The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

Mississippi River Basin Healthy Watersheds Initiative (MRBI) Watershed Assessment for:

Long Branch Watershed (HUC-10280103204)
Spring Branch-Elk Creek Watershed (HUC-102801031302)
Turkey Creek Watershed (HUC-102801031301)

Deliverable # 1 – Inventory of the Watershed
Deliverable # 2 – Resource Analysis of the Watershed
Deliverable # 3 –Identification of Conservation Needs on Vulnerable Acres

FINAL

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SCOPE AND OBJECTIVES

In 2009, the U.S. Department of Agriculture through the National Resources Conservation Service (NRCS) began the Mississippi River Basin Healthy Watersheds Initiative (MRBI) to work with landowners to implement voluntary conservation practices designed to reduce nutrients entering the Gulf of Mexico. The goal of the MRBI program is to improve water quality, restore wetlands, and enhance wildlife habitat while ensuring economic viability of agricultural lands in high-priority watersheds within the Mississippi Basin (USDA, 2017). However, watershed-scale evaluations identifying specific pollution sources and the conservation practices needed to improve water quality are needed to aid field office staff responsible for working with landowners. Therefore, a comprehensive planning effort aimed at prioritizing specific landscapes, crop types, and the conservation practices available is needed to help NRCS field staff implement the MRBI program where it will be the most effective considering limited available resources.

The Missouri State Office of the NRCS contracted the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University (MSU) to perform a watershed assessment study for three HUC-12 watersheds within the Lower Grand River watershed, Turkey Creek (102801031301), Spring Branch-Elk Creek (102801031302), and Long Branch (102801031204) located in Linn, Chariton and Sullivan Counties, Missouri. Soil and streambank erosion has been identified as major concern for water quality for streams within the Lower Grand River watershed and water quality monitoring shows high levels of nutrients, bacteria, and suspended sediment (MDNR 2014). Sections of the Lower Grand River downstream of the these three watersheds are listed under the Missouri Department of Natural Resources (MDNR) Section 303(d) list of impaired waters for *E. Coli* pollution (MDNR, 2018A). Furthermore, the Turkey Creek watershed and the Spring Branch-Elk Creek watershed flow directly into Silver Lake on the Swan Lake National Wildlife Refuge that has experienced recent sedimentation problems (USFWS 2011). Additionally, Long Branch flows into West Yellow Creek just upstream of one of the water supply intakes for the City of Brookfield, Missouri.

The purpose of this assessment is to provide NRCS field staff with the necessary information to identify locations within the watershed where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. The specific objectives of this assessment are to:

(1) Complete a comprehensive inventory of existing data in the watershed including information related to geology, soils, hydrology, climate, land use, and any existing biological or chemical monitoring data available;

(2) Perform a resource assessment of the watershed that includes analysis of the data gathered in the watershed inventory that includes identification of nonpoint source pollutants, water quality impairments, rainfall-runoff characteristics, and a field-based stream bank conditions assessment;
(3) Provide NRCS staff with information on the resource concerns within the watershed, specific field conditions that contribute that most to the water quality impairment, and what conservation practices should be implemented for the existing conditions to get the most water quality benefit.

DESCRIPTION OF THE WATERSHED

Location

Turkey Creek, Spring Branch-Elk Creek, and Long Branch watersheds are located within the greater Lower Grand River watershed (HUC-8# 10280103) of north-central Missouri and southern Iowa (Figure 1). Turkey Creek (33,770 acres) and Spring Branch-Elk Creek watershed (20,455 acres) are primarily located in Linn County, Missouri with the outlet of the watersheds in Chariton County, Missouri and are part of the larger Elk Creek watershed (HUC-10# 1028010313) (Figure 2). Both watersheds flow into Silver Lake that is within the Swan Lake National Wildlife Refuge (SLNWR). The Long Branch watershed (30,668 acres) headwaters flow south from Sullivan County, Missouri into Linn County, Missouri where it joins the West Yellow Creek near Brookfield, Missouri (population of 4,420). Long Branch is within the larger West Yellow Creek watershed (HUC-10# 1028010312).

Climate

Northern Missouri has a warm and temperate continental climate with hot summers and moderate winters (Peel, Finlayson and Mcmahon, 2007). Over the 30 year period from 1988-2017, the average annual rainfall at Brookfield, Missouri ranged from 26.1-61.8 inches with an average of 41.3 inches per year (Table 1). The highest monthly rainfall totals (>5 inches) occur in early summer during the month of June, with generally less precipitation (<3 inches) during the winter months (Figure 3A). Between 1988-2017, average annual temperature ranged from 49.9-56.2°F with an average of 53.2°F (Table 1). Over that period, average monthly temperatures range from about 27°F in January to near 77°F in July (Figure 3B). Over the last 30 years, the overall annual precipitation was around 40 inches per year for the majority of that time (Figure 4A). The exception would be a period of relatively high rainfall from 2007-2010, where the five-year moving average was near 50 inches per year. Annual average temperature decreased from about 55°F in 1988, to near 51°F by 1997 (Figure 4B). However, temperatures have increased steadily since then to over 53°F in 2017.

Solar radiation and evaporation trends are similar to temperature trends for Brookfield. From 2000-2017, average daily solar radiation by month ranged from about 6.5 MJ/m^2 in December up to around 24.3 MJ/m^2 in July with an average of 15.7 MJ/m^2 (Figure 5A). Between 2012-2017, monthly average daily estimated evaporation ranged from around 0.04 inches in December to about 0.24 inches in June with an average of 0.14 inches over the entire year (Figure 5B).

Geology, Topography, and Geomorphology

The watersheds are located in the Chariton Hills section and the Grand River Dissected Plain section of the Dissected Till Plain Province (Nigh and Schroeder 2002). The region is characterized by gently rolling plains where local relief typically between 80-150 ft (Nigh and Schroeder, 2002). The underlying bedrock consists of Pennsylvanian age interbedded limestone, shale and coal beds of the Cherokee Group and the Marmaton limestone (Nigh and Schroeder 2002). These bedrock formations are exposed along some major stream courses where streams have cut through the overlying glacial till and loess flowing from north to south. There are several till formations identified in this region with varying amounts of clays, sands, and gravels left from the melting ice sheets (Rovey and Balco 2011). Loess thicknesses over the majority of the Lower Grand watershed are approximately 5 to 10 feet deep (Nigh and Schroeder, 2002). Typically, stream channels in the Lower Grand River watershed are filled with sand and silt from excessive streambank erosion due to poor riparian corridors, channelization, and levee construction (Pitchford and Kerns, 2018). The NRCS has not published regional curves describing stream channels in the Central Lowlands of the Interior Plains.

Landscape and Soils

The Lower Grand watershed is within the Central Dissected Till Plains Major Land Resource Area (MLRA) (USDA 2006). The Dissected Till Plains consist of rolling hills intersected with uniformly level upland divides and level alluvial lowlands (USDA 2006). Upland soils, side slopes, and narrow ridgetops formed over loess and glacial till, or entirely of glacial till (Benham 1990). Elevations within the watershed range from 649-1,013 feet with elevations generally higher towards the northern portion of the Long Branch sub-watershed (Figure 6). LiDAR derived slope ranges from 0%-77% percent with a majority of the land having slope of <3%, expect for in the Long Branch sub-watershed where slopes are generally higher (>3%) (Figure 7). Slopes <3% are generally found in the uplands and valley bottoms, while the steeper slopes, that are not road embankments, are located along the valley margin.

The majority of the upland soils in each of the study watersheds are classified as alfisols (>69%) with mollisols covering a majority of the valley margins and valley bottoms with Long Branch having more alfisols and less mollisols compared to the two watersheds (Table 2, Figure 8). Upland soils in these three watersheds generally have poor infiltration rates, with majority of the soils in each watershed having a Hydrological Soil Group of C/D (slow/very slow) or Group D (very slow) (Table 2, Figure 9) (USDA 2009a). Again, the Long Branch watershed has significantly more soils classified as Group D (very slow) than the other two watersheds. Soils were also classified by Land Capability Classification, which is a way to describe the suitability of a soil to grow field crops (USDA 2018). Within the three watersheds, land capability classes range from Class 2-6 and limitations for subclasses (e) erosion and (w) water (Table 2). Erosion tends to be the major limitation along the uplands area of the watershed (or in areas with steeper slope) and wetness tends to be the limitation in the developed area around Brookfield and along the valley bottoms (Figure 10). The majority of the soils in all three watersheds are classified in the 3e category which have severe limitations that reduce the choice of plants or require special conservation practices (USDA 2018). The Long Branch watershed has significantly more soils (28.5%) with the 4e classification which have very severe limitations restricting the choice of plants or require very careful management. The majority of the soils within the three watersheds have a soil erosion K-factor between 0.3 and 0.4, with K-factors >0.4 found primarily in the urbanized areas and the southern valley margins of the Spring Branch-Elk Creek watershed (Table 2, Figure 11). Overall, soils in the Long Branch watershed have higher runoff and erosion potential compared to the other two watersheds. A complete list of soil series found within the watershed is available in the Appendix A.

Hydrology and Drainage Network

The main channels of the Turkey Creek, Long Branch, and Spring Branch-Elk Creek watersheds generally flow from north to south, with the majority of tributary drainage flowing from the east and the west into the main stem (Figure 7). Streams within the Lower Grand River watershed are flashy and rise rapidly after storm events, but recede quickly back to base flow with the majority of runoff occurring in June (Pitchford and Kerns, 2018). There are a total of 390 miles of mapped streams within the three watersheds, with only 61 miles classified as permanent flow (Table 3). Turkey Creek has the largest length of permanent streams with a total of 30 mi, while Spring Branch-Elk Creek has the shortest at 14 mi. There are a total of 401 acres of lakes and ponds within the three watersheds.

There are no major water users within the three study watersheds, however the City of Brookfield gets a portion of its water supply from intakes located immediately downstream of the confluence of Long Branch and West Yellow Creek. The City of Brookfield utilizes three water supply intakes that supplied 488 million gallons of water in 2017. These intakes are Brookfield Reservoir, West Yellow Creek, and Brookfield Lake (Table 4). Brookfield Reservoir and West Yellow Creek are both located downstream of the Long Branch watershed and these two sources supplied over half of the water to Brookfield in 2017.

Land Use and Land Cover

The Lower Grand watershed is mostly an agricultural watershed, but has significant amounts of mixed land uses. Land use for the watershed was determined using the 2013-2017 National Agricultural Statistics Service (NASS) Crop Database. Crop classes were combined to look at the general overall picture of land use in the watershed. In general, the Long Branch watershed is mainly grass/pasture land, while Spring Branch-Elk Creek and Turkey Creek watersheds are dominated by crop land. The Long Branch watershed has about 50% grass and pasture land, while having only around 15% of the land in row crops as of 2017 (Figure 12 and Table 5). In contrast, 48.9% of the Spring Branch-Elk Creek watershed and 44.2% Turkey Creek watersheds are in row crops, while having only 22.4% and 26.8% in grass/pasture land respectively. However, the amount of land in corn and soybeans has increased in all three watersheds from 2013-2017 by 6-9%, while the amount of grass/pasture land has decreased suggesting a conversion to land uses with potentially higher pollution potential (Table 6).

Previous Work and Other Available Data

TMDLs and Management Plans

Currently, there are no Total Maximum Daily Loads (TMDL) for streams within the three watersheds in this study. However, there is a TMDL scheduled for the Grand River in Livingston and Chariton Counties, which includes portions of the Grand River downstream of the project watersheds (MDNR 2018B). There are several streams outside of the three watersheds, but within the Lower Grand watershed that are on the 303(d) impaired streams list for bacteria and low dissolved oxygen due to rural nonpoint source pollution that are similar to the three watersheds in this study (MDNR 2018A). Additionally, a healthy watershed plan was established for the Lower Grand River watershed in 2016 that specifically states that reduction of streambank and soil erosion, sediment, nutrients, and bacteria from agricultural nonpoint sources was important to maintain and improve water quality within the watershed (MDNR 2016). One of the main objectives of this plan was to increase the amount of funding available for implementing best-practices in the watershed.

Surface and Ground Water Monitoring Stations

There are no United States Geological Survey (USGS) gaging stations within the three watersheds. The closet gaging station near Sumner, MO is approximately 7 miles upstream on the Lower Grand River from the Yellow Creek confluence (USGS Gaging Station # 06902000). To be able to predict discharge within the study watershed, 24 nearby USGS gaging stations were used to complete drainage area based regression equations to be able to estimate discharge from different size watersheds within the study area (Figure 13). A list of the USGS gaging stations can be found in Appendix B. If resources became available to install one gaging station within each watershed, possible locations would be on Long Branch at Heathy Road (UTM Zone 15N Northing: 4,409,882.17 Easting: 493,879.17), on Turkey Creek at Ginger Road (UTM Zone 15N Northing: 4,399,061.06 Easting: 486,381.87), and/or on Elk Creek at Iguana Road (UTM Zone 15N Northing: 4,395,106.31 Easting: 491,376.30). Additionally, there is a ground water monitoring station in Mendon, approximately 3 miles south and outside of the Spring Branch-Elk Creek watershed (Site Number: 393544093075601). This well has been operating since 2009 and data from this station shows an overall decline in ground water levels in this area and can vary as much as 15 feet (Figure 14).

Water Quality Sampling Data

There are a total of four water quality monitoring sites with data available for this project, and all four are located within the Long Branch watershed in Linn County (Figure 15). These four sites have from 1-31 samples collected and analyzed for nutrients and sediment from 2004-2006 (Table 7). These samples were collected by Premium Standard Farms Inc. and Versar Inc. Additionally, the USGS performed a study along the Missouri River to assess changes in nutrient concentrations over time, which includes one site on the Lower Grand River at the USGS gage at Sumner. At this site concentrations of TN and TP decreased about 3% between 2011-2015, which was the lowest decrease among watersheds that were studied (Krempa and Flickinger, 2017). Furthermore, this study indicates the Lower Grand site may have the lowest decrease in nutrients because it did not receive additional funding through the MRBI program from 2011-2015.

There are a number of permitted point sources and animal feeding operations within the three watersheds. The Laclede wastewater treatment plant is within the Turkey Creek watershed and the Brookfield wastewater treatment plant is within the Spring Branch-Elk Creek watershed (Table 8, Figure 15). The remaining permitted point sources are mostly land application sites, with a large concentration in the west-central portion of the Turkey Creek watershed. There are several animal feeding operations within the upper Long Branch watershed in Sullivan County that are used for hog production that include land application of manure (Table 9, Figure 15).

Biological Monitoring Data

There are no biological monitoring data available within the three study watersheds. However, a series of fish studies were conducted on Elk, Honeyhouse, Turkey, and Yellow Creeks that border Swan Lake National Wildlife Refuge in Chariton County. Fish samples were analyzed for various metal and organic contaminants that likely came from agricultural nonpoint source pollution from the surrounding areas, but were not considered toxic as of 1993 (Nash 1993). Additionally, biological assessments have been completed on several streams within the Lower Grand River watershed, but not within the three watershed study area. A biological assessment of West Fork Locust Creek in Linn and Sullivan Counties showed streams were able to fully support aquatic life (MDNR 2008).

Summary

The purpose of this report is to provide the information necessary to describe the study watershed for the Mississippi River Healthy Watershed Initiative (MRBI) in three HUC-12 watersheds within the Lower Grand River watershed Spring Branch-Elk Creek (10280103132), Turkey Creek (102801031301), and Long Branch (102801031204). Soil and streambank erosion have been identified as major concern for water quality for streams within the Lower Grand River watershed and water quality monitoring shows high levels of nutrients, bacteria, and suspended sediment. The purpose of the full watershed assessment is to provide NRCS field staff with the necessary information to identify locations within the watershed where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. Therefore, this first phase of the project provides a general description of the watershed and inventories the data that will be used in subsequent phases of the project. Information collected for the initial phase of the project provides the geographical, physical, hydrological, and water quality attributes of the watershed along with documentation of available data sources (Table 10).

RESOURCE ANALYSIS OF THE WATERSHED

The resource analysis of the watershed will include evaluation of water quality data within the watershed, observed channel conditions from both historical aerial photography and on-site visual assessment, and water quality modeling results and load reduction analysis. Ultimately these results will help establish what land uses are producing the most pollution and what practices would be the most useful in reducing nutrient and sediment loads within the watershed.

Water Quality Analysis

Summary statistics for all nutrient and sediment samples were used to evaluate water quality by looking at both the range of mean concentrations and variability among sites. All water quality data was downloaded from the MDNR Water Quality Assessment System website. Of the three watersheds in this study, data was only available for four sites within the Long Branch watershed. At these sites, average concentrations of total phosphorus (TP) ranged from 0.180-0.438 mg/L, mean concentrations of total nitrogen (TN) ranged from 0.26-0.90 mg/L, and average total suspended sediment (TSS) concentrations ranged from 22.7-88.2 mg/L (Table 11). The site with the most number of samples is 602/14.3 located in the middle of the watershed with a total number of 31 samples collected for TP and sediment (Figure 15 and Table 11). Here, TP ranges from 0.050-7.300 mg/L with an average of 0.438 mg/L. Average sediment concentration for this site is 65 mg/L with a range of 4.0-817 mg/L. Downstream of 602/14.3 average nutrient and sediment concentrations decrease, suggesting a significant pollution source is located upstream of this site (Figure 16). However, concentrations increase again near the mouth of the watershed suggesting another pollution source is influencing water quality at this site as well. While the number and distribution of samples available in these watersheds are limited, these data are likely indicative of water quality conditions in the other two watersheds within the study.

Total phosphorus concentrations within the Long Branch Creek watershed are elevated compared to established reference concentration for the ecoregion, but nitrogen concentrations are relatively close to the reference condition. Ambient water quality criteria suggested reference conditions for these streams are 0.71 mg/L TN and 0.092 mg/L TP based on the 25th percentile value for streams within the Central Irregular Plains region (Table 12, USEPA 2000). This sample set shows that Long Branch Creek has mean total phosphorus concentrations two to five times higher than regional reference condition. However, average total nitrogen concentrations at three of the four sites in the watershed are lower than the reference condition and the other site is only slightly higher. These data suggest conservation practices that can reduce phosphorus in runoff can be important component in improving and protecting water quality in these watersheds. As stated earlier, a healthy watershed plan was established for the Lower Grand River watershed in 2016 that specifically states that reduction of streambank and soil erosion, sediment, nutrients, and bacteria from agricultural nonpoint sources was important to maintain and improve water quality within the watershed (MDNR 2016).

Channel Stability and Riparian Corridor Assessment

<u>Aerial Photo Methods</u>

Aerial photographs from 1997 and 2015 were obtained from the Missouri Spatial Data Information Service (MSDIS) online data server and were obtained rectified (Table 13). The error involved in the transformation was quantified using point-to-point error analysis. A total of 10 locations on both sets of aerials were evaluated for the point-to-point errors within each of the 12-digit HUC watershed boundary. Overall, mean point-to-point errors ranged from 7.18-9.58 ft for the three watersheds (Table 14). Streams channels for each year were digitized to identify and measure changes over time. Both bank lines were digitized for the main stem and larger tributaries. However, since many of these channels were small and some of the channel bank was obstructed by vegetation, the channel centerline was digitized where it could clearly be seen at a scale of 1:1,500 (Martin and Pavlowsky 2011).

Channel Classification

Tributary channels and the main stem of all three watersheds were further classified by identifying historical channel changes through interpretation of aerial photos between the years of 1997 and 2015. Channels were first characterized as modified or natural. Modified channels were further classified as either channelized or ponded. Finally, natural channels were classified as either stable or active. Active channels were identified by assessing planform changes since 1997 by overlay analysis of the digitized channel using error buffer which is based on the mean point-to-point error for each watershed to account biases attributed to rectification (Martin and Pavlowsky 2011). Active reaches were identified as areas where the buffers between did not overlap for at least 100 ft to account for rectification errors. If the channel was obstructed by vegetation or not visible in both aerials, it was classified as not visible. A flow chart was developed to assist in channel classification during aerial photo interpretation (Figure 17).

Long Branch – The Long Branch watershed had the highest number of total stream miles and the smallest percentage of actively eroding streams of the three watersheds in this study. Channel classification results show of the 182 total stream miles within the watershed, 69.5 mi (38%) of the tributary channels could not be evaluated due to vegetation obstruction or poor photo quality and were classified as not visible (Table 15). Of the remaining stream miles, 17.2 mi (9%) were channelized, 2.6 mi (1%) impounded, 88.2 (48%) were stable, and only 4.4 mi (2%) were active. Most of the actively eroding channels within the watershed are along the main stem of the creek (Figure 19).

Spring Branch-Elk Creek - The Spring Branch-Elk Creek watershed had the smallest number of total stream miles of the three watersheds in this study and most of the active channel erosion is along the main channel. Of the 65.3 total stream miles within the watershed, 26.6 miles (41%) were classified as not visible mainly due to vegetation obstruction (Table 15). In Spring Branch-Elk Creek watershed, 4.0 miles (6%) of the visible streams were channelized, 26.4 miles (40%) were stable and only 8.4 miles (13%) were actively eroding determined by these methods. While there is only 8.4 miles of active channel in the Spring Branch-Elk Creek watershed, much of it is concentrated on the main stem of Elk Creek (Figure 19).

Turkey Creek – The Turkey Creek watershed had the most active stream reaches of the three watersheds in this study. Of the 138 total tributary stream miles within the watershed, 33.5 miles (20%) could not be classified due to obstruction of the channel by vegetation (Table 15). Of the remaining streams, 88.2 miles (48%) was classified as stable, 7.9 miles (9%) were channelized, 2.0 miles (2%) were a dam or pond, and 22.1 miles (17%) were actively eroding. Most of the actively eroding channels within the watershed are along the main stem of the creek, however there are some areas within the tributary network with a high concentration of actively eroding channels (Figure 19).

Evaluation of the visible stream channels suggests that streams in this area may adjust to watershed disturbance though processes other than lateral migration. Due to rectification errors between the photo years, subtle changes between the bank lines cannot be quantified. However, these methods do identify larger scale bank erosion and widening that can be used to quantify sediment contributions from channel instability. The amount of channelization within the Long Branch and Turkey Creek watersheds suggests landowners may have been dealing with channel stability problems or flooding in the past. Additionally, the lower main stem in particular has been heavily channelized (before 1997) with levees construction. Although these features are not always clear in the aerial imagery, a one meter resolution LiDAR DEM was used to reference when classifying the streams. Studies have shown that channelized streams are often much larger than the original channel and slope is increased due to straightening of the channel causing incision in the channelized reach and sedimentation problems downstream (Simon and Rinaldi 2000, Davis 2007). These observations suggest that channel incision and widening may be an important mechanism for adjustment in these streams and this effect cannot be fully evaluated through aerial photo analysis alone for such small streams (Simon and Rinaldi 2000, Harden et al. 2009).

Riparian Corridor Analysis

The presence of a healthy riparian corridor can provide resistance to erosion during floods and filter runoff water moving from the uplands to the stream (Rosgen 1996, Montgomery and MacDonald 2002, USDA 2003). The riparian corridors for the three watersheds in this study were evaluated by creating a buffer around the 2015 digitized stream layer and overlaying that layer on the 2015 aerial photo. A 50 ft buffer was used on first and second order streams and a 100 ft buffer was placed around streams third order and larger (USDA 2014). The area within the buffer was classified into the following: Good, Moderate, and Poor (Figure 18). A Good classification represents portions of streams in which adequate riparian tree coverage extends the width of the buffer on both sides of the stream. A Moderate class signifies one side of the stream buffer meets the good classification, but the other side does not. Alternatively, the Moderate classification can also indicate a situation where riparian coverage reaches the extent of the buffer, but the tree coverage is sparse. Finally, the Poor classification is assigned to portions of the stream where the riparian corridor does not extend to the limits of the buffer on either side of the stream.

Long Branch - Approximately 70% of the riparian corridors along streams in the Long Branch watershed were classified as poor or moderate mostly along the tributaries. Within the Long Branch watershed, 55.4 mi (30%) of the total 182 mi of the streams were classified as having a good riparian corridor (Table 16). Around 77.5 miles of stream (43%) were classified as having moderate riparian corridor. Finally, there are approximately 49.2 stream miles (27%) classified as having poor riparian corridor. Most of the streams classified as poor or moderate are located along tributaries (Figure 20). Typically, poor riparian corridors were located within crop or pasture fields in the uplands. Additionally, there were only a few locations along the main stem where streams were classified as having a poor riparian buffer.

Spring Branch-Elk Creek - The riparian corridors within the Spring Branch-Elk Creek watershed had the highest percentage of streams in the poor category of the three watersheds in this study. There is approximately 28.4 miles (43%) of channel with poor riparian corridor and another 20.6 miles (32%) classified as moderate (Table 16). The spatial distribution of the poor and moderate riparian corridor in the Spring Branch-Elk Creek watershed is concentrated in the many tributaries that flow into Spring Branch-Elk Creek particularly in the northern most section of the watershed (Figure 20). Approximately 16.3 miles (25%) of the channel was classified as having a good riparian corridor. While this does not guarantee these areas are stable, riparian vegetation provides conditions for unstable streambanks to recover by providing roughness during floods to lower velocities and roots can help armor and hold together bank materials to reduce sediment losses via mass wasting (Rosgen 1996, Zaimes et al. 2004, USDA 2014).

Turkey Creek – The Turkey Creek watershed has the highest percentage of good riparian corridors of all three watersheds assessed for this study. About 57.9 miles (44%) of the streams were classified as having a good riparian corridor and most are located along the main stem and major tributaries (Table 16, Figure 20). Around 30.2 miles (22%) of streams in the Turkey Creek watershed have a poor riparian corridor and 49.9 miles (36%) are moderate. Most of the poor riparian corridors in the Turkey Creek watershed are concentrated in the smaller headwaters streams within the watershed.

Visual Stream Survey Results

A modified rapid visual stream survey was conducted on both upstream and downstream portions of all public road crossings within the watershed following an established NRCS protocol (USDA 1998). The protocol was modified by only focusing on five physical stream channel indicators, riparian corridor evaluation, and the presence of manure indicating livestock access to the stream (Appendix C). Based on the assessment, each site receives an overall score between 1 and 10, with <6.0 considered poor, 6.1 – 7.4 fair, 7.5 – 8.9 good, and >9.0 excellent.

Long Branch - For the Long Branch watershed, 198 sites were evaluated using the modified visual stream assessment protocol. Of these 198 sites, 55.6% are rated as poor, 22.7% as fair, 15.2% as good, and 6.6% as excellent (Figure 21). Most of the poor ratings were due to channelization, poor riparian conditions, and presence of livestock within the stream. Streams within cropland use were often engineered into terraced grass waterways. Occasionally there were croplands with insufficient natural vegetation buffers between the crops and the streams and these would lower the evaluation score at the site. Stream condition in pastured lands varied depending on livestock grazing intensity and presence or condition of the riparian corridor. Streams in the poor category typically exhibited poor riparian cover, over-grazing, and cattle access to the stream that greatly decreases the score of a site. Many streams in these pastures also had moderate to severe erosion. The main stem within the Long Branch watershed consistently had incised, unstable banks. Some levees along the main stem prevent appropriate access to the floodplain. Additionally, bank widening and rapid incision has caused the channel to erode into the levees, creating taller bank heights for the main stem. Almost all the main stem had a good riparian corridor, which agrees with the riparian corridor assessment. Also, some of the streams in the uplands were also unstable and were incised by headcuts that were often stopped at the road. These streams show severe channel instability downstream and normal, stable streams upstream of the crossing. This migrating incision indicates a drop in base level downstream or complex responses to watershed disturbance. Overall, streams within the cropland areas scored better than streams within pastured areas and the main stem. Streams in pastures show more signs of instability and may be a target for conservation practices to decrease nonpoint sources of nutrients and sediment in the watershed. Examples of sites evaluated for the Long Branch watershed can be found in Appendix D.

