# WATERSHED BASED PLAN

## FOR THE

# STILLWATER CREEK WATERSHED

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# Table of Contents

# List of Figures

# List of Tables

# List of Acronyms

**BMPs:** Best Management Practices
**BOD:** Biochemical Oxygen Demand
**CAFO:** Concentrated Animal Feeding Operation
**CFU:** Colony Forming Units
**EC:** E. Coli
**ENT:** Enterococci Bacteria
**EPA or USEPA:** United States Environmental Protection Agency
**OCC:** Oklahoma Conservation Commission
**OWRB:** Oklahoma Water Resources Board
**OSU:** Oklahoma State University
**OCES:** Oklahoma Cooperative Extension Service
**NLCD:** National Land Cover Database
**NPDES:** National Pollutant Discharge Elimination System
**NRCS:** Natural Resource Conservation Service
**NTU:** Nephelometric Turbidity Unit
**ODAFF:** Oklahoma Department of Agriculture, Food, and Forestry
**ODEQ:** Oklahoma Department of Environmental Quality
**OWQS:** Oklahoma Water Quality Standards
**PPWS:** Public and Private Water Supply
**WAG:** Watershed Advisory Group
**WBP:** Watershed Based Plan
**WWTP:** Waste Water Treatment Plant
**SC:** Stillwater Creek
**SCIP:** Stillwater Creek Implementation Project
**SCWBP:** Stillwater Creek Watershed Based Plan
**SCW:** Stillwater Creek Watershed
**SWAT:** Soil Water Assessment Tool
**TMDL:** Total Maximum Daily Load
**TSS:** Total Suspended Solids
**USDA:** United States Department of Agriculture
**USGS:** United States Geological Service
**WEPP:** Water Erosion Prediction Project
**WQS:** Water Quality Standards

# Introduction

The Stillwater Creek Watershed (SCW) is one of Oklahoma's top 25 impaired watersheds for nonpoint source (NPS) pollution in Oklahoma's §319 Management Program. As a source of drinking water and recreational activities, it is necessary to develop a WBP for the SCW. The Nonpoint Source Program and Grants Guidelines for States and Territories for FY 2004 and Beyond requires a *Watershed Based Plan* (WBP) to be completed prior to implementation using incremental funds. The guidance defines the 9 key components to be addressed in a watershed-based plan, much of which builds from the strategies outlined in the *Watershed Restoration Action Strategy* (WRAS). These components include: 1) identification of causes and sources that will need to be controlled to achieve load reductions, 2) estimate of load reductions expected from the management measures described, 3) a description of the management measures that will need to be implemented to achieve load reductions, 4) an estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources or authorities who will bear responsibility, 5) an information/education component that will be used to enhance public understanding of the project and encourage early participation in the overall program, 6) a schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious, 7) a description of interim, measurable milestones for determining whether control actions are being implemented, 8) a set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made or whether the Watershed Plan or Total Maximum Daily Load (TMDL) needs to be revised, and 9) a monitoring component to evaluate the effectiveness of the implementation efforts over time.

This plan refers to the initiation of best management practices (BMPs) in the SCW in order to address the NPS pollution. Sediment and turbidity are the major NPS concerns for the watershed, primarily due to agriculture, roadside erosion, and urban runoff. The SCIP facilitated watershed education, demonstration, and installation of best management practices (BMPs) in order to initiate a long-term, watershed scale effort to reduce NPS loading to levels where impairments and threats to SCW are eliminated. The Stillwater Creek Watershed-Based Plan (SCWBP) will allow forward progression of implementation practices addressing NPS pollution.

This project involved the collaboration of government agencies as well as OSU and local landowners. Data was collected from OCC stream monitoring sites and OWRB lake sites in order to determine the effects of the implementation project on water quality, although positive results are not expected to be evident immediately. Much of the information used to compile the SCWBP is derived, in part, from the outcome of the SCIP. Much of the data was amended from the final report, completed by the Oklahoma Conservation Commission in 2006.

# Causes and Sources

## Watershed Characterization

The SCW is located in the counties of Payne, Noble, and Logan in North Central Oklahoma. The watershed is part of the Lower Cimarron sub-basin and has an area of 276 square miles, encompassing Hydrologic Unit Codes 11-050003030 and 11-050003040. The principal stream, Stillwater Creek, is impounded in the western half of the watershed to form Lake Carl Blackwell. The stream then continues throughout the watershed and converges into the Cimarron River, draining the town of Stillwater, campus of Oklahoma State University (OSU) and associated research farms, and mixed-use property. The watershed also drains Lake McMurtry in the Northwest part of the watershed. Other tributaries to Stillwater Creek include Little Stillwater Creek, North Stillwater Creek, Brush Creek, East Brush Creek and Boomer Creek. Figure 1 outlines the watershed boundary and location within the state.

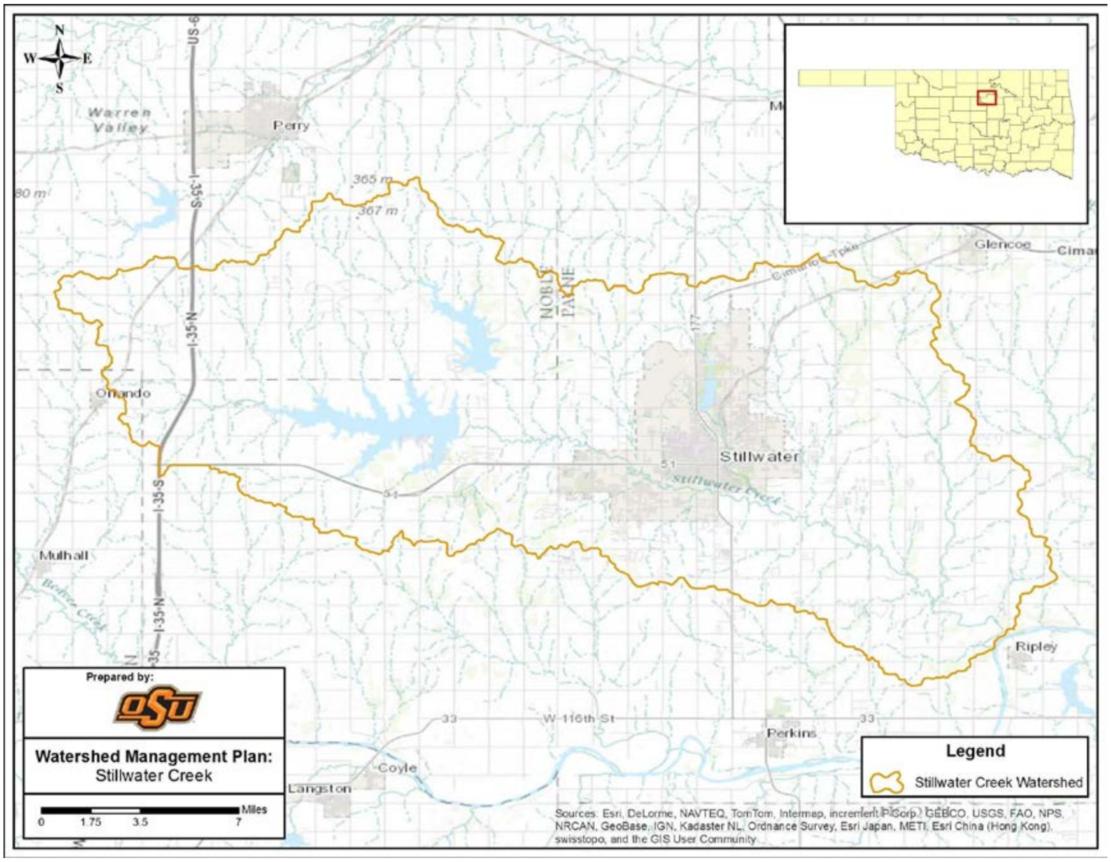


**Figure 1: Stillwater Creek Watershed**
**Stillwater Creek Watershed Location. Watershed Boundary Dataset for HUC 10-1105000301. USDA/NRCS.**

## *Physical & Natural Features*

Elevation in the watershed generally slopes from Northwest to Southeast (Storm, White, & Stoodley, 2003). Figure 2 shows highest elevation in the Northwest near 1231 feet to roughly 790 feet where SC converges with the Cimarron River.

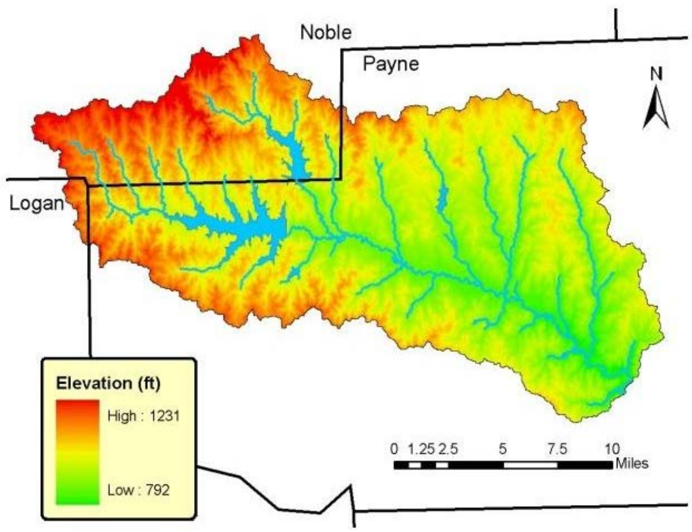


**Figure 2: USGS Digital Elevation Model for SCW**
**Storm, White, & Stoodley, 2013.**

The SCW falls in the Cross Timbers ecoregion, a complex mosaic of upland deciduous forest, savanna, and prairie. Predominant are the Post Oak, Blackjack Oak, and Black Hickory with Blackjack becoming more common in the west. Beneath and between trees, are rough leaf dogwood and redbud. Low shrubby plants like buckbrush and fragrant sumac provide habitat and food for small wildlife species. A variety of grasses and wildflowers that are typical of the prairie thrive in the sunny gaps between trees. Indian Grass, Big Bluestem, Coneflowers, and Indian Blanket shoot up in areas of abundant sunlight. This community of forests, if undisturbed, can enhance flood prevention, soil protection, wildlife habitat, and water filtration (Crawfard & Johnson, 2015).

Most of the soils in the SCW do not percolate adequately (Crall, 2006). The watershed is dominated by the Mollisol soil order. This watershed is characterized by a humid subtropical climate and Red Permian shales and sandstones as main bedrock types, dominated by red iron oxides (Kang, Storm, & Martson, 2010).

The geology of the watershed is predominantly of the Central Red-Bed Plains, characterized by Permian red shales and sandstones which form gently rolling hills and broad, flat plains. There are occasional Western Sand-Dune Belts, characterized by hummocky fields of grass-covered, stabilized sand dunes and some active dunes, occurring mainly on north sides of major rivers. The sand is from quaternary alluvium and terrace deposits. Also present in the northwest part of the watershed are the Cimarron Gypsum Hills, characterized by escarpments and badlands developed on Permian gypsums and shales. Locally abundant sinkholes and caves occur in this region (Johnson, 2008).

## *Land Use*

Pasture and rangeland, forested areas, cropland, and urban areas are among the highest land use practices throughout the watershed. There are a total of 252 farms and ranches in the Stillwater Creek Watershed. Land use percentages are shown in Table 1. Although land is primarily privately owned, OSU owns a large portion, including Lake Carl Blackwell. Grazing is predominant at OSU research facilities and farms with ranch cattle, pig, sheep, and dairy farms as well as range cattle operations. There are research farms as well. Much of the farmland outside OSU is rangeland with low-intensity grazing. Figure 3 shows land cover for Stillwater Creek with Table 1 providing a breakdown of land cover percentages**.** Data was obtained from the 2011 NLCD.

