MODELING THE IMPACTS OF EROSION AND SEDIMENT CONTROL PRACTICES FOR ROADWAY CONSTRUCTION SITES ON WATER QUALITY IN OKLAHOMA

By

MARYAM AHMADVAND

Bachelor of Science in Applied Geology

Kharazmi University

Tehran, Iran

2009

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May 2020

MODELING THE IMPACTS OF EROSION AND SEDIMENT CONTROL PRACTICES FOR ROADWAY CONSTRUCTION SITES ON WATER QUALITY IN OKLAHOMA

Thesis Approved:

Dr. David, J. Lampert

Thesis Adviser

Dr. Rifat Bulut

Dr. Gregory G., Wilber

ACKNOWLEDGEMENTS

This study is intended as part of a larger project for the Oklahoma Department of Transportation.

I owe a debt of gratitude to my adviser, Dr. David J. Lampert, for his continued support, guidance, and advice throughout my journey and his careful attention to detail and constant help. His patience and immense knowledge helped me throughout my research and writing of this thesis. I could not have imagined completing this work without his mentorship.

Thanks, and appreciation also to my other committee members Dr. Rifat Bulut and Dr. Gregory G. Wilber, for their thorough critique of this project.

Thanks, and appreciation to Mr. Dave Lightle, Erosion Model Consultant, who kindly helped and gave me access to the adjust RUSLE_2 construction database, which is the result of his many years' experience at the Natural Resources Conservation Service (NRCS).

I also would like to thank Mr. Caleb Stone from USDA-NRCS Stillwater for his time and excellent advice.

I am especially grateful to my dear husband, Saeid, who always motivated me during my studies. I cannot thank you enough for encouraging me throughout this experience. This accomplishment would not have been possible without you.

Name: MARYAM AHMADVAND

Date of Degree: MAY 2020

Title of Study: MODELING THE IMPACTS OF EROSION AND SEDIMENT CONTROL PRACTICES FOR ROADWAY CONSTRUCTION SITES ON WATER QUALITY IN OKLAHOMA

Major Field: CIVIL ENGINEERING

Abstract: Construction typically requires mass clearing and grading, causing project site areas to be unstable. As a result, they lack ground cover to protect against rainfall and runoff, which results in soil degradation and erosion. Erosion introduces nonpoint source (NPS) suspended solids pollution into water bodies, which diminishes water quality and reduces the lifetime of water resources. In the past few years, there has been a significant improvement in water quality using erosion and sedimentation best management practices (BMPs). Despite improvements in NPS management, many challenges remain due to the complexity of BMP implementation. Desirable environmental protection and appropriate drainage and erosion control are only achieved when drainage, erosion and sediment control (ESC) work together.

The Oklahoma Department of Transportation (ODOT) is responsible for implementing approaches to reduce environmental impacts of construction on thousands of bridges and culverts across the state. The goals of this project were to summarize existing BMPs for ESC and to estimate the impacts of BMP implementation on suspended solids loadings in Oklahoma.

The annual soil erosion rate for select Oklahoma counties was determined using ArcGIS Pro to run the Revised Universal Soil Loss Equation, Version 2 (RUSLE_2) based on soil, land use, elevation, and climatic data. All factors used in RUSLE_2 were calculated with local data from the United States Department of Agriculture, Natural Resources Conversation Service (USDA_NRCS). Moreover, the RUSLE_2 Graphical User Interface (GUI) was used with a database of ODOT projects to estimate sediment loadings from the roadway construction sites into Oklahoma waterways. Furthermore, the efficiency of BMPs for multiple combinations of different land surface conditions (soil erodibility and slope) were evaluated. The estimates of sediment yield from the ODOT construction sites were then compared with background sediment production in each county to estimate the impacts of construction and BMPs on water quality in Oklahoma.

The mean annual sediment yield for select Oklahoma counties from 2010-2017 was 0.05 and ranged from 0.002 to 0.3728 tons per hectare per year (t/ha/yr). The average annual erosion prediction for this study is similar to previous Oklahoma estimates of 0.027 to 0.0465 tons/acre/year for good to excellent land conditions. The results indicate that, in some cases, construction sites can increase the annual erosion rates up to 40 times the natural erosion rate. In some cases, by using ESC BMPs, sediment yields can be decreased up to 90 percent relative to unprotected construction site surfaces. The model results show a high correlation between slope steepness and the efficiency of erosion blanket BMPs. Temporary seeding with mulching BMPs acts better in the area with higher average rainfall. Finally, sediment production controls, such as silt fences and fiber logs, exhibited better efficiency in low to the medium slope areas.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Chapter Page

LIST OF CHARTS

LIST OF FIGURES

Chapter Page

CHAPTER I

INTRODUCTION

The construction of roadways typically consists of mass clearing and grading, leaving many site areas unstable and lacking ground cover to preserve toward rainfall-induced erosion. The main pollutants from construction sites are sediments. Roadway systems may include several drainage areas and convey significant runoff and sediment from off-site, which results in intensive inspection requirements of drainage outlets and stormwater discharge outfalls subject to stormwater regulations. Designers need to select appropriate erosion and sediment control (ESC) measures that are effective and applicable to the roadway design to collect and convey runoff from impervious areas to maintain the structural integrity of the roadway and protect public safety. The effectiveness of the ESC measures on a site is highly dependent on proper implementation of a well-prepared ESC plan. According to the American Society of Civil Engineers (ASCE) and Water Environment Federation (WEF), stormwater runoff from unprotected exposed areas on construction sites causes 35-45 tons of sediment yields per acre per year [1]. On the other hand, expanded urban areas increase the amount of impervious surface and the runoff. Excess stormwater runoff is considered a diffuse pollutant source that is difficult to control, since pollutants in runoff can potentially end up in water bodies and cause impairment [2]. Due to the magnitude of land-disturbing activities and their effects on the environment, authorities charged with management of infrastructure such as the Oklahoma Department of Transportation (ODOT) are required to maintain ESC programs to reduce environmental impacts of construction. ODOT and is committed to reducing the stormwater impacts of construction of their bridges and roadways. This thesis is intended as part of a larger project funded by ODOT to have a better understanding of ESC Best Management Practices (BMPs).

One aspect of this thesis was to develop an ESC decision guide document to assist ODOT staff, land developers, consultants, and contractors across Oklahoma to implement appropriate ESC on construction sites. Maintaining a proper plan for installing and inspecting BMPs reduces erosion and sedimentation on exposed construction sites. Protection of exposed areas should be the primary goal in the ESC plan design. Impoundment BMPs promote sedimentation by reducing flow velocity of runoff. To minimize or prevent degradation of downstream water resources and stabilize construction assets, erosion control should be viewed as the primary goal whereas sediment control should be viewed as a contingency plan. In particular, areas of elevated erosion potential where fine particles will not readily settle out in a practical time frame should receive a greater emphasis on erosion control. Sediment control measures can then be incorporated to capture and settle sediment and prevent or minimize the sedimentation into receiving waters. However, measures to address both erosion and sediment control are required for most sites [3].

As had been noted, the primary objectives of the project funded by ODOT were to identify existing opportunities to reduce the environmental impact of transportation infrastructure construction. Equally important, the second objective was developing a practical and applicable ESC decision design guide document for use by ODOT field engineers and other personnel. Accordingly, useful and convenient categorization was achieved after communications with ODOT engineers from different departments and perspectives. A literature review was conducted of available resources, including other state Department of Transportation ESC guideline reports, ESC handbooks, and journal articles. The results were compiled into appropriate categories for BMP implementation by both: 1) site construction activities and 2) intended BMP application. For each BMP, the functional life longevity and its categorization as either temporary and permanent were provided (Appendix 1).

ESC BMPs are measures to prevent the release of toxic and hazardous chemicals to receiving water, under the National Environmental Policy Act (NEPA) permit [4]. BMPs for erosion control are measures that have been developed and proven to work on construction sites. The best result is obtained when they are properly planned and constructed. These measures reduce erosion and sedimentation potential by stabilizing exposed soil or reducing surface runoff flow velocity.

In the past few years, implementation of measures including ESC BMPs to comply with the Clean Water Act have resulted in a significant improvement in water quality. Despite improvements in nonpoint source (NPS) management, many challenges remain due to the complexity of BMP implementation. BMP implementation for organizations such as ODOT is costly, and these costs should be weighed against their environmental benefits. The environmental impacts of the implementation of BMPs on water quality in Oklahoma are unclear, however. The efficiency of the BMPs extremely depends on the site status such as soil type and slope steepness, over and above the lack of sufficient study in this topic in the state leads us to study the BMPs efficiency in the roadway construction site in Oklahoma. Only a few documents were conducting and reporting data for assessing BMP effectiveness on a broader scale [60]. We checked the International Stormwater BMP database, but there is no record of BMP efficiency in Oklahoma [6].

The second aspect of the thesis was to generate long-term cumulative performance information for several types of stormwater BMPs used on construction sites in the state of Oklahoma, USA, using RUSLE 2.0. Temporary seeding annual ryegrass with mulch, 1-inch compost blankets with seed were evaluated as erosion control BMPs, while Standard Silt fences and Fiber logs were evaluated as sediment control BMPs. In total 470 modeled scenarios has been analyzed. To compare the sediment yield from construction sites to natural background production levels, maps of annual estimated erosion based on the RUSLE_2 equation were determined in the ArcGIS pro. The rainfall factor, soil erodibility factor, slope length and steepness factor, cover management factor, and support practice factor maps were created.

This thesis addresses the absence of knowledge of the effects of BMPs at highway construction sites in Oklahoma on water pollution loadings. The structure of this thesis is as follows:

Chapter I presents an introduction to ESC and an overview of the problem. Chapter II reviews relevant literature on the erosion and sedimentation, especially sedimentation from roadway construction sites. The Clean Water Act (CWA) policy history and ODOT's obligations to comply with these regulations are reviewed. Then, background on the Revised Universal Soil Loss Equation that was employed during this study and the science behind the RUSLE_2 GUI are described. Each of the different factors used in RUSLE_2 are explained in detail. Chapter III describes methods used to assess background erosion and sediment production and the impacts of BMPs analyzed with the model in this thesis. Chapter IV provides an overview of the key results of the analysis and the work that has been done on these topics. This chapter also presents the discussion and the main contributions of the study to the current knowledge base. Finally, Chapter V summarizes the findings and recommendations for future research.

CHAPTER II

LITERATURE REVIEW

Soil is a major foundation of life on Earth and the global ecosystem. Soils are constantly being generated on land surfaces and eroded away via geological processes. Therefore, understanding the natural and human causes of soil erosion are fundamental component of sustainability. Soils are generated through chemical, physical, and biological weathering processes of parent rocks. Soils are eroded by detachment of a portion of the soil profile or soil surface due to the movement of wind or water across the surface. Soil generation processes can take hundreds or thousands of years, while erosion processes can take place much more rapidly.

Erosion and sedimentation processes occur daily on all soils. The rate of erosion is approximately equal to the rate of soil creation about 0.2 tons per acre per year [7]. Human activities increase the rates of erosion, however, which create challenges from a long-term sustainability perspective. Agricultural runoff might cause erosion of the topsoil; moreover, it may also transport agricultural chemicals that are bound to the eroded particles. In the agricultural runoff case, in addition to excess sediment, the potential of toxins into an aquatic system is a significant matter [8]. According to [9] due to agricultural intensification in the USA, limiting the agriculture’s NPS pollution cost about $5 billion annually. Erosion and sedimentation happen naturally, but the rate of soil erosion from construction sites during urban development is much more than from natural erosion and sedimentation processes.

Construction sites can increase the erosion up to 40,000 times greater than undisturbed conditions [10]. The construction of roadways typically consists of mass clearing and grading, leaving many soil surface areas unstable. Inadequate ground cover exposes the soil to erosion factors such as rainfall, and increases the risk of erosion [1]; [11].

Washed out sediments will eventually enter streams or wetlands. The suspended solids in the water interfere with the photosynthesis of plant life. In addition, suspended solids may carry other pollutants, such as metals, pesticides, or nutrients, into streams, or cause organic enrichment of streams. Sedimentation may change the flow characteristics of a water body and result in physical barriers and increased possibility of flooding [7]. Rhoades et al. began to conduct the research in 1966 that estimated the sediment yield from several small watersheds subjected to different land use in Chickasha Oklahoma [12]. Measured sediment loadings for the years 1967 to1971 were 0.027 to 0.0465 ton/ac/yr for lands in good to excellent condition and 2.65 to 5.95 ton/ac/yr for lands in poor to fair condition [12]. The latest estimates from the NRCS National Resources Inventory (NRI) showed an average of 2.56 ton/ac/yr of erosion in 2002, 2.55 ton/ac/yr in 2007, 2.59 ton/ac/yr in 2012, and 2.61 ton/ac/yr in 2015 [13].

According to [14], the average quantity of sediment concentration from construction sites can be 40 times more than natural and agricultural areas, and could be as high as 50,000 to 150,000 t/mi^2/yr Erosion and sediment related pollution can cause damages such as lowering farm productivity, also increase the costs of drinking water treatment for removing the sediment [7] [15]. In addition, sedimentation has a notable environmental impact on navigation, water supplies, water quality, and ecology. The deposition of the sediments decreases the capacity of the reservoir water supplies [6] [9]. Sediment deposition can also cause a reduction in the navigational capacity of waterways and consequently requires dredging channel depths [15] [18]. Costs for dredging channel can reach $5 per ton of eroded soil in areas of significant shipping [21]. However, depending on the amount and the area, bed degradation might have the potential to negatively impact the navigation structures, levees and floodwalls, bridges, water supply-intakes, and a host of other features. According to [24], the average annual cumulative expenses (investments and repairs) to adjust for degradation would be $5.3 million assuming the fiscal year 2017. The estimated cost due to problems caused by erosion and sedimentation is anywhere from $3.7 to $14 billion per year in the United States [25]. The governing condition of water systems such as biogeochemical conditions, hydrodynamics, and other environmental conditions can dominate the behavior and distribution of contaminants in sediments [26]. Erosion and sedimentation can have a significant effect on aquatic systems and negatively affected fish habitats (Figure 2-1) [8] [18] [20]. For the aforementioned reasons, it is essential to use BMPs and have an understanding of the impact of different BMPs to reduce the financial and environmental cost of erosion and sedimentation.

Figure 2-1 Sediment resulting from construction activity can diminish fish habitat, reduce oxygen levels, increase water temperatures, and reduce overall water quality [32].

2-1 The erosion process

Soil erosion involves detachment, transport, and deposition of particles. Raindrop and shear forces from runoff water cause the detachment of soil particles. Runoff usually occurs when the rainfall intensity exceeds the infiltration rate of the soil. Normally, sediments are detached from soil surfaces and transported downslope by the flowing water forces. Some soil particles are also detached and transported by raindrop splash. Therefore, soil erodibility has an inverse relationship with a soil's infiltration rate. The quantity of transported materials depends on the runoff water velocity. Large runoff velocity increases the sediment carrying capacity of flowing water. When the velocity of runoff decreases, sediments will be deposited. Small channelized flows in the watershed are known as rills. The spaces in between rills are called interrill areas. In erosion, soil is removed from exposed upland rill and interrill areas. Raindrop impact and sheet flow are the main causes of interrill erosion. Rill erosion generally occurs when channels form by concentrated flow in the microrelief channel of adequate depth and slope. Rill erosion is a therefore a function of both slope length and steepness, while interrill erosion is a function of slope steepness and independent from slope length. Erosion processes for overland flow can be explained with basic continuity equation:

$$\frac{\partial q_s}{\partial x} + \rho_s \frac{\partial (cy)}{\partial t} = D_r + D_i \qquad \text{Equation 1}$$

Where q_s is the sediment load, x is a downslope distance, ρ_s is a sediment particles mass density, c is the sediment concentration, y is the flow depth, t is time, D_r is deposition rate or rill erosion, and D_i is sediment delivery to the rill areas from interrill areas. In this equation, term $\frac{\partial q_s}{\partial x}$ shows the change in sediment flow rate along the slope, while term $\rho_s \frac{\partial (cy)}{\partial t}$ shows the change in sediment storage over time [33].

2-2 Clean Water Act (CWA) history

The National Environmental Policy Act (NEPA) was enacted in 1970 to promotes the enhancement of the environment. In 1972, the Clean Water Act (CWA) was passed that authorized the Environmental Protection Agency (EPA) to prevent and eliminate discharge of pollution from point sources and to regulate stormwater [34]. Under the CWA, pollution into navigable waters is prohibited unless a National Pollutant Discharge Elimination System (NPDES) permit is obtained. In the original CWA legislation, regulated point sources included sewage treatment plants, storm sewers, pipes and man-made ditches, and industrial, municipal, and other facilities that discharge directly into surface waters. In 1987, EPA modified the CWA to enable regulation of storm water discharges from industrial activities that disturb land areas of equal or more than five acres. Permits from such areas are known as Phase I NPDES permits. At that time, there was different option for industrial facilities to conform with the permit requirements. However, in 1992 EPA created a general procedure to provide a more manageable permitting process that covers discharges from more than one facility. These rules reduced costs, decreased the complexity of the permitting process and minimized the monitoring and reporting relative to a general permit [35]. General permits require pollution prevention plans and compliance within six months.

In 1999, Phase II regulations of storm water discharges from smaller construction activities that disturb land areas greater than one acre were implemented [36]. Stormwater requirements are one element of the comprehensive permit program along with the NPDES, which are authorized in Section 401 of the CWA along with an approved Storm Water Pollution Prevention Plan (SWPPP) or a Construction General Permit (CGP) [35]; [37]. Phase II regulations require builders to apply for a CGP, submit and comply with a SWPPP and by utilizing the BMPs to prevent stormwater pollution [1]; [37]. One of the main causes of failure to meet SWPPP discharge requirements at construction sites is associated with a lack of BMPs, which can increase construction costs through penalties [2].

Since 1996, under EPA’s approval of the Oklahoma Pollutant Discharge Elimination System (OPDES) program, the Oklahoma Department of Environmental Quality (ODEQ) has had stormwater permitting and enforcement responsibility for large and small construction activities. This obligation does not include construction activities associated with oil and gas extraction, agricultural activities and construction activities which are located on Indian County Land in Oklahoma. The permit was reissued to ODEQ in 2017, and authorizations issued under the permit shall expire in 2022 [38] [39].

To serve the CWA it is necessary to have an Effective Erosion and Sediment Control Plan (ESCP). The ESCP should identify the potential causes of erosion and sedimentation and identify strategies to minimize the amount of erosion and sediment by providing measures to control problems while the construction is ongoing [40]. An appropriate ESCP consists of design, coordination, maintenance, and operation [41]. A good understanding of ESC process systems is a primary requirement of successful construction designs [3]. In order to that obtain this aim, it is necessary to forecast ESC efficiency by comparing the sediment production before and after BMP implementation. At all sites, the design of the ESC plan should be a flexible process that responds to new information is obtained throughout the construction life cycle [42].

The goals of Section 401 of the CWA are to reduce non-point sources of pollution from construction activities. ODOT maintains hundreds of construction sites across Oklahoma that are subject to CWA rules. One main goal of this thesis was to estimate the impacts of ESC BMP implementations of sediment loadings into Oklahoma waterways. Forecasting these impacts requires a model that predicts sediment yields from construction areas based on soil and weather conditions that also incorporates the effects of BMPs.

2-3 Universal Soil Loss Equation Model

Attempts to calculate the amount of soil erosion by water started in nineties. Eventually, in 1965 and 1978, Wischmeier, Smith, and others developed the Universal Soil Loss Equation (USLE) [43]. The USLE is a logical culmination of several decades of expertise innovation effort and dedication. Since the USLE’s introduction, it has become a major soil conservation planning tool in the United States and other countries. The USLE and its modifications, including the Revised Universal Soil Loss Equation (RUSLE), estimate the long time average annual soil loss generated by water erosion by multiplying the natural factors of erosion including rainfall erosivity, soil erodibility, slope length, and steepness and anthropogenic factors such as land cover and management and conservation practices [44]; [43]; [33]. RUSLE is a widely used and powerful model to calculate the average erosion from a designated area over a designated time. In addition to predicting the soil loss from cropland, rangeland, and specific management systems, RUSLE can be used to predict the soil loss from a nonagricultural conditions such as construction sites [43]. The U. S. Department of Agriculture developed this model based on a set of mathematical equations to help make better decisions in soil conservation planning. RUSLE can be used to help determine what conservation practices might apply to a landscape. Even though the original RUSLE application was agriculture, primarily cropland production, the revisions have broadened the program’s applicability to be useful to other land-disturbing activities like construction sites [45]. Site topography, ground cover, and BMPs used are the most variable factors in determining erosion in construction sites. The calculation in the RUSLE is more involved than USLE; however, similar to USLE, each factor in this model is presented by a single number [43]. Due to the success of USLE and RUSLE_1, the RUSLE_2 has been established to achieve better erosion prediction. The RUSLE_2 contains new vegetative biomass production routine [46] [47].

2-4 The Revised Universal Soil Loss Equation, Version 2

RUSLE_2 is a computer-based technology that estimates average annual rill and interrill erosion based on particular site conditions [48] [49]. RUSLE_2 contains a variety of mathematical equations and an extensive database. RUSLE_2 can be applied wherever mineral soils are exposed to the erosive forces of impacting raindrops and overland flow, and it is land use independent. RUSLE_2 can be used on different land use such as cropland, pastureland, rangeland, construction sites, reclaimed mine land, landfills, mine tailings, mechanically disturbed and burned forestlands, military training sites, and similar lands [48]. The RUSLE_2's features give the user the ability to describes a specific site. Accordingly, RUSLE_2 uses this data to predict erosion estimates for alternative erosion control practices for this particular site.

The science used in RUSLE_2 (i.e., mathematical equations) was developed by USDA-Agricultural Research Service. The University of Tennessee had lead responsibility for developing the RUSLE_2 computer program. The user interface and the RUSLE_2 database for cropland were developed by the USDA-Natural Resources Conservation Service [50]. RUSLE_2 was designed to meet several requirements, such as desired conservation and erosion control planning decisions based on available erosion research data, accepted erosion science, field experience, and professional judgment [48] [51]. RUSLE_2 computes values for the three major erosion processes of detachment, transport, and deposition. The experiential equation form of the USLE used to compute sediment detachment, and to measure sediment transport and deposition, process-based equations are used. These equations use a point in time and a location on an overland flow path to produce average annual and spatial estimates for segments along the overland flow path and the entire overland flow path. The USLE original form is as follow:

$$A = RKLSCP \quad \text{Equation 2}$$

Where A is average annual erosion rate (mass/ area. year), R is erosivity factor (erosivity unit/ area. Year), K is soil erodibility factor (mass/ erosivity unit), L is equal to slope length factor (dimensionless), S is slope steepness factor (dimensionless), C is cover management factor (dimensionless), and P is support practice factor (dimensionless). The USLE uses the product of the RK terms to measure erosion for unit plot conditions and then uses the terms LSCP to adjust the unit plot erosion and actual field conditions [48] [51].

Base on the mathematics of the USLE equation structure, RUSLE_2 computes an average daily erosion as follow:

$$a = rklScp_p p_c p_d \quad \text{Equation 3}$$

Where r is a daily erosivity (erosivity unit/ area. day), k is daily soil erodibility factor (mass/ erosivity unit), l is equal to daily slope length factor (dimensionless), c is daily cover management factor (soil loss ratio) (dimensionless), p_p is daily ponding subfactor (dimensionless), p_c is daily contouring subfactor (dimensionless), and p_d is equal to daily subsurface drainage subfactor (dimensionless). RUSLE_2 is the accumulation of spatial and temporal integration. The spatial integration controls the absolute equations along the overland flow path for each day, and temporal integration is the sum of daily values for the computation duration. The average annual erosion is the sum of the daily values divided by the number of years (duration) in the computation[48] [52].

$$A = \frac{\sum_{i=1}^{365N} r_i k_i l_i s_i c_i p_i}{N} \quad \text{Equation 4}$$

Where N is total number of years in analysis period and all other factors are sum for the ith day in computational period [52].

2-5 RUSLE _2 input factors

2-5-1 Climate (weather) (R-factor)

RUSLE_2 uses monthly erosivity, precipitation, and temperature and the 10 years_ 24-hour precipitation amount variables. The Erosivity (R) factor is the main variable in the equations used to compute detachment caused by erosive rainfall at a location where erosion happens [48] [52].

Precipitation and temperature have an impact on the amount of biomass loss in soil and also affect the temporal distribution of soil erodibility. To consider the effect of ponding on erosivity, RUSLE_2 GUI uses the 10 year-24 hours precipitation amount. Beside 10 year-24 hours, precipitation amount is a representative storm index that use to estimate the deposition on concave overland flow path profiles, deposition by dense vegetation strips, deposition in terrace channels, and the effectiveness of contouring. Since the RUSLE_2 uses the daily values for erosivity, precipitation, and temperature, the model converts the monthly erosivity, precipitation, and temperature inputs into daily values. To do so, the procedure assumes that daily values change linearly within each month based on a two-piece linear equation. Accordingly to obtain a mean daily value for the month the average monthly value is divided by number of days in the month

[48]. In very low rainfall areas when negative values are computed daily, precipitation and erosivity values are set to zero.

To compute the storm erosivity with maximum 30-minute intensity, the following equation is provided:

$$r_s = EI_{30} \qquad \text{Equation 5}$$

where r_s is equal to storm erosivity, E is storm energy, and I_{30} is maximum 30-minute intensity.

Storm energy is calculated using

$$E = \sum_{k-1}^{m} e_k \Delta V_k \qquad \text{Equation 6}$$

Where e_k is unit energy (energy content per unit area per unit rainfall depth) in the k^{th} period, and $\Delta V_k$is the amount (depth) of rainfall in the k^{th} period, k is index for periods during the rainstorm where rainfall intensity is considered uniform, and m is the number of periods in the rainstorm.

Unit energy is measured from the following:

$$e_k = 0.29[1 - 0.72 \exp(-0.82 i_k)] \qquad \text{Equation 7}$$

Where e_k is the unit energy [MJ/(mm·ha)] for the k_{th} period and i_k is the rainfall intensity (mm/h) for the k_{th} period.

Data for storms less than 0.5 inches (12 mm), non-rainfall precipitation events, and extreme storm erosivity events with a return period greater than 50 years are excluded in the RUSLE_2 estimates of storm erosivity[48].

As it has been discussed, the erosivity value should reflect the 10-year 24-hour precipitation amount and unit energy at the location. The RUSLE_2 uses the following equation to compute the erosivity for the 10-year 24-hour precipitation amount:

$$EI_{10y24h} = 2\alpha_m P_{10y24h} \quad \text{Equation 8}$$

in this equation, EI_{10y24h} presents the storm erosivity associated with the 10 year-24 hour precipitation amount, α_m is the maximum monthly erosivity density at the location, and P_{10y24h} is the 10-year 24-hour precipitation amount. The coefficient of 2 was obtained by calibrating equation to observed values for the 10-year EI from recent precipitation data in the Eastern US.

The RUSLE_2 does not consider erosion by snowmelt. Previous research on Erosion at Morris, Minnesota showed that even in an area with a large amount of snowfall, only a small amount (about seven percent of the total erosion) occurred by snowmelt [48].

To compute runoff depth, RUSLE_2 uses the NRCS curve number method as a function of precipitation amount. Curve number values may differ with cover-management, hydrologic soil group, and antecedent soil moisture. RUSLE_2 used the following as the main equation to compute curve number values is:

$$N = [N_{u100} - s_u(1 - s_c)] f_B \exp\,(b_D B_s) \quad \text{Equation 9}$$

Where N is the curve number, which is used to compute runoff. N_{u100} is a curve number value that represents the effect of ground cover and soil roughness. s_u is the change in curve number per unit change in the soil consolidation subfactor, f_B is a fraction, which along with the term exp $(b_D B_s)$, describes the main effect of soil biomass and its interaction with soil consolidation on curve number, b_D is a function of the soil consolidation subfactor s_c, and B_s represents the soil biomass [48] [53].

Due to the lack of proper information in many parts of the world, many studies have been performed to measure the R factor based on accessible rainfall data. Estimation of the rainfall erosivity factor is a complicated process and required the years of data. Reference [54] presents the R factor as a function of mean annual precipitation. Equation 10 is a power function developed by NRCS [55] to estimate the rainfall erosivity factors in the Continental U.S. based on a regression of some data. This equation has been used to derive the R factor in the prediction of annual erosion estimated in this thesis.

$$R = 0.04830P^{1.510} \qquad \text{Equation 10}$$

Where R is rainfall erosivity factor, and P is the average annual precipitation.

2-5-2 Soil Erodibility (K-factor)

The soil erodibility factor (K factor) is the major soil variable used in RUSLE_2. The soil erodibility factor in RUSLE_2 is not an inherent soil property like soil texture but is a measure of soil erodibility under unit plot conditions. This factor can describe as a measure of the susceptibility of soil particles or surface materials to transportation and detachment by the amount of rainfall and runoff input [52]. Soil erodibility, as defined in RUSLE_2, is an empirically measured soil erodibility where cover-management effects are removed so that the measured erosion represents how inherent soil properties and local climate affect the erodibility. The RUSLE_2 uses the same soil erodibility factor as the USLE and RUSLE1. Moreover, the RUSLE_2 soil erodibility factor is a function of the local climate in addition to soil properties. As a result, the RUSLE_2 soil erodibility factor would be higher in a location with frequent, high, intense rainfall with another location with the same soil properties. RUSLE_2 uses the soil erodibility nomograph, which takes location into account. The equation for the RUSLE_2 standard soil erodibility nomograph is as following:

$$K = (k_t k_o + k_s + k_p)/100 \qquad \text{Equation 11}$$

In this equation K represents the soil erodibility factor, $\mathrm{k_t}$ is texture subfactor, $\mathrm{k_o}$ is organic matter subfactor, $\mathrm{k_s}$ is soil structure subfactor, and $\mathrm{k_p}$ is the soil profile permeability subfactor. Since the empirical derivation of the standard soil erodibility nomograph was from a relatively small database, RUSLE_2 uses the modified standard soil erodibility nomograph. In the RUSLE_2 modified nomograph, computed soil erodibility values decrease as soil structure goes from fine granular to blocky, platy, and massive and decreases as soil structure go from fine granular to coarse granular. For high clay and high sand soils, the values computed with the RUSLE_2 modified soil erodibility nomograph are less than the values estimated with the standard nomograph [48].

2-5-2-1 Texture subfactor (k_t)

The soil texture subfactor is described by the following equation:

$$k_{tb} = 2.1[(P_{sl} + P_{vfs})(100 - P_{cl})]^{1.14}/1000 \quad \text{Equation 12}$$

$$k_t = k_{tb} \qquad \text{if } P_{sl} + P_{vfs} \leq 68\% \quad \text{Equation 13}$$

Where P_{sl} is percentage of silt, P_{vfs} is the percentage of very fine sand based on the total soil primary particles, and P_{cl} is a clay percentage [52] [48].

The most critical variable in estimating soil erodibility is the soil texture. The USDA classification has been estimated the standard soil texture such as clay loam, silt loam, or sandy loam; however, it might not work for a very fine sand fraction with the silt fraction. A mechanical investigation of the soil is needed to determine the very fine sand fraction. The Equation 14 generated in RUSLE_2 for measuring the very fine sand fraction from sand, silt, and clay content:

$$P_{vfs} = (0.74 - 0.62P_{sd}/100)P_{sd} \quad \text{Equation 14}$$

Where P_{vfs} and P_{sd} are very fine sand and sand amount in percent [52] [48].

The RUSLE_2 graphical curves for k_t verses $P_{sl} + P_{vfs}$ for percentage above 68 percent are as below:

$$k_{t68} = 2.1[68(100 - P_{cl})]^{1.14}/1000 \quad \text{Equation 15}$$

$$k_t = k_{tb} - [0.67(k_{tb} - k_{t68})^{0.82}] \qquad \text{if } P_{sl} + P_{vfs} \leq 68\%$$ Equation 16

Where k_{t68} is base soil texture subfactor in a condition which $P_{sl} + P_{vfs} \leq 68\%$.

2-5-2-2 Organic matter subfactor (k_o)

Equation 17 presents the organic matter subfactor in the soil erodibility nomograph.

$$k_o = (12 - O_m)$$ Equation 17

Where O_m present inherent soil organic matter percentage. This factor is based on the inherent soil organic matter content of the soil in unit plot conditions. The experimental plots which have been used for developing the soil erodibility nomograph were not in unit plot condition. RUSLE_2's cover-management relationships considered the biomass additions, and organic farming practices that affect rill and interrill erosion. Thus, the organic matter relationship in the soil erodibility nomograph cannot be used to evaluate those effects. However, measured erosion values adjusted to unit plot conditions, but for organic matter content values is not applied. [48] [50].

2-5-2-3 Soil structure subfactor (k_s)

Subfactor, which measures the potential of the soil profile in unit-plot conditions for generating runoff, describes as the soil permeability subfactor. To rate the soil profile for infiltrating precipitation and reducing runoff, six permeability classes from rapid to very slow (1 to 6) are used in RUSLE_2. Also, this rating class reflects the existing resting layers (such as rock, claypan, or fragipan) and the presence of rock fragments in the unit plot condition. The equation for the permeability subfactor is given as below:

$$k_p = 2.5(P_r - 3)$$ Equation 18

Where P_r is present the soil profile permeability class. (1 – rapid, 2 – moderate rapid, 3 – moderate, 4 – slow to moderate, 5 – slow and, 6 – very slow) [48] [50] [52] [56].

2-5-2-4 Soil structure subfactor (k_s)

The RUSLE_2 modified soil erodibility nomograph uses the following equation to estimate the soil structure subfactor:

$$k_s = 3.25(2 - S_s) \quad \text{Equation 19}$$

Where S_s is soil structure class. Both standard and RUSLE_2 modified nomographs use equations referenced to a midpoint (which is the fine granular structure for soil structure subfactor) [52] [48] [56].

To estimate the K factor map and predicted the annual erosion for Oklahoma counties, K factors related to each specific soil were derived from the USDA website [57].

2-5-3 Topography or Slope length and Steepness (LS-factors)

RUSLE_2 calculates the erosion and sediment load values employing the numerical solution written as a function of distance along the overland flow path (spatial integration). Moreover, RUSLE_2 implements a temporal integration with considering the slope length beside with soil erodibility and cover-management values. The RUSLE_2 assumes the overland flow streamlines are parallel. Base on the simple base erosion model, converging overland flow is about 7/6 times the parallel streamlines, and diverging overland flow is about 5/6 times. One of the major improvements of RUSLE_2 in comparison to the RUSLE1 and USLE is counting the slope length exponent values as a function of overland flow path steepness, soil, and cover-management conditions. Besides, RUSLE_2 automatically calculates slope length exponent values from basic input data.

As discussed, RUSLE_2 uses Equation 2 to estimate erosion and sediment load on non-uniform overland flow paths. The non-uniform overland flow path is divided into segments, and each segment treated as a step rather than a continuous change. At the intersection of two segments, the average of the steepness of the two segments would be considered for the path where steepness changes continuously along the overland flow path. Overall, RUSLE_2 is considered to provide satisfactory outcomes for most conservation planning applications.

2-5-3-1 Slope length (L factor)

Such as RUSLE1, the slope length index in the RUSLE_2 is a function of the rill to interrill erosion ratio. However, the slope length exponent in the RUSLE_2 is modified daily as cover-management conditions change. There are several exceptions, such as the erosion processes that occur during the winter Req conditions (equal erosivity for the winter months in the region where erosion is elevated in the winter months). The slope length exponent for Req conditions is time-invariant and does not vary with the rill to interrill erosion ratio. The majority of the erosion while Req conditions is by surface runoff. Investigation shows that the amount and the velocity of runoff increases by increases in the slope length (L factor) and slope steepness (S factor). The slope length factor in RUSLE_2 is given by the following equation:

$$L = (m + 1)({}^{x}/_{\lambda_u})^m$$

Equation 20

Where L is equal to slope length factor; x is the distance from the origin of over land flow path (m); λ_u is the length of unit; and m is the slope length exponent, which varies from 0 to 1 and is a function of the rill to interrill erosion ratio given by following equation:

$$m = \frac{\beta}{1 + \beta}$$

Equation 21

Where β is the ratio of rill sediment load to interrill erosion sediment load.

2-5-3-2 Steepness (S factor)

The RUSLE_2 use the same equation for interrill erosion as in the RUSLE1. The following equation explained the steepness factor and is referenced to the unit-plot steepness. Based on the unit-plot steepness, the equation gives a value of 1 for nine percent steepness. Even though the overland flow path steepness and the interrill steepness are not always the same as the land steepness, RUSLE_2 assumes the interrill steepness the same as the overland flow path steepness.

$$S_i = 3{s_i}^{0.8} + 0.56 \qquad \text{Equation 22}$$

where S_i is the interrill erosion steepness factor, s_i is the steepness of the interrill area (sine of slope angle).

This steepness factor is normalized to the nine steepness of the unit plot, and the steepness of the rill area is the same as the overland flow path steepness, which can differ from the land steepness. The steepness factor for rill erosion is given by the following equation:

$$S_r = {}^{s_r}/_{0.0896} \qquad \text{Equation 23}$$

Where S_r is the rill erosion steepness factor and s_r is the steepness of the rill area (sine of slope angle).

Different cover-management conditions generate significantly different steepness factors for rill-interrill. Hence, the relation of rill-interrill erosion to overland flow path steepness should be a function of the rill to interrill erosion ratio and critical shear stress at which rill erosion begins. RUSLE_2 uses the constant steepness relationship, according to the following equation:

$$S = 10.8s + 0.03 \quad s_p \leq 9\% \qquad \text{Equation 24}$$

$$S = 16.8s - 0.50 \quad s_p \geq 9\% \qquad \text{Equation 25}$$

$$Where\ s = tan^{-1}({}^{s_p}/_{100}) \qquad \text{Equation 26}$$

Where S is steepness factor, s is overland flow path steepness (sine of slope angle), and s_p is the overland flow path steepness (100 times tangent of slope angle).

2-5-4 Cover Management (C-factor)

In Equation 2, the C term represents the main effect of cover management on erosion. The cover management factor reflects the effect of ground cover on erosion which is formed from several subfactors. A daily cover-management c factor value is computed using daily values for each of the subfactors as present by following equation:

$$c = c_c g_c s_r r_h s_b s_c s_m \quad \text{Equation 27}$$

Where c is the daily cover-management factor, c_c is the daily canopy subfactor, $g_c$is the daily ground (surface) cover subfactor, $s_r$is the daily soil surface roughness subfactor, $r_h$is the daily ridge height subfactor, s_b is the daily soil biomass subfactor, $s_c$is the daily soil consolidation subfactor, and s_m is the daily antecedent soil moisture subfactor used.

2-5-5 Support Practice (P-factor)

The support practices factor (P factor) accounts for the effect of the protection practices on rill and interrill erosion. RUSLE_2 considers erosion control structure and practices such as terracing, contouring, ridging, strip cropping, and subsurface drainage, as well as other runoff and erosion control structures that reduce the rate and amount of runoff and erosion. Generally, these erosion control structures reduce the sediment amount by modifying the gradient, surface flow pattern, and velocity of runoffs. The Support Practice Factor (P) in RUSLE_2 is determined as the ratio of soil loss with a specific support practice and the corresponding loss with upslope and downslope tillage. The P factor can be determined by the following equations, which are similar to RUSLE1 equations:

$$p_b = a_c(s_m - s_c)^4 + p_{bm} \qquad s_c < s_m \quad \text{Equation 28}$$

$$p_b = c_c(s_c - s_m)^{1.5} + p_{bm} \qquad s_m \leq s_c < s_{be} \quad \text{Equation 29}$$

$$p_b = 1 \quad s_{be} \le s_c \tag{Equation 30}$$

Where p_b is equal to base contouring subfactor value, p_{bm} is the minimum base contouring value, s_c is a scaled land steepness (sine of slope angle), s_m is the land steepness (sine of slope angle) at which p_b is equal to p_{bm}, and s_{be} is the steepness (sine of slope angle) at which the contouring subfactor reaches 1. The coefficients of the a_c and c_c are computed as below:

$$a_c = {(1 - p_{bm})}/{s_m{}^4} \tag{Equation 31}$$

$$c_c = {(1 - p_{bm})}/{(s_{be} - s_m)^{1.5}} \tag{Equation 32}$$

The boundary conditions are:

$p_b = 1$ at $s_c = 0$,

$p_b = p_b$ at $s_c = s_m$,

$p_b = 1$ at $s_c = s_{be}$,

and at $s_c = s_m$ slope is equal to 0 for Equation 28 and Equation 29 [52] [48].

Benavidez et al., (2018) is suggesting in the condition where no support practices observed the P factor is 1.0 [58]. The difficulty of estimating the P factor by using sub-factors leads to many studies ignoring it by giving their P factor value of 1.0 [59].

2-6 Best Management Practices

BMPs are measures to prevent the release of toxic and hazardous chemicals to receiving water, under the NPDES permit [60]. Further, erosion control BMP measures have been developed and proven to work on construction sites. Since BMPs might contain synthetic materials, understanding the effects of the BMPs themselves in the environment is essential. The impact of individual BMPs on releasing nitrate and heavy metals to navigable water has been studied using the water quality simulation model, Soil Water Assessment Tool (SWAT). The BMP products' SWAT model studies results suggest that BMPs can contribute to pollution by releasing heavy metals. However, not all the BMP products generate the same amount of heavy metals release. [61]; [62]. ESC best results are obtained when the BMPs are properly planned and constructed. These measures reduce erosion and sediment potential by stabilizing exposed soil or reducing the surface runoff flow velocity. Although BMP’s can reduce the amount of sediment leaving the site, no single practice is 100% effective. The BMP’s can be divided into two categories: erosion prevention practices and sediment control practices. Typically, erosion prevention practices cover the ground surface to prevent any of the types of erosion from occurring. Vegetation cover, riprap, mulch, hydro mulching, and blankets are some of the erosion practice examples. Technically these BMPs absorb the energy of a raindrop’s impact and reduce the amount of sheet erosion. Other erosion control BMPs such as diversions, check dams, slope drains, and storm drain protection, are primarily used to prevent rill and gully erosion from starting by trapping the sediments onsite. On the other hand, sediment control practices attempt to prevent soil particles that are already carried by stormwater from leaving the site and entering navigable waters. Sediment control practices include silt fences, sediment traps, sediment basins, check dams, and even vegetative cover [7].

To understand the ESC and improve the efficiency of BMPs, ESC measures have been investigated from different aspects. One of the most abundant water pollutants in rural and agricultural areas is nitrate. Even though nitrate is an essential nutrient for plants, an excessive presence of nitrate in soil and water is considered an environmental pollution. Reducing the leaching nitrate until zero is practically impossible; however, using combined BMPs helps to reduce this process. In addition to nitrate reduction, cost analysis of BMPs evaluated by different studies concluded that the total cost of SWPPP is under one percent of the total construction site costs [63]; [61]. As mentioned, sediments are the major pollutants from construction; to gain understanding about the amount of sediments produced due to disturbances of soil in construction sites, RUSLE 2.0 software can be used. RUSLE 2.0 is based on the USLE and empirical research. The RUSLE 2.0 software can evaluate the amount of sediment generated by construction sites and base of the result the efficiency of BMPs for reducing erosion and sedimentation can be estimated. Several research studies have been conducted to estimate the BMPs' effectiveness to decrease the sediment from construction sites using the RUSLE 2.0, including studies of natural gas well sites and agricultural fields [10] [64]. Likewise, another study used RUSLE 2.0 and ArcGIS in Nigeria to estimate the rate of soil erosion and soil loss potential. According to this study, RUSLE 2.0 was able to indicate the areas on a site with a high risk of soil erosion. Depending on the outcome presented, the areas of priority that should be first conserved are classified by the model based on the severity level of soil loss. Using the RUSLE software therefore helps to reduce time and cost of soil conservation, especially on larger watersheds [52].

2-7 BMP efficiency rating

In this thesis, BMPs efficiency rating is used to help understand BMP performance. The efficiency ratio is defined as Equation 33:

$$ER = \frac{SY\ without\ BMPs - SY\ with\ BMPs}{SY\ without\ BMPs} \qquad \text{Equation 33}$$

Where ER is the BMP efficiency rating, SY is the sediment yield without ESC BMPs, and SY is the sediment yield with ESC BMPs [65] [10]. The BMP efficiency rating is the ratio of sediment removed by the BMP that otherwise would have left the construction site. Therefore, ER is a proper parameter for ESC planners to choose suitable BMPs for required site management goals. According to [10], the site management goal is the measure of the acceptable level of reduced sediment yield through erosion prevention and sediment removal. The management goal might be changed in different areas. For example, a BMP ER of 80% will remove 80% of the sediment that would have left the site if the BMPs have not been employed. Clearly, according to the specific management goals of any site, the combination of BMPs might be applied to attain the plan requirement.

