Cedar Creek Watershed Protection Plan

Developed by

The Cedar Creek Watershed Partnership

June 2008

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EXECUTIVE SUMMARY

Background

The Cedar Creek Reservoir Watershed Protection Plan is a comprehensive watershed-based strategy to improve water quality for human use in Cedar Creek Reservoir and the network of creeks from which the Reservoir draws its supply of water. The Plan was developed by a partnership of state and federal agencies, public and private organizations and individuals herein referred to as "stakeholders." The Cedar Creek Watershed Protection Plan has been assembled to address impairments to the water body as identified in the 2006 Texas Water Quality Inventory and 303(d) list as indicated by the Environmental Protection Agency in enforcement of the Clean Water Act. The Plan describes the state of the watershed, presents a strategic plan to limit pollution which will include the establishment of Best Management Practices, and proposes a monitoring plan to determine the success of the Plan.

The stated objective of the Cedar Creek Watershed Protection Plan is to reduce the level of the substance chlorophyll-*a* within the Reservoir. Chlorophyll-*a* is a photosynthetic product that serves as an indicator of algae growth within a water body. Water quality monitoring by Tarrant Regional Water District demonstrates an increasing level of chlorophyll-*a* within the reservoir over the last 18 years. This trend is the result of high nutrient levels, particularly phosphorus, in the water. Activities within the watershed which contribute to the release of these nutrients have been the focus of the study.

As of October, 2007 project leaders and stakeholders had agreed in principal on the basic goal of reducing phosphorus loadings in the Cedar Creek Watershed by 35 percent. It is forecasted that the proposed best management practices introduced to lower phosphorus will also assist in the reduction of nitrogen and sediment loadings.

Implementation of the plan is slated for the fall of 2008 although it should be noted that the Plan will act as a living document; subject to revision as the performance is evaluated.

The Cedar Creek Partnership

The Cedar Creek Watershed Partnership is an organization of landowners, agricultural producers, city, county, state and federal officials, and empowered citizens working to improve the welfare of Cedar Creek Reservoir and Watershed. The strategy to protect the Cedar Creek Watershed was developed by the Cedar Creek Watershed Partnership.

The general stakeholder advisory group was asked to serve on a work group suited to their interests and constituencies. These groups are:

Urban Stormwater and Wastewater Treatment Plants
Rural and Agricultural
Education and Outreach

The purpose of these groups is to focus on the establishment and funding of best management practices and affiliated programs designed to reduce the loadings of pollutants into Cedar Creek

Watershed. These teams will advise the project staff on the viability of proposed locations and strategies as well as review and provide input into the formulation of the watershed protection plan.

State of the Watershed

The Watershed

Construction of Cedar Creek Reservoir began in 1960 with formation of the Joe B. Hogsett Dam which was completed in 1965. The Reservoir was filled to capacity by 1969 as a 34,000 acre water body with a storage capacity of 678,000 acre-feet (1 acre-foot = 325,851 gallons). The reservoir is fed by the tributaries of Jones Creek, Walnut Creek, Williams Creek, Mill Creek, Bachelor Creek, Big Brushy Creek, Little Cottonwood Creek, Eagan Creek, Kings Creek, Cedar Creek, Lacy Fork, Crooked Creek, and Caney Creek. The resulting watershed touches Kaufman, Henderson, Rockwall, and Van Zandt Counties for a total of 1007 square miles south east of Dallas.

Figure 0.1 Cedar Creek Watershed and Towns

As the Cedar Creek Reservoir nears its 40th birthday, the associated watershed faces challenges linked with changing landuse. A history of agricultural practices and associated use of fertilizers and land degradation have impaired water quality. Population increases within encompassing counties of Kaufman, Henderson, Rockwall and Van Zandt have resulted in an increase of Wastewater Treatment Plants. Additionally, changing economic and demographic conditions have lead to a transition from cropland into pastureland. Housing developments and urban growth, primarily in the north portion of the watershed, have created a high rate of sediment and nutrient flow transported via stormwater runoff encountering permeable and non permeable surfaces.

According to US Census Bureau data, populations in the four counties that encompass the Cedar Creek Watershed are anticipated to grow significantly over the next 50 years, increasing the stress and potential loadings of nutrients and sediment within the watershed.

Such factors have contributed to the placement of the Cedar Creek Reservoir on the 2004 and 2006 Texas Commission on Environmental Quality 303(d) listings of impaired water bodies as mandated by the Clean Water Act. In an effort to promote pollutant reductions that will allow for removal of the Reservoir from the list, the Tarrant Regional Water District has partnered with the Texas Water Resources Institute, Texas AgriLife Extension Service, Texas AgriLife Research, Texas AgriLife Research and Extension Urban Solution Center at Dallas, the Environmental Protection Agency, United States Department of Agriculture-Natural Resources Conservation Service and numerous other organizations in the creation and implementation of a this watershed protection plan.

Water Quality

The Tarrant Regional Water District (TRWD) has been proactive in evaluating water quality on its reservoirs. In 2005, the District conducted a comprehensive 17-year study to evaluate lake water quality. The report found an increasing trend in chlorophyll-*a*, the green pigment in plants that is used for photosynthesis. Increasing chlorophyll-*a* levels are indicative of increased algae growth which can be correlated to high phosphorus and nitrogen levels in the reservoir. Low Secchi Disk readings, a field test which indicates the clarity of water, also point to algae growth within the water column.

The abundance of algae identified in the report is associated with high concentrations of total and dissolved organic carbon. The proportion of blue-green algae is high during the summer growing season, and low oxygen concentrations develop at bottom depths during this time. The low oxygen concentrations in deep waters appear to stimulate internal loading of nutrients within the sediment, setting up a positive feedback that is likely to maintain eutrophic (*waters high in nutrients that support a proliferation of plant life, including algae*) conditions in Cedar Creek Reservoir. Algal abundance roughly doubled during the 17-year study. 2006 Chlorophyll-*a* counts show a median concentration 16.5 ug/L. This number represents a total reservoir upward annual trend of 3.85 percent.

Table 0.1 Water Quality Standards for Cedar Creek and TCEQ (TCEQ 2006) (TRWD 2007).

Substance	**Cedar Creek Reservoir Concentration**	**TCEQ Standard**
Chlorophyll-*a*	19.5 ug/L (at intake)	23.47 ug/L
Nitrogen	.097 mg/L (at intake)	.995 mg/L
Phosphorus	0.08 mg/ L (at intake)	.068 mg/L
Dissolved Oxygen	Depressed	5.0 mg/L
pH	8.1	6

State Assessment and Reporting

Section 303(d) of the Clean Water Act requires that individual states submit to the environmental protection agency a listing of impaired water bodies based on established criteria developed for the uses of water supply, recreation, fish consumption, and the proliferation of aquatic life:

a) State assessment reports
(1) Contents
The Governor of each State shall, after notice and opportunity for public comment, prepare and submit to the Administrator for approval, a report which—
(A) identifies those navigable waters within the State which, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain applicable water quality standards or the goals and requirements of this chapter;
(B) identifies those categories and subcategories of non- point sources or, where appropriate, particular nonpoint sources which add significant pollution to each portion of the navigable waters identified under subparagraph (A) in amounts which contribute to such portion not meeting such water quality standards or such goals and requirements;
(USC 33:26:3§1329)

Such water bodies are then recommended for management measures either in the form of establishing a strict Total Maximum Daily Load (TMDL) to regulate activities within the watershed or the establishment of a watershed protection planning effort: a stakeholder based plan based on volunteer pollution mitigation measures.

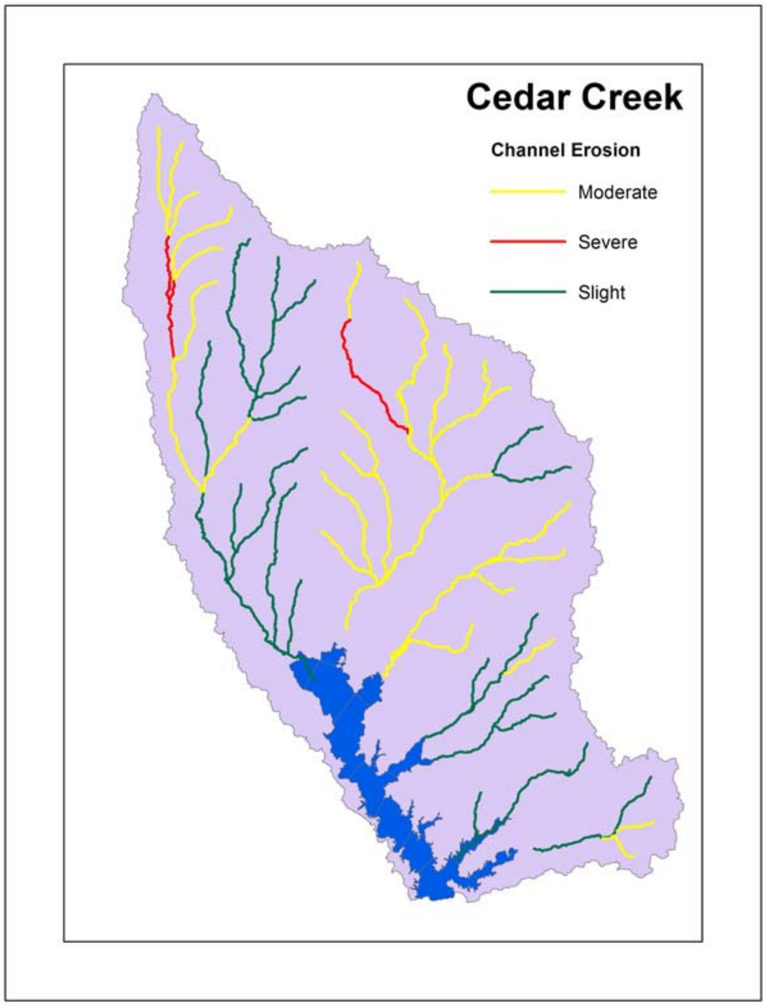
Wastewater Treatment

Point source discharges of treated wastewater present a source of loadings into the Watershed. At the time of this writing, nine wastewater treatment plants operate within the Cedar Creek Watershed with plans for an additional four of which have recently been constructed or are in the planning phases in Kaufman County. Existing plants employ a variety of methods to achieve compliance with current Texas Commission on Environmental Quality (TCEQ) standards however, implementation of new facilities and engineering to comply with projected upgrades in water quality standards is encouraged. Industrial discharges outside of municipal jurisdictions are minimal

Agriculture

Despite the growth of urban areas such as Terrell and Rockwall, agriculture continues to be the predominant landuse within the Watershed. Geographic Information Systems modeling indicates that a full 64 percent of the land mass is used as pastureland with an additional 6 percent devoted to row crops. This dynamic presents an interesting challenge for watershed planning as nutrients in fertilizers become the main source of nonpoint source pollutant loadings. Excessive use of fertilizers on row crops has resulted in nitrogen and phosphorus loadings that are transported over the land and into tributaries during periods of heavy rainfall. Livestock practices that permit the free roaming of cattle into riparian areas as well as overgrazing encourage erosion of stream banks and sedimentation of water bodies.

Figure 0.2 Cedar Creek Channel Erosion



According to Texas A&M University Spatial Sciences Laboratory modeling, nonpoint source contribution account for 51 percent of the total watershed phosphorus loading in the watershed. Remediation of nutrient loads presents the challenge of creating and implementing best management practices. Cedar Creek Watershed planners have recommended nutrient management, construction of retention ponds, vegetation buffers between pasture/crop lands and riparian areas, and practices such as rotational grazing, contour farming and crop variation.

Education & Outreach

Watershed protection requires the establishment of educational and outreach programs to inform stakeholders on the condition of the watershed, best management practices to mitigate pollutants, and the role of individuals in the process of achieving water quality goals. Education and outreach programs will focus on urban best management practices and the impartment of behavioral changes among urbanites to prevent pollutant loadings into stormwater collection systems. Partnerships with the Texas Master Gardener programs of Henderson and Kaufman Counties will allow members to serve as ambassadors and educators for best management practices.

The outreach component will seek to offer technical and financial assistance to property owners, agricultural producers, and urban officials in the establishment of structural and behaviorally-based best management practices appropriate for the reduction of pollutant loadings. Programs targeting homeowners will focus on rainwater harvesting, lawn fertilizer management, and septic system maintenance.

Sources and Causes of Pollution

Modeling and monitoring of water quality at all five Tarrant Regional Water District reservoirs began in 1989. The 17- year study determined that Cedar Creek Reservoir is heavily influenced by sediment and nutrient loadings from the surrounding landscape that have the potential to impair the reservoir in a variety of ways. Most prominent among these: the proliferation of Chlorophyll-*a*, an indicator of algal growth. High Chlorophyll-*a* counts can signify issues with water clarity, oxygen content, and proliferation of aquatic life.

Table 0.2 Watershed Pollutant Loadings per Landuse (TAMU 2007).

Source (% of total watershed)	Sediment	Phosphorus	Nitrogen
Urban land (6.39%)	7.37%	13.29%	7.37%
Wastewater Treatment Plant (N/A)	0.10%	12.11%	7.21%
Pasture (63.52%)	15.73%	22.57%	44.06%
Crop land (6.17%)	41.79%	42.52%	23.51%

Institutional Framework

The Cedar Creek Watershed Protection Plan is a collaborative effort of many local, state, federal, and non-governmental organizations. Funding, technical support, and logistical leadership have each been provided by the following entities under the coordination of the North Central Texas Water Quality Project:

Federal Agencies:

U.S. Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS)
U.S. Environmental Protection Agency (EPA)

State Agencies:

Texas AgriLife Extension Service
Texas AgriLife Research
Texas Commission on Environmental Quality
Texas Parks & Wildlife Department
Texas State Soil and Water Conservation Board

Local/ Regional Agencies:

Kaufman-Van Zandt Soil and Water Conservation District
Tarrant Regional Water District

Local Governments:

City of Athens
City of Kaufman
City of Kemp
City of Mabank
City of Terrell
City of Tool
Henderson County
Kaufman County
Rockwall County
Van Zandt County

Interest Groups:

Environmental Co-Op of Kaufman County
Texas Master Gardeners of Kaufman County

Elected Officials:

Office of State Representative Betty Brown
Office of State Senator Bob Deuell
Office of State Senator Robert Nichols

About the North Central Texas Water Quality Project

The North Central Texas Water Quality Project is a collaborative effort of the Texas Water Resources Institute, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Commission on Environmental Quality, Texas State Soil and Water Conservation Board, and Tarrant Regional Water District. Funding for the project comes from the Environmental Protection Agency and the United States Department of Agriculture-Natural Resources Conservation Service.

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Cedar Creek Reservoir and Watershed Protection Plan

1. CHAPTER 1: Watershed Management

Watershed Management is a relatively new approach to improving water quality which accounts for the human impacts and natural occurrences within a geographically defined basin that drains to a common water body. This approach has been embraced in recent years over previous efforts to manage water quality within political jurisdictions at the municipal, county, and state levels. The watershed approach allows for an accounting of all land and water based human and natural activities that may impact water quality system allowing for a holistic approach to management. Once pollutant loadings and sources are identified water managers can choose from two approaches:

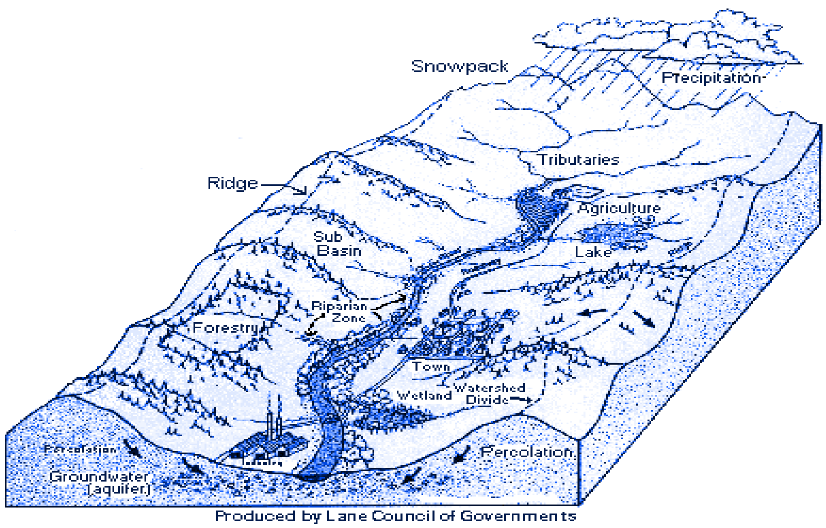
1. The establishment of a Total Maximum Daily Load (TMDL) program that establishes set allowable pollutant concentrations in designated water bodies that are enforceable by local, state, and federal regulation. This can be done by limiting activities or mandated installation of structural best management practices. TMDL programs have, in the past, been the preferred method of addressing watershed pollutants.

2. Creation of a stakeholder input bases watershed protection plan based upon implementation of voluntary structural and behavioral best management practices (BMPs). These include the enlistment of willing land owners in installing filter strips, grassed waterways, etc. Educational programming in the form of public awareness campaigns and workshops on subjects such as lawn fertilizer management and rainwater harvesting provide a means for behavioral changes among watershed residents

Watershed Definition

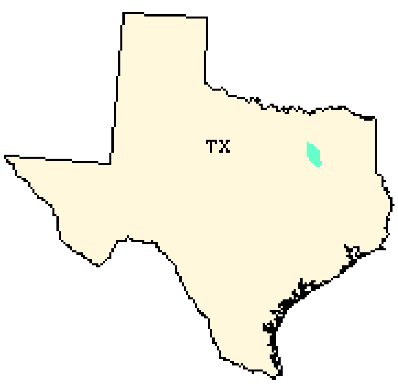
A watershed is a land mass formed by elevation changes, slope, and other geographic and topographical features that allow for the drainage of surface water in the form of streams, rivers, and stormwater runoff to a single reservoir, lake, or river. Watersheds are typically part of a larger basin system and can also be subdivided into the smaller units known as subwatersheds and catchments. From a water quality standpoint, this approach allows for the delineation of geographic areas within an area of concern to be subdivided for strategic management and funding purposes. For each watershed, the United States Geologic Survey has assigned a 12-digit Hydrological Unit Code (HUC) as part of a system of geographic identification of watershed systems. The Cedar Creek Watershed is HUC# 12030107.

Figure 1.1 Basic Watershed Hyrdography (EPA 2007).



The Cedar Creek Watershed is 1007 square miles located primarily south east of Dallas, Texas. The watershed is defined by the drainages of Big Brushy, Lacey, Kings, and Cedar Creeks into Cedar Creek Reservoir. It is part of the larger Trinity River Basin and is neighbored by the Trinity River to the west and Sabine River to the east.

Figure 1.2 Location of Cedar Creek Watershed (EPA 2007).