Spring Branch-Elk Creek - A total of 82 crossings were evaluated for a total of 164 possible evaluations. However, established grassed waterways and urban streams were excluded. Therefore, a total of 122 sites were ultimately completed. Of these 122 sites, 13.1% were rated as poor, 30.3% as fair, 38.5% as good, and 18.0% as excellent (Figure 21). Most of the poor ratings were due to channelization, poor riparian conditions, and the presence of livestock within the stream. Streams in cropland areas generally appear to be stable, while streams in pasture areas are typically more unstable. Observations along the main stem of Spring Branch-Elk Creek included that there was good riparian coverage over the majority of the stream.

However, the main stems show many indications of incision and bank widening. In areas where livestock has access to the stream, riparian conditions are often poor, with no trees and eroding banks, and bank were often trampled. Overall, streams within the cropland areas appear stable and generally are not producing excessive sediment through erosion at this time. Conversely, streams in pastures show more signs of instability and may be a target for conservation practices to decrease nonpoint sources of nutrients and sediment in the watershed. Examples of sites evaluated for the Spring Branch-Elk Creek watershed can be found in Appendix E.

Turkey Creek – In the Turkey Creek watershed, a total of 106 crossings were visited for a total of 212 possible evaluations. However, due to implemented grass waterways, railroad embankment, or other visual impairments a total of 196 sites were ultimately completed. Of these 196 sites, 19.4% were rated as poor, 19.9% as fair, 41.3% as good, and 27.6% as excellent (Figure 21). Most of the poor ratings were due to channelization, poor riparian conditions, and presence of livestock within the stream. In general, streams in cropland areas generally appear to be stable, while streams in pasture areas are typically more unstable. The majority of the streams in areas of crops were often channelized into grass waterways. Along the main stem of Turkey Creek streams generally had good riparian corridors, but also had indicators of incision and bank widening. Riparian conditions in areas where livestock have access to the stream varied from no trees and eroding banks (many banks were trampled down) to a thin line of mature trees where channel conditions were not as unstable. As with the other watershed, streams in pastures show more signs of instability and may be a target for conservation practices to decrease nonpoint sources of nutrients and sediment in the watershed. Examples of sites evaluated for the Turkey Creek watershed can be found in Appendix F.

Rainfall–Runoff Relationship

Annual and monthly runoff rates for the selected Lower Grand watersheds were estimated using equations developed from 24 USGS gaging stations in the region. Monthly runoff rates are important for understanding the seasonal variability and how rainfall-runoff relationships correspond to land management and annual runoff rates will be used to help validate the STEPL model hydrology results. A list of the equations used for this analysis of monthly mean discharge values can be found in Appendix G. Mean annual discharge for the Long Branch watershed is 32.5 ft^3/s, 21.6 ft^3/s for Spring Branch-Elk Creek, and 35.8 ft^3/s for Turkey Creek (Figure 22). Total runoff volume for the Long Branch watershed was 23,545 ac-ft, 15,648 ac-ft for Spring Branch-Elk Creek, and 25,935 ac-ft for the Turkey Creek watershed. For all watersheds, average discharge peaks in the month June and is the lowest in October. Average runoff as a percentage of rainfall for the Long Branch watershed was 22.1%, Turkey Creek was 22.2%, and 22.0% for Spring Branch-Elk Creek. Monthly mean runoff as a percentage of rainfall is highest in the late winter and early spring and lowest in the late summer and early fall ranging from less than 8% in August to 40-43% in February. The remainder of the rainfall is either lost to evapotranspiration or moved through the soil into groundwater storage through infiltration (USDA, 2009b). These estimates are comparable with existing literature that state evapotranspiration rates for Missouri range from 60–70% (Sanford and Selnick 2013).

Water Quality Modeling

STEPL Model

Existing water quality loads in the watershed and the influence of conservation practices on load reductions was estimated from a predictive model (STEPL). The Spreadsheet Tool for Estimating Pollutant Load (STEPL) uses simple algorithms to calculate nutrient and sediment loads from different land uses and load reductions from implementation of conservation practices (Tetra Tech, Inc 2017). Annual nutrient loading was calculated based on the annual runoff volume and pollutant concentrations. The annual sediment load from sheet and rill erosion was calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. Loading reductions resulting from the implementation of conservation practices was computed from known efficiencies. Accuracy is primarily limited by the wide variability in event mean concentrations (EMCs) across watersheds since EMCs are used to calculate annual pollutant loadings.

For this study, each watershed was modeled with inputs following methods outlined in the STEPL user's guide. Model inputs include drainage area, soil hydrologic group, land use, animal numbers, and estimates on septic systems within the watershed. Land use was derived from the 2017 USDA Crop database. Animal numbers were calculated per acre of pasture within the watershed using animal number ratio of one animal per 2.5 acres of pastureland based on input from local staff. Long Branch was the only watershed in this study with CAFO operations and 61,824 swine were entered under animal numbers (MDNR 2019). The number of septic systems within each watershed was based an area ratio of the low intensity developed land use and provided by the STEPL online database. Details about the inputs for each watershed can be found in Appendix H.

Lateral stream bank erosion was accounted for by calculating length of actively eroding banks, migration rates from historical aerial photo analysis, and bank heights from a LiDAR digital elevation model (DEM) datasets identified earlier in this report. Annual migration rates were estimated by overlaying the bank lines from each aerial photo year. The areas between the 1997 and 2015 photos that do not overlap were considered the bank erosion polygons. Additionally, an error buffer used for the polygons to account for the difference in photos. The area of bank erosion was then divided by the length to calculate a mean width. The mean width was then divided by the number of years between photos to establish an average annual migration rate for each bank erosion polygon. Each individual polygon was assessed for the Long Branch and Turkey Creek watersheds. This method identified a total of 166 eroding stream banks in the Long Branch watershed and 159 eroding stream banks in the Turkey Creek watershed (Appendix I-K). Because STEPL has a limited number of available entries for eroding streambanks (100), an area weighted average height and rate were calculated for the Turkey Creek and Long Branch watersheds to be entered into the model. In the Spring Branch-Elk Creek watershed, polygons within active reaches were combined and an area weighted average was used for both the migration rate and the bank height. This method identified a total of 36 eroding stream reaches within the Spring Branch-Elk Creek watershed. Average eroding bank length for Long Branch and Turkey Creek watersheds was 90.8-134 ft, average bank heights ranged from 4.5-8.6 ft, and migration rates from 0.46-0.61 ft/yr. Spring Branch-Elk Creek had an average reach length of 607 ft, average area weighted bank height of 5.6 ft, and average area weighted annual migration rate was 0.85 ft/yr.

There have already been conservation practices implemented within the three study watersheds that need to be addressed in the existing load calculations. For this, estimates of the percentage of cropland with existing conservation practices was calculated based on input from area staff. In this watershed it was estimated that 20% of the cropland already was terraced, 15% had cover crops, and 30% was no-till. These estimates were used to calculate combined efficiencies within the STEPL model's BMP calculator and applied to the watershed (Table 17). The resulting loads then will reflect a total load that takes these existing conservation practices into account.

Long Branch - Average yields for the Long Branch watershed were 9.06 lb/ac/yr for nitrogen, 1.53 lb/ac/yr phosphorus, and 0.71 T/ac/yr of sediment (Table 18). Runoff rates were 0.83 ac-ft/ac/yr and the percentage of rainfall as runoff was 26.9% for the watershed. Modeled percent runoff is relatively close to the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 22.1% for the watershed. The relative agreement of these two methods adds confidence to the STEPL modelled runoff results. Additionally, results also show that existing conservation practices have reduced nitrogen loads by about 9.5%, phosphorus loads by 17.4%, and sediment loads by 17.9% for cropland sources in the watershed.

Spring Branch-Elk Creek - Average yields for the Spring Branch-Elk Creek watershed were 6.23 lb/ac/yr for nitrogen, 1.21 lb/ac/yr phosphorus, and 0.66 T/ac/yr of sediment (Table 18). Runoff rates were 0.75 ac-ft/ac/yr and the percentage of rainfall as runoff was 24.3% for the watershed. Modeled percent runoff is relatively close to the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 22.0% for the watershed.

Additionally, results also show that existing conservation practices have reduced nitrogen loads by about 12.7%, phosphorus loads by 20.6%, and sediment loads by 21.7% for cropland sources in the watershed.

Turkey Creek - Average yields for the Turkey Creek watershed were 6.35 lb/ac/yr for nitrogen, 1.12 lb/ac/yr phosphorus, and 0.49 T/ac/yr of sediment (Table 18). Runoff rates were 0.89 ac-ft/ac/yr and the percentage of rainfall as runoff was 29.0% for the watershed. Modeled percent runoff is relatively close to the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 22.2% for the watershed. Furthermore, results also show that existing conservation practices have reduced nitrogen loads by about 12.6%, phosphorus loads by 21.5%, and sediment loads by 24.1% for cropland sources in the watershed.

When assessing model results by sources for the three watersheds in this study, the majority of the nutrient and sediment load is from agricultural nonpoint source pollution. However, urban land use and streambank erosion are also contributing significantly to the total nutrient and sediment load in these watersheds. Model results show crop and pastureland account for 82-93% of the nutrient loads and around 75-87% of the sediment load in the three watersheds (Table 19). Despite the existing conservation practices, cropland accounts for 40-68% of the nutrient loads and 50-73% of the sediment loads in the all three watersheds. Pastureland is the second highest contributor for in the watershed at around 19-53% of the nutrient load and 12-30% of the sediment load. However, streambank erosion is a significant contributor at around 11-22% of the total sediment load in each watershed. Additionally, urban land use can be a significant source of nutrients, especially in the Spring Branch-Elk Creek watershed where it contributes about 10% of the nutrient load.

<u>Load Reduction Analysis</u>

Load reduction for the three watersheds in this study were modeled with STEPL using established conservation practice efficiencies. The efficiencies of combined practices were calculated with STEPL’s BMP Calculator. A total of ten cropland conservation practice scenarios and eight pastureland scenarios were ultimately modeled. A description of each combined conservation practice scenario with calculated efficiencies can be found in Appendix L. Load reductions of nitrogen, phosphorus, and sediment were modeled based on the percentage of cropland and pastureland within the watershed that were treated. The result is a load reduction matrix for all three watersheds showing the load reduction for the different percentage of cropland and pastureland treated in 10% increments.

Cropland scenarios start with the use of cover crops as the first level of conservation practices and from there terraces, no-till, water and sediment control basins, and nutrient management are added or combined. Land retirement was also used as a scenario to show what would happen if the cropland was taken out of production. For pastureland, the first level practice was livestock exclusion and alternative water sources. From there, grade stabilization, prescribed grazing, water and sediment control basins, and forest buffers were added and combined. Since the pastureland and cropland were modeled separately within each watershed, the combined load reductions can be added together for each watershed for a combined effect.

Long Branch - Load reduction analysis for the Long Branch watershed shows that pastureland conservation practices can achieve slightly higher nitrogen reduction, and cropland higher phosphorus and sediment reductions depending on the conservation practice implemented. For instance, the most intensely managed cropland scenario is one that combines cover crops, terraces, no till, and nutrient management. If that scenario was applied to 50% of the 9,137 acres of cropland (4,569 acres) within the watershed, load reduction would be 17.0% for nitrogen, 27.1% for phosphorus, and 25.8% for sediment (Tables 20-22). In contrast, applying the most intensely managed scenario to 50% of the 15,475 acres of pastureland (7,738 acres), which is grade stabilization, water and sediment control basin, and prescribed grazing the reduction would be 22.5% for nitrogen, 14.6% for phosphorus, and 12.0% for sediment. These scenarios indicate combining cropland and pastureland practices in this watershed can substantially reduce nutrient and sediment loads in the watershed. Additionally, if all the cropland within the watershed was taken out of production, the resulting load reduction would be 42.4% for nitrogen, 53.9% phosphorus, and 56.0% sediment.

Spring Branch-Elk Creek - Load reduction analysis indicates implementation of cropland conservation practices can significantly reduce nutrient and sediment loads in the Spring Branch-Elk Creek watershed, particularly for phosphorus and sediment. For example, the most intensely managed cropland scenario is one that combines cover crops, terraces, no till, and nutrient management. If that scenario was applied to 50% of the 10,464 acres of cropland (5,232 acres) within the watershed, load reduction would be 21.0% for nitrogen, 30.6% for phosphorus, and 32.1% for sediment (Tables 23-25). In contrast, applying the most intensely managed scenario to 50% of the 6,092 acres of pastureland (3,046 acres), which is grade stabilization, water and sediment control basin, and prescribed grazing, which would reduce nitrogen 13.6%, phosphorus 7.2%, and sediment 4.5%. This suggests focusing on cropland conservation practices would be the most beneficial to reduce nutrients and sediment in this watershed. Additionally, if all the cropland within the watershed was taken out of production, the resulting load reduction would be 50.8% for nitrogen, 62.6% phosphorus, and 69.6% sediment.

Turkey Creek – In the Turkey Creek watershed, load reduction analysis indicates substantial nutrient and sediment reduction can be achieved through implementation of cropland conservation practices since the relative amount of cropland within the watershed is so high. By applying the most intensely managed cropland scenario that combines cover crops, terraces, no till, and nutrient management to 50% of the 17,552 acres of cropland (8,776 acres) within the watershed, load reduction would be 22.3% for nitrogen, 33.3% for phosphorus, and 34.8% for sediment (Tables 26-28). Alternatively, by applying the most intensely managed scenario to 50% of the 9,112 acres of pastureland (4,556 acres), which is grade stabilization, water and sediment control basin, and prescribed grazing the reduction would be 15.5% for nitrogen, 8.3% for phosphorus, and 5.0% for sediment. This suggests focusing on cropland conservation practices would be the most beneficial to reduce nutrients and sediment in this watershed. Additionally, if all the cropland within the watershed was taken out of production, the resulting load reduction would be 55.2% for nitrogen, 66.7% phosphorus, and 75.4% sediment.

Summary

The purpose of this section of the report is to provide results of the resource analysis of the watershed (Deliverable #2) for the Mississippi River Basin Healthy Watersheds Initiative (MRBI) Watershed Assessment for Long Branch Watershed (HUC-10280103204), Spring Branch-Elk Creek Watershed (HUC-102801031302), and the Turkey Creek Watershed (HUC-102801031301). Available water quality data was limited to the Long Branch watershed and indicates nutrient concentrations exceed regional ambient water quality criteria suggested reference conditions for streams in the Central Irregular Plains region. This is particularly true for phosphorus, which was 2-5 times higher than the reference concentration. It is assumed data collected from the Long Branch watershed is similar for the other two watersheds within this study. As stated earlier, a healthy watershed plan was established for the Lower Grand River watershed in 2016 that specifically states that reduction of streambank and soil erosion, sediment, nutrients, and bacteria from agricultural nonpoint sources is important to maintain and improve water quality within the watershed (MDNR 2016).

Both historical aerial photos and a visual stream assessment were used to evaluate potential contributions of streambank erosion to water quality problems within the watershed. The majority of actively eroding reaches within the watershed were located along the main stem of the stream suggesting sediment being released though bank erosion is an important component of the total sediment load in the watershed. Due to the small size of the tributary streams within the watershed, overhead vegetation, and photo quality limitations, a complete classification of all the small tributary streams was not always possible. The riparian corridor assessment does show most poor riparian corridors are located in the headwaters and most of the good riparian areas are along the main stem of the stream. Since most of the stream bank erosion appears to be in the main stem of the stream, this suggests the stream is adjusting to some disturbance that is not being mitigated by the presence of a forested riparian corridor. Stream reaches assessed in the visual stream survey showed that much of the areas with poor riparian corridor were areas where livestock had access to the stream. Additionally, streams draining cropland generally had some sort of vegetative buffer and appeared to be relatively stable compared to those in pastureland.

Water quality modeling results indicate cropland overwhelmingly produces the majority of the nonpoint source pollution within the watershed. Model results show cropland accounts for 40-65% of the nutrient loads and 50-73% of the sediment loads in all three watersheds. Pastureland is the second highest contributor at nearly 19-53% of the nutrient load and 12-30% of the sediment load. However, streambank erosion is a significant contributor at 11-30% of the total sediment load in these watersheds. Additionally, urban land use is a significant source of nutrients, especially in the Spring Branch-Elk Creek watershed where it contributes about 10% of the nutrient load. Modelling results also indicate existing conservation practices, such as existing terraces, are responsible for slightly reducing the exiting loads within the watershed. Load reduction analysis suggests and that additional conservation practices can further reduce loads with the implementation of terraces, cover crops, no-till, and nutrient management. Furthermore, pastureland practices can significantly reduce nutrient and sediment loads in the Long Branch watershed, which is a heavily pastured watershed.

IDENTIFICATION OF CONSERVATION NEEDS

Resource Priorities

In the three watersheds evaluated for this study, the top resource priority identified in this assessment is the reduction of sediment from nonpoint agricultural land use. Regionally, soil and streambank erosion have been identified as major concern for water quality for streams within the Lower Grand River watershed (MDNR 2014). Furthermore, the Turkey Creek watershed and the Spring Branch-Elk Creek watershed flow directly into Silver Lake on the Swan Lake National Wildlife Refuge that has experienced recent sedimentation problems (USFWS 2011). STEPL modeling results show the majority of the sediment load is coming from cropland, particularly in the Spring Branch-Elk Creek and Turkey Creek watersheds. Load reduction estimates suggest implementation of conservation practices on cropland can have a much higher rate of reduction compared to pasture land practices. Total cropland acres for each watershed are 9,137 acres in the Long Branch watershed, 10,464 acres in the Spring Branch-Elk Creek watershed, and 17,588 acres in the Turkey Creek watershed. Furthermore, the trend over the last five years is for more land to be converted to cropland. Therefore, implementing cropland conservation practices will be the most effective in reducing sediment loads as this land use type generates higher pollutant loads and many of the crop practices are more efficient at reducing loads.

Conservation Planning

One of the main goals of this project is to use this assessment to help guide where conservation practices would be the most beneficial to meet water quality goals. This will be accomplished by using a management unit ranking, a vulnerable acres classification, and a conservation practice rating system.

Management Units

To better plan for locations to implement conservation practices, the three HUC-12 watersheds were split into 30 smaller watersheds, or management units (MU) (Figure 23). MUs will allow field staff to evaluate potential projects based on a system that would rank geographic areas within the watershed. STEPL was used to estimate sediment yields for each management unit with drainage areas ranging from 1,385-4,960 acres (Table 29). Of the seven MUs with the highest sediment yields (all >1 T/ac/yr), four are located in Long Branch, two are in Spring Branch-Elk Creek, and one is in Turkey Creek. These higher sediment yields in the Long Branch watershed are generally related to higher LS factors, while higher sediment yields in the Turkey Creek and Spring Branch-Elk Creek are related to higher K factors. Overall, isolating specific areas within these three watersheds that are potentially generating higher sediment loads will eventually help guide conservation practice implementation strategies.

Vulnerable Acres Classification

To identify areas with the most pollution potential within a proposed project, a vulnerable acres ranking system was developed to help field staff isolate problem areas and prioritize projects within the same MU. Four risk classes were used to rank the agricultural land within the watershed based on the resources analysis of the watershed, STEPL modeling, and the VSA. Highest Risk land represents the most critical areas for pollution potential from the landscape and should be prioritized for planning. High Risk are areas that have significant risk as a pollution source, but not as high as the Highest Risk category. The Moderate Risk category could see potential gains from conservation practices but are a lower priority. Low Risk lands have adequate treatment of the landscape. Remaining areas of urban land use and water were classified as “other”. A description of each class type is detailed below and summarized in Table 30.

Highest Priority – For these watersheds the highest vulnerability classification for conservation planning was based on cropland located on highly erodible soils. Highly erodible soils were identified using the Erodibility Index (EI) (USDA 2019). The EI is the ratio of potential erodibility (PE) to the soil loss tolerance (T). Soils were classified as highly erodible when EI ≥8. The EI for all of the soil series within the watershed were calculated using a series of equations detailed here.

Equation 1.
Potential Erodibility (PE) is calculated using:

$$PE = R \times K \times LS$$

Where:
R = rainfall and runoff (Wischmeier and Smith 1978)
K = susceptibility of the soil to water erosion (from soil survey)
LS = combined effect of slope length and steepness (See Equation 2 below)

Equation 2.
The LS is calculated as follows:

$$LS = (0.065 + (0.0456 \times S) + (0.006541 \times S^2)) \times (SL \div C)^{NN}$$

Where:
S = slope% (from soil survey)
SL = Slope length (from soil survey)
C = constant 22.1 metric (72.5 English units)
NN = see value below

- If S <1, then NN = 0.2
- If S ≤1 and <3, then NN = 0.3
- If S ≤3 and <5, then NN = 0.4
- If S ≥5, then NN = 0.5

Equation 3.
The EI is calculated as follows:

$$EI = PE/T$$

Where:

PE = potential erosion
T = soil loss tolerance (from soil survey)

Within these three watersheds, 15,614 acres are classified in the highest priority category, or roughly 18.4% of the watershed area (Figure 24).

High Priority - All other cropland that was not in the highest vulnerability category was placed in the high vulnerability category for conservation planning. There is a total of 22,995 acres of high priority acres in these three watersheds, or about 27.1% of the total drainage area.

Moderate Priority - Land within the moderate priority category would be all pasture land within the watershed. This totals 29,078 acres, or 34.3% of the total area of the three study watersheds.

Low Priority - Low priority acres was defined as all of the forested areas within the watershed or land adjacent to a stream with good riparian corridor. Within the three study watersheds there are 10,112 low priority acres, or 11.9% of the total area.

N/A – This category represents all urban land use and land classified as water or wetlands within the three study watersheds. This represents 7,095 acres, or 8.4% of the total land area.

<u>Conservation Practice Ranking</u>

The final part of the conservation planning portion of this project is to identify the conservation practices that are best suited to help reduce sediment loads from the Long Branch, Spring Branch-Elk Creek, and Turkey Creek watersheds. For this, each conservation practice, or combination of conservation practices, was ranked based on the highest benefit per acre treated for each watershed. Ranking was based on the percentage of sediment reduction achieved by each practice or combination of practices. Cropland practices make up the top nine rankings for the three study watersheds (Table 31). This is a result of cropland having a relatively higher load per acre and cropland conservation practices having relatively high efficiency ratings. Pastureland conservation practices rank in the bottom half of all practices identified in this project because pastureland has a relatively lower sediment load and conservation practices have lower efficiencies compared to conservation practices on cropland. While this analysis suggests treating cropland would ultimately be more efficient in reducing sediment loads, this analysis does not include economic or social aspects that may prohibit or encourage certain practices over others.

CONCLUSIONS

The purpose of this report is to provide the Missouri State office of the NRCS the results of a watershed assessment study of three HUC-12 watersheds within the Lower Grand River, Turkey Creek (102801031301), Spring Branch-Elk Creek (102801031302), and Long Branch (102801031204) located in Linn, Chariton, and Sullivan Counties in Missouri. These assessments support the Mississippi River Basin Healthy Watersheds Initiative (MRBI) designed to work with landowners to implement voluntary conservation practices to reduce nutrients entering the Gulf of Mexico. The goal of the MRBI program is to improve water quality, restore wetlands, and enhance wildlife habitat while ensuring economic viability of agricultural lands in high-priority watersheds within the Mississippi River Basin (USDA, 2017). Ultimately, this watershed assessment provides NRCS field staff with the necessary information to identify locations within the study watersheds where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. The assessment included three phases, 1) resource inventory, 2) resource analysis, and 3) identification of resource needs. There are seven main conclusions for this assessment:

1) While there are no impaired stream segments within the three study watersheds, soil and streambank erosion have been identified as major water quality concern for streams within the Lower Grand River watershed. Therefore, reducing the sediment loads coming from these watersheds was identified by this assessment as the top resource concern to be addressed by implementation of conservation practices aimed at reducing erosion;

2) Limited water quality data was only available for the Long Branch watershed. These data show average phosphorus concentrations in the Long Branch watershed are 2-5x higher than ambient reference conditions, while nitrogen concentrations remain relatively low. Furthermore, the USGS analysis of long-term water quality trends suggests the Lower Grand River has not seen improvement over the study period due to the lack of conservation practices aimed at nonpoint agricultural sources compared to other watersheds draining to the Missouri River;

3) Historical aerial photo analysis was used to identify potential contributions of streambank erosion to water quality problems within the study watersheds and to evaluate riparian corridor vegetation. Due to the small size of some of the streams within the watershed, overhead vegetation, and photo quality limitations, a complete classification of all the streams was not possible. Also, some streams within these watersheds have been modified either by channelization or by pond construction. Of the non-modified reaches, only a small

portion showed evidence of significant lateral migration suggesting perhaps streams in the area may adjust to watershed disturbance by incision and widening that is difficult to assess on aerials. The riparian corridor assessment showed areas along the mainstems typically have adequate forested buffers, but many of the tributaries had moderate-poor forested buffers within the riparian zone.

4) The visual stream survey helped confirm the channel instability within areas of poor riparian corridor and the extent of channelization within the watershed. However, streams appear to be eroding from a process of incision and bank widening rather that lateral migration. This suggests bank erosion estimates from the interpretation of aerial photography is likely underestimating contributions from bank erosion. More extensive field observations would be required to verify this trend that is beyond the scope of this study;

5) Water quality modeling results show agricultural land use overwhelmingly produces the majority of the nonpoint source pollution within the watershed. Results show that agricultural land accounts for over 75-86% of the sediment load within the three study watersheds. Streambank erosion is also a major source sediment contributor responsible for 11-22% of the total annual sediment load;

6) Load reduction analysis suggests that significant sediment reduction is attainable using combinations of conservation practices aimed at reducing erosion from cropland within these three watersheds. Model results show that existing practices are already reducing sediment loads by around 20% compared to not having any implementation on the land. Load reduction analysis estimates further significant sediment load reductions can be attained by implementation of highly managed systems on cropland that include cover crops, no-till, and terraces. Sediment load reductions by implementing these systems can be almost as effective as taking the land out of crop production; and

7) Management units, vulnerable acres, and conservation practice rankings were all created to help field staff prioritize areas and evaluate potential projects. Management units direct conservation practices to specific areas of the watershed. Vulnerable acres within management units can be used to evaluate projects within management units. Finally, conservation practices are ranked in order of effectiveness for cropland and pasture land.

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TABLES

Table 1. Annual rainfall and average annual temperature for Brookfield, MO (1988-2017).