2-8 Effects of compaction on erosion

Soils at construction sites are typically compacted, which affects their erodibility. To assess the effects of compaction on soil erodibility, Hanson and Hunt (2007) [30] conducted the jet erosion test (JET) in the laboratory experiments on different soil types. Their study results are as follow: 1) compaction near optimum water content creates a structure most resistant to erosion, 2) higher compaction effort at a given water content increases erosion resistance, and 3) soil properties including texture and plasticity, influence erosion resistance as much or more than compaction factors. Similarly, another study by Ekwue and Harrilal (2009) [31]examining the effect of compaction on erosion showed the most critical factors that affected soil loss were soil type and soil slope. The impact of soil texture on soil erosion depends on the slope gradient, and the increase was most significant in the sandy soil and less pronounced in the clay loam and the clay soil. In this study, the results indicated that the soil loss decreased with increasing peat content in all cases and likewise declined with increasing compaction effort. In this thesis, the effect of the compaction on annual erosion was ignored, but according to the available studies it might reduce erosion and deserves more investigation

2-9 Objective of research

It has been proven that the proper planning, installation, and inspection of BMPs reduces erosion and sedimentation on exposed construction sites. However, the amount of prevented sediment on construction site in Oklahoma associated with transportation infrastructure has not been investigated. There is insufficient information about ESC and the effects of ODOT construction activities on navigable waters in Oklahoma. The primary objective of this thesis is to generate long-term cumulative performance information for several types of stormwater BMPs used on construction sites in the state of Oklahoma, USA, using RUSLE 2.0. Estimating these effects could have important impacts for policymakers that are interested in determining the economic efficiency of various strategies to reduce non-point source pollution. Construction site conditions differ from place to place and are affected by many factors. Each individual construction site requires a unique ESC plan that should meet the specific design requirements of the construction site. Many ESC BMPs are potentially applicable for an ESC plan. The best methods can be determined for different site specifications by estimating the sediment prevented using BMPs.

CHAPTER III

METHODOLOGY

Roadways construction is a type of land disturbing activity that includes different techniques including clearing and grubbing, developing access roads, cutting and filling slopes, etc.[66]. These construction activities have the potential to accelerate soil loss due to land cover modifications, increased slopes, and runoff flow concentration. The erosion potential of construction sites should be estimated and used to determine strategies to prevent erosion, and minimize the impacts of sites, particularly in environmentally sensitive areas. Distinguishing these areas assists in determining the right erosion and sediment control (ESC) measures and improving their function to reduce sediment production [3]. In this thesis, ArcGIS Pro and RUSLE 2.0 have been utilized to estimate the sediment yields due to roadway construction sites in Oklahoma with and without erosion and sediment control BMPs. The results are then compared with background sediment loadings to ascertain the impacts on Oklahoma waterways. Figure 3-1 was created using the data provided by the Oklahoma Department of Transportation (ODOT) [67] that shows construction activities from 2010 to 2017. Detailed records of BMPs used at different sites were not available as a database, but according to the data provided by ODOT, the most common ESC BMPs used in roadways construction in Oklahoma are silt fences, sodding, silt dikes, mulching, rip rap, seeding, sediment filters, rock filter dams, and fiber logs (Appendix-1).

The USLE and its modifications, RUSLE, were used to estimate the average annual soil loss generated by water erosion through multiplying the natural factors such as rainfall erosivity, erodibility, slope length, and steepness and anthropogenic factors such as cover and management, and conservation practices [10].

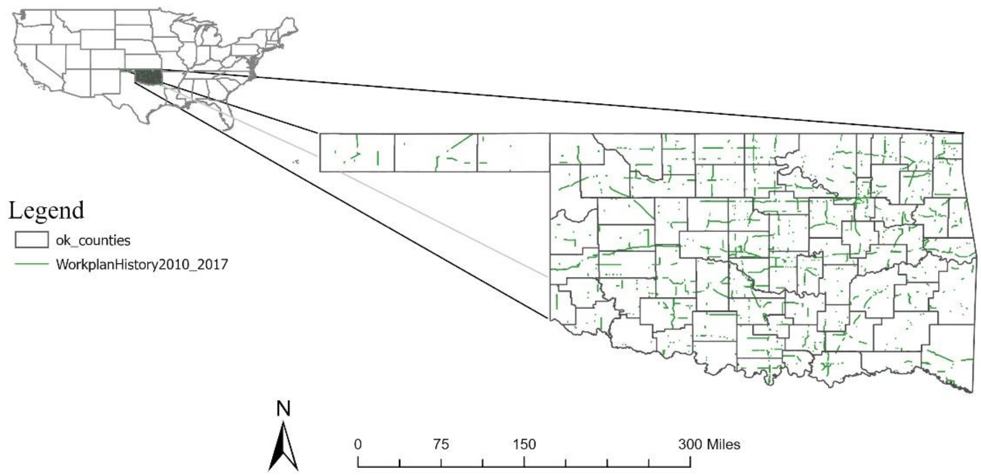

Figure 3-1 Study area, Oklahoma State, USA

Several approaches can be applied in RUSLE_2 to evaluate soil loss for large areas. For this research, the approach used by USDA-NRCS for the National Resources Inventory (NRI) was applied. This method uses the slope length through the deposition point or a concentrated flow area to compute soil loss. The measured soil loss depends only on the slope steepness. Even though this procedure significantly reduces the number of sample points needed to obtain an accurate estimate, it cannot be used where the primary variables, such as soil erodibility or steepness, depend on landscape position [68].

3-1 Modeling Construction site annual erosion with RUSLE_2 GUI

For each cross-section, five different scenarios have been considered. In addition to the construction site without practices scenario, four other scenarios with BMPs have been estimated. BMPs evaluated include temporary seeding annual ryegrass with mulch, 1-inch compost blanket with seed, standard silt fences, and fiber logs. Overall, 470 different scenarios were modeled for eight counties.

These ESC BMPs were modeled on both the cut and fill slopes. The silt fence and fiber log BMPs were modeled at one location at the lowest point of the slope profile. Each BMP was assessed for all possible combinations of soil types in the construction area with their respective erodibility values (K factors) and slope profiles. For each cross section, the erosion amount from the construction site without erosion or sediment control BMPs was first computed. Next, all soil erodibility and slope steepness conditions were modeled. For unsupported construction site modeling, it the entire cut and fill slopes were assumed to be disturbed and exposed to erosion factors. In the next step, the annual sediment yield was estimated for construction sites with standard silt fences. One silt fence was assumed to be installed at the lowest part of the slope. The same clearing and grading conditions with volunteer vegetation for the entire surface of the slope were assumed. Fiber logs were assumed to be installation at the same location as silt fences for comparison of the two BMPs. For the other two model conditions, the BMPs were assumed to cover the entire surface of the profile.

The runoff potential for construction sites surface soils was estimated from the data provided on the USDA website [69]. The map of the hydrologic soil group was created by using the data derived from [69] [70] (Figure 3-2). The runoff potential directly relates to the infiltration rate of the area. Four main hydrologic soil groups range from Group A, which has a high infiltration rate (low runoff potential) to Group D, which has a very slow infiltration rate (high runoff potential). Soil types, surface slope steepness, and slope length vary from place to place. The soil surface information was determined using the NRCS data from the RUSLE_2 database for each construction site and each county (Figure 3-3). The other major factor impacting the soil loss is the land cover management; the information related to Oklahoma provided by the NRCS [71] (Figure 3-4).

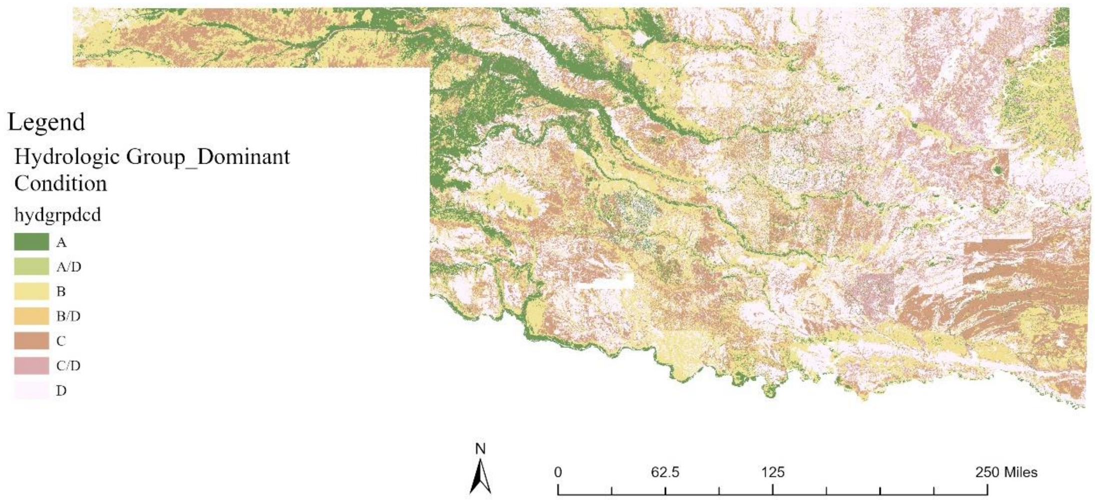

Figure 3-2 Oklahoma state hydrologic group map

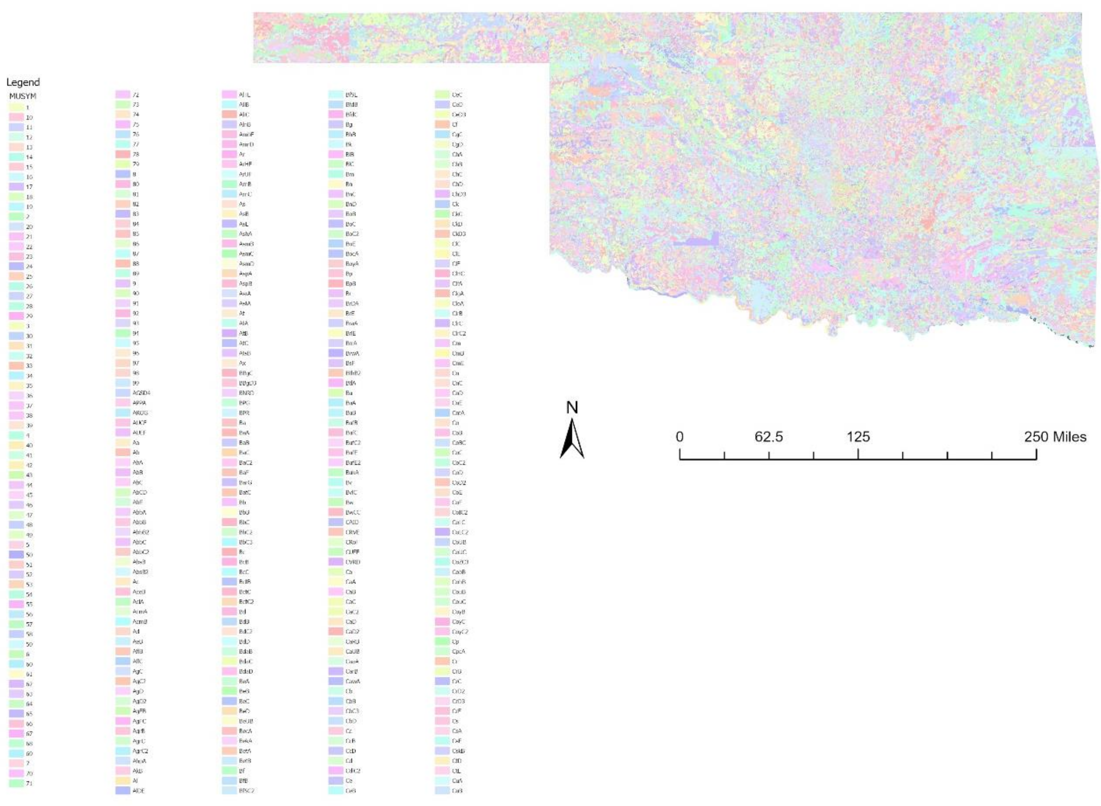

Figure 3-3 Oklahoma state Gridded Soil Survey Geographic (gSSURGO) map

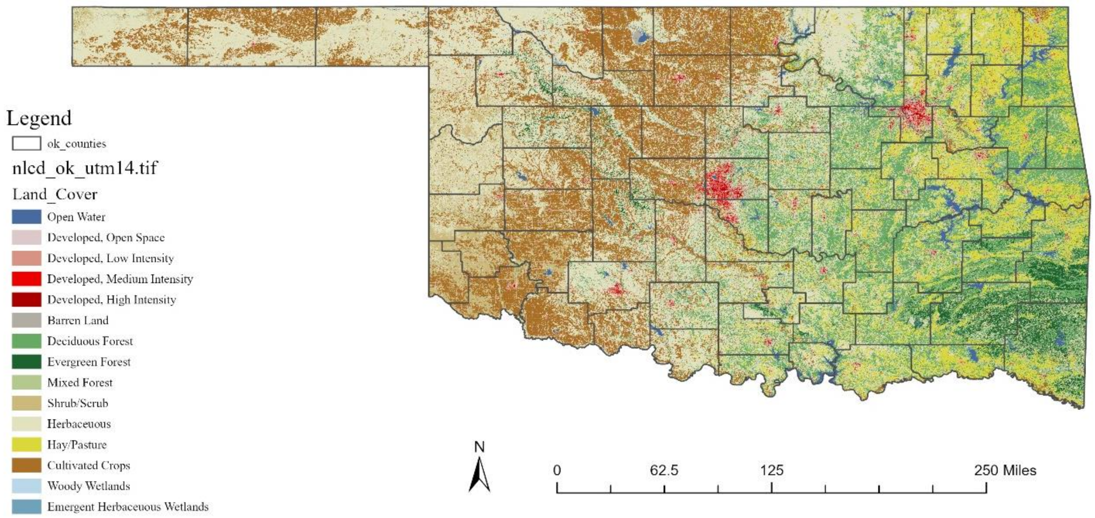

Figure 3-4 Oklahoma state land cover map

3-2 Annual erosion amount with ArcGIS pro based on RUSLE modeling analyses

The GIS analysis was executed for RUSLE_2 to determine annual soil loss on a pixel-by-pixel basis and the spatial distribution of the soil erosion in Oklahoma. First of all, different RUSLE_2 factors were assessed independently. Then, as Table 3-2 shows, the annual erosion estimation was obtained by multiplication of the LS, C, K, R, and P factors.

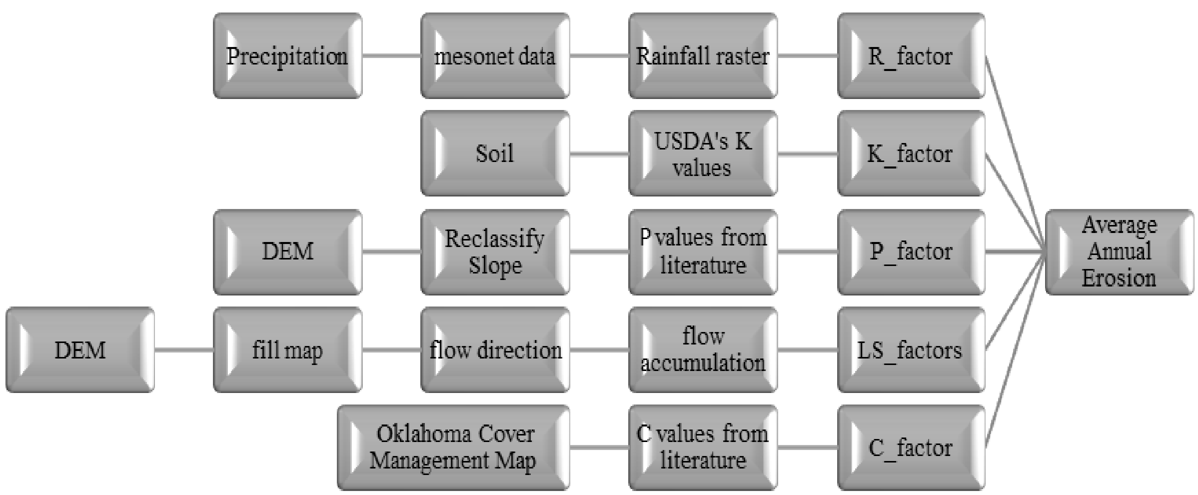

Table 3-1 The soil erosion framework for the RUSLE model.

In this research, the distribution of the average annual rainfall of the study area for seven years period (2010-2017) was used to calculate the erosivity value. For this purpose, the Oklahoma Mesonet precipitation data were used. Then by using the interpolation spatial analyst tools and masking the laster layer for desire county's border, the rainfall layer was made. The final R factor layer was obtained after applying the Equation 10 on the rainfall layer.

The K factor reflects the erodibility of the soil by water. To create a map of K factors, data for each individual soil type was extracted from the USDA Web Soil Survey website [57]. Then, with the help of ArcGIS Pro, the new files were added to the map that shows the K-values for each soil type cell.

The LS factor map was created based on a digital elevation model (DEM) and slope raster. By using the hydrology tool in the ArcGIS, Fill, Flow direction, and flow accumulation map extract from the elevation. In the next step, the Map Algebra tool has been employed, and with the help of the LS factor equation in the literature review chapter, LS factor raster was calculated. To create the P factor map, with the help of the reclassification tool in ArcGIS Pro, the following contouring P values were used for the slope map according the Table 3-2 [72]:

Table 3-2 Support practice factor base on slope (%)

Slope (%)	Contouring P factor
0 – 7	0.55
7 – 11.3	0.6
11.3 -17.6	0.8
17.6 – 26.8	0.9
26.8 >	1.0

The available Oklahoma land cover map was used as a base map [69]. Then to create the C factor map for Oklahoma, the contouring C factor was determined using data from previous studies shown in Table 3-3 [73] [74] [59].

Table 3-3 Cover management factor values

Landcover	C_factor
Barren Land	0.45
Cultivated Crops	0.5
Deciduous Forest	0.087
Developed, High Intensity	0
Developed, Low Intensity	0.06
Developed, Medium Intensity	0.03
Developed, Open Space	0.012
Emergent Herbaceous Wetlands	0.05
Evergreen Forest	0.001
Herbaceous	0.035
Mixed Forest	0.088
Open Water	0
Shrub/Scrub	0.45
Woody Wetlands	0.005

The data analysis procedure for Cimarron County is explained here in detail. The same process was applied to all other counties in this study.

3-3 Cimarron County

The first study area is located in Cimarron County (Figure 3-5). The runoff potential for soils in the area is generally moderate (Soil Group B = moderate infiltration rate), but in some areas, it is high (Soil Group D= very slow infiltration rate). The erosion risk for surface soils varies from low to high (erosion K factor ranging from 0.15 to 0.43), although the majority of soils in the area are moderately erodible (K = 0.24 to k=0.28) [75]. Moderately erodible soils have Kim loam or Travessilla stony loam surface layers. Area soils with lower erodibility are usually loamy soils on lightly sloping, while highly erodible soils consist of Travessilla soils with 3 to 12 percent slope. The monthly average precipitation for Cimarron County in 2010 was approximately 5.1 inches [76].

Erodibility values (K factors) for Cimarron County soils were classified into the following categories: low (Corlena, K= 0.15), moderate (Conlen loam, K= 0.32), and high (Travessilla stony loam, K= 0.43). Slope profiles used in the model runs were based on slopes modified for Highway sites starting from slopes of 1.0% (low), 3.0% (moderate) and 9.0% (high) [76]. The RUSLE_2 result is only accurate for rill and interrill areas, correspondingly the profile segments areas of studying chooses in the regions that RUSLE_2 result are accurate. Figure 3-5 shows the construction sites in Cimarron County in detail, as well as the map of land cover, elevation and soil surface slope.

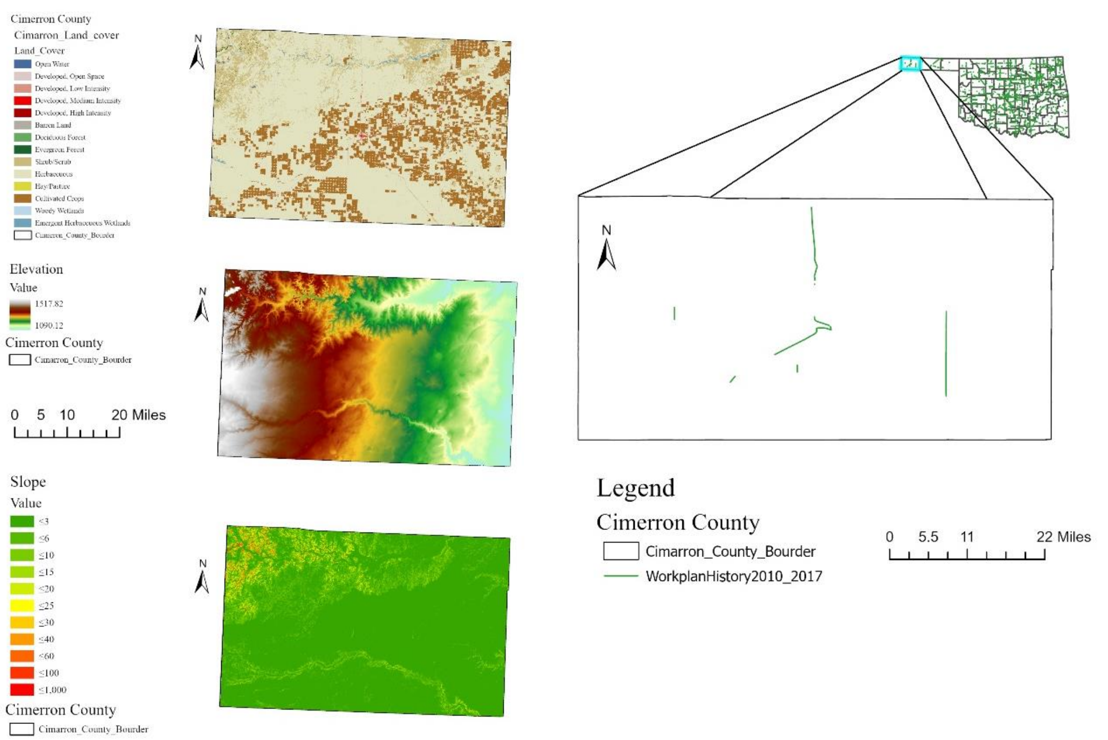

Figure 3-5 ODOT construction site in Cimarron County Ok. Cimarron County's Land cover map; Cimarron County's Elevation map; Cimarron County's Slope map.

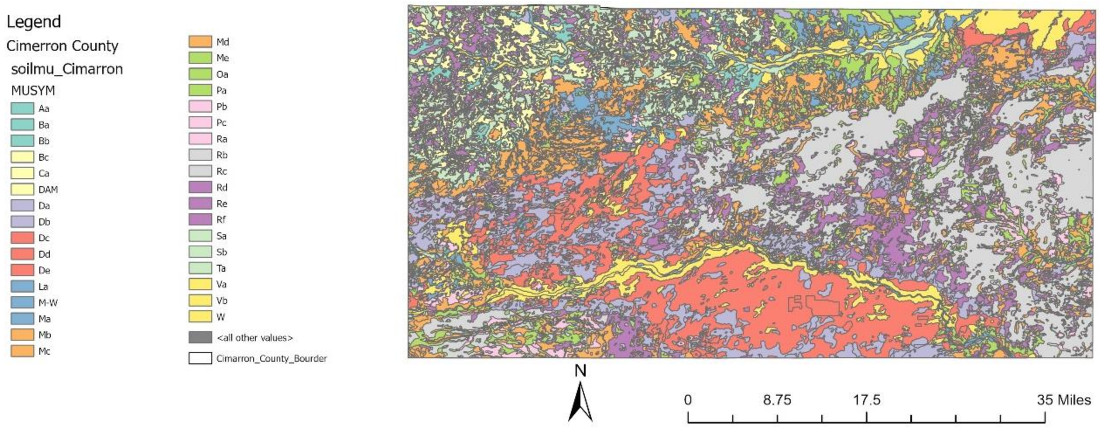

Figure 3-6 Cimarron County's soil type map

To estimate the annual sediment yield from ODOT Cimarron County construction sites, some cross-sections were analyzed along roadway construction sites at an interval distance of 10,000 ft. Therefore, ten soil profiles perpendicular to the roadway construction sites along the slope direction were computed (Table 3-4). Figure 3-7 shows the unprotected profile drawn with the RUSLE_2 graphical user interface (GUI) for a construction site study area in Cimarron County. Each of the profiles was created for the unique condition governing each section of the site. For example, Figure 3-7 shows three different soil type sections (Rf, Vb, and Ba) and three different slope steep nesses (9%, 8% and 2.1%). The figure also shows the construction site with no practices and clearing and grading with volunteer vegetation as a land cover management approach (Table 3-4). A similar procedure followed for each profile in each county that was analyzed.

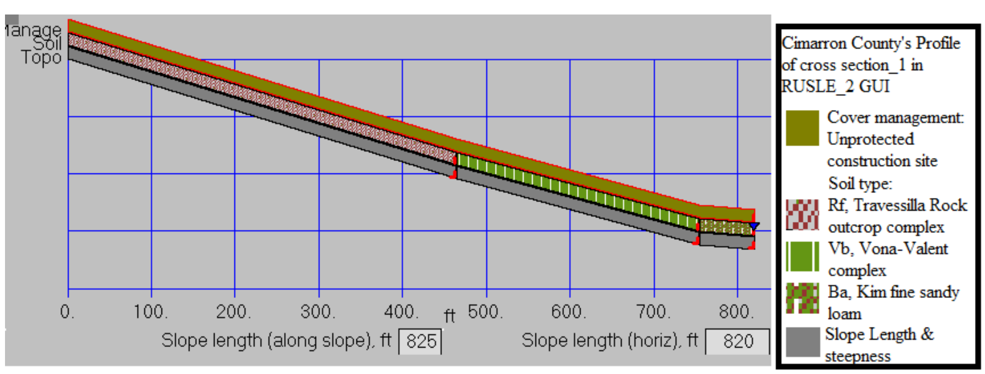

Figure 3-7 Example profile section created with the RUSLE_2 GUI to calculate the sediment yield in construction site in Cimarron County.

Table 3-4 Cimarron modeled segments' soil type, slope steepness, and slope length

Cimarron county	Soil type	Slope Steepness (%)	Slope length (horizontally) ft.	Total Slope length ft.
Segment_1	Rf, Travessilla Rock outcrop complex, Travessilla stony loam 55%	9	465	822
	Vb, Vona-Valent complex, Valent loamy fine sand 35%	8	290	
	Ba, Kim fine sandy loam, Kim fine sandy loam 93%	2.1	67	
Segment_2	La, Corlena loamy fine sand occasionally flooded 95%	2.5	200	565
	Bc, Kim loam 85%	2.5	365	
Segment_3	Bb, Kim loam 91%	3	588	641
	Sa, Spur Clay Loam, Spur clay occasionally flooded, cool 95%	1	53	
Segment_4	Bc, Kim loam 85%	6	402	1033
		2	631	
Segment_5	Rf, Travessilla Rock outcrop complex, Travessilla stony loam 55%	13	221	694
	Ta, Travessilla Stony Loam, Travessilla Stony Loam 85%	9	247	
	Bc, Lim Loam 85%	3	226	
Segment_6	Rb, Sherm Clay loam 90%	1	275	956
	Pa, Sunray Clay loam 90%	1	269	
	Da, Dalhart Fine Sandy loam 80%	1	412	
Segment_7	Re, Gruver Loam 90%	1	578	1340
	Rb, Sherm Clay Loam 90%		762	
Segment_8	Md, Conlen-Dalhart complex, Conlen Loam 55%	3	566	1371
	Re, Gruver Loam 90%	1	372	
	Rb, Sherm Clay Loam 90%	1	433	
Segment_9	Rb, Sherm Clay loam 90%	1	608	1211
	Pa, Sunray Clay loam 90%		472	
	Rb, Sherm Clay loam 90%		131	
Segment_10	Md, Conlen-Dalhart complex, Conlen Loam 55%	3	575	944
	Rb, Sherm Clay Loam, Sherm Clay loam 90%	1	369	

CHAPTER IV

RESULTS & DISCUSSION

In this thesis, the estimated sediment production from ODOT construction sites was compared with the annual erosion production in Oklahoma counties. Sediment production from sites was assessed using the RUSLE_2 GUI, while background erosion was assessed using the RUSLE in ArcGIS Pro. RUSLE_2 GUI results are considered moderately accurate if they are within ±50% of the real yield [46]. The annual sediment yield results are plotted as bar charts that show the amount of sediment yield under various scenarios from construction sites under the following conditions: (1) unprotected, (2) protected from sediment transport with silt fences, (3) protected from erosion with temporary seeding and mulching, (4) protected from erosion with sediment control blankets, and (5) protected from sediment transport with fiber logs. The bar charts show the prevented sediment production for each BMP. Since sediment catchments vary widely in land use and topography, in our modeled sediment yields result, some of the cross-sectional areas have higher values of soil loss, which may be due to their steeper slope.

The GIS analysis was executed to estimate background erosion and sediment production in select Oklahoma counties. Soil erosion maps are presented in units of tons/acre/year in Oklahoma. For each county, the climate (R-factors), soil erodibility (K-factors), slope length and steepness (LS-factors), cover management (C-factors), and support practice (P-factors) were developed into gridded map products (Appendix 3). The annual erosion map for each county was then calculated by multiplying them together (Appendix 3). After generating the erosion maps, statistics were compiled for each county from the annual erosion map. The mean of annual erosion is illustrated in Figure 4-1.

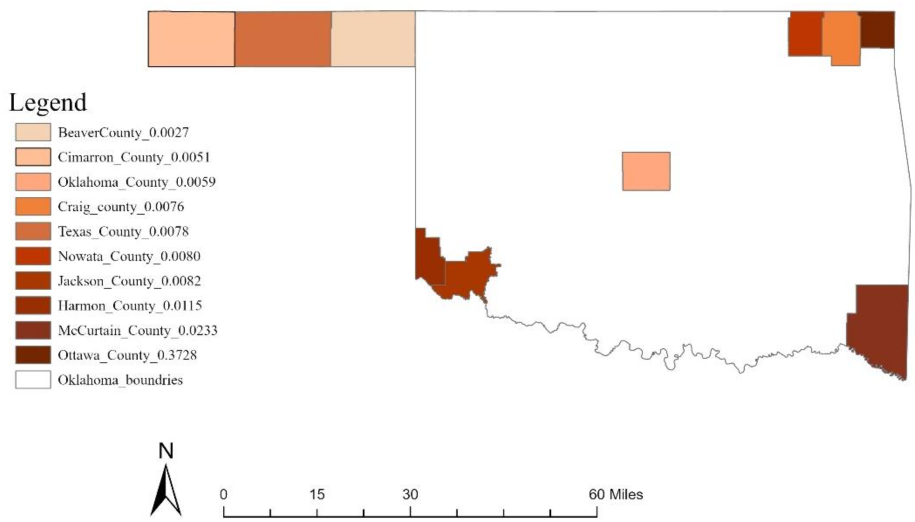

Figure 4-1 Analyzed counties and their average natural annual erosion (tons/acre/year)

4-1 Cimarron County

The results from Cimarron County are showed here in detail. Similar procedures were used in other counties to estimate sediment production from background sources and construction sites. The results for the other counties are shown in the Appendix. The estimated sediment yield from the unprotected construction of the roadway in Cimarron County with RUSLE_2 GUI shows an average of 5.76 tons/acre/year. The observed maximum soil loss was about 14 tons/acre/year. and the minimum soil loss was about 2.29 tons/acre/year. As shown Figure 4-7 the mean natural annual sediment yield in Cimarron County, is about 0.14 tons/acre/year Results from the RUSLE_2 GUI construction site without protection showed 40 times more sediment yield than natural annual erosion.

4-1-1 Potential annual soil erosion estimation for Cimarron County

The rainfall factor, soil erodibility factor, slope length and steepness factor, cover management factor, and support practice factor maps were determined as shown in Figure 4-2 to Figure 4-6. The annual average soil loss raster map created from Equation 2 and shown in Figure 4-7.

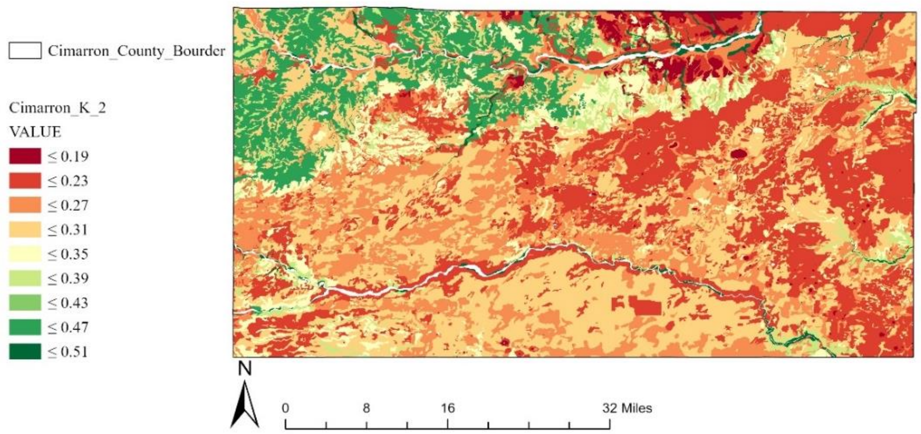

Figure 4-2 RUSLE_2 soil erodibility factor (K) map for Cimarron County

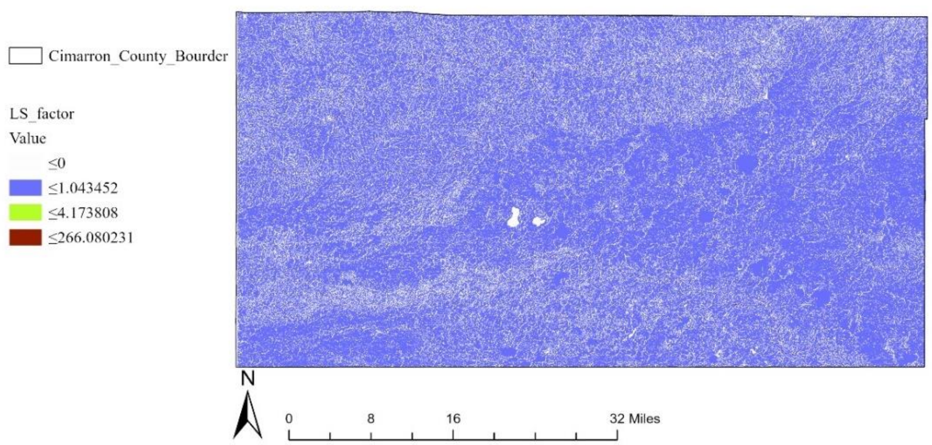

Figure 4-3 RUSLE_2 slope length and steepness factor (LS) map for Cimarron County

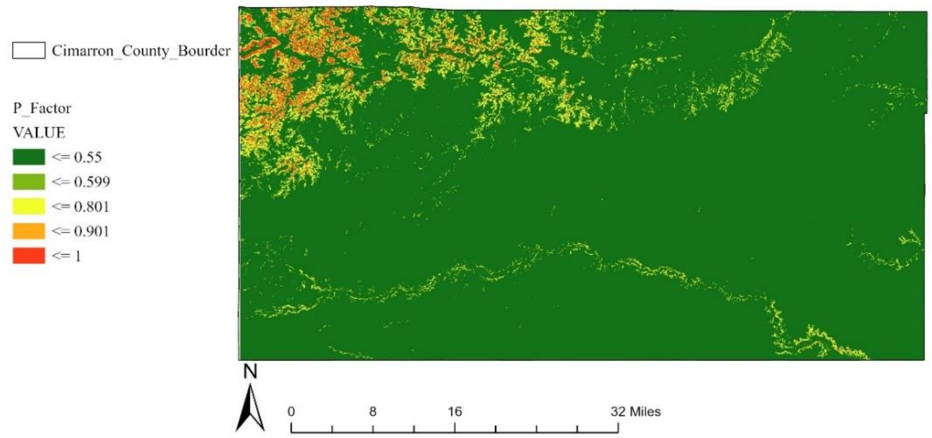

Figure 4-4 RUSLE_2 support practice factor (P) map for Cimarron County

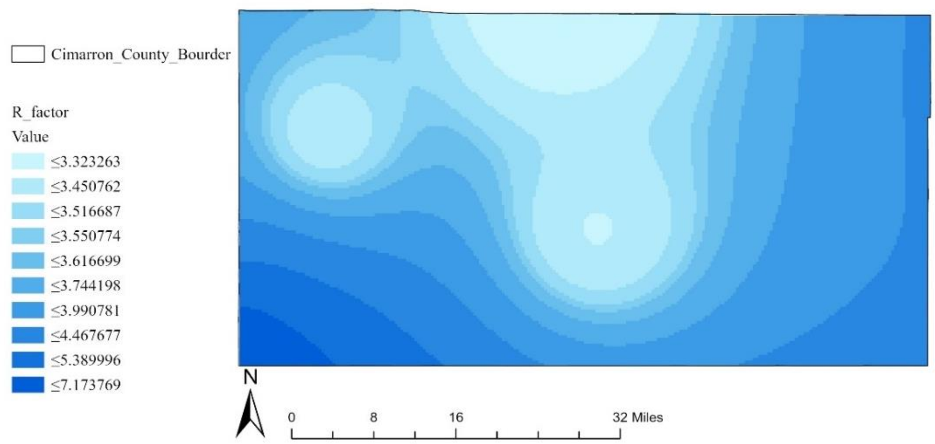

Figure 4-5 RUSLE_2 rainfall erosivity factor (R) map for Cimarron County

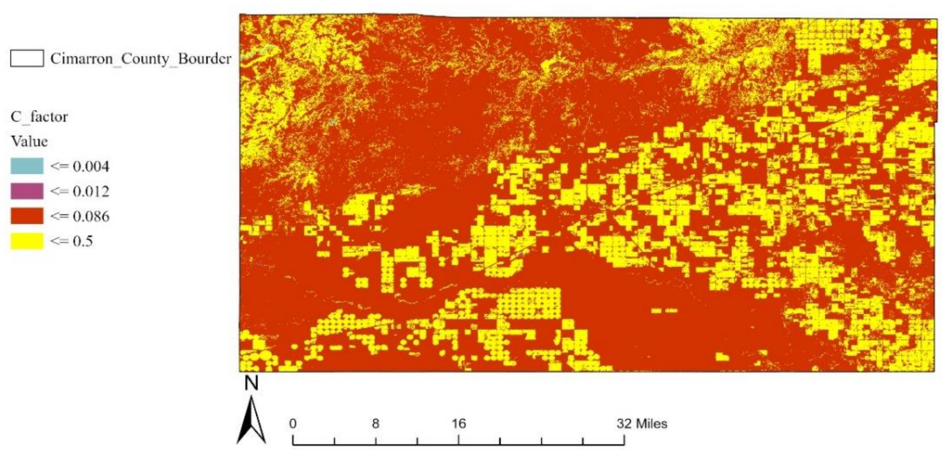

Figure 4-6 RUSLE_2 cover management factor (C) map for Cimarron County

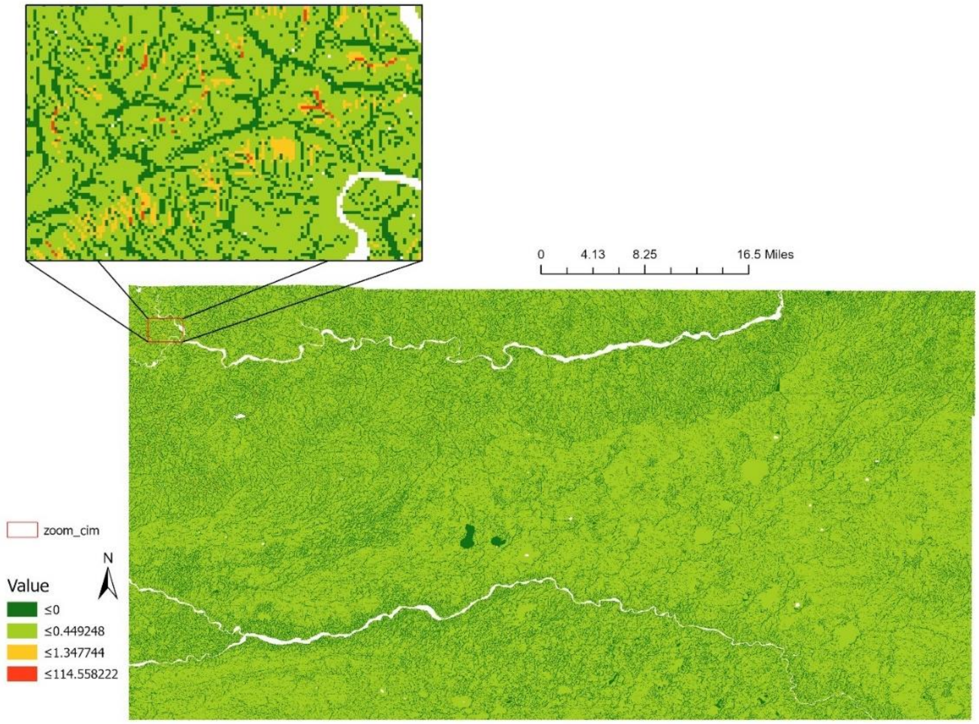

Figure 4-7 Annual predicted average soil loss (tons/acre/year) map for Cimarron County

As shown in Figure 4-7 in the zoom-out section, the sediment yield is notably higher in some locations than other areas. To identify the reason for these high yields, the condition of the region was studied in detail. The area has a soil type as the following table and the slope map shown in Figure 4-8. The governing soil hydrologic group is mainly type D, which produces high runoff and low infiltration. As a result, the soil type average soil erodibility factor of the domain is higher. In the next level, the land cover of the area is presented. According to the land cover map of Oklahoma, the area with high erosion consists of shrub/scrub with land cover factor value of 0.45. As expected, because of the steeper slope and more substantial slope steepness factor, the potential for severe runoff and low infiltration in addition to the higher soil erodibility and cover management factors, the erosion was more severe in this area.

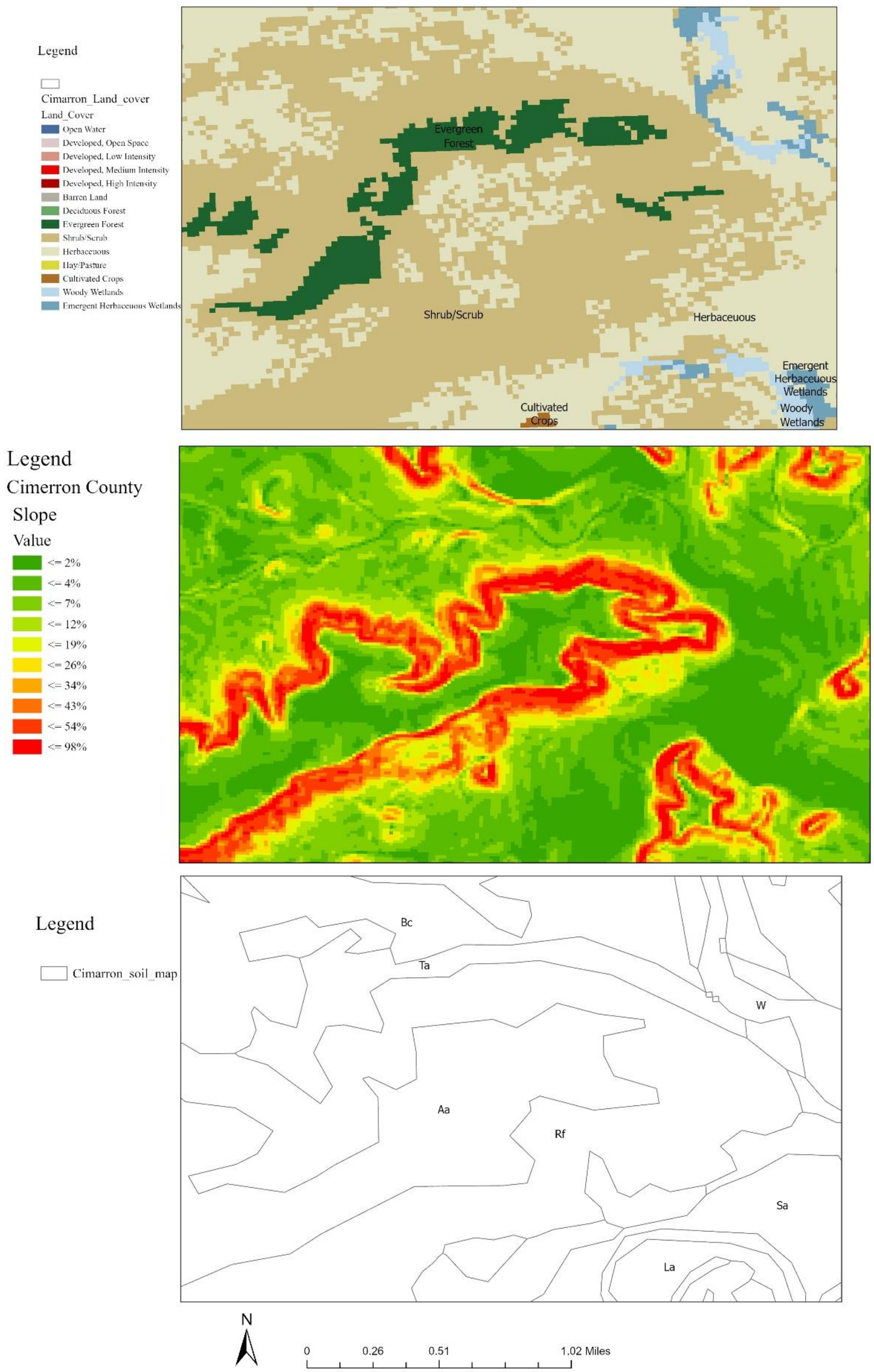

Figure 4-8 Land cover, slope and soil type map for north west area in Cimarron County

Table 4-1 soil type with the hydrologic group type for north west of Cimarron County

Rf—Travessilla-Rock outcrop complex, 10 to 50 percent slopes	
Hydrologic Soil Group	D
Aa—Apache cobbly clay loam, 1 to 3 percent slopes	
Hydrologic Soil Group	D
Bc—Kim loam, 3 to 5 percent slopes	
Hydrologic Soil Group	B
Ta—Travessilla stony loam, 3 to 12 percent slopes	
Hydrologic Soil Group	D
La—Corlena loamy fine sand, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	A
Sa—Spur clay loam, 0 to 1 percent slopes, occasionally flooded, cool	
Hydrologic Soil Group	B

Figure 4-9 shows the distribution of pixel values for each factor used to calculate the annual erosion for Cimarron County. The same procedure was used for every studied county. Chart 4-1 and Table 4-2 show the correlation of coefficient of RUSLE factors on the annual erosion maps. As shown in the chart, the slope length and steepness factor (LS) has the most extensive impact. The next most important influence was the support practice factor (P factor). The support practice factor itself is relevant to the slope steepness (Table 3-2). In addition to the P factor, the LS factor, which is based on the slope length and steepness effects, makes the impact of slope more important than other factors.