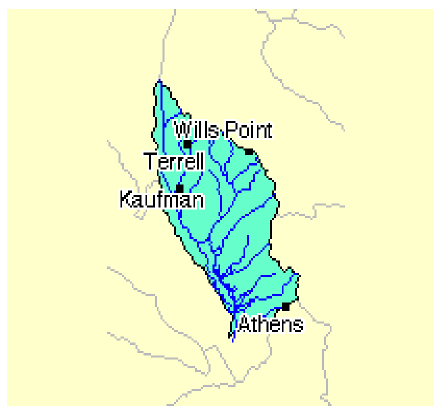
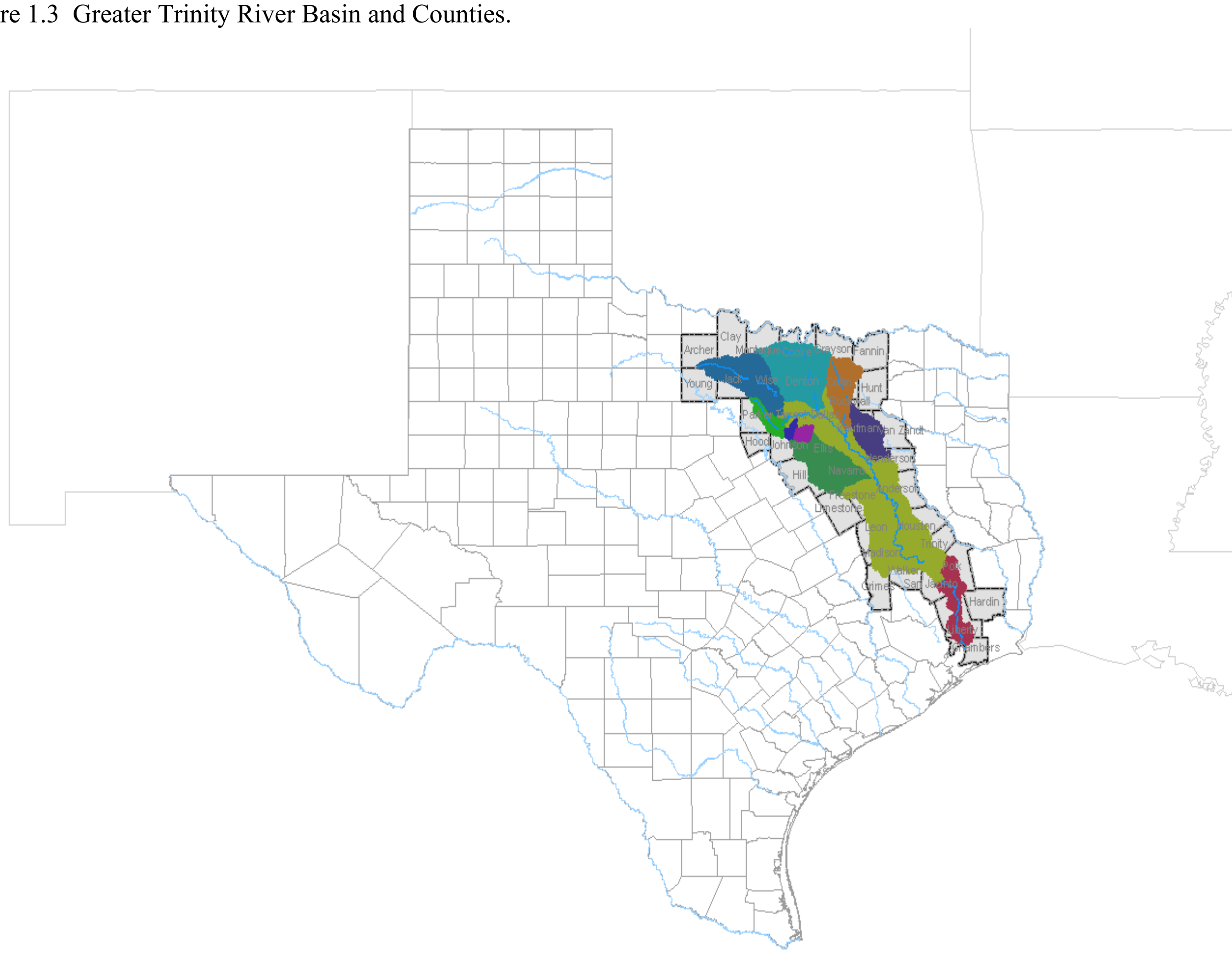


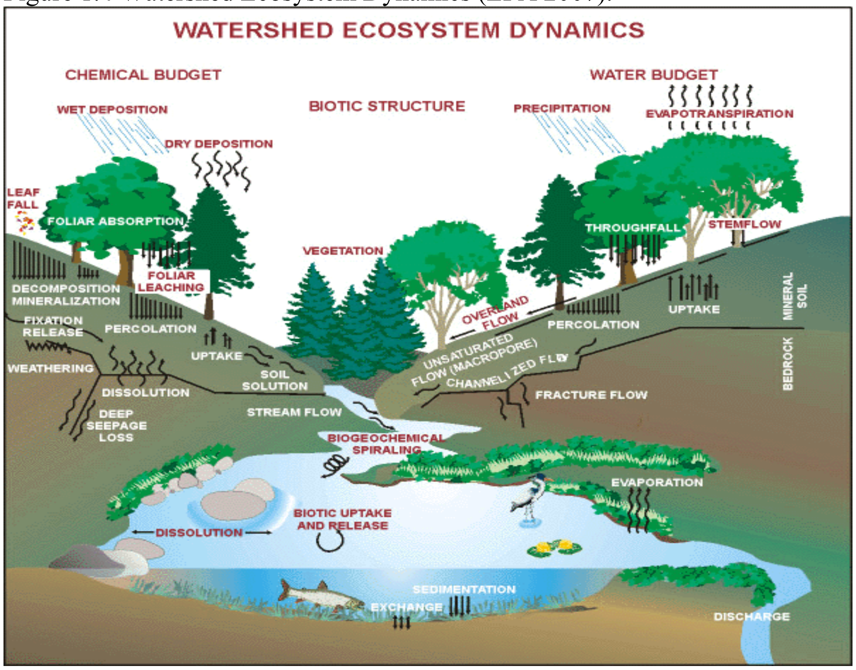
Figure 1.3 Greater Trinity River Basin and Counties.



Linking Watersheds to Water Quality

Because watersheds can encompass such a large land mass, the activities of humans such as agriculture, industry, and property development have an effect on amount of pollutants and sediments that are delivered into water bodies. Natural processes also play a role in impacting water quality through evaporation, atmospheric deposition, infiltration, and the decomposition of organic matter. While knowledge of the function and potential of these processes is helpful to accessing current conditions, the purpose of watershed planning is to identify and mitigate the sources of human produced pollutants. By evaluating the impact of pollutants on these natural processes, watershed managers can simulate the potential impact nutrients and sediment within the watershed. For example excessive nutrients from fertilizers, herbicides, and pesticides, can result in an abundance of plant life and eventual oxygen depletion of the water as the plants die off and decompose. Because a watershed represents a basin that drains into a common water body, investigation of climate, landuse, human activity, and soil types of the entire watershed area factor in to the equation of water quality.

Figure 1.4 Watershed Ecosystem Dynamics (EPA 2007).



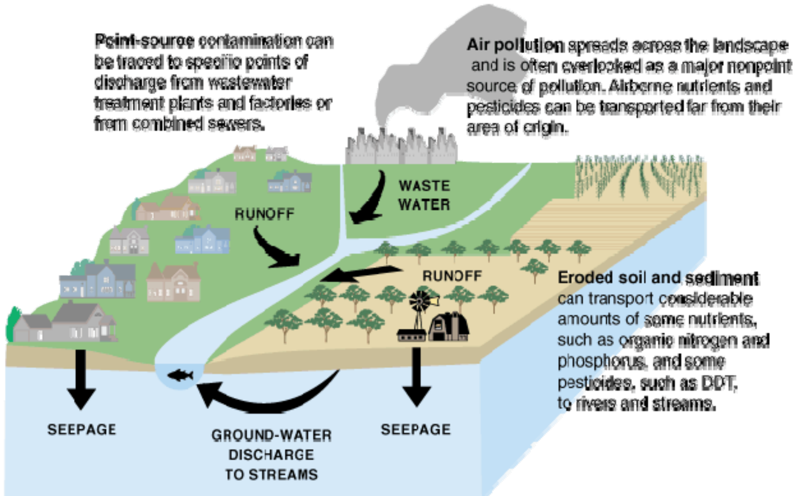
For the purposes of water quality planning, regulators such as the United States Environmental Protection Agency and Texas Commission on Environmental Quality have classified the forms of water pollution into two broad categories:

Point Source Pollution

Point Source pollution is a directly defined and accountable form of water pollution that is loaded directly into a watershed as a result of human activity. Wastewater treatment plant, industrial and municipal stormwater system discharges are all examples of point source pollution. Point source pollution is worsened by illegal discharges, dumping pollutants into storm drains, and outdated permitting programs for wastewater treatment plants that do not utilize the best available technology.

Point source pollution can be regulated through municipal ordinances such as requiring auto filling stations to install on-site controls for spilled gasoline. Other point sources must be legally permitted by federal and (or) state regulatory agencies to discharge pollutants under licensing programs. In the state of Texas, the Texas Commission on Environmental Quality (TCEQ) is charged with issuing permits for discharges from wastewater treatment plants (WWTP), industry, and confined animal feeding operations (CAFO) as part of the Texas Permitted Discharge Elimination System (TPDES). Municipal Storm Sewer Systems (MS4's) are also regulated by permit under the supervision of The Texas Commission on Environmental Quality.

Figure 1.5 Watershed Processes (EPA 2007).



Nonpoint Source Pollution

Nonpoint source pollution results from the cumulative effect of stormwater run off and erosion within the watershed. Nonpoint source (NPS) pollutants can include fertilizers, pesticides, herbicides, and spilled fuel. Nonpoint source pollution is amplified by inefficient agricultural practices, the elimination of wetlands and other natural features that can reduce pollution and sedimentation, and the construction of impervious surfaces such as asphalt parking lots and roadways that reduce infiltration of rainwater into the ground.

Because nonpoint source pollution results from watershed wide sources and practices, it is more difficult to regulate than point source pollution. In most instances, nonpoint source pollutants are mitigated through the instillation and adoption of best management practices, a series of structural and behavioral practices that are designed to reduce the flow of pollutants into watersheds. Best management practices may include the construction of urban wetlands, the creation of vegetated buffer zones next to drainages or riparian areas, and responsible use of fertilizers and pesticides. Education programs and campaigns for urban landscaping and agricultural practices are also considered best management practices.

Benefits of a Watershed Approach

As watersheds are determined by the landscape and not political boundaries, watersheds often cross municipal, county and state boundaries. By using a watershed perspective, all potential sources of pollution entering a waterway can be better identified and evaluated. Just as important, all stakeholders in the watershed can be involved in the process. A watershed stakeholder is anyone who lives, works, or recreates in the watershed. These individuals have a direct interest in the quality of the watershed and are affected by planned efforts to address water quality issues. Individuals, groups and organizations within a watershed can become involved as stakeholders in planning and executing initiatives to protect and improve local water quality Stakeholder involvement is critical for selecting, designing, and implementing management measures to successfully improve water quality. Stakeholders offer the various perspectives of their constituencies and allow for the formation of a plan that is not only feasible but palatable to those most impacted.

Watershed Protection Planning

A Watershed Protection Plan (WPP) is an active document created to format strategies and timelines for action to improve water quality in a designated watershed. Most watershed protection plans are developed by local stakeholders through voluntary, non-regulatory water resource management. Public participation is critical throughout plan development and implementation, as ultimate success of any Watershed Protection Plan depends on stewardship of the land and water resources by landowners, businesses, and residents of the watershed. The Cedar Creek Watershed Protection Plan defines a strategy and identifies opportunities for widespread participation of stakeholders across the watershed to work together and as individuals to implement voluntary practices and programs that restore and protect water quality in Cedar Creek Reservoir.

Elements of the Watershed Protection Plan

The Cedar Creek Watershed Protection Plan is produced under the auspices of the Environmental Protection Agency. In promoting watershed based planning, the EPA has outlined nine elements necessary to a successful establishment of a watershed protection plan. The following steps provide a template for creation, implementation, and review of watershed protection efforts. While the composition and strategy of watershed protection plans vary, the basic elements should include the following:

1. Identify sources and causes of pollution
2. Estimate necessary load reductions
3. Describe point and nonpoint source management measures
4. Assess the technical and financial assistance needed
5. Design an informational/educational component
6. Develop a schedule of implementation
7. Set interim measurable milestones for progress
8. Establish criteria to determine load reductions
9. Create a monitoring component

The following plan touches on all nine elements although not necessarily in the order presented by EPA. The plan provides a comprehensive examination of the history, science, and solutions behind improving the water quality in the Cedar Creek Reservoir and Watershed.

2. CHAPTER 2: State of the Cedar Creek Watershed

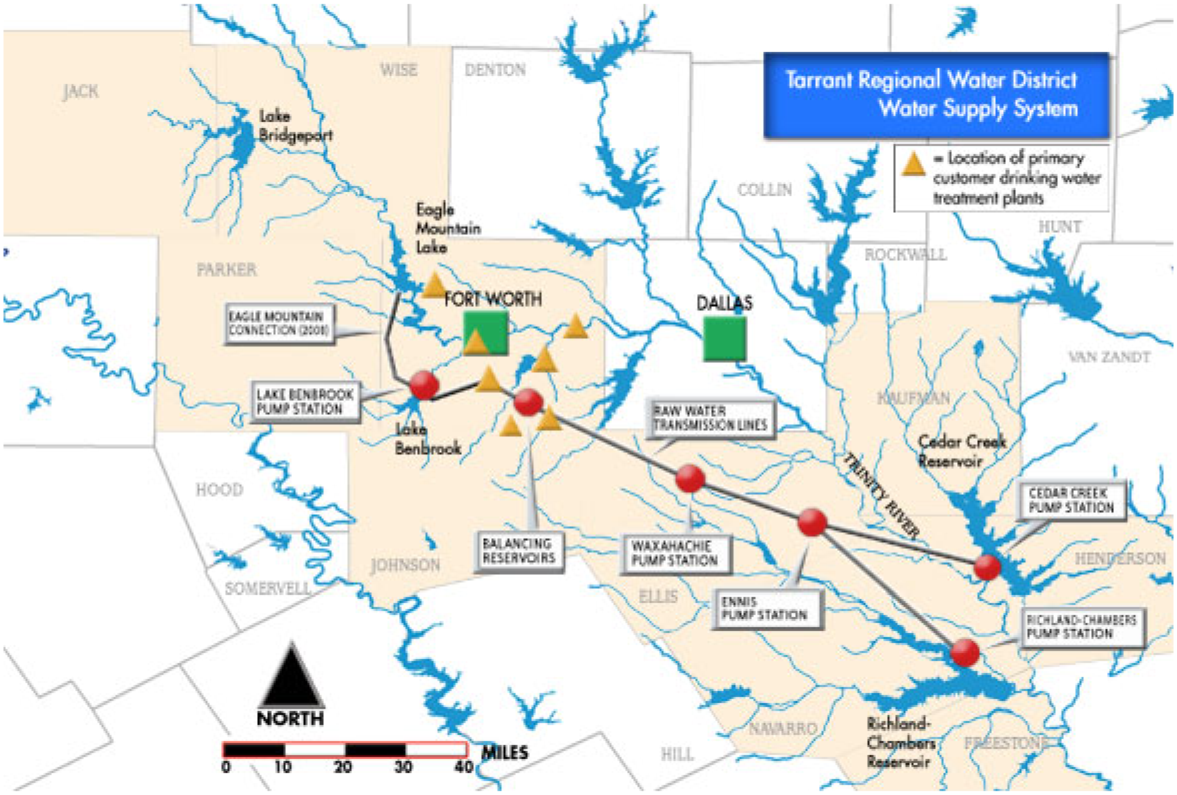
Cedar Creek watershed is shared among the counties of Henderson, Kaufman, Rockwall, and Van Zandt. Each county has a heritage steeped in agricultural tradition that is evolving due to the proximity of the watershed to the economically booming Dallas. While the ecological conditions have permitted use for farming and ranching, increasing populations, technologies, and changing landuses pose a unique challenge to maintaining water quality. It is this combination of the effects of historical agricultural practices and increasing urbanization of Cedar Creek Watershed lands that present the current challenges to maintaining water quality in Cedar Creek Reservoir.

History

The high plains region of North East Texas containing 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 Regional Water District (TRWD) 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 south east 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 the Metroplex were targeted for reservoir construction due to the higher rainfall amounts and lower human population of such areas. Construction of the 91-foot tall, 17539-foot earthen Joe Hogsett Dam started in 1960. Due to a heavy rainfall trend in the late 1960's, Cedar Creek 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 1980's an additional pipeline was added to parallel the Cedar Creek water line. While portions of this piped water are removed in route to Ft. Worth by the City of Arlington and other Tarrant Regional Water District water customers, the remaining supply is fed into balancing ponds southeast of Fort Worth to allow for uninterrupted flow during peak usage times (Tarrant Regional Water District).

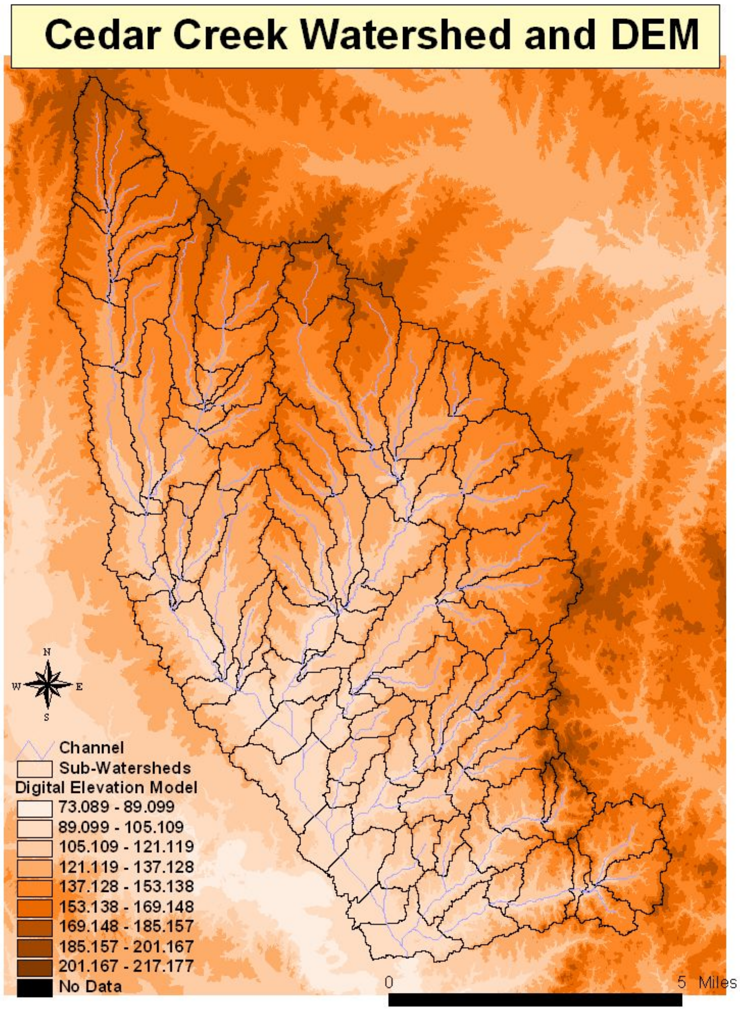
Figure 2.1 Tarrant Regional Water District Water Supply System (TRWD 2007).



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 stormwater to the Sabine River while the western boundary represents a split of the drainage between Cedar Creek and 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. Prior to the construction of Cedar Creek Reservoir, Cedar Creek drained into the Trinity River to the southwest of the current reservoir site.

Figure 2.2 Cedar Creek Watershed and Digital Elevation Model



Ecology

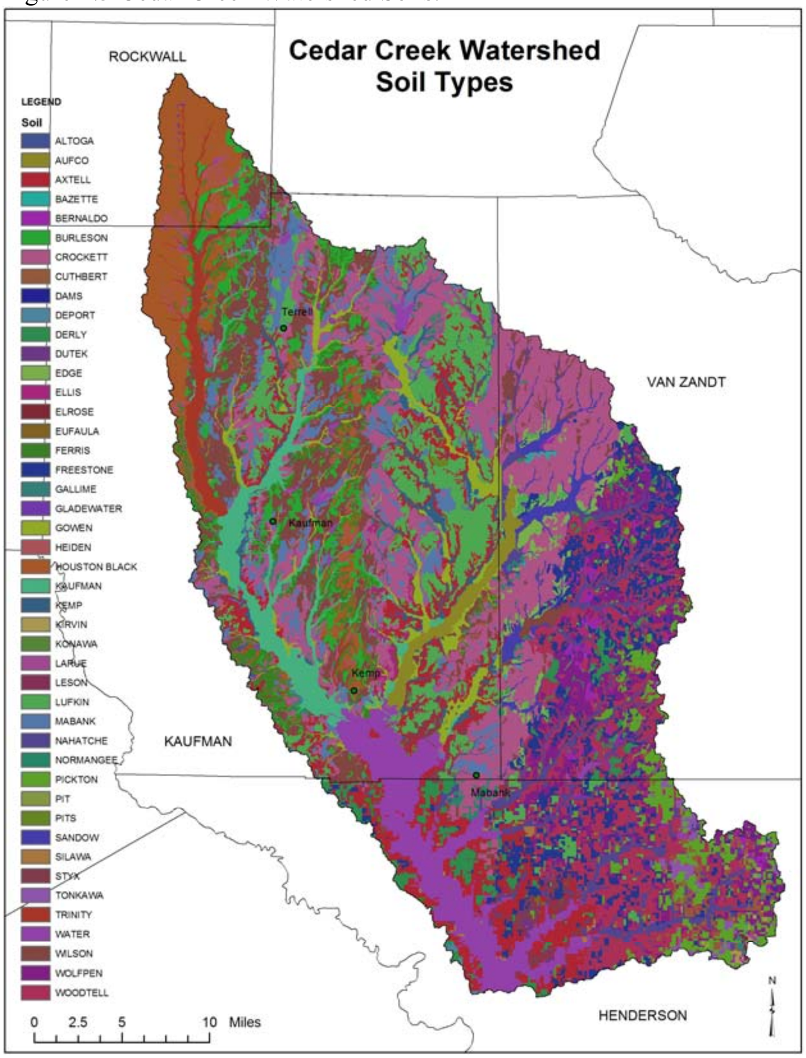
Vegetation within the watershed consists primarily of prairie grasses including little and big bluestem, Indian grass, switch grass, grama, and Virginia wild rye. In the northern portion of the watershed, pastureland has replaced native grasses with Bermuda, Johnson grass, and clover. Woody undergrowth 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.

