IMPROVING THE WATER QUALITY IN THE LAKE HUDSON WATERSHED IN MAYES COUNTY, OKLAHOMA

By

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Abstract: Water quality in the State of Oklahoma is governed by the Clean Water Act (CWA). Lower Lake Hudson was listed on the EPA's 303 (d) Impaired Waters List for not meeting the dissolved oxygen water quality standard in 2016. The Grand River Dam Authority (GRDA) manages Lake Hudson. It is a hydroelectric reservoir along the Grand River. GRDA, in collaboration with Oklahoma Conservation Commission (OCC) and Oklahoma State University (OSU), sought to implement management measures in the Lake Hudson Watershed in order to improve water quality. A riparian habitat watershed assessment was conducted for the subwatersheds in Mayes County in order to determine critical areas that require protection. The condition of the riparian areas of the watershed were assessed using visual interpretation of aerial images in a GIS environment. The critical areas were then modeled using the Environmental Protection Agency's (EPA's) Spreadsheet Tool for Estimating Pollutant Load (STEPL) model to estimate pollutant loading within the Lake Hudson Watershed. The application of riparian forest buffers as a best management practice (BMP) was used to calculate load reductions. Riparian forest buffers were economically evaluated in the prioritized areas using the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) cost-share program as a conservation option. Conservation easement evaluation methods used in Oklahoma were contemplated as a possible benchmark for this watershed as another option. The results of the riparian assessment, STEPL modeling, economic evaluation of riparian buffer implementation, and the conservation easement evaluation will collectively inform water quality improvement efforts in the Lake Hudson Watershed.

Keywords: Riparian, assessment, watershed, STEPL, model, Hudson

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CHAPTER I

INTRODUCTION

1.1 Background

Freshwater is an invaluable resource that forms a vital component of the water cycle for anthropogenic needs. Freshwater is stored in rivers, lakes, reservoirs, creeks and streams (Dodds & Whiles, 2010). Water quality and water quantity are the two most important factors when considering this resource. Water quality is important for human and ecosystem functioning and can be protected through a range of strategies that address specific sources of pollutants.

The Clean Water Act (CWA) is the primary federal law governing water pollution in the State of Oklahoma. It provides a framework that helps to regulate pollutant discharges into waterbodies as well as water quality standards for surface waters (EPA, 2013). Section 303 (d) of the CWA requires every state to identify waterbodies such as streams, lakes, and rivers that do not meet their relevant water quality standards (ODEQ, 2016). These waterbodies are then referred to as impaired and must be prioritized depending on the severity of their impairments and the associated designated beneficial uses of the waterbodies (ODEQ, 2016). Lower Lake Hudson was listed on the 2016 Environmental Protection Agency (EPA) 303 (d) Impaired Waters List for low dissolved oxygen.

The Lake Hudson Watershed is located in Mayes County, Oklahoma. Lake Hudson, also known as the Markham Ferry Reservoir, is the second hydroelectric project along the Grand River that is found in this watershed. The reservoir is owned and operated by the Grand River Dam Authority (GRDA). It produces 211 million kWhs electricity per year. The Federal Energy Regulatory Commission (FERC) requires sustainable harvesting of hydroelectric power in order to minimize risk to the environment. GRDA, in collaboration with Oklahoma Conservation Commission (OCC) and Oklahoma State University (OSU), are seeking to implement management measures to protect the water quality of the Lake Hudson Watershed.

1.2 Purpose of the Study

Management measures such as riparian buffer restoration have known benefits of mitigating Non-Point Source (NPS) pollution within a watershed. NPS pollution is produced from diffuse sources. This makes it difficult to pinpoint its origin (Lewis, 1999). NPS pollution is one of the leading causes of water quality problems. It has harmful effects on drinking water supplies, recreation, fisheries, and wildlife (Lewis, 1999). The implementation of riparian buffers using a cost-share program such as the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) is a means of protecting water quality. Another method of conserving the value of riparian areas is through the purchase of conservation easements. A conservation easement is a legally binding agreement between a landowner and a government agency or land trust, that limits varying uses of the property in order to preserve it from a conservation perspective (Park & Allaby, 2013). The purpose of the easement in this study is to maintain and improve water quality.

There are three components to this study: 1) Riparian habitat assessment, 2) Spreadsheet Tool for Estimating Pollutant Load (STEPL) modeling of pollutant loads, and 3) Economic evaluation of implementing a riparian buffer and the purchase of conservation easements in critical areas of the watershed. The first component is a riparian habitat assessment of subwatersheds of the Lake Hudson Watershed. This is a visual assessment utilizing geographical information systems (GIS) to identify areas in the watershed that have poorly vegetated riparian areas and prioritize them for conservation efforts in order to mitigate the effects of NPS.

The second component is a modeling estimate of pollutant loads from the Lake Hudson Watershed. Watershed modeling is a useful method to estimate pollutant loading (EPA, 2013). EPA's STEPL model is used to estimate load reduction resulting from NPS activities. Pollutants such as nitrogen, phosphorus, biological oxygen demand (BOD), and sediment are modeled. Pollutant load reductions using the riparian forest buffer as a best management practice (BMP) are modeled and the results are compared. Attaining conservation goals depends on planning tools such as models like STEPL to assist in the resource management process.

Financial assistance to implement management measures is also critical to the success of the intervention. The economic viability of riparian buffer implementation and the evaluation of the different methods of conservation easements are assessed as the third component of this study. Economic costs are estimated using the NRCS EQIP cost-share program. These estimates are evaluated from both a management and landowners' perspective. The methods of conservation easement evaluations used in Oklahoma are reviewed and examples provided for similar water quality objectives.

1.3 Research Objectives

The objective of this study is to address the water quality concerns in the Lake Hudson Watershed by assessing the riparian areas of the watershed, the causes of impairments and recommendations on implementing BMPs to address these issues. The specific objectives of this research are to:

1. Assess, and prioritize the riparian areas via visual interpretation of remotely sensed aerial data in a GIS environment;

2. Determine the pollutant loads in the watershed using the STEPL model and apply the riparian buffer as a BMP scenario to model pollutant load reductions in the watershed;

3. Compute the cost of implementing riparian buffers in the prioritized areas using the NRCS EQIP cost-share program;

4. Review the methods of conservation easement evaluations used in Oklahoma as a benchmark for future conservation initiatives.

The outcomes of this study provide identification of key areas within the Lake Hudson Watershed that require protection. They should be prioritized for riparian buffer implementation and/or the purchase of conservation easements. The economic assessment provides a cost estimate of these conservation measures that can improve water quality and potentially result in the removal of Lower Lake Hudson from the EPA's 303 (d) Impaired Waters List. Conservation measures around riparian zones have been the focus for two reasons: 1) they are the last line of defence to protect a waterbody from pollutants and 2) the GRDA owns the land around the dam and are able to influence conservation measures with surrounding private property owners that have land within the riparian zones.

CHAPTER II

LITERATURE REVIEW

2.1 Beneficial Uses of Water in the Lake Hudson Watershed

Water quality addresses the condition of a waterbody to meet the water quality standards in order to fulfill a specific need. A designated use is a legal description of a desired use that a waterbody must be healthy enough to support (OWRB, 2017b). The beneficial uses that are currently designated in the Lake Hudson Watershed are the following: 1) Public and Private Water Supply; 2) Fish and Wildlife Propagation; 3) Agriculture; 4) Primary Body Contact Recreation; 5) Fish Consumption; and 6) Aesthetics (ODEQ, 2016). Lake Hudson is the primary water supply for the Locust Grove and Mayes County Rural Water District 6 water systems (SDWIS, 2017). There is insufficient information available to determine if the designated uses for public and private water supply and fish consumption are supported (ODEQ, 2016). The designated uses for agriculture, aesthetics, and primary body contact recreation are fully supported. Lower Lake Hudson does not support a Warm Water Aquatic Community (WWAC) due to low dissolved oxygen (ODEQ, 2016). This is a sub-category of fish and wildlife propagation (ODEQ, 2016).

2.2 Water Quality in the Lake Hudson Watershed

Water quality standards in Oklahoma are frequently not attained due to three main causes of impairments: 1) pathogens, 2) turbidity, and 3) low dissolved oxygen (ODEQ, 2016).

The causes and sources of impairments aid in the identification of management measures that can be used to target these pollutants and improve water quality. The cause of impairment in Lower Lake Hudson is low dissolved oxygen. Pollutants causing this condition can be both point and non-point sources. Point sources emanate from discrete discharges. They consist of municipal wastewater treatment plants that discharge into the tributaries of Lake Hudson (EPA, 2018). The municipalities include: 1) Pensacola Public Works Authority located north of Lake Hudson that discharges into Big Cabin Creek, 2) Salina Public Works Authority found southeast of Lake Hudson that discharges into Neosho River, and 3) Langley Public Works Authority situated north of Lake Hudson that discharges into the Neosho River (EPA, 2018). These point sources are permitted through Oklahoma Department of Environmental Quality (ODEQ) regulations under the National Pollutant Discharge Elimination System (NPDES) rules.

NPS pollutants are less discrete, more pervasive, and unregulated. They enter from diffuse sources such as agricultural and storm water runoff (ODEQ, 2016). The combined effects of various land uses results in NPS, and it is usually driven by meteorological events such as runoff during rainfall events (Brooks, Ffolliott, & Magner, 2013). Soil disturbances increase the availability of sediment sources. They increase the potential for erosion, runoff, and downslope sedimentation during rainfall events. The source of NPS pollution for Lake Hudson is categorized as unknown, according to the 2016 ODEQ Integrated Report (ODEQ, 2016). Agricultural activities contribute to NPS pollution through, 1) the improper management of fertilizer application, 2) grazing practices, and 3) animal feedlots and manure application (EPA, 2003). Some examples of NPS pollutants entering the Lake Hudson Watershed could be fertilizers and soil from agricultural lands, sediment from eroding stream banks, and bacteria and nutrients from livestock.

Unsuitable land application of fertilizers could result in large amounts being washed off during rainfall events and ending up in streams. Lower Lake Hudson’s impairment is low dissolved oxygen (ODEQ, 2016). These low levels of dissolved oxygen can be a result of excessive nutrient loading (NOAA, 2019). Lower Lake Hudson had nutrient values of 0.68 Mg/L to 1.73 Mg/L of total nitrogen and 0.075 Mg/L to 0.156 Mg/L of total phosphorus. The Lake Hudson Watershed is known to be a nutrient limited watershed, and this means that excess nutrients can adversely affect the designated beneficial uses of this watershed (OWRB, 2012). The Oklahoma Water Resources Board (OWRB) employs the Carlson's Trophic State Index (TSI), using chlorophyll-a concentrations to calculate the trophic status of a lake (OWRB, 2015). The TSI is linked to the nutrients that run off the land and increase primary production. A TSI value of 1) below 40 is oligotrophic with low nutrient levels, 2) 41-50 is mesotrophic with moderate nutrient levels, 3) 51-60 is eutrophic with high nutrient levels, and 4) over 61 is hypereutrophic with excessive nutrients (OWRB, 2015). The OWRB (2017a) declared Lower Lake Hudson as eutrophic with a TSI of 60 and a chlorophyll-a concentration of 19.56 mg/m3.

Primary production affects the amount of dissolved oxygen through both the processes of photosynthesis and respiration (Dodds & While, 2010). The dissolved oxygen concentration in a lake fluctuates both spatially and temporally. Lake stratification refers to the different layers in the vertical profile of a waterbody, as a result of drastic changes in the temperature difference during spring or summer (Bass, 2008). The water temperature at the surface (epilimnion) during the summer increases and the concentration of oxygen decreases due to gas solubility (Dodds & Whiles, 2010). Diurnal cycles change the amount of oxygen available during the day when photosynthesis creates oxygen, and at night when respiration takes up oxygen (Dodds & While, 2010). These diurnal fluctuations in oxygen are more pronounced in eutrophic lakes (Dodds & While, 2010). Bacterial respiration can cause oxygen levels to plunge in lower layers (hypolimnion) of the lake when large amounts of decomposing plant material are present. This negatively impacts aquatic life (Bass, 2008).

Northeastern Oklahoma is well-known for its poultry industry. Poultry (814,283 chickens) and cattle (30,719) are the two largest groups of livestock found in the watershed (Tetra Tech, 2018). Tributaries of the Lake Hudson Watershed, such as Saline Creek and Little Saline Creek, are impaired for enterococcus (ODEQ, 2016). Enterococcus is a bacterium that occurs as a result of fecal contamination. This results in high levels of bacteria in a stream (EPA, 2003). Erosion of grazing land as well as grazing in the riparian areas, coupled with improper management of cattle and poultry wastes, could be potential sources of NPS in the watershed.

Uncontrolled levels of NPS pollution have led to the impairment of Lower Lake Hudson. This compromises its ability to support WWAC as one of its beneficial uses (ODEQ, 2016). The dissolved oxygen concentration is less than 2.0 Mg/L in up to 58% of the water column reported for the month of August (OWRB, 2017b). OWRB (2017b) has prescribed screening levels of dissolved oxygen to support WWAC, the oxygen levels need to be 4.0Mg/L from 16 June to 15 October and 5.0 Mg/L from 16 October to 15 June. No more than 50% of the water volume should have a dissolved oxygen concentration of less than 2.0 mg/L in a lake (OWRB, 2017b).

2.3 Mitigating Impacts through Riparian Buffer Restoration and Conservation Easement Purchase

Watersheds can be protected against agricultural NPS pollution through the implementation of BMPs that can result in lower contamination levels. Riparian buffer zone restoration is a well-known BMP used in watershed management to reduce pollutant loads and improve water quality (Sheridan, 1999; EPA, 2003). Riparian buffers are typically comprised of a mixture of trees, shrubs, grasses, and forbs adjacent to a stream that help to mitigate the impacts of various land uses (Schultz, Isenhart, & Long, 2013). Healthy, well-maintained riparian buffers for stream systems serve many vital ecological functions. Plant and animal biodiversity, water quality protection, erosion control, and recreational appeal are a few of the ecosystem services that riparian buffers provide (OCES & OCC, 1998). They also serve to slow concentrated flows from runoff. This allows sediment and nutrients to settle in the floodplain (OCES & OCC, 1998). Riparian areas can function as barriers to limit transportation of sediments and other pollutants to streams.

There are various approaches that are used to determine the ideal width for riparian forest buffers. Buffer widths of 75 to 100 feet (~22 to 30 m) are generally recommended to produce water quality and wildlife benefits (Palone & Todd, 1998). Schultz et al., (2013) proposed that when determining buffer width, "wider is better." Being conservative with buffer widths is largely recommended to achieve water quality objectives as numerous studies support the conclusion that buffer efficiency at filtering out pollutants increases with width (Hawes & Smith, 2005). Surface flow discharge of nitrogen and phosphorus are reduced as a function of riparian buffer width (Weissteiner, Bouraoui, & Aloe, 2013).

The Oklahoma Cooperative Extension Service (OCES) and OCC (1998) guidelines for riparian buffers recommend a three-zone system with specific widths to allow for optimal pollution removal and streambank protection. The minimum widths are 15 feet for Zone 1, 60 feet for Zone 2 and 20 feet for Zone 3. Zone 1 is undisturbed to allow for natural ecosystem function and is comprised of native trees (OCES & OCC, 1998). This zone lowers stream temperature by shading the water and providing a soil/water interface to encourage the removal of pollutants (OCES & OCC, 1998). Zone 2 is the intermediate area and it will create an area for nutrient storage in woody vegetation. Native shrubs and woody vegetation are found here, and it is more managed than Zone 1 (OCES & OCC, 1998). Zone 3 is vegetated with dense perennial grasses and forbs, and is the zone where runoff is controlled (OCES & OCC, 1998).

Water quality can also be protected though the purchase of conservation easements. A conservation easement is a voluntary, legal agreement that permanently limits land use in order to protect its conservation values (NCED, 2020). Some important benefits of conservation easements include: 1) the ability to lower the costs to state agencies or land trusts for protecting land, 2) landowner retains various private property rights, 3) donation of conservation easements may have tax benefits to landowners, 4) land is kept in private ownership, and 5) provides economic benefit to the area (NCED, 2020). Braza (2017) found that more habitats in agricultural lands were protected when conservation easements were in place. The purchase of conservation easements can limit the use of critical riparian areas as pastureland in the Lake Hudson Watershed.

2.4 Modeling Load Reductions using the STEPL Model

Implementation of riparian buffers can effectively improve water quality and limit soil loss (Schultz et al., 2013). Quantifying the impact of an implemented riparian buffer as a BMP is critical to understanding its efficacy. The STEPL Model is a spreadsheet tool that is designed to determine nutrient and sediment loads from various land uses. It is used to illustrate the average annual pollutant loadings from NPS (EPA, 2018). The MS Excel spreadsheet incorporates algorithmic calculations that are customized to assist in decision making at a planning level (EPA, 2018). The tool also calculates load reductions from implementing BMPs (EPA, 2018).

A limitation of the STEPL model is that it could not reliably identify watershed pollutant sources (Nejadhashemi, et al., 2011). Nejadhashemi, et al. (2011) recommends STEPL to evaluate relative contribution of the various land uses to the total pollution load in less complex watershed planning. A review of 14 watershed models by Borah, Ahmadisharaf, Padmanabhan, Imen, and Mohamoud (2019) found that STEPL ranked as one of the lowest of this multi-model comparison for both TMDL development and implementation (Borah et al., 2019). A limitation of the model is that daily or seasonal sediment yield or nutrient loadings could not be determined. Borah et al. (2019) found that the model could be used as a preliminary planning tool in estimating loads and load reductions from BMPs and could therefore serve as an initial TMDL implementation tool.

STEPL can be used as a tool in watershed management. STEPL can be used in at least three of the nine EPA Watershed Based Plan (WBP) elements: 1) Identifying land use sources associated to pollutants such as nitrogen, phosphorus, BOD, and sediment, 2) estimating pollutant loading into the watershed and the expected load reductions, and 3) describing management measures that will achieve load reductions and target critical areas (EPA, 2013). Elk City, Lake Winnipesaukee, Lower Animas River, Poplar Creek and Little Beaver Creek are WBPs that have utilized STEPL for their modeling needs.

The Elk City Lake WBP in Oklahoma uses STEPL to determine source loads due to the absence of stream data for the pollutants from the different land uses (OCC, 2008). STEPL does not simulate bacteria loading, so this plan used the same delivery method of other NPS pollutants such as sediment. These vary according to land use (OCC, 2008).

The main concern for Lake Winnipesaukee was phosphorus loading and its impact on water quality (LWWA, 2010). The Lake Winnipesaukee Watershed Management Plan utilizes the STEPL Model to determine phosphorus loading. It identified areas that required restoration or protection, and phosphorus load reductions from implementing BMPs (LWWA, 2010). A large part of the management plan focused on both reducing and preventing phosphorus runoff into Lake Winnipesaukee due to the large economic impacts that have been associated to the deteriorating water quality (LWWA, 2010).

The Lower Animas River WBP in New Mexico employed the STEPL Model to calculate the nutrient and sediment loading of different land use types in each of their six Hydrologic Unit Code (HUC) 12 subwatersheds (NMED, 2016). The estimated pollutant load reflects only processes taking place within each subwatershed. It excluded pollutants moving from one subwatershed to another in order to compare the relative differences in pollutant loads that were expected from subwatersheds with varying extents of land uses (NMED, 2016).

The Poplar Creek WBP in Illinois estimated pollutant loads for their ten watershed planning units with STEPL (IEPA, 2018). STEPL simulates BMP combinations for Poplar Creek and suitable practices were selected based on a sensitivity analysis. The sensitivity analysis determines how a certain BMP performed. It also determines the most suitable BMP for a specific type of land use (IEPA, 2018). The load reduction goals were then quantified from BMP implementation and the associated loading reductions (IEPA, 2018).

The most recent project piloted by the United States Department of Agriculture (USDA) through a partnership between the NRCS and OCC is the National Water Quality Initiative (NWQI). This project assessed the Little Beaver Creek Watershed in Oklahoma (OCC, 2019). Little Beaver Creek is ranked as a number one priority for NPS watersheds in western Oklahoma (OCC, 2019). The project objectives are to reduce pathogens, turbidity, and total dissolved solids (OCC, 2019). The watershed assessment stage includes a visual aerial GIS riparian assessment, a SWAT model assessment and STEPL modeling for pollutant loading (OCC, 2019). Proposed BMPs based on the results of this pilot project will be used for future conservation efforts (OCC, 2019).

The riparian habitat assessment for Lake Hudson will be used to identify critical areas of pollutant loading in the watershed. The STEPL model will be used as a preliminary planning tool to conduct a basic quantitative analysis of loads and load reductions. The current pollutant loads will be determined, and pollutant load reductions will be modeled using riparian buffer restoration in critical pastureland. The results will be incorporated into a WBP for the Lake Hudson Watershed informing management conservation options on improving water quality.

2.5 Economic Costs Linked to Riparian Buffers

There are two types of costs associated with NPS pollution. The first cost involves reducing the pollutant loads. The next cost is associated with the impacts caused by the pollution (EPA, 2015). The costs of dealing with the pollution impacts are considered externalities because they reflect the costs to society and not to the producer of the pollutants (Tietenberg & Lewis, 2012). Examples of external costs are the loss of recreational activities, aesthetics or drinking water provided by a waterbody. The proactive approach of pollution prevention is far more economical in managing NPS and its impacts (EPA, 2015).

