WATERSHED BASED PLAN

FOR

WALNUT BAYOU WATERSHED

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List of Acronyms

AECP: Agricultural Conservation Easement Program

BMP: Best Management Practice

BUMP: Beneficial Use Monitoring Program

CAFO: Concentrated Animal Feeding Operation

CCA: Critical Conservation Area

CLEAR: Clean Lakes, Estuaries, and Rivers

CN: Curve Number

CRM: Crop Residue Management

CRP: Conservation Reserve Program

CSP: Conservation Stewardship Program

CWA: Clean Water Act (Federal Water Pollution Control Act, 33 U.S.C. 1251 et seq.)

CWMP: Cooperative Watershed Management Program

DO: Dissolved Oxygen

ENT: Enterococcus

ETEP: EPA Tribal Environmental Plans

EPA: Environmental Protection Agency

EQIP: Environmental Quality Incentives Program

FSA: Farm Service Agency (USDA)

FWP: Fish and Wildlife Propagation

GIS: Geographic Information System

GLWAF: Grand Lake Watershed Alliance Foundation

HAWQS: Hydrologic and Water Quality System

HUC: Hydrologic Unit Code

HWCG: Healthy Watersheds Consortium Grants

IBI: Index of Biotic Integrity

I/E: Information and Education

MYA: Million Years Ago

NEEF: National Environmental Education Foundation

NLCD: National Land Cover Database

NPDES: National Pollutant Discharge Elimination System

NPS: Non-Point Source

NRCS: Natural Resources Conservation Services

NTT: Nutrient Tracking Tool

NTU: Nephelometric Turbidity Unit

OACD: Oklahoma Association of Conservation

OCC: Oklahoma Conservation Commission

OCES: Oklahoma Cooperative Extension Service

ODAFF: Oklahoma Department of Agriculture, Food and Forestry

ODEQ: Oklahoma Department of Environmental Quality

OPDES: Oklahoma Pollutant Discharge Elimination System

OSU: Oklahoma State University

OSWD: Onsite Wastewater Disposal

OWRB: Oklahoma Water Resources Board

PBCR: Primary Body Contact Recreation

PPWS: Public and Private Water Supply

RBS: Riparian Buffer Specifications

RBMP: Rotating Basin Monitoring Program

RCPP: Regional Conservation Partnership Program

SRA: Source Reduction Assistance Grant Program

SSURGO: Soil Survey Geographic

STATSGO: State Soil Geographic

STEPL: Spreadsheet Tool for Estimating Pollutant Load

SWAT: Soil and Water Assessment Tool

TMDL: Total Maximum Daily Load

TSS: Total Suspended Solids

USACE: U.S. Army Corps of Engineers

USDA: United States Department of Agriculture

USGS: United States Geological Survey

WAG: Watershed Advisory Group

WB-250: Walnut Bayou (OK311100010250)

WBID: Waterbody Identification

WBP: Watershed Based Plan

WQS: Water Quality Standards

WWAC: Warm Water Aquatic Communities

WWTP: Waste Water Treatment Plant

Introduction

The Walnut Bayou Watershed is located in southern Oklahoma and is impaired for Non-Point Source (NPS) pollution according to the 2016 Integrated Water Quality Report (ODEQb, 2016). NPS pollution is one of the leading causes of water quality problems in many of the U.S. states that lead to harmful effects on drinking water supplies, recreation, fisheries and wildlife (EPA, n.d.). The Water Quality Division of the Oklahoma Conservation Commission (OCC) addresses NPS in the State of Oklahoma (OCC, 2014).

The Walnut Bayou Watershed is impaired for turbidity, Enterococcus and dissolved oxygen (DO) and is listed on the 303(d) Impaired Waters List of the 305(b) Integrated Water Quality Report (ODEQ, 2016). The objective of this Watershed Based Plan (WBP) is to improve water quality standards for all designated beneficial uses. This WBP consists of several management practices to take place within the Walnut Bayou Watershed in order to address these NPS impairments.

According to Environmental Protection Agency (EPA)(2013) creation guidelines, a WBP entails nine elements: 1) Identifying causes and sources of pollution; 2) Estimating pollutant loading into the watershed and the expected load reductions; 3) Describing management measures that will achieve load reductions and target critical areas; 4) Estimating amounts of technical and financial assistance and the relevant authorities needed to implement the plan; 5) Developing an information/education component; 6) Developing a project schedule; 7) Describing the interim measurable milestones; 8) Identifying indicators to measure progress; and 9) Developing a monitoring plan.

Study Area

Walnut Bayou is a hydrologic unit code (HUC) 10 watershed, located in southern Oklahoma. Walnut Bayou River is the main channel that drains the watershed. It flows from the northwest to the southeast and passes through parts of Carter and Love Counties before joining the Red River (Figure 1).

The area of the delineated watershed is about 864 km^2. Falconhead Airport-37K, Oknoname 085006 and Oknoname 085005 Reservoirs (cultural features), Falconhead Country Club, and Falconhead Resort Country Club are some of the features found within the basin.

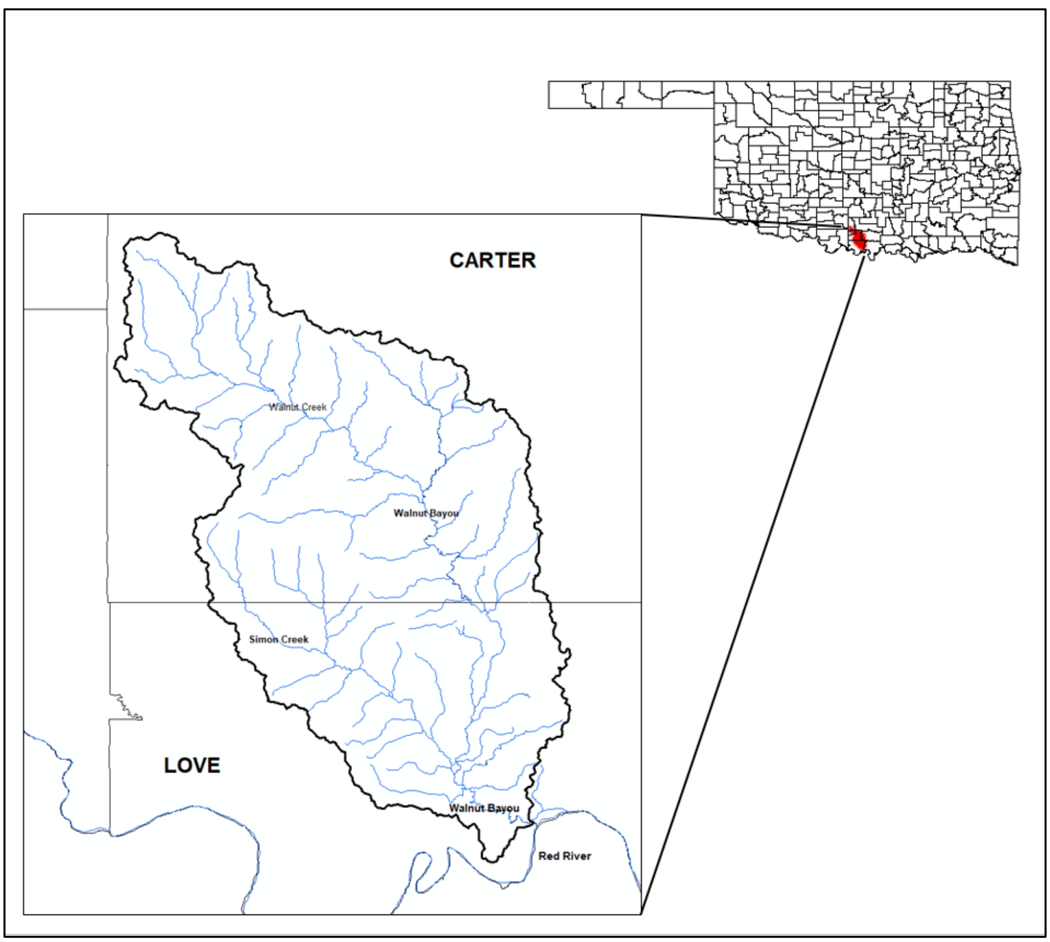

Figure 1: Location of the Walnut Bayou Watershed in Oklahoma (Created on ArcGIS, 2019)

Characterization of the Walnut Bayou Watershed

The Walnut Bayou Watershed is drained by Walnut Bayou River. United States Geological Survey (USGS) (n.d.) gauge number 07315900, Walnut Bayou near Burneyville, records the runoff flow from the watershed. As shown in Figure 2, the watershed consists of nine HUC-12 sub-watersheds and 24 waterbodies (Table 1). Simon Creek is the longest tributary in the Walnut Bayou Watershed. Most parts of the watershed are covered by grasslands (49%) and deciduous forests (33%). Hay is also an important crop, covering about 12 percent of the watershed (NLCD, 2016). More details about the agricultural crops and land use can be found in Appendix A (Table A.1).

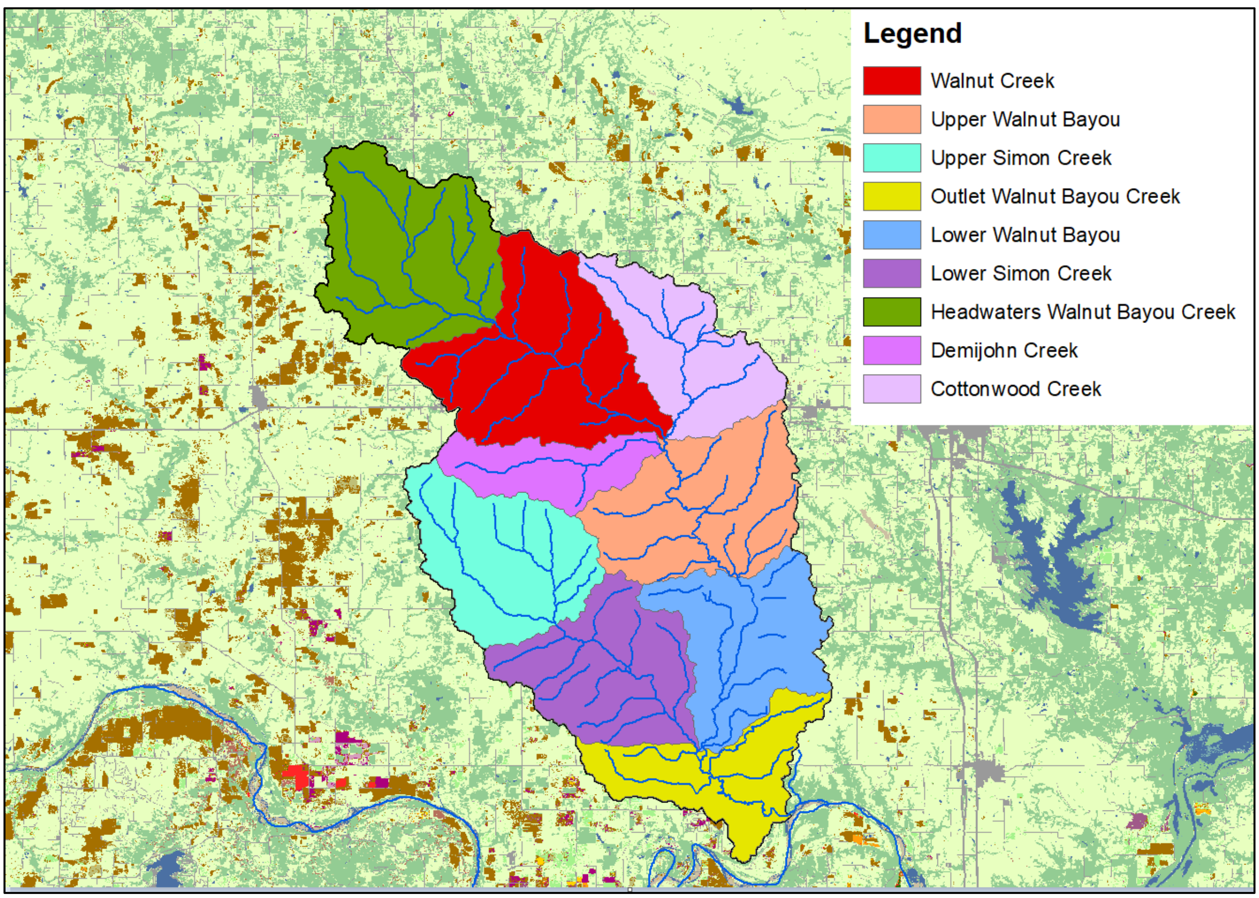

Figure 2: Walnut Bayou Watershed HUC 1113020106 (Created on ArcGIS, 2019)

Table 1: List of HUC12 Sub-Watersheds and Waterbodies in the Study Area (USGS, n.d.)

HUC	Waterbody	Name	Area (km^2)	Mean Slope
111302010601	OK311100030070-00 OK311100030110-00 OK311100030120-00 OK311100030130-00 OK311100030140-00 OK311100030150-00	Headwaters Walnut Bayou Creek	122	0.03
111302010602	OK311100030190-00 OK311100030090-00	Cottonwood Creek	81	0.03
111302010603	OK311100030100-00 OK311100030160-00 OK311100030180-00 OK311100030070-00	Upper Walnut Creek	137	0.03
111302010604	OK311100030080-00	Demijohn Creek	48	0.03
111302010605	OK311100030010-00 OK311100030050-00 OK311100030060-00 OK311100030070-00	Upper Walnut Bayou	112	0.028
111302010606	OK311100030020-00 OK311100030030-00	Upper Simon Creek	99	0.03
111302010607	OK311100030020-00	Lower Simon Creek	98	0.03
111302010608	OK311100030010-00 OK311100030040-00	Lower Walnut Bayou	93	0.029
111302010609	OK311100010250-00 OK311100010260-00	Outlet Walnut Bayou Creek	73	0.029

Elevation

The USGS Digital Elevation Map (DEM) was developed to identify the elevation changes and distribution of ground elevation of the watershed (Figure 3). The general slope of the watershed increases from northwest to southeast. The highest point in the watershed is about 350.5 m and the lowest point is about 201.5 m at the watershed's outlet. The average slope of the basin is between 0.27 to 3 percent, which is considered relatively levelled (USDA, n.d.).

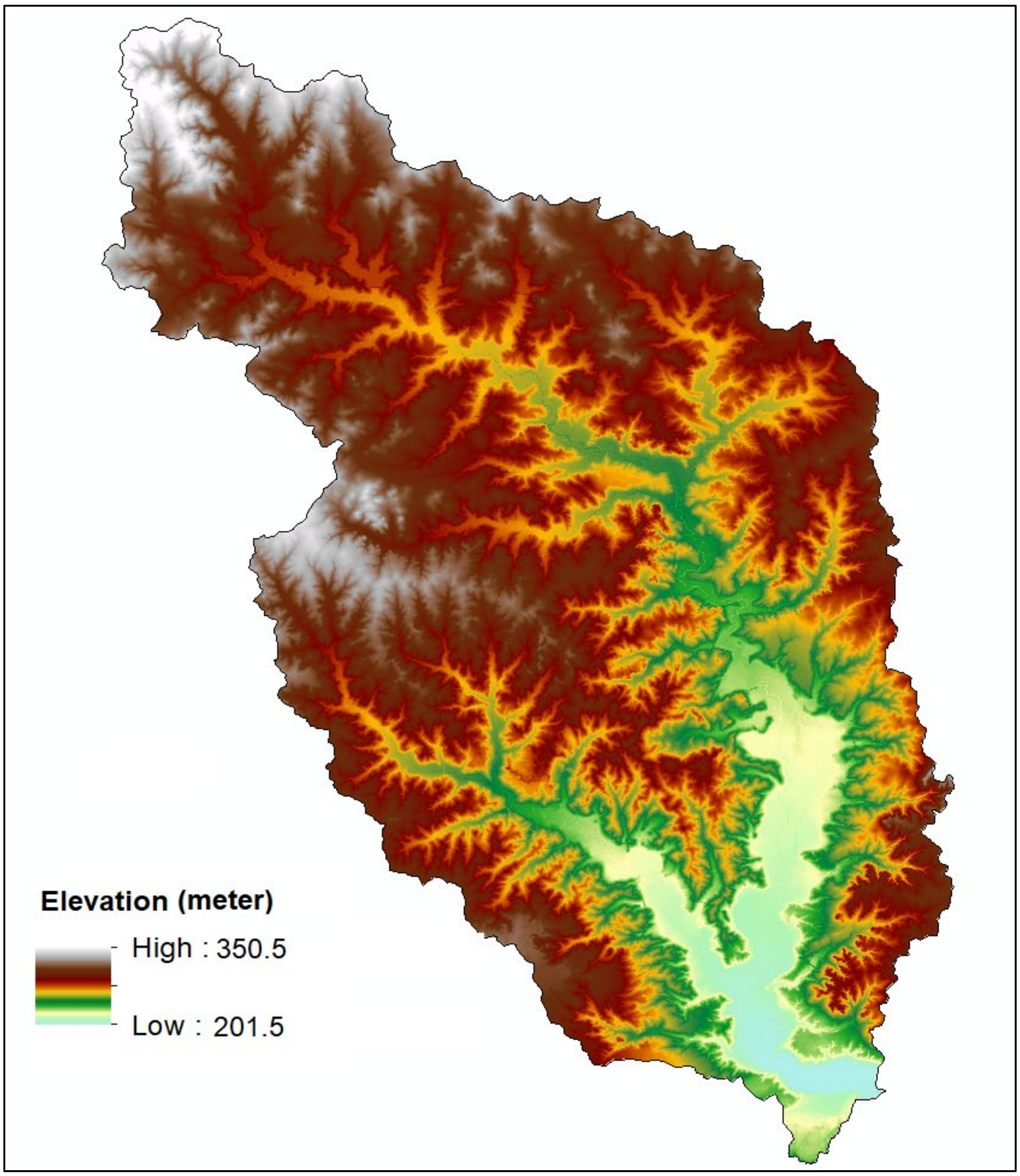

Figure 3: Elevation Map of the Study Area (Created on ArcGIS, 2019)

Ecoregions

Ecoregions provide a framework by grouping similar ecosystems and environmental conditions together for ecosystem assessment, research, inventory, monitoring, and management (Omernik & Bailey, 1997). Walnut Bayou Watershed is in the Cross Timbers ecoregion, with most of its area located inside ecoregion level 4, called the Western Cross Timbers. Figure 4 shows the level 3 and level 4 ecoregions in the study area.