Soils

Soils within the Cedar Creek Watershed are slightly acidic with dark and light loamy surfaces and clayey subsoils (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.

Figure 2.3 Cedar Creek Watershed Soils.



Water Resources

The Cedar Creek Watershed totals 1007 square miles situated southeast of Dallas. As a part of the Trinity River basin, the water from the Cedar Creek Watershed drains into the Gulf of Mexico at Galveston Bay. Cedar Creek Reservoir is a 33,623-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 637,000 acre-feet and is designated for the use of public water consumption under TCEQ standards. The

Cedar Creek Reservoir Watershed is comprised by a network of tributary streams flowing west and southwest into the Reservoir.

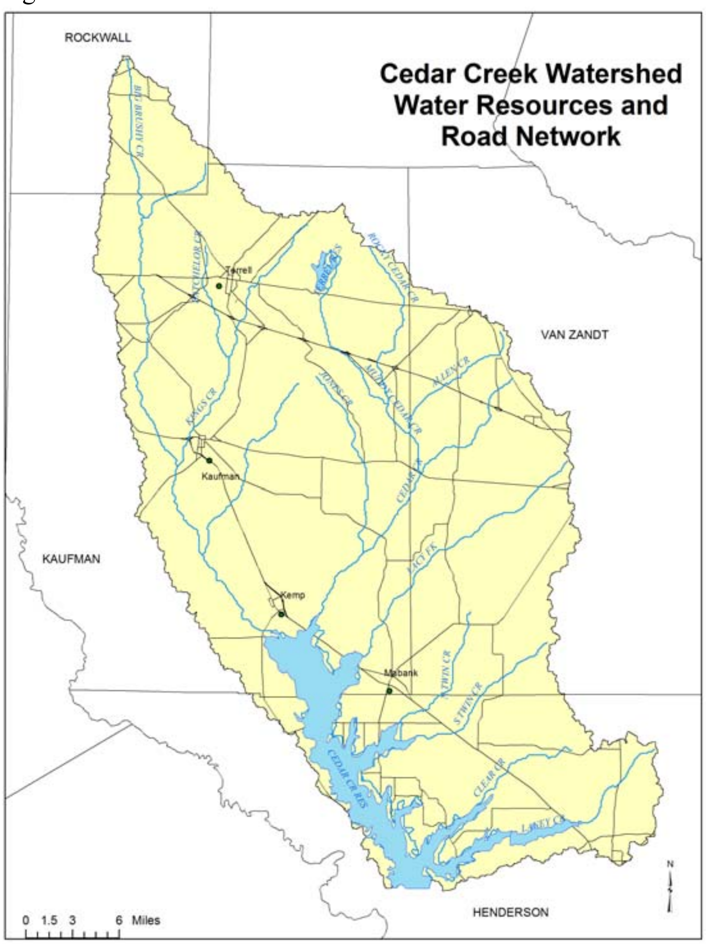
Tributaries

The main tributaries of Cedar Creek include Kings Creek, Bachelor Creek, Jones Creek, Big Brushy Creek, and Laney Creek, and Lacy Fork. Flood control efforts conducted in the 1950's by the Army Corps of Engineers resulted in straightening of sections of Kings Creek and Big Brushy Creek. Meanwhile the lower sections of Big Brushy Creek and Cedar Creek have formed wetlands on their respective routes. The southern portion of the watershed supports a bottomland hardwood forest in the lower portions of Laney and Clear Creeks.

Terrell Reservoir

Also noteworthy is the presence of Terrell Reservoir in the northeast portion of the watershed. Also known as Terrell City Lake, the reservoir was formed by the impounding of Cedar Creek in 1955. It is owned and operated by the city of Terrell and serves as a municipal water supply and recreation area. The reservoir's storage area is 8,300 acre-feet. At its emergency spillway crest elevation, the reservoir's capacity is 12,400 acre-feet with a surface area of 1,150 acres (Handbook of Texas).

Figure 2.4 Cedar Creek Watershed Water Resources and Road Network.



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).

Figure 2.5 Cedar Creek Watershed Weather Stations.

3. CHAPTER 3: Current Conditions

The condition of lands within the Cedar Creek Watershed represents a shift toward increased urbanization and the resulting issues. This region of upland prairie (EPA 2007) was farmed extensively during the early part of the 20th Century. Agricultural usage gradually transitioned from row crops to pasture and rangeland for the raising of cattle for beef and dairy, resulting in increased erosion and sedimentation of streams and the establishment of non-native grass species, such as Johnson grass. As portions of the watershed area move toward urbanization, new water quality issues in Cedar Creek Reservoir and the surrounding tributaries arise. Stormwater runoff from construction projects, greater totals of impervious cover, and increased effluent flows from wastewater treatment plants present new challenges for water quality planners.

The North Central Texas Council of Government (NCTCOG) forecasts that the populations of member watershed counties (Kaufman and Rockwall) will grow at rates of 245 percent and 158 percent, respectively, by the year 2030. (NCTCOG 2007). Information from the US Census Bureau indicates that a total of 2,240 building permits were issued in 2006, the majority of which are in the aforementioned counties.

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. There are currently no Confined Animal Feeding Operations located in the watershed. However, livestock operations can threaten water quality due to the concentration of nutrients resulting from manure that flows into watershed creeks and streams. Furthermore, grazing operations 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. 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.

Water Quality

In an effort to reinforce the effectiveness of the 1970 Clean Water Act, the EPA added a watershed-based approach to mitigating water quality issues during the 1990's. By using a strategy of management efforts based on drainage basins, local authorities could tackle the issues holistically allowing for examination and mitigation of all contributing factors.

In Texas, the enforcement efforts shifted from the US Environmental Protection Agency to the Texas Natural Resources Conservation Commission (now called the Texas Commission on Environmental Quality or TCEQ). The Texas Commission on Environmental Quality administrates water quality by permitting discharges from wastewater treatment plants, industrial activities, and Confined Animal Feeding Operations. Additionally, the Texas Commission on Environmental Quality regulates construction and transportation projects, municipal stormwater, and surface water quality.

In doing so, the Texas Commission on Environmental Quality is mandated by the Environmental Protection Agency to produce a biannual listing of impaired surface water bodies that do not meet pre-established load standards for designated pollutant indicators including Dissolved Oxygen, pH, and Chlorophyll-*a*, and sediment. This listing, known as the 303(d) list (named for the section of the Clean Water Act that it is mandated under), provides a glimpse of the overall water quality concerns in the state of Texas. In 2006, Cedar Creek Reservoir was listed as "impaired" under the 303(d) list for high levels of pH. However, it is result of a 16-year monitoring program by Tarrant Regional Water District that reveals a trend of increasing Chlorophyll-*a* as the focus of this Watershed Protection Plan.

Table 3.1 Draft Nutrient Criteria for Texas Reservoirs.

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

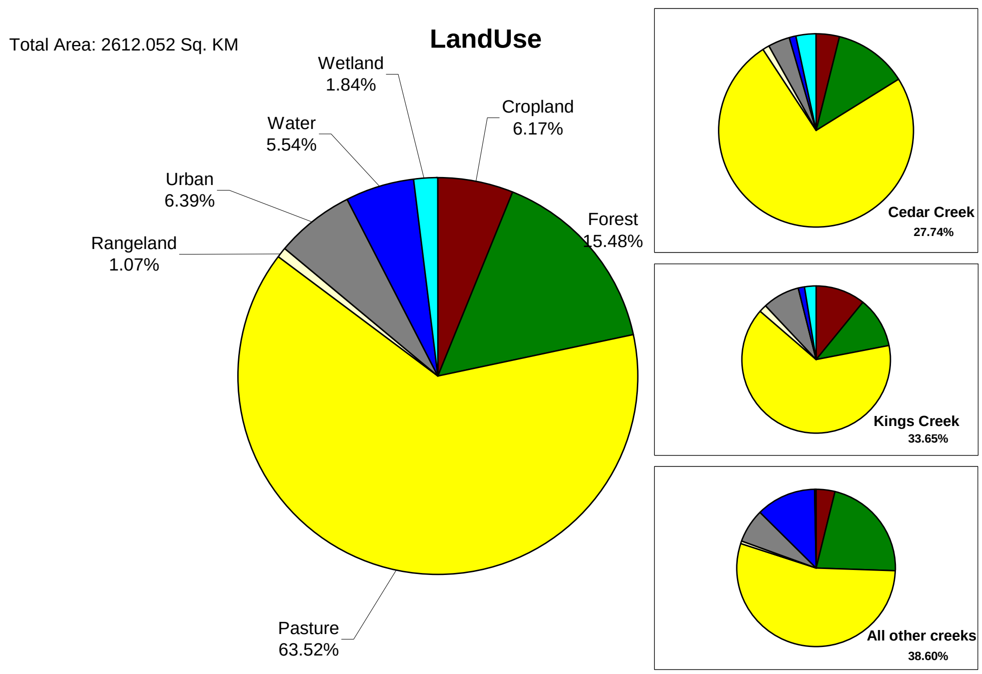
4. CHAPTER 4: Methods of Analysis

Water quality within the Cedar Creek Watershed has been performed in three different methods:

Landuse Classification

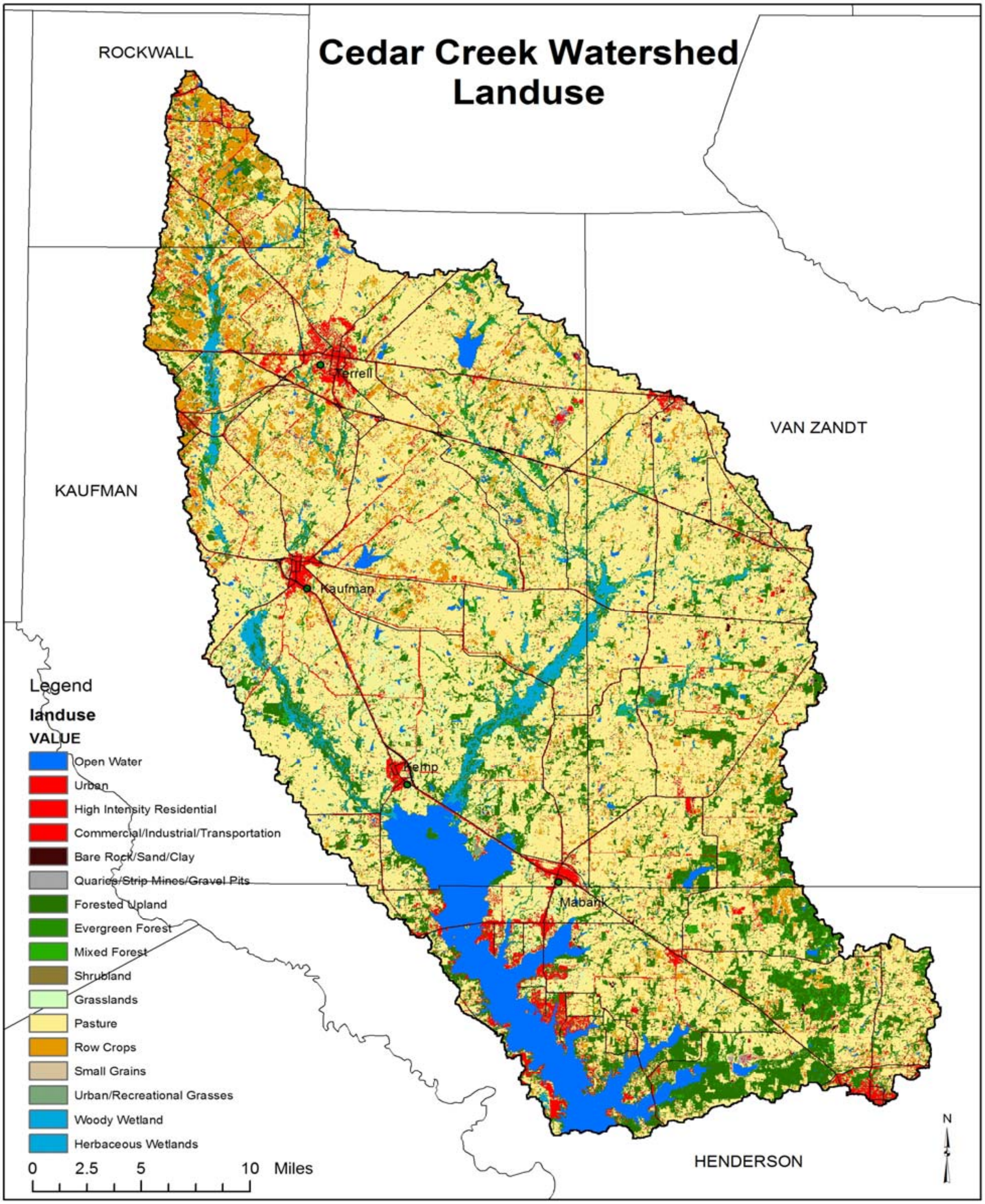
Using survey data and computer modeling, the Spatial Sciences Laboratory at Texas A&M University produced a map of the various landuses within the Cedar Creek Watershed. Linking landuse to pollution sources is a vital part of watershed protection planning as it allows for the creation of pollutant reduction strategies catered to specific areas of the watershed.

Figure 4.1 Cedar Creek Watershed Landuse Percentages.



As of April 2007, the majority (63 percent) landuse for the Cedar Creek Watershed consists of pastureland. Forest cover occupies 15.48 percent of the watershed, primarily in the southeastern areas. 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 landuse.

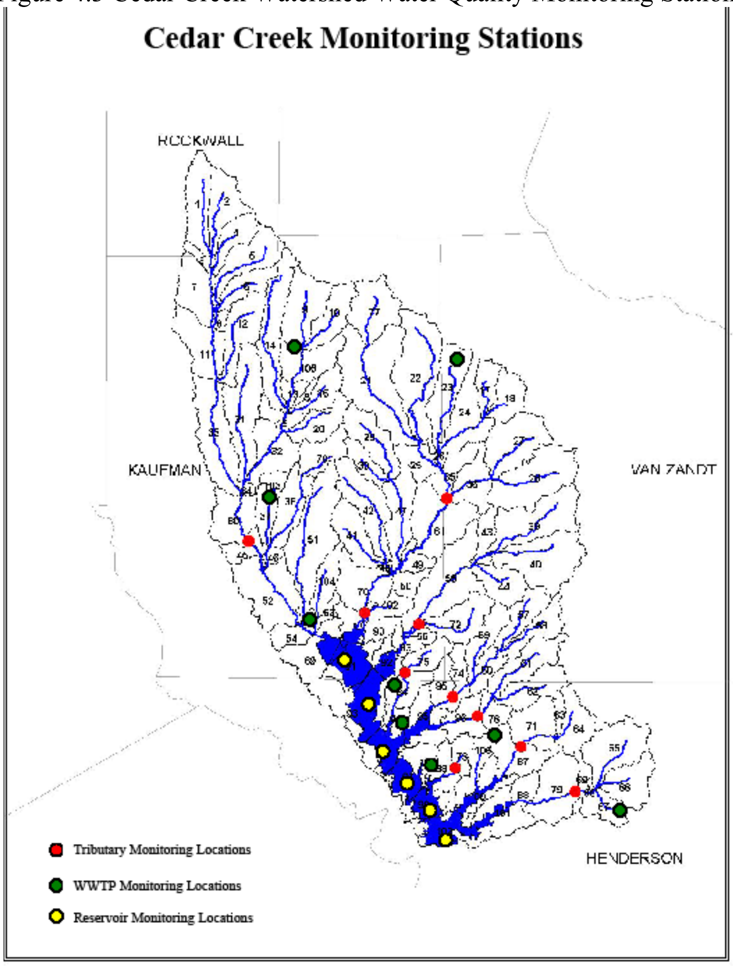
Figure 4.2 Cedar Creek Watershed Landuse.



Ambient Water Quality Monitoring

Direct sampling and laboratory testing of water quality provides a more traditional method for analysis. This method has been performed at designated locations with the Cedar Creek Reservoir and Watershed by Tarrant Regional Water District and the Texas Commission on Environmental Quality as part of requirements 305(b) of the Clean Water Act (33 USC §1329) However, with the advent of watershed-based planning, ambient water quality testing has proven inadequate for analysis of landscape level processes that effect nutrient and sediment loads on a larger scale.

Figure 4.3 Cedar Creek Watershed Water Quality Monitoring Stations.



Computer Modeling

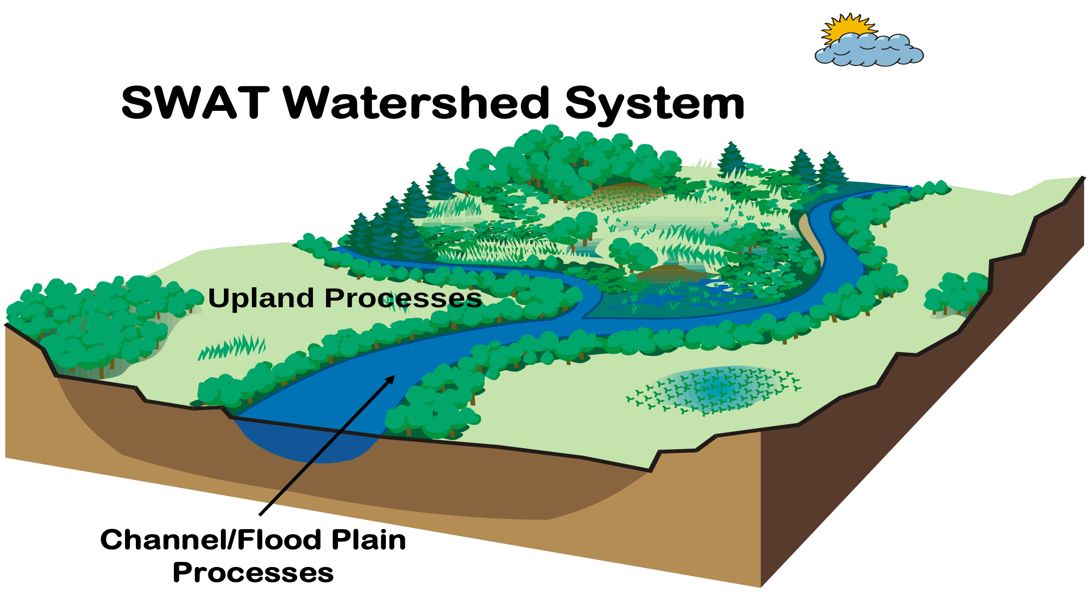
Spatial Science researchers have developed a variety of computer based models to simulate the results of climate, soil type, landuse, and other historical data on pollutant levels within a designated watershed. These models allow for forecasting of future watershed conditions and displays variable data such as the effect certain best management practices may have on water quality.

The following computer models were used to assess current trends in Cedar Creek Reservoir and Watershed and to estimate the impact of various best management practices. Numerous computer models have been established by engineers throughout the United States. The following were used for analysis of water quality and effectiveness of best management practices in the Cedar Creek Watershed:

SWAT (Soil and Water Assessment Tool)

SWAT is a physically-based watershed and landscape simulation model developed by the USDA-Agricultural Research Service. Major components of the model include hydrology, weather, erosion, soil temperature, crop growth, nutrients, pesticides and agricultural management. SWAT also has the ability to predict changes in sediment, nutrients, such as organic and inorganic nitrogen and organic and soluble phosphorus, pesticides, dissolved oxygen, bacteria and algae loadings from different management conditions in large basins. SWAT has been successfully applied to model water quality issues including sediments, nutrients and pesticides in watersheds. In the case of 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. 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.

