.9	4.92	23.63
Kaufman	7300	.62	1.6	2.85	13.53
Kemp	1133	.1	*11.7*	3.18	14.36
Mabank	2400	.24	46.8	3.89	11.77
Terrell	14379	2.8	7.7	4.03	19.71
Wills Point	3700	.38	79	2.64	12.03

*Athens North Wastewater Treatment Plant processes approximately 40% of the city of Athens' wastewater. The remaining amount is handled by Athens West WWTP which does not discharge into the Cedar Creek Watershed.
Italics represent violation of current TPDES permit standard for assigned WWTP.
Population projections for 2005 are drawn from Texas Water Development Board Estimates.
Daily flow and TSS surveys are taken from individual WWTP data submitted to APAI Report
Average TP and TN data taken from TRWD site-based testing.

1.4 SWAT (Soil and Water Assessment Tool)

The Soil and Water Assessment Tool (SWAT) is a watershed and landscape simulation model designed to help scientists and decision makers manage soil and water resources at the watershed and river basin scales in mixed-use watersheds that include urban, suburban, and agricultural aspects. The model operates on a continuous, daily-time step, which makes it capable of simulating changes over many years. The SWAT system is a multi-functional modeling tool that can be used to answer questions about the function and management of watersheds that are both large and small. Simulation of the watershed encompasses all aspects of the hydrologic cycle including land, water, and atmospheric interactions SWAT mimics the flow of water within the watershed, allowing it to assess water quality and quantity changes due to alterations in global climate, land use, policy, and technology. In addition, SWAT is linked to state-of-the-art GIS interfaces for easy output visualization. The model information can be used to evaluate both present and future management scenarios and their economic and environmental impacts. (Gassman , et al. 2007).

The SWAT model was developed by a team of USDA-Agricultural Research Service, USDA-Natural Resources Conservation Service, and Texas A&M University System engineers and scientists over the last 25 years. Over the last decade, US Environmental Protection Agency, US Department of Agriculture, and a large number of engineers and scientists in the United States and around the world have become users and have contributed substantial resources to the model, its databases, and interface development. Constant updates by the development team make SWAT a model that is constantly evolving to meet the needs of its users (Gassman , et al. 2007).

The SWAT system has been used successfully in many projects worldwide which are documented in over 500 peer-reviewed scientific publications. Over 500 scientists and engineers have been trained in the use of the system, and more than 30 universities are using the tool in academic courses. Software, databases, user interfaces, and publications are available at the SWAT website, http://www.brc.tamus.edu/swat/ (SWAT 2009).

SWAT relies on site-specific inputs such as hydrology, weather, climate, topography, soil, crop, and management information. With this information, SWAT can predict changes in sediment, nutrients (organic and inorganic nitrogen and organic and soluble phosphorus), pesticides, Dissolved Oxygen, bacteria and algae loadings from different management conditions in large basins. SWAT can also be coupled with other models that pass on input data. This is particularly useful in climate change studies. SWAT can be used for a diverse set of assessments which are ideal for analyzing changes in urban land use, climate, and water quality. SWAT is also idea for stream restoration planning and soil and water conservation (Gassman , et al. 2007).

For the Cedar Creek Watershed Protection Plan, SWAT was employed to determine the sediment yield of the watershed and to discern the amounts of Total Nitrogen and Total Phosphorus the sediment contains. Spatial Scientists were able to model current and predict future loadings within individual sub-basins allowing project leaders to concentrate effort and expenditures in problem areas. SWAT Modeling was also used to assess the effectiveness of a variety of designated best management practices toward the reduction of sediment, phosphorus, and nitrogen.

1.4.1 Land use Classification

Utilizing SWAT for watershed planning requires the establishment of a detailed land use map to drive modeling and assist watershed planners and stakeholders in arriving at a management solution. To develop a quality land use map, researchers relied on satellite imagery, local surveys, and ground truthing to confirm results. The various land uses of the watershed were categorized and color-coded to provide a visually stark illustration of current conditions shown in figure 1.4. This map of baseline land use allowed the computer model to accurately determine the pollutant potential for all areas of the Cedar Creek Watershed. For instance, the sediment and phosphorus loadings that originate from a wetland area will greatly differ from those coming from croplands.

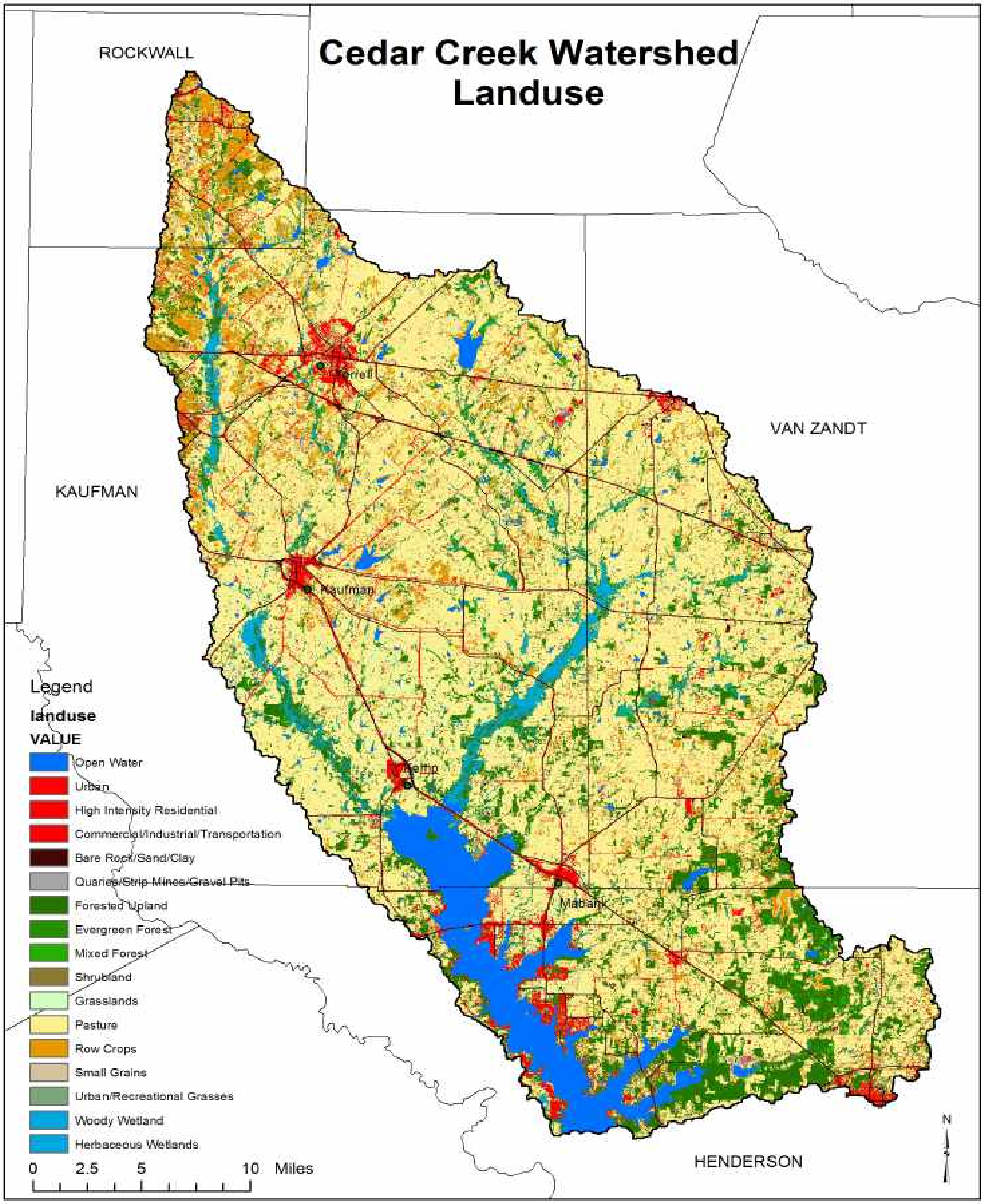


Figure 1.4 Cedar Creek Watershed Landuse (TAMU-SSL 2007).

1.5 Sub Basin Analysis Utilizing SWAT

Combining the inputs of land use, soils, climate, point source loadings, channel erosion, and historical nutrient applications by watershed farmers, modelers were able to produce maps demonstrating the origin and levels of targeted nutrients. Analysis of hydrology and topography of the watershed allowed for the division of the watershed into 106 small sub-basins as shown in figure 1.5. Each sub-basin operates as a micro watershed within the larger Cedar Creek basin. The planned result was to pinpoint the sub-basins in which management efforts could be concentrated to achieve lowered phosphorus loadings leading to a reduction in chlorophyll-*a* within Cedar Creek Reservoir.

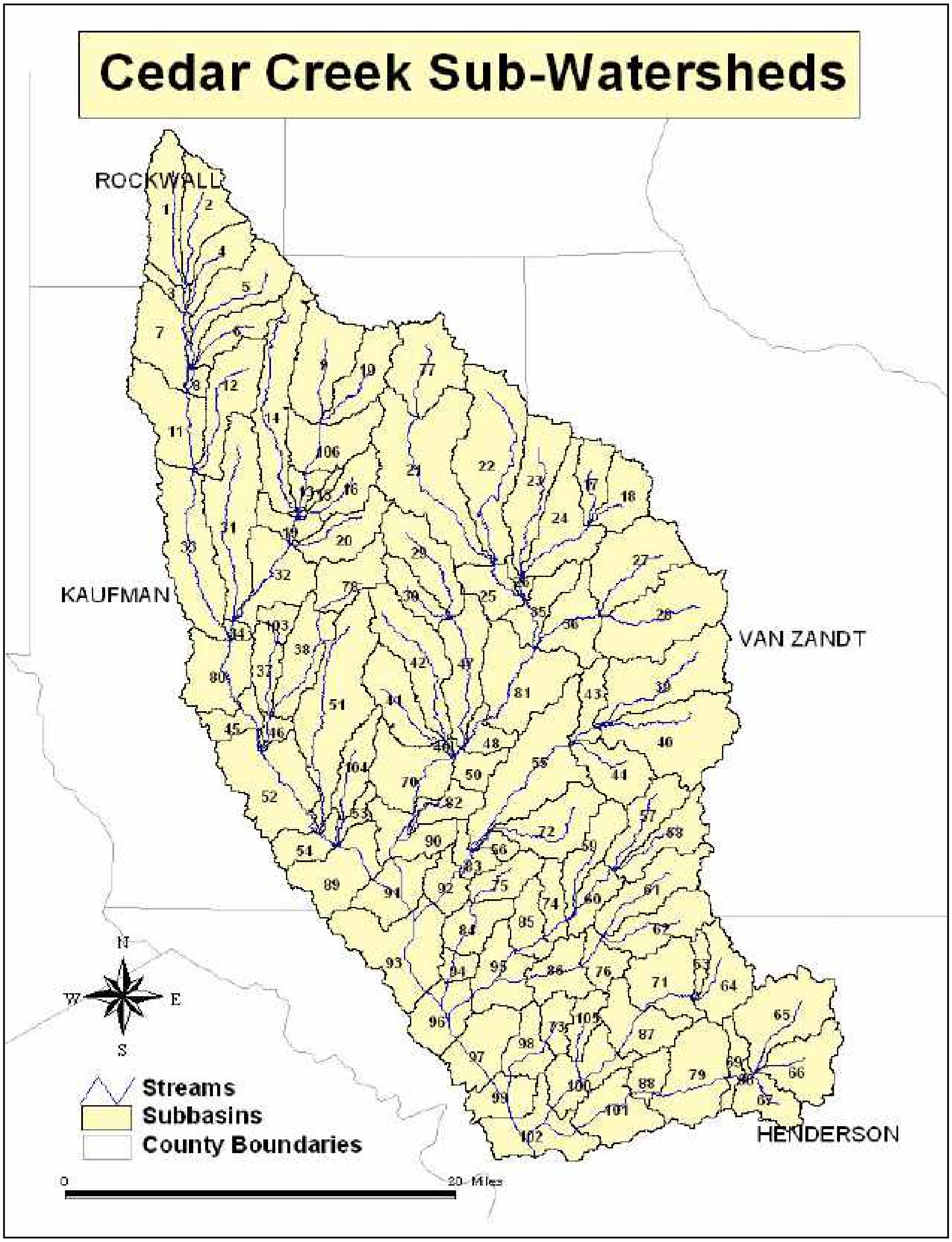


Figure 1.5 Sub-basin delineation for the Cedar Creek Watershed

1.5.1 MAPPING AND QUANTIFYING POLLUTANT SOURCES AND LOADINGS

Modeling efforts identified the sub-basin origination of sediment, as shown in figure 1.6, phosphorus, as shown in figure 1.7, and nitrogen, as shown in figure 1.8. Additionally, SWAT modeling determined the percentages the pollutants originating from each land use. Sediment is represented in figure 1.9, nitrogen is shown in figure 1.10, and phosphorus is outlined in figure 1.11.

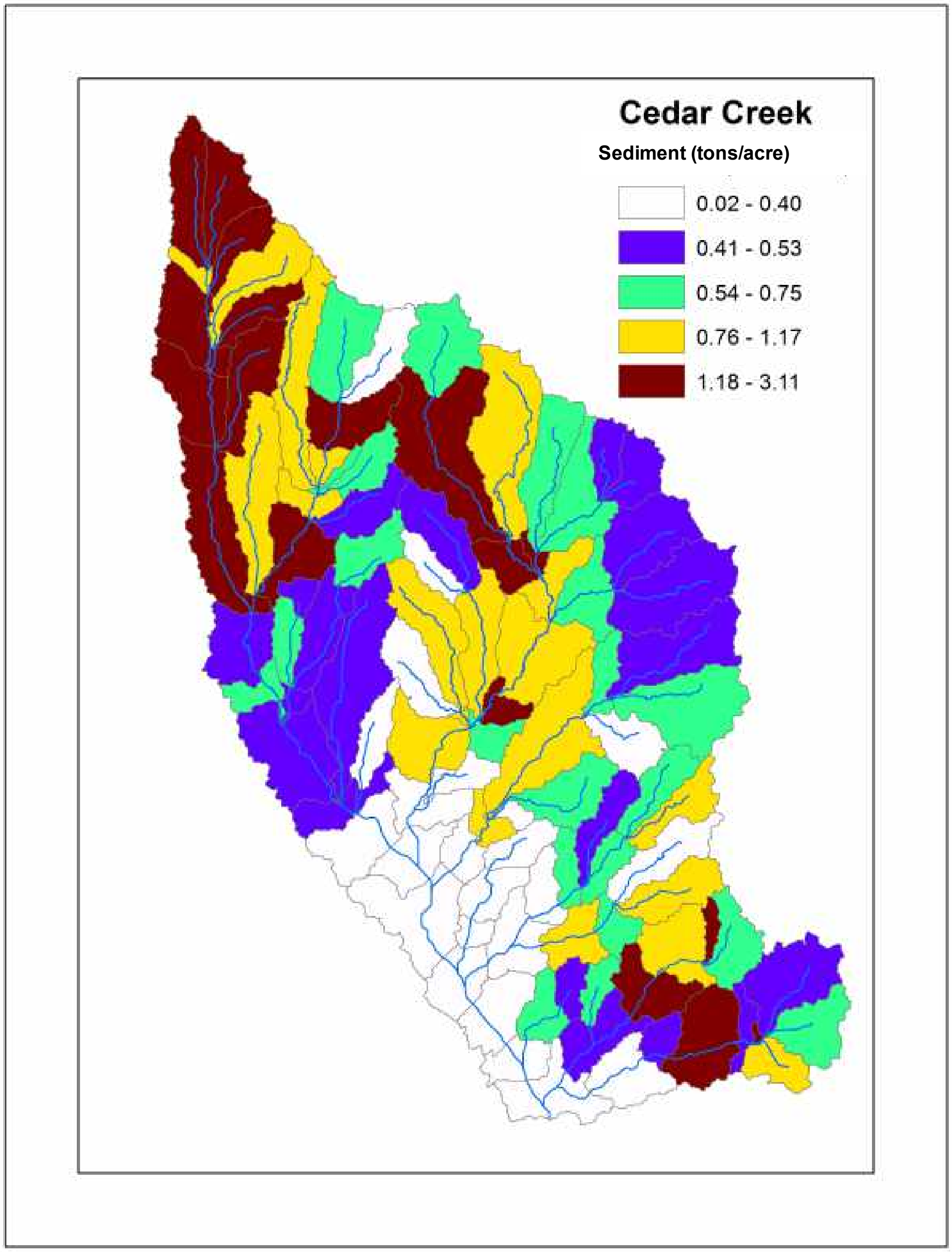


Figure 1.6 Sediment loadings by Sub-basin for the Cedar Creek Watershed (TAMU-SSL 2009).

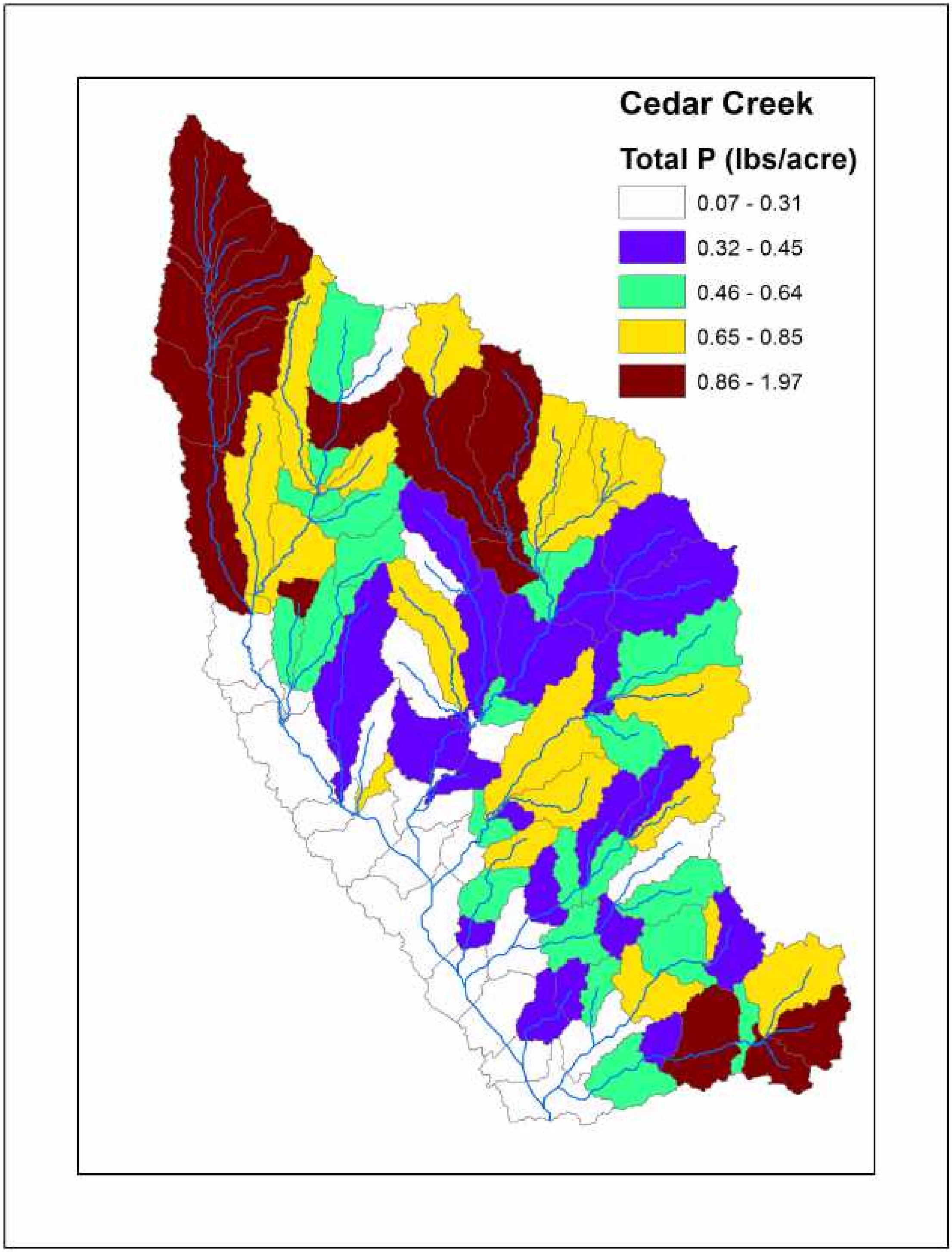


Figure 1.7 Total Phosphorus Loadings by sub-basin for the Cedar Creek Watershed (TAMU-SSL 2009).