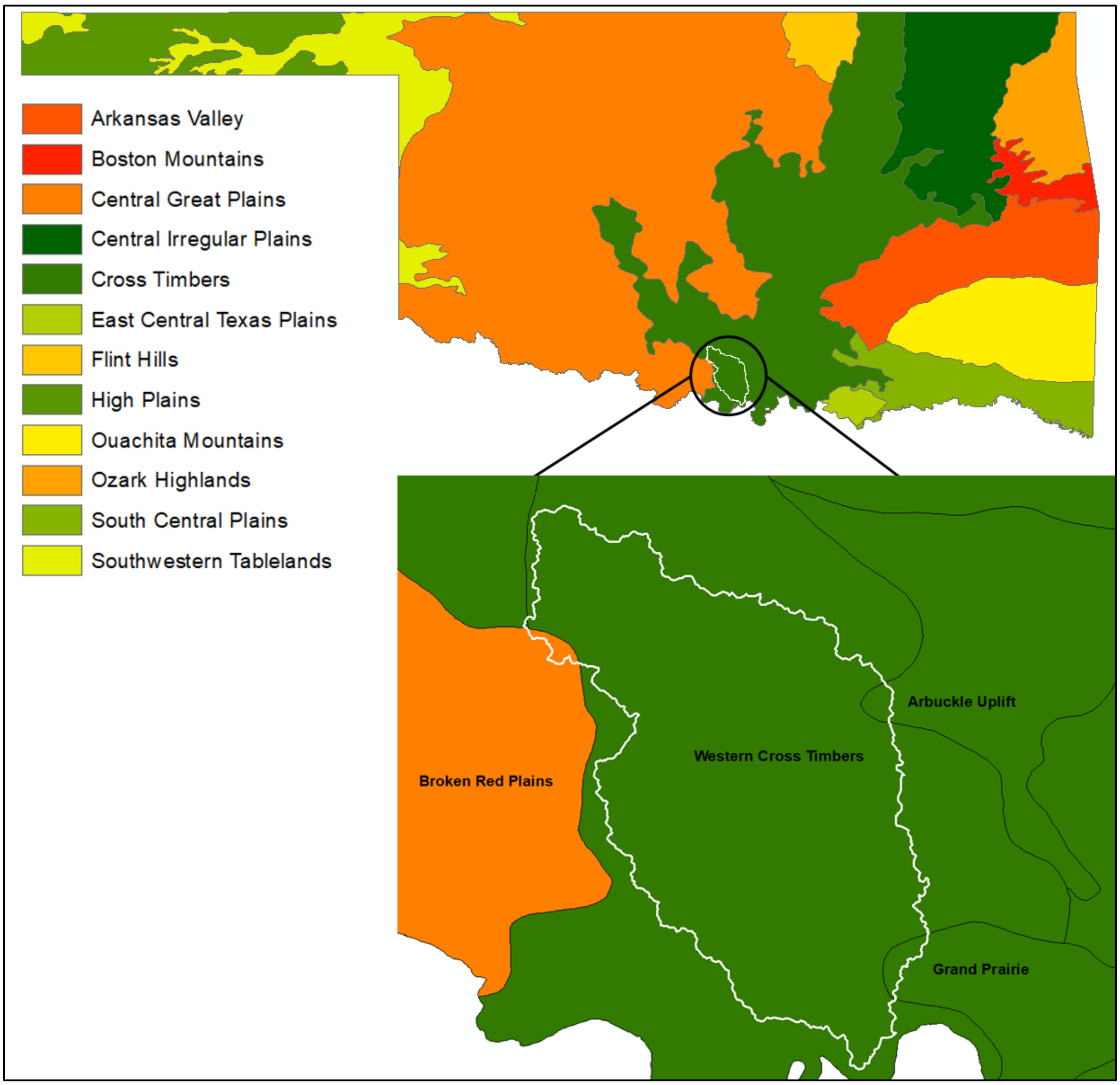

Figure 4: Level 3 and Level 4 Ecoregions in the Study Area (Created on ArcGIS, 2019)

The Western Cross Timbers is one of the level 4 ecoregions of the Cross Timbers. It is about 1836 km^2 with elevation ranges from 198 to 365.76 m. River beds are mostly sandy or clay. Upland soils are considered to be in the alfisols soil groups while the floodplains mainly belong to the entisols or vertisols soil group. Upland soils can be highly erodible. Mean annual precipitation in the area is normally 762-965 mm. The minimum temperature is about -3ºC in January, while the maximum temperature is about 35ºC in July. Annually, about 225-235 days of the year are frost free. Most of the ecoregion is covered by grasslands, pastureland, and woodland. Agricultural areas can also be seen in some parts. Main crops are small grains, grain and forage sorghum, and peanuts. Oil production is also popular in this ecoregion. The potential vegetation in this region is mostly cross timber (blackjack oak, post oak and little bluestem). Blackjack oak, post oak, and understory grasses can be found in areas with coarse-textured soils, while prairie vegetation can be found in fine-textured soils. Riparian vegetation includes pecans, black walnut, American elm, and cottonwood (Disney, Hellgren, Davis, Leslie & Engle, 2008; EPA, n.d.).

Geology

Based on the location of the Walnut Bayou Watershed, there are two primary geomorphic provinces within the study area. A geomorphic province is a spatial area with similar geologic features, which were created during the same period and by the same geologic events. This can include large features such as folds or faults, or several smaller related attributes (Curtis, Ham & Johnson, 2008; Levin, 2013).

The majority of the first province is located under Carter County and the western edge of Love County. This province is known as the Central Red-Bed Plains, characterized predominantly by the deposition of red shales and sandstones during the Permian Period, which occurred approximately 240 to 300 Million Years Ago (MYA) (Curtis, Ham & Johnson, 2008; Levin, 2013). The red color of the sedimentary rock is a visible indicator that the sediment was deposited in shallow to intermediate zone of marine habitat. The sediment oxidized when the ocean retreated, exposing it to the atmosphere and turning it red (Levin, 2013). The upper portion of Walnut Bayou Watershed is located within this province.

The second geomorphic province underlays the southern edge of Carter County and the majority of Love County. These areas are identified as Dissected Coastal Plain, which was deposited approximately 66 to 146 MYA during the Cretaceous Period. This province contains primarily sands, clays, and limestones (Curtis, Ham & Johnson, 2008). These beds are un-lithified, meaning they have not undergone the process by which sediment becomes a rock. The areas that contain sands and some clay were deposited in a non-marine environment, such as a river. As the river opened to the paleo-ocean, a loss of energy occurred and more fine-grained clays and limestones were deposited towards the river mouth (Levin, 2013).

On the southernmost edge of Love County, and thus the south-easternmost point of the watershed, the Cretaceous-deposited province is overlain by quaternary alluvium and terrace deposits. The beds were most likely deposited between 2.58 million years ago and recent history, during the Quaternary Period. These rocks consist of sand, silt, clay and gravel sediment (Johnson, 2008a). The rock type is characterized by unconsolidated alluvium deposits, which is found in current-day flood plains and stream beds. These alluvial sediments are underlain by terrace deposits or older alluvial deposits that were deposited when a stream naturally meandered to a different location (Johnson, 2008b; Levin, 2013). These deposits indicate the low-velocity side of the bank, also known as the point bar, where the lack of energy causes sediment to settle and deposit rather than erode the bank.

Soil Classification

The two main datasets used for soil types in the USA are the State Soil Geographic (STATSGO) database, which was developed by the National Cooperative Soil Survey (USDA, n.d.) and the Soil Survey Geographic (SSURGO) database, which was collected by the National Cooperative Soil Survey (USDA-NRCS, n.d.). The SSURGO database contains more detailed information and is available for most parts of the United States at the County level (USDA, n.d.; Geza & McCray, 2008).

According to the STATSGO database, the main classes of soil in the study area are OK156 and OK154 (HAWQS, 2019). These classes are mainly sandy (more than 85% sand), or a top layer of 30 cm thick sandy loam with 40-150 cm of sandy clay loam below (ChEAS, n.d.; USDA, n.d.). Sandy soils and sandy loam soils have higher percolation rates, reducing the runoff generated from rainfall. However, these soils cannot hold a significant amount of water or nutrients.

Both soil types contain some percentage of clay. Clay is very fine-grained sediment that has small pore space between its particle grains. Because of this, clay is oftentimes referred to as an aquiclude or aquitard and is a standard rock type that is looked for when determining the initial health of, and protection of, aquifers. This is because contaminated water that infiltrates the soil will not pass through the layer of clay, but instead flows along the clay boundary. If the soils have not filtered the contaminated water by the time the clay layer ends, the contaminated water can then come into contact with the water that flowed below the aquitard and on towards the Red River. Therefore, as clay increases in soils the risk of runoff increases as well. Because clay is cohesive, however, the risk of erosion to high-clay soils decreases (Haverkamp & Parlange, 1986; Thinksoils, n.d.). The SSURGO soil types of the study area are shown in Figure 5 and Appendix A (Table A.2).

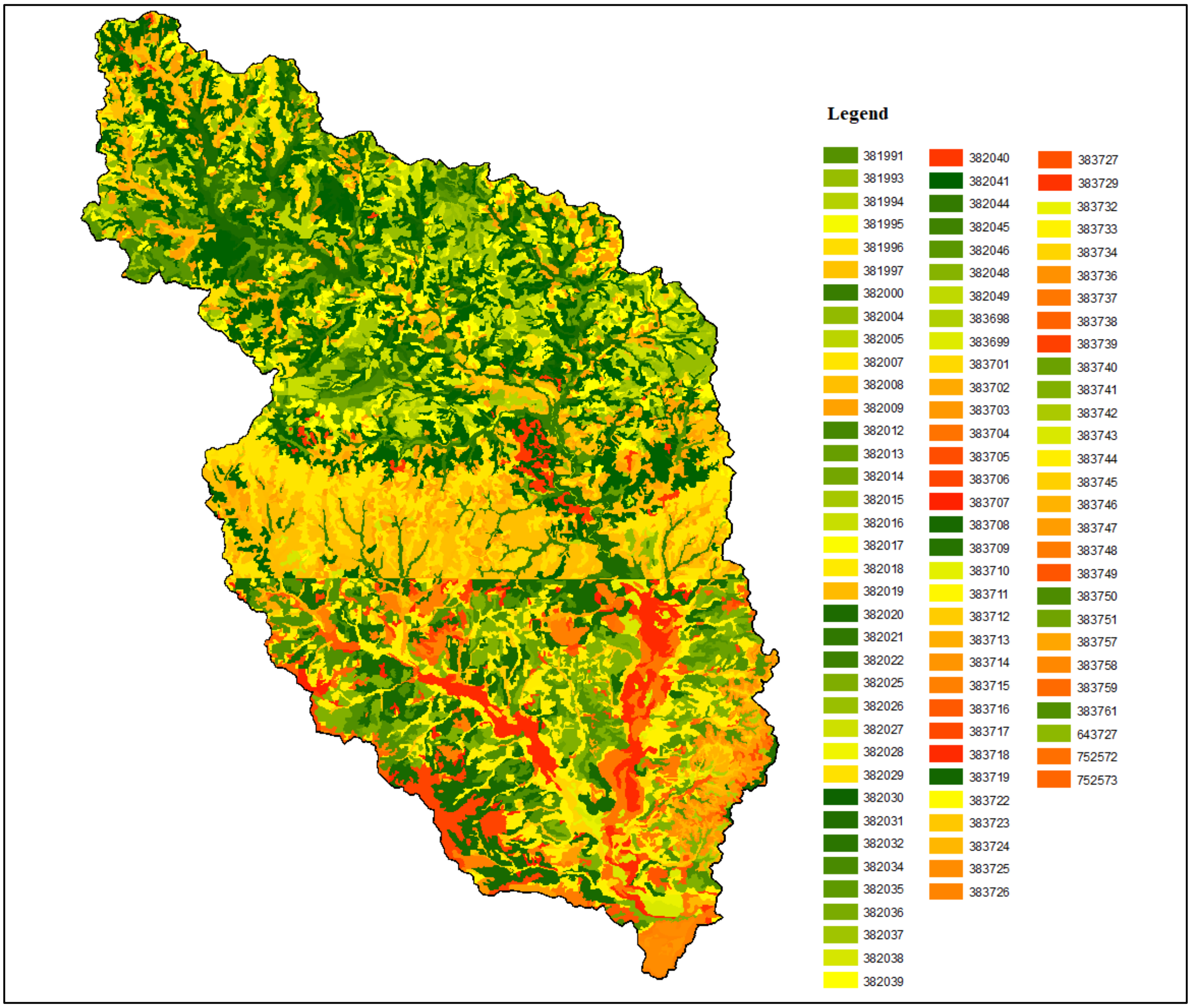

Figure 5: SSURGO Soil Types in the Study Area (Created on ArcGIS, 2019)

Hydrogeology

The Walnut Bayou Watershed is located within the Red River Drainage Basin, which has a drainage area of 64,563.22 km^2 and the total available water in the basin is 13,272,819,602 m3 (Luza, 2008). The Walnut Bayou Watershed has a drainage area of 864 km^2 (ArcGIS, 2019) and available water is 88,678,578 m^3 (Luza, 2008). This indicates that the Walnut Bayou Watershed consists of approximately 1.34 percent of the Red River Drainage Basins' drainage area, and contributes to 0.67 percent of its estimated available water.

The Walnut Bayou Watershed's general direction of flow is from its headwaters in the northwest portion towards the southeast, where the Walnut Bayou River empties into the Red River (Figure 3). There are three principal ground-water aquifers within this watershed system, each with specific hydrologic properties. Based on the information provided by Johnson (2008b), the three types are the Oscar Group - area b, the Antlers Sandstone, and the Quaternary alluvium and terrace deposits, located in the upper portion, lower portion, and south-easternmost portion of Walnut Bayou Watershed, respectively. Each of these areas has unique lithology, which in turn affects the porosity. Porosity, in turn, affects the flow rate of water, filtration of water and contaminants, and the amount of water the rock body can hold.

As water travels from the headwaters to the lower portion of the watershed, water movement slows down as pore space between particles decreases. Because the Antler Sandstones contain un-lithified sand (Johnson, 2008b), friction is present as the water moves through the small pore spaces of this system. The friction causes the contaminants to stick to the pore space walls, allowing the water to naturally filter (Levin, 2013; Guwahati, 2009). The flowing water also creates drag as it pushes between pore spaces, slowing the water's movement slightly (Guwahati, 2009). Because of this, the common yield moving into the lower portion's aquifer system decreases. However, the yield increases as it enters into the final aquifer system, which is made of unlithified sediments with larger pore space (Johnson, 2008b; Levin, 2013).

Land Use and Land Cover

The majority of the study area is covered by pasture (58%) and deciduous forests (35%). The rest of the area is developed open space areas, low intensity developed areas, and open waters. A variety of crops such as winter wheat, alfalfa, corn, cotton, oats, and rye, are cultivated in small portions of the land (Figure 6). Winter wheat is the main farming crop in the area covering about one percent of the study area (USDA, 2016). Table 2 shows the brief characteristics of land use in the study area. The extended table can be found in Appendix A (Table A.1).

Table 2: Summary of Land Use / Land Cover Distribution in the Study Area (USDA, 2016)

Land Use / Cover	Area (km^2)	Percentage
Barren	0.64	0.1
Deciduous Forest	302.97	35.1
Developed Area	39.21	4.54
Fallow/Idle Cropland	0.8	0.1
Grassland/Pasture	500.197	57.9
Open Water	6.09	0.7
Other Hay/Non-Alfalfa	3.66	0.4
Winter Wheat	8.96	1.0
Other	1.35	0.16

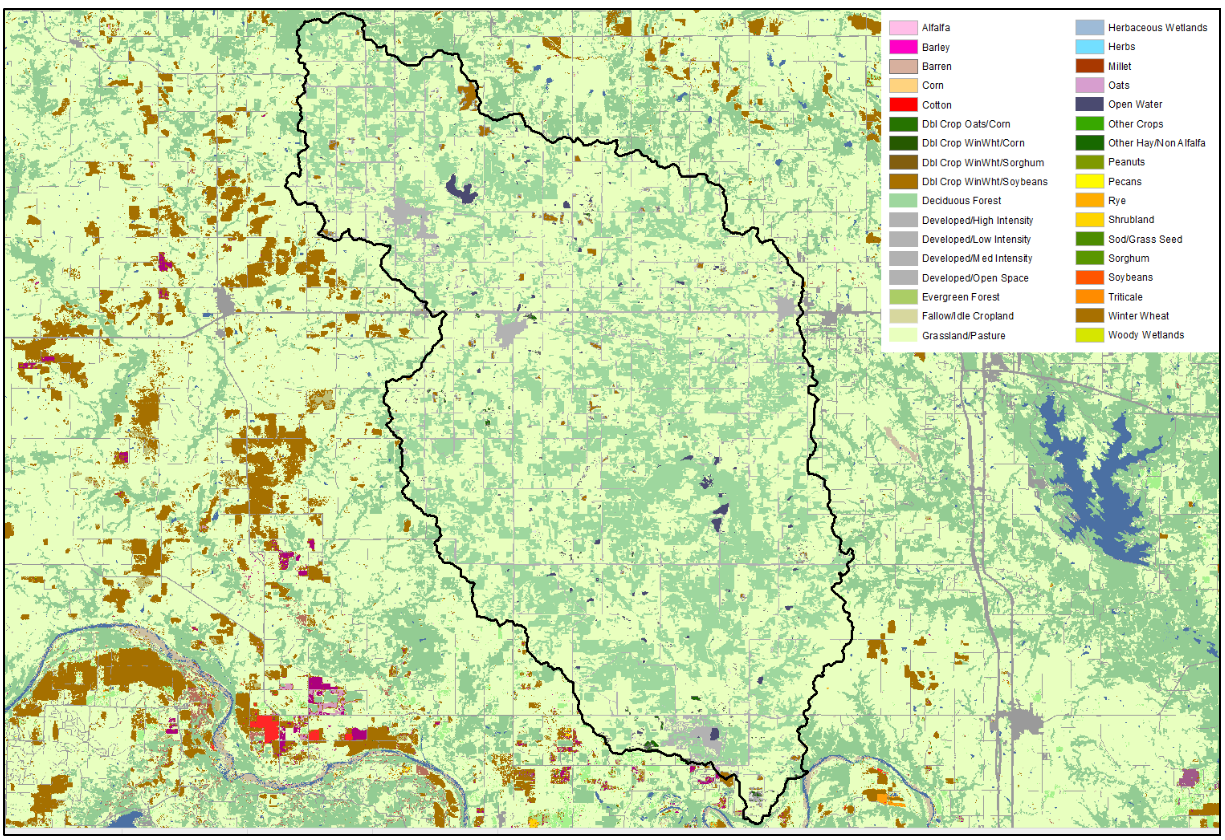

Figure 6: Crop Data Layer Map of the Study Area (Created on ArcGIS, 2019)

Climate

The average annual precipitation is between 91 and 99 mm. The maximum average monthly precipitation, calculated using data from 1971 to 2000, is about 13 mm in May (Oklahoma Climatological Survey, n.d.). The average annual temperature varies between 28.5ºC in July to about 5ºC in January (Oklahoma Climatological Survey, n.d.). Table 3 shows the simulated climate characteristics of the HUC12 watersheds from 1963 to 2010 using Hydrologic and Water Quality System (HAWQS, n.d.).

Table 3: Climate Condition of the HUC12 Sub-Watersheds in the Study Area (HAWQS, n.d.)

HUC	Area (km^2)	Dominant Land Use	Soil	Slope (in m/m)	CN	Precipitation (in mm/yr)	ET (in mm/yr)
111302010601	122	Grassland, Forest	*SL-SCL	0.03	60	896.6	615
111302010602	81	Grassland, Forest, Hay	*SL-SCL	0.03	60	911.9	620
111302010603	137	Grassland, Forest, Hay, Winter Wheat	*SL-SCL	0.03	60	901.7	605
111302010604	48	Grassland, Forest, Hay	*SL-SCL	0.03	61	904.2	610
111302010605	112	Grassland, Forest	*SL-SCL	0.028	60.8	904.2	620
111302010606	99	Grassland, Forest	*SL-SCL	0.03	52	894.1	617
111302010607	98	Grassland, Forest, Hay	*SL-SCL	0.03	53	904.2	627
111302010608	93	Grassland, Forest, Hay	**S/SL-SCL	0.029	63	909.3	627
111302010609	73	Grassland, Forest, Hay	**S/SL-SCL	0.029	60	906.8	625

***SL-SCL: Sandy Loam (30cm) and Sandy Clay Loam (40-150cm)**

****S/SL-SCL: Sandy or Sandy Loam (30cm) and Sandy Clay Loam (40-150cm)**

Hydrologic Modeling

Hydrology is a study of the distribution and origin of water and the different phenomena from the earth's atmosphere to the earth's surface, and in the soil and rocks, as well as the relation and interaction of the water in these phenomena together (Meyer, 1917). A complete hydrological study includes data collection and analysis for all components, such as air temperature, precipitation, evaporation, and evapotranspiration. A general simulation using the Hydrologic and Water Quality System (HAWQS) and Soil and Water Assessment Tool (SWAT) models were completed, for a general idea of the regional hydrological processes in the watershed.

SWAT (Arnold, Srinivasan, Muttiah & Williams, 1998) is a numerical model used globally to simulate hydrology and water resources of a watershed. SWAT's ability to simulate hydrological processes under the impacts of water and land management practices and different climate forecasts has made it applicable in a wide variety of water resources studies (Abbaspour et al., 2007; Srinivasan, Zhang & Arnold, 2010). However, for a more accurate result the model needs proper calibration based on available observed data (Gassman, Reyes, Green & Arnold, 2007). HAWQS is an online water quantity and quality model based on SWAT.