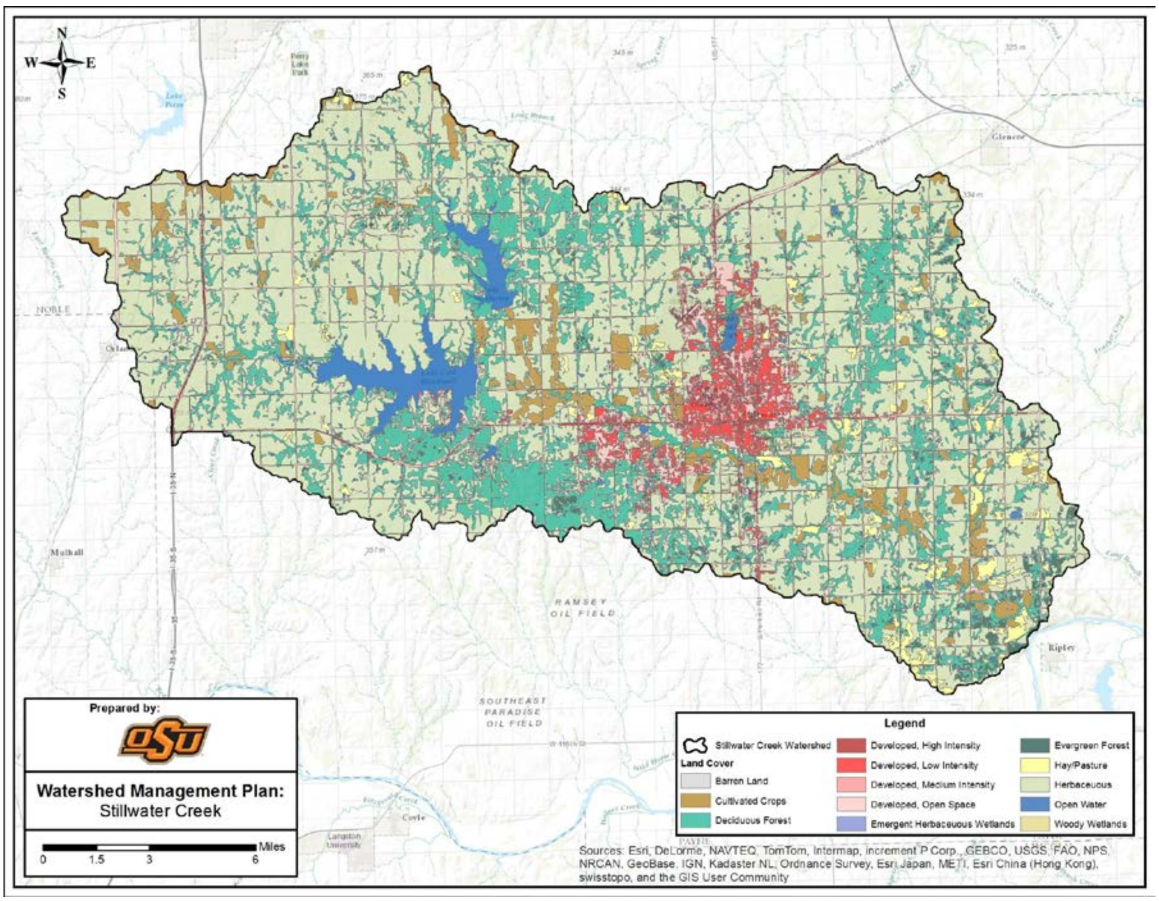


**Figure 3: Land Use Cover for SCW**
**Land use cover classification for Stillwater Creek watershed. USDA/NRCS. National Geospatial Center of Excellence, 2011. National Land Cover Dataset.**

**Table 1: Land Cover Percentage in the SCW.**

| Land Cover | Watershed Cover | | Land Cover | Watershed Cover |
|---|---|---|---|---|
| Herbaceous | 57.05% | | Developed, Low Intensity | 2.81% |
| Deciduous Forest | 19.94% | | Hay/Pasture | 2.45% |
| Developed Open Space | 6.53% | | Evergreen Forest | 1.33% |
| Cultivated Crops | 4.90% | | Developed, Medium Intensity | 1.27% |
| Open Water | 3.24% | | Other | 0.49% |

**USDA/NRCS National Geospatial Center of Excellence, 2011. National Land Cover Dataset.**

## *Human Population*

The SCW is an urbanizing watershed that supports agricultural land (pasture, grassland, and crops) and an expanding impervious area (4%). The city of Stillwater was established in 1889 at the confluence of two streams, now known as Boomer and Stillwater Creeks with a population of roughly 300. Early on, the watershed was characteristic of rural settlements, with farming as the predominant activity (Kang et al., 2010). The United States Census Bureau estimates the 2014 population for Payne County to be near 80,000, with around 47,000 residing in Stillwater (United States Census Bureau, 2015). This increase in population has transformed a large portion of the watershed area from rural to urban over the years. The expanding campus of Oklahoma State University has also led to an increase in impervious surface area in the watershed. Urban runoff generated from impervious areas largely enters Stillwater Creek via Boomer Creek and other secondary outfalls.

## *Waterbody Conditions*

Portions of SC are listed as impaired according to the 2014 303(d) list prepared by EPA and are displayed in Table 2. Roughly 91 miles of streams are impaired within the SCW in addition to lakes Carl Blackwell, McMurtry, and Boom. Dominant pollutants include turbidity, E. Coli, and Enterococci bacteria with dissolved oxygen and nitrates impairing a lesser extent of the watershed.

**Table 2: Stillwater Creek Waterbodies on the 2014 303(d) list.**

| Waterbody Name | Waterbody ID | Location | Waterbody Type | Size | Unit |
|---|---|---|---|---|---|
| Little Stillwater Creek | OK620900040050_00 | Huc: 11050003 | River | 13.9 | Miles |
| Little Stillwater Creek | OK620900040300_00 | Huc: 11050003 | River | 4.7 | Miles |
| Stillwater Creek | OK620900040010_00 | Huc: 11050003 | River | 1.6 | Miles |
| Stillwater Creek | OK620900040040_00 | Huc: 11050003 | River | 3.5 | Miles |
| Stillwater Creek | OK620900040070_00 | Huc: 11050003 | River | 5.9 | Miles |
| Stillwater Creek | OK620900040070_10 | Huc: 11050003 | River | 16.4 | Miles |

| | | | | | |
|---|---|---|---|---|---|
| Stillwater Creek | OK620900040270_00 | Huc: 11050003 | River | 2.2 | Miles |
| Stillwater Creek | OK620900040270_10 | Huc: 11050003 | River | 6.4 | Miles |
| Stillwater Creek, North | OK620900040220_00 | Huc: 11050003 | River | 3.8 | Miles |
| Stillwater Creek, North | OK620900040230_00 | Huc: 11050003 | River | 6.8 | Miles |
| Brush Creek | OK620900040090_00 | Huc: 11050003 | River | 6.6 | Miles |
| Brush Creek | OK620900040100_00 | Huc: 11050003 | River | 9.7 | Miles |
| Brush Creek | OK620900040130_00 | Huc: 11050003 | River | 9.8 | Miles |
| Carl Blackwell Lake | OK620900040280_00 | Huc: 11050003 | Freshwater Lake | 3,370.0 | Acres |
| McMurtry Lake | OK620900040240_00 | Huc: 11050003 | Freshwater Lake | 1,155.0 | Acres |
| Boomer Lake | OK620900040190_00 | Huc: 11050003 | Freshwater Lake | 260.0 | Acres |

According to OCC's Blue Thumb Program, Stillwater Creek scores slightly higher in habitat assessment than the reference average for the Central Great Plains eco-region. The stream scores high, with in-stream cover and canopy cover shading, leading to cooler and less variable water temperatures. The stream also scores high in channel alteration and streamside cover, meaning the creek channel is stable due to the presence of hard clay and vegetation along the bank, providing food for bugs and fish in addition to creek stability. Stillwater Creek scores in the medium category for pool variability, as there little difference in water depth across the stream. Attributes in the low category include pool bottom substrate, presence of rocky runs or riffles, flow, bank stability, bank vegetation stability, and channel sinuosity.

Impounding Stillwater Creek just west of the city of Stillwater created Lake Carl Blackwell in 1937 for water supply and recreation. The lake contains 61,500 acre-feet of water supply storage, with a surface area of 3,370 acres (Oklahoma Conservation Commission, 2006).

Lake McMurtry was created in 1971 as a water supply, flood control, and recreation lake. The City of Stillwater owns Lake McMurtry; it is managed by the nonprofit group Lake McMurtry Friends. Located on North Stillwater Creek in Noble County, the lake contains 5,000 acre-feet of flood control storage and 19,733 acre-feet of water supply storage, with a surface area of 1,155 acres (Oklahoma Conservation Commission, 2006).

## Causes

Assigned beneficial uses in the SCW include public, private, and emergency water supply; primary and secondary body contact recreation; fish and wildlife propagation (warm water and habitat limited aquatic community); agriculture; aesthetics; sensitive water supply; and industrial and municipal processes and cooling water.

According to a 2014 waterbody report, the overall status of the SCW is impaired. The main pollutants are Enterococcus bacteria, Escherichia coli (E. Coli), and turbidity (EPA, 2015).

Multiple waterbodies in the SCW have been or currently are on the EPA's 303(d) list of impaired waterbodies over the years. Tables 3, 4, and 5 summarize waterbody listings and their respective pollutants.

**Table 3: Lake Carl Blackwell 303(d) Listing History**

| | **Lake Carl Blackwell** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Cause** | **1998** | **2002** | **2004** | **2006** | **2008** | **2010** | **2012** | **2014** |
| Siltation | ● | | | | | | | |
| Suspended Solids | ● | | | | | | | |
| Pesticides | | | | | | | | |
| Nutrients | | | | | | | | |
| Unknown toxicity | | | | | | | | |
| Turbidity | | ● | ● | ● | ● | ● | ● | ● |
| Taste | | | | ● | | ● | ● | |
| Color | | | | ● | | ● | ● | |
| Odor | | | | ● | | ● | ● | |
| Algal growth | | | | | ● | ● | ● | ● |
| Oxygen depletion | | | | | | | | ● |
| Pathogens | | | | | | | | ● |

**Table 4: Lower Stillwater Creek 303(d) Listing History**

| | **Stillwater Creek (Lower)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Cause** | **1996** | **1998** | **2002** | **2004** | **2006** | **2010** | **2012** | **2014** |
| Siltation | | | | | | | | |
| Suspended Solids | | | | | | | | |
| Pesticides | | | | | | | | |
| Nutrients | | | | | | | | |
| Unknown toxicity | ● | ● | | | | | | |
| Turbidity | | | ● | ● | ● | ● | ● | ● |
| Taste | | | | | | | | |
| Color | | | | | | | | |
| Odor | | | | | | | | |
| Algal growth | | | | | | | | |
| Oxygen depletion | | | | ● | ● | ● | ● | ● |
| Pathogens | | | | | | | | ● |

**Table 5: Lake McMurtry 303(d) Listing History**

| Cause | McMurtry Lake | | | | |
|---|---|---|---|---|---|
| | 2006 | 2008 | 2010 | 2012 | 2014 |
| Siltation | | | | | |
| Suspended Solids | | | | | |
| Pesticides | | | | | |
| Nutrients | | | | | |
| Unknown toxicity | | | | | ● |
| Turbidity | ● | | ● | ● | |
| Taste | | | | | |
| Color | | | | | |
| Odor | | | | | |
| Algal growth | | | | | |
| Oxygen depletion | ● | ● | ● | | |
| Pathogens | | | | | |

## Sources

Probable sources contributing to impairment in the SCW include grazing in riparian or shoreline zones; highway, road, or bridge runoff; municipal point source discharge (WWTP); agricultural production; on-site treatment systems (septic systems and similar decentralized systems); permitted runoff from CAFOs; oil and natural gas activities; rangeland grazing; residential districts; unknown source; lagoons; wildlife (EPA, 2014). With only three permitted NPDES facilities in the watershed boundaries, NPS is the main source of pollution in SCW (Oklahoma Conservation Commission, 2006).

### *Point Sources*

Point sources are associated with municipalities, industry, or other discharges of pollutants from a single pipe or outfall directly into surface water (Brooks, Ffolliott, & Magner, 2013). Point sources are permitted through the National Pollutant Discharge Elimination System. Storm et al. (2003) state there are few point sources in the watershed which are not expected to be significant. Potential point sources include CAFOs and small municipalities. The City of Stillwater WWTP (Figure 4) is the largest permitted point source within the watershed and discharges into Brush Creek approximately one-half mile upstream of its confluence with Stillwater Creek. Stillwater's NPDES permit number is OK0027057. The City's WWTP discharge limitations for the permitted design capacity are shown in Table 6. Multiple attempts were made to contact personnel at City of Stillwater to update information, but phone calls and emails were not returned by time of publication.