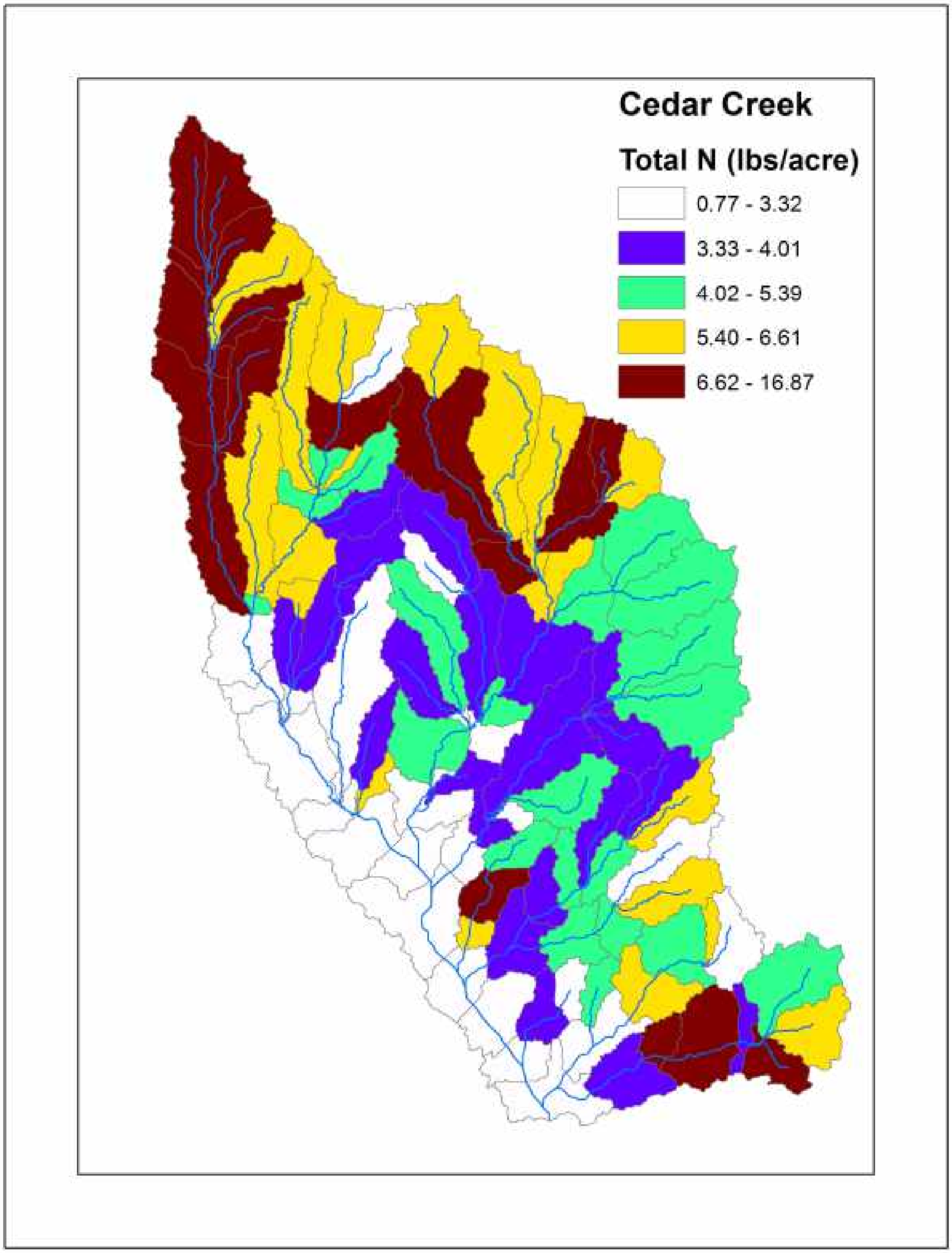


Figure 1.8 Total Nitrogen loadings by sub-basin for the Cedar Creek Watershed (TAMU-SSL).

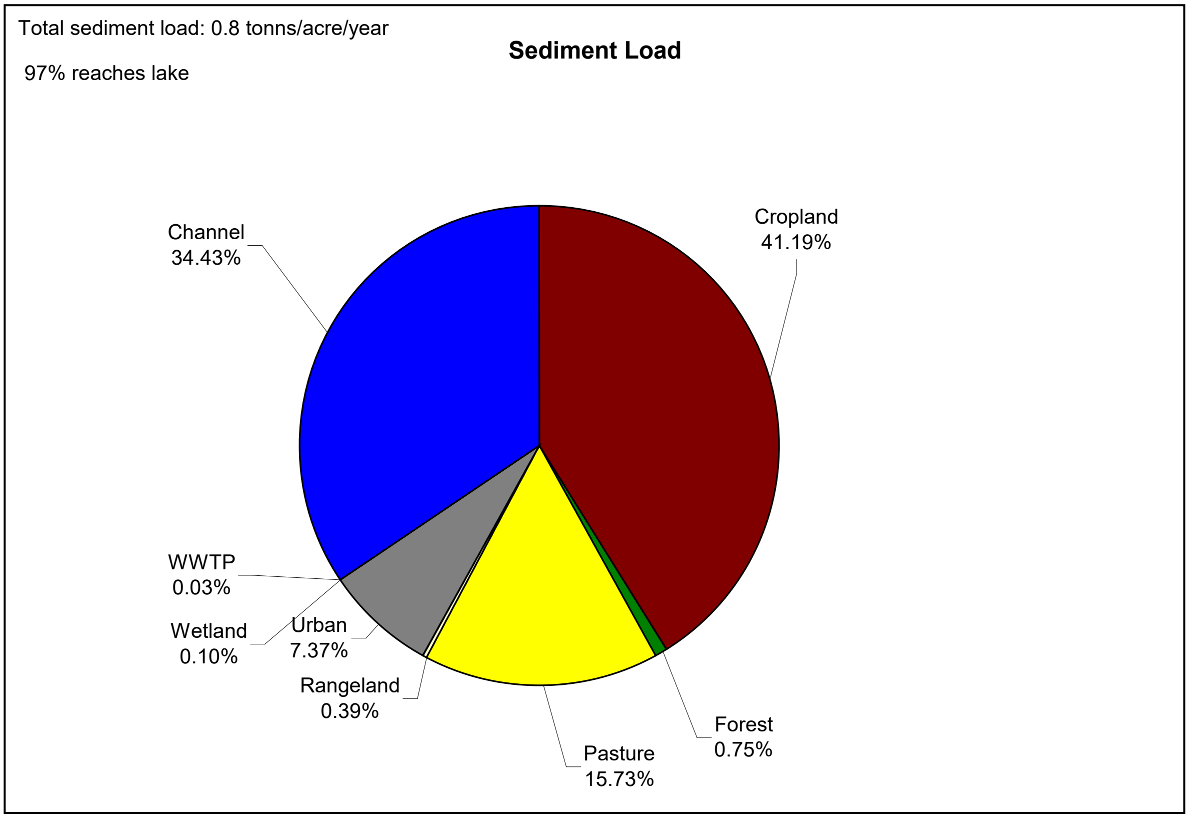


Figure 1.9 Sediment source percentages for Cedar Creek Reservoir

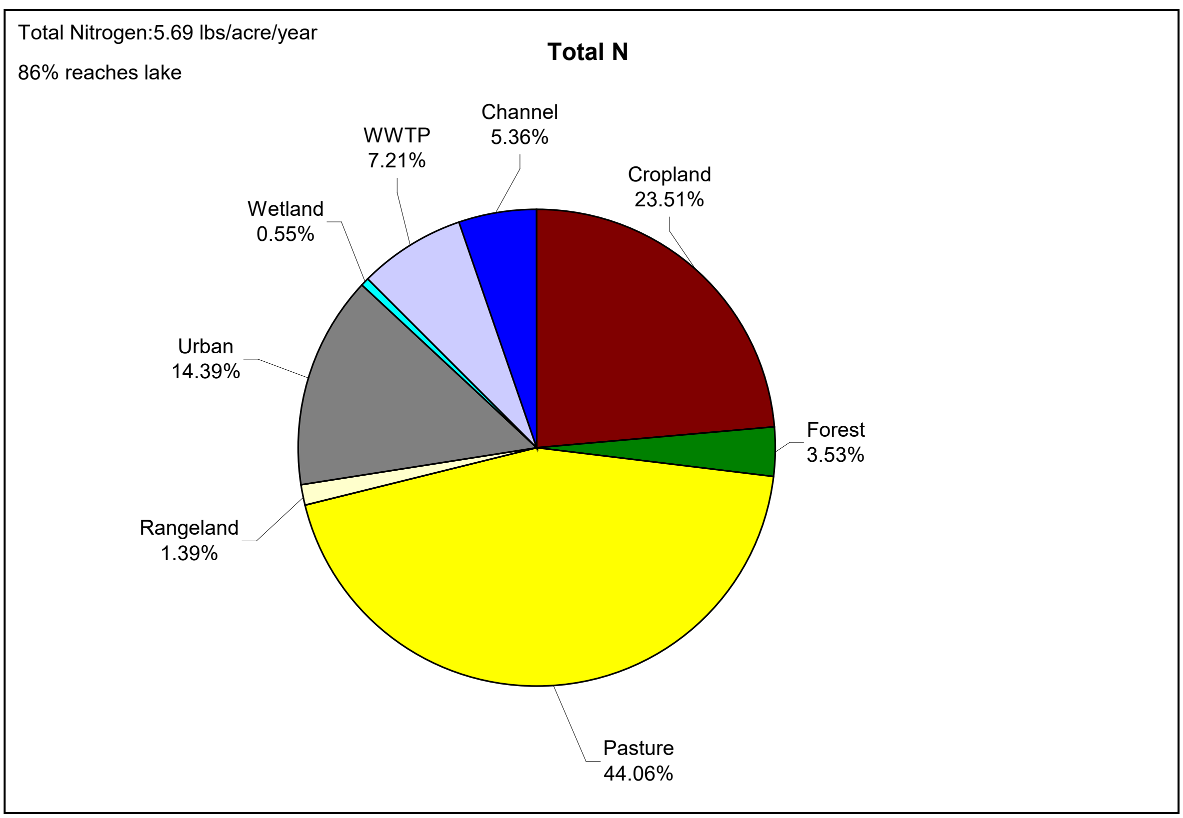


Figure 1.10 Nitrogen source percentages for Cedar Creek Reservoir

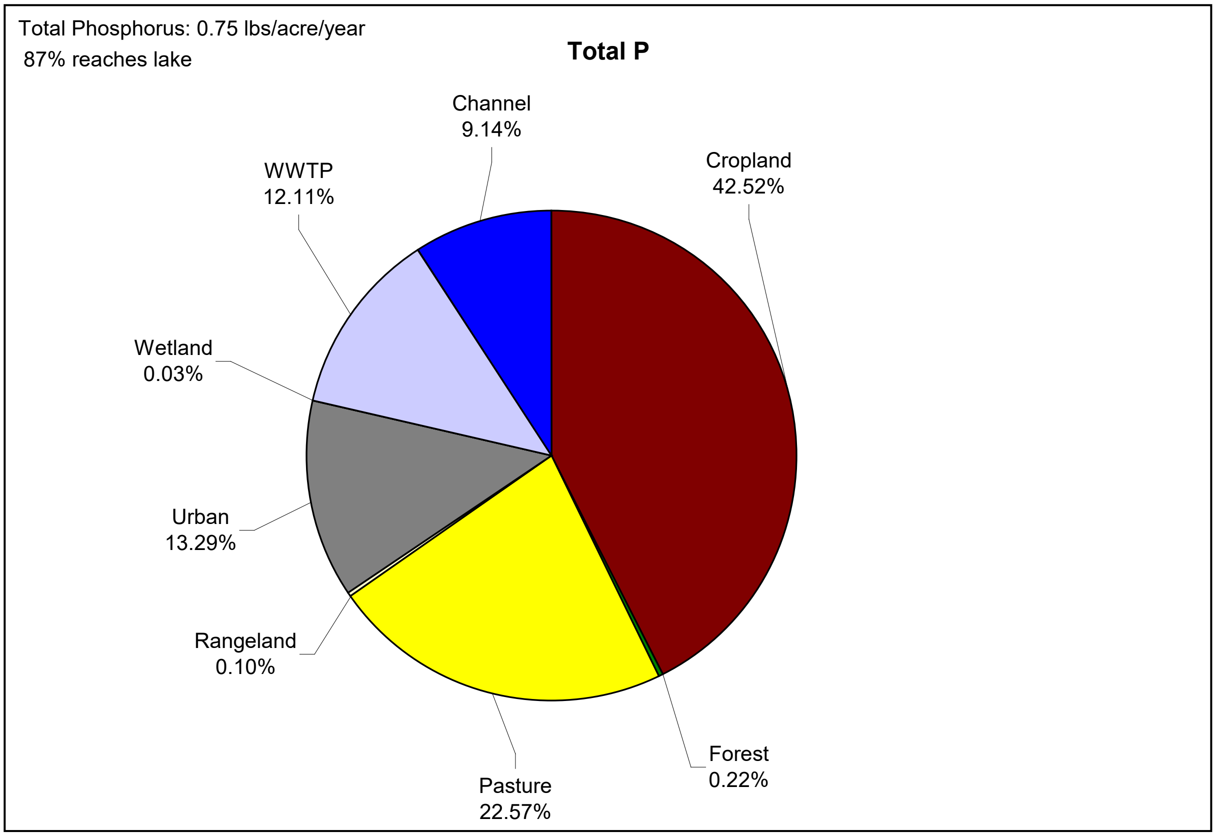


Figure 1.11 Phosphorus point source percentages for Cedar Creek Reservoir

1.5.2 INTERPRETING THE RESULTS OF SWAT ANALYSIS

Interpretation of these findings showed a consistent trend of origination in the Kings and Brushy Creek sub-watersheds in the north eastern portion of the watershed. When comparing this analysis to the original land use map, planners determined that areas with current use for row crop farming practices represented the largest source of nutrient and sediment loadings. Evaluation of current and historical farming practices revealed the prevalence of significant fertilizer use combined with heavy tillage of the highly erodible clay soils.

Additionally, investigation of local knowledge confirmed that the aforementioned tributary basins have been subject to large concentrations of urban development and the resulting increase in impervious surfaces such as asphalt and concrete parking lots and roadways. The consequential land disturbance, loss of pasture and crop lands able to absorb rainfall allowed for a higher volume and velocity of storm water entering the tributaries. These conditions allow for expanded transport of sediment and nutrient loadings to the reservoir.

SWAT analysis of watershed pollutant souring provided a starting point to understanding the overall water quality issues facing Cedar Creek Reservoir. To complete the picture, watershed planners needed to understand how the watershed-based loadings would impact the reservoir .

1.5.3 IDENTIFICATION OF SUB-BASINS WITH HIGHEST PHOSPHORUS LOADINGS

To aid in future development of a management solution, SWAT modelers with the spatial sciences laboratory at Texas A&M developed a listing of the top phosphorus producing sub-basins in the watershed. This report allowed for the beginning of plans to target specific areas for the implementation of management practices to reduce the flow of phosphorus and associated sediment to the reservoir. This analysis also produced a ranking of the top 20 phosphorus producing sub-basins allowing for prioritization of the implementation of management measures.

Table 1.1 Listing of top phosphorus producing subbasins in the Cedar Creek Watershed.

SUBBASIN	HRU	LANDUSE	HRU Area	Rank by TP	Ranking	Subbasin #	Area	Accum. Area	%
1	1	GRSG	9.22	3	1	2	11.67	11.67	7.2
2	1	GRSG	11.67	1	2	8	1.37	13.04	8.1
3	1	GRSG	0.33	15	3	1	9.22	22.26	13.8
3	2	GRSG	0.60	15	4	12	5.48	27.75	17.2
4	1	GRSG	0.51	9	5	7	9.82	37.57	23.3
4	2	GRSG	1.49	9	6	67	1.21	38.78	24.1
4	3	GRSG	2.29	9	7	6	3.71	42.49	26.4
5	1	GRSG	2.17	14	8	11	7.21	49.70	30.9
5	2	GRSG	1.25	14	9	4	4.29	53.99	33.5
5	3	GRSG	3.06	14	10	21	5.30	59.29	36.8
6	1	GRSG	0.62	7	11	79	1.93	61.22	38.0
6	2	GRSG	1.02	7	12	106	2.58	63.80	39.6
6	3	GRSG	1.30	7	13	66	1.78	65.58	40.7
6	4	GRSG	0.76	7	14	5	6.47	72.05	44.7
7	1	GRSG	1.69	5	15	3	0.93	72.99	45.3
7	2	GRSG	8.13	5	16	33	6.17	79.16	49.1
8	1	GRSG	0.16	2	17	103	0.46	79.62	49.4
8	2	GRSG	0.24	2	18	68	0.06	79.68	49.5
8	3	GRSG	0.70	2	19	17	0.70	80.38	49.9
8	4	GRSG	0.27	2	20	40	2.32	82.70	51.3
11	1	GRSG	7.21	8					
12	1	GRSG	1.66	4					
12	2	GRSG	3.82	4					
17	1	GRSG	0.70	19					
21	1	GRSG	3.50	10					
21	2	GRSG	1.80	10					

1.6 Water Quality Analysis Simulation Program (WASP)

Daily mass loadings from the SWAT model were supplied to the Water Quality Analysis Simulation Program (WASP) model (version 6.2) (EPA, 2003) to simulate reservoir water quality. WASP is a mechanistic, mass balance model used to interpret or predict possible changes in water quality of ponds, lakes, reservoirs, rivers and coastal waters brought about by pollutants. Use of the WASP modeling techniques allowed project consultants to determine the loadings of sediment and nutrients within segmented “top down” and “side view” model of Cedar Creek Reservoir (Figure 1.12). WASP provides water quality planners a dynamic tool to assess management strategies such as nutrient reduction. WASP was used in the Cedar Creek planning efforts to systematically determine the necessary phosphorus load reductions to result in a statistically significant reduction in Chlorophyll-*a*. (TWRD 2007)

The USEPA Water Analysis Simulation Program (WASP) model was calibrated for an 11-year period (1991 – 2001) for Cedar Creek Reservoir. Nutrient loads to Cedar Creek came from four (4) sources:

- SWAT was used to estimate the watershed loading to WASP including both nonpoint source (NPS) loading and point source (PS) loading from 7 wastewater treatment plants (WWTPs).
- Point source loading from two plants that directly discharge to the reservoir were input directly to WASP. All WWTP loadings were based on one year of self-reported nutrient data from the plants.
- Benthic flux of nutrients was based upon changes in Hypolimnetic concentrations during stratified periods.
- Atmospheric loading was based upon rainfall analysis at Richland Chambers Reservoir.

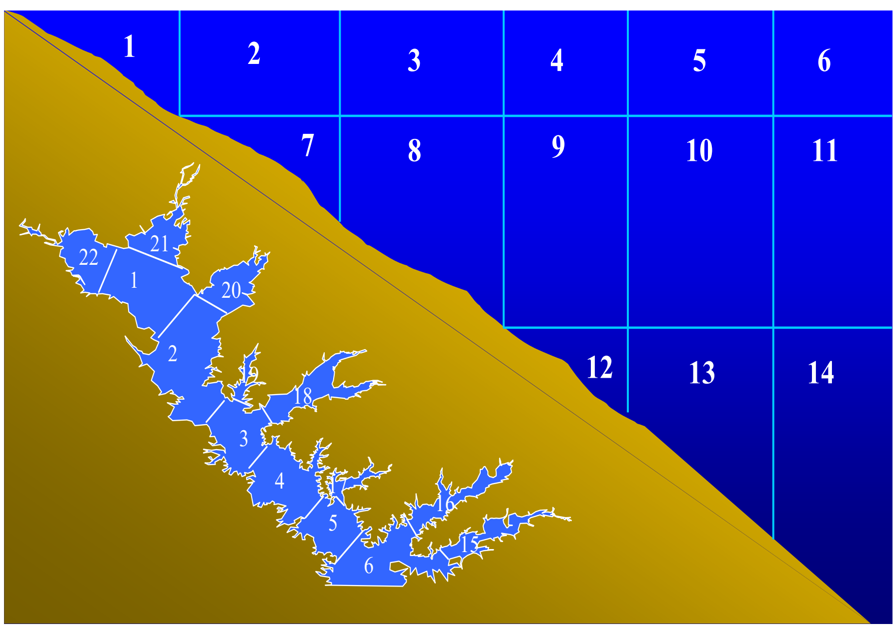


Figure 1.12 Cedar Creek Segmentation for WASP Modeling (Espey Consultants).

1.6.1 WASP Nutrient Budget for Cedar Creek Reservoir

Accounting for the sources of pollutants within the Cedar Creek Reservoir is an important step to guiding the process of watershed protection planning. An analysis of reservoir nutrient content by Tarrant Regional Water District demonstrated the sources of nitrogen (figure 1.13) and phosphorus in the reservoir (Figure 1.15). Non point sources such as farming and ranching are most significant, followed by waste water treatment, a result of the urbanization of the watershed. Naturally occurring processes such as atmospheric deposition (precipitation) and flux (reservoir chemical processes) account for nutrient loadings as well. To enhance stakeholder understanding and provide a comparable illustration to the SWAT percentages listed above, TRWD modelers created summary pie charts of nitrogen (figure 1.14) and phosphorus (figure 1.16) sources for Cedar Creek Reservoir.

