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

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

Upper Apple Creek Watershed (HUC12# 071401050401)
Middle Apple Creek Watershed (HUC12# 071401050403)

FINAL

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

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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 River 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 on two 12-digit hydrologic unit code (HUC) watersheds, the Upper Apple Creek (071401050401) and Middle Apple Creek (071401050403) watersheds located within the larger Upper Mississippi-Cape Girardeau watershed in southeast Missouri. Since the potential for ground water contamination is high due to the areas karst topography, agricultural nonpoint source pollution has been identified as a major concern in the Upper Mississippi-Cape Girardeau watershed (MDNR 2014). Furthermore, a Healthy Watershed Plan developed in 2017 specifically recommends reduction of stream bank erosion and implementation of agricultural best management practices within the Upper Mississippi-Cape Girardeau watershed (MDNR 2017).

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

The Upper Apple Creek and Middle Apple Creek watershed are located within the larger Upper Mississippi-Cape Girardeau watershed (HUC-8# 07140105) that includes portions of southeast Missouri and southwest Illinois (Figure 1). The Upper Apple Creek (34,291 acres) and Middle Apple Creek (47,043 acres) watersheds are two of five watersheds that make up the Apple Creek-Mississippi River Basin (HUC-10# 0714010504). The headwaters of Apple Creek flow from southwest Perry County and northeast Bollinger County into Perry and Cape Girardeau Counties and then east to the confluence of the Mississippi River (Figure 2). The main stem of Apple Creek is the border between Perry and Cape Girardeau counties.

Climate

Missouri's climate is characterized by a large range of temperatures with hot, humid summers and cold winters due to its location in the middle of the continent (Frankson et al. 2017). Over a 30 year period from 1988-2017, the average annual rainfall for Perryville, Missouri ranged from 25.4-60.7 inches with an average of 43.4 inches per year (Table 1). The highest monthly rainfall totals (>5 inches) occur in the late spring months of April and May, with generally less precipitation (<3 inches) during the winter months of December through February (Figure 3). Between 1988-2017, the average annual temperature ranged from 52.2-57.7 °F with an average of 55.2 °F (Table 1). Over the same period, average monthly temperatures range from 31.6 °F in January to 77.3 °F in July (Figure 3). Over the last 30 years, there has been a slight but steady increase in precipitation while temperature trends show a minor decrease but have remained fairly consistent (Figure 4). Solar radiation and evaporation trends are similar to monthly temperature trends for this watershed. From 2000-2017, average daily solar radiation by month ranged from 6.31 MJ/m^2 in December up to 21.74 MJ/m^2 in June with an average of 14.28 Mj/m^2 (Figure 5). For the same period, monthly average daily estimated evaporation ranged from about 0.03 inches in December to 0.2 inches in June with an average of 0.11 inches over the entire year (Figure 5).

Geology, Topography, and Geomorphology

The Apple Creek watershed is located on the eastern edge of the Ozark Plateau Province of the Interior Highlands (USDA 2006). The area is characterized by broad, flat to gently rolling dissected plains underlain by Ordovician-age limestone and capped by glacial loess (Nigh and Schroader, 2002). Elevations within the watershed range from 359.0-885.7 feet with higher elevations in the western portion of the Upper Apple Creek watershed (Figure 6). Slope ranges from <2%->45% percent with a majority of the land having slope of between 4-10% (Figure 7). The highest slopes (>20%) are generally found along the hillslopes and valley margins of the Upper Apple Creek watershed. There is extensive karst development between the Mississippi River and Interstate 55 south of St. Louis with large areas of sinkholes that are connected to the regions springs and resurgences and are particularly vulnerable to ground water pollution (Vandike 1985). Dye tracing maps indicate that sinkholes and losing streams in the northern portions of the Upper and Middle Apple Creek watersheds are connected via karst conduits to springs and gaining sections of streams outside of the topographic drainage basin boundary (Figure 8). Streams in the upper portions of the watershed are relatively steep with gravel bed loads and become less steep moving downstream where the valleys are entrenched into the bluffs near the Mississippi River (Nigh and Schroader, 2002). Published regional curves have been developed for typical channel morphology analysis of streams in the Ozark Plateaus physiographic regions that can be used as a reference for channel geometry of streams in the Apple Creek for drainage areas <400 mi^2 (USDA 2018a) (Figure 9).

Landscape and Soils

The Upper and Middle Apple Creek watersheds are within the western portion of the Central Mississippi Valley Wooded Slopes Major Land Resource Area (MLRA) (USDA 2006). This MLRA includes the dissected hills and floodplains of the Mississippi River and the lower sloped karst plains further west. Loess is the dominant parent material for soils in these watersheds that is thickest near the Mississippi River and thinner moving upstream (Festervand 1986). The majority of soils in the Upper and Middle Apple Creek watershed are alfisols which cover over 90% of both watersheds (Table 2, Figure 10). Floodplain soils are mostly inceptisols in with entisols being more common along floodplains in the upper portion of the Upper Apple Creek watershed. Upland soils in the Upper Apple Creek watershed have high-moderately high runoff with 77.9% classified as hydrologic soil group C and 12.2% in group D (Table 2, Figure 11)(USDA 2009a). Upland soils in Middle Apple Creek have moderately high runoff rates with 89.7% classified as hydrologic soil group C. Floodplain soils within both watersheds are within hydrologic soil group B, which has relatively low runoff potential.

Land Capability Classifications are used to determine the suitability of a soil to grow common field or pasture crops (USDA 2018b). Within the greater Apple Creek watershed, land capability classes range from classes (2-7) with (2) representing very slight to moderate limitations on use, and 7 representing very severe limitations on use that make them generally unsuited to cultivation. By far the most common capability subclasses found in both watersheds is (e) erosion with 3e and 4e the most common which limit plant selection or requires conservation practices due to susceptibility to erosion (Table 2, Figure 12). The Upper Apple Creek also has some soils with subclass (w) excess water/ poor drainage and (s) which is a limitation in the root zone of the soil due to stones, low moisture capacity/ fertility, or salinity/sodium content. Subclass (w) is the only other limitation found in the Middle Apple Creek watershed.

Soils within the Upper and Middle Apple Creek watersheds have high susceptibility to erosion. Soils were classified by soil erosion K-factor, which predicts the long-term average soil loss from sheet/rill erosion under annual crop systems and conservation practices. In these two watersheds, 72% of all of the soils in the Upper Apple Creek watershed and 97.8% of soils in the Middle Apple Creek watershed have a soil erosion K-factor >0.4 (Table 2, Figure 13). Additionally, 25.9% of all soils in the Upper Apple Creek watershed with a soil erosion K-factor of 0.3-0.4. A complete list of soil series found within both Apple Creek watersheds is available in Appendix A.

Hydrology and Drainage Network

Apple Creek begins in southern Perry County along State Highway 51 and flows east to the confluence with the Mississippi River in southeast Perry County and northeast Cape Girardeau County (Figure 2). Major tributaries to Apple Creek include Allie Creek, Poor Creek, Sandy Creek, Little Apple Creek, Hughes Creek, and Buckeye Creek. There is a total of 282.3 miles of mapped streams within the watershed with only 75.5 miles of streams with permanent flow (Table 3). There are a total of 133 reservoirs and small ponds that make up 129.1 acres within the watershed, with Stallings Brothers Lake being the largest at 14.7 acres. There are two large wells along the southern border of the Middle Apple Creek watershed in Cape Girardeau County that belong to the Cape Girardeau and Perry Counties Public Water Supply District #1. From 2013-2017 these two wells pumped on average over 40 million gallons of groundwater per year (Table 4).