Water quality management at a watershed scale is important as it allows for an integrated approach to managing land use and its effects on the surrounding waterbodies. The most cost-effective approach for managing water quality requires targeting BMP efforts in areas that will yield the highest return. The riparian assessment highlights critical areas that provide a form of prioritization for management measures in the Lake Hudson Watershed.

The economic cost of establishing riparian buffers consists of construction, maintenance and opportunity costs (Bonham, Bosch, & Pease, 2006). These costs refer to the land preparation costs when installing the buffer, maintenance costs throughout the lifespan of the buffer, and land opportunity costs (Bonham et al., 2006). Landowners can be assisted through technical and financial assistance. This can offset the loss of converting agricultural lands to riparian buffers (Basnyat, Teeter, Lockaby, & Flynn, 2000).

Riparian buffer costs are site-specific and will depend on the length and width of the buffer, and the vegetation species used (Passeport, Tournebize, Chaumont, Guenne, & Coquet, 2013; Yang & Weersink, 2004). There is only the cost of maintenance once the riparian zone is vegetated. Various funding sources are available to landowners from federal, state, and private assistance programs. EQIP is available through NRCS and it is the largest conservation program available through USDA. It 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 (NRCS, 2019). It is a voluntary program that has contract duration of between one to five years (NRCS, 2019).

2.6 Review of Methods of Conservation Easement Evaluations in Oklahoma

The valuation methods of conservation easements are reviewed for the possible purchase of easements in the Lake Hudson Watershed, as a means of incentivizing water quality protection. Conservation easements are stewardship opportunities for landowners to protect valuable resources. There are various valuation methodologies for conservation easements (Sherwood, 2014). Conservation easements vary greatly in value according to the Land Trust Alliance (LTA, 2019).

An analysis of stewardship costs revealed that there is no precise guide for calculating costs based on the size of the easement (TNC, 2016). There is a wide scale of economic costs that range from $100 an acre to $1,000 an acre per year depending on the size of the easement (TNC, 2016). These costs vary widely due to both conservation value and market value (Sherwood, 2014). The main issue regarding easements is whether the easement affects the use of the property changing its highest and best use (Sherwood, 2014).

Market value is usually viewed as fair payment by the courts. There are many methods that are used to measure the fair market value of conservation easement such as the comparable sales method, the before and after method, reproduction cost method, income valuation method and fixed percentage method (Carson, 2015). Other methods include the summation method or state method and highest and best use (Sherwood 2014; Guerra, n.d.).

The most common method for easement valuation is the before and after method. It is widely accepted by appraisers as the method of choice (Šnajberg, 2015). The Code of Federal Regulations includes a section for easements and appraising property subject to easements. The appraisal procedure is from the Yellow Book of Generally Accepted Government Auditing Standards (GAGAS) (UASFLA, 2016). The value of the easement is based on the difference between the value of the whole property before and after the easement was put into place

(Sherwood, 2014). This valuation methodology can be used both for federal and state acquisitions and the market value of properties are used to calculate before and after values (Sherwood, 2014).

The summation method, also called the state method as it is adopted by many states, estimates the value of an easement in addition to the damages caused to the remaining part of the property (Guerra, n.d.). Two evaluations are conducted, one for the easement compensation and the other for the damages. The compensation value is the same as the before and after method and any damages could be offset by any benefits from the easement (Sherwood, 2014). Market sales of properties without easements are used to appraise the easement values (Guerra, n.d.).

Market values are linked to the highest and best value of a property. The highest and best use incorporates four criteria, namely: 1) physically possible, 2) legally permissible, 3) financially feasible, and 4) maximally productive, according to the Fifth Edition of The Dictionary of Real Estate Appraisal by the Appraisal Institute. Three approaches are used to estimate fair market value: 1) the cost approach, 2) sales comparison approach, and 3) income approach. The sales comparison approach is the preferred method in conservation easement appraisals as it provides a reliable estimate (McLaughlin, 2015). Sales that have recently taken place of properties that are similar are used to determine the “before” easement value. The best fit properties are those that are nearby, have other similar features, and have a highest and best use that is equivalent (McLaughlin, 2015).

The before and after method has been adopted for conservation easement evaluation in Oklahoma (A. Johnson, personal communication, January 27, 2020; M. Patton, personal communication, November 25, 2019). An example is the City of Tulsa, that had purchased conservation easements in Delaware County which is a part of the Eucha-Spavinaw Watershed. The purpose of the easements was to preserve water quality and they were evaluated using the market values of property from 2018-2019. The average easement was approximately 62% of the appraised value.

The acquisition costs per acre ranged from $642 to $2,700, with an average of $1,427.96 (A. Johnson, personal communication, January 27, 2020). This excludes management costs. This includes monitoring costs to enforce compliance to the terms of easement contract by the City of Tulsa, as the easement holder. Land Legacy, US Fish and Wildlife, and the State of Oklahoma also hold conservation easements in this watershed (Land Legacy, 2016).

Land Legacy uses conservation appraisal valuers to determine the highest and best use, for the before and after easement values (M. Patton, personal communication, November 25, 2019). Property with an average of 40% development rights has an easement value of approximately $6,000 per acre, while properties with an average of 25% development rights has an easement value of approximately $7,500 per acre. The raw value of land in Delaware County varies widely from $11,000 per acre to $400,000 per acre.

There are also both federal and state tax benefits for conservation easements in Oklahoma. The federal tax benefits are: (1) tax deductions that are equal to 50% of their annual income in the case of a donated conservation easement, (2) the tax deduction for a conservation agreement can last up to 15 years, and (3) farmers and ranchers that qualified, could deduct up to 100% of their income (Patton, Goodman, Engle, Bidwell, & Crace, 2017). Donated easements must be held in perpetuity for them to be tax deductible. The value of taxable estate will decrease by the value of the easement, in the case of a donation or sale of a conservation easement, (Clark, Tankersley, Smith, & Starns, 2007).

The state tax benefit is an ad valorem tax. Ad valorem tax (based on the assessed value of a property), is used for conservation easement programs and conservation practices such as the implementation of riparian forest buffers through state or federal cost-share programs (OTC, 2016). Ad valorem property taxes are assessed for the value of property that is non-exempt and is based off the county assessor property values (Ward, 2012).

The assessed value of real estate is calculated as the market value multiplied by the county ratio in Oklahoma. The assessed value is then be multiplied by the levy to provide the tax value (L. Melchior, personal communication, March 6, 2020). Land that has a market value of $10,000 is multiplied by the county rate of 11.2% and provides an assessed value of $1,120, as an example. The assessed value is then multiplied by the levy (.08539) and provides the ad valorem taxes of $96 for the land.

Conservation easements are beneficial to both easement encumbered landowners and surrounding property landowners. Reeves, Mei, Bettinger, and Siry (2018) found that conservation easements have a positive effect on value of surrounding properties. The positive economic benefit is through the generation of tax revenue as a result of increasing the surrounding value of properties (Reeves et al., 2018). Some of the characteristics that influences these property values includes proximity, development potential, and forest characteristics (Reeves et al., 2018). About 80% or more of a property's appraised fair market value depends on proximity to urban areas, development potential and other factors (Land Legacy, 2016).

CHAPTER III

METHODOLOGY

There were three components that made up the methodology of this study (Figure 1). The Lake Hudson Watershed boundary was delineated, and the study area was characterized. The first component included an in-depth riparian habitat assessment using GIS (ArcGIS). The spatial extent of riparian woody vegetation cover was visually estimated, and the landowners of the critical areas were identified. The second component included the modeling of pollutant loads for the subwatersheds using STEPL. Pollutant load reductions were subsequently computed using riparian buffers as a BMP. An economic valuation was then completed as the third component to calculate costs of buffer implementation in critical areas of the watershed.

3.1 Study Area

Watershed Boundary

The Lake Hudson Watershed is comprised of twenty subwatersheds (542,578 acres) that were classified according to a 12-digit HUC. This study focused on the seven subwatersheds that are found in Mayes County. They surround and include Lake Hudson (Figure 2). Each HUC12 subwatershed contains a waterway that ultimately drains into Lake Hudson. Table 1 lists the subwatersheds within the Lake Hudson Watershed in Mayes County and their corresponding HUC numbers and area characteristics. The total area covered by these subwatersheds is 203,569 acres.

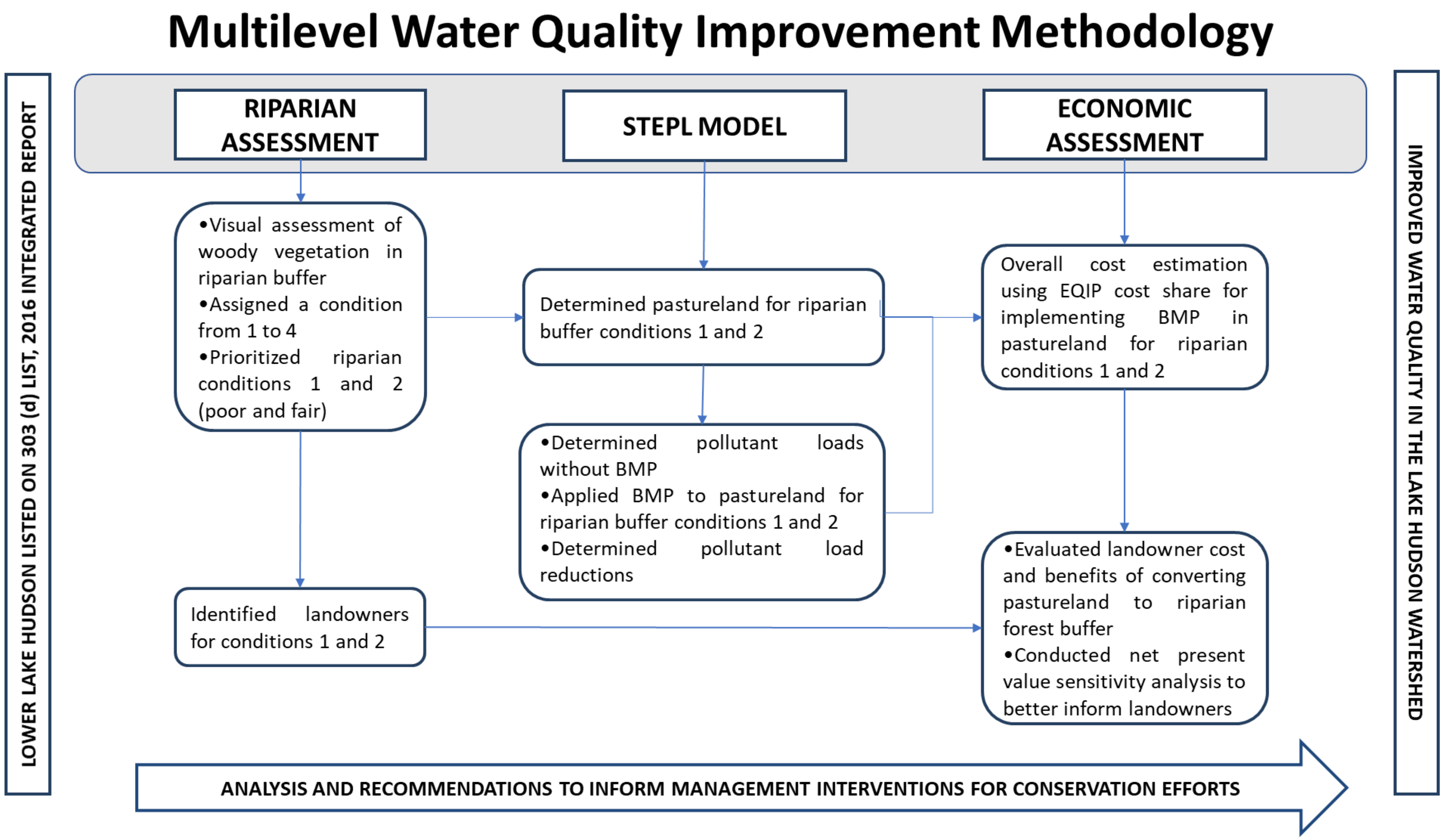

Figure 1: Methodology Process Flow

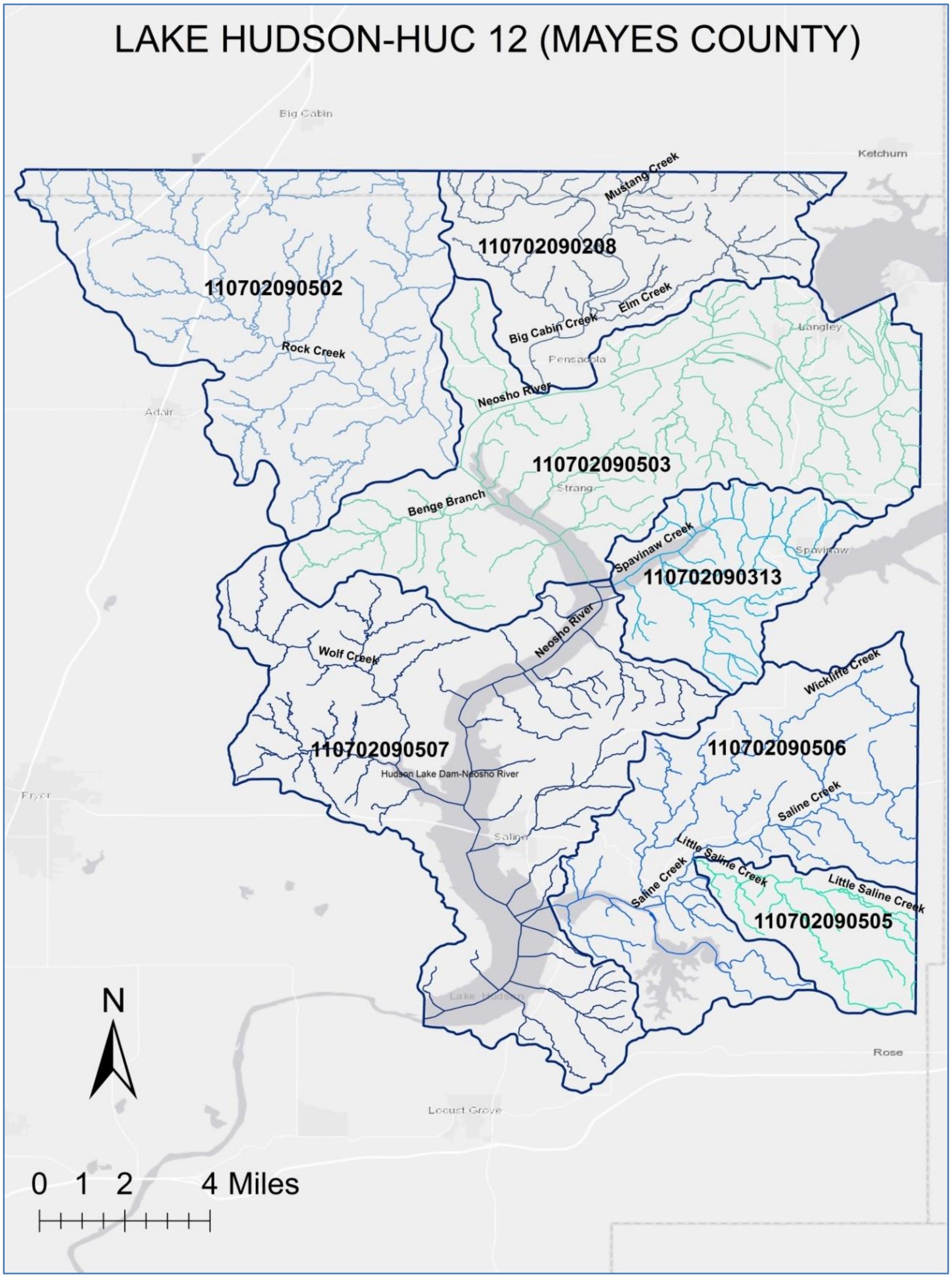

Figure 2: Lake Hudson Watershed HUC12 Subwatersheds in Mayes County

Table 1: Lake Hudson Watershed HUC12 Subwatersheds in Mayes County

HUC12	**Name**	**Area (Acres)**
110702090208	Outlet Big Cabin Creek	37,021
110702090313	Outlet Spavinaw Creek	9,237
110702090502	Rock Creek	36,534
110702090503	Hudson Lake-Neosho River	37,719
110702090505	Little Saline	15,224
110702090506	Wickliffe Creek	30,676
110702090507	Hudson Lake Dam-Neosho River	37,158
Total Area		**203,569**

Hydrologic Soil Groups

The USDA-NRCS (2009) classifies soils based off their runoff potential. There are four hydrologic soil groups from A to D, with A indicating the highest infiltration and D, the lowest infiltration. The seven subwatersheds soils belonged to the hydrologic soil groups B and C. Group B soils had moderately low runoff potential and were well drained. These soils typically had a loamy texture and were moderately deep to deep (USDA-NRCS, 2009). Little Saline subwatershed was the only one with Group B soils (Tetra Tech, 2018). Group C soils had moderately high runoff potential and were poorly drained (USDA-NRCS, 2009). These soils consisted of moderately fine to fine textured soils (USDA-NRCS, 2009). The remaining six subwatersheds (Wickliffe Creek, Outlet Spavinaw Creek, Hudson Lake Dam-Neosho River, Hudson Lake-Neosho River, Outlet Big Cabin Creek, and Rock Creek) had Group C soils (Tetra Tech, 2018).

Land Use and Land Cover

Agriculture was the primary land use throughout the Lake Hudson Watershed (Table 2). The primary land cover was pastureland. It covered approximately 55% of the watershed and accounted for 11,261acres (Figure 3) (Homer et al., 2011). The second largest land cover was forested areas. They covered about 31% of the watershed and accounted for 62,993 acres (Homer et al., 2011) (Figure 3). Forests occurred more heavily to the east of Lake Hudson, which is the southern part of the Lake Hudson Watershed.

Table 2: Land Use/ Cover for the Lake Hudson Watershed (Homer et al., 2011)

Land Use Type	**% of Watershed**	**Acres**
Urban	5.53	11,261
Cropland	2.21	4,501
Pastureland	55.21	112,411
Forest	30.94	62,993
Water	6.03	12,276
Others	0.08	166

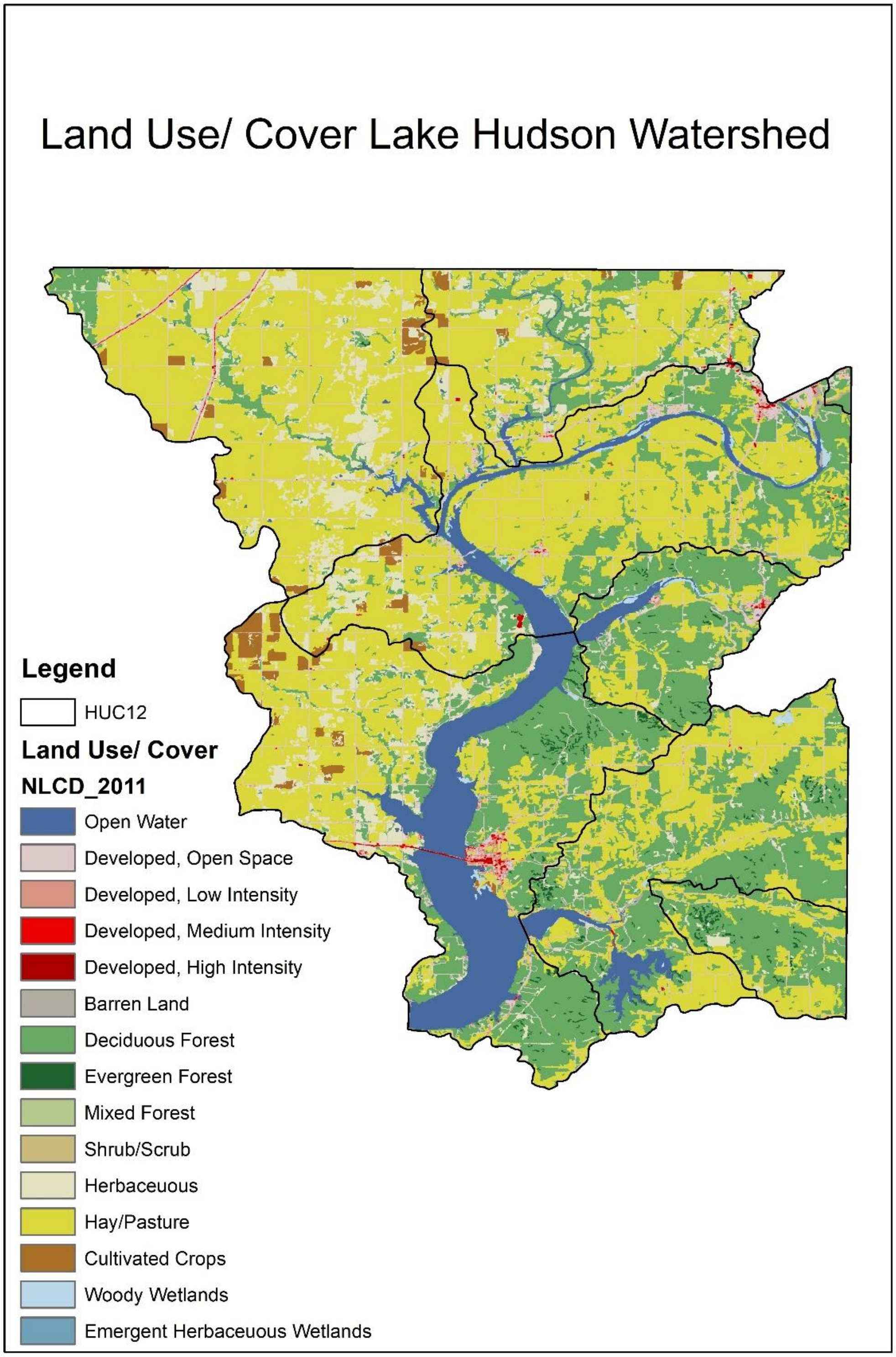

Figure 3: Land Cover Data for the Lake Hudson Watershed (Homer et al., 2011)

3.2 Riparian Assessment Using ArcMap 10.5.1 Geographic Information System

The purpose of the riparian habitat assessment was to help identify key areas within the watershed that needed protection or enhancement in order to preserve or improve the water quality in Lake Hudson. These areas would potentially be targeted for conservation practices or easements. The riparian assessment component consisted of two steps. The first step was the riparian habitat assessment that is detailed below. The second step was to overlay the ownership and property data and identify the property owners for the assessed portions of land.