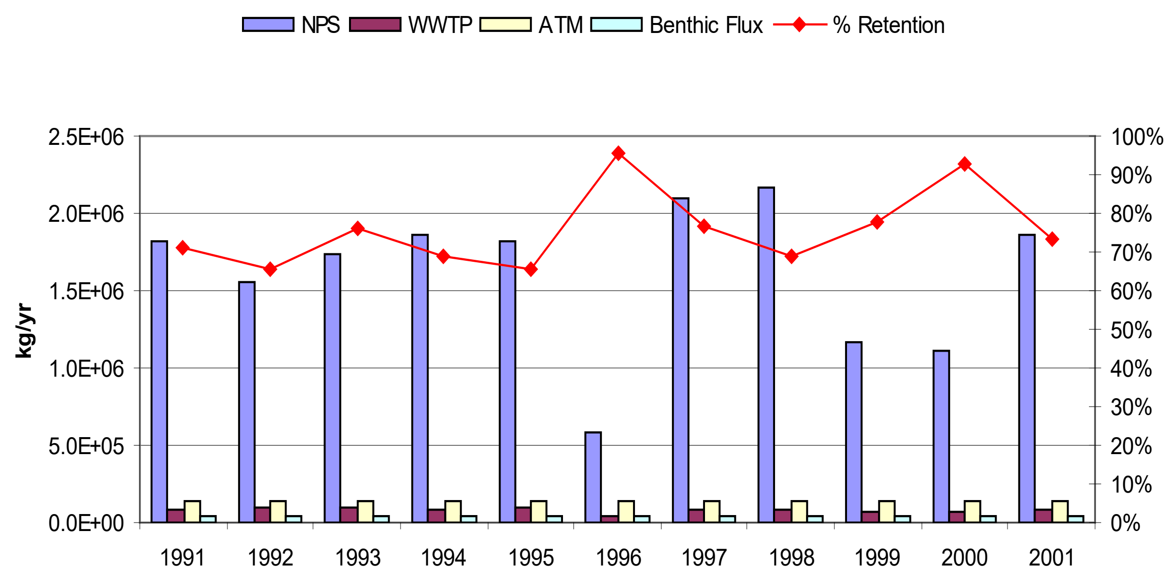


Figure 1.13 Cedar Creek Nutrient Budget – Total Nitrogen (1991-2001)

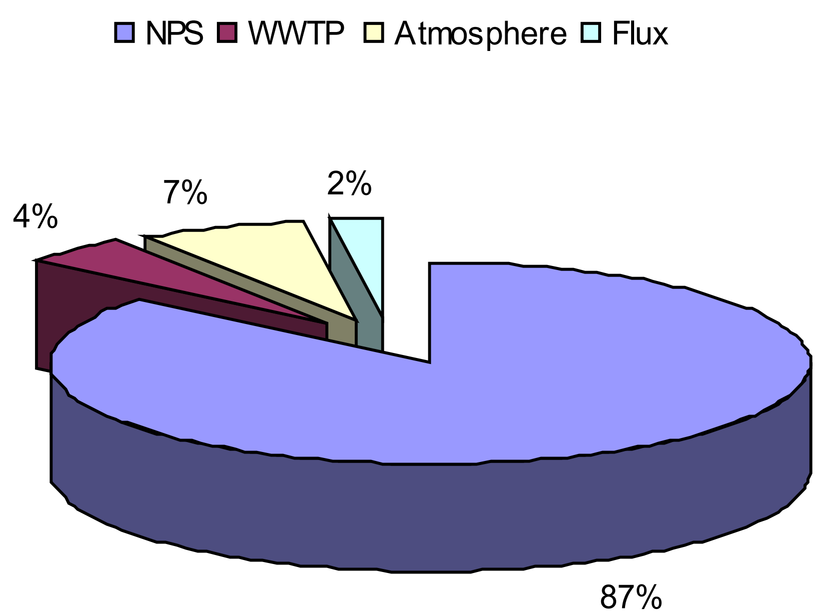


Figure 1.14 Cedar Creek Average 11-Year Total Nitrogen Budget

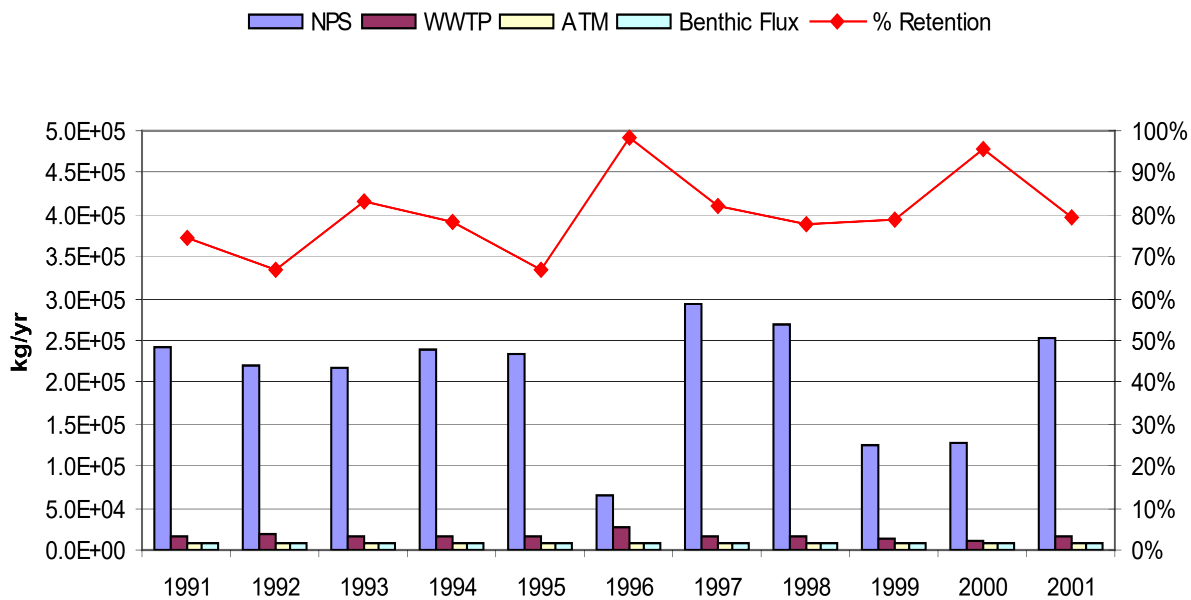


Figure 1.15 Cedar Creek Nutrient Budget – Total Phosphorus (1991-2001)

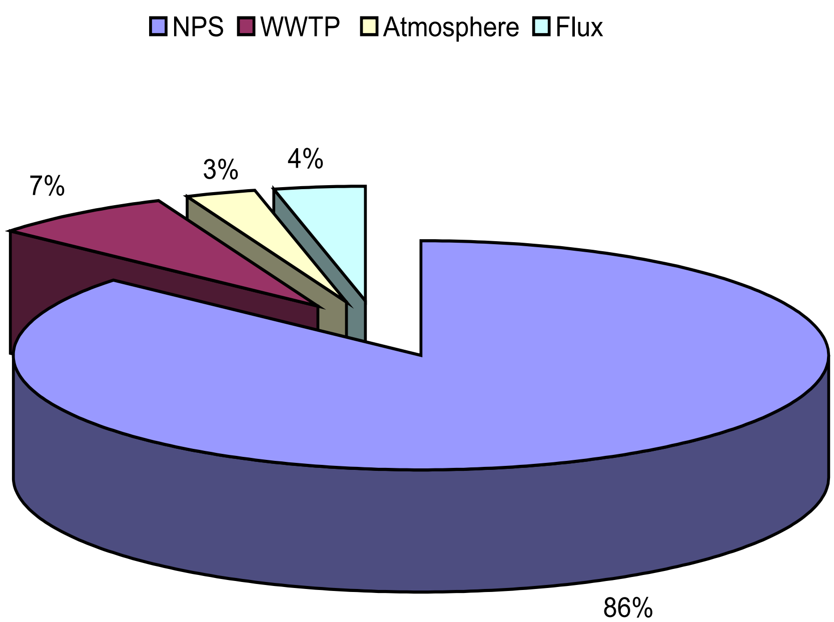


Figure 1.16 Cedar Creek Average 11-Year Total Phosphorus Budget Annual load of 224,000 kg/yr

1.7 Source Analysis to Drive Watershed Protection

Modeling of Cedar Creek Reservoir and the associated watershed using the SWAT and WASP models allowed watershed planners to conclude that reversing the rising trend of chlorophyll-*a* as driven by phosphorus loadings would management solution targeting non-point source pollution. Analysis determined that the areas of urban transition, cropland, and pasture produced the highest contributions to reservoir phosphorus loads. Armed with the necessary data to back this, watershed planners began development of a stakeholder-based watershed protection planning effort. The primary strategy of watershed planners was to solicit the advice to local agricultural producers, agency officials, and political leaders in the selection of palatable management practices for targeted areas of the watershed that would work to reduce nutrient and sediment loadings within the reservoir.

Additionally, the point source report of wastewater treatment plants allowed for the inclusion of local water utility operators in the planning effort. Although wastewater treatment operations are permitted and monitored by the Texas Commission on Environmental Quality, achievable reductions in the phosphorus content of plant discharge represented a crucial part of the management solution.
Stakeholders were briefed on the function of the SWAT and WASP computer models to ensure maximum confidence and support of the conclusions presented by watershed planners and to promote thoughtful discussion of current watershed conditions and possible solutions.

1.7.1 Utilizing Computer Modeling to Establish Water Quality Goals

To advance the development of formalized watershed protection efforts, modelers with TRWD performed WASP simulations with graduated reductions in watershed based phosphorus loadings to determine the impact upon Cedar Creek Reservoir water quality. Beginning with a proposed 25% reduction, modelers reduced the P loadings at increments of 5% until arriving at a 35% reduction. At this level, reservoir based chlorophyll-*a* trends began to level and, in time, begin to decrease. With stakeholder acceptance of a 35% reduction as a guiding principal, watershed planners set about crafting a proposed management solution that would meet this stated goal.

1 Description and Implementation of Management Measures

Creation of a comprehensive management plan to reduce phosphorus and sediment loadings requires the evaluation of existing practices to determine their effectiveness and appropriateness for Cedar Creek Watershed. Selection of best management practices began with the introduction of all practices for cropland, pasture, and urban areas to stakeholders. Work groups representing each of the aforementioned land uses vetted the various structural (built) and non-structural (behavioral change) practices approved for water quality improvement by the USDA- NRCS. Suggested measures were then put through an economic optimization model to determine practice efficiency for project dollar spent. The final result is a suite of 8 optimal best management practices allowing for maximum pollutant reduction and minimum project dollars spent to implement and maintain each installed practice through the life of the watershed protection plan. To verify the success of the management solution, the SWAT computer model forecasted watershed pollutant reductions for intervals of 3, 6, and 10 years. WASP modeling confirmed the targeted 35% phosphorus reduction for a management solution implementation period of 11 years (TRWD 2009).

1.1 Cropland Operations

Despite making up only 6.17% of the land use in the Cedar Creek Watershed, croplands due to current and historical use account for a large portion of the nutrient loadings. Of particular concern are the croplands located in the Kings Creek basin flowing though southern Rockwall and northwest Kaufman Counties (figure 3.1). In total, 42 percent of Phosphorus loadings and 23 percent of Nitrogen loadings originate on watershed croplands. Phosphorus and nitrogen-based fertilizers used in excess have been demonstrated to runoff from fields during rain events and are transported through the watershed resulting in a eutrophic cycle in which excessive nutrients spur the growth of aquatic plant life which blocks out sunlight to benthic organisms and food sources.

To assist in determining the proper placement for selected best management practices, SWAT modelers identified sub-basins within the watershed containing the largest concentrations of crop lands. Doing so has also allowed project leaders to predict the phosphorus, nitrogen, and sediment loadings coming out of each sub-basin. To support the management solution, agricultural producers within targeted sub-basins will be selected to partner on the installation of structural conservation practices.

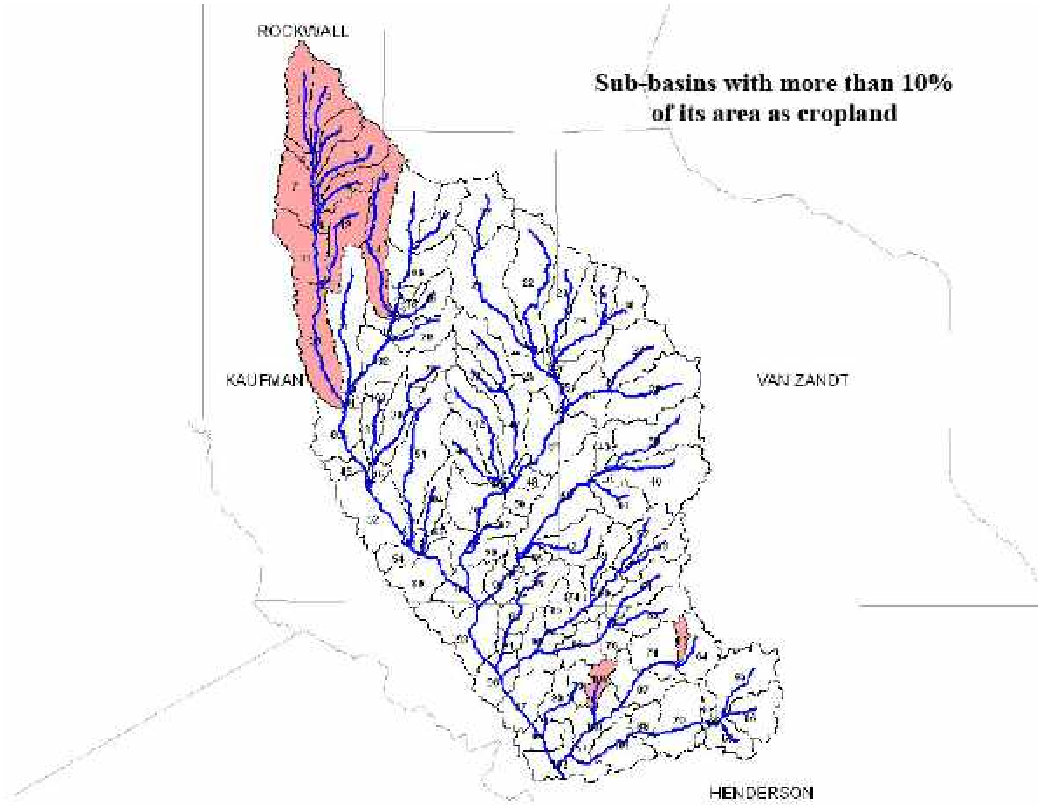


Figure 1.1 Cedar Creek Watershed sub-basins with 10% or more cropland (TAMU-SSL 2008)

1.1.1 Filter Strips

Filter strips are vegetated areas that are situated between surface water bodies (i.e., streams and lakes) and cropland, grazing land, forestland, or disturbed land (Figure 3.2). They are generally located where runoff water leaves a field with the intention that sediment, organic material, nutrients, and chemicals can be trapped or filtered from the runoff water. Specifically-designed vegetative strips slow runoff water leaving a field so that larger particles, including soil and organic material can settle out. Due to entrapment of sediment and the establishment of vegetation, nutrients can be absorbed into the sediment that is deposited and remain on the field landscape, enabling plant uptake (USDA-NRCS Conservation Practice Guide 2003).


Figure 1.2 Filter Strip (NRCS Online Photo Gallery).

The impact of installation of filter strips in targeted sub-basins is illustrated in Figure 3.3.

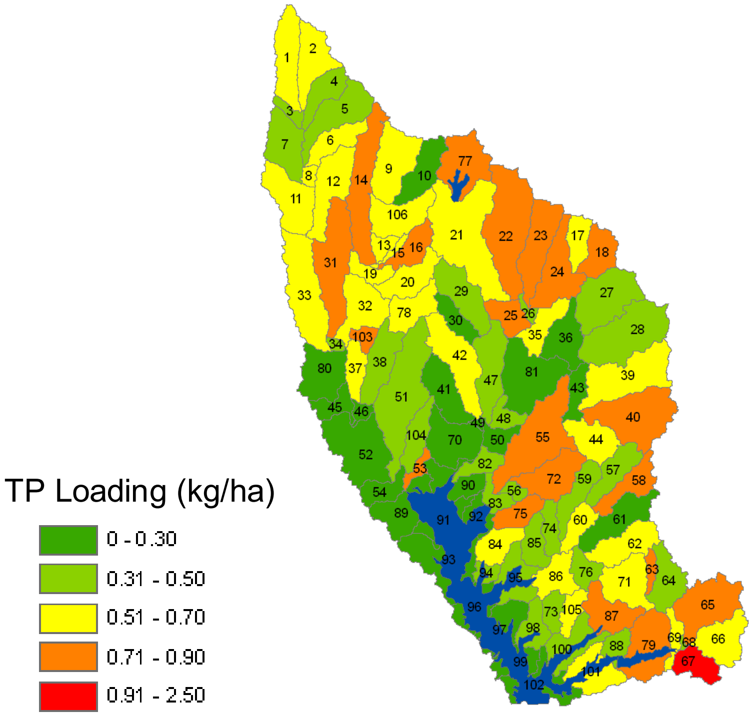


Figure 1.3 Cedar Creek Watershed sub-basin Phosphorus loadings after implementation of filter strips (TAMU-SSL 2009).

1.1.2 Grade Stabilization

Grade stabilization structures are constructed lakeside and streambank reinforcements placed to reduce erosion and sedimentation from steep embankments that are prone to soil loss during storm events. Structures must be logistically situated for maximum effectiveness. This practice must be strategically engineered from concrete, steel, or other fabricated material (Figure 1.4).

Figure 1.4 Cedar Creek Watershed sub-basin Phosphorus loadings after implementation of filter strips (TAMU-SSL 2009).

The impact of grade stabilization structure implementation on Cedar Creek Watershed sub-basins is illustrated in Figure 1.5.

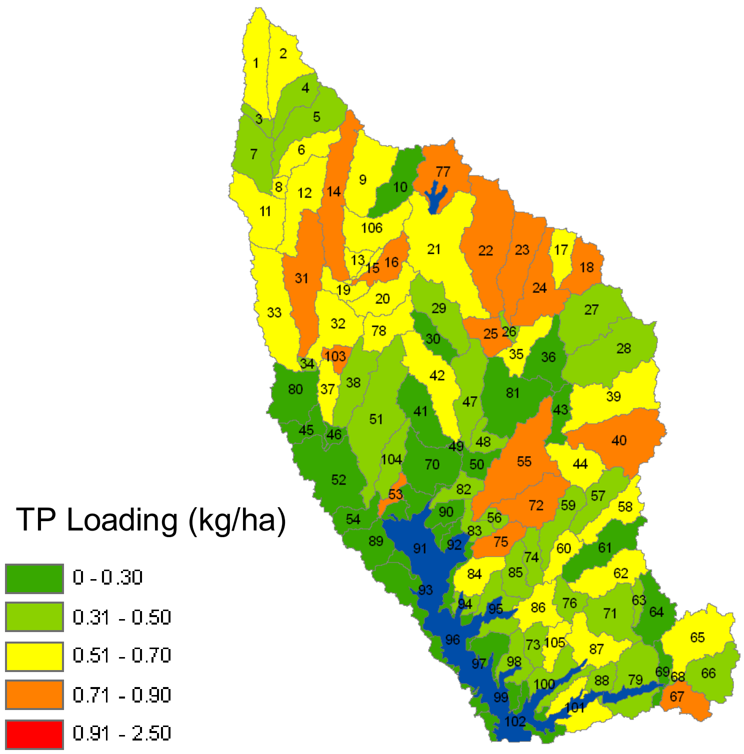


Figure 1.5 Cedar Creek Watershed sub-basin phosphorus loadings with filter strips and graded stabilization structures (TAMU-SSL 2009).

1.1.3 Grassed Waterways

Grassed waterways are natural or constructed channels established for the transport of concentrated flow at safe velocities using adequate vegetation. The vegetative cover slows the water flow, minimizing channel surface erosion. When properly constructed, grassed waterways can safely transport large flows of runoff down slopes (Figure 1.6). The vegetation improves the soil aeration and water quality due to its nutrient removal through plant uptake and sorption by the soil (USDA-NRCS Conservation Practice Guide 2003).

Figure 1.6 Grassed Waterway (NRCS Online Photo Gallery).

The cumulative effect of grassed waterways combined with filter strips and grade stabilization structures on Cedar Creek Watershed sub-basins is shown in figure 1.7.

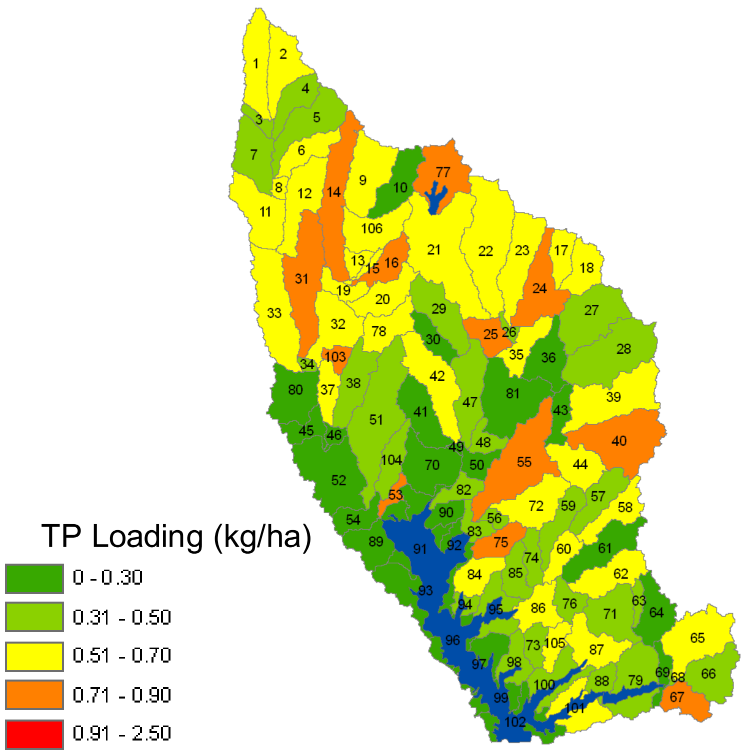


Figure 1.7 Cedar Creek Watershed sub-basin phosphorus loadings with filter strips, graded stabilization structures, and grassed waterways (critical area planting) (TAMU-SSL 2009).