Year	Total Rainfall (in)	Average Temperature (F°)
1988	26.1	55.4
1989	*32.4	*51.3
1990	42.8	55.9
1991	35.1	55.9
1992	41.6	*53.1
1993	55.2	*51.7
1994	31.5	51.6
1995	*44.0	52.5
1996	*38.6	49.9
1997	41.4	51.3
1998	55.1	54.7
1999	33.7	54.0
2000	37.7	52.6
2001	44.8	53.4
2002	36.5	53.1
2003	36.7	52.3
2004	48.0	52.2
2005	31.9	54.0
2006	38.8	54.5
2007	43.7	53.8
2008	61.8	50.8
2009	52.6	51.6
2010	49.3	52.4
2011	35.3	52.8
2012	35.1	56.2
2013	40.6	50.5
2014	39.5	50.3
2015	51.6	*53.8
2016	33.2	56.0
2017	36.4	55.8
n	30	30
Min	26.1	49.9
Mean	41.3	53.2
Max	61.8	56.2

data source: http://mrcc.isws.illinois.edu/CLIMATE/)

Missing data were retrieved from nearby stations: *Chillicothe 3S and *Long Branch Reservoir

Table 2. Watershed soil characteristics summary

Long Branch

Soil Order	%	Hydrologic Soil Group	%	Soil Erosion K-Factor	%	Land Capability Classification	%
Alfisol	82.1	B	0.8	<0.2	0.2	2w	5.6
Entisol	0.03	B/D	4.3	0.2-0.3	32.4	3w	12.0
Mollisol	17.7	C	3.7	0.3-0.4	67.3	2e	2.1
Other	0.1	C/D	18.6	>0.4	0.03	3e	50.2
		D	72.5	Other	0.1	4e	28.5
		Other	0.1			6e	1.6
						Other	0.1

Spring Branch-Elk Creek

Soil Order	%	Hydrologic Soil Group	%	Soil Erosion K-Factor	%	Land Capability Classification	%
Alfisol	69.2	B	0.1	<0.2	0.0	2w	14.8
Entisol	0.6	B/D	9.9	0.2-0.3	0.3	3w	10.2
Mollisol	30.1	C/D	74.7	0.3-0.4	75.5	2e	12.5
Other	0.1	D	15.3	>0.4	24.1	3e	62.2
		Other	0.1	Other	0.1	4e	0.2
						Other	0.1

Turkey Creek

Soil Order	%	Hydrologic Soil Group	%	Soil Erosion K-Factor	%	Land Capability Classification	%
Alfisol	74.6	B	0.7	<0.2	0.3	2w	6.4
Entisol	0.2	B/D	8.4	0.2-0.3	2.8	3w	11.8
Mollisol	25.1	C	1.8	0.3-0.4	93.0	2e	9.1
Other	0.1	C/D	56.6	>0.4	4.0	3e	70.4
		D	32.4	Other	0.1	4e	2.3
		Other	0.1			6e	0.1
						Other	0.1

Table 3. Drainage network summary

Water Feature	Length/Area
Total Streams	**390 mi**
Permanent Flow	61 mi
Spring Branch-Elk Creek	14 mi
Turkey Creek	30 mi
Long Branch	17 mi
Intermittent Flow	329 mi
Spring Branch-Elk Creek	49 mi
Turkey Creek	136 mi
Long Branch	144 mi
Waterbodies	
Ponds/Lakes	401 ac
Spring Branch-Elk Creek	82 ac
Turkey Creek	162 ac
Long Branch	157 ac

Table 4. City of Brookfield water supply sources (2013-2017)

ID	Facility Name	Usage (millions of gallons)					
		2013	2014	2015	2016	2017	% Change
A	Brookfield Reservoir	35	205	171	166	158	351
B	West Yellow Creek	19	202	166	144	141	642
C	Brookfield Lake	185	233	189	188	189	2.0
	Total	239	640	526	498	488	104

Table 5. Generalized crop data classification from 2013-2017

Long Branch General Land Use/Land Cover	Year 2013	2014	2015	2016	2017	%Change 2013-2017
Row Crops	8.9%	13.0%	7.3%	14.7%	14.9%	67.6
Dbl Crop	0.1%	0.1%	0.1%	0.1%	0.2%	114.7
Small Grains	1.3%	0.1%	0.5%	0.7%	0.1%	-90.6
Alfalfa and other Hay	12.9%	13.1%	11.9%	13.5%	15.1%	16.9
Fallow/Idle Cropland and Barren	0.0%	0.0%	5.4%	3.4%	0.0%	150.0
Developed Land	4.0%	4.3%	4.3%	15.0%	4.2%	5.0
Forest	13.0%	12.9%	14.5%	0.6%	13.9%	7.3
Grass/Pasture	58.7%	55.8%	54.9%	51.2%	50.4%	-14.2
Woody Wetlands	0.8%	0.4%	0.8%	0.5%	0.7%	-3.1
Open Water	0.3%	0.3%	0.4%	0.4%	0.4%	22.7
Spring Branch-Elk Creek **General Land Use/Land Cover**	**Year** **2013**	**2014**	**2015**	**2016**	**2017**	**%Change 2013-2017**
Row Crops	42.9%	44.8%	38.6%	47.8%	48.9%	14.0
Dbl Crop	0.5%	1.1%	0.0%	1.5%	0.2%	-59.2
Small Grains	0.7%	1.0%	1.3%	1.4%	1.0%	31.1
Alfalfa and other Hay	5.0%	5.2%	6.1%	6.0%	7.0%	40.3
Fallow/Idle Cropland and Barren	0.0%	0.0%	9.0%	0.0%	0.1%	29.7
Developed Land	11.3%	10.7%	10.8%	10.7%	10.7%	-5.2
Forest	7.2%	7.5%	6.3%	6.9%	6.9%	-4.2
Grass/Pasture	29.9%	28.0%	24.2%	22.8%	22.4%	-25.1
Woody Wetlands	2.0%	1.2%	3.3%	2.6%	2.3%	18.9
Open Water	0.3%	0.3%	0.4%	0.3%	0.4%	22.1
Turkey Creek **General Land Use/Land Cover**	**Year** **2013**	**2014**	**2015**	**2016**	**2017**	**%Change 2013-2017**
Row Crops	34.4%	37.9%	26.9%	43.5%	44.2%	28.3
Dbl Crop	1.1%	1.2%	1.0%	0.9%	0.5%	-52.9
Small Grains	2.9%	2.7%	2.3%	1.8%	0.8%	-71.6
Alfalfa and other Hay	5.3%	5.0%	5.3%	6.0%	6.6%	23.5
Fallow/Idle Cropland and Barren	0.0%	0.0%	13.8%	0.0%	0.0%	-19.0
Developed Land	4.8%	4.7%	4.7%	4.7%	4.7%	-3.7
Forest	12.5%	13.3%	12.9%	12.5%	13.1%	4.8
Grass/Pasture	35.2%	32.7%	28.9%	26.5%	26.8%	-23.8
Woody Wetlands	3.2%	2.2%	3.8%	3.8%	2.9%	-9.8
Open Water	0.3%	0.3%	0.3%	0.3%	0.3%	-2.5

Table 6. Specific crop data from 2013-2017 with percent change.

Long Branch	**Year**					**% Change**
Class Name	**2013**	**2014**	**2015**	**2016**	**2017**	**2013-2017**
Corn	1.5%	3.9%	2.4%	3.9%	4.5%	188.2
Soybeans	7.3%	9.1%	4.7%	10.6%	10.4%	42.8
Deciduous Forest	12.7%	12.8%	14.0%	14.2%	13.6%	7.1
Grass/Pasture	58.7%	55.8%	54.9%	51.2%	50.4%	-14.2
Woody Wetlands	0.8%	0.4%	0.8%	0.5%	0.7%	-3.1
Spring Branch-Elk Creek	**Year**					**% Change**
Class Name	**2013**	**2014**	**2015**	**2016**	**2017**	**2013-2017**
Corn	15.1%	15.2%	17.0%	15.7%	20.0%	32.6
Soybeans	27.8%	29.6%	21.6%	32.0%	28.8%	3.8
Dbl Crop Winht/Soybeans	0.5%	1.1%	0.0%	1.5%	0.2%	-59.2
Deciduous Forest	7.2%	7.5%	6.1%	6.7%	6.9%	-3.8
Grass/Pasture	29.9%	28.0%	24.2%	22.8%	22.4%	-25.1
Woody Wetlands	2.0%	1.2%	3.3%	2.6%	2.3%	18.9
Turkey Creek	**Year**					**% Change**
Class Name	**2013**	**2014**	**2015**	**2016**	**2017**	**2013-2017**
Corn	12.4%	12.6%	11.9%	13.9%	13.5%	9.5
Soybeans	22.0%	25.3%	15.0%	29.5%	30.6%	39.2
Dbl Crop Winht/Soybeans	1.1%	1.2%	1.0%	0.9%	0.5%	-52.9
Deciduous Forest	12.5%	13.2%	12.6%	12.2%	13.1%	4.9
Grass/Pasture	35.2%	32.7%	28.9%	26.5%	26.8%	-23.8
Woody Wetlands	3.2%	2.2%	3.8%	3.8%	2.9%	-9.8

Table 7. Water quality monitoring sites with nutrient and sediment data summary.

Site ID	TP (n)	TP start date	TP end date	TP Mean (mg/L)	TN (n)	TN start date	TN end date	TN Mean (mg/L)	TSS (n)	TSS start date	TSS end date	TSS Mean (mg/L)
602/1.8	5	10/14/2006	9/17/2007	0.264	2	10/17/2006	9/17/2007	0.65	5	10/14/2006	9/17/2007	88.2
602/6.7	3	10/15/2006	3/27/2007	0.180	1	10/17/2006	10/17/2006	0.26	3	10/15/2006	3/27/2007	22.7
602/9.8	6	10/15/2006	9/17/2007	0.200	3	10/17/2006	9/17/2007	0.61	6	10/15/2006	9/17/2007	27.7
602/14.3	31	4/26/2004	9/17/2007	0.438	3	10/17/2006	9/17/2007	0.90	31	4/26/2004	9/17/2007	65.1

n = sample number

TP = total phosphorus

TN = total nitrogen

TSS = total suspended sediment

602 = Long Branch Site Number

Table 8. Permitted point sources within the watershed.

Site Number	Facility Name	Type	Stream	Waste	Status
1	Laclede Wastewater Treatment Facility	Outfall	TRIB TURKEY CR	Domestic (Sanitary) Wastewater	Expired
2	Brookfield Swimming Pool WWTF	Outfall	Unnamed tributary to Elk Creek	Domestic (Sanitary) Wastewater	Effective
3	Brookfield Southwest WWTF	Outfall	Elk Creek	Domestic (Sanitary) Wastewater	Effective
4	Professional Pump	Land Application Site	Unnamed tributary to Long Branch	Sludge/Biosolids	Effective
5	Professional Pump	Land Application Site	Tributary to Long Branch	Sludge/Biosolids	Effective
6	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
7	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
8	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
9	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
10	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
11	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
12	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
13	Professional Pump	Land Application Site	Tributary to Turkey Creek	Sludge/Biosolids	Effective
14	Professional Pump	Land Application Site	Unnamed tributary to Long Branch	Nonprocess	Effective
15	Professional Pump	Land Application Site	Tributary to Long Branch	Nonprocess	Effective
16	Professional Pump	Land Application Site	Tributary to Turkey Creek	Nonprocess	Effective
17	Professional Pump	Land Application Site	Tributary to Turkey Creek	Nonprocess	Effective
18	Professional Pump	Land Application Site	Tributary to Turkey Creek	Nonprocess	Effective
19	Professional Pump	Land Application Site	Tributary to Turkey Creek	Nonprocess	Effective
20	Professional Pump	Land Application Site	Tributary to Turkey Creek	Nonprocess	Effective
21	Professional Pump	Land Application Site	Tributary to Turkey Creek	Nonprocess	Effective
22	Professional Pump	Land Application Site	Tributary to Turkey Creek	Nonprocess	Effective
23	Professional Pump	Land Application Site	Trubutary to Turkey Creek	Nonprocess	Effective
24	City of Brookfield Swimming Pool	Outfall	Tributary to Elk Creek	Non-Domestic Process Water	Effective

Table 9. Animal Feeding Operations

Site ID	Permit ID	Disposal Type	Site Use	AFO Class	Swine >55lb	Swine <55lb	Est Liquid Discharge (gallons)	Treatment Type	Waste Type	Rec Stream
1	MO0118737	Outfall Pipe	Hogs	Class IA	0	0	4,139,179	Land Application	Manure	Trib Long Branch
2	MO0118737	Outfall Pipe	Hogs	Class IA	0	0	0	N/A - Instream Monitoring	N/A - Instream Monitoring	Trib. Long Branch
3	MO0118737	Outfall Pipe	Hogs	Class IA	0	0	0	N/A - Instream Monitoring	N/A - Instream Monitoring	Trib. Long Branch
4	MO0118737	Outfall Pipe	Hogs	Class IA	0	0	0	N/A - Instream Monitoring	N/A - Instream Monitoring	Trib. Long Branch
5	MO0118737	Outfall Pipe	Hogs	Class IA	0	0	0	Storm Water	Storm Water	W YELLOW CR/LONG CR
6	MO0118737	Wastewater Lagoon	Hogs	Class IA	8,832	0	5,601,290	Land Application	Manure	Trib. Long Branch
7	MO0118737	Wastewater Lagoon	Hogs	Class IA	8,832	0	5,601,290	Land Application	Manure	Trib. Long Branch
8	MO0118737	Wastewater Lagoon	Hogs	Class IA	8,832	0	5,818,100	Land Application	Manure	Trib. Long Branch
9	MO0118737	Wastewater Lagoon	Hogs	Class IA	8,832	0	5,862,995	Land Application	Manure	Trib. Long Branch
10	MO0118737	Wastewater Lagoon	Hogs	Class IA	8,832	0	5,813,720	Land Application	Manure	Trib. Long Branch
11	MO0118737	Wastewater Lagoon	Hogs	Class IA	8,832	0	5,578,295	Land Application	Manure	Trib. Long Branch
12	MO0118737	Wastewater Lagoon	Hogs	Class IA	8,832	0	5,862,630	Land Application	Manure	Trib. Long Branch

Table 10. Data and source summary with web site address

Data Needed	Source	Agency	Within Watershed	Nearby Watershed	Website
HUC 8 Watershed	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
HUC 10 Watershed	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
HUC 12 Watershed	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
Stream Network	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
Soils (polygons)	NRCS Geospatial Data Gateway	USDA	x		https://datagateway.nrcs.usda.gov
Soils (attributes)	NRCS Web Soil Survey	USDA	x		https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
Precipitation	Cli-mate	MRCC	x		http://mrcc.isws.illinois.edu/CLIMATE/
Temperature	Cli-mate	MRCC	x		http://mrcc.isws.illinois.edu/CLIMATE/
Solar Radiation	Missouri Climate Center	UMC		x	www.climate.missouri.edu
Evapotranspiration	Missouri Climate Center	UMC		x	www.climate.missouri.edu
Elevation (LiDAR)	MSDIS	UMC	x		http://msdis.missouri.edu/
Geology	MSDIS	UMC	x		http://msdis.missouri.edu/
Land Use/Land Cover	National Agricultural Statistics Service	USDA	x		www.nass.usda.gov
Hydrology	National Water Information System	USGS		x	https://waterdata.usgs.gov/nwis/rt
Groundwater Levels	Groundwater Watch	MDNR		x	https://groundwaterwatch.usgs.gov
Major Water Users	MSDIS	MDNR	x		http://msdis.missouri.edu/
Point Sources	MSDIS	MDNR	x		http://msdis.missouri.edu/
Water Quality	MDNR Water Quality Assessment System	MDNR	x		http://www.dnr.mo.gov/mocwis_public/wqa/waterbodySearch.do

HUC = Hydrologic Unit Code
WWTF = Waste Water Treatment Facility
NRCS = National Resource Conservation Service
MSDIS = Missouri Spatial Data Information Service
USGS = United States Geological Survey
USDA = United States Department of Agriculture
MRCC = Midwest Regional Climate Center
UMC = University of Missouri-Columbia
MDNR = Missouri Department of Natural Resources

Table 11. Water quality data summary

Site ID	n	TP (mg/L)					TN (mg/L)						TSS (mg/L)					
		min	mean	max	stdev	cv%	n	min	mean	max	stdev	cv%	n	min	mean	max	stdev	cv%
602/1.8	5	0.140	0.264	0.370	0.117	44.2	2	0.600	0.650	0.700	0.071	10.9	5	28	88.2	170	75.0	85.0
602/6.7	3	0.140	0.180	0.260	0.069	38.5	1	0.260	0.260	0.260	NA	NA	3	8.0	22.7	52	25.4	112.1
602/9.8	6	0.070	0.200	0.290	0.103	51.6	3	0.260	0.607	1.300	0.600	99.0	6	13	27.7	51	18.3	66.0
602/14.3	31	0.050	0.438	7.300	1.288	294.1	3	0.600	0.900	1.300	0.361	40.1	31	4.0	65.1	817	147.6	226.7

n = sample number
TP = total phosphorus
TN = total nitrogen
TSS = total suspended sediment
602 = Long Branch Site Number

Table 12. Ambient water quality criteria recommendations for total nitrogen (TN) and total phosphorus (TP), Ecoregion IX (USEPA 2000)

Parameter	25^{th} Percentile	Range
TN (mg/L)	0.71	0.28 – 6.23
TP (mg/L)	0.093	0.010-2.090

Table 13. Aerial photography used for channel change analysis

Photo Year	Source	Type	Resolution (ft)
1997	USGS	Black and White Photo	3.3
2015	USGS	Color High Resolution	0.5

Table 14. Point-to-point (PTP) errors by watershed

Watershed	Range PTP Error (ft)	Mean PTP Error (ft)
Long Branch	1.64-11.64	7.18
Spring Branch-Elk Creek	3.64-24.57	9.58
Turkey Creek	1.23-13.12	7.31

Table 15. Stream classification analysis summary

Watershed	Total Length (mi)	Channelized	Impoundment	Stable	Active	Not Visible
Turkey Creek	138.0	7.9 (9%)	2.0 (2%)	92.6 (52%)	22.1 (17%)	33.5 (20%)
Spring Branch-Elk Creek	65.3	4.0 (6%)	0.0 (0%)	26.4 (40%)	8.4 (13%)	26.5 (41%)
Long Branch	182.0	17.2 (9%)	2.6 (1%)	88.2 (48%)	4.4 (2%)	69.5 (38%)

Table 16. Riparian corridor analysis summary

Watershed	Total length (mi)	Good	Moderate	Poor
Turkey Creek	138.0	57.9 (42%)	49.9 (36%)	30.2 (22%)
Spring Branch-Elk Creek	65.3	16.3 (25%)	20.6 (32%)	28.4 (43%)
Long Branch	182.0	55.4 (30%)	77.5 (43%)	49.2 (27%)

Table 17. Existing conservation practice estimates for cropland in the watershed

Conservation Practices	% of Cropland
No Practices	47.6
Cover Crop	8.4
Terraces	11.9
Terrace and Cover Crop	2.1
No-till	20.4
No-till and Terraces	5.1
No-till and Cover Crop	3.6
No-till, Terraces, and Cover Crops	0.9
Cropland with Conservation	52.4%
Cropland without Conservation	47.6%
Combined Efficiencies	N = 0.291 P = 0.503 Sed = 0.580

Table 18. STEPL model results

Watershed ID	Total Ad (ac)	Runoff (ac-ft)	Runoff Yield (ac-ft/ac)	% Rainfall as runoff	Annual Load			Annual Yield			Mean Concentration		
					N- lb/yr	P- lb/yr	Sed- t/yr	N- lb/ac/yr	P- lb/ac/yr	Sed- t/ac/yr	N- mg/L	P- mg/L	Sed- mg/L
Long Branch	30,668	25,443	0.83	26.9	277,953	47,066	21,674	9.06	1.53	0.71	4.02	0.680	627
Spring Branch-Elk Creek	20,455	15,355	0.75	24.3	127,435	24,786	13,567	6.23	1.21	0.66	3.05	0.594	650
Turkey Creek	33,770	30,157	0.89	29.0	214,282	37,735	16,634	6.35	1.12	0.49	2.61	0.460	406

Table 19. STEPL results by sources

Sources	N Load (lb/yr)	%	P Load (lb/yr)	%	Sediment Load (t/yr)	%
Long Branch						
Urban	9,985	3.6	1,548	3.3	229	1.1
Cropland	112,806	40.6	24,745	52.6	10,840	50.0
Pastureland	146,884	52.8	17,425	37.0	6,460	29.8
Forest	1,802	0.6	855	1.8	126	0.6
Septic	45.4	0.0	17.8	0.0	0.0	0.0
Streambank	6,431	2.3	2,476	5.3	4,019	18.5
Total	277,953	100	47,066	100	21,674	100
Spring Branch-Elk Creek						
Urban	14,665	11.5	2,264	9.1	337	2.5
Cropland	63,920	50.2	15,611	63.0	8,627	63.6
Pastureland	43,531	34.2	4,818	19.4	1,566	11.5
Forest	495	0.4	236	1.0	31.6	0.2
Septic	26.3	0.0	10.3	0.0	0.0	0.0
Streambank	4,798	3.8	1,847	7.5	3,005	22.2
Total	127,435	100	24,786	100	13,567	100
Turkey Creek						
Urban	11,975	5.6	1,856	4.9	275	1.7
Cropland	116,473	54.4	25,577	67.8	12,103	72.8
Pastureland	81,130	37.9	8,329	22.1	2,262	13.6
Forest	1,551	0.7	758	2.0	46.4	0.3
Septic	13.4	0.0	5.2	0.0	0.0	0.0
Streambank	3,139	1.5	1,208	3.2	1,947	11.7
Total	214,282	100	37,735	100	16,634	100

Table 20. Nitrogen load reduction results for Long Branch watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Nitrogen load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.1	1.5	2.3	3.0	3.8	4.5	5.3	6.0	6.8	7.5
Terrace	1.4	2.8	4.2	5.6	7.0	8.4	9.9	11.3	12.7	14.1
Cover Crop and Terrace	1.9	3.9	5.8	7.8	9.7	11.7	13.6	15.5	17.5	19.4
Cover Crop and No-Till	2.5	5.0	7.4	9.9	12.4	14.9	17.3	19.8	22.3	24.8
Cover Crop, No-Till, Nutrient Management	2.9	5.9	8.8	11.7	14.6	17.6	20.5	23.4	26.3	29.3
Water and Sediment Control Basin	3.0	6.1	9.1	12.2	15.2	18.3	21.3	24.4	27.4	30.5
No-Till and Terrace	2.7	5.4	8.2	10.9	13.6	16.3	19.0	21.8	24.5	27.2
Cover Crop, No-Till, and Terrace	3.1	6.1	9.2	12.3	15.4	18.4	21.5	24.6	27.6	30.7
Cover Crop, No-Till, Terrace, and Nutrient Management	3.4	6.8	10.2	13.6	17.0	20.4	23.8	27.2	30.6	34.0
Land Retirement	4.2	8.5	12.7	16.9	21.2	25.4	29.7	33.9	38.1	42.4
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	1.4	2.8	4.2	5.6	7.0	8.4	9.8	11.2	12.6	14.0
Grade Stabilization Structure	3.6	7.2	10.8	14.3	17.9	21.5	25.1	28.7	32.3	35.9
Livestock Exclusion, Alternative Water, and Prescribed Grazing	3.0	5.9	8.9	11.9	14.8	17.8	20.7	23.7	26.7	29.6
Grade Stabilization Structure and Prescribed Grazing	4.1	8.1	12.2	16.2	20.3	24.4	28.4	32.5	36.6	40.6
Water and Sediment Control Basin	2.8	5.7	8.5	11.4	14.2	17.0	19.9	22.7	25.5	28.4
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	3.8	7.6	11.4	15.2	19.0	22.8	26.6	30.4	34.2	38.0
Grade Stabilization Structure and Water and Sediment Control Basin	4.3	8.6	12.9	17.2	21.5	25.8	30.1	34.4	38.6	42.9
Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	4.5	9.0	13.5	18.0	22.5	26.9	31.4	35.9	40.4	44.9

Table 21. Phosphorus load reduction results for Long Branch watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Phosphorus load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.5	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.7	5.3
Terrace	2.2	4.4	6.5	8.7	10.9	13.1	15.3	17.5	19.6	21.8
Cover Crop and Terrace	2.5	5.0	7.5	10.1	12.6	15.1	17.6	20.1	22.6	25.2
Cover Crop and No-Till	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4	46.0
Cover Crop, No-Till, Nutrient Management	5.0	10.1	15.1	20.2	25.2	30.2	35.3	40.3	25.3	50.4
Water and Sediment Control Basin	4.8	9.5	14.3	19.0	23.8	28.5	33.3	38.0	42.8	47.6
No-Till and Terrace	5.0	10.1	15.1	20.1	25.1	30.2	35.2	40.2	45.3	50.3
Cover Crop, No-Till, and Terrace	5.1	10.2	15.4	20.5	25.6	30.7	35.8	41.0	46.1	51.2
Cover Crop, No-Till, Terrace, and Nutrient Management	5.4	10.8	16.3	21.7	27.1	32.5	38.0	43.4	48.8	54.2
Land Retirement	5.4	10.8	16.2	21.6	27.0	32.4	37.7	43.1	48.5	53.9
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9.0
Grade Stabilization Structure	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.4	20.6	22.9
Livestock Exclusion, Alternative Water, and Prescribed Grazing	2.0	4.0	5.9	7.9	9.9	11.9	13.9	15.8	17.8	19.8
Grade Stabilization Structure and Prescribed Grazing	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
Water and Sediment Control Basin	2.3	4.7	7.0	9.4	11.7	14.0	16.4	18.7	21.1	23.4
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	2.4	4.9	7.3	9.8	12.2	14.7	17.1	19.6	22.0	24.5
Grade Stabilization Structure and Sediment Control Basin	2.9	5.8	8.6	11.5	14.4	17.3	20.1	23.0	25.9	28.8
Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	2.9	5.8	8.8	11.7	14.6	17.5	20.5	23.4	26.3	29.2

Table 22. Sediment load reduction results for Long Branch watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Sediment load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.6	1.2	1.8	2.4	2.9	3.5	4.1	4.7	5.3	5.9
Terrace	2.4	4.7	7.1	9.4	11.8	14.2	16.5	18.9	21.2	23.6
Cover Crop and Terrace	2.7	5.4	8.1	10.9	13.6	16.3	19.0	21.7	24.4	27.1
Cover Crop and No-Till	4.7	9.4	14.0	18.7	23.4	28.1	32.7	37.4	42.1	46.8
Cover Crop, No-Till, Nutrient Management	4.7	9.4	14.0	18.7	23.4	28.1	32.7	37.4	42.1	46.8
Water and Sediment Control Basin	5.1	10.1	15.2	20.3	25.4	30.4	35.5	40.6	45.6	50.7
No-Till and Terrace	5.1	10.2	15.2	20.3	25.4	30.5	35.6	40.7	45.7	50.8
Cover Crop, No-Till, and Terrace	5.2	10.3	15.5	20.7	25.8	31.0	36.2	41.3	46.5	51.7
Cover Crop, No-Till, Terrace, and Nutrient Management	5.2	10.3	15.5	20.7	25.8	31.0	36.2	41.3	46.5	51.7
Land Retirement	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.8	50.4	56.0
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	0.5	0.9	1.4	1.8	2.3	2.7	3.2	3.7	4.1	4.6
Grade Stabilization Structure	1.8	3.7	5.5	7.3	9.2	11.0	12.8	14.7	16.5	18.3
Livestock Exclusion, Alternative Water, and Prescribed Grazing	1.9	3.9	5.8	7.8	9.7	11.7	13.6	15.5	17.5	19.4
Grade Stabilization Structure and Prescribed Grazing	2.0	4.1	6.1	8.2	10.2	12.2	14.3	16.3	18.3	20.4
Water and Sediment Control Basin	2.1	4.2	6.3	8.4	10.5	12.6	14.7	16.8	18.9	21.0
Livestock Exclusion, Alternative Water, Prescribed Grazing, and Forest Buffer	2.2	4.4	6.6	8.8	11.1	13.3	15.5	17.7	19.9	22.1
Grade Stabilization Structure and Sediment Control Basin	2.4	4.7	7.1	9.4	11.8	14.2	16.5	18.9	21.2	23.6
Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	2.4	4.8	7.2	9.6	12.0	14.3	16.7	19.1	21.5	23.9

Table 23. Nitrogen load reduction results for Spring Branch-Elk Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Nitrogen load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.8	1.6	2.5	3.3	4.1	4.9	5.8	6.6	7.4	8.2
Terrace	1.8	3.6	5.3	7.1	8.9	10.7	12.5	14.2	16.0	17.8
Cover Crop and Terrace	2.4	4.7	7.1	9.4	11.8	14.1	16.5	18.8	21.2	23.6
Cover Crop and No Till	3.2	6.5	9.7	12.9	16.2	19.4	22.6	25.8	29.1	32.3
Cover Crop, No Till, Nutrient Management	3.7	7.4	11.1	14.8	18.5	22.2	26.0	29.7	33.4	37.1
Water and Sediment Control Basin	3.8	7.7	11.5	15.4	19.2	23.1	26.9	30.8	34.6	38.4
No-Till and Terrace	3.5	7.1	10.6	14.1	17.7	21.2	24.7	28.3	31.8	35.4
Cover Crop, No-Till, and Terrace	3.9	7.8	11.7	15.5	19.4	23.3	27.2	31.1	35.0	38.9
Cover Crop, No-Till, Terrace, and Nutrient Management	4.2	8.4	12.6	16.8	21.0	25.2	29.4	33.6	37.8	42.0
Land Retirement	5.1	10.2	15.2	20.3	25.4	30.5	35.5	40.6	45.7	50.8
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	0.9	1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.6
Grade Stabilization Structure	2.2	4.4	6.5	8.7	10.9	13.1	15.2	17.4	19.6	21.8
Livestock Exclusion, Alternative Water, Prescribed Grazing	1.8	3.6	5.3	7.1	8.9	10.7	12.5	14.3	16.0	17.8
Grade Stabilization Structure and Prescribed Grazing	2.5	4.9	7.4	9.9	12.3	14.8	17.3	19.7	22.2	24.6
Water and Sediment Control Basin	1.7	3.4	5.1	6.8	8.5	10.2	11.9	13.6	15.3	17.0
Livestock Exclusion, Alternative water, Prescribed Grazing, Forest Buffer	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.3	20.6	22.9
Grade Stabilization Structure and Sediment Control Basin	2.6	5.2	7.8	10.4	13.0	15.6	18.2	20.8	23.4	26.0
Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	2.7	5.4	8.2	10.9	13.6	16.3	19.0	21.8	24.5	27.2