Riparian Habitat Assessment Methodology

The riparian assessment was designed to qualitatively assess vegetative cover for the subwatersheds. Each subwatershed HUC (e.g. 110702090208) is referred to using the last 3 digits as follows: 313, 208, 502, 503, 505, 506, and 507. ArcMap 10.5.1 desktop was used for the riparian habitat condition assessment. The National Hydrography Dataset (NHD) hi-resolution (USGS) flowline data was overlaid onto high resolution ortho-imagery (ESRI website live link) at a 1:3000 scale (OCC, 2019). A 30m (98ft) buffer was created on either side of the NHD flowline using the proximity toolset in the Analysis Toolbox in ArcMap. An aerial visual estimation of the vegetative cover was conducted within the buffer for all stream reaches within HUCs 313, 208, 502, 503, 505, 506, and 507. The amount of apparent perennial woody vegetation was determined using the visual vegetative cover assessment (OCC, 2019).

All NHD hi-resolution stream segments were assigned an initial numeric value based on the identified woody vegetation present in the buffer (Figure 4). All segments were then evaluated for riparian condition: a) Riparian condition 0 represented a stream segment where the buffer lies within the reaches of the stream and is not applicable for management measures; b) Riparian condition 1 denoted a poor stream segment condition with no apparent vegetation in the buffer requiring priority improvement; c) Riparian condition 2 depicted a fair stream segment condition with sparse apparent vegetation in the buffer requiring improvement; d) Riparian condition 3 showed a good stream segment where the buffer was mostly vegetated requiring no intervention; e) Riparian condition 4 displayed an excellent stream segment with a buffer that was fully vegetated with vegetation exceeding the buffer requiring no intervention. Riparian conditions 1 and 2 were considered critical for management intervention in this study.

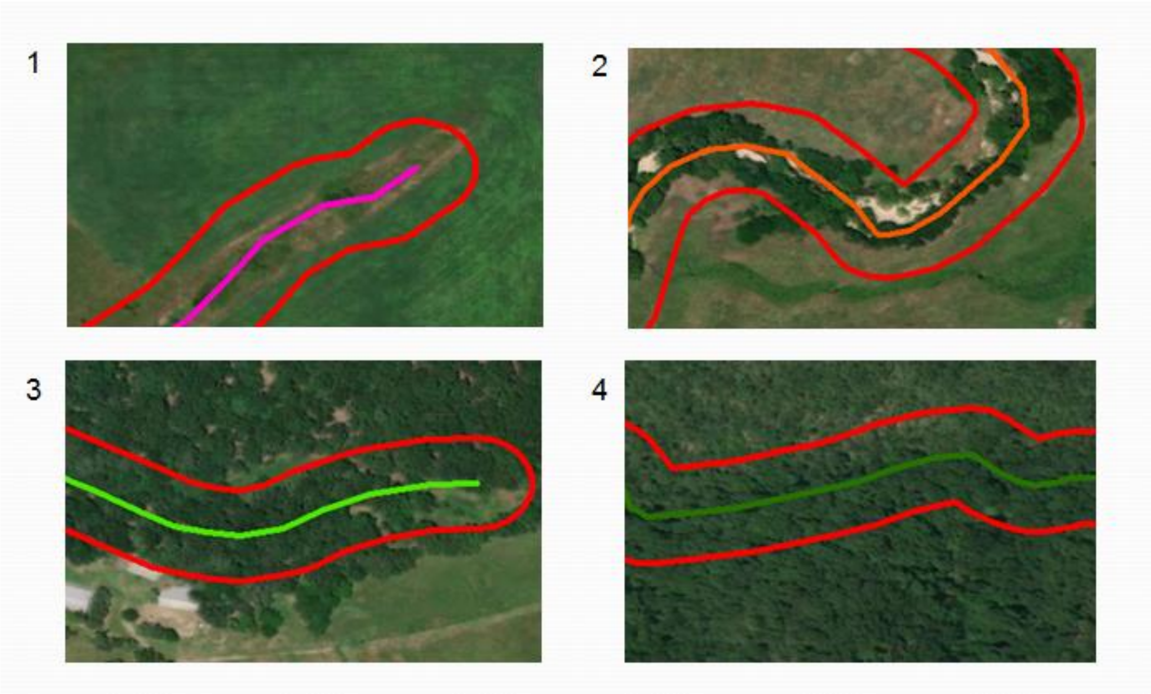

Figure 4: Riparian Condition Assessment Methodology-Stream Segments Assigned a Numeric Value Based on the Vegetation Present in the Buffer

Ownership and Property Data Methodology

The overlay toolset in the Analysis Toolbox was used and the riparian habitat assessment layer was overlaid with the parcel layer, which was obtained from Mayes County Assessor's Office (L. Melchior, personal communication, January 31, 2019). The spatial query method, "select by location", was used to find areas that intersected between the riparian habitat assessment layer and the parcel layer (Figure 5). The spatial selection method, "intersect the source layer", returned any parcel of land that either fully or partially overlapped the stream features. The property owners for riparian conditions 1 and 2 were determined per HUCs 208, 313, 208, 502, 503, 505, 506, and 507. The identity tool was used to determine what portions of critical riparian areas overlapped each land parcel.

The riparian habitat assessment was concluded once the riparian area of all subwatersheds were visually assessed and assigned a riparian condition based on the woody vegetation found within the buffer. The property ownership information was obtained for all land parcels that contained riparian conditions 1 and 2.

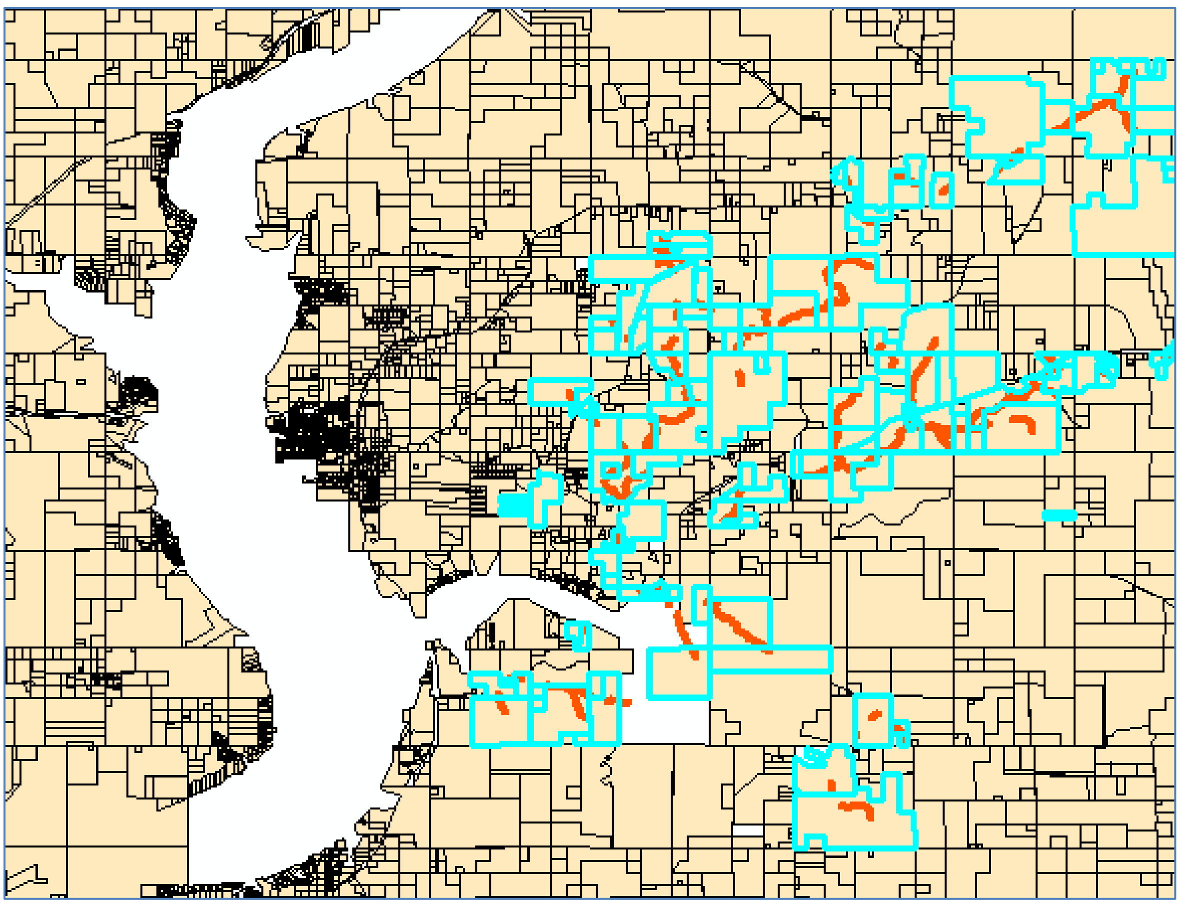

Figure 5: Ownership and Property Data Methodology-Intersection of Stream Layer and Parcel Layer to Identify Property Owners

3.3 STEPL Modeling

The STEPL modeling was conducted using STEPL Version 4.4 developed in March 2018 by Tetra Tech for the EPA.

STEPL Simulation Overview

A basic characteristic of the STEPL Model included modeling of the watershed at a subwatershed level using mixed land use types (Tetra Tech, 2018). The simulation type was continuous, and it generated yearly loading outcomes (Penn State, 2011). The excess rainfall or the amount that can run off the surface was calculated using the SCS runoff curve number (Tetra Tech, 2018). This was based upon the soil and land cover conditions.

The amount of pollutants nitrogen, phosphorus, BOD, and sediment were used as water quality parameters (EPA, 2018). The overland sediment transport method for the different land uses were derived by the Universal Soil Loss Equation (USLE) and delivery ratio (Tetra Tech, 2018). The USLE equation used to calculate the long-term average annual soil loss (A) was as follows:

$$A = R*K*L*S*C*P$$

The six factors were: R - rainfall and runoff; K - soil erodibility; L - slope length; S -slope steepness; C - cover and management; P - support practice (Brooks et al., 2013). The delivery ratio for sediment depended on the area of the watershed (Tetra Tech, 2018). Nitrogen, phosphorus, and BOD were calculated using two sources: 1) nutrient loads from land uses, which are calculated by pollutant coefficients and annual direct runoff, and 2) nutrient loads in sediment that are calculated by soil nutrient concentrations and sediment load (IEPA, 2018).

Assumptions of the STEPL Model

STEPL is an uncalibrated tool and estimates watershed pollutant loading based on coarse data, such as Event Mean Concentrations (EMC), which is the average reduction in pollutant concentration for a given stormwater treatment practice. A limitation of STEPL is that the calculations for water quality are determined by EMCs (EPA, 2018). Loading accuracy is restricted by the differences in EMCs in the study area (Penn State, 2011). This is due to a single event mean concentration representing pollutant concentration for all storm events. Only storm events are used to estimate pollutant loads based on average rainfall amounts (IEPA, 2018). Tetra Tech (2018) suggests STEPL use in the preliminary planning stages to determine the effect of land use changes on pollutant loads. This model can produce high confidence level results even though the model resolution is coarse, but the outcomes are dependent on how good the input data is (Penn State, 2011).

Creating a New STEPL Spreadsheet for the Lake Hudson Watershed

A STEPL sheet was created for the Lake Hudson Watershed using seven subwatersheds. There were no gully formations and impaired streambanks selected, as gully and streambank sources are separate from the model. STEPL does not model gully and streambank erosion as USLE calculates only sheet and rill erosion (Tetra Tech, 2018). The option for initialization was set to zero for initial land use areas and animal numbers. The spreadsheet was generated with tables customized using these parameters.

Input Sheet

Mayes was selected as the county and Oklahoma as the state on the input sheet. The OK-Mayes Weather Station was used for rainfall parameters. This data was calculated from 1981-2013 at the station level and not at the county level. The average annual rainfall was 44 inches. The average rain days receiving more than 5mm/day totalled 90 rain days.

The option to treat all subwatersheds as a part of a single watershed was selected. The sediment delivery ratio was calculated using the total watershed area. The groundwater output was not selected as surface water pollutant loads needed to be measured.

Ten input tables are included in the input sheet. The first four tables required inputs and the remaining six tables contained default values (Tetra Tech, 2018). Information for the Lake Hudson Watershed in Mayes County was extracted from the STEPL Model Input Data Server in order to populate the input tables (Tetra Tech, 2018). This spreadsheet contained land use area, number of agricultural animals, septic system data and hydrologic soil groups from various sources (Table 3). The location data assisted with populating parameters such as the USLE automatically.

Table 3: STEPL Input Server Data Sources

Input Information	**Source of Data**
Agricultural Animals	USDA Census of Agriculture, 2012
Land Use	NLCD and USDA Cropland Data Layer (CDL), 2011
HUC 12 Boundaries	NRCS-USDA and US Federal and State Agencies, County Boundaries-US Census Bureau
Septic System Data	National Environmental Service Centre: 1992 and 1998 summary of the status of onsite wastewater treatment systems in the United States
Hydrologic Soil Group	USDA State Soil Geographic (STATSGO) database

The watershed land use and precipitation details were populated in Table 1. The number of agricultural animals (beef cattle, dairy cattle, swine, sheep, horse, chicken, turkey, and duck) were inputted in STEPL Table 2, together with the number of months that manure was applied to cropland and pastureland. It is assumed that manure application was the same across the watershed and that the manure application was applied during one month in spring. The septic system and illegal direct wastewater discharge information was completed in Table 3. There was the option to modify the USLE parameters, however, this was not changed from what was automatically specified once the weather station was selected (Table 4). Data input in STEPL Table 5 was for soil hydrologic groups. Six of the seven subwatersheds were a soil Group C and one subwatershed was a soil Group B. These hydrologic soil groups were assigned a letter from A to D, with A indicating the highest infiltration and D, the lowest infiltration. The remaining optional input tables (Table 6, 6a, 7, 7a, 8, 9 and 10) were not modified.

BMP Sheet

This sheet provided for the selection of a BMP from a list of BMPs for each subwatershed. There were six categories of BMPs: cropland, pastureland, forest, feedlots, urban, and user-defined (Tetra Tech, 2018). The BMP functionality included efficiencies based on the percentage of area that it was applied to. Another option was the combined BMP efficiency that could be calculated when detailed information regarding multiple BMPs and their interactions in the watersheds were known (Tetra Tech, 2018).

The BMP category used for the Lake Hudson Watershed was pastureland since this was primary land use. The pastureland BMPs selected from the list were 1) Forest Buffer (minimum 35 feet wide), 2) Livestock Exclusion Fencing, and 3) Alternative Water Supply. The BMPs applied in each subwatershed were calculated as the critical pastureland riparian acres as a percentage of the total pasture area. The combined BMP efficiency of these management practices applied in parallel to the pastureland were used to calculate the pollutant removal efficiency.

Total Load and Graphs Sheet

The Total Load Sheet displayed the final outcomes of the subwatersheds pollutant loads and load reductions. This was the summary of annual nutrient and sediment loads for each subwatershed. These load summaries were used for the graphs that were generated in the Graphs Worksheet depicted in the results section.

3.4 Economic Costs of Buffer Implementation

There were no cost estimates available to inform management measures that needed to be implemented in the Lake Hudson Watershed at the time of this study. The dominant land use in this watershed was pastureland. The costs for buffer implementation were evaluated according to the critical riparian areas that were linked to pastureland. Costs of buffer implementation included both landowner costs evaluation and total costs of implementation per subwatershed.

Total Costs of Riparian Forest Buffer Implementation per Subwatershed

The pasture land cover for riparian conditions 1 and 2 (riparian habitat assessment) were determined. The critical pastureland riparian areas that required management intervention were used to determine the extent of riparian buffer implementation for the subwatersheds. The critical riparian length was converted to a buffer area using the equation (OCC, 2019):

[Critical riparian length* (2) * (98-foot buffer width) / 43560 (square feet to get acres)]

The costs of buffer implementation were estimated using the NRCS EQIP cost-share program and its 2019 Practice Payment Schedule as a guideline (Table 4) (NRCS, 2019). Landowners are compensated a dollar price for a conservation practice that they have been implemented in a cost-share program. Riparian Buffer Practice 391 was used to estimate buffer implementation costs. The costs are a one-time cost for installation. Maintenance costs are not included in this cost-share program (NRCS, 2019). The costs of providing an alternate water supply and exclusion from use of riparian areas (access control) were used, as these conservation practices are necessary to implement a riparian forest buffer.

Table 4: Cost Estimates for Riparian Forest Buffer (Adapted from EQIP 2019 Payment Schedule)

Description	**Total Cost**	**Landowner Reimbursement in EQIP Program**	**Landowner Cost**
Planting based on hand planting bareroot seedlings	$384.00 per acre	$288.00 per acre	$96.00 per acre
Fencing Cost	$2.32 per foot	$1.74 per foot	$0.58 per foot
Watering Systems for Livestock	$ 5,000 per 40 acres	$ 2,500 per 40 acres	S2,500 per 40 acres
Access Control	$23.60 per acre	$17.70 per acre	$5.90 per acre

The NRCS EQIP pricing, was used to estimate the total costs for riparian forest buffer implementation for all subwatersheds.

Landowner Costs of Implementing Riparian Forest Buffer

Cost-Benefit Analysis (CBA) is an effective method to evaluate the tradeoffs of implementing a riparian buffer through EQIP. It compared the benefits and costs over time. Net Present Value (NPV) was used to formulate the CBA and interpret the merit of implementing riparian buffer practices. The cost and benefits were analyzed using T-charts that evaluated the economic feasibility using partial budgeting. These values of the benefits and costs were then computed into the NPV equation. The net returns were then calculated over the buffer practice expected life span and converted to present values.

Basic Economic Analysis Using T-Charts

The T-chart is a simple method of showing the advantages and disadvantages of an option. The objective for landowners enrolling in the EQIP program was for the financial benefits to exceed costs. Benefits could be shown either as increased income or as reduced costs (NRCS, 2013). T-charts were a relatively easy way to conduct an economic analysis using partial budgeting. The T-chart determined the benefits and costs of a conservation option which could aid landowners in decision making.

Cost-Benefit Analysis

The costs and benefits derived from the T-charts were then be populated into the NPV equation, in order to better understand the value over time. Opportunity cost is referred to the economic rent of investing in the conservation practice (NRCS, 2015). Discount rate is the interest rate used to determine the present value of costs and benefits that would occur in the future, for a conservation initiative (Tietenberg & Lewis, 2012). A discount rate of 2.75% was used to evaluate EQIP as this is the rate used for water resource projects involving federal funds (NRCS, 2019).

Net Present Values

Net present value showed the time value of money (Tietenberg & Lewis, 2012). The discounted cash flow methodology was used to calculate the NPV of each of the pastureland incomes (NRCS, 2015). Cash flow was the amount of dollars flowing in and out. The NPV equation was used, where C is the sum of all future cash flows over (N) which is the 5-year maximum for the EQIP period. This was then discounted back to the present using a rate of return (r) or discount value of 2.75% in this case. The total future cash flow was determined by deducting the total costs from the total benefits. The EQIP cost-share was amortized using a 3% discount rate as this is the rate used for agricultural related projects (AAEA, 2000). This was to reflect the utilities of the EQIP cost-share that could not be fully captured in the benefits of implementing EQIP.

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n}$$

The three components detailed in the methodology, 1) the riparian assessment, 2) STEPL modeling of pollutant loads and load reductions using the riparian buffer BMP, and 3) the economic valuation of the riparian buffer BMP and the conservation easement evaluation methods, will collectively be used to inform conservation efforts in the Lake Hudson Watershed.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained for the different study components, 1) Riparian Assessment, 2) STEPL Modeling, and 3) Economic Assessment are presented and discussed. The riparian habitat assessment results highlighted the subwatersheds with poor riparian conditions that required intervention and provided ownership data for those portions of land. The STEPL model predicted the subwatersheds with the highest pollutant loads. The application of a riparian buffer as a pastureland BMP in the critical areas indicated the subwatersheds in which load reductions would be the greatest, as well as the associated the land uses to pollutants loads after BMP application. The economic assessment of the cost of buffer implementation from a management and landowner perspective informed the viability of conservation options.