Table 4-2 The effect of RUSLE factors on the final erosion map

RUSLE factor	COVARIANCE MATRIX	CORRELATION MATRIX
C	0.001	0.043
LS	0.028	0.345
K	0.001	0.061
P	0.001	0.124
R	0.016	-0.016

By studying the RUSLE factor's correlation coefficients on the annual erosion map, it appears that the slope length and steepness factor play a major role in indicating the annual sediment amount. The support practice factor has the second most impact on the result. Also, in the areas where cultivated crops are the principal land cover management, the effect of the cover management factor is higher on the impact of support practice factor (Appendix 3).

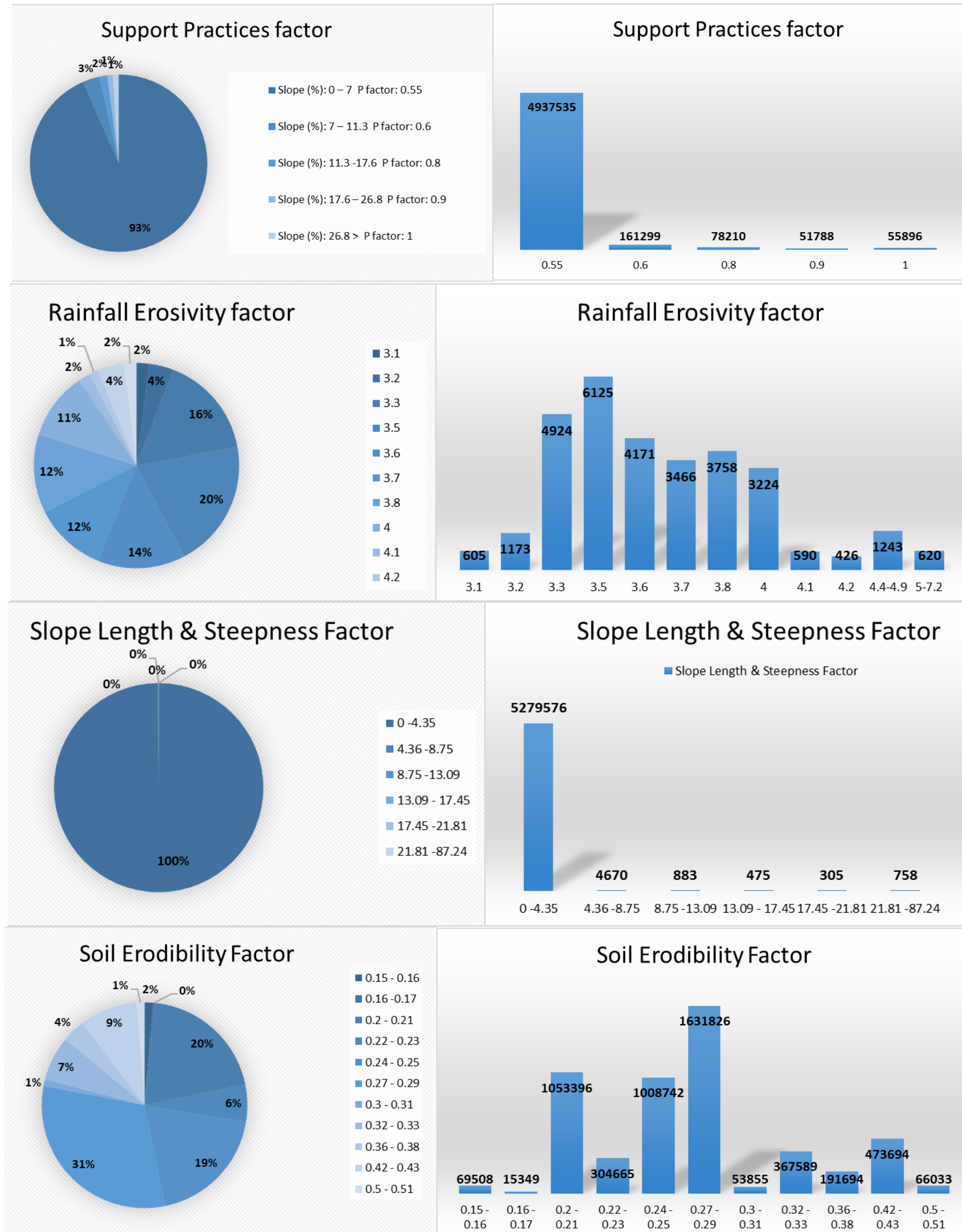

Figure 4-9 Distribution of different RUSLE factors values for calculating the Cimarron County annual erosion map

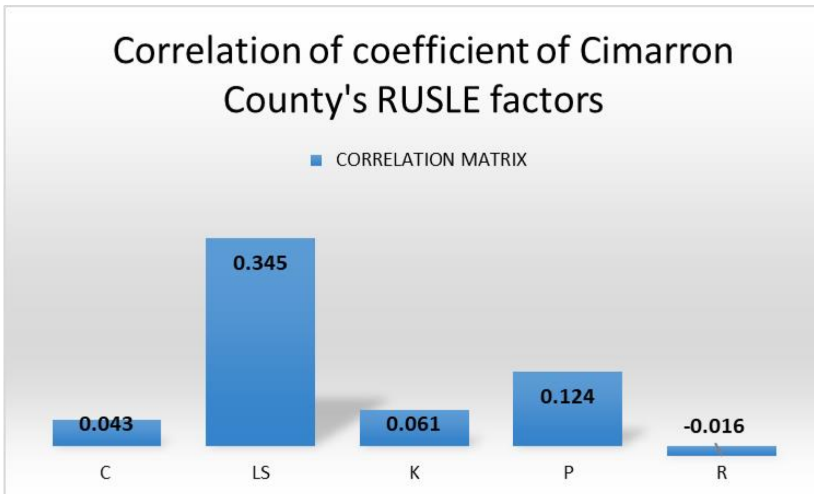

Chart 4-1 Correlation of coefficient of Cimarron County's RUSLE factors in producing the erosion map

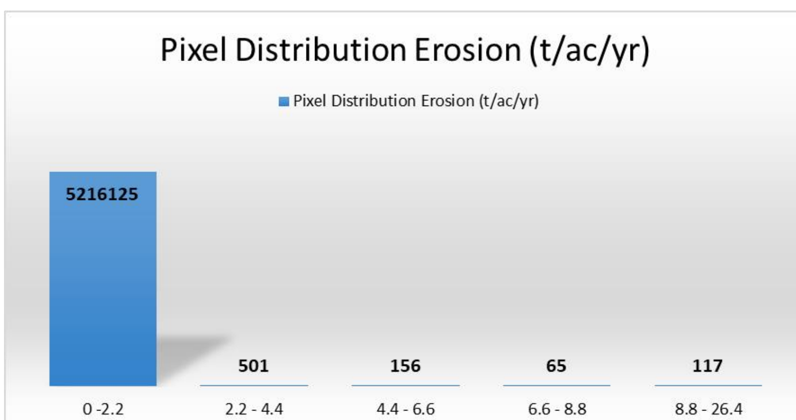

Figure 4-10 Distribution of annual erosion values for erosion map

4-1-2 Effects of slope on sediment generation and BMP effectiveness

Chart 4-1 shows the sediment yield for various ESC BMP scenarios for two select construction sites in Cimarron County. The cross-sectional areas having higher values of soil loss is primarily due to the steeper slopes. Furthermore, in some cross-sections with a greater area and steeper slope, the efficiency of the erosion and sediment control blanket is higher, which decreases the sediment yields more than other BMPs.

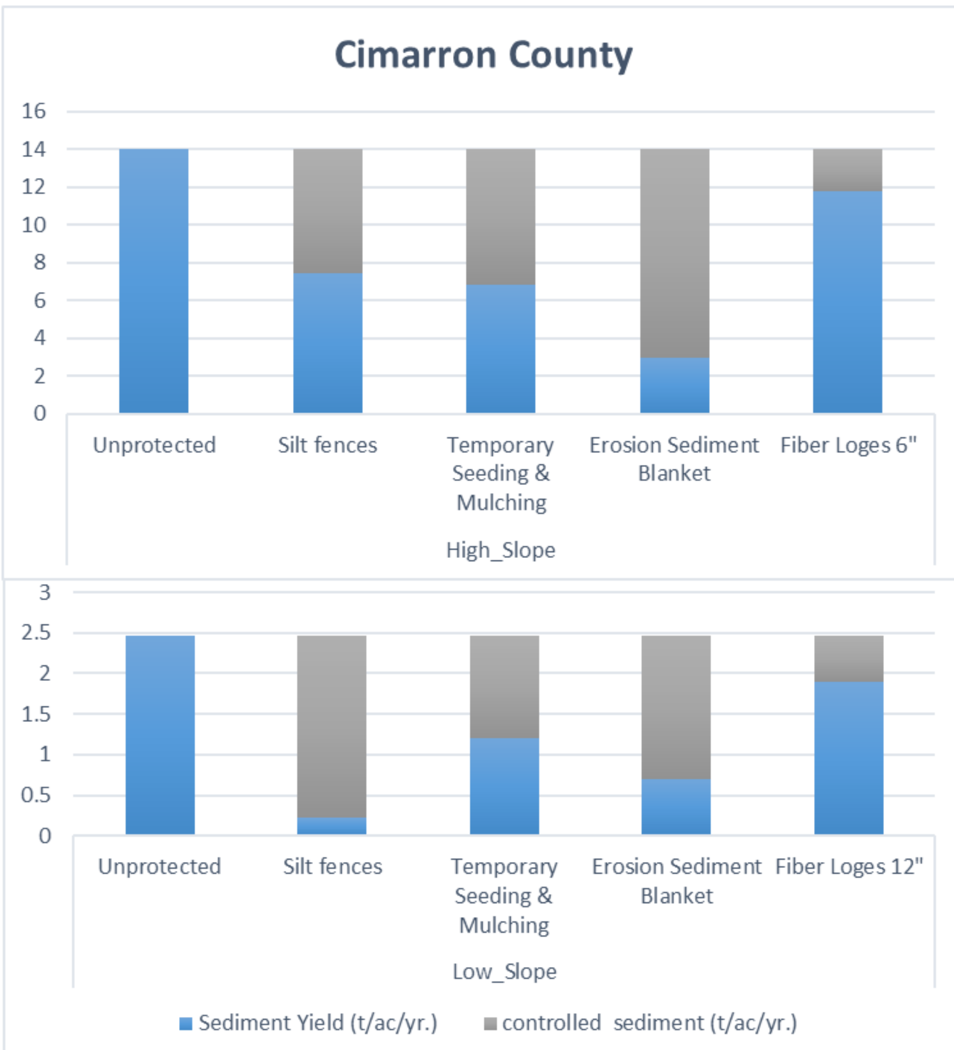

Chart 4-2 Cimarron County's low and high slope, RUSLE_2 GUI results

4-2 Average annual soil loss result

Only a few studies have previously estimated erosion rates at scale in Oklahoma. Rhoades et al. [12] estimated the annual erosion amount from 1967 to 1971 for watersheds in Chickasha, Oklahoma. The results showed that lands in good to excellent condition (no evidence of active gullies) were between 0.027 and 0.0465 ton/ac/yr, while for lands in poor to fair condition (the grassland cultivated from 1900 to 1940 then back to rangeland and cause severe erosion), eroded at rates between 0.027 and 0.0465 ton/ac/yr, while for lands in poor to fair condition eroded at rates between 2.65 and 5.95 ton/ac/yr [12]. Another source of erosion estimation in Oklahoma is the NRCS's National Resources Inventory, which was last published in 2015. They estimated erosion in crop lands (cultivated and non-cultivated cropland, not the background soils) by water present as an average of 2.56 ton/ac/yr of erosion in 2002, 2.55 ton/ac/yr in 2007, 2.59 ton/ac/yr in 2012, and 2.61 ton/ac/yr in 2015 [13]. In this study, with the help of ArcGIS Pro, RUSLE2 was applied to estimate the base map for natural annual erosion in Oklahoma. A summary of estimated annual erosion data are shown in Table 4-3. The annual erosion maps for other counties can be find in Appendix 3.

In the RUSLE modeling, soil erodibility factors in areas covered with water and impervious urban areas were assumed to have a soil erodibility factor of zero. Cover management factors were assumed to be zero for miscellaneous water bodies and large dams, which, as shown in Table 4-3, resulted in no erosion.

In each county, several spots were perceived as exhibiting extremely high erosion rates, which might be the result of particular soil type or severe slope steepness. For example, the southern part of McCurtain County has a low erosion rate from unprotected construction sites (average of 9.73 t/ac/yr.), while the central part of the county has a high erosion rate (average of 138.14 t/ac/yr.) due to the high slope. The slope steepness degree is the primary reason for this behavior as shown in Chart 4-5. McCurtain County, with a maximum annual erosion rate of 849.778 t/ac/yr, has the highest maximum amongst the study counties. Results from Harmon County shown in Chart 4-3 illustrate that a low slope has low erosion from unprotected construction sites. The slope steepness in the area is very low, about 0.5%. Profiles with the same conditions (soil type, climate factor) but with lower slope have lower annual erosion rates. Increasing the length of the profile increases the erosion rate and reduces the efficiency of fiber logs and silt fences to mitigate sediment yield as shown in Chart 4-4.

The average annual erosion amount for the study counties from 2010-2017 was 0.050 t/ac/yr, which is in agreement with the estimate from Rhoades et al. [12] for good to excellent land condition 0.027 to 0.0465 t/ac/yr.

Table 4-3 Estimated background sediment production in select counties

County	Area (acres)	MAX Sediment yield (tons/acre/year)	MEAN Sediment yield (tons/acre/year)	Standard deviation for Sediment yield (tons/acre/year)	Annual Sediment Load (Ton/year)
Cimarron	1178000	114.5	0.005	0.136	6006
Texas	1311000	100.7	0.008	0.196	10214
Beaver	1164000	229.6	0.003	0.199	3194
Ottawa	310000	655.0	0.373	3.718	115555
Craig	488000	236.5	0.008	0.338	3727
Nowata	372000	91.6	0.008	0.267	2993
Harmon	345000	40.2	0.012	0.145	3969
Jackson	515000	47.8	0.008	0.150	4230
McCurtain	1217000	849.7	0.023	0.893	28334
Oklahoma	460,000	65.8	0.006	0.193	2715

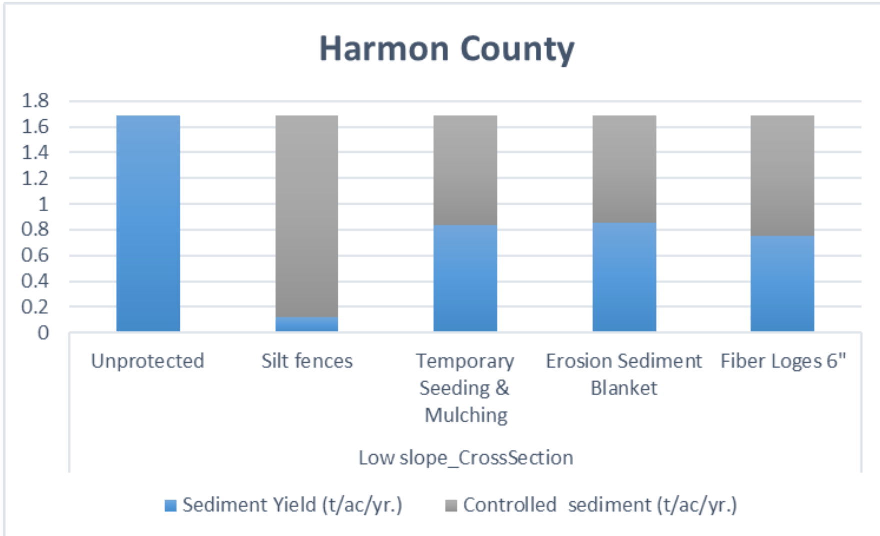

Chart 4-3 Harmon County’s low slope cross section, RUSLE_2 GUI results

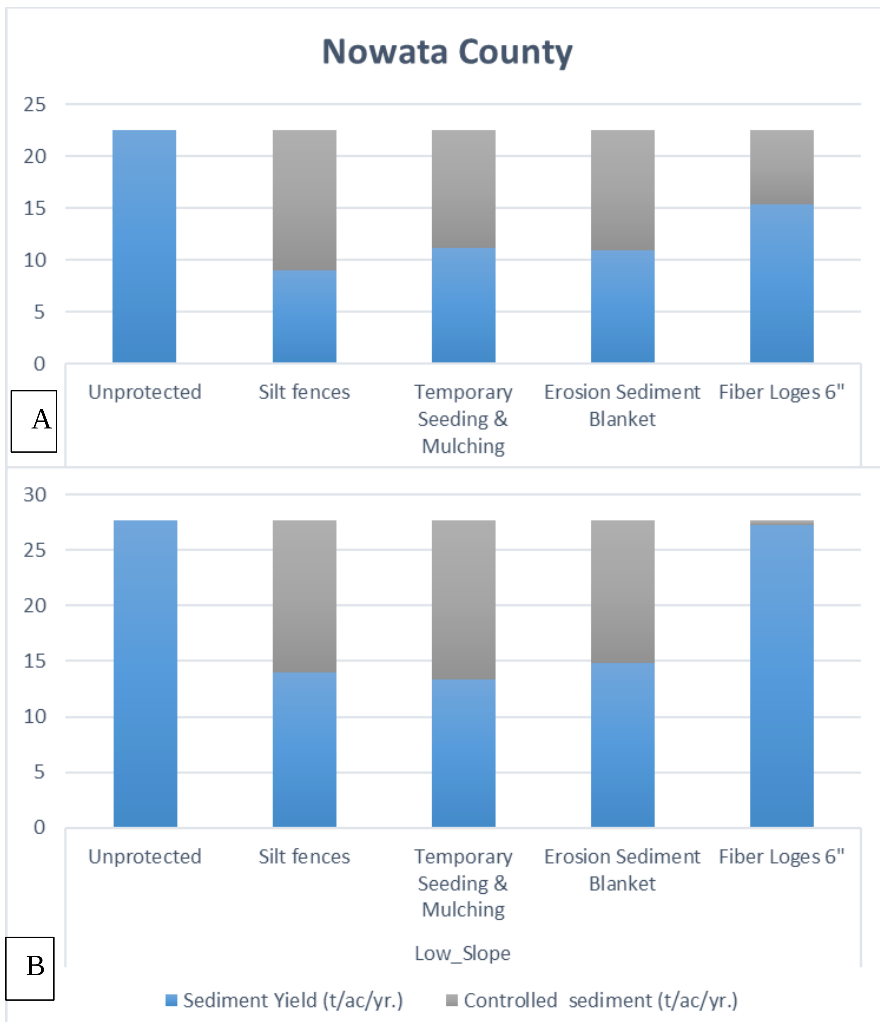

Chart 4-4 Nowata County’s low slope cross section, Chart A presents a profile with a slope length of 288 ft, Chart B present profile with slope length of 576 ft.

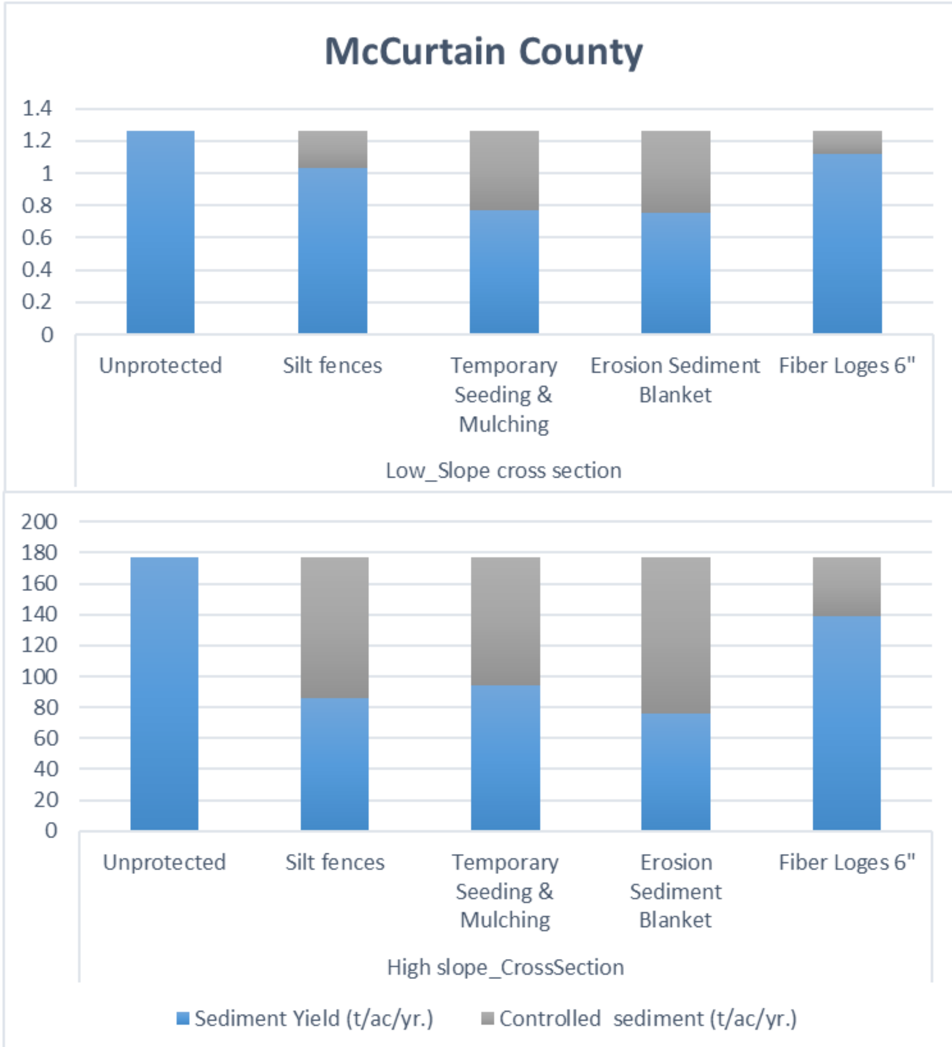

Chart 4-5 Comparison of low and high slope cross sections on sediment yield

The annual erosion amount of Ottawa County, with an average of 0.373 t/ac/yr, presents the highest mean between studied counties. After comparing the model inputs and different average annual erosion amounts, it was observed that the rainfall erosivity factor in the counties with a higher rate of annual erosion was higher than the counties with lower annual erosion. Figure 4-11 shows the peak erosivity factor for Ottawa County in June with the R factor of 43, which stays high until September. The peak R factor for a low rate erosion county such as Cimarron County is about 23 in July. The erosivity factor chart can provide the best vision for the construction projects, which are at the planning level. With a proper planning schedule considering the peak month for erosivity factor, the erosion amount can be diminished.

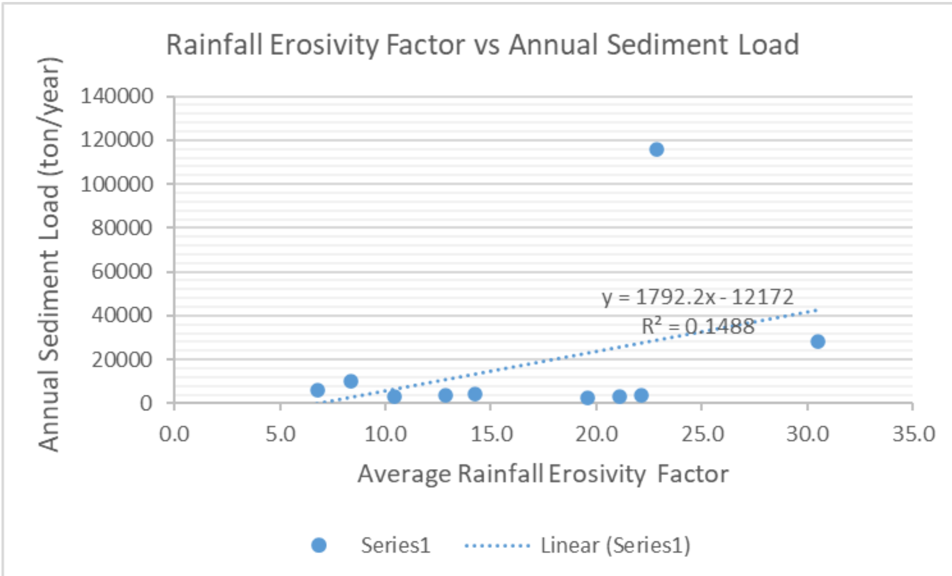

Figure 4-11 comparing average rainfall erosivity factor with the annual sediment load.

4-3 Erosion from unprotected construction sites

For each cross-sectional profile, the erosion amount from the construction site with no ESC BMPs was estimated to provide a baseline for sediment yield. Table 4-5 presents the ODOT construction projects IDs for sites around Oklahoma, the size of the construction site, and the sediment production from roadway construction. Depending on the construction quantity and the governing natural conditions, the construction site can deliver from 2% to 9% of the entire produced sediment in each county (Table 4-5). In our study, we assumed the whole construction site area is cleared and degraded; however, in the real world, it might be different, and in the result, the amount of produced sediment be less than the estimated in this study.

As an illustration, the processes of calculating the sediment yield for Harmon County is explained as follows. The same procedure has been followed for the other modeled constructions and other counties. As was described in the methodology chapter, depending on the roadway construction site length, some cross-section profiles were considered. For instance, the ODOT construction with ID Number of "STPY-133B (087) SS" located at Harmon county has a length of 6.1 miles. According Figure 4-12, 7 cross section profiles were used to estimate the sediment yield in RUSLE_2 GUI. Each profile has a distinct length and produced a separate sediment yield. Toward having a better perception to compare the generated sediment yield from each unprotected construction site. The average annual sediment yield calculated for the whole construction site length (Table 4-4).

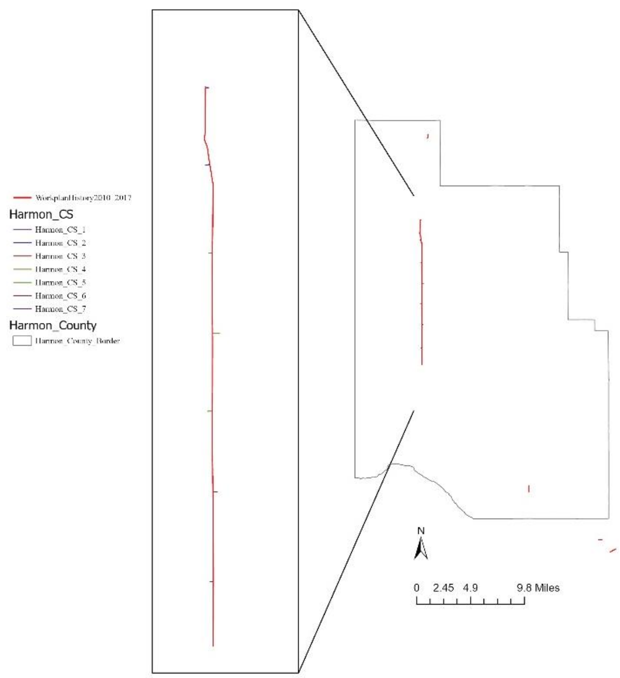

Figure 4-12 Harmon County locations of studied cross sections with the distance of 10,000 ft

Table 4-4 Harmon County sediment yield from unprotected construction site

Harmon County	**Sediment Yield (t/ac/yr.) from Unprotected site**
Cross section_1	100.00
Cross section_2	82.80

Cross section_3	17.70
Cross section_4	1.69
Cross section_5	6.94
Cross section_6	8.91
Cross section_7	4.38
Average Sediment yield	31.77

Table 4-5 Annual sediment yields from unprotected ODOT construction sites

County	**Roadway construction Project ID**	**Average Sediment yield (t/ac/yr)**	**Length (mi)**	**Width (mi)**	**Area (acre)**	**Sediment yield (t/yr)**
Cimarron	J1-3337(023) & NHY-017N(002)	7.74	10.30	0.22	1453	11251
Cimarron	SEC1302Y-133N(050)HP	5.75	2.27	0.16	237.46	1365
Cimarron	J3- 1867(004)	2.46	8.00	0.13	655.52	1615
Texas	NHY-008N(059) & NHY-008N(065)	3.49	7.90	0.07	356.94	1246
Texas	J1-4971(041)	3.59	3.60	0.13	288.36	1035
Texas	NHY-008N(019)	3.98	4.70	0.11	344.95	1373
Texas	SSP-170N(152)SS	6.72	7.30	0.12	544.14	3657
Texas	J2-9653(004)	96.50	3.00	0.14	277.67	26795
Texas	J3-0402(004)	24.20	2.27	0.10	146.47	3545
Texas	SSP-170C(127)	3.16	3.50	0.14	302.70	957
Beaver	J2-7011(004)	3.79	3.00	0.05	93.94	356
Beaver	J3-1064(004)	35.31	4.90	0.07	205.50	7257
Beaver	SSP-104C(054)SS	2.92	2.00	0.16	208.24	608
Beaver	J2-7007(004)	6.49	1.00	0.25	163.03	1058
Ottawa	J2-4277(007) & J1-2573(008) & BRFY-058C(237) & STPY-058C(240)	32.51	13.37	0.06	517.20	16814
Ottawa	J2-20896(004)	14.89	3.62	0.07	161.33	2402
Ottawa	J2-7016(004)	15.70	1.50	0.07	62.44	980
Ottawa	J3-2695(004)	20.07	4.77	0.04	115.23	2313
Craig	J2-8901(004)	47.12	9.16	0.07	437.90	20634
Craig	SSP-118C(096)SS	46.80	4.75	0.08	230.49	10787
Craig	BRFY-118C(093)SS	108.00	0.75	0.07	33.55	3623
Craig	J3-1962(004)	91.70	1.72	0.04	41.91	3843
Nowata		29.37	12.00	0.07	505.77	14854
Nowata	J2-8094(004)	25.29	3.06	0.08	165.05	4174
Nowata	J2-4269(007)	108.07	3.65	0.11	254.10	27460
Nowata	J2-7025(004)	22.93	5.38	0.08	290.41	6659

Harmon	J3-1825(004)	31.77	13.10	0.08	650.58	20669
Jackson	STPY-133B(087)SS	7.93	6.10	0.07	281.83	2235
McCurtain	SEC1702Y-145B(153)SS & STPY-145C(150) & J2-4409(004) & J2-4219(004)	138.14	22.60	0.07	1033.73	142801
McCurtain	J2-6343(004)	9.73	7.20	0.07	332.36	3234

In McCurtain County case because most of the roadway construction sites had a high slope and the rainfall erosivity factor of the county was high. Besides, the hydrologic soil group of the county located in the hydrologic soil group D, which has a very slow infiltration rate and high runoff potential. Overall, all the conditions lead to a higher erosion rate from the unprotected construction site, which is almost equal to the entire total erosion in the county.

Table 4-6 Percentage of the unprotected construction site erosion from total erosion

County	Annual County erosion (t/yr)	Construction erosion (t/yr)	Total erosion (t/yr)	Construction erosion/Total county erosion%
Cimarron	6007	14231	20237	70
Texas	10214	38606	48820	80
Beaver	3194	9279	12473	70
Ottawa	115555	22514	138064	20
Craig	3727	38887	42614	90
Nowata	2993	53148	56142	90
Harmon	3969	20669	24638	80
Jackson	42236	2235	6465	30
McCurtain	28334	146034	174369	80

4-4 1-inch compost blanket with seed

Sediments are the main pollution from active construction sites. The primary goal of using BMPs is to reduce and prevent erosion and keep the sediment on the site. In our research, out with 470 various conditions, (Appendix_4) the 1_inch compost blanket with seed provided the highest efficiency rate in steeper slope.

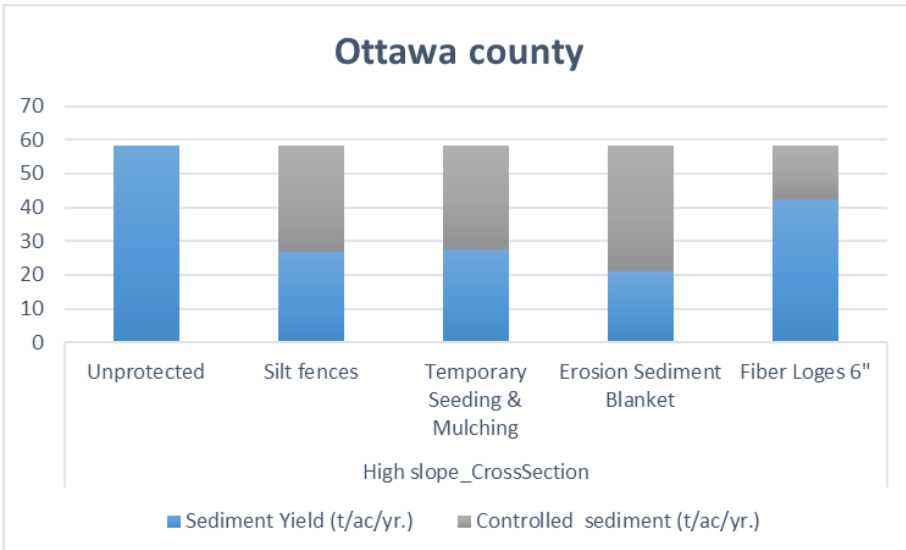

Chart 4-6 Ottawa County's high slope cross section and performance of the erosion blanket, RUSLE_2 GUI results

4-5 Temporary seeding with mulching versus sediment control blankets

Generally speaking, 1-inch erosion control blanket with seeding showed higher efficiencies than the temporary seeding with mulch. But under different climate conditions with higher precipitation such as in Ottawa County, the peak R factor is about 43. Higher precipitation makes the site suitable for vegetation, and temporary seeding with mulch products shows a higher efficiency rate than a 1-inch erosion and sediment control blanket. Because of higher annual precipitation, Ottava County shows a higher R factor than the counties in the northwest of Oklahoma (Figure 4-11). Even though the LS factor has a major effect on erosion amount, clearly the higher R factor will lead to more annual soil erosion. Chart 4-7 shows one example of temporary seeding with mulch BMPs in a low slope cross section.

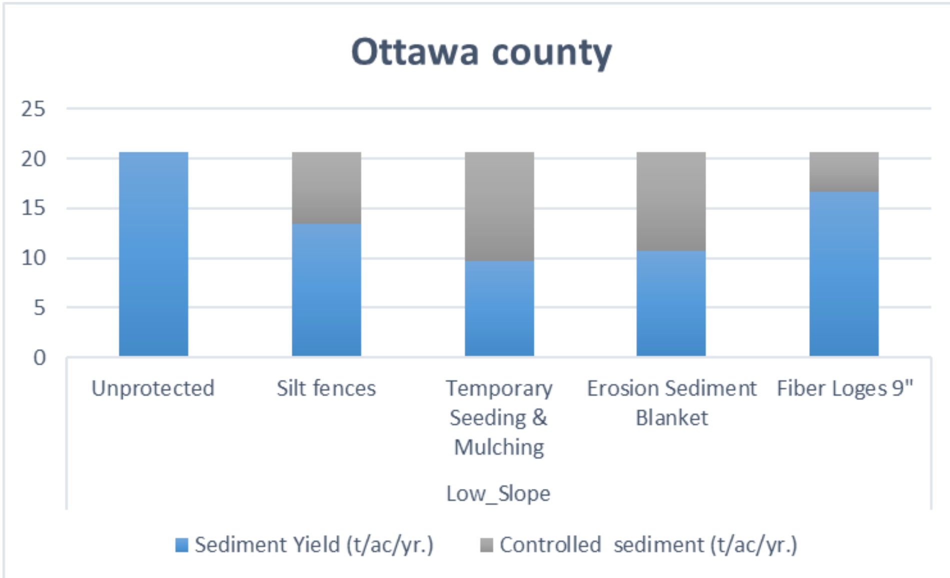

Chart 4-7 Temporary seeding with mulch BMPs performance in Ottawa County's low slope cross section, RUSLE_2 GUI results

4-6 Silt fences

In comparison with the other BMPs that have been studied, silt fences showed higher productivity on low to medium slope construction sites. Additionally, after different scenarios with the same condition but different slope length, it was noted that there is a correlation between silt fences performance and slope length. By increasing the slope length, the efficiency of silt fences decreases insignificantly. Chart 4-8 compares the performance of silt fences to the other BMPs.

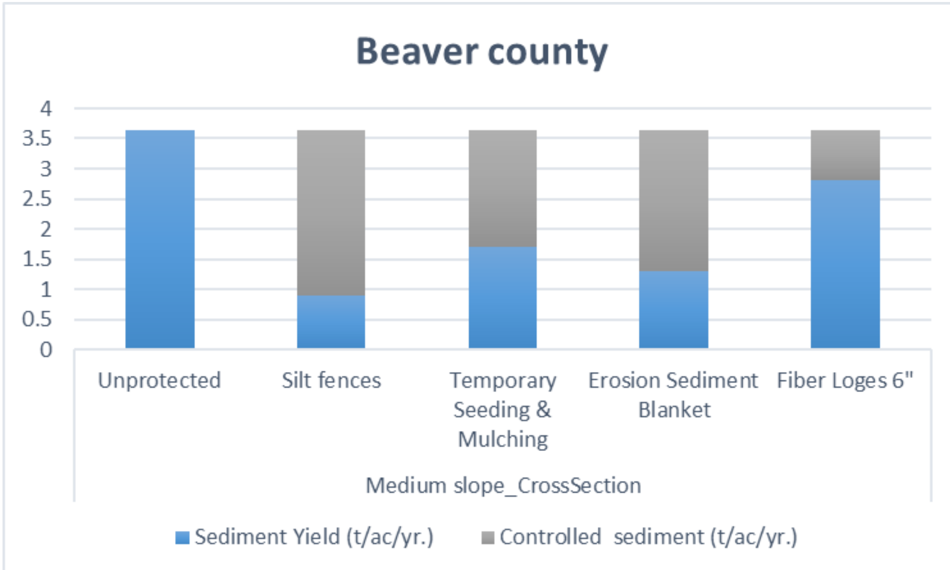

Chart 4-8 Standard silt fence performance in a medium slope cross section in Beaver County

4-7 Fiber Logs 6 inch

Fiber logs are sediment control products, and similar to silt fences showed better performance on the low to medium slopes. Chart 4-9 shows performance of fiber logs for sediment control on a low slope. Generally, fiber logs showed the lowest efficiency rate among the BMPs.

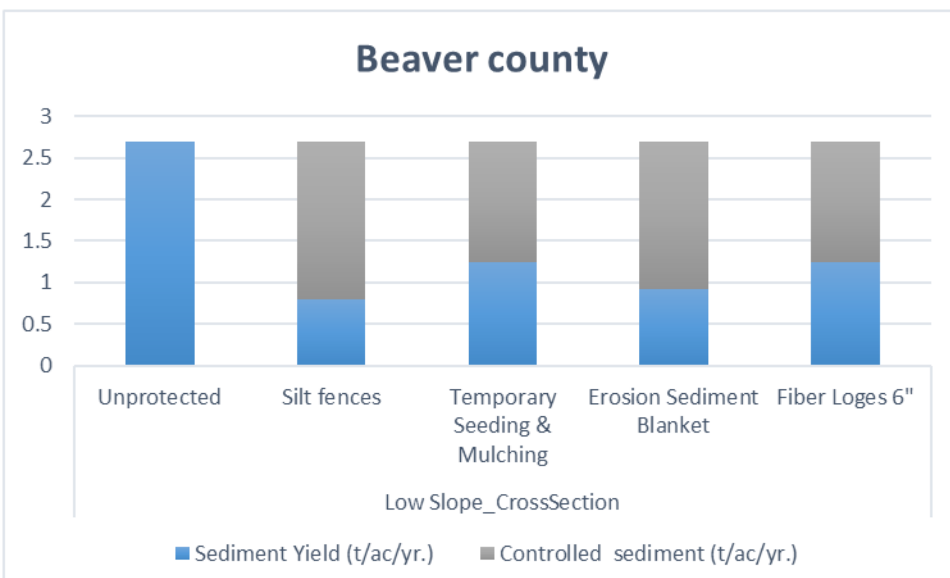

Chart 4-9 Fiber loges 6” performance in Beaver County’s Low slope cross section, RUSLE_2 GUI results

CHAPTER V

CONCLUSIONS

Erosion control at construction sites is an emerging water quality control issue. The construction of roadways typically consists of mass clearing and grading which caused many soil surface site areas exposed toward rainfall and erosion factors and induced erosion. The main pollutants from construction sites are sediments.

ESC BMPs reduce the impacts of construction sites. In this thesis, the effectiveness of various BMPs was evaluated at construction sites throughout Oklahoma. The results were used to compare the sediment production from ODOT construction sites to background levels. An additional goal was to identify existing opportunities to reduce the environmental impact of transportation infrastructure construction. A practical ESC decision design guide document for use by ODOT field engineers and other personnel was developed. The document contains a useful and convenient categorization for BMPs. The principal aspect of the thesis was to generate long-term cumulative performance information for several types of stormwater BMPs used on construction sites in the state of Oklahoma, USA, using RUSLE 2.0. Temporary seeding annual ryegrass with mulch, 1-inch compost blankets with seed were evaluated as erosion control BMPs, while Standard Silt fences and Fiber logs were evaluated as sediment control BMPs. Annual erosion maps for different counties were developed to have a better judgment of how construction sites affect erosion and sedimentation at a large scale.

5-1 Key Conclusions

The results of this investigation have demonstrated the following key ideas:

1. The slope steepness degree has a direct relation with the produced erosion from the construction site. With the increase of the slope steepness, the erosion will increase. Besides the slope steepness, the slope length has a similar effect. The increase in the length can induce higher sediment yield.
2. Areas with higher average monthly rainfall have a higher rainfall erosivity factor which leads to higher annual erosion and higher produced sediment from construction sites. The high average monthly rainfall also improves the efficiency of some BMPs, such as temporary seeding with mulching.
3. The cover management (C) factors have a strong impact on sediment production. Cultivated crops have the highest C-Factor of 0.5, while developed land with high intensity had a cover management factor of 0.1. Areas with a higher C factor will be produced higher average annual erosion.
4. Construction sites without protection on average can produce 40 times more sediment than the natural erosion rate.
5. BMPs reduce the overall sediment loading from construction sites. In some cases, the BMPs can reduce the erosion up to 95 percent.

5-2 Potential Future Research

This study opens a significant number of pathways for further research and education, and it might inspire discussions about how ESCs products could be designed to provide better protection.