Land Use and Land Cover

The Upper and Middle Apple Creek watersheds have mixed agricultural land uses with significant amounts of both row crops and pasture land, with Middle Apple Creek watershed having more row crops than the Upper Apple Creek watershed. Land use for Apple Creek watershed was determined using the 2013-2017 National Agricultural Statistics Service (NASS) Crop Database. Crop classes were combined to assess the overall trends of land use within the watershed. Over the five year period, grass and pasture land averaged 37.8% of the land use within the Upper Apple Creek watershed and 36.9% of the land use in the Middle Apple Creek watershed (Table 5, Figure 14). Forest land was the second highest category at 29.1% of the Upper Apple Creek watershed area and 24.1% of the Middle Apple Creek watershed. Row crops, double crops, small grains, and fallow ground, together made up 13.6% of the total land use in the Upper Apple Creek watershed and 23.1% of total land use in the Middle Apple Creek watershed. Developed land cover only accounted for less than 7% for both the Upper and Middle Apple Creek watersheds.

From 2013 to 2017, there has been a large increase in soybeans and a decrease in the amount of grass and pasture land in both watersheds. Over a five year period from 2013-2017, the percentage of land growing soybeans went from 5.7% to 13.2% in the Upper Apple Creek watershed and 9.0% to 17.0% in the Middle Apple Creek watershed (Table 6). Over that same period the amount of land growing corn remained fairly consistent. However, the amount of land in grass/pasture decreased by about 7% in the Upper Apple Creek watershed and 9% in the Middle Apple Creek watershed. This suggests a conversion of grass/pasture lands to row crops has occurred in these two watershed in the last five years.

Previous Work and Other Available Data

TMDLS and Management Plans

There are currently no Total Maximum Daily Loads (TMDLs) or watershed management plans within the larger Apple Creek watershed. However, there was a Healthy Watershed Plan developed for the large Upper Mississippi-Cape Girardeau watershed in conjunction with the Our Missouri Waters initiative by MDNR. This plan was developed by local stakeholders to identify challenges and develop priorities within the watershed (MDNR 2017). This plan outlines several priorities within this larger watershed, but specifically addresses the need to reduce stream bank erosion and utilize agricultural best management practices for cropland and pasturelands. Furthermore, sinkholes and losing streams in the Upper and Middle Apple Creek are connected to the Cinque Hommes Creek through karst connections found using dye tracing methods (Figure 8). Currently, Cinque Hommes Creek is listed on the state 303d list of impaired waters due to *E. Coli* from rural nonpoint sources pollution with a TMDL scheduled to be completed in 2024-2028 (MDNR 2018a, MDNR 2018b).

Surface and Ground Water Monitoring Stations

There are no United States Geological Survey (USGS) gaging stations in the larger Apple Creek watershed. To be able to predict discharge within the study watershed, 21 nearby USGS gaging stations were used to complete drainage area based regression equations to estimate discharge from different size watersheds near the study area (Figure 15). A list of the USGS gaging stations can be found in Appendix B. If resources became available to install a gaging station within the watershed, a possible location would be on Apple Creek at U.S. Highway 61 (E: 260,334 N: 4,164,566 UTM Zone15N). Additionally, there is a well that monitors groundwater levels located approximately ten miles west of the watershed where Perry, Bollinger, and Madison County intersect (Site Number: 373559090082901). This well has been in operation since 1960 and data from this station shows a steady decrease in groundwater levels from 1960-1973 (Figure 16). Since the mid-1970s, however, groundwater levels have steadily increased by almost 20 feet while the variability has decreased.

Water Quality Sampling Data

There are a total of six water quality monitoring sites within the larger Apple Creek watershed. Four of these sites are located along the main stem in the Upper Apple Creek watershed, one is located at Apple Creek Spring in the Middle Apple Creek watershed, and one is located just north of the watershed on Indian Creek a few miles before its confluence with Apple Creek (Figure 17). The monitoring site located at Apple Creek Spring had the most complete set of data with >60 nutrients and TSS samples collected from 2007-2010 (Table 7). The monitoring site located at the furthest downstream location along Apple Creek had 25 nutrients samples available and no TSS samples available from 2000-2013. The site located on Indian Creek had 26 nutrients and TSS samples collected between 2007-2009. The remaining monitoring sites on Apple Creek had <5 nutrient samples and no TSS samples available for all sites. Additionally, a site on Apple Creek was chosen as a reference site for developing nutrient criteria for the region (MDNR 2005). There is only one permitted point source within the two study watersheds and is a land application site owned by Buchheits Inc. (Table 8).

Biological Monitoring Data

Biological data was also collected at the water quality monitoring site located furthest downstream along Apple Creek. The biological data examined at this monitoring station included eight samples of invertebrate biotic data that was collected in the months of either March or September from 2000-2013. Multiple types of invertebrate indices were used to assess water quality in Apple Creek including the Biotic Index, EPT Taxa Richness, Shannon Diversity Index, and Total Taxa Richness (Hilsenhoff, 1988). For each sample, the indices value was normalized to unitless scores and combined to give an overall Missouri Stream Condition Index (MSCI) score. The samples collected had an overall MSCI score that ranged between 12-18 with an average of 14 (Table 9). The MSCI can be interpreted using three impairment categories that state that scores in the range of 16-20 indicate no impairment, 10-14 indicate impairment, and 4-8 indicate high impairment (Rabeni et al., 1997). The samples collected along Apple Creek tend to fluctuate between no impairment and impairment for assessments between 2000 and 2012.

Summary
The purpose of this report is to provide the information necessary to describe the study watershed (deliverable #1) for the Mississippi River Basin Initiative (MRBI) watershed assessment for the Upper Apple Creek (HUC12#071401050401) and Middle Apple Creek (HUC12#071401050403) watersheds in southeast Missouri. The area has high potential for ground water contamination due to the amount of karst development in the area. Additionally, agricultural nonpoint source pollution has been identified as a major concern in the Upper Mississippi-Cape Girardeau watershed. Stakeholders have identified stream bank erosion and implementation of agricultural best management practices as important for water quality and ground water protection within the larger Upper Mississippi-Cape Girardeau watershed. The purpose of this 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. 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, 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 Upper and Middle Apple Creek 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. The Upper Apple Creek watershed site 1799/29, located along the main stem near the outlet, has the most complete water quality dataset for nutrients of all the monitoring sites in both watersheds (Figure 17). At this site, the average TP concentration was 0.058 mg/L ranging from 0.01-0.220 mg/L (Table 11). The average TN concentration was 0.78 mg/L with a range between 0.19-1.97 mg/L. The only water quality site within the Middle Apple Creek watershed is located at Apple Creek Spring (Site 1799/18.9/1.1). Here, the average

TP concentration was 0.119 mg/L with a range of 0.010-1.100 mg/L and no TN concentration was reported. The TP concentration at the Apple Creek Spring site is about 2x higher than the average TP concentration in the main stem of Upper Apple Creek. This suggests groundwater may be susceptible to runoff through karst conduits and areas of known sinkholes and losing streams may be important areas to promote conservation practices. Ambient water quality criteria has the nutrient reference conditions for this stream set at 1.67 mg/L TN and 0.083 mg/L TP based on the 25th percentile value for streams within the Interior River Lowland region (Table 12, USEPA 2000). These data suggest that the spring has elevated TP concentrations when compared to the regional reference conditions. However, the nutrient concentrations at the main stem site in the Upper Apple Creek watershed are near or below the reference condition. This suggests the Upper Apple Creek watershed may be receiving less pollution from agricultural runoff compared to the Middle Apple Creek watershed. Furthermore, it is important to note the number of sites and the spatial and temporal distribution of samples in these two watersheds are limited.