As previously mentioned, USGS gauge 07315900 Walnut Bayou near Burneyville is the only streamflow gauge in the watershed. The daily flow data is available from the end of 1960 to 1971, with a four-year gap between January 1964 and September 1968. In order to simulate the general hydrological characteristics of the watershed, the HAWQS model was applied. Figure 7 compares the simulated flows of the model with recorded data at the outlet of the watershed for the period of 1968 to 1971.

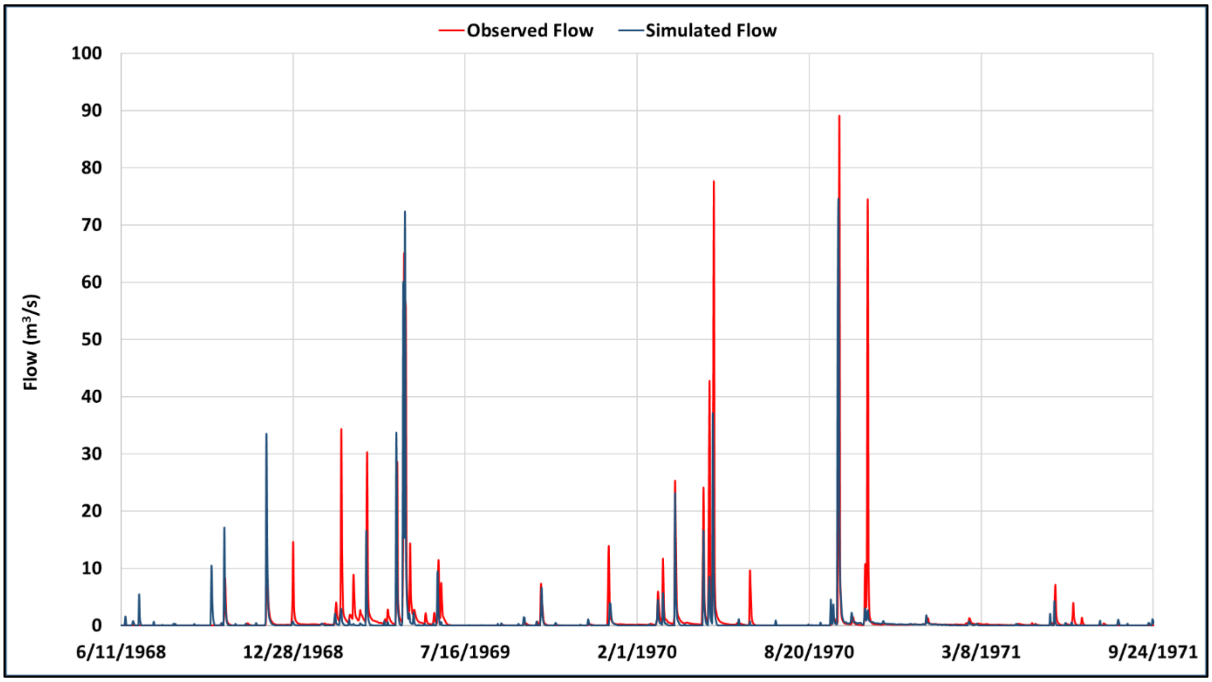

Figure 7: Comparing the HAWQS Simulated Flow and Observed Flow at USGS Gauge 07315900 (HAWQS, 2019)

Figure 7 shows that an uncalibrated HAWQS model is able to simulate the hydrology of the watershed in a fairly acceptable way. However, it failed to simulate six events, as seen by absent peaks in the figure. This shows that in this stage, the HAWQS results should be used with discretion. More accurate models such as SWAT should be applied after calibration and validation to get reliable results for the next stages of the plan. Figure 8 shows the results of an outflow simulation from 1963 to 2010. According to the USGS gauge data, the highest flow in the basin is 89 m^3/s on the 24th of September, 1970. The uncalibrated HAWQS model estimates much higher flows during the modeled time periods.

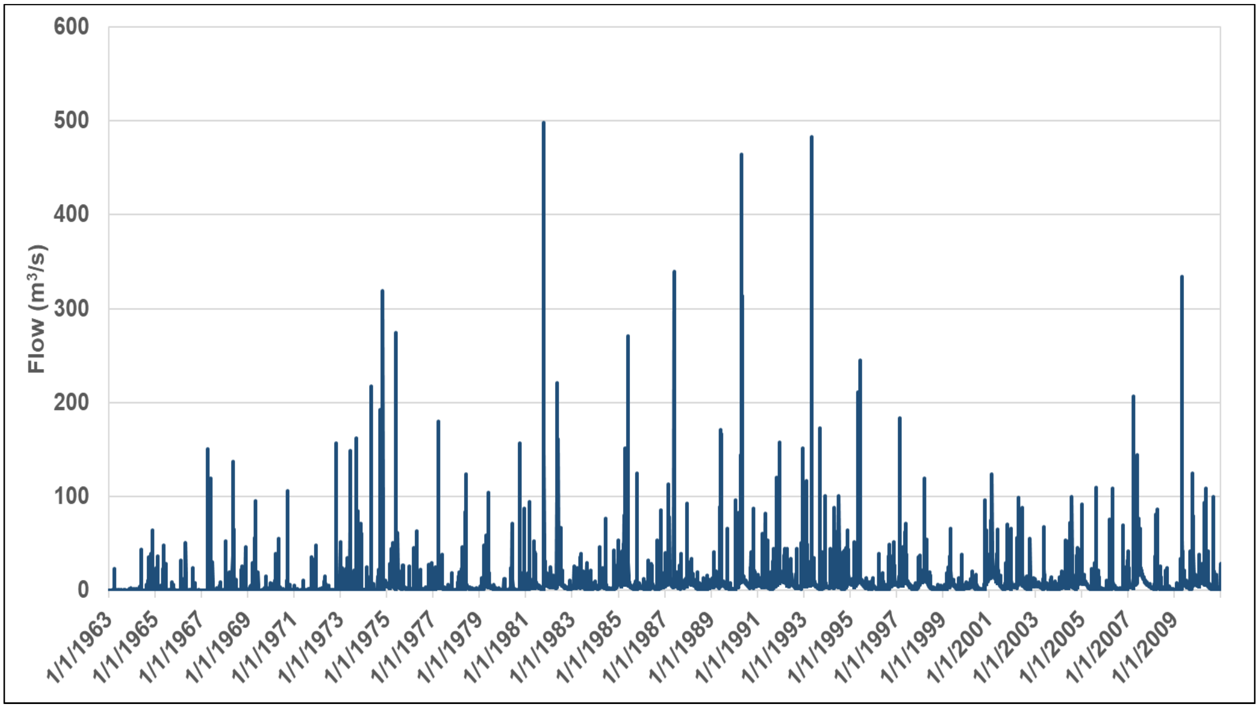

Figure 8: HAWQS Flow Simulation for the Outflow of the Walnut Bayou Watershed (1963-2010) (HAWQS, 2019)

Figure 9 shows the monthly average rainfall-runoff events in the study area based on information from USGS gauges and average monthly precipitation reported at the county websites (USGS, n.d.; Oklahoma Climatological Survey, n.d.).

The successful simulation of the hydrology of the watershed depends on applying detailed information and data on weather parameters, field measurements, point sources, management operations and activities such as irrigation, fertilization, grazing, and harvest along the watershed. A reliable model should reproduce results that are comparable with the field data. However, to provide a suitable proof of concept, a SWAT model of the watershed is developed and calibrated, using available data. The results are shown in Appendix A. (Figures A.1 to A.6).

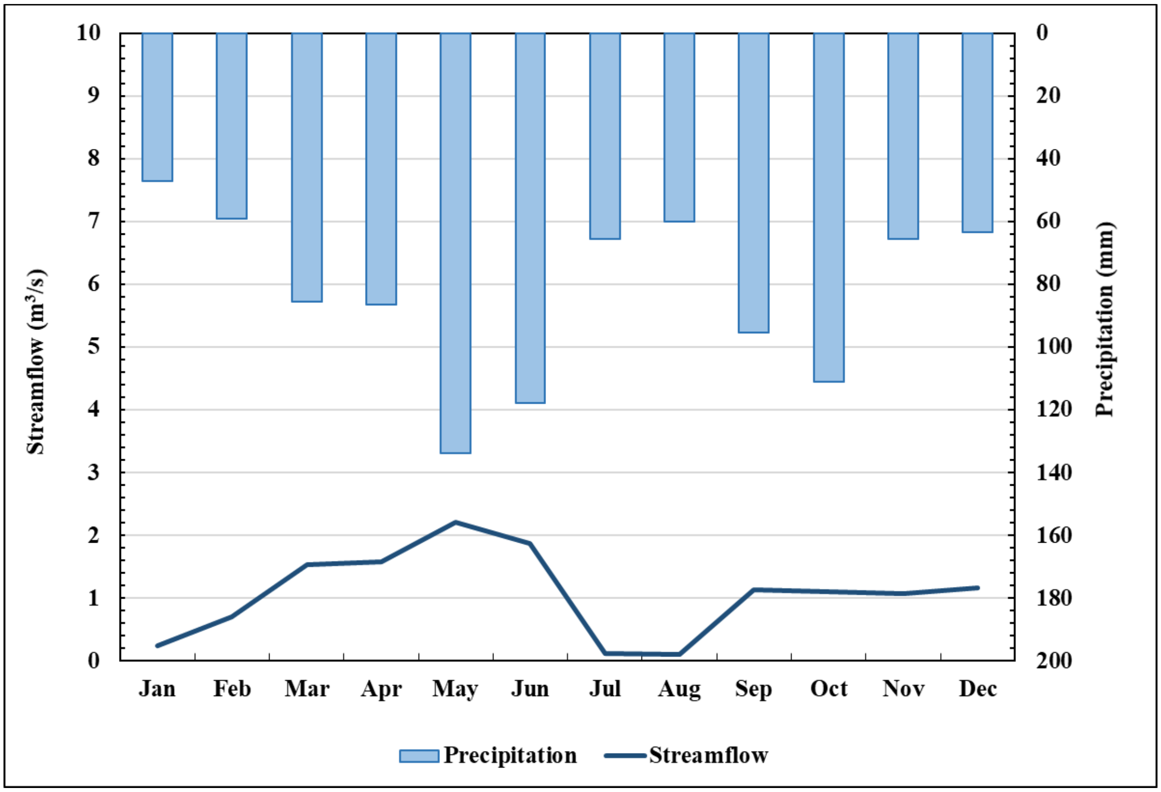

Figure 9: Monthly Variations of Precipitation and Streamflow in the Walnut Bayou Watershed (Created on Excel, 2019)

The SWAT results are aimed to demonstrate the modeling applicability for the purposes of the project and should be used considering the following limitations:

- The model is only calibrated for daily outflow based on available data. It needs to be calibrated and validated for more current streamflow, sediment transport, and water quality records.
- The weather data used for the current model is based on SWAT database. Applying the more updated data from stations in the study area would increase the final results accuracy.
- The fertilization application in the area is estimated using the auto-fertilization function and the general information from USDA office at Love County and Carter County, Pauls Valley Technical Service Office, and Oklahoma Cooperative Extension. Detailed information such as the type and schedule of fertilizers application in each farm will increase the reliability of the final results.

- Simulating the sources of impairment and the area affected by it requires detailed input data such as location of sources and rates of discharge.

County Demographics

The two counties of the study area are located in southern Oklahoma. Love County is 1,377.87 km^2 (okcounties.org, n.d.) and borders Texas. It had a population of over 10,000 in 2017 (U.S. Census Bureau, n.d.). Carter County is 2,160.05 km^2 and is the county north of Love County, with a population of 48,190 in 2017 (U.S. Census Bureau, n.d.; okcounties.org, n.d.).

Beneficial Uses

Beneficial uses are designated for all waters of the state and are protected through restrictions imposed by the anti-degradation policy statement, narrative water quality criteria, and numerical criteria (OWRB, 2015a). The specified beneficial uses for the waterbodies in the study area are found in Appendix A (Table A.4.) include (ODEQ, 2016b):

- Aesthetics (AES)
- Agriculture (AG)
- Habitat Limited Aquatic Community
- Fish & Wildlife Propagation (FWP)
- Warm Water Aquatic Community (WWAC)
- Fish Consumption (FISH)s
- Navigation
- Primary Body Contact Recreation (PBCR)
- Secondary Body Contact Recreation (SBCR)
- Public and Private Water Supply (PPWS)

Sources and Causes of Pollution

Sources of Pollution

Sources of water pollution can either be point or nonpoint. The 2016 Water Quality in Oklahoma - Integrated Report listed the potential sources of pollution for the impaired waterbodies in the study area and their associated codes as outlined by the EPA in Table 4 (ODEQ, 2016b; EPA, 2016).

Table 4: Unconfirmed Potential Sources of Impaired Waterbodies (ODEQ, 2016b; EPA, 2016)

Potential Sources	**Definition**
39	Drought-Related Impacts
46	Grazing in Riparian or Shoreline Zones
92	On-Site Treatment Systems (Septic/Similar Decentralized Systems)
108	Rangeland Grazing
136	Wildlife Other than Waterfowl
140	Source Unknown

Point Sources

A point source is defined as single, confined and identifiable source of pollution, such pipes or drains related to industries, municipalities or other discharges of pollutants that directly enter a waterbody (EPA, n.d.). Point source discharges are allowed and regulated through ODEQ according to the National Pollutant Discharge Elimination System (NPDES) of the EPA (EPA, n.d.). NPDES-permitted facilities that empty refined wastewater in Oklahoma are currently needed to monitor for fecal coliform and total suspended solids (TSS) in accordance to their permits (Brooks, Ffolliott & Magner, 2013; ODEQ, 2016a)

The major municipalities around the Walnut Bayou Watershed are Burneyville and Marysville. There is one OPDES-permitted facility in the Walnut Bayou Watershed with no discharges to the waterbody (ODEQ, 2016a).While the no-discharge facility (Table 5) does not discharge wastewater directly into the watershed, it is conceivable that the collection system related to the facility may be a source of bacteria loading to surface waters. EPA has also identified concentrated animal feeding operations (CAFOs) as potentially significant sources of contamination when they lack proper management and have the potential to cause serious impacts on water quality (ODEQ, 2016a).

Table 5: OPDES No-Discharge Facility in Walnut Bayou Watershed (ODEQ, 2016a)

Facility	Facility ID	County	Facility Type	Type	Watershed
Falconhead Prop. Owners Association	S11104	Love	Lagoon (Total Retention)	Municipal	Walnut Bayou

Non-Point Sources

NPS pollution is often called diffuse pollution and refers to the inputs and impacts which happen over a wide area and are not easily attached to a single source (EPA, n.d.). They are often affiliated with particular land uses as opposed to individual point source discharges (OCC, 2009). First, the relatively homogeneous land use/cover categories throughout the watershed are associated with rural agricultural, forest and range management activities which have influenced the origin and pathways of pollutant sources to surface water (ODEQ, 2016a).

Agricultural activity includes the cultivation of winter wheat in a small portion of the area. In Oklahoma, winter wheat is generally cultivated using different methods. These methods include graze-grain, graze-out, and grain only. In almost all methods, fertilizers are applied to the soil twice during the growing season, before and after planting. The fertilizer before planting season has a combination of 46, 0, and 0 percent of N, P, and K, respectively. After planting season, the fertilizer changes to a combination of 32, 23 and 0 percent of N, P, and K, respectively. Herbicides such as Chem-Surf 90, Quelex, and Olympus are also used at least once (Turner, et al., 2017). In the rangelands, applying fertilizers is the most common management operation. Herbicides are especially used in introduced-forage pastures (Bidwell & Woods, n.d.). Appendix A (Table A.5.) shows the amount of Nitrogen resulted from HAWQS run for all subbasins.

Second, the concentration levels of fecal coliform bacteria that were measured in the water quality data collected from streams draining urban communities are often greater than water quality standards for a state (ODEQ, 2016a). Runoff from urban areas that do not have operating permission of the MS4 program (stormwater discharges from municipal sources) can be a considerable source of fecal coliform bacteria (ODEQ, 2016a).

Based on data collected by ODEQ (2016a), turbidity that is estimated using TSS may emanate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks. General information on bacteria and/or TSS loading associated with NPS within the watershed is presented in Tables 6-9 (ODEQ, 2016a). The potential NPS for bacteria were analyzed according to the fecal coliform load produced in the sub-watersheds (ODEQ, 2016a). In this report, the NPS that were considered for bacteria were: wildlife (deer), non-permitted agricultural activities and domesticated animals, pets (dogs and cats), and Failing Onsite Wastewater Disposal (OSWD) systems and illicit discharges.

- Wildlife

A significant source of fecal coliform bacteria found in streams is represented by warm-blooded animals, including wildlife such as mammals and birds (ODEQ, 2016a). Fecal coliform can be added to waterbodies from the defecation of animals with direct access to the riparian zone or when runoff washes over the feces and carries the contaminants into the waterbody (ODEQ, 2016a). However, due to the lack of data for wildlife and avian populations, the amount of bacteria loading from wildlife was estimated as a general type (ODEQ, 2016a).

The Oklahoma Department of Wildlife and Conservation's (ODWC) county data provided a rough estimation of the deer population for study area. Only a portion of the total fecal coliform loading produced by the deer population actually enters a waterbody (ODEQ, 2016a). The estimated population and fecal coliform production for deer in Walnut Bayou Creek Watershed is illustrated in Table 6.

Table 6: Estimated Population and Fecal Coliform Production for Deer (ODEQ, 2016a)

Waterbody ID and Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 109 cfu/day) of Deer Population
OK311100010250_00 Walnut Bayou	21,376	201	0.0094	101

- Non-Permitted Agricultural Activities and Domesticated Animals

Some non-permitted agricultural activities occur in the watershed that can be concentrated sources of bacteria loading, or create unstable stream banks that result in increased TSS loading (ODEQ, 2016a). The agricultural activities typically associated with livestock operations are of greatest concern (Drapcho & Hubbs, 2002; ODEQ, 2016a). These activities include: using farm animal manure as fertilizer; grazing animals in pastures and leaving their feces on land surfaces; allowing direct access for animals to open waterbodies (ODEQ, 2016a).

Using the 2012 U.S Department of Agriculture's (USDA) (2012) county agricultural census data, a rough estimate of numbers for commercially raised farm animals, as well as the area where manure was applied, was determined. The estimates are presented in Table 7.

Table 7: Commercially Raised Farm Animals and Manure Application (ODEQ, 2016a)

Waterbody ID and Name	Cattle	Dairy Cows	Horses	Goats	Sheep & Lambs	Hogs & Pigs	Chickens & Turkeys	Ducks & Geese	Acres of Manure Application
OK311100010250_00 Walnut Bayou	1,547	3	153	59	10	15	51	1	54

Adequate information to describe or quantify the relationship between in-stream concentrations of bacteria and land application or defecation, as well as the contributions of sediment loading coming from destabilized stream banks or eroded pasture fields by commercially raised farm animals, was not available at the time of this WBP. For the purpose of the TMDLs presented here, land application of commercially raised farm animal manure is mentioned as a potential source of bacteria loading to the watershed (ODEQ, 2016a).

Table 8 illustrates fecal coliform production from each group of commercially raised farm animal in the Walnut Bayou Creek (OK311100010250), henceforth referred to as WB-250. This was estimated using the calculated animal populations and fecal coliform production rates from ODEQ (2016a). Only a small portion of the fecal coliform, introduced directly by deposition or washed into the waterbody by runoff, are expected to contribute bacteria loading (ODEQ, 2016a).

Table 8: Estimated Fecal Coliform Production for Commercially Raised Farm Animals in WB-250 x109 number/day (ODEQ, 2016a)

Waterbody ID	Cattle	Dairy Cows	Horses	Goats	Sheep	Pigs & Hogs	Chickens & Turkeys	Ducks & Geese	Total
OK311100010250_00	160,888	303	64	708	120	162	7	2	162,255

- Domestic Pets

Fecal matter from dogs and cats, which can be transported to streams by runoff from urban and suburban areas, is another potential source for bacteria loading. The estimated number of pets using the U.S. Census data at the block level (U.S. Census Bureau, 2010) showed that 179 dogs and 202 cats are found within the urban areas of WB-250.