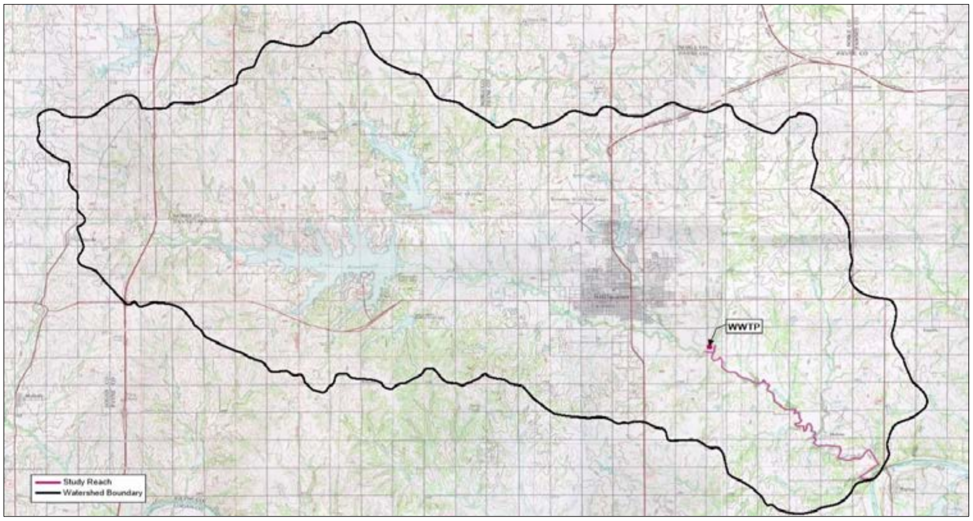


**Figure 4: Stillwater Waste Water Treatment Plant Location**
**Camp Dresser and McKee, 2000.**

**Table 6: City of Stillwater's WWTP Discharge Limitations**

| | Discharge Limitations | | |
|---|---|---|---|
| | | Concentration (mg/L) | |
| **Effluent characteristics** | Mass (lb/day) Daily Average | Monthly Average | Weekly Average |
| Biochemical Oxygen Demand 5-Day ($BOD_5$) | 583.8 | 10 | 15 |
| Total Suspended Solids (TSS) | 875.7 | 15 | 23 |
| Ammonia ($NH_3$-N) | 116.8 | 2 | 3 |
| Fecal Coliform (May 1-September 30) | | 200/100 | 400/100 |

**Storm et al., 2000.**

### *Nonpoint Sources*

Nonpoint source pollution (NPS) refers to pollution from multiple diffuse sources, rather than a single outfall. NPS pollution is largely runoff driven, as pollutants attach themselves to water molecules or are washed into streams and other waterbodies following precipitous events. Similarly, infiltrated precipitation may move pollutants to underground sources of drinking water (Storm et al., 2000). NPS pollution can stem from background sources, as well as a variety of human activities. Sediment and nutrients are major NPS concerns for the SCW, primarily due to agriculture, roadside erosion, and urban runoff (Storm et al., 2003). As mentioned previously, NPS pollution is the main causative factor for impairment in SC.

**Rural Land Use:** Pastures are a major NPS source of nutrients. This land accounts for 41.13% of land cover in SWAT 2000 and WEPP modeling and contributed 9.83% of sediment load, about 46.5% and 81% of total and soluble phosphorus, respectively, in 2003 (Storm et al., 2003). About 60% of the nitrogen in runoff also comes from this land use practice. Wheat is the major crop in the watershed, with about 8% of the total land cover and is grown for grain, as well as grazing.

This activity is the source for about 75% of the sediment yields, 50% of the total phosphorus, 16% soluble phosphorus, and about 31% of the nitrogen in runoff (Storm et al., 2003). Figure 5 shows sediment-bound mineral phosphorus loading across the SCW as predicted by SWAT 2000. Figure 6 shows nitrate in runoff across the Stillwater Creek Watershed as predicted by the SWAT 2000 model.

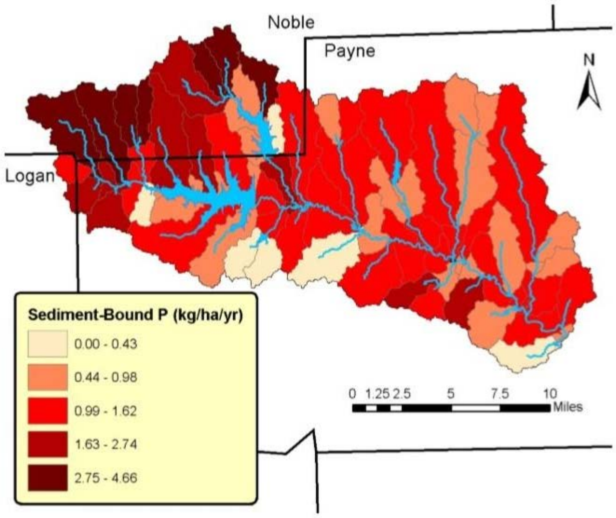


**Figure 5: Sediment-Bound Mineral Phosphorus Loading Across the SCW**
**Modeled with SWAT 2000, does not include sediment-bound organic phosphorus. Storm et al., 2003.**

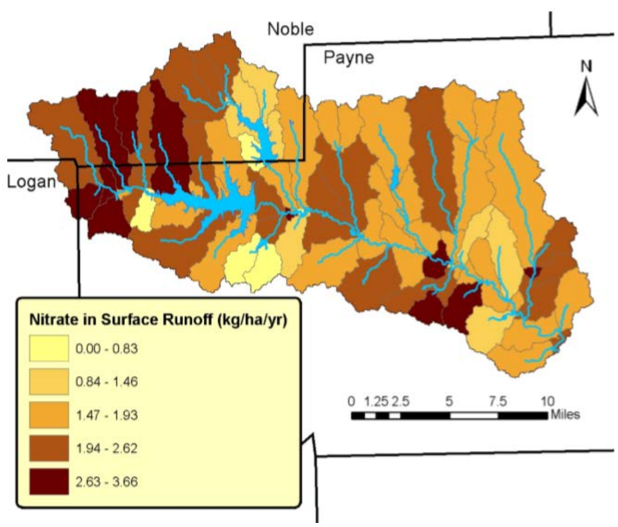


**Figure 6: Nitrate Runoff Across SCW**
**Modeled with SWAT 2000. Storm et al., 2000.**

There are approximately 480 km of unpaved roads in the SCW (Oklahoma Conservation Commission, 2006). Rural roads in the region are typically incised below the surrounding land, meaning there is little opportunity for sediment to be routed away from roads before reaching streams. About 80% of unpaved roads above Lake Carl Blackwell drain directly into streams, while the remaining 20% drain into vegetated areas where some filtering of sediment may occur (Turton, Smolen, & Stebler, 2009).

Several studies have examined the sediment load due to rural roads in this watershed. A 2009 study estimated annual sediment load to streams from unpaved roads in the watershed as up to 35% of the total sediment delivered to Stillwater Creek. However, Storm et al. (2003) estimated the long-term mean annual load from road erosion to be only 14,000 tons, or 11% of the annual sediment budget for the watershed. Based on either estimate, unpaved roads contribute a significant amount to the overall annual sediment budget in SCW, despite the fact that they occupy an insignificant percent (other category) of the watershed area.

**Urban Land Use:** Kang and Marston (2006) found that urbanization is one land use practice that modifies the landscape and alters flow and sediment discharge into streams. Urban or impervious area accounts for roughly 10.61% of the SCW. Urban or municipal activities were listed in EPA's report on SC waterbody conditions for 2014 (EPA, 2015).

**Septic Systems:** Although the human population in the watershed does not likely contribute significantly to watershed loading through septic tanks, it is important to demonstrate BMPs to address potential NPS pollution in the watershed. Parsons estimates there are 10.3 septic tanks per square mile along SC, with Fecal Coliform counts from septic systems estimated at $26x10^9$ counts per day (2012).

**Wildlife**: Studies have shown that wild birds and mammals represent a major source of the fecal bacteria found in streams. Deer has been shown to be one of the major contributors to Fecal Coliform from wildlife, producing 17 cuf/day on the land surface (Parsons 2012).

### *Relative Contribution of Sources*

Storm et al. (2003) determined the contribution by land cover to runoff, sediment yield, phosphorus and nitrogen, using data collected from 1990 to 2001. Modeled results are presented in Table 7. Contribution by land cover was predicted and the results are presented in Tables 8 and 9. The amount of load entering Lakes Boomer, Carl Blackwell, and McMurtry was also predicted and is displayed in Table 10. It is important to note that there are no updated watershed models as there have not been significant changes in land use or population dynamics within the watershed.

**Table 7: Simulated Loads by Land Cover for SCW**

| Land Cover | Area ($km^2$) | Runoff (mm) | Water Yield (mm) | Sediment Yield (Mg/ha) | Total P (kg/ha) | Soluble P (kg/ha) | Total N in Surface Runoff (k//ha) |
|---|---|---|---|---|---|---|---|
| Deciduous Forest | 130.3 | 77.4 | 223.9 | 0.0 | 0.0 | 0.0 | 0.2 |
| Evergreen Forest | 18.4 | 94.3 | 257.9 | 0.0 | 0.0 | 0.0 | 0.2 |
| Mixed Forest | 5.7 | 95.8 | 216.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| Pasture | 298.2 | 241.2 | 217.2 | 0.4 | 2.9 | 1.6 | 6.0 |
| Brushy Rangeland | 55.7 | 165.0 | 238.3 | 0.2 | 0.2 | 0.0 | 0.8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Grassy Rangeland | 93.7 | 175.8 | 227.6 | 0.2 | 0.2 | 0.0 | 1.0 |
| Sorghum | 0.5 | 363.4 | 334.5 | 14.2 | 8.0 | 0.4 | 21.1 |
| Urban | 25.6 | 206.4 | 173.9 | 0.2 | 0.8 | 0.4 | 1.7 |
| Water | 30.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Wheat for Grain | 39.4 | 293.8 | 344.0 | 17.2 | 17.8 | 1.8 | 18.8 |
| Graze out Wheat | 17.6 | 291.0 | 337.6 | 12.1 | 13.0 | 1.3 | 14.6 |
| Road and Bar ditches | 9.6 | - | - | - | - | - | - |

**Based on SWAT 2000 simulation, Jan 1990-Oct 2001. Storm et al., 2003.**

**Table 8: SWAT and WEPP Predicted Loads in SCW by Land Cover**

| Land Cover | Area ($km^2$) | Sediment Yield (Mg) | Total P (kg) | Soluble P (kg) | Total N in Surface Runoff (kg) |
|---|---|---|---|---|---|
| Deciduous Forest | 128.6 | 512 | 236 | 52 | 2651 |
| Evergreen Forest | 18.1 | 80 | 44 | 15 | 441 |
| Mixed Forest | 5.6 | 24 | 12 | 2 | 136 |
| Pasture | 294.2 | 11643 | 85709 | 46931 | 179851 |
| Brushy Rangeland | 54.9 | 1051 | 981 | 158 | 4495 |
| Grassy Rangeland | 92.4 | 2126 | 2016 | 271 | 9236 |
| Sorghum | 0.5 | 668 | 375 | 18 | 988 |
| Urban | 25.3 | 523 | 2079 | 1146 | 4240 |
| Water | 29.8 | 0 | 0 | 0 | 0 |
| Wheat for Grain | 38.8 | 67846 | 70216 | 6886 | 74013 |
| Graze out Wheat | 17.3 | 21241 | 22809 | 2368 | 25649 |
| Road and Bar ditches | 9.6 | 12743 | - | - | - |
| Total | 715.2 | 118456 | 184477 | 57849 | 301702 |