Channel Stability and Riparian Corridor Assessment

<u>Aerial Photo Methods</u>

Two sets of aerial photographs were used to identify changes in channel locations using standard methods. Aerial photographs from 1996 and 2015 were obtained from the Missouri Spatial Data Information Service (MSDIS) online data server pre-rectified (Table 13). Differences between the two photos due to transformation errors 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 HUC-12 watershed boundary. Point-to-point errors ranged from 6.5-18.6 ft for an average of 10.8 ft (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 the tributary 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). Digitized lines representing the channel position from each year were then compared to identify areas of change and to quantify lateral migration rates and large-scale channel widening. Due to the size of the stream channels and the point-to-point error between photos, only the largest areas of bank erosion could be identified.

<u>Channel Classification</u>

Tributary channels and the main stem of the Upper and Middle Apple Creek watersheds were further classified by identifying historical channel changes by further interpretation of aerial photos between the years. Channels were first characterized as modified or natural. Modified channels were further classified as either channelized or dammed. Natural channels were further classified as either stable or active. Active channels were identified by assessing planform changes since 1996 by overlay analysis of the digitized channel using a 5.4 ft buffer which is based off the 10.8 ft mean point-to-point error to account for biases attributed to rectification (Martin and Pavlowsky 2011). Active reaches were identified as areas where the buffers did not overlap for at least 100 ft of stream length. 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 18).

Upper Apple Creek - Channel classification results show the majority of the tributary channels and the main stem were classified in stable condition, but a large portion have been modified in the past. However, a considerable portion of the stream channels in the watershed could not be evaluated due to vegetation obstruction. Of the 165.4 total stream miles within the watershed, 30.0 mi (13%) were classified as not visible (Table 15). Of the remaining stream miles, 31.3% of all channels were modified with 17% of channels being channelized and 14.3% impounded by a dam. It was also determined that 38.7% of all channels were in stable condition with only 7.3% being active. Most of the active channel reaches were along the main stem and major tributaries (Figure 20).

Middle Apple Creek – Channel classification analysis on the Middle Apple Creek watershed shows the majority of the streams are stable, there are many channelized and dammed reaches, and most of the active reaches are along the main stem. Of the total 228.6 miles of streams within the watershed, 37.5 miles (23%) were not visible on both sets of aerials (Table 15). Of the remaining stream miles, 64.1 miles (39%) were stable, 51.8 miles (31%) were channelized or dammed, and only 12.0 miles (7%) were classified as active using these methods. Many of the channelized, dammed, and not visible reaches were the headwaters streams while most of the tributaries were classified as stable (Figure 20). However, the majority of the main stem of the Middle Apple Creek watershed was classified as active.

Evaluation of the visible stream channels suggests that the majority of the streams in this area do not adjust to watershed disturbance through excessive lateral migration, with the exception of the main stem in Middle Apple Creek. Assessment of channel planform changes over time indicates relatively low rates of lateral migration within the tributaries of the both watersheds. These observations suggest that channel incision and widening may be the more dominate mechanism for adjustment in these streams, and this effect cannot be determined through aerial photo analysis for such small streams (Simon and Rinaldi 2000, Harden et al. 2009). Furthermore, the amount of human modified streams within the area suggests landowners may have been dealing with channel stability problems in the past. 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).

Riparian Corridor Analysis

The existence 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 corridor along streams in the Upper and Middle Apple Creek watersheds 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 19). 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. This method can only detect forested riparian buffers and aerial photo analysis cannot detect a healthy grassed buffer that maybe appropriate in some situations. However, for this assessment it is assumed that the lack of a forested buffer within these areas can intensify sediment loss and nutrient loading via mass wasting and limit filtration of overland flows from nearby fields (USDA 2014).

Upper Apple Creek – The riparian corridor along streams in the Upper Apple Creek watershed are mostly classified in the moderate and poor category, and this classification is consistently distributed among streams in the headwaters, tributaries, and along the main stem. In the Upper Apple Creek watershed, 78.2 miles (47%) of streams are in the moderate category while 44.5 miles (26%) are in the poor category (Table 16). There are 44.7 miles (27%) of channels classified as having a good riparian corridor. The spatial distribution of all three riparian corridor categories within the Upper Apple Creek watershed are evenly spread out across the watershed with no specific area or channel size dominating any one category (Figure 21). However, with the majority of the streams within the watershed being classified as either moderate or poor, the Upper Apple Creek watershed may benefit from riparian corridor enhancement.

Middle Apple Creek - The majority of the streams within the Middle Apple Creek watershed were classified as having either moderate or poor riparian corridors with the majority of these being located in the tributaries and headwater streams. The moderate and poor classification makes up a combined total of 180.2 miles (79%) of the total stream miles within the watershed (Table 16). The poor classification within the HUC-12 is generally concentrated in the headwater streams whereas the moderate classification is concentrated within tributary streams (Figure 21). There are 48.4 mi (21%) of streams within the watershed classified as good and these reaches are typically along the main stem of Middle Apple Creek and larger tributaries. These results suggest the Middle Apple Creek watershed may benefit from riparian corridor enhancement, particularly in the headwater stream areas.

<u>Visual Stream Survey Results</u>
A modified rapid visual stream survey was conducted upstream and downstream of all public road crossings with the watershed following NRCS protocols (USDA 1998). The protocol was modified by only focusing on five physical stream channel and riparian corridor variables 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.

Upper Apple Creek - Streams in pasture areas are typically more unstable and streams with an adequate riparian corridor tended to show fewer indicators of instability in the Upper Apple Creek watershed. The majority of channels in pastured areas in poor condition had underdeveloped riparian zones that had limited canopy cover and bank instability. Additionally, these pasture areas are also where livestock have access to the stream indicated by manure presence in the stream along with other indicators of bank instability. The range of channel conditions within the pastured areas and in croplands generally follow the quality of the riparian corridor along the stream. Riparian conditions in areas where livestock have access to the stream varied from no trees and eroding banks to a thin line of mature trees where channel conditions were not as unstable. Channel condition was mainly dependent on the riparian zone but location within the watershed was also a factor. Many of the channels deemed in poor condition were located in the headwaters of the watershed that had limited riparian development. Along the main stem of Upper Apple Creek streams were in relatively good condition, however, in some areas the riparian zone was not adequate for the width of the stream which also limited canopy cover. Overall, streams in this watershed evaluated for this project appeared to be fairly stable and in relatively good condition with evaluation scores ranging from moderate to good (Figure 22). Examples of the sites evaluated with overall scores can be found in Appendix D.

Middle Apple Creek - In Middle Apple Creek watershed, streams in cropland areas appear to be generally more stable than those in pastures and the main stem of Apple Creek. Most streams located within pasture areas tended to have more indicators of instability with instances of incised streams intersecting large, open pastures. Streams crossing pasture lands range in severity due primarily to changes in riparian area and subsequent bank instability. Poor riparian conditions affected by direct livestock access to the stream were associated with some of the lowest stream assessment scores in the watershed. These areas were often times characterized by zones of no riparian vegetation and highly trampled banks resulting from direct access to the stream. Other times these areas had a thin, discontinuous line of mature trees surrounding the stream which provided only minor amounts of bank protection. Along the main stem of Apple Creek the channel displayed signs of instability such as falling trees and undercut banks. Consequently, many areas along the main stem have been lined with rip-rap in attempt to combat further bank erosion and failure of steep, unstable banks. Wooded headwater streams tend to be some of the most stable reaches in the watershed. Evaluation scores ranged from poor-good within the watershed and were generally in poorer condition than streams in the Upper Apple Creek watershed (Figure 22). Overall, streams located in pasture areas and along the main stem show the highest levels of instability and perhaps should be targeted for programs designed to enhance the riparian corridor. Examples of the sites evaluated with overall scores can be found in Appendix E.