The following are potential ideas for future research:

1. Estimate BMP efficiency by integrating different methods together
2. Analyze the annual erosion in Oklahoma by different approaches

3. Measure the cost and benefits of erosion and sedimentation in ODOT construction projects
4. Investigate the erosion and sedimentation from the construction sites in Oklahoma with other available models such as the InVEST model, WEPP
5. Monitor runoff directly from test sites for erosion to validate models

REFERENCES

[1] S. Kelting and D. Eads, “Implementation, Management, and Cost of the Clean Water Act and Storm Water Pollution Prevention Plan,” *Procedia Eng.*, vol. 171, pp. 419–424, 2017, doi: 10.1016/j.proeng.2017.01.352.

[2] K. Alsharif, “Construction and stormwater pollution: Policy, violations, and penalties,” *Land Use Policy*, vol. 27, no. 2, pp. 612–616, Apr. 2010, doi: 10.1016/j.landusepol.2009.08.002.

[3] “Erosion and sediment Control Manual.” Government of Alberta Transportation, 2011.

[4] *Guidance manual for Developing Best Management Practices (BMP).pdf*. office of water (EN-336): United States Environmental Protection Agancy, 1993.

[5] “Urban Stormwater BMP Performance Monitoring,” p. 248, 2002.

[6] “BMP Database.” http://www.bmpdatabase.org/ (accessed Mar. 14, 2020).

[7] “Erosion and sediment Control Manual.” Government of Alberta Transportation, 2011.

[8] “Effects of Sediment on the Aquatic Environment:” https://www.nrcs.usda.gov/wps/portal/nrcs/detail/?cid=nrcs143_014201#intro (accessed Mar. 14, 2020).

[9] S. Rasoulzadeh Gharibdousti, G. Kharel, and A. Stoecker, “Modeling the impacts of agricultural best management practices on runoff, sediment, and crop yield in an agriculture-pasture intensive watershed,” *PeerJ*, vol. 7, Jul. 2019, doi: 10.7717/peerj.7093.

[10] D. J. Wachal, K. E. Banks, P. F. Hudak, and R. D. Harmel, “Modeling erosion and sediment control practices with RUSLE 2.0: a management approach for natural gas well sites in Denton County, TX, USA,” *Environ. Geol.*, vol. 56, no. 8, pp. 1615–1627, Feb. 2009, doi: 10.1007/s00254-008-1259-3.

[11] M. K. Gnagey, “Wetlands and open space: The impact of environmental regulations on land use patterns,” *J. Environ. Manage.*, vol. 225, pp. 148–159, Nov. 2018, doi: 10.1016/j.jenvman.2018.07.088.

[12] *Proceedings, Volume 2*. the University of Wisconsin - Madison, 1986.

[13] “Oklahoma | 2015 <acronym title="National Resources Inventory">NRI</acronym> | NRCS.” https://www.nrcs.usda.gov/Internet/NRCS_RCA/reports/nri_eros_ok.html (accessed Mar. 22, 2020).

[14] M. G. Wolman and A. P. Schick, “Effects of construction on fluvial sediment, urban and suburban areas of Maryland,” *Water Resour. Res.*, vol. 3, no. 2, pp. 451–464, Jun. 1967, doi: 10.1029/WR003i002p00451.

[15] D. Dearmont, B. A. McCarl, and D. A. Tolman, “Costs of water treatment due to diminished water quality: a case study in Texas,” *Water Resour. Res.*, vol. 34, no. 4, pp. 849–853, 1998.

[16] J. Fan and G. L. Morris, “Reservoir sedimentation. II: Reservoir desiltation and long-term storage capacity,” *J. Hydraul. Eng.*, vol. 118, no. 3, pp. 370–384, 1992.

[17] G. A. Fox *et al.*, "Reservoir Sedimentation and Upstream Sediment Sources: Perspectives and Future Research Needs on Streambank and Gully Erosion," *Environ. Manage.*, vol. 57, no. 5, pp. 945–955, May 2016, doi: 10.1007/s00267-016-0671-9.
[18] M. A. Gill, "Sedimentation and useful life of reservoirs," *J. Hydrol.*, vol. 44, no. 1–2, pp. 89–95, 1979.
[19] C. J. Vörösmarty, M. Meybeck, B. Fekete, K. Sharma, P. Green, and J. P. Syvitski, "Anthropogenic sediment retention: major global impact from registered river impoundments," *Glob. Planet. Change*, vol. 39, no. 1–2, pp. 169–190, 2003.
[20] L. Hansen and D. Hellerstein, "The value of the reservoir services gained with soil conservation," *Land Econ.*, vol. 83, no. 3, pp. 285–301, 2007.
[21] L. T. Hansen, V. E. Breneman, C. W. Davison, and C. W. Dicken, "The cost of soil erosion to downstream navigation," *J. Soil Water Conserv.*, vol. 57, no. 4, pp. 205–212, 2002.
[22] J. Zhu, Q. Zeng, D. Guo, and Z. Liu, "Optimal control of sedimentation in navigation channels," *J. Hydraul. Eng.*, vol. 125, no. 7, pp. 750–759, 1999.
[23] H. Bokuniewicz and J. Liu, "Stability of Layered Dredged Sediment Deposits at Subaqueous Sites," in *OCEANS 81*, 1981, pp. 752–754.
[24] "MoRiverBedDegStudy2017.pdf." Accessed: Mar. 14, 2020. [Online]. Available: https://www.marc2.org/assets/environment/mobeddeg/MoRiverBedDegStudy2017.pdf.
[25] R. G. Paterson, M. I. Luger, R. J. Burby, E. J. Kaiser, H. R. Malcom, and A. C. Beard, "Costs and benefits of urban erosion and sediment control: The North Carolina experience," *Environ. Manage.*, vol. 17, no. 2, pp. 167–178, Mar. 1993, doi: 10.1007/BF02394687.
[26] J. Eggleton and K. V. Thomas, "A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events," *Environ. Int.*, vol. 30, no. 7, pp. 973–980, Sep. 2004, doi: 10.1016/j.envint.2004.03.001.
[27] P. Kemp, D. Sear, A. Collins, P. Naden, and I. Jones, "The impacts of fine sediment on riverine fish," *Hydrol. Process.*, vol. 25, no. 11, pp. 1800–1821, 2011, doi: 10.1002/hyp.7940.
[28] C. P. Newcombe and D. D. MacDonald, "Effects of suspended sediments on aquatic ecosystems," *North Am. J. Fish. Manag.*, vol. 11, no. 1, pp. 72–82, 1991.
[29] D. H. Wilber and D. G. Clarke, "Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries," *North Am. J. Fish. Manag.*, vol. 21, no. 4, pp. 855–875, 2001.
[30] G. J. Hanson and S. L. Hunt, "Lessons Learned using Laboratory JET Method to Measure Soil Erodibility of Compacted Soils," *Appl. Eng. Agric.*, vol. 23, no. 3, pp. 305–312, 2007, doi: 10.13031/2013.22686.
[31] E. I. Ekwue and A. Harrilal, "Effect of soil type, peat, slope, compaction effort and their interactions on infiltration, runoff and raindrop erosion of some Trinidadian soils," *Biosyst. Eng.*, vol. 105, no. 1, pp. 112–118, Jan. 2010, doi: 10.1016/j.biosystemseng.2009.10.001.
[32] "Importance of erosion control Erosion Control Handbook 2." Department of transportation of Minesota, 2006.
[33] C. T. Haan, B. J. Barfield, and J. C. Hayes, *Design hydrology and sedimentology for small catchments*. San Diego, Calif: Academic Press, 1994.
[34] "Clean water act," *United States Environmental Protection Agency*, Mar. 11, 2019. https://www.epa.gov/laws-regulations/summary-clean-water-act.
[35] C. Copeland, "Stormwater Permits: Status of EPA's Regulatory Program," p. 14.
[36] "National Pollutant Discharge Elimination System (NPDES) Storm Water Program Questions and Answers," p. 20.
[37] J. Ock, R. R. A. Issa, and I. Flood, "Analysis tools for stormwater controls on construction sites," in *2016 Winter Simulation Conference (WSC)*, Dec. 2016, pp. 3337–3344, doi: 10.1109/WSC.2016.7822364.
[38] "Final-CGP-2017.pdf." Accessed: Jan. 21, 2020. [Online]. Available: https://www.deq.ok.gov/wp-content/uploads/water-division/Final-CGP-2017.pdf.

[39] "OKR10 Construction Stormwater," *Oklahoma Department of Environmental Quality*. https://www.deq.ok.gov/water-quality-division/wastewater-stormwater/stormwater-permitting/okr10-construction-stormwater/ (accessed Jan. 21, 2020).
[40] "ODOT Roadway Drainage Manual," Oklahoma Department of transportation, 2014.
[41] URS Corporation – North Carolina, "Erosion and Sediment Control Design and Construction Manual," North Carolina Department of Transportation, Erosion and sediment control manual, 2014.
[42] URS Corporation – North Carolina, "Erosion and Sediment Control Design and Construction Manual," North Carolina Department of Transportation, Erosion and sediment control manual, 2014.
[43] "AH_703.pdf." Accessed: Jan. 17, 2020. [Online]. Available: https://www.ars.usda.gov/ARSUserFiles/64080530/RUSLE/AH_703.pdf.
[44] E. S. Khoboso and H. R. Beckedahl, "A Review of Road–Related Soil Erosion: An Assessment Of Causes, Evaluation Techniques And Available Control Measures," Eart Sci. Res. J., vol. 19, no. 1, pp. 73–80, 2015.
[45] "Revised Universal Soil Loss Equation (RUSLE) - Welcome to RUSLE 1 and RUSLE 2: USDA ARS." https://www.ars.usda.gov/southeast-area/oxford-ms/national-sedimentation-laboratory/watershed-physical-processes-research/docs/revised-universal-soil-loss-equation-rusle-welcome-to-rusle-1-and-rusle-2/ (accessed Jan. 21, 2020).
[46] S. K. Balkissoon, "Evaluation of RUSLE 2 to estimate soil loss from pastures," p. 104.
[47] G. Ozsoy, E. Aksoy, M. S. Dirim, and Z. Tumsavas, "Determination of Soil Erosion Risk in the Mustafakemalpasa River Basin, Turkey, Using the Revised Universal Soil Loss Equation, Geographic Information System, and Remote Sensing," *Environ. Manage.*, vol. 50, no. 4, pp. 679–694, Oct. 2012, doi: 10.1007/s00267-012-9904-8.
[48] G. R. Foster, "RUSLE2 Science Documentation," p. 355, 2008.
[49] "The future of RUSLE: Inside the new Revised Universal Soil Loss Equation - ProQuest." https://search-proquest-com.argo.library.okstate.edu/docview/220967948/fulltext/A8E89D6D8D6643A7PQ/1?accountid=4117 (accessed Mar. 17, 2020).
[50] "Revised Universal Soil Loss Equation, Version 2." https://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm (accessed Mar. 17, 2020).
[51] N. Widman, "RUSLE2 - Instructions & User Guide," p. 27.
[52] E. K. Nwakor, C. C. Mbajiorgu, and K. N. Ogbu, "ASSESSMENT OF SOIL EROSION USING RUSLE2 MODEL AND GIS IN UPPER EBONYI RIVER WATERSHED, ENUGU STATE, NIGERIA," IJRSG, vol. 4, no. 4, pp. 7–17, 2015.
[53] Kinnell, "A Review of the Science and Logic Associated with Approach Used in the Universal Soil Loss Equation Family of Models," *Soil Syst.*, vol. 3, no. 4, p. 62, Sep. 2019, doi: 10.3390/soilsystems3040062.
[54] "Cooper R-factor-Final.pdf." Accessed: Mar. 23, 2020. [Online]. Available: https://www.engr.colostate.edu/~pierre/ce_old/Projects/linkfiles/Cooper%20R-factor-Final.pdf.
[55] K. G. Renard and J. R. Freimund, "Using monthly precipitation data to estimate the R-factor in the revised USLE," *J. Hydrol.*, vol. 157, no. 1–4, pp. 287–306, May 1994, doi: 10.1016/0022-1694(94)90110-4.
[56] "SSURGO | NRCS Soils." https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr12/tr/?cid=nrcs142p2_010596 (accessed Mar. 17, 2020).
[57] "Web Soil Survey - Finished." https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx (accessed Apr. 01, 2020).
[58] R. Benavidez, B. Jackson, D. Maxwell, and K. Norton, "A review of the (Revised) Universal Soil Loss Equation ((R)USLE): with a view to increasing its global applicability and improving

soil loss estimates," *Hydrol. Earth Syst. Sci.*, vol. 22, no. 11, pp. 6059–6086, Nov. 2018, doi: 10.5194/hess-22-6059-2018.
[59] H. A. Adornado, M. Yoshida, and H. A. Apolinares, "Erosion Vulnerability Assessment in REINA, Quezon Province, Philippines with Raster-based Tool Built within GIS Environment," *Agric. Inf. Res.*, vol. 18, no. 1, pp. 24–31, 2009, doi: 10.3173/air.18.24.
[60] "owm0274.pdf." Accessed: Jan. 21, 2020. [Online]. Available: https://www3.epa.gov/npdes/pubs/owm0274.pdf.
[61] M. B. Haas, B. Guse, and N. Fohrer, "Assessing the impacts of Best Management Practices on nitrate pollution in an agricultural dominated lowland catchment considering environmental protection versus economic development," *J. Environ. Manage.*, vol. 196, pp. 347–364, Jul. 2017, doi: 10.1016/j.jenvman.2017.02.060.
[62] Y. Wu, L. Yang, F. Büyüksönmez, R. E. Beighley, Z. Gu, and M. Grey, "Evaluation of Soil Erosion and Sediment Control Products for Release of Heavy Metals," *Environ. Eng. Sci.*, vol. 27, no. 10, pp. 905–914, Oct. 2010, doi: 10.1089/ees.2010.0149.
[63] J. Renkenberger *et al.*, "Effectiveness of Best Management Practices with Changing Climate in a Maryland Watershed," *Trans. ASABE*, vol. 60, no. 3, pp. 769–782, 2017, doi: 10.13031/trans.11691.
[64] D. J. Wachal, "Characterizing Storm Water Runoff from Natural Gas Well Sites in Denton County, Texas," p. 133.
[65] U. G. W. Clyde, "Determining Urban Stormwater Best Management Practice (BMP) Removal Efficiencies," p. 32.
[66] "CHAPTER 6 ROAD CONSTRUCTION TECHNIQUES." http://www.fao.org/3/T0099E/T0099e06.htm (accessed Feb. 12, 2020).
[67] "Oklahoma Department of Transportation." http://gis-okdot.opendata.arcgis.com/ (accessed Mar. 29, 2020).
[68] "RUSLE2 Users Reference Guide." USDA agricultural research service Washington, D.C., 2008.
[69] "USDA:NRCS:Geospatial Data Gateway:Order Data." https://gdg.sc.egov.usda.gov/GDGOrder.aspx (accessed Mar. 17, 2020).
[70] "gSSURGO_UserGuide.pdf."
[71] "Home | NRCS Soils." https://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/ (accessed Mar. 17, 2020).
[72] F. Karamage *et al.*, "USLE-Based Assessment of Soil Erosion by Water in the Nyabarongo River Catchment, Rwanda," *Int. J. Environ. Res. Public. Health*, vol. 13, no. 8, p. 835, Aug. 2016, doi: 10.3390/ijerph13080835.
[73] "726.pdf." Accessed: Mar. 22, 2020. [Online]. Available: https://www.tucson.ars.ag.gov/unit/publications/PDFfiles/726.pdf.
[74] P. Chuenchum, M. Xu, and W. Tang, "Estimation of Soil Erosion and Sediment Yield in the Lancang–Mekong River Using the Modified Revised Universal Soil Loss Equation and GIS Techniques," *Water*, vol. 12, no. 1, p. 135, Dec. 2019, doi: 10.3390/w12010135.
[75] "Custom Soil Resource Report for Baca County, Colorado, and Cimarron County, Oklahoma," p. 56.
[76] "Web Soil Survey - Finished." https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx (accessed Apr. 01, 2020).

APPENDIXES

7-1 Appendix 1 – BMPs Categories

Table 7-1 Application for BMPs Based on Construction Activities

ESC Best Management Practices	Construction Activities												Post Construction
	Site Preparations	Clearing and Grubbing	Stripping	Borrow Pits	Stockpiles	Cut Slopes	Fill Slope	Ditches/Channels	Culverts	Temporary Haul Roads	Soil Stabilization	Sediment Containment	Post Construction Monitoring
Reinforced Silt Fence	√	√	√	√	√	√	√		√	√		√	
Gabions								√	√				√
Compost Blanket					√	√	√			√			√
Fiber Rolls and Wattles				√	√	√	√					√	
Berm interceptor		√	√	√	√	√	√			√			√
Storm Drain Inlet								√	√				√
Rock Check Dam								√				√	√
Silt Dike								√				√	
Rolled Erosion Control Products (RECP)					√	√	√	√					√
Riprap Armoring								√	√				√
Cellular Confinement System						√	√	√					√
Energy Dissipators								√	√				√

Sediment Traps and Basins			√					√				√	√
Slope Drains						√	√						√
Seeding				√	√	√	√	√			√		√
Mulching				√	√	√	√	√			√		√
Straw Mulching and Crimping (Straw Anchoring)				√		√	√				√		√
Hydroseeding				√	√	√	√	√			√		√
Hydromulching				√	√	√	√	√			√		√
Topsoiling				√	√	√	√	√					√
Sodding				√	√	√	√	√			√		√
Riparian Zone Preservation		√	√	√	√	√	√	√	√	√			√
Stabilized Worksite Entrances	√	√	√	√	√	√	√	√	√	√			√
Slope Texturing				√	√	√	√			√			√

Table 7-2 Erosion and Sediment Control BMPs based on their application

ESC Best Management Practices	Applications				ESCs Type				Functional longevity	
	Slope	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Erosion Control -Source Control	Erosion Control -Runoff Control	Sediment Control Filling and Entrapment	Sediment Control Impoundment	Temporary	Permanent
Berm Interceptor	√		√	√			√		√	√
Cellular Confinement System	√	√			√					√
Compost Blanket	√		√	√	√		√		√	

Energy Dissipator	√	√				√				√
Gabions		√				√	√			√
Hydroseeding	√	√	√	√	√				√	
Hydromulching	√	√	√	√	√				√	
Mulching	√	√	√	√	√				√	
Riparian Zone Preservation	√	√	√	√	√		√		√	
Riprap Armoring	√	√			√					√
Rock Check Dam		√		√		√	√		√	√
Rolled Erosion Control Product (RECP)	√	√			√				√	√
Fiber Rolls and Wattles	√					√	√		√	
Sediment Traps/ Basins		√		√				√		√
Seeding	√	√	√	√	√				√	√
Reinforced Silt Fence	√		√	√			√		√	
Slope (Down) Drains	√					√			√	√
Slope Texturing	√		√	√	√	√			√	
Sodding	√	√	√	√	√				√	√
Storm Drain Inlet/Sediment Barrier			√				√		√	
Straw Mulching and Crimping (Straw Anchoring)	√			√	√				√	
Silt Dike		√				√	√		√	
Topsoiling	√	√	√	√	√				√	√

7-2 Appendix 2 – Oklahoma Department of Transportation's BMPs database

Comments	County	Project #	Center of Project	Endpoints	City	Total Area	Disturbed Area	Soil Type	BMPs
Grade, Drain Bridge and Surface	Canadian	STPY-009C(247)	35.5441/-97.7424	35.5290/-97.7424 35.5578/-97.7453	Yukon	56.5	32	Dale Silt Loam	Sod, Mulch, Silt Fence, Silt Dikes, Rock Filter Dam, Paved Ditch with liner, Rip Rap
Resurface Asphalt	Texas	NHPP-008N(092)FP							
Interchange	Pittsburg	NHPP-261N(084)	34.910278 - 95.745278	34.8936/-95.7753 34.9317/-95.7383	McAlester	49.42	37.28	Sandy Clay	SF, SD, Fiber Log, RipRap, Inlet Sed Filter, Paved Ditch, Sed Filters
Reviewed 9/11/18; email to Mark Murphy	Beckham, Washita, Kiowa	STP-038B(232)SS	35° 7' 3" / -99° 21' 37"	35.0741 / -99.3600 35.1603 / -99.3603	Sentinel	167.4	150.35	Silt Loam	SF, sed filter, SD, RFD, Sod, RR
Grade, Drain & Surface	Alfalfa	ACSTP-102B(025)SS	36.5789/-98.4622	36.5790/-98.4265 36.5787/-98.4800	Carmen	32.35	28.23	Stony Silt Loam	SF, SD, Paved Ditch, Sod, Seed, Mulch
Grade, Drain, Bridge & Surface	Alfalfa	STP-102B(025)SS							
Reconstruct Added Lanes	Oklahoma								
Grade Drain Surfacing and bridge	Cleveland		35.1894/-97.30722	35.1892/-97.3360 35.2319/-97.1769	Norman	104.84	83.07	Silty Sand -Sandy Lean Clay	Sod, Mulch, SF, SD, Paved ditch w Liner, Sed Basins, Sed Filters, Rip Rap
Reviewed 8/27/18; email to Randy	Grady	STP-126C(063)	35° 18' 18" / -97° 53' 44"	35.3080 / -97.9330 35.3052 / -97.8620	Minco	84.78	45.73	Stony Clay	SF, Sed filter, SD, Sod, RR
Reviewed 3/7/19-KT. Emailed 3/6/19 for revisions	Pawnee	J2-0314(004)	36.3272/ -96.7883	36.3379/-96.8007 36.3135/-96.7784	Pawnee	28.05	12.28	Foraker-shilder/ Lucien Complex	Sod, Sedding, Veg Mulch, SF, SD, RFD, Paved Ditch, Sediment Filter, Sediment Removal, Rip Rap
Interchange, Emailed Erin 2/26	Rogers and Tulsa	NHPPI-0044-2(422)238	36.1625/-95.7945	36.1625/-95.8028 36.1625/-95.7847	Catoosa, Tulsa	59.93	27.32	Apperson, Dennis, and Summit series	
State Highway Reviewed5/6/19-KT emailed Julianne for revisions	Cimarron	NHPP-034N(001)PM	36.7297/-102.5131	36.7319/-102.5125 36.7275/-102.5131	Boise City	11.16	11.16	Sherm clay loam	
Grade, Drain & Surface	Texas	NHPP-008N(090)FP	36° 55' 51" / -101° 06' 12"	36.906871 / -101.139442 36.940054 / -101.090124	Tyrone	83.4	57.1	Sandy Lean Clay	Sod, Veg Mulch, SF, SD, RFD
Email Faulkner 6/3/19	Grady	J2-0962(004)	41	No	No/East Bill's Creek	34.93472/-98.05027			
Grade Drain Surfacing	Cleveland	STPY-114C(111)	35.053611/ -97.335556	35.0714/-97.3353 35.0211/-97.3359	Lexington	60.3	35.3	A-4A-6	SF, SD, RFD, Paved Ditch w/ protection, Sed Basins, Sed Filters, Sed Removal, Rip Rap, Inlet Sed Filters, Sod, Seed, Mulch
Reviewed at 90%	Seminole	XXXX-XXXX(XXX)	35d 11' 26"/ -96d 36' 01"				93.5, 146 or 252?		
Bridge & Approaches	Seminole	FTP-167B(122)PM	35° 10' 33" / -96° 34' 57.6"	35.1778 -96.5849 35.1690 -96.5752	Lima	39.7	19.77	Silty Sand	SF, Fiber log, Sod
Resurface	Okfuskee Co	NHPPI-4000-(077)PM	35.4307/-96.2049	35.4295/-96.2060 35.4300/-96.2034		265	2.73	Silty Clay	temporary fiber log
	Pottawatomie	SSP-163C(328)SS	35.2606/-97.0539	35.3043/-97.0539 35.2589/-97.0543		84.08	48.22	Sandy Loam	seed/ sodd, veg mulch, SF, SD, RFD, paved ditch liner, temp sediment filter, RR
	Pontotoc	STP-162B(187)SS						Fine Sandy Loam, Loamy fine sand	Seed/ Sodd, Veg Mulch, Stabalized construction exit,

									SF, SD, RFD, Paved ditch liner, Sediment filters, RR
Grade, Drain, & Surface	Seminole	SSP-167C(102)SS	35° 14' 0.56" / -96° 32' 44.20"	35.239448 / -96.555396 35.232858 / -96.537672	Wewoka	25.38	14.71	Fill Soil, Sandy Loam, Clay Loam	Sod, Veg Mulch, SF, SD, RFD, Paved Ditch
Silane Project	Cleveland/ McClain/ Garvin/ Seminole/ Hughes	STP-262F(054)PM							
Bridge Waterproof Seal	Choctaw, Atoka, McCurtain, Marshall								
Bridge and Approaches	Pawnee	STP-159B(058)SS	36.3011/-96.4638	36.3012/-96.4638 36.3007/-96.4636	Cleveland	15.62	4.96	Silty Sand with Gravel	SF, SD, Perimeter Dikes, Slope Drain, Paved Ditch w/ Liner protection, Mulch, Sod, Seed
Grain, Drain, Resurface Reviewed 5/29/19-KT	McClain	NHPPI-0035(297)SS	35.1535/-97.4781	35.1578/-97.4813 35.1466/-97.4706	Goldsby	67.65	12.90	Silty Loam, Clay Loam	Seed/Sodd, Veg Mulch, SF, Temp Fiber Log, Temp Sediment removal
Widen and resurface, reviewed 3/22KT	Pontotoc	STP-162B(207)SS	34.7067/ -96.6350	34.7128/-96.6345 34.6812/-96.6348	Ada	60.08	36.37	Clay, Silty Clay and Clay Loam	Seed/ Sodd, Stabalized construction exit, SF, SD, RFD, Paved Ditch liner, Temporary sediment filters, Inlet sediment filter
Reviewed 6/28- KT Emailed amanda for revisions	Pontotoc	SSP-162B(192)SS	34.6718/-96.6345			28.35		Durant Loam Hieden Clay	seed/ sodd, veg mulch, SF, SD, RFD, paved ditch, temporary sediment removal
	Alfalfa	STP-102B(106)SS	36.7972/-98.3377	36.7974/-98.3716 36.8001/-98.2861	Cherokee	110.91	64.23	Buttermilk Silt Loam	
Saline Project	Dewey/Washita/Beckham	STP-220F(063)PM							
State Highway	Harper	SSP-130C(149)SS							
Preventatitve Maintenance	Div 4	STP-252F(053)PM							
Bridge Paint	Noble	STP-252F(054)PM							
Bridge Paint	Noble	STP-252F(055)PM							
State Highway	Pottawatomie		34.986041 - 96.985343	34.986041 - 96.985343	Asher	77.24	40.30	Port Loam	
	Pottawatomie		34*59'9.1140"/-97*02'19.280"	34*59'9.1140"/-97*02'19.280" 34*59'9.7044/-96*59'72348	Asher				
Reviewed 10/18/18; email to Ben	Washington	NHPP-018N(053)	36° 43' 41" / -95° 51' 0"	36.7280 / -95.8971 36.7280 / -95.8012	Bartlesville	116	80	Sandy Clay	SF, SD, RFD, Fiber log, RR, Sod
Bridge Water Proof Seal	Noble	STP-252F(053)PM							
Joint Seal and Repair	Leflore/ Bryan	NHPP-207N(081)PM							
Bridge Painting	Bryan	NHPP-NBIP(527)PM							
Resurfacing	Stephens	STPY-043C(141)SS	34.6378/-97.80	34.6408/-97.8441 34.6408/-97.7567	Bray	104.06	59.81	Sandy Clay Loam	
ROW Clearance for 24428(04)	Grady Co.								
Reviewed 5/22/18; email to Elyazgi	Osage	STP-157C(133)PM	36° 30' 7" / -96° 41' 28"	36.5025 / -96.6928 36.5014 / -96.6895	Ralston	4.25	3.72	Silty Sand	SF, SD, Sod, RFD, RR
Grade, Drain & Surface	Cimarron	CIRB-213C(024)RB	36° 31' 22" / -102° 04' 06"	36.500220 / -102.068308 36.544695 / -102.068187	Texhoma	27.2	16.28	Clay Loam	Sod, Veg Mulch, SF, SD, RR

Bridge and Approach Plans	Kay	CIRB-136C(162)CI	36.883611 -97.285278	36.883663/-97.286544 36.883319/-97.283411	NA	13.54	9.97	Lela Clay	SF, SD, RipRap
Grade Drain Surface & Bridge	Noble	CIRB-152C(161)RB	36.3803/-97.1753	36.3554/-97.1756 36.4058/-97.1752	Red Rock	38.92	23.65	Silty Clay	SD, SF, Rip Rap, Sod, Mulch,
Grade Drain and Surface	Noble	CIRB-252(056)RN	36.434722 - 97.175278	36.405680/-97.175321 36.463271/-97.170563	Red Rock	42.7	23.27	Silty Clay	Sod, Mulch, SF, SD, Rip Rap
Bridge	Nowata	CIRB-153D(160)RB	36^48'02"/-95^40'17"	36.8007/-95.6744 36.8003/-95.6683	Delaware	10.46	10.46	Silt Loam	SF, SD, Rip Rap, Sod, Mulch
Bridge and Approach	Osage	STP-157C(167)CI	36° 36' 13" / -96° 54' 12"	36.604763 / -96.905579 36.603220 / -96.901892	Ponca City	10.2	10.2	Silt Loam	Sod, Veg Mulch, SF, SD, RR
Grade, Drain & Surface, Final plans good to go 3/14/19	Garfield	STP-224B(056)SS	36.4344/ -97.8860		Enid	42.07	7.89	Fine Sandy Loam	Sood/ Seed, SF,
Preventative Maintenance Project	Alfalfa	STP-230F(031)PM							
Bridge Water Proof Seal	Harper	STP-230F(032)PM							
Grade Drain Surface & Bridge	Canadian	NHPP-209N(051)SS	35.5195/-97.9511	35.217/-97.9524 35.5129/-97.9477	El Reno		11		SF, SD, Fiber Log, RipRap, Inlet Sed Filter
Grade, Drain & Surface	Major								
Right of Way Clearance	Rogers	STP-266B(069)RW				206.53		Sandy lean Clay	
Reviewed 8/27/28	Logan	STP-242C(057)SS	36° 6' 58" / -97° 27' 2.5"	36.1160 / -97.4612 36.1160 / -97.4439	Mulhall	11.61	6.79	Silty Clay	SF, SD, Sed filter, RFD, Sod, RR
Reviwed at 90% 3/14/19-KT	Cherokee		35.9252/ -94.8813	35.9226/-94.8873 35.9298/-94.8687	Briggs	51.32	31.39	Gravely Silt Loam	Seed/Sod, SF, SD, RFD, Paved Ditch, Inlet Sediment Filter
Reviewed 8/27/18;	Logan	STP-242C(058)SS	36° 6' 57" / -97° 25' 53"	36.1158 / -97.4325 36.1158 / -97.4307	Mulhall	3	2.78	Loam	SF, Sed filter, SD, Sod, RR
Intersection mod	Osage								
Grade, Drain, Surface & Bridge	McClain	NHPPI-3500(074)PM	35° 07' 01" / -97° 26' 35"	35.123929 / -97.450044 35.110962 / -97.437753	Goldsby	40.42	14.1	Silt Loam Teller Loam	Sod, Veg Mulch, Construction Exit, SF, SD, Sed. Filters
Reviewed 4/17/18; email to Matt VanAuken	Tulsa	STP-172B(284)IG	36° 8' 1" / -96° 6' 58"	36.1291 / -96.1161 36.1380 / -96.1103	Sand Springs	12.5	10.9	Very Fine Sandy Loam	SF, Sed filter, Sod, RR
Reviewed 9/6/18; no email	Woodward	CIRB-177C(113)RB	36° 29' 32" / -98° 56' 38"	36.4741 / -99.0319 36.4925 / -98.9414	Mooreland	59.88	41.77	Silty Clay	SF, SD, Sod, RR
Reveiwed 9/6/18; email to Roland Sison	Coal	STP-115C(103)PM	34° 32' 7" -96° 5' 41"	34.5350 / -96.0958 34.5340 / -96.0850	Coalgate	12	8.76	Sandy Clay	SF, RFD, SD, Fiber log, Sod
Bridge Rehab	Oklahoma								
Grade, Drain, Resurface & Bridge Plans90% Review 4/10/19-KT Emailed Amanda with Changes	Garvin	J2-7830-(004)	34.7948/-98.1203	34.7972/-98.1218 34.7972/-98.1197	Fletcher	10.87	6.94	Clarita Clay & Garvin Silty Clay Loam	Sodd/ Seed, Veg Mulch, SF, SD, Paved Ditch liner, RR
Reviewed 8/14/18	Roger Mills	STP-265B(017)SS	35° 42' 57" / -99° 41' 41"	35.7124 / -99.6947 35.7195 / -99.6948	Hammon	4.98	4.98	Silt Loam	SF, SD, Sod, Exit
Grade Drain Surface	Custer	J2-7811(008)	35.5328/-98.6815	35.5328/-98.6815 35.5328/-98.6815	Weatherford	14.55	8.62	Silty/sand	Seed/ Sodd, Veg Mulch, SF, Sediment Filters, Sediment Removal
	Blaine	J2-7913(010)	35.8411/- 98.3655	35.8412/-98.4116 35.8412/-98.3478	Watonga	31.52	27.52	Silty Sand	

Reviewed 8/14/18; email to Asghar	Jackson	STP-233C(038)PM	34° 28' 46" / -99° 40' 52"	34.4794 / -99.6811 34.4793 / -99.6764	Eldorado	7.52	4.1	Sandy Clay	SF, Fiber log, Sod
Bridge & approaches, Review 3/20/19-KT	Pawnee	STP-259B(034)SS	36.3033/ -96.4638	36.3042/-96.4639 36.3019/-96.4637	Cleveland	2.24	1.27	Alluvium & Vamoosa Units	Sodd/ Seed, Veg Mulch, Stabalized Construction Exit, SF, SD, RR
Reviewed 9/11/18; email to Patty	McIntosh	NHPPI-4000(066)PM	35° 27' 28" / -95° 31' 42"	35.4582 / -95.5361 35.4576 / -95.5182	Checotah	77.9	32.1	Silt Loam	SF, SD, Sod, Sediment Basin
Reviewed 8/10/18	Stephens	STP-269C(049)SS	34° 21' 35.7" / -97° 53' 37.5"	34.3609 / -97.8947 34.3588 / -97.8926	Comanche	3.43	2.46	Loam	SF, SD, Sod
Grade, Drain & Surface, Re-Reviewed KT, 3/1/19	Garfield	STP-224B(058)SS	36.4345/ -97.8860	36.5670/-97.8289 36.4939/-97.8732	Enid	42.07	7.89	Fine Sandy Loam	Silt Fence, Sedmiment Trap, Sodding
Grade, Drain & Surface	Garfield	STP-224B(059)SS	36.564964 - 97.87298	36.536313/-97.872108 36.593256/-97.875198	NA	19.88	4.37	Fine Sandy Loam	SF, Sod
Bridge and Approach	Osage	STP-257B(035)	36.9391/-96.2048	36.9378/-96.2050 - 36.9405/-96.2046	Pawhuska		13.1		Sod, Mulch, Paved Ditch, Sed Filters, SF SD
Highway	Bryan		33.7500/-96.2000	33.7494/-96.1944 33.7656/-96.2063	Hendrix	34.86	13.25	Sandy Loam	Washout, Construction entrances, cleanup, silt fence, site inspections, trainings, seeding sodding, waste management, fiber logs, check dams
Bridge and Approaches	Osage	STP-257B(038)	36.9702/-96.1955	36.9712/-96.1955 36.9691/-96.1954	Chautauqua		11.3		SF, SD, Sed Filter, Mulch, Seed, sod,
Bridge and Approaches-Reviewed 5/28 KT	Lincoln	J2-8034(004)	35.6908/ -97.0761	35.6926/-97.0727 35.6901/-97.0780	Wellston	11.18	2.86	Teller, Ashport clay, easpur, and Pulaski I, fine sandy loams, coyle & seminole soils	sodd/seed, veg mulch, SF, SD, temporary fiber log, TSR, rip rap
Reviewed 8/17/18; email to Asghar	Cotton	STP-217C(041)PM	34° 16' 31" / -98° 23' 17"	34.2753 / -98.3894 34.2753 / -98.3810	Walters	18.09	10.53	Port Loam	Slope drain, SF, SD, Sod
Resurface Asphalt	Bryan	NHPP-022N(218)3P							
Resurface Concrete	Lincoln	STP-241C(060)3P							
Bridge & Approaches	Beaver	STP-204C(027)CI	36.732316 / -100.386239	36.732273 / -100.391861 36.732291 / -100.380145	Beaver	4	2.42	Silty Sand	RR, SF, SD, Veg Mulch, Sod
Resurface (asphalt)	Pottawatomie	SSr-2628(051)SR				3.2	2.9	Alluminum underlain by Duncan Sandstone	Seed/Sodd, Veg Mulch, SF, SD, Sediment Filters
Co Road rehab and Bridge	Haskell	CIRB-231C(040)RB	35.3002/-94.8536	35.3177/-94.8142 35.2619/-94.8675	Brent	45.58	24.5	Counts-Dela & Carnasaw Bengal Clebit Complex	Silt fence, Dikes, sodding, mulching,
Grade, Drain, Bridge & Surface	Sequoyah	CIRB-268D(058)RB	35° 26' 04" / -94° 51' 09"	35.434514 / -94.859066 35.434479 / -94.847779	Sallisaw	9.3	7.5	Silty Sand Clayey Gravel	Sod, Veg Mulch, SF, SD, RR, Const. Exit
reveiwed by Tanner 2/8/18; email to Gary Harrison	McIntosh	CIRB-246C(039)RB	35° 25' 15.2" / -95° 27' 5.2"	35.3917 / -95.4619 35.4644 / -95.4514	Checotah	30.68	20.18	Sandy Lean Clay	SF, SD, Sod, RR
Bridge & Approaches	Nowata	STP-253D(044)CI	36° 39' 48" / -95° 37' 46"	36.670186 / -95.629618 36.655521 / -95.629446	Nowta	2.54	2.54	Silty Loam	Sod, Veg Mulch, SF, SD, RR
Bridge & Approaches	Pontotoc	STP-262C(043)CI	34.8253/-96.6514	34.8251/-96.6530 34.8251/-96.6511	Ada	3.44	2.45	Darnell-Stephenville, Verdigris silty loam, newalla sandy loam,	seed/ sod, veg mulch, stabalized construction exit, SF, SD, RR, Inlet sediment filter

								verdigris and cleora soils	
	Custer	SSP-220B(064)SS	35.739722/-98.765278	35.7398/-98.7672 35.7398/-98.7638	Thomas	20.95	13.48	Silty Loam	
Reviewed by Tanner 4/2/18; email to Oscar and Leslie	Beckham	J2-8775(004)	35 14 23 / -99 23 59	35.2391/-99.3998 35.2404/-99.3998	Carter	3.55	2.95	Silt Loam	Veg Mulch, Permanent Sodd/ Seed, SF, SD,
Reviewed 9/12/18; email to Sara	Jackson	SSP-233C(039)PM	34° 31' 39" / -99° 31' 14"	34.5265 / -99.5251 34.5279 / -99.5187	East Duke	1.64	1.64	Clay Loam	SF, SD, Sod
Bridge and Approaches	Kiowa	STP-238C(052)PM	34° 38' 29.77" / -98° 54' 48.32"	34.642584 / -98.915984 34.640960 / -98.911958	Snyder	3.45	1.99	Sandy Clay	Sod, Veg Mulch, SF, SD, Rock Filter Dams
Bridge Rehabilitation/ Saline	Stephens/ Commanche/ Cotton/ Jefferson/ Love/ Carter/ Murray	STP-269F(053)PM							
Bridge Painting.Review 3/20/19-KT	Caddo/ Murry/ Carter	STP-208F(068)PM							
Bridge Joint Seal Repair	Comanche	STRP-216F(082)PM							
Bridge Joint Seal Repair	Comanche	STP-216F(082(PM							
Trail Improvements	Oklahoma	STP-155E(919)EH	35.4824/-97.3911	35.4844/-97.3932 35.4785/-97.3885	Midwest City	1.46	1.44	clayey & humus-rich soil	Construction exit, SF, SD, RR
Reviewed 9/28/18; email to Chad ALL CHANGES MADE	Oklahoma	STP-155(922)EH	35° 33' 56.5" / -97° 17' 24.5"	35.5657/-97.2915 35.5657/-97.2883	Jones	1.09	0.37	Sandy Loam	SF, Sed Filter, SD, Sod
Roman Nose Boardwalk Trail	Blaine	TAP-206E(059)TP	35.9355/ -98.4281	35.9354/ -98.4282 35.9358/ -98.4279	Watonga	1.75	1.12	Knoco-Rock Outcrop Complex 20-40% slopes	Seed, sodd/ seed, silt fence, temp fiber log, RR
Bridges and Approaches	Pushmataha	STP-264B(062)PM	34.3284/-95.4917	34.3285/-95.4926 34.3284/-95.491	Finley	10.13	2.37	Clay Loam, Silty Clay	SF, SD, Mulch, Sod
Reviewed 4/11/19- KT	Pushmataha	J2-8837(004)	34.6476/-95.1277	34.6476/-95.1277 34.6493/-95.1249	Tuskahoma	3.02	0.8	Gravely Silt Loam	SF, SD, Seed/ Sodd, Veg Mulch
Traffic Lights	Cleveland								
Reviewed 10/22/18	Pottawatomie	STP-263C(066)PM	35° 19' 59.5" / -96° 50' 41"	35.3332 / -96.8497 35.3332 / -96.8393	Shawnee	11.4	8	Fine Sandy Loam	SF, RFD, fiber log, RECP, Sod
Reviewed 10/19/18; no email	Garvin	SSP-8938(004)	34° 42' 46" / -97° 24' 19"	34.7109 / -97.4054 34.7138 / -97.4054	Antioch	2.9	2.9	Fine Sandy Loam	SF, SD, RFD, Sod
Reviewed 6/18/18; Mandatory tie to 29760(04); email to Mattie	Okmulgee	NHPP-256N(034)PM	35° 44' 16.7" / -96° 0' 17.3"	35.7074 / -95.9867 35.7601 / -96.0149	Beggs	4.63	2.27	Silty Clay	Sed filt, Sod, SD
I40 Rehab	Sequoyah	NHPPI-4000-(076)PM	35.4933/-95.0075	35.686/-94.9377 35.4897/-95.0795	Vian	436.15	181.4	Stony Fine Sandy Loam	Silt Dikes, Silt Fence, Sodding, Sed Filters
Reviewed 8/14/18	Beckham	STP-205N(078)PM	35° 25' 19" / -99° 23' 15"	35.4219 / -99.3936 35.4220 / -99.3824	Elk City	5.4	2.66	Fine Sandy Loam	SF, Sed Filter, SD, RFD, Sod
Reviewed 8/30/18; email to Sara	Beckham	STP-205C(079)PM	35.2141 / -99.9059	35.2152 / -99.9121 35.2150 / -99.8985	Erick	7.62	4.48	Silt Loam	SF, Sed Filt, SD, RFD, Sod
Resurface Asphalt	Texas	SSR-008(084)SR							
Bridge Rehabilitation	Washita	SBR-275C(048)SB							
Reviewed 3/14/19 KT	Cleveland	STP-214B(068)AG	35.2108/ -97.4059	35.2162/-97.4060 35.2042/-97.4057	Norman	12.86	10.58	Lean Clay w/ Sand to sandy lean clay	Sodd/ Seeding, SF, SD, Sediment Filters, temporary fiber log
Widening and Reconstruction	Cleveland	STP-214B(069)AG	35.2253/-97.4056	35.2183/-97.4959 35.2327/-97.4056	Norman	14.49	11.83	Lean Clay with Sand, Silty Sand	Temp Sed Filter, SF, SD, Sod, Fiber Log,
Bridge and Approaches	Marshall	STP-248D(044)CI	34.118056/-96.910833	34.1165/-96.9113 34.1192/-96.9113	Oakland/McMillan	2.21	1.15	Sandy Loam	Silt Fence, Silt Dikes, Rip Rap
Bridge and approach	Jefferson	STP-234D(046)	34.2464/-97.6325	34.2472/-97.6326 34.2457/-97.6326		1.13	0.49	Port-oscar complex	seed/ sodd, eg mulch, SF, SD, RFD, RR
Bridge & Approaches	Muskogee	CIRB-251C(095)RB	35° 49' 38" / -95° 45' 32"	35.827236 / -95.764419	Haskell	4.33	3.22	Silty Sand and Clay	Sod, Veg Mulch, Const. Exit, SF, SD, RR