**SWAT 2000. Storm et al, 2003.**

**Table 9: SWAT and WEPP Predicted Load Percentage in SCW by Land Cover**

| Land Cover | Area ($km^2$) | Sediment Yield (Mg) | Total P (kg) | Soluble P (kg) | Total N in Surface Runoff (kg) |
|---|---|---|---|---|---|
| Deciduous Forest | 17.98 | 0.43 | 0.13 | 0.09 | 0.88 |
| Evergreen Forest | 2.54 | 0.07 | 0.02 | 0.03 | 0.15 |
| Mixed Forest | 0.78 | 0.02 | 0.01 | 0.00 | 0.05 |
| Pasture | 41.13 | 9.83 | 46.46 | 81.3 | 59.61 |
| Brushy Rangeland | 7.68 | 0.89 | 0.53 | 0.27 | 1.49 |
| Grassy Rangeland | 12.92 | 1.79 | 1.09 | 0.47 | 3.06 |
| Sorghum | 0.06 | 0.56 | 0.20 | 0.03 | 0.33 |
| Urban | 3.54 | 0.44 | 1.13 | 1.98 | 1.41 |
| Water | 4.17 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wheat for Grain | 5.43 | 57.27 | 38.06 | 11.90 | 24.53 |
| Graze out Wheat | 2.42 | 17.93 | 12.36 | 4.09 | 8.50 |
| Road and Bar ditches | 1.34 | 10.76 | | | |
| | 100 | 100 | 100 | 100 | 100 |

**SWAT 2000. Storm et.al, 2003.**

**Table 10: SWAT Predicted Loading from Upland Areas in the Drainage Area of Lakes in the SCW**

| Reservoir | Surface Area (ha) | Drainage Area ($km^2$) | Flow (CMS) | Sediment (Mg/yr) | Organic N (kg/yr) | Organic P (kg/yr) | Surface Runoff Nitrate (kg/yr) | Soluble P (kg/yr) | Sediment Bound Mineral P (kg/yr) |
|---|---|---|---|---|---|---|---|---|---|
| Boomer | 102 | 23.6 | 0.12 | 2,176 | 4,416 | 656 | 4,342 | 1,803 | 2,417 |
| Carl Blackwell | 1,400 | 197.2 | 1.33 | 43,451 | 55,654 | 7,911 | 47,013 | 18,600 | 39,687 |
| McMurtry | 465 | 64.9 | 0.49 | 19,545 | 21,950 | 3,004 | 10,323 | 5,013 | 14,840 |

**SWAT 2000. Storm et al, 2003.**

# Load Reductions and Criteria

Turton et al. (2009) demonstrated that sediment yield from unpaved roads can be reduced by up to 80% using BMPs, even on a limited budget. Based on modeling and assessment of SCW (Storm et al. 2003), certain areas were targeted as high priority to reduce NPS sediment loading due to runoff from unpaved county roads. Limited implementation of BMPs on unpaved roads was applied in the SCIP and demonstrated a reduction of road related sediments by 61% and 81%, respectively (Oklahoma Conservation Commission, 2006). Implementation of BMPs in areas of highest erodibility (Figure 7) on unpaved roads is recommended to help reduce turbidity.

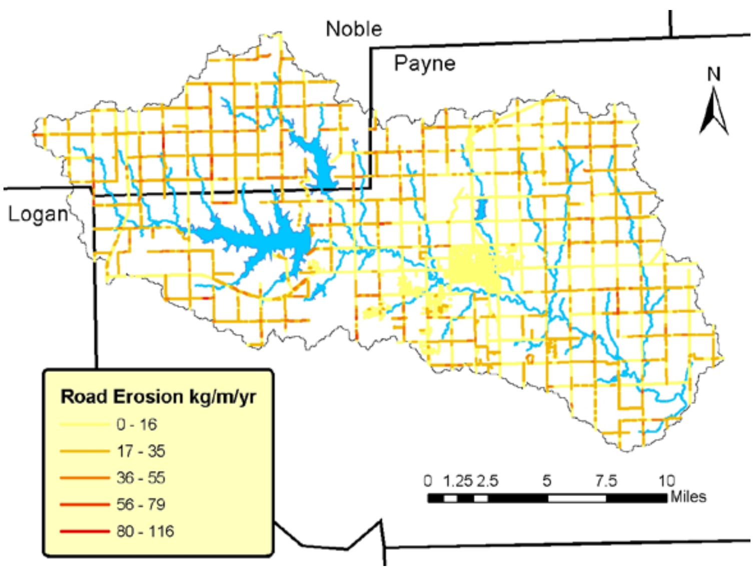


**Figure 7: Estimated Road Erosion Rates Based on WEPP Modeling**
**Storm et al., 2003**

Soil surveys were used in targeting, and highly erosive soil types within the watershed were identified. Location of erosive soils and critical problem land uses were superimposed in an electronic environment to target likely sources of sediment loading. The most erosive areas were found to be fields, overgrazed pastures, and construction areas. Figure 8 shows the relative location of highly erodible areas within the watershed. The most erodible areas are shown as eroding at a rate of about 20 mtons/ha or about 10 tons per acre (Storm, White, & Stoodley, 2003). SWAT tools also modeled phosphorus and nitrate loading.

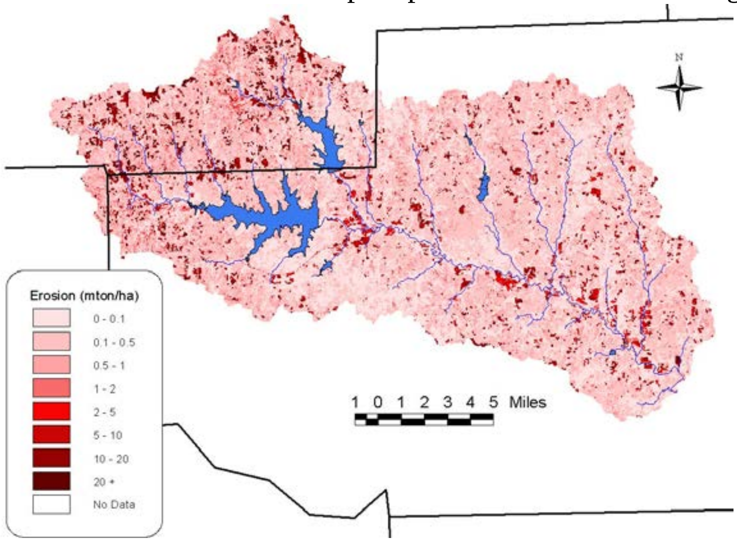


**Figure 8: Erosion Rates**
**Based on SWAT 2000 modeling. Storm et al., 2003.**

Modeling using the PRedICT model with input from the targeting and SWAT model runs completed by Storm et al. (2003) suggested that implementation dollars available could be sufficient for a 20% reduction in phosphorus (reduction of 36,895 kg/yr) and sediment (reduction of 23,691,200 kg sediment/yr) loading to Stillwater Creek. However, the targeting suggested row crop areas (Oklahoma Conservation Commission, 2006).

**Load Reduction Goal for Bacteria and Turbidity:** The most recent TMDL for turbidity and bacteria was produced in 2012 Bacteria and Turbidity Total Maximum Daily Loads for the Cimarron River Study Area, prepared by Parsons (2012).

**Bacteria:** As noted earlier, the 2014 waterbody report for SWC lists the overall watershed as impaired by Enterococcus bacteria (ENT), Escherichia coli (E. Coli), and turbidity (EPA, 2015).

**E. Coli:** The 2012 Geometric Mean Concentration for E. Coli was recorded as 169/100 ml (Parsons, 2012). For swimming advisory and permitting purposes, E. Coli shall not exceed a monthly geometric mean of 126/100 ml based upon a minimum of no less than five samples collected over a period of no more than 30 days. The necessary load reduction is estimated to be 33% (Parsons, 2012). The goal of this WBP is to achieve that reduction over a 10-year timeframe. An initial goal is 18% reduction to be met within five years of implementation, with the remaining 15% to be achieved over the following five years.

**Enterococci:** The 2012 Geometric Mean Concentration for ENT was recorded as 205 count/100 ml (Parsons, 2012). For swimming advisory and permitting purposes, ENT shall not exceed a monthly geometric mean of 33/100 ml based upon a minimum of no less than five samples collected over a period of no more than 30 days. The necessary load reduction is estimated to be

85% (Parsons, 2012). The objective of this WBP is to reduce ENT by 40% within the first five years of implementation, with the remaining 45% reduction to be achieved over the following five years.

**Turbidity:** According to the 2012 TMDL report, water quality criteria for Turbidity are exceeded in the SCW. The average turbidity in 29 samples was found to be 45 NTU, with 10% of the samples exceeding criterion for Stillwater Creek (Parsons, 2012). Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits: Cool Water Aquatic Community/Trout Fisheries: 10 NTUs; Lakes: 25 NTU; and other surface waters: 50 NTUs. Numerical criteria listed here apply only to seasonal base flow conditions. Elevated turbidity levels may be expected during several days after a runoff event. The load reduction target for TSS is 20% to meet recommended criterion for turbidity. BMPs will also incorporate the two-phase 10-year plan to meet the target of 10% reduction within the first five years of implementation and an additional 10% reduction in the next five years.

## Management Measures

The goal is to continue implementing BMPs utilized in the SCIP to achieve the targeted TMDL reductions for each pollutant of concern. The SCIP prioritized and grouped BMPs into the following major categories:

(1) Riparian establishment and management
(2) Erosion control
(3) Pasture and cropland management.

The focus of the practices was to implement nutrient and sediment reductions to SCW and Lake Carl Blackwell, with the ultimate goal of achieving beneficial use support. The program focused implementation in the targeted areas along the tributaries and mainstems of Stillwater Creek as defined by the SWAT targeting mechanism. In addition, the project used a ranking index to ensure maximum benefit for project funds. Establishment and management of riparian areas was and will continue to be the top priority, followed by erosion control practices, then land management, and lastly, waste management.

**Riparian Establishment and Management**: Priority treatment for small waterways and first order streams make up the greatest portion of the watershed drainage system. The Conservation Districts, under guidance for the WAG, will implement the following practices in order to reduce sediment, bacteria and nutrient levels.

1) **Fencing for Riparian Management:** Landowners look upon the riparian areas as critically needed, highly productive pasture. However, heavily grazed riparian areas function poorly as nutrient traps, and cattle trails become channels for direct transport of nutrients to the stream. Fencing to exclude cattle from certain areas along a stream will continue by installing additional fencing and maintenance of existing exclusionary

structures in a cost share program with NRCS/USDA. The goal is to utilize a three zone buffer system and establish riparian areas extending 30 feet beyond timberline by the end of the 5th year. Limited grazing or flash grazing will allow landowners to grant livestock access to the riparian zone for a brief period in summer when streambanks are most stable (due to lack of rain) and with sufficient time for regrowth before the end of the growing season. In addition, during limited grazing, landowners will be required to pull livestock out of the area prior to the point where it becomes overgrazed.

2) **Permanent Vegetative Establishment** The planting of Bermuda and other grasses within the riparian zone has been and will continue to be encouraged by providing cost share funds for seed, seedbed preparation, and fertilizer (if necessary). Permanent vegetation in riparian buffer areas should help reduce runoff of both sediment and bacteria from cropland and pasture. If necessary, some fertilizer may be applied to existing vegetation to improve riparian zones.

3) **Off Stream Watering:** Pastures where the stream is the primary or sole source of water for livestock will be encouraged to be provided with an alternate source to allow riparian management. Studies have shown off-stream water sources can substantially reduce the impact of cattle, even without fencing the stream. Off-stream watering assistance will be offered only for perennial sections of the stream and to landowners who do not already have a water supply for livestock other than the stream. Watering options may include pond excavation and freeze-proof water tanks.

**Erosion Control**

1) **Permanent Vegetative Establishment:** Erosion control is one of the top priorities for BMP implementation. Poorly managed pastures and croplands can contribute a great deal of sediment to streams, and establishing good vegetative cover on surrounding land is important to slow overland runoff and encourage biofiltration of pollutants before they enter the stream.

2) **Structural Practices:** Appropriate grade stabilization structures will be offered in order to retard or prevent the erosion of soil on hillsides. Establishment of grassed waterways to slow the movement of soil during runoff events will be encouraged in addition to structures such as terraces.