Table 24. Phosphorus load reduction results for Spring Branch-Elk Creek watershed. Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Phosphorus load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.6	1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.6	6.3
Terrace	2.6	5.1	7.7	10.3	12.8	15.4	18.0	20.5	23.1	25.7
Cover Crop and Terrace	3.0	5.9	8.9	11.8	14.8	17.7	20.7	23.6	26.6	29.6
Cover Crop and No Till	5.3	10.6	15.9	21.2	26.5	31.8	37.1	42.4	47.4	53.0
Cover Crop, No Till, Nutrient Management	5.6	11.3	16.9	22.6	28.2	33.9	39.5	45.1	50.8	56.4
Water and Sediment Control Basin	5.6	11.1	16.7	22.3	27.8	33.4	39.0	44.5	50.1	55.7
No-Till and Terrace	5.8	11.6	17.4	23.1	28.9	34.7	40.5	46.3	52.1	57.8
Cover Crop, No-Till, and Terrace	5.9	11.8	17.7	23.5	29.4	35.3	41.2	47.1	53.0	58.9
Cover Crop, No-Till, Terrace, and Nutrient Management	6.1	12.2	18.4	24.5	30.6	36.7	42.9	49.0	55.1	61.2
Land Retirement	6.3	12.5	18.8	25.0	31.3	37.5	43.8	50.1	56.3	62.6
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	0.5	0.9	1.4	1.8	2.3	2.8	3.2	3.7	4.1	4.6
Grade Stabilization Structure	1.1	2.3	3.4	4.5	5.7	6.8	7.9	9.1	10.2	11.3
Livestock Exclusion, Alternative Water, Prescribed Grazing	1.0	1.9	2.9	3.8	4.8	5.7	6.7	7.6	8.6	9.5
Grade Stabilization Structure and Prescribed Grazing	1.2	2.5	3.7	4.9	6.2	7.4	8.6	9.9	11.1	12.3
Water and Sediment Control Basin	1.1	2.3	3.4	4.6	5.7	6.8	8.0	9.1	10.3	11.4
Livestock Exclusion, Alternative water, Prescribed Grazing, Forest Buffer	1.2	2.4	3.6	4.8	6.0	7.2	8.3	9.5	10.7	11.9
Grade Stabilization Structure and Sediment Control Basin	1.4	2.8	4.3	5.7	7.1	8.5	9.9	11.3	12.8	14.2
Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	1.4	2.9	4.3	5.8	7.2	8.6	10.1	11.5	13.0	14.4

Table 25. Sediment load reduction results for Spring Branch-Elk Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Sediment load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.7	1.5	2.2	2.9	3.7	4.4	5.1	5.9	6.6	7.3
Terrace	2.9	5.9	8.8	11.7	14.6	17.6	20.5	23.4	26.4	29.3
Cover Crop and Terrace	3.4	6.7	10.1	13.5	16.8	20.2	23.6	26.9	30.3	33.7
Cover Crop and No Till	5.8	11.6	17.4	23.2	29.0	34.8	40.6	46.4	52.3	58.1
Cover Crop, No Till, Nutrient Management	5.8	11.6	17.4	23.2	29.0	34.8	40.6	46.4	52.3	58.1
Water and Sediment Control Basin	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7	63.0
No-Till and Terrace	6.3	12.6	18.9	25.2	31.6	37.9	44.2	50.5	56.8	63.1
Cover Crop, No-Till, and Terrace	6.4	12.8	19.2	25.7	32.1	38.5	44.9	51.3	57.7	64.1
Cover Crop, No-Till, Terrace, and Nutrient Management	6.4	12.8	19.2	25.7	32.1	38.5	44.9	51.3	57.7	64.1
Land Retirement	7.0	13.9	20.9	27.8	34.8	41.7	48.7	55.6	62.6	69.6
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.6	1.7
Grade Stabilization Structure	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.5	6.2	6.9
Livestock Exclusion, Alternative Water, Prescribed Grazing	0.7	1.5	2.2	2.9	3.7	4.4	5.1	5.9	6.6	7.3
Grade Stabilization Structure and Prescribed Grazing	0.8	1.5	2.3	3.1	3.9	4.6	5.4	6.2	6.9	7.7
Water and Sediment Control Basin	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0
Livestock Exclusion, Alternative water, Prescribed Grazing, Forest Buffer	0.8	1.7	2.5	3.3	4.2	5.0	5.9	6.7	7.5	8.4
Grade Stabilization Structure and Sediment Control Basin	0.9	1.8	2.7	3.6	4.5	5.4	6.2	7.1	8.0	8.9
Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9.0

Table 26. Nitrogen load reduction results for Turkey Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Nitrogen load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	1.0	1.9	2.9	3.8	4.8	5.7	6.6	7.6	8.5	9.6
Terraces	1.9	3.7	5.6	7.4	9.3	11.1	12.9	14.8	16.6	18.5
Cover Crop and Terraces	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.2	22.8	25.4
Cover Crop and No Till	3.3	6.6	9.9	13.1	16.4	19.7	22.9	26.2	29.5	32.8
Cover Crop, No-Till, and Nutrient Management	3.8	7.7	11.5	15.4	19.3	23.1	27.0	30.8	34.7	38.4
Water and Sediment Control Basin	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.1
No Till and Terraces	3.6	7.2	10.8	14.4	18.0	21.6	25.2	28.8	32.4	36.0
Cover Crop, No-Till and Terrace	4.0	8.1	12.1	16.2	20.3	24.3	28.4	32.4	36.5	40.5
Cover Crop, No-Till, Terrace, and Nutrient Management	4.5	8.9	13.4	17.8	22.3	26.7	31.1	35.6	40.0	44.6
Land Retirement	5.5	11.0	16.5	22.1	27.6	33.1	38.7	44.2	49.7	55.2
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	1.0	2.0	3.0	3.9	4.9	5.9	6.8	7.8	8.8	9.9
Grade Stabilization Structure	2.5	5.0	7.4	9.9	12.4	14.8	17.3	19.7	22.2	24.8
Livestock Exclusion and Alternative Water, Prescribed Grazing	2.0	4.0	6.0	8.1	10.1	12.1	14.2	16.2	18.2	20.2
Grade Stabilization Structure and Prescribed Grazing	2.8	5.6	8.4	11.3	14.1	16.9	19.8	22.6	25.4	28.1
Water and Sediment Control Basin	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.2	17.1	19.1
Livestock Exclusion, Alternative Water, Prescribed Grazing, and Forest Buffer	2.6	5.2	7.8	10.4	13.0	15.6	18.2	20.8	23.4	26.1
Grade Stabilization Structure and Water and Sediment Control Basin	3.0	5.9	8.9	11.8	14.8	17.7	20.6	23.6	26.5	29.6
Grade Stabilization Structure and Water and Sediment Control Basin, and Prescribed Grazing	3.1	6.2	9.3	12.4	15.5	18.6	21.7	24.8	27.9	31.0

Table 27. Phosphorus load reduction results for Turkey Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Phosphorus load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.7	1.3	2.0	2.6	3.3	3.9	4.5	5.2	5.8	6.6
Terraces	2.7	5.4	8.1	10.8	13.5	16.2	18.9	21.6	24.3	27.1
Cover Crop and Terraces	3.1	6.2	9.4	12.5	15.7	18.8	21.9	25.1	28.2	31.2
Cover Crop and No Till	5.7	11.3	17.0	22.7	28.4	34.0	39.7	45.4	51.0	56.7
Cover Crop, No-Till, and Nutrient Management	6.2	12.3	18.5	24.6	30.8	36.9	43.0	49.2	55.3	61.6
Water and Sediment Control Basin	5.9	11.8	17.7	23.6	29.5	35.4	41.3	47.2	53.1	59.0
No Till and Terraces	6.2	12.4	18.6	24.8	31.0	37.2	43.4	49.6	55.8	62.0
Cover Crop, No-Till and Terrace	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7	63.1
Cover Crop, No-Till, Terrace, and Nutrient Management	6.6	13.3	19.9	26.6	33.3	39.9	46.6	53.2	59.9	66.5
Land Retirement	6.7	13.3	20.0	26.7	33.4	40.0	46.7	53.4	60.0	66.7
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	0.6	1.1	1.7	2.2	2.8	3.3	3.8	4.4	4.9	5.5
Grade Stabilization Structure	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.0
Livestock Exclusion and Alternative Water, Prescribed Grazing	1.1	2.1	3.2	4.3	5.4	6.4	7.5	8.6	9.6	10.6
Grade Stabilization Structure and Prescribed Grazing	1.4	2.8	4.2	5.7	7.1	8.5	10.0	11.4	12.8	14.1
Water and Sediment Control Basin	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	12.9
Livestock Exclusion, Alternative Water, Prescribed Grazing, and Forest Buffer	1.3	2.7	4.0	5.4	6.8	8.1	9.5	10.8	12.2	13.5
Grade Stabilization Structure and Water and Sediment Control Basin	1.6	3.2	4.9	6.5	8.2	9.8	11.4	13.1	14.7	16.2
Grade Stabilization Structure and Water and Sediment Control Basin, and Prescribed Grazing	1.6	3.3	4.9	6.6	8.3	9.9	11.6	13.2	14.9	16.5

Table 28. Sediment load reduction results for Turkey Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	Sediment load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	7.9
Terraces	3.2	6.3	9.5	12.7	15.9	19.0	22.2	25.4	28.5	31.7
Cover Crop and Terraces	3.6	7.3	10.9	14.6	18.3	21.9	25.6	29.2	32.9	36.5
Cover Crop and No Till	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7	62.9
Cover Crop, No-Till, and Nutrient Management	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7	62.9
Water and Sediment Control Basin	6.8	13.6	20.5	27.3	34.2	41.0	47.8	54.7	61.5	68.2
No Till and Terraces	6.8	13.7	20.5	27.4	34.3	41.1	48.0	54.8	61.7	68.4
Cover Crop, No-Till and Terrace	6.9	13.9	20.8	27.8	34.8	41.7	48.7	55.6	62.6	69.5
Cover Crop, No-Till, Terrace, and Nutrient Management	6.9	13.9	20.8	27.8	34.8	41.7	48.7	55.6	62.6	69.5
Land Retirement	7.5	15.1	22.6	30.1	37.7	45.2	52.7	60.2	67.8	75.4
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	1.9
Grade Stabilization Structure	0.8	1.5	2.3	3.1	3.9	4.6	5.4	6.2	6.9	7.7
Livestock Exclusion and Alternative Water, Prescribed Grazing	0.8	1.6	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.2
Grade Stabilization Structure and Prescribed Grazing	0.9	1.7	2.6	3.4	4.3	5.1	5.9	6.8	7.6	8.6
Water and Sediment Control Basin	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	8.9
Livestock Exclusion, Alternative Water, Prescribed Grazing, and Forest Buffer	0.9	1.9	2.8	3.7	4.7	5.6	6.5	7.4	8.4	9.3
Grade Stabilization Structure and Water and Sediment Control Basin	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Grade Stabilization Structure and Water and Sediment Control Basin, and Prescribed Grazing	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.1

Table 29. Annual sediment yield ranked by Management Unit.

MU ID	Ad (acres)	Crop (acres)	Pasture (acres)	Annual Yield Sed (T/ac/yr)	Priority Rank
1	4,197	1,398	2,198	1.38	1
4	1,720	509	1,731	1.37	2
15	2,646	2,353	1,609	1.14	3
28	2,538	1,755	535	1.13	4
8	1,779	483	1,037	1.09	5
29	2,900	2,114	438	1.05	6
6	3,143	1,148	1,390	1.00	7
10	1,385	414	682	0.99	8
26	1,850	1,638	562	0.91	9
30	2,315	1,423	431	0.90	10
13	2,599	1,066	876	0.89	11
2	2,508	588	1,400	0.88	12
21	3,560	2,781	322	0.88	13
3	4,934	1,181	2,611	0.86	14
14	3,710	2,214	835	0.86	15
7	2,121	709	892	0.80	16
9	3,851	1,249	1,827	0.80	17
17	3,648	2,059	1,131	0.78	18
19	3,736	2,247	683	0.77	19
22	1,822	809	900	0.74	20
5	2,739	395	1,004	0.74	21
12	2,365	760	1,090	0.69	22
27	1,625	1,044	346	0.67	23
11	2,277	1,052	747	0.66	24
25	2,680	1,300	320	0.58	25
24	2,438	1,289	508	0.51	26
20	3,292	1,290	355	0.48	27
18	4,391	1,308	1,267	0.48	28
16	4,960	1,370	854	0.39	29
23	2,375	352	534	0.36	30

Table 30. Summary of vulnerability classification for the three study watersheds.

Vulnerability Class	Land Use and Conditions	Acres (%)
Highest	Cropland with Erodibility Index ≥8	15,614 (18.4%)
High	Cropland with Erodibility Index <8	22,995 (27.1%)
Moderate	Pasture	29,078 (34.3%)
Low	Forest	10,112 (11.9%)
N/A	Urban Water and wetlands	7,095 (8.4%)
	Total	84,893 (100.0%)

Table 31. Ranked conservation practices by largest sediment load reduction.

Rank	Practice	Land Use
1	Land Retirement	Crop
2	Cover Crop, No-Till, Terrace, and Nutrient Management	Crop
3	Cover Crop, No-Till, and Terrace	Crop
4	No-Till and Terrace	Crop
5	Water and Sediment Control Basin	Crop
6	Cover Crop, No-Till, and Nutrient Management	Crop
7	Cover Crop and No-Till	Crop
8	Cover Crop and Terrace	Crop
9	Terrace	Crop
10	Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	Pasture
11	Grade Stabilization Structure and Water and Sediment Control Basin	Pasture
12	Livestock Exclusion, Alternative Water, Prescribed Grazing, and Forest Buffer	Pasture
13	Water and Sediment Control Basin	Pasture
14	Grade Stabilization Structure and Prescribed Grazing	Pasture
15	Livestock Exclusion, Alternative Water, and Prescribed Grazing	Pasture
16	Grade Stabilization Structure	Pasture
17	Cover Crop	Crop
18	Livestock Exclusion and Alternative Water	Pasture

FIGURES

Figure 1. Lower Grand basin in northern Missouri, southern Iowa.

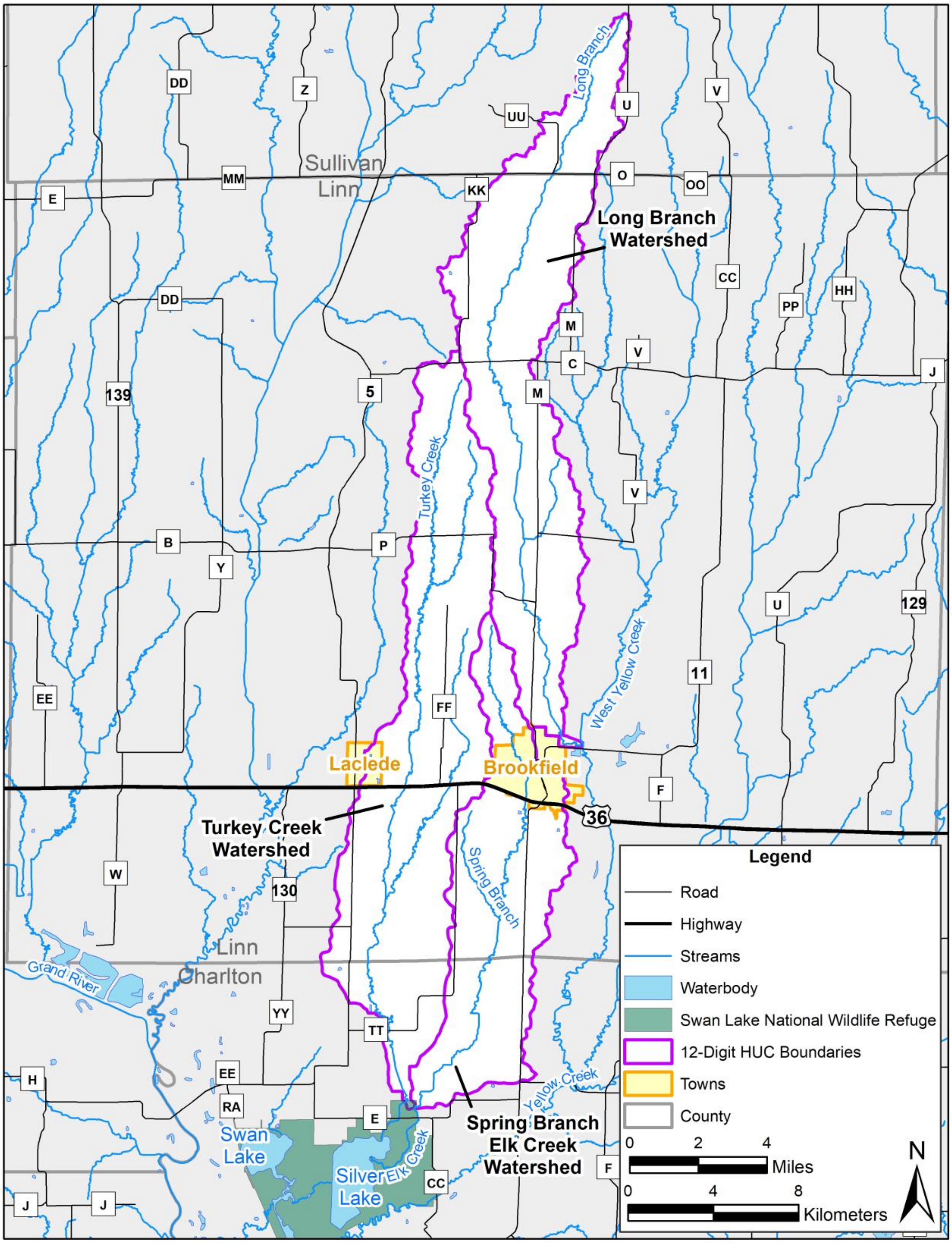


Figure 2. The Turkey Creek, Long Branch, and Spring Branch-Elk Creek watersheds.

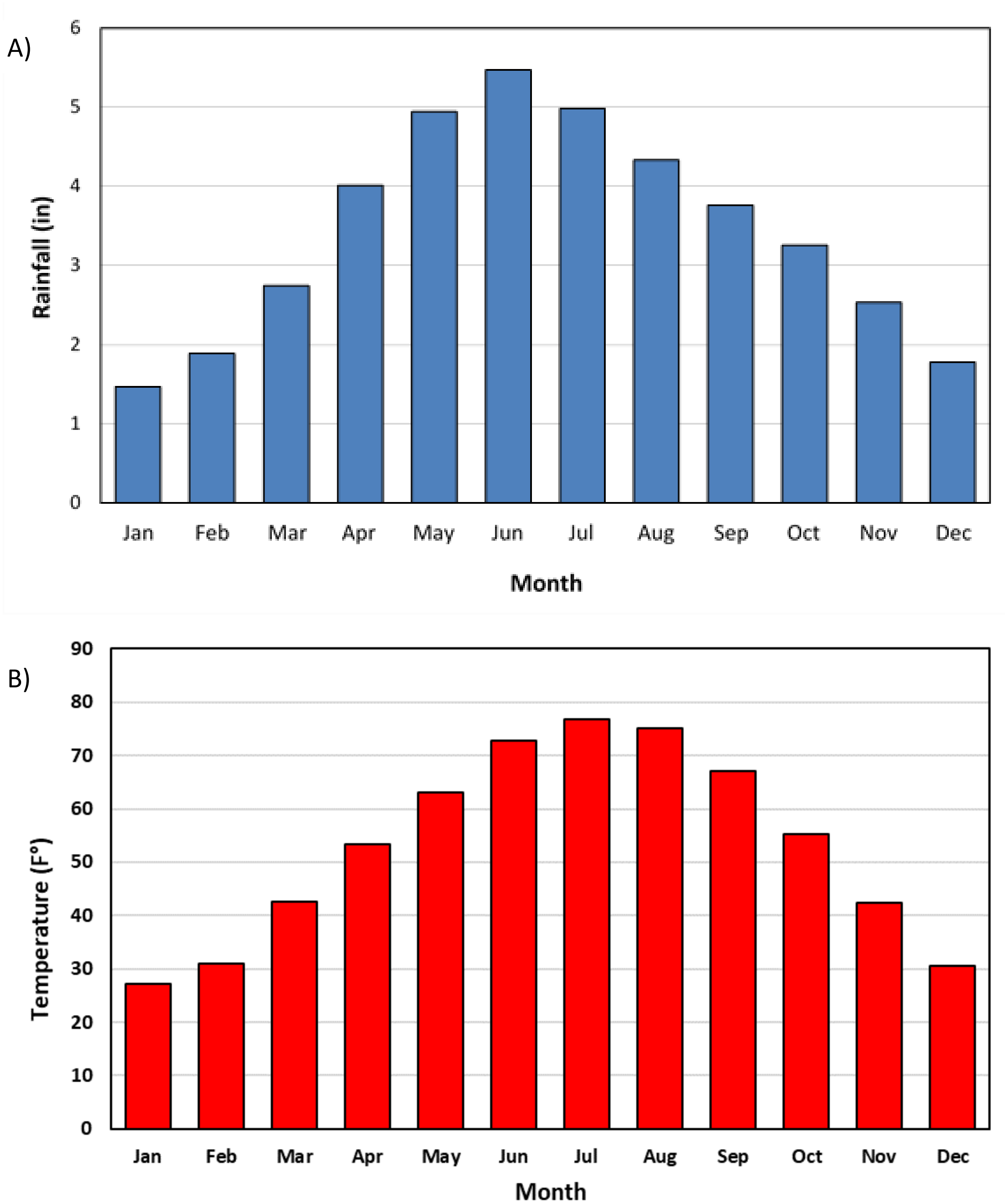
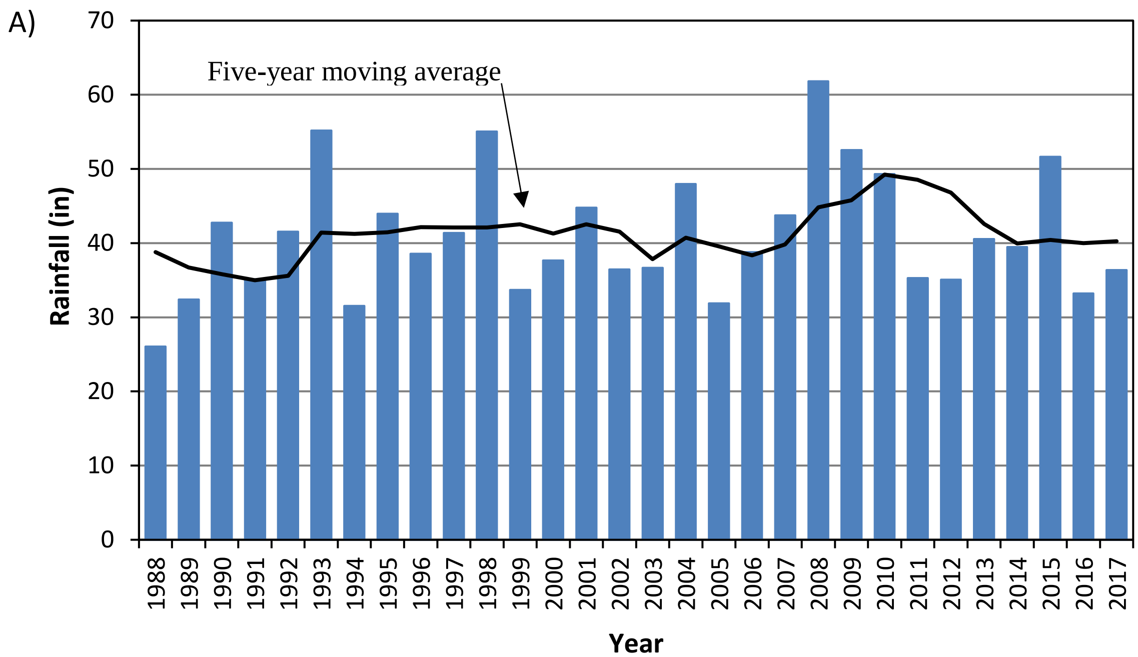


Figure 3. Mean monthly A) rainfall and B) temperature from 1987-2017 for Brookfield, MO.



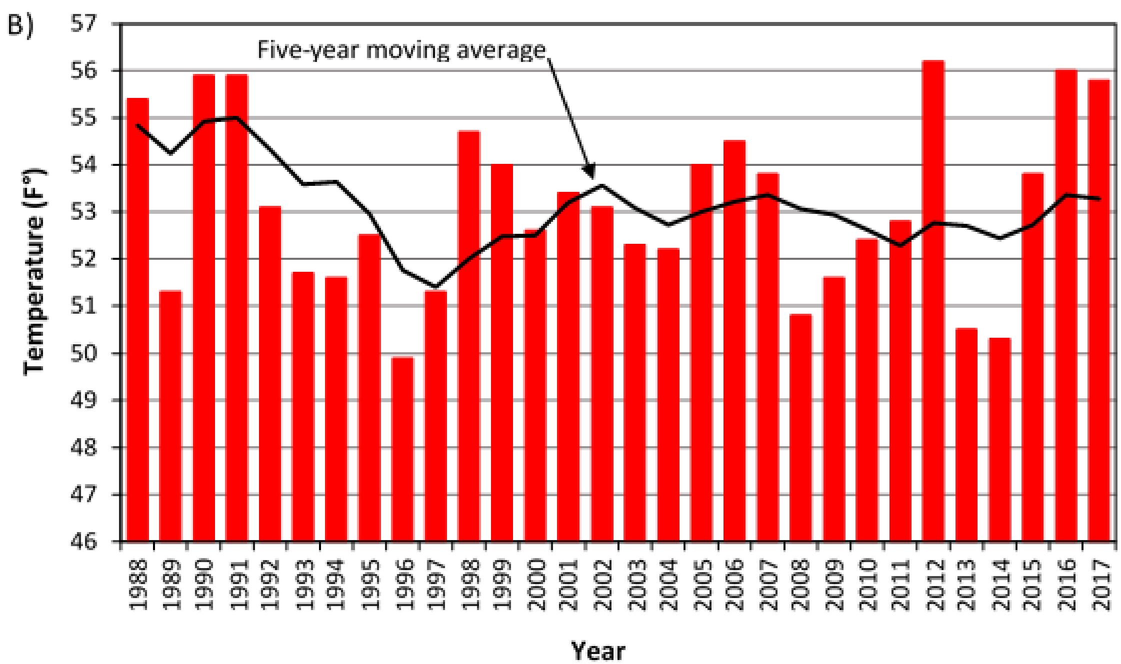


Figure 4. A) Annual total rainfall and B) average annual temperature from 1988-2017 for Brookfield, MO.