				35.827354 / -95.754578					
Bridges & Approaches	Okmulgee	CIRB-256D(049)RB	35° 36' 47" / -96° 5' 10"	35.611700 / -96.086246 35.620561 / -96.086220	Okmulgee	?	3.04	Silt Loam	Sod, Veg Mulch, SF, SD, RR
Bridge & Approach Reviewed 3/28/19-KT	Murray	CIRB-250C(021)RB	34.4992/-97.1580	34.4994/-97.1571 34.4984/-97.1584	Davis	4.82	1.08	Vanoss Unit Enderlain by Oscar Unit	Seed/Sodd, Veg Mulch, SF, SD, RR
Bridge and Approach	Tillman/Jackson		34*30'25.81/-99*12'26.34"		Tipton	24.2	14.08	Jester Loamy Fine Sand	Riprap,SF,SD,Sod
Reviewed 9/21/18; email to Oscar and Mark Claravall	Custer	SSP-4000(067)PM	35° 32' 13" / -98° 38' 27"	35.5364 / -98.6430 35.5365 / -98.6389	Weatherford	?	1	Silt Loam	SF, Sed filter, SD, fiber log, Sod
Bridge Painting 4/16 JG	Custer, Beckham, Washita, Tillman	SSP-220F(065)SS							
Bridge & Approach, Reviewed 90% KT 5/14/19	Garvin		34.6418/-97.1779	34.6440/-97.1895 34.6424/-97.1733	Wynnewood	25.25	19.31	Silty Clay Loam	Seed/ Sodd, SF, SD,
Bridge Rehabilitation	Lincoln	SBR-241C(012)SB							
Reviewed 2/25 KT& JG	Rogers	NHPP-019N(135)PM	36.16458/-95.62341	36.1647/-95.6194 36.1647/-95.6281	Dover	62.6	10.71	Osage Clay, Osage silt clay loam	
Bridge Rehabilitation	Garvin	SBR-9608(004)SB							
Bridge & Approaches	Johnston	STP-235C(037)PM	34° 21' 40.96" / -96° 37' 24.48"	34.361201 / -96.629101 34.361222 / -96.615798	Milburn	13.56	7.11	Silty Clayey Sand	Sod, Veg Mulch, SF, SD, RR
Reviewed 11/7/18; email to Leslie	Okmulgee	NHPP-256N(045)PM	35° 26' 38.9" / -95° 58' 8"	35.4411 / -95.9704 35.4535 / -95.9643	Henryetta	27.93	12.84	Silt Loam	SF, Sod
Interstate HWY	Tulsa	J2-9693(004)	36.0889/-96.0296	36.0889/-96.0324 36.0890/-96.0269	Tulsa	9.4	8.18	Light Yellow to Sandy Clay	SF SD RFD Sod Fiber Logs
Bridge and Approaches	Tulsa	NHPPI-4400-(054)PM	36.088913/-96.011677	36.086382/-96.011934 36.089676/-96.011591	Tulsa	5.15	9.96	Silty Clay	SF, SD, Fiber Log, RR, Inlet Sed Filter, Sod, RFD
Bridge Rehab	Coal	J2-9731(004)							
Resurface 35	McClain	NHPPI-3500-(077)PM	34.9271/-97.3613	34.9381/-97.3665 34.9139/-97.3555	Wayne	180	2.25	Silt Loam, Silty Clay	Fiber Log
Bridge & Approach	Seqouyah	NHPPI-4000-(075)PM							
Reviewed 6/18/18; Mandatory tie to 28967(04); email to Mattie	Okmulgee	HSIPG-256N(041)PM	35° 41' 19" / -95° 58' 21"	35.6663 / -95.9620 35.7074 / -95.9867	Okmulgee	88.55	13	Silty Loam	Sod, Sed Filter, SD
Can't find plans in PW or PD	Pontotoc	STP-262C(045)3P							
	Delaware	STP-221D(043)CI							
Grade, Drain, Bridge & Surface	Jefferson	CIRB-234C(045)RB	34° 1' 3" / -98° 2' 6"	34.013405 / -98.034980 34.085942 / -98.034534	Waurika	55.46	34.15	Easpur Loam	Sod, Veg Mulch, SF, SD, RR
Bridge & Approaches	Atoka	STP-203D(069)CI	34° 35' 37" / -95° 53' 21"				2.5		
Bridge	Stephens	STP-269D(055)Cl	34.5069/-97.9183	34.5071/-97.9198 34.5071/-97.9169	Duncan	2.66	2.66	Hennessey Unit	
Reviewed 11/5/18; email to Brandon Dudgeon	Atoka	CIRB-203C(067)RB	34° 19' 0" / -96° 10' 38.3"	34.3169 / -96.1859 34.3169 / -96.1696	Tushka	9.7	4.25	Sandy Loam	SF, SD, Sod
Reviewed 11/1/18; email to Brandon Dudgeon	Marshall	CIRB-248D(040)RB							
Bridge & Approaches	Pittsburg	STP-261D(083)CI	34° 56' 58" / -96° 01' 27"	34.948709 / -96.024905	McAlester	2.05	1.22	Silt Loam	Temp. Seeding, Sod, Veg Mulch, SF, SD, RR

				34.950455 / -96.023171					
Co. Bridge	Blaine	CIRB-206D(048)RB	36.0733/-98.4233	36.0740/-98.4234 36.0727/-98.4234		3.99	3.07	Norge Loam, Yahola and Port Soils, Lovedale Fine Sandy Loam	SF SD Sod Mulch Rip Rap, Paved Ditch
Bridges and Approaches	Blaine	CIRB-206D(049)RB							
County Bridge	Kiowa	STP-238D(056)CI							
Bridge Paint	Tulsa	SSP-272F(268)SS							
Reviewed 4/27/18; email to Mark Murphy	Beckham	STP-205B(076)PM	35° 17' 0" / -99° 38' 24"	35.2777 / -99.6399 35.2887 / -99.6399	Sayre	14.3	5.59	Loamy fine Sand	SF, sed filter, SD, Sod
Reviewed 7/5/18; email to Greg	Love	NHPPI-3500-(061)SS	33° 51' 11" / -97° 8' 3"	33.8536 / -97.1387 33.8536 -97.1316	Marietta	4.87	3.31	Loam	SF, SD, Sod
Resurface	Bryan	NHPP-13N(174)PM	34.193786 - 96.241575	34.135733/-96.269305 34.228890/-96.224330	Caney	34.7	1.43	Clay Silty Clay	SF Sod Mulch
Resurface Asphalt	Marshall	SSR-248C(046)SR							
Concrete Pavement Rehabilitation, No environmental notes included	Kingfisher	STP-237B(049)PM							
	Carter	STP-210D(071)CI							
County Bridge and Approach Reviewed 5/6/19-KT	Carter	STP-210D(070)CI	34.4634/-97.5236	34.4639/-97.52288 34.4626/-97.5234	Ratliff City	2.56	2.56	Addington Unit	
Bridge & Approaches	Nowata	STP-253D(045)CI	36° 37' 35" / -95° 31' 02"	36.626733 / -95.521643 36.626527 / -95.503618	Nowata	1.74	1.74	Silty Clay Loam	Sod, Veg Mulch, SF, SD, RR
Bridge Rehab	Tulsa	NHPPI-2440-(016)PM							
Intersection Modification, Emailed Amanda 3/1/19	Cleveland	STP-214B(091)AG	35.2439/-97.4804	35.2439/-97.4804	Norman	1.16	0.29	Bethany Silt Loam, Kirkland Silt Loam, Kirkland-Urban, Land-Pawhuska	Fiber log, temporary sediment filter, inlet sediment filter, sod
	Washington	CIRB-274D(O24)RB	36.4825/-95.8842	36.4836/-95.8842 36.4817/-95.8842	Ramona	3.27	3.27	Verdigris Silt Loam	Silt Fence, Silt Dikes, Rip Rap, Sod, Mulch
Pavement Rehab	Noble	SSR-252C(047)							
Resurface Asphalt	Noble	SSR-252C(044)SR							
Resurface Asphalt	Noble	SSR-252C(042)SR							
	Grant		36.7877/-97.7455		Medford	34.14	3.15	Silt Loam	Seed/ Sod, SF, SD, Veg Mulch
Water proff seal	Muskogee	STP-251(098)PM							
Joint Seal/ Repair	Muskogee	NHPPI-4000(079)PM							
Bridge & Approaches	McCurtain	STP-245D(055)CI							
Co Bridge	Custer	STP-220C(067)CI	35.7912/-99.0439		Arapaho	2.81	2.13	Clairmont Silt Loam	SF SD Rip Rap
Bridge & Approaches	Ottawa	CIRB-258D(051)RB				0.56	0.56	Osage Verdigris Complex	
Bridge Rehab	Ottawa	CIRB-258D(049)RB	36.9728/-94.8462	36.9738/-94.8471 36.9717/-94.8456	Cardin	1.84	1.28	Verdigirs Silt Loam	

Bridge & Approaches	Rogers	STP-266D(064)CI	36° 23' 16" / -95° 34' 44"	36.388723 / -95.578950 36.387362 / -95.578977	Claremore	1.74	1.74	Silty Loam Clay	Sod, Veg Mulch, SF, SD, RR
Bridge & Approaches	Rogers	STP-266D(065)CI	36° 51' 05" / -95° 36' 01"	36.387107 / -95.585456 36.387052 / -95.582372	Claremore	2.3	2.3	Silty Loam Clay	Sod, Veg Mulch, SF, SD, RR
Grading, Surfacing & Drainage	Tulsa	STP-272B(258)IG	33° 18' 01" / -95° 50' 53"	36.293445 / -95.848233 36.306899 / -95.848130	Owasso	15.2	13	Lean Clay w/ Sand and Clayey Sand w/ Gravel	Sod, SF, SD, Rock Filter Dams, RR, Inlet Sediment Filters
Reviewed 6/25/18; email to Sara and Michael Sharkness and Asghar Molla esmail	Beckham	NHPPI-4000-(061)PM	35° 23' 22" -99° 24' 9"	35.3852 / -99.3999 35.3944 / -99.4051	Elk City	7.5	7.5	Silt Loam	SF, sed filter, SD, RFD, Sod
Concrete Pavement Rehabilitation	Oklahoma	NHPPI-4400-(037)PM	35.4228/-97.5775	35.4603/-97.5757 35.3963/-97.5749	Oklahoma City	250	1.74	Sandy Lean Clay	Temp Seed, Veg Mulch, SF, SD, Temporary Fiber Log, Temporary Sediment Filter
Bridge Rehabilitation	Oklahoma	NHPPI-4400-(039)PM							
Bridge Rehabilitation	Oklahoma	NHPPI-4400-(040)PM							
Pavement Rehab	Creek	STP-219B(071)PM							
Brdige Rehab	Washita								
Resurface Asphalt	Greer/ Beckham	STP-205F(082)3P							
Bridge & Approach	Ellis Co.	STP-223C-(019)CI	36.4931/-99.9558	36.4931/-99.9565 36.4932/-99.9553	Catesby	2.09	1.58	Lincoln Loamy Fine Sand	seed, sodd, silt dike, silt fence
Bridge & Approach	Tillman	STP-271D(065)CI	34.2617/-99.0592	34.2617/-99.0595 34.2617/-99.0588		2.06	1.54	Tillman and Foard Soils	Seed/ Sod, Veg mulch, SF, SD, RR
Bridge Rehabilitation, Reviwed 2/25 by Kathryn SWMP has correct information	Le Flore	SBR-240C(072)SB	34° 41' 43" / -94° 49' 54"	34.695354 / -94.834891 34.695368 / -94.827798	Lenox	5.58	1.87	Alluvium	Temp. Seed, Sod, Veg Mulch, SF, SD
County Bridge	Atoka	STP-203D9060)CI	34.2828/-95.9617	34.2869/-95.9710 34.2792/-95.9551	Lane	1.6	1.1	Carnasaw-Clebit-Pirum	Sodd/ Seed, SF, SD, RR
Bridge & Approaches	Pawnee	STP-259D(051)CI	36.289895 / -96.852231	36.289895 / -96.853647 36.290033 / -96.849098	Glencoe	4.65	2.76	Sandy Loam	Sod, SF, SD, RR
County Bridge	Canadian County	STP-209C(071)CL	35.3913/-97.9730	35.3912/-97.9734 35.3914/-97.97247	Union City	9.27	6.72	Alluvium, Dog creek unit	
Resurfacing Plans	Atoka	STP-203C(068)CI							
Bridge & Approaches	Choctaw	STP-212D(044)CI							
Grading Drainage and surfacing plans	Pontotoc	CIRB-262C(048)RB	34.6219/-96.6877	34.6249/-96.6347 34.6221/-96.7396	ADA	71.2	54.3	Lean clat, fat clay, clayey and silty sand	Sod, SF, SD, Paved ditch, TSR, Rip rap
New Bridge	Cleveland	STP-214D(088)CI							
Bridge Rehab 4/16	Carter								
Bridge Rehab 4/16	Murray	SBR-3500(080)SB							
Resurface Asphalt	Mccurtain	SSR-016N(012)SR							
Resurface Asphalt	Bryan	NHPP-022N(219)3P							
Reviewed 10/19/18	Sequoyah	SBR-268F(051)SB							

Resurface Asphalt	Rogers	SSR-266C(066)SR							
Resurface Asphalt	Rogers	SSR-266C(057)SR							
Bridge Rehabilitation	Craig	SBR-218C(074)SB							
Bridge Rehab	Craig								
Bridge Rehabilitation	Creek	J3-136(004)SB							
Bridge Rehabilitation	Delaware	SBR-221C(045)SB							
Bridge Rehabilitation	Nowata	SBR-253C(046)SB	36° 51' 05" / -95° 36' 01"	36.851396 / -95.601376 36.851348 / -95.599672	Lenapah	1.73	1.39	Clay Silty Clay Loam	Sod, Veg Mulch, SF, SD
Bridge Rehabilitation	Tulsa	SBR-272N(257)SB							
Resurface Asphalt	Grant	SSR-227B(026)SR							
Resurface Asphalt	Okmulgee	SSR-256N(042)SR							
Bridge and Approaches	Love	CIRB-243C(031)RB	33.7614/-97.1245	33.7635/-97.1239 33.7594/-97.1239	Thackerville	4.58	2.73	Fine Sandy Loam	
Grading, Surfacing, Drainage for Paved Trail	Oklahoma	TAP-255D(327)AG							
Sidewalk Improvement Project	Rogers								
Recontruct - No Added Lanes	Oklahoma	STP-255B(455)AG	35° 28' 43" / -97° 33' 23"	35.474264 / -97.569564 35.477059 / -97.563951	Oklahoma City	10.68	1.43	Fine Loam	Sod, SF, Inlet Sediment Filter
Street Widening	Oklahoma	STP-255B(461)AG	35D26'8.81	35.4353/-97.3882 35.4353/-97.3712	Midwest City		4.9	Harrah Fine Sandy Loam, Stephenville Newalla Complex	Silt Fence, sod/seed
Vehicle Impact Repair	Cleveland	SAP-214N(095)ES							
	Blaine	STP-206B(055)3P							
Resurface Asphalt	Major	SSR-247C(023)SR							
Resurface Asphalt	Alfalfa	SSR-202C(038)SR							
Resurface Asphalt	Alfalfa	SSR-202C(039)SR							
Resurface Asphalt	Kiowa	STP-238B(054)3P							
Resurface	Alfalfa	ACSTP-202C(037)CI,							
Grade, Drain and Surface	Cimarron	STP-213C(026)CI	36° 40' 32" / -102° 32' 8"	36.675673 / -102.553356 36.675631 / -102.517325	Boise City	16.17	9.8	Sandy Lean Clay	Sod, Veg Mulch, SF, SD
Bridge Rehabilitation	Blaine	SBR-206B(060)SB							
Grade Drain and Surface	Harmon	J3-1825(004)	34.798274/-99.912231	34.713089/-99.912574 34.896326/-99.914634	McKnight	9.70	4.19	Silty Sand	SF, SD, Sed Filters, Concrete Blanket
Resurface Asphalt	Seminole	SSR-1830(004)SR							
Resurface Ashpalt	Garvin	NHPPI-3500-(051)SS							

Grade Drain Surfacing	Johnston Co	NA	34.220978/-96.674183	34.2405/-96.6879 34.2359/-96.6794	Tishomingo	20.22	8.01		Rock Filter Dams, Temp Sed Filters, SD, Fiber Log, SF, Sod, Mulch
Reviewed 2/7/2019, Emailed Julianne For Revisions 2/26	Grant	STP-227C(023)Cl	36.85516/ -97.82139	36.81088/ -97.82149 36.85516/ -97.8212	Clyde	25.23	14.9	Silt Loam	
Need plans to review, NOI says 172 acres disturbed. Emailed Angie 5/3/19	Bryan	NHPP-207N(083)RW	33.9372/ -96.4233	33.9455/ -96.4174 33.9268/-96.4337	Calera and Durant	215.65	172.95	Sandy Fat Clay to lean clay with sand	Permanent sodd/ seed, veg mulch, SF, SD, Temporary Fiber Log, Paved Ditch w/ ditch liner, temp sediment basin, RR, Inlet sediment filter
Bridge Approach	Tulsa	J3-1885(004)	36.2058/-95.9681	36.2060/-95.9699 36.205833/-95.9681	Tulsa	4.6	1.93	cl	Seed, Sod, Construction exit, Silt fence, Silt Dike, Temp Sed Filters, Mulching
Bridge and Approach	Jefferson	ERSTP-234C(033)CI	34° 00' 46" / -98° 00' 42"	34.012692 / -98.014571 34.012941 / -98.008434	Ryan	1.27	1.27	Minco Loam	Sod, Veg Mulch, SF, SD, RR
Bridge Rehab	Kay	SBR							
Bridge Rehabilitation	Oklahoma	NHPPI-4400(041)PM							
Resurface Asphalt	Osage	STP-257C(070)3P							
Resurface Asphalt	Rogers	STP-266C(067)3P							
Resurface Asphalt	Osage	STP-257C(071)3P							
Bridge Seal(Not the mammal)	Tulsa	SSP-272F(267)SS							
Joint Seal (Still not the mammal)	Washington	SSP-272F(269)SS							
Resurface Asphalt	Grady	STP-226B(076)3P							
Resurface Asphalt	Stephens	SSR-011N(103)SR							
Bridge Rehab	Garvin	SBR-3500(083)SB							
Resurface Asphalt	Pushmataha, Mccurtain	SSR-017N(253)SR							
Bridge Repair	Dewey	ERSTP-222C(021)ER							
Resurface Asphalt	Adair	SSR-201N(037)SR							
Resurface Asphalt	Haskell	STP-231B(037)3P							
Resurface Asphalt	Okmulgee	STP-256B(048)3P							
Resurface Asphalt	Sequoyah	SSR-268C(054)SR							
Resurface(asphalt)	Oklahoma/ Canadian								
Grade, Drain & Surface	Tulsa	STP-272C(261)CI	36° 16' 43" / -95° 54' 33"	36.278680 / -95.909566 36.278452 / -95.893910	Owasso	6.25	6.25	Silt Loam	Sod, Veg Mulch, SF, SD
Bank Protection	Oklahoma	ACERSTP-255N(358)ER							
Resurface Asphalt	Marshall	STP-248C(038)CO							
Resurfacing Plans	Marshall	STP-248C(038)CI							
Resurfacing Plans	Marshall	CIRB-248D(041)RB							

Resurfacing	Pittsburg	CIRB-261C(089)RB	34.7675/-96.0750	34.7686/-96.0795 34.7540/-96.0215	Ashland	10.667	0.0	Bates Fine Sandy Loam	
Grading, Draining & Surfacing	Wagoner	STP-273C(051)CI	35° 59' 18" / -95° 45' 11"	35.988375 / -95.761371 35.988340 / -95.744041	Broken Arrow	7.388	7.019	Coweta-bates and dennis silt	Sod, SF, Construction Exit
Grade, Drain, Bridge & surface plans	Sequoyah	STp-268C(056)CI	35.5156/-94.8850	35.5358/-94.8854 35.4531/-94.8851	Pinhook Corner	74.53	52.33	Hector-Linked-Enders Complex	seed/ sod, veg mulch, SF, SD, RR
Intersection, Re-Reviewed 3/14/19 & Emailed Leslie & Erin	Tulsa	45-1104	35.9739/-97.8687	35.9739/-97.8687 35.9739/-97.8687	Bixby	2.2			Temp Seed, Seed/Sodd, Construction Exit, SF, Sediment Filters
Bridge & Approaches	Oklahoma	STP-255C(487)CI	35.5656/-97.2546	35.5657/-97.2552 35.5662/-97.2502	Jones	2.45	1.32		Seed, sodd, veg mulch, SF, SD, Sediment Filters, RR
Resurface Asphalt; email to Brandon Dudgeon	McClain	STP-244C-(065)CI							
	Tulsa	HSPG-272F(180)TR							
Reviewed 4/12/18; email to Gary Harrison	Logan	STP-242C(070)AG	35° 47' 00 / -97° 26' 34"	35.7689 / -97.4429 35.7978 / -97.4428	Guthrie	33.6	20.48	Silty Clay	SF, SD, Sod
Resurface Asphalt	Creek	SSR-219B(067)SR							
Resurface Asphalt	Creek	SSR-219B(068)SR							
	Muskogee	SBR-251C(096)SB	35.842778/-95.6775	35.8434/-95.6774 35.8422/-95.6774	Haskell	3.58	1.62	Fine Sandy Loam, Sandy Clay Loam, Loamy Fine Sand	
Bridge Rehabilitation	Wagoner	SBR-273C(052)SB							
Resurface Asphalt	Dewey	SSR-222F(034)SR							
Resurface Asphalt	Alfalfa	SSR-202B(040)SR							
Asphalt Resurfacing	Cimmarron	NHPP-032N(005)3P							
Asphalt Resurfacing	Cimmarron	NHPP-032N(006)3P							
Bridge Rehabilitation	Sequoyah	SBR-268C(060)SB							
Bridge Rehab	Canadian	SBR							
Resurface Asphalt	McClain	SSR-244C(063)SR							
Resurface Asphalt	McClain	SSR-2763(004)SR							
Resurface Asphalt	Pontotoc	STP-262C(052)3P							
Bridge Rehab	Garfield	SBR-24N(066)SB				2.16	0.12		
Resurface Asphalt	Sequoyah	SSR-268C(057)SR							
Bridge Rehab	Comanche	SBR-4400(038)SB							
Resurface Asphalt	Grady	SSR-226C(075)SR							
Resurface Asphalt	Jefferson	SSR-234B(044)SR							
Sidewalk Improvements	Haskell	HSIPG-231B(040)AD							
Sidewalk Improvements	Garvin	299S(149)EC	34.622975/-97.396455	34.625306/-97.396497 34.622957/-97.394116	Elmore City			Teller Urban Land Complex	SF Inlet Sed Filter, Sod

Bridge & Approaches	Oklahoma	STP-255C(487)CI	35.7259/-97.5987	35.7258/-97.6000 35.7259/-97.5932	Edmond	1.24	0.84	silt loam	
ADA Projects for Compliance	Grady	HSIPG-226B(081)AD							
ADA Improvements	Stephens	HSIPG-269N(050)AD							
Storm water Plan is not complete, Emailed Greg for Revisions 2/26	Caddo	HSIPG-208C(066)AD				1.9			
ADA Improvements	Logan								
ADA Improvements	Choctaw	HSIPG-212N(045)AD	34.0103/-95.5000	34.0102/-95.4952 34.0029/-95.4847	Hugo	1.36	1.36	Durant Silt Loam	?Seed/ Sod, SF, RFD, Temp Sediment Filter
Resurface Asphalt	Mccurtain	SSR-016N(013)SR							
Reviewed 11/8/18; email to Lenae Clements	Carter	TAP-210E(067)TP	34° 10' 20.5" / -97° 7' 34.4"	34.1721 / -97.1265 34.1713 / -97.1241	Ardmore	2.6	1.04	Sandy Clay	SF, Sod
Sidewalk Project & SH-7 Pavement Replacement	Murray	TAP-250D(022)TP SSP-250N(018)PM	34° 30' 22.94" / -97° 06' 35.74"	34.505645 / -97.116080 34.506395 / -97.099643	Davis	10.2	10.2	?	
Multipurpose trail, emailed Julianne 2/26/19, Emailed Lisa and Julianne again 3/14 for revisions	Oklahoma	TAP-255C(490)TP NHPP-255N(489)EH	35.652/-97.371	35.6524/-97.3892 35.6542/-97.3541	Edmond	12.29	12.29	Dennis-Pharoah, Dennis-Radley, Newtonia silt loam, okemah-parsons-pharoah	
Pedestrian Improvements	Beckham	TAP-205N(084)TP	35.410657 / -99.404909	35.409167 / -99.404789 35.412077 / -99.404819	Elk City	2.5595	1.1101	Fine Sandy Loam	Sod, Stab. Const. Exit, SF, Fiber Log, ST, SF, Sandbag Berms
Pedestrian Improvements	Kiowa	TAP3-2987(004)							
Reviewed 11/2/18; email to Lenae Clements	Pottawatomie	TAP-263D(065)TP	35° 25' 44" / -97° 05' 44"	35.4317 / -97.0956 35.4272 / -97.0996	Mcloud	7.05	1.1	Littleaxe Fine Sandy Loam	SF, Sod, RR
Lake Ponca Trail, Emailed Julianne 2/26	Kay	TAP-2236F-(031)TP	36.7215/-97.0205	36.728/-97.0211 36.7207/-97.0224	Ponca City	34.5	2.2	Agra-Foraker	
	Blaine								
Trail Bridge	Blaine	TAP-206E(059)TP	35.93481/ -98.43119						
	Payne	TAP-260D-(033)TP	36.1302/ -97.0630	36.1305/-97.0631 36.130/-97.0631	Stillwater	3.22	1.32	Easpur Loam	Sodd/Seed, Veg Mulch, SF, RFD, RR, Inlet Sediment Filter
Boomer Creek Improvements	Payne	TAP-260D(033)TP							
Emailed2/26, 3/6/19: Does not need permit (discussed with Amber & Bret Cabbiness) SWMP removed/ updated	Kingfisher	TAP-237E(048)TP	35.7258/ -97.9751	35.7259/-97.9758 35.7256/-97.9744	Okarche	2.616	2.28	Kingfisher silt loam	
Reviewed 11/1/18; email to Lenae Clements	Wagoner	TAP-273A(049)IG	35.9518 / -95.6367	35.9530 / -95.6467 35.9518 / -95.6350	Coweta	1.21	1.07	Silt Loam	SF, Sed filter, SD, Sod
Bridge Rehabilitation	Oklahoma	SBR-255N(446)SB							
Bridge Rehabilitation	Oklahoma	NHPPI-4400(043)PM							
Approach Slab Research	Bryan	SPRY-0010(075)RS							
Resurface Asphalt	Latimer	SSR-239B(036)SR							
Resurface Asphalt	Pittsburg	NHPP-013N(168)3P							
Resurface Asphalt	Coal	SSR-3413(004)SR							

Resurface Asphalt	Coal	SSR-215N(029)SR							
Resurfacing Project, Reviewed 3/20/19-KT	Tillman	SSR-271B(062)SR							
Resurface Asphalt	McIntosh	NHPP-246N(040)3P							
Cable Barrier	Grady	HSIPG-226N(067)TR	34.7308/-97.9585	34.7808/-97.9674 34.6825/-97.9582	Rush Springs		35.41		SF, SD, Inlet filter, Sed Filter, Sod
Joint Seal	Oklahoma	STP-255F(473)3B							
Bridge Painting	Oklahoma	STP-NBIP(526)3B							
Grading Surfacing Water Line Improvements	Kay	STP-236B(062)UR	36.7097/-97.0962	36.7098/-97.1033 36.7099/-97.0852	Ponca City	3	3	Bethany Silt Loam and Milan Loam	Sod, Silt Fence, Silt Dikes
Pavement Marking and Rumble Strips Project	Multiple in Div. 1	HSIPG-251F(091)TR							
Intersection	Oklahoma	STPG-3739(004)Ag							
Resurface Asphalt	Pontotoc	STP-262C(055)3P							
ADA Improvements	Logan								
Intersection Modification	Oklahoma	ACSTP-255C(491)PM							
Resurface Asphalt	Oklahoma	NHPPI-4000(082)3P							
Pavement Rehab	Garfield	SSR-224C(064)							
Asphalt Overlay	Logan	SSR-242C(072)SR							
Signage	Oklahoma								
Grade, Drain, & resurface	Marshall	SSR-248N(047)SR	33.9973/ -96.6708	33.9953/-96.6720 33.9975/-96.6696	Kingston	30.95	30.95	Sandstone/ shale	
Resurface Asphalt	Atoka	NHPP-013N(169)3P							
Resurface Asphalt	Hughes	MC-232C(062)							
Bridge Rehabilitation	Seqouyah	SBR-4000(080)SB							
Bridge Repair	Love	SAP-3500(075)SS							
Bridge Impact Repair Project	Tulsa	SAP-014N(101)SS							
Resurface Asphalt	Seminole	MC-267C(079)							
Resurface Asphalt	Okmulgee	MC-256N(053)							
Pavement Rehabilitation	Okmulgee	MC-256N(054)							
Bridge Over-Height Vehicle Impact Repair	Pontotoc	SAP-363N(056)ES							
Patching	Grady/Caddo	MC-226c(082)							
Bridge Paint	McIntosh	NHPP-NBIP(530)3B							
Joint Seal Repair	Atoka	STP-203C(070)3B							
Bridge Painting	Cleveland	STP-NBIP(531)3B							
Joint Seal/Repair	McClain	STP-244F(067)3B							

Signing	Love	HSIPG-243F(033)TR							
Speed Limit Signs	McCurtain								
Joint Seal/Repair	Oklahoma	STP-255F(501)3B							
Bridge and Approach	Rogers	STP-266D(073)CI	36.426944/ -95.508056	36.426910/-95.509214 36.427186/-95.507498	Foyil	4.19	4.19	Verdigris Silty Clay Loam	RipRap, Inlet Sed Filter, SF, SD, Sod
Joint Seal/Repair	Stephens	STP-269F(060)3B							
Signage	Tulsa	STP-272F(270)PM							
Signing	Tulsa	STP-272F(271)PM							
Joint Seal Repair	Tulsa								
Joint Seal Repair	Washita								
ADA	Woods	STP-276B(039)AD							
Joint Seal Repair	Woods	STP-276(036)3B							

7-3 Appendix 3 – Annual Erosion Results

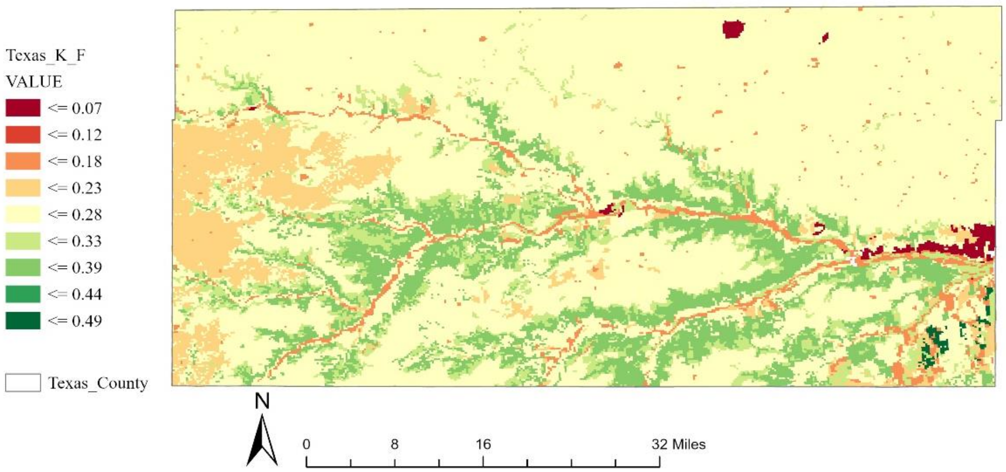

Figure 7-1 RUSLE_2 soil erodibility (K) map for Texas County

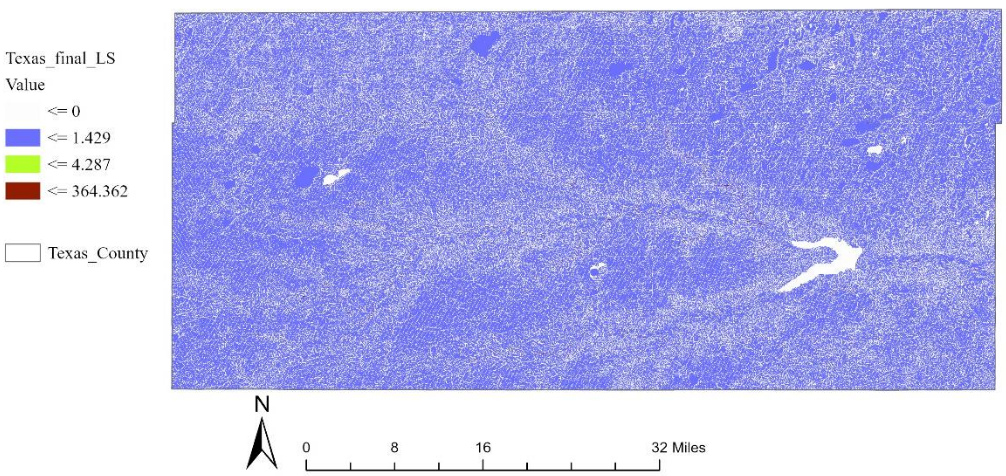

Figure 7-2 RUSLE_2 slope length and steepness factor (LS) map for Texas County

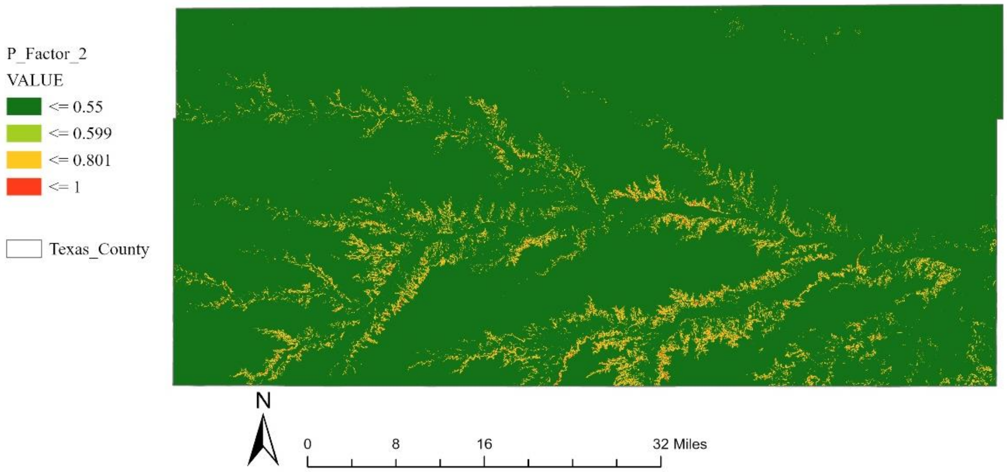

Figure 7-3 RUSLE_2 support practice factor (P) map for Texas County

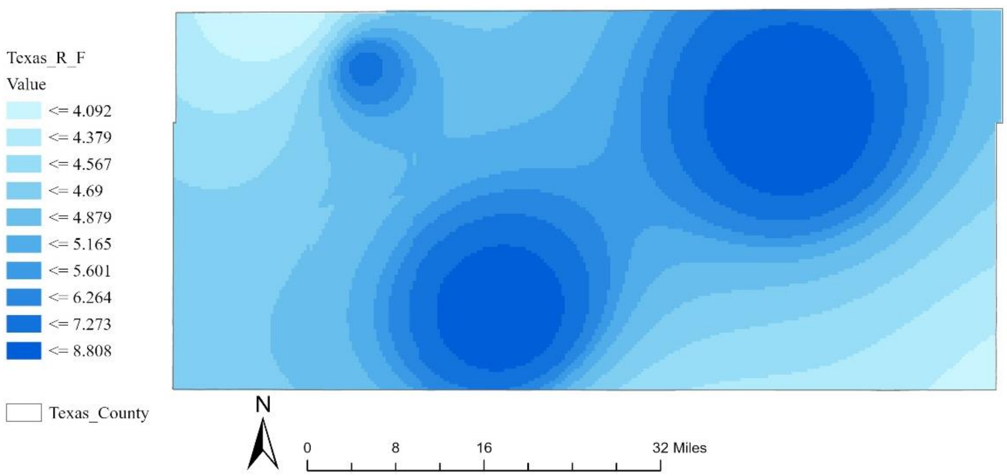

Figure 7-4 RUSLE_2 rainfall erosivity factor (R) map for Texas County

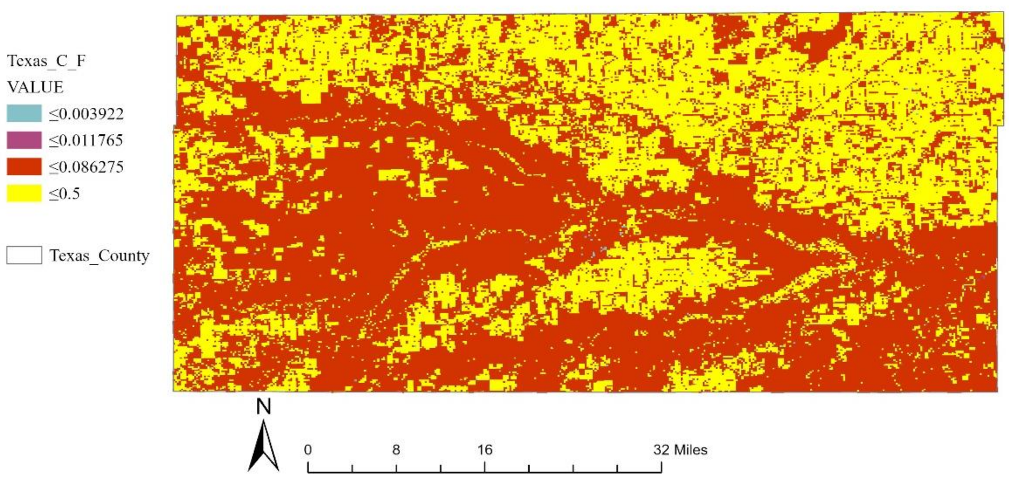

Figure 7-5 RUSLE_2 cover management factor (C) map for Texas County

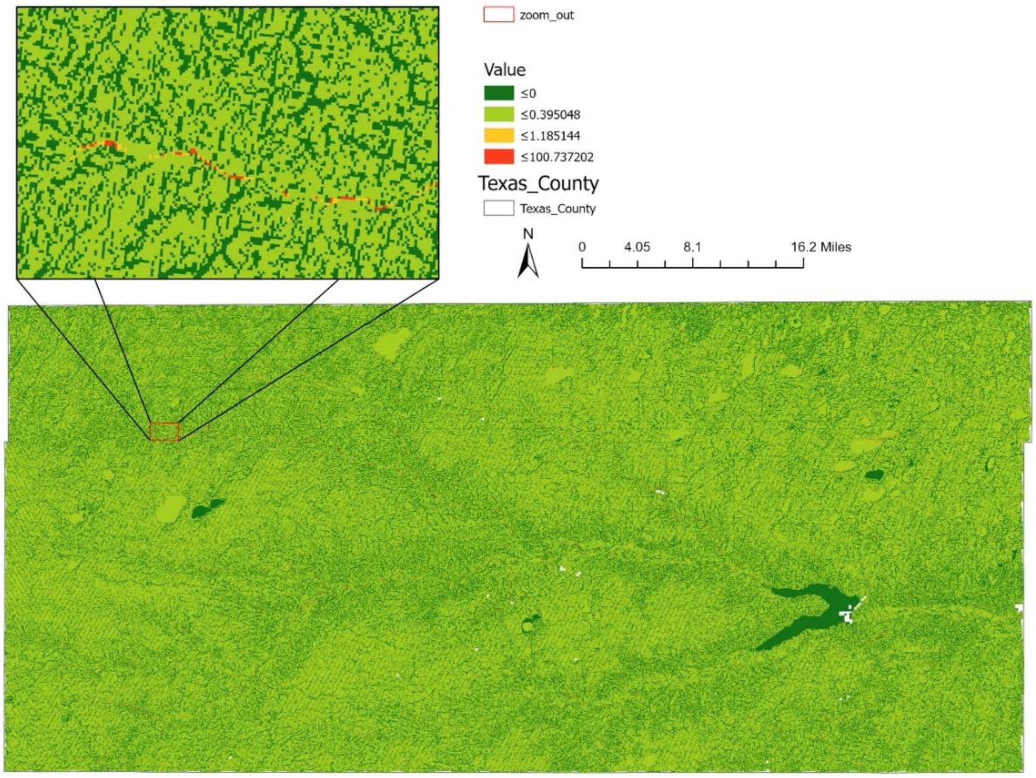

Figure 7-6 Annual predicted average soil loss (tons/acre/year) map for Texas County

As you can see in the Figure 7-6in the zoom-out section, the sediment yield is notably higher than the other area. To identify the reason, the condition of the region studied particularly. The area has a soil type as shown in Table 7-3. The governing soil hydrologic group is mainly A to B type, which shows low to medium runoff and high infiltration. Further, by considering the soil type average soil erodibility factor of the pixels with high erosion is about an average (about 0.18 to 0.23). In the next level, the land cover of the area has been studied. According to the land cover map of Oklahoma, the area with high erosion is consists of shrub/scrub with land cover factor value of 0.45. The mentioned area showed high LS factor. As shown in Table 7-4 base on correlation factor of different RUSLE factors, LS and P factor shows the largest participation on the final erosion map.