**Land Management**

1) **Vegetative Planting**: Over-grazed and poorly grassed fields and pastures have been found to be a significant source of erosion in the watershed. Fertilization of poor pastureland and cropland in the watershed allows for the establishment of better quality and quantity of vegetative cover. Previous projects have planted sixty acres of grass to create field borders and filter strips, reducing the amounts of nutrients and sediment entering streams. Continuation of similar projects outlined in the SCIP is recommended.

2) **Heavy Use Areas:** Large animals such as cattle can severely affect areas around feeding or watering facilities, where heavy traffic compacts soil and destroys stabilizing vegetative cover, increasing localized soil erosion. In addition, heavy traffic is typically accompanied by increased waste deposition, which can lead to increased bacteria in runoff. Installation of concrete feeding pads for round hay bale feeding or gravel and grading in loafing areas are modifications that can reduce runoff of sediment, nutrients, and bacteria from heavy use areas.

    a. Winter feeding facilities are more elaborate structures that are designed to reduce runoff of sediment, nutrients, and bacteria from feeding areas. Landowners typically overwinter and feed cattle in the same areas of a pasture that is easily accessible and provide a reliable source of shelter and water. Often, these areas are close to creeks, ravines, or dry channels where water and shelter from the wind is available. Unfortunately, these areas can become trampled, overgrazed, and laden with waste, becoming susceptible to runoff. By providing a sheltered feeding area away from the stream, winter feeding facilities reduce this problem. Structures typically have a concrete floor with a lip to contain waste. In addition, roughly one-third of the structure is devoted to dry manure storage, sized sufficiently to store up to 3 months worth of manure until it can be properly land applied. Structures such as these were utilized in the SCIP and will continue to be encouraged as necessary.

3) **Use Exclusion—Cross-Fencing:** In order to keep pastures in optimal condition, overgrazing must be avoided. Landowners may use cross-fencing to rotate cattle to various pastures and, thus, prevent overgrazing. To successfully cross-fence livestock, water must be available in each pasture and will be offered through cost share, similar to off stream watering outlined above.

In addition to the listed conventional BMPs, the replacement of functioning wetland ecosystems within this watershed could prove beneficial to the water quality in Stillwater Creek and Lake Carl Blackwell. In 2013, with the assistance of the Oklahoma Wetland Work Group, the OCC finalized the State's Wetland Program Plan (WPP). The purpose of the WPP is to guide and focus wetland related activities within the state. In order to meet this objective, two action items were identified:

- Integrate federal, state, and non-governmental organization (NGO) wetland restoration, enhancement, creation, and protection (RECP) programs, promote wetland RECP, and develop informational tools for land-users.
- Integrate wetland RECP with watershed based approaches (OCC 2013).

To achieve these goals, the OCC has undertaken a pilot project that has resulted in development of an assessment methodology to identify, catalogue, and rank wetland resources based on the potential to alleviate NPS impacts to receiving waters. Currently, the assessment tool has been completed and applied in three priority watersheds, and field-validation of the results of the assessment tool is ongoing. This effort will provide targeting for protection and restoration of wetland resources and an avenue through the NPS program or other voluntary program to implement those efforts to protect/restore wetlands and water quality. The OCC is committed to applying this assessment protocol through all watersheds in Oklahoma, as funding becomes available, to incorporate this process into each WBP. Wetland development and restoration to mitigate the impacts of nutrients and sediment in the Stillwater Creek Watershed will be evaluated as funding becomes available.

## Financial and Technical Assistance

Financial assistance is difficult to predict and is constantly changing throughout the implementation process. Funding needs are based upon the goals defined by SWAT (Storm et al., 2003), PRedICT (Evan et al., 2003) models, the SCIP, and previous costs outlined in the Stillwater Creek Implementation Project report (2006) composed by OCC. The majority of implementation funding was focused on land management practices and the establishment of riparian areas. Cost share programs are available through the Conservation Reserve Enhancement Program (CREP) provided by the USDA and Farm Service Agency (FSA). Table 11 is a list of practices and the potential funding provided by Environmental Quality Incentives Program (EQIP) through NRCS. Funding estimates are conservative and will most likely change as the goals evolve.

**Table 11: Possible Funding for Implementation of BMPs through EQIP.**

| Best Management Practice | Estimated Cost |
|---|---|
| Pond Construction | $10,000 maximum |
| Fencing | $.75/ft |
| Riparian Field Border | $230.75/Ac |
| Riparian Forest Buffer | $86.34/Ac |
| Native Grass Filter Strip | $305.11/ Ac |
| Grassed Waterway | $723.70/Ac |
| Farm Limited Riparian Control | $.17/LnFt |
| Streambank/Shoreline Shaping Protection | $6.45/LnFt |
| Wetland Creation | $1.34/CuYd |
| Water Tank (500-1000 gal) | $1,326.60 |
| Basic Nutrient Management | $3.19/Ac |
| Steel Grade Stabilization Structure | $10.96/SqFt |

Continuation of water and soil monitoring will be necessary to track the effects of the implemented practices. The potential cost of the lab analysis of the collected samples is conservative and will differ depending on the contaminant chosen for analysis (Table 12). Funding will also be needed to supply the monitoring equipment, to cover the cost of maintenance of the equipment, and the manpower to obtain the samples.

**Table 12: Potential Lab Analysis Costs of Collected Samples**

| Sample Type | Estimated Cost | Agency Responsible |
|---|---|---|
| Water Quality (livestock, household, irrigation) testing | $15/sample | OSU soil/Water & Forage Analytical Lab |
| Soil (organic matter, nitrogen) testing | $8/sample | OSU soil/Water & Forage Analytical Lab |

Computer modeling for the SCW has already been completed by Storm et al. (2003). However, as the best management practices are implemented and the goals are met, up to date models may be needed to track the changes to the watershed. To ensure that the computer models are efficiently updated, additional funding may be necessary.

Further funding will be needed for a program coordinator that will most likely be employed by the OCC. Financial support will be provided to the program coordinator for salary, mileage and vehicle maintenance, and outreach and education coordination.

Table 13 reflects the cost provided by OCC for the project coordinator. Salary and fringe are self-explanatory. Travel is used to cover per diem, lodging, etc. for trips to training, etc. Vehicle represents costs for an owned vehicle, so the cost is double if leased. District support represents the cost OCC pays to the local Conservation District for office space. Supplies represent expenses like office supplies, mailing expenses, etc.

**Table 13: Project Coordinator Costs**

| **Position** | **Salary** | **Fringe** | **Travel** | **Contractual** | **Contractual** | **Supplies** |
|---|---|---|---|---|---|---|
| | | | | **District Support** | **Vehicle** | |
| **Watershed Project Coordinator** | **$48,939** | **$33,500** | **$1,200** | **$8,000** | **$2,624** | **$2,000** |

**Table 14: Possible Costs of BMPs**

| **Best Management Practice** | **Estimated Cost** |
|---|---|
| Pond Construction | $2,500.00/pond |
| Fencing | $1.00/LnFt |
| Riparian Field Border | $5.00/Ac |
| Riparian Forest Buffer | $5.00/Ac |
| Native Grass Filter Strip | $53.00/Ac |
| Grassed Waterway | $425.00/CuYd |
| Farm Limited Riparian Control | $115.00/Ac |
| Water Tank (500-1000 gal) | $945.00/tank |
| Basic Nutrient Management | $4,200.00/system |
| Steel Grade Stabilization Structure | $2135.00/structure |

Table 14 includes a breakdown of cost per best management practices. Cost estimates for management practices listed in Table 14 are based upon previous §319 funds supplied for the 2001 SCWIP (OCC). Implementation of these best management practices requires a cost share with the landowner of 25% with agency funding of 75% conservatively totaling $400,000. Funding needs are heavily dependent upon landowner cooperation and enrollment.

In the previous WBP for Stillwater Creek (2006), in Payne County, 31 landowners participated in BMP implementation, and 22 landowners participated in Noble County. Cooperator landholdings included approximately 3% of the total watershed, about 5,300 acres. State funds paid $135,537.78 toward BMP installation while EPA funds provided $146,337.43. In total, landowners in the two counties contributed $165,964.99 in match funds, or approximately 37%.

NRCS had active programs in both Payne and Noble counties, with approximately 73 Payne Co. landowners receiving $252,173.00 from 2001 to 2006, and 35 Noble Co. landowners receiving $238,272.00 in the same time period. Practices that have been implemented through EQIP in these counties include grade stabilization structures, waterways, terraces, ponds, fencing, grass planting, and filter strips, some of the same practices that were popular in the OCC program, as well as gully shaping, cedar tree removal, lespedeza spraying, musk thistle spraying, mixed brush spraying, and water control structures (OCC, 2006 Stillwater Final Report).

Cost share practices and rates are based off the master list of Best Management Practices (BMP) and component parts for each BMP that have been recommended for implementation in the Stillwater Creek Watershed as approved by the Oklahoma Conservation Commission**.**

| **Cost Share Practices** | | **Cost Share Rates** |
|---|---|---|
| **Riparian Area Establishment/Management** | | |
| Components: | 1) Vegetative Planting | 75% |
| | 2) Off Site Watering | 80% |
| | 3) Fencing | 75% |
| **Road Erosion and Special Projects** | | |
| Components: | 1) Vegetative Plantings | 75% |
| | 2) Structural Practices | 75% |
| **Land Management, Pasture, and Cropland** | | |
| Components: | 1) Vegetation Planting | 75% |
| | 2) Heavy Use Areas | 75% |
| | 3) Use Exclusion | 100% |

Education and outreach efforts are important in maintaining awareness of the contamination to Stillwater Creek. Funding needs for education and outreach could include $300,000 for a Nonpoint Source Education Program for Producers supplied by the OCES, and $47,500 for a Soil Sampling Technique and Nutrient Variability Demonstration provided by OSU. Education costs are based upon previously provided outreach program funding in the Lake Eucha/Lake Spavinaw Watershed Based Plan (OCC, 2007). Other possible outreach needs can be fulfilled by the use of volunteer groups, such as Blue Thumb **(approximately $6,000 annually through OCC)**. A conservative overall estimate for implementation of the WBP is $1.5 million, based on §319 funding provided for the SCIP, adjusted to account for inflation and doubled, based on our load reduction timeline of roughly 10 years.

## Information and Education Component

Educational efforts for SCW should be long-lasting, wide reaching, and developed to address the goals of a WBP in order to provide public awareness and outreach programs. Educational practices should be implemented by a variety of group partnerships, coordinated by a project coordinator, and advised by a Watershed Advisory Group (WAG). Partnerships that have successfully implemented educational components for the Stillwater Creek Watershed include: the Payne and Noble County Conservation Districts, the Natural Resources Conservation Service (NRCS), OSU, the Oklahoma Cooperative Extension Service (OCES), and the Oklahoma Water Resources Board (OWRB). The project coordinator, employed by the OCC, should be a local resident who will work with the individual landowners to develop conservation plans and agreements in line with the watershed-based plan goals. The WAG is comprised of local producers, city officials, OSU faculty, and NRCS staff who can advise the various partnerships on cost-share rates and best practices. The specific educational goals may include:

- Raise awareness of best environmental practices in local residents and producers
- Increase interest, support, and number of volunteers in the Blue Thumb Program
- Involve the community in ownership and understanding of the environmental issues
- Create a media presence
- Evaluate the success of the educational and outreach practices in order to improve the quality of activities.

The education and outreach regarding Stillwater Creek Watershed, as a whole, has not been addressed in a coordinated manner. There are several programs providing public involvement and education on an individual basis for specific pieces of the watershed. These include education programs offered through OSU Cooperative Extension Service, Blue Thumb (through OCC), as well as programs through the City of Stillwater and local programs through schools and local conservation districts. The education practices that are collectively contributing to the public outreach efforts in the Stillwater Creek Watershed are summarized in no particular order below:

The Oklahoma Cooperative Extension Service (OCES) has implemented several runoff management practices, such as permeable pavements and stream restorations, in the Botanic Garden at OSU. These technologies are available for public tours and demonstrations. Experts provide educational workshops and activities and answer questions from visitors. Special events are held throughout the year to showcase the innovative technologies.

The Teal Ridge wetland in Stillwater was created through a partnership with the Payne County Conservation District (CCD). OCC has experience with Lincoln CCD (OCC 1999) and Delaware CCD (OCC 1998) for wetland restorations. Education signage were installed to educate visitors about the area, and the OCES continues to conduct research regarding facets of this ecosystem.