4.1 Riparian Assessment Using ArcMap 10.5.1 Geographic Information System

Riparian Habitat Assessment

The riparian assessment data were rendered into maps that included a road and boundary layer. The maps for HUCs 313, 208, 502, 503, 505, 506 and 507 are depicted in Appendix A, Figures A-1 to A-7 respectively. The corresponding tables for each subwatershed map showing the amount of riparian length per riparian condition are presented in Appendix A, Tables A-1 to A-7

HUC 208 Stream Riparian Condition

Forty four percent of the stream lengths exhibited little to no riparian vegetation, based on the analysis of the riparian condition assessment of HUC 208. This length was equivalent to 78.56 km of a total of 179.32 km (Appendix A, Table A-1). Appendix A, Figure A-1 illustrates which portions of this subwatershed fell into the various riparian conditions.

HUC 313 Stream Riparian Condition

Thirty five percent of the stream length exhibited little to no riparian vegetation based on the analysis of the riparian condition assessment of HUC 313. This length was equivalent to 50.44 km of a total of 144.64 km (Appendix A, Table A-2). Appendix A, Figure A-2 illustrates which portions of this subwatershed fell into the various riparian conditions.

HUC 502 Stream Riparian Condition

Seventy six percent of the stream length exhibited little to no riparian vegetation based on the analysis of the riparian condition assessment of HUC 502. This length was equivalent to 307.09 km of a total of 404.74 km (Appendix A, Table A-3). This represented the largest portion that was impaired in comparison to the other HUCs in the watershed. Appendix A, Figure A-3 illustrates which portions of this subwatershed fell into the various riparian conditions.

HUC 503 Stream Riparian Condition

Forty seven percent of the stream length exhibited little to no riparian vegetation based on the analysis of the riparian condition assessment of HUC 503. This length was equivalent to 240.57 km of a total of 512.78 km (Appendix A, Table A-4). This represented the third largest portion that was impaired in comparison to the other HUCs in the watershed. Appendix A, Figure A-4 illustrates which portions of this subwatershed fell into the various riparian conditions.

HUC 505 Stream Riparian Condition

Forty nine percent of the stream length exhibited little to no riparian vegetation based on the analysis of the riparian condition assessment of HUC 505. This length was equivalent to 55.72 km of a total of 112.72 km (Appendix A, Table A-5). Appendix A, Figure A-5 illustrates which portions of this subwatershed fell into the various riparian conditions.

HUC 506 Stream Riparian Condition

Forty six percent of the stream length exhibited little to no riparian vegetation based on the analysis of the riparian condition assessment of HUC 506. This length was equivalent to 148.86 km of a total of 326.08 km (Appendix A, Table A-6). Appendix A, Figure A-6 illustrates which portions of this subwatershed falls into the various riparian conditions.

HUC 507 Stream Riparian Condition

Fifty two percent of the stream length exhibited little to no riparian vegetation based on the analysis of the riparian condition assessment of HUC 507. This length was equivalent to 277.08 km of a total of 536.44 km (Appendix A, Table A-7). This represented the second largest portion that was impaired in comparison to the other HUCs in the watershed. Appendix A, Figure A-7 illustrates which portions of this subwatershed fell into the various riparian conditions.

Overall Analysis

The overall assessment of all the subwatersheds displayed in Figure 6 show that bulk of the riparian areas were condition 2, which indicated sparse woody vegetation cover. Riparian condition 2 accounted for 37% of the stream lengths assessed (Table 5). Riparian condition 1 accounted for 16% of the stream lengths assessed, which had no vegetative cover. A total of 58% of the stream length assessed were critical and required management intervention. Riparian conditions 3 and 4 accounted for 39% of the stream lengths assessed (Table 5), which indicated that the buffer was mostly vegetated.

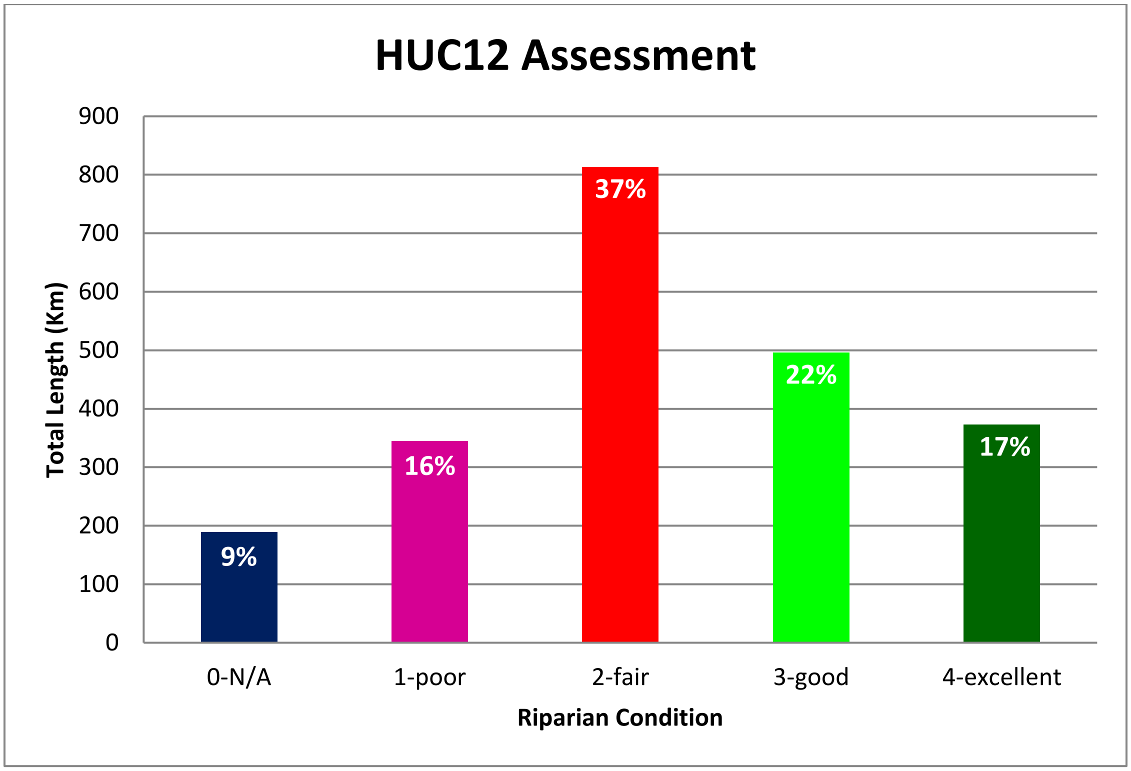

Figure 6: Overall HUC12 Riparian Assessment

Table 5: Overall HUC 12 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
0-N/A	9	189.43
1-poor	16	344.67
2-fair	37	813.64
3-good	22	496.05
4-excellent	17	372.94
Total Length (KM)		**2,216.73**

Table 6: HUC12 Riparian Conditions 1 and 2

HUC12	Name	Length (KM)	Rip_1 & 2 (KM)	%
110702090502	Rock Creek	404.74	307.09	76%
110702090507	Hudson Lake Dam-Neosho River	536.44	277.08	52%
110702090503	Hudson Lake-Neosho River	512.78	240.57	47%
110702090506	Wickliffe Creek	326.08	148.86	46%
110702090208	Outlet Big Cabin Creek	179.32	78.56	44%
110702090505	Little Saline	112.72	55.72	49%
110702090313	Outlet Spavinaw Creek	144.64	50.44	35%

HUC's 502, 507, and 503 exhibited the three most noteworthy stream lengths with little to no riparian vegetation, which could be major potential sources of nutrients and sediment to Lake Hudson (Table 6). These findings were consistent with the land use in this watershed (Figure 3). Agriculture was the dominant land use and pasture and hay was the primary land cover on the western part of the watershed. This could have accounted for the more degraded riparian conditions seen in HUC's 502, 507, and 503. Deciduous forests were the dominant land cover on the eastern and southern parts of the watershed. This could have attributed to the better riparian conditions seen in HUC's 208, 313, 505, and 506. Rangeland has a low to moderate potential for pollutant loads while forests are likely to have low pollutant loads (Heathcote, 1998). Pastureland is more managed than rangeland with the application of soil amendments and higher stocking rates. It is therefore more susceptible to soil erosion (Blanco-Canqui & Lal, 2008). Pastureland could potentially have relatively high pollutant loads for both sediment and nutrients as a result of disturbance and management.

Ownership and Property Data Results

The property owners for riparian conditions 1 and 2 were determined for HUCs 208, 313, 208, 502, 503, 505, 506, and 507 (Appendix B, Tables B-1 - 14). There was a total of 605 account numbers for property owners in the Lake Hudson Watershed. Accounts are linked to land parcels. Property owners that had multiple accounts owned more than one parcel of land. HUC 507 had the greatest number of land parcels (65) with critical riparian lengths greater than or equal to 1km, followed by HUC 502 (62), and HUC 503 (50) (Table 7).

Table 7: Number of Account Numbers for Critical Riparian Lengths per Subwatershed

	Total No. of Accounts	**Account No. > /=1km**
HUC 208	63	17
HUC 313	36	15
HUC 502	140	62
HUC 503	146	50
HUC 505	22	12
HUC 506	64	32
HUC 507	134	65
Total	**605**	**253**

The maximum length per land parcel for riparian condition 1 was 5.16 km located in HUC 208, followed by 5.01 km in HUC 507 (Table 8). The maximum length per land parcel for riparian condition 2 was 9.43 km located in subwatershed HUC 506, followed by 6.37 km in HUC 507.

Table 8: Maximum and Minimum Critical Lengths per Subwatershed per Land Parcel

Outlet Big Cabin Creek	Highest KM	Lowest KM
HUC208-Riparian Condition 1 Ownership	5.16	0.01
HUC208-Riparian Condition 2 Ownership	3.24	0.01
Outlet Spavinaw Creek		
HUC313-Riparian Condition 1 Ownership	1.23	0.03

HUC313-Riparian Condition 2 Ownership	2.35	0.01
Rock Creek		
HUC502-Riparian Condition 1 Ownership	3.92	0.01
HUC502-Riparian Condition 2 Ownership	4.27	0.03
Hudson Lake-Neosho River		
HUC503-Riparian Condition 1 Ownership	3.79	0.03
HUC503-Riparian Condition 2 Ownership	3.79	0.02
Little Saline		
HUC505-Riparian Condition 1 Ownership	2.31	0.76
HUC505-Riparian Condition 2 Ownership	4.14	0.02
Wickliffe Creek		
HUC506-Riparian Condition 1 Ownership	2.98	0.04
HUC506-Riparian Condition 2 Ownership	9.43	0.03
Hudson Lake Dam-Neosho River		
HUC507-Riparian Condition 1 Ownership	5.01	0.01
HUC507-Riparian Condition 2 Ownership	6.37	0.02

Conclusion of Results for the Riparian Assessment

The riparian habitat assessment revealed that the greatest lengths of critical riparian areas were found in HUC 507, HUC 503, and HUC 502. The total number of land parcels was the highest for HUC 503 (146), HUC 502 (140), and HUC 507 (134). The number of land parcels that contained more than 1 km of critical riparian areas were the highest for HUC 507 (65), HUC 502 (62), and HUC 503 (50).

4.2 STEPL Modeling

Total Pollutant Loads

The total pollutant loads for all the subwatersheds are listed in Table 9. The highest nitrogen, phosphorus, BOD, and sediment loads were for HUC 502, followed by HUC 208, and HUC 503.

The lowest pollutant loads were for subwatersheds HUC 313, HUC 506, and HUC 505. BOD was the highest pollutant load, followed by nitrogen and phosphorus loads. The sediment load was 13,844 tons per year.

Table 9: Total Pollutant Loads

Subwatershed	N Load (lb/year)	P Load (lb/year)	BOD Load (lb/year)	Sediment Load (t/year)
W7-HUC 502	344,839	38,108	1,000,087	3,367
W6-HUC 208	289,135	32,943	838,472	2,918
W5-HUC 503	288,017	33,832	826,007	2,712
W4-HUC 507	199,556	24,688	570,844	2,349
W1-HUC 506	157,989	20,079	450,823	1,418
W3-HUC 505	78,060	11,735	185,911	706
W2-HUC 313	32,865	4,478	99,639	373
Total	**1,390,460**	**165,862**	**3,971,784**	**13,844**

Pollutant Load Reductions with BMP

The pastureland BMPs were applied and the load reductions are shown in Table 10. The total nitrogen reduction was 18,196 pounds per year, phosphorus reduction was 1,585 pounds per year, BOD reduction was 1,724 pounds per year, and sediment reduction was 269 tons per year for all subwatersheds.

Table 10: Pollutant Load Reductions with Pasture BMP Application

Subwatershed	N Reduction (lb/year)	P Reduction (lb/year)	BOD Reduction (lb/year)	Sediment Reduction (t/year)
W1-HUC 506	290	25	27	4
W2-HUC 313	108	9	10	2
W3-HUC 505	85	8	12	2
W4-HUC 507	4,082	355	386	60
W-5HUC 503	2,109	184	199	31

W6-HUC 208	1,343	117	127	20
W7-HUC 502	10,179	886	962	150
Total	**18,196**	**1,585**	**1,724**	**269**

The loads reduced after BMP application were the highest for HUC 502 (W7), followed by HUC 507 (W4), and HUC 503 (W5) (Figures 7 and 8). These subwatersheds have the largest areas of pastureland that fall within the critical riparian buffer. Figure 7 shows the nitrogen, phosphorus, and BOD load reductions per subwatershed per year. HUC 502 reductions were 10,179 pounds of nitrogen, 886 pounds of phosphorus, and 962 pounds of BOD. HUC 507 reductions were 4,082 pounds of nitrogen, 355 pounds of phosphorus, and 386 pounds of BOD. HUC 503 reductions were 2,109 pounds of nitrogen, 184 pounds of phosphorus, and 199 pounds of BOD.

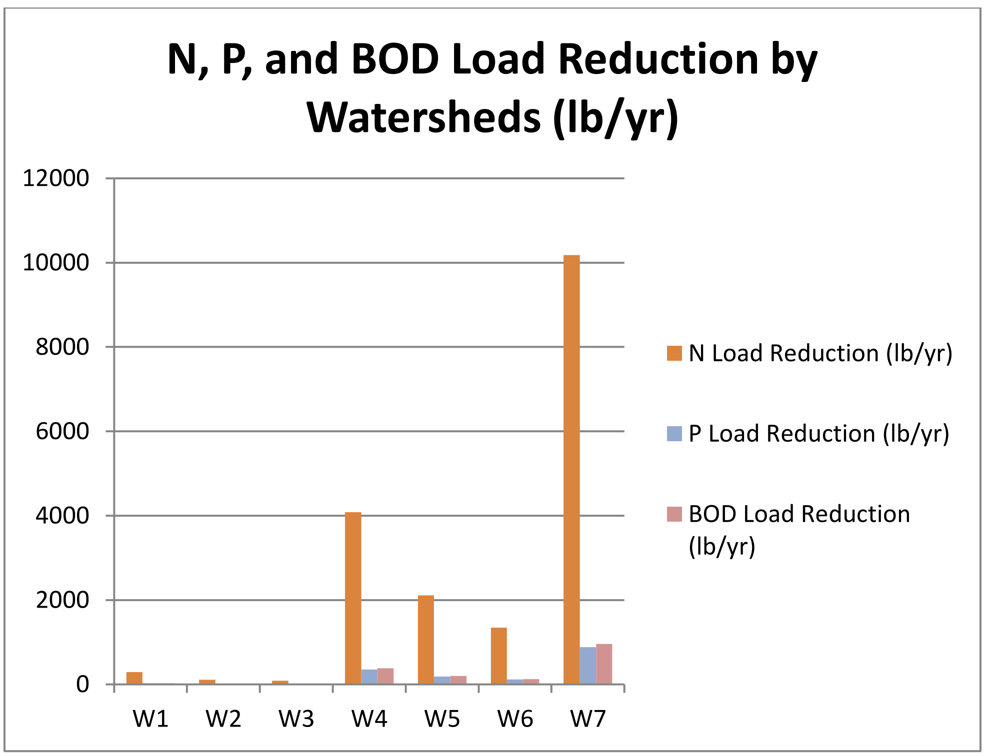

Figure 7: Load Reductions of Nitrogen, Phosphorus, and BOD per Subwatershed

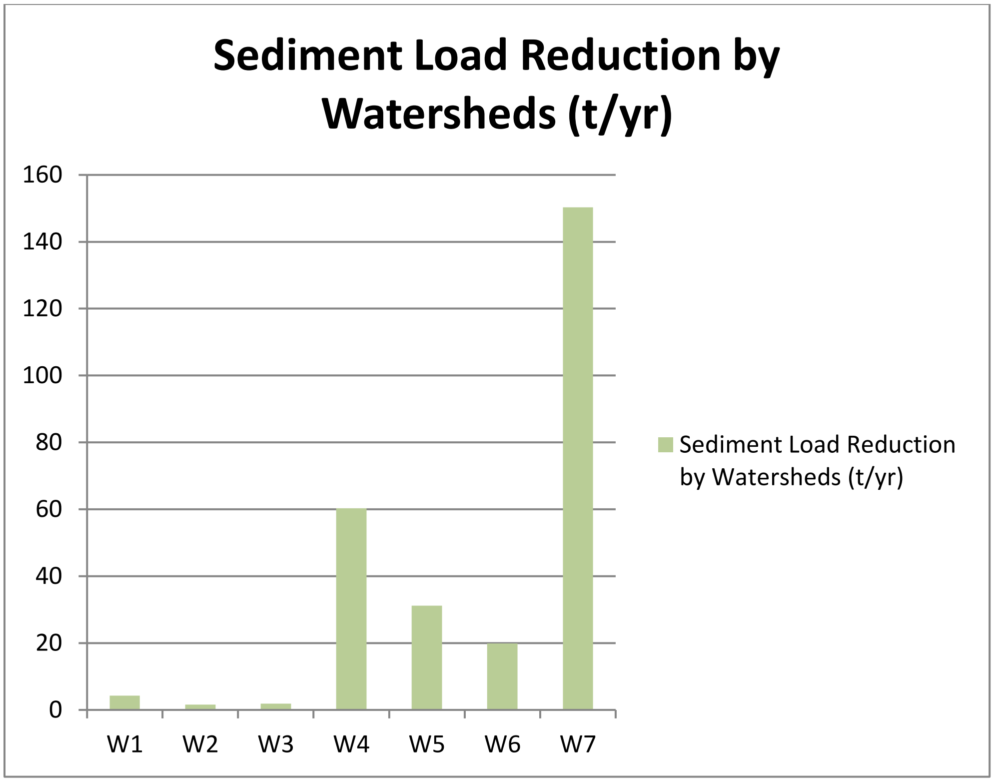

Figure 8: Load Reduction of Sediment Per Subwatershed

Figure 8 illustrates the sediment load reductions per subwatershed per year. The sediment reductions for HUC 502 (W7), HUC 507 (W4), and HUC 503 (W5) were 150, 60, and 31 tons respectively per year.

Loads by Land Uses (with BMP)

The pollutant loads associated to the land uses are depicted in Table 11. An analysis of the impact from land use indicated that pastureland and feedlots were the leading causes of nitrogen and phosphorus loads, while pastureland and urban land use were the main cause of BOD and sediment loads. Pastureland was the largest contributor to all pollutant types after BMP application (Figure 9).