Rainfall–Runoff Relationship

Annual and monthly runoff rates for the Upper and Middle Apple Creek watersheds were estimated using equations developed from USGS gaging stations in the region. Monthly runoff rates are important for understanding, seasonal variability, how rainfall-runoff relationships correspond to land management, and annual runoff rates that 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 F. Based on these equations, mean annual discharge for the Upper Apple Creek watershed is 69.3 ft^3/s and 94.4 ft^3/s for the Middle Apple Creek watershed (Figure 23-24). Total runoff volume for the Upper Apple Creek watershed was 50,143 ac-ft and 68,304 ac-ft for the Middle Apple Creek watershed. For both watersheds, average discharge peaks in the month of April and is lowest in September. Average runoff as a percentage for the Upper Apple Creek watershed was 40.4% and 40.1% for the Middle Apple Creek watershed. The remainder of the rainfall is either lost to evapotranspiration or moves through the soil into groundwater storage through infiltration (USDA 2009b). These estimates are somewhat high compared to the literature where evapotranspiration rates for Missouri range from 60-70% (Sanford and Selnick 2013). Monthly mean runoff as a percentage of rainfall for both watersheds is highest in late winter and early spring and lowest in the late summer and early fall ranging from just over 15% in September to 60-65% in April.

Water Quality Modeling

STEPL Model

Existing water quality loads in the watershed and the influence of best management practices (BMPs) on load reductions were 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 on the landscape (Tetra Tech, Inc 2017). Annual nutrient loads were 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, the entire 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. 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 G.

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 1996 and 2015 photos that did not overlap were used to create bank erosion polygons. Additionally, a buffer based on the point-to-point error analysis was used around each polygon to account for differences in the photos due to the rectification process. The final 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. This method identified a total of 225 eroding stream banks in the Upper Apple Creek watershed and 187 eroding stream banks in the Middle Apple Creek watershed (Appendix H-I). Average eroding bank length for Upper and Middle Apple Creek watersheds ranged from 170-416 ft, average bank heights ranged from 6.8-11.8 ft, and migration rates from 0.92-1.07 ft/yr. Since STEPL has a limited number of available entries for eroding streambanks (100), an area weighted average height and rate were calculated for the both watersheds to be entered into the model.

There have already been conservation practices implemented within these two 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 10% of the cropland already had water and sediment control basins, 15% had cover crops, and 20% were using no-till (Appendix J). 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.

Upper Apple Creek - Average yields for the Upper Apple Creek watershed were 7.61 lb/ac/yr for nitrogen, 1.47 lb/ac/yr phosphorus, and 0.87 T/ac/yr of sediment (Table 18). Runoff rates were 0.76 ac-ft/ac/yr and the percentage of rainfall as runoff was 20.7% for the watershed. Modeled percent runoff is low compared to the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 40.4% for the watershed. These two methods produced annual runoff rates that were around 50% different. Since these two methods were so different, smaller gaging stations that include some across the river in Illinois were used to predict runoff (Appendix K). Annual runoff predicted from these gages was about 30% different than the STEPL results, which suggests the original gages compiled for this study may not be representative of the Apple Creek watershed. Further intensive hydrological analysis of regional gages and rainfall patterns in representative landscapes that would be required to fully understand the differences between the STEPL model and the predicted runoff from nearby gages is beyond the scope of this project. Adjustments could be made to the soil hydrologic group number in STEPL to produce similar results. However, this was not adjusted in the model for this project and the original hydrological soil group was used in STEPL. Additionally, results also show that existing conservation practices have reduced nitrogen loads by about 5.4%, phosphorus loads by 9.4%, and sediment loads by 10.6% for cropland sources in the watershed.

Middle Apple Creek - Average yields for the Middle Apple Creek watershed were 8.81 lb/ac/yr for nitrogen, 1.84 lb/ac/yr phosphorus, and 1.23 T/ac/yr of sediment (Table 18). Runoff rates were 0.87 ac-ft/ac/yr and the percentage of rainfall as runoff was 22.6% for the watershed. Similar to Upper Apple Creek, modeled percent runoff was low compared to the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 40.1% for the watershed. These two methods produced annual runoff rates that were around 60% different. Annual runoff predicted from the revised gaging stations outlined above resulted in a 45% difference compared to the STEPL results. Again, adjustments could be made to the soil hydrologic group value in STEPL to produce similar results. However, this was not adjusted for this project and the original hydrological soil group was used in the STEPL model. Additionally, results also show that existing conservation practices have reduced nitrogen loads by about 7.4%, phosphorus loads by 11.9%, and sediment loads by 11.7% for cropland sources in the watershed.

When assessing model results by sources for these two watersheds, the majority of the nutrient and sediment load is from agricultural nonpoint source pollution. However, streambank erosion is also contributing significantly to the total nutrient and sediment loads, particularly in the Middle Apple Creek watershed. Model results show crop and pastureland account for 79-89% of the nutrient load and around 66-79% of the sediment load in the two watersheds (Table 19). Pastureland is the highest contributor of nutrients and sediment in the Upper Apple Creek watershed accounting for 66.0% of the nitrogen load, 49.6% of the phosphorus load, and 40.8% of the sediment load. In the Middle Apple Creek watershed, cropland is the highest contributor of phosphorus (44.9%), and sediment (42.6%), but pastureland is the highest contributor to nitrogen (51.9%). Streambank erosion contributes significantly to the total sediment load in each watershed accounting for 17.7% of the load in the Upper Apple Creek watershed and 32.2% of the load in the Middle Apple Creek watershed.

Load Reduction Analysis

Load reduction for the two 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 seven 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 J. 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 both 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 field borders, grassed waterways, grade stabilization, no-till, and water and sediment control basins were 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, conservation practices included in the analysis were forage and biomass planting, alternative water, winter feeding facilities, critical area planting, access control, prescribed grazing, heavy use protection, grade stabilization, and livestock exclusion. 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.

Upper Apple Creek - Load reduction analysis for the Upper Apple Creek watershed shows that the most beneficial conservation practices for reduction of nitrogen would be achieved in pasturelands while implementation of conservation practices on cropland would also increase the reduction benefit. For example, by applying livestock exclusion, alternative water, and heavy use protection to 50% of the 16,959 acres of pastureland (8,480 acres), the reduction for nitrogen would be 16.2%, phosphorus 15.3%, and sediment 14.5% (Tables 20-22). Furthermore, applying a water and sediment control basin to 50% of the 5,370 acres of cropland (2,685 acres) within the watershed, load reduction would be an additional 10.2% for nitrogen, 16.9% for phosphorus, and 19.3% for sediment. This combination would result in a total reduction of 26.2% for nitrogen, 31.2% for phosphorus, and 29.3% for sediment. Additionally, if all the cropland within the watershed was taken out of production, the resulting load reduction would be 26.4% for nitrogen, 32.2% phosphorus, and 33.8% sediment. These scenarios indicate pastureland conservation practices can achieve the highest reductions of nutrients and sediment, however by combining cropland and pastureland practices in this watershed these practices can substantially reduce nutrient and sediment loads in the watershed.

Middle Apple Creek - Load reduction analysis indicates implementation of cropland conservation practices can reduce nutrient and sediment loads in the Middle Apple Creek watershed, but when combined with pastureland practices significant reductions can be attained. An example would be if water and sediment control basins were applied to 50% of the 12,225 acres of cropland (6,113 acres) within the watershed, load reduction would be 14.0% for nitrogen, 21.2% for phosphorus, and 21.3% for sediment (Tables 23-25). Additionally, applying livestock exclusion, alternative water, and heavy use protection to 50% of the 20,281 acres of pastureland (10,141 acres), the reduction for nitrogen would be 12.2%, phosphorus 10.0%, and sediment 8.0%. This combination would result in a total reduction of 26.2% for nitrogen, 31.2% for phosphorus, and 29.3% for sediment. This analysis suggests both cropland and pastureland conservation practices are necessary to make significant reduction in 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 35.4% for nitrogen, 47.3% phosphorus, and 46.8% sediment.