The OCC partnered with the Payne and Noble County Conservation Districts, the Natural Resources Conservation Service (NRCS), OSU, the Oklahoma Cooperative Extension Service (OCES), the Oklahoma Water Resources Board (OWRB) for the Stillwater Creek Implementation project. These partners created an online fact sheet titled "Stillwater Creek Watershed Implementation Project" to inform the public of their efforts. Other fact sheets for the watershed include "Protecting Our People – Protecting Our Natural Resources" created by the NRCS in cooperation with the OCC, and "Know Your Stream: Rotating Basin Summary" created by the OCC.

The OCC and the Payne and Noble County Conservation Districts work with OSU to develop and implement education programs and to expand the ongoing Blue Thumb volunteer monitoring education efforts in the watershed. Blue Thumb also provides workshops and tours to inform citizens about agricultural best practices. Oklahoma Water Watch (OWW), a volunteer lake-monitoring program through the OWRB, provided educational trainings focused on OSU students and staff in order to expand the volunteer base monitoring Lake Carl Blackwell.

The following practices could be implemented to ensure the educational goals are met by continuing previous efforts and implementing future educational practices:

- Public demonstrations for soil sampling technique, water quality monitoring and nutrient variability;
- A website as a resource for all education opportunities and watershed information, including informative videos, social media outlets, and upcoming events;
- Public meetings and listening sessions held throughout the watershed;
- Regular media coverage of activities/issues (both at local and State levels).
- Nonpoint source education programs that involve segments of the community ranging from school children to agricultural producers to homeowners and local residents;
- Programs that encourage local citizens to experience "ownership and understanding" of environmental issues such as volunteer monitoring, cleanup events, and other educational grassroots efforts to address the problem.

## Implementation Schedule and Interim Milestones

The Stillwater Creek Watershed Based Plan is developed to occur over a 10-year period. Characterization of NPS will occur in 2015 and will continue to be updated as new 303 (d) lists are published. The use of §319 implementation funds will last up to five years, depending on the number of producers to enroll in programing. Monitoring of BMPs will occur annually throughout implementation to allow managers and WAG members to determine the success of implementation or if additional measures are necessary. Watershed planning is an iterative process. Following implementation of this 10-year plan, the SCWBP will be updated every three years, beginning in 2025, to reflect the constantly evolving challenges and information within the watershed. Table 15 provides a rough breakdown of the schedule for implementation.

**Table 15: Implementation Schedule for SCW**

| Milestone Description | Due Date |
|---|---|
| Hire project coordinator | August 2019 |
| NRCS conservation certification training to be completed by project coordinator | October 2019 |
| Educational workshops (soil sampling technique, water quality monitoring and nutrient variability) | August 2019 – July 2020 |
| Pre-Implementation Plan written to provide guidance | November 2019 |
| Organize WAG | August-September 2019 |
| Prioritize BMPs with WAG and identify areas of highest concern | October-November 2019 |
| Compile water quality data prior to implementation | |
| Implement BMPs | November2019-December 2022 |
| Tours of various demonstration farms | Throughout project life |
| Monitor water quality and track BMPs progress | Throughout project life |
| Watershed Report | July 2029 |
| Revise Watershed Plan | Revise every 3 years |

Educational programing and outreach will target audiences in the watershed to inform them of different types of BMPs, how they can be utilized, and what pollutant each will target. The goal is to encourage citizens to voluntarily enact BMPs on their land, no matter the implementation scale. Educational programming will take place for five years and utilize a variety of agencies including, but not limited to, OCC, Blue Thumb volunteer monitoring program, OWRB Water Watch lake monitoring, OSU and OCES, NRCS, and County Conservation Districts. Programing will be evaluated and updated on an annual basis to ensure material and targeting efforts are providing the most current information and direction for the watershed.

Implementation of BMPs will take place over a three-year period, starting in 2018 and conclude at the end of 2021. However, depending on response from stakeholders, BMP activity may be shortened or extended to accommodate need. Water quality data will be monitored before, during, and after implementation in order to gauge effectiveness and reduction. This load reduction will be demonstrated with water quality data collected throughout the plan period or demonstrated through documentation of reductions at the source. A more detailed account of the schedule, general goals and actions, interim milestones for each category, and overall load reductions of each pollutant are available in Table 15. Trend analyses will be performed on various datasets at set intervals, the results of which will determine revisions to the WBP based on measurable changes that have occurred in water quality.

**Table 16: Detailed Schedule of Milestones**

| Goal | Action | Parameter to Address | Load Reduction of Primary Parameters to Attain within 5 Years of Implementation | Ultimate Total Load Reduction to Attain | Year to Begin | Year to Evaluate and Make Necessary Adjustments | Year to Complete |
|---|---|---|---|---|---|---|---|
| **Characterize point and NPS pollution** | **Targeting sources** | **Sediment, Bacteria, Nutrients, BOD,** | **-** | **-** | **2019** | **2020** | **Update with each new 303(d) list** |
| **Develop Education and Outreach** | **County Conservation Districts, NRCS, OSU, OCES, OWRB, OCC, Blue Thumb** | **Sediment, Bacteria, Nutrients, Pathogens** | **10% TSS** | **20% TSS** | **2019** | **Annually** | **2024** |
| | | | **18% E. Coli** | **33% E. Coli** | | | |
| | | | **40% ENT** | **85% ENT** | | | |
| **Implement BMPs** | **-** | **-** | **-** | **-** | **2019** | **-** | **2022** |
| ***Address turbidity*** | **Riparian Buffer, Erosion Control, Land Mgmt.** | **Sediment, Bacteria, Nutrients, Pathogens** | **10%** | **20%** | **2019** | **Annually** | **2024** |
| ***Address E. Coli*** | | | **18%** | **33%** | | | |
| ***Address Entercocci*** | | | **40%** | **85%** | | | |
| **Long term water quality monitoring program** | **OCC** | **Sediment, Bacteria, Nutrients, Pathogens, BOD,** | **-** | **-** | **2019** | **Annually** | **Ongoing** |
| | **Blue Thumb** | | | | | | |
| | **OWRB/ OWW** | | | | | | |
| | **City of Stillwater** | | | | | | |

## Water Quality Benchmarks

The ultimate impairment reduction for SCW is to reach levels allowing the waterbody to attain its beneficial uses. Overland mitigation and movement of nutrients and sediment are expected after the application of BMPs. Restoration of the watershed is in compatibility with required standards that are targeted in this project, so that it can be removed from impairment. Support determination is used for short-term numerical variables, which requires a three-step process:

- Samples exceeding the prescribed criterion or screening level for any variable are identified
- The number of samples exceeding the prescribed criterion or screening level is divided by the total number of samples collected to obtain a percent exceedance
- The percent exceedance is compared to a range of prescribed percent exceedances to determine use support. The prescribed percent exceedances are:
    - Supporting — less than or equal to 10% percent
    - Partially supporting — greater than 10% but less than 25% percent
    - Not supporting — greater than or equal to 25%

Assessment of PPWS Support as beneficial use is conducted by assessing toxicant concentrations to evaluate use support. At OWRB only metals are considered in the toxicant category. Only one variable needs to violate the assessment protocol for the beneficial use to be partially supported or not supported.

The beneficial uses designated for Lake Carl Blackwell are water supply and recreation, and will be further discussed in the lake monitoring section. A water supply level of 25 NTU is required; however, in Lake Carl Blackwell, 36% of 14 data samples exceeded this amount. The average turbidity was reported to be 27 NTU. Chlorophyll-a in Lake Carl Blackwell creates another water quality issue and limits its designated beneficial use.

Lake McMurtry has designated beneficial uses of water supply, flood control, and recreation. Similar to Lake Carl Blackwell, Lake McMurtry is also facing water quality problems of turbidity and chlorophyll-a. With an average turbidity of 19 NTU, 11% of 9 samples exceeded the 25 NTU standard.

Boomer Lake has the beneficial uses of water supply, flood control, and recreation. It is facing the water quality problems of turbidity, dissolved oxygen and chlorophyll-a. Out of 12 samples, 42% of the samples exceeded the targeted 25 NTU and the average turbidity was 24 NTU (OWRB, 2014).

Chlorophyll-a is directly related to turbidity and the water bodies with high turbidity have higher chlorophyll-a ranges (Randolph & Wilhm, 1984). Excessive phosphorus levels in waterbodies favor algae growth and thus the highest range of chlorophyll-a index.

## Monitoring Plan

A monitoring plan is necessary to gauge and evaluate the overall success of the implementation efforts. Monitoring is vital in determining progress in reducing pollutant loads and protecting the natural resources of the watershed for future generations. The objective of the monitoring plan for this WBP is to develop a long-range monitoring program with clearly defined specifications that will manage the restoration of the watershed and protect its natural resources for future generations.

The monitoring efforts described in this WBP is based on Oklahoma's Water Quality Standards and Use Support Assessment Protocols, which define the process by which beneficial use support can be determined. As the WBP evolves and expands to be more inclusive of the entire watershed and all the parameters of concern, it is anticipated that this list will expand and contract.

In order for the WBP to become an integral part of the entire watershed restoration program, it must be amenable to revision and update. The Stillwater Creek WBP has been developed as a dynamic document that will be revised to incorporate the latest information, address new strategies, and define new partnerships between watershed stakeholders. It is anticipated that at least biannual revisions may be necessary and that the responsibility for such revisions will rest primarily with the Oklahoma Conservation Commission (OCC), with support from the Oklahoma Department of Environmental Quality (ODEQ), Office of the Secretary of the Environment (OSE) and the NPS Working Group. It is understood that the water quality goals and the technical approach set forth in this WBP may not be comprehensive, so they may be expanded in the future, especially as ODEQ's work with the TMDL/WMP is completed. Federal and state funding allocations for future water quality projects designed to address the Stillwater Creek Watershed problems should not be based solely upon their inclusion in this WBP. The WBP should be considered a focal point for initial planning and strategy development.

Monitoring is a vital part of NPS projects implemented across the state and nationally. Data is needed to characterize pollutant loading from watershed sources and to prioritize areas for implementation to reduce pollution. Data is also vital to evaluate success of load reduction strategies and pollution abatement measures. Calculating loading for tracking water quality changes and for use in developing total maximum daily load allocations (TMDLs) is best accomplished through the use of automated water samplers.

OCC has developed unique methods for deploying and maintaining auto-samplers that have proven vital in documenting the effects of implementation in the short term of success dictated by national NPS Program requirements. Currently, auto-samplers are used to collect continuous flow weighted composite samples. Because auto-samplers provide continuous data, they can be used to show statistical significance in water quality changes such as those resulting from success of implementation projects within a shorter period of time. Pre-implementation data will be compared to the post implementation data collected to determine if implementation and education efforts have improved water resources in the project area.

It is recognized that no singular activity will realistically result in the required reduction. Numerous strategies will be employed in concert to achieve the desired result. This document is not intended as a final, static plan, but rather one that will be updated as needed to reflect new information, resources, and necessary adjustments in implementation strategy.

The following parameters will continue to be monitored in the Stillwater creek watershed:

- Water quality: sediments, suspended solids, turbidity, nutrients, fecal bacteria, temperature, dissolved oxygen, pH, conductivity, hardness, alkalinity, chlorophyll-a, metals, BOD, and pesticides
- Taste and odor problems
- Sediment quality: nutrients, metals, pesticides, and other organics of concern
- Hydraulic budget: in-stream flows, groundwater levels, aquifer recovery
- Groundwater quality: nutrients, metals, pesticides, pH
- Land use/Land cover: acreage in different land covers, quality and type of land use, timing and other variables of associated management practices
- Riparian Condition: quality of riparian zones in the watershed - to include quality and type of vegetation, degree of impact or stability, condition of stream banks, and primary source of threat or impact.
- Aquatic Biological Communities: assessment of the condition of fish and benthic macroinvertebrate communities related to reference streams and biocriteria
- BMP and other implementation efforts: type, extent, and when possible, specific location of management practices to include a prediction of the potential load reduction effected by implementation of BMPs
- Behavioral Change: participation in Watershed Based Plan-related activities and behavioral changes of affected communities.