- Failing On-Site Wastewater Disposal (OSWD) Systems and Illicit Discharges

OSWD systems and illicit discharges can be a source of bacteria loading to waterbodies. Bacteria loading from failing OSWD systems can be carried to streams through groundwater or runoff from surface ponding. Fecal coliform-polluted groundwater may discharge to streams through springs and seeps (ODEQ, 2016a). It is estimated that areas with more than 15.44 OSWD systems per square kilometer have potential pollution problems (Canter & Knox, 1986; ODEQ, 2016a). An estimation of sewered and unsewered households and the average number of septic tanks per square kilometer of the WB-250 is summarized in Table 9.

Table 9: Estimated Sewered and Unsewered Households (ODEQ, 2016a)

Waterbody ID and Name	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	# of Septic Tanks / Mile2
OK311100010250_00	Walnut Bayou	27	57	2	86	2

According to the reported concentrations from various publications (Metcalf & Eddy 1991; Canter & Knox, 1985; Cogger & Carlile, 1984), concentrations of fecal coliform in septic tank effluent was estimated to be 106 per 100 mL of effluent. There are 147 septic tanks in WB-250, of which 18 have failed or do not work well. The load from failing septic systems within WB-250 is estimated approximately 100 billion counts per day.

Causes of Pollution

WB-250 and Healdton Municipal Lake are the only two waterbodies in the Walnut Bayou Watershed that are impaired and listed on the 303(d) list, according to the Clean Water Act. WB-250 is impaired for bacteria (Enterococcus), and DO, while Healdton Municipal Lake is impaired for turbidity (ODEQ, 2016b; OCC, 2014). Table 10 illustrates the impaired uses and the causes of impairment of WB-250 and Healdton Municipal Lake (ODEQ, 2016b).

Table 10: Causes of Impairment and Impaired Uses (ODEQ, 2016b)

Waterbody ID and Name	WB Size	WB Category	Cause Category	Impaired Use	Cause of Impairment	TMDL Priority
OK311100010250_00 Walnut Bayou	17.41 (km)	5a	5a	WWAC	Oxygen, Dissolved	4
			5a	PBCR	Enterococcus	4
OK311100030130_00 Healdton Municipal Lake	1.5 (km^2)	5a	5a	WWAC	Turbidity	4

Walnut Bayou Watershed has no continuous, permitted point source with respect to bacteria. Therefore, NPS of bacteria are the expected cause of impairment for PBCR use (ODEQ, 2016a). The agricultural NPSs previously listed are likely to be the main contributor to bacteria loading (ODEQ, 2016a). The other major NPS categories in WB-250 include commercially raised farm animals, pets, deer, and septic tanks. It has been estimated that commercially raised farm animals are the main source (99.45%) of fecal coliform load in WB-250. The estimated loads caused by pets, deer and septic tanks are 0.43, 0.06 and 0.06 percent respectively (ODEQ, 2016a). Permitted construction activities in the watershed contribute to some TSS loading. NPS of TSS is likely to be the cause of impairment with respect to WWAC use. Sediment loading into streams can result from natural erosional processes, such as weathering of soils, rocks, and uncultivated lands from geological abrasion (ODEQ, 2016a). TSS or sediment loading can also occur during non-runoff conditions as a consequence of anthropogenic activities in riparian corridors, which lead to erosive conditions (ODEQ, 2016a). Due to insufficient data for establishing the background conditions for TSS/turbidity, separating background loading from NPS due to natural or anthropogenic sources is not possible when developing TMDLs (ODEQ, 2016a).

Load Reduction Criteria

According to the Water Quality in Oklahoma 2016 Integrated Report (ODEQ, 2016), a completed and finalized TMDL report has not been created for WB-250, Healdton Lake, or any part of the Walnut Bayou Watershed. According to the 303(d) List of Impaired Waters the TMDLs for the waterbodies of the Walnut Bayou Watershed are a priority level 4. This means that they are not scheduled for data collection until 2025 and monitoring will begin once completed in 2027. A draft was created for 303(d) waterbodies in the Red River Drainage Basin that are impaired by bacteria and/or turbidity, only. Therefore, the criteria for load reduction for dissolved oxygen is based on current knowledge of pollutant levels within the waterbodies and attainment designations, both of which were determined and outlined by the OCC (2017). The 2016 Bacterial and Turbidity TMDL Draft Report for Streams in the Red River Area were used to determine the load reductions for bacteria and turbidity (ODEQ, 2015).The load reductions below will reflect criteria to attain designated beneficial uses of impaired waterbodies. Currently WB-250 is not supporting PBCR and WWAC, while Healdton Lake is not supporting WWAC (ODEQ, 2016b).

For implementation and management scheduling purposes, the load reductions will be measured over two cycles, each consisting of five years. In each of these cycles, the load reduction will be expected to achieve a 60 percent improvement based on the recommended total load reduction by the end of cycle 1, and the remaining 40 percent of the total by the end of cycle 2. A summary of the total load reductions and the targets at the end of both cycles can be found in Table 11. The table summarizes the expected load reduction for each impairment, in the Walnut Bayou Watershed where R_T is the total reduction expected at the end of a ten year mitigation schedule; 60-R_T is the expected total after cycle 1; and 40-R_T is the expected total after cycle 2. The table is broken down to compare R_T as an amount and percent, followed by 60-R_T as both an amount and percent, and finally 40-R_T as both an amount and percent. *Note that DO is a load reduction, despite the value increasing. Low DO implies poor water quality and increasing it is understood as an improvement. Therefore, it appears as a negative value in the Table 11.

Table 11: Target Load Reduction Breakdown for the Walnut Bayou Watershed

Waterbody	Impairment	STD Value	Unit	Current Value	Target	Reduction Total (R_T)	Reduction Total (R_T) as a percent	Cycle 1 Target 60-R_T	Cycle 1 Target 60-R_T as a percent	Cycle 2 Target 40-R_T	Cycle 2 Target 40-R_T as a percent
WB-250	DO	5 to 6	mg/L	1.20	6.10	-4.90	-408.00	-2.94	-244.80	-1.96	-163.20
	ENT	<33	cfu/100mL	112.00	29.68	82.32	73.50	44.00	49.39	32.93	29.00
Lake Healdton	TSS	25	NTU	29.00	22.00	7.00	24.00	4.20	14.48	2.80	9.66

WB-250 has two water quality monitoring stations along its length according to the ODEQ (2015). One station (311100030010-001AT) is located in the northern portion of the WB-250 waterbody, while the other station (OK311100-03-0010G) is located in the southern portion. The two stations are on opposing sides of the Falconhead Airport-37K. The stations will henceforth be referred to as WB-250-01AT and WB-250-10G, respectively.

Dissolved Oxygen

To determine if a waterbody has attained beneficial use with respect to DO, the ODEQ (2016b) states that a minimum of ten samples must be collected and analyzed from the waterbody. Of the samples collected, at least 90 percent of the samples must have a DO concentration greater than 6.0 mg/L between the 1st of April and the 15th of June and greater than 5.0 mg/L from the 16th of June to the 31st of March for WWAC, which is considered a subcategory of FWP use (ODEQ, 2015).

In 2017 the OCC determined that WB-250-10G had a DO measurement of 7.9 mg/L, equating to 80.89 percent saturation, for most of the year. However, 16 percent of the samples were found to have low DO, preventing WB-250 from attainment with respect to DO. Table 12 provides the low DO levels observed by the OCC (2017), which were collected in 2014.

The total load reduction target for DO, based on the last sample date provided by the OCC (2017), is to increase levels by a total of 408 percent of the last measurement within ten years. The last measurement provided, shown in Table12, was 1.2 mg/L and should be brought up to the more stringent requirement of 6.1 mg/L to account for the attainment during the recreational period (1st of April to 15th of June). To achieve this based on two five-year cycles, the overall total increase (408%) will be divided into a 60 percent goal and a 40 percent goal. In the first five-year cycle, the DO should increase 244.8 percent (2.94 mg/L). In the second five-year cycle, the DO should increase by 163.2 percent (1.96 mg/L).

Table 12: DO Sample Levels in the Third Monitoring Cycle of 2014 (OCC, 2017)

% Samples with Low DO	Site Name	WBID	Date	DO
16%	Walnut Bayou	OK311100-03-0010G	6/3/2014	4.48
			7/14/2014	2.61
			9/8/2014	1.2

Enterococcus

The ODEQ (2015) determined the geometric mean of ENT to be 112 colonies/mL. According to the OCC no ENT sampling had been conducted in their 2017 report. For PBCR purposes, the ODEQ (2016b) determined that for a waterbody to attain beneficial use with respect to ENT a minimum of ten samples must be collected and analyzed. Further the samples must be taken during the designated recreational period (1st of May to the 30th of September). The waterbody must have a geometric mean that does not exceed 33 colonies/100 mL.

The ODEQ (2015) determined that in 2013 the ENT concentration for WB-250 had a geometric mean of 112 colonies/100 mL. The necessary load reduction has been determined to be 73.5 percent (82.32 colonies/100mL) in ten years. The mid-term evaluation after the first cycle would see a reduction of 44 percent (49.39 colonies/100 mL) of the total load reduction, followed by a reduction of the remaining 29 percent (32.93 colonies/100 mL) in the second five-year cycle.

Turbidity

For a waterbody to attain a beneficial use designation with respect to turbidity, the ODEQ (2016b) determined that at least ten samples must be collected and analyzed during seasonal base flow conditions. Of the samples collected, the ODEQ (2016b) has determined that measurements cannot exceed: 25 Nephelometric Turbidity Units (NTUs) and 50 NTUs for lakes and other surface waters, respectively. With respect to FWP, a waterbody is considered to have attained beneficial use with respect to turbidity if ten percent or less of the samples collected exceed the screening levels set forth above; or if the criteria are determined to be fully supporting but threatened, and are not expected to yield another determination other than fully supporting within two years of the initial determination.

Based on the 303(d) List of Impaired Waters created by the ODEQ (2016b), Healdton Municipal Lake (OK311100030130_00) is considered impaired with respect to turbidity. According to the Oklahoma Water Resource Board (OWRB) (2015), out of four site visits between November 2005 and August 2006 the average turbidity for Healdton Lake was 29 NTUs, where 100 percent of the samples exceeded the attainment level of 25 NTUs for lakes.

The target for TSS load reduction should be to attain approximately 22 NTUs based on the targets set by ODEQ (2016b; 2015) for other waterbodies. This would require a load reduction of approximately 24 percent (7 NTU) in the designated ten-year mitigation period. To achieve this, the lake should see a reduction of 14.5 percent (4.2 NTU) in the first cycle, followed by the remaining 9.7 percent (2.8 NTU) in the second cycle.

Management Measures

In order to address and achieve the desired pollutant reduction, Best Management Practices (BMP) should be implemented. These practices are tools that, when properly implemented over time, should result in lower contamination levels that meet WQS set by federal, state and tribal government bodies (Hoorman & McCutcheon, n.d.; SARE, 2012). The BMPs identified below were chosen based on feasibility, effectiveness and common sense practices while trying to curb the negative impacts on surrounding agriculture and development. The BMPs for the Walnut Bayou Watershed were prioritized and separated into several major categories:

1) Riparian Buffer Zone Restoration Efforts
2) Grazing and Agricultural Management
3) Erosion Control

The focus of these three categories is to reduce contaminant loading that has resulted in low DO, high ENT and TSS levels, which have impaired WB-250 and Lake Healdton. The plan will subsequently limit the amount of other contaminants that have found their way into the waterbody, preventing future impairments that may have otherwise have occurred without BMP implementation.

Performance Standards should be set by stakeholders before implementation. The purpose of the PS, considered as a general BMP, is to establish the criteria for the plan's monitoring and reporting of mitigation activities. The PS will also set the standard of how the degree of success will be measured for all impairments, and will set a standard to determine if the site has achieved the desired outcomes (Hoorman & McCutcheon, n.d.; Harman, Starr, Carter, Tweedy, Clemmons, Suggs & Miller, 2012). The PS should include the standard mitigation monitoring expected over the ten year mitigation period. They will follow a schedule similar to the load reductions discussed in the previous section. This means the monitoring will occur during two cycles, each with a desired implementation amount (Harman et al., 2012). The first cycle is a five-year cycle that will see a 60 percent implementation of BMP with the purpose of meeting load reduction targets. The second cycle is another five-year cycle that will see the remaining 40 percent of the BMPs installed and working, which should lead to the planned target reduction a few years after completion.

Riparian Buffer Zone Restoration Efforts

A riparian buffer zone is the last line of defense for any riparian area (N.K. Coch, personal communication, November 2016). There are several ecosystem services that a riparian buffer provides in order to help a waterbody remain healthy. First, they trap sediments that would otherwise increase turbidity and remove contaminants that flow into the waterbody due to surrounding land use. Second, they provide necessities to wildlife such as food, shelter, nesting areas and travel corridors. Third, they provide shade for terrestrial and aquatic life. Finally, they help reduce the effects of NPS on the waterbody (OCES & OSU, 1998; N. K. Coch, personal communication, November 2016; Harman et al., 2012).

OCES and OSU (1998) have created guidelines for consideration with regards to the planning and creation of riparian buffers in order to maximize effectiveness and success. Their guidelines suggest a three zone system, each of specific widths to allow optimal pollution removal and streambank protection, while being made of certain vegetation. The report suggests a total minimum width of 28.96 m, broken down into 4.57, 18.29, and 6.10 m, respectively. An example of a 3 Zone buffer system can be found in Figure 10. The guidelines set forth by OCES & OSU (1998) detail the purpose and vegetation for each zone as follows:

- ***Zone 1*** is an area 4.57 m wide that should be undisturbed to allow for natural ecosystem function. This zone will lower stream temperature by shading the water and will provide a soil/water interface to encourage the removal of pollutants (Hoorman & McCutcheon, n.d.; Chesapeake Bay Foundation, n.d.; Harman et al., 2012; OCES & OSU, 1998). The vegetation in Zone 1 should be predominantly a species that will allow the riparian system to stabilize (Nagal, 2015; OCES & OSU, 1998). This should include native species to the area, such as historically planted trees (OCES & OSU, 1998). The width of Zone 1 will be measured from the edge of the streambank and measured in the direction of overland flow.

- ***Zone 2*** is the intermediate area and will create an area for nutrient storage in trees (Nagal, 2015; OCES & OSU, 1998). It should be a minimum width of 18.29 m. It is also production zone, creating the carbon source for the ecosystem to work properly (OCES & OSU, 1998). Like Zone 1, this zone should be predominantly species that help stabilize the area. It is suggested that this vegetation include deciduous trees because it improves the production potential of the area. It is also suggested to plant evergreens because they continue to be productive through the winter (OCES & OSU, 1998).
  - ***Zone 3*** should be a minimum of 6.10 m and is where runoff is controlled. This zone should be predominantly made of dense grasses and forb (Nagal, 2015; OCES & OSU, 1998).

Using the same cycle system used in the load reductions, the implementation of the buffer should be 60 percent completed by the end of the first five-year cycle, and the remaining 40 percent by the end of the second cycle. By the end of the first cycle, 11.58 m of the minimum 28.96 m three zone buffer should have proper vegetation and management practices being conducted. This 11.58 m area covers the entirety of Zone 1 and 7.01 m (38.3%) of Zone 2. In the second cycle, the remaining total of 17.37 m will be built to reflect proper buffer zone management. This will cover the remaining 11.28 m (61.7%) of Zone 2 and the entirety of Zone 3's completion.

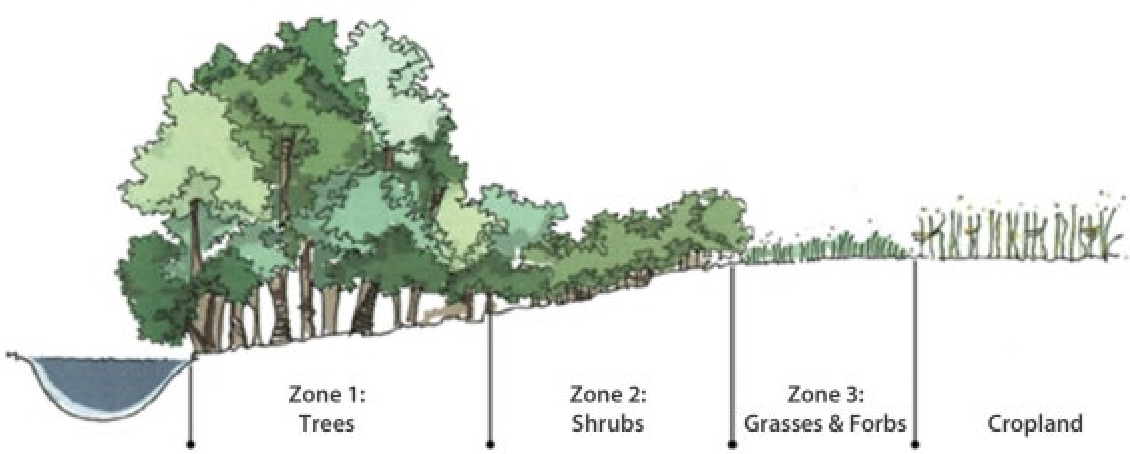

Figure 10: A 3-Zone Riparian Buffer (Lara Nagal, 2015)

In order to prevent these areas from harm, to maximize their beneficial potential, the following practices are suggested:

1) ***Fencing for riparian and shoreline management***

Cattle that are allowed to roam and graze will gravitate towards waterbodies for both shade and water (Hoorman & McCutcheon, n.d). Their constant presence within the riparian zone causes several problems if allowed in excess. Overgrazing of vegetation along the stream banks decreases the riparian zone's ability to filter and trap pollutants that are introduced to the waterbody with runoff (N. K. Coch, personal communications, November 2016; Hoorman & McCutcheon, n.d; Chesapeake Bay Foundation, n.d.). The heavy weight and movement of the cattle can cause compaction of soil and increased erosion along the stream banks (Hoorman & McCutcheon, n.d), especially during wet conditions. By creating fencing at the border of the buffer system, the cattle-created pollution, erosion, and spread of waterborne bacteria from fecal matter will decrease as the buffer grows and provides its services (Chesapeake Bay Foundation, n.d.).

For sensitive areas that require fencing, an alternative option could be the use of natural fencing. This can include rocks, boulders or even hedges and trees that are placed along the stream bank outside the determined riparian buffer zone (Hoorman & McCutcheon, n.d; Nagal, 2015). The natural fencing will still prevent livestock from wandering too close to the waterbody. Dependent on the type of natural fence chosen, it may also provide shading for the livestock away from the buffer area.

2) ***Vegetative rehabilitation and establishment***

The presence of vegetation in the riparian buffers will help reduce the presence of both sediment and bacteria from fecal matter being loaded into the waterbody. Utilizing riparian buffer strips, and introducing woody or grassy vegetation along the streambank in the riparian buffer zone can help reduce eutrophication, temperature extremes, bank instability and erosion (Hoorman & McCutcheon, n.d). The woody species are a good addition to vegetative rehabilitation and establishment because strips are usually very adaptable to varying climates and thrive in areas where vegetation can survive year-round (EPA, 1996).

Grazing and Agricultural Management

1) *Fencing for rotational grazing system*

Shortening the time period that cattle have to graze on an area of land will allow plants to regrow leaves and re-establish roots (SARE, 2012). This constant presence of food will prevent the cattle from needing to enter the riparian area, reducing the presence of fecal matter and erosion potential. Although some farmers will argue that this method is expensive and takes the land next to the riparian area out of production, it has been proven that when managed properly, rotational grazing can reduce the impacts caused along and within streambanks and waterbodies (Hoorman & McCutcheon, n.d.). By the end of the first cycle, 60 percent of the area should be implementing this BMP, while the remaining 40 percent of land should be implementing it by the end of the second cycle. Neighboring farmers are not required to implement it at the same time; the 60 and 40 percent is a watershed-wide amount and therefore the fencing can be semi-sporadic based on property lines prior to the end of the ten-year plan. It is expected that there will be a lag time from when a farmer agrees to participate in rotational grazing to when the farmer is fully promoting and utilizing a proper rotational grazing system.