1.1.4 Terracing

Terraces are series of earthen embankments constructed across fields at designed vertical and horizontal intervals based on land slope, crop rotation, and soil conditions (Figure 3.8). Construction of terraces involves a heavy capital investment to move large quantity of earth for forming earthen embankments. Hence terracing should be considered only if other low-cost alternates are determined to be ineffective. Terracing is recommended for land with a grade of 2% percent or higher. (USDA-NRCS Conservation Practice Guide 2003)

Figure 1.8 Terracing. (NRCS Online Photo Gallery)

The cumulative effect of filter strips, grade stabilization structures, grassed waterways, and terracing on Cedar Creek Watershed sub-basins is illustrated in figure 1.9.

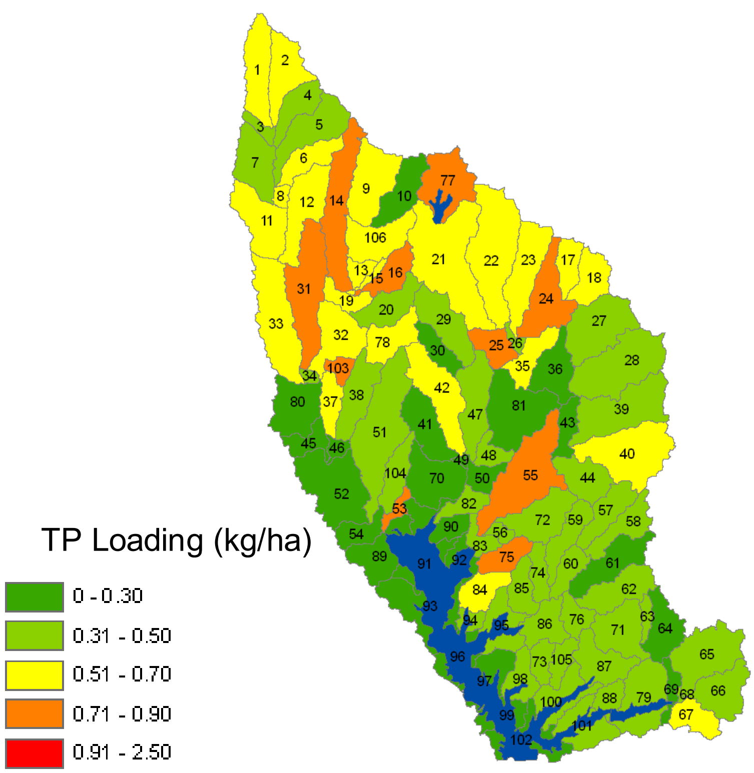


Figure 1.9 Cedar Creek Watershed sub-basin phosphorus loadings with filter strips, graded stabilization structures, grassed waterways (critical area planting), and terracing (TAMU-SSL).

1.1.5 Pasture and Range Planting (Conversion of Cropland to Pasture)

The planting of pastures and crop lands with native or introduced vegetation allows for reduction and absorption of nutrients (Figure 3.10). Grass, forbs, legumes, shrubs and trees work to restore a plant community similar to historically natural conditions yet sensitive to the nutritional needs of livestock and native species. Further, native or introduced forage species that are well adapted to North Central Texas could be planted periodically to maintain a dense vegetative cover and improve the hydrologic condition of the farmlands (USDA-NRCS Conservation Practice Guide 2003).

Figure 1.10 Pasture Planting. (NRCS Online Photo Gallery)

The cumulative effect of filter strips, grade stabilization structures, grassed waterways, terracing, and pasture planting on Cedar Creek Watershed sub-basins is illustrated in figure 1.11.

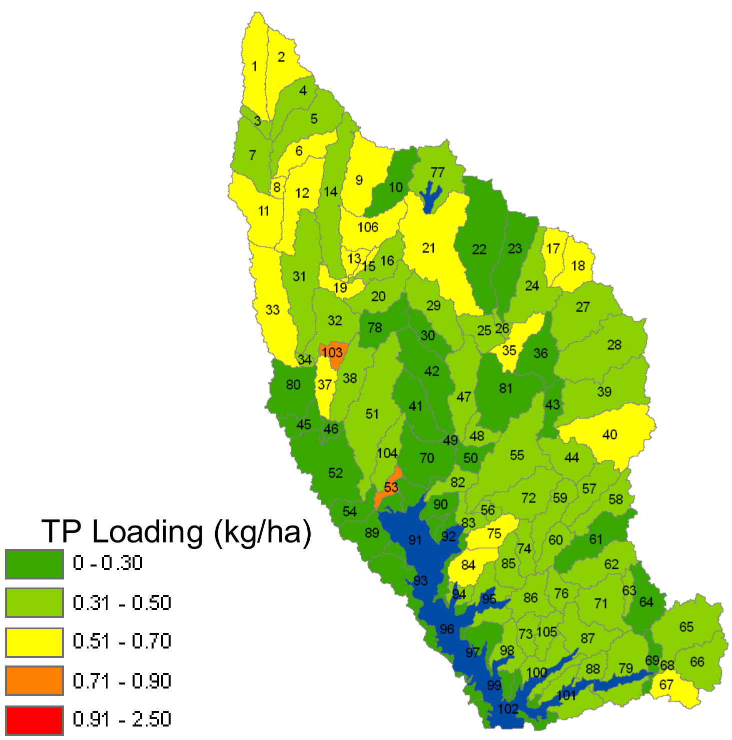


Figure 1.11 Cedar Creek watershed sub-basin P loadings with filter strips, graded stabilization structures, grassed waterways (critical area planting), terracing, and cropland conversion to pasture (TAMU-SSL 2009).

1.1.6 Pasture and Rangeland

Rangelands and pasturelands account for the majority landuse within the Cedar Creek Watershed (figure 1.12). While nutrient and sediment loads are significantly reduced by the use of land for pasture (in comparison to urban and cropland), the abundance of pastureland and rangeland still mandate serious consideration of practices to mitigate water quality concerns. Additionally, overgrazing of pasture and rangeland reduces the vegetative cover needed to filter nutrients and trap sediment during a rain event. As with the identification of targeted cropland areas, SWAT modelers have produced a map of watershed subbasins with high concentrations of pasture to assist in the selection of locations for potential best management practices.

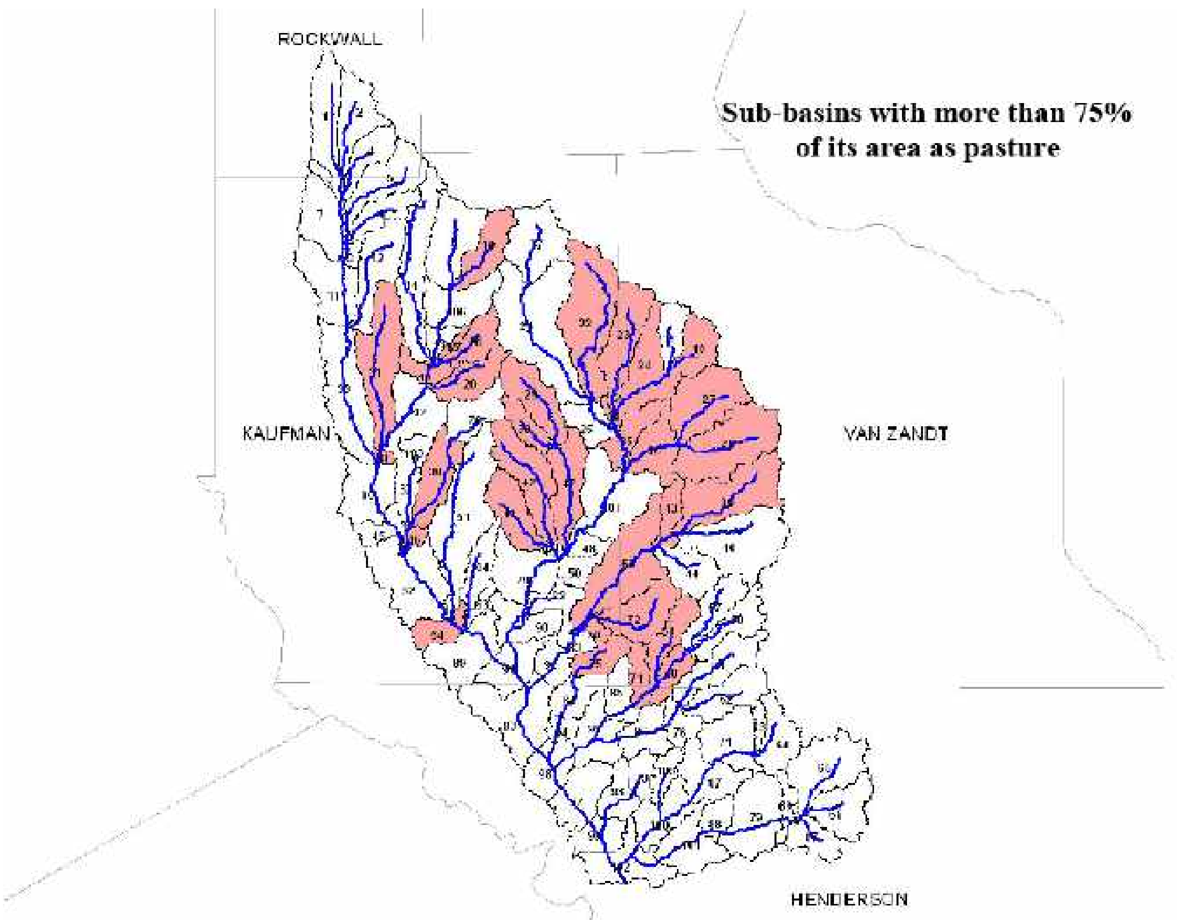


Figure 1.12 Cedar Creek Watershed sub-basins with 75% or more pasture (TAMU-SSL 2008).

1.1.7 Prescribed Grazing

Prescribed, or rotational, grazing manages the controlled harvest of vegetation with livestock to improve or maintain the desired species composition and vigor of plant communities, which improves surface and subsurface water quality and quantity.

Prescribed grazing also includes the combined use of fencing and stock watering facilities as shown in figure 1.13 (USDA-NRCS Conservation Practice Guide 2003).

Figure 1.13 Prescribed Grazing (NRCS Online Photo Gallery).

Figure 1.14 is an illustration of the cumulative effects of filter strips, graded stabilization structures, grassed waterways (critical area planting), terracing, and cropland conversion to pasture, and prescribed grazing

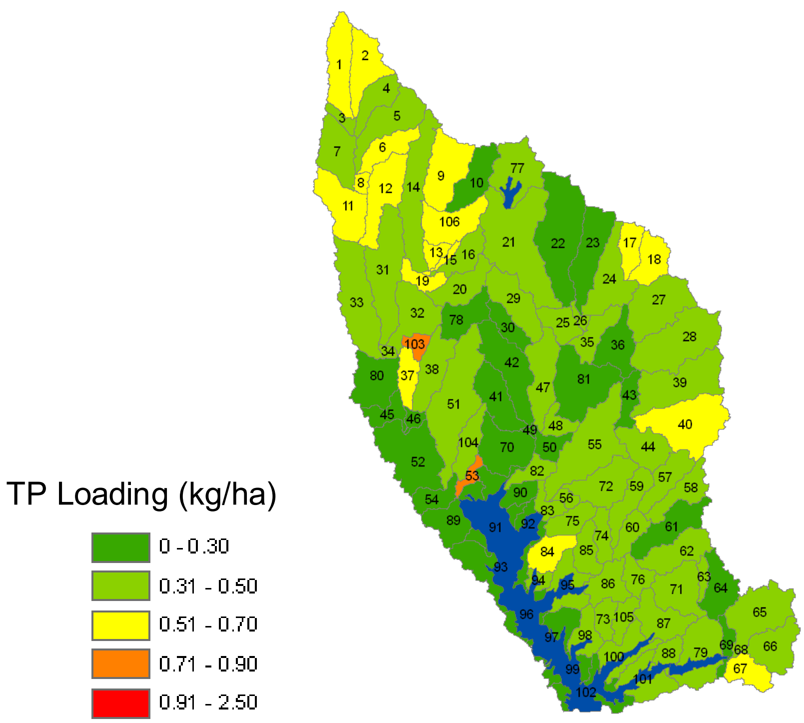


Figure 1.14 Cedar Creek watershed sub-basin phosphorus loadings with filter strips, graded stabilization structures, grassed waterways (critical area planting), terracing, and cropland conversion to pasture, and prescribed grazing (TAMU-SSL 2009).

1.2 Urban Stormwater Management

Because of the limited and geographically-dispersed populations of many of the watershed municipalities, members of the urban workgroup have recommended a strategy of working to implement rules and ordinances on a county or watershed level. Such measures would include regulation of construction and road improvement practices, regular inspection and repair of on-site sewage facilities, and restrictions on the fertilization and irrigation of large properties such as city-owned athletic complexes.

Another proposed strategy is to focus primarily on communities adjacent to Cedar Creek Reservoir to restrict fertilizer use among residents. This suggestion has been played out in the management proposal of a 2,000 foot buffer strip surrounding the Reservoir in which fertilizer and pesticide use can be restricted.

1.2.1 2000 Foot buffer Strip Surrounding Lake (Urban Nutrient Management)

This proposed practice seeks to regulate the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize urban nonpoint source pollution of surface and groundwater resources. The practice encourages the limited use of phosphorus-based fertilizers, proper blends of fertilizers to be available to watershed consumers, and the encouragement of landscaping techniques that require limited fertilizer and irrigation (USDA-NRCS Conservation Practice Guide 2003).

Figure 1.15 provides an illustration of the combined effects of Phosphorus reduction on Cedar Creek Watershed sub-basins.

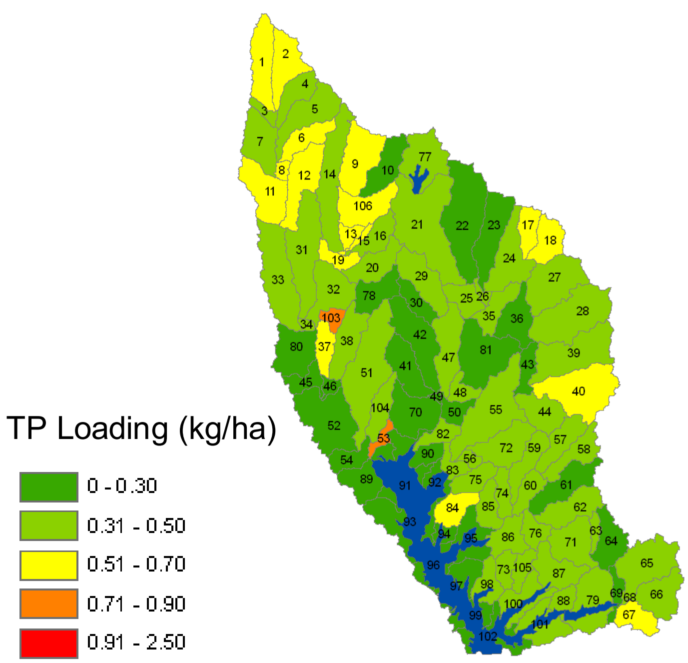


Figure 1.15 Cedar Creek watershed sub-basin phosphorus loadings with filter strips, graded stabilization structures, grassed waterways (critical area planting), terracing, cropland conversion to pasture, prescribed grazing, and establishment of a 2000 foot nutrient management buffer surrounding the reservoir (TAMU-SSL 2009).

1.2.2 City-Specific Wastewater Treatment Plant Management Measures

As the population of the Cedar Creek Watershed has expanded, so too has the demand for wastewater treatment facilities. Modeling of wastewater treatment plant discharges and recommended upgrades for the watershed plan are based on the nine plants in operation (figure 3.16) and evaluated in a 2007 Alan Plummer Associates, Inc. report. Point source discharges from wastewater treatment plants are regulated by the Texas Commission on Environmental Quality as part of a regulation and permitting process. A proposed series of graduated improvements to each operating plant has been outlined by the environmental engineering firm of Alan Plummer Associates, Inc. following extensive surveys of the outflows (table 3.1) and infastructure of each plant. The proposed structural improvements will allow each plant to reduce pollutant discharges beyond current permit requirements. It is possible that in the future as watershed populations grow, the associated addition of new wastewater treatment plants will mandate that upgrades be made to existing plants to maintain more rigorous discharge standards.

The following are proposed management measures necessary to achieve the following targeted Phosphorus load reductions for Cedar Creek Watershed Wastewater Treatment Plants:

Level I Current Phosphorus Level for individual plant (Table 3.1)
Level II Maximum of 1.0 mg/L Phosphorus
Level III Maximum of .5 mg/L Phosphorus

Figure 1.16 Wastewater Treatment Plant Locations in Cedar Creek Watershed (APAI 2008).

Table 1.1Statistical Data for Cedar Creek Watershed Wastewater Treatment Plants (APAI 2008)

Plant	Population Served (2005)	Average Daily Flow (MGD) (2005)	Average TSS (mg/L)	Average TP (mg/L)	Average TN (mg/L)
Athens North	12,390	.42	8.7	2.85	13.53
Cherokee Shores	1,730	.09	18.3	4.3	37.8
East Cedar Creek	7,150	ND	ND	2.17	23.38
Eustace	839	.06	73.9	4.92	23.63
Kaufman	7,300	.62	1.6	2.85	13.53
Kemp	1,133	.1	11.7	3.18	14.36
Mabank	2,400	.24	46.8	3.89	11.77
Terrell	14,379	2.8	7.7	4.03	19.71
Wills Point	3,700	.38	79	2.64	12.03

In coordinating this evaluation, the engineering firm Alan Plummer Associates, Inc. established the necessary best management practices and associated costs to achieve three different effluent levels (table 3.2). Sources of information for the evaluations included site visits, interviews with plant personnel, reviews of existing plans and historical reports, data collected by plant personnel for Tarrant Regional Water District, data acquired through the Texas Commission on Environmental Quality (TCEQ), and responses to a questionnaire developed specifically for the Cedar Creek Watershed Protection Plan.

Table 1.2 Recommended Upgrades for Cedar Creek Wastewater Treatment Plants (APAI 2008).

Plant	Projected Flows	Level I	Level II
Athens	North WWTP 2005 = 0.50 2010 = 0.54 2020 = 0.65 2030 = 0.78 2040 = 0.94 2050 = 1.14	Expand influent pumping system, replace tricking filter rock media with plastic media, duplicate aeration basin and aeration, and double drying bed size.	Add denitrifying filter to meet TN limit and alum addition for P removal.
Cherokee Shores	2005 = 0.08 2010 = 0.09 2020 = 0.11 2030 = 0.13 2040 = 0.15 2050 = 0.18	Existing facility is capable of treating the projected flows through the year 2050.	Add alum addition for P removal, a denitrifying filter for N reduction, and an in line mixer.
East Cedar Creek	2005 = 0.71 2010 = 0.82 2020 = 1.00 2030 = 1.17 2040 = 1.36 2050 = 1.60	Once treatment units are optimized, expansion required between 2030 and 2040. Add oxidation ditch, clarifier, filter, and chlorine contact basin.	Operate oxidation ditch for denitrification. Alum addition for P removal.
Eustace	2005 = 0.084 2010 = 0.088 2020 = 0.097 2030 = 0.106 2040 = 0.115 2050 = 0.126	Add two 15 hp aerators, clarifier, RAS/WAS pumps and piping, and disinfection system.	Add alum for P removal.
Kaufman	2005 = 0.73 2010 = 0.83	Convert existing aeration system to fine bubble	Denitrifying filter to meet TN limit. Alum

	2020 = 1.09 2030 = 1.30 2040 = 1.47 2050 = 1.65	diffusers instead of adding aeration basins. Expand WAS and RAS system. Add IFAS to aeration basins, add final clarifier, and additional ultraviolet disinfection equipment.	addition required for P removal.
Kemp	2005 = 0.113 2010 = 0.113 2020 = 0.113 2030 = 0.113 2040 = 0.113 2050 = 0.113	Existing facility is capable of treating the projected flows through the year 2050.	Operate oxidation ditch for denitrification. Alum addition for P removal. May require additional drying beds for alum sludge.
Mabank	2005 = 3.23 2010 = 3.42 2020 = 4.19 2030 = 4.87 2040 = 5.32 2050 = 5.76 3	Expansion required between 2030 and 2040. Expand headworks and pumping capacity. Add aerators to stabilization ponds and uprate the bio-tower. Add chlorine disinfection and drying beds.	Maintain pond volume for N removal and add alum for P removal.
Plant	**Projected Flows**	**Level I**	**Level II**
Terrell	2005 = 3.23 2010 = 3.42 2020 = 4.19 2030 = 4.87 2040 = 5.32 2050 = 5.76 3	Expansion required between 2020 and 2030. Add additional headworks with screens and grit removal. Add influent pump capacity, Sequencing Batch Reactors and sand filters. Expand chlorine contact basin and add gravity belt thickener.	Add denitrifying filters to existing treatment train. Optimize SBRs for denitrification. Alum addition for P removal.
Wills Point	2005 = 0.37 2010 = 0.39 2020 = 0.42 2030 = 0.46 2040 = 0.48 2050 = 0.51	Once current expansion is complete, facility is capable of treating the projected flows through the year.	Operate ponds for de-nitrification, and dredge ponds to maintain volume. Add earthen pond divider. Alum addition for P removal.

1.3 Cumulative Effects of BMP Implementation

Project leaders turned to SWAT modeling to better understand the cumulative effect of combining each of the selected BMPs to the targeted sub-basins. In doing so practices were ranked according to their appropriateness for targeted areas and cost performance for phosphorus removal. This allowed for verification that the outlined strategy would result in the targeted 35% phosphorus reduction goal.