With each WBP-related program, as well as for the WBP as a whole, baseline conditions will be established and monitored prior to implementation. A monitoring schedule and Quality Assurance Project Plan (QAPP) will be developed based on the type of project and timing of its implementation. Monitoring results will be reported to the appropriate entities as defined in the QAPP.

## Baseline Data

### *Water Quality*

Significant water quality monitoring has occurred in the Stillwater Creek Watershed, which is being updated on a regular basis throughout the watershed. The City of Stillwater, OCC, OWRB, and OSU used portions of this data to establish baseline conditions. A final 2012 bacteria and turbidity total maximum daily loads for the Cimarron River study area has been developed (ODEQ, 2012). The result of water quality monitoring by every agency is by the following:

**Oklahoma Conservation Commission**. In the water quality monitoring report which was written by Blue Thumb Program in Water Quality Division of OCC in February 2012, it was reported that the dissolved oxygen content of Stillwater Creek displays lower saturation levels in the late summer months and throughout the fall.

**Oklahoma Conservation Commission, Water Quality Division.** Stillwater Creek Watershed Implementation Project (2006)

A considerable amount of water quality monitoring has occurred since 2000 and is ongoing in the Stillwater Creek Watershed. Data collected from 2000-2006 at three OCC sites on Stillwater Creek (Figure 9) was examined to assess whether any detectable changes in water quality was occurring.

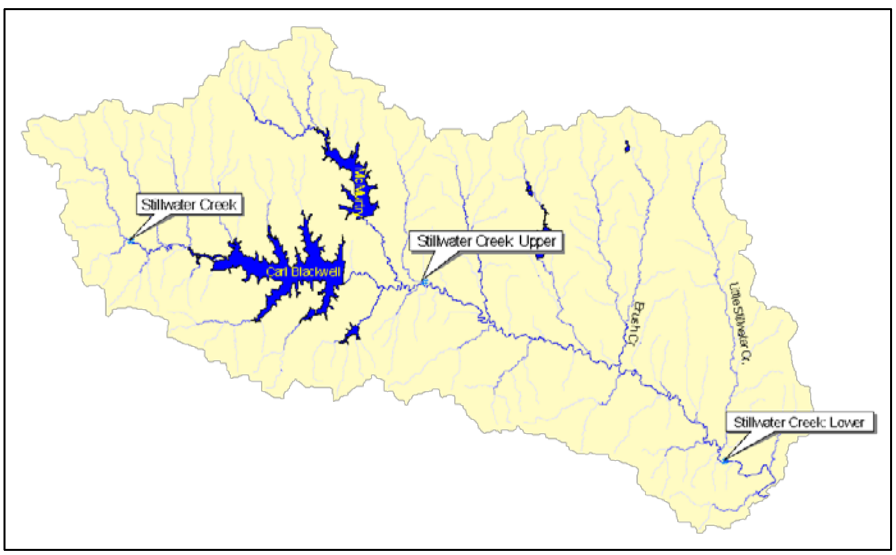


**Figure 9: OCC Monitoring Sites**

For the "Stillwater Creek: Upper" and "Stillwater Creek: Lower" sites, high nutrient and sediment values tended to be inversely related to high flow. At the site "Stillwater Creek," located above Lake Carl Blackwell, high nutrient levels tended to correspond with high discharge values. These relationships seemed to indicate that point sources might contribute significantly to the nutrient and sediment load in Stillwater Creek downstream of Lake Carl Blackwell, while nonpoint source pollution was responsible for much of the nutrient and sediment load upstream of the lake (OCC, 2006).

**The Oklahoma Water Resources Board.** The Oklahoma Water Resources Board (OWRB) 1999 Beneficial Use Monitoring Program report noted that Lake Carl Blackwell was excessively turbid and that summer anoxic conditions may threaten its fish and wildlife propagation beneficial use (Storm, 2003). The OWRB designed and implemented a project to assess various shoreline stabilization methods in Lake Carl Blackwell.

**Oklahoma Integrated Report – 2010:** The 2010 Oklahoma Integrated Report for SCW is provided in Table 17 (ODEQ, 2010).

**Table 17: Oklahoma Integrated Report - 2010**

| Waterbody ID | Waterbody Name | Waterbody Size | Category | TMDL Date |
|---|---|---|---|---|
| OK620900040040 | Stillwater Creek | 3.53 miles | 5a | 2018 |
| Couse of impairment | Impaired use | Unconfirmed Potential Sources | | |
| Nitrates | Public and Private Supply | 8,46,85,87,92,100,108,111,128,133,136,140 | | |
| Enterococcus | Primary Body Contract Recreation | 46,69,85,92,100,108,111,128,133,136,140 | | |
| Escherichia coli | Primary Body Contract Recreation | 46,69,85,92,100,108,111,128,133,136,136,140 | | |

| Waterbody ID | Waterbody Name | Listing Couse | Delisting Justification | TMDL ID |
|---|---|---|---|---|
| OK620900040040 | Stillwater Creek | Chloride | WQS attained for chloride, 0 of 42 samples exceeded criteria | |

**City of Stillwater.** The City of Stillwater modeled the total maximum daily load for the wastewater treatment plant expansion by conducting a survey and modeling the QUAL2E. Water quality data, including flow, constituent concentrations, and travel time, were collected during the survey.

QUAL2E DO simulation, including chloride, ultimate carbonaceous biochemical oxygen demand (CBOD) as $CBOD_{20}$, organic nitrogen, nitrate, nitrite, ammonia, total phosphorus, dissolved phosphorus, and chlorophyll-a. Temperature, DO, and pH measurements were made in the field at the times of sample collection.

Fourteen sampling locations were selected which include: eight sites on Stillwater Creek, two sites on Brush Creek, one site on Little Stillwater Creek, one site at the Stillwater WWTP, and two sites on the Cimarron River.

The result of QUAL2E after calibration illustrated that under the initial point loading of the Stillwater WWTP at 10 mgd with its existing concentration limits, minimum DO levels were not violated in any of the reaches for winter. For the summer and spring seasons, DO levels were violated in reaches 1 through 7.

### *Taste and Odor Problems*

**Oklahoma Water Resources Board**. The upper Arkansas watershed planning region report showed that the Sensitive Water Supplies (SWS) designation applied to public and private water supplies possessing conditions, making them more susceptible to pollution events, thus requiring additional protection. This designation restricted point source discharges in the watershed and instituted a 10 µg/L (micrograms per liter) chlorophyll-a criterion to protect against taste and odor problems and reduce water treatment costs (OWRB, 2012).

### *Hydraulic Budget*

**USGS**. Gauging system

**City of Stillwater**. Hydraulic characteristics observed during the water quality survey. Data gained from the travel time study (travel time versus flow). Lake level and discharge monitoring (Camp, Dresser and McKee, 2000).

**OCC**- Stillwater Creek Watershed Implementation Project and Blue Thumb program (OCC, 2006)

### *Land Use/Land Cover*

**NRCS and OCC**. Color digital orthophotos (2003)

**OSU Biosystems and Agricultural Engineering.** Stillwater Creek Modeling and Land Cover Classification (Storm, 2003)

**OCC**. Stillwater Creek Watershed Implementation Project

### *Riparian Condition*

**NRCS and OCC**. Color digital orthophotos (2003)

**OSU Biosystems and Agricultural Engineering**. Stillwater Creek Modeling and Land Cover Classification (Storm 2003)

**OCC**. Stillwater Creek Watershed Implementation Project

**NRCS.** Established a "Lake Carl Blackwell Local Emphasis Area (LEA)" consisting of all land that drains into Stillwater Creek and Lake Carl Blackwell. As part of this project, Logan, Payne, and Noble counties were implementing practices to provide sediment and erosion control measures on land that will reduce excessive sedimentation into Stillwater Creek and Lake Carl Blackwell.

### *Aquatic Biological Communities*

One fish collection and habitat assessment was performed for three sites over the course of the project (Stillwater Creek, Stillwater Creek: Upper, Stillwater Creek: Lower). In addition, macroinvertebrate collections were gathered twice a year, once during the winter period and once during the summer.

In general, the biological communities of the three Stillwater Creek sites were healthy relative to the high quality sites in the ecoregion. Of the three sites, Stillwater Upper had the best fish collection, the best habitat, and the highest average macroinvertebrate scores. The Stillwater site above Lake Carl Blackwell had the lowest fish and habitat scores but about the same average macroinvertebrate score as the Lower site. The biological communities and the habitat of the sites will be monitored in the future to assess any changes.

Stillwater Creek (above Lake Carl Blackwell) was not listed on the 303(d) list for pathogens in either 1998 or 2002 due to insufficient data, and it still does not have sufficient data to assess the designated Primary Body Contact Recreation (PBCR) use. However, Stillwater Creek Lower was nominated for listing on the 2006 list as not attaining the PBCR use due to E. coli. Stillwater Creek Upper has been assigned a Secondary Body Contact Recreation (SBCR) use, and it meets the required bacteria levels to attain that designated use.

### *Best Management Practices and other Implementation Efforts (Coverage)*

**NRCS/FSA**. Have established a "Local Emphasis Area" consisting of all land that drains into Stillwater Creek and Lake Carl Blackwell. Funding should be provided for sediment and erosion control measures, with special consideration given to establishing permanent vegetation on cropland, adopting conservation tillage practices, and the development and protection of conservation buffers. The NRCS will continue to focus available EQIP fund-ing in the watershed through this project, which should result in further water quality improvements.

**OCC**

- Stillwater Creek Watershed Implementation Project
- Policies and Approved Conservation Practices For Stillwater Creek Watershed
- §319 Non Point Pollution Cost-Shares, FY 2001 §319(h) Project 3 C9-996100-9 Stillwater Creek Watershed Implementation Project, (2005)

**OSU**. Stillwater Creek Modeling and Land Cover Classification (Storm 2003)

**ODEQ.** Bacteria and turbidity total maximum daily loads for the Cimarron River study area, Oklahoma (OK620900, OK620910)

**OWRB**. Infrastructure upgrades supported through the State Revolving Fund Loan program.

**OCC, OWRB, and OSU.** OCC contracted with the OWRB to develop a shoreline stabilization project for the lake and with OSU to develop a rural road erosion control project.

## Data Collection Responsibilities

It is the project managers' responsibility to manage additional data required specific to any individual project. Project managers must make sure data is submitted to ODEQ for inclusion in the Oklahoma State Water Quality Database, which eventually is uploaded to the National STORET (STOrage and RETrieval) database. The project manager is also responsible to report data for any individual work plan (EPA, 2014).

Monitoring results of all projects will eventually be presented in a final report to the OCC. In addition to people dealing with the monitoring work plan, and individuals working on the WBP, the following groups and agencies will be involved in monitoring activates:

- City of Stillwater
- OWRB:
    - Beneficial Use Monitoring Program
    - Oklahoma Water Watch Monitoring Program
- OCC:
    - Rotating Basin Monitoring Program
    - Priority Watershed Project Monitoring
    - Blue Thumb Monitoring Project
- USGS:
    - Surface and groundwater quality and quantity monitoring
    - Special studies
- ODAFF:
    - Soil sampling associated with CAFO regulations
    - Stream Monitoring

## Monitoring Details

### *Stream Monitoring*

The OCC is tasked with monitoring, assessing, and evaluating waters of the state for the impacts of NPS pollution. The best way to monitor, assess, and characterize NPS pollution is to work on small scale watersheds close to the source. The OCC samples streams on a rotating basis in each of the state's 11 major basins for a two year period, once every five years (Wallace, 2012). Results of monitoring are reported in the State's biannual Integrated Water Quality Assessment Report. Based on this report, OCC provides the tools to assess and then restore water quality in Oklahoma (OWRB, 2012).

There are three monitoring sites in the watershed. In data collected between 2000 and 2006, significant decreasing trends were observed for both turbidity and total suspended solids at one of the sites. This decreasing trend was due to BMPs implemented in SWC which include riparian area establishment, roadside erosion, land management (pasture and cropland),

and waste management. However, many of the lakes and several watershed streams remain impaired for NPS related pollutants. The OCC used data collected from 2000-2006 to assess whether any detectable changes in water quality are occurring after the project implementation. The NRCS has defined and established all land draining into Lake Carl Blackwell and Stillwater Creek as a Local Emphasis Area. Figure 10 presents the monitoring sites in the SCW (OWRB, 2012). The closest monitoring site to the City of Stillwater is just north of state Highway 51, as SC passes Sangre Road. As there are no point sources of bacteria in the SCW, the bacterial impairment is caused by NPS, with livestock expected to be the largest contributor, as there is a large population of livestock in the watershed.