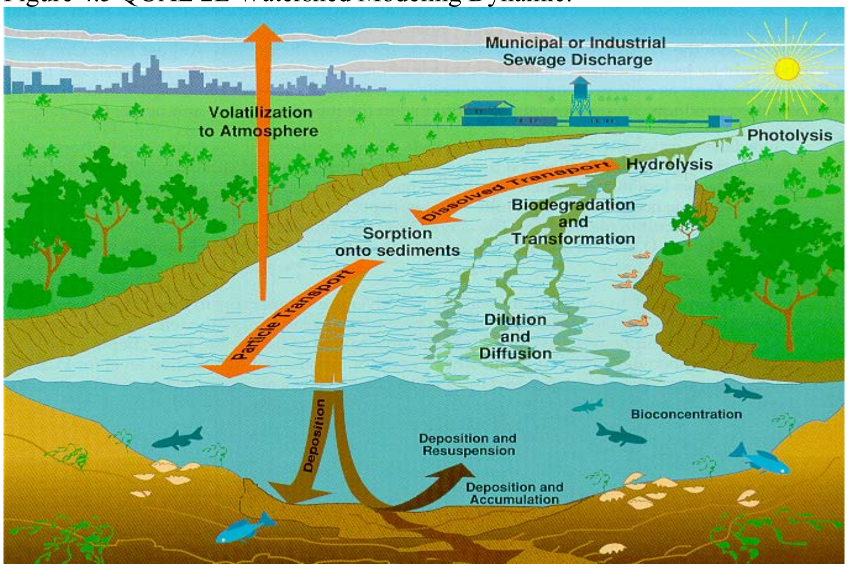
Figure 4.4 Soil and Water Assessment Tool System.



QUAL2E

A channel-based water quality model that can illustrate how a river will react to certain chemicals, nutrients, and sediment loads. QUAL2E helps to determine the effects of chemical processes such as advection, dispersion, dilution, and pollutant reactions (Chapra 1997). QUAL2E is a one-dimensional steady state in-stream model supported by EPA. It is applicable to sectional well-mixed streams. The model includes the effects of advection, dispersion, dilution and pollutant reactions, interactions, sources and sinks. Cedar Creek consultants utilized the QUAL2E model to demonstrate the effects of natural stream processes on the vast network of tributary channels that flow to throughout the watershed to Cedar Creek Reservoir. As a result, planners are able to determine the impact of human related erosion on nutrient cycles adapt management measures as necessary

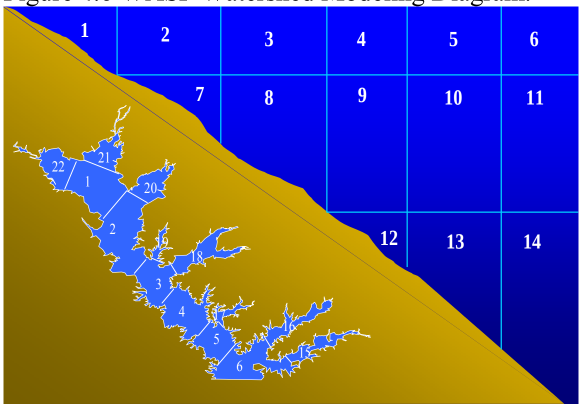
Figure 4.5 QUAL 2E Watershed Modeling Dynamic.



Water Quality Analysis Simulation Program

Output loadings from the SWAT and QUAL2E models drive the Water Quality Analysis Simulation Program (WASP) model (version 6.x) (EPA, 2003) to simulate the reservoir water quality. WASP is a finite-difference model used to interpret or predict possible changes in water quality of ponds, lakes, reservoirs, rivers and coastal waters brought about by pollutants. The model can be applied in one, two or three dimensions, and allows flexibility in defining initial and boundary conditions. Use of the WASP modeling techniques allowed project consultants to determine the loadings of sediment and nutrients within the sectioned portions of Cedar Creek Reservoir. WASP has provided readings for each geographic section as well as designated depths allowing for an accurate picture of how reservoir processes impact the settling and disbursal of pollutants.

Figure 4.6 WASP Watershed Modeling Diagram.

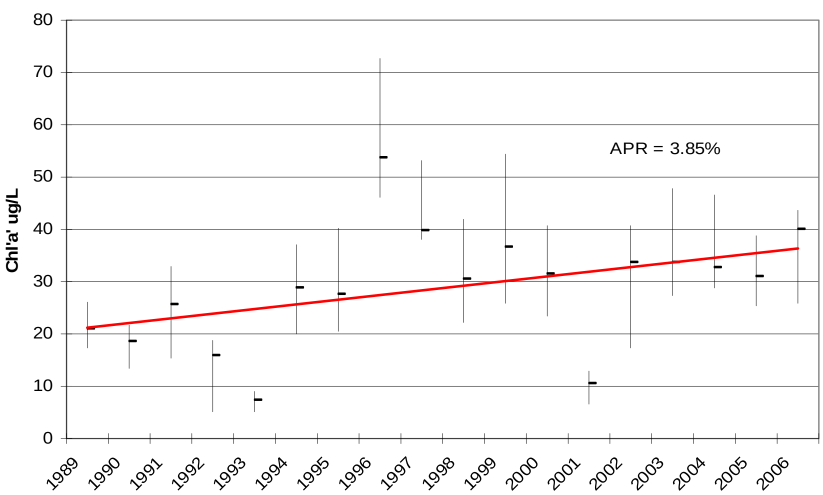


17-year TRWD Study

The impetus for development of a Watershed Protection Plan for Cedar Creek comes on the heels of a 17-year water quality study performed by Tarrant Regional Water District. Reservoir managers were charged with producing a longer term snapshot 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.

An examination of the Chlorophyll-*a* data demonstrated a rising trend of Chlorophyll-*a* in the Cedar Creek Reservoir at an annual percentage rate of 5.18 percent. When compared to other Texas reservoirs, this places Cedar Creek among the top Chlorophyll-*a* water bodies in the state of Texas.
Ambient analysis and modeling of the past 17 years has demonstrated an increasing trend of the algae indicator substance Chlorophyll-*a* in Cedar Creek Reservoir resulting from excessive nutrient loadings.

Figure 4.7 Chlorophyll-*a* 17-Year Analysis.



Nutrient Issues

By use of the SWAT modeling technique employed by the Texas A&M Spatial Sciences Laboratory, the project technical advisory group was able to determine the sources and estimated loadings of nitrogen, phosphorus, and sediment in the Cedar Creek Watershed. Maps were created to designate location, landuse, and other technical data to enable targeting of specific strategies for pollutant reduction. Additionally, the engineering firm of Alan Plummer Associates, Inc. performed site analyses of each of the nine wastewater treatment plants in the watershed and provided specific recommendations for infrastructure upgrades to reduce point source pollutants.

Data Limitations

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

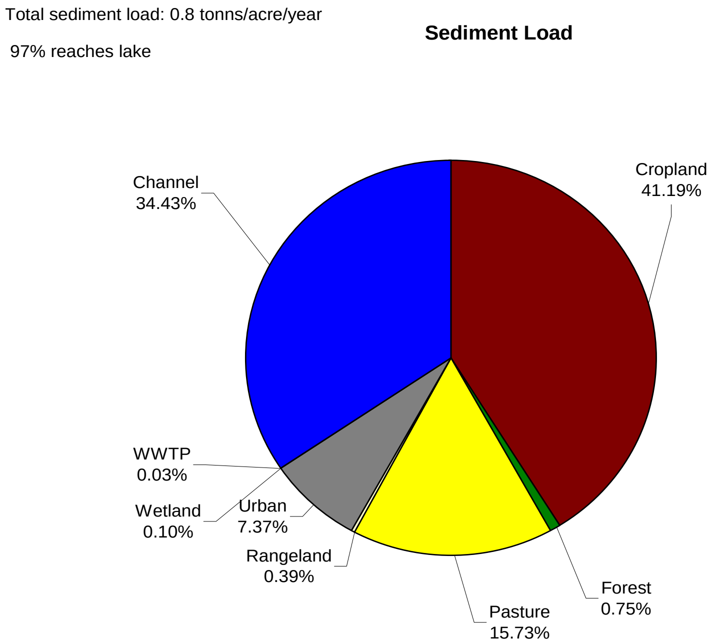
While significant effort was spent collecting reliable data, data for some sources is currently very limited. In addition, it is important to remember that information collected in the Cedar Creek Watershed represents a snapshot in time of the actual processes at work. Whether associated with human activities, weather patterns, or other factors, Cedar Creek and other watersheds are extremely dynamic in nature, and conditions change dramatically between years and even within a given season. Because of this, the actual input of pollutants from different sources in the Cedar Creek Watershed varies considerably over time. The analyses performed here represent a best estimate of current conditions.

5. CHAPTER 5: Estimate of Pollutant Loads and Sources

Pollution Sources and Targeted Loads

Following United States Environmental Protection Agency guidelines for watershed protection planning, the Cedar Creek Project leadership focused on the identification of applicable pollutant sources for the Watershed. In doing so, a general reduction of phosphorus in the amount of 35 percent was decided as a reasonable and effective goal for achieving a reduction on the Chlorophyll-*a* count. Technical advisors are confident that best management practices proposed to allow the phosphorus reduction will also result in nitrogen and sediment reductions. The emphasis on areas of origin will promote a specified approach sensitive to the environmental and human dimension issues related to each.

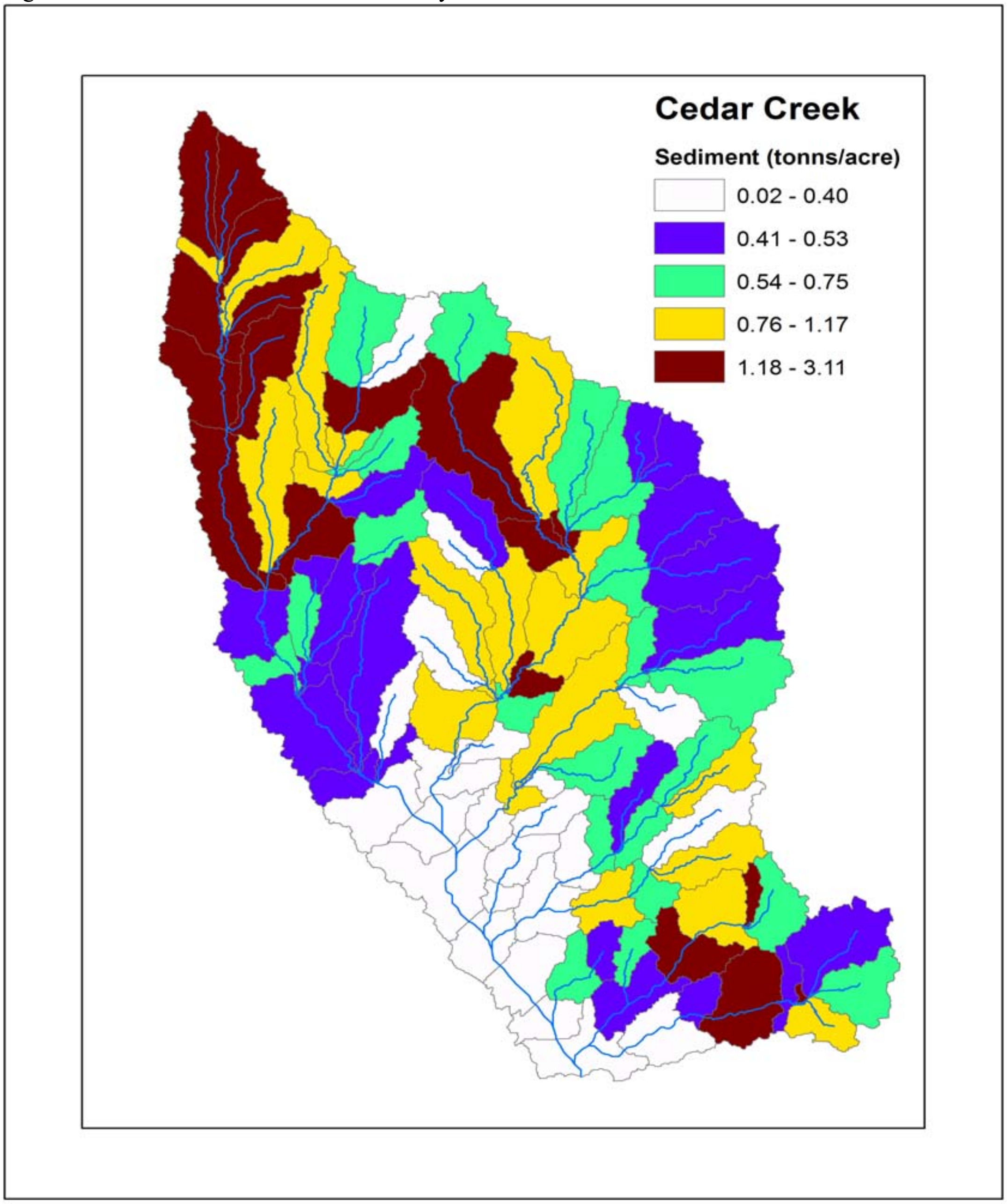
Figure 5.1 Sediment Load by Landuse for Cedar Creek Watershed.



Channel Erosion

Erosion of stream banks can result from the lack of vegetative cover to hold soil in place during a rainfall event. The resulting sedimentation serves as a transport for nutrients such as phosphorus and nitrogen. Channel erosion can be caused by farming, livestock grazing and construction activities.

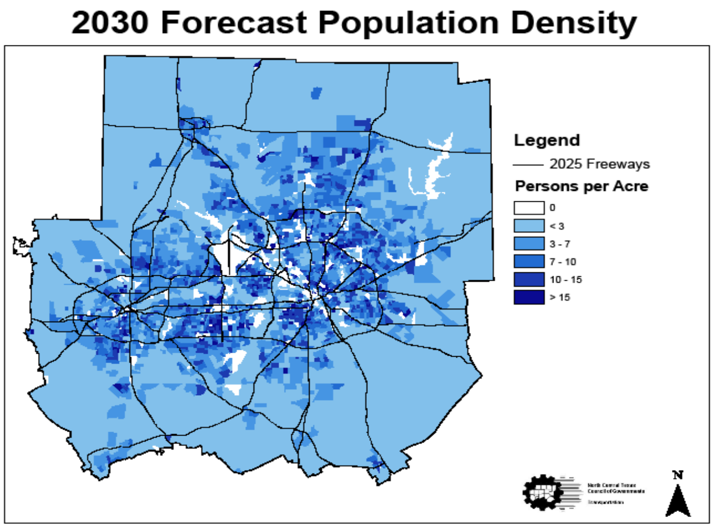
Figure 5.2 Sediment Load Concentrations by Subbasin.



Construction

Supplying housing to the expanding Dallas workforce has presented a challenge to Dallas and the surrounding counties. Consumption of existing agricultural lands in all directions for new housing developments has created a multitude of issues for environmental planners.

Figure 5.3 North Texas Council of Governments Population Density (NCTCOG 2007).

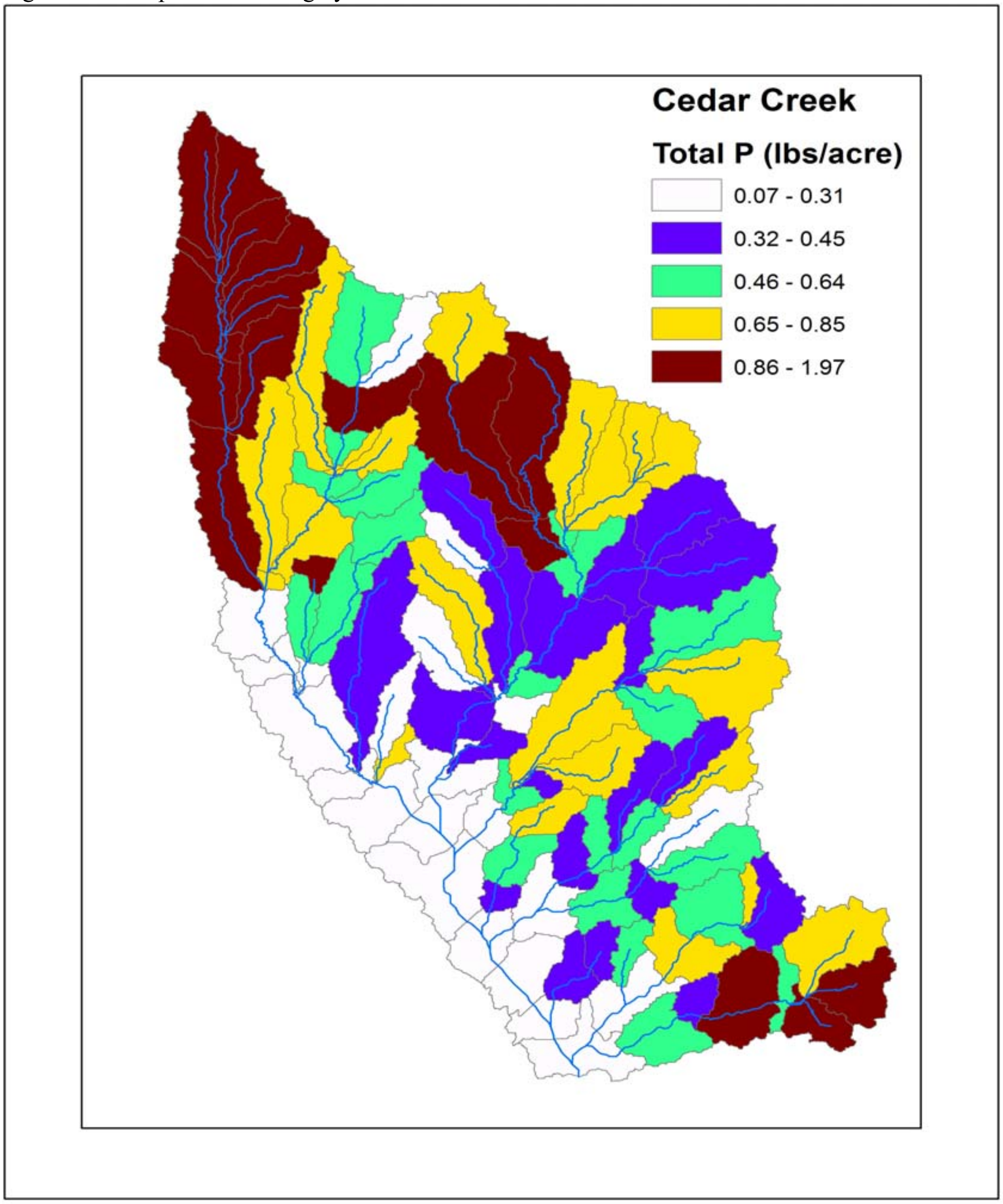


The prevalence of new construction is especially threatening in the areas of the watershed occupied by southern Rockwall County and north western Kaufman County due to the rate at which these lands are being developed for commercial and residential usage. Construction activities are regulated by counties and municipalities under the direction of the Texas Commission on Environmental Quality and require developers to create and post plans (Stormwater Pollution Prevention Plan or SWP3) for best management practices to mitigate sediment loss from soil disturbance. The permanent effect of construction is the loss of pervious surfaces such as vegetative cover and soils which slow and absorb stormwater runoff. Development and the resulting concrete, asphalt, and landscaping accelerate the flow of stormwater creating a higher sedimentation and flooding potential.

Croplands

Croplands account for a large portion of the nutrient loadings in the Cedar Creek Watershed. 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. Decaying vegetation utilizes oxygen during decomposition and depletes levels of dissolved oxygen within the reservoir and channels of the watershed that animal and plant life depend on.

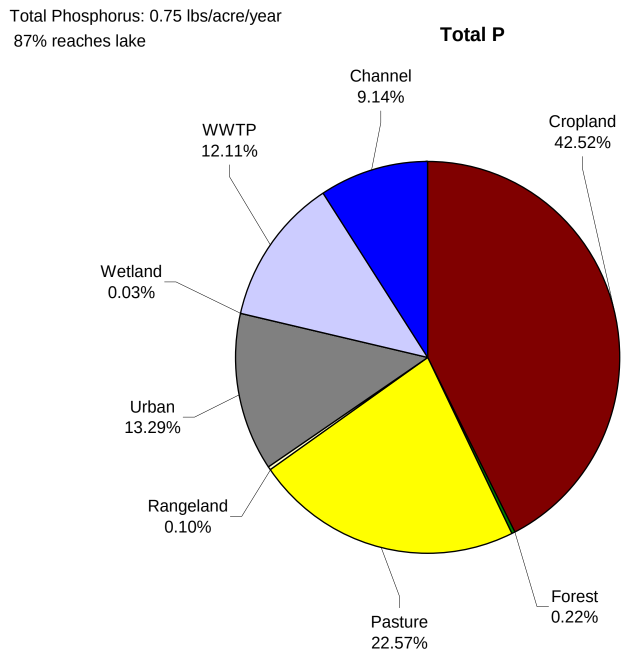
Figure 5.4 Phosphorus Loading by Subbasin.