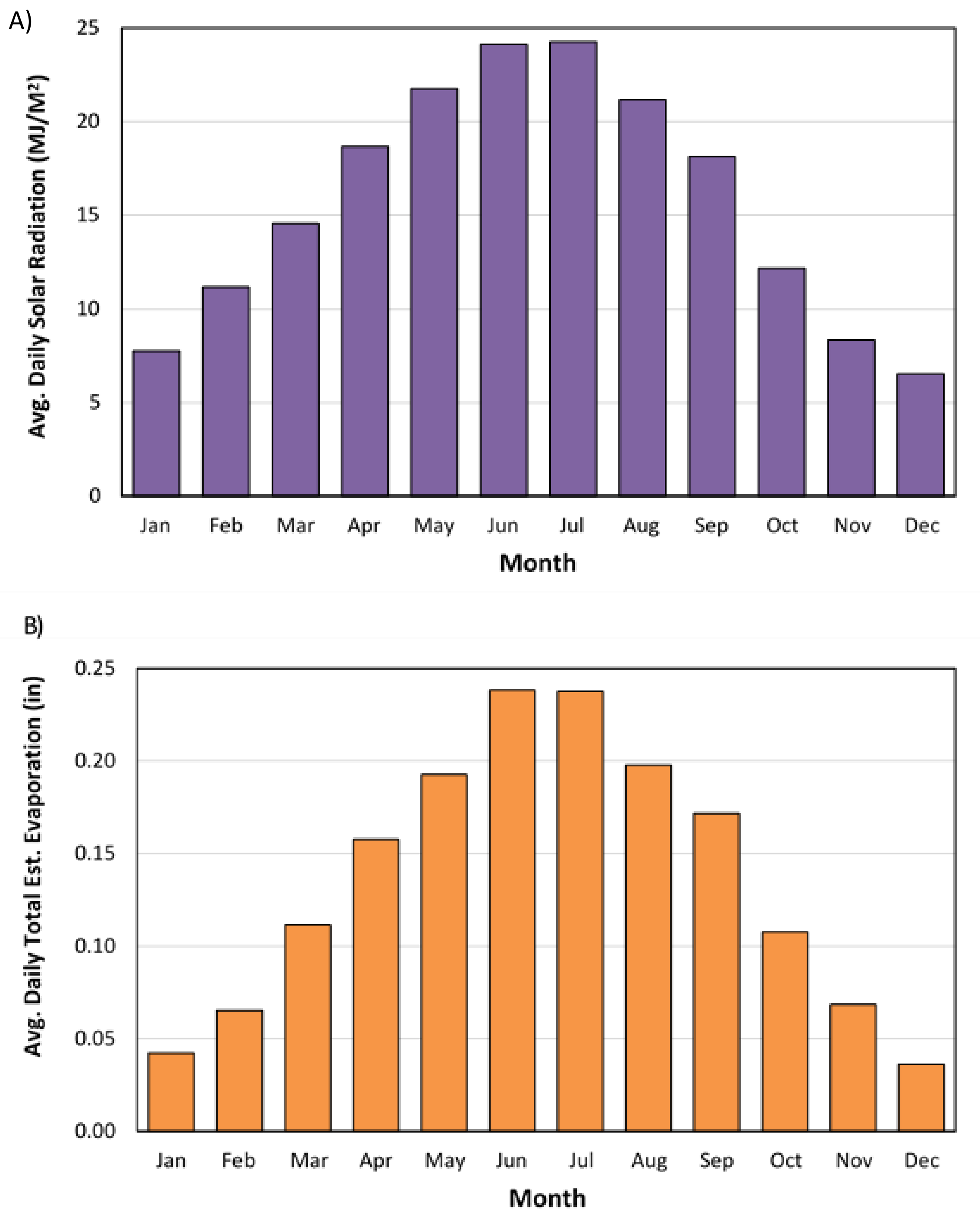


Figure 5. Average daily A) solar radiation (2000-2017) and B) estimated evaporation (2012-2017) for Linneus, Linn County MO.

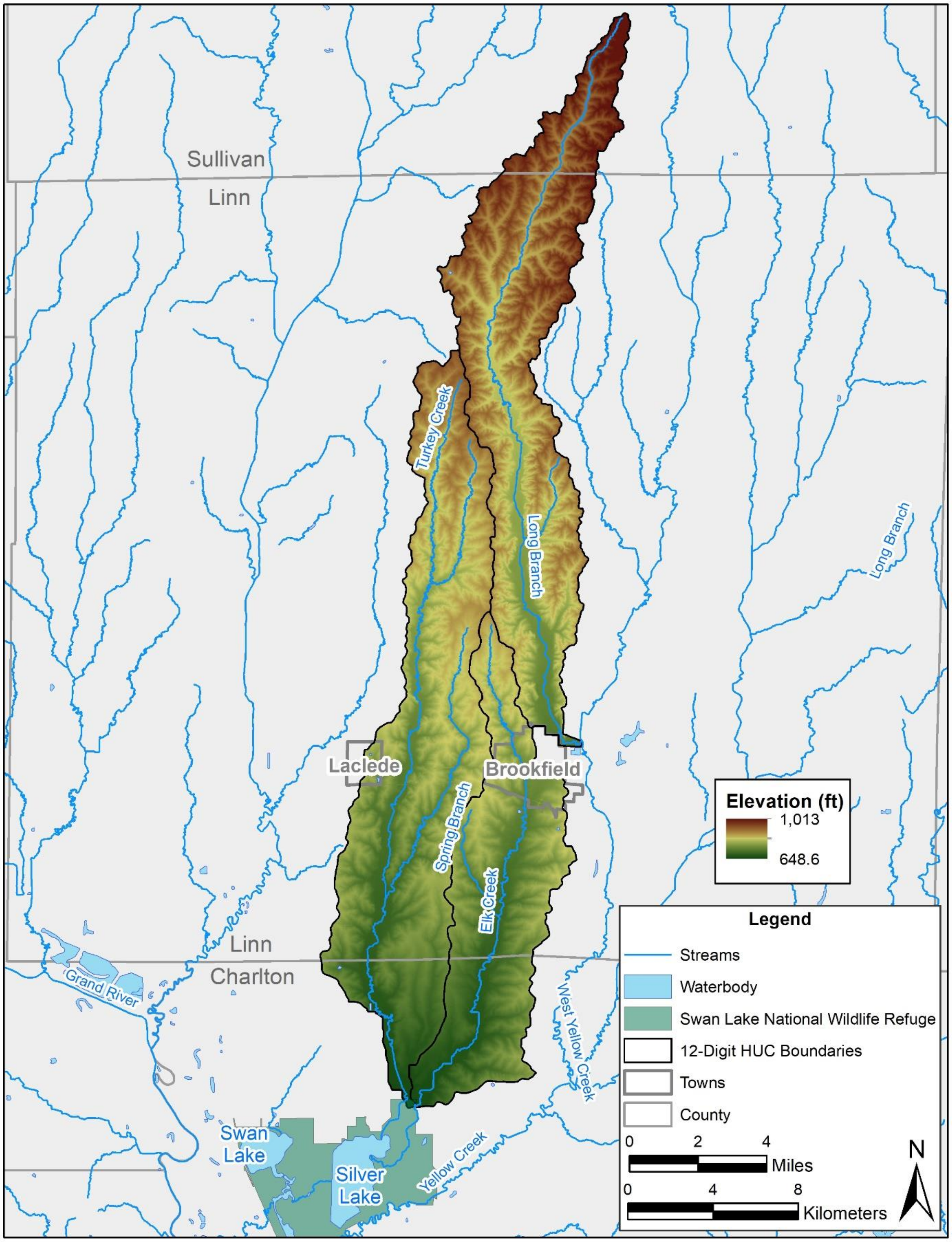


Figure 6. LiDAR elevations within the watershed.

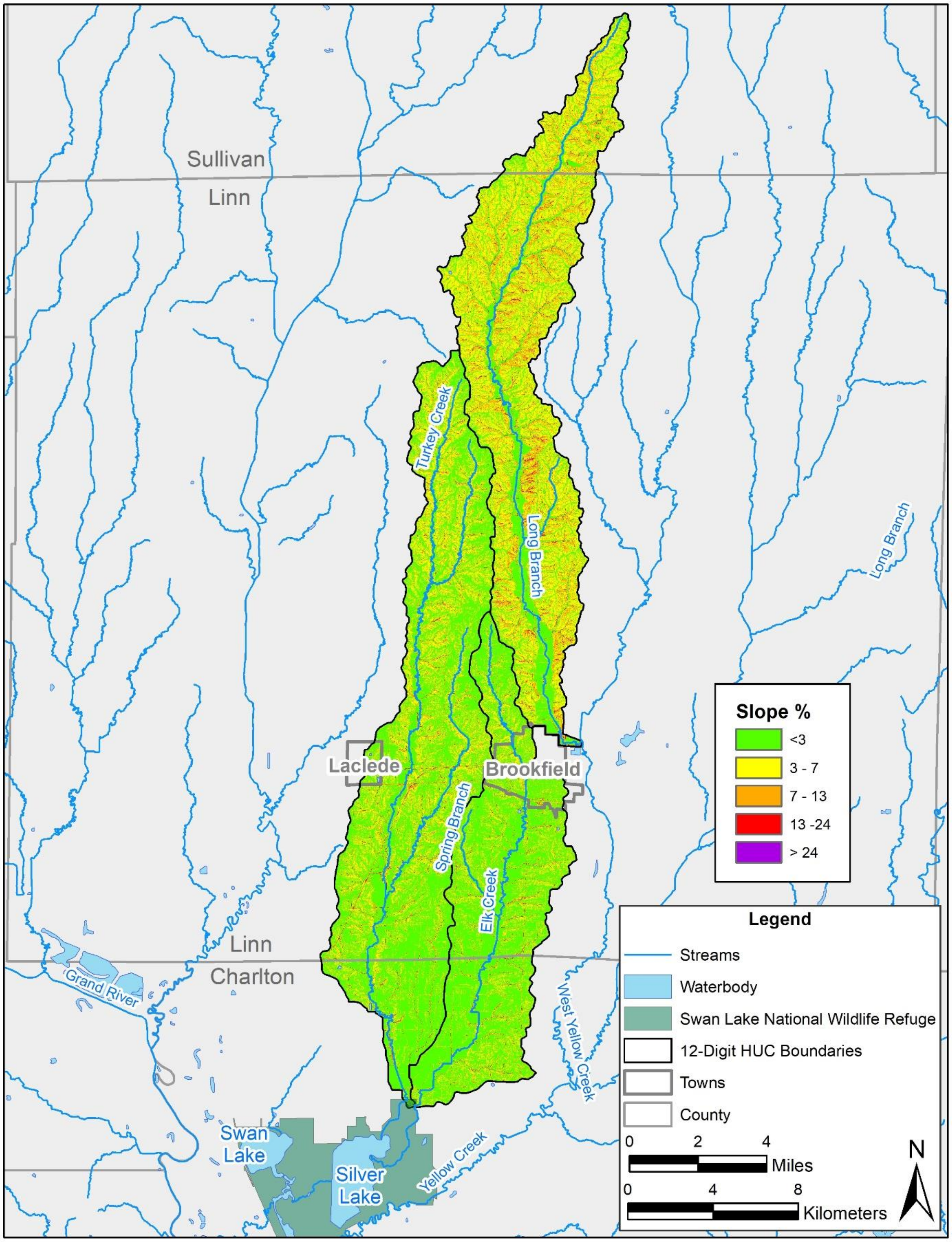


Figure 7. LiDAR based slope classification across the watershed.

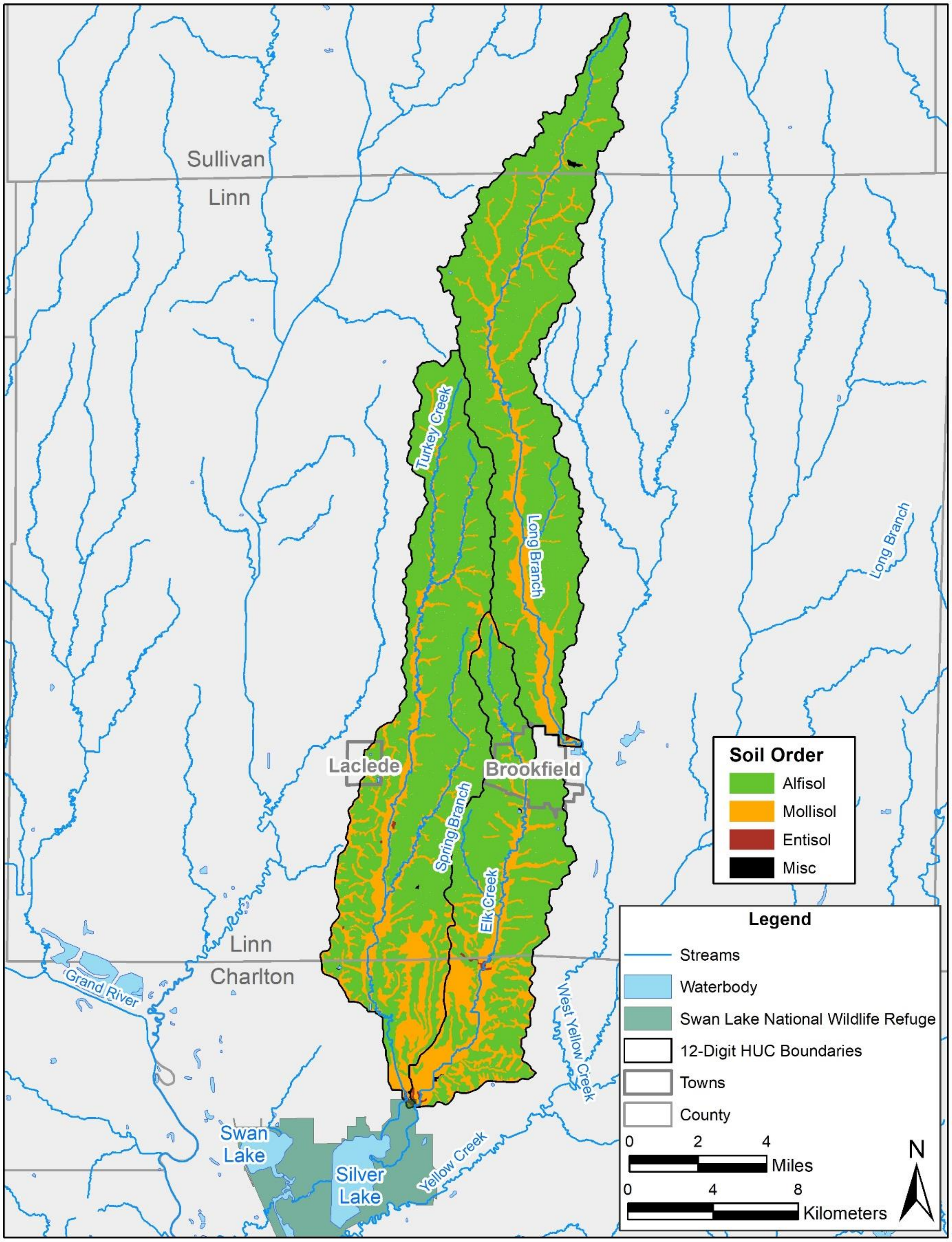


Figure 8. Soil series classified by order.

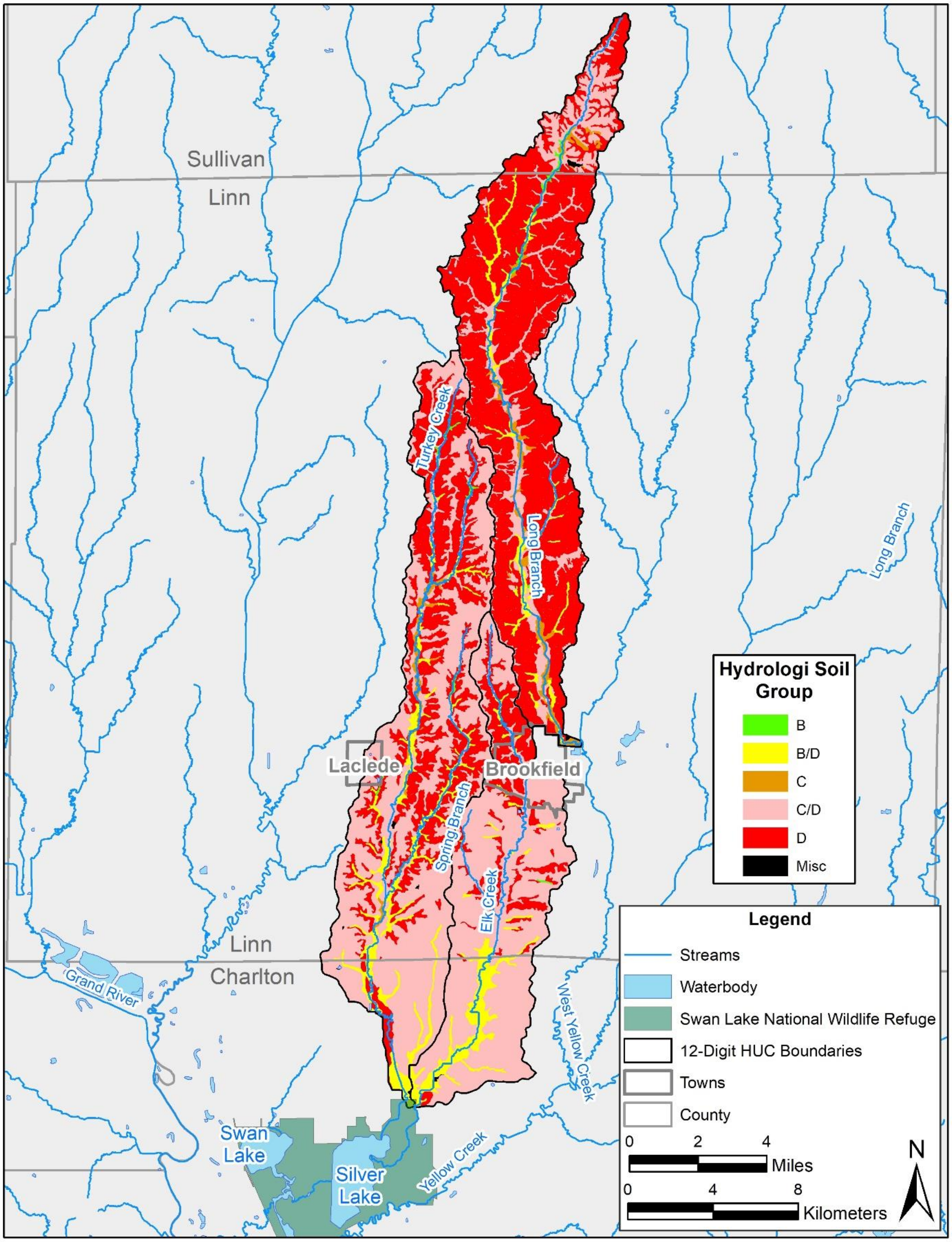


Figure 9. Soil series classified by hydrologic soil group.

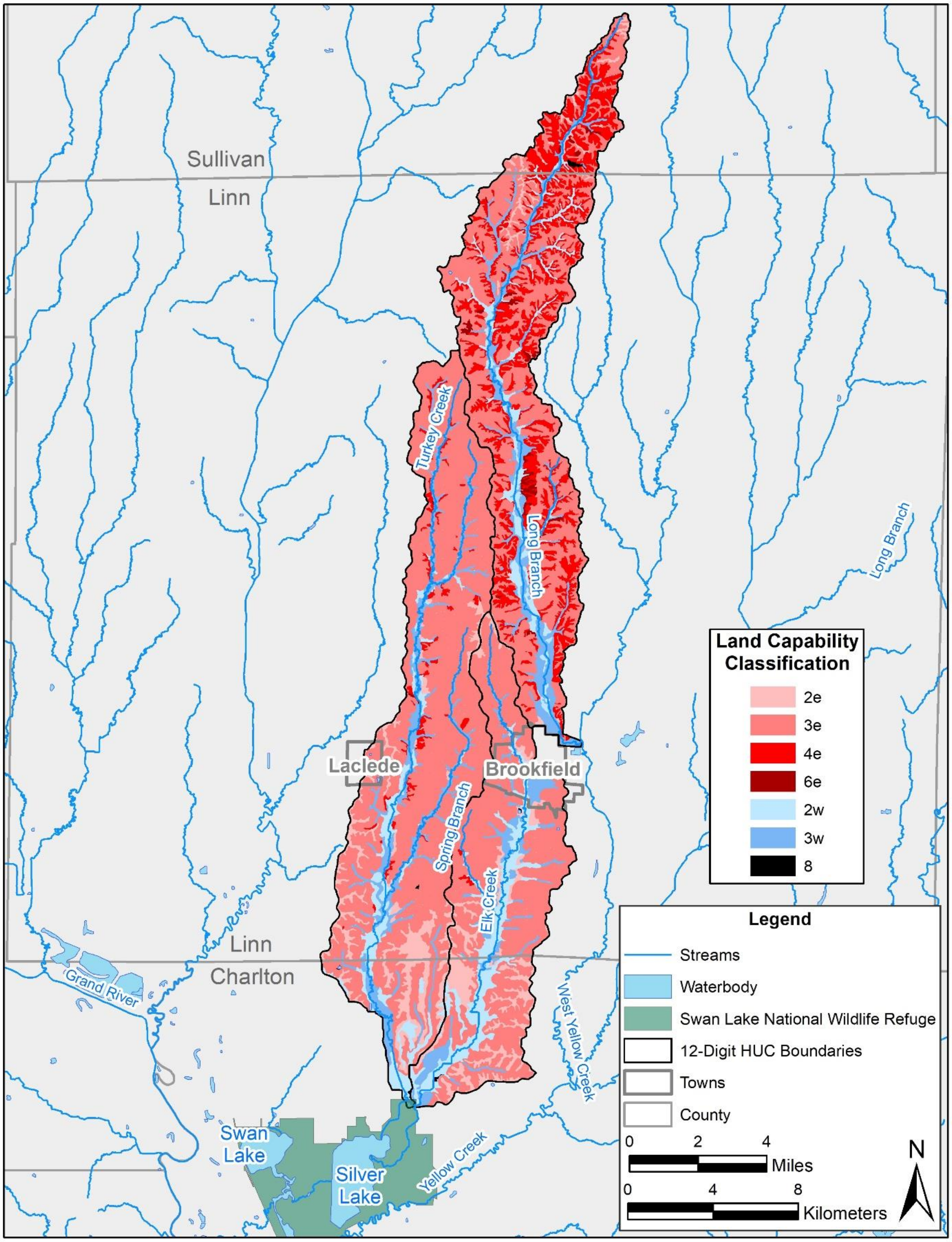


Figure 10. Soil series classified by land capability classification.

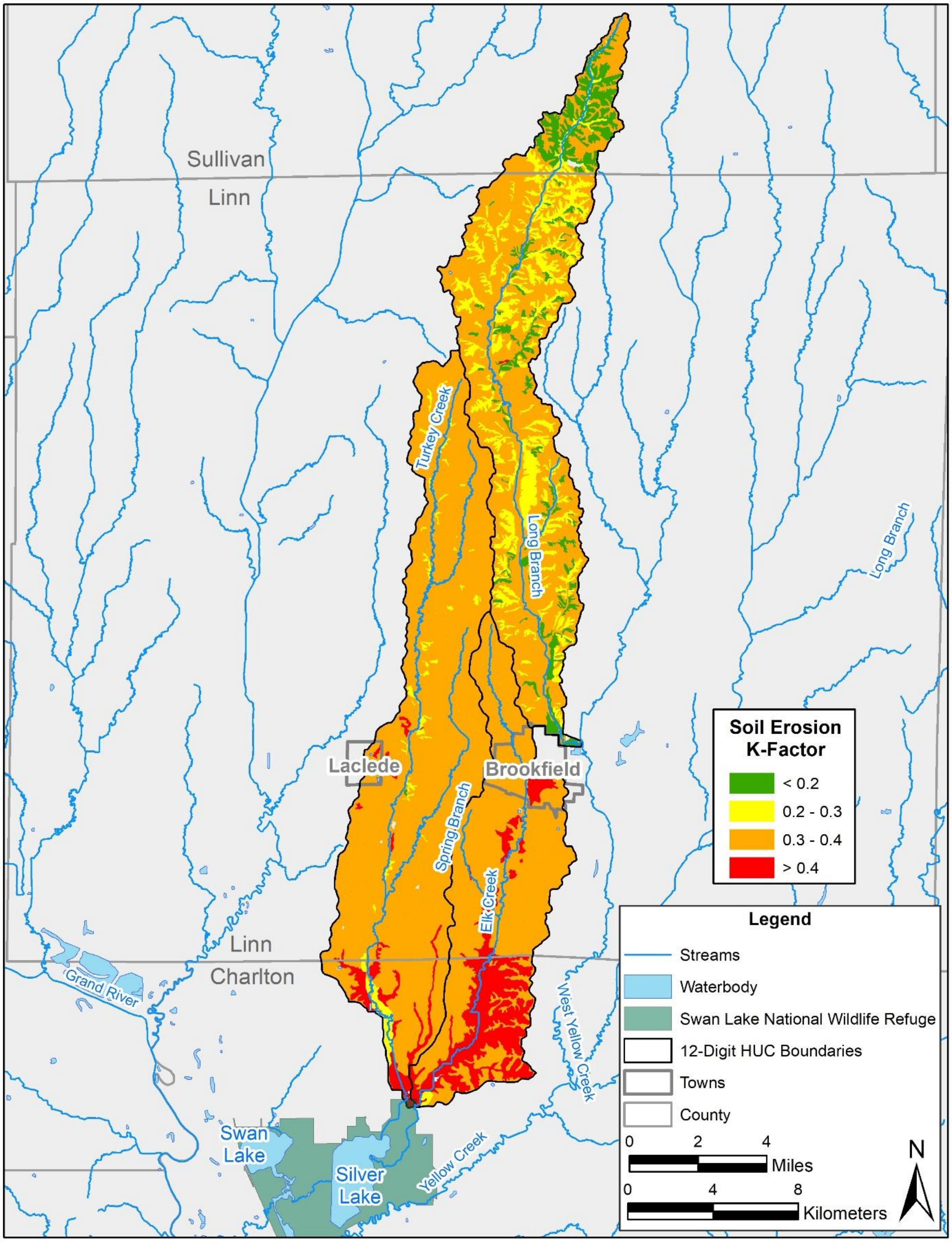


Figure 11. Soil series classified by soil erosion K-factor.

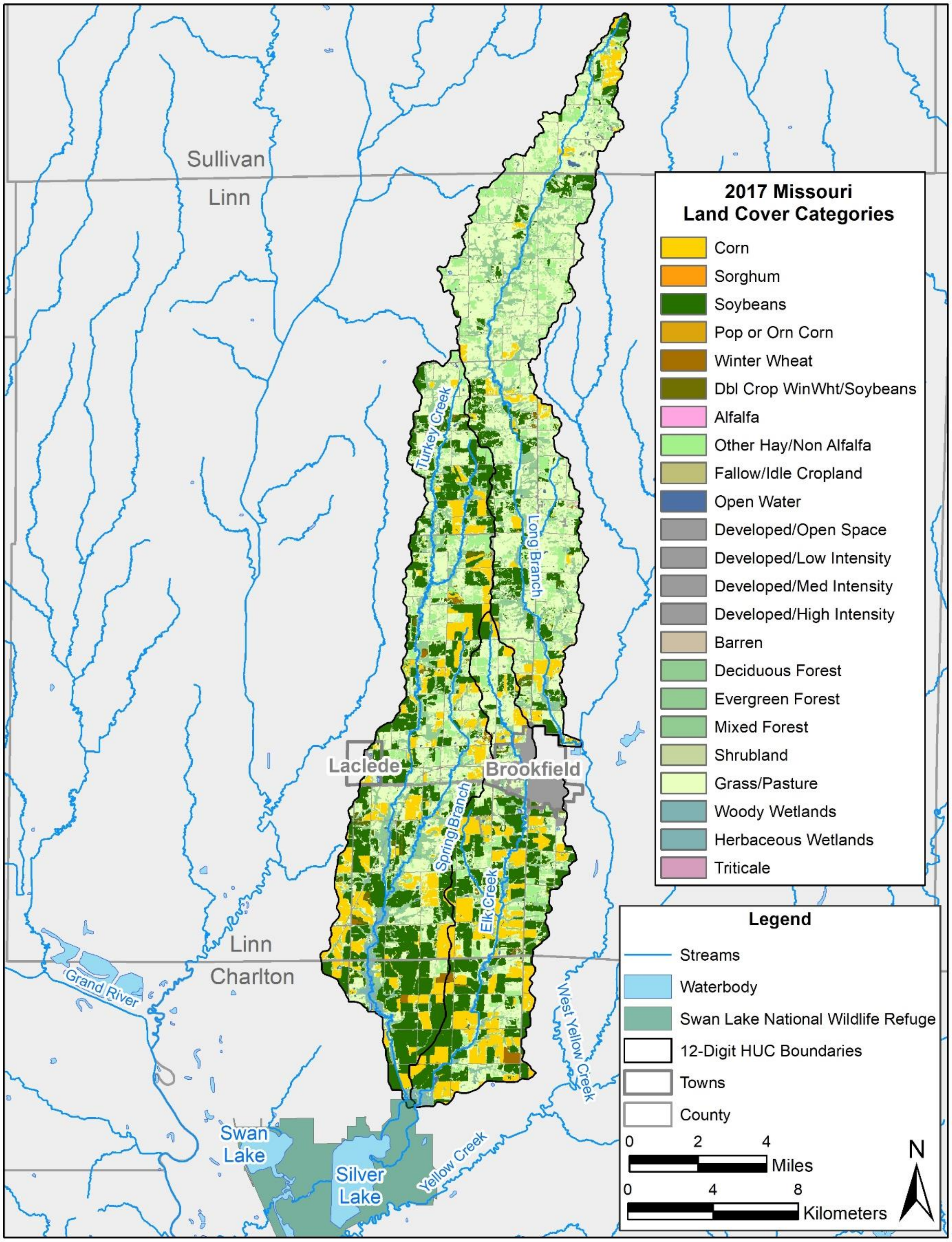


Figure 12. 2017 crop data from the NASS.