Table 7-3 soil type with the hydrologic group type for north west of Texas County

Ln—Happy ditch loamy fine sand, 0 to 2 percent slopes, occasionally flooded	
Hydrologic Soil Group	A
VoC—Vona loamy fine sand, 3 to 8 percent slopes	
Hydrologic Soil Group	A
Vp—Vona, Otero, and Plack soils, 3 to 20 percent slopes	
Hydrologic Soil Group	A
Mp—Veal-Potter complex, 3 to 12 percent slopes, cool	
Hydrologic Soil Group	B
DaA—Dalhart fine sandy loam, 0 to 1 percent slopes	
Hydrologic Soil Group	B
DaB—Dalhart fine sandy loam, 1 to 3 percent slopes	
Hydrologic Soil Group	B

Table 7-4 The effect of RUSLE factors on the Texas final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
P	0.0389	0.0002
R	-0.0044	-0.0006
LS	0.7255	0.0766
C	0.0061	0.0002
K	0.0058	0.0001

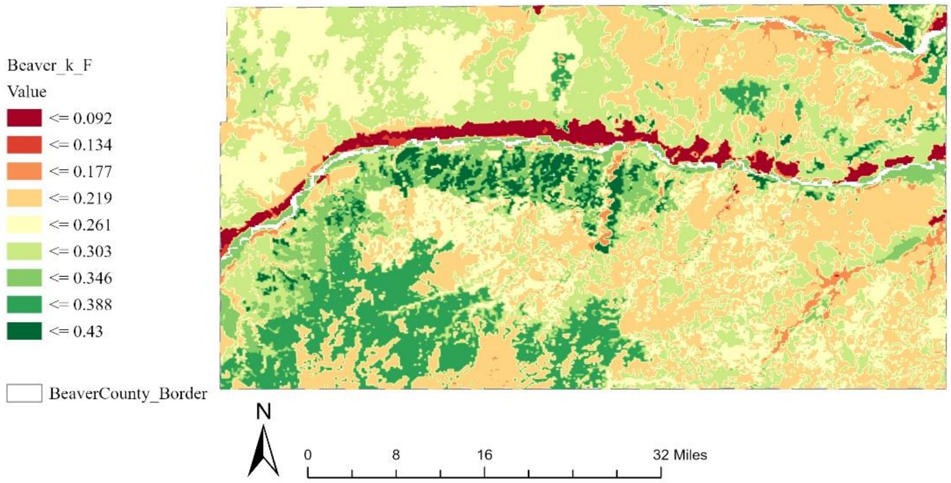

Figure 7-7 RUSLE_2 soil erodibility (K) map for Beaver County

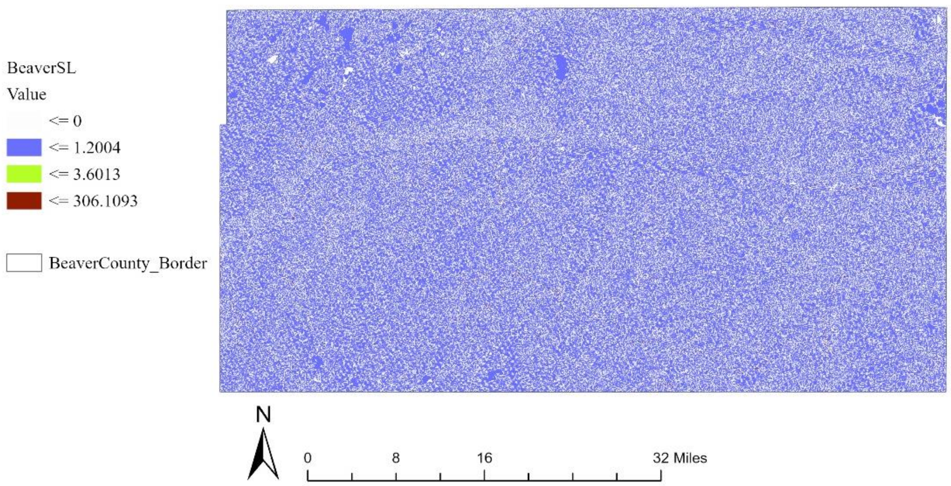

Figure 7-8 RUSLE_2 slope length and steepness factor (LS) map for Beaver County

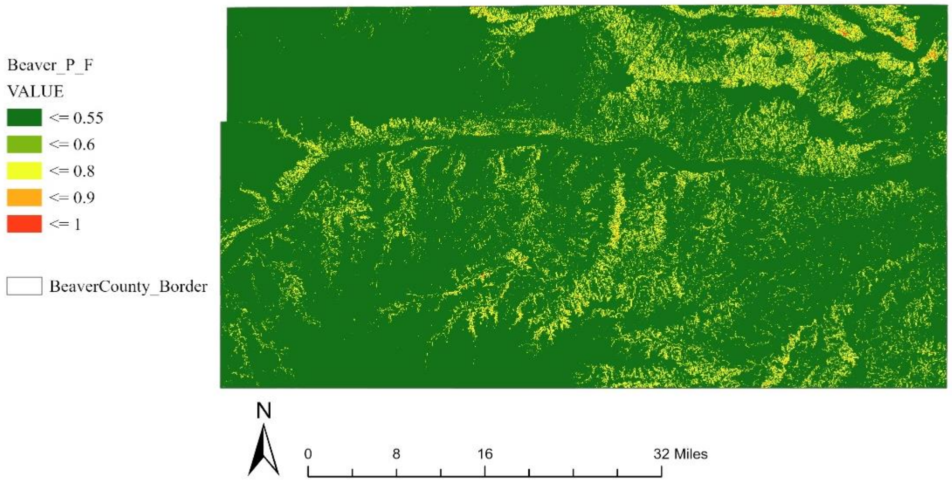

Figure 7-9 RUSLE_2 support practice factor (P) map for Beaver County

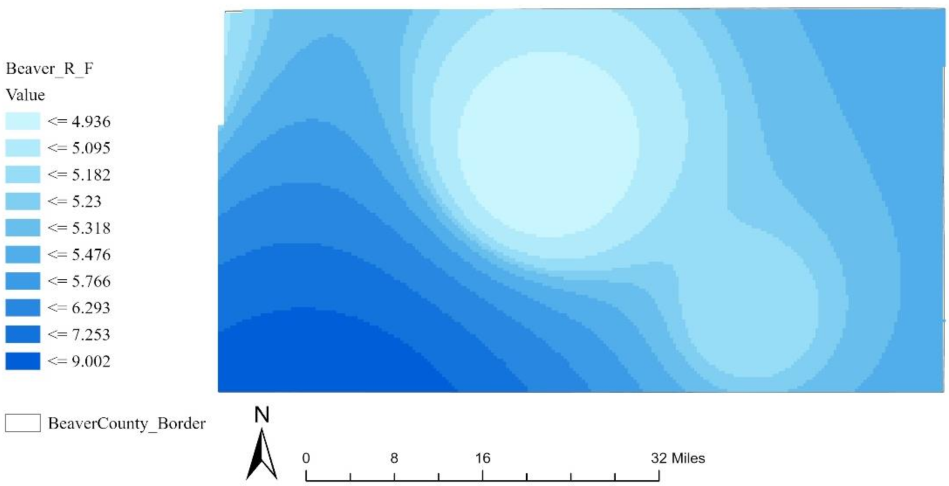

Figure 7-10 RUSLE_2 rainfall erosivity factor (R) map for Beaver County

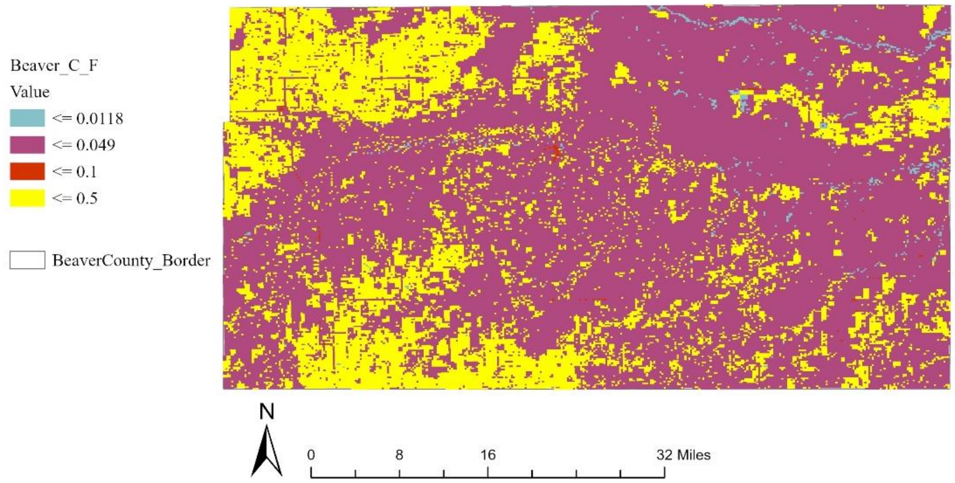

Figure 7-11 RUSLE_2 cover management factor (C) map for Beaver County

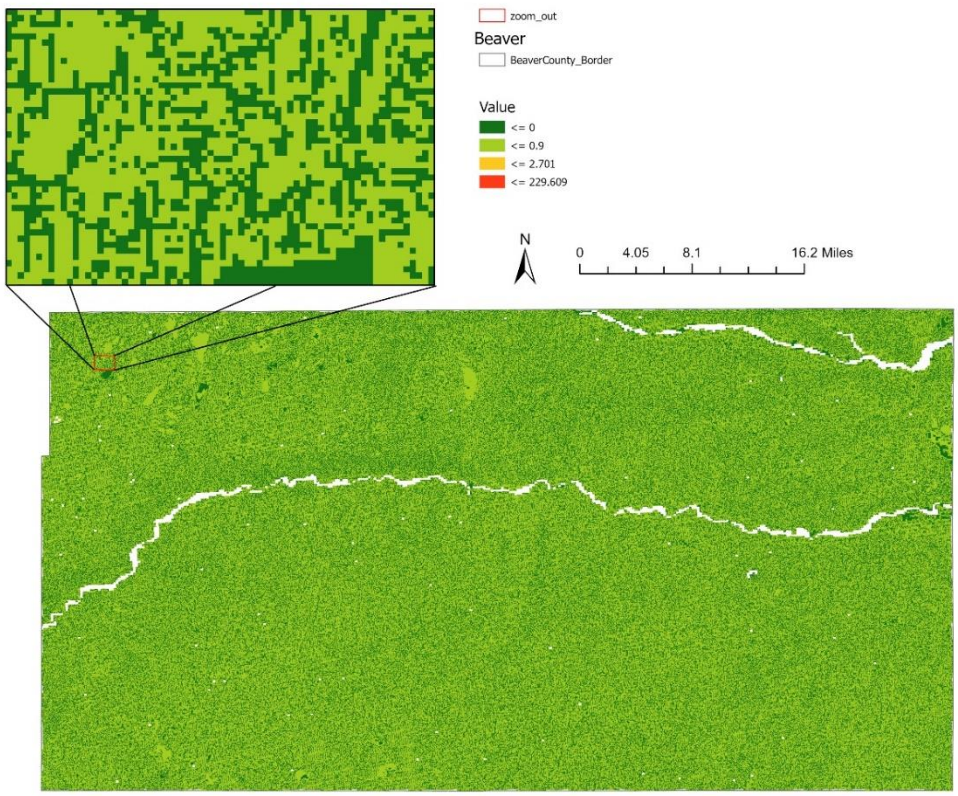

Figure 7-12 Annual predicted average soil loss (tons/acre/year) map for Beaver County

As shown in the Figure 7-12 in the zoom-out section, the condition of the region studied particularly. The area has a soil type as shown in Table 7-5. The governing soil hydrologic group is mainly A to D type, which shows low to medium runoff and high infiltration to high runoff and low infiltration. Further, by considering the soil type, soil erodibility factor of the pixels have a value about 0.24 to 0.28. In the next level, the land cover of the area has been studied. According to the land cover map of Oklahoma, the area consists of cultivated crop with land cover factor value of 0.5. The mentioned area showed high LS factor. As shown in Table 7-6 base on correlation factor of different RUSLE factors, LS and P factor shows the largest participation on the final erosion map. In Beaver County cover management factor correlation with final erosion map is noticeably high.

Table 7-5 soil type with the hydrologic group type for north west of Beaver County

PfB—Vona fine sandy loam, 3 to 5 percent slopes	
Hydrologic Soil Group	A
Pt—Vona-Tivoli complex, 5 to 30 percent slopes	
Hydrologic Soil Group	A
Pr—Vona loamy fine sand, 3 to 5 percent slopes	
Hydrologic Soil Group	A
RcA—Darrouzett clay loam, 0 to 1 percent slopes	
Hydrologic Soil Group	C
DaA—Dalhart fine sandy loam, 0 to 1 percent slopes	
Hydrologic Soil Group	B
DaB—Dalhart fine sandy loam, 1 to 3 percent slopes	
Hydrologic Soil Group	B
Ra—Ness clay, 0 to 1 percent slopes, frequently ponded	
Hydrologic Soil Group	D

Table 7-6 The effect of RUSLE factors on the Beaver final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
K	0.00277	0.00003
R	-0.00120	-0.00016
C	0.01121	0.00040
P	0.01884	0.00016
SL	0.50299	0.06586

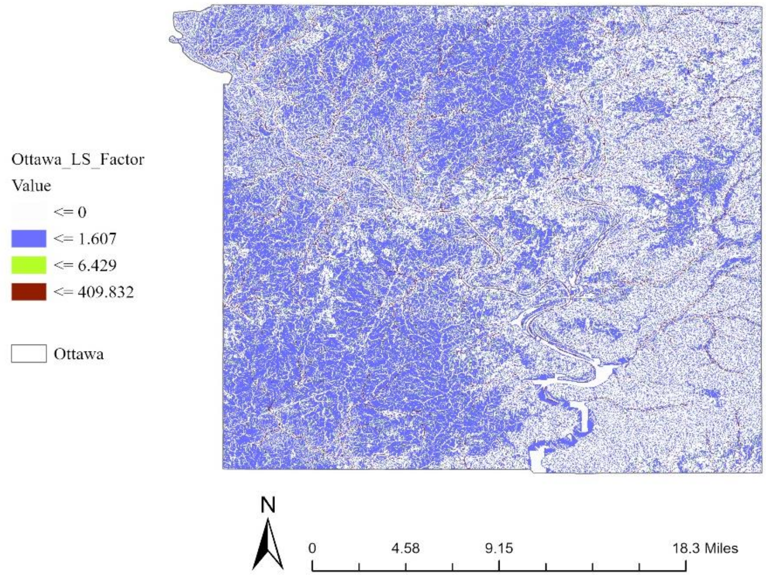

Figure 7-13 RUSLE_2 slope length and steepness factor (LS) map for Ottawa County

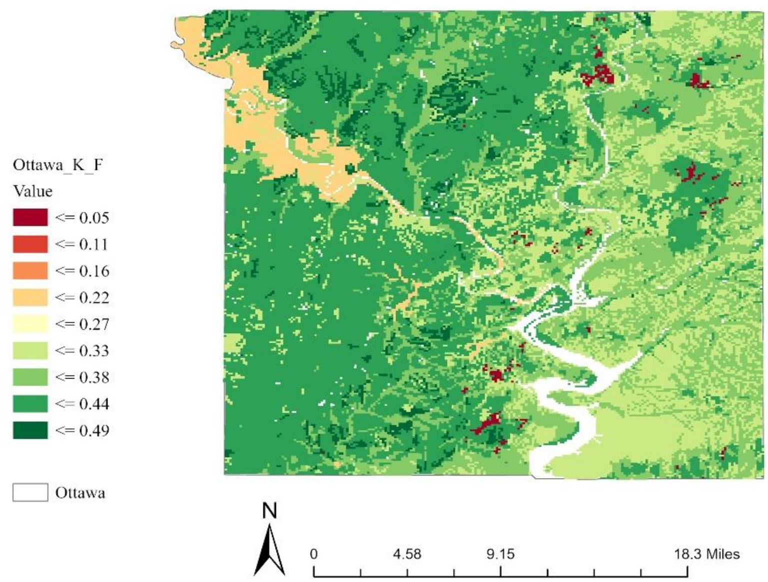

Figure 7-14 RUSLE_2 soil erodibility (K) map for Ottawa County

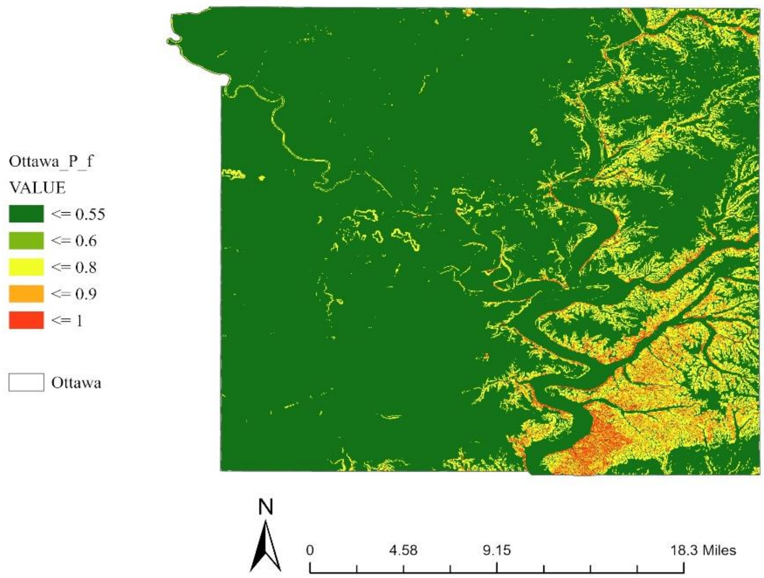

Figure 7-15 RUSLE_2 support practice factor (P) map for Ottawa County

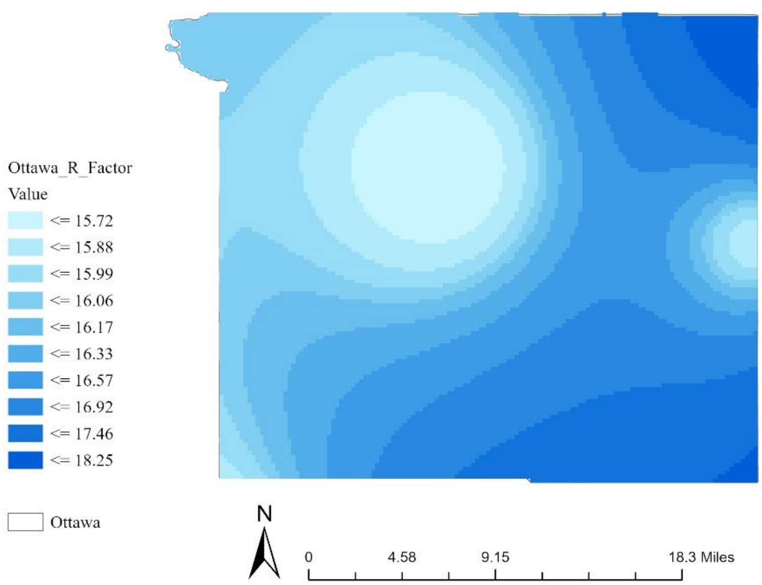

Figure 7-16 RUSLE_2 rainfall erosivity factor (R) map for Ottawa County

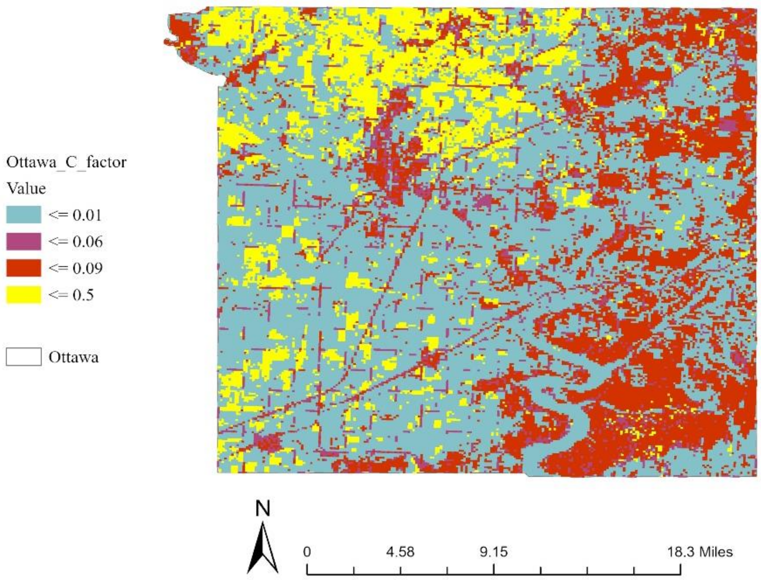

Figure 7-17 RUSLE_2 cover management factor (C) map for Ottawa County

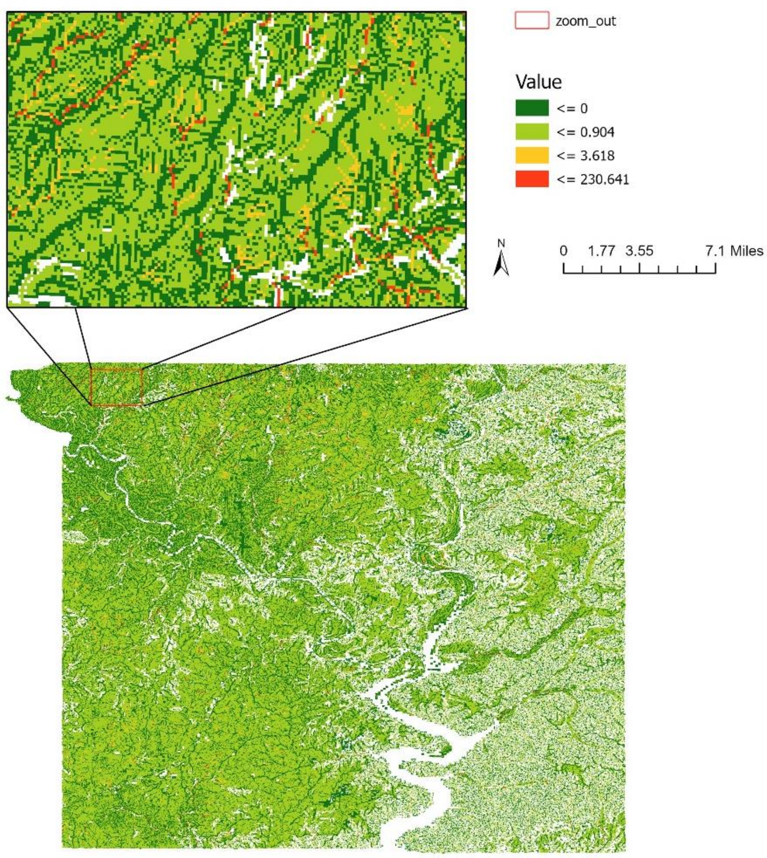

Figure 7-18 Annual predicted average soil loss (tons/acre/year) map for Ottawa County

As shown in the Figure 7-18 in the zoom-out section, the condition of the region studied particularly. The area has a soil type as shown in Table 7-7. The governing soil hydrologic group is mainly type D and, in some cases, it is B type, which shows High runoff and low infiltration. Further, by considering the soil type, areas with higher erosion rate have a soil erodibility value factor of the 0.43 to 0.49. In the next level, the land cover of the area has been studied. According to the land cover map of Oklahoma, the area consists of cultivated crop with land cover factor value of 0.5. The mentioned area showed noticeably high LS factor. As shown in Table 7-6 base on correlation factor of different RUSLE factors, LS and C factor shows the largest participation on the final erosion map.

Table 7-7 soil type with the hydrologic group type for north west of Ottawa County

TaA—Taloka silt loam, 0 to 1 percent slopes	
Hydrologic Soil Group	D
Br—Eram-Verdigris complex, 0 to 20 percent slopes	
Hydrologic Soil Group	D
PaA—Parsons silt loam, 0 to 1 percent slopes	
Hydrologic Soil Group	D
Os—Osage silty clay, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	D
Ln—Lightning silt loam, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	D
DnB—Dennis silt loam, 1 to 3 percent slopes	
Hydrologic Soil Group	C/D
PaB—Parsons silt loam, 1 to 3 percent slopes	
Hydrologic Soil Group	D
Vd—Verdigris silt loam, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	B
Ad—Osage-Verdigris complex, 0 to 1 percent slopes, frequently flooded	
Hydrologic Soil Group	D

Table 7-8 The effect of RUSLE factors on the Ottawa final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
C	0.13843	0.06355
R	-0.02032	-0.02848
P	-0.00873	-0.00221
K	0.01011	0.00191
LS	0.24758	3.66386

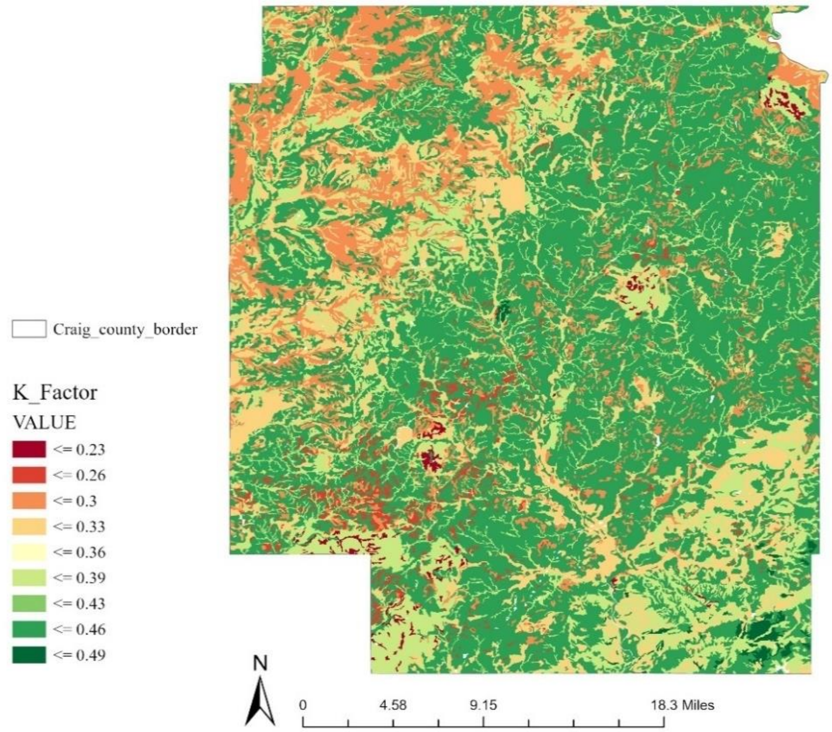

Figure 7-19 RUSLE_2 soil erodibility (K) map for Craig County

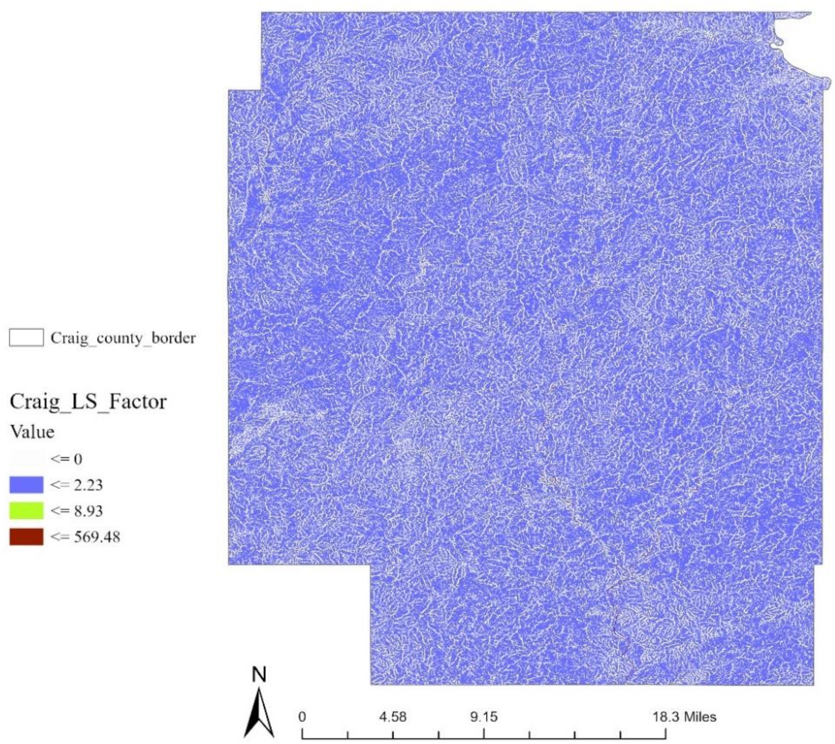

Figure 7-20 RUSLE_2 slope length and steepness factor (LS) map for Craig County

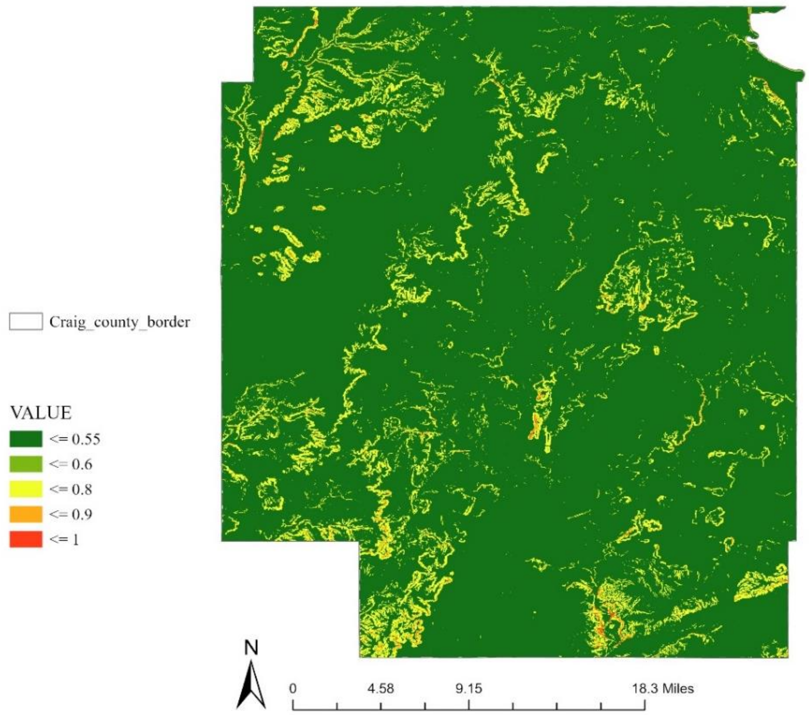

Figure 7-21 RUSLE_2 support practice factor (P) map for Craig County

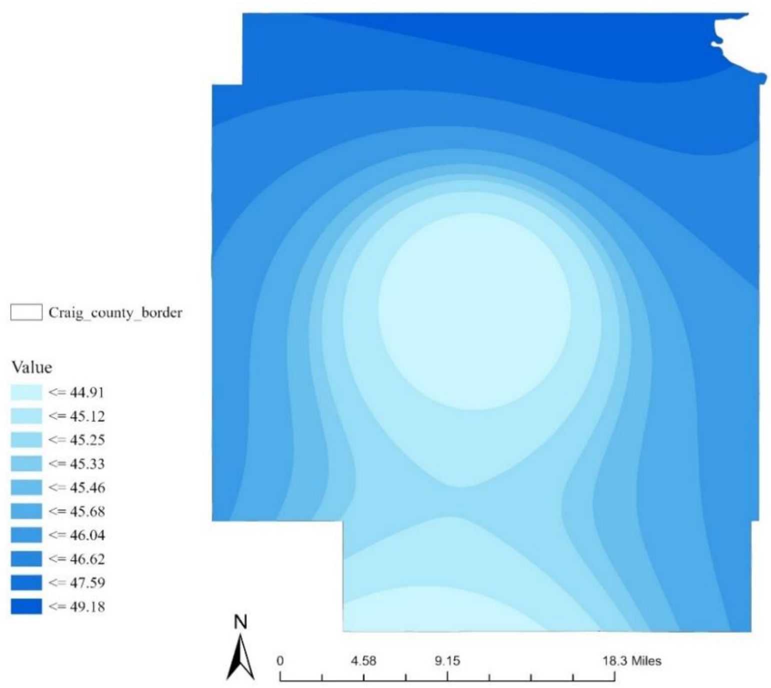

Figure 7-22 RUSLE_2 rainfall erosivity factor (R) map for Craig County

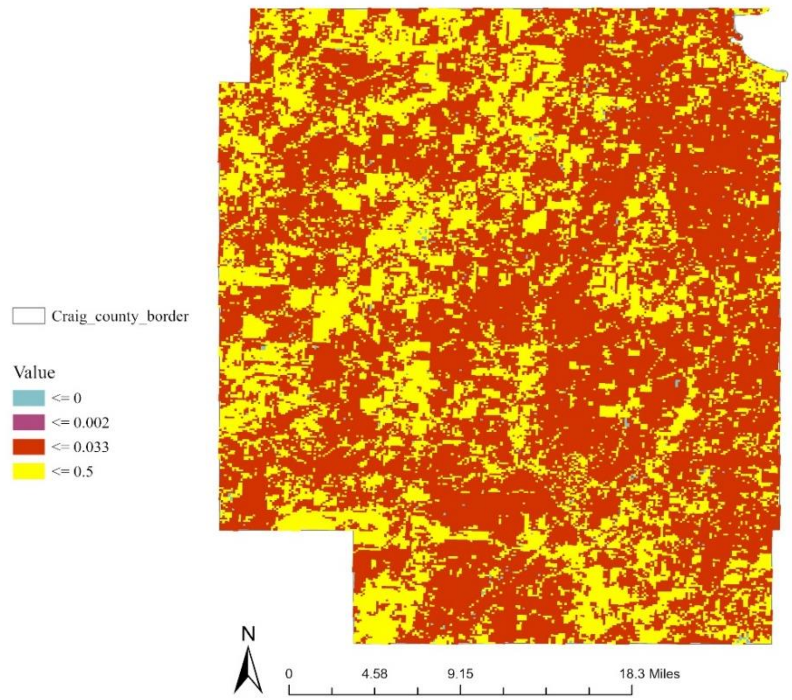

Figure 7-23 RUSLE_2 cover management factor (C) map for Craig County

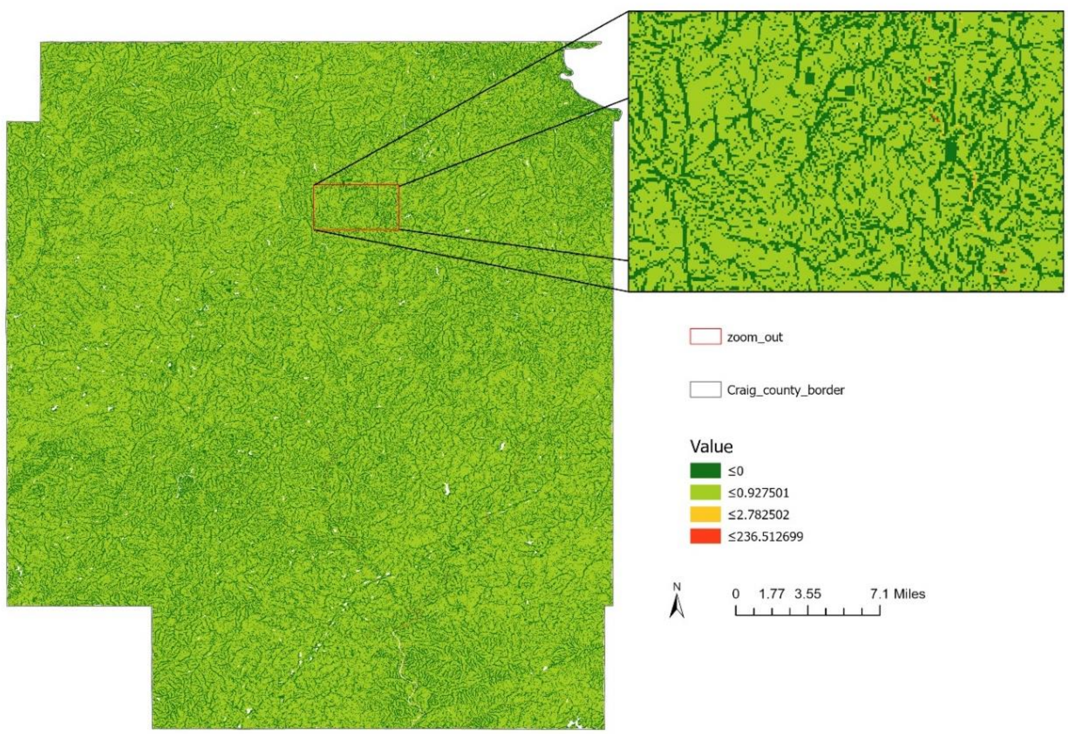

Figure 7-24 Annual predicted average soil loss (tons/acre/year) map for Craig County

As shown in the Figure 7-24 in the zoom-out section, the condition of the region studied particularly. The area has a soil type as shown in Table 7-9. The governing soil hydrologic group is mainly type D and, in some cases, it is C and B type, which shows High runoff and low infiltration. Further, by considering the soil type, areas with higher erosion rate have a soil erodibility value factor of the 0.3 to 0.43. In the next level, the land cover of the area has been studied. According to the land cover map of Oklahoma, the area that shows higher erosion rate were located on the region consists of evergreen forest and herbaceous with land cover factor value of 0.001 to 0.035. The mentioned area showed noticeably high LS factor. As shown in Table 7-10 base on correlation factor of different RUSLE factors, LS and P factor shows the largest participation on the final erosion map.

Table 7-9 soil type with the hydrologic group type for north of Craig County

SuC2—Apperson silty clay loam, 3 to 5 percent slopes, eroded	
Hydrologic Soil Group	D
WgSD—Wagstaff-Shidler complex, 1 to 8 percent slopes	
Hydrologic Soil Group	D
SuB—Apperson silty clay loam, 1 to 3 percent slopes	
Hydrologic Soil Group	D
ChA—Choteau silt loam, 0 to 1 percent slopes	
Hydrologic Soil Group	C
Ot—Mayes silty clay loam, 0 to 1 percent slopes	
Hydrologic Soil Group	D
DnC—Dennis silt loam, 3 to 5 percent slopes	
Hydrologic Soil Group	C/D
PaA—Parsons silt loam, 0 to 1 percent slopes	
Hydrologic Soil Group	D
Ve—Verdigris silty clay loam, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	C
Ra—Radley silt loam, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	B
Lg—Lightning-Healdton complex, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	D
DnC2—Dennis silt loam, 3 to 5 percent slopes, eroded	
Hydrologic Soil Group	C/D
CoF—Collinsville-Vinita complex, 2 to 30 percent slopes	
Hydrologic Soil Group	D

Table 7-10 The effect of RUSLE factors on the Craig final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
R	-0.0055	-1.38E-03
C	0.01906	5.76E-04
P	0.03131	4.41E-04
LS	0.75606	4.41E-04
K	-0.00075	-1.37E-05

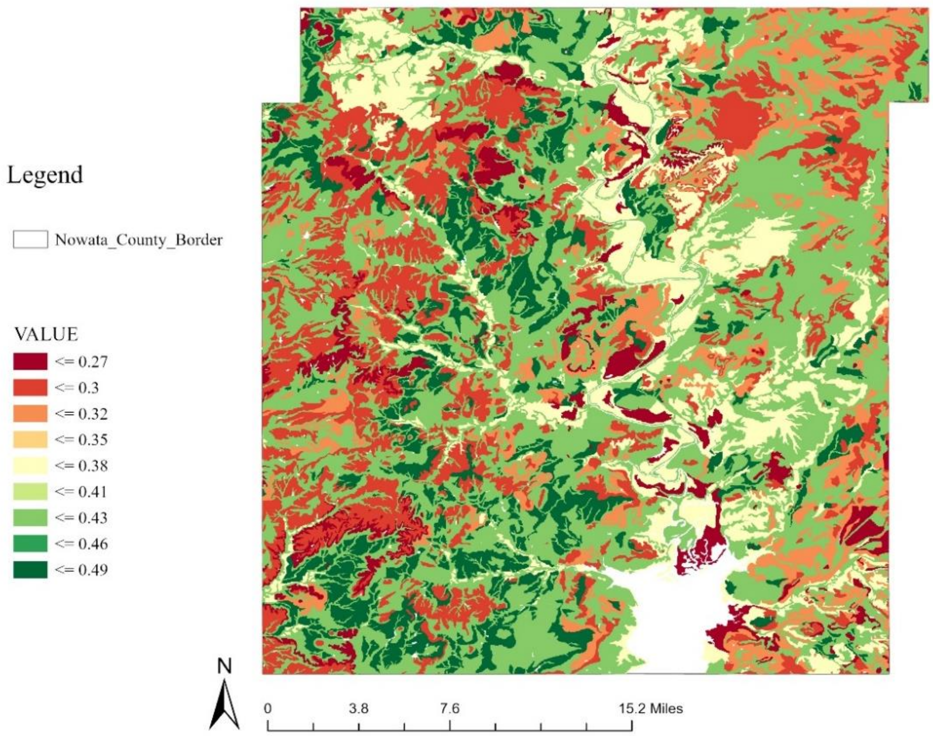

Figure 7-25 RUSLE_2 soil erodibility (K) map for Nowata County

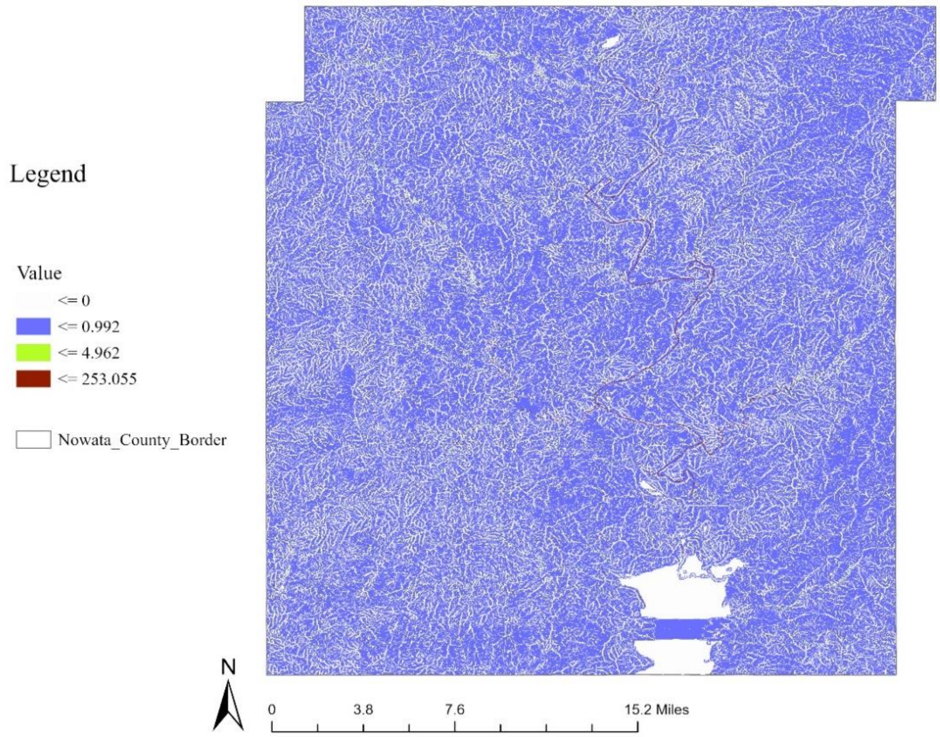

Figure 7-26 RUSLE_2 slope length and steepness factor (LS) map for Nowata County

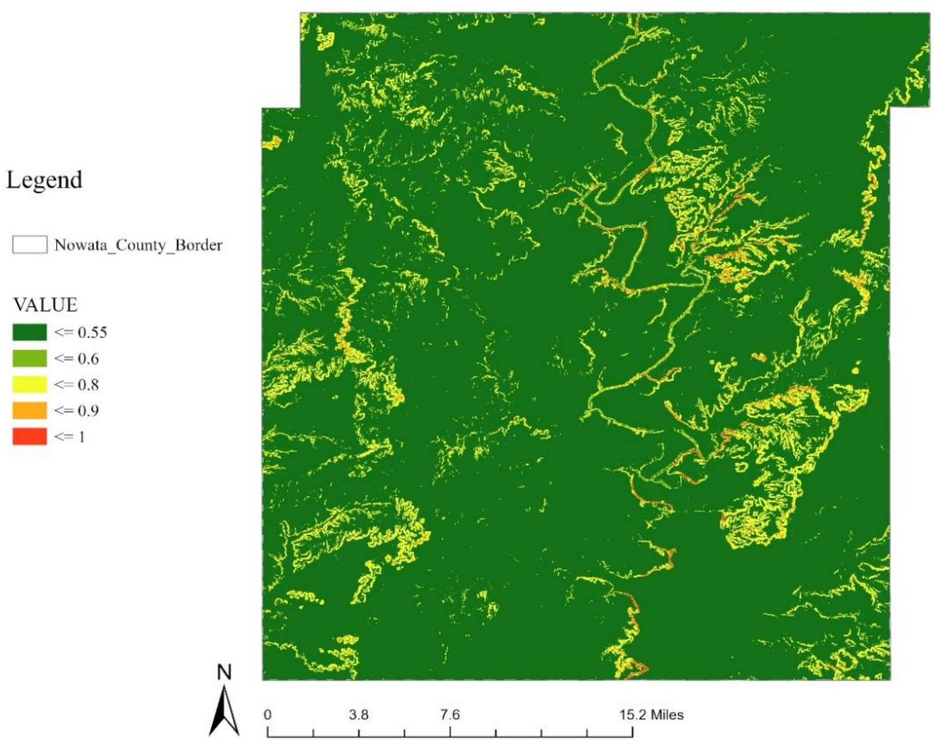

Figure 7-27 RUSLE_2 support practice factor (P) map for Nowata County

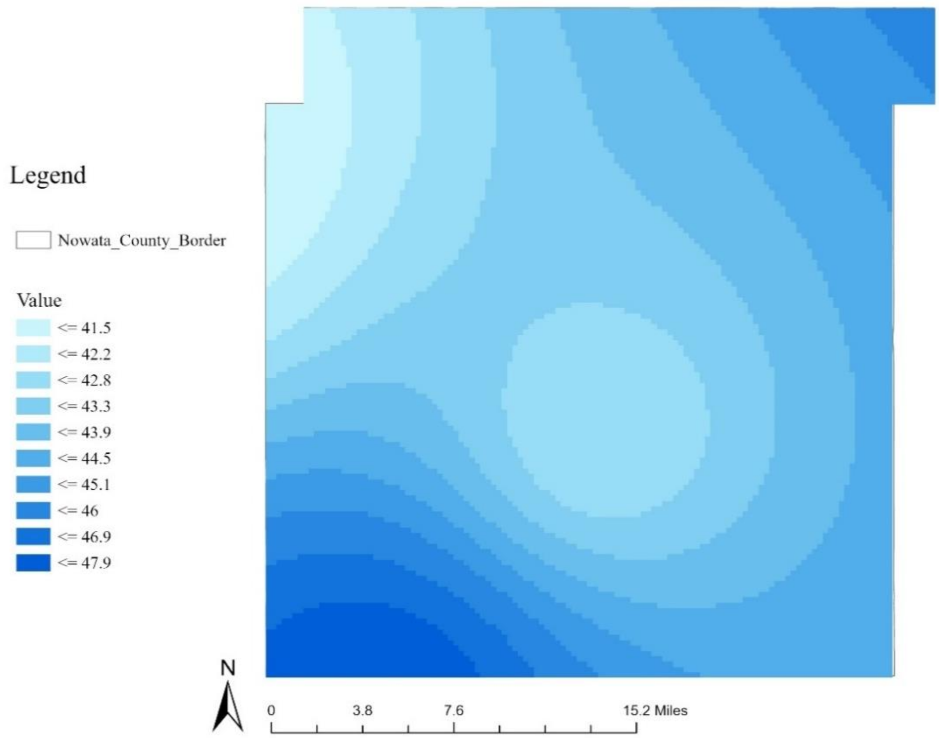

Figure 7-28 RUSLE_2 rainfall erosivity factor (R) map for Nowata County

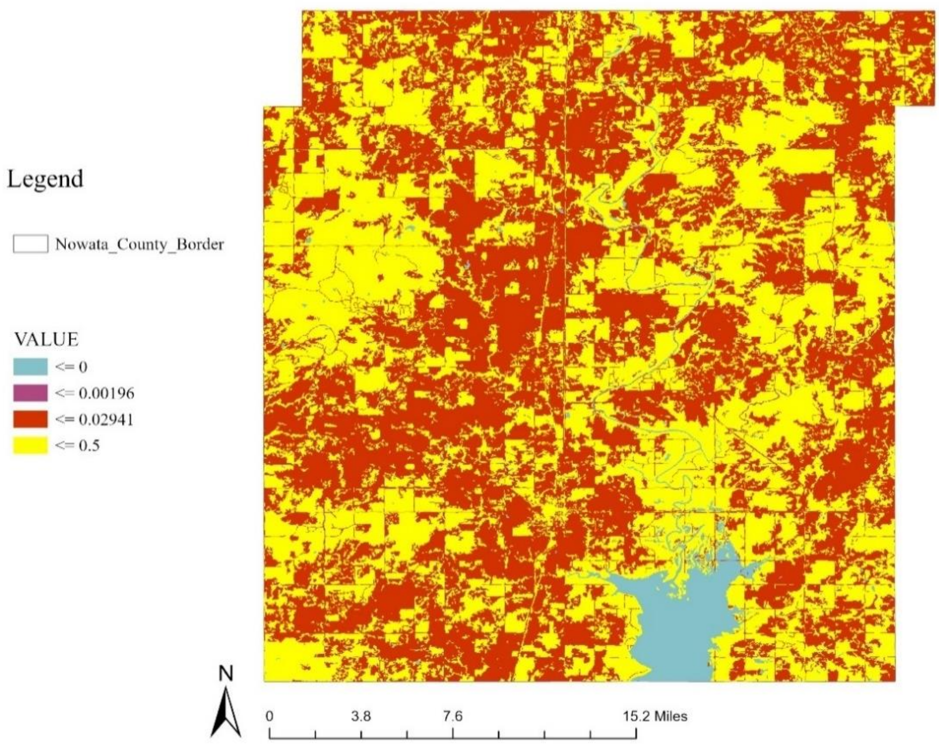

Figure 7-29 RUSLE_2 cover management factor (C) map for Nowata County

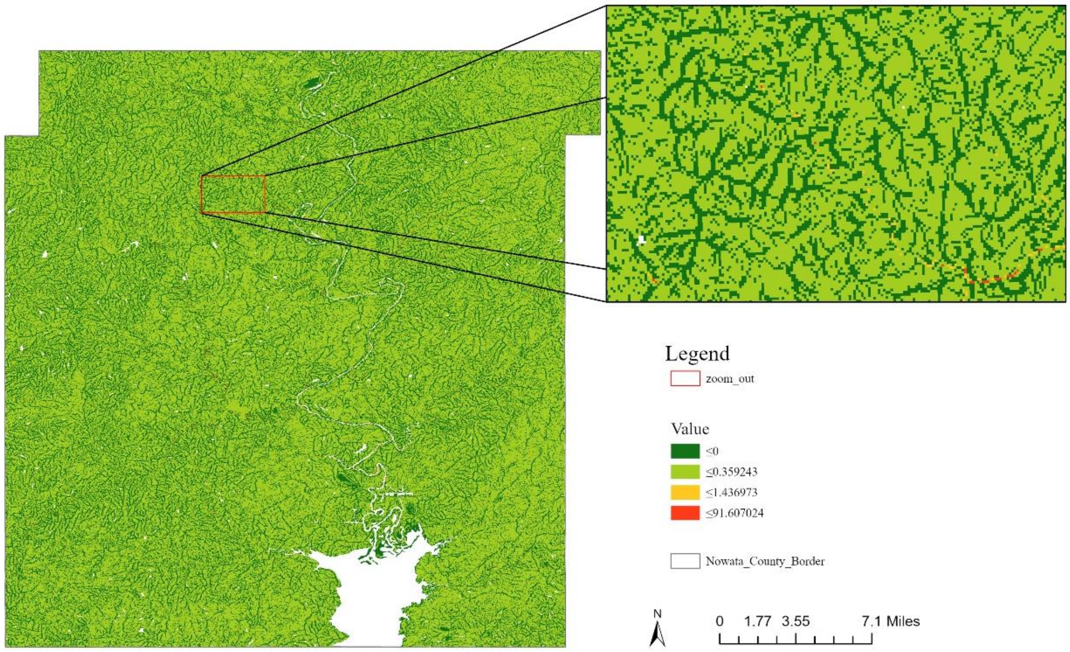

Figure 7-30 Annual predicted average soil loss (tons/acre/year) map for Nowata County

As shown in the Figure 7-30 in the zoom-out section, the condition of the region studied particularly. The area has a soil type as shown in Table 7-11. The governing soil hydrologic group is mainly type D and, in some cases, it is C and B type, which shows High runoff and low infiltration. Further, by considering the soil type, areas with higher erosion rate have a soil erodibility value factor of 0.43. In the next level, the land cover of the area has been studied. According to the land cover map of Oklahoma, the area that shows higher erosion rate were located on the region consists of deciduous forest and herbaceous with land cover factor value of 0.087 to 0.035. The mentioned area showed noticeably high LS factor. As shown in Table 7-12 base on correlation factor of different RUSLE factors, LS and P factor shows the largest participation on the final erosion map.