Pasture and Rangeland

Rangelands and pasturelands account for the majority landuse within the Cedar Creek Watershed. 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 within the Cedar Creek Watershed still mandate serious consideration of practices to mitigate water quality concerns. Riparian areas are often grazed increasing sedimentation of stream banks. Additionally, overgrazing of pasture and rangeland reduces the vegetative cover needed to filter nutrients and trap sediment that would otherwise runoff of the land in a rain event.

Figure 5.5 Total Phosphorus by Landuse.



Wastewater Treatment Plants

As the population within the Cedar Creek Watershed grows, so too has the need for wastewater treatment facilities. Models of wastewater treatment plant discharges and upgrades for the watershed plan are based on the nine plants in operation during a 2007 Alan Plummer Associates, Inc. report. A plant is currently under construction at the Las Lomas development and an additional plant has been approved for the Windmill Farms development in Kaufman County. Typically, 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 series of graduated improvements to each operating plant has been outlined by the environmental engineering firm of Alan Plummer Associates, Inc. The proposed structural improvements would allow each plant to reduce permitted discharges beyond currently permitted 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 discharges standards.

Figure 5.6 Wastewater Treatment Plant Locations in Cedar Creek Watershed.

Table 5.1 Surveyed Discharges for Cedar Creek Wastewater Treatment Plants

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.

Reservoir

Because Cedar Creek Reservoir serves as a water supply for Tarrant County, the quality of water stored in the Reservoir is of primary concern. Sediment and nutrients from throughout the watershed are transported via stormwater tributary streams and often settle in the reservoir body. However, many natural processes that occur within reservoirs can exacerbate water quality issues. Eutrophication (a process of oxygen depletion resulting from excess vegetation), evaporation, biotic uptake, dissolution, and thermal layering can each work to promote pollutant levels in Cedar Creek reservoir. Several methods exist for mitigating the effects of these processes but lake managers are limited by the expense and temporary nature of such solutions. While "in reservoir" best management practices such as water column mixing and alum addition will be considered, project leadership has embraced the strategy of mitigating and preventing pollutant loadings at their respective sources rather than taking a "band aid" approach.

Urban

Urban water quality issues result primarily from the amount of impervious cover to be found in municipal areas. Parking lots, roadways, and the footprint of structural development reduce the amount of natural landscape capable of absorbing and filtering urban stormwater. Additionally, the use of household chemicals, yard waste, fertilizers, and pet waste contribute to excessive nutrient loadings. Without the filtering effects of vegetated cover, a rain event can work to spread sediment and nutrients throughout the watershed. Controlling urban water pollution requires a coordinated effort of education programs, ordinances, and encouragement of adopting behavioral and structural best management practices.

6. CHAPTER 6: 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.

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.*"

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.

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

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.

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.

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 and Extension Urban Solutions Center
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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.

7. CHAPTER 7: Management Measures

Based on thorough evaluation of water quality data and supporting information characterizing the watershed, the work groups identified management measures which will be necessary to achieve recommended pollutant reductions in the Cedar Creek Watershed. Water quality modeling and analysis supported the focusing on specific sources to most efficiently achieve reduction goals. Management measures are proposed to address both nutrient and sediment concerns. In most cases, steps taken to reduce nutrient loads in the watershed also will result in reductions in sediment loading.

The following sections will outline the management measures intended to reduce the sediment and nutrient loads from potential pollutant sources in the Cedar Creek Watershed.

Urban Stormwater Management

Currently no municipalities within the Cedar Creek Watershed fall under the mandates of Phase I or Phase II Municipal Separate Storm Sewer Systems (MS4). The City of Terrell, in the northern portion of the watershed is poised to grow significantly and will most likely fall under Phase II mandate in the near future while portions of southern Rockwall County may face annexation by the City of Rockwall, a Phase II City.

As a result, stakeholders and other city administrators have chosen to emphasize education programming and outreach campaigns to encourage behavioral changes among urbanites living within the watershed plan.

City representatives worked with Cedar Creek Watershed Protection Technical Advisory group personnel to identify both ongoing urban stormwater management measures that have been implemented and will be continued, as well as additional measures that cities plan to implement as a part of their commitment to the Cedar Creek Watershed Partnership. In many cases, proactive efforts on the part of cities already are reducing pollutant loading. Below are descriptions of existing and planned management measures for each of the individual cities.

Table 7.1 City-Specific Stormwater Management Practices.

Urban Stormwater Management Measures
Common Goals ● Implement non-structural components of MS4 permits on a voluntary basis in advance of program requirements ● Conduct stormwater engineering analyses and city-wide assessments to determine placement of structural management measures in individual cities
Athens
Gun Barrel City
Kaufman
Kemp
Mabank
Seven Points
Terrell
Tool

Wastewater Management

Wastewater management in both centralized treatment facilities and private septic systems is and will continue to be important in the Cedar Creek Watershed, particularly as the population of the area increases. Planning for this future growth, as well as addressing existing infrastructure issues is a priority to the Cedar Creek Watershed Partnership. Wastewater Treatment Plants in the watershed are operated by a combination of municipalities and/or private entities. All Wastewater Treatment Plants must comply with site-specific regulations contained in a Texas Pollution Discharge Elimination System (TPDES) permit issued by the Texas Commission on Environmental Quality. Municipalities manage the means of conveyance to Wastewater Treatment Plants and are charged with the upkeep and maintenance of these collection systems.

Table 7.2 Current TPDES Permit Levels and Existing Infrastructure for Cedar Creek WWTPs.

Plant	Current TPDES Permit Levels	Existing Infrastructure
Athens	CBOD = 10 mg/L (Mar. – Nov.) CBOD = 20 mg/L (Dec. – Feb.) TSS = 15 mg/L (Mar. – Nov.) TSS = 20 mg/L (Dec. – Feb.) NH3 = 2 mg/L (Mar. – Nov.) NH3 = 3 mg/L (Dec. – Feb.) Flow = 1.027 MGD	Bar screen, grit removal, Imhoff tanks, supernatant to tricking filters, aeration for six hours, final clarification, and chlorination. Sludge disposed on drying beds and periodically disposed of off-site.
Cherokee Shores	BOD5 = 10 mg/L TSS = 15 mg/L NH3 = 5 mg/L TN = 20 mg/L TP = 2 mg/L Flow = 0.15 MGD	Equalization, activated sludge, final clarification, sand filtration, and chlorination. Sludge aerobically digested and disposed off-site.
East Cedar Creek	BOD5 = 10 mg/L TSS = 15 mg/L Flow = 0.626 MGD	Treatment facility currently under expansion. Bar screen, two oxidation ditches w/ RAS, final clarification, sand filtration, and chlorination. Sludge is dried and landfilled.
Eustace	BOD5 = 30 mg/L TSS = 90 mg/L Flow = 0.125 MGD	Bar screen, oxidation ditch w/o RAS as pre-aeration basins, two stabilization ponds w/ 21day detention time. Disinfection not required.
Kaufman	CBOD = 10 mg/L TSS = 15 mg/L NH3 = 3 mg/L (May – Oct.) NH3 = 5 mg/L (Nov. – Apr.)	Bar screen, grit removal, stormwater holding basins, two aeration basins w/ RAS, two final clarifiers, sand filtration and ultraviolet disinfection. Sludge belt press and lime blending. Sludge disposed off-site.
Kemp	CBOD = 5 mg/L TSS = 5 mg/L NH3 = 2.0 mg/L Flow = 0.2 MGD	Bar screen, grit removal, oxidation ditch w/ RAS, two final clarifiers, and chlorination. Sludge drying beds.
Mabank	CBOD = 30 mg/L TSS = 90 mg/L NH3 = 2 mg/L Flow = 0.4 MGD	Bar screen, grit removal, oxidation ditch w/o RAS followed by three stabilization ponds, and a nitrifying bio-tower. Disinfection not required. Sludge is periodically dredged from the ponds and disposed off-site
Terrell	CBOD = 10 mg/L	Flow equalization, bar screen, grit

	TSS = 15 mg/L NH3 = 6.0 mg/L Flow = 4.5 MGD	removal primary clarification, two-stage trickling filter, final clarification, with chlorination and dechlorination. Portable belt press solids dewatering.
Wills Point	Present BOD5 = 30 mg/L TSS = 90 mg/L Flow = 0.51 MGD Planned CBOD = 10 mg/L TSS = 15 mg/L NH3 = 3 mg/L Flow = 0.80 MGD	Two new stabilization ponds are currently under expansion. Bar screen, two facultative lagoons, three stabilization ponds exist. Disinfection not required. Sludge is periodically dredged from the ponds and disposed off-site.

In areas where no public sewer services are available, county and local governments are responsible for the inspection and permitting of septic systems. Tarrant Regional Water District is granted authority over on-site systems located within 2,000 feet of Cedar Creek Reservoir. Inspections are typically conducted when new systems are installed and in association with complaints filed with the authorized agent.

Common Goals

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

Wastewater Treatment Facilities

- All plants will work to adopt recommended upgrades as outlined in the WWTP evaluation commissioned by the engineering firm Alan Plummer Associates, Inc.
- All plants will begin monthly self-monitoring of effluent for bacteria and nutrients.
- All plant operators will demonstrate the appropriate licenses and certifications and be current on continuing education opportunities.

Wastewater Infrastructure

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

City-Specific Wastewater Treatment Plant Management Measures

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
Level II	1.0 Mg/L Phosphorus
Level II	.5 Mg/L Phosphorus

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. 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 7.3 City-Specific WWTP Management Measures.

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	Existing facility is capable of treating the projected flows through the year 2050.	Operate oxidation ditch for denitrification. Alum addition for P removal. May	Add denitrifying filter to meet TN limit, carbon source for denitrification and additional alum

	2050 = 0.113		require additional drying beds for alum sludge.	for lower P limit.
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.

Agricultural and Rural Management Measures

To achieve sediment and nutrient load reduction goals established for Cedar Creek Reservoir, specific best management practices and combinations of practices will be implemented on agricultural land. Guided by the Agricultural work group, it was determined that this would best be achieved by developing voluntary site-specific management plans for individual operations. Both the Natural Resources Conservation Service and Texas State Soil and Water Conservation Board offer planning assistance for agricultural producers. Water Quality Management Plans (WQMPs) are developed by local Soil and Water Conservation Districts (SWCDs) under the statewide Soil Board program and are tailored to meet the needs of each operation. The Natural Resources Conservation Service offers options for development and implementation of both specific practices (as part of the Environmental Quality Incentives Program (EQIP) and whole farm resource management plans), which are essentially the same as Water Quality Management Plans. Cost-share assistance is available through associated programs to offset implementation costs.

Pasture / Rangeland Operations

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

Cropland Operations

SWAT modeling of the Cedar Creek Watershed has allowed project leaders to determine the phosphorus, nitrogen, and sediment loadings coming out of each sub watershed. Using this data, the Cedar Creek Watershed Protection Plan was able to target specific agricultural producers within troubled sub-watersheds for the installation of structural best management practices.

Combined Agricultural Management Measures

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

Prescribed Grazing

Manages the controlled harvest of vegetation with grazing animals to improve or maintain the desired species composition and vigor of plant communities, which improves surface and subsurface water quality and quantity. Controlled harvest of vegetation through grazing rotation that allows for establishment of a dense vegetative stand could reduce soil erosion and retain soil nutrients. Further, native or introduced forage species that is well adapted to North Central Texas could be planted periodically to maintain a dense vegetative cover and improve the hydrologic condition of the farmland. Similarly, well adapted perennial vegetation such as grasses, legumes, shrubs and trees could be planted in rangeland with medium to low vegetation cover.

Figure 7.1 Prescribed Grazing.

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 water flows down slopes. This BMP can reduce sedimentation of nearby water bodies and pollutants in runoff. The vegetation improves the soil aeration and water quality due to its nutrient removal through plant uptake and sorption by the soil. Entrapment of sediment and the establishment of vegetation allow nutrients to be absorbed into trapped sediments to remain in the agricultural field rather than being deposited into waterways. A grassed waterway is often used to safely discharge the overland runoff to the main channel thus preventing the formation of gullies. Grassed waterways are graded to required dimensions based on the field conditions and natural vegetations are established to maintain the grade. It can also be used in conjunction with other conservation measures such as terraces to safely convey the excess runoff.

Figure 7.2 Grassed Waterway.

Riparian Buffer

Riparian area is a fringe of land that occurs along the stream or water courses with grass and herbaceous cover. If the riparian buffer is not adequately established and farming activities occur till the edge of the stream, the banks become unstable resulting in significant sloughing and channel scour. Establishing and maintaining a good riparian buffer, stabilizing channels and protecting shorelines using live stakes, riprap and gabions could considerably reduce the channel erosion.

Figure 7.3 Riparian Buffer.

Watering Facilities
Places a device (tank, trough, or other watertight container) to provide livestock an alternative access to water and protects streams, ponds, and water supplies from contamination.

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. They are generally in locations when runoff water leaves a field with the intention that sediment, organic material, nutrients, and chemicals can be filtered from the runoff water. Filter strips are also known as vegetative filter or buffer strips. 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.

Figure 7.4 Filter Strip.

Nutrient Management
Manages the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize agricultural nonpoint source pollution of surface and groundwater resources. 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.

Crop Residue Management
Establishes permanent vegetative cover to protect soil and water resources. The established conservation cover allows that residue crops remain on harvested fields. Crop residue management includes those practices that reduces soil disturbance during tillage and maintains ample plant residue cover on the surface for a portion of the year or all year around. Crop residue management protects the soil from the direct erosive impact of rainfall and could effectively reduce sheet and rill erosion and retains the top soil nutrients

Contour Farming
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.

Figure 7.5 Contour Farming.

Sediment Basin

Earthen embankments or detention structures constructed across the channel or across the slope of a farmland could reduce the peak flow velocity of the water and detain the coarse sediment particles. Currently the Cedar Creek watershed contains about 120 inventory-sized dams (as defined by the Texas Commission on Environmental Quality), which includes flood prevention dams, farm ponds, and other privately owned dams.

Pasture Planting

The planting of pastures and crop lands with native vegetation that will allow for reduction and absorption of nutrients. Range and pasture planting require the establishment of adapted perennial vegetation (preferably native). 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.

Figure 7.6 Pasture Planting.

Fencing
Fencing is a constructed barrier that will prevent access to drainages and streambeds to animals and humans. This will permit the existence of vegetation and other impediments to erosion, sedimentation, and nutrient loadings.

Figure 7.7 Fencing.

Stream Restoration
Stream restoration is a concept that encompasses a variety of constructed practices to mitigate and prevent the erosion and sedimentation of channel areas. These include the planting of stream banks with native vegetation, installation of rocks (rip rap), planting spikes or rods, and reconstructing channels to slow flow. The appropriate structural and vegetative measures are dictated by site specific conditions. Stream restoration is targeted to prevent the loss of land or landuses adjacent to streams and maintain the flow capacity of streams and constructed channels while reducing off-site or downstream effects of sediment resulting from stream bank erosion.

Figure 7.8 Stream Restoration.

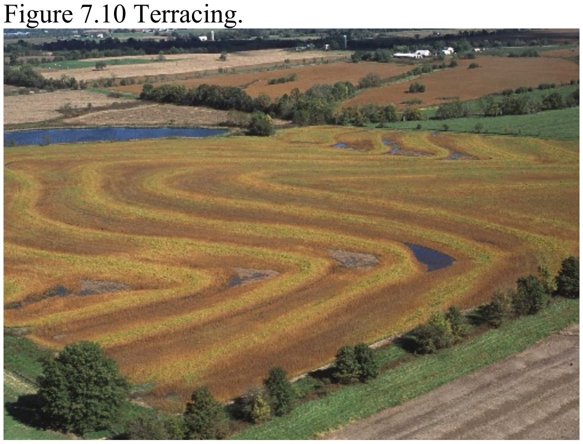
Constructed Wetlands
Constructed wetlands provide a sediment retention and nutrient removal system that uses natural chemical, physical, and biological processes involving wetland vegetation, soils, and their associated microbial populations to improve water quality. Constructed wetlands are designed 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.

Figure 7.9 Constructed Wetland.

Terracing

Terraces are series of earthen embankments constructed across the field slope at designed vertical and horizontal intervals based on land slope and soil conditions. Construction of terraces involves a heavy capital investment to move large quantity of earth for forming the earthen embankment. Hence it has to be used only if other low cost alternates are determined to be ineffective. Terracing is recommended for land with a grade of two percent or higher.

Figure 7.10 Terracing.



Performance Summary

SWAT Modeling of proposed best management practices provides a view of the performance of the various practices within the Cedar Creek Watershed. A comprehensive report of modeling activities provided by The Texas A&M University Spatial Sciences Laboratory and summarized in the following table. The report includes the number of potentially treatable areas within the Cedar Creek Watershed and reduction in sediment and nutrients associated with implementation of the practice.

Table 7.4 Pollutant Reduction Performance of Best Management Practices.

Practice	Area (hectares)	Length (km)	% Sediment Reduction	% N Reduction	% P Reduction
Cropland BMPs					
Terrace (Practice #600) (Cropland with >= 2% slope)	4,386.34		-7%	-1.5%	-7%
Contour Farming (Practice #330) (Cropland with >= 2% slope)	4,386.34		-6%	-1%	-6%
Crop Residue Management (Practice #329, 344, 345, 346) (Conventional till to minimum till)	16,104.80		-5.3%	-2.5%	-3.5%
Conversion of Cropland to Grass – Pasture Planting (Practice #512)	16,104.80		-28%	-18.5%	-35%
Grassed Waterway (Practice #412) (In 14 subbasins with more than 10% cropland)	35,112.2733 Tributary channel length 186.6km		-5%	-2.75%	-1.6%
Filter Strips (Practice #393) (15m width)	16,104.80		-22%	-17%	-30%
Fertilizer/Nutrient Management (Practice #590) [25% reduction in Mineral P application (25kg/ha) in cropland] (Actual N rate: 67kg/ha; P – 34kg/ha)	16,104.80		0%	0%	-2%
Practice	**Area (hectares)**	**Length (km)**	**% Sediment Reduction**	**% N Reduction**	**% P Reduction**
Pasture and Rangeland BMPs					
Prescribed Grazing (Practice #528) Fencing (Practice #382) Water Facility (Practice # 614)	165,919.70		-8%	-15.6%	-5.6%
Fertilizer/Nutrient Management (Practice #590) [25% reduction in Nitrogen application (50 kg/ha) in Pastureland] (Actual N rate: 67	165,919.70		0%	-3%	0%

kg/ha)					
Pasture Planting (Practice #512) (Same as Prescribed Grazing (Practice #528))	165,919.70		-8%	-15.6%	-5.6%
Range Planting (Practice #550)					
Grassed Waterways (Practice #412) (In 33 subbasins with more than 75% Pasture) (33 subbasins with a total tributary channel length of 409.3 km)	83,819.4414		-4%	-6%	-2%
Urban nutrient BMP					
Actual fertilizer rate: Nitrogen: 190 kg/ha Phosphorus: 30kg/ha Reduced to: Nitrogen: 50 kg/ha Phosphorus: 2.5 kg/ha	16,636.62		0%	-10%	-13%

Practice	Area (hectares)	Length (km)	% Sediment Reduction	% N Reduction	% P Reduction
Channel BMPs					
Riparian Buffer Strips (Practice #390, 391) (Maintaining a good vegetative buffer and cover in and around the channels)		653.887	-23%	-4.3%	-5.3%
On or Off Channel Water and Sediment Control Basin (Practice #638)	Assume 53 structures, each with a maximum surface area of 3.5hectares and a volume of 195,000 m^3	-1.6%	-0.4%	-0.2%	
Channel Stabilization (Practice #584) (Same as Riparian Buffer)		653.887	-23%	-4.3%	-5.3%
Streambank and Shoreline Protection (Practice #580) (Same as Riparian Buffer)		653.887	-23%	-4.3%	-5.3%
Watershed BMPs					
Wetland Creation (Practice #658)					