2) *Off-Stream Watering and Alternative Shade*

Cattle gravitate towards riparian areas due to the high availability of shade and presence of running water (Hoorman & McCutcheon, n.d.). The installation of water sources that are located away from the riparian area will prevent contamination and erosion. According to Hoorman and McCutcheon (n.d), livestock will choose to drink from an off-stream water trough 92 percent of the time when compared to the stream, resulting in a 77 percent reduction in streambank erosion and a 90 percent reduction of TSS. Hoorman and McCutcheon (n.d) also observed similar reductions in bacteria, nitrogen and phosphorus (as cited from Sheffield et al., 1997). Like the other BMPs, this will occur with 60 percent of the farmers building and using off-stream watering systems in the first cycle, and the remaining 40 percent in the second cycle.

3) Land Use

It is important to have cropland and pastures with rich soils that can continuously support vegetation that can be cultivated or grazed by livestock. Traditional farming and plowing leaves the soil exposed to the sun and heat, drying it out and increasing erosion potential by wind. Flash flooding is also possible with dry soils during quick and heavy rain events (N. K. Coch, personal communication, November 2016). The lack of organic matter also reduces the nutrients in the soil, decreasing productivity into the future. As with the previous BMPs, there should be a 60 percent increase in improved land use in the first five-year cycle, and a 40 percent increase in the second five-year cycle.

Cover crops help decrease nutrient loading through runoff by absorbing excess fertilizer that may have been left from a season's main harvest (Chesapeake Bay Foundation, n.d.). It helps to reduce runoff and erosion by sheltering the soil from the sun. It also helps create a layer of organic matter that can be eaten by livestock or that will die and release nutrients back into the soil (Chesapeake Bay Foundation, n.d; Hoorman & McCutcheon, n.d.; Harman et al., 2012).

Erosion Control

Streambank stabilization and restructuring

Steep slopes increase velocity and erosion of the waterbodies (N. K. Coch, personal communication, November 2016). Therefore, streambank stabilization may require the slope of the beds to be changed to a gentler slope. For slopes that require stabilization, it is expected that 60 percent of the impaired areas will have an effective, albeit adjusting, stabilization tool installed by the end of the first five-year cycle, and the remaining 40 percent in the second five-year cycle.

An alternate to lessening the slopes of a streambed include vegetative rehabilitation and establishment. Due to erosion caused by livestock, the introduction of vegetative species will help hold the soil together with the reach and structure provided by their roots (N. K. Coch, personal communication, November 2016), allowing for increased stabilization. It also decreases the velocity of runoff entering the waterbody and removes pollutants that flow with runoff.

Technical and Financial Assistance

Site specific conservation plans to install BMPs have to be developed for an effective reduction in pollution to see improvement in the water quality of the streams. In order to know the exact location for the application of BMPs, watershed-wide targeted studies (modeling and streambank stability) have to be carried out. A majority of the funding will be required for the installation of riparian buffer strips and land management practices. SWAT can be used to simulate the quality and quantity of surface and groundwater and predict the impact of land use, land management practices, and climate change. It is widely used in assessing soil erosion prevention and control, NPS pollution control and regional management in watersheds. The modeling can be used in assessing the major load contributions to the streams.

Cost Estimates for BMP Implementation

Funding for WBP in the U.S. is provided based on a cost-share-basis through government agencies. The cost-share rates are dependent on the purpose and the area it is intended for. Funding for the WBP is estimated based on the Grand Lake Watershed Plan (GLWAF, 2008), Stillwater Creek Watershed Implementation Project (OCC, n.d), and North Canadian River Watershed Based Plan (OCC, 2008). Inputs from the Lake of the Arbuckles Watershed Restoration Plan have also been taken into account. Table 13 lists the potential funds required for the WBP. However, this should be taken as an approximate estimation as the funding constantly changes throughout the implementation process.

Table 13: Estimated Funding Needs for the Walnut Bayou WBP

Task	Program	Total
Project Management	319 Project	$100,000
BMP Implementation	319 Project	$300,000
	EQIP	$70,000-$140,000 annually
Education and Outreach	319 Project	$200,000
Monitoring	319 Project	$50,000
	OCC, OWRB, Blue Thumb	$75,000 startup, and $25,000 annually
Computer Modeling	SWAT Project to target NPS pollution (OCC via OSU)	$200,000

An additional $250,000 will be required for updating the watershed plan after first cycle of five years. An overall estimate for the WBP is $2.825 million, based on 319 funding and adjusted for inflation based on our load reduction timeline of ten years. Various funding sources are available to landowners from federal, state and private assistance programs. In order to take advantage of the funding through various sources it is imperative for landowners to develop site-specific conservation plans and a beneficial working relationship with NRCS and OCC staff.

Potential Funding Sources

U.S Department of Agriculture/Natural Resources Conservation Services

Environmental Quality Incentives Program (EQIP)

EQIP is USDA's largest conservation program, which provides technical assistance and funding on a cost-share basis to farmers and ranchers for improvement in the quality of soil-, air- and water-related natural resources on their land. It is a voluntary program and the contracts' duration does not exceed the maximum of ten years (NRCS, n.d.). Table 14 lists the possible funding available through the Oklahoma EQIP funding program.

Table 14: Possible Funding for Implementation of BMPs through EQIP

Best Management Practice	Estimated Cost
Pond Construction	$10,000 maximum
Fencing	$1.02/ft
Riparian Field Border	$230.68/Ac
Riparian Forest Buffer	$94.92/Ac
Native Grass Filter Strip	$271.26/ Ac
Grassed Waterway	$1005.88/Ac
Farm Limited Riparian Control	$.16/LnFt
Streambank/Shoreline Shaping Protection	$10.69/LnFt
Wetland Creation	$3.10/CuYd
Water Tank (500-1000 gal)	$1,326.60
Basic Nutrient Management	$6.20/Ac
Steel Grade Stabilization Structure	$27.43/SqFt

Conservation Stewardship Program (CSP)

CSP provides technical and financial assistance for the conservation of, and improvement of, existing conservation systems on tribal and private working lands. It helps to develop a CSP for the improvement of grazing conditions, increasing crop yields and developing wildlife habitat (NRCS, n.d.). It provides funding on an annual scale for installation and maintenance of conservation activities, and the supplemental payment for adopting a resource-conserving crop (annually). Table 15 lists the possible funding through the Oklahoma CSP program.

Table 15: Possible Funding for Implementation of BMPs through CSP

Best Management Practice	Estimated Cost
Cover crop	$9.29/Ac
Pond	$0.46/CuYd
Stream Habitat Improvement and Management	$3274.04/Ac
Prescribed Grazing	$20.5/Ac
Watering facility	$0.11/ gal
Cover crop to reduce wind erosion	$7.92/Ac
Reduced tillage for water erosion	$3.89/Ac
Field border for water erosion along the edges of the field	$480.06/Ac
Increase riparian forest buffer width to reduce sediment loading	$1355.43/Ac
Extend filter strips to reduce excess sediment in surface water	$674.74/Ac
Manage livestock access to waterbodies to reduce pathogens in surface water	$2.13/ft
Grazing management for improvement and maintenance of riparian and watershed function erosion	$8.18/Ac

Regional Conservation Partnership Program (RCPP)

RCPP is a partnership-based program in which project partners apply for funding which is then distributed to private landowners. These conservation partners work with Natural Resources Conservation Service (NRCS) to help agricultural producers and forest landowners to implement conservation activities for the sustainable use of soil, water, and other natural resources. RCCP can be applied to any agricultural or non-industrial private forest land after USDA determines it as eligible and the practices would help in achieving the conservation benefits (NRCS, n.d.).

The eligible partners for this WBP include American Indian tribes, NRCS, OCC, Oklahoma Department of Agriculture, Food and Forestry, Oklahoma Forestry Services (ODAFF), agricultural or silvicultural producer associations, Oklahoma Association of Conservation Districts (OACD), Noble Research Institute and OSU (NRCS, n.d.).

Carter and Love counties in Oklahoma lie in the Prairie Grasslands Conservation Region, one of the most threatened ecosystems in North America according to USDA (n.d.). It is identified as Critical Conservation Area (CCA), and is eligible to receive 35 percent of the RCCP funding. Recent examples in Oklahoma that have used the RCCP include Elk City Lake Watershed RCCP project (OCC, n.d.) and Middle and Lower Neosho Basin RCCP project (OCC, n.d.) which address the water quality issues in the respective watersheds.

Agricultural Conservation Easement Program (AECP)

Through ACEP, NRCS provides technical and financial assistance to various partners to protect farmland and wetlands and limit the non-agricultural uses of the land by purchasing Agricultural Land Easements. It helps the ranchers, landowners, and other entities to protect, restore, and enhance wetlands, grasslands, and working farms and ranches through conservation easements. Through this program, NRCS aims to protect the nation's food supply by protecting agricultural land from being converted to non-agricultural uses. ACEP also protects grazing uses by conserving grassland, including rangeland, pastureland, and shrubland (NRCS, n.d.).

Under the Agricultural Land Easement component, the NRCS may contribute up to 50 percent of the fair market value of the agricultural land easement. If NRCS determines the grassland to be of special environmental significance, it may contribute up to 75 percent of the fair market value of the agricultural land easement (NRCS, n.d.).

U.S. Environmental Protection Agency (EPA)

The EPA-Tribal Environmental Plans (ETEP) is jointly developed plans by the EPA and the tribes that support the tribal environmental goals. ETEPs are practical documents that lead to informed decisions about the allocation of financial and technical assistance for environmental programs. This requires coordination between the EPA staff and the tribes (EPA, 2018).

Environmental Education (EE) Grants

Under the EE grants program, EPA provides financial assistance for the projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques. This program requires a non-federal 25 percent match of the total project cost (EPA, 2018). There are various other sources of funds available through various government agencies. If in the future additional funding is required, these programs in Appendix A (Table A.6.) should be considered.

Public Outreach and Education

An information and education (I/E) component to engage citizens is essential in order to meet the WBP goals and objectives. As described in the Management Measures section of this document, implementation of the BMPs will require strong interest, cooperation and establishing trusting relationships with the land and farm owners. The I/E component is designed to increase public participation in the implementation of BMPs and for their continued involvement throughout the duration of the plan. The goals of the I/E program for the Walnut Bayou WBP include:

1. Create public awareness regarding water quality issues in the watershed
2. Educate the public on the benefits of adopting best management practices
3. Increase community involvement in the watershed guardianship
4. Develop a strong working relationship between landowners, municipal officials, business and agricultural communities
5. Evaluate the impact of educational and public outreach activities on the water quality and address the shortcomings

The various organizations for public outreach and education in the Walnut Bayou Watershed could include OCC, OSU, OCES, ODAFF, Noble Research Institute (NRI), NRCS, Love and Carter County conservation districts, and OWRB. It is imperative to form a Watershed Advisory Group (WAG) to guide the individual landowners to develop conservation practices by adopting BMPs. The WAG should include members from the local community, Chickasaw Nation, city officials, OSU faculty, OCC, and NRCS staff who can advise the various partnerships on cost-share rates and best practices. The educational practices needed for the educational and outreach campaign are:

1. Organization of at least two educational events which emphasis on the importance of riparian buffer establishment and other BMPs
2. Production and distribution of educational pamphlets in key areas, which are identified as responsible in terms of NPS pollution
3. Organization of training events especially for school children to promote local awareness

This goal is to establish a monitoring team that would take an interest in the watershed conservation efforts, stream water quality, and ultimately helps in monitoring efforts in the future. I/E programs shall continue throughout the duration of the project so that the landowners, farmers and the general public especially students do not lose interest in preserving the water quality of the Walnut Bayou Watershed. This can be achieved by developing strong partnerships and with the availability of funds from sources such as National Environmental Education Foundation (NEEF) and Environmental Education grants.

NRI is located in the town of Ardmore in Carter County and has a team of scientists, consultants, agricultural economists, plant breeders, wildlife biologists, genomicists, and professionals from various backgrounds that work on agricultural research, producer relations, and the education of the students of all ages. Its research areas include Agronomy, Genomics, Cell Biology and Plant Development, Plant Physiology and Translational Research. It organizes events to educate the community on various aspects of BMPs. NRI would be of immense help in imparting education to the community.

The I/E component could also be extended through Oklahoma Blue Thumb, an education extension of OCC funded through EPA's Section 319 Program, which is a statewide citizen-based program that trains the citizens on various aspects of stream water quality. It also organizes workshops and tours regarding agricultural BMPs to inform the citizens of their importance in controlling NPS pollution. This provides an opportunity for stakeholders to directly participate in improving the water quality.

Implementation Schedule and Interim Milestones

This WBP is designed to be implemented over a ten years. At the end of this period, the increase of DO, the reduction of turbidity, and the reduction of ENT should be fully achieved. To accomplish this goal, a brief implementation schedule is presented, followed by detailed interim milestones of this plan. Dates and financial costs are only estimates and are subject to change. The estimation was based on the entire watershed area to calculate the possibility of the worst-case scenario. The entire WBP work plan can be found in the Appendix A (Table A.7.). The project schedule for the implementation phase is presented in Table 16 with estimated timelines.

Table 16: Implementation Schedule for Walnut Bayou Watershed (Barnes et al., 2015)

Task Description	**Due Date**
Hire project coordinator	January 2020
Pre-Implementation Plan written to provide guidance and starting point for the WBP	January 2020 to January 2022
Organize WAG	January to February 2020
Compile water quality data for baseline prior to implementation	June 2020 to June 2022
Prioritize BMPs with WAG and identify areas of the highest concern	September 2020 to September 2022
Identify stakeholders and engage them and potential BMP volunteers (information and education)	October 2022 to December 2026
Implement BMPs	November 2020 to November 2025
Complete watershed assessment	August-2030
Monitor water quality and track BMP progress	During and after the project in five years cycles
Revise WBP	Every third year

Characterization of NPS should begin in the first year, and should carry on with the new CWA Section 303(d) lists that will be published. During the program, each part of the implementation should meet with BMPs and reports should be documented after each quarterly monitoring phase. This will allow the WAG to respond to environmental changes and shortcomings in the established methods. After successfully implementing the WBP, monitoring should take place every third year to revise and update the plan as stated by EPA's protocols (EPA, 2013).

Measuring the progress of the WBP is a benchmark, which is connected to the required improvements in the water quality of the watershed. This WBP is a small-scale plan that was designed for a HUC-10 watershed. Although NPS pollution can be decreased within a ten-year period on a small scale, the flowing surface water will require decades to recover entirely. Mid- and long-term water quality benchmarks are expected to be established by local groups in the areas as part of the WBP (GLWAF, 2008). The three main management objectives for this WBP can be found in Appendix A (Table A.8.). Each management objective was divided into milestones for the short-, mid- and long-terms to achieve the desired water quality improvement as listed below (EPA, 2013).

Short-Term Tasks (First Half of Cycle 1)

- Establish WAG and define tasks by position
- Contract a project coordinator
- Further develop WAG
- Complete watershed modeling
- Start a streambank stability study
- Prepare contracts
- Contact partners and clients
- Identify stakeholders
- Conduct field monitoring
- Collect samples from impaired sites
- Update baseline data

- Develop Walnut Bayou Watershed Health Index
- Promote ten or more local and regional workshops/events to engage stakeholders
- Hold annual meetings for WAG
- Review and analyze all point source permits within the watershed
- Develop an educational video for the entire watershed
- Develop and distribute watershed fact sheets
- Develop a water quality improvement website for the WBP where results will be recorded for the public
- Establish a fixed monitoring site for Healdton Municipal Lake and one for WB-250 for DO and TSS (sediments and/or nutrients) (GLWAF, 2008)

Mid-Term Tasks (Second Half of Cycle 1)

- Publicize Walnut Bayou Watershed Health Index
- Update watershed plan via modeling results
- Complete Strategic Plan of WAG
- Develop an action plan for establishing appropriate point source discharge rates for nutrients and sediments throughout the watershed based on TMDLs and modeling
- Distribute educational videos of the watershed and fact sheets to five or more nearby schools
- Increase DO in WB-250 by 60 percent by the end of cycle 1
- Decrease the number of colonies of ENT in WB-250 by 60 percent by the end of cycle 1
- Decrease TSS in Healdton Municipal Lake by 60 percent by the end of cycle 1
- Monitor water quality to measure the success of the implemented plan (GLWAF, 2008)

Long-Term Tasks (Cycle 2)

- Update WBP management goals according to the results from cycle 1
- Determine and implement corrective solutions for conflicting WQS on a watershed basis
- Expand implementation to encompass the entire Red River Basin
- Implement the action plan to improve water quality
- Increase DO in WB-250 by 40 percent by the end of cycle 2
- Decrease the number of colonies of ENT in WB-250 by 40 percent by the end of cycle 2

- Decrease TSS in Healdton Municipal Lake by 40 percent by the end of cycle 2
- Continue water quality monitoring to demonstrate the success of the implemented plan (GLWAF, 2008)

Tables 17 to 19 provide details to the interim milestones with respect to three management objectives.

Table 17: Interim Milestones for the First Management Objective (USGS, n.d.; EPA, 2013)

<table>
<tr><th rowspan="2">Target Value/Goal</th><th colspan="2">Interim Targets for Dissolved Oxygen from 1.2 mg/L to > 5/6 mg/L</th><th rowspan="2">Indicators to Measure Progress</th></tr>
<tr><th>Mid-term
(2-5 years)</th><th>Long-term
(>5 years)</th></tr>
<tr><td>> 6.0 mg/L (1 April -15 June)</td><td>Goal is 2.88 mg/L DO increase by the end of Cycle 1 (2020 to 2025)

● Decrease nutrient and sediment load in the impaired waterbody

● Fewer bacteria and algae will help increase DO

● Native aquatic plants can improve DO

● Removing sludge</td><td>Goal is 1.92 mg/L DO increase by the end of Cycle 2 (2025 to 2030)

● Tasks same as Cycle 1</td><td rowspan="2">● Fish collection (seasonal sampling)

● Monitoring aquatic plants healthy (are not decaying)

● Aquatic insects collection (seasonal sampling)

● Measuring DO via data collection
● Measure turbidity with Secchi-disk

● Measure water temperature</td></tr>
<tr><td>> 5.0 mg/L (16 June - 31March)</td><td>Goal is 2.28 mg/L DO increase by the end of Cycle 1 (2020-2025)

● Removing sludge

● Native aquatic plants can improve DO

● Decrease nutrient and sediment load in the impaired waterbody

● Fewer bacteria and algae will help increase DO</td><td>Goal is 1.52 mg/L DO increase by the end of Cycle 2 (2025 to 2030)

● Tasks same as Cycle 1</td></tr>
</table>

Table 18: Interim Milestones for the Second Management Objective (EPA, 2013; Cherokees Watershed Alliance Foundation Inc., GLWAF, 2008)

Interim Targets for Turbidity(From 29 to 25 NTU)		Indicators to Measure Progress
Mid-term (Second Half of Cycle 1)	**Long-term (Cycle 2 and On)**	
The target decrease is 2.4 NTU ● Achieve a 60 percent reduction in sediment load to Healdton Municipal Lake by restoring eroded banks and placing silk fence around critical sites or constructional area ● Eliminate direct sources of organic waste to Healdton Municipal Lake by installing residential sewer lines to the WWTP of the city of Healdton sites and during deforestation ● Reduce bank erosion on the lake and sediment loading by 60 percent by re-establishing vegetation along the lake and by installing silt fence around nearby construction ● Install water tanks for livestock and shady place ● Control wildlife ● Control livestock to deny access to the waterbody	The target decrease is 1.6 NTU ● Tasks same as Cycle 1	● Measure turbidity with Secchi-disk and/or a turbidity sensor ● Collecting surface water sample and measure turbidity in laboratory

Table 19: Interim Milestones for the Third Management Objective (USGS, n.d.; EPA, 2013)

Interim Targets for Enterococcus from 112 to 33 colonies/ 100mL		
Mid-term (Second Half of Cycle 1)	**Long-term (Cycle 2 and On)**	**Indicators to Measure Progress**
Target decrease is 47 colonies/100 mL ● No swimming is allowed in the lake ● All targets for turbidity decrease and DO increase ● No fishing and boating allowed until water quality improves ● Keep away livestock from the waterbody ● Keep away wildlife (e.g. deer, coyotes) from the waterbody	Target decrease is 32 colonies/100 mL ● Tasks same as Cycle 1	● Collecting water samples during the designated recreational period (between 1May and 30 September)

Monitoring Plan

Monitoring is one of the most critical elements of the WBP, especially in the context of NPS management. It helps to track and assess the results of the management interventions throughout the implementation of the WBP. Monitoring also allows for resources to be directed at priority areas and primary causes of impairments, thereby focusing the efforts in this watershed to track water quality. Water quality monitoring in Oklahoma involves various agencies. The OCC collaborates with other state and federal agencies to collect water data for monitoring purposes as well as addressing NPS water quality issues. State-level agencies include ODEQ, OWRB, the Corporation Commission and ODAFF (OCC, 2014). Federal agencies are EPA, USGS, U.S. Army Corps of Engineers (USACE) and the NRCS from USDA (OCC, 2014). The following parameters will continue to be monitored in the Walnut Bayou Watershed:

- Water Quality
- Aquatic Biological Communities
- Implemented BMPs (Riparian conditions, agricultural practices, erosion control)

Baseline Data

Oklahoma Conservation Commission

Data was collected for WB-250-10G (Table 20) as a part of the OCC Rotating Basin Monitoring Program (RBMP). There is a fixed sampling site (Figure 11) that falls under the Basin Group 4 of the RBMP, and is sampled every five weeks over a two year period (OCC, 2017). The first cycle ran from June 2004 to May 2006, the second cycle ran from June 2009 to May 2011, and the third cycle of monitoring in these basins occurred from June 2014 to May 2016 (OCC, 2017).