Table 11: Total Loads by Land Use after BMP Application

Sources	**N Load (lb/yr)**	**P Load (lb/yr)**	**BOD Load (lb/yr)**	**Sediment Load (t/yr)**
Pastureland	943,663	79,853	3,086,827	9,104
Feedlots	234,883	46,977	313,177	0
Urban	95,941	14,815	372,890	2,203
Cropland	77,091	12,434	146,080	1,874
Forest	20,686	10,198	51,085	394
Total	**1,372,264**	**164,277**	**3,970,060**	**13,574**

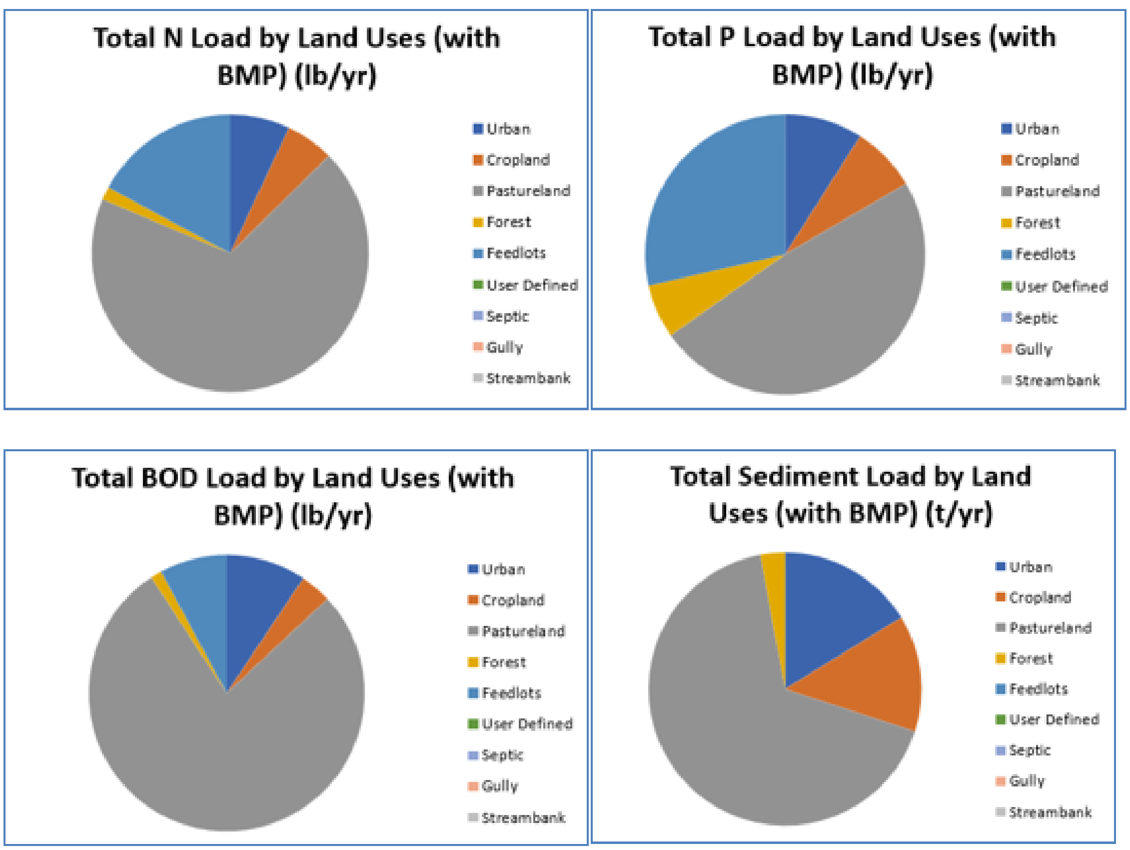

Figure 9: Loads by Land Use with BMP application for the Lake Hudson Watershed

Conclusion of Results for the STEPL Model

The highest pollutant loads could be explained by the percentage of land use cover which highlights pastureland in these subwatershed areas. HUC 502 with the highest percentage (80%) of pastureland had the highest impact, followed by HUC 208 (65%), and HUC 503 (61%). HUC 313 had the lowest percentage pastureland as its land use (26%), followed by HUC 506 (41%), and HUC 505 (43%). HUC 502, HUC 208, and HUC 503, each had 6% urban and 0.02% feedlot land uses.

Pastureland was the largest contributor to all pollutant types according to the model simulation. The pollutant types ranged from nutrients, bacteria, and sediment. The number of animals that are stocked in an area determine the effect that it will have on the land cover in pastureland. Some grazing practices could deplete the vegetative cover leading to severe erosion. Livestock can compact the soil, increasing the bulk density, and reducing infiltration (Sharrow, 2007). Water quality is compromised when animals graze in sensitive riparian areas adjacent to water bodies. Nutrients and bacteria are added through fecal matter and streambanks are eroded when animals are present. Pasturelands and rangelands accounted for 26% of sediment and 25% of nitrogen to surface waters in the United States each year (Welsch, 1991).

Another issue related to livestock are feedlots. These are small confinements in which large numbers of animals are kept. These could contribute significantly to animal wastes. The issue with feedlots is linked to the runoff of waste that carry pathogens, viruses, and bacteria like E. coli and Enterococus leading to water quality problems (ODEQ, 2016).

The application of manure leads to high levels of nitrogen, phosphorus, and is a source for BOD. Poultry and cattle are the main sources of animal manure in the watershed. Heathman, Sharpley, Smith, and Robinson (1994) found that poultry litter application on soil increased the concentrations of nitrogen and phosphorus in runoff. Schreiber, Rechenburg, Rind, and

Kistemann (2015) established that spreading manure greatly increased the possibility of contamination of a land use type, that could result in higher concentrations of micro-organisms in waterbodies after a rainfall event. Pollutants could run off and leach if land applications are not well managed, thereby degrading the water quality. Nutrient Management Plans (NMPs) are an important step in conservation planning, with the objective of maximizing yields and minimizing nutrient losses to the environment. The poultry houses and feedlots that generate substantial amounts of manure have NMP's as a part of the waste management regulations to monitor and control NPS in Oklahoma. The 4 R's in nutrient management are applying the right fertilizer source, at the right rate, at the right time, and in the right place (Ehmke 2012, cited in Edwards et al., 2015).

Urban stormwater runoff is a significant source of NPS pollution. The main pollutant sources are chemical and biological NPS pollutants (EPA, 2003). Pathogens, E. coli, and bacteria result from failed septic systems, sewage effluent, and pet waste. Nutrients such as nitrogen and phosphorus could come from lawn fertilizers and industrial pollution. Urban surface areas are highly impervious and heavily compacted. These affect water quality through impeding water infiltration and causing increased surface runoff. The increased amount of runoff can lead to flooding and there is less natural filtration of the water (Edwards et al., 2015). Camara, Jamil, and Abdullah (2019) found that activities in urban development affected the hydrological processes such as runoff and erosion and therefore had a greater impact on water quality. Urban and developed land use have greater amounts of soil disturbance and permanent reductions in infiltration, which result in poor water quality (Edwards et al., 2015).

The riparian habitat assessment conducted revealed that most impaired riparian conditions were found in HUC 502, followed by HUC 507, and HUC 503. STEPL predicted the highest pollutant loads for HUC 502, followed by HUC 208, and HUC 503. The implication for management intervention is critical in HUC 502 and HUC 503, since the potential pollutant loading is greatly increased by the poorly vegetated riparian areas in these subwatersheds. The risk and susceptibility to erosion, runoff, and sedimentation is intensified.

4.3 Economic Costs of Buffer Implementation

Total Costs of Riparian Forest Buffer Implementation Per Subwatershed

The total riparian forest buffer costs were estimated for all subwatersheds using NRCS EQUIP costs (Table 12). The riparian forest buffer implementation costs for the Lake Hudson Watershed are depicted in Figure 10. HUC 502 had the maximum cost of $1,074,540 for the implementation of 652 acres of riparian buffer. The second highest cost was for HUC 507 to implement 261 acres at a cost of $430,918. The minimum cost was for HUC 313 to implement 7 acres at a cost of $11,354.

The total cost of riparian forest buffer in critical pastureland was $1,925,588 for the Lake Hudson Watershed. These costs assumed that buffer implementation would require planting, fencing, access control, and water systems for each critical acre. This may not be the case in reality as some areas would already have fencing, existing trees, water well or tanks. Some areas may not require off-site watering if livestock were not kept in these areas. The participation rates of landowners would also need to be known.

Table 12: Total Cost of Riparian Buffer Implementation for Critical Pastureland in the Lake Hudson Watershed

EQIP NRCS COST-LAKE HUDSON WATERSHED			
LH-208 Outlet Big Cabin Creek			
Crit. Riparian Pasture		**EQIP Practice**	**[1]Cost**
[2]Pasture Area (Acres)	86	[3]Planting ($384 / acre)	33,036
		[4]Access Control ($23.60 / acre)	2,030
Pasture Length (Feet)	19,120	[5]Fencing (critical riparian length times 2*$2.32/ft)	88,717
Pasture Length (Mile)	4	[6]Watering System (1-mile fence = 40 acres=1 system $5000)	18,106

Total Cost			**141,889**
LH-313 Outlet Spavinaw Creek			
Crit. Riparian Pasture		**EQIP Practice**	**[1]Cost**
[2]Pasture Area (Acres)	7	[3]Planting ($384 / acre)	2,644
		[4]Access Control ($23.60 / acre)	162
Pasture Length (Feet)	1,530	[5]Fencing (critical riparian length times 2*$2.32/ft)	7,099
Pasture Length (Mile)	0.29	[6]Watering System (1-mile fence = 40 acres=1 system $5000)	1,449
Total Cost			**11,354**
LH-502 Rock Creek			
Crit. Riparian Pasture		**EQIP Practice**	**[1]Cost**
[2]Pasture Area (Acres)	652	[3]Planting ($384 / acre)	250,185
		[4]Access Control ($23.60 / acre)	15,376
Pasture Length (Feet)	144,798	[5]Fencing (critical riparian length times 2*$2.32/ft)	671,861
Pasture Length (Mile)	27	[6]Watering System (1-mile fence = 40 acres=1 system $5000)	137,119
Total Cost			**1,074,540**
LH-503 Hudson Lake-Neosho River			
Crit. Riparian Pasture		**EQIP Practice**	**Cost**
[2]Pasture Area (Acres)	135	[3]Planting ($384 / acre)	51,872
		[4]Access Control ($23.60 / acre)	3,188
Pasture Length (Feet)	30,021	[5]Fencing (critical riparian length times 2*$2.32/ft)	139,300
Pasture Length (Mile)	6	[6]Watering System (1-mile fence = 40 acres=1 system $5000)	28,429
Total Cost			**222,789**
LH-505 Little Saline			
Crit. Riparian Pasture		**EQIP Practice**	**[1]Cost**
[2]Pasture Area (Acres)	8	[3]Planting ($384 / acre)	3,139
		[4]Access Control ($23.60 / acre)	193
Pasture Length (Feet)	1,817	[5]Fencing (critical riparian length times 2*$2.32/ft)	8,429
Pasture Length (Mile)	0.34	[6]Watering System (1-mile fence = 40 acres=1 system $5000)	1,720
Total Cost			**13,481**
LH-506 Wickliffe Creek			
Crit. Riparian Pasture		**EQIP Practice**	**[1]Cost**

[2]Pasture Area (Acres)	19	[3]Planting ($384 / acre)	7,129
		[4]Access Control ($23.60 / acre)	438
Pasture Length (Feet)	4,126	[5]Fencing (critical riparian length times 2*$2.32/ft)	19,144
Pasture Length (Mile)	0.78	[6]Watering System (1-mile fence = 40 acres=1 system $5000)	3,907
Total Cost			**30,618**
LH-507 Hudson Lake Dam-Neosho River			
Crit. Riparian Pasture		**EQIP Practice**	**[1]Cost**
[2]Pasture Area (Acres)	261	[3]Planting ($384 / acre)	100,330
		[4]Access Control ($23.60 / acre)	6,166
Pasture Length (Feet)	58,067	[5]Fencing (critical riparian length times 2*$2.32/ft)	269,433
Pasture Length (Mile)	11	[6]Watering System (1-mile fence = 40 acres=1 system $5000)	54,988
Total Cost			**430,918**

Notes related to Table 11:

[1] All costs for the implementation of EQIP conservation practices derived from the NRCS 2019 Payment Schedule.

[2] Critical Riparian Pasture Area (Acres) obtained by: [critical riparian length*2* (98 ft buffer width) / 43560 (square ft)]

[3] Planting Costs were calculated at $384 / acre

[4] Access Control was calculated at $23.60 / acre

[5] Fencing Cost were calculated by: [critical riparian length times 2*$2.32/ft]

[6] Watering System was calculated using: 1-mile fence = 40 acres=1 watering system at $5000

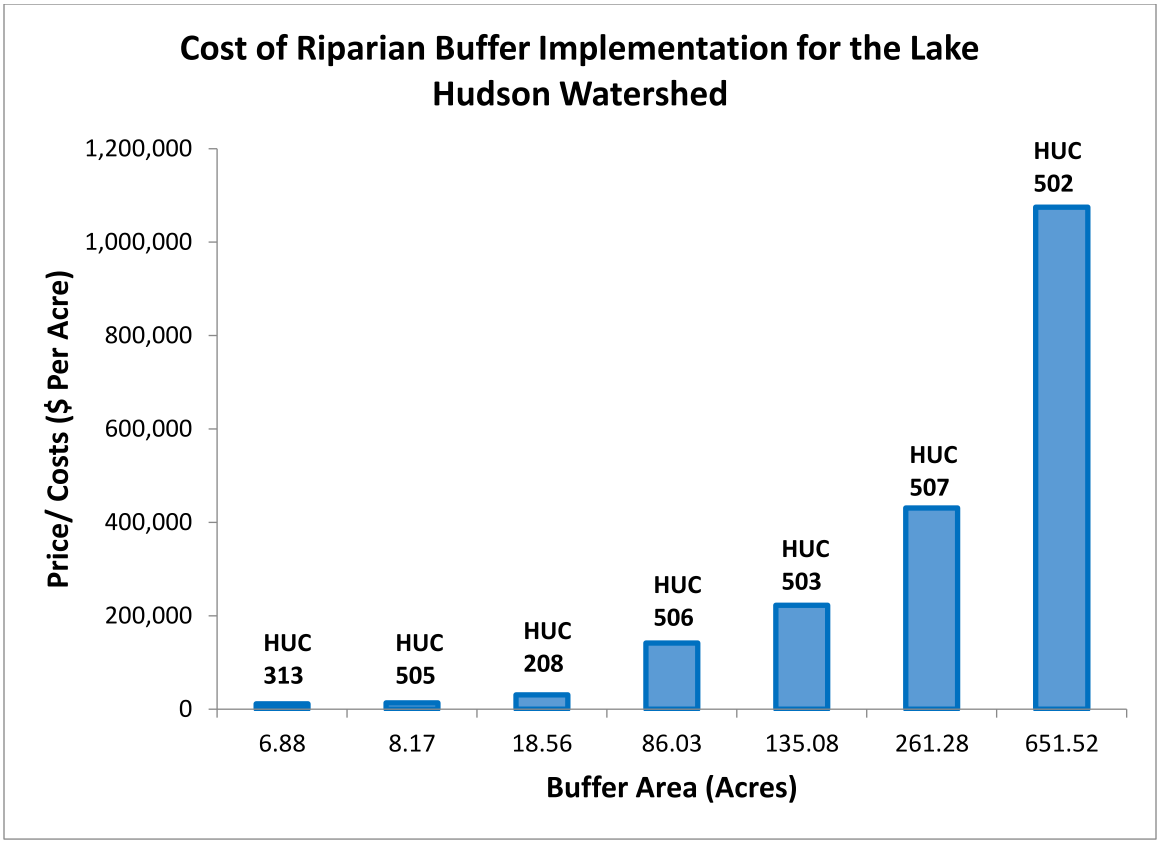

Figure 10: Implementation Cost of Riparian Buffer for the Lake Hudson Watershed

Landowner Costs of Implementing Riparian Forest Buffer

<u>Basic Economic Analysis Using T-Charts Results</u>

The economic analysis results using the T-Chart is provided in Table 13. The total increase in income amounted to $26,415 and the total decrease in cost was $26,966 and these accounted for the positive effects of the T-chart. The total income increases, and cost reductions were $53,381. The total decrease in income was $32,400 and the total increase in cost $9,638 which accounted for the negative effects of the T-chart. The total income reductions and cost increases were $42,038. The overall resultant change in net income was $11,343.

Table 13: Basic Economic Analysis Using T-Charts

Proposed Changed: Establishing a riparian buffer on 40 acres of critical riparian pastureland by enrolling in the 5-year EQIP Program			
Positive Effects	**Value**	**Negative Effects**	**Value**
Income Increase		**Income Decrease**	
[1]*EQIP Cost-Share Payment*		*Pasture Revenue Income*	
Planting Costs		**Rental**	
Based on hand planting bareroot seedlings ($288/acre)	11,520	[11]Based on pasture rental ($13.5/acre/month) over 5 years	32,400
Fencing Costs			
Fencing Costs ($1.74/ft) (5280ft =1mile=40acres)	9,187		
Incentive to exclude use of riparian area			
Access Control ($17.70/acre)	708		
Watering System			
Water tank, well, pipes (5280ft=1mile=1 watering system)	5,000		
Total increase in income	**[10]26,415**	**Total decrease in income**	**32,400**
Cost Decrease		**Cost Increase**	
Production Expenses Over 5 Years		[1]*EQIP Landowner Cost Over 5 Years*	
[2]Hay Harvesting (2/year-$14.32/acre)	5,728	**Planting Costs**	
[3]Grazing ($25.70/acre/year)	5,140	Planting based on hand planting bareroot seedlings ($96/acre)	3,840
[4]Soil Tests (2/period*$10/sample*20 samples* 2)	680	**Fencing Costs**	
[5]Maintain Fences ($122.80/1320ft/year) *4*5yrs	2,456	Fencing Costs ($0.58/ft)	3,062
[6]Nutrients (50 lb. N/acre *45 cents/lb.)	4,500	**Exclusion Costs**	
[7]Pasture and Hay Planting ($79.64/acre) once off	3,186	Access Control ($5.90/acre)	236

		Watering System	
Tax Benefit		Water tank, well, pipes	2,500
[8]Ad Valorem Real Estate Property Tax ($ 1380*0.112*0.08539)/acre/year	2,600		
Other Benefits			
[9]Reduced Soil Erosion Over EQIP Period ($6.45/acre)	258		
[9]Improved Water Quality Over EQIP Period ($42.40/acre)	1,696		
[9]Fertilizer Lost Through Erosion Over EQIP Period ($18.06/acre)	722		
Total decrease in cost	**26,966**	**Total increase in costs**	**9,638**
Total income increases and cost reductions	**53,381**	**Total income reductions and cost increases**	**42,038**
Change in Net Income	**11,343**		

Notes related to Table 13:

EQIP Cost-Share:

[1] Values were derived from the NRCS 2019 Payment Schedule (NRCS, 2019)

Production Expenses:

[2]Hay Harvesting cost obtained from Oklahoma Cooperative Extension Fact Sheets-Oklahoma Farm and Ranch Custom Rates, 2017-2018, based on hay swathing twice a year (Sahs, 2018)

[3]Grazing costs obtained NRCS 2019 Payment Schedule based on prescribed grazing with weekly moves (NRCS, 2019)

[4]Soil Tests based on NRCS Guideline (every 3 to 5 years, 15-20 samples for every 20 acres, $10 per sample) (NRCS, 2009)

[5]Maintain Fences pricing obtained from the Ag Decision Maker Estimated Costs for Livestock Fencing (File B1-75, 2012), average cost of 5 different types of fencing based on a 1,320 ft/year (ISU, 2012)

[6]Nutrients cost obtained from Oklahoma Cooperative Extension Fact Sheets-Fertilizing Bermudagrass Hay and Pasture, based on nitrogen required for Bermuda Grass 50 pounds N/acre at 45 cents per lb. (average of Urea and Urea Ammonium Nitrate)

[7]Pasture and Hay Planting obtained from NRCS-OK (2007) based on the average cost of establishing forage (Bermuda, introduced, native), once off cost that lasts 10 years, assumed perennial grasses.

[8]Ad Valorem Real Estate Property Tax Benefit obtained from Mayes County Assessor's Office, based on an average levy (0.8539) for Mayes County, a 11.2% county ratio (market value X county ratio X levy) (L. Melchior, personal communication, March 6, 2020). Market value obtained from 2019 Oklahoma Agricultural Stats 2019 (USDA-NASS, 2019).

[9]Reduced soil erosion, improved water quality values, and fertilizer lost through erosion costs were assumed over the 5-year period of EQIP over a ton loss of soil. Values obtained from Duffy (2012), using USDA-NRCS studies.

[10]The additional income tax on increased income from the EQIP cost-share payment is subject to tax, however, this was not included as the decrease in income from foregone revenue offsets this income.

Pasture Revenue Income

[11]Opportunity costs were measured as pasture rental rates to take the land out of production using Oklahoma Cooperative Extension Pasture Rental Rates: 2018-19, sourced from USDA/NASS, Quick Stats (Sahs, 2019)

Cost-Benefit Analysis Results

The primary upfront costs with riparian forest buffers were associated with planting, fencing, exclusion to the riparian area, and providing an off-site watering system. The maintenance of riparian buffers may have required weed control, repairs to damaged fences, and replacing seedlings that perished (Klapproth & Johnson, 2009). The exclusion fencing was necessary to keep livestock out of the riparian areas. This had a three-fold effect: 1) allowed newly planted vegetation to establish, 2) aided in stream bank stabilization, and 3) reduced bank erosion.

The significant long-term cost of these practices resulted in the annual opportunity cost of foregone revenue associated with pastureland that was no longer used for production. The rent approach was used to determine opportunity costs, that were derived from annual land rents and in this case that was pastureland (Wünscher, Engel, &Wunder, 2011). The direct benefits included cost-share payments for planting, fencing, access control, and the watering system. There was also a decrease in production costs for this area which included grazing, hay harvesting, soil testing, fence maintenance, planting, and nutrient costs. Other benefits included ad valorem state property tax savings, reduced soil erosion, reduced loss of fertilizers, and improved water quality (NRCS, 2013). The acres of land that have a conservation practice are exempt from real estate property tax and ad valorem tax is only paid for the portion of land that is non-exempt.

The results of the cost-benefit analysis are depicted in Table 14. The present value of total costs amounted to $39,475 and the present value of total benefits $51,000. The net benefit of investing over a 5-year period in EQIP is $11,524. EQIP had a NPV greater than zero, which implies that this program has economic merit. The cost-benefit analysis indicated that enrolling pastureland in EQIP to implement riparian forest buffers would be beneficial to the landowners.