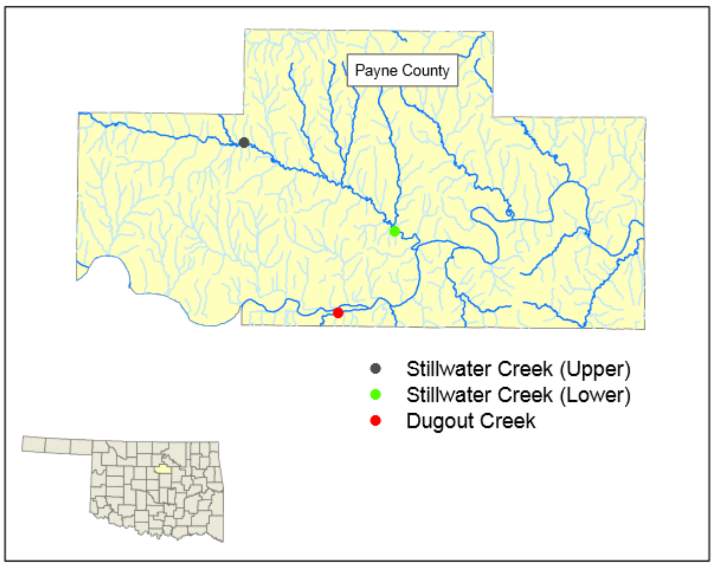


**Figure 10: OCC Rotating Basin Monitoring Sites Within Payne County**
OWRB, 2012.

### *Point Source Monitoring*

Information on discharges from the City of Stillwater's WWTP is provided to the NPDES Discharge Monitoring Report (DMR). This data provides information on evaluating changes in water quality entering SC over time. Parameters reported in the DMRs include monthly and daily maximum flow, pH, TSS, Total Ammonia, Total Phosphorus, Total Nitrate-N, Total Chlorine, BOD, and Fecal Coliform.

### *Lake Monitoring*

The purpose of the OWRB's Clean Lakes Program is to evaluate, restore and maintain the recreational benefits of Oklahoma's publicly owned lakes, primarily municipal and major water supply lakes. The program consists of three distinct efforts: lake assessment, citizens monitoring and diagnostic/feasibility studies. OWRB is also responsible for developing OWQS and evaluating beneficial use attainment. OWRB developed a Beneficial Use Monitoring Program to achieve those goals, among others (OWRB, 2012).

OWRB gathers quarterly information on Oklahoma's major lakes on a two year rotating schedule. Vertical profiles at one meter intervals for dissolved oxygen (mg/l and percent saturation), pH, temperature, conductivity, salinity, total dissolved solids, and oxidation-reduction potential are collected at a minimum of three sites per lake to represent riverine, transition, and lacustrine zones. Water samples are collected at surface and bottom layers in the lacustrine zone, and surface layers in the transition and riverine zones.

Lake water quality parameters include alkalinity, total hardness, chloride, turbidity, sulfate, total suspended solids, total settleable solids, Secchi disk depth, chlorophyll-a, nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, Kjeldahl nitrogen, orthophosphorus, and total phosphorus. Sites are accessed by boat, reducing the likelihood of lake bottom disturbance. Carl Blackwell and Lake McMurtry are suitable for OWRB's Lake Monitoring Program.

### *Benefits of Monitoring Plan*

Implementation of a monitoring plan will aid in enabling the SCW project managers to meet the ultimate goal of restoring beneficial use support to the watershed. Additionally, further monitoring will help identify locations where restorative activities should continue to be focused on in the future. Finally, evaluation of BMP success could not be completed without sound, focused monitoring of the SCW.

### *Future Monitoring*

As technology and financial resources become available, monitoring procedures and programs can expand to include additional NPS pollutants such as toxins and endocrine disrupters. The monitoring program can potentially be designed to identify NPS pollution causes and sources originating from surface water, groundwater, and aerial borne pollutants. Data collected under this monitoring plan can help identify and define the relative contributors of different sources to the changes in water quality in the watershed. Continuous data collection in the SCW can also help the WBP adapt to the ever changing needs of the creek to maintain its water quality (Wallace, 2012).

# References

Brooks, K. N., Folliott, P. F., & Magner, J. A. (2013). *Hydrology and the management of watersheds.* Ames, IA: John Wiley & Sons, Inc.

Camp Dresser and McKee. (2000). *Stillwater Creek Total Daily Maximum load Modeling for Waste Water Treatment Plant Expansion Wasteload Allocation.* Stillwater: City of Stillwater.

Crall, E. (2006). *Oklahoma's Nonpoint Source Program.* Retrieved from Stillwater Creek Watershed implementation Project: http://www.ok.gov/conservation/documents/NPS

Crawfard, P. H., & Johnson, E. (2015). *Cross Timbers.* Retrieved from 5TH Poster of the Biodiversity of Oklahoma Series: http://www.biosurvey.ou.edu/posters/CrossTimbersEcoregion

Donald, J., Somlen, M. D., & Stebler, E. (2009). Effectiveness of BMPs in Reducing Sediment from Unpaved Roads in the Stillwater Creek, Oklahoma Watershed. *American Water Resources Association (JAWRA)*, 1343-1351.

Empower Results, LLC. (2009). *Big Walnut Creek Watershed Alliance.* Retrieved from Big Walnut Creek Watershed Management Plan: http://www.bigwalnutwatershed.org/managementPlan

EPA. (2015, July 29). *2014 Waterbody Report for Stillwater Creek*. Retrieved July 24, 2015, from Environmental Protection Agency: http://ofmpub.epa.gov/tmdl_waters10/attains_waterbody.control?p_au_id=OK620900040040_00&p_cycle=2014

EPA. (2014, January 15). *Environmental Protection Agency*. Retrieved July 21, 2015, from STORET/WQX: http://www.epa.gov/storet/

EPA. (2003, March). *Environmental Protection Agency.* Retrieved July 23, 2015, from Elements of a state water monitoring and assessment program: http://water.epa.gov/type/watersheds/monitoring/statemonitoring.cfm

Fay, L., Akin, M., & Shi, X. (2012). *Cost-Effective and Sustainable Road Slope Stabilization and Erosion Control.* Washington D.C: Library of Congress Control No. 2012934386; Project 20-05 (Topic 42-09) ISSN 0547-5570 ISBN 978-0-309-22362-1. Transportation Research Board: National Cooperative Highway Research Program.

Hoorman , J. J., & McCutcheon , J. (2005, April). Livestock and Streams Best Management Practices to Control the Effects of Livestock Grazing Riparian Areas. *Extension Factsheet, School of Environment and Natural Resources, the Ohio State University*.

Johnson, E., Geissler, G., & Murray, D. (2010). *The Oklahoma Forest Resource Assessment. A comprehensive analysis of forest-related conditions, trends, threats, and opportunities.* Oklahoma City, Oklahoma Department of Agriculture, Food, and Forestry.

Johnson, K. S. (2008). *Oklahoma Geological Surveys.* Retrieved from Educational Publication: http://www.ogs.ou.edu/pubsscanned

Kang, R. S., & Marston, R. A. (2006). Geomorphic effects of rural-to-urbans land use conversion on three streams in the Central Redbed Plains of Oklahoma. *Geomorphology (79)*, 488-506.

Kang, R. S., Storm, D. E., & Martson, R. A. (2010). Downstream Effects of Urbanization on Stillwater Creek, Oklahoma. *Physical Geography (31)*, 186-201.

Michie, R. (2010). *Cost Estimate to Restore Riparian Forest Buffers and Improve Stream Habitat in the Willamette Basin, Oregon.* Portland: Oregon Department of Environmental Quality, Water Quality Division, Watershed Management Section.

OCC. (2010). *Oklahoma Conservation Commission.* Retrieved July 22, 2015, from Know Your Stream: Rotating Basin Site Summary: http://www.ok.gov/conservation/documents/Payne%20County,%20Central%20Great%20Plains%20Site%20Summary%202014%20%28Report%29.pdf

ODEQ. (2010). *Oklahoma Department of Environmental Quality.* Retrieved July 20, 2015, from Water Quality in Oklahoma: http://www.deq.state.ok.us/wqdnew/305b_303d/2010/2010%20Oklahoma%20Integrated%20Report.pdf

ODEQ. (2012, July 31). *Oklahoma Department of Environmental Quality.* Retrieved July 22 2015, from PUBLIC NOTICE: AVAILABILITY OF DRAFT BACTERIA AND TURBIDITY TMDLs FOR THE CIMARRON RIVER AREA WATERSHED: http://www.deq.state.ok.us/wqdnew/tmdl/PublicNoticeCimarronRiverBacterialTurbidity.pdf

Oklahoma Conservation Commission. (2000). *Oklahoma's Nonpoint Source Pollution Program Annual Report.* Oklahoma: Oklahoma Conservation Commission Water Quality Program.

Oklahoma Conservation Commission. (2006). *Stillwater Creek Watershed Implementation Project.* Water Quality Division. USEPA Grant # C9 - 996100-9.

Oklahoma Forest Services. (2007). *Oklahoma Forest Services*. Retrieved from A Division of the Oklahoma Department of Agriculture, Food, and Forestry: http://forestry.publishpath.com

OWRB, (2012). *Oklahoma Water Resources Board.* Retrieved July 20, 2015, from Upper Arkansas Watershed Planning Design Report:

http://www.owrb.ok.gov/supply/ocwp/pdf_ocwp/WaterPlanUpdate/regionalreports/OCWP_UpperArkansas_Region_Report.pdf

OWRB. (2014). *Oklahoma Water Resources Board.* Retrieved July 19, 2015, from Oklahoma Lakes Report: Beneficial Use Monitoring Program: http://www.owrb.ok.gov/quality/monitoring/bump/pdf_bump/Current/Lakes/BUMPLakesReport.pdf

Parsons. (2012). *2012 Bacteria and Turbidity Total Maximum Daily Loads for the Cimarron River Study Area (OK620900, OK620910).* Oklahoma City: Oklahoma Department of Environmental Quality.

Pruitt, B. A., Melgaard, D. L., Howard, H., Flexner, M. C., & Able, A. S. (2001). CHATTOOGA RIVER WATERSHED ECOLOGICAL/SEDIMENTATION PROJECT. *Federal Interagency Sedimentation Conference.* Reno, Nevada: USEPA.

Randolph, J. C., & Wilhm, J. (1984). *Oklahoma State University Library.* Retrieved July 19, 2015, from SEASONAL VARIATION IN THE PHYTOPLANKTON AND THE TROPHIC STATE OF A SOUTHERN GREAT PLAINS RESERVOIR: http://digital.library.okstate.edu/OAS/oas_pdf/v64/p57_62.pdf

Storm, D. E., Gade, D., Tejral, R., Somlen, M. D., Kenkel, P., & Gregory, M. S. (2000). *Estimating Watershed Level Nonpoint Loading for the State of Oklahoma.* USEPA OKK TASK # 78 - FY 1996 §319(h) TASK # 2010 - Output #3.

Storm, D. E., White, M. J., & Stoodley, S. H. (2003). *Stillwater Creek Modeling and Land Cover Classification.* Oklahoma City: Oklahoma Conservation Commission.

Turton, D. J., Smolen, M. D., & Stebler, E. (2009). Effectiveness of BMPs in Reducing Sediment from Unpaved Roads in the Stillwater Creek, Oklahoma Watershed. *American Water Resources Association (JAWRA)* , 1343-1351.

United States Census Bureau. (2015, May 28). *United States Census Bureau*. Retrieved July 27, 2015, from State & County QuickFacts: http://quickfacts.census.gov/qfd/states/40/4070300.html

Wallace, S. (2012, May 17). *Oklahoma Conservation Commission*. Retrieved July 23, July, from Stillwater Creek: S. Sangre Road: http://www.ok.gov/conservation/Agency_Divisions/Water_Quality_Division/WQ_Blue_Thumb/BT_Data_Interpretations/BT_Stillwater_Creek:_S._Sangre_Road.html