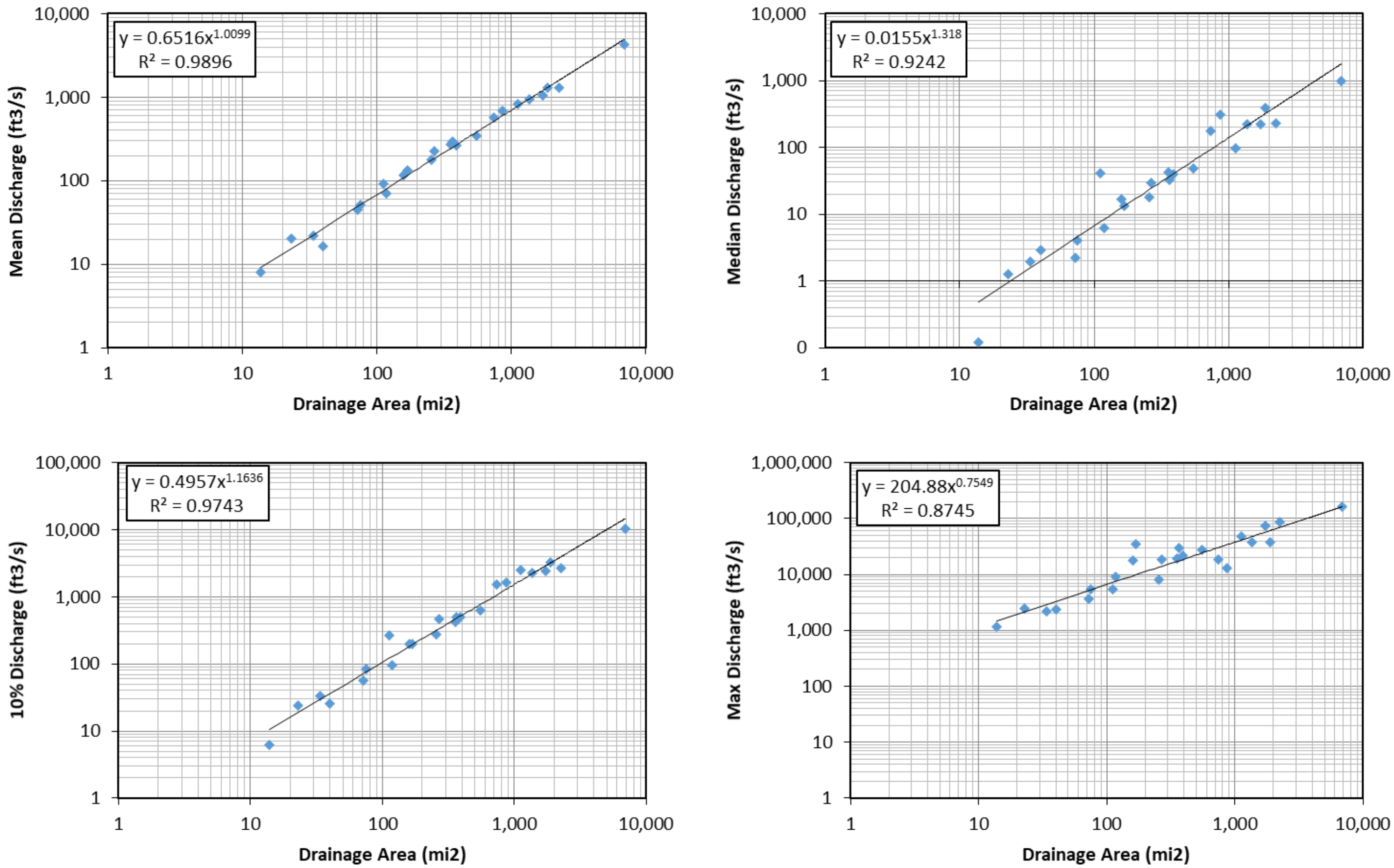


Figure 13. Drainage area and discharge relationships for 24 USGS gaging stations near the study watershed.

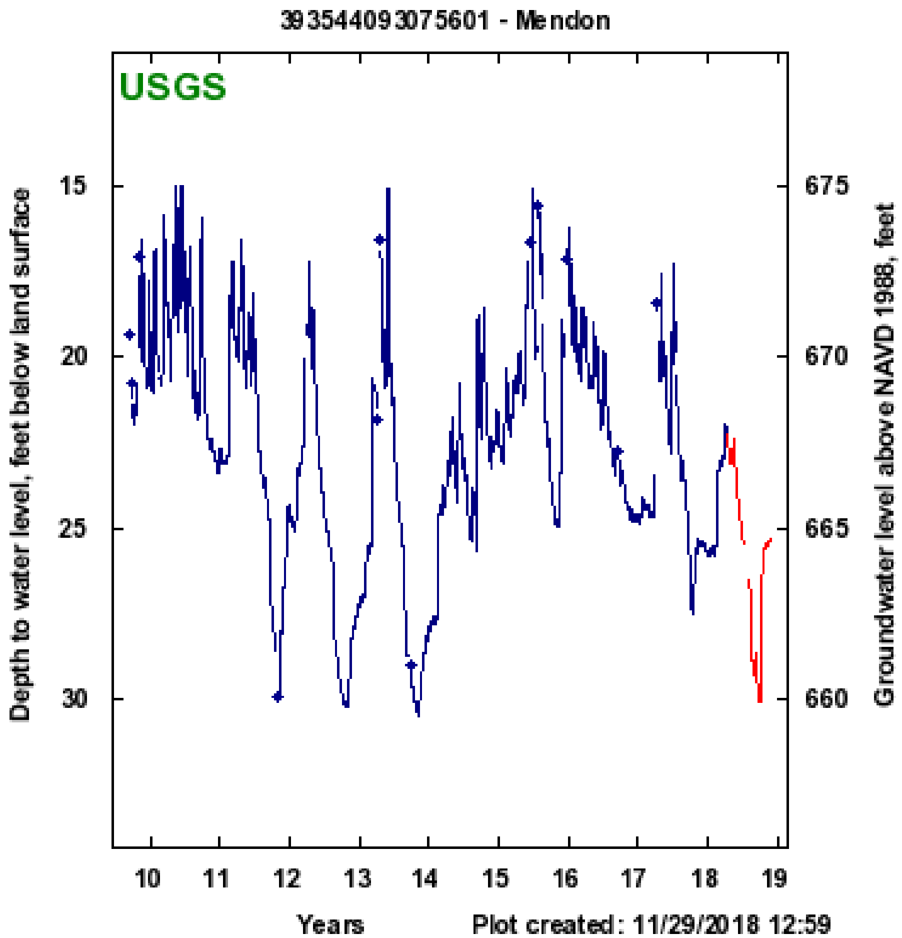


Figure 14. Ground water level change for Mendon (2009-2018).

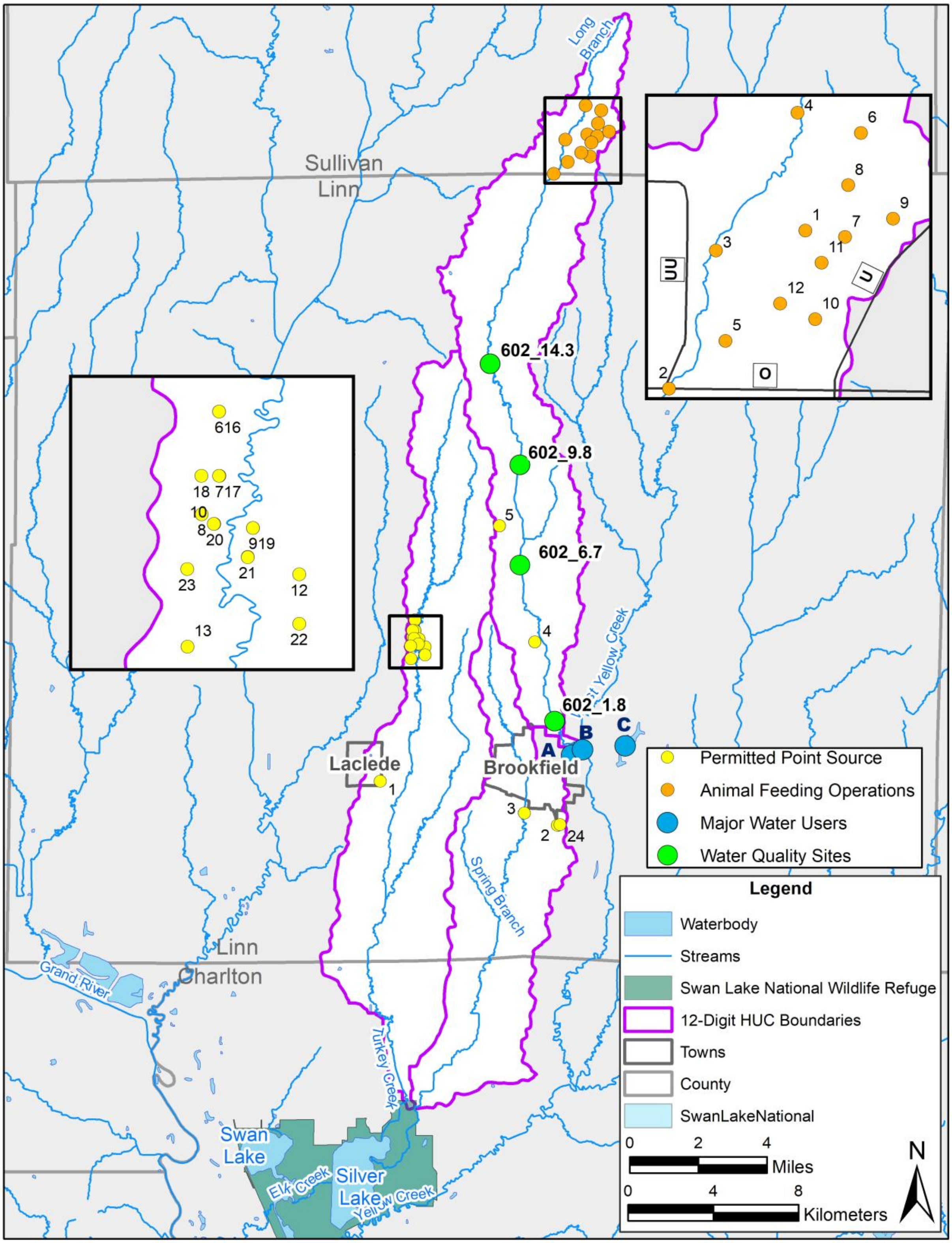


Figure 15. Permitted point sources and water quality monitoring station locations.

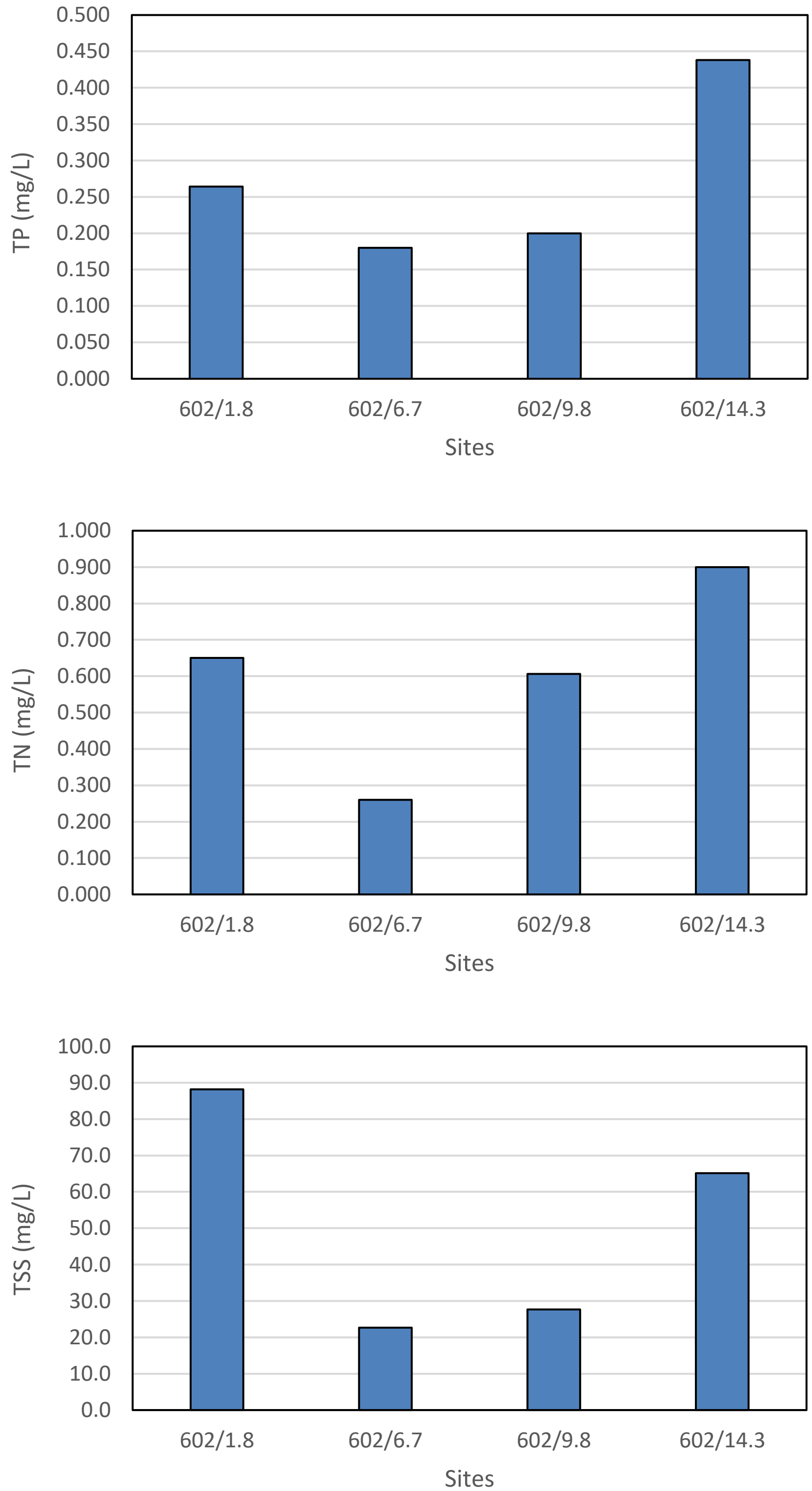


Figure 16. Average concentrations of TP, TN, and TSS for the Long Branch watershed

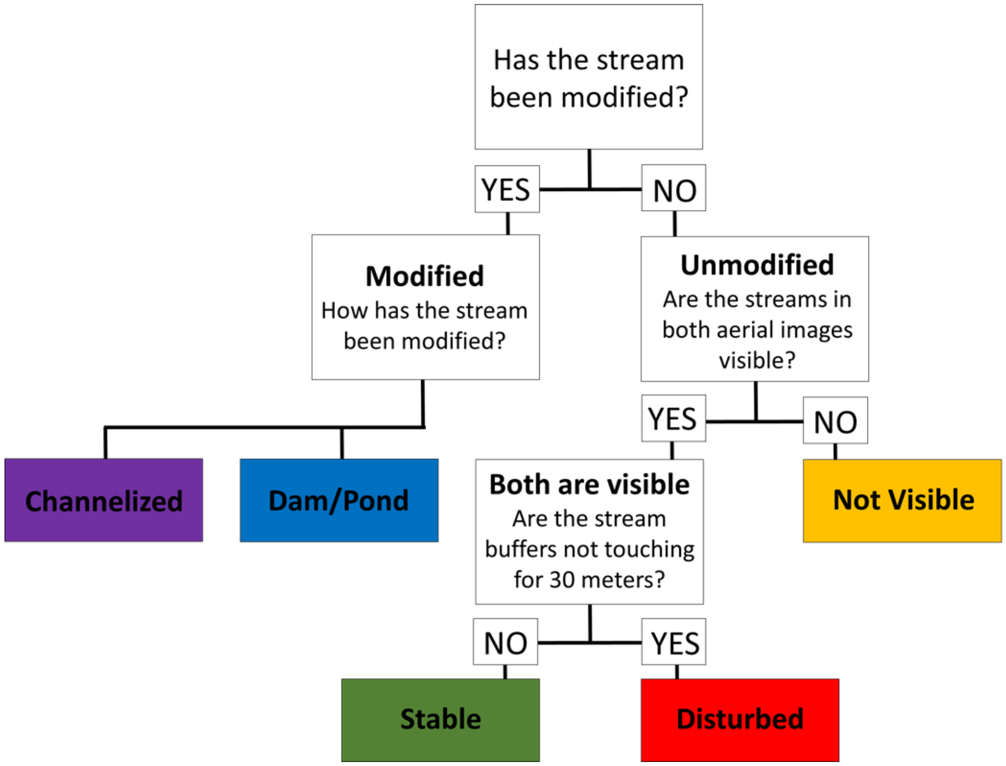


Figure 17. Flow chart showing decision tree for classifying stream channels from aerial photo analysis.

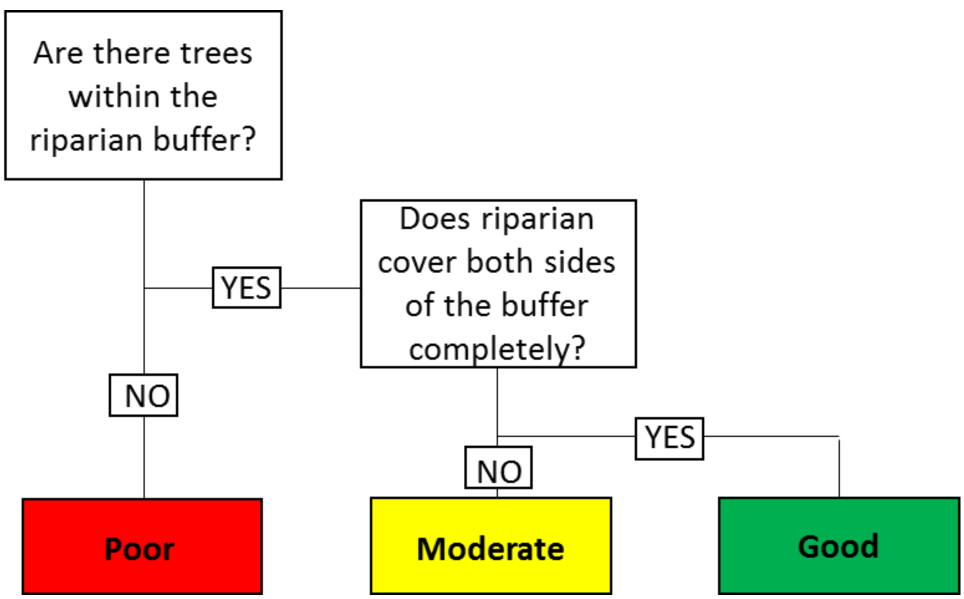


Figure 18. Flow chart showing decision tree for riparian corridor assessment from aerial photo analysis.