Table 1.3 Pollutant Reduction percentages for optimal eight best management practices (TAMU-SSL 2009)

Pollutant Reduction	Total P	Total N	Sediment
Baseline	188670 tons 171,158,545 kg	1419380 tons 1,287,639,876 kg	450000 tons 408,233,133 kg
with FS Reduction(%)	14.2%	9.8%	8.3%
w/FS + GSS	16.1%	11.5%	10.8%
w/FS +GSS+GWP	17.1%	13.4%	11.9%
w/FS+GSS+GWP+TR	21.4%	14.0%	16.3%
w/FS+GSS+GWP+TR+WWTP	25.9%	15.6%	16.3%
w/FS+GSS+GWP+TR+WWTP+CP	31.7%	18.6%	20.0%
w/FS+GSS+GWP+TR+WWTP+CP+PG (15.5%)	32.8%	21.4%	21.3%
w/FS+GSS+GWP+TR+WWTP+CP+PG (25%)	33.1%	22.7%	21.8%
w/FS+GSS+GWP+TR+WWTP+CP+PG (25%)+BUF	34.6%	25.5%	21.2%
TOTAL POLLUTANT REMOVAL	123480 tons 112,019,172 kg	1057260 tons 959,130,138 kg	354600 tons 321,687,709 kg

1.4 Management Measures Eliminated from Consideration

Stakeholder preferences, land use, topography, and other considerations allowed project leaders and stakeholders to eliminate several proposed conservation practices from consideration for the Cedar Creek Watershed Plan. However, many of these practices may be revisited should watershed conditions change and are represented in this report to serve as a contextual reference for other watershed protection planning efforts.

1.4.1 Contour Farming

Contour farming (figure 1.17) is a method of row cropping that utilizes the natural topography of the land in such a manner as to reduce erosion and pollutant loadings. Study of the contour and slope is necessary to promote the slowing and capture of drainage into rivers and lakes. Contour farming involves performing critical farming operations (tillage, planting and other operations that disturb the soil) along the contour of the field. Contour farming practices must be placed in lands that possess a 2% or higher slope (USDA-NRCS Conservation Practice Guide 2003).

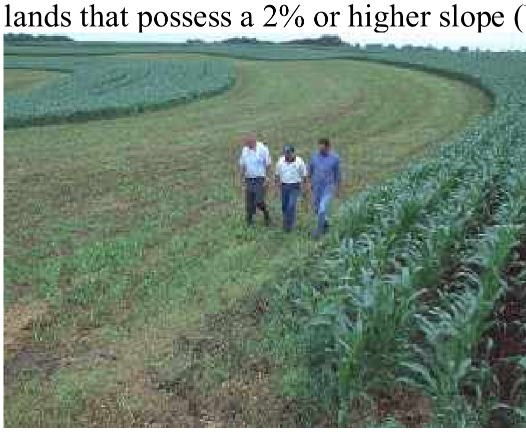


Figure 1.17 Contour Farming. (NRCS Online Photo Gallery).

1.4.2 Fertilizer/ Nutrient Management

This practices works to manage 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. Preliminary soil testing is an important element of nutrient management. The practice encourages the budget and supply of nutrients for plant production, and proper utilization of manure and organic by-products (USDA-NRCS Conservation Practice Guide 2003).

Figure 1.18 Fertilizer and Nutrient Management (NRCS Online Photo Gallery).

1.4.3 Urban Nutrient Management

Education and outreach programming works to encourage stakeholders to control the effects of landscaping and lawn care practices (figure 3.19) on stormwater. Lawns produce significant amounts of nutrient-rich runoff that can potentially cause eutrophication in streams, lakes, and estuaries. Pesticide runoff can contaminate drinking water supplies with chemicals toxic to both humans and aquatic organisms.

Figure 1.19 Urban Nutrient Management (NRCS Online Photo Gallery).

1.4.4 Riparian Buffer Strips, all except critical area and Riparian Buffer Strips, only in Critical Areas

A riparian area is a fringe of land that occurs along the stream or water course with grass and herbaceous cover. If the riparian buffer is not adequately established and farming activities occur near the edge of the stream, the banks may become unstable, resulting in significant sloughing and channel scour. Establishing and maintaining a good riparian buffer (figure 3.20). may require fencing as a complimentary management practice to ensure the establishment of the buffer. (USDA-NRCS Conservation Practice Guide 2003)

Figure 1.20 Riparian Buffer (NRCS Online Photo Gallery).

1.4.5 Wetland Creation at the end of lower Kings Creek and Wetland Creation at the end of Cedar Creek

Constructed wetlands provide a sediment retention and nutrient removal system utilizing natural chemical, physical, and biological processes involving wetland vegetation, soils, and their associated microbial populations to improve water quality (figure 3.21). Constructed wetlands are designed to use water quality improvement processes occurring in natural wetlands, including high primary productivity, low flow conditions, and oxygen treatment to anaerobic sediments. Nutrient retention in wetlands systems occurs via sorption, precipitation, and incorporation. (USDA-NRCS Conservation Practice Guide 2003)

Figure 1.21 Constructed Wetland (NRCS Online Photo Gallery).

1.4.6 Reservoir-based Management Measures

A small handful of measures can be taken at the reservoir level to mitigate the effect of pollutant loadings on the water bodies. While effective, these practices can be expensive and do not work to address the issue of watershed based pollutants.

Hypolimnetic Aeration

Water column mixing utilizes the thermal properties of the reservoir to settle sediments and nutrients, preventing their transport via a mechanized system of mixing the water 9fgure 3.22).

This practice is accomplished by utilizing mechanical apparatus at strategic locations within the reservoir.

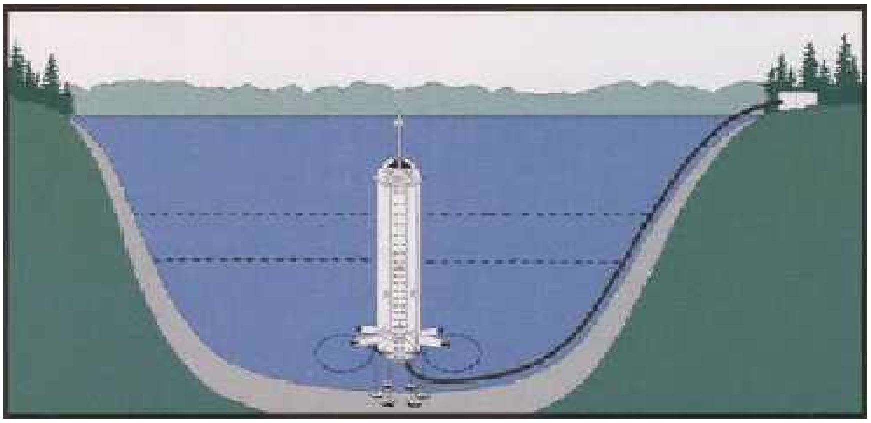


Figure 1.22 Hypolimnetic aeration (Airation.com 2009).

P Inactivation with Alum

The addition of powdered alum at various lake depths is designed to suppress the mixing and transport of phosphorus and nitrogen. Alum is a chemical treatment of storm water runoff entering a wet pond by injecting liquid alum into storm sewer lines on a flow-weighted basis during rain events. Alum works by "settling out" pollutants and sediments at the bottom of water bodies, preventing the transport and utilization of nutrients, pathogens, and metals.

Hypolimnetic Water Release from Reservoir

The stratification of thermal layers within the reservoir allow for the settling of phosphorus and sediments in the lower layers. The release of thermal layers of water with higher concentrations of pollutants prevent the adverse effects such as eutrophication and loss of reservoir storage volume.

1.4.7 All nine WWTP from Level I to Level III quality status

Level III status requires the adoption of Level II measures with the addition of those listed to reduce Phosphorus outflows from 1.0 mg/ liter to .5 mg/ liter. The requirements to accomplish these proposed standards are listed in the table below in table 3.5.

Table 1.4 City-Specific WWTP Management Measures. (APAI 2008).

Plant	Projected Flows	Level I	Level II	Level III
Athens	North WWTP 2005 = 0.50 2010 = 0.54 2020 = 0.65 2030 = 0.78 2040 = 0.94 2050 = 1.14	Expand influent pumping system, replace tricking filter rock media with plastic media, duplicate aeration basin and aeration, and double drying bed size.	Add denitrifying filter to meet TN limit and alum addition for P removal.	Add carbon source for denitrification, and increase alum dosage for lower P limit. Equipment is already in place.

Cherokee Shores	2005 = 0.08 2010 = 0.09 2020 = 0.11 2030 = 0.13 2040 = 0.15 2050 = 0.18	Existing facility is capable of treating the projected flows through the year 2050.	Add alum addition for P removal, a denitrifying filter for N reduction, and an in line mixer.	Add carbon source for denitrification, and increase alum dosage for lower P limit.
East Cedar Creek	2005 = 0.71 2010 = 0.82 2020 = 1.00 2030 = 1.17 2040 = 1.36 2050 = 1.60	Once treatment units are optimized, expansion required between 2030 and 2040. Add oxidation ditch, clarifier, filter, and chlorine contact basin.	Operate oxidation ditch for denitrification. Alum addition for P removal.	Denitrifying filter to meet TN limit. Add carbon source for denitrification and additional alum for lower P limit
Eustace	2005 = 0.084 2010 = 0.088 2020 = 0.097 2030 = 0.106 2040 = 0.115 2050 = 0.126	Add two 15 hp aerators, clarifier, RAS/WAS pumps and piping, and disinfection system.	Add alum for P removal.	Denitrifying filter to meet TN limit, and additional carbon source for denitrification. Additional alum for lower P limit.
Kaufman	2005 = 0.73 2010 = 0.83 2020 = 1.09 2030 = 1.30 2040 = 1.47 2050 = 1.65	Convert existing aeration system to fine bubble diffusers instead of adding aeration basins. Expand WAS and RAS system. Add IFAS to aeration basins, add final clarifier, and additional ultraviolet disinfection equipment.	Denitrifying filter to meet TN limit. Alum addition required for P removal.	Add carbon source for denitrification, and additional alum for lower P limit.
Kemp	2005 = 0.113 2010 = 0.113 2020 = 0.113 2030 = 0.113 2040 = 0.113 2050 = 0.113	Existing facility is capable of treating the projected flows through the year 2050.	Operate oxidation ditch for denitrification. Alum addition for P removal. May require additional drying beds for alum sludge.	Add denitrifying filter to meet TN limit, carbon source for denitrification and additional alum for lower P limit.
Plant	**Projected Flows**	**Level I**	**Level II**	**Level III**
Mabank	2005 = 3.23 2010 = 3.42 2020 = 4.19 2030 = 4.87 2040 = 5.32 2050 = 5.76 3	Expansion required between 2030 and 2040. Expand headworks and pumping capacity. Add aerators to stabilization ponds and uprate the bio-tower. Add chlorine disinfection and drying beds.	Maintain pond volume for N removal and add alum for P removal.	Add denitrifying filter to meet TN limit, carbon source for denitrification and additional alum for lower P limit.

Terrell	2005 = 3.23 2010 = 3.42 2020 = 4.19 2030 = 4.87 2040 = 5.32 2050 = 5.76 3	Expansion required between 2020 and 2030. Add additional headworks with screens and grit removal. Add influent pump capacity, Sequencing Batch Reactors and sand filters. Expand chlorine contact basin and add gravity belt thickener.	Add denitrifying filters to existing treatment train. Optimize SBRs for denitrification. Alum addition for P removal.	Carbon source for denitrification and additional alum for lower P limit.
Wills Point	2005 = 0.37 2010 = 0.39 2020 = 0.42 2030 = 0.46 2040 = 0.48 2050 = 0.51	Once current expansion is complete, facility is capable of treating the projected flows through the year.	Operate ponds for denitrification, and dredge ponds to maintain volume. Add earthen pond divider. Alum addition for P removal.	Denitrifying filter to meet TN limit, with possible additional carbon source. Additional alum for lower P limit.

1.5 Economic Performance Analysis for Selected Best Management Practices

The objective of performing an economic performance analysis of the Cedar Creek Watershed Protection Plan is to identify the most economical (i.e., least-cost) means of reducing (and/or preventing) phosphorus (P), nitrogen (N), and sediment (Sed) inflows into the Cedar Creek Reservoir and assist in facilitating the development of a sustainable, scientifically-based, and economically-feasible watershed protection plan. Management and consulting engineers estimate current annual P, N, and Sed inflows of (a) 208, (b) 1,565, and (c) 496,035 English tons (ET), respectively, and they advise substantial reductions of these inflows are required to meet water quality standards outlined for the project. Specifically, a 35% reduction in annual P inflows is targeted. During 2002-2009, Texas AgriLife Extension Service and Texas AgriLife Research scientists, in conjunction with Tarrant Regional Water District (TRWD) managers, Natural Resources Conservation Service (NRCS) professionals, and others worked to identify a portfolio of Best Management Practices (BMPs) capable of contributing to such reductions. Economists' responsibilities consist of translating the nutrient/sediment reduction information, related costs, and associated benefits for the respective BMPs (as identified by other team members) into a "Most Economical Best Management Practices" (MEBMP) portfolio.

1.5.1 Modeling

The modeling framework for this project, which integrates and facilitates use of the various features of the described economics methodology, is designated BMPEconomics©. Utilization of the Soil and Water Assessment Tool (SWAT) and Water Quality Analysis Simulation Program (WASP) modeling techniques has enabled the project team to integrate land use features of the Cedar Creek Reservoir Watershed and reservoir dynamics (nutrient fate and transport, flux, and evapotranspiration) with the economic and financial considerations of BMPEconomics© to provide the basis for a feasible, comprehensive watershed protection plan.
Daily mass loadings and inflows from the SWAT model were supplied to the WASP model to simulate the reservoir water quality The WASP model was applied in the Cedar Creek planning efforts to systematically estimate the necessary P load reductions that would result in a statistically-significant reduction in Chlorophyll-*a*.

Two research modeling components are required to develop useful economic information for TRWD's management and to identify and enable implementation of the most cost-efficient strategies for reducing the objectionable inflows into the Cedar Creek Reservoir: (a) economic and financial cost analyses for each of the viable BMPs (termed Challenger BMPs hereafter), and (b) identifying optimal MEBMP portfolios of the Challenger BMPs. Economists' (and others') in-depth understanding of the problem and collaborative merging with the technical capabilities of team members are essential for the success of these economic components.

1.5.2 Data Assimilation

A first step toward realizing the objective of a desired 35% reduction in P inflows is to review all of the BMPs identified for consideration by other aspects of the Cedar Creek Reservoir Watershed project and to eliminate practices for which there is a consensus (among the NCTXWQ team members,TRWD management, and stakeholders) that (a) duplications (or inferiorities) exist with regards to other BMPs being evaluated, or (b) their technical and/or economic feasibility is very improbable. Following such a general, but organized, objective "sifting," an array of economic and financial information is identified and organized for each Challenger BMP remaining as a candidate for TRWD's consideration, including:

- reduction impacts on P, N, and Sed inflows expressed in the same units, i.e., as a total percent of the overall target per individual item or total of items comprising the BMP;
- expected life (i.e., years of productive reduction in P, N, and/or Sed) for the total BMP; construction period, i.e., when will reduction impacts in P, N, and Sed inflows begin – what length of time is required to construct and implement the BMP;
- initial investment costs required (i.e., construction or program implementation costs);
- recurring annual operating and maintenance costs;
- timing (i.e., expected useful life) and associated costs of intermittent capital replacement required to insure each BMP attains its expected useful life;
- current level of implementation and likelihood of additional adoption;
- appropriate inflation rate by which to increase future years' costs; and
- any inducement payments required for affected entities and/or individuals to encourage/secure their participation.

In the process of identifying appropriate initial construction, maintenance, and intermittent capital replacement costs (during a series of meetings with North Central Texas Water Quality project team members and stakeholders), several of the original BMPs were eliminated from further consideration. The respective BMPs were eliminated due to perceived technical infeasibilities, apparent redundancies (or explicit incorporation, e.g., educational programs, soil testing) with other BMPs considered, excessively high costs, and/or lack of substantive information to support economic analyses.

The BMPs remaining after the "sifting" process were labeled as "Challengers." SWAT analyses were conducted for each individual Challenger BMP in those sub-watershed areas in which the respective BMPs were considered feasible. Potential sub-watershed areas (hectares/acres) of implementation within the total watershed were identified in these analyses, accompanied by an estimate of the potential overall reduction in P, N, and Sed inflows into Cedar Creek Reservoir associated with each BMP. For selected BMPs (those affiliated with the Reservoir-in-Lake category), WASP modeling was used to identify their respective effectiveness levels. For the composite "urban suite" BMP in the Urban category, TRWD management and project economists extrapolated effectiveness levels from journal-published research. For the wetland BMPs in the Watershed category, SWAT analyses were modified by TRWD management and project economists to reflect expected operation procedures such as harvest of nutrient-rich plants and upkeep of the wetlands. The Challenger BMPs are identified in **Table 1.5.**

Subsequently, the sub-watershed areas potentially affected by each of the Challenger BMPs were reviewed and revised according to estimates of (a) current existing occurrences of the BMPs within the watershed, (b) maximum possible adoption rates, and (c) perceived "most-likely" marginal adoption rates by the appropriate decision makers within the Cedar Creek Reservoir Watershed. Adequate funding was assumed to be available for the construction and maintenance of the respective BMPs through a 50-year planning horizon. Project team members, joined by several agricultural stakeholders and their advisors, participated in the Delphi technique interview process to review these estimates. The Delphi process involved interviewing several of the noted experts repeatedly until a consensus was reached, representing what is perceived as the most accurate information possible under the project's existing funding and time constraints. Identified during these discussions were levels of monetary incentive payments that would be required to induce landowners to participate in implementing the various agricultural BMPs. Following the elicitation of the above-noted probable Challenger BMP adoption rates and the associated revisions of the areas potentially affected, the original SWAT and WASP estimates were adjusted to reflect each BMP's ability to reduce P, N, and Sed inflows into the Cedar Creek Reservoir.

Table 1.5 Challenger BMPs Identified for Cedar Creek Watershed Protection

AGEC BMP Number	NCTXWQ BMP Number	NRCS Practice Number	BMP Category	Description
1	#001	#512	Cropland	Conversion of Cropland to Grass
2	#001A	#330	Cropland	Contour Farming
3	#003	#590	Cropland	Fertilizer/ Nutrient Mgmt
4	#004	#393	Cropland	Filter Strip
5	#006	#412	Cropland	Grassed Waterway in Critical Cropland Areas
6	#007	#600	Cropland	Terracing
7	#101	#528	Pasture & Rangeland	Prescribed Grazing
8	#105	#512; #528	Pasture & Rangeland	Pasture Planting
9	#107	#412	Pasture & Rangeland	Critical Pastureland Area Planting
10	#402	#410	Pasture & Rangeland	Grade Stabilization
11	#s 201 - 209		Urban	Phase II Urban BMPs
12	#210		Urban	Voluntary Urban Nutrient Management
13	#211		Urban	Required Urban Nutrient Management in 2,000 ft Buffer Strip around the Reservoir

14	#301A	#390, #391	Channel	Riparian Buffer Strips - All Except Critical Areas
15	#302	#584	Channel	Riparian Buffer Strips - Only in Critical Areas
16	#401A1	#658	Channel	Wetland Creation - Lower Kings Creek
17	#401B1	#658	Channel	Wetland Creation - End Cedar Creek
18	#501		Reservoir-in-Lake	Hypolimnetic Aeration
19	#502B		Reservoir-in-Lake	P Inactivation with Alum
20	#505		Reservoir-in-Lake	Hypolimnetic Water Release from Reservoir
21	#701	PS-1A	WasteWater Treatment Plant	WWTP - from Level I to Level II quality
22	#702	PS-1B	WasteWater Treatment Plant	WWTP - from level I to Level III quality

1.5.3 Identifying "Most Economical Best Management Practices" (MEBMP) Portfolios

The decisions confronting Cedar Creek Reservoir Watershed decision makers are representative of a classic economic problem:

- attempting to achieve one or more objectives simultaneously; subject to
- several alternative choices of action(s); and
- numerous physical and fiscal constraints.

Each BMP is an alternative available to the decision makers. In determining the optimal MEBMP solution, application of the BMPEconomics© model allows consideration of the technical nutrient/sediment reduction performance of each BMP and the internally-calculated annual costs per unit of P, N, and Sed inflow reductions toward meeting Cedar Creek Reservoir Watershed decision makers' objectives. The BMPs which enter into the optimal MEBMP solution may also be limited by certain constraints specified in the model, including various fiscal and physical limitations, e.g., initial investment capital, annual operating funds, and marginal most-likely adoption rates in qualified sub-watersheds.

1.5.4 Economic and Financial Costs

Comprising the first component of BMPEconomics©, a Microsoft® Excel® spreadsheet was constructed to calculate the annuity equivalent costs for each of the Challenger BMPs, assuming 100% implementation of the marginal most-likely adoption rates within the SWAT- (and WASP-)

designated sub-watershed areas of the Cedar Creek Reservoir Watershed. Explicit recognition of the adjusted SWAT effectiveness levels in terms of P, N, and Sed inflow reductions for each Challenger BMP were incorporated into the spreadsheet, along with the details of the sub-watershed areas (within the total watershed) that could potentially be affected by full implementation of the expected marginal most-likely adoption rate. Additional specifications were declared, allowing the calculation of units (e.g., acres, structures, etc.) for each specific Challenger BMP that could be imposed on the potentially-affected areas. The requisite initial capital investments (and expected useful lives) associated with each Challenger BMP were also identified.