Table 7-11 soil type with the hydrologic group type for north of Nowata County

CbB—Coweta-Bates complex, 1 to 5 percent slopes	
Hydrologic Soil Group	D
CeC—Coweta-Eram complex, 5 to 15 percent slopes	
Hydrologic Soil Group	D
ErD—Eram-Radley complex, 0 to 8 percent slopes	
Hydrologic Soil Group	D
DnB—Dennis silt loam, 1 to 3 percent slopes	
Hydrologic Soil Group	C/D
WagB—Wagstaff silty clay loam, 1 to 3 percent slopes	
Hydrologic Soil Group	D
OkA—Okemah silt loam, 0 to 1 percent slopes	
Hydrologic Soil Group	C/D
PaA—Parsons silt loam, 0 to 1 percent slopes	
Hydrologic Soil Group	D
PaB—Parsons silt loam, 1 to 3 percent slopes	
Hydrologic Soil Group	D
RD—Radley silt loam, 0 to 1 percent slopes, frequently flooded	
Hydrologic Soil Group	B
DnC—Dennis silt loam, 3 to 5 percent slopes	
Hydrologic Soil Group	D
NoB—Nowata silt loam, 3 to 5 percent slopes	
Hydrologic Soil Group	C
Wa—Wynona silty clay loam, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	C/D

Table 7-12 The effect of RUSLE factors on the Nowata final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
R	-0.0084	-0.0025
P	0.0472	0.0006
K	0.0135	0.0002
LS	0.3803	0.1604
C	0.0219	0.0004

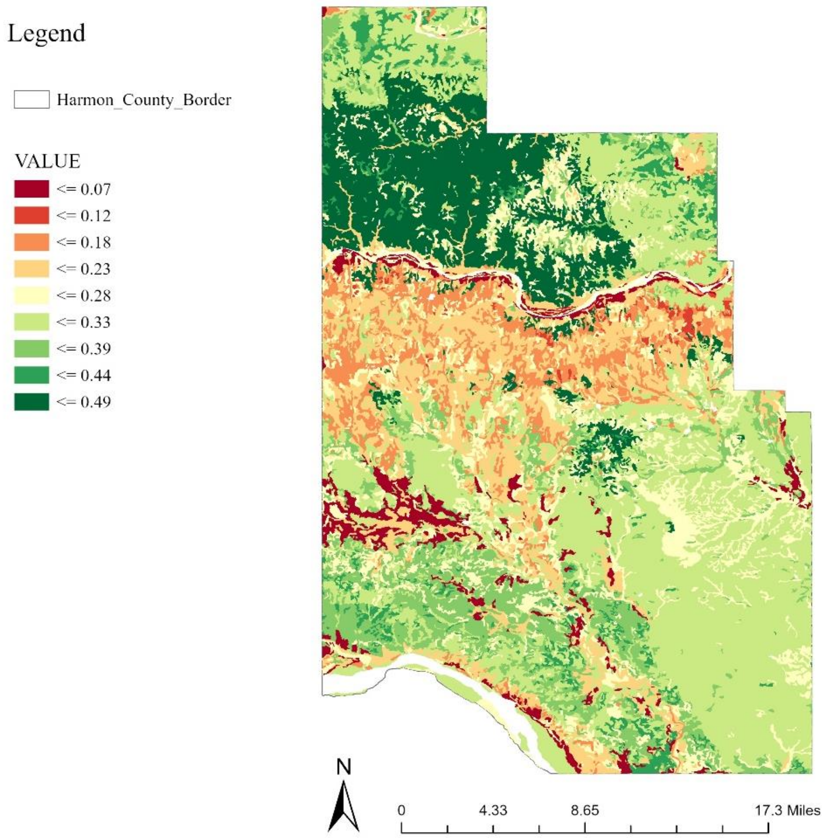

Figure 7-31 RUSLE_2 soil erodibility (K) map for Harmon County

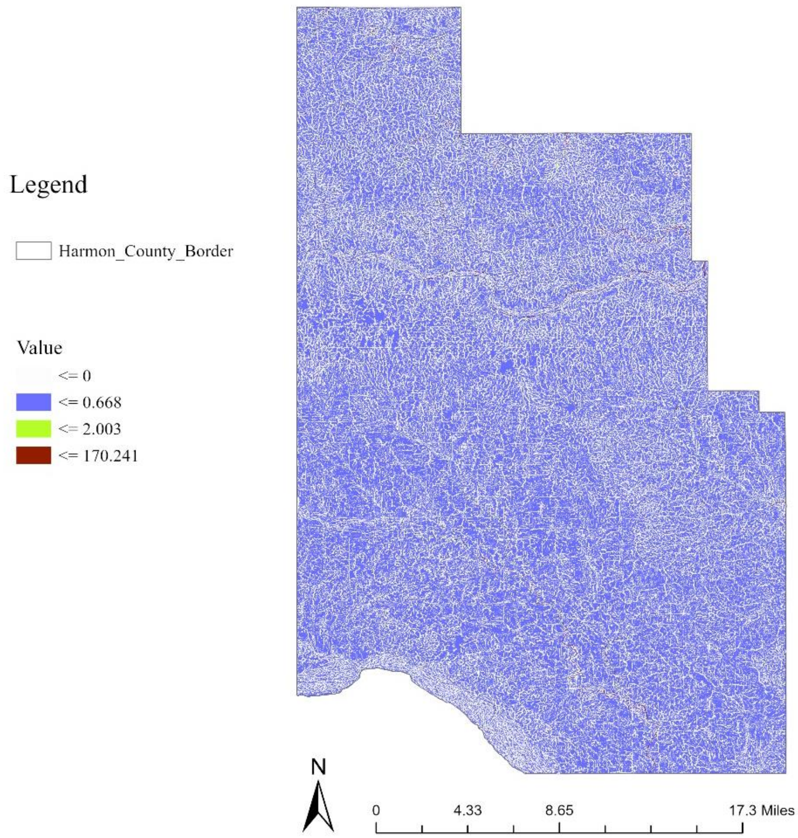

Figure 7-32 RUSLE_2 slope length and steepness factor (LS) map for Harmon County

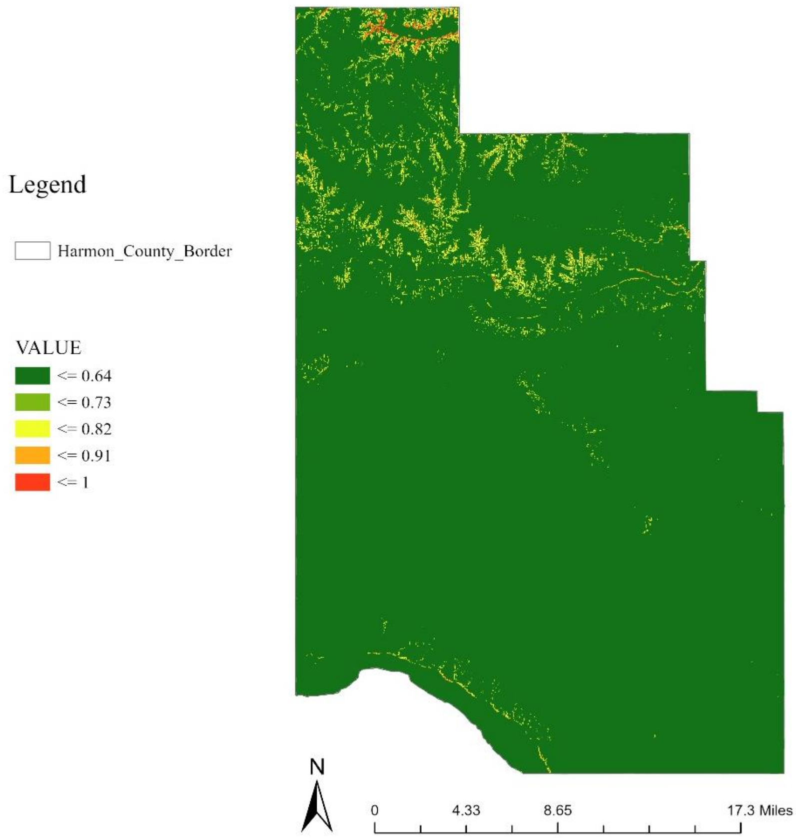

Figure 7-33 RUSLE_2 support practice factor (P) map for Harmon County

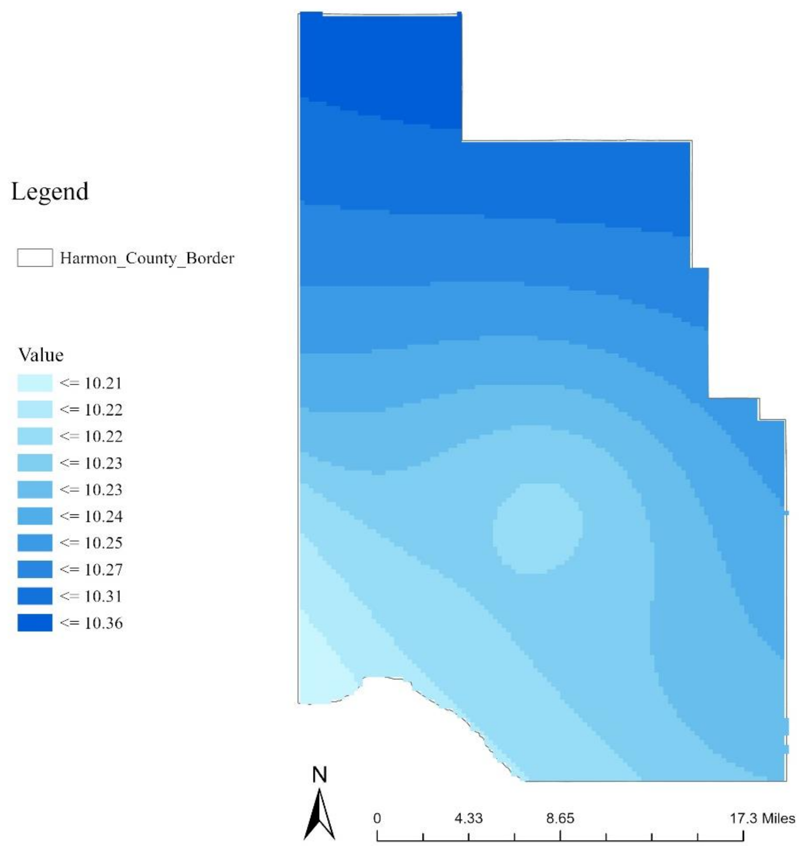

Figure 7-34 RUSLE_2 rainfall erosivity factor (R) map for Harmon County

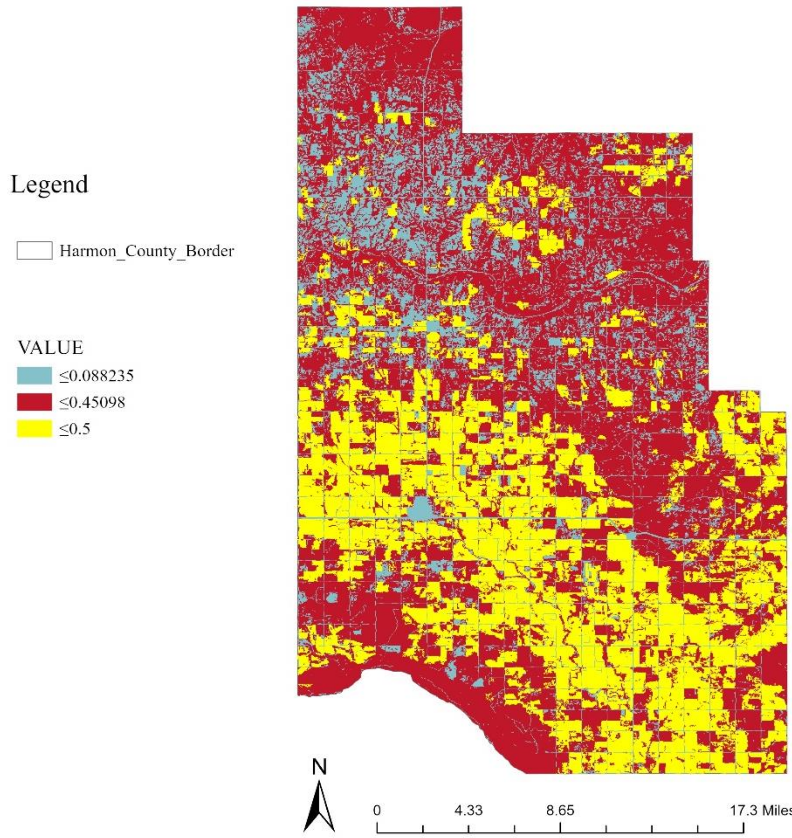

Figure 7-35 RUSLE_2 cover management factor (C) map for Harmon County

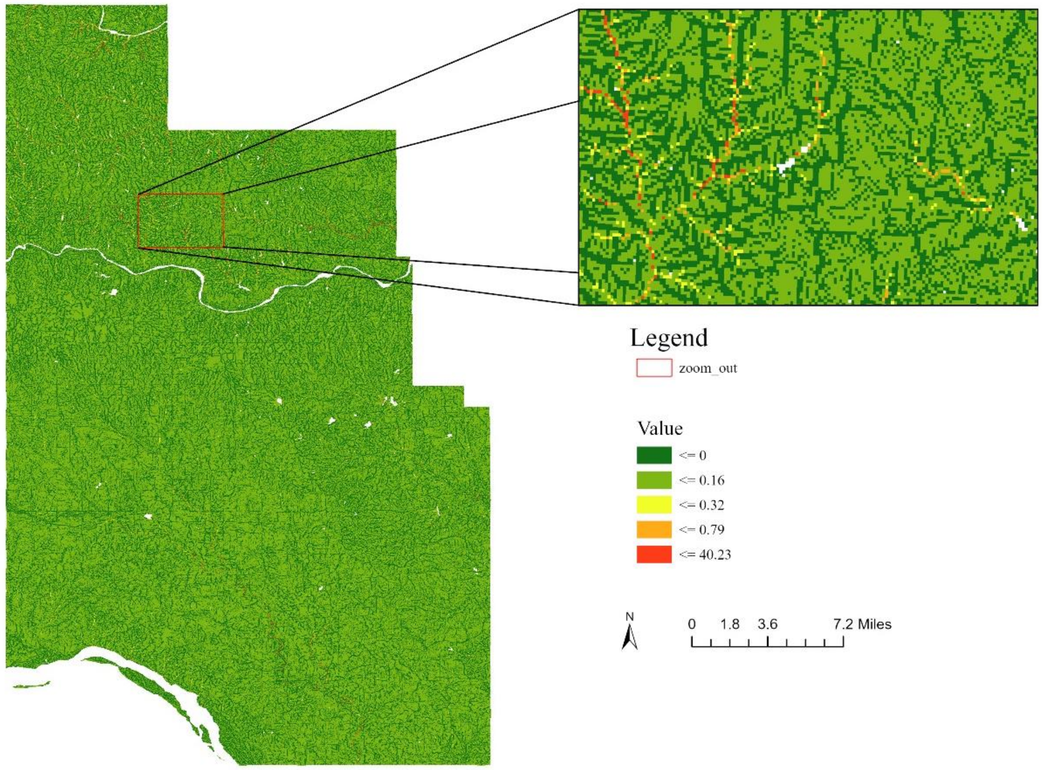

Figure 7-36 Annual predicted average soil loss (tons/acre/year) map for Harmon County

As shown in the Figure 7-36 in the zoom-out section, the condition of the region studied particularly. The area has a soil type as the following in Table 7-13. The governing soil hydrologic group is mainly type C and, in some cases, it is A, B and D type, which shows relatively high runoff and low infiltration. Further, by considering the soil type, areas with higher erosion rate have a soil erodibility value factor of 0.49. In the next level, the land cover of the area has been studied. According to the land cover map of Oklahoma, the area that shows higher erosion rate mostly were located on the region consists of shrub scrub with land cover factor value of 0.45. The mentioned area showed noticeably high LS factor. As shown in Table 7-14 base on correlation factor of different RUSLE factors, LS factor shows the largest participation on the final erosion map. P and R factor shows the same correlation in final erosion map in the Harmon county.

Table 7-13 soil type with the hydrologic group type for north Harmon County

11—Carey loam, 1 to 3 percent slopes	
Hydrologic Soil Group	B
38—Madge loam, 0 to 1 percent slopes	
Hydrologic Soil Group	B
67—Woodward loam, 1 to 3 percent slopes, warm	
Hydrologic Soil Group	C
70—Woodward-Quinlan complex, 3 to 5 percent slopes	
Hydrologic Soil Group	C
51—Shrewder fine sandy loam, 1 to 3 percent slopes	
Hydrologic Soil Group	A
39—Madge loam, 1 to 3 percent slopes	
Hydrologic Soil Group	B
69—Woodward-Quinlan complex, 1 to 3 percent slopes	
Hydrologic Soil Group	C
48—Quinlan-Rock outcrop complex, 12 to 45 percent slopes	
Hydrologic Soil Group	D
71—Woodward-Quinlan complex, 5 to 12 percent slopes	
Hydrologic Soil Group	C
27—Hardeman fine sandy loam, 5 to 8 percent slopes, cool	
Hydrologic Soil Group	A
DodA—Dodson loam, 0 to 1 percent slopes	
Hydrologic Soil Group	C
49—Quinlan-Woodward complex, 3 to 5 percent slopes, eroded	
Hydrologic Soil Group	D

Table 7-14 The effect of RUSLE factors on the Harmon final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
R	0.0941	0.0161
P	0.0941	0.0005
C	0.0237	0.0004
LS	0.5874	0.0269
K	0.0387	0.0005

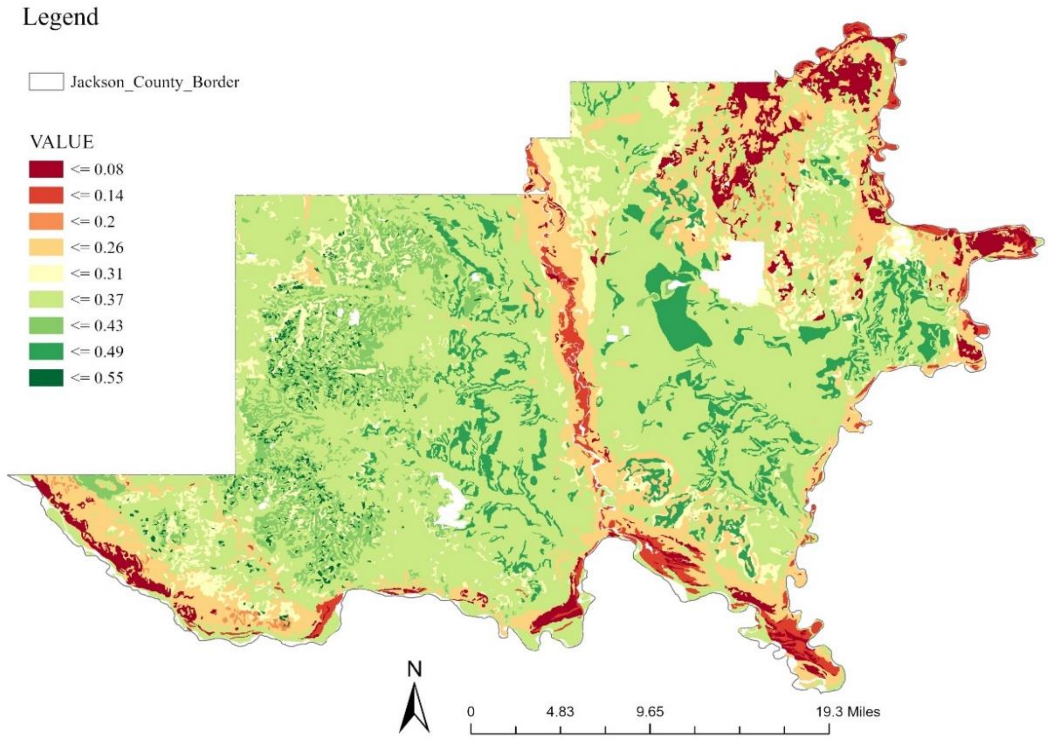

Figure 7-37 RUSLE_2 soil erodibility (K) map for Jackson County

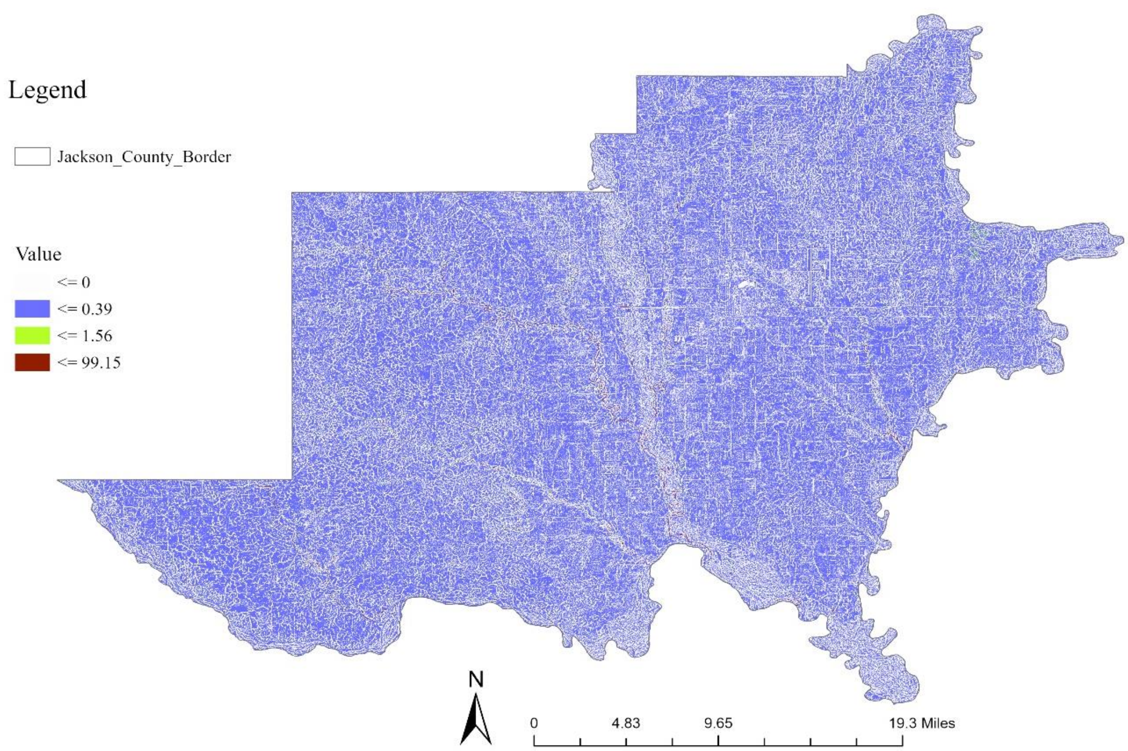

Figure 7-38 RUSLE_2 slope length and steepness factor (LS) map for Jackson County

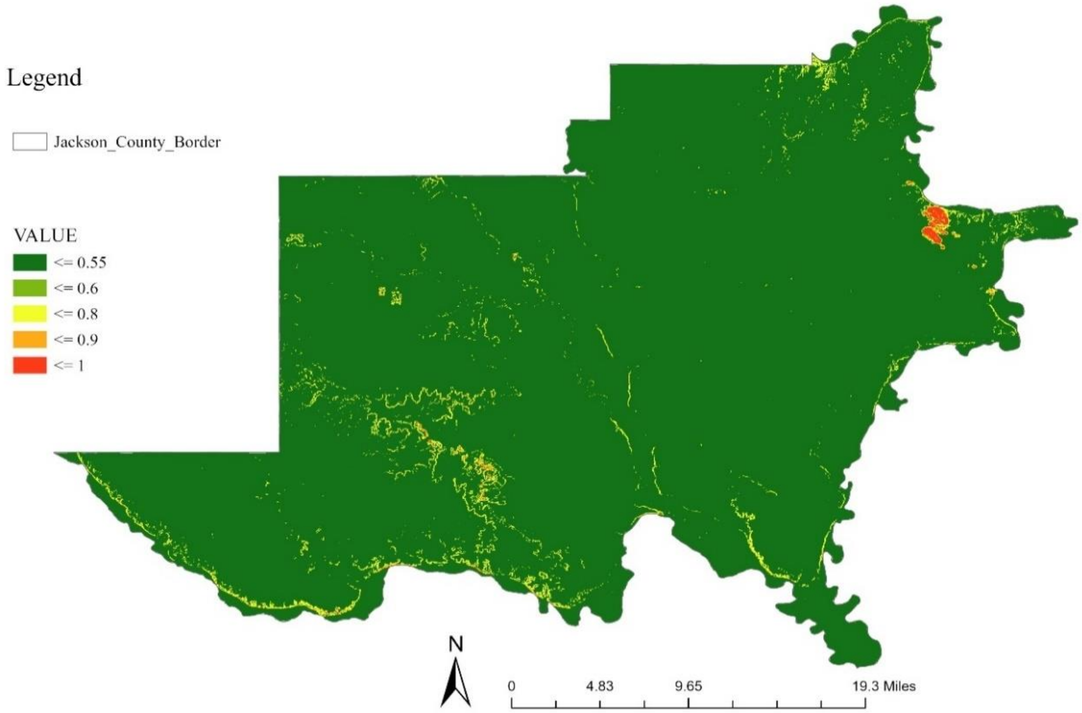

Figure 7-39 RUSLE_2 support practice factor (P) map for Jackson County

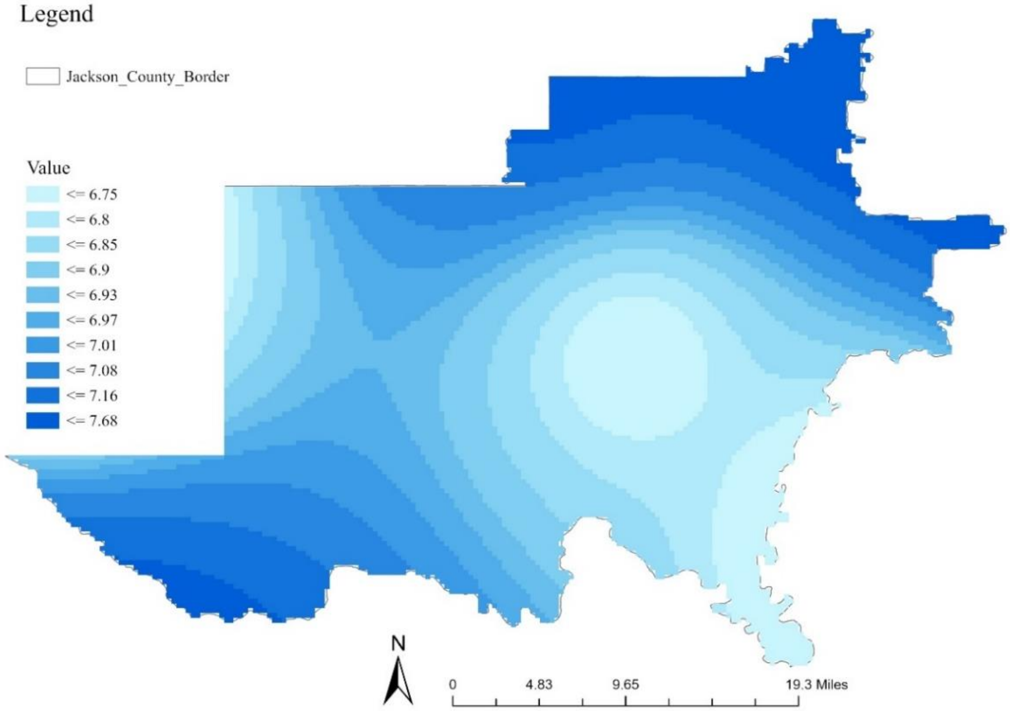

Figure 7-40 RUSLE_2 rainfall erosivity factor (R) map for Jackson County

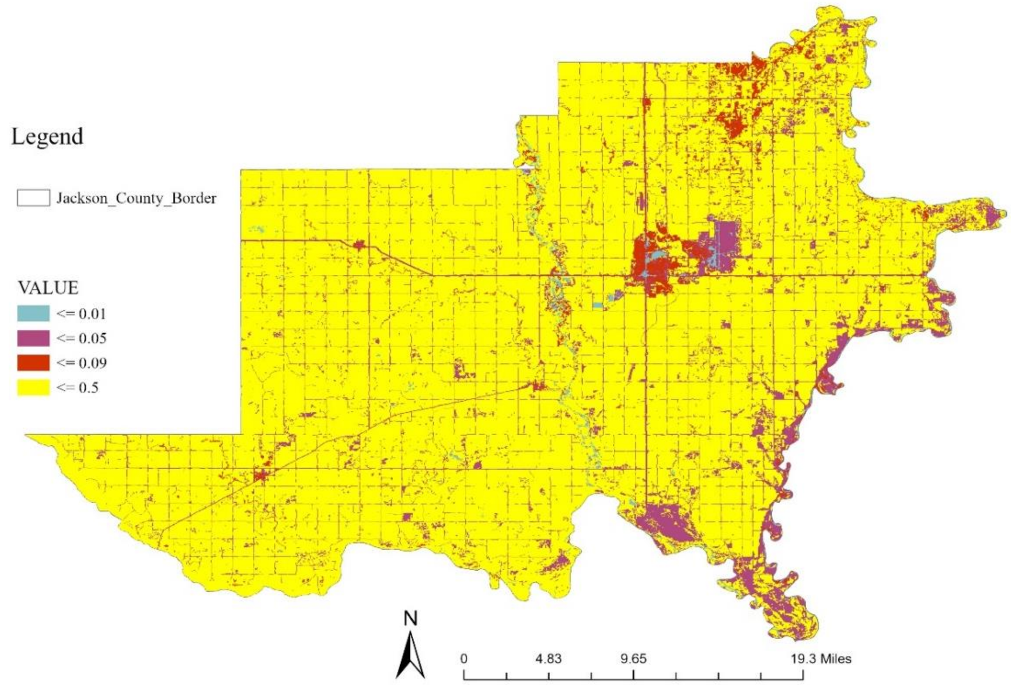

Figure 7-41 RUSLE_2 cover management factor (C) map for Jackson County

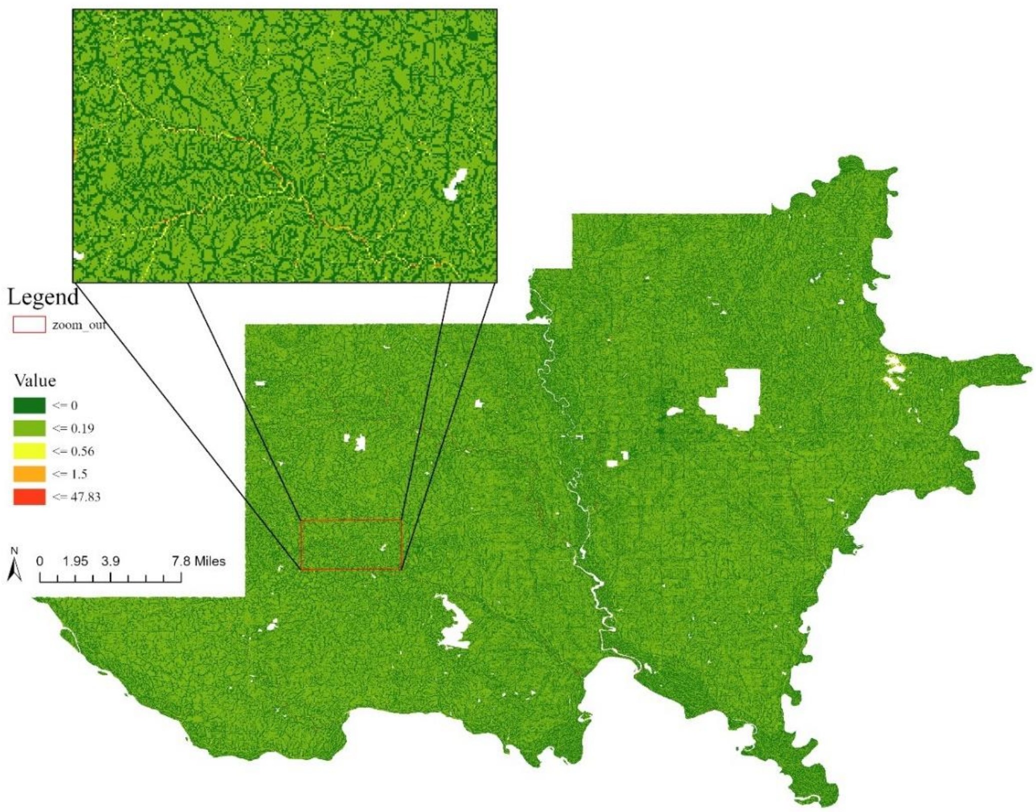

Figure 7-42 Annual predicted average soil loss (tons/acre/year) map for Jackson County

As shown in the Figure 7-42 in the zoom-out section, the condition of the region studied particularly. The area has a soil type as the following in Table 7-13. The governing soil hydrologic group is mainly type C and, in some cases, it is A, B and D type, which shows relatively high runoff and low infiltration. Further, by considering the soil type, areas with higher erosion rate have a soil erodibility value factor of 0.49. In the next level, the land cover of the area has been studied. According to the land cover map of Oklahoma, the area that shows higher erosion rate mostly were located on the region consists of shrub scrub with land cover factor value of 0.45. The mentioned area showed noticeably high LS factor. As shown in Table 7-14 base on correlation factor of different RUSLE factors, LS and P factor shows the largest participation on the final erosion map.