Table 20: WB-250-10G for the Rotating Basin Monitoring Program (OCC, 2017)

Site Name	Walnut Bayou
WBID	OK311100-03-0010G
Latitude	33.918
Longitude	-97.281
Legal description	NW NW SW 26-7S-1W
County	Love
Ecoregion	Cross Timbers

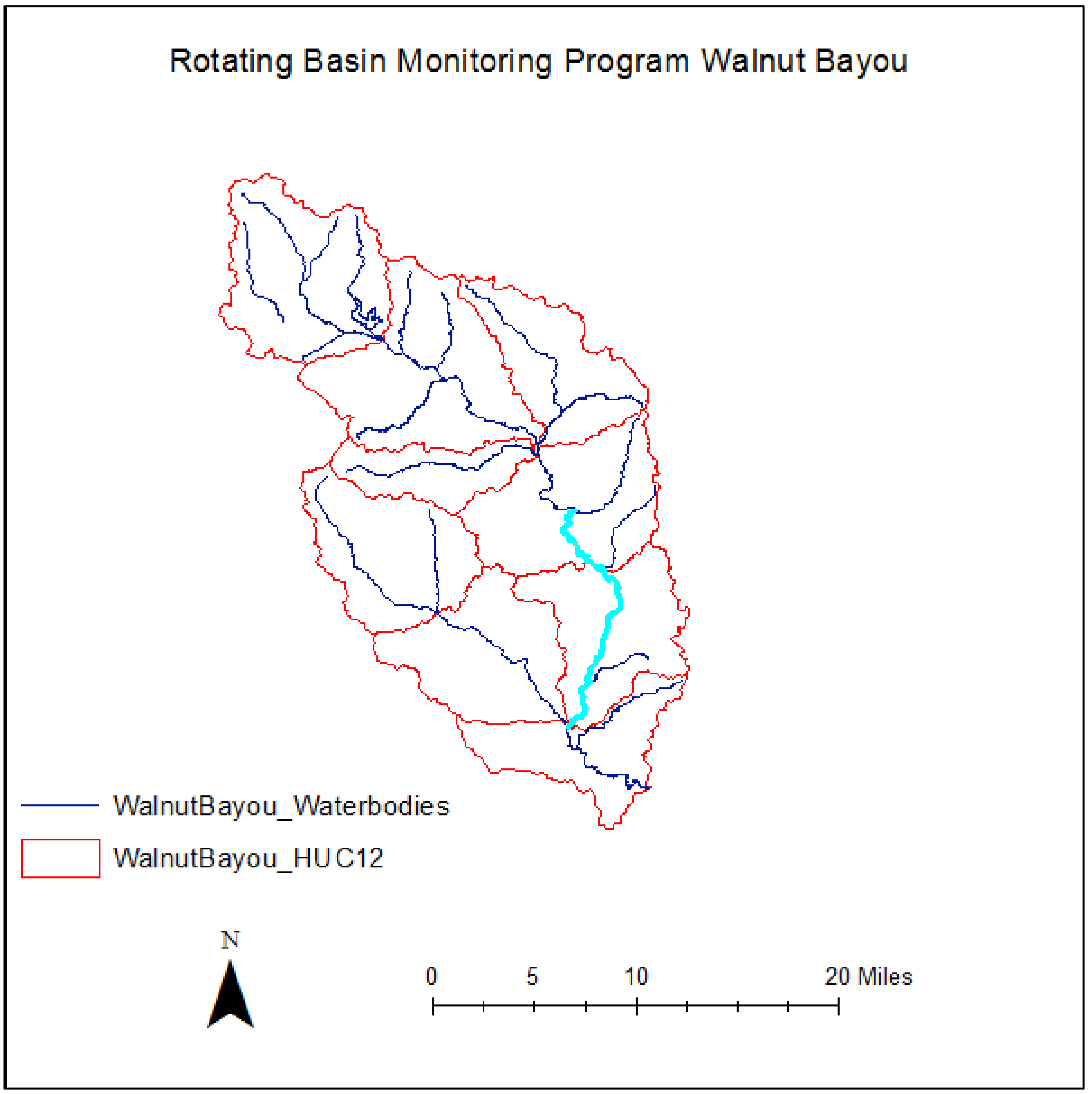

Figure 11: WB-250 Monitoring (Created on ArcMap, 2019)

- Water Quality

At the start of the third cycle in the rotating basin monitoring (June 2014), physical and chemical parameters were sampled. This included nitrate, nitrite, orthophosphate, total phosphorus, total Kjeldahl nitrogen, ammonia, chloride, sulfate, total suspended solids, and total dissolved solids (OCC, 2017). Water quality measurements were also taken at the site for water temperature, DO, pH, conductivity, alkalinity, hardness, turbidity, and instantaneous discharge (Table 21) (OCC, 2017).From the 1st of May to the 30th of September 2014, other samples were collected for assessing E.coli and ENT bacteria during the summer when recreational activities were high (OCC, 2017). Further observations for odor, excessive bottom deposits, surface scum, oil/grease, and foam were conducted at the site (OCC, 2017).

Table 21: Mean Values of Water Quality Parameters Collected at WB-250-10G (OCC, 2017)

Site Name	**Walnut Bayou**
WBID	OK311100-03-250-0010G
DO (mg/L)	7.9
DO % Sat	80.89
Turbidity (NTU)	103.27
Alkalinity (CaCO3)	197.5
Conductivity (µS/cm)	808.1
Hardness (mg/L)	261.8
pH (SU)	7.96
Temperature (°C)	17.7
Flow (cms)	0.65

This site is designated as a WWAC and has a DO level of 7.9 mg/L, which is above the critical DO level of 5.0 mg/L most of the year (OCC, 2017). This means that it meets the standards for DO. Only 16 percent of the samples taken at WB-250-10G had low DO (OCC, 2017).

A waterbody with a geometric mean of more than 126 colonies/100 mL for E.coli is impaired for PBCR (OCC, 2017). WB-250-10G has a geometric mean of 46.07 colonies/100 mL which is below the indicated standard, indicating that it meets the standards for E.coli (OCC, 2017).

- Biological Monitoring

A habitat assessment for WB-250-10G was conducted and the resultant score showed that it was a high quality site (OCC, 2017).

- Fish Collections

The IBI scores for WB-250-10G showed it was fair for its designated WWAC use on a Likert scale from excellent to very poor (OCC, 2017). A comparison of fish data from cycle 1 (2004 to 2005), cycle 2 (2009 to 2010), and cycle 3 (2014 to 2015), showed the IBI score of WB-250-10G decreased from good in 2004 to fair in 2009 and remained at fair in 2014 (OCC, 2017).

- Macroinvertebrate Collections

The macroinvertebrate values for the two-year cycle 3 monitoring period indicated that WB-250-10G was slightly impaired (OCC, 2017).

- Watershed Assessment

The watershed top three land uses are grasslands/herbaceous (46%), followed by deciduous forest (34%) and pasture/hay (12%) (OCC, 2017).

- NPDES (Permitted Land Use)

There are four NPDES permits, 5,973 (O&G permits are being updated), one retention lagoon and one public water intake (OCC, 2017).

- Designated Use Support Assessment

WB-250-10G is fully supporting agriculture, fish consumption and public/private water supply (ODEQ, 2016a). There is insufficient information for aesthetic use (ODEQ, 2016a). Designated uses that are not supported are WWAC and PBCR (ODEQ, 2016a).

Oklahoma Water Resources Board (OWRB)

- Beneficial Use Monitoring Program (BUMP)

The OWRB launched its first comprehensive water quality monitoring and assessment effort through the implementation of the Beneficial Use Monitoring Program (BUMP) in 1998 to monitor surface water (OWRB, 2009). The Oklahoma Comprehensive Water Plan (2012) has more than ten years of data for surface water quality trends. WB-250-10G at Burneyville is a BUMP stream data site and has been visited 31 times since January 2013 until present (OWRB, 2015). The in-situ parameters measured are water temperature, turbidity, pH, DO and hardness (OWRB, 2015). The minerals monitored are total dissolved solids, specific conductivity, chloride, and sulfate (OWRB, 2015). The nutrients measured include total phosphorus, total nitrogen, nitrate/nitrite and chlorophyll, and bacteria such as E.coli and ENT (OWRB, 2015). The data collected at WB-250-10G at this monitoring site indicated that the beneficial use of FWP is not supported due to turbidity (OWRB, 2015).

- Lake Monitoring

The Healdton City Lake located in Carter County has five sampling sites (Figure 12) and was sampled four times between November 2005 and 2006 (OWRB, 2015).

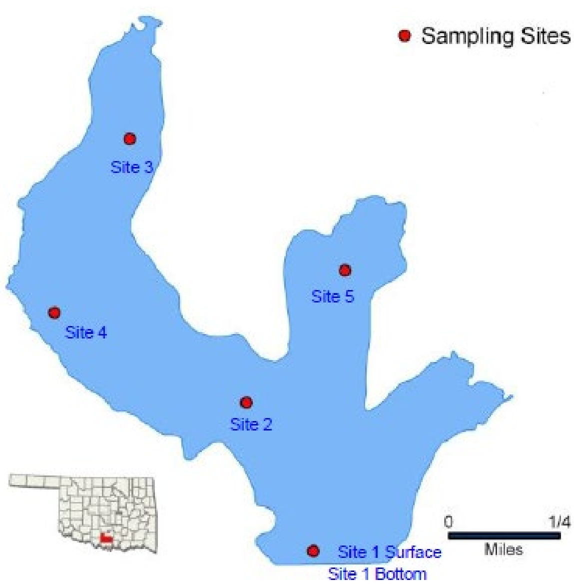

Figure 12: BUMP Monitoring Sites at Healdton City Lake (OWRB, 2015)

The in-situ parameters measured were average turbidity, average Secchi disk depth, water clarity rating, chlorophyll-a, trophic state index and trophic class (OWRB, 2015). The profile measurements included salinity, specific conductivity, pH, DO and oxidation-reduction potential (OWRB, 2015). The nutrients monitored were surface total phosphorus, surface total nitrogen, and nitrogen to phosphorus ratio (OWRB, 2015). The monitoring results showed that this lake was mesotrophic and phosphorus limited with regards to nutrients (OWRB, 2015). The pH was neutral to slightly alkaline (OWRB, 2015). Turbidity was an average of 48 NTU which is much higher than the WQS for Oklahoma, which is 25 NTU for lakes (OWRB, 2015). Therefore, Healdton City Lake did not support its beneficial use of FWP due to turbidity (OWRB, 2015).

Data Collection Responsibilities for Current and Future Monitoring

The project manager will be responsible for collecting supplementary monitoring data from the sources mentioned above. All monitoring efforts will be based on WQS for Oklahoma and Use Support Assessment Protocols. These protocols are used to define how beneficial use is supported (OCC, 2017). This data must also be submitted to ODEQ with the intention of including it in the Oklahoma State Water Quality Database (OCC, 2017).

- ***Oklahoma Conservation Commission: Rotating Basin Monitoring Program***

The most current monitoring in the RBMP is the fourth cycle of monitoring that started in Spring 2016 and continues through May 2018 for which the final report has not yet been released (OCC, 2017). Future monitoring will be conducted through a fifth cycle which will occur from June 2018 through May 2020, and will have a frequency period of five weeks (OCC, 2017).

- ***Blue Thumb***

The Blue Thumb Program incorporates volunteer monitoring as a method of education with the assistance of OCC. Currently, there are no Blue Thumb stream monitoring sites in Love and Carter Counties (OCC, 2014). BMP sites for priority areas in the watershed can be identified for monitoring approximately once a month.

- ***Oklahoma Water Resources Board: Lake Monitoring***

The BUMP Lake Monitoring for Healdton City Lake will be monitored by the OWRB. Lakes are sampled on a five-year rotation (OWRB, 2015).

- ***TMDL (WB-250)***

WB-250 is impaired by ENT and is not attaining the designated use for PBCR (ODEQ, 2016a). It is a priority level 4 TMDL, which will be done in 2025 (ODEQ, 2016a). A total of 73.5 percent reduction is required for ENT (ODEQ, 2016a), hence monitoring for this impairment will be based on load reduction criteria in this WBP. The TMDL percent reduction required to meet water quality targets for total suspended solids is 63.5 percent (ODEQ, 2016a). This waterbody is also impaired for turbidity but not listed in the 303(d)/TMDL list (ODEQ, 2016a). This waterbody has potential pollutant NPS for bacteria and turbidity (ODEQ, 2016a).

- ***Point Sources***

As previously mentioned, there are no continuous, permitted point sources of bacteria in the WB-250 which require bacterial TMDLs (ODEQ, 2016a).

- ***Implemented BMPs***

Riparian Buffer Zone Restoration Efforts

A riparian assessment for this watershed can be done using GIS and remotely sensed data. This can aid in identifying key areas within the watershed that need protection and should be prioritized for conservation efforts. A baseline riparian assessment can take place at the beginning of the first cycle and then a follow-up should be conducted at the end of cycle 1. A second follow-up should be conducted at the end of cycle 2 when the implementation of BMPs has been completed. NRCS and OCC will monitor riparian conditions through aerial imagery and Light Detection and Ranging (LIDAR), which is a remote sensing system that can be used to measure vegetation height across broad areas (Wasser, n.d.).

Grazing and Agricultural Management

Numerical models such as SWAT (Arnold et al, 1998), Spreadsheet Tool for Estimating Pollutant Load (STEPL) (EPA, 2018) and Nutrient Tracking Tool (NTT) (USDA, n.d.) could be applied to simulate the effect of different grazing and agricultural practices on the watershed sustainability and the quantity and quality of water. SWAT, STEPL and NTT can be used as tools to predict future conditions and impacts of suggested BMPs for any land use changes and their associated nutrient, sediment loading and bacterial loads in order to find ways to optimize the BMPs' results. A baseline SWAT assessment can take place in the initial two years of WBP implementation. Then the STEPL and NTT models can be used to follow up at the end of cycle 1 and cycle 2, when the implementation of BMPs have been completed to assess load reductions and nutrient and sediment losses.

Erosion Control

SWAT and STEPL models can be used to assess the BMPs for erosion control, including vegetation cover management and slope remediation. STEPL has a BMP tool to assess gully and stream bank erosion (Tetra Tech, 2018).

Benefits of Monitoring Plan

The monitoring strategy will determine how effectively the WBP is implemented. The plan will track the progress of pollutant reduction and the attainment of WQS. This plan will ultimately help to determine if the WBP needs to be revised after evaluating the effectiveness of the implementation efforts over time, measured against the load reduction criteria and milestones.

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Appendix A

Table A.1. Land Use / Land Cover Combination of the Study Area (USDA, 2016)

Land Use / Cover	Area (m^2)	Area (acre)	Percentage
Alfalfa	85227	21	0.010
Barley	4926	1	0.001
Barren	644385	159	0.075
Corn	24796	6	0.003
Cotton	8181	2	0.001
Double Crop Oats/Corn	900	0.2	0.0001
Double Crop Winter Wheat /Corn	576	0.1	0.0001
Double Crop Winter Wheat /Sorghum	18107	4	0.002
Double Crop Winter Wheat /Soybeans	8997	2	0.001
Deciduous Forest	302970105	74865	35.1
Developed/High Intensity	345725	85	0.04
Developed/Low Intensity	7411427	1831	0.86
Developed/Med Intensity	1870981	462	0.22
Developed/Open Space	29579939	7309	3.42
Evergreen Forest	239957	59	0.028
Fallow/Idle Cropland	804015	199	0.09
Grassland/Pasture	500197280	123601	57.9
Herbaceous Wetlands	111335	28	0.013
Herbs	576	0.1	0.0001
Millet	2700	1	0.0003
Oats	95947	24	0.011
Open Water	6094753	1506	0.706
Other Crops	1153	0.3	0.0001
Other Hay/Non Alfalfa	3660541	905	0.42
Peanuts	900	0.2	0.000
Pecans	94741	23	0.011

Rye	137153	34	0.016
Shrub land	37692	9	0.004
Sod/Grass Seed	213022	53	0.025
Sorghum	70074	17	0.008
Soybeans	64707	16	0.007
Triticale	92533	23	0.011
Winter Wheat	8956621	2213	1.04
Woody Wetlands	34992	9	0.004

Table A.2. SSURGO Soil Types in the Study Area (USDA, n.d.)