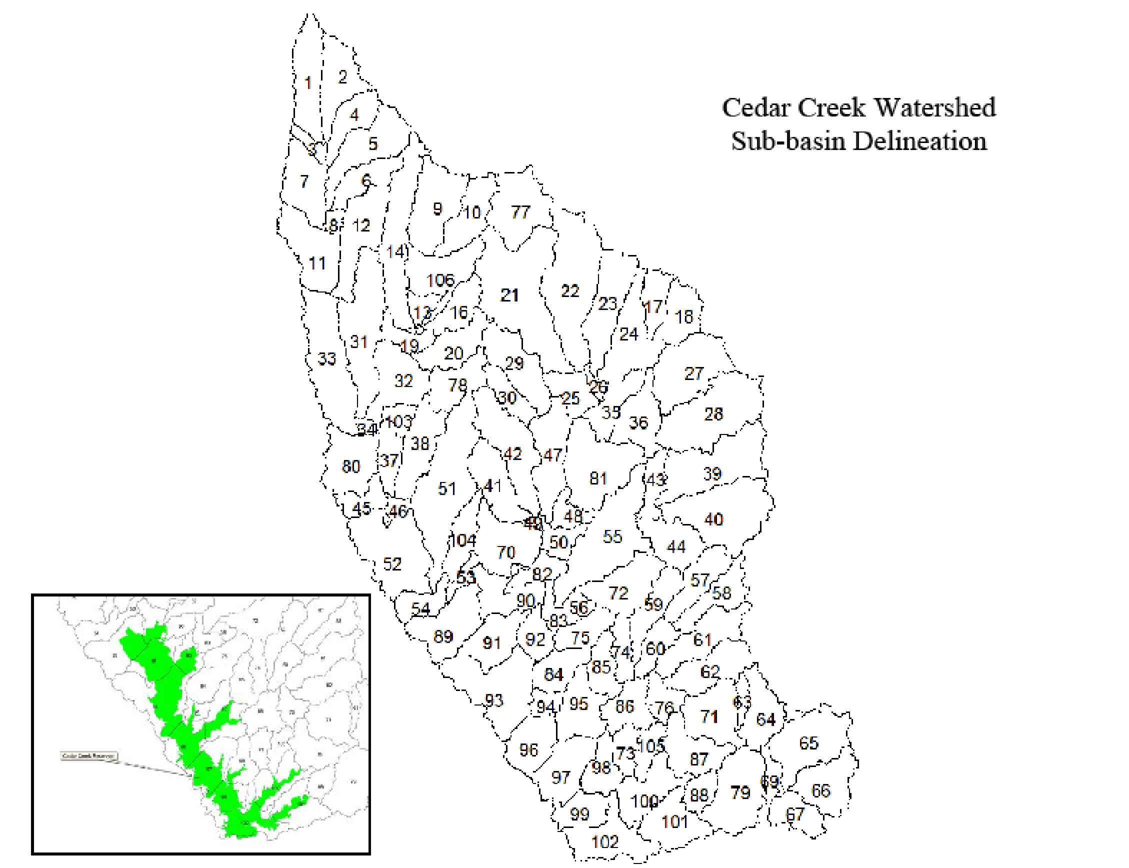
Grade Stabilization Structures (Practice #410)	33,051.5442 (Let's assume that we are building a small drop structure per 1000ha; 33 structures approximately)	-2.4%	-1.6%	-2.3%

Practice	Area (hectares)	% Sediment Reduction	% N Reduction	% P Reduction
2050 scenario 3% cropland and 3% pasture to Urban 2050 WWTP loads (i.e Urban area almost doubles)	16,636.62	-7%	-7%	-11%
2050 scenario with urban nutrient BMP	16,636.62	-7%	-16%	-21%

Targeting Subwatersheds

With the assistance of the Texas State Soil and Water Conservation Board, the Cedar Creek Technical Advisory Group adopted a strategy of best management practice selection based on the topography, hydrology, and landuses for each of the 98 subwatersheds within the Cedar Creek Watershed. In some instances, subwatersheds have been combined due to similarities in the aforementioned criteria. Additionally, in most instances, a combination of best management practices are recommended in order to maximize pollutant reductions.

Figure 7.11 Cedar Creek Watershed Subbasin Delineation.



As a result of this approach, watershed planners were able to develop the following summary of selected best management practice cost, performance, and total impact on the water quality of the Cedar Creek Watershed.

Table 7.5 BMP Selection and Performance Data by Subwatershed.

Subwatershed	Loading (lbs/day)			BMP	Subwatershed Reduction			Treatment area	Installation Cost	Cost per lb pollutant Reduction			Total Watershed Reduction		
	N	P	Sed		N	P	Sed			N	P	Sed	N	P	Sed
34	23	29	31	Grassed waterway	.53	.61	.70	100 acres							
				Sediment Pond	.61	.69	.73	75 acres							
				Pasture Planting	.49	.53	.55	1000 acres							

Reservoir Management

Pollutant reduction measures will also be taken within the Cedar Creek Reservoir proper and implemented by the Tarrant Regional Water District. Reservoir management protocol is not formally a part of the stakeholder portion of the Watershed Protection Plan. Such measures have not been funded or decided upon at this time but may include the following measures:

Alum Addition

The addition of powdered alum at various lake depths is designed to suppress the mixing and transport of phosphorus and nitrogen.

Grade Stabilization

The use of constructed reinforcements along the lake side to reduce sedimentation and the washing of steep grades into the reservoir.

Water Column Mixing

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.

8. CHAPTER 8: Outreach and Education Strategy

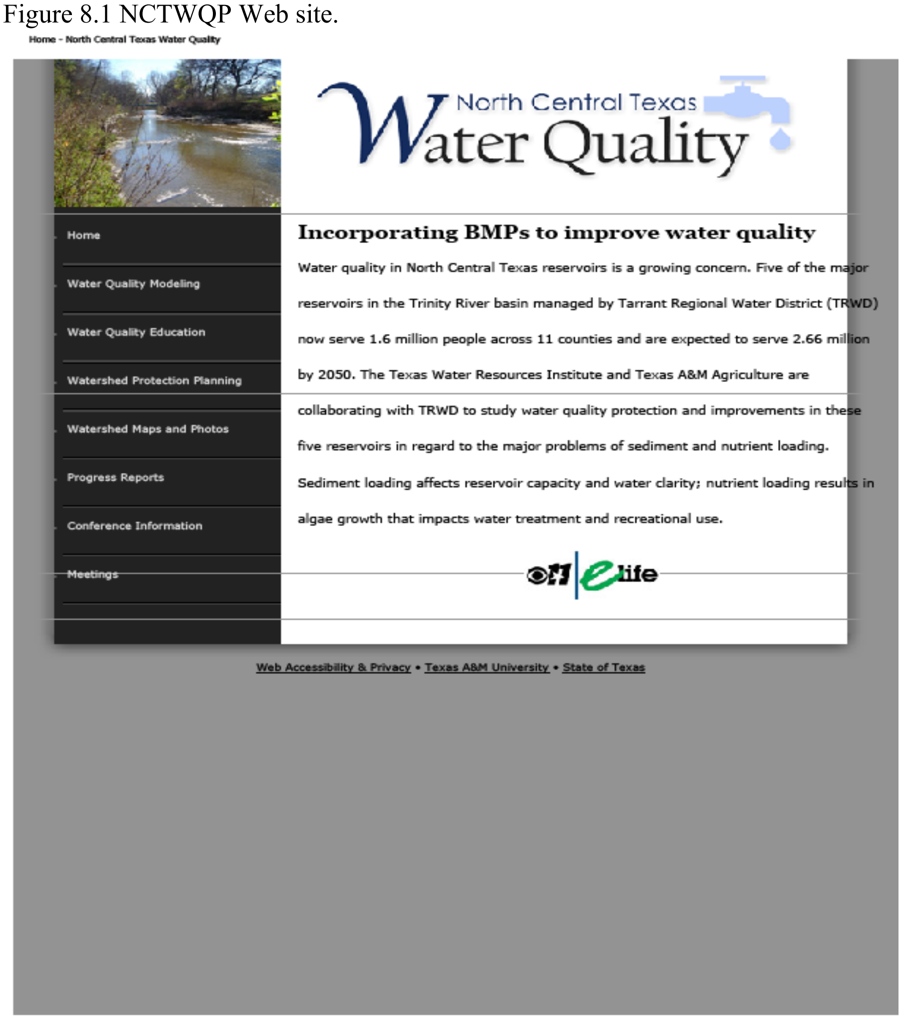
Media and Publicity Efforts

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

Project Web site

The Cedar Creek Watershed Partnership website (http://nctx-water.tamu.edu) is maintained by Texas AgriLife Research and Extension Urban Solutions Center and hosted by Texas A&M AgriLife Texas Water Resources Institute. The site includes background information on the watershed, the Partnership, water quality, access to the Watershed Protection Plan, and a public meeting schedule with information presented at previous meetings.

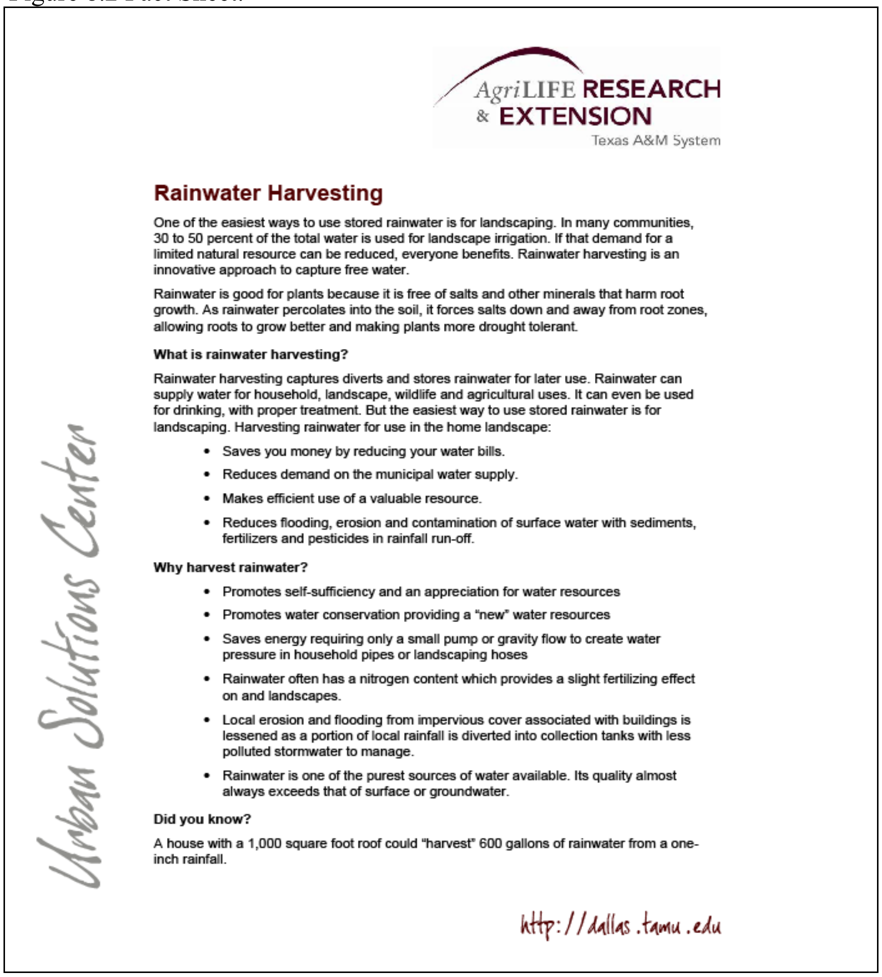
Figure 8.1 NCTWQP Web site.



Fact Sheets

Texas AgriLife Extension Service produced a series of fact sheets targeted to Cedar Creek Stakeholders. These sheets feature information on selected best management practices and provide general information regarding the health of the watershed. These sheets are available on-line, by request, and at government offices and places where farming and gardening supplies are sold. Fact sheets will also be provided to city water utility managers in each watershed with permission to include selected fact sheets to water customers included or separate from billing statements.

Figure 8.2 Fact Sheet.



AgriLIFE RESEARCH & EXTENSION
Texas A&M System

Urban Solutions Center

Rainwater Harvesting

One of the easiest ways to use stored rainwater is for landscaping. In many communities, 30 to 50 percent of the total water is used for landscape irrigation. If that demand for a limited natural resource can be reduced, everyone benefits. Rainwater harvesting is an innovative approach to capture free water.

Rainwater is good for plants because it is free of salts and other minerals that harm root growth. As rainwater percolates into the soil, it forces salts down and away from root zones, allowing roots to grow better and making plants more drought tolerant.

What is rainwater harvesting?

Rainwater harvesting captures diverts and stores rainwater for later use. Rainwater can supply water for household, landscape, wildlife and agricultural uses. It can even be used for drinking, with proper treatment. But the easiest way to use stored rainwater is for landscaping. Harvesting rainwater for use in the home landscape:

- Saves you money by reducing your water bills.
- Reduces demand on the municipal water supply.
- Makes efficient use of a valuable resource.
- Reduces flooding, erosion and contamination of surface water with sediments, fertilizers and pesticides in rainfall run-off.

Why harvest rainwater?

- Promotes self-sufficiency and an appreciation for water resources
- Promotes water conservation providing a "new" water resources
- Saves energy requiring only a small pump or gravity flow to create water pressure in household pipes or landscaping hoses
- Rainwater often has a nitrogen content which provides a slight fertilizing effect on and landscapes.
- Local erosion and flooding from impervious cover associated with buildings is lessened as a portion of local rainfall is diverted into collection tanks with less polluted stormwater to manage.
- Rainwater is one of the purest sources of water available. Its quality almost always exceeds that of surface or groundwater.

Did you know?

A house with a 1,000 square foot roof could "harvest" 600 gallons of rainwater from a one-inch rainfall.

http://dallas.tamu.edu

Outreach and Education Work Group

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

Watershed Protection Campaign Brochure

A professional brochure outlining Cedar Creek Watershed water quality issues will be made available for distribution to the public. The publication will highlight water quality concerns, best management practices, and provide contact information for the North Central Texas Water Quality Project.

Tributary and Watershed Roadway Signage

Contingent upon funding, signs will be developed and posted along major roads notifying travelers that they are entering the watershed or when they are crossing Cedar Creek or a significant tributary.

Outreach at Local Events

Outreach efforts in the form of informational booths, demonstrations, and a guest speaker’s bureau will be made available to watershed area groups. Targeted events will be county fairs, livestock expositions, gardening clubs, city governments, and youth activities.

Targeted Pollutant Source Outreach Efforts

Agriculture

Soil Testing Campaigns

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

Nutrient Management Education

Training events will be organized and conducted by Texas AgriLife Extension, Soil Board, and Natural Resources Conservation Service personnel to educate agricultural producers regarding sound nutrient management practices in row and forage crop production systems. These events will be held annually in conjunction with soil testing campaigns in the fall or spring.

Crop Management Seminars

Annual or biennial crop management and production seminars will be organized and conducted by Texas AgriLife Extension, Soil Board, and Natural Resources Conservation Service personnel and will include training to promote the use of recommended management practices for reducing pesticide and sediment loss.

Urban Stormwater

Stormwater BMP Demonstrations

When and where preferred, urban stormwater BMPs are to be promoted and implemented, cities in cooperation with Texas AgriLife Extension, and Texas Commission on Environmental Quality will sponsor field demonstrations. Invitations will be sent to builders and developers, city staff, university employees, and engineers. Notices of instructional events will be promoted in local print media, local radio broadcasts, and via established contact lists of Texas AgriLife Extension.

Site Assessment Visits
Project consultants will conduct site assessment visits to municipal operations in the Cedar Creek Watershed. Stormwater experts will consult with municipal officials regarding the installation of best management practices and possible funding sources. Assessments will focus on enhancing stormwater and wastewater infrastructure and operational efficiency.

Urban Nutrient Management Education
The Texas Smartscape Program and other educational campaigns will be engaged to provide training workshops to educate the general public regarding proper rates and timing of fertilizer and pesticide application for lawns and landscapes. City, county and private landscape maintenance providers will be solicited to participate in these training workshops. In addition, similar trainings will be provided through Master Gardener programs and by working with local homeowner associations.

Wastewater

Wastewater Treatment Facility Consulting
A comprehensive analysis of each existing wastewater treatment plant that discharges within the Cedar Creek Watershed has been performed by the engineering firm Alan Plummer Associates, Inc. Project personnel will work with WWTP operators to ensure that recommended upgrades and performance standards are met in within designated timeline.

Illegal Dumping

Identification of Priority Clean-up Sites
Road crossings and other accessible areas of illegal dumping will be identified with stakeholder input. These sites will be assessed and prioritized for cleanup by NCTWQP based on extent of the problem and potential for environmental impacts. Site descriptions, photographs, and indications of challenges (traffic, slope, brush and fencing hazards) that could affect cleanup efforts will be obtained. Private landowners associated with priority sites will be identified to obtain permission for access. Based on site prioritization, the following activities will be conducted:

Site Cleanup Projects
Cleanups will be conducted at the most critical sites utilizing a contractor with heavy equipment to remove large debris and trash. Proper disposal of debris, post-cleanup photographs, and a report on each event including amount and type of debris removed will be undertaken.

Signs
NCTWQP will coordinate with Cedar Creek Watershed Counties to post signs at cleanup sites and at other identified watershed dumping sites to discourage future activity.

Community Cleanup Events
Two community cleanup events sponsored by TRWD will be conducted to remove smaller debris from watershed streams and also capitalize on public involvement to improve awareness of the overall Cedar Creek Watershed project. Educational materials will be distributed at these events and provided to cities and counties for other community-sponsored events in the watershed.

9. CHAPTER 9: Measures of Success

Project leaders have established a handful of numeric criteria to drive the selection of BMPs based on the ability of such measures to achieve the stated goals of pollutant reduction, citizen participation, and facility upgrades to Wastewater Treatment Plants. The bedrock goal of the Cedar Creek Watershed Protection Plan is to reduce phosphorus loadings in Cedar Creek Reservoir by 35 percent from 2006 levels. The technical advisory group is confident that the proposed best management practices devoted to P reduction will also result in the ancillary effect of reducing nitrogen (N), sediment, and Chlorophyll-*a* counts within the reservoir.

WWTP Outputs

Reduction of pollutants discharged from wastewater treatment plants is contingent upon the adoption of recommended upgrades outlined earlier in this watershed protection plan.

Urban Nonpoint Source Education Programs

The success of educational programming targeting urban Nonpoint Source Pollution will be determined by the number of participants in workshops and seminars. Attitude change and resulting actions will be surveyed to determine effectiveness of outlined programs and media campaigns.

Number of Rural Best Management Practices Installed

Best management practices for agricultural and rural areas will be targeted at specific subwatersheds based on applicability and funding availability. The total amount of best management practice installation will be measured in linear feet or acres depending on the specific practice outlines.

303(d) List status

Listing of Cedar Creek Reservoir and Watershed tributaries on future 303(d) surveys will provide a tangible and public method for gauging the overall effectiveness of the host of practices administered.

Ambient Water Quality Monitoring Data

Direct water quality monitoring from appointed areas within the watershed on a quarterly basis will allow for an incremental view of the progress achieved by the implemented facets of the watershed protection plan. Additionally, this will allow for the revision of ineffective portions of the Plan toward achieving an improvement in reduction of nutrient and sediment loadings.

Modeling Projections

Use of the computer based models SWAT, QUAL2E, and WASP on a regular basis will also provide a determination of the progress of the watershed protection plan allowing for projections of pollutant loadings and Chlorophyll-*a* counts as management measures are realized.

10. CHAPTER 10: Implementation Program

Technical and Financial 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 Cedar Creek stakeholders alone. As a result, direct support from one or a combination of several entities will be essential to achieve water quality goals in the watershed. Focused and continued implementation of key restoration measures will require the creation of multiple full-time equivalent positions in the watershed to coordinate and provide technical assistance to stakeholders.

Urban Stormwater and Wastewater Management Measures

Structural and programmatic urban stormwater controls are the responsibility of individual cities in the watershed. However, identification and design of specific improvements to stormwater conveyances and wastewater treatment facilities are beyond the scope of many smaller municipal operations. Professional engineering analysis will be essential to assess construction of new structural controls and upgrades to existing components of both stormwater and wastewater facilities.

Agricultural Management Measures

Technical support from Texas State Soil and Water Conservation Board and 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.

Schedule and Milestones

The implementation schedule and milestones presented in Table 10.1 are the result of planning efforts of the Steering Committee and work groups, in coordination with county and city officials, and other watershed stakeholders. A 10-year project timeline has been constructed for implementation of the 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.

Table 10.1 Implementation for Selected Best Management Practices.

BMP Type	Scheduled Implementation	Contingent upon
Channel		
Construction		
Cropland		
WWTP		
Reservoir		
Urban		
Monitoring Program		
Education and Outreach		

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. Some of the key potential funding sources that will be explored include:

Clean Water Act State Revolving Fund

The State Revolving Fund (SRF) administered by the 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.

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.