Summary

The purpose of this section of the report is to provide results of the resource analysis of the watershed (Deliverable #2) for Mississippi River Basin Healthy Watershed Initiative (MRBI) watershed assessment of the Upper Apple Creek Watershed (HUC12# 071401050401) and the Middle Apple Creek Watershed (HUC12# 071401050403). Water quality data shows Apple Creek spring has 2X higher average TP concentration than the site on the main stem of Upper Apple Creek. This suggests groundwater may be susceptible to runoff through karst conduits, and areas of known sinkholes and losing streams may be important areas to promote conservation practices. Using ambient water quality criteria as a reference, TP concentrations at the spring are elevated. However, the nutrient concentrations at the main stem site in the upper watershed are near or below the reference condition. While the number of water quality sites in these watersheds are limited, this suggests the Upper Apple Creek watershed may be receiving less pollution from agricultural runoff compared to the Middle Apple Creek watershed.

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 and sediment being released through bank erosion is an important component of the total sediment load in the watershed. 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. Stream reaches assessed in the visual stream survey showed that streams in pastures generally showed more signs of instability, had poor riparian corridors, and livestock had access to the stream. Additionally, streams draining cropland generally had some sort of vegetative buffer and appeared to be relatively more stable compared to those in pastureland.

Water quality modeling results indicate pasture and cropland are both contributing significantly to nonpoint source pollution within the watershed. Model results indicate agricultural nonpoint sources can account for about 80% of the nutrient and sediment loads in these two watersheds. Additionally, streambank erosion is a significant contributor to the total sediment load in these watersheds, specifically in the Middle Apple Creek watershed. Modelling results also indicate existing conservation practices have reduced the exiting loads within the watershed to some degree. Load reduction analysis suggests pastureland conservation practices would be the most beneficial in the Upper Apple Creek watershed and cropland conservation practices the most beneficial in the Middle Apple Creek watershed. However, without implementation of conservation practices in both pasture and cropland, significant load reductions cannot be achieved.

IDENTIFICATION OF CONSERVATION NEEDS

Resource Priorities

In the Upper Apple Creek watershed, the top resource priority identified is the reduction of nitrogen and sediment is the top priority in the Middle Apple Creek watershed. STEPL modeling results suggests nearly 3x higher nitrogen loads are coming from pastureland (66.0%) compared to cropland (23.0%) in the Upper Apple Creek watershed. For Middle Apple Creek, STEPL modeling results indicate the majority of sediment is coming from cropland (42.6%) and the second highest source is streambank erosion (32.2%). Furthermore, the karst area in the northern portion of the Middle Apple Creek watershed was identified as the top resource concern from agriculture nonpoint source pollution. Dye tracing experiments link this area to an impaired stream to the north near Perryville. Load reduction estimates suggest implementation of conservation practices in the Upper Apple Creek watershed should be focused on pastureland and cropland should be the focus in the Middle Apple Creek watershed. Total amount of pastureland in each watershed is 16,959 acres in the Upper Apple Creek watershed and 20,281 acres in the Middle Apple Creek watershed. However, total cropland is only 5,370 acres in the Upper Apple Creek watershed and 12,225 acres in the Middle Apple 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 priority acres classification, and a conservation practice rating system.

Management Units

To better plan for locations to implement conservation practices, both watersheds were split into 28 smaller watersheds, or management units (MUs) (Figure 25). MUs will allow field staff to evaluate potential projects based on a system that would spatially rank geographic areas within the watershed. STEPL was then used to estimate nitrogen and sediment yields for each MU in both watersheds ranging from about 1,500-3,900 acres (Table 26). In the Middle Apple Creek watershed, MU #15 represents the karst area identified as one of the top resource concerns during this assessment. Therefore, MU #15 will be the highest ranked MU due to the susceptibility for pollution in the shallow groundwater and the connectiveness to impaired streams to the north. The three highest ranked MUs in the Middle Apple Creek watershed (#s

3, 6, and 10) are located in areas with high percentages of cropland and elevated erosion potential. In the Upper Apple Creek watershed, the three MUs with the highest ranking (#s 24, 27, and 28) are all located within the northwest portion of the watershed. The landscape in this area is are more susceptible to runoff as the land is on relatively steeper slopes and soil types can generate more runoff in these MUs.

Vulnerable Acres Classification

To identify areas with the most pollution potential within a proposed project, a vulnerable acres classification system was developed to help field staff isolate problem areas and rank projects within the same MU. Four risk classes were used to rank the agricultural land within the watershed based on the resource 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 "N/A" (Figure 26). A description of each class type is described below and summarized in Table 27.

Highest Vulnerability – There are three situations that will classify the land for the highest vulnerability for conservation planning. The first condition is cropland located on highly erodible soils with slopes ≥8%. 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 two study watersheds was 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)

The second situation that places land into the highest category is pastureland on soils classified in Hydrological Soil Group (HSG) D with slopes >4%. Finally, pastureland on soils classified in HSG C with slopes >6% are also placed into the highest category. In the Upper and Middle Apple Creek watersheds 33,277 acres (40.9%) are classified in the highest vulnerability category.

High Vulnerability - There are four conditions that will classify the land in the high vulnerability for conservation planning category. First, The first condition is cropland located on highly erodible soils with slopes <8%. The second condition is pastureland on soils classified in HSG D with slopes <4%. The third condition is pastureland on soils classified in HSG C with slopes <6%. Finally, pastureland on soils classified in HSG B with slopes >6% are also placed into the highest category. There is a total of 15,899 acres (19.5%) of high vulnerability acres in the Middle Apple Creek watershed.

Moderate Vulnerability - Land within the moderate vulnerability category would be all of the remaining cropland and pastureland within the watershed. The Upper and Middle Apple Creek watersheds have 5,653 acres (7.0%) of moderate vulnerable acres.

Low Vulnerability - Low vulnerability acres are all of the forested areas within the watershed. Within the Upper and Middle Apple Creek watershed there are 21,382 low priority acres (26.3%).

N/A – This category represents all urban land use and land classified as water or wetlands within the two study watersheds. This represents 5,123 acres, or 6.3% 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 for the Upper and Middle Apple Creek watersheds. For this, each conservation practice, or combination of conservation practices, was ranked based on the highest benefit by percentage of land treated for each watershed for both pasture and cropland. Ranking for the Upper Apple Creek watershed was based on nitrogen reduction and the ranking for the Middle Apple Creek watershed was based on sediment reduction. The top three rankings in Upper Apple Creek are pastureland conservation practices (Table 30). The top practice for reducing the nitrogen load is treating pastureland with a grade stabilization structure. The two other top practices in this watershed are a prescribed grazing/alternative water system and a livestock exclusion/alternative water system. There is a total of 16,959 acres of pastureland within the Upper Apple Creek watershed.