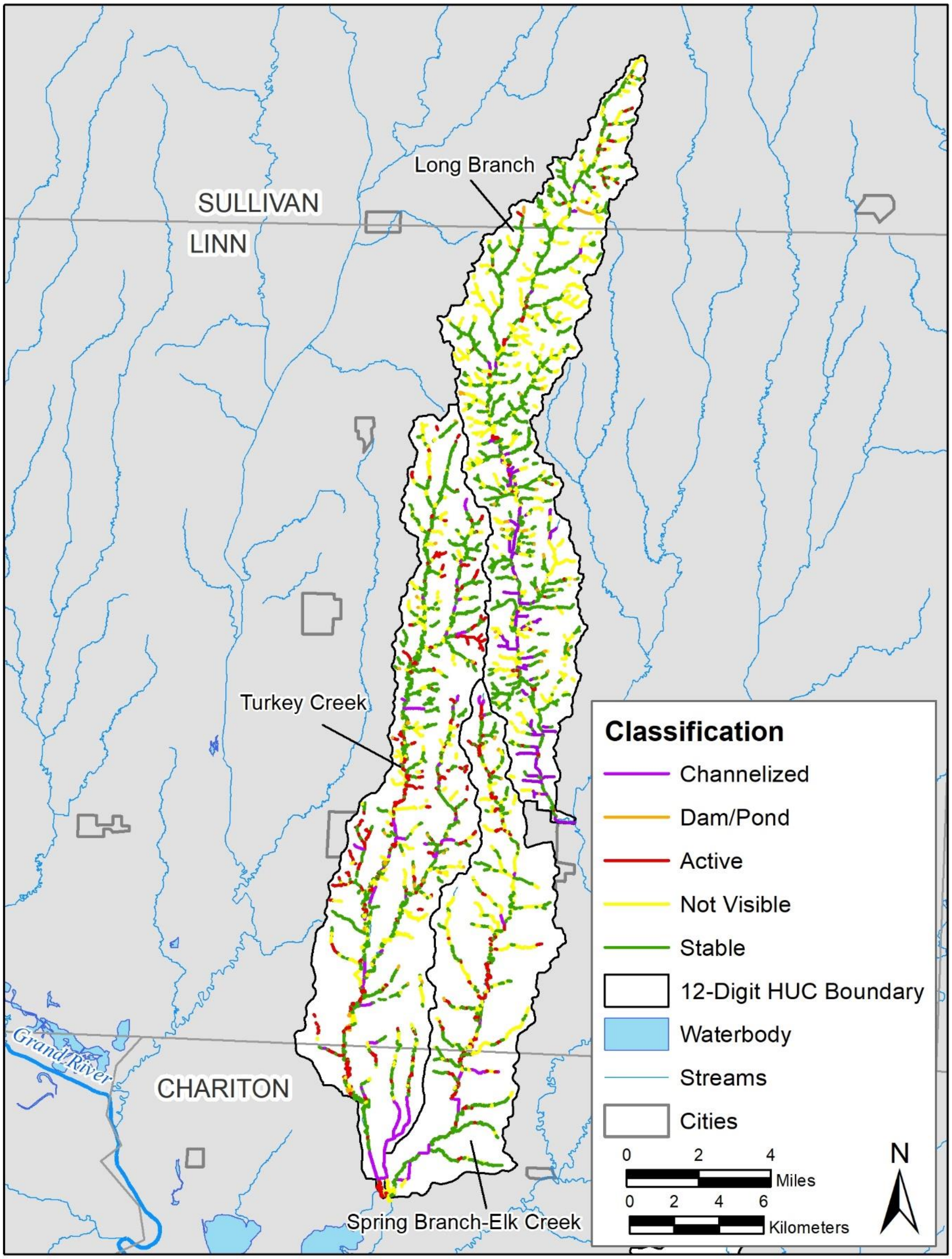


Figure 19. Channel stability classification

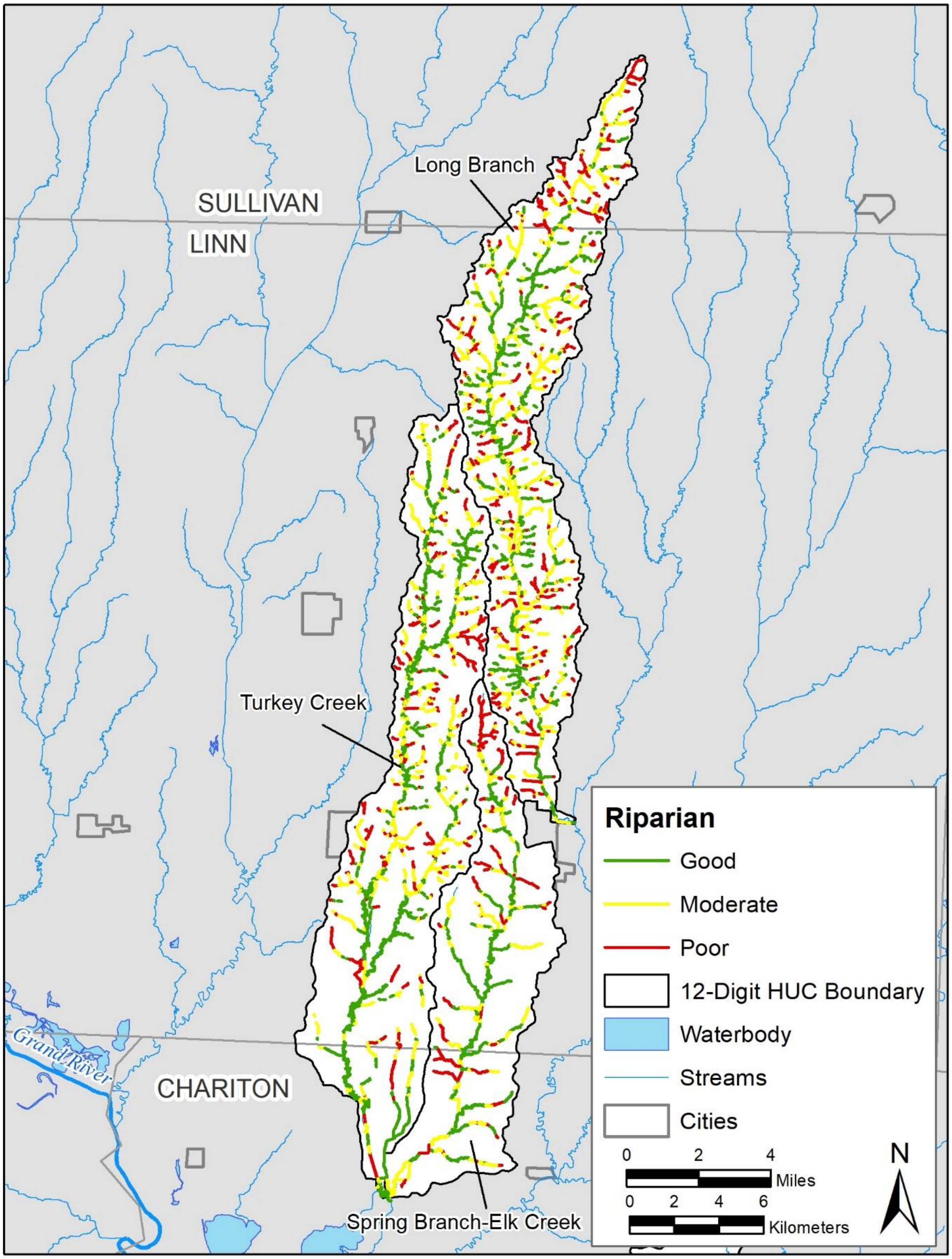


Figure 20. Riparian corridor classification

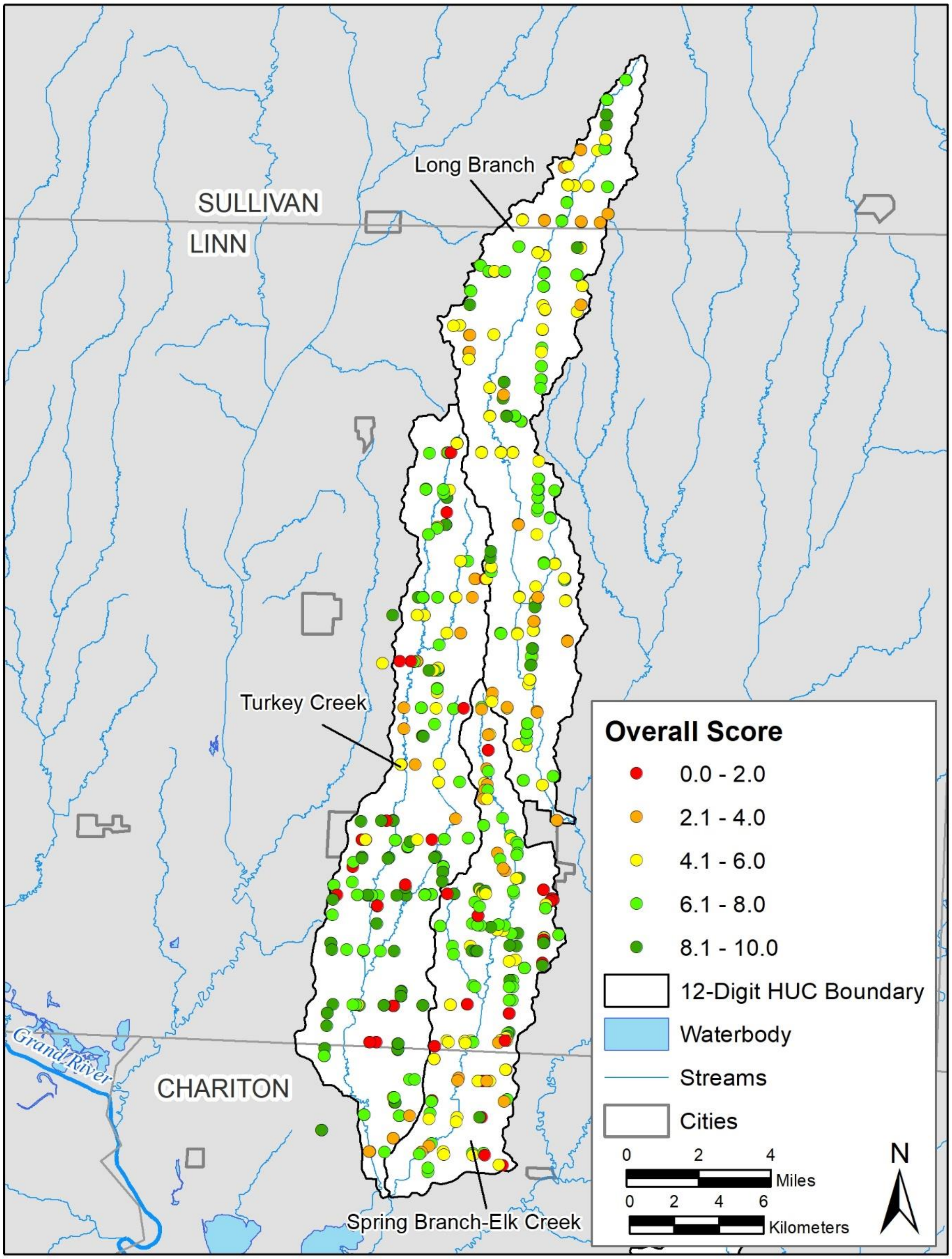


Figure 21. Visual stream assessment results

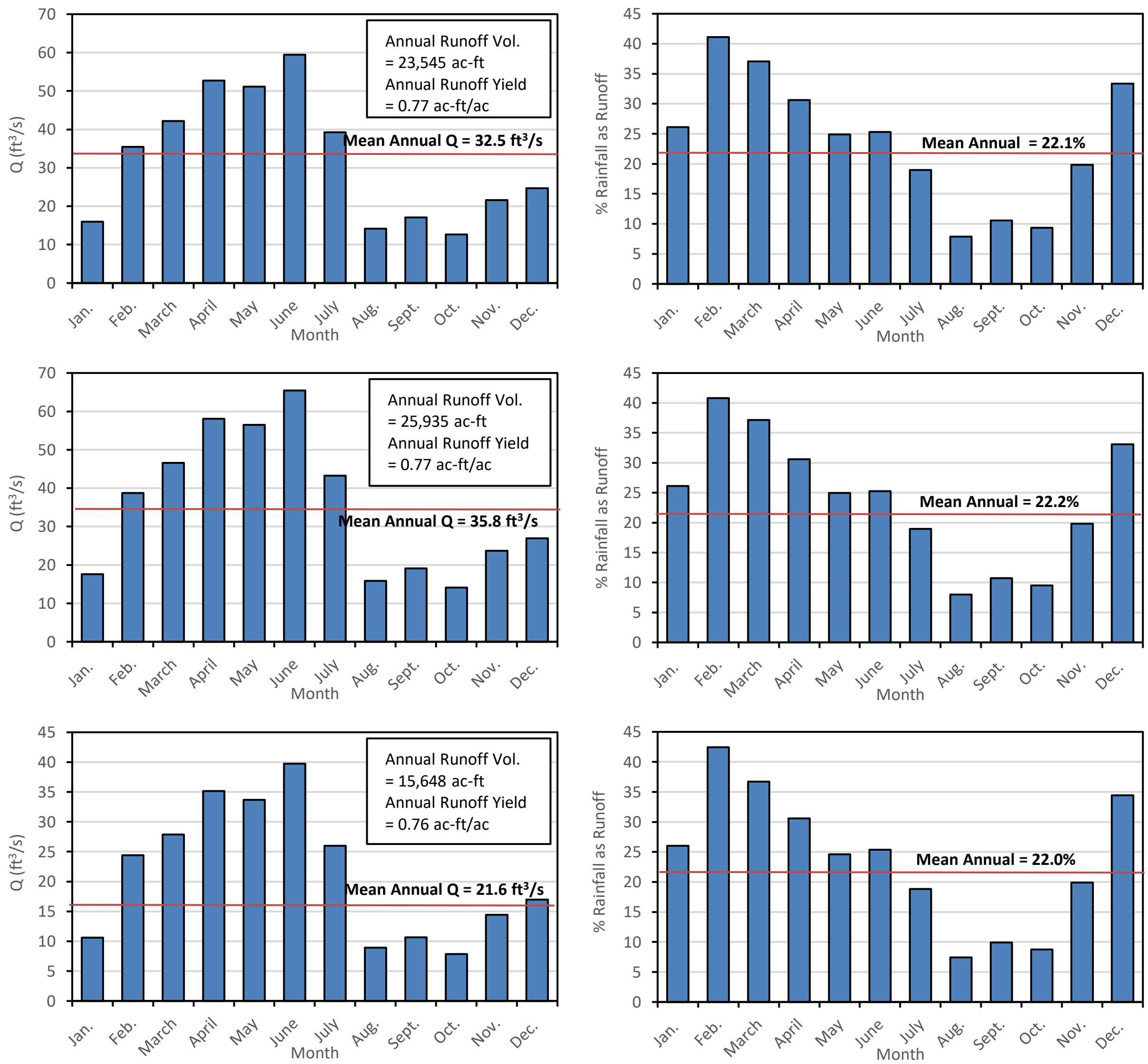


Figure 22. Mean monthly discharge and runoff percentage for the A), B) Long Branch the C), D) Turkey Creek, and E), F) Spring Branch-Elk Creek watersheds.

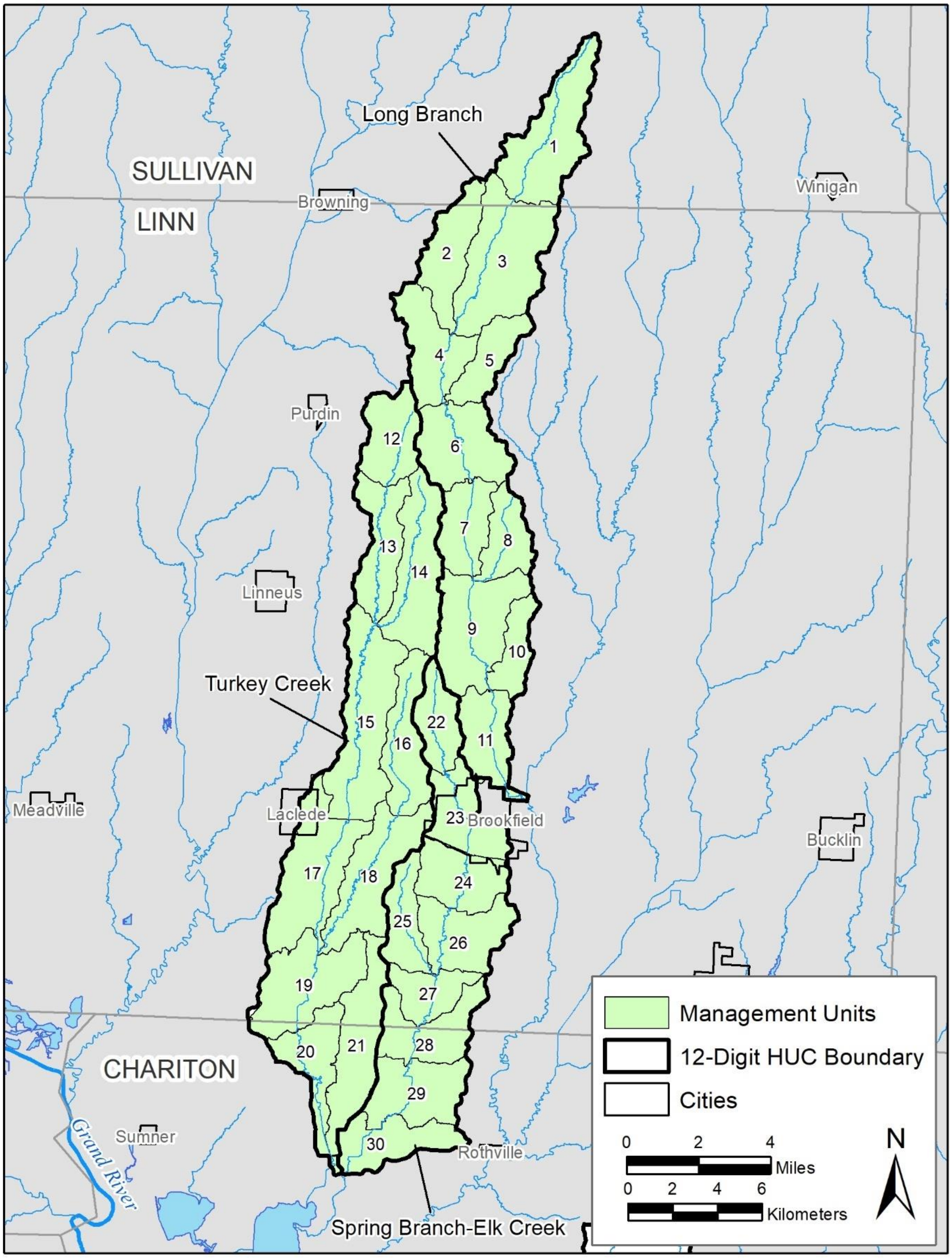


Figure 23. Management units within the three study watersheds in the Lower Grand River.

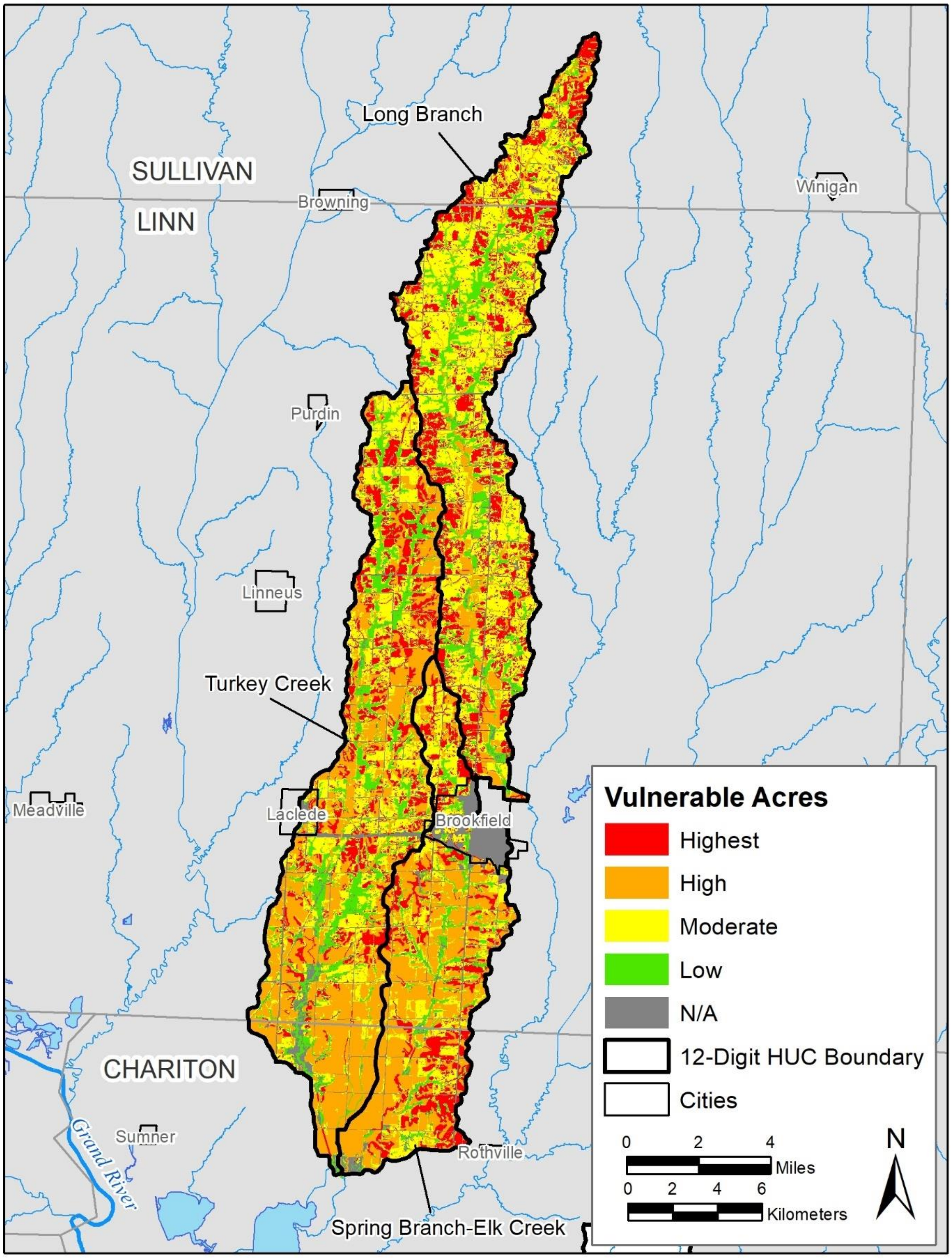


Figure 24. Distribution of vulnerable acres classification within the three study watersheds.

APPENDICES

Appendix A. Soil series data and information for within the watershed.

MU#	Acres	% Area	Series Name	Hydrologic Soil Group	Landform	K Factor	Soil Order	Land Capability Classification	Slope % Range
13505	178	0.2%	Blackoar silt loam	B/D	Floodplain	0.37	Mollisol	2w	1
13539	132	0.2%	Kennebec silt loam	B	Floodplain	0.37	Mollisol	3w	1
13625	240	0.3%	Kennebec silt loam	B	Floodplain	0.37	Mollisol	3w	2
30027	18,923	22.3%	Armstrong clay loam	D	Upland	0.37	Alfisol	3e	7
30028	512	0.6%	Armstrong clay loam	C/D	Upland	0.32	Alfisol	4e	7
30030	394	0.5%	Armstrong clay loam	D	Upland	0.37	Alfisol	4e	12
30031	138	0.2%	Armstrong clay loam	C/D	Upland	0.32	Alfisol	6e	12
30033	540	0.6%	Armstrong loam	D	Upland	0.37	Alfisol	2e	4
30034	7,325	8.6%	Armstrong loam	D	Upland	0.37	Alfisol	3e	4
30052	57	0.1%	Gara clay loam	C	Upland	0.32	Alfisol	6e	17
30054	1,817	2.1%	Gara clay loam	C/D	Upland	0.2	Alfisol	4e	12
30055	66	0.1%	Gara clay loam	C	Upland	0.32	Alfisol	4e	12
30066	3	0.0%	Gorin silt loam	C	Upland	0.43	Alfisol	2e	4
30085	4,951	5.8%	Grundy silt loam	C/D	Upland	0.37	Mollisol	2e	4
30095	241	0.3%	Keswick clay loam	D	Upland	0.28	Alfisol	4e	7
30100	0	0.0%	Keswick loam	D	Upland	0.32	Alfisol	3e	7
30106	3,026	3.6%	Kilwinning silt loam	C/D	Upland	0.37	Alfisol	3e	4
30116	14,289	16.8%	Lagonda silt loam	C/D	Upland	0.37	Alfisol	3e	4
30120	1,374	1.6%	Lagonda silty clay loam	C/D	Upland	0.43	Alfisol	3e	7
30175	424	0.5%	Pershing silty clay loam	D	Upland	0.32	Alfisol	3e	4
30222	267	0.3%	Winnegan clay loam	D	Upland	0.28	Alfisol	6e	17
30224	188	0.2%	Winnegan clay loam	D	Upland	0.28	Alfisol	4e	12
30246	57	0.1%	Olmitz loam	C	Upland	0.17	Mollisol	2e	4
34005	717	0.8%	Gifford silt loam	D	Terrace	0.37	Alfisol	2e	4
34008	49	0.1%	Gifford silt loam	D	Terrace	0.37	Alfisol	3e	7
34020	473	0.6%	Colo silty clay loam	C/D	Terrace	0.28	Mollisol	2w	4
34021	5	0.0%	Gifford silt loam	D	Terrace	0.37	Alfisol	3w	4
36004	2,399	2.8%	Blackoar silt loam	B/D	Floodplain	0.37	Mollisol	3w	1
36010	305	0.4%	Colo silty clay loam	C/D	Floodplain	0.28	Mollisol	3w	1
36014	1,242	1.5%	Fatima silt loam	C	Floodplain	0.32	Mollisol	3w	1
36016	455	0.5%	Humeston silt loam	C/D	Floodplain	0.37	Mollisol	3w	1
36025	108	0.1%	Landes loam	B	Floodplain	0.24	Mollisol	3w	1
36034	165	0.2%	Portage silty clay	D	Floodplain	0.2	Mollisol	3w	1
36037	75	0.1%	Tice silt loam	B/D	Floodplain	0.37	Mollisol	3w	1
36040	395	0.5%	Tuskeego silty clay loam	D	Floodplain	0.28	Alfisol	3w	1
36042	3,464	4.1%	Vesser silt loam	C/D	Floodplain	0.32	Mollisol	2w	1
36063	25	0.0%	Zook silty clay loam	C/D	Floodplain	0.28	Mollisol	2w	3

MU#	Acres	% Area	Series Name	Hydrologic Soil Group	Landform	K Factor	Soil Order	Land Capability Classification	Slope % Range
36072	1,065	1.3%	Blackoar silt loam	B/D	Floodplain	0.37	Mollisol	3w	2
36080	11	0.0%	Fatima silt loam	C	Floodplain	0.32	Mollisol	3w	2
36082	122	0.1%	Humeston silt loam	C/D	Floodplain	0.37	Mollisol	3w	2
36091	635	0.7%	Vesser silt loam	C/D	Floodplain	0.32	Mollisol	3w	2
36102	210	0.2%	Zook silty clay loam	C/D	Floodplain	0.28	Mollisol	3w	3
36116	190	0.2%	Zook silty clay loam	D	Floodplain	0.32	Mollisol	2w	1
50001	1,450	1.7%	Armstrong loam	C/D	Upland	0.43	Alfisol	3e	7
50011	37	0.0%	Winnegan loam	D	Upland	0.24	Alfisol	6e	29
54000	971	1.1%	Chariton silt loam	C/D	Terrace	0.43	Alfisol	3w	1
60022	5,013	5.9%	Leonard silt loam	C/D	Upland	0.37	Alfisol	3e	3
60078	546	0.6%	Crestmeade silt loam	C/D	Upland	0.37	Mollisol	2w	1
60206	850	1.0%	Purdin clay loam	D	Upland	0.2	Alfisol	4e	17
60207	33	0.0%	Purdin clay loam	D	Upland	0.2	Alfisol	4e	17
60208	484	0.6%	Purdin clay loam	D	Upland	0.2	Alfisol	4e	12
60209	4,952	5.8%	Purdin loam	D	Upland	0.24	Alfisol	4e	12
64031	308	0.4%	Triplett silt loam	C/D	Terrace	0.37	Mollisol	3w	1
66004	172	0.2%	Dockery silt loam	B/D	Floodplain	0.49	Entisol	3w	1
66068	111	0.1%	Carlow silty clay	D	Floodplain	0.24	Mollisol	3w	1
66074	297	0.3%	Chequest silty clay loam	C	Floodplain	0.2	Mollisol	3w	1
66106	2,002	2.4%	Speed silt loam	B/D	Floodplain	0.43	Mollisol	2w	1
66139	314	0.4%	Speed silt loam	B/D	Floodplain	0.43	Mollisol	3w	2
99001	71	0.1%	Water	NA	NA	NA	NA	NA	NA
99003	8	0.0%	Miscellaneous water	NA	NA	NA	NA	NA	NA
99021	27	0.0%	Udorthents	NA	NA	0.37	Entisol	4e	2

Appendix B. USGS gaging stations near the watershed.

USGS Gage ID	Station Name	Stream	Start Year	Years of Record	Ad (mi²)	Elevation (ft)	90%	50%	10%	Max	Mean
06902995	Hickory Branch near Mendon, MO	Hickory Branch	2010	8	13.8	668.00	0.01	0.12	6.16	1,160	8.06
06906150	Long Branch Creek near Atlanta, MO	Long Branch Creek	1995	23	23.0	814.75	0.01	1.27	24.0	2,500	20.1
06901205	East Locust Creek near Boynton, MO	East Locust Creek	2013	5	33.8	852.00	0.02	1.93	33.4	2,220	21.9
06901250	Little East Locust Creek near Browning, MO	Little East Locust Creek	2010	8	40.1	763.00	0.03	2.87	26.0	2,340	16.6
06900640	Muddy Creek near Chula, MO	Muddy Creek	2010	8	72.2	690.00	0.12	2.24	55.8	3,640	44.7
06909500	Moniteau Creek near Fayette, MO	Moniteau Creek	1948	70	75.1	607.93	0.00	4.0	83.0	5,430	50.6
06906200	East Fork Little Chariton River near Macon, MO	East Fork Little Chariton River	1971	47	112	741.50	4.90	41.0	266.0	5,460	92.8
06899900	Medicine Creek at Lucerne, MO	Medicine Creek	2010	8	118	870.00	0.37	6.23	95.6	9,100	70.8
06895000	Crooked River near Richmond, MO	Crooked River	1948	70	159	706.34	0.53	17.0	198.0	17,900	117.7
06903700	South Fork Chariton River near Promise City, IA	South Fork Chariton River	1967	51	168	913.70	0.83	13.2	196.0	34,700	132.6
06896000	Wakenda Creek at Carrollton, MO	Wakenda Creek	1948	70	256	641.17	1.80	18.0	275.6	7,990	178.7
06906000	Mussel Fork near Musselfork, MO	Mussel Fork	1948	70	267	639.25	2.20	29.0	473.0	18,300	227.6
06900050	Medicine Creek near Laredo, MO	Medicine Creek	2000	18	355	739.00	5.61	42.2	420.0	19,400	275.4
05502300	North Fork Salt River at Hagers Grove, MO	North Fork Salt River	1974	44	365	702.26	4.40	33.0	503.0	30,200	294.4
06899700	Shoal Creek near Braymer, MO	Shoal Creek	1957	61	391	700.00	2.01	40.0	500.0	22,000	267.9
06901500	Locust Creek near Linneus, MO	Locust Creek	1929	89	550	692.60	4.79	48.0	623.5	27,300	343.7
06904010	Chariton River near Moulton, IA	Chariton River	1979	39	740	800.00	27.0	178.0	1,530	18,600	578.8
06904050	Chariton River at Livonia, MO	Chariton River	1974	43	864	770.00	32.0	310.0	1,650	13,200	691.1
06908000	Blackwater River at Blue Lick, MO	Blackwater River	1922	96	1,120	593.79	5.50	96.0	2,530	48,400	835.1
06904500	Chariton River at Novinger, MO	Chariton River	1930	88	1,370	737.65	24.4	225.0	2,300	38,100	942.1
06899500	Thompson River at Trenton, MO	Thompson River	1928	90	1,720	710.29	30.0	225.0	2,420	73,800	1,061
06905500	Chariton River near Prairie Hill, MO	Chariton River	1929	89	1,870	632.66	44.0	390.0	3,220	37,700	1,315
06897500	Grand River near Gallatin, MO	Grand River	1921	97	2,250	707.71	28.0	228.0	2,650	85,500	1,297
06902000	Grand River near Sumner, MO	Grand River	1924	94	6,880	631.20	138.0	1,000	10,500	166,000	4,285

Appendix C. Score sheet for visual stream survey

Channel Condition:

Natural; no structures, dikes. No evidence of down-cutting or excessive lateral cutting	Evidence of past channel alteration, but with significant recovery of channel and banks. Any dikes or levies are set back to provide access to an adequate flood plain.	Altered channel; <50% of the reach with riprap and/or channelization. Excess aggradation; braided channel. Dikes or levees restrict flood plain width.	Channel is actively downcutting or widening. >50% of the reach with riprap or channelization. Dikes or levees prevent access to the flood plain.
10	7	3	1

Hydrologic Alteration:

Flooding every 1.5 to 2 years. No Dams, No dikes or other structures limiting streams access to the flood plain. Channel is not incised.	Flooding occurs only once every 3 to 5 years; limited channel incision.	Flooding occurs only once every 6 to 10 years: channel deeply incised.	No flooding; channel deeply incised or structures prevent access to flood plain or dam operations prevent flood flows. Flooding occurs on a 1-year rain event or less.
10	7	3	1

Riparian Zone:

Natural Vegetation extends at least two active channel widths on each side.	Natural vegetation extends one active width both sides. Or If less than one width covers entire flood plain.	Natural vegetation extends half of the active channel width on each side.	Natural vegetation extends a third of the active channel width on each side. OR, filtering function moderately compromised.	Natural Vegetation less than 1/3 of active channel width on each side. OR, Lack of regeneration OR, Filtering severely function compromised.
10	8	5	3	1

Bank Stability:

Banks are stable; banks are low (at elevation of flood plain); 33% or more of eroding surface area of banks in outside bends id protected by roots that extend to the base-flow elevation.	Moderately stable; banks are low, less than 33% of eroding surface	Moderately unstable; banks may be low but typically high; outside bends are actively eroding (overhanging vegetation at top of bank, some mature trees falling into stream annually, some slope failures apparent.	Unstable; banks may be low, but typically are high; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent).
10	7	3	1

Canopy Cover:

> 75% of water surface shaded and upstream 2 to 3 miles generally well shaded.	>50% shaded in reach Or >75% in reach, but upstream 2 to 3 miles poorly shaded.	20 to 50% shaded.	< 20% of water surface in reach shaded.
10	7	3	1

Manure Presence:

	Evidence of livestock access to riparian zone	Occasional manure in stream or waste storage structure located on the flood plain	Extensive amount of manure on banks or in stream. or Untreated human waste discharge pipes present.
	5	3	1

Appendix D. Examples for VSA survey for Long Branch.