Table 14: Cost-Benefit Analysis of Converting Pastureland to Riparian Forest Buffer

CBA of Establishing a Riparian Buffer on 40 Acres of Pastureland by Enrolling in 5year EQIP Program						
	1	2	3	4	5	Total
COSTS ($)						
Planting costs	828	828	828	828	828	
Fencing Costs	660	660	660	660	660	
Exclusion Costs	51	51	51	51	51	
Watering System	539	539	539	539	539	
Foregone grazing	6,480	6,480	6,480	6,480	6,480	
Total Cost	8,558	8,558	8,558	8,558	8,558	
PV of Cost @2.75%	8,329	8,106	7,889	7,678	7,473	**39,475**
BENEFITS ($)						
EQIP Cost-Share Planting costs	2,484	2,484	2,484	2,484	2,484	
EQIP Cost-Share Fencing Costs	1,981	1,981	1,981	1,981	1,981	
EQIP Cost-Share Exclusion Costs	153	153	153	153	153	
EQIP Cost-Share Watering System	1,078	1,078	1,078	1,078	1,078	
Hay Harvesting	1,146	1,146	1,146	1,146	1,146	
Grazing	1,028	1,028	1,028	1,028	1,028	
Soil Tests	0	0	340	0	340	
Maintain Fences	491	491	491	491	491	
Nutrients	900	900	900	900	900	
Pasture and Hay Planting	637	637	637	637	637	
Reduced Soil Erosion Over EQIP Period	0	0	0	0	258	
Improved Water Quality Over EQIP Period	0	0	0	0	1,696	
Fertilizer Lost Through Erosion Over EQIP Period	0	0	0	0	722	
Ad Valorem Real Estate Property Tax Benefit	520	520	520	520	520	
Total Benefit	10,418	10,418	10,758	10,418	13,434	
PV of Benefit @2.75%	10,139	9,868	9,917	9,346	11,730	**51,000**
NET BENEFIT						
PV (@2.75%)	1,810	1,761	2,028	1,668	4,257	**11,524**

<u>Net Present Value Sensitivity Analysis</u>

A sensitivity analysis using discount rates from 1-5% was used to determine the effect on the NPV (Figure 11) as current interest rates are low (1.75%) and any fluctuations would fall within this range. A landowner may have to borrow money to implement these practices, as reimbursement only takes places after the practice is in place. This analysis is important to inform landowners of how any changes in the future with regards to discount rates may affect their net benefit.

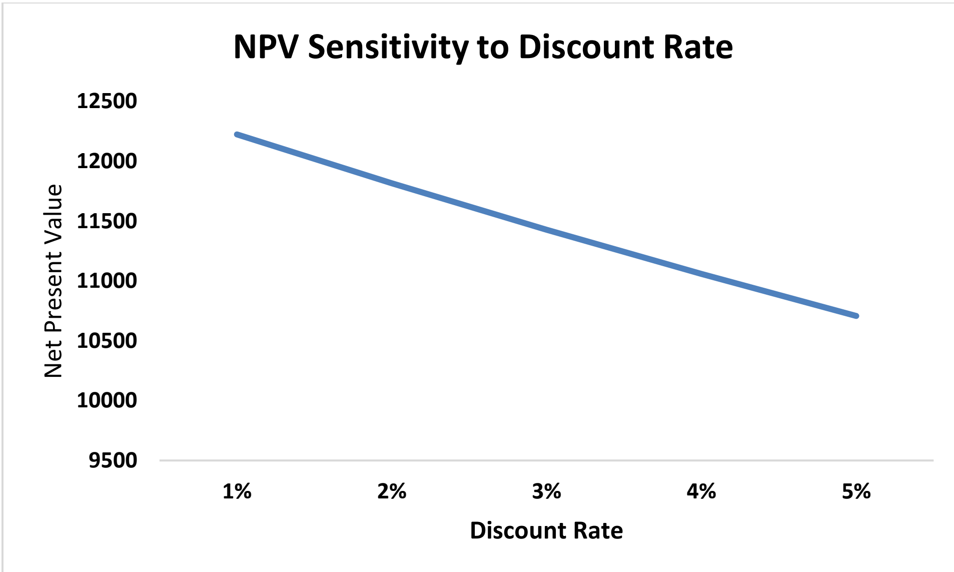

Figure 11: Net Present Value Sensitivity to Discount Rate

The discount rate increased as the NPV decreased. The use of lower discount rates (2.75%) for social projects supported the view that landowners should act now to protect their land for the future. A lower discount rate implies a lower risk in the present value of money invested. This meant that the landowners could invest in implementing conservation practices now that would bring benefit to their families or land in the future.

Conclusion of the Economic Assessment

The economic analysis concluded a positive return on investing in the EQIP cost-share program. The net present value returned a positive value over the 5-year EQIP period. The T-chart analysis indicated a positive net income after considering the positive and negative aspects of implementing a riparian forest buffer as a conservation practice through the EQIP cost-share program.

CHAPTER V

CONCLUSION

The Lake Hudson Watershed is a nutrient limited watershed that is at risk of not supporting its designated beneficial uses due to an excess of nutrients. This study provided a baseline to prioritize conservation efforts in the Lake Hudson Watershed in terms of critical areas, pollutant loads, and economic feasibility.

Limitations of this Study

A limitation of this riparian habitat assessment was the application of a uniform 98-foot buffer on either side of the NHD stream segment as opposed to a variable buffer. The uniform buffer worked well for the stream channels that were narrower, however, for wider stream channels the buffer fell within the reaches of the stream. In such cases, a proper riparian condition could not be assigned. This was the case for 9% (189 km) of riparian length in this study. A riparian habitat assessment using a variable buffer is recommended for future studies as this will also affect the total cost of buffer implementation in the watershed.

Implications of this Study

The riparian habitat assessment is a rapid method of highlighting the critical areas in the watershed that could be targeted for conservation effort either through the EQIP cost-share program or through the purchase of conservation easements. The implementation of riparian forest buffers was explored as a conservation initiative as they have been found to be effective at filtering phosphorus, nitrogen, and sediment. The riparian assessment highlighted subwatersheds

HUC 507, HUC 503, and HUC 502 as having the most denuded riparian areas. These subwatersheds also had the greatest number of land parcels that contained poorly vegetated riparian areas.

The riparian assessment method used in this study was adapted from the NWQI initiative for the Little Beaver Creek found in western Oklahoma. The methodology was designed to assess streams in western Oklahoma, in the Central Great Plains and Cross Timbers ecoregions. It is interesting to note that applying these methods to the Lake Hudson Watershed, in northeastern Oklahoma, found in the Ozark Highlands and Central Irregular Plain ecoregions, produced meaningful results regardless of this difference. This assessment supports the replicability of this method on streams found on the eastern side of Oklahoma.

Watershed modeling has become an integral part of watershed management. The STEPL Model provides baseline data which can be used for the preliminary planning of conservation practices. STEPL is one of the simpler modeling tools used to quantify pollutant loading in a watershed, requires minimal data input and is useful for long-averaging time periods.

In this study, STEPL was effective in providing a snapshot of pollutant loads and load reductions using riparian buffers as a BMP. The STEPL model predicted HUC 502, HUC 208, and HUC 503 as the potential sources with the highest pollutant load for nitrogen, phosphorus, BOD, and sediment. The STEPL model further depicted pastureland as the main land use source of pollutants even after BMPs were applied to pastureland, that were connected to the riparian zones. The most dominant land use type is pastureland which is a major contributor of NPS and signifies the necessity for other BMP application throughout the watershed and not limited to riparian areas. Proper stocking rates, rotational grazing, and proper litter storage are other BMPs associated with pasture management. Conservation practices for other contributing land uses such as feedlots and urban areas need to be explored.

The riparian assessment and STEPL model results accentuate the importance of priority intervention in HUC 502 and HUC 503. The improvement focus areas would be 1) HUC 208, which STEPL has modeled as having the second highest pollutant loading, and 2) HUC 507 that the riparian habitat assessment demonstrated as having the second largest critical riparian area, of all the subwatersheds.

Cost effectiveness increases the likelihood of BMP implementation that can restore and protect a watershed from NPS pollution. The economic feasibility of riparian forest buffer implementation was assessed from a watershed to a landowner level. The NRCS EQIP costing schedule provided estimates of buffer implementation. The riparian buffer implementation costs represented the costs for buffer implementation in each subwatershed addressing critical riparian pasture areas irrespective of landowner participation rates. The economic assessment revealed that HUC 502, HUC 507, and HUC 503 had the highest costs when compared to the other subwatersheds. The economic feasibility from a landowner perspective was a positive change in net income after considering the positive and negative effects of riparian buffer implementation positive. The cost-benefit analysis returned a positive net benefit over the term of EQIP enrollment, which is a selling point to landowners considering cost-share initiatives.

The economic feasibility of enrolling in a cost-share program was evaluated from a landowners' perspective in this study, however, it would be useful to determine how many landowners would be willing to participate in a cost-share conservation option. Surveys can be conducted for landowners in this watershed to determine their actual willingness to pay for conservation management options of implementing riparian buffers to protect water quality. Surveys are costly in terms of time, money, and effort, and could be considered as a next step for the Lake Hudson Watershed.

The benefits of improving the riparian areas around Lake Hudson have the potential to mitigate NPS pollution within the watershed. Implementation of cost-share initiatives and easements can improve water quality and potentially result in Lake Hudson's removal from the EPA 303 (d) Impaired Waters List.

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APPENDICES

APPENDIX A: Riparian Condition Analysis Using ArcMap 10.5.1 Geographic Information System

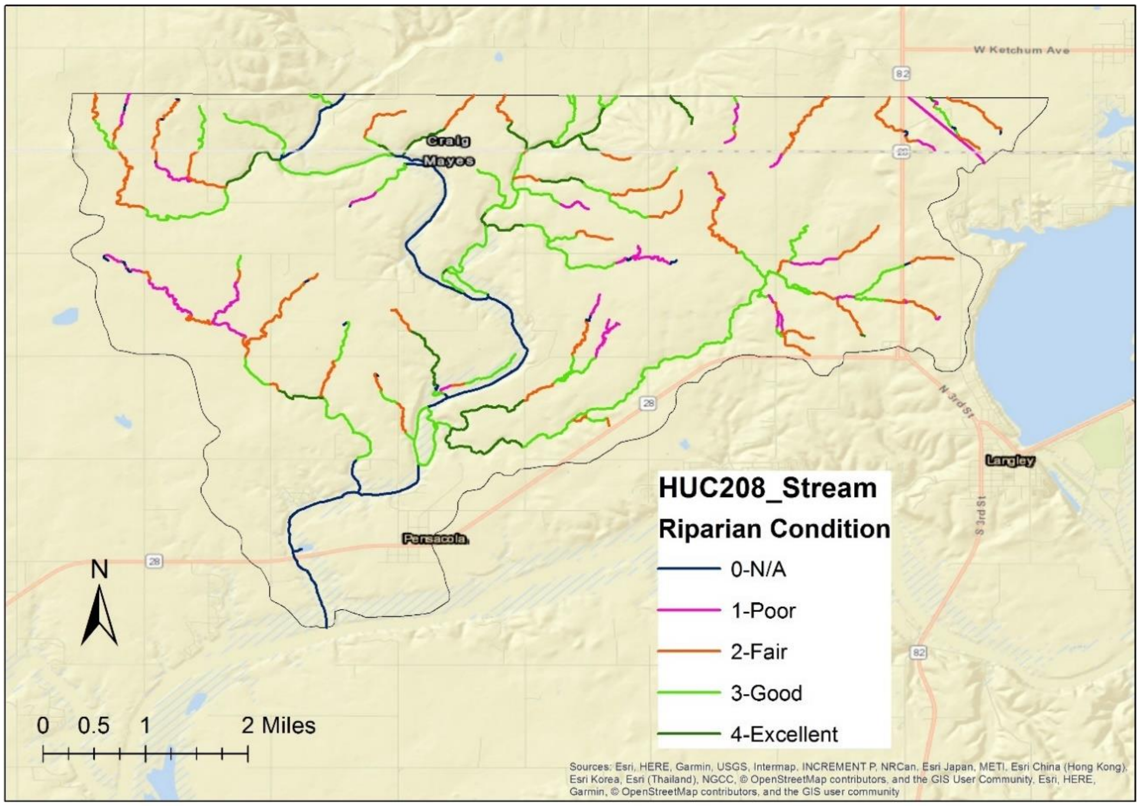

Figure A-1: Riparian Assessment of HUC 208

Table A-1: HUC 208 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
0	10	17.14
1	14	24.89
2	30	53.66
3	35	62.92
4	12	20.71
Total Length (KM)		**179.32**

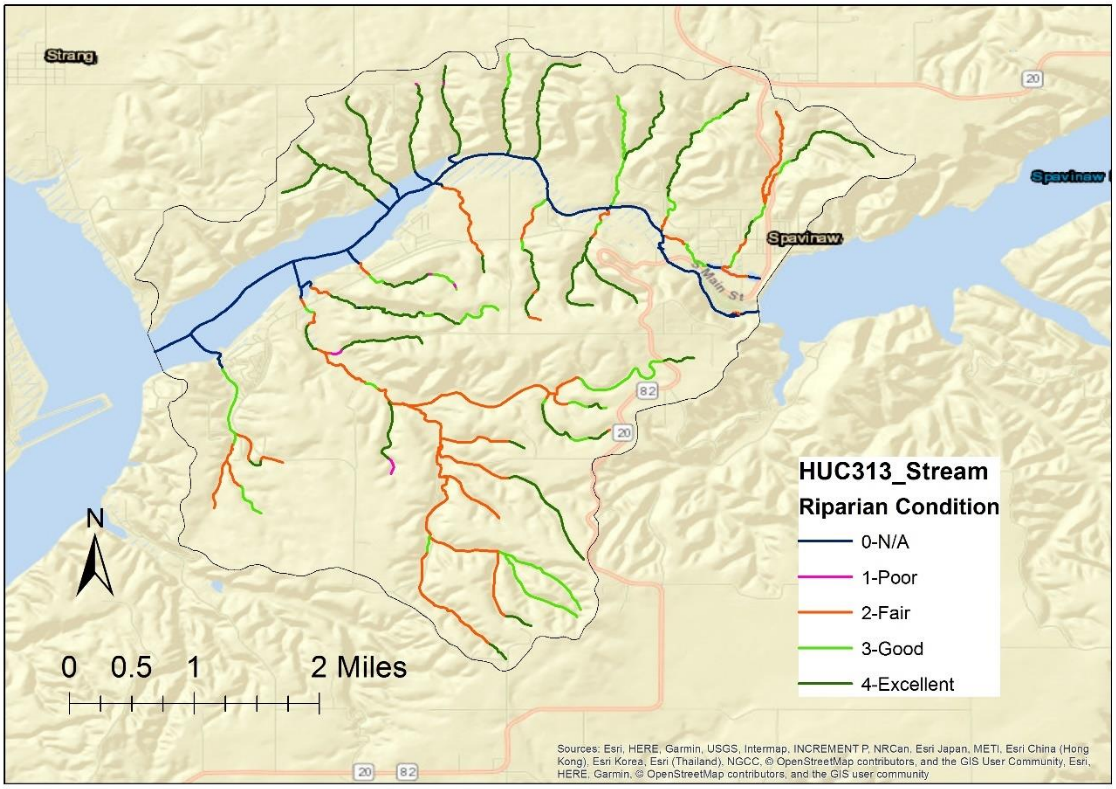

Figure A-2: Riparian Assessment of HUC 313

Table A-2: HUC 313 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
0	8	12.26
1	4	5.40
2	31	45.04
3	26	36.97
4	31	44.98
Total Length (KM)		**144.64**

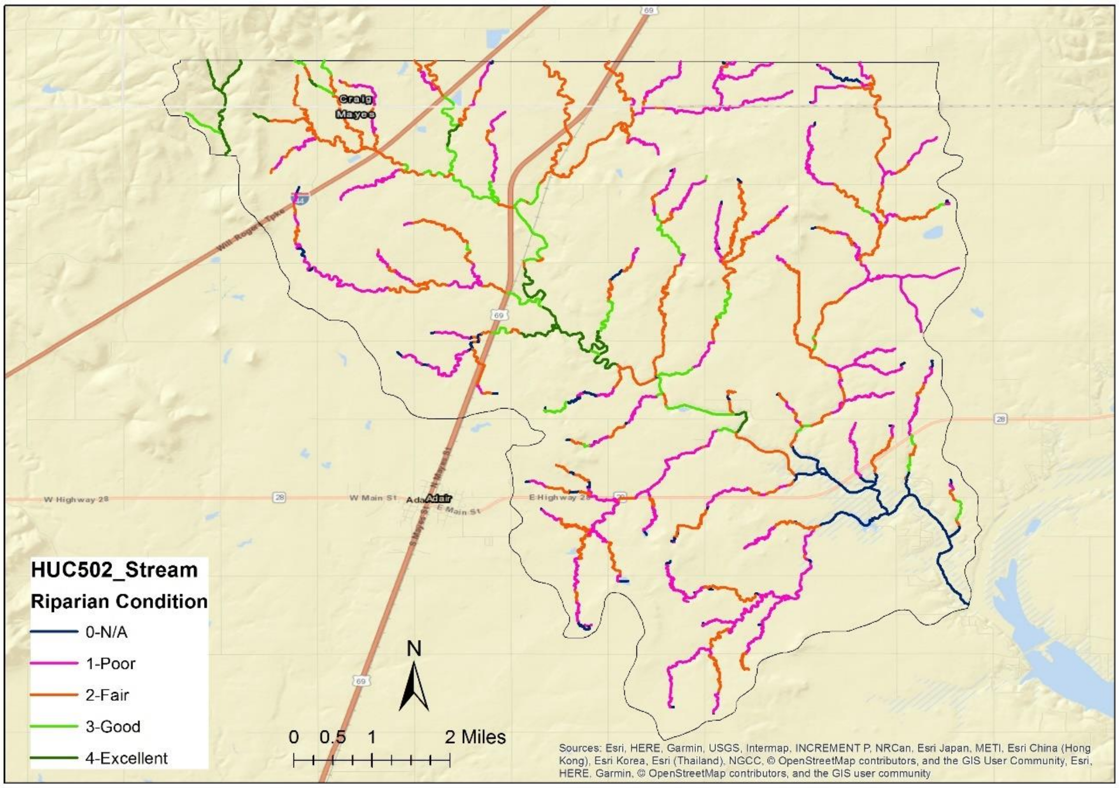

Figure A-3: Riparian Assessment of HUC 502

Table A-3: HUC 502 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
0	5	19.57
1	35	140.62
2	41	166.47
3	14	56.93
4	5	21.16
Total Length (KM)		**404.74**

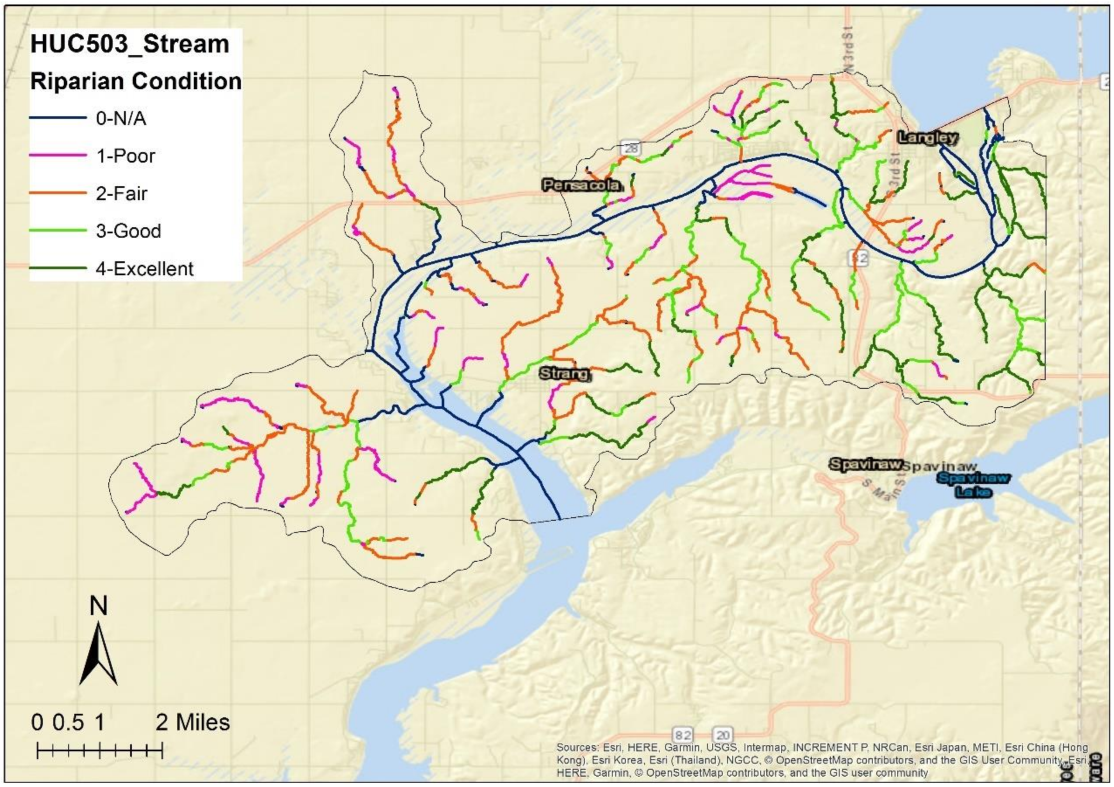

Figure A-4: Riparian Assessment of HUC 503

Table A-4: HUC 503 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
0	12	59.23
1	13	66.14
2	34	174.43
3	21	108.28
4	20	104.72
Total Length (KM)		**512.78**