Corresponding annual operating and maintenance costs and, if appropriate, intermittent capital replacement costs, and timing thereof, were also identified. Estimates of initial and/or annual incentive inducement payments to decision makers were also incorporated into the spreadsheet as deemed appropriate for the respective Challenger BMPs. Costs were identified in 2008 values and a 2.043% annual inflation rate was assumed for increasing costs throughout the assumed 50-year planning horizon. A social discount rate of 4.900% was assumed to facilitate calculations of net present values of costs and annuity equivalents.

1.5.5 Optimal MEBMP Portfolios of Challenger BMPs

The optimization facet of the economic analyses involves investigating a baseline situation considered to be the most representative of the current circumstances in the Cedar Creek Reservoir Watershed, while considering all Challenger BMPs as eligible for adoption and implementation. In that baseline situation, the predominant attribute worthy of mention is a required reduction of 35% (i.e., 72.8 ET) of P inflows into the Cedar Creek Reservoir. Subsequently, several sensitivity scenarios are evaluated to (a) check the stability of the baseline situation results, (b) identify those assumptions which, when altered, lead to perceptibly different results, and (c) distinguish those assumptions which apparently have limited to no impact on the results. The principal categories of the sensitivity scenarios analyzed are:

- required P inflow reduction levels;
- consideration of alternative annual flow levels;
- combined simultaneous inflow reduction level requirements for P, N, and Sed; and
- requiring the inclusion or exclusion of individual BMP categories in the solution.

A series of meetings among the project team members and with Cedar Creek Reservoir Watershed stakeholders were held during the project, 2007-2009. Such meetings involved the project team (a) discussing planned activities, (b) reporting on activities and preliminary results, and (c) indicating final results of the optimal MEBMP portfolio of least-cost BMPs and the several other related aspects of the watershed protection plan. Stakeholders were asked to assist in the (a) selection of preferred management practices, (b) examination of selected practices, (c) identification of funding sources, and (d) development of the educational and outreach portion of the watershed protection plan. Three groups were formed to advise on the following targeted constituencies: (a) agricultural, (b) urban and wastewater, and (c) education and outreach. Stakeholders were able to choose in which group to participate based on their areas of interest and experience. Each group was led by a member of the project leadership team in structured discussions designed to solicit input.

1.5.6 Economic Results

In **table 1.6**, the marginal units most likely to be adopted (assuming adequate available funding support) are identified for each Challenger BMP within the Cedar Creek Reservoir Watershed, along with the annuity equivalents of all respective costs. Nutrient and sediment inflow reduction expectations and cost information are combined to relate the cost per unit of P, N, and Sed inflow reductions. In calculating these costs per unit of inflows reduction, each item is evaluated independently, assuming all costs are associated with reducing that item and ignoring any allocation of costs toward reducing the other items. Also displayed in **Table 1.6** are the ranked orders of each Challenger BMP in terms of least cost per English ton (ET) reduction for P, N, and Sed, respectively (1 signifying least cost, 2 next least cost, etc.), with the BMPs sorted in the table according to ascending-order of costs per English ton reduction in P inflows into the Cedar Creek Reservoir.

Table 1.6 Ranking of likely to be implemented best management practices by cost per unit of phosphorus removal.

						Annuity Equivalent Cost per English ton of			Ranked Order --1 is Lowest Cost, 2 is next Lowest Cost, …		
AGEC BMP Number	NCTXWQ BMP Number	Description	Marginal Units Affected	Units	Annuity Equivalent of All Costs	P Inflows Reduction	N Inflows Reduction	Sed Inflows Reduction	P Inflows Reduction	N Inflows Reduction	Sed Inflows Reduction
4	#004	Filter Strip	947.5	acs	$ 179,729	$ 5,761	$ 1,351	3	1	1	1
10	#402	Grade Stabilization	33	structures	46,783	9,780	1,869	4	2	3	2
9	#107	Critical Pastureland Area Planting	511.4	acs	98,429	25,264	1,503	7	3	2	3
6	#007	Terracing	77.4	acs	167,195	38,283	23,747	16	4	12	5
2	#001A	Contour Farming	1,625.8	acs	111,955	41,869	33,393	18	5	15	6
21	#701	WWTP - from Level I to attain Level II quality	All Nine (9) WWTP	project	486,869	50,892	19,449	∞	6	10	16
1	#001	Conversion of Cropland to Grass	7,959.0	acs	940,976	64,637	16,255	34	7	8	9
7	#101	Prescribed Grazing	102.5	acs	227,392	70,289	3,354	21	8	4	7
13	#211	Required Urban Nutrient Management in 2,000 ft Buffer Strip around the Reservoir	1	program	163,522	70,694	4,748	∞	9	5	16
12	#210	Voluntary Urban Nutrient Management	1	program	314,292	96,770	20,533	224	10	11	15
14	#301A	Riparian Buffer Strips - All Except Critical Areas	86.4	miles	189,046	113,625	17,261	10	11	9	4
22	#702	WWTP - from level I to attain Level III quality	All Nine (9) WWTP	project	1,431,804	129,899	33,894	∞	12	16	16
18	#501	Hypolimnetic Aeration	1	project	436,652	131,224	∞	∞	13	19	16
19	#502B	P Inactivation with Alum	1	project	949,828	144,988	∞	∞	14	19	16
8	#105	Pasture Planting	163,995.0	acs	772,232	157,478	7,514	46	15	6	10
5	#006	Grassed Waterway in Critical Cropland Areas	428.5	acs	78,691	212,836	16,166	28	16	7	8

						Annuity Equivalent Cost per English ton of			Ranked Order --1 is Lowest Cost, 2 is next Lowest Cost, …		
AGEC BMP Number	NCTXWQ BMP Number	Description	Marginal Units Affected	Units	Annuity Equivalent of All Costs	P Inflows Reduction	N Inflows Reduction	Sed Inflows Reduction	P Inflows Reduction	N Inflows Reduction	Sed Inflows Reduction
11	#s 201 - 209	Phase II Urban BMPs	1	program	$ 3,410,093	$ 212,948	$ 25,642	$ 196	17	13	14
16	#401A1	Wetland Creation - Lower Kings Creek	1	wetland	959,253	286,487	32,269	65	18	14	11
17	#401B1	Wetland Creation - End Cedar Creek	1	wetland	759,348	579,559	46,667	97	19	17	13
3	#003	Fertilizer/ Nutrient Mgmt	29,846.2	acs	2,197,088	704,293	∞	∞	20	19	16
15	#302	Riparian Buffer Strips - Only in Critical Areas	3.5	miles	207,647	768,033	165,896	82	21	18	12
20	#505	Hypolimnetic Water Release from Reservoir	1	project	2,020,451	1,494,625	∞	∞	22	19	16

Table 1.7 includes a detailed specification of the inclusion or exclusion of each of the Challenger BMPs in the optimal MEBMP scenario for the Cedar Creek Reservoir Watershed. The included BMPs are listed here, in ascending order (i.e., lowest to highest) of cost per unit of P inflow reductions, with all except BMP101 in the solution at their maximum possible level:

- BMP004: Filter Strip;
- BMP402: Grade Stabilization;
- BMP107: Critical Pastureland Area Planting;
- BMP007: Terracing;
- BMP701: WWTP - from Level I to attain Level II quality;
- BMP001: Conversion of Cropland to Grass;
- BMP101: Prescribed Grazing; and
- BMP211: Required Urban Nutrient Management in 2,000 ft Buffer Strip around the Reservoir.

The last column of **Table 1.7** identifies the "reduced costs" of including a BMP not in the optimal MEBMP solution. These values are, in effect, the penalty or increase in costs that would occur if one unit of a non-optimal BMP were used in place of one or more of the optimal BMPs. These calculated values are somewhat complex in that they account for the differing P inflow reduction performance levels and associated AEV of the respective BMPs. Because of the integer programming nature of the BMPEconomics© linear programming model, these values must be carefully interpreted.

Table 1.7 Specific BMPEconomics© Optimization Results for baseline situation analysis of challenger BMPs.

AGEC BMP Number	NCTXWQ BMP Number	Description	Solution Level (%)	Reduced Cost ($) [b]
1	#001	Conversion of Cropland to Grass	100	$0
2	#001A	Contour Farming	0 [c]	$0
3	#003	Fertilizer/ Nutrient Mgmt	0	$1,977,816
4	#004	Filter Strip	100	$0
5	#006	Grassed Waterway in Critical Cropland Areas	0	$52,703
6	#007	Terracing	100	$0
7	#101	Prescribed Grazing	65.53 [d]	$0
8	#105	Pasture Planting	0	$427,553
9	#107	Critical Pastureland Area Planting	100	$0
10	#402	Grade Stabilization	0	$667,254
11	#s 201-209	Phase II Urban BMPs	100	$0
12	#210	Voluntary Urban Nutrient Management	0	$2,284,500
13	#211	Required Urban Nutrient Management in 2,000 ft Buffer Strip around the Reservoir	0	$86,007

14	#301A	Riparian Buffer Strips - All Except Critical Areas	100 [d]	$937
15	#302	Riparian Buffer Strips - Only in Critical Areas	0	$72,102
16	#401A1	Wetland Creation - Lower Kings Creek	0	$188,644
17	#401B1	Wetland Creation - End Cedar Creek	0	$723,902
18	#501	Hypolimnetic Aeration	0	($4,536,767) [e]
19	#502B	P Inactivation with Alum	0	($8,841,590) [e]
20	#505	Hypolimnetic Water Release from Reservoir	0	$0
21	#701	WWTP - from Level I to Level II quality	100	($185,563) [e]
22	#702	WWTP - from level I to Level III quality	0	$657,045

[a] Current levels of inflows into the reservoir are estimated to be 188,670 kg (208 ET) of P, 1,419,380 kg (1,565 ET) of N, and 450,000 MT (496,035 ET) of Sed (i.e., sediment).

[b] The amount by which the annuity equivalent cost of the respective BMP must be decreased in order for the BMP to enter the optimal MEBMP solution, holding all other things constant (HAOTC). Alternatively, it is the amount by which the annual cost of this solution will increase if one unit of the respective BMP is forced into the solution, HAOTC.

[c] Because of the exclusivity constraint and the relative costs per unit of P inflows reduction, BMP007 is in the optimal MEBMP solution and BMP001A is not.

[d] Because of the 0,1 integer nature of BMP211 and the requisite 72.8 ET reduction in P inflows, BMP211 is at 100% and BMP101, although with a less expensive per unit of P reduction, is at less than 100%.

[e] A negative reduced cost signifies the additional cost reduction that could be achieved if the upper limit was not constraining the level of this and other integer BMPs. Cautious interpretation is advised in regards to reduced costs and dual prices resulting from an integer model.

Table 1.8 Optimal best management practices for 35% Phosphorus Reduction in the Cedar Creek Watershed

BMP Number	Description	BMP Category	P Inflows Reduction (% of Average Annual	P Inflows Reduction (% Share of Reduction in Annual Inflows)
#004	Filter Strip	Cropland	15.0%	43%
#402	Grade Stabilization	Pasture & Rangeland	2.3%	7%
#107	Critical Pastureland Area Planting	Pasture & Rangeland	1.9%	5%
#007	Terracing	Cropland	2.1%	6%
#701	WWTP - from Level I to Level II quality	WasteWater Treatment Plant	4.6%	13%
#001	Conversion of Cropland to Grass	Cropland	7.0%	20%
#101	Prescribed Grazing	Pasture & Rangeland	1.0%	3%
#211	Required Urban Nutrient Management in 2,000 ft Buffer Strip Around the Reservoir	Urban	1.1%	3%
		Total	35.0%	100.0%

Table 1.9 Phosphorus reduction by land-use for implementation of optimal best management practices

BMP Category	P Inflows Reduction (% of Average Annual Inflows)	P Inflows Reduction (English tons)
Cropland	24.1%	39.9
Pasture & Range	5.2%	28.6
Urban	1.1%	2.1
WWTP	4.6%	2.3
Total	35.0	72.9

1.5.7 Summary Comments Regarding Baseline Situation's Optimal MEBMP Solution.

Considering and accepting all of the assumptions developed in the course of the SWAT, WASP, and BMPEconomics© modeling, a 35% reduction (72.8 ET) of P inflows into the Cedar Creek Reservoir is achievable. Using a select-subset portfolio of the 22 Challenger BMPs facilitates this reduction in a cost-minimizing way. On an annual basis, the financial costs for achieving this 35% reduction are approximately $2.25 million ($2,232,513). Initial construction and establishment costs are approximately $13.0 million ($12,972,663). The optimal MEBMP portfolio of least-cost BMPs includes several agricultural-related BMPs. When the costs of the respective BMPs are translated into a cost per unit of P inflow reductions (after considering the impacts of most-likely adoption rates and the resulting adjusted-SWAT effectiveness rates) for each BMP, several of the Challenger BMPs are found to be relatively cost inefficient in comparison to those eight BMPs included in the optimal MEBMP solution (for the baseline situation).

1.5.8 Post-Economic Optimal MEBMP Solution SWAT and WASP Analyses

There is some question as to whether implementing the optimal MEBMP solution based on a modeled 35% total P inflows reduction will actually realize the desired impacts in Cedar Creek Reservoir. Subsequent to the BMPEconomics© modeling and analyses, the optimal MEBMP solution for the Cedar Creek Reservoir Watershed baseline situation was examined using the SWAT and WASP models. The objective of these analyses was to validate the potential of the optimal MEBMP economic solution to achieve the targeted 35% reduction in P inflows into the Cedar Creek Reservoir. Following introduction of the first, lowest-cost BMP (i.e., BMP004 “Filter Strip” is the least expensive on a per P inflows reduction basis) into the relevant sub-watersheds, the SWAT model was used to reevaluate the potential for the next lowest-cost BMP (i.e., BMP402 “Grade Stabilization”) accomplishing reductions in P inflows, assuming the presence of BMP004. This process was repeated in a stepwise-manner, while taking into account those BMPs already assumed to be implemented, sequentially introducing BMP107 (Critical Pasture Area Planting), BMP007 (Terracing), BMP701 (WWTP upgrade to Level II), BMP001 (Conversion of Cropland to Grass), and BMP211 (2,000 feet Buffer of Nutrient Management Surrounding the Reservoir) into those remaining eligible sub-watersheds with the highest likelihood of generating P inflow reductions. In total, 35.0% of P inflows are reduced, according to this framework of analysis; thus, the SWAT model confirms the validity of the BMPEconomics© optimal MEBMP solution for the Cedar Creek Reservoir Watershed baseline situation.

The WASP model was initially used in the Cedar Creek Project to provide direction on the degree of P inflows reduction that would be necessary to translate into a reduction in chlorophyll-*a* that was meaningful. The daily watershed loading file was systematically reduced by a scaling factor from 15% to 65% to determine when chlorophyll-*a* was significantly ($p<0.05$) less than the calibration results at two sites in the main pool of the reservoir. This exercise determined a 30-35% reduction in total P inflows is necessary to see a statistically-significant reduction that would be necessary to translate into a meaningful chlorophyll-*a* reduction. Using the revised daily watershed loading file generated by the SWAT model to reflect adoption and implementation of the eight BMPS in the optimal MEBMP solution, the WASP model was used to evaluate (a) total phosphorus (TP) and (b) chlorophyll-*a* at segment six of the Cedar Creek dam for three scenarios:

(1) the original calibrated model;
(2) the optimal MEBMP solution with the eight BMPs for the baseline situation; and
(3) the systematic reduction of 35% scenario.

The WASP modeling results for these scenarios suggest that the eight BMPs in the baseline situation’s optimal MEBMP solution will reduce the P loading to a sufficient level to result in significant reductions in the chlorophyll-*a* targeted by this project.

1.6 Technical Assistance

Successful implementation of the Cedar 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 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. Table 4.8 is an illustration of the roles that local, state, and federal agencies will play in the development and implementation of the Cedar Creek Plan.

Table 1.10 Agency Roles in Cedar Creek Watershed Protection Planning Efforts.

Agency	**Description of support for Watershed Protection Planning**
United States Department of Agriculture – Natural Resources Conservation Service	Consultation on Conservation Practices, funding for projects
Texas Parks & Wildlife Department	Advisory on wildlife and land management impacts
Texas Commission on Environmental Quality	Permitting of Wastewater Treatment Plant's, water quality testing, assembly of 303(d) list
Texas State Soil and Water Conservation Board	Funding, consultation on land management
Texas AgriLife Extension Service	Liaison between project organizers and agricultural producers; Development, organization, and implementation of educational programming
Spatial Sciences Laboratory, Texas A&M University	Modeling of Conservation Practices, Modeling of watershed conditions, mapping of watershed boundaries and features
Texas AgriLife Research and Extension Urban Solutions Center	Organization of stakeholders, assembly of grant funding, writing and submittal of WPP
Environmental Protection Agency	Funding of WPP efforts through 319 grant program; Template and consultation for WPP efforts
Tarrant Regional Water District	Funding, scientific and management support for project leadership
Department of Agricultural Economics, Texas A&M University	Advisory on cost-benefit data of conservation practices
North Central Texas Council of Governments	Demographic and urban data forecasting and support

1.6.1 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.

1.6.2 Agricultural Management Measures

Technical support from Texas State Soil and Water Conservation Board and United States Department of Agriculture Natural Resources Conservation Service 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 development and implementation of Water Quality Management Plan in the watershed is in the works. Targets for the number of livestock and cropland Plans 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 continued demand for enhanced technical assistance, assuming water quality monitoring results indicate the need for continued improvement.

1.6.3 Education and Outreach

Educational programming for the Cedar Creek Watershed will focus on watershed awareness and stewardship. Development and delivery of these messages to the targeted audiences will be carried out through a partnership between the Kaufman County Environmental Coop and Texas AgriLife Extension Service. Full details of the plans for outreach are reflected in chapter 5.

1.7 Sources of Funding

Successful acquisition of funding to support implementation of management measures will be critical for the success of the Cedar 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 already been secured, either in part or full (e.g. Clean Water Act (CWA) Section 106 funding for outreach and education efforts). 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.

Clean Water Act State Revolving Fund

The State Revolving Fund (SRF) administered by the Texas Water Development Board 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 permit holders in the Cedar Creek Watershed will be assisted in pursuit of these funds to assist in treatment upgrades and to improve treatment efficiency within the watershed.

Economically-Distressed Area Program

The Economically Distressed Area Program (EDAP) is administered by the Texas Water Development Board 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 (EQIP) is administered by the Natural Resources Conservation Service. 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. (USDA-NRCS 2009)

Farm and Ranchland Protection Program

The Farm and Ranch Lands Protection Program (FRPP) is a voluntary program that helps farmers and ranchers keep their land in agriculture and prevents conversion ofagricultural land to non-agricultural uses. The program provides matching funds to State, Tribal, and local governments and nongovernmental organizations with existing farmland protection programs to purchase conservation easements. These entities purchase easements from landowners in exchange for a lump sum payment, not to exceed the appraised fair market value of the land's development rights. The easements are perpetual easements. (USDA-NRCS 2009)

Grassland Reserve Program

The Grassland Reserve Program (GRP) is a voluntary program for landowners and operators to protect grazing uses and related conservation values by conserving grassland, including rangeland, pastureland, shrubland, and certain other lands. The program emphasizes support for working grazing operations; enhancement of plant and animal biodiversity; and protection of grassland and land containing shrubs and forbs under threat of conversion. (USDA-NRCS 2009)

Resource Conservation and Development Program

The Resource Conservation and Development (RC&D) Program is reauthorized in the Farm Security and Rural Investment Act of 2008 (2008 Farm Bill). The RC&D program increases opportunities for volunteer, locally elected and civic leaders in designated RC&D areas to plan and complete projects for resource conservation and community development. Program objectives focus on "quality of life" improvements achieved through natural resources conservation and community development. Such activities lead to sustainable communities, prudent land use, and the sound management and conservation of natural resources. (USDA-NRCS 2009)

Stewardship Incentive Program

The Stewardship Incentive Program (SIP) provides technical and financial assistance to encourage non-industrial private forest landowners to keep their lands and natural resources productive and healthy. Qualifying land includes rural lands with existing tree cover or land suitable for growing trees and which is owned by a private individual, group, association, corporation, Indian tribe, or other legal private entity. Eligible landowners must have an approved Forest Stewardship Plan and own 1,000 or fewer acres of qualifying land. Authorizations may be obtained for exceptions of up to 5,000 acres. (USDA-NRCS 2009)

Conservation Grazing Lands Program

The Conservation of Private Grazing Land Program (CPGL) is a voluntary program that helps owners and managers of private grazing land address natural resource concerns while enhancing the economic and social stability of grazing land enterprises and the rural communities that depend on them. (USDA-NRCS 2009)

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentive Program (WHIP) is a voluntary program for developing or improving high quality habitat that supports fish and wildlife populations of National, State, Tribal, and local significance. Through WHIP, the USDA's Natural Resources Conservation Service (NRCS) provides technical and financial assistance to private and Tribal landowners for the development of upland, wetland, aquatic, and other types of wildlife habitat. (USDA-NRCS 2009)

Conservation Security Program

The Conservation Security Program (CSP) is a voluntary conservation program that supports ongoing stewardship of private agricultural lands by providing payments for maintaining and enhancing natural resources. CSP identifies and rewards those farmers and ranchers who are meeting the highest standards of conservation and environmental management on their operations. CSP provides financial and technical assistance to promote the conservation an improvement of soil, water, air, energy, plant and animal life, and other conservation purposes on Tribal and private working lands. Working lands include cropland, grassland, prairie land, improved pasture, and range land, as well as forested land that is an incidental part of an agriculture operation. (USDA-NRCS 2009)

Conservation Stewardship Program

The Conservation Stewardship Program (CSP) encourages agricultural and forestry producers to maintain existing conservation activities and adopt additional ones on their operations. CSP is a new voluntary conservation program that provides financial and technical assistance to conserve and enhance soil, water, air, and related natural resources on their land. CSP provides opportunities to both recognize excellent stewards and deliver valuable new conservation. (USDA-NRCS 2009)

Regional Water Supply and Wastewater Facility Planning Program

The Texas Water Development Board offers grants for analyses 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 Cedar Creek Plan as outlined in the engineering report of Alan Plummer Associates, Inc.