AREASYMBOL	MUKEY	MUSYM	MUNAME
OK019	381991	1	Bergstrom silt loam, 0 to 1 percent slopes, occasionally flooded
OK019	382013	3	Bunyan loam, 0 to 1 percent slopes, occasionally flooded
OK019	382035	5	Chickasha loam, 1 to 3 percent slopes
OK019	382045	6	Chickasha loam, 3 to 5 percent slopes
OK019	382046	7	Chickasha loam, 3 to 5 percent slopes, eroded
OK019	382048	9	Clarita silty clay, 3 to 5 percent slopes
OK019	381993	11	Durant loam, 1 to 3 percent slopes
OK019	381994	12	Durant loam, 3 to 5 percent slopes
OK019	381995	13	Elandco clay loam, 0 to 1 percent slopes, occasionally flooded
OK019	381996	14	Eufaula fine sand, 5 to 15 percent slopes
OK019	381997	15	Healdton silt loam, 0 to 1 percent slopes, occasionally flooded
OK019	382000	18	Gracemont and Gracemore soils, 0 to 1 percent slopes, frequently flooded
OK019	382004	21	Konawa fine sandy loam, 0 to 1 percent slopes
OK019	382005	22	Konawa fine sandy loam, 1 to 3 percent slopes
OK019	382007	24	Konsil loamy fine sand, 0 to 3 percent slopes

OK019	382008	25	Konsil loamy fine sand, 3 to 8 percent slopes
OK019	382009	26	Konsil and Weatherford soils, 1 to 8 percent slopes, gullied
OK019	382012	29	Miller silty clay, 0 to 2 percent slopes, frequently flooded
OK019	382014	30	Normangee loam, 3 to 5 percent slopes
OK019	382015	31	Normangee loam, 3 to 5 percent slopes, eroded
OK019	382016	32	Normangee clay loam, 3 to 5 percent slopes, severely eroded
OK019	382017	33	Oil waste land
OK019	382018	34	Pits
OK019	382019	35	Pulaski fine sandy loam, 0 to 1 percent slopes, occasionally flooded
OK019	382020	36	Pulaski and Bunyan soils, 0 to 1 percent slopes, frequently flooded
OK019	382021	37	Renfrow silt loam, 1 to 3 percent slopes
OK019	382022	38	Renfrow silt loam, 3 to 5 percent slopes
OK019	382025	40	Steedman clay loam, 5 to 20 percent slopes
OK019	382026	41	Stephenville-Darnell complex, 3 to 8 percent slopes
OK019	382027	42	Tamford-Grainola complex, 5 to 12 percent slopes
OK019	382028	43	Watonga silty clay, 0 to 1 percent slopes, rarely flooded
OK019	382029	44	Weatherford fine sandy loam, 1 to 3 percent slopes

OK019	382030	45	Weatherford fine sandy loam, 3 to 5 percent slopes
OK019	382031	46	Weatherford fine sandy loam, 1 to 5 percent slopes, eroded
OK019	382032	47	Weatherford-Duffau complex, 3 to 8 percent slopes
OK019	382034	49	Wilson silt loam, 0 to 1 percent slopes
OK019	382036	50	Wilson silt loam, 1 to 3 percent slopes
OK019	382037	51	Windthorst very fine sandy loam, 1 to 3 percent slopes
OK019	382038	52	Windthorst fine sandy loam, 3 to 5 percent slopes
OK019	382039	53	Windthorst fine sandy loam, 3 to 8 percent slopes, eroded
OK019	382040	54	Windthorst-Darnell-Rock outcrop complex, 5 to 25 percent slopes
OK019	382041	55	Windthorst-Weatherford complex, 5 to 12 percent slopes
OK019	382044	58	Zaneis loam, 3 to 5 percent slopes
OK085	383698	Ba	Steedman-Heiden complex, 5 to 20 percent slopes
OK085	383699	Bv	Brewer rarely flooded-Vanoss complex, 0 to 1 percent slopes
OK085	383701	CmB	Catoosa-Shidler complex, 1 to 3 percent slopes
OK085	383702	Cn	Tussy-Aledo complex, 3 to 30 percent slopes
OK085	752573	DAM	Large dam
OK085	383703	DcD	Heiden clay, 5 to 8 percent slopes

OK085	383704	DdC	Heiden-Burleson complex, 3 to 5 percent slopes
OK085	383705	De	Matoy-Aledo complex, 1 to 5 percent slopes
OK085	383706	DoB	Dougherty loamy fine sand, 0 to 3 percent slopes
OK085	383707	DoC	Dougherty and Konsil soils, 3 to 5 percent slopes
OK085	383708	DoD	Dougherty and Konsil soils, 5 to 8 percent slopes
OK085	383709	DtB	Durant loam, 1 to 3 percent slopes
OK085	383710	DtB2	Durant clay loam, 1 to 5 percent slopes, eroded
OK085	383711	DuB2	Konsil loamy fine sand, 0 to 3 percent slopes, eroded
OK085	383712	DuC2	Konsil loamy fine sand, 3 to 5 percent slopes, eroded
OK085	383713	Et	Zaneis and Durant soils, 1 to 5 percent slopes, severely eroded
OK085	383714	EuB	Eufaula soils, 0 to 3 percent slopes
OK085	383715	EuC	Eufaula soils, 3 to 8 percent slopes
OK085	383716	Gm	Elandco silt loam, 0 to 1 percent slopes, occasionally flooded
OK085	383717	Go	Elandco clay loam, 0 to 1 percent slopes, occasionally flooded
OK085	383718	Gw	Elandco silt loam, 0 to 1 percent slopes, frequently flooded
OK085	383719	LbB	Scullin loam, 1 to 3 percent slopes
OK085	383722	Ls	Gaddy loam, 0 to 1 percent slopes, frequently flooded

OK085	383723	Lv	Pulaski and Bunyan soils, 0 to 1 percent slopes, frequently flooded
OK085	383724	Mr	Miller clay, 0 to 1 percent slopes, occasionally flooded
OK085	383725	MsA	Slaughterville fine sandy loam, 0 to 1 percent slopes
OK085	383726	MsB	Slaughterville fine sandy loam, 1 to 3 percent slopes
OK085	383727	MsC	Slaughterville fine sandy loam, 3 to 5 percent slopes
OK085	752574	M-W	Miscellaneous water
OK085	383729	Nc	Ashport clay loam, 0 to 1 percent slopes, occasionally flooded
OK085	383732	Ps	Bunyan loam, 0 to 1 percent slopes, frequently flooded
OK085	383733	Pu	Pulaski fine sandy loam, 0 to 1 percent slopes, occasionally flooded
OK085	383734	Pv	Pulaski fine sandy loam, 0 to 1 percent slopes, frequently flooded
OK085	383736	Rk	Rock outcrop-Talpa complex, 12 to 60 percent slopes
OK085	383737	Rn	Roebuck and Garvin soils, 0 to 1 percent slopes, frequently flooded
OK085	383738	SbB	Weatherford fine sandy loam, 1 to 3 percent slopes
OK085	383739	SbC	Weatherford fine sandy loam, 3 to 5 percent slopes
OK085	383740	SbC2	Weatherford fine sandy loam, 1 to 5 percent slopes, eroded
OK085	383741	SbD	Weatherford fine sandy loam, 5 to 8 percent slopes
OK085	383742	SdB	Slidell-Sanger complex, 1 to 3 percent slopes

OK085	383743	Se	Healdton and Oscar soils, 0 to 1 percent slopes, occasionally flooded
OK085	383744	Sw3	Weatherford-Windthorst-Konsil complex, 1 to 8 percent slopes, severely eroded
OK085	383745	Sy	Eufaula and Weatherford soils, 8 to 25 percent slopes
OK085	383746	Ta	Aledo gravelly loam, 1 to 12 percent slopes
OK085	383747	TfA	Teller fine sandy loam, 0 to 1 percent slopes
OK085	383748	TfB	Teller fine sandy loam, 1 to 3 percent slopes
OK085	383749	TmA	Teller loam, 0 to 1 percent slopes
OK085	383750	TmB	Teller loam, 1 to 3 percent slopes
OK085	383751	VaA	Vanoss loam, 0 to 1 percent slopes
OK085	752572	W	Water
OK085	383757	Wb	Gracemont and Gracemore soils, 0 to 1 percent slopes, frequently flooded
OK085	383758	WdC	Windthorst fine sandy loam, 1 to 5 percent slopes
OK085	383759	WdC2	Windthorst fine sandy loam, 1 to 5 percent slopes, eroded
OK085	383761	WsD	Windthorst-Weatherford complex, 5 to 12 percent slopes

Table A.3. Watershed Simulation Results for HUC10 and HUC 12 subbasins (HAWQS, 2019)

HUC	Surface Runoff (mm/yr)	Maximum Upland Sediment Yield (ton/ha)	Average Upland Sediment Yield (Mg/ha)	Inlet/Point Source Sediment (Mg/yr)	Instream Sediment change (Mg/ha)
1113020106	48.38	3.66	0.1	143.6	0
111302010601	66.52	0.95	0.03	18.54	0
111302010602	60.23	1.36	0.05	17.1	0
111302010603	64.35	1.48	0.03	53.46	0
111302010604	51.79	2.43	0.07	9.612	0
111302010605	57.56	2.43	0.04	87.18	0
111302010606	44.67	1.5	0.02	18.26	0
111302010607	34.6	1.88	0.02	40.78	0
111302010608	59.45	2.43	0.03	102.8	0
111302010609	54.12	4.63	0.04	153.15	0

Table A.4. Defined Beneficial Uses for the Study Area (ODEQ, 2016b)

No.	Waterbody ID	Waterbody Name	Size (Lake Acres or Stream Miles)	Type	Category	Aesthetic (AES)	Agriculture (AG)	Habitat Limited Aquatic Comm	Warm Water Aquatic Comm (WWAC)	Fish Consumption	Navigation	Primary Body Contact Rec (PBCR)	Secondary Body Contact Rec (SBCR)	Public and Private Water Supply (PPWA)
1	OK311100010250_00	Walnut Bayou	10.82	R	5a	I	F		N	F		N		F
2	Ok311100010260-00	Dry Creek	7.23	R	3	X	X		X	X		X		
3	OK311100030010_00	Walnut Bayou	14.97	R	3	I	I		X	X		I		X
4	OK311100030020_00	Simon Creek	19.84	R	2	I	F		I	X		X		I
5	OK311100030030_00	Simon Creek, North	5.44	R	3	X	X		X	X		X		
6	Ok311100030040-00	Cherokee Creek	3.62	R	3	X	X		X	X		X		
7	OK311100030050_00	Polecat Creek	5.32	R	3	I	I		I	X		X		
8	OK311100030060_00	Bull Creek	7.04	R	3	X	X	X		X			X	
9	OK311100030070_00	Walnut Creek (Walnut Bayou)	28.38	R	3	I	I		I	X	X		I	
10	OK311100030080_00	Demijohn Creek	9.82	R	3	X	X		X	X		X		
11	OK311100030090_00	Cottonwood Creek	11.37	R	3	I	I		I	X		X		I
12	OK311100030100_00	Red Oak Creek	4.62	R	3	I	I		I	X		X		
13	OK311100030110_00	Oil Branch	0.84	R	2	I	F		I	X		X		
14	OK311100030120-00	Oil Branch	5.01	R	3	X	X		X	X		X		

15	OK311100030130-00	Healdton Municipal Lake	370	L	5a	F	F		N	I		F		I
16	OK311100030140-00	Whiskey Creek	5.9	R	2	I	F	X		X			X	
17	OK311100030150-00	Red Branch	3.76	R	3	X	X		X	X		X		
18	OK311100030160-00	Rexroat Branch	4.48	R	3	X	I		I	X		X		
19	OK311100030170-00	Healdton Branch	2.37	R	3	I	I		I	X		X		
20	OK311100030180_00	Walnut Creek	7.56	R	3	X	X	X		X			X	
21	OK311100030190_00	Cottonwood Creek, Unnamed Tributary of	4.9	R	3	X	X	X		X			X	

F = Fully Supporting X = Not Assessed I = Insufficient Information **N = Not Supporting**

Table A.5. Results for Nutrients in Subbasins (HAWQS, 2019)

HUC	Final Organic N (kg/ha)	Final NO3 (kg/ha)	Total Fertilizer N(kg/ha)	Final Organic P (kg/ha)	Final Min P(kg/ha)	Total Fertilizer P(kg/ha)	Average Biomass (Mg/ha)	Average Yield (Mg/ha)	N removed in Yiled (kg/ha)	P removed in Yiled (kg/ha)	Plant Uptake N (kg/ha)	Plant Uptake P (kg/ha)	Total Fertilizer N (kg/ha)	Total Fertilizer P (kg/ha)
1113020106	4047.3	12.96	36.2	558	3321.8	0.033	17.65	1.87	32.3	6.025	72.2	16.93	36.2	0.033
111302010601	3424.7	10.5	22.11	452.6	3487.3	0.103	19.5	1.35	20.2	3.9	52.7	11.63	22	0.103
111302010602	3954.41	9.1	66.5	597.6	3069	0.022	15.85	3.3	56.77	10.585	113.97	27.9	66.5	0.022
111302010603	3899.99	10.11	28.85	521.26	3401	0.069	17.6	1.665	25.86	5	62.156	14.103	28.85	0.069
111302010604	3291.66	10.4	37.8	470.4	3286.44	0.039	18.4	1.94	32.79	6.14	77.6	18.3	37.78	0.039
111302010605	3639.94	10.5	39.4	510.59	3288.2	0.044	19.44	2.1	34.5	6.5	77.7	18.24	39.4	0.044
111302010606	3034.3	11.32	42	444.4	3180.87	0.022	21	2.135	36.7	6.8	84.8	19.9	42.04	0.022
111302010607	3575.14	10.8	42.03	511.77	169.5	0.011	23	2.08	36.5	6.8	83.6	20	42	0.011
111302010608	3802.5	10.63	38.7	531.36	3325.2	0.037	20.28	2.04	33.74	6.37	7707	18.2	38.7	0.037
111302010609	4075.13	10.8	40.6	567	3282	0.03	20.7	2.121	35.4	7	80.3	19	40.5	0.032

Table A.6. Funding Programs Available Through Different Agencies

Funding	**Agency**
Conservation Reserve Program (CRP)	USDA-FSA
Highly Erodible Land Initiative	USDA-FSA
Clean Lakes, Estuaries and Rivers (CLEAR)	USDA-FSA
Cooperative Watershed Management Program (CWMP)	U.S. Bureau of Reclamation
Oklahoma's State Funded Conservation Cost Share Program	OCC
Five Star and Urban Waters Restoration Grant Program	National Fish & Wildlife Foundation
Healthy Watersheds Consortium Grants (HWCG)	EPA
Pollution Prevention (P2) Grant Program	EPA
Source Reduction Assistance Grant Program (SRA)	EPA
319 Grant Program for States and Territories	EPA
Tribal 319 Grant Program	EPA

Table A.7. Watershed-Based Work Plan (EPA, 2013)

Parameter	Walnut Bayou Watershed (HUC 1113020106) Management Plan
Period	2020-2030
Geographic scope	864 km^3
Critical areas	29.5 km^3
Goal statement	Improving surface water quality within the watershed.
Objectives and key elements	● Increasing the Index of Biotic Integrity (IBI) from fair (36) to excellent (60) by the end of cycle 2 ● Identifying the causes and sources of turbidity and decreasing it by 60 percent by the end of cycle 1, and by 40 percent by the end of cycle 2 ● Identifying the causes and sources of ENT and decreasing it by 60 percent by the end of cycle 1, and by 40 percent by the end of cycle 2 ● Identifying load reductions expected within the first half of cycle 1 ● Identifying the best management practices (BMPs) needed in the first half of cycle 1 ● Identifying stakeholders within the first half of cycle 1 ● Establishing Watershed Advisory Group (WAG) and determining responsibilities and tasks within the first half of cycle 1 ● Identifying critical areas, and collecting samples throughout the monitoring period ● Educating and giving advice to landowners about BMPs
Implementation	● Crop Residue Management (CRM): teaching/informing farmers about conservation practices ● Providing conservation technical and financial assistance to private landowners, tribes and other organizations by NRCS (Farm Bill Program) ● Designing erosion control terrace system by engineers for the critical areas ● Buffers: restore the riparian area by 60 percent at the end of cycle 1 on the critical sites following the three-zone RBS according to Cooper (1998) (zone 1 is a minimum width of 4.57 m, zone 2 is a minimum width of 18.29 m, and zone 3 is a minimum width of 6.10 m), and by 40 percent at the end of cycle 2 ● Field buffers: planting recommendations for riparian areas by forestry

	services for zone 1 ● Recommendation for native grass mix for zone 2 and 3 by NRCS and Cooper (1998). ● Recruiting volunteers (Blue Thumb).
Costs	Total estimation: $2.825 million ● $200,000 for information and education ● $375,000 for monitoring and reporting ● $100,000 for project management ● $200,000 for Computer modeling ● $250,000 for updating Walnut Bayou WBP (second half of cycle 1) ● $1.7 million for BMPs
Schedule	● Begin slowly and accelerate (build on successes) ● Establishing interim milestones: - 2020 to 2025: stabilize eroding streambanks by 60 percent - 2025 to 2030: restore the riparian area by 40 percent ● I/E should have been carried out during the ten-year period and completed year by year ● Preparing annual reports that track progress during the ten-year period and throughout the monitoring ● Coordinating with partners throughout the entire implementation period
Monitoring (A Detailed Monitoring Plan can be found in the Monitoring section)	● Environmental – surface water quality, riparian conditions, tons of soil erosion reduced, surface runoff control, improved diversity in aquatic biological communities, implemented BMPs ● Administrative – all contracts approved, funds expended and funds obliged (relevant investors) ● Social – landowners contacted, wildlife management contacted, changes in public understanding resulting from information and education

*Note:
Financial estimates are adopted from Cherokees Watershed Alliance Foundation Inc. (2008)
CRM - Leaving the crop residue undisturbed after harvesting the crop helps controlling erosion because the soil stays covered (USDA, 2005).
3-zone RBS according to Cooper (1998)

Table A.8. Management Objectives

Management Objective	Increase/Reduction in Impaired Waterbodies	Deadline
1. Increasing Dissolved Oxygen Ten samples of the total between 1April – 15 June (target value > 6.0 mg/L) seasonally collected annually Between 16 June – 31 March (target value > 5.0 mg/L)	● DO increase by 2.88 mg/L ● DO increase by 1.92 mg/L ● DO increase by 2.28 mg/L ● DO increase by 1.52 mg/L	● Cycle 1 (2020 to 2025) ● Cycle 2 (2025 to 2030) ● Cycle 1 (2020 to 2025) ● Cycle 2 (2025 to 2030)
2. Reducing Enterococcus Ten samples of the total (goal is 33 colonies/100 mL) every year during the designated recreational period (between the 1May – 30 September)	● ENT decrease by 47 colonies/100 mL ● ENT decrease by 32 colonies/100 mL	● Cycle 1 (2020 to 2025) ● Cycle 2 (2025 to 2030)
3. Reducing Turbidity Ten samples of the total (goal is 25 NTU) over ten years	● Turbidity decrease by 2.4 NTU ● Turbidity decrease by 1.6 NTU	● Cycle 1 (2020 to 2025) ● Cycle 2 (2025 to 2030)

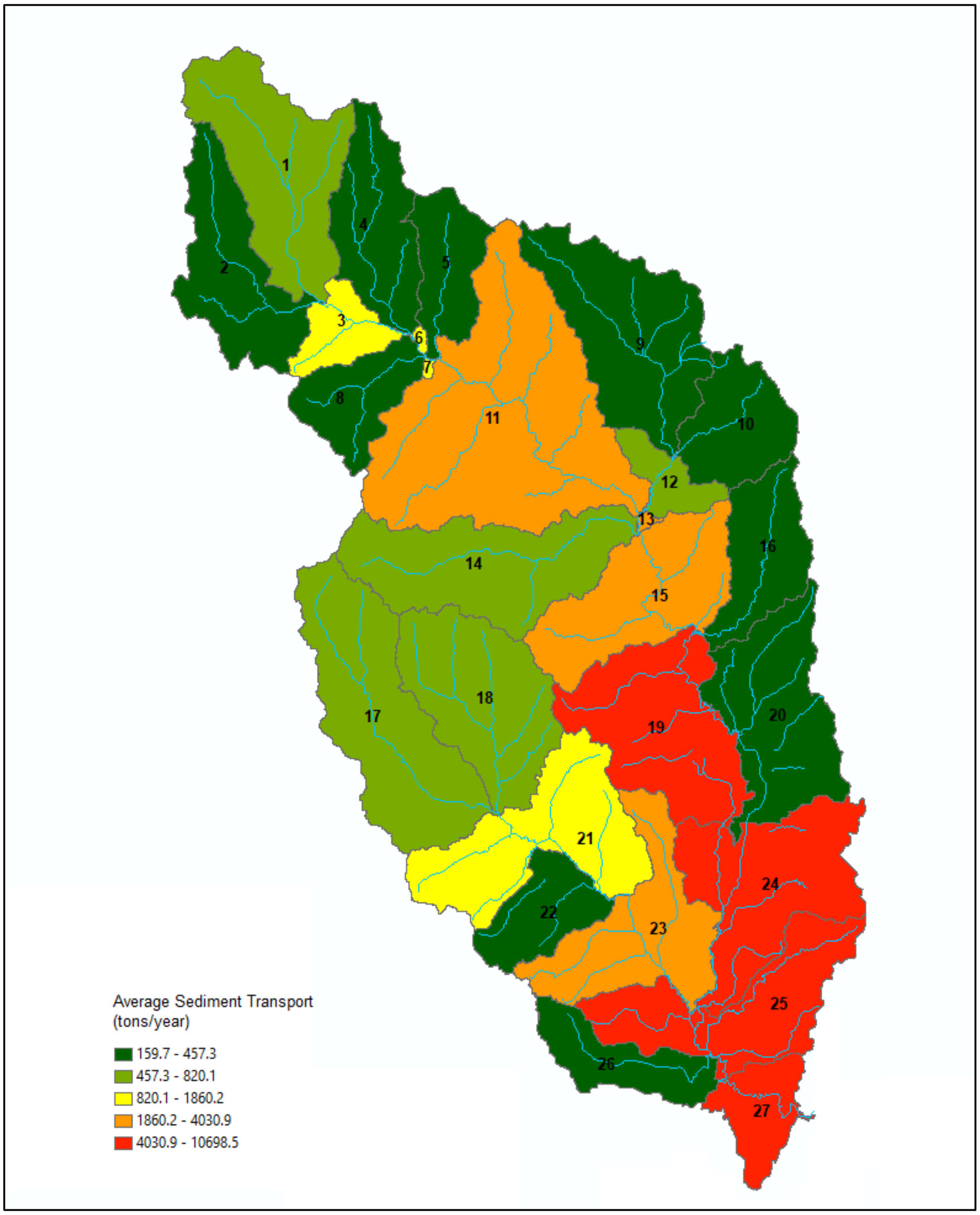

Figure A.1. Annual Average Sediment Transport (tons/year) (SWAT, 2019)