In the Middle Apple Creek watershed, cropland conservation practices make up the top six in the ranking (Table 30). This is a result of cropland having a relatively higher load per acre and cropland conservation practices having relatively high efficiency ratings. The top three practices are land retirement, water and sediment control basins, and cover crop and no-till. Pastureland conservation practices rank in the bottom 8 of the 15 practices identified in this project because pastureland has a relatively lower load and lower efficiencies than cropland, especially for sediment reduction. Overall there is more pastureland (20,281 acres) to treat versus cropland (12,225 acres) in the watershed. However, results of this assessment suggest treating cropland in Middle Apple Creek would ultimately be more efficient in reducing sediment loads. Additionally, 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 a watershed assessment for the Upper and Middle Apple Creek watersheds, which are part of the Mississippi River Basin Healthy Watershed Initiative (MRBI). Agricultural nonpoint source pollution has been identified as a major concern in the larger Upper Mississippi-Cape Girardeau watershed and addressing both stream bank erosion and implementation of agricultural best management practices have been identified as important for water quality and ground water protection. The northern portion of the Middle Apple Creek watershed in particular has a high potential for ground water contamination due to the amount of karst development in the area. Ultimately, the purpose of this 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. The assessment included three phases, 1) resource inventory, 2) resource analysis, and 3) identification of resource needs. There are eight main conclusions for this assessment:

1) There are currently no Total Maximum Daily Loads (TMDLs) or watershed management plans within the larger Apple Creek watershed. However, there was a Healthy Watershed Plan developed for the larger Upper Mississippi-Cape Girardeau watershed that specifically addresses the need to reduce stream bank erosion and utilize agricultural best management practices for cropland and pasturelands. Furthermore, sinkholes and losing streams in the Upper and Middle Apple Creek are connected via karst conduits to the Cinque Hommes Creek listed on the state 303d list of impaired waters due to *E. Coli* from rural nonpoint sources;

2) Limited water quality data suggest the shallow groundwater may be susceptible to runoff through karst conduits in areas of known sinkholes and losing streams. Results show that Apple Creek Spring has elevated TP concentrations when compared to the regional reference conditions. However, the nutrient concentrations at the main stem site in the upper watershed are near or below the reference condition. This suggests the Upper Apple Creek watershed may be receiving less pollution from agricultural runoff compared to the Middle Apple Creek watershed. However, it is important to note the number of sites and the spatial and temporal distribution of samples in these two watersheds are limited;

3) 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 and sediment being released through bank erosion is an important component of the total sediment load in the watershed. Stream reaches assessed in the visual stream survey indicate streams along pastures generally showed more signs of instability, had poor riparian corridors, and livestock had access to the stream. Additionally, streams draining cropland generally had some sort of vegetative buffer and

appeared to be relatively more stable compared to those in pastureland;

4) While most of the actively eroding stream banks in both watersheds were located along the main stem of Apple Creek, the riparian corridor assessment shows most poor riparian corridors are located in the headwaters and most of the good riparian areas are along the main stem of the stream. This indicates the stream is adjusting to increased flooding and stream bank erosion rates may even be higher without the presence of a forested buffer along the main channel;

5) Water quality modeling results indicate pasture and cropland are both contributing significantly to nonpoint source pollution within the watershed accounting for nearly 80% of the nutrient and sediment loads in these two watersheds. Pastureland is the top contributor in the Upper Apple Creek watershed and cropland is the top contributor in the Middle Apple Creek watershed. Additionally, streambank erosion is a significant contributor to the total sediment load in these watersheds, specifically in the Middle Apple Creek watershed;

6) Nitrogen loading from pastureland was identified as the primary resource concern for the Upper Apple Creek watershed. Load reduction analysis suggests that implementation of prescribed grazing/alternative water or livestock exclusion/alternative water systems on pastures would be most effective practices in reducing the nitrogen load;

7) Reduction of the sediment load was the top resource concern identified in the Middle Apple Creek watershed. Model results indicate that practices such as installing water and sediment control basins and implementation of cover crop/no-till on cropland can have the most benefit in reducing erosion in the watershed. This may be even more important in the future as the trend over the last few years has been to convert more land to crops in this watershed; and

8) Management units and priority acres were created to help field staff prioritize areas and evaluate potential projects. Management units direct conservation practices to specific areas of the watershed based on nitrogen yields in the Upper Apple Creek and sediment yields in the Middle Apple Creek watershed. Priority acres within each management unit can be used to evaluate projects within management units.

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TABLES

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

Year	Total Rainfall (in)	Average Temperature (°F)
1988	25.4	57.1
1989	32.2	54.2
1990	47.5	56.6
1991	34.7	56.4
1992	32.0	54.7
1993	51.7	53.7
1994	37.0	54.3
1995	39.9	54.2
1996	48.2	53.1
1997	38.7	53.6
1998	50.5	57.6
1999	47.8	55.7
2000	34.5	55.1
2001	51.8	56.2
2002	49.6	55.4
2003	42.9	53.9
2004	44.5	54.7
2005	35.1	56.1
2006	48.0	56.0
2007	36.6	56.0
2008	60.7	53.4
2009	58.0	54.6
2010	36.8	55.2
2011	50.6	55.9
2012	28.8	57.7
2013	50.6	53.2
2014	42.5	52.2
2015	60.6	54.9
2016	43.3	56.7
2017	42.5	56.5
n	30	30
Min	25.4	52.2
Mean	43.4	55.2
Max	60.7	57.7

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

Table 2. Upper Apple Creek Watershed and Middle Apple Creek Watershed soil characteristic summaries.

Upper Apple Creek Watershed							
Soil Order	**%**	**Hydrologic Soil Group**	**%**	**Soil Erosion K-Factor**	**%**	**Land Capability Classification**	**%**
Alfisol	90.9	A	0.7	<0.2	0.3	2e	0.8
Inceptisol	4.7	B	8.6	0.2-0.3	1.6	2s	0.8
Ultisol	0.1	C	77.9	0.3-0.4	25.9	2w	1.2
Entisol	4.2	D	12.2	>0.4	72.0	3e	35.3
other	0.2	C/D	0.3	other	0.2	3w	7.3
		other	0.2			4e	37.9
						4s	0.1
						4w	0.2
						6e	1.3
						6s	10.1
						7e	4.7
						other	0.2

Middle Apple Creek Watershed							
Soil Order	**%**	**Hydrologic Soil Group**	**%**	**Soil Erosion K-Factor**	**%**	**Land Capability Classification**	**%**
Alfisol	90.0	B	8.9	0.2-0.3	0.3	2e	10.0
Inceptisol	9.0	C	89.7	0.3-0.4	1.4	2w	0.1
Ultisol	0.1	B/D	0.6	>0.4	97.8	3e	32.5
Entisol	0.3	C/D	0.2	other	0.5	3w	4.3
other	0.5	other	0.5			4e	40.5
						6e	6.7
						7e	0.3
						other	0.5

Table 3. Drainage network summary.

Water Feature	Length/Area	
<u>Streams</u>	282.3	miles
Permanent Flow	75.5	miles
Intermittent Flow	206.8	miles
<u>Waterbodies</u>		
Ponds and Lakes	129.1	acres

Table 4. Major water users within the watershed.

Type	Yearly Water Usage (gallons)					Average Annual Usage 2013-2017 (Gallons)
	2013	2014	2015	2016	2017	
Well 1	22,521,860	24,024,790	28,690,920	24,933,370	27,314,990	25,497,186
Well 2	12,647,700	14,737,680	16,173,230	14,547,190	15,648,030	14,750,766

Table 5. Generalized crop data (%) for the Upper Apple Creek and the Middle Apple Creek Watersheds from 2013-2017.