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, Total Maximum Daily Load 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 through the Texas Commission on Environmental Quality, Section 106 funds have already been allocated to assist in a number of activities, particularly outreach and public education components, in the Cedar Creek Watershed.

Section 319(h) Federal Clean Water Act

The US Environmental Protection Agency provides funding to states to support projects and activities that meet federal requirements of reducing and eliminating nonpoint source pollution. In Texas, both Texas State Soil and Water Conservation Board and Texas Commission on Environmental Quality receive 319(h) funds to support nonpoint source projects, with the Soil Board funds going to agricultural and silvicultural issues and Texas Commission on Environmental Quality funds going to urban and other non-agricultural issues. 319(h) funds from Texas State Soil and Water Conservation Board supported the development of the Cedar Creek Watershed Protection Plan, and the Texas Commission on Environmental Quality funding has already been appropriated to implement some of the management measures recommended in the plan.

Supplemental Environmental Project Program

The Supplemental Environmental Projects Program (SEPP) administered by the Texas Commission on Environmental Quality 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 Grant Program

The Targeted Watersheds Grants Program is administered by the Environmental Protection Agency 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.

Water Quality Management Plan Program

The Water Quality Management Plan (WQMP) program is administered by the Texas State Soil and Water Conservation Board. Also known as the 503 program, Management Plans are 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 Soil and Water Conservation Districts, 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.

Local Funding

County and municipal budgeting for watershed improvement activities such as the implementation of best management practices on public lands and the enforcement of stormwater control ordinances. While outreach and education activities gain traction, overall stewardship of residents will increase leading to a demand of local leadership to provide funding for watershed programs. This can be accomplished through a variety of means including taxation, boat ramp fees, groundwater well permits, and surcharges attached to water bills.

Trinity River Basin Initiative

Agencies working in cooperation with the Cedar Creek Watershed Partnership will be eligible for participation in the Trinity Basin Initiative, a small grant program funded by the Texas Commission on Environmental Quality and the Texas State Soil and Water Conservation Board. These funds are administered by The Texas AgriLife Research and Extension Urban Solutions Center at Dallas and will be directed toward educational and outreach programming, demonstration best management practice locations, and to supplement existing programs and activities.

Corporate
Retail outfits such as Wal-Mart and Recreational Equipment International (REI)devote a portion of annual revenues to environmental causes. In the case of the aforementioned, these funds can be applied for and administered on the local level. Other corporations with operations within the Cedar Creek Watershed will be researched for potential support including in kind donations of materials and labor.

Research
Opening of the Cedar Creek Watershed to researchers to investigate the effectiveness of integrated best management practices will allow for the funding of BMP implementation through targeted research grants solicited by individual researchers. Funding for investigative activities within the watershed is available through traditional channels such as TSSWCB and TCEQ programs but may also be eligible for support from institutions such as the National Science Foundation.

Tarrant Regional Water District
Increases in raw water supply rates charged by TRWD to municipal clients will be evaluated for the potential to fund watershed and reservoir water quality improvement activities. Rate increases will be presented under the guise of water quality improvement and will be offset by the reduced cost of treating water at the municipal level.

Cedar Creek Watershed Foundation
The Cedar Creek Watershed Partnership will investigate the creation of a 501(c) (3) organization known as the Cedar Creek Watershed Foundation to solicit grants from public funds, private endowments, and individual donations. The Foundation will be established with the goal of establishing an eventual separation of the Cedar Creek Partnership from professional affiliations (AgriLife, TRWD, etc.) and prepare stakeholders for the transition to planned local fiscal and logistical management of the watershed and associated activities.

1.8 Outreach and Education

Outreach and education funding will be disseminated through the North Central Texas Water Quality Project to representatives of Kaufman County Environmental Co-op and Texas AgriLife Extension. NCTWQP will seek to fund these activities through funding from the Texas Commission on Environmental Quality. Kaufman County Environmental Co-op will receive funding to devote staffing directly to the educational activities of the Cedar Creek Watershed Partnership targeted to schools, youth organizations, and urban dwellers. Funding to AgriLife Extension will account for the resources required to produce informational programming such as fact sheets, rain barrels, and educational props as well as to conduct training of Texas Master Gardeners to serve as ambassadors for watershed protection and pollution reduction.

1.9 Financial Assistance for Implementation Administration

Aspects of implementation of the Cedar Creek Watershed Protection Plan will require funding to maintain long term management of the project elements such as education, coordination of management practice installation and maintenance, computer modeling, and water quality testing programs. Approval of the Cedar Creek Watershed Plan by the US Environmental Protection Agency will qualify the Cedar Creek Partnership to seek funding for sustained implementation efforts such as the hiring of a watershed coordinator to oversee all aspects of the Cedar Creek Watershed Protection Plan.

1.10 Phased Implementation of the Management Solution

1.10.1 Targeting Sub-watersheds for Management Practice Implementation

With the assistance of the Texas State Soil and Water Conservation Board, the Cedar Creek Technical Advisory Group adopted a strategy of selection of specific conservation practices based on the topography, hydrology, and land uses for each of the sub-basins within the Cedar Creek Watershed. Sub-watersheds have been color-coded to illustrate the severity phosphorus loadings. Additionally, in most instances, a suite of practices are recommended in order to maximize pollutant reductions. The targeting of specific sub-watersheds will allow for maximum funding to be directed toward areas that, if corrected, will demonstrate the largest impact on water quality. Such methodology will allow for prioritization of the plan implementation and provide the most direct path to demonstrable water quality improvement.

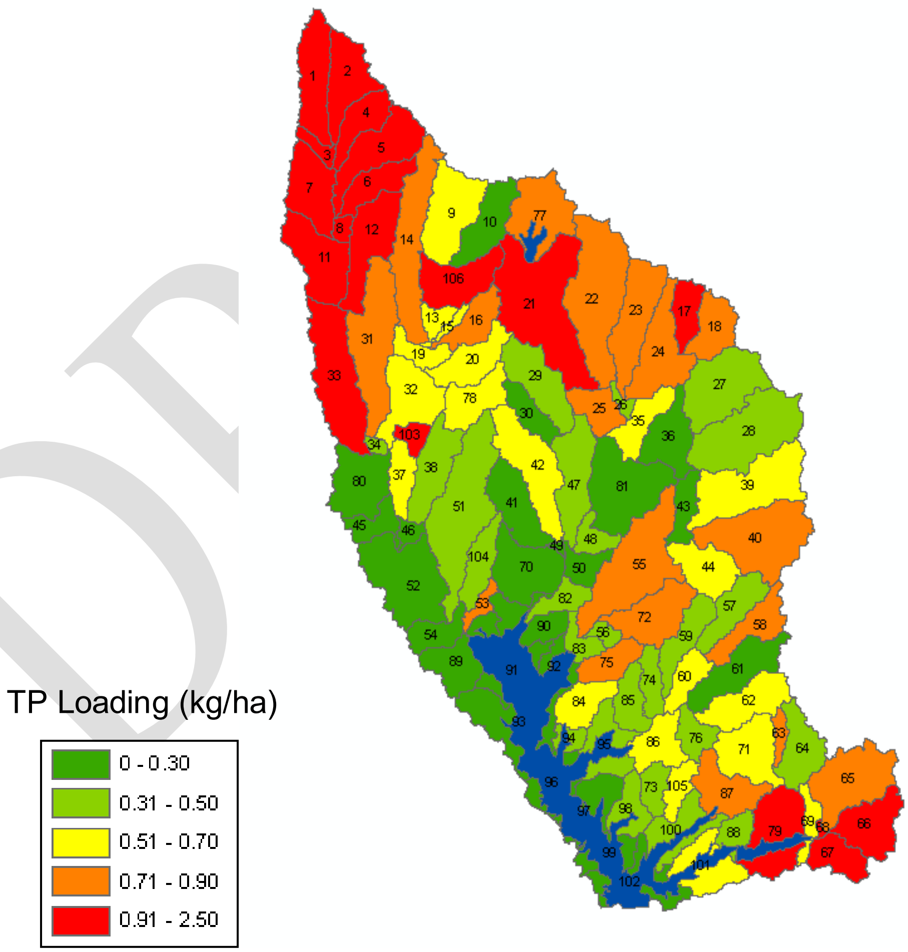


Figure 1.23 Cedar Creek Watershed Baseline Phosphorus Loadings by Sub-basin (TAMU-SSL 2009).

1.10.2 Schedule of Implementation

Numbered sub-basin maps of the watershed have been produced via SWAT Modeling to illustrate the accumulative impact of the staggered BMP implementation.

The schedule of implementation identified in tables 6.1, 6.2, and 6.3 is based on each of the optimal individual practices and the targeted sub-basins for periods of 1-3, 4-6, and 7 to 10+ years. Priority sub-basins for each timeframe have been listed in order of implementation based upon the rate of overland phosphorus flow throughout the watershed. Color-coded maps for each phase of implementation are in illustration of the progress that is forecasted in phosphorus reduction (figures 6.2,
6.3, 6.4). Progress assumes the location of cooperative landowners or agricultural producers as well as the securing of funding to encourage swift construction and timely and proper operation and maintenance of practices.

1.10.3 Phase I Implementation 1 to 3 years

Table 1.11Best Management Practice implementation 1 to 3 Years (TAMU-SSL 2009).

Practice	Filter Strips	Grade Stabilization Structure	Grassed Waterway	Terracing	Cropland Conversion to Pasture	Prescribed Grazing	2,000 Ft. Buffer Strip of Nutrient Management Surrounding the Reservoir
Sub-basin	2, 8, 1, 12, 7, 67, 6	58, 62, 63, 64, 65	22, 16	40, 67, 87, 58, 72	77, 16, 75, 31, 55	53, 103, 40, 9, 2, 15, 67, 84, 106, 37	89-102

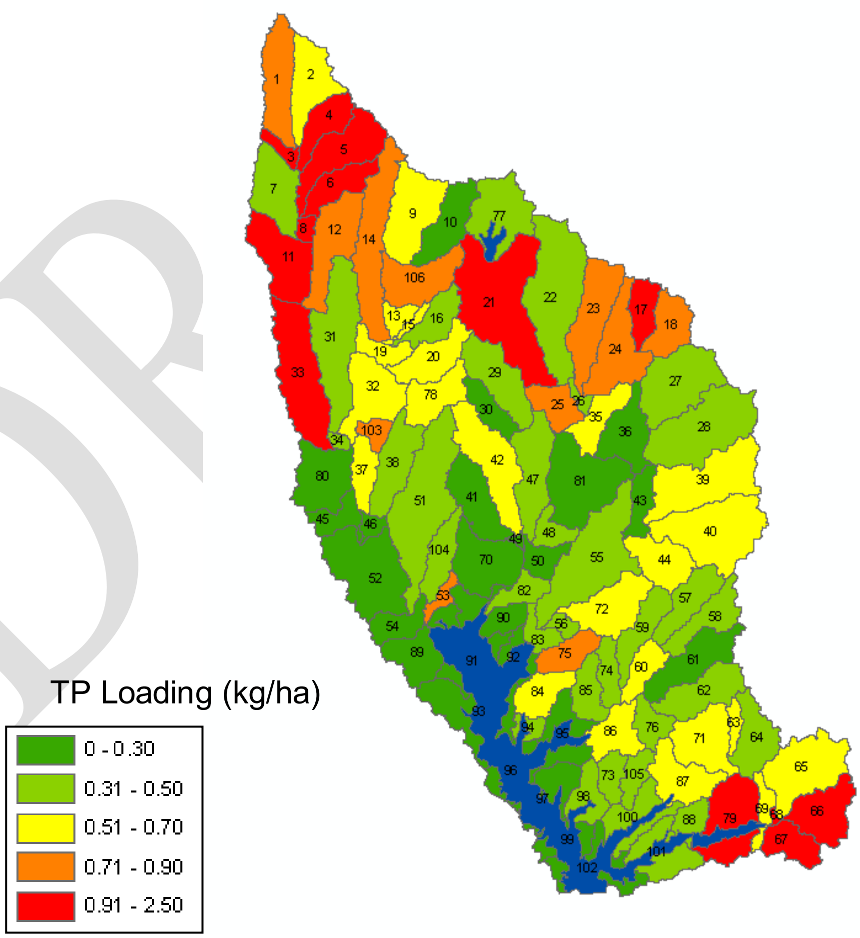


Figure 1.24 Cedar Creek Watershed Phosphorus Reduction for 1 to 3 Years (TAMU-SSL 2009).

1.10.4 Phase II Implementation: 4 to 6 Years

Table 1.12Best Management Practice Implementation 4 to 6 Years.

Practice	**Filter Strips**	**Grade Stabilization Structure**	**Grassed Waterway**	**Terracing**	**Cropland Conversion to Pasture**	**Prescribed Grazing**	**2000 Ft. Buffer Strip of Nutrient Management Surrounding the Reservoir**
4 to 6 years	11, 4, 21, 79, 106, 66	66, 67, 69, 71, 79	75, 23	21, 44, 105, 65, 20	103, 14, 24, 25, 42	19, 18, 17, 12, 13, 1, 21, 11, 8	89-102

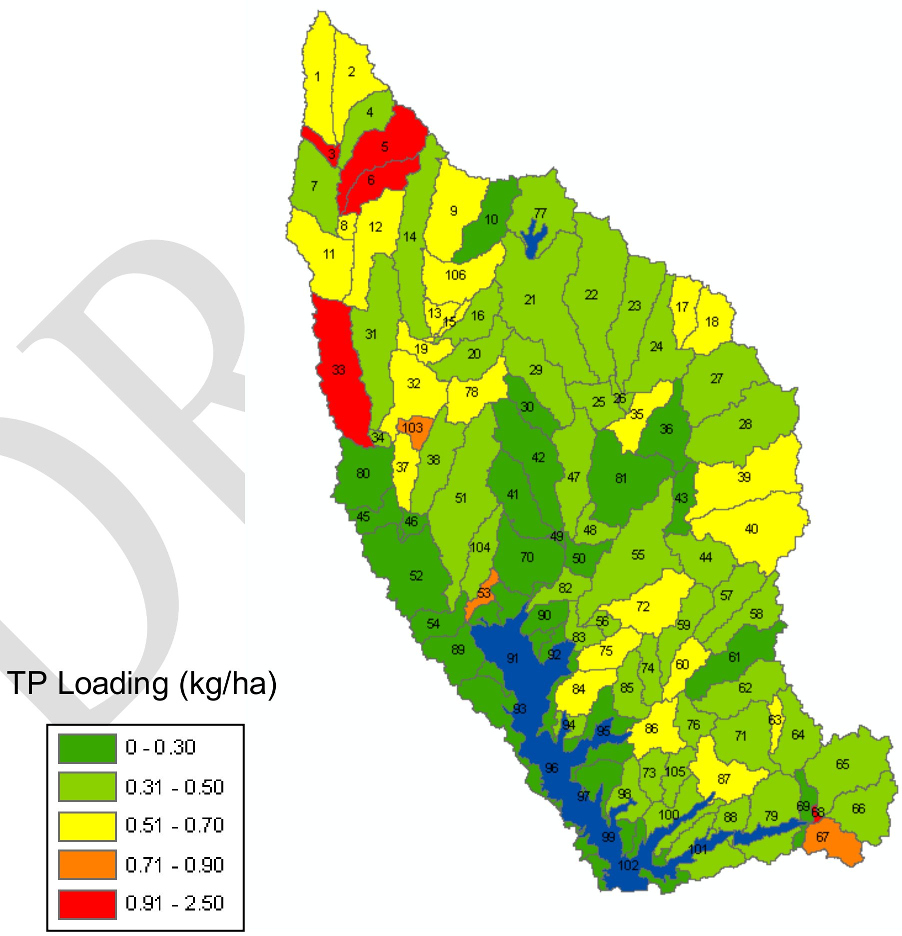


Figure 1.25 Cedar Creek Watershed Phosphorus Reduction for 4 to 6 Years (TAMU-SSL 2009).

1.10.5 Phase III Implementation: 7 to 10 Years

Table 1.13 Best Management Practice Implementation 7 to 10 Years

Practice	Filter Strips	Grade Stabilization Structure	Grassed Waterway	Terracing	Cropland Conversion to Pasture	Prescribed Grazing	2000 Ft. Buffer Strip of Nutrient Management Surrounding the Reservoir
7 to 10 years	5, 3, 33, 103, 68, 17	87, 88, 100, 101	72, 18	86, 101, 60, 62, 39	23, 32, 22, 78, 67	6, 75, 33, 35, 74, 98, 57, 57, 94, 32	Implementation Complete

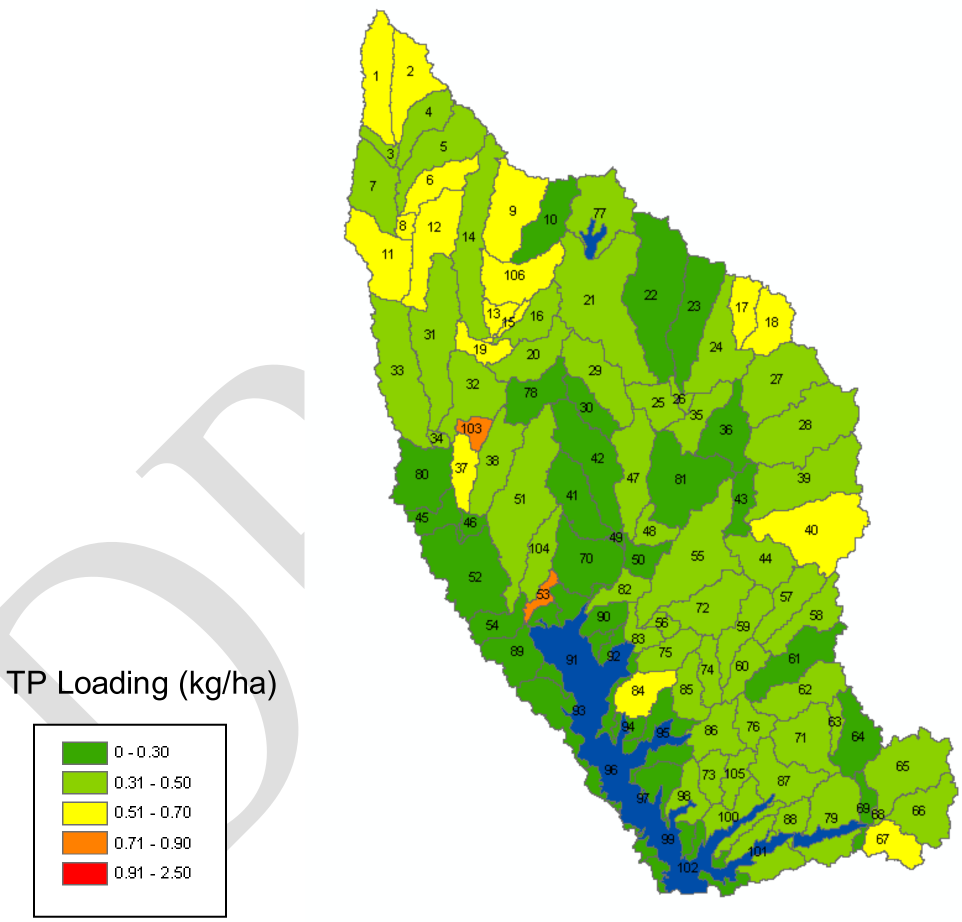


Figure 1.26 Cedar Creek Watershed Phosphorus Reduction for 7 to 10 Years (TAMU-SSL 2009).

1 Education and Outreach Plan

In developing the Cedar Creek Watershed Protection Plan, the Education & Outreach Work Group worked to follow the U.S. Environmental Protection Agency's *Getting in Step- A Guide for Conducting Watershed Outreach Campaigns*. This program is designed to aid in the process of constructing a comprehensive strategy to increase public awareness, participation in the implementation of best management practices, and promote watershed stewardship. The program steps are:

1. Define goals and objectives
2. Identify target audience
3. Determine message
4. Package materials
5. Distribute educational material and message
6. Evaluation

1.1 Driving Forces, Goals and Objectives for Education and Outreach

The driving force for the development of the Cedar Creek watershed education and outreach campaign is to provide information to targeted audiences that will assist in reversing the trend of nutrient and sediment loadings that have contributed to the impairment of Cedar Creek Reservoir. The goal of the Cedar Creek Reservoir Watershed educational program is to provide information to watershed stakeholders regarding the status of the reservoir and watershed and future conditions. Emphasis must be placed on the concept that the activities of people living in the watershed and around the lake will impact reservoir water quality. The informational program will utilize key messages to foster watershed stewardship demonstrated through the implementation of best management practices on a personal level.

The objectives for the educational and outreach portion of the watershed are ambitious and targeted toward long-term public awareness regarding water quality in Cedar Creek Reservoir. Programmers will seek to identify and link with groups within the watershed conducting environmental education programs to develop educational strategies to increase awareness of pollutant sources and conservations practices to limit those pollutants already in the watershed from reaching the reservoir.

1.2 Identifying and Analyzing Target Audiences

A variety of audiences will be targeted during the educational program to publish and share information with the public. Among these are those who work, live, play, or conduct business within the boundaries of the watershed. A typical roster of watershed stakeholders will include agricultural producers (farmers and ranchers), wildlife managers, small acreage landowners, sportsmen, homeowners, and youth.