Table 7-15 soil type with the hydrologic group type for west Jackson County

AsmB—Aspermont silt loam, 1 to 3 percent slopes	
Hydrologic Soil Group	B
CVRD—Cottonwood-Vinson-Rock outcrop complex, 1 to 8 percent slopes	
Hydrologic Soil Group	D
VeTE—Vernon-Talpa complex, 1 to 12 percent slopes, stony	
Hydrologic Soil Group	D
RuwA—Rups silty clay loam, 0 to 1 percent slopes, frequently flooded	
Hydrologic Soil Group	C
WtlA—Westill clay loam, 0 to 1 percent slopes	
Hydrologic Soil Group	D
WtlB—Westill clay loam, 1 to 3 percent slopes	
Hydrologic Soil Group	B
TlvB—Tilvern clay loam, 1 to 3 percent slopes	
Hydrologic Soil Group	D
NipA—Nipsum silty clay loam, 0 to 1 percent slopes	
Hydrologic Soil Group	C
EatA—Eastall silty clay, 0 to 1 percent slopes	
Hydrologic Soil Group	D
LacB—La Casa silty clay loam, 1 to 3 percent slopes	
Hydrologic Soil Group	C
VerC—Vernon clay loam, dry, 3 to 5 percent slopes	
Hydrologic Soil Group	D
HolA—Hollister silty clay loam, 0 to 1 percent slopes MLRA 78C	
Hydrologic Soil Group	D
SuuA—Spur clay loam, 0 to 1 percent slopes, occasionally flooded	
Hydrologic Soil Group	B
KoBE—Knoco-Badland complex, dry, 1 to 12 percent slopes	

Hydrologic Soil Group	D

Table 7-16 The effect of RUSLE factors on the Jackson final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
K	0.00760	0.00006
R	-0.00752	-0.00008
C	0.00882	0.00010
LS	0.71885	0.02152
P	0.03659	0.00008

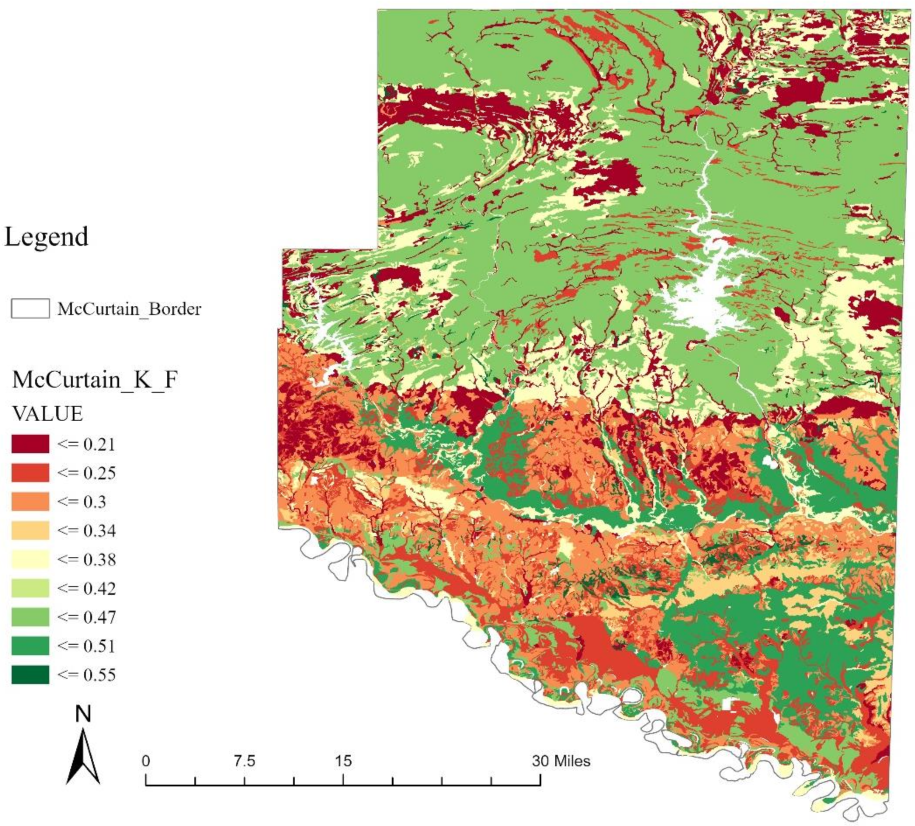

Figure 7-43 RUSLE_2 soil erodibility (K) map for McCurtain County

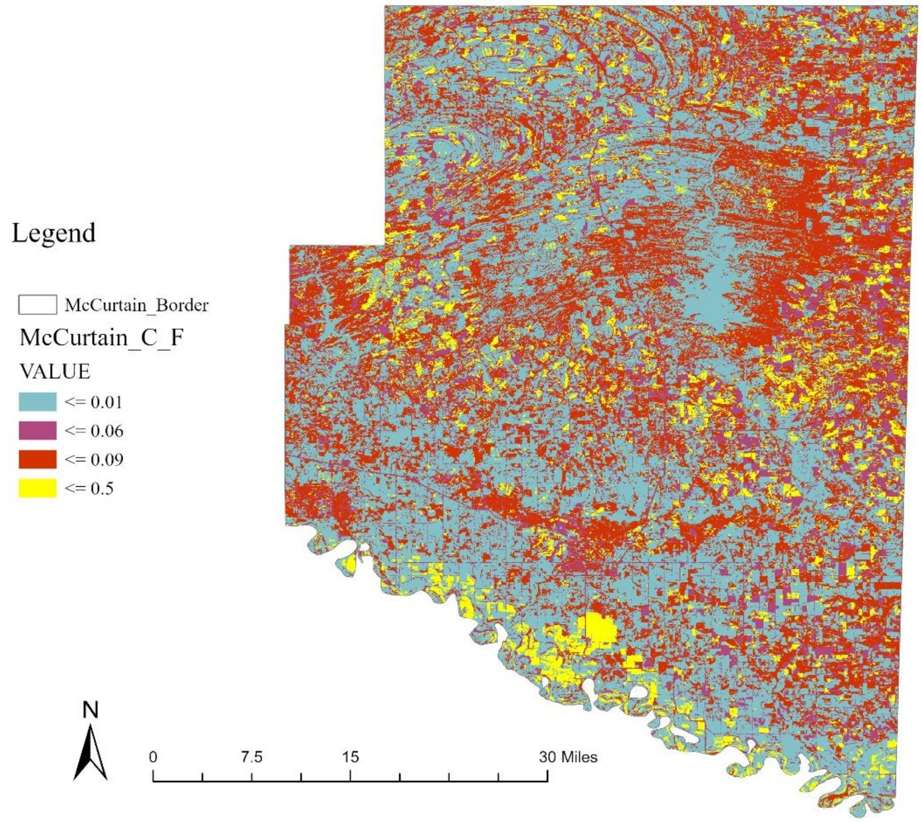

Figure 7-44 RUSLE_2 cover management factor (C) map for McCurtain County

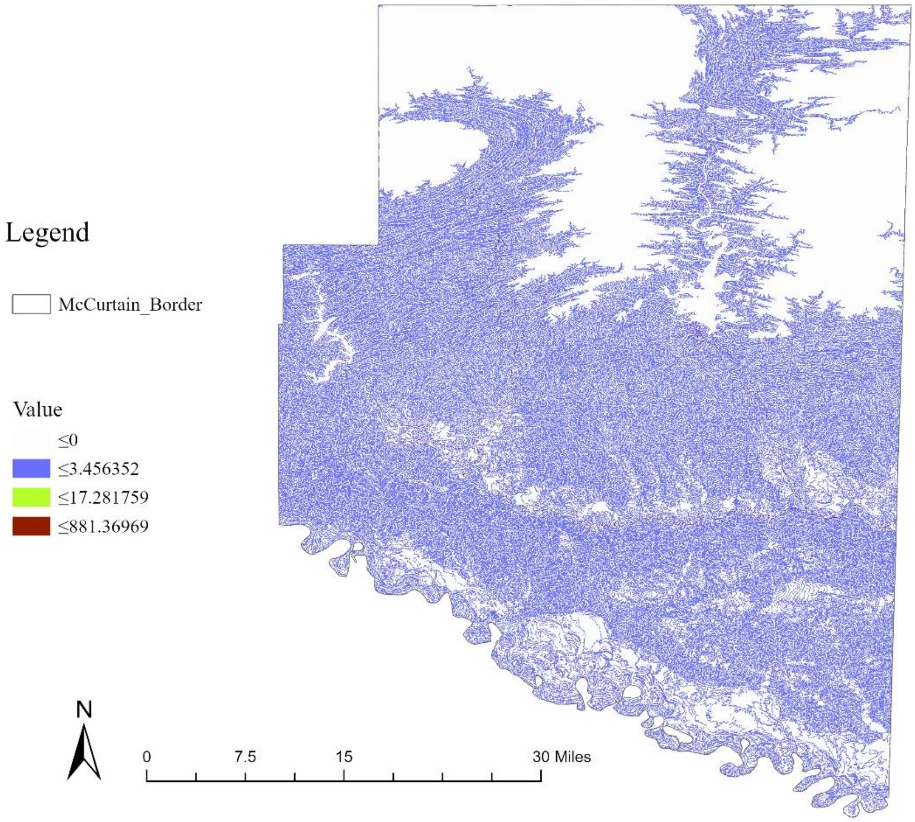

Figure 7-45 RUSLE_2 slope length and steepness factor (LS) map for McCurtain County

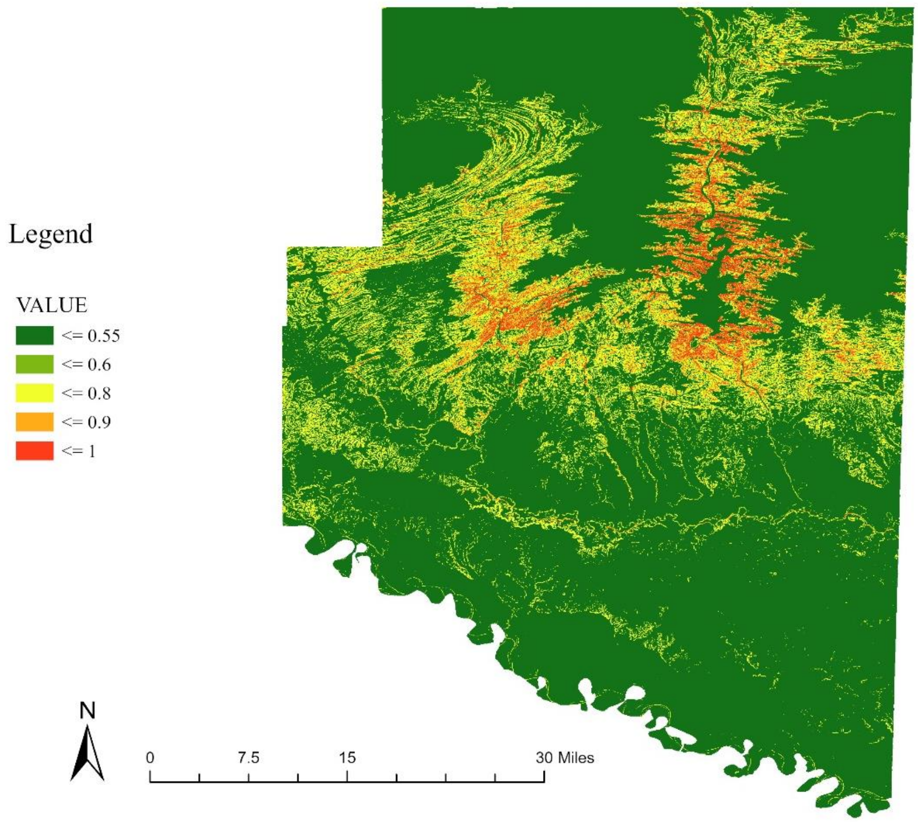

Figure 7-46 RUSLE_2 support practice factor (P) map for McCurtain County

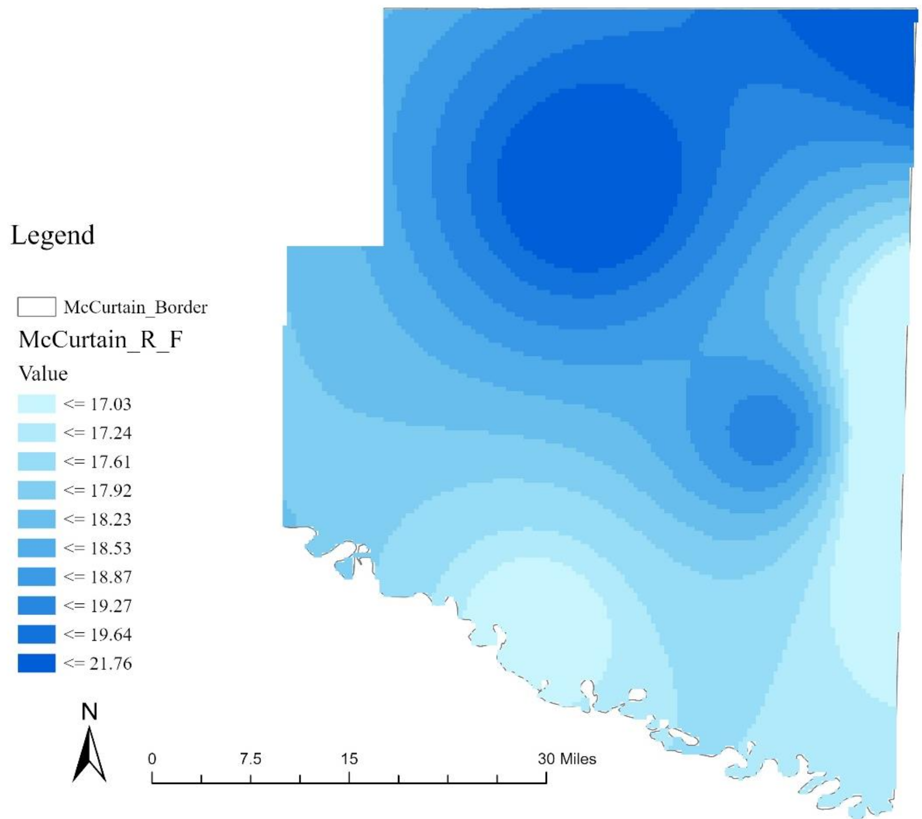

Figure 7-47 RUSLE_2 rainfall erosivity factor (R) map for McCurtain County

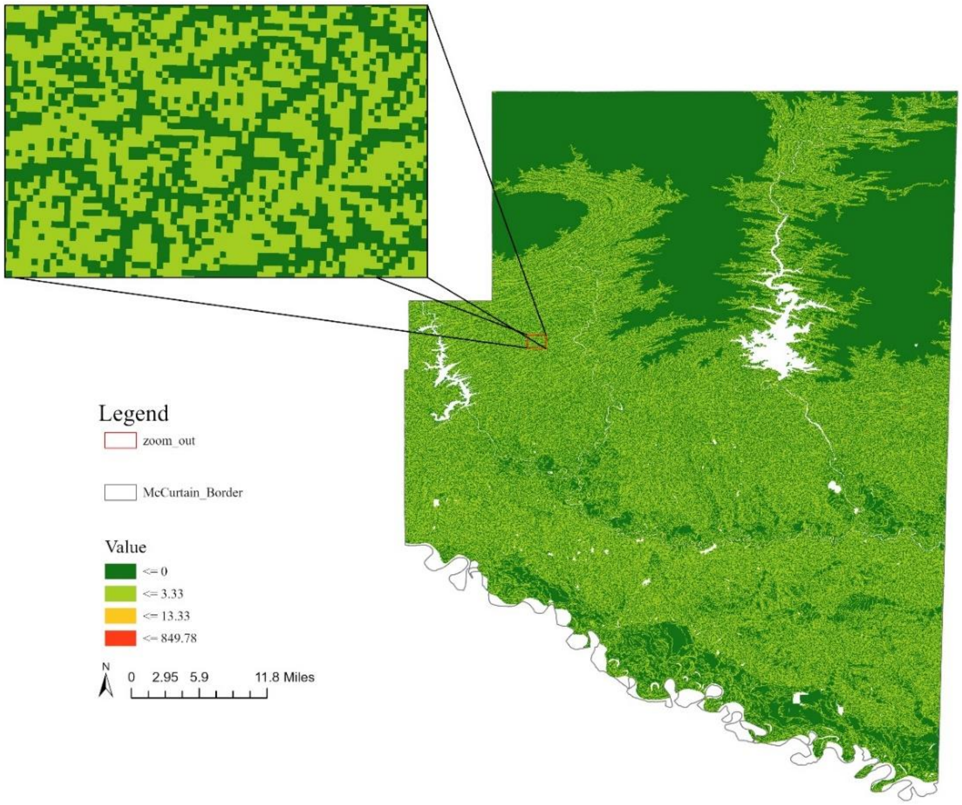

Figure 7-48 Annual predicted average soil loss (tons/acre/year) map for McCurtain County

As shown in the Figure 7-48 in the zoom-out section, the condition of the region studied particularly. The area has a soil type as the following in Table 7-17. The governing soil hydrologic group is mainly type C, which shows relatively high runoff and low infiltration. In the next level, the land cover of the area has been studied. The mentioned area showed noticeably high LS factor. As shown in Table 7-18 base on correlation factor of different RUSLE factors, LS and P factor shows the largest participation on the final erosion map.

Table 7-17 soil type with the hydrologic group type for west McCurtain County

SmC—Sherwood-Zafra complex, 1 to 5 percent slopes	
Hydrologic Soil Group	B
SmE—Sherwood-Zafra complex, 5 to 12 percent slopes	
Hydrologic Soil Group	B
PeB—Pickens-Alikchi complex, 0 to 3 percent slopes	
Hydrologic Soil Group	D

GsE—Clebit-Carnasaw-Stapp association, 12 to 20 percent slopes	
Hydrologic Soil Group	B
AkB—Alikchi loam, 0 to 3 percent slopes	
Hydrologic Soil Group	D
CmE—Carnasaw-Clebit association, 12 to 20 percent slopes	
Hydrologic Soil Group	C
CnD—Carnasaw-Zafra complex, 1 to 8 percent slopes	
Hydrologic Soil Group	C
ShB—Sherwood fine sandy loam, 1 to 3 percent slopes	
Hydrologic Soil Group	B
PcE—Pickens gravelly silt loam, 5 to 15 percent slopes	
Hydrologic Soil Group	D

Table 7-18 The effect of RUSLE factors on the McCurtain final erosion map

RUSLE Factors	CORRELATION MATRIX	COVARIANCE MATRIX
R	0.00515	0.00353
C	0.02144	0.00180
K	0.0013	0.00008
P	0.04161	0.00283
LS	0.48061	0.75333

7-4 Appendix 4

Table 7-19 Estimated sediment yield from construction site in Cimarron County with RUSLE_2

Cimarron county	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment control blanket	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	14	7.43	6.81	2.97	11.8
Cross section_2	6.33	1.1	2.99	1.63	3.55
Cross section_3	3.02	1.57	1.43	0.784	2.4
Cross section_4	6.91	1.72	3.17	1.68	2.38
Cross section_5	8.45	6.45	3.14	3.57	6.98
Cross section_6	2.46	0.228	1.2	0.704	1.9
Cross section_7	9.04	0.407	1.13	0.672	1.46
Cross section_8	2.51	0.82	1.21	0.683	1.56
Cross section_9	2.29	0.347	1.13	0.679	1.78
Cross section_10	2.59	1.05	1.19	0.668	1.54
Average Sediment yield	5.76	2.1122	2.34	1.404	3.535
MAX Sediment yield	14	7.43	6.81	3.57	11.8
MIN Sediment yield	2.29	0.228	1.13	0.668	1.46

Table 7-20 Efficiency rating for different BMPs used in Cimarron County

Cimarron county	Best Management Practices	Efficiency Rating (ER)
Cross section_1	Silt fences	0.47
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.79
	Fiber Loges 6"	0.16
Cross section_2	Silt fences	0.83
	Temporary Seeding & Mulching	0.53
	Blanket for whole section	0.75
	Fiber Loges 6"	0.44
Cross section_3	Silt fences	0.48
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.74
	Fiber Loges 6"	0.21

Cross section_4	Silt fences	0.75
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.76
	Fiber Loges 6"	0.65
Cross section_5	Silt fences	0.24
	Temporary Seeding & Mulching	0.63
	Erosion Sediment Blanket	0.58
	Fiber Loges 6"	0.17
Cross section_6	Silt fences	0.91
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.71
	Fiber Loges 6"	0.44
Cross section_7	Silt fences	0.95
	Temporary Seeding & Mulching	0.87
	Erosion Sediment Blanket	0.92
	Fiber Loges 6"	0.84
Cross section_8	Silt fences	0.67
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.73
	Fiber Loges 6"	0.38
Cross section_9	Silt fences	0.85
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.70
	Fiber Loges 6"	0.22
Cross section_10	Silt fences	0.59
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.74
	Fiber Loges 6"	0.40

Table 7-21 Estimated sediment yield from construction site in Texas County with RUSLE_2

Texas County	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	3.51	1.11	1.43	1.07	3.37
Cross section_2	3.26	0.90	1.44	1.20	3.25
Cross section_3	3.39	1.16	1.43	1.19	2.70
Cross section_4	3.81	1.35	1.54	1.18	2.42
Cross section_5	3.72	1.04	1.48	1.18	2.66
Cross section_6	3.45	0.65	1.50	1.24	2.90
Cross section_7	2.80	0.61	1.28	1.10	1.60
Cross section_8	5.15	2.08	2.07	1.65	3.26
Cross section_9	2.51	0.53	1.14	0.98	1.40
Cross section_10	7.68	2.55	3.04	2.39	5.67
Cross section_11	9.97	6.97	4.10	2.51	8.79
Cross section_12	11.00	9.28	4.58	2.57	10.00
Cross section_13	182.00	56.00	74.20	40.30	159.00
Cross section_14	24.20	8.60	9.24	6.39	21.10
Cross section_15	3.16	0.75	1.40	1.17	1.78
Average Sediment yield	17.97	6.24	7.32	4.41	15.33
MAX Sediment yield	182.00	56.00	74.20	40.30	159.00
MIN Sediment yield	2.51	0.53	1.14	0.98	1.40

Table 7-22 Efficiency rating for different BMPs used in Texas County

Texas county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.68
	Temporary Seeding & Mulching	0.59
	Erosion Sediment Blanket	0.70
	Fiber Loges 6"	0.04
CrossSection_2	Silt fences	0.72
	Temporary Seeding & Mulching	0.56
	Erosion Sediment Blanket	0.63
	Fiber Loges 6"	0.00
CrossSection_3	Silt fences	0.66

	Temporary Seeding & Mulching	0.58
	Erosion Sediment Blanket	0.65
	Fiber Loges 6"	0.20
CrossSection_4	Silt fences	0.65
	Temporary Seeding & Mulching	0.60
	Erosion Sediment Blanket	0.69
	Fiber Loges 6"	0.36
CrossSection_5	Silt fences	0.72
	Temporary Seeding & Mulching	0.60
	Erosion Sediment Blanket	0.68
	Fiber Loges 6"	0.28
CrossSection_6	Silt fences	0.81
	Temporary Seeding & Mulching	0.57
	Erosion Sediment Blanket	0.64
	Fiber Loges 6"	0.16
CrossSection_7	Silt fences	0.78
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.61
	Fiber Loges 6"	0.43
CrossSection_8	Silt fences	0.60
	Temporary Seeding & Mulching	0.60
	Erosion Sediment Blanket	0.68
	Fiber Loges 6"	0.37
CrossSection_9	Silt fences	0.79
	Temporary Seeding & Mulching	0.55
	Erosion Sediment Blanket	0.61
	Fiber Loges 6"	0.44
CrossSection_10	Silt fences	0.67
	Temporary Seeding & Mulching	0.60
	Erosion Sediment Blanket	0.69
	Fiber Loges 6"	0.26
CrossSection_11	Silt fences	0.30
	Temporary Seeding & Mulching	0.59
	Erosion Sediment Blanket	0.75
	Fiber Loges 6"	0.12
CrossSection_12	Silt fences	0.16
	Temporary Seeding & Mulching	0.58
	Erosion Sediment Blanket	0.77
	Fiber Loges 6"	0.09
CrossSection_13	Silt fences	0.69
	Temporary Seeding & Mulching	0.59

	Erosion Sediment Blanket	0.78
	Fiber Loges 6"	0.13
CrossSection_14	Silt fences	0.64
	Temporary Seeding & Mulching	0.62
	Erosion Sediment Blanket	0.74
	Fiber Loges 6"	0.13
CrossSection_15	Silt fences	0.76
	Temporary Seeding & Mulching	0.56
	Erosion Sediment Blanket	0.63
	Fiber Loges 6"	0.44

Table 7-23 Estimated sediment yield from construction site in Beaver County with RUSLE_2

Beaver County	**Sediment Yield (tons/acre/year) from Unprotected site**	**Sediment Yield (tons/acre/year) from site with silt fences**	**Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching**	**Sediment Yield (tons/acre/year) from site with erosion and sediment**	**Sediment Yield (tons/acre/year) from site with 6" fiber logs**
Cross section_1	5.04	1.42	1.85	1.09	3.72
Cross section_2	2.69	0.80	1.25	0.92	1.24
Cross section_3	3.64	0.90	1.71	1.31	2.81
Cross section_4	88.10	32.60	47.00	30.40	65.40
Cross section_5	12.00	3.64	5.10	3.42	9.59
Cross section_6	5.84	0.81	2.64	1.89	5.03
Cross section_7	2.92	0.47	1.37	1.01	2.02
Cross section_8	6.49	1.90	2.49	1.40	3.67
Average Sediment yield	15.84	5.32	7.93	5.18	11.69
MAX Sediment yield	88.10	32.60	47.00	30.40	65.40
MIN Sediment yield	2.69	0.47	1.25	0.92	1.24

Table 7-24 Efficiency rating for different BMPs used in Beaver County

Beaver county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.72
	Temporary Seeding & Mulching	0.63
	Erosion Sediment Blanket	0.78
	Fiber Loges 6"	0.26
CrossSection_2	Silt fences	0.70
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.66
	Fiber Loges 6"	0.54
CrossSection_3	Silt fences	0.75
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.64
	Fiber Loges 6"	0.23
CrossSection_4	Silt fences	0.63
	Temporary Seeding & Mulching	0.47
	Erosion Sediment Blanket	0.65
	Fiber Loges 6"	0.26
CrossSection_5	Silt fences	0.70
	Temporary Seeding & Mulching	0.58
	Erosion Sediment Blanket	0.72
	Fiber Loges 6"	0.20
CrossSection_6	Silt fences	0.86
	Temporary Seeding & Mulching	0.55
	Erosion Sediment Blanket	0.68
	Fiber Loges 6"	0.14
CrossSection_7	Silt fences	0.84
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.65
	Fiber Loges 6"	0.31
CrossSection_8	Silt fences	0.71
	Temporary Seeding & Mulching	0.62
	Erosion Sediment Blanket	0.78
	Fiber Loges 6"	0.43

Table 7-25 Estimated sediment yield from construction site in Ottawa County with RUSLE_2

Ottawa County	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	15.40	5.77	7.59	8.29	10.30
Cross section_2	26.40	11.40	12.50	13.70	18.50
Cross section_3	20.60	13.40	9.71	10.70	16.60
Cross section_4	58.30	26.70	27.60	21.20	42.40
Cross section_5	39.10	7.96	19.10	21.20	38.70
Cross section_6	25.80	4.25	12.70	14.10	14.80
Cross section_7	42.00	18.20	19.80	21.70	22.70
Cross section_8	18.20	8.07	8.75	9.55	12.40
Cross section_9	18.80	10.90	9.11	10.00	14.20
Cross section_10	7.66	1.70	4.11	4.43	7.36
Cross section_11	15.70	3.42	7.93	8.55	15.40
Cross section_12	17.60	9.24	8.58	9.20	12.90
Cross section_13	16.90	7.22	8.08	8.80	11.60
Cross section_14	25.70	7.22	12.70	13.80	25.20
Average Sediment yield	24.87	9.68	12.02	12.52	18.79
MAX Sediment yield	58.30	26.70	27.60	21.70	42.40
MIN Sediment yield	7.66	1.70	4.11	4.43	7.36

Table 7-26 Efficiency rating for different BMPs used in Ottawa County

Ottawa county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.63
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.33
CrossSection_2	Silt fences	0.57

	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.30
	Silt fences	0.35
CrossSection_3	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 9"	0.19
	Silt fences	0.54
CrossSection_4	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.64
	Fiber Loges 6"	0.27
	Silt fences	0.86
CrossSection_5	Temporary Seeding & Mulching	0.67
	Erosion Sediment Blanket	0.64
	Fiber Loges 6"	0.34
	Silt fences	0.84
CrossSection_6	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.45
	Fiber Loges 6"	0.43
	Silt fences	0.57
CrossSection_7	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.46
	Silt fences	0.56
CrossSection_8	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.32
	Silt fences	0.42
CrossSection_9	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.47
	Fiber Loges 6"	0.24
	Silt fences	0.78
CrossSection_10	Temporary Seeding & Mulching	0.46
	Erosion Sediment Blanket	0.42
	Fiber Loges 6"	0.04
	Silt fences	0.78
CrossSection_11	Temporary Seeding & Mulching	0.49
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02
	Silt fences	0.48
CrossSection_12	Temporary Seeding & Mulching	0.51

	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.27
CrossSection_13	Silt fences	0.57
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.31
CrossSection_14	Silt fences	0.72
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02

Table 7-27 Estimated sediment yield from construction site in Craig County with RUSLE_2

Craig County	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment [illegible]	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	67.50	31.60	31.10	31.70	67.50
Cross section_2	25.50	8.27	12.40	13.70	16.40
Cross section_3	50.60	13.30	23.80	25.30	35.20
Cross section_4	20.40	16.30	9.54	10.40	20.30
Cross section_5	71.60	23.20	32.60	35.20	70.30
Cross section_6	72.60	27.50	40.30	27.90	72.60
Cross section_7	41.80	18.40	19.40	19.90	41.20
Cross section_8	26.00	10.70	12.60	14.00	18.00
Cross section_9	108.00	26.90	49.80	53.90	103.00
Cross section_10	91.70	32.70	41.80	36.40	90.30
Average Sediment yield	57.57	20.89	27.33	26.84	53.48
MAX Sediment yield	108.00	32.70	49.80	53.90	103.00
MIN Sediment yield	20.40	8.27	9.54	10.40	16.40

Table 7-28 Efficiency rating for different BMPs used in Craig County

Craig county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.53
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.53
	Fiber Loges 6"	0.00
CrossSection_2	Silt fences	0.68
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.36
CrossSection_3	Silt fences	0.74
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.50
	Fiber Loges 6"	0.30
CrossSection_4	Silt fences	0.20
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.49
	Fiber Loges 6"	0.00
CrossSection_5	Silt fences	0.68
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.51
	Fiber Loges 6"	0.02
CrossSection_6	Silt fences	0.62
	Temporary Seeding & Mulching	0.44
	Erosion Sediment Blanket	0.62
	Fiber Loges 6"	0.00
CrossSection_7	Silt fences	0.56
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.52
	Fiber Loges 6"	0.01
CrossSection_8	Silt fences	0.59
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.31
CrossSection_9	Silt fences	0.75

	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.50
	Fiber Loges 6"	0.05
CrossSection_10	Silt fences	0.64
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.60
	Fiber Loges 6"	0.02

Table 7-29 Estimated sediment yield from construction site in Nowata County with RUSLE_2

Nowata county	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	33.20	11.80	16.30	17.90	32.70
Cross section_2	22.10	6.88	10.80	11.90	21.70
Cross section_3	39.40	18.10	18.70	18.30	38.80
Cross section_4	16.60	5.61	8.29	9.14	16.30
Cross section_5	19.50	8.97	9.23	9.20	19.00
Cross section_6	30.40	12.20	14.40	15.80	23.80
Cross section_7	44.40	14.80	20.70	20.80	33.30
Cross section_8	7.76	4.76	4.08	4.51	5.80
Cross section_9	22.60	5.89	10.70	10.70	21.10
Cross section_10	45.50	11.60	21.20	20.70	45.10
Cross section_11	61.70	19.20	28.10	28.60	51.00
Cross section_12	22.50	8.94	11.20	10.90	15.30
Cross section_13	240.00	114.00	107.00	93.70	175.00
Cross section_14	36.30	15.20	17.40	19.20	25.20
Cross section_15	15.00	7.62	7.47	8.26	11.00
Cross section_16	17.50	10.60	8.49	9.41	13.40
Average Sediment yield	42.15	17.26	19.63	19.31	34.28
MAX Sediment yield	240.00	114.00	107.00	93.70	175.00

MIN Sediment yield	7.76	4.76	4.08	4.51	5.80

Table 7-30 Efficiency rating for different BMPs used in Nowata County

Nowata county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.64
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02
CrossSection_2	Silt fences	0.69
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02
CrossSection_3	Silt fences	0.54
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.02
CrossSection_4	Silt fences	0.66
	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.45
	Fiber Loges 6"	0.02
CrossSection_5	Silt fences	0.54
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.53
	Fiber Loges 6"	0.03
CrossSection_6	Silt fences	0.60
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.22
CrossSection_7	Silt fences	0.67
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.53
	Fiber Loges 6"	0.25
CrossSection_8	Silt fences	0.39

	Temporary Seeding & Mulching	0.47
	Erosion Sediment Blanket	0.42
	Fiber Loges 6"	0.25
	Silt fences	0.74
CrossSection_9	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.53
	Fiber Loges 6"	0.07
	Silt fences	0.74
CrossSection_10	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.00
	Silt fences	0.69
CrossSection_11	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.17
	Silt fences	0.60
CrossSection_12	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.52
	Fiber Loges 6"	0.32
	Silt fences	0.53
CrossSection_13	Temporary Seeding & Mulching	0.55
	Erosion Sediment Blanket	0.61
	Fiber Loges 6"	0.27
	Silt fences	0.58
CrossSection_14	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.47
	Fiber Loges 6"	0.31
	Silt fences	0.49
CrossSection_15	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.45
	Fiber Loges 6"	0.27
	Silt fences	0.39
CrossSection_16	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46

Fiber Loges 6"	0.23

Table 7-31 Estimated sediment yield from construction site in Ottawa County with RUSLE_2

Ottawa County	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	15.40	5.77	7.59	8.29	10.30
Cross section_2	26.40	11.40	12.50	13.70	18.50
Cross section_3	20.60	13.40	9.71	10.70	16.60
Cross section_4	58.30	26.70	27.60	21.20	42.40
Cross section_5	39.10	7.96	19.10	21.20	38.70
Cross section_6	25.80	4.25	12.70	14.10	14.80
Cross section_7	42.00	18.20	19.80	21.70	22.70
Cross section_8	18.20	8.07	8.75	9.55	12.40
Cross section_9	18.80	10.90	9.11	10.00	14.20
Cross section_10	7.66	1.70	4.11	4.43	7.36
Cross section_11	15.70	3.42	7.93	8.55	15.40
Cross section_12	17.60	9.24	8.58	9.20	12.90
Cross section_13	16.90	7.22	8.08	8.80	11.60
Cross section_14	25.70	7.22	12.70	13.80	25.20
Average Sediment yield	24.87	9.68	12.02	12.52	18.79
MAX Sediment yield	58.30	26.70	27.60	21.70	42.40
MIN Sediment yield	7.66	1.70	4.11	4.43	7.36

Table 7-32 Efficiency rating for different BMPs used in Ottawa County

Ottawa county	**Best Management Practices**	**Efficiency Rating (ER)**
CrossSection_1	Silt fences	0.63

	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.33
CrossSection_2	Silt fences	0.57
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.30
CrossSection_3	Silt fences	0.35
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 9"	0.19
CrossSection_4	Silt fences	0.54
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.64
	Fiber Loges 6"	0.27
CrossSection_5	Silt fences	0.86
	Temporary Seeding & Mulching	0.67
	Erosion Sediment Blanket	0.64
	Fiber Loges 6"	0.34
CrossSection_6	Silt fences	0.84
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.45
	Fiber Loges 6"	0.43
CrossSection_7	Silt fences	0.57
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.46
CrossSection_8	Silt fences	0.56
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.32
CrossSection_9	Silt fences	0.42
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.47
	Fiber Loges 6"	0.24
CrossSection_10	Silt fences	0.78
	Temporary Seeding & Mulching	0.46
	Erosion Sediment Blanket	0.42
	Fiber Loges 6"	0.04
CrossSection_11	Silt fences	0.78
	Temporary Seeding & Mulching	0.49

	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02
CrossSection_12	Silt fences	0.48
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.27
CrossSection_13	Silt fences	0.57
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.31
CrossSection_14	Silt fences	0.72
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02

Table 7-33 Estimated sediment yield from construction site in Harmon County with RUSLE_2

Harmon county	**Sediment Yield (tons/acre/year) from Unprotected site**	**Sediment Yield (tons/acre/year) from site with silt fences**	**Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching**	**Sediment Yield (tons/acre/year) from site with erosion and sediment control**	**Sediment Yield (tons/acre/year) from site with 6" fiber logs**
Cross section_1	100.00	30.40	43.90	33.70	83.80
Cross section_2	82.80	30.40	36.10	28.60	56.00
Cross section_3	17.70	7.44	7.41	6.88	16.00
Cross section_4	1.69	0.12	0.83	0.86	0.76
Cross section_5	6.94	1.89	2.90	2.48	4.33
Cross section_6	8.91	0.38	3.83	3.82	8.88
Cross section_7	4.38	0.82	2.13	2.18	2.42
Average Sediment yield	31.77	10.21	13.87	11.22	24.60
MAX Sediment yield	100.00	30.40	43.90	33.70	83.80
MIN Sediment yield	1.69	0.12	0.83	0.86	0.76

Table 7-34 Efficiency rating for different BMPs used in Harmon County

Harmon county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.70
	Temporary Seeding & Mulching	0.56
	Erosion Sediment Blanket	0.66
	Fiber Loges 6"	0.16
CrossSection_2	Silt fences	0.63
	Temporary Seeding & Mulching	0.56
	Erosion Sediment Blanket	0.65
	Fiber Loges 6"	0.32
CrossSection_3	Silt fences	0.58
	Temporary Seeding & Mulching	0.58
	Erosion Sediment Blanket	0.61
	Fiber Loges 6"	0.10
CrossSection_4	Silt fences	0.93
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.49
	Fiber Loges 6"	0.55
CrossSection_5	Silt fences	0.73
	Temporary Seeding & Mulching	0.58
	Erosion Sediment Blanket	0.64
	Fiber Loges 6"	0.38
CrossSection_6	Silt fences	0.96
	Temporary Seeding & Mulching	0.57
	Erosion Sediment Blanket	0.57
	Fiber Loges 6"	0.00
CrossSection_7	Silt fences	0.81
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.50
	Fiber Loges 6"	0.45

Table 7-35 Estimated sediment yield from construction site in Craig County with RUSLE_2

Craig County	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	67.50	31.60	31.10	31.70	67.50
Cross section_2	25.50	8.27	12.40	13.70	16.40
Cross section_3	50.60	13.30	23.80	25.30	35.20
Cross section_4	20.40	16.30	9.54	10.40	20.30
Cross section_5	71.60	23.20	32.60	35.20	70.30
Cross section_6	72.60	27.50	40.30	27.90	72.60
Cross section_7	41.80	18.40	19.40	19.90	41.20
Cross section_8	26.00	10.70	12.60	14.00	18.00
Cross section_9	108.00	26.90	49.80	53.90	103.00
Cross section_10	91.70	32.70	41.80	36.40	90.30
Average Sediment yield	57.57	20.89	27.33	26.84	53.48
MAX Sediment yield	108.00	32.70	49.80	53.90	103.00
MIN Sediment yield	20.40	8.27	9.54	10.40	16.40

Table 7-36 Efficiency rating for different BMPs used in Craig County

Craig county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.53
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.53

	Fiber Loges 6"	0.00
CrossSection_2	Silt fences	0.68
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.36
CrossSection_3	Silt fences	0.74
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.50
	Fiber Loges 6"	0.30
CrossSection_4	Silt fences	0.20
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.49
	Fiber Loges 6"	0.00
CrossSection_5	Silt fences	0.68
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.51
	Fiber Loges 6"	0.02
CrossSection_6	Silt fences	0.62
	Temporary Seeding & Mulching	0.44
	Erosion Sediment Blanket	0.62
	Fiber Loges 6"	0.00
CrossSection_7	Silt fences	0.56
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.52
	Fiber Loges 6"	0.01
CrossSection_8	Silt fences	0.59
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.31
CrossSection_9	Silt fences	0.75
	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.50
	Fiber Loges 6"	0.05
CrossSection_10	Silt fences	0.64

Temporary Seeding & Mulching	0.54
Erosion Sediment Blanket	0.60
Fiber Loges 6"	0.02

Table 7-37 Estimated sediment yield from construction site in Nowata County with RUSLE_2

Nowata county	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	33.20	11.80	16.30	17.90	32.70
Cross section_2	22.10	6.88	10.80	11.90	21.70
Cross section_3	39.40	18.10	18.70	18.30	38.80
Cross section_4	16.60	5.61	8.29	9.14	16.30
Cross section_5	19.50	8.97	9.23	9.20	19.00
Cross section_6	30.40	12.20	14.40	15.80	23.80
Cross section_7	44.40	14.80	20.70	20.80	33.30
Cross section_8	7.76	4.76	4.08	4.51	5.80
Cross section_9	22.60	5.89	10.70	10.70	21.10
Cross section_10	45.50	11.60	21.20	20.70	45.10
Cross section_11	61.70	19.20	28.10	28.60	51.00
Cross section_12	22.50	8.94	11.20	10.90	15.30
Cross section_13	240.00	114.00	107.00	93.70	175.00
Cross section_14	36.30	15.20	17.40	19.20	25.20
Cross section_15	15.00	7.62	7.47	8.26	11.00
Cross section_16	17.50	10.60	8.49	9.41	13.40
Average Sediment yield	42.15	17.26	19.63	19.31	34.28
MAX Sediment yield	240.00	114.00	107.00	93.70	175.00
MIN Sediment yield	7.76	4.76	4.08	4.51	5.80

Table 7-38 Efficiency rating for different BMPs used in Nowata County

Nowata county	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.64
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02
CrossSection_2	Silt fences	0.69
	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.02
CrossSection_3	Silt fences	0.54
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.02
CrossSection_4	Silt fences	0.66
	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.45
	Fiber Loges 6"	0.02
CrossSection_5	Silt fences	0.54
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.53
	Fiber Loges 6"	0.03
CrossSection_6	Silt fences	0.60
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.48
	Fiber Loges 6"	0.22
CrossSection_7	Silt fences	0.67
	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.53
	Fiber Loges 6"	0.25
CrossSection_8	Silt fences	0.39
	Temporary Seeding & Mulching	0.47
	Erosion Sediment Blanket	0.42
	Fiber Loges 6"	0.25
CrossSection_9	Silt fences	0.74

	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.53
	Fiber Loges 6"	0.07
	Silt fences	0.74
CrossSection_10	Temporary Seeding & Mulching	0.53
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.00
	Silt fences	0.69
CrossSection_11	Temporary Seeding & Mulching	0.54
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.17
	Silt fences	0.60
CrossSection_12	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.52
	Fiber Loges 6"	0.32
	Silt fences	0.53
CrossSection_13	Temporary Seeding & Mulching	0.55
	Erosion Sediment Blanket	0.61
	Fiber Loges 6"	0.27
	Silt fences	0.58
CrossSection_14	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.47
	Fiber Loges 6"	0.31
	Silt fences	0.49
CrossSection_15	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.45
	Fiber Loges 6"	0.27
	Silt fences	0.39
CrossSection_16	Temporary Seeding & Mulching	0.51
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.23

Table 7-39 Estimated sediment yield from construction site in Jackson County with RUSLE_2

Jackson County	**Sediment Yield (tons/acre/year) from Unprotected site**	**Sediment Yield (tons/acre/year) from site with silt fences**	**Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching**	**Sediment Yield (tons/acre/year) from site with erosion and sediment blanket**	**Sediment Yield (tons/acre/year) from site with 6" fiber logs**
Cross section_1	2.54	1.16	1.28	1.21	1.63
Cross section_2	9.56	1.77	4.56	4.25	5.73
Cross section_3	2.10	1.07	1.06	1.01	1.41
Cross section_4	25.20	10.30	11.40	8.09	17.40
Cross section_5	4.49	1.37	2.14	2.02	2.74
Cross section_6	3.69	0.90	1.51	1.36	3.28
Average Sediment yield	7.93	2.76	3.66	2.99	5.37
MAX Sediment yield	25.20	10.30	11.40	8.09	17.40
MIN Sediment yield	2.10	0.90	1.06	1.01	1.41

Table 7-40 Efficiency rating for different BMPs used in Jackson County

Jackson County	**Best Management Practices**	**Efficiency Rating (ER)**
CrossSection_1	Silt fences	0.54
	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.52
	Fiber Loges 6"	0.36
CrossSection_2	Silt fences	0.81
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.56
	Fiber Loges 6"	0.40
CrossSection_3	Silt fences	0.49

	Temporary Seeding & Mulching	0.50
	Erosion Sediment Blanket	0.52
	Fiber Loges 6"	0.33
CrossSection_4	Silt fences	0.59
	Temporary Seeding & Mulching	0.55
	Erosion Sediment Blanket	0.68
	Fiber Loges 6"	0.31
CrossSection_5	Silt fences	0.69
	Temporary Seeding & Mulching	0.52
	Erosion Sediment Blanket	0.55
	Fiber Loges 6"	0.39
CrossSection_6	Silt fences	0.76
	Temporary Seeding & Mulching	0.59
	Erosion Sediment Blanket	0.63
	Fiber Loges 6"	0.11

Table 7-41 Estimated sediment yield from construction site in McCurtain County with RUSLE_2

McCurtain County	Sediment Yield (tons/acre/year) from Unprotected site	Sediment Yield (tons/acre/year) from site with silt fences	Sediment Yield (tons/acre/year) from site with Temporary seeding and mulching	Sediment Yield (tons/acre/year) from site with erosion and sediment	Sediment Yield (tons/acre/year) from site with 6" fiber logs
Cross section_1	208.00	98.80	108.00	88.10	156.00
Cross section_2	84.90	32.10	45.60	37.10	84.00
Cross section_3	283.00	167.00	152.00	113.00	219.00
Cross section_4	57.80	30.10	31.70	26.40	42.80
Cross section_5	121.00	15.40	65.20	59.00	118.00
Cross section_6	199.00	50.50	105.00	84.10	132.00
Cross section_7	60.70	29.00	32.40	24.70	48.30
Cross section_8	177.00	85.70	94.30	75.80	139.00
Cross section_9	187.00	89.20	97.90	85.60	108.00
Cross section_10	91.70	31.80	47.80	28.70	53.00

Cross section_11	49.40	19.77	27.40	21.60	30.20
Cross section_12	2.56	1.86	1.58	1.60	2.19
Cross section_13	1.26	1.03	0.77	0.76	1.12
Cross section_14	15.80	2.04	9.00	7.56	9.17
Cross section_15	5.07	2.42	3.05	2.93	3.21
Cross section_16	5.97	1.42	3.53	3.48	3.42
Cross section_17	27.70	9.08	15.60	14.90	27.00
Average Sediment yield	158.95	99.30	84.33	64.72	125.30
MAX Sediment yield	283.00	167.00	152.00	113.00	219.00
MIN Sediment yield	57.80	32.10	31.70	26.40	42.80

Table 7-42 Efficiency rating for different BMPs used in McCurtain County

McCurtain County	Best Management Practices	Efficiency Rating (ER)
CrossSection_1	Silt fences	0.53
	Temporary Seeding & Mulching	0.48
	Erosion Sediment Blanket	0.58
	Fiber Loges 6"	0.25
CrossSection_2	Silt fences	0.62
	Temporary Seeding & Mulching	0.46
	Erosion Sediment Blanket	0.56
	Fiber Loges 6"	0.01
CrossSection_3	Silt fences	0.41
	Temporary Seeding & Mulching	0.46
	Erosion Sediment Blanket	0.60
	Fiber Loges 6"	0.23
CrossSection_4	Silt fences	0.48
	Temporary Seeding & Mulching	0.45
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.26
CrossSection_5	Silt fences	0.87
	Temporary Seeding & Mulching	0.46
	Erosion Sediment Blanket	0.51
	Fiber Loges 6"	0.02
CrossSection_6	Silt fences	0.75
	Temporary Seeding & Mulching	0.47
	Erosion Sediment Blanket	0.58
	Fiber Loges 6"	0.34
CrossSection_7	Silt fences	0.52
	Temporary Seeding & Mulching	0.47
	Erosion Sediment Blanket	0.59

	Fiber Loges 6"	0.20
CrossSection_8	Silt fences	0.52
	Temporary Seeding & Mulching	0.47
	Erosion Sediment Blanket	0.57
	Fiber Loges 6"	0.21
CrossSection_9	Silt fences	0.52
	Temporary Seeding & Mulching	0.48
	Erosion Sediment Blanket	0.54
	Fiber Loges 6"	0.42
CrossSection_10	Silt fences	0.65
	Temporary Seeding & Mulching	0.48
	Erosion Sediment Blanket	0.69
	Fiber Loges 6"	0.42
CrossSection_11	Silt fences	0.60
	Temporary Seeding & Mulching	0.45
	Erosion Sediment Blanket	0.56
	Fiber Loges 6"	0.39
CrossSection_12	Silt fences	0.27
	Temporary Seeding & Mulching	0.38
	Erosion Sediment Blanket	0.38
	Fiber Loges 6"	0.14
CrossSection_13	Silt fences	0.18
	Temporary Seeding & Mulching	0.39
	Erosion Sediment Blanket	0.40
	Fiber Loges 6"	0.11
CrossSection_14	Silt fences	0.87
	Temporary Seeding & Mulching	0.43
	Erosion Sediment Blanket	0.52
	Fiber Loges 6"	0.42
CrossSection_15	Silt fences	0.52
	Temporary Seeding & Mulching	0.40
	Erosion Sediment Blanket	0.42
	Fiber Loges 6"	0.37
CrossSection_16	Silt fences	0.76
	Temporary Seeding & Mulching	0.41
	Erosion Sediment Blanket	0.42
	Fiber Loges 6"	0.43
CrossSection_17	Silt fences	0.67
	Temporary Seeding & Mulching	0.44
	Erosion Sediment Blanket	0.46
	Fiber Loges 6"	0.03

VITA

Maryam Ahmadvand

Candidate for the Degree of

Master of Science

Thesis: MODELING THE IMPACTS OF EROSION AND SEDIMENT CONTROL PRACTICES FOR ROADWAY CONSTRUCTION SITES ON WATER QUALITY IN OKLAHOMA

Major Field: Civil Engineering

Biographical:

Education:

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

Completed the requirements for the Master of Science in Hydrogeology at Azad University of North Tehran, Tehran, Iran in May 2013.

Completed the requirements for the Bachelor of Science in Applied Geology at Kharazmi University, Tehran, Iran in May 2009.

Experience:

Geology Expert in Espeer Mining Service CO. Tehran, Iran. March 2013-Jul 2015

Art Teacher in Oloome Noo high school, Tehran, Iran, 2013