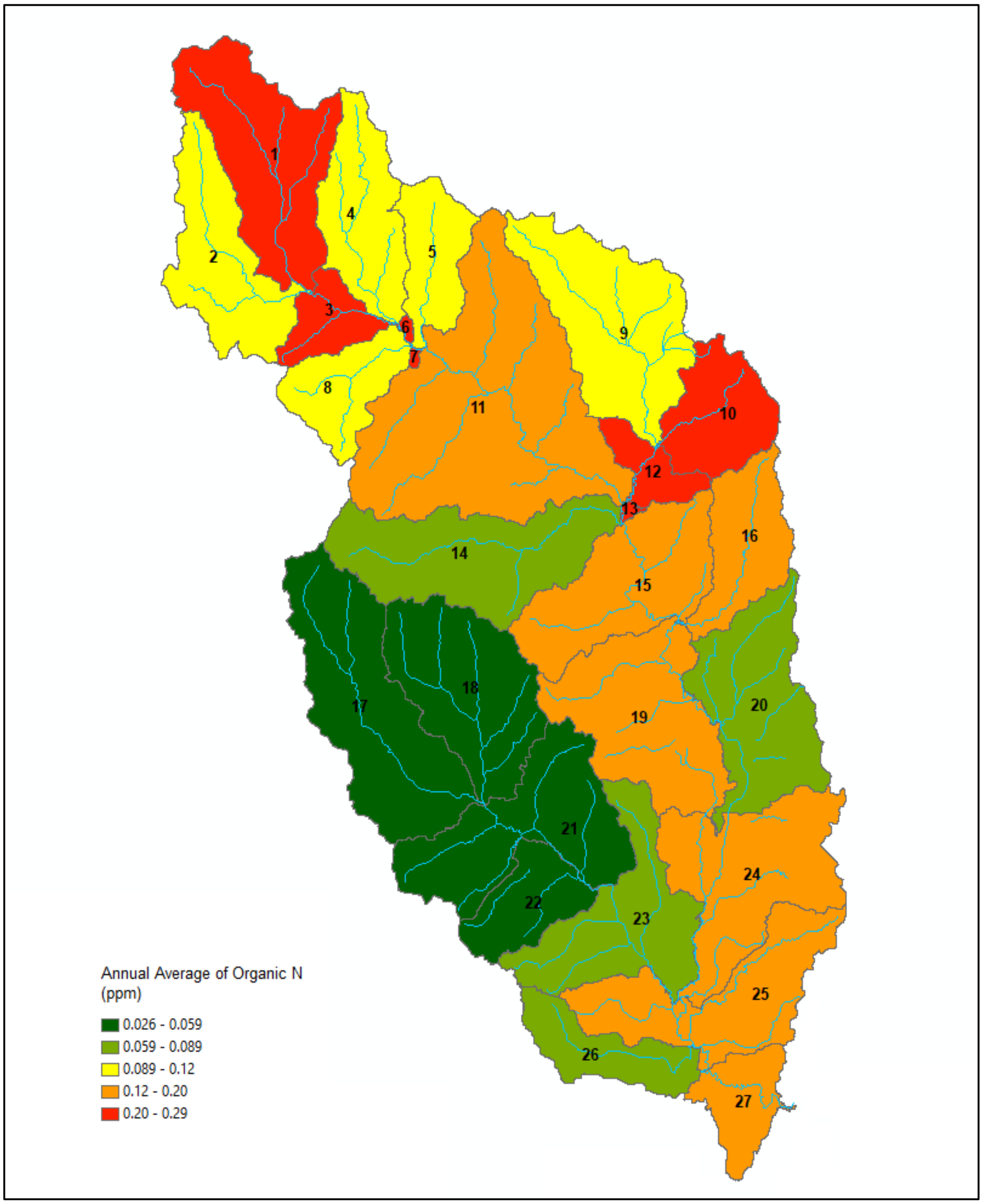

Figure A.2. Annual Average Organic Nitrogen (ppm) (SWAT, 2019)

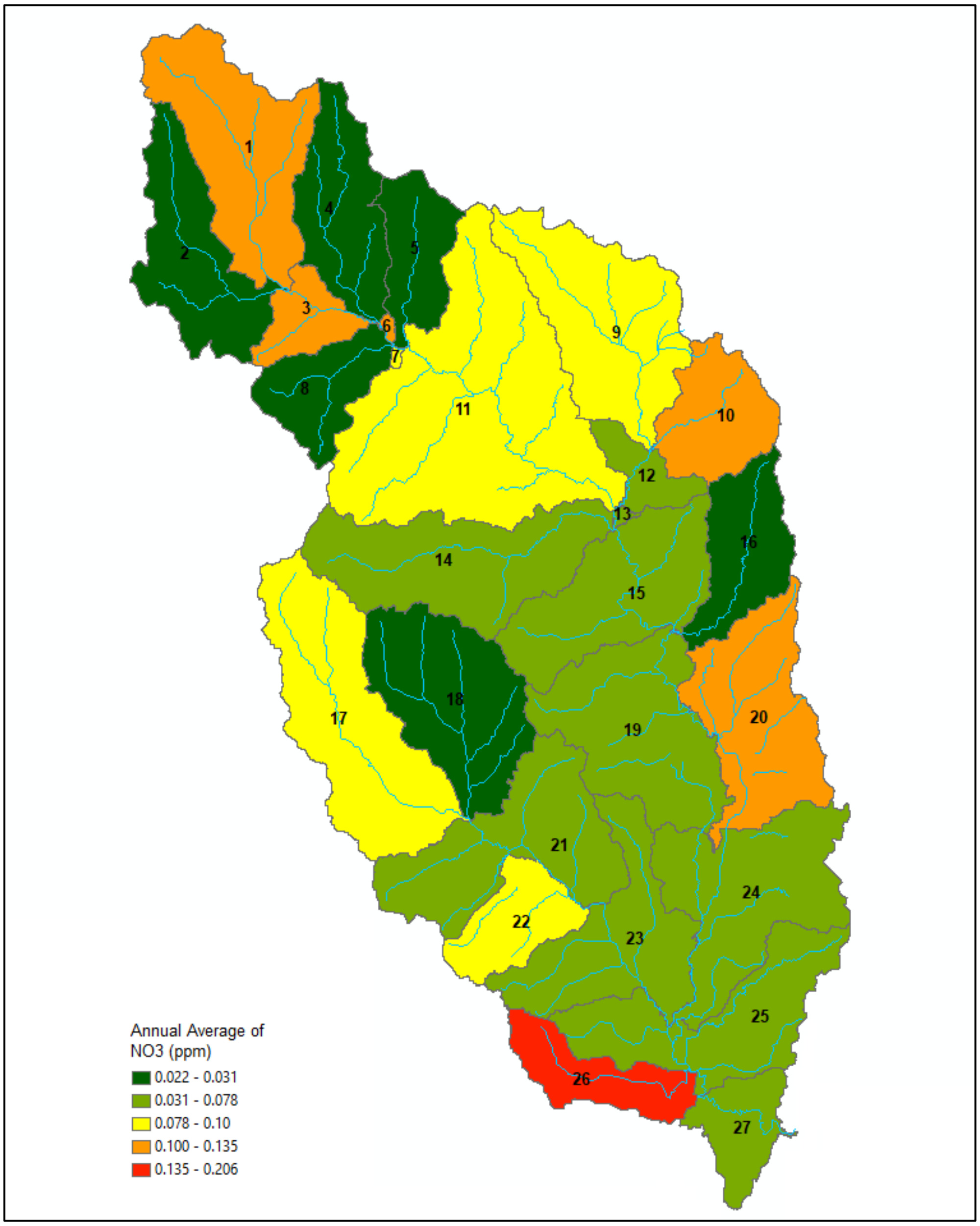

Figure A.3. Annual Average of Nitrate (ppm) (SWAT, 2019)

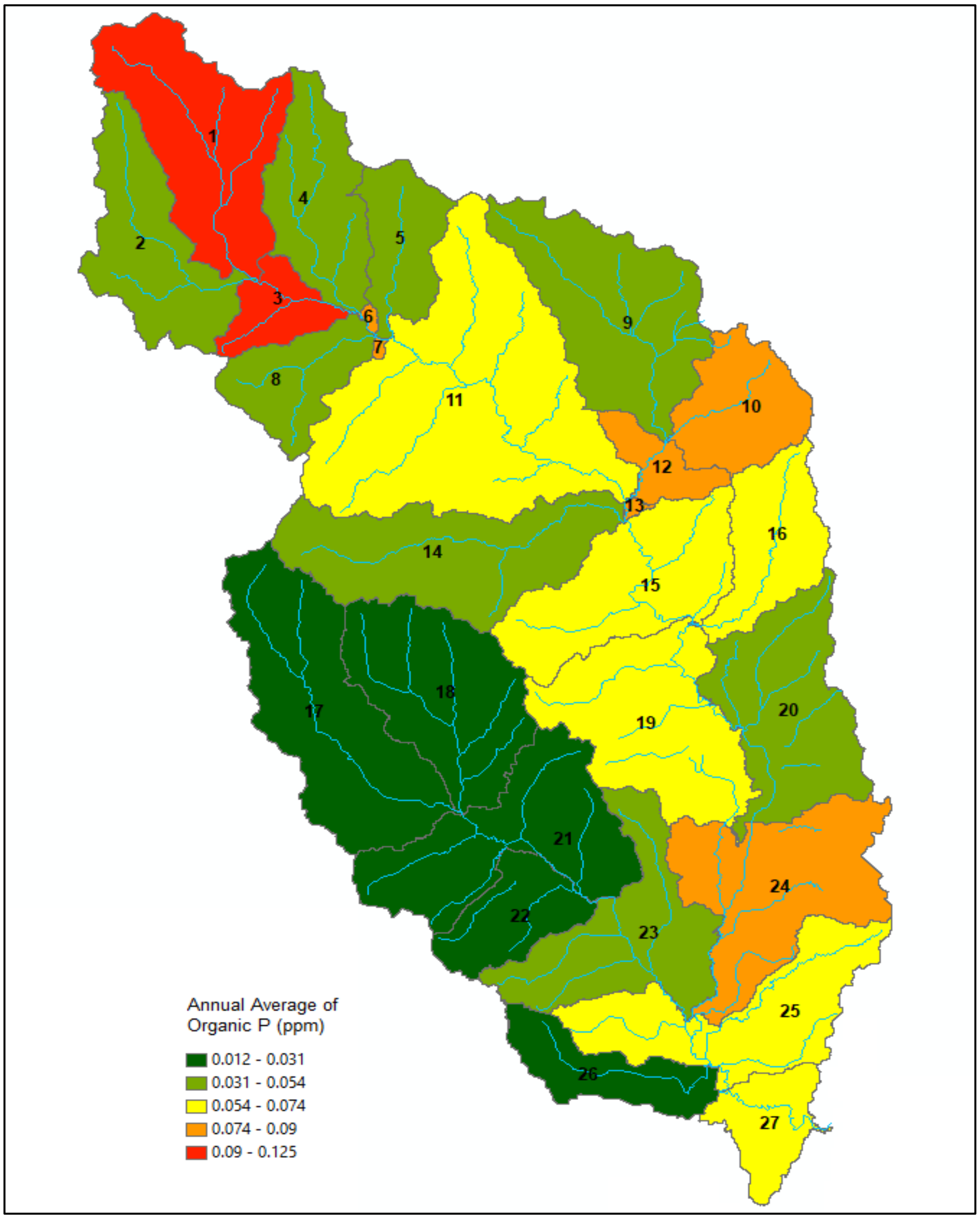

Figure A.4. Annual Average Organic P (ppm) (SWAT, 2019)

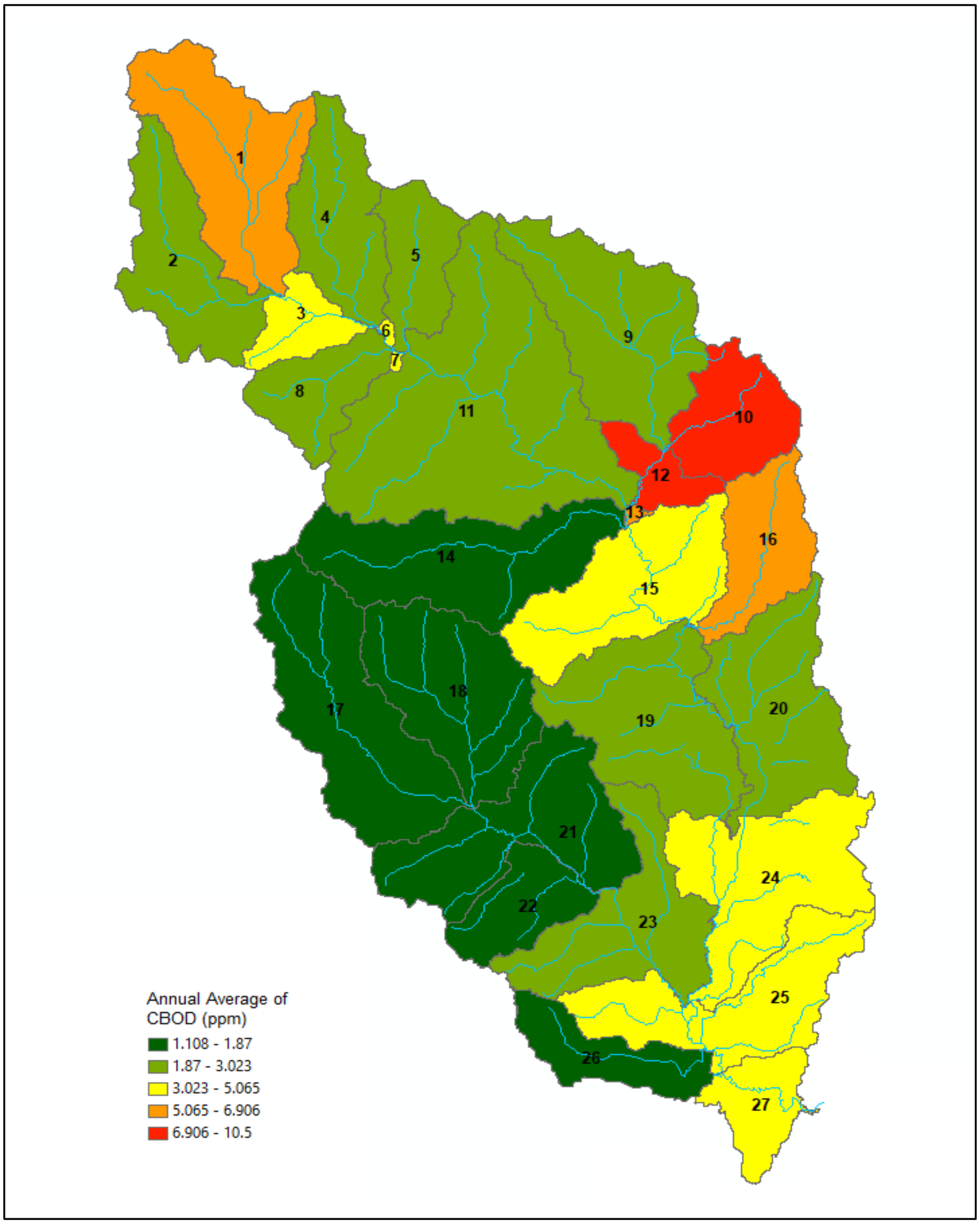

Figure A.5. Annual Average Carbonaceous Biochemical Oxygen Demand (ppm) (SWAT, 2019)

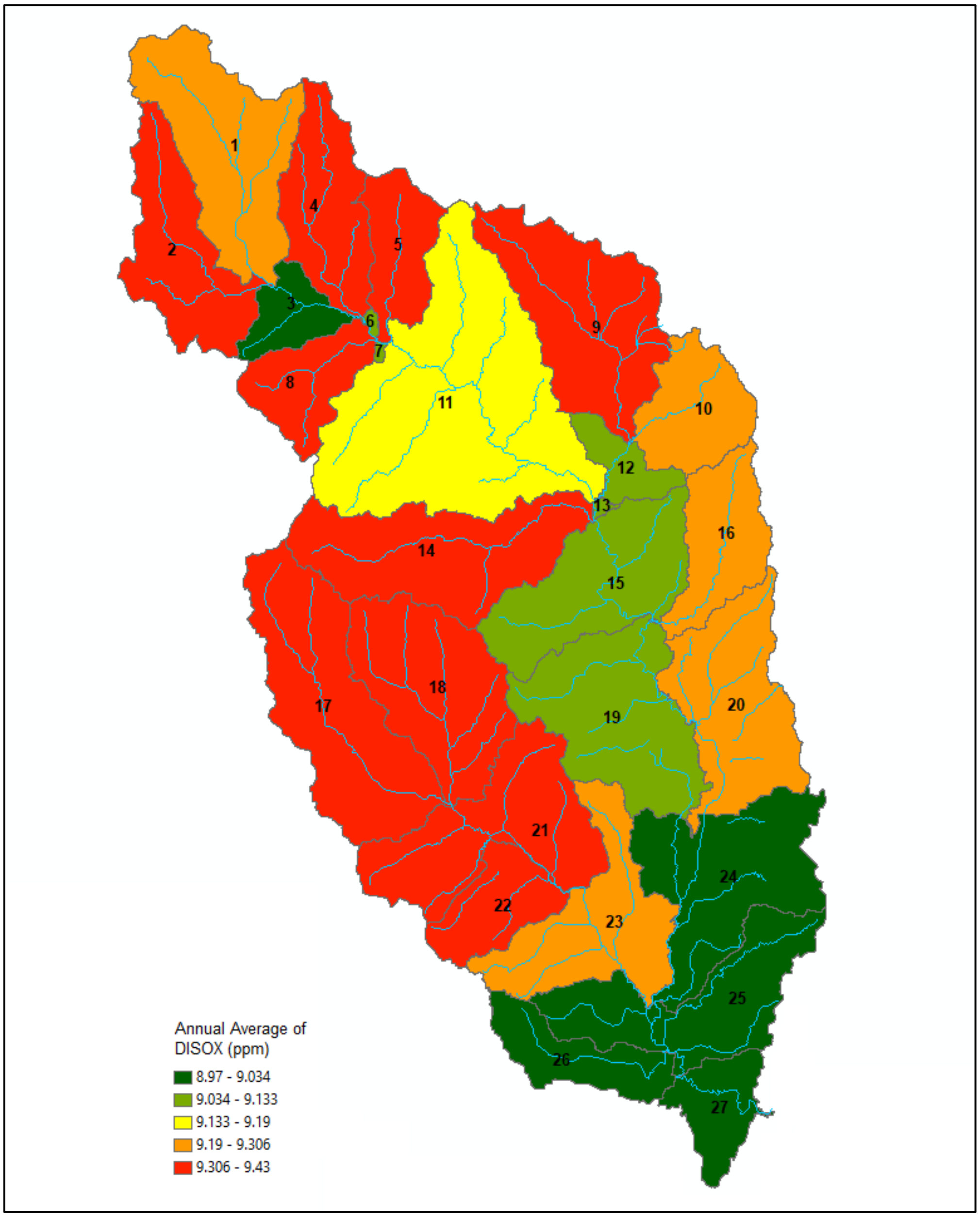

Figure A.6. Annual Average of Dissolved Oxygen (ppm) (SWAT, 2019)