Outreach and Education

In addition to the implementation of management measures, some financial and technical assistance will be required to conduct the outreach and education measures designed to improve public awareness and participation throughout the process. Cooperation among personnel from the Texas AgriLife Extension Service, Texas State Soil and Water Conservation Board, Texas Commission on Environmental Quality, and Tarrant Regional Water District will be vital to successful engagement of watershed stakeholders. In addition, city and county staff will play an important role in the dissemination of important information released through the Cedar Creek Watershed Partnership. Development of educational materials will be done by these organizations and others, though some assistance will likely be required in the design and construction of larger visuals, such as billboards or watershed signs. Funding for some of these activities will be supported through routine outreach efforts by these groups. However, additional funding will be required to enhance and sustain these efforts and will be sought from outside sources. Clean Water Act 106 funds will support a number of these strategies and represent an important step in informing the public about watershed planning efforts.

Expectations

Expected load reductions for sediment and total phosphorus by monitoring and modeling as a result of full implementation of recommended management measures in the Cedar Creek Watershed are presented in Table 7.5. Certainly, precise estimates of attainable load reductions are difficult to determine, and may change over time due to significant changes in landuse and pollutant sources. However, these estimates will be used to demonstrate expected improvement toward target water quality goals for the watershed. With active local stakeholder engagement and participation in plan implementation and continued support from cooperating groups and agencies, the activities outlined here will make significant progress toward improving water quality in the Cedar Creek Watershed.

Appendices

Appendix A: Elements of Successful Watershed Plans

A. Identification of Causes and Sources of Impairment

An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in the watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan). Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed. Information can be based on a watershed inventory, extrapolated from a subwatershed inventory, aerial photos, GIS data, and other sources.

B. Expected Load Reductions

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

C. Proposed Management Measures

A description of the management measures that will need to be implemented to achieve the estimated load reductions and an identification (using a map or description) of the critical areas in which those measures will be needed to implement the plan. These are defined as including BMPs (best management practices) and measures needed to institutionalize changes. A critical area should be determined for each combination of source and BMP.

D. Technical and Financial Assistance Needs

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

E. Information, Education, and Public Participation Component

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

F. Schedule

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

G. Milestones

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

H. Load Reduction Evaluation Criteria

A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether the watershed-based plan needs to be revised. The criteria for loading reductions do not have to be based on analytical water quality monitoring results. Rather, indicators of overall water quality from other programs can be used. The criteria for the plan needing revision should be based on the milestones and water quality changes.

I. Monitoring Component

A monitoring component to evaluate effectiveness of the implementation efforts over time, measured against the criteria established under the evaluation criteria. The monitoring component should include required project-specific needs, the evaluation criteria, and local monitoring efforts. It should also be tied to the State water quality monitoring efforts.

Appendix B: Cedar Creek Watershed Protection Plan Ground Rules

Cedar Creek Reservoir Watershed Partnership
Ground Rules

Per Environmental Protection Agency Guidelines regarding stakeholder collaboration on the development of Watershed Protection Plans (WPP's), the following are the Ground Rules for the Cedar Creek Reservoir Watershed Partnership (hereafter referred to as the Partnership) agreed to and signed by the members of the Cedar Creek Reservoir Watershed Partnership Steering Committee (hereafter referred to as the Steering Committee) in an effort to develop and implement a watershed protection plan.

The signatories to these Ground Rules agree as follows:

GOALS

The goal of the Partnership is to develop and implement a Watershed Protection Plan to improve and protect the water quality of the Cedar Creek Reservoir and Watershed. According to the draft *2004 Texas Water Quality Inventory and 303(d) List*, Cedar Creek Reservoir exhibits elevated nutrient levels and is impaired by excessive sediment loading into the reservoir causing elevated Chlorophyll a levels.

POWERS

The role of the Steering Committee is to formulate recommendations to be used in drafting the WPP. Furthermore, the Steering Committee will help guide the implementation of the WPP to success. Formal Steering Committee recommendations will be identified as such in the planning documents and meeting summaries.

Although formation of the Steering Committee was facilitated by Texas AgriLife Extension Service, Texas AgriLife Research and the Tarrant Regional Water District (TRWD), the Steering Committee is an independent group of watershed stakeholders and individuals with an interest in restoring and protecting the designated uses and the overall health of the Cedar Creek Reservoir and Watershed.

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

TIME FRAME

Development of a Cedar Creek WPP will require at least a 10-month period. The Steering Committee will function under an August 2008 target date to complete the initial development of the WPP. Achieving water quality improvement in Cedar Creek Reservoir may require significant time as implementation is an iterative process of executing programs and practices followed by achievement of interim milestones and reassessment of strategies and recommendations. The Steering Committee will function throughout the 10-month initial development period and may continue to function thereafter as a recommendation of the WPP.

STEERING COMMITTEE MEMBERSHIP SELECTION

The Steering Committee is composed of stakeholders from the Cedar Creek Watershed. Initial solicitation of members for equitable geographic and topical representation was conducted using three methods: 1) consultation with the Texas AgriLife Extension County Agents, Kaufman-Van Zandt Soil & Water Conservation District, Tarrant Regional Water District, Texas AgriLife Research and local and regional governments, 2) meetings with the various stakeholder interest groups and individuals, and 3) self-nomination or requests by the various stakeholder groups or individuals.

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

STEERING COMMITTEE

Members include both individuals and representatives of organizations and agencies. A variety of members serve on the Steering Committee so as to reflect the diversity of interests within the Cedar Creek Reservoir and Watershed and to incorporate the viewpoints of those who will be affected by the WPP.

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

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

Committee members will be expected to assist with the following:

- Identify the desired programs and practices to improve watershed quality conditions;
- Prioritization of programs and practices to achieve goals;
- Help develop a WPP document;
- Assist in the implementation of the WPP at the local level; and
- Communicate implications of the WPP to other affected parties in the watershed.

Steering Committee members will be asked to sign the final WPP as acknowledgement of participation in the formulation of the plan.

The Steering Committee will not elect a chair, but rather remain a facilitated group. Texas AgriLife Extension Service and/or Tarrant Regional Water District will serve as the facilitator.

In order to carry out its responsibilities, the Steering Committee has discretion to form work groups to carry out specific assignments from the Committee. Steering Committee members will serve on a work group and represent that work group at Steering Committee meetings to bring forth information and recommendations.

WORK GROUPS

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

- Agricultural and Rural Source Work Group
- Outreach and Education Work Group
- Urban Stormwater and Wastewater Treatment Plant Work Group

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

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

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

TECHNICAL ADVISORY GROUP

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

- Texas Commission on Environmental Quality
- Texas AgriLife Extension Service
- Texas AgriLife Research
- Texas Department of Agriculture
- Texas Parks & Wildlife Department
- Texas State Soil and Water Conservation Board
- Texas Farm Bureau
- Texas Water Development Board
- Tarrant Region Water District
- United States Environmental Protection Agency
- United States Department of Agriculture - Natural Resources Conservation Service

REPLACEMENTS AND ADDITIONS

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

ALTERNATES
Members unable to attend a Steering Committee meeting (an absentee) may send an alternate. An absentee should provide advance notification to the facilitator of the desire to send an alternate.

An alternate attending with prior notification from an absentee will serve as a proxy for that absent Steering Committee member and will have voting privileges. An alternate attending without advance notification will not be able to participate in Steering Committee votes.

Absentees may also provide input via another Committee member or send input via the facilitator. The facilitator will present such information to the Committee.

ABSENCES
All Steering Committee members agree to make a good faith effort to attend all Steering Committee meetings. Three absences in a row of which the facilitator was not informed of beforehand or without designation of an alternate constitute a resignation from the Steering Committee.

DECISIONMAKING PROCESS
The Steering Committee will strive for consensus when making decisions and recommendations. Consensus is defined as everyone being able to live with the decisions made. Consensus inherently requires compromise and negotiation.

If consensus cannot be achieved, the Steering Committee will make decisions by a simple majority vote. If members develop formal recommendations, they will do so by two-thirds majority vote.

Steering Committee members may submit recommendations as individuals or on behalf of their affiliated organization.

It should be noted that a WPP is a voluntary plan of action and by agreeing to serve on the Steering Committee you in no way are committing yourself or your organization to implement suggested Best Management Practices.

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

FACILITATOR
The Texas AgriLife Extension Watershed Coordinator and the Texas AgriLife Research Project Manager are independent positions, financed by the US EPA and USDA-NRCS through federal

grant funds. Each has specific roles to perform in facilitating the Partnership and Steering Committee.

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

Over the 10-month development period, regular meetings of either the Steering Committee or Work Groups will occur every other month. The Steering Committee may determine the need for additional meetings. Steering Committee and Work Group meetings will be scheduled to accomplish specific milestones in the planning process.

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

OPEN DISCUSSION
Participants may express their views candidly and in a professional manner. The input of all participants shall be viewed with equal importance by the Steering Committee.

AGENDA
Texas AgriLife Extension Service and Tarrant Regional Water District, in consultation with Steering Committee members are charged with developing the agenda. The anticipated topics are determined at the previous meeting and through correspondence. A draft agenda will be sent to the Steering Committee with the notice of the meeting. Agendas will be posted on the project Web site (http://nctx-water.tamu.edu). Agenda items may be added by members at the time that the draft agenda is provided. The Texas AgriLife Extension Service Coordinator will review the agenda at the start of each meeting and the agenda will be amended if needed and the Committee agrees. The Committee will then follow the approved agenda unless they agree to revise it.

MEETING SUMMARIES
Texas AgriLife Extension Service will take notes during the meetings and may provide audio recording. Meeting summaries will be based on notes and/or the recording. Texas AgriLife Extension Service and Tarrant Regional Water District will draft meeting notes and distribute them to the committee for their review and approval. All meeting summaries will be posted on the project website.

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

PUBLIC/ MEDIA COMMENTARY

Individuals shall not comment on behalf of the Steering Committee as a whole unless authorized by the Committee to do so. Members will not speak for the Texas AgriLife Extension Service or Tarrant Regional Water District and neither the Texas AgriLife Extension Service nor Tarrant Regional Water District speak for Steering Committee members. If Committee spokespersons are needed, they will be selected by the Steering Committee.

DEVELOPMENT AND REVISION OF GROUNDRULES

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

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

Control Measure	What is Required	Best Management Practices
Public Education and Outreach	Implement a public education program to distribute educational materials to the community about the impacts of stormwater discharges on local water bodies and the steps that can be taken to reduce stormwater pollution	Brochures or fact sheets
		Recreational guides
		Alternative information sources
		A library of educational materials
		Volunteer citizen educators
		Event participation
		Educational programs
		Storm drain stenciling
		Stormwater hotlines
		Economic incentives
		Public Service Announcements
		Tributary signage
Public Participation/Involvement	Provide opportunities for citizens to participate in program development and implementation	Public meetings/citizen panels
		Volunteer water quality monitoring
		Volunteer educators/speakers
		Storm drain stenciling
		Community clean-ups
		Citizen watch groups
		"Adopt A Storm Drain" programs
Illicit Discharge Detection and Elimination	Develop, implement and enforce an illicit discharge detection and elimination program	A storm sewer system map showing outfalls and receiving waters
		Legally prohibit non-stormwater discharges into the MS4
		Implement a plan to detect and address non-stormwater discharges into the MS4
		Educate public employees, businesses, and the general public about the hazards of illegal discharges and improper disposal of waste
Construction Site Runoff Control	Develop, implement, and enforce an erosion and sediment control program for construction activities that disturb 1 or more acres of land	Have an ordinance or other regulatory mechanism requiring the implementation of proper erosion and sediment controls on applicable construction sites

<table>
<tr><th>Control Measure</th><th>What is Required</th><th colspan="2">Best Management Practices</th></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td colspan="2">Have procedures for site plan review of construction plans that include requirements for the implementation of BMPs to control erosion and sediment and other waste at the site</td></tr>
<tr><td colspan="2">Have procedures for site inspection and enforcement of control measures</td></tr>
<tr><td colspan="2">Have sanctions to ensure compliance (established in the ordinance or other regulatory mechanism)</td></tr>
<tr><td colspan="2">Establish procedures for the receipt and consideration of information submitted by the public</td></tr>
<tr><td rowspan="5">Post-Construction Runoff Control</td><td rowspan="5">Develop, implement, and enforce a program to reduce pollutants in post-construction runoff to their MS4 from new development and redevelopment projects that result in the land disturbance of greater than or equal to 1 acre</td><td rowspan="2">Non-Structural BMPs</td><td>Planning Procedures</td></tr>
<tr><td>Site-Based BMPs</td></tr>
<tr><td rowspan="3">Structural BMPs</td><td>Stormwater Retention/Detention BMPs</td></tr>
<tr><td>Infiltration BMPs</td></tr>
<tr><td>Vegetative BMPs</td></tr>
<tr><td rowspan="5">Pollution Prevention/Good Housekeeping</td><td rowspan="5">Develop and implement an operation and maintenance program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations into the storm sewer system</td><td colspan="2">Employee training on how to incorporate pollution prevention/good housekeeping techniques into municipal operations</td></tr>
<tr><td colspan="2">Maintenance procedures for structural and non-structural controls</td></tr>
<tr><td colspan="2">Controls for reducing or eliminating the discharge of pollutants from areas such as roads and parking lots, maintenance and storage yards</td></tr>
<tr><td colspan="2">Procedures for the proper disposal of waste removed from separate storm sewer systems</td></tr>
<tr><td colspan="2">Ensure that new flood management projects assess the impacts on water quality and examine existing projects for incorporation of additional water quality protection devices or practices</td></tr>
</table>

Appendix D: Best Management Practice Selection by Subwatershed

Subwatershed	Loading (lbs/day)			BMP	Subwatershed Reduction			Treatment area	Installation Cost	Cost per lb pollutant Reduction			Total Watershed Reduction		
	N	P	Sed		N	P	Sed			N	P	Sed	N	P	Sed
34	23	29	31	Grassed waterway	.53	.61	.70	100 acres							
				Sediment Pond	.61	.69	.73	75 acres							
				Pasture Planting	.49	.53	.55	1000 acres							

Appendix E: Stakeholder Survey of BMP Preferences and Results

BMP Prioritization

Please prioritize the following best management practices with 1 being the most important and 29 being the least important/effective.

____ Grassed Waterways
____ Rotational Grazing
____ Terracing
____ Crop Residue Management
____ Pasture Planting
____ Water Facility
____ Riparian Buffer Strips
____ Wetland Creation
____ Sand Filters
____ Rainwater Harvesting
____ Non-point Source Pollution
____ Grade Stabilization
____ Residential Fertilizer Mgmt
____ Septic System Maintenance
____ Reservoir BMPs
____ Filter Strips
____ Contour Farming
____ Nutrient Management
____ Cropland Conversion to Pasture
____ Range Planting
____ Fencing
____ Channel Stabilization
____ Construction Site Management
____ Detention Ponds
____ Bioswales / Rain Gardens
____ Sedimentation Basins/Ponds
____ Illegal Dumping Prevention
____ Pet Waste Management
____ Soil Testing

List additional BMPS that should be considered:

____

____

____

____

____

Likelihood of Implementation

Please evaluate the following best management practices for their likelihood to be implemented by stakeholders within the watershed with 1 being completely unlikely and 5 being completely likely.

Grassed Waterways	1	2	3	4	5
Filter Strips	1	2	3	4	5
Rotational Grazing	1	2	3	4	5
Contour Farming	1	2	3	4	5
Terracing	1	2	3	4	5
Nutrient Management	1	2	3	4	5
Crop Residue Management	1	2	3	4	5
Cropland Conversion to Pasture	1	2	3	4	5
Pasture Planting	1	2	3	4	5
Range Planting	1	2	3	4	5
Water Facility	1	2	3	4	5
Fencing	1	2	3	4	5
Riparian Buffer Strips	1	2	3	4	5
Channel Stabilization	1	2	3	4	5
Wetland Creation	1	2	3	4	5
Construction Site Management	1	2	3	4	5
Sand Filters	1	2	3	4	5
Detention Ponds	1	2	3	4	5
Rainwater Harvesting	1	2	3	4	5
Bioswales / Rain Gardens	1	2	3	4	5
Non-point Source Pollution	1	2	3	4	5
Sedimentation Basins/Ponds	1	2	3	4	5
Grade Stabilization	1	2	3	4	5
Illegal Dumping Prevention	1	2	3	4	5
Residential Fertilizer Mgmt	1	2	3	4	5
Pet Waste Management	1	2	3	4	5
Septic System Maintenance	1	2	3	4	5
Soil Testing	1	2	3	4	5
Reservoir BMPs	1	2	3	4	5

List potential barriers to implementation of BMPs within the watershed:

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Effectiveness of BMPs

Please evaluate the following best management practices for their effectiveness to improve water quality in the watershed with *1 being completely ineffective and 5 being completely effective.*

Grassed Waterways	1	2	3	4	5
Filter Strips	1	2	3	4	5
Rotational Grazing	1	2	3	4	5
Contour Farming	1	2	3	4	5
Terracing	1	2	3	4	5
Nutrient Management	1	2	3	4	5
Crop Residue Management	1	2	3	4	5
Cropland Conversion to Pasture	1	2	3	4	5
Pasture Planting	1	2	3	4	5
Range Planting	1	2	3	4	5
Water Facility	1	2	3	4	5
Fencing	1	2	3	4	5
Riparian Buffer Strips	1	2	3	4	5
Channel Stabilization	1	2	3	4	5
Wetland Creation	1	2	3	4	5
Construction Site Management	1	2	3	4	5
Sand Filters	1	2	3	4	5
Detention Ponds	1	2	3	4	5
Rainwater Harvesting	1	2	3	4	5
Bioswales / Rain Gardens	1	2	3	4	5
Non-point Source Pollution	1	2	3	4	5
Sedimentation Basins/Ponds	1	2	3	4	5
Grade Stabilization	1	2	3	4	5
Illegal Dumping Prevention	1	2	3	4	5
Residential Fertilizer Mgmt	1	2	3	4	5
Pet Waste Management	1	2	3	4	5
Septic System Maintenance	1	2	3	4	5
Soil Testing	1	2	3	4	5
Reservoir BMPs	1	2	3	4	5

Comments:

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BMP Survey Results

BMP Prioritization																														Average	Mode	Median
Grassed Waterway	11	2	6	12	9	8	11	4	10	5	2	27	14	15	8	2	4	2	6	3		9		6	5	5	5	7		**8**	**2**	**6**
Filter Strips	16	16	12	4	15	12	14	29		6	3	17	15	3	9	3	26	3	2	1		13		7	7	6	6	9		**10**	**3**	**9**
Rotational Grazing	15	15	23	17	26	7	23	5		23	11	9	11	21	20	8	25	10	7	22	10	20		10	27	16	13	15		**16**	**15**	**15**
Contour Farming	17	7	10	15	20	24	27	9		12	6	11	3	13	10	4	27	6	14	4		22		11	9	14	4	8		**12**	**4**	**11**
Terracing	14	8	15	22	13	25	24	6	8	13	12	19	4	14	11	9	24	7	18	2		28		19	10	15	26	10		**14**	**14**	**13.5**
Nutrient Management	1	11	20	7	3	6	10	10		1	5	21	22	6	2	18	15	5	4	14	4	7		8	16	9	14	6		**9**	**6**	**7.5**
Crop Residue Management	3	12	16	10	12	16	20	7		4	13	15	2	12	7	6	14	20	13	7	1	25		20	24	10	9	14		**12**	**12**	**12**
Cropland Conversion to Pasture	22	24	14	19	2	13	22	1	2	29	14	16	30	8	24	1	7	23	5	29		23		12	14	2	16	16		**15**	**14**	**15**
Pasture Planting	6	28	9	16	25	17	17	3		11	7	12	21	7	22	10	13	21	8	23		24		9	13	17	8	21		**15**	**17**	**13**
Range Planting	23	27	28	18	29	11	15	2		20	10	13	20	9	21	11	8	33	3	24		14		13	12	13	10	20		**16**	**20**	**14**
Water Facility	21	23	5	23	28	21	21	14		24	24	2	17	29	19	12	11	24	19	20		4		21	23	29	27	13		**19**	**21**	**21**
Fencing	12	29	11	14	30	10	9	11		16	25	22	26	22	25	7	19	19	15	21		27		19	26	20	18	5		**18**	**19**	**19**
Riparian Buffer Strips	10	5	18	2	18	1	19	20	9	8	9	18	25	2	6	5	23	9	1	9		21		5	8	7	21	4		**11**	**9**	**9**
Channel Stabilization	24	4	8	11	17	9	16	12		10	4	23	9	17	18	20	1	8	20	16		3		17	1	1	17	19		**12**	**17**	**12**
Wetland Creation	9	1	2	1	19	2	12	15	7	7	18	8	12	16	26	17	5	16	9	18	7	1		25	20	23	20	3		**12**	**1**	**12**
Construction Site Management	4	3	19	3	1	14	8	25	1	3	1	4	1	1	4	15	9	18	10	5	8	11		4	2	3	3	1		**7**	**1**	**4**
Sand Filters	19	13	17	25	27	28	18	23		19	23	25	16	28	23	28	20	17	27	11		26		24	15	25	23	26		**22**	**23**	**23**
Detention Ponds	28	18	3	6	14	4	7	19		15	15	3	8	10	15	14	18	14	11	6		10		3	3	22	11	2		**11**	**3**	**11**
Rainwater Harvesting	26	14	22	26	10	26	3	24		22	27	20	18	20	29	27	6	15	26	28	6	2		27	22	24	22	25		**20**	**26**	**22**
Bioswales/ Rain Gardens	27	20	19	27	22	27	4	27		21	28	24	24	18	28	26	16	13	23	27	5	18		28	21	21	25	12		**21**	**27**	**22.5**
Non point Source Education	2	6	1	9	5	20	1	16		2	22	1	5	11	5	19	21	1	25	26	2	17		1	18	8	1	18		**10**	**1**	**7**
Sedimentation Basins/Ponds	25	19	6	4	4	5	5	18		14	19	10	7	4	16	16	17	12	16	10	9	15		2	4	12	12	11		**11**	**4**	**11.5**
Grade Stabilization	20	22	8	21	16	18	13	8		9	8	26	13	5	17	13	12	25	21	12		16		16	6	18	19	28		**16**	**8**	**16**
Illegal Dumping Prevention	8	10	7	20	23	15	26	26	3	26	16	28	19	24	27	22	3	27	29	17		6		22	28	26	2	17		**18**	**26**	**21**
Residential Fertilizer Mgmt	5	9	25	13	6	3	2	21	6	18	17	6	29	19	3	25	22	11	12	15	3	8		14	17	11	24	23		**14**	**6**	**13**
Pet Waste Management	29	25	29	28	24	22	29	28	4	17	29	29	28	25	14	29	29	26	28	25		29		29	29	28	28	30		**26**	**29**	**28**
Septic System Maintenance	7	17	27	5	21	19	25	22	5	25	21	7	23	23	13	24	10	28	22	8		12		15	25	27	7	22		**18**	**7**	**21**
Soil Testing	13	26	4	8	11	23	6	13		28	26	5	27	26	1	21	28	4	17	19		19		23	11	19	15	27		**17**	**26**	**19**
Reservoir BMPs	18	21	13	29	7	29	28	17		27	20	14	6	30	12	23	2	29	24	13		5		26	19	4	29	29		**19**	**29**	**20**