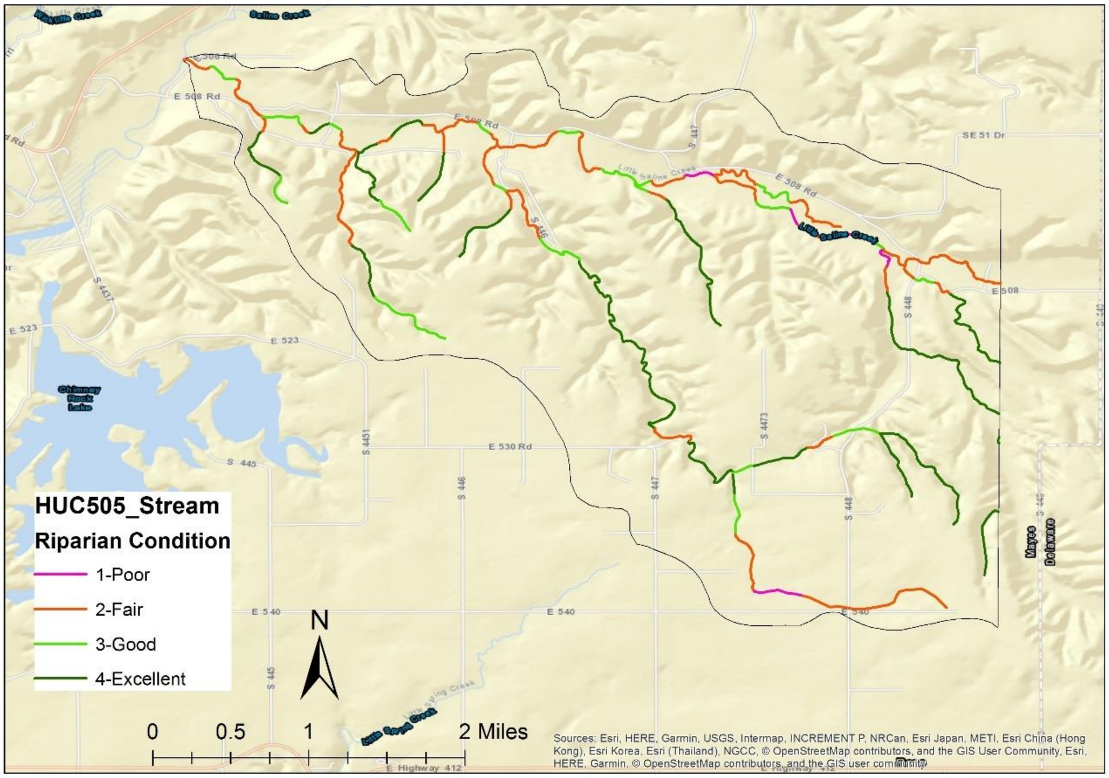

Figure A-5: Riparian Assessment of HUC 505

Table A-5: HUC 505 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
1	7	7.67
2	43	48.05
3	27	30.69
4	23	26.31
Total Length (KM)		**112.72**

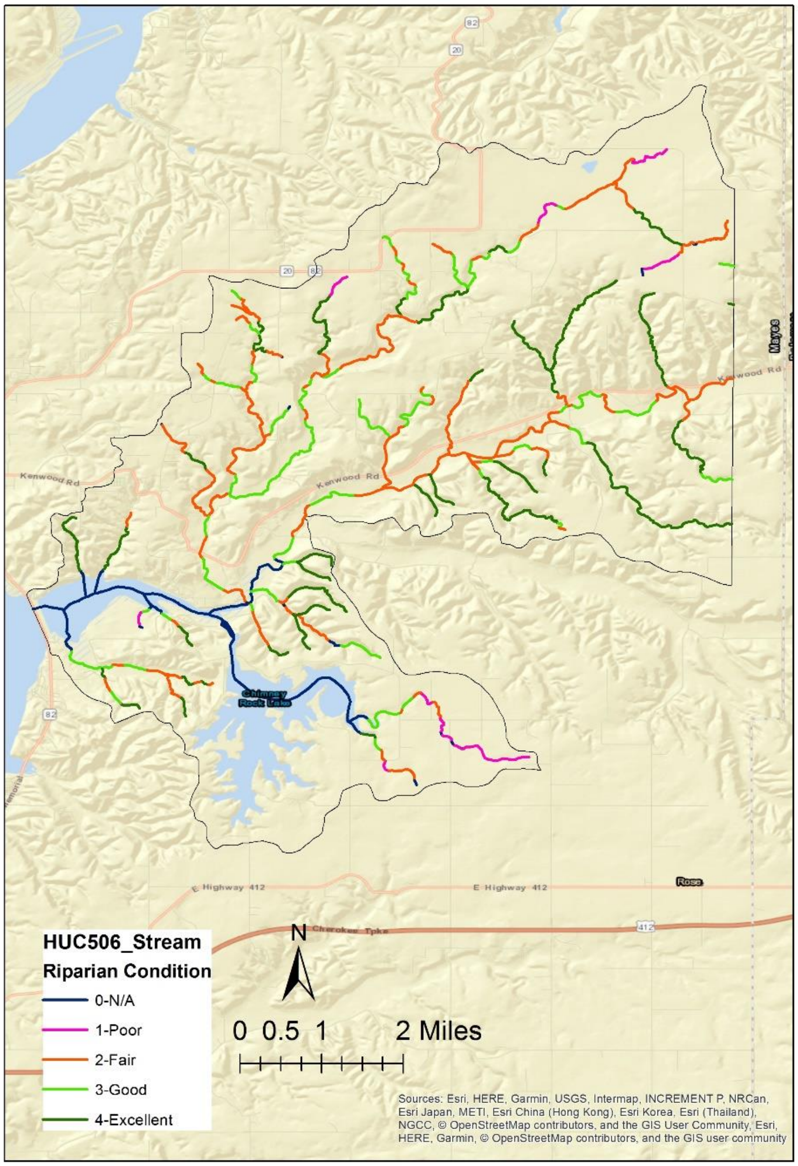

Figure A-6: Riparian Assessment of HUC 506

Table A-6: HUC 506 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
0	5	15.37
1	3	10.29
2	42	138.57
3	31	100.20
4	19	61.65
Total Length (KM)		**326.08**

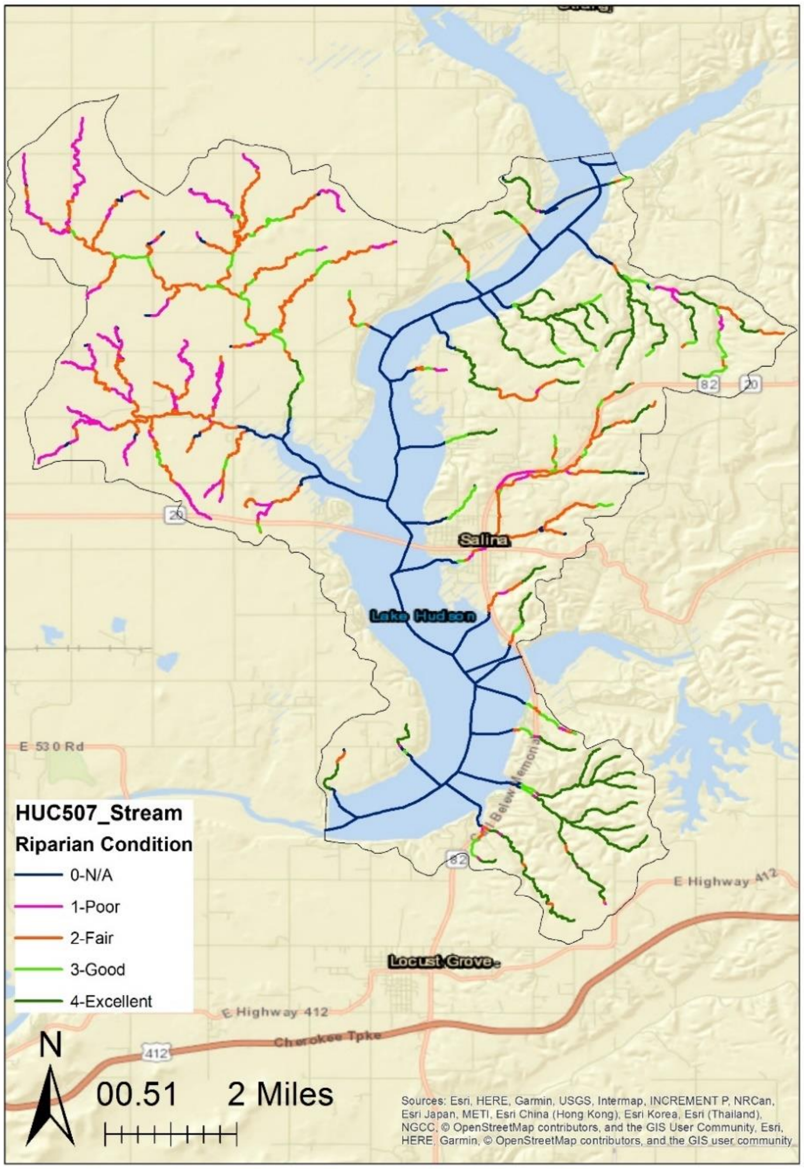

Figure A-7: Riparian Assessment of HUC 507

Table A-7: HUC 507 Riparian Condition

Riparian Condition	Percent Length (%)	Total Length/Condition (KM)
0	12	65.87
1	17	89.66
2	35	187.42
3	19	100.07
4	17	93.42
Total Length (KM)		**536.44**

APPENDIX B: Property Ownership for Riparian Conditions 1 and 2

Table B-1: Ownership for Riparian Condition 1 for HUC 208

HUC208-Riparian Condition 1 Ownership							
LENGTHKM	NAME	ACRES	ACCOUNT	LENGTHKM	NAME	ACRES	ACCOUNT
5.16	L BRUCE	4.64	490011177	0.08	VISTA DEL RIO RANCH LLC	6.4	490011362
1.45	S LANDRY	11.28	490011345	0.07	VISTA DEL RIO RANCH LLC	89	490011364
1.40	P CARROLL	170	490010593	0.06	B WILSON	10	490011315
1.22	J HARRIS	57.4	490010640	0.05	P CARROLL	220	490010588
1.16	W SUFFICOOL	100	490011291	0.05	J ELLIS	19.98	490011281
1.08	J LONG	160	490010495	0.04	G THOMPSON	199.64	490011283
0.74	M JANTZ	79	490010511	0.04	BEACON HILL RANCH FAMILY	65	490011302
0.74	J GRAVES	30	490010597	0.04	D MINSON	154	490011309
0.41	W WOOLBRIGHT	145	490011341	0.03	CARROLL FAMILY TRUST	159.18	490011317
0.26	K JARVIS	39	490010574	0.02	T ASHLEY	20	490010573
0.25	R BLAND	120	490011311	0.01	J WANDELL	80	490010666
0.09	P TROUT	33.3	490011298				

Table B-2: Ownership for Riparian Condition 2 for HUC 208

HUC208-Riparian Condition 2 Ownership							
LENGTHKM	NAME	ACRES	ACCOUNT	LENGTHKM	NAME	ACRES	ACCOUNT
3.24	B GILMORE	38	490010525	0.51	T MOORE	10	490011347
2.08	R WILSON	22	490034400	0.45	J WANDELL	80	490010666
1.93	R JOHNSON	10	490031695	0.41	G THOMPSON	199.64	490011283
1.65	T BRIXEY	101.51	490032368	0.38	R ADAMS	80	490011352
1.45	S HARP	26.67	490011278	0.37	T MOELLER	30	490011344
1.40	P CARROLL	220	490010588	0.32	S LANDRY	11.28	490011345
1.36	J GILMORE	39.29	490010509	0.23	B WILSON	10	490011315
1.30	R BLAND	120	490011311	0.21	A ANDRES	62.02	490011522
1.22	J HARRIS	57.4	490010640	0.14	D MORRISON	2.6	490034220
1.16	P MARTIN	60	490010660	0.11	R MILLIKAN	15.69	490029570
1.15	G COLVIN	170	490010607	0.10	C COLLINS	80	490010603
0.98	J WANDELL	40	490010661	0.07	J JARVIS	39.46	490010514
0.97	B MORRISON	40	490011299	0.07	A MCKEE	60	490010594
0.76	L RAINBOW LAND CO	12.27	490011336	0.06	J BELL	24.66	490029569
0.74	V BORGSTROM	39.25	490010510	0.04	K JUNGERMANN	70	490011346
0.72	M MARTIN	147.74	490011334	0.04	C CARLSON	10	490010610
0.63	B HATZENBUEHLER	16	490010589	0.04	C CHANEY	44.18	490011294
0.60	W SUFFICOOL	90	490011292	0.03	G ANDERSON	180	490010486
0.53	VISTA DEL RIO RANCH LLC	89	490011364	0.02	T BYSURA	2.16	490011273
0.52	L GOINS	328.66	490010508	0.01	B CASON	176.89	490011297

Table B- 3: Ownership for Riparian Condition 1 for HUC 313

HUC313-Riparian Condition 1 Ownership			
LENGTHKM	NAME	ACRES	ACCOUNT
1.23	H WEST	10	490009233
1.23	M MONTGOMERY	9.32	490009186
1.16	A GREGORY	70	490009472
1.07	CCC REVO FAMILY TRUST	515.35	490009617
0.95	R MILLER	15	490009445
0.95	N WILLIAMS	94.1	490009413
0.03	E JONES	130	490009231

Table B- 4: Ownership for Riparian Condition 2 for HUC 313

HUC313-Riparian Condition 2 Ownership								
LENGTHKM	NAME	ACRES	ACCOUNT		LENGTHKM	NAME	ACRES	ACCOUNT
2.35	H SHERMAN	12.8	490009344		0.70	T ADAMS	10	490009531
2.26	J TORBERT	10	490009511		0.67	D JONES	4.66	490024415
2.05	CCC REVOCABLE FAMILY TRU	23.76	490033139		0.66	T DAVIS	20	490009624
1.91	J KNOTTS	8.2	490009301		0.61	J COLE		490014287
1.87	R HENSON	10	490009363		0.59	L PASCOE	6.68	490009466
1.69	T ADAMS	80	490009503		0.33	D VANDERHAGEN	2.85	490009411
1.38	G JONES	17.79	490009385		0.28	W EATON	140	490009622
1.31	M MCCULLUM	10	490009283		0.24	H SANDERS	207	490009506
1.25	R COTRILL	20	490009543		0.10	J STONEBARGER		490024279
1.19	CCC REVO FAMILY TRUST	515.35	490009617		0.07	CITY OF TULSA	170	490009347
1.05	H SANDERS	40	490009509		0.07	T ADAMS	120	490009529
0.94	M BRADFORD	1.34	490024412		0.07	B KNAPP		490014711
0.94	J JACKSON	60	490009534		0.01	W TRAMMELL		490014263
0.90	P DUNCAN	10.3	490009468		0.01	F JONES	143.04	490009513
0.72	C ROBERTSON	86.62	490009349					

Table B- 5: Ownership for Riparian Condition 1 for HUC 502

HUC502-Riparian Condition 1 Ownership							
LENGTHKM	NAME	ACRES	ACCOUNT	LENGTHKI	NAME	ACRES	ACCOUNT
3.92	W WILLIS	263.97	490010714	0.80	C PROPP	140	490010206
3.05	C WEBB	238	490010356	0.76	B HENDRICKS	280	490010424
3.04	H BAUER	30	490010535	0.75	TATE FAMILY TRUST	251.48	490010541
2.66	M KEMP	160	490010345	0.72	S EGNOR	60.64	490010267
2.55	B HAMILL	158.99	490010224	0.65	P CASKEY	29.8	490010943
2.38	M ARMITAGE	270	490010744	0.61	J EASTIN	80	490010352
2.21	P JONES	65	490010537	0.60	QUAPAW INVESTMENTS LLC	320	490008026
1.88	L QUAPAW INVESTMENTS	430.71	490010946	0.59	QUAPAW INVESTMENTS LLC	20	490020381
1.73	QUAPAW INVESTMENTS LLC	556.62	490008571	0.59	J HEFNER	80	490010569
1.60	R RAMSEY	37	490010354	0.54	C OSBORN	30	490010427
1.53	T JACKS	70	490010580	0.48	W COUCH	260	490010476
1.48	TRISTATE WHITETAILS UNLI	43.5	490010927	0.43	QUAPAW INVESTMENTS LLC	230	490008117
1.48	SCHNEIDER FAMILY TRUST	60	490010309	0.37	QUAPAW INVESTMENTS LLC	466.52	490010955
1.44	R MALCHOW	163.5	490034882	0.36	QUAPAW INVESTMENTS LLC	230	490008575
1.40	S HENDREX	154.95	490010279	0.32	R KOEHN	128.92	490010940
1.39	T DAVENPORT	40	490010520	0.32	M RICHARDS	10	490010421
1.39	M WHITE	194.07	490010230	0.31	S PEPER	80	490010318
1.30	E PETERS	125.2	490008574	0.25	P CASKEY	155	490010702
1.25	R WILLIAMS	160	490010690	0.22	R NAIL	60	490010439
1.24	M PERKINS	5	490010921	0.17	J EASTIN	158.46	490010398
1.23	M KEMP	90	490010350	0.15	R HAMILL	266.87	490010225
1.19	QUAPAW INVESTMENTS LLC	640	490008025	0.11	R GILPIN	110.05	490010555
1.18	L QUAPAW INVESTMENTS	60	490010942	0.10	J HEFNER	80	490033750
1.09	S JOHNSTONE	10	490010749	0.06	G ARNOLD	80	490010308
1.04	D KOEHN	160	490010691	0.05	QUAPAW INVESTMENTS LLC	400	490010483
1.04	C GREEN	170.8	490036927	0.05	W COUCH	40	490020373
1.00	V WEST	152.41	490032554	0.04	SCHNEIDER FAMILY TRUST	320	490010205
0.98	C HEFNER	53.08	490010564	0.03	B SCHNEIDER	235	490010416
0.94	E JONES	9	490010543	0.03	J GREGORY	160	490010552
0.93	I KEMP STONE CO	60.08	490029411	0.03	J GREGORY	160	490010556
0.90	D TROYER	6	490010400	0.03	G WILSON	68.7	490010277
0.87	D TROYER	264	490010274	0.01	L KING	285	490010323
0.86	J PEPER	40	490010437	0.01	M ARMITAGE	451.78	490010739

Table B- 6: Ownership for Riparian Condition 2 for HUC 502

HUC502-Riparian Condition 2 Ownership								
LENGTHKM	NAME	ACRES	ACCOUNT		LENGTHKM	NAME	ACRES	ACCOUNT
4.27	C PROPP	361	490010214		0.90	D TROYER	6	490010400
3.92	R GILPIN	110.05	490010555		0.87	J GREGORY	160	490010556
3.24	S CRAWFORD	70	490010332		0.87	D TROYER	264	490010274
3.11	L KING	285	490010323		0.86	A TANGREN	20	490020193
3.05	C WEBB	238	490010356		0.80	C OSBORN	30	490010427
3.04	G GARRISON	40	490033749		0.79	C HEFNER	20	490010570
2.86	J GREGORY	80	490010712		0.72	J PROCTER	41.85	490010269
2.84	C PROPP	140	490010206		0.65	P CASKEY	29.8	490010943
2.66	M KEMP	60	490010299		0.61	V GILPIN	20	490010310
2.55	S MILLER	20	490010219		0.59	J FRIESEN	10	490020383
2.38	M ARMITAGE	270	490010744		0.59	J GILPIN	20	490037350
2.21	B PARMAN	90	490010536		0.54	M ARMITAGE	451.78	490010739
2.09	J BEVONI	160	490010325		0.54	W BARLASS	137	490010218
2.00	C PROPP	125	490010216		0.52	C PROPP	80	490010210
1.95	R HAMILL	266.87	490010225		0.42	QUAPAW INVESTMENTS LLC	466.52	490010955
1.93	J EASTIN	3.5	490034941		0.39	M SCHWARTZLANDER	47.7	490010935
1.88	C DOWNS	40	490010949		0.39	R NAIL	60	490010439
1.80	W COUCH	260	490010476		0.37	M SCHWARTZLANDER	70	490031626
1.73	E PETERS	125.2	490008574		0.35	R KOEHN	50.36	490010727
1.67	M WHITE	196.91	490010228		0.34	M KEMP	144.51	490010305
1.53	T JACKS	70	490010580		0.33	QUAPAW INVESTMENTS LLC	640	490008025
1.52	R KOEHN	128.92	490010940		0.30	R NAIL	20	490020194
1.48	M WHITE	194.07	490010230		0.27	D RUSSELL	2.52	490034379
1.48	SCHNEIDER FAMILY TRUST	70	490010312		0.26	S DAVENPORT	19.95	490010440
1.48	QUAPAW INVESTMENTS LLC	20	490020381		0.25	J EASTIN	158.46	490010398
1.44	B SCHNEIDER	235	490010416		0.23	M SCOTT	39.8	490010725
1.39	B GILMORE	40	490034035		0.22	C RICHARDS	90.2	490010418
1.35	M KEMP	160	490010345		0.18	J GREGORY	40	490033797
1.30	QUAPAW INVESTMENTS LLC	556.62	490008571		0.15	L KING	131	490010705
1.29	QUAPAW INVESTMENTS LLC	46.68	490031184		0.14	S JACKSON	27.52	490010568
1.24	M PERKINS	5	490010921		0.13	TOWN OF ADAIR	70	490020386
1.23	M KEMP	90	490010350		0.13	T CLAIR	16	490033796
1.18	L QUAPAW INVESTMENTS	20	490020385		0.11	QUAPAW INVESTMENTS LLC	400	490010483
1.08	J HEFNER	80	490033750		0.08	J EASTIN	80	490010352
1.04	C GREEN	170.8	490036927		0.08	K CAMERON	130	490010429
0.98	C HEFNER	53.08	490010564		0.04	P HUGLEY	80	490010276
0.93	D PAYTON	28	490010737		0.03	GRDA	2.48	490010905