Site # 154: Downstream

Channel condition	10
Hydrologic alteration	5
Riparian zone	1
Bank stability	7
Canopy cover	1
Manure presence	

Overall Score
4.8

Site # 101: Upstream

Channel condition	3
Hydrologic alteration	3
Riparian zone	3
Bank stability	3
Canopy cover	5
Manure presence	

Overall Score
3.4

Site # 116: Downstream

Channel condition	5
Hydrologic alteration	10
Riparian zone	10
Bank stability	7
Canopy cover	3
Manure presence	

Overall Score
7.0

Site # 53: Downstream

Channel condition	10
Hydrologic alteration	9
Riparian zone	1
Bank stability	7
Canopy cover	1
Manure presence	1

Overall Score 4.8

Site # 57: Downstream

Channel condition	10
Hydrologic alteration	3
Riparian zone	1
Bank stability	1
Canopy cover	1
Manure presence	5

Overall Score 3.5

Site # 157: Upstream

Channel condition	1
Hydrologic alteration	1
Riparian zone	1
Bank stability	1
Canopy cover	1
Manure presence	1

Overall Score 1.0

Site # 101: Downstream

Channel condition	10
Hydrologic alteration	5
Riparian zone	1
Bank stability	3
Canopy cover	1
Manure presence	3

Overall Score
4.0

Site # 12: Upstream

Channel condition	10
Hydrologic alteration	5
Riparian zone	8
Bank stability	5
Canopy cover	10
Manure presence	5

Overall Score
7.0

Site # 12: Downstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	10
Bank stability	10
Canopy cover	3
Manure presence	0

Overall Score
8.6

Appendix E. Examples for VSA survey for Spring Branch-Elk Creek.

Site # 2: Downstream

Channel condition	1
Hydrologic alteration	5
Riparian zone	1
Bank stability	3
Canopy cover	1
Manure presence	

Overall Score
2.2

Site # 22: Downstream

Channel condition	3
Hydrologic alteration	1
Riparian zone	3
Bank stability	3
Canopy cover	3
Manure presence	1

Overall Score
2.3

Site # 25: Upstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	10
Bank stability	10
Canopy cover	10
Manure presence	

Overall Score
10

Site # 72: Upstream

Channel condition	3
Hydrologic alteration	10
Riparian zone	3
Bank stability	7
Canopy cover	10
Manure presence	

Overall Score
6.6

Site # 15: Downstream

Channel condition	
Hydrologic alteration	
Riparian zone	
Bank stability	
Canopy cover	
Manure presence	

Grass Waterway

Site # 5 Upstream

Channel condition	5
Hydrologic alteration	7
Riparian zone	7
Bank stability	7
Canopy cover	7
Manure presence	

Overall Score
6.6

Site # 81: Downstream

Channel condition	10
Hydrologic alteration	3
Riparian zone	1
Bank stability	3
Canopy cover	1
Manure presence	1

Overall Score 3.2

Site # 36: Upstream

Channel condition	
Hydrologic alteration	
Riparian zone	
Bank stability	
Canopy cover	
Manure presence	

Urban Stream

Site # 29: Downstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	1
Bank stability	10
Canopy cover	1
Manure presence	

Overall Score 6.4

Appendix F. Examples from VSA survey for Turkey Creek.

Site # 6: Downstream

Channel condition	10
Hydrologic alteration	7
Riparian zone	10
Bank stability	7
Canopy cover	7
Manure presence	

Overall Score
8.2

Site # 6: Upstream

Channel condition	2
Hydrologic alteration	3
Riparian zone	3
Bank stability	3
Canopy cover	2
Manure presence	

Overall Score
2.6

Site # 59: Downstream

Channel condition	8
Hydrologic alteration	5
Riparian zone	3
Bank stability	2
Canopy cover	5
Manure presence	5

Overall Score
4.7

Site # 59: Upstream

Channel condition	8
Hydrologic alteration	6
Riparian zone	3
Bank stability	5
Canopy cover	7
Manure presence	5

Overall Score
5.7

Site #99: Downstream

Channel condition	7
Hydrologic alteration	10
Riparian zone	10
Bank stability	10
Canopy cover	1
Manure presence	

Overall Score
7.6

Site # 99: Upstream

Channel condition	1
Hydrologic alteration	1
Riparian zone	1
Bank stability	5
Canopy cover	1
Manure presence	1

Overall Score
1.7

Site # 45: Downstream

Channel condition	10
Hydrologic alteration	7
Riparian zone	9
Bank stability	8
Canopy cover	9
Manure presence	

Overall Score
8.6

Site #45: Upstream

Channel condition	10
Hydrologic alteration	8
Riparian zone	9
Bank stability	9
Canopy cover	9
Manure presence	

Overall Score
8.6

Site # 19: Downstream

Channel condition	10
Hydrologic alteration	3
Riparian zone	10
Bank stability	2
Canopy cover	10
Manure presence	

Overall Score
7.0

Site # 19: Upstream

Channel condition	10
Hydrologic alteration	3
Riparian zone	10
Bank stability	3
Canopy cover	10
Manure presence	

Overall Score
7.2

Site #1: Downstream

Channel condition	10
Hydrologic alteration	4
Riparian zone	8
Bank stability	5
Canopy cover	7
Manure presence	

Overall Score
6.8

Site # 1: Upstream

Channel condition	1
Hydrologic alteration	2
Riparian zone	8
Bank stability	6
Canopy cover	3
Manure presence	

Overall Score
4.0

Appendix G. Monthly mean discharge equations developed from regional USGS gaging stations.

Month	R^2	b_0	b_1	Long Branch Ad = 48.0 mi^2 Q (ft^3/s)	Turkey Creek Ad = 52.8 mi^2 Q (ft^3/s)	Spring Branch-Elk Creek Ad = 32.0 mi^2 Q (ft^3/s)
Jan.	0.97	0.3213	1.0090	16.0	17.6	10.6
Feb.	0.99	0.9939	0.9234	35.4	38.7	24.4
March	0.98	0.8014	1.0240	42.2	46.6	27.9
April	0.94	1.0964	1.0005	52.7	58.0	35.1
May	0.96	0.9458	1.0309	51.1	56.5	33.7
June	0.98	1.2700	0.9936	59.4	65.4	39.7
July	0.97	0.7727	1.0147	39.2	43.3	26.0
Aug.	0.90	0.1733	1.1380	14.2	15.8	8.9
Sept.	0.88	0.1911	1.1609	17.1	19.1	10.7
Oct.	0.94	0.1387	1.1652	12.6	14.1	7.9
Nov.	0.98	0.4620	0.9930	21.6	23.7	14.4
Dec.	0.96	0.7027	0.9193	24.7	27.0	17.0

Appendix H. STEPL model inputs for the three Lower Grand watershed.

Watershed	Total		Land Use (ac)					# of Animals		Low Density	# Septic
	Ad (ac)	HSG	Urban	Cropland	Pastureland	Forest	Other	Beef Cattle	Swine (Hog)	Residential (ac)	Systems
Long Branch	30,668	D	1,320	9,137	15,475	4,428	308	6,190	61,824	232	73
Spring Branch-Elk Creek	20,455	C	2,204	10,464	6,092	1,634	61	2,437	114	1,099	264
Turkey Creek	33,770	D	1,583	17,588	9,060	4,436	1,103	3,624	125	513	134

Appendix I. Eroding streambank inputs into STEPL for Long Branch

Feature ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
1	70.0	2.0	873.6	12.5	0.69
2	58.7	2.1	748.4	12.8	0.71
3	108.9	8.2	2,395.4	22.0	1.22
4	149.1	3.2	3,760.7	25.2	1.40
5	54.1	4.6	448.6	8.3	0.46
6	91.6	2.5	1,591.5	17.4	0.97
7	219.5	3.5	6,699.1	30.5	1.70
8	147.3	6.6	1,966.9	13.4	0.74
9	76.3	3.1	269.6	3.5	0.20
10	327.4	6.1	9,681.7	29.6	1.64
11	86.4	4.1	1,153.8	13.4	0.74
12	108.6	2.8	2,210.2	20.3	1.13
13	43.1	2.6	230.2	5.3	0.30
14	194.7	11.9	1,725.0	8.9	0.49
15	101.8	6.9	2,316.7	22.7	1.26
16	149.4	3.4	2,277.9	15.3	0.85
17	113.5	3.8	2,204.7	19.4	1.08
18	34.1	9.5	130.7	3.8	0.21
19	72.0	10.7	766.5	10.6	0.59
20	62.8	9.6	657.4	10.5	0.58
21	99.9	2.1	1,985.6	19.9	1.10
22	99.5	1.2	1,207.4	12.1	0.67
23	77.6	1.7	658.8	8.5	0.47
24	48.1	6.2	477.0	9.9	0.55
25	318.2	5.0	8,312.7	26.1	1.45
26	35.7	3.6	141.9	4.0	0.22
27	141.1	4.5	1,655.4	11.7	0.65
28	66.6	3.1	407.7	6.1	0.34
29	114.4	2.0	1,666.2	14.6	0.81
30	28.9	3.0	97.5	3.4	0.19
31	90.3	1.2	1,255.4	13.9	0.77
32	104.1	2.1	1,803.2	17.3	0.96
33	240.7	9.4	8,438.6	35.1	1.95
34	117.6	0.8	2,043.0	17.4	0.97
35	134.4	1.7	1,355.7	10.1	0.56
36	34.3	1.3	203.4	5.9	0.33
37	49.2	2.1	555.9	11.3	0.63
38	69.4	3.0	572.5	8.3	0.46
39	80.1	1.2	1,242.1	15.5	0.86
40	155.1	0.6	4,152.7	26.8	1.49
41	104.3	4.2	2,000.0	19.2	1.07
42	60.1	6.0	499.4	8.3	0.46
43	75.1	5.4	480.4	6.4	0.36
44	117.3	1.5	783.0	6.7	0.37
45	58.2	3.1	334.6	5.7	0.32
46	65.8	2.5	313.4	4.8	0.26
47	59.7	2.5	591.8	9.9	0.55
48	248.1	1.0	3,909.9	15.8	0.88
49	43.8	7.9	204.7	4.7	0.26
50	43.6	2.1	68.4	1.6	0.09
51	130.7	2.6	481.3	3.7	0.20
52	379.5	2.0	1,348.3	3.6	0.20
53	36.5	2.4	172.7	4.7	0.26
54	97.9	2.1	565.5	5.8	0.32
55	36.9	1.5	163.4	4.4	0.25
56	66.2	5.0	1,001.7	15.1	0.84
57	37.9	4.6	222.9	5.9	0.33
58	108.8	3.6	2,186.9	20.1	1.12
59	430.8	1.6	24,011.3	55.7	3.10
60	50.5	0.3	624.7	12.4	0.69
61	57.5	0.2	579.7	10.1	0.56

Feature ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
62	181.1	0.5	3,478.3	19.2	1.07
63	83.6	4.5	509.0	6.1	0.34
64	46.1	4.2	352.4	7.6	0.42
65	48.5	2.5	349.0	7.2	0.40
66	23.3	2.9	80.8	3.5	0.19
67	67.2	3.0	552.2	8.2	0.46
68	63.3	2.3	347.5	5.5	0.30
69	156.3	0.2	1,736.6	11.1	0.62
70	204.6	14.4	3,130.9	15.3	0.85
71	109.6	8.9	1,096.4	10.0	0.56
72	396.1	11.8	4,669.4	11.8	0.65
73	211.4	12.3	5,732.1	27.1	1.51
74	184.7	12.8	3,283.0	17.8	0.99
75	186.7	8.7	2,275.5	12.2	0.68
76	218.2	12.3	3,684.6	16.9	0.94
77	166.6	11.8	1,076.9	6.5	0.36
78	69.3	7.2	607.5	8.8	0.49
79	91.6	13.1	814.3	8.9	0.49
80	81.0	13.8	864.1	10.7	0.59
81	225.4	13.4	3,707.5	16.4	0.91
82	239.1	11.5	3,123.7	13.1	0.73
83	700.4	17.1	10,580.2	15.1	0.84
84	118.3	11.2	1,391.5	11.8	0.65
85	105.0	11.8	555.8	5.3	0.29
86	270.9	12.1	3,494.0	12.9	0.72
87	195.2	13.9	1,599.9	8.2	0.46
88	150.3	12.6	2,788.5	18.6	1.03
89	131.0	12.5	923.2	7.0	0.39
90	96.6	12.3	561.1	5.8	0.32
91	129.6	11.5	2,571.4	19.8	1.10
92	266.3	12.1	3,055.7	11.5	0.64
93	133.9	11.8	1,301.8	9.7	0.54
94	95.8	12.0	966.6	10.1	0.56
95	123.4	11.3	960.2	7.8	0.43
96	63.4	9.8	446.5	7.0	0.39
97	112.4	11.8	2,207.1	19.6	1.09
98	167.9	14.0	2,278.2	13.6	0.75
99	126.3	11.6	1,842.8	14.6	0.81
100	109.2	14.9	1,024.8	9.4	0.52
101	139.4	11.4	1,323.2	9.5	0.53
102	133.1	9.4	918.4	6.9	0.38
103	202.6	13.4	2,498.7	12.3	0.69
104	219.4	12.7	3,405.2	15.5	0.86
105	105.9	12.3	830.9	7.8	0.44
106	178.8	16.1	1,414.1	7.9	0.44
107	112.8	12.5	1,219.6	10.8	0.60
108	140.6	16.3	2,219.1	15.8	0.88
109	197.1	15.7	2,673.5	13.6	0.75
110	423.5	11.5	7,020.6	16.6	0.92
111	107.1	19.7	637.9	6.0	0.33
112	51.6	9.8	223.8	4.3	0.24
113	133.6	10.5	1,436.5	10.8	0.60
114	208.0	15.4	1,649.0	7.9	0.44
115	215.7	11.0	1,135.0	5.3	0.29
116	137.3	10.9	746.8	5.4	0.30
117	214.1	10.2	2,660.7	12.4	0.69
118	90.0	10.8	805.2	8.9	0.50
119	311.5	10.8	1,661.6	5.3	0.30
120	206.8	9.5	2,070.5	10.0	0.56
121	149.2	9.8	2,075.8	13.9	0.77
122	93.4	8.1	1,619.4	17.3	0.96
123	79.0	9.4	563.5	7.1	0.40
124	84.9	6.6	420.4	5.0	0.28

Feature ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
125	304.4	11.5	6,135.8	20.2	1.12
126	86.6	2.6	615.1	7.1	0.39
127	126.9	9.6	938.0	7.4	0.41
128	147.7	12.8	2,390.1	16.2	0.90
129	93.6	8.9	562.3	6.0	0.33
130	151.5	7.5	1,055.0	7.0	0.39
131	83.1	6.6	880.9	10.6	0.59
132	131.7	13.4	1,614.6	12.3	0.68
133	305.8	10.5	4,161.8	13.6	0.76
134	82.0	18.3	403.4	4.9	0.27
135	85.3	9.8	625.7	7.3	0.41
136	59.1	11.2	292.6	5.0	0.28
137	98.4	16.8	894.7	9.1	0.51
138	88.6	17.4	1277.3	14.4	0.80
139	108.3	11.2	712.8	6.6	0.37
140	45.9	11.2	145.8	3.2	0.18
141	101.7	15.2	455.9	4.5	0.25
142	183.7	15.5	1020.3	5.6	0.31
143	285.4	11.8	1136.7	4.0	0.22
144	98.4	10.5	793.1	8.1	0.45
145	164.0	15.9	656.5	4.0	0.22
146	39.4	15.1	276.6	7.0	0.39
147	59.1	18.0	723.9	12.3	0.68
148	301.8	13.4	3340.0	11.1	0.61
149	85.3	14.8	753.2	8.8	0.49
150	128.0	14.7	805.8	6.3	0.35
151	39.4	15.2	161.3	4.1	0.23
152	98.4	15.3	397.8	4.0	0.22
153	82.0	14.4	504.0	6.1	0.34
154	160.8	10.8	1730.3	10.8	0.60
155	55.8	14.2	218.2	3.9	0.22
156	65.6	13.7	597.7	9.1	0.51
157	190.3	14.0	1629.2	8.6	0.48
158	167.3	13.6	926.0	5.5	0.31
159	78.7	11.2	584.9	7.4	0.41
160	278.9	11.3	2031.6	7.3	0.40
161	49.2	11.5	672.9	13.7	0.76
162	88.6	7.7	596.2	6.7	0.37
163	128.0	10.3	1053.4	8.2	0.46
164	315.0	8.8	2040.9	6.5	0.36
165	154.2	10.8	842.5	5.5	0.30
166	85.3	11.2	603.8	7.1	0.39
Average	**134.0**	**8.6**	**1,743**	**11.0**	**0.61**

Appendix J. Eroding streambank inputs into STEPL for Spring Branch-Elk Creek

Reach ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
1	543	8.2	3,958	8.0	0.44
2	1,246	5.0	12,094	11.0	0.61
3	1,216	5.7	15,190	20.9	1.16
4	777	1.3	12,541	19.2	1.07
5	2,189	9.0	19,217	11.2	0.62
6	233	4.6	1,793	8.1	0.45
7	467	3.3	3,052	7.8	0.43
8	190	5.7	2,584	16.6	0.92
9	1,539	10.5	13,059	10.7	0.59
10	667	4.3	4,670	7.6	0.42
11	634	5.8	11,011	22.4	1.24
12	435	3.9	4,013	13.0	0.72
13	416	7.5	2,461	6.2	0.35
14	715	8.2	5,666	9.5	0.53
15	3,085	9.8	35,314	13.3	0.74
16	651	2.6	13,235	22.0	1.22
17	985	7.6	9,406	14.8	0.82
18	126	4.3	1,769	14.1	0.78
19	308	7.3	10,370	42.0	2.33
20	536	4.3	9,930	34.7	1.93
21	238	9.4	3,389	16.6	0.92
22	643	6.2	10,919	28.8	1.60
23	532	7.2	6,041	22.8	1.27
24	578	4.9	3,555	7.6	0.42
25	144	3.9	755	5.2	0.29
26	886	3.2	5,561	8.0	0.44
27	172	3.2	913	5.4	0.30
28	143	6.2	2,468	17.3	0.96
29	167	4.4	1,047	6.9	0.38
30	80	0.8	1,022	12.8	0.71
31	453	4.4	2,579	7.3	0.40
32	125	4.3	4,726	38.0	2.11
33	161	6.6	2,655	16.5	0.91
34	415	8.4	5,682	13.7	0.76
35	60	2.3	492	8.3	0.46
36	90	6.9	2,263	25.2	1.40
Average	**607**	**5.6**	**6,817**	**15.4**	**0.85**

Appendix K. Eroding streambank inputs into STEPL for Turkey Creek

Feature ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
1	141.2	3.3	491	3.5	0.19
2	62.3	9.0	288	4.6	0.26
3	91.4	9.0	620	6.8	0.38
4	91.6	9.2	322	3.5	0.20
5	265.5	9.2	4,149	15.6	0.87
6	113.9	9.0	1,677	14.7	0.82
7	38.8	10.5	113	2.9	0.16
8	96.3	10.5	690	7.2	0.40
9	280.4	10.7	3,945	14.1	0.78
10	93.0	10.7	732	7.9	0.44
11	7.8	10.5	4	0.6	0.03
12	263.1	10.5	3,073	11.7	0.65
13	106.6	9.0	759	7.1	0.40
14	160.2	12.3	1,580	9.9	0.55
15	108.3	11.5	538	5.0	0.28
16	104.2	10.2	528	5.1	0.28
17	186.9	9.8	1,990	10.6	0.59
18	25.2	8.2	52	2.1	0.12
19	121.0	9.8	1,423	11.8	0.65
20	84.7	9.0	320	3.8	0.21
21	34.8	9.0	321	9.2	0.51
22	67.9	8.5	510	7.5	0.42
23	358.1	9.0	3,629	10.1	0.56
24	10.1	10.5	20	2.0	0.11
25	324.2	8.5	2,673	8.2	0.46
26	24.3	9.0	50	2.1	0.11
27	19.1	8.5	19	1.0	0.06
28	48.7	8.5	326	6.7	0.37
29	86.7	10.5	736	8.5	0.47
30	218.8	8.5	1,445	6.6	0.37
31	13.4	10.5	22	1.6	0.09
32	480.7	9.8	4,391	9.1	0.51
33	319.6	9.7	2,827	8.8	0.49
34	31.7	11.5	120	3.8	0.21
35	464.1	9.6	3,986	8.6	0.48
36	32.8	11.5	143	4.3	0.24
37	233.5	10.3	1,960	8.4	0.47
38	118.4	10.2	646	5.5	0.30
39	52.1	8.2	271	5.2	0.29
40	218.4	6.6	1,655	7.6	0.42
41	98.7	9.0	951	9.6	0.54
42	127.9	9.8	832	6.5	0.36
43	149.4	9.8	2,375	15.9	0.88
44	277.4	7.6	1,361	4.9	0.27
45	36.3	7.4	168	4.6	0.26
46	22.6	6.9	99	4.4	0.24
47	388.7	7.7	3,325	8.6	0.48
48	28.4	6.9	23	0.8	0.04
49	58.4	6.9	243	4.2	0.23
50	33.1	5.6	173	5.2	0.29
51	116.6	5.9	966	8.3	0.46
52	20.0	4.1	112	5.6	0.31
53	1.8	5.9	151	86.3	4.79

Feature ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
54	44.2	2.3	209	4.7	0.26
55	50.5	1.5	475	9.4	0.52
56	37.8	2.5	174	4.6	0.26
57	76.8	3.6	342	4.5	0.25
58	67.8	2.6	947	14.0	0.78
59	68.8	4.6	824	12.0	0.67
60	32.6	2.6	231	7.1	0.39
61	250.5	6.1	2,015	8.0	0.45
62	126.8	6.2	1,465	11.6	0.64
63	46.5	5.9	398	8.6	0.48
64	101.4	2.6	884	8.7	0.48
65	55.9	3.3	275	4.9	0.27
66	118.2	3.6	1,829	15.5	0.86
67	180.5	2.0	1,487	8.2	0.46
68	198.3	3.3	1,546	7.8	0.43
69	145.2	1.0	666	4.6	0.25
70	53.3	3.0	87	1.6	0.09
71	138.5	3.6	1,156	8.3	0.46
72	46.9	3.3	121	2.6	0.14
73	112.8	3.0	782	6.9	0.39
74	42.7	4.3	336	7.9	0.44
75	115.9	1.5	867	7.5	0.42
76	80.7	3.9	594	7.4	0.41
77	47.9	3.3	406	8.5	0.47
78	261.1	1.3	2,705	10.4	0.58
79	189.6	4.6	1,676	8.8	0.49
80	33.4	1.1	105	3.1	0.17
81	140.5	3.6	1,746	12.4	0.69
82	83.6	1.3	200	2.4	0.13
83	61.4	5.7	420	6.9	0.38
84	32.2	6.6	279	8.7	0.48
85	41.2	7.4	128	3.1	0.17
86	25.2	3.0	116	4.6	0.26
87	126.7	4.3	2,667	21.1	1.17
88	40.3	1.3	308	7.6	0.42
89	56.2	4.9	247	4.4	0.24
90	68.2	5.2	635	9.3	0.52
91	92.9	1.3	599	6.4	0.36
92	87.5	1.0	636	7.3	0.40
93	115.7	1.2	560	4.8	0.27
94	117.7	0.3	507	4.3	0.24
95	44.1	10.2	356	8.1	0.45
96	87.5	11.8	906	10.4	0.58
97	86.8	12.1	413	4.8	0.26
98	36.9	8.5	81	2.2	0.12
99	27.4	2.6	145	5.3	0.30
100	151.3	8.2	813	5.4	0.30
101	44.9	9.8	258	5.7	0.32
102	62.7	9.8	106	1.7	0.09
103	31.5	3.6	265	8.4	0.47
104	33.5	3.6	135	4.0	0.22
105	40.3	2.1	183	4.5	0.25
106	62.4	2.6	200	3.2	0.18
107	39.5	5.2	367	9.3	0.52
108	57.1	6.9	618	10.8	0.60

Feature ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
109	91.0	6.7	284	3.1	0.17
110	45.1	5.7	462	10.3	0.57
111	172.0	4.1	1,992	11.6	0.64
112	28.1	3.3	89	3.2	0.18
113	47.8	3.0	455	9.5	0.53
114	115.8	5.7	1,678	14.5	0.80
115	36.7	4.9	139	3.8	0.21
116	51.4	4.6	102	2.0	0.11
117	39.9	5.2	340	8.5	0.47
118	321.5	9.8	1,767	5.5	0.31
119	48.7	0.5	150	3.1	0.17
120	89.9	0.3	509	5.7	0.31
121	40.9	3.9	83	2.0	0.11
122	43.1	3.6	112	2.6	0.14
123	41.5	4.6	91	2.2	0.12
124	32.0	5.2	162	5.1	0.28
125	64.1	4.6	411	6.4	0.36
126	138.9	5.9	1,006	7.2	0.40
127	172.8	9.8	2,154	12.5	0.69
128	35.2	9.8	176	5.0	0.28
129	114.3	9.0	2,894	25.3	1.41
130	212.1	6.9	3,332	15.7	0.87
131	371.4	1.6	6,827	18.4	1.02
132	32.4	1.0	83	2.6	0.14
133	45.8	5.2	390	8.5	0.47
134	120.6	4.9	2,136	17.7	0.98
135	129.9	4.6	1,767	13.6	0.76
136	93.3	5.2	958	10.3	0.57
137	30.8	1.3	128	4.1	0.23
138	336.6	3.0	3,764	11.2	0.62
139	35.4	5.2	161	4.5	0.25
140	71.1	5.2	816	11.5	0.64
141	49.3	6.6	366	7.4	0.41
142	30.9	4.9	190	6.2	0.34
143	53.1	5.7	672	12.7	0.70
144	65.9	6.6	812	12.3	0.69
145	32.7	5.7	108	3.3	0.18
146	30.9	4.1	110	3.6	0.20
147	279.5	6.6	5,781	20.7	1.15
148	83.9	4.3	692	8.3	0.46
149	50.3	4.9	387	7.7	0.43
150	84.2	3.3	749	8.9	0.49
151	309.3	4.1	8,342	27.0	1.50
152	54.5	3.9	356	6.5	0.36
153	120.2	3.9	1,849	15.4	0.85
154	132.8	3.0	2,045	15.4	0.86
155	61.2	3.3	1,212	19.8	1.10
156	33.6	2.5	106	3.1	0.17
157	95.8	3.3	1,269	13.2	0.74
158	34.7	2.3	235	6.8	0.38
159	87.4	4.9	1,494	17.1	0.95
Average	**90.8**	**4.5**	**949**	**8.3**	**0.46**

Appendix L. Combined conservation practice efficiencies for selected practices

List of Practices	Combined BMP Efficiencies		
Cropland	Nitrogen	Phosphorus	Sediment
Cover Crop	0.196	0.070	0.100
Terrace	0.253	0.308	0.400
Cover Crop and Terrace	0.399	0.356	0.460
Cover Crop and No-Till	0.397	0.709	0.793
Cover Crop, No-Till, and Nutrient Management	0.546	0.872	0.793
Water and Sediment Control Basin	0.550	0.685	0.860
No-Till and Terrace	0.440	0.783	0.862
Cover Crop, No-Till, and Terrace	0.550	0.799	0.876
Cover Crop, No-Till, Terrace, and Nutrient Management	0.661	0.911	0.876
Land Retirement	0.898	0.808	0.950
Pasture Land			
Livestock Exclusion and Alternative Water	0.309	0.384	0.187
Grade Stabilization Structure	0.750	0.750	0.750
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.591	0.524	0.794
Grade Stabilization Structure and Prescribed Grazing	0.852	0.807	0.833
Water and Sediment Control Basin	0.550	0.685	0.860
Livestock Exclusion, Alternative Water, Prescribed Grazing, and Forest Buffer	0.776	0.714	0.904
Grade Stabilization Structure and Water and Sediment Control Basin	0.887	0.921	0.965
Grade Stabilization Structure, Water and Sediment Control Basin, and Prescribed Grazing	0.933	0.939	0.977