Likilihood to Implement																														Average	Mode	Median
Grassed Waterway	3	1	4		4	3	3	5	1	4	4	2	4	4	3	4	5	3	4	1		5		4	4	4	5	5		**4**	**4**	**4**
Filter Strips	3	1	4	3	4	3	3		4	3	4	4	2	4	3	4	3	4	4	1		5		4	4	3	5	4		**3**	**4**	**4**
Rotational Grazing	2	3	5	3	4	2	3	5	5	4	5	3	5	4	2	5	4	3	3	3		5		3	3	4	5	4		**4**	**3**	**4**
Contour Farming	3	4	4	4	2	3	2	2	4	4	4		5	5	3	4	3	2	3	2		5		3	3	2	4	4		**3**	**4**	**3**
Terracing	3	4	4	2	3	3	1	2	4	3	3	4	4	5	2	2	3	2	1	4		5		3	2	2	2	2		**3**	**2**	**3**
Nutrient Management	5	5	5	4	4	1	4	5	3	3	4	3	3	4	4	5	3	3	4	1		5		4	3	3	3	3		**4**	**3**	**4**
Crop Residue Management	5	3	3	3	2	2	3	4	3	3	3	4	3	4	3	5	4	4	5	1		5		4	3	2	4	2		**3**	**3**	**3**
Cropland Conversion to Pasture	2	2	3	4	1	1	3	5		2	4	2	1	3	2	5	4	3	3	3		4		3	3	3	2	1		**3**	**3**	**3**
Pasture Planting	3	1	4		1	1	4	5	3	4	3	5	3	4	2	4	4	4	4	3		5		3		3	3	2		**3**	**3**	**3**
Range Planting	3	1	1		2	1	4	5	3	4	3	3	3	4	2	4	4	4	4	2		5		3		3	3	3		**3**	**3**	**3**
Water Facility	4	3	4		4	1	3	3	5	2	3	5	3	3	3	5	3	2	3	1		5		2	3	2	2	4		**3**	**3**	**3**
Fencing	3	1	3	2	4	3	2	5	4	3	2	4	2	3	1	5	4	3	3	2		5	5	2	4	4	2	3		**3**	**3**	**3**
Riparian Buffer Strips	4	2	4	4	3	1	3	1	3	4	3	2	3	3	3	4	3	3	4	1		4		2	4	2	3	4		**3**	**3**	**3**
Channel Stabilization	4	1	2		2	1	2	1	1	4	2	2	4	2	2	2	3	3	3	1		4		3	4	2	2	1		**2**	**2**	**2**
Wetland Creation	4	2	4	3	1	1	3	1	2	2	2	4	4	2	2	4	4	3	4	1		3	4	2	2	2	2	4		**3**	**2**	**2**
Construction Site Management	5	4	4	3	5	1	2	3	5	3	5	3	5	4	3	5	4	4	4	1		5	5	3	4	3	5	3		**4**	**5**	**4**
Sand Filters	4		3	3	2	3	2	3	3	2	1	1	2	2	3	2	4	3	3	3		4		2	3	2	2	2		**3**	**3**	**3**
Detention Ponds	4	3	4	4	4	1	4	1	4	2	4	2	4	3	3	4	4	4	5	2		4	4	4	4	3	4	4		**3**	**4**	**4**
Rainwater Harvesting	3	3	4	2	2	3	5	1	3	4	1	4	4	2	3	3	4	4	3	1		5	4	1	3	3	2	2		**3**	**3**	**3**
Bioswales/ Rain Gardens	3	2	4	3	2	4	5	1	2	4	2	3	3	2	2	3	5	4	3	1		3	4	3	3	3	2	3		**3**	**3**	**3**
Non point Source Education	5	4	5		4	1	5	5	5	4	3	4	5	3	5	5	3	5	4	1		4	5	4	4	4	5	3		**4**	**5**	**4**
Sedimentation Basins/Ponds	3	2	4	3	4	1	5	5	3	4	4	3	5	3	2	4	3	3	3	1		4		4	4	3	3	4		**3**	**3**	**3**
Grade Stabilization	4	4	3		4	4	4	5	3	4	2	3	4	3	3	4	4	4	3	1		4		3	4	3	3	3		**3**	**4**	**4**
Illegal Dumping Prevention	5	3	2		4	1	3	1	4	4	5	2	5	3	3	3	5		2	1		5	5	3	3	2	5	4		**3**	**5**	**3**
Residential Fertilizer Mgmt	5	4	4	2	2	1	4	3	3	3	3	2	2	3	3	4	5	4	4	1		5	5	4	3	3	3	3		**3**	**3**	**3**
Pet Waste Management	4	4	4	2	2	1	1	1	3	3	1	2	4	3	3	2	3	3	2	1		4	4	1	3	3	2	4		**3**	**3**	**3**
Septic System Maintenance	5	3	4	4	3	1	4	3	4	2	3	5	5	3	3	5	5	3	4	1		4	5	3	4	3	3	4		**4**	**3**	**4**
Soil Testing	4	4	5	4	4	4	5	5	3	2	1	3	2	2	5	5	5	4	4	1		5		3	4	4	3	3		**4**	**4**	**4**
Reservoir BMPs	3	2	4	2	3	5	2	2	3	2	3	2	4	4	3	3	1	4	4	1		4		3	2	3	2	2		**3**	**2**	**3**

Effectiveness of BMP																														Average	Mode	Median
Grassed Waterway	4	4	4	4	4	2	4	5	1	3	5	4	4	4	4	5	3	4	4	1		4		3	4	4	5	4		**4**	**4**	**4**
Filter Strips	3	4	4	4	4	2	4	4	4	3	5	4	4	5	4	5	3	4	5	1		4		3	4	4	5	3		**4**	**4**	**4**
Rotational Grazing	3	3	2	4	3	2	3	5	5	2	3	3	3	3	2	4	4	4	4	4		4		2	3	3	3	5		**3**	**3**	**3**
Contour Farming	3	4	3	4	3	3	2	4	4	3	4	4	3	3	5	5	3	4	4	3		4		3	4	3	5	5		**4**	**3**	**4**
Terracing	3	4	4	4	2	3	5	5	4	3	5	4	3	3	5	5	2	4	4	4		4		3	4	3	4	5		**4**	**4**	**4**
Nutrient Management	5	5	5	4	4	1	4	5	3	5	4	3	4	4	5	5	3	5	5	2		5		4	3	3	4	4		**4**	**5**	**4**
Crop Residue Management	4	4	4	4	3	1	3	5	3	4	5	3	4	4	3	5	3	4	4	1		5		4	3	3	4	4		**4**	**4**	**4**
Cropland Conversion to Pasture	4	4	3	4	4	2	4	5		4	4	3	5	4	2	5	4	3	5	1		4		3	3	3	3	5		**4**	**4**	**4**
Pasture Planting	3	3	4		2	1	4	5	3	4	3	4	3	3	3	3	4	4	4	3		5		2	3	3	3	3		**3**	**3**	**3**
Range Planting	3	3	1		2	1	4	5	3	4	3	3	3	3	3	3	4	3	5	3		5		2	4	4	3	4		**3**	**3**	**3**
Water Facility	2	3	4		2	1	3	4	5	2	2	4	3	4	4	3	4	4	4	1		4		2	3		2	5		**3**	**4**	**3**
Fencing	3	1	3	3	3	3	4	5	4	3	2	4	3	3	4	2	3	3	4	3		4		2	3	4	3	5		**3**	**3**	**3**
Riparian Buffer Strips	4	4	4	4	4	1	4	4	3	4	3	4	4	5	5	3	3	3	5	1		5		3	4	4	5	5		**4**	**4**	**4**
Channel Stabilization	4	5	4	4	3	1	3	3	1	3	4	3	5	4	5	3	4	4	4	3		5		3	4	3	5	3		**4**	**3**	**4**
Wetland Creation	5	5	4	5	4	1	4	3	2	4	3	2	4	5	3	3	3	4	5	4		4		4	3	2	3	5		**4**	**4**	**4**
Construction Site Management	4	5	2	5	3	1	5	4	5	5	4	3	5	5	4	4	3	4	4	1		4		4	4	4	5	5		**4**	**4**	**4**
Sand Filters	4	4	3	4	4	3	4	2	3	4	3	3	3	4	4	2	4	3	3	1		4		2	3	2		2		**3**	**4**	**3**
Detention Ponds	4	3	4	4	5	1	5	5	4	4	4	4	5	4	4	4	4	4	4	1		4	4	4	4	2	3	5		**4**	**4**	**4**
Rainwater Harvesting	4	4	2	2	2	3	5	2	3	3	1	4	4	4	2	3	4	3	3	3		4	4	2	3	2	4	3		**3**	**4**	**3**
Bioswales/ Rain Gardens	4	3	2	2	2	3	4	1	2	3	1	4	3	5	3	3	4	3	3	4		4	5	2	3	2	2	3		**3**	**3**	**3**
Non point Source Education	5	4	5		3	1	4	5	5	4	2	4	2	3	4	4	3	5	4	4		4	4	4	3	4	5	1		**4**	**4**	**4**
Sedimentation Basins/Ponds	3	3	3	5	5	1	5	5	3	3	3	4	5	4	3	4	3	4	4	1		4		4	4	3	3	4		**4**	**3**	**4**
Grade Stabilization	4	4	4	4	4	1	3	5	3	3	3	2	5	4	4	4	2	4	3	2		4	5	3		3	4	3		**3**	**4**	**4**
Illegal Dumping Prevention	3	3	2		3	1	3	3	4	3	2	3	4	3	3	4	4	4	3	1		4	5	2	2	2	5	4		**3**	**3**	**3**
Residential Fertilizer Mgmt	5	5	2	3	4	1	4	5	3	5	3	4	2	3	5	4	4	4	5	1		5	4	3	2	4	5	2		**4**	**5**	**4**
Pet Waste Management	3	3	1	2	2	3	1	2	3	5	1	3	2	2	3	2	2	3	3	3		3	4	1	2	2	2	3		**2**	**3**	**2**
Septic System Maintenance	4	3	4	4	2	1	3	4	4	3	2	5	4	3	4	5	3	3	4	1		4	4	3	2	2	4	3		**3**	**4**	**3**
Soil Testing	5	3	5	4	4	3	4	5	3	2	2	3	2	2	5	5	3	4	4	1		4		3	3	4	3	3		**3**	**3**	**3**
Reservoir BMPs	4	4	5	1	4	4	3	5	3	4	3	3	3	2	3	3	4	4	4	1		5		3	3	3	2	1		**3**	**3**	**3**

Glossary of Terms

Algae - Plants that lack true roots, stems, and leaves. Algae consist of nonvascular plants that attach to rocks and debris or are free floating in the water. Such plants may be green, blue-green, or olive in color, slimy to the touch, and usually have a coarse filamentous structure.

Ambient - Refers to the existing water quality in a particular water body.

Ammonia-Nitrogen (NH3-N) - Ammonia, naturally occurring in surface and wastewaters, is produced by the breakdown of compounds containing organic nitrogen.

Attainable Use - A use which can be reasonably achieved by a water body in accordance with its physical, biological, and chemical characteristics whether it is currently meeting that use or not.

Best Management Practices - Schedules of activities, maintenance procedures, and other management practices to prevent or reduce the pollution of water in the state from point and nonpoint sources, to the maximum extent practicable.

Biological Integrity - The species composition, diversity, and functional organization of a community of organisms in an environment relatively unaffected by pollution.

Bloom - The accelerated growth of algae and/or higher aquatic plants in a body of water. This is often related to pollutants that increase the rate of growth.

BMP - Best Management Practices.

Channelization - Straightening and deepening streams so water will move faster, a method of flood control that disturbs fish and wildlife habitats and can interfere with a waterbody's ability to assimilate waste.

Chlorophyll-*a* - Photosynthetic pigment which is found in all green plants. The concentration of chlorophyll a is used to estimate phytoplankton biomass (all of the phytoplankton in a given area) in surface water.

Conductivity - A measure of the electrical current carrying capacity. Dissolved substances in water dissociate into ions with the ability to conduct electrical current. Conductivity is a measure of how salty the water is; salty water has high conductivity.

Contact Recreation - Recreational activities involving a significant risk of ingestion of water, including wading by children, swimming, water skiing, diving, and surfing.

CR - Contact recreation.

Criteria - Water quality conditions which are to be met in order to support and protect desired use.

Designated Use - A use which is assigned to specific water bodies in the Texas Surface Water Quality Standards. Typical uses which may be designated for specific water bodies include domestic water supply, categories of aquatic life use, recreation categories, and aquifer protection.

Dissolved Oxygen (DO) - The oxygen freely available in water. Dissolved oxygen is vital to fish and other aquatic life and for the prevention of odors. Traditionally, the level of dissolved oxygen has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life.

DO - Dissolved oxygen.

Ecological Impact - The effect that a man-made or natural activity has on living organisms and their abiotic (non-living) environment.

E. Coli - Escherichia coli, a subgroup of fecal coliform bacteria that is present in the intestinal tracts and feces of warm-blooded animals. It is used as an indicator of the potential presence of pathogens.

Eutrophication - The slow aging process during which a lake, estuary or bay evolves into a bog or marsh and eventually disappears.

Fecal Coliform - A portion of the coliform bacteria group which is present in the intestinal tracts and feces of warm-blooded animals; heat tolerant bacteria from other sources can sometimes be included. It is used as an indicator of the potential presence of pathogens.

Habitat - The area in which an organism lives.

Impoundment - A body of water confined by a dam, dike, floodgate or other barrier.

Indicator Organisms - An organism, species, or community that indicates the presence of a certain environmental condition or conditions.

MCL - Maximum Contaminant Level (for public drinking water supplies).

Natural Vegetative Buffer - An area of either natural or native vegetation which buffers the water body from terrestrial runoff and the activities of man.

Nitrate-Nitrogen (NO3-N) - A compound containing nitrogen which can exist as a dissolved solid in water. Excessive amounts can have harmful effects on humans and animals.

Nitrite-Nitrogen (NO2-N) - An intermediate oxidation state in the nitrification process (ammonia, nitrite, nitrate).

Nonpoint Source - Pollution sources which are diffuse and do not have a single point of origin or are not introduced into a receiving stream from a specific outfall. The pollutants are generally carried off the land by stormwater runoff. The commonly used categories for nonpoint sources are: agriculture, forestry, urban, mining, construction, dams and channels, land disposal and saltwater intrusion.

Noncontact Recreation - Aquatic recreational pursuits not involving a significant risk of water ingestion, including fishing, commercial and recreational boating, and limited body contact.

Nutrient - Any substance used by living things to promote growth. The term is generally applied to nitrogen and phosphorus in water and wastewater, but is also applied to other essential and trace elements.

Orthophosphate (O-P) - Nearly all phosphorus exists in water in the phosphate form. The most important form of inorganic phosphorous is orthophosphate, making up 90% of the total. Orthophosphate, the only form of soluble inorganic phosphorus that can be directly utilized, is the least abundant of any nutrient and is commonly the limiting factor.

Outfall - A designated point of effluent discharge.

pH - The hydrogen-ion activity of water caused by the breakdown of water molecules and the presence of dissolved acids and bases.

Phosphorus - Essential nutrient to the growth of organisms. In excessive amounts, it can contribute to the eutrophication of lakes and other water bodies.

Photosynthesis - The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll using sunlight as an energy source.

Point Source - Any discernible, confined and discrete conveyance from which pollutants or wastes are or may be discharged into or adjacent to water.

PS - Public water supply.

Public Drinking Water Supply - A water body designated to provide water to a public water system.

Receiving Water - A river, stream, lake or other body of surface water into which wastewater or treated effluent is discharged.

Reservoir - Any natural or artificial holding area used to store, regulate or control water.

Riparian Zone - Generally includes the area of the stream bank and out onto the flood plain which is periodically inundated by the flood waters from the stream. Interaction between this terrestrial zone and the stream is vital for the health of the stream.

Runoff - The part of precipitation or irrigation water that runs off land into streams and other surface water.

Sampling Event - Refers to all samples taken at a single station at one time.

Sediment - Particles and/or clumps of particle of sand, clay, silt, and plant or animal matter carried in water and are deposited in reservoirs and slow moving areas of streams and rivers.

Segment - A water body or portion of a water body which is individually defined and classified in the Texas Surface Water Quality Standards. A segment is intended to have relatively homogeneous chemical, physical, and hydrological characteristics. A segment provides a basic unit for assigning site-specific standards and for applying water quality management programs of the agency. Classified segments may include streams, rivers, bays, estuaries, wetlands, lakes, or reservoirs.

Significant Aquatic Life Use - A broad characterization of aquatic life which indicates that a subcategory of aquatic life use (limited, intermediate, high, or exceptional) is applicable.

Standards - The designation of water bodies for desirable uses and the narrative and numerical criteria deemed necessary to protect those uses.

Stormwater - Rainfall runoff, snow melt runoff, surface runoff, and drainage.

Sulfate (SO4-2) - Sulfate is derived from rocks and soils containing gypsum, iron sulfides and other sulfur compounds. Sulfates are widely distributed in nature.

Surface Water Quality Standards - The designation of water bodies for desirable uses and the narrative and numerical criteria deemed necessary to protect those uses.

TCEQ - Acronym for the Texas Commission on Environmental Quality.

TDS - Total dissolved solids.

Test Results - Refers to the values for each individual water quality parameter that resulted from sampling. Some researchers refer to test results as data points.

TMDL - Total maximum daily load.

Total Maximum Daily Load (TMDL) - The total amount of a substance that a water body can assimilate and still meet the Texas Surface Water Quality Standards.

Total Dissolved Solids - The amount of material (inorganic salts and small amounts of organic material) dissolved in water and commonly expressed as a concentration in terms of milligrams per liter.

Tributary - A stream or river that flows into a larger stream or other body of water.

USGS - Acronym for the United States Geological Survey.

Water Quality Standards - Established limits of certain chemical, physical, and biological parameters in a water body; water quality standards are established for the different designated uses of a water body (e.g., aquatic life use, contact recreation, public water supply).

Watershed - The area of land from which precipitation drains to a single point. Watersheds are sometimes referred to as drainage basins or drainage areas.

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