As the population of the watershed continues to grow, those involved in management of public and private lands such as golf course managers and municipal parks and recreation staff must be included among target audiences for watershed awareness. Those directly involved with the ongoing growth and development of the watershed must be reached as well such as developers, elected officials, chambers of commerce, civic organizations, media, and realtors.

1.3 Message Development and Delivery

These messages address the overall education & outreach objectives and emphasize the value of natural resources associated with the Cedar Creek Watershed, issues of the watershed, and measures to correct and reverse the current course of water pollution. Messages defining the value of the natural resources must consider the importance of soil conservation practices to maintain quality agricultural conditions, the monetary impact of recreation such as fishing and boating, and wildlife viewing, and the enhancement of lakeside property values linked to a clean water body.

Development of watershed-based messages must emphasize both problems facing the watershed and the proposed solutions that stakeholders can act upon in either and individual or a collective basis. These must begin with basic watershed definition and an understanding of the challenges facing the Cedar Creek watershed. Stakeholders must be made aware of the types, sources, and effects of pollutants flowing to Cedar Creek Reservoir including eutrophication and the infilling of the reservoir with sediment.

Based on the findings of the watershed plan, solutions that will be presented to the public will emphasize the implementation of agricultural best management practices and wastewater treatment plant upgrades. In anticipation of population growth, the management of urban stormwater will become and priority. Education of city dwellers regarding landscaping, city ordinances, storm drain labeling, pet waste cleanup and water quality monitoring activities will prepare the populace for long-term watershed protection and improvement.

1.4 The Cedar Creek Reservoir Watershed Education and Outreach Plan

The Cedar Creek Reservoir and Watershed Education and Outreach Plan is a multi-faceted approach that accounts for branding, message identification, targeting audiences, message delivery, evaluation, and seeking partnerships with appropriate agencies to maximize resources and avoid duplication of efforts. The North Central Texas Water Quality Project has charged the Kaufman County Environmental Co-op and Texas AgriLife Extension with the development and implementation of the education and outreach plan. Each group will receive project funding and will be guided by the following strategies:

1.4.1 Establishing a Brand

The primary goal of a quality education and outreach plan is to develop a consistent and recognizable brand for the watershed protection project. Project leaders must decide on a formal name for the watershed protection effort and maintain the use of the name throughout the planning, implementation, and review stages of the project. In the case of the Cedar Creek Watershed Protection Plan, the effort has been dubbed "The Cedar Creek Watershed Partnership." This simple name reflects the scope of the project as being watershed based and the responsibility of water quality as belonging to multiple parties.

Branding of any entity is a crucial step to developing public relations, increasing organizational profile, and advancing the goals of the agency or partnership. By beginning with a simple and recognizable graphic logo, stakeholders can identify the impact of the project in print and broadcast media, informational materials, advertising, and outreach efforts such as workshops and seminars.

A successful way to begin such branding efforts and jump-start local interest is to conduct a logo design contest for youth. This will allow for direct contact with students, teachers, and parents within the watershed and provide the media with fresh material regarding watershed protection efforts. Use of youth-created graphics will convey an unstated message that future health, security, and prosperity are all dependent on clean watersheds. A publically-developed logo will allow for local ownership of project advertising, informational materials, programming, and labeling of best management practice demonstration sites.

1.4.2 Delivering Basic Facts about the Cedar Creek Watershed

Under the direction of Texas AgriLife Research, specialists, county agents, and volunteer groups such as the Texas Master Gardeners will work to distribute the basic facts about the Cedar Creek Watershed to targeted audiences in the following methods:

- Develop campaign brochures that include numerous photographs, illustrations, simple graphics, maps and easily read text
- Develop different presentations for targeted audiences
- Create fact sheets and FAQs (Frequently Asked Questions)
- Produce a video of watershed definition, issues, and stakeholder involvement.

1.4.3 Increasing Awareness and Community Involvement in the Cedar Creek Reservoir Watershed Protection Plan

Due to the organization's presence within and knowledge of the watershed, Kaufman County Environmental Co-op will take a leading role in increasing awareness and involvement in the watershed planning process. This will be conducted though the utilization of signage, television, radio, newspapers, and other targeted advertising strategies. Additionally it is anticipated that the Co-op will engage in a strategy of personal contact involving presentations at schools and civic meetings, tables at local festivals and environmental and agricultural events, direct mail, and utility bill stuffers. Many of these responsibilities will fall under the auspices of general watershed education as outlined in table 5.1.

Table 5.1 General watershed education and outreach protocol.

<table>
<tr><th>Target Audience</th><th>Responsible Organization</th><th>Action</th><th>Conveyance</th></tr>
<tr><td rowspan="4">General Watershed Awareness</td><td rowspan="4">Kaufman County Environmental Co-op</td><td>Knowledge of watershed definition and function</td><td rowspan="4">Signage
Radio
Newspapers
Festivals, public gatherings,
Speaking engagements</td></tr>
<tr><td>Watershed address and boundaries</td></tr>
<tr><td>Point and Non-point source pollution</td></tr>
<tr><td>Stewardship and individual responsibility</td></tr>
</table>

		Awareness of Cedar Creek Watershed Planning Efforts	

1.4.4 Developing Partnerships for Message Distribution

Both Texas AgriLife Extension Service and Kaufman County Environmental Co-op will work collaboratively to develop partnerships with business, community-based organizations and Non-Governmental Agencies (NGO's) supporting environmental education and conservation programs for message distribution. Among these with be Kaufman/Van Zandt Soil and Water Conservation District, Texas Department of Agriculture, and local USDA-NRCS field technicians. Outside of agriculture, the CCWPP will seek to work with sporting groups such as Ducks Unlimited, and the Bass Anglers Sportsmen Society as well as the Texas Chapter of American Fisheries. Those with economic interests such as trade associations, realtors, and local chambers of commerce will be recruited to assist with spreading the message of watershed protection. The inclusion of youth organizations such as 4-H, scout groups, and FFA will provide much needed manpower in disseminating fact sheets and soil test kits to the general public. Lastly, it will be incumbent upon local environmental groups such as the Sierra Club, Texas Wildlife Association, Trinity River Environmental Education Society (TREES), Keep Texas Beautiful, and the Trinity Basin Conservation Foundation to provide volunteer efforts to public education events and to apply pressure to local and regional media to cover watershed issues.

1.4.5 Create Micro-campaigns for Specific Target Audiences

Within the context of message distribution, the Cedar Creek Watershed Partnership has produced a listing of targeted micro campaigns to reach specific audiences as is summarized in table 5.2.

Table 5.2 Targeted Micro-campaigns for watershed education and outreach

Target Audience	**Responsible Organization**	**Action**	**Conveyance**
Agricultural Producers	Texas AgriLife Extension	Educate agricultural producers on more environmentally responsible application levels and rates of fertilizer	Workshops, one-on- one consultations, e mail or mailing
		Promote conservation programs sponsored by NRCS, SWCD and other organizations that provide technical assistance and funding for the implementation of conservation measure and practices	
		Sponsor soil testing campaigns	Homeowners Associations, Master Gardeners Associations
		Construct BMP demonstrations as a learning tool	Work with cities and counties to find suitable sites

		Utilize fact sheets, presentations and other information to educate agricultural producers on:	
		Agricultural conservation practices including stream protection	Workshops, one-on- one consultations, e mail or mailing
		Cost and Benefits of implementing conservation practices	
		Stocking rates and overgrazing	


Figure 1.1 Second Grade Students in Terrell learn about watershed pollution

Target Audience	Responsible Organization	Action	Conveyance
Small Acerage Landowners	Texas AgriLife Extension, Kaufman County Environmental Co-op	Construct BMP demonstrations as a learning tool	Cities and Counties to find proper locations
		Utilize fact sheets, presentations and other information to educate small acreage landowners on:	Workshops, one-on- one consultations, e mail or mailing
		Land stewardship	
		Septic system maintenance	
		Stocking rates and overgrazing	
		Pond management	
		When to fertilize and what with	
		Pasture planting	

Sportsmen	Kaufman County Environmental Co-op	Distribute watershed informational brochures	Local fishing support businesses such as bait shops, marinas, sporting goods stores, fishing guides, boat dealerships, etc.
		Create a specific event or task to encourage angler ownership of the Cedar Creek and Watershed	Texas Parks & Wildlife, Cedar Creek Chamber of Commerce
		Organize a fishing tournament on Cedar Creek Reservoir and distribute fact sheets to each fisherman with their entry	
		Organize fisherman for clean up days	Local fishing and wildlife groups

Target Audience	Responsible Organization	Action	Conveyance
Schools and Youth Organizations	Kaufman County Environmental Coop	Identify all after-school programs including: Learning Centers Private After-School Care School Extracurricular Programs (i.e. Rodeo Club, Science Club, etc.)	Parents, school district, scout groups
		Create a youth-based learning curriculum for the Cedar Creek Reservoir Watershed	TREES (Trinity River Environmental Education Society)
		Distribute TREES "Talking Trash" DVDs to schools to teach students the effects of pollution on our watersheds	Local PTAs
		Use schools as a distribution point for basic information about the Cedar Creek Reservoir Watershed to distribute to the families of school children through "back-pack stuffers"	Local Science Teachers
		Reach out to area science teachers through the regional education service center to provide basic information on the Cedar Creek Watershed Protection Plan and offer suggestions for school projects they can incorporate into their lessons to raise interest among students in their role in helping the Cedar Creek Watershed	
		Utilize stream trailers, rainfall simulators, rainwater harvesting table top display, Enviroscape, and dual flush toilet as hands-on visual teaching tools to raise interest and awareness of the Cedar Creek Watershed current and future conditions	Texas AgriLife Extension, Master Gardener Associations

Target Audience	Responsible Organization	Action	Conveyance
Gardeners/ Homeowners	Texas AgriLife Extension, Kaufman County Environmental Co-op	Educate large retail businesses of garden supplies or other fertilizer vendors on more environmentally responsible application levels and rates	Workshops, one-on- one consultations, e mail or mailing
		Promote neighborhood association recognition for environmentally friendly landscaping	Workshops, one-on- one consultations, e mail or mailing, Homeowners Associations and other local meetings
		Utilize fact sheets, presentations and other information to educate homeowners on:	Workshops, one-on- one consultations, e mail or mailing, Homeowners Associations and other local meetings
		Rainwater harvesting	
		Stormwater management	Local municipalities, unincorporated lakeside communities
		Pet waste disposal	Local animal control, veterinary clinics, animal rescue organizations, Homeowners Associations and other local meetings

Target Audience	**Responsible Organization**	**Action**	**Conveyance**
Gardeners/ Homeowners	Texas AgriLife Extension, Kaufman County Environmental Co-op	Proper lawn fertilization	Workshops, one-on- one consultations, e mail or mailing, Homeowners Associations and other local meetings, Sponsor soil testing campaigns
		Urban landscape management	Workshops, one-on- one consultations, e mail or mailing, Homeowners Associations and other local meetings
		Onsite wastewater treatment	Workshops, one-on- one consultations, e mail or mailing
		Gray water	
		Soil Testing	Workshops, one-on- one consultations, e mail or mailing, Homeowners Associations and other local meetings, Sponsor soil testing campaigns
		Grass clipping/leave disposal	Workshops, one-on- one consultations, e mail or mailing, Homeowners Associations and other local meetings
		Water supply corporations	Utility bill mailings
		Tax Bills	Informational stuffers
		Master Gardener programs	Develop demonstrations of BMPs for visual reference of practices that demonstrate the effectiveness of reducing runoff and pollution transport

Target Audience	Responsible Organization	Action	Conveyance
Greenspace Management/Developers	Texas AgriLife Extension, Kaufman County Environmental Co-op	Develop a listing of stormwater control and green infrastructure measures developers can use and implement into designing a new neighborhood	Workshops, one-on- one consultations, e mail or mailing
			Press Releases to Newspapers: The Monitor – Forney, The Pilot, Kaufman County Life
		Golf Courses, parks, open space	Workshops, one-on- one consultations, e mail or mailing

Influential People and Organizations	Kaufman County Environmental Coop	TV News: Channel 5 and 11	Press releases, follow up contact
		Elected Leaders	Present WPP at City Council Meetings and Commissioners Courts
		Chamber of Commerce	Speaking engagements, endorsements
		Radio: KLM, Cedar Creek Area media	Press releases, follow up contact
		Water customers/ water supply corporations	Utility bill stuffers or direct message printing

Figure 1.2 Texas AgriLife's Stream Trailer demonstrates erosion and stream processes to Cedar Creek Stakeholders.

Target Audience	Responsible Organization	Action	Conveyance
Collaborate with Governmental Agencies Offering Environmental E&O	Texas AgriLife Extension Service, Kaufman County Environmental Co-op	Clean Texas Greenscapes	water summit
		Texas Department of Agriculture (TDA)	
		Stop the Drop	
		Texas Water Development Board	
		The Water Smart Campaign	
		Water Wise Council of Texas	
		United States Department of Agriculture – Natural Resource Conservation Service field office(USDA-NRCS)	site demonstrations, one-on-one consultations
		Texas Parks and Wildlife Department (TPWD)	water summit
		Soil and Water Conservation Districts (SWCD)	site demonstrations, one-on-one consultations
		Trinity River Authority (TRA)	water summit
		Tarrant Regional Water District (TRWD	Water summit, direct contact with WWTP operators and water customers
		East Texas Council of Governments	water summit
		North-Central Texas Council of Government (NCTCOG)	
		Texas AgriLife Extension Service	water summit, fact sheets, one-on-one consultations
		Texas AgriLife Research	Provide research opportunities for BMP installation
		Kaufman County Environmental Co-op	Work through local cities and counties
		East Cedar Creek Freshwater Supply District	Develop wastewater education information for public distribution

Establish a Practice of Ongoing Campaign Evaluation	Texas AgriLife Research	Stakeholder Surveys of knowledge Improvement	telephone, e mail, mail
		Stakeholder Surveys of behavioral change	
		Census of number of participants	Conduct during workshops, follow up e mail, telephone calls
		Number of practices Installed resulting from outreach	telephone, e mail, mail

1 Watershed Milestones

Because baseline data for land use and nutrient and sediment loadings were collected by a combination of ambient water quality sampling and computer modeling. The purpose for doing so it twofold: to determine (1) that actual load reductions have occurred and (2) the tracked reductions are a direct result of the proposed management plan. By maintaining the methodology that established the watershed protection effort, the most accurate comparison can be made as to the progress of reducing phosphorus and the associated impairment of chlorophyll-*a* as the implementation of the plan continues.

1.1.1 Maintenance of Planned BMP Implementation Schedule

While the implementation schedule for BMP implementation outlined by the Cedar Creek Watershed Plan in chapter 7 is ambitious, the intent is to demonstrate the maximum pollutant reduction figures in the first five years of the project. Maintaining the established schedule will require full coordination of funding, cooperation of landowners, and committed leadership. The keeping of the plan schedule and modeled results the plan will prove the Cedar Creek Watershed Plan to be politically expedient by appealing to policy makers as a noteworthy example of the success of the watershed planning method. This is anticipated to keep the project at the forefront of funding and grant programs that will be necessary to sustain the watershed plan through the projected ten year lifespan.

The implementation schedule and milestones presented in Table 7.1 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 Cedar 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.
Best Management Practice Implementation

Conservation practices will be targeted at specific sub-watersheds based on applicability and funding availability. The implementation of conservation practice installation will be measured in linear feet or acres depending on the specific practice outlines. Proposed phosphorus reductions are dependant upon following the proposed schedule of implementation as outlined in table 6.1. Results may vary should the schedule be revised due to land use changes, availability of funding, and lack of participating landowners. Milestones for the implementation of best management practices are shown in table 7.1.

Table 7.1 Milestones for implementation of BMPs by linear feet, acreage, and number of units installed (TAMU-SSL 2009).

Practice	Filter Strips	Grade Stabilization Structure	Grassed Waterway	Terracing	Cropland Conversion to Pasture	Prescribed Grazing	2000 Ft. Buffer Strip of Nutrient Management Surrounding the Reservoir
1 to 3 years	XXX	XXX	XXX	XXX	XXX	XXX	XXX
4 to 6 years	XXXX	XXX	XXX	XXX	XXX	XXX	XXX
7 to 10 years	XXX	XXX	XXX	XXX	XXX	XXX	XXX

1.2 SWAT and WASP Modeling

In order to establish a full and comparable evaluation and comparison of existing conditions to those that will occur as a result of BMP implementation, SWAT and WASP models will be conducted to reflect the new conditions for the Cedar Creek watershed. At intervals of 3, 6, and 10 years, each model will be recalibrated to reflect the BMPs that have been implemented. Additionally, evolving conditions of each watershed such as rainfall level, urban development, and land use changes will drive the re-calibration of the existing models to ensure the effectiveness of the watershed management program. Comparison of future SWAT and WASP modeling at the 3, 6, and 10 year intervals will be compared with the mapping produced to demonstrate the predicted results of implementation from chapter 7 (*note: Taesoo needs to make these*). SWAT will provide a full sub-watershed analysis of phosphorus, nitrogen, and sediment loadings while WASP will illustrate the resulting chlorophyll-*a* levels and be plotted against the overall trend to determine if the chlorophyll-*a* levels are rising at a faster rate (higher APR), rising at the current rate (3.85% APR), or rising more slowly (lower APR) or has leveled or is dropping.

1.3 Ambient Water Quality Sampling and Analysis

Recalling that much of the effort of the Cedar Creek Watershed Plan is drawn upon the results of a 19 year Tarrant Regional Water District study of ambient water quality sampling, monitoring in the same manner will provide an accurate and useful gauge of project progress. Water quality monitoring at designated areas within the watershed on a quarterly basis will allow for a frequent and incremental view of the progress achieved by the implemented management measures of the watershed protection plan. Sampling will require the professional collection and analysis of water in predetermined sites at the reservoir and tributaries in the watershed. Because this is the methodology used to determine impaired water bodies the results will be useful not only in providing a series of snapshot of water quality condition as the plan progresses but is also the means by which TCEQ uses to create the 303(d) listing of impaired water bodies. Current analysis and listing for the listing is for excessive pH and low salinity and low levels of Dissolved Oxygen. Removal of Cedar Creek Reservoir from the 303(d) list for pH concerns as it has been listed in 2002, 2004, 2006 and 2008 would represent a major milestone for the Cedar Creek Watershed Partnership and testify to the success of the established watershed plan.

1.3.1 Phosphorus Reductions

Maintaining the stakeholder set goal of 35% overland phosphorus reduction for the watershed goal is the cornerstone of the Cedar Creek watershed protection plan. The suite of management practices selected is modeled via SWAT to achieve the targeted reduction with efficient use of project funds and summarized in table 7.2.

Table 7.2 Milestones for total watershed phosphorus reduction (TAMU-SSL 2009).

	Watershed Phosphorus Reduction
1 to 3 years	XXX
4 to 6 years	XXXX
7 to 10 years	XXX

1.3.2 Decreasing Trend in Chlorophyll-*a*, Dissolved Oxygen, and pH

Demonstrable decreases in the current constituencies of concern for Cedar Creek Reservoir must be measured against the TCEQ established standards for the water body. A successful watershed planning effort based on phosphorus reduction is anticipated to result in decreasing trends of Chlorophyll-*a*, Dissolved Oxygen, and pH while resulting in removal of the reservoir from the state 303(d) list of impaired water bodies. Projected reductions for each constituent are shown in table 7.3. Monitoring of chlorophyll-*a*, DO, and pH will confirm the Cedar Creek Partnership strategy of targeting a single pollutant (phosphorus) to address a number of indicator constituencies.

Table 7.3 Reduction Milestones of Chlorophyll-*a*, Dissolved Oxygen, and pH (TAMU-SSL 2009).

	Chlorophyll-*a*	Dissolved Oxygen	pH
1 to 3 years	XXXX	XXX	XXX
4 to 6 years	XXX	XXX	XXX
7 to 10 years	XXX	XXX	XXX

1.4 Educational and Outreach Events and Impacted Behavior

Apart from the pollutant reduction totals that will be tested and modeled, milestones for the educational and outreach portion. Success of educational programming targeting nonpoint source pollution will be determined by the number of participants in workshops and seminars and the resulting attitude changes among participants. Surveys performed at staggered intervals will gauge the adoption of behavioral change over time and determine if participation in educational and outreach programming can lead to the exertion of political pressure upon local leaders by stakeholders to adopt watershed friendly ordinances and fund the implementation of management practices.

1.5 Removal from Texas Water Quality Inventory

A driving force behind the creation and implementation of the Cedar Creek Watershed Protection Plan is the placement of Cedar Creek Reservoir on the Texas Water Quality Inventory as mandated by section 303(d) of the 1973 Clean Water Act beginning in 2002. Stakeholders and project leadership are confident that the management measures outlined in the WPP provide a comprehensive strategy for reducing the level of Chlorophyll-*a* in the reservoir and thus bringing reservoir pH into line with existing state standards.

1.6 Sustaining a Clean Watershed and Reservoir

The process of watershed plan development not works to create a comprehensive plan for the improvement of the quality of water in a targeted lake, river, stream, bay, or estuary. Included in this methodology is the priority of putting power and "ownership" of water resources into the hands of local stakeholders. It is in this spirit that the Cedar Creek Plan has evolved. The blue print for reducing nutrients and sediment in Cedar Creek Lake is established but the success of the plan lies in the fortitude of local stakeholders to maintain its course. The cooperation of local residents, officials, and agency personnel is necessary to ensure clean waters for the future but also to foster a new generation of advocates for watershed protection.