Upper Apple Creek						
General Land Use/ Land Cover	**Year**					**2013-2017 Average**
	2013	**2014**	**2015**	**2016**	**2017**	
Row Crops	6.5	2.0	10.8	10.0	12.2	8.3
Dbl Crop	6.2	4.4	3.3	4.5	2.9	4.3
Small Grains	0.8	0.6	1.1	1.0	0.4	0.8
Alfalfa and other Hay	13.3	13.3	12.6	14.0	16.6	14.0
Fallow/Idle Croplands and Barren	0.1	0.1	0.6	0.2	0.1	0.2
Developed Land	5.3	5.6	5.3	5.2	5.3	5.3
Forest	27.9	29.3	30.3	29.0	29.2	29.1
Grass/Pasture	39.7	44.5	35.8	35.9	32.9	37.8
Open Water	0.3	0.2	0.2	0.2	0.3	0.2

Middle Apple Creek						
General Land Use/ Land Cover	**Year**					**2013-2017 Average**
	2013	**2014**	**2015**	**2016**	**2017**	
Row Crops	14.6	16.2	17.6	20.3	22.3	18.2
Dbl Crop	4.8	4.0	3.6	3.9	2.8	3.8
Small Grains	1.1	0.8	1.5	1.1	0.6	1.0
Alfalfa and other Hay	7.4	8.4	9.3	10.8	10.5	9.3
Fallow/Idle Croplands and Barren	0.0	0.0	0.3	0.1	0.1	0.1
Developed Land	6.2	6.3	6.4	6.3	6.3	6.3
Forest	23.6	23.1	25.0	24.4	24.2	24.1
Grass/Pasture	41.9	40.8	36.0	32.8	32.8	36.9
Open Water	0.3	0.2	0.2	0.3	0.3	0.3

Table 6. Specific selected crop data for the Upper Apple Creek and Middle Apple Creek Watersheds from 2013-2017 with percent change.

Upper Apple Creek						
Class Name	**Year**					**% Change 2013-2017**
	2013	**2014**	**2015**	**2016**	**2017**	
Corn	2.42	2.22	2.85	3.63	2.50	3.09
Soybeans	5.66	8.57	10.11	8.81	13.21	133.34
Dbl Crop WinWht/Soybeans	7.69	4.96	4.06	5.65	3.71	-51.81
Deciduous Forest	34.46	33.12	37.58	36.24	37.45	8.68
Grass/Pasture	49.06	50.47	44.68	45.00	42.37	-13.64

Middle Apple Creek						
Class Name	**Year**					**% Change 2013-2017**
	2013	**2014**	**2015**	**2016**	**2017**	
Corn	8.11	7.22	9.91	9.99	9.93	22.49
Soybeans	9.01	11.94	11.25	14.84	17.03	89.11
Dbl Crop WinWht/Soybeans	5.52	4.61	4.34	4.49	3.26	-40.88
Deciduous Forest	27.52	29.63	33.22	32.41	32.59	18.43
Grass/Pasture	49.06	48.25	43.55	40.10	39.72	-19.04

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

Site ID	TP (n)	TP Start	TP End	TP Mean (mg/L)	TN (n)	TN Start	TN End	TN Mean (mg/L)	TSS (n)	TSS Start	TSS End	TSS Mean (mg/L)
1799/10.1/4.7	26	12/17/2007	12/12/2009	0.149	NA	NA	NA	NA	35	4/3/2007	12/12/2009	16.8
1799/18.9/1.1	62	12/17/2007	9/14/2010	0.119	NA	NA	NA	NA	78	4/3/2007	9/14/2010	17.7
1799/29.0	25	3/14/2000	3/26/2013	0.058	25	3/14/2000	3/26/2013	0.78	3	3/20/2012	3/26/2013	5.3
1799/30.9	3	2/10/2011	9/15/2011	0.018	3	2/10/2011	9/15/2011	0.41	NA	NA	NA	NA
1799/32.2	1	3/2/2006	3/2/2006	0.030	1	3/2/2006	3/2/2006	0.72	NA	NA	NA	NA
1799/33.2	2	3/2/2006	5/18/2006	0.040	2	3/2/2006	5/18/2006	0.92	NA	NA	NA	NA

n = sample number

TP = total phosphorus

TN = total nitrogen

TSS = total suspended sediment

NA = not available

Table 8. Permitted point sources within the watershed.

Site Number	Facility Name	Type	Stream	Waste	Status
1	Buchheits Inc.	Land Application Site	Tributary of Apple Creek	Nonprocess	Effective

Table 9. Water quality monitoring sites with invertebrate biotic data.

Site ID	Sample Date	Biotic Index		EPT Taxa Richness		Shannon Diversity Index		Total Taxa Richness		Missouri Stream Condition Index (MSCI)
		Value	Score	Value	Score	Value	Score	Value	Score	
1799/29.0	3/26/2013	6.7	3	16	3	2.57	3	77	3	12
1799/29.0	9/19/2012	6.3	5	23	5	2.73	3	81	3	16
1799/29.0	3/20/2012	6.4	3	22	5	3.35	5	104	5	18
1799/29.0	9/29/2011	6.7	3	20	3	2.31	3	81	3	12
1799/29.0	3/21/2001	6.6	3	16	3	3.01	3	89	3	12
1799/29.0	9/26/2002	6.98	3	10	3	1.61	3	44	3	12
1799/29.0	9/19/2000	6.4	3	24	5	3.11	5	81	3	16
1799/29.0	3/14/2000	6.8	3	21	3	3.32	5	88	3	14

Table 10. Data 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/
Stream Geomorphology	NRCS-National Water Management Center	USDA		x	www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/manage/hydrology/?cid=nrcs143_015052
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
Water Quality	MDNR Water Quality Assessment System	MDNR	x		http://www.dnr.mo.gov/mocwis_public/wqa/waterbodySearch.do
Biological Data	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. Summary of water quality data for the Upper and Middle Apple Creek watershed

Site ID	TP (mg/L)						TN (mg/L)						TSS (mg/L)					
	n	**min**	**mean**	**max**	**stdev**	**cv%**	**n**	**min**	**mean**	**max**	**stdev**	**cv%**	**n**	**min**	**mean**	**max**	**stdev**	**cv%**
1799/10.1/4.7	26	0.010	0.149	0.686	0.144	96.8	NA	NA	NA	NA	NA	NA	35	0.9	16.8	84.4	22.7	135.1
1799/18.9/1.1	62	0.010	0.119	1.100	0.175	147.3	NA	NA	NA	NA	NA	NA	78	78	0.0	17.7	644.9	74.2
1799/29.0	25	0.010	0.058	0.220	0.056	96.8	25	0.19	0.78	1.97	0.51	65.7	3	5.0	5.3	6.0	0.6	10.8
1799/30.9	3	0.010	0.018	0.035	0.014	78.7	3	0.27	0.41	0.49	0.12	30.1	NA	NA	NA	NA	NA	NA
1799/32.2	1	NA	0.030	NA	NA	NA	1	NA	0.72	NA	NA	NA	NA	NA	NA	NA	NA	NA
1799/33.2	2	0.040	0.040	0.040	0.000	0.0	2	0.86	0.92	0.97	0.08	8.5	NA	NA	NA	NA	NA	NA

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)	1.67	0.47 – 7.09
TP (mg/L)	0.083	0.001-1.60

Table 13. Aerial photography used for channel change analysis

Photo Year	Source	Type	Resolution (ft)
1996	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)
Upper Apple Creek	6.8-18.6	10.8
Middle Apple Creek	6.5-18.6	10.8

Table 15. Stream classification analysis summary

Watershed	**Total Length (mi)**	**Channelized**	**Pond/Dam**	**Stable**	**Active**	**Not Visible**
Upper Apple Creek	165.4	18.6	16.8	147.3	15.8	30.0
		8%	7%	64%	7%	13%
Middle Apple Creek	228.6	28.1	23.7	64.1	12.0	37.5
		17%	14%	39%	7%	23%

Table 16. Riparian corridor analysis summary

Watershed	**Total Length (mi)**	**Good**	**Moderate**	**Poor**
Upper Apple Creek	165.4	44.7	78.2	44.5
		27%	47%	26%
Middle Apple Creek	228.6	48.4	106.6	73.6
		21%	47%	32%

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

Conservation Practices	% of Cropland
No Practices	61.2
Cover Crop	10.8
Water and Sediment Basins	6.8
Water and Sediment Basins and Cover Crop	1.2
No-till	15.3
No-till and Water and Sediment Basins	1.7
No-till and Cover Crop	2.7
No-till, Water and Sediment Basins, and Cover Crops	0.3
Cropland with Conservation	38.8%
Cropland without Conservation	61.2%
Combined Efficiencies	N = 0.332 P = 0.528 Sed = 0.614