Table B- 7: Ownership for Riparian Condition 1 for HUC 503

HUC503-Riparian Condition 1 Ownership								
LENGTHKM	NAME	ACRES	ACCOUNT		LENGTHKM	NAME	ACRES	ACCOUNT
3.79	K SANDERS	70.5	490008500		0.70	SNOW LAND AND CATTLE CO	3.64	490036289
3.42	M MEADOWS	79	490009203		0.68	D HUGHES	28.21	490011487
2.09	L CABE	59.62	490010767		0.64	H WEST	30	490011540
1.97	J FRIESEN	15	490008569		0.62	R BLEDSOE	77.95	490011501
1.94	E PETERS	40	490008585		0.61	W JOHNSON	80	490009101
1.82	A BRANNON	80	490008745		0.59	SHANE BEST TRUCKING INC	100	490032070
1.75	SHANE BEST TRUCKING INC	100	490011635		0.50	C BOGLE	107.97	490011424
1.67	CCC REVO FAMILY TRUST	100	490008672		0.48	J RICKARD	13.8	490031917
1.63	D CATES	19.96	490011042		0.44	G STUTZMAN	40	490008728
1.55	C JAMES	18.49	490009159		0.44	SNOW LAND AND CATTLE CO	106.2	490011554
1.54	ODOT	103.89	490031759		0.43	SNOW LAND AND CATTLE CO	147.58	490011551
1.37	B PHILLIPS	35	490011498		0.37	R COATS	120	490009178
1.25	E PETERS	67.47	490008576		0.37	A KOEHN	40	490008596
1.23	G KNOTTS	220.5	490011435		0.23	V THOMPSON	12	490008747
1.21	J BERKSTRESSER	8.16	490008782		0.21	J JARVIS	160	490010681
1.20	BOLIN LAND AND CATTLE CO	304	490008505		0.18	B WILLYARD	126.9	490008759
1.13	T WHEELER	17.52	490010818		0.17	G MARTIN	100	490008742
1.11	M ARMITAGE	270	490010744		0.15	R BOGLE	192.75	490011604
1.04	R BAKER	40	490011033		0.11	W RICE	60	490008587
1.03	J TEEL	3	490008775		0.08	M RATLIFF	15	490008816
0.92	E PETERS	35	490032796		0.07	E LAWSON	153.45	490010770
0.83	D LAY	116.02	490010825		0.03	T SUI	100	490010685
0.83	E COFFEY	58.3	490008579		0.03	W WILSON	160	490011050
0.81	BOLIN LAND AND CATTLE CO	246	490011026		0.03	D CATES	160	490008497
0.78	C GREEN	170.8	490036927		0.03	J GOOCH	68.08	490009158
0.75	A MCKAY	30	490010824					

Table B- 8: Ownership for Riparian Condition 2 for HUC 503

HUC503-Riparian Condition 2 Ownership							
LENGTHKM	NAME	ACRES	ACCOUNT	LENGTHKM	NAME	ACRES	ACCOUNT
3.79	M STOCKTON	80	490011051	0.60	V MARANG	20	490009162
3.44	BJD STRANG RANCH LLC	300	490009193	0.59	SHANE BEST TRUCKING INC	100	490032070
3.06	B WEGSCHEID	6	490009154	0.55	J ANDERSON	40	490029804
2.56	R ARMBRISTER	117	490011630	0.54	SNOW LAND AND CATTLE CO	106.2	490011554
2.29	B ROGERS	50.25	490008730	0.53	E LAWSON	153.45	490010770
2.16	SHANE BEST TRUCKING INC	160	490011675	0.51	R SCHILT	168	490008488
2.09	C POTTER	9.63	490010768	0.51	A ASBURY	20	490011665
2.08	T HIBBARD	120	490008766	0.42	S BEST	304.36	490011557
1.97	J MALCHOW	80	490008592	0.41	R AKIN	11	490022652
1.97	R HOPPER	57.41	490008710	0.37	S CROSS	136.37	490011565
1.92	SHANE BEST TRUCKING INC	40	490011639	0.36	D GREY		490015348
1.92	T WILKINS	28.32	490010810	0.34	COBB-VANTRESS INC	635	490011731
1.91	T SIMONS	100	490008671	0.31	M BOGLE	88	490011576
1.91	ODOT	4.1	490033767	0.28	J MARDIS	80	490009160
1.75	SHANE BEST TRUCKING INC	100	490011635	0.27	M PERKINS	20	490031223
1.67	D GOFF	75	490008491	0.26	G MARTIN	100	490008742
1.63	BOLIN LAND AND CATTLE CO	84	490011025	0.26	S CROSS	8	490011612
1.55	M WALLACE	80	490011666	0.26	K BRYD	48	490011532
1.48	D JOHNSON	180	490008831	0.25	R BOGLE	153.88	490033746
1.47	S SHIVE	78.5	490034466	0.25	E COFFEY	58.3	490008579
1.34	C GREEN	170.8	490036927	0.23	T BROWN	9.85	490010814
1.32	R ZINNIKAS	240	490011660	0.23	R BOGLE	192.75	490011604
1.31	G KNOTTS	220.5	490011435	0.23	M STOCKTON	155.47	490011654
1.25	C PETERS	10	490032025	0.20	M STOCKTON	33.93	490011651
1.22	L JONES	57.01	490009200	0.20	T THOMPSON	20	490008746
1.19	BOLIN LAND AND CATTLE CO	304	490008505	0.16	D PATTERSON	25.2	490011350
1.13	J KERR	36.03	490011549	0.16	LAKE VALLEY RANCH & RESO		490013835
1.09	M ARMITAGE	270	490010744	0.14	R SCHILT	80	490008487
1.05	R BLEDSOE	77.95	490011501	0.13	R DANIELS	20	490008743
1.00	R BOGLE	80	490011603	0.12	J HAYES	113.86	490010811
0.95	D JOHNSON	80	490011661	0.10	R HUGHES	25	490011485
0.95	R COATS	120	490009178	0.09	M RATLIFF	15	490008814
0.95	ODOT	103.89	490031759	0.09	T WHEELER	17.52	490010818
0.94	J WATT	60	490008830	0.07	P CARROLL	241.94	490011483
0.92	E PETERS	35	490032796	0.06	D LAY	93.02	490011638
0.86	G FLOYD	67.86	490008589	0.06	CCC REVO FAMILY TRUST	11.09	490010809
0.82	B GAY	197	490008593	0.06	T STRAIGIS	1.25	490029636
0.81	BOLIN LAND AND CATTLE CO	246	490011026	0.06	E PETERS	60	490008583
0.79	GROWING PRAIRIE HOLDINGS	50	490011650	0.06	W BUTTS	160	490035109
0.78	B HENDRICKS	117.8	490010895	0.05	NEAL FAMILY TRUST	10	490009156
0.75	W WILSON	160	490011050	0.05	A BALL	19.42	490029464
0.71	J WOOD	64.7	490011656	0.04	W RICE	170	490008755
0.71	J BOGLE	179	490011035	0.04	W RICE	60	490008587
0.71	W WILSON	90.49	490011048	0.04	T FREE	55.24	490033315
0.70	T SUI	100	490010685	0.03	W JOHNSON	80	490009101
0.62	R ROBBINS	95	490008756	0.03	D HUGHES	28.21	490011487
0.61	J KIPER	120	490011663	0.02	A KOEHN	40	490008596
0.61	G RUDICK	100	490033085				

Table B- 9: Ownership for Riparian Condition 1 for HUC 505

HUC505-Riparian Condition 1 Ownership			
LENGTHKM	NAME	ACRES	ACCOUNT
2.31	G BARRETT	30	490003752
1.89	A WOLF	51.05	490007281
0.82	W BALL	40	490033601
0.76	R BLACK	120	490007296

Table B- 10: Ownership for Riparian Condition 2 for HUC 505

HUC505-Riparian Condition 2 Ownership			
LENGTHKM	NAME	ACRES	ACCOUNT
4.14	C DRURY	20	490007398
2.94	W BALL	70.85	490007276
2.31	D KING	40	490003751
2.14	R BLACK	9.15	490007277
1.89	R BLACK	120	490007296
1.73	R BALL	140	490007297
1.61	R BLACK	40	490007286
1.13	R GRIGG	400	490007304
1.07	K MORTON	106.12	490007217
1.05	H QUANTIE	37.79	490007402
0.80	E COWAN	71.62	490036740
0.79	C MONTGOMERY	80	490007303
0.76	B WALTERS	200	490007295
0.66	Y SMITH	173.66	490007222
0.59	R DRY	45	490007306
0.30	W BALL	40	490033601
0.06	W BALL	40	490007283
0.02	D CUNNINGHAM	20	490003735

Table B- 11: Ownership for Riparian Condition 1 for HUC 506

HUC506-Riparian Condition 1 Ownership			
LENGTHKM	NAME	ACRES	ACCOUNT
2.98	CCC REVO FAMILY TRUST	325	490009704
2.75	R ROSE	158	490006862
1.70	D BLACKFORD	97.5	490031003
1.45	R ALBERTY	5	490034336
0.44	G KERNS	90	490006548
0.38	B HOBBS	5	490007377
0.17	D HOGAN	189.84	490003757
0.07	R MONK	344.97	490003781
0.05	J LEE	450	490006772
0.04	J COWAN	159.9	490006755

Table B- 12: Ownership for Riparian Condition 2 for HUC 506

HUC506-Riparian Condition 2 Ownership								
LENGTHKM	NAME	ACRES	ACCOUNT		LENGTHKM	NAME	ACRES	ACCOUNT
9.43	D CHANCELLOR	30.2	490029627		1.00	R KING	7.02	490007056
3.85	L EATON	300	490007101		0.99	SALINA DRILLERS LLC	40	490006913
2.98	CCC REVO FAMILY TRUST	325	490009704		0.91	V FLETCHER	19.7	490007355
2.98	J BUTCHER	224.64	490035549		0.90	SPAVINAW HILLS WILDLIFE	640	490009729
2.94	T KERNS	11.5	490007237		0.84	J WILLIAMS	14.31	490006554
2.83	R SQUIRREL	6.77	490007027		0.78	J COWAN	159.9	490006755
2.75	M PRITCHETT	40	490006926		0.78	C CAGLE	50	490009705
2.64	W DANIELS	104	490007146		0.77	DEHART LIVING TRUST	39.19	490007113
2.51	M PRITCHETT	150	490006916		0.74	T GONZALEZ	26.38	490031778
2.29	T BODINE	26.81	490007335		0.72	D DANIELS	40	490007140
2.16	P COOK	12	490006801		0.67	DLB LLC	64.85	490031142
1.97	L SIPES	88.64	490007076		0.66	D WILLIAMS	137.88	490003777
1.85	D FOX	68.96	490009722		0.62	W DUNIPHIN	38	490030662
1.81	G BLEDSOE	34	490006948		0.59	C LANE	40	490006923
1.71	T EATON	72.7	490034169		0.56	DON & GIRLS LLC	160	490007360
1.70	D BLACKFORD	97.5	490031003		0.56	R MONK	344.97	490003781
1.62	P VANDALL	10	490007190		0.54	MID AMERICA MORTGAGE INC	6.54	490007095
1.45	M CAGLE	10	490030812		0.48	W CHANCELLOR	197.83	490007062
1.42	W BUTCHER	75.36	490007024		0.46	R JOHNSON	40	490007071
1.39	G PASSMORE	197.51	490007070		0.45	J HOWELL	6.26	490006986
1.34	B SQUIRREL	62	490006458		0.34	DEHART LIVING TRUST	51.5	490006914
1.30	GRDA	160	490007348		0.33	BIG SALINE 60 LLC	67.46	490007092
1.21	K GATES	10	490006795		0.33	J LEE	450	490006772
1.17	M HARRIS	0.49	490007227		0.18	R JOHNSON	75	490007096
1.10	INDIAN (JOHN SMITH)	30	490006754		0.10	M HAYES	155.7	490009720
1.07	T PHELAN	15	490007208		0.04	DON & GIRLS LLC	160	490007319
1.02	M WILLHOITE	83.54	490007356		0.03	C HALL	30	490007325

Table B- 13: Ownership for Riparian Condition 1 for HUC 507

HUC507-Riparian Condition 1 Ownership							
LENGTHKI	NAME	ACRES	ACCOUNT	LENGTHKM	NAME	ACRES	ACCOUNT
5.01	G MARTIN	170	490008955	0.64	S GREENWAY	268.6	490005920
3.94	C STUTZMAN	170	490008287	0.56	J KIRBY	135.45	490033917
3.75	W SMITH	29.16	490002769	0.54	M MILLER	70	490008286
2.75	R EVANS	150	490008957	0.53	W CHUPP	100	490005912
2.74	D CATES	123.32	490009661	0.53	D UNRUH	238.57	490008819
2.60	J EAGLE	40	490002828	0.50	E RUSH	64.02	490005843
2.46	P KING	160	490008804	0.48	S ANDERSON	10	490032693
2.43	C WHITEDAY	4	490006017	0.42	J HUGHES	50.21	490009635
2.23	B TRUE	32.12	490005908	0.25	E FRISBIE	50	490037316
2.06	S LEONARD	80	490005925	0.23	B TRUE	69.42	490005902
1.86	K KERNS	138.2	490006439	0.21	M TAYLOR	10	490005181
1.73	B CHITWOOD		490013849	0.18	B KESTER	141	490037313
1.53	G MILLER	68.4	490008849	0.17	T THOMAS	40	490035858
1.48	B STUTZMAN	55	490008289	0.16	T HADDAN	104	490005919
1.48	M STIPES	40	490006116	0.15	C CAGLE	50	490009003
1.46	T HADDAN	80	490005439	0.14	A LEONARD	27.19	490033015
1.35	J HALPAIN	240	490002599	0.13	R MILLER	40	490008297
1.28	H CLAYTON	37.5	490005441	0.12	D MCGOVERN	6	490005152
1.26	K COUSATTE	73.28	490032099	0.12	M CLAYTON	40	490005160
1.22	JOHNSON FAMILY REVO TRUS	65	490036900	0.10	E TROYER	140	490008480
1.13	J CASEBEER	80	490036378	0.10	C PROCTOR	100	490005435
1.10	T BURNS	75	490005815	0.09	Q BEEN	80.05	490005162
1.10	A COBLENTZ	86.66	490008315	0.09	L GRACE	7.65	490002638
1.05	B HARRIS	3	490023956	0.07	W WILLYARD	51.29	490008800
1.03	S OSBORN	40	490005440	0.03	T PARKS	160	490036964
0.89	HOMEPLACE PROPERTIES LLC	190	490005165	0.03	D CHANCELLOR	33.3	490033458
0.86	JOHNSON FAMILY REVO TRUS	51	490006733	0.02	G TRAMEL	75	490002831
0.75	A PITTENGER	20	490031014	0.01	M ARMITAGE	628.37	490008277
0.74	J ARNOLD	130	490005449				

Table B- 14: Ownership for Riparian Condition 2 for HUC 507

HUC507-Riparian Condition 2 Ownership							
LENGTHKM	NAME	ACRES	ACCOUNT	LENGTHKM	NAME	ACRES	ACCOUNT
6.37	B COBLENTZ		490015065	1.03	S OSBORN	40	490005440
5.01	E WILLIS	125.15	490008996	0.93	D BENSLEY	0.8	490008888
3.94	M ARMITAGE	628.37	490008277	0.82	E TRUE	28.88	490005913
3.75	K CONNER	110	490002840	0.82	C WILLYARD	19.1	490031202
2.75	O NEWTON	115	490008966	0.78	H KLEEMAN	110	490009018
2.74	R DAVIS	6	490006840	0.76	D CHANCELLOR	33.3	490033458
2.60	J NEEL	15	490002834	0.76	J KENDRICK	10	490008307
2.46	P KING	160	490008804	0.75	M HALL	20	490008981
2.43	T BURNS	69.8	490032572	0.71	R INGRAM	28.14	490033537
2.34	R BONAVENTURA	74	490005890	0.55	B KESTER	141	490037313
2.06	S LEONARD	80	490005925	0.52	T HADDAN	104	490005919
1.97	P MERCKLING	10	490009652	0.49	W BUTTS	60	490009005
1.86	M MATLOCK	13	490006442	0.48	D COATS	40	490006146
1.81	D CATES	123.32	490009661	0.48	S ANDERSON	10	490032693
1.78	G GEBHARD	7.5	490006099	0.43	S GREENWAY	268.6	490005920
1.78	R OLIVER	15.08	490006143	0.43	S GRAYSON	20	490029633
1.73	K SCHMOLL		490013848	0.35	C CAGLE	50	490009003
1.72	H DUNIPHIN	58	490006879	0.34	L COUCH	80	490008964
1.62	G WILLIS	55	490005940	0.25	R GULLEY	10	490008879
1.48	E TROYER	80	490008301	0.23	J PARTAIN	0.5	490005151
1.48	C PENLAND	6	490006121	0.21	KAMO ELECTRIC COOP	1.61	490032202
1.47	D THIBEAULT	41	490006566	0.20	D MCGOVERN	6	490005152
1.46	T HADDAN	80	490005439	0.17	B TRUE	130	490005901
1.42	G KNIGHT	28	490008952	0.17	D EICHELBERGER	134.72	490008992
1.32	W SMITH	29.16	490002769	0.16	E FRISBIE	50	490037316
1.29	S WEBB	2.02	490031323	0.14	M SOUKUP	21.55	490005835
1.28	J SILLS	2.5	490031122	0.14	W CHUPP	100	490005912
1.26	G FIELDS	79	490035976	0.13	E RUSH	64.02	490005843
1.22	JOHNSON FAMILY REVO TRUS	51	490006733	0.11	R MILLER	157.32	490008977
1.18	W DAVENPORT	113.97	490031841	0.08	M MILLER	70	490008286
1.15	L LITKE	40	490006250	0.07	D UNRUH	238.57	490008819
1.14	J TIBBETS	10	490008983	0.06	E MILLER	100	490008291
1.12	M BACK	27.51	490006229	0.05	E TRUE	79	490005438
1.11	S WEAVER	55	490008986	0.04	BEST DUMP TRUCKING INC	30	490006337
1.10	T BURNS	75	490005816	0.03	L SALINA DRILLERS	10.46	490006345
1.10	A COBLENTZ	86.66	490008315	0.03	C COLLINS	19	490005814
1.08	Q BEEN	80.05	490005162	0.02	C DAVIS	257.13	490008308
1.08	R COGER	1.32	490031226	0.02	B GAGE	49.83	490009017
1.05	GRDA		490023635				

VITA

Kavina Eksteen

Candidate for the Degree of

Master of Science

Thesis: IMPROVING THE WATER QUALITY IN THE LAKE HUDSON WATERSHED IN MAYES COUNTY, OKLAHOMA

Major Field: Environmental Science

Biographical:

Education:

Completed the requirements for the Master of Science in Environmental Science at Oklahoma State University, Stillwater, Oklahoma in May, 2020.

Completed the requirements for the Honours Bachelor of Science in Environmental Management at University of South Africa, Johannesburg, South Africa in 2013.

Experience:

Graduate Research Assistant (Fall 2018-Fall 2020): Worked on compiling a watershed-based management plan for Lake Hudson.

Executive Secretary for the Conservation Director at CapeNature (Oct 2013-Jun 2018): Administrative, financial, and project management skills

Office Administrator for Forest Fire Association Non-Profit Organization (Jun 2013-Oct 2014): Administrative support and client liaison

Senior Researcher at the South African Medical Research Council Violence, Injury and Peace Research Unit (Aug-Oct 2014): Literature reviews, stakeholder engagement, statistical analysis of data, presentation of results and section write-ups

Public Relations and Education Officer at the City of Johannesburg Emergency Management Services (Dec 2007-Mar 2013): Developed and implemented life safety awareness programs, conducted awareness displays and exhibitions, analyzed and monitored monthly injury data and activities, project management, budget tracking and procurement

Emergency Call Taking Supervisor for the City of Johannesburg Customer Relationships Centre (Mar 2003-Nov 2007): Managed a team of 12 incident coordinators on a shift system. Training and development of staff, quality assurance, reporting and back-end statistical analysis of contact center data.