Table 18. STEPL model results

Watershed	Total Ad (ac)	Runoff (ac-ft)	Runoff Yield (ac-ft/ac)	% Rainfall as Runoff	Annual Load N-lb/yr	Annual Load P-lb/yr	Annual Load Sed-t/yr	Annual Yield N-lb/ac/yr	Annual Yield P-lb/ac/yr	Annual Yield Sed-t/ac/yr	Mean Concentration N-mg/L	Mean Concentration P-mg/L	Mean Concentration Sed-mg/L
Upper Apple Creek	34,291	26,006	0.76	20.7	261,042	50,300	29,794	7.61	1.47	0.87	3.69	0.711	843
Middle Apple Creek	47,043	40,780	0.87	22.6	414,644	86,386	57,863	8.81	1.84	1.23	3.74	0.779	1,044

Table 19. STEPL results by sources

Sources	N Load (lb/yr)	%	P Load (lb/yr)	%	Sediment Load (t/yr)	%
Upper Apple Creek						
Urban	15,111	5.8	2,333	4.6	347	1.2
Cropland	60,006	23.0	17,386	34.6	11,336	38.0
Pastureland	172,245	66.0	24,968	49.6	12,147	40.8
Forest	5,201	2.0	2,349	4.7	685	2.3
Septic	34.5	0.0	13.5	0.0	0	0.0
Streambank	8,446	3.2	3,252	6.5	5,279	17.7
Total	261,042	100	50,300	100	29,794	100
Middle Apple Creek						
Urban	26,438	6.4	4,082	4.7	607	1.0
Cropland	137,165	33.1	38,747	44.9	24,622	42.6
Pastureland	215,174	51.9	29,320	33.9	13,289	23.0
Forest	6,003	1.4	2,738	3.2	716	1.2
Septic	57.6	0.0	22.6	0.0	0.0	0.0
Streambank	29,807	7.2	11,476	13.3	18,629	32.2
Total	414,644	100	86,386	100	57,863	100

Table 20. Nitrogen load reduction results for Upper Apple Creek watershed

List of Practices	Nitrogen load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.3	3.7
Field Borders	1.8	3.6	5.4	7.3	9.1	10.9	12.8	14.6	16.4	18.1
Grassed Waterways	1.8	3.6	5.4	7.3	9.1	10.9	12.8	14.6	16.4	18.1
Grade Stabilization Structure	2.0	4.1	6.1	8.1	10.2	12.2	14.2	16.2	18.3	20.4
Cover Crop and No Till	1.8	3.5	5.3	7.0	8.8	10.5	12.2	14.0	15.7	17.6
Water and Sediment Control Basin	2.0	4.1	6.1	8.1	10.2	12.2	14.2	16.2	18.3	20.3
Land Retirement	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.2	22.8	25.3
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Forage and Biomass Planting	0.9	1.7	2.6	3.5	4.4	5.2	6.1	7.0	7.8	8.7
Alternative Water	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9.1
Winter Feeding Facilities	2.3	4.5	6.8	9.0	11.3	13.5	15.7	18.0	20.2	22.6
Critical Area Planting	1.4	2.9	4.3	5.8	7.3	8.7	10.2	11.6	13.1	14.4
Access Control	1.9	3.7	5.6	7.4	9.3	11.1	12.9	14.8	16.6	18.5
Prescribed Grazing, Alternative Water, and Heavy Use Protection	3.7	7.4	11.1	14.8	18.5	22.2	25.9	29.6	33.3	37.1
Grade Stabilization Structure	4.7	9.4	14.0	18.7	23.4	28.0	32.7	37.3	42.0	46.8
Livestock Exclusion, Alternative Water, Heavy Use Protection	3.2	6.4	9.7	12.9	16.2	19.4	22.6	25.9	29.1	32.2

Table 21. Phosphorus load reduction results for Upper Apple Creek watershed

List of Practices	Phosphorus load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.4	0.8	1.2	1.5	1.9	2.3	2.6	3.0	3.4	3.8
Field Borders	2.7	5.4	8.1	10.7	13.4	16.1	18.7	21.4	24.1	26.9
Grassed Waterways	2.7	5.5	8.2	10.9	13.7	16.4	19.1	21.8	24.6	27.3
Grade Stabilization Structure	3.1	6.1	9.2	12.2	15.3	18.3	21.3	24.4	27.4	30.6
Cover Crop and No Till	3.2	6.3	9.5	12.7	15.9	19.0	22.2	25.4	28.5	31.7
Water and Sediment Control Basin	3.4	6.7	10.1	13.5	16.9	20.2	23.6	27.0	30.3	33.7
Land Retirement	3.8	7.5	11.3	15.0	18.8	22.5	26.2	30.0	33.7	37.6
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Forage and Biomass Planting	0.3	0.5	0.8	1.1	1.4	1.6	1.9	2.2	2.4	2.7
Alternative Water	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.1
Winter Feeding Facilities	1.8	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.2	18.0
Critical Area Planting	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	14.9
Access Control	2.2	4.4	6.7	8.9	11.2	13.4	15.6	17.9	20.1	22.2
Prescribed Grazing, Alternative Water, and Heavy Use Protection	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.2	22.8	25.3
Grade Stabilization Structure	3.4	6.7	10.1	13.5	16.9	20.2	23.6	27.0	30.3	33.7
Livestock Exclusion, Alternative Water, Heavy Use Protection	3.0	6.1	9.1	12.2	15.3	18.3	21.4	24.4	27.5	30.4

Table 22. Sediment load reduction results for Upper Apple Creek watershed

List of Practices	**Sediment load reduction by % of land treated**									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.4	0.9	1.3	1.8	2.3	2.7	3.2	3.6	4.1	4.5
Field Borders	2.9	5.8	8.7	11.6	14.5	17.4	20.3	23.2	26.1	29.0
Grassed Waterways	2.7	5.8	8.7	11.6	14.5	17.5	20.4	23.4	26.3	29.0
Grade Stabilization Structure	3.3	6.7	10.0	13.4	16.8	20.1	23.5	26.8	30.2	33.5
Cover Crop and No Till	3.5	7.1	10.6	14.2	17.8	21.3	24.9	28.4	32.0	35.4
Water and Sediment Control Basin	3.8	7.7	11.5	15.4	19.3	23.1	27.0	30.8	34.7	38.4
Land Retirement	4.2	8.5	9.1	17.0	21.3	25.5	29.8	34.0	38.3	42.4
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Forage and Biomass Planting	0	0	0	0	0	0	0	0	0	0
Alternative Water	0.7	1.4	2.0	2.7	3.4	4.0	4.7	5.3	6.0	6.8
Winter Feeding Facilities	1.5	3.9	4.4	5.8	7.3	8.7	10.2	11.7	13.1	14.6
Critical Area Planting	1.5	3.1	4.6	6.1	7.7	9.2	10.7	12.2	13.8	15.3
Access Control	2.3	4.5	6.8	9.0	11.3	13.5	15.7	18.0	20.2	22.6
Prescribed Grazing, Alternative Water, and Heavy Use Protection	2.3	4.6	7.0	9.3	11.7	14.0	16.3	18.7	21.0	23.2
Grade Stabilization Structure	2.7	5.5	8.2	10.9	13.7	16.4	19.1	21.8	24.6	27.3
Livestock Exclusion, Alternative Water, Heavy Use Protection	2.9	5.8	8.7	11.6	14.5	17.4	20.3	23.2	26.1	28.9

Table 23. Nitrogen load reduction results for Middle Apple Creek watershed

List of Practices	**Nitrogen load reduction by % of land treated**									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.5	1.0	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.2
Field Borders	2.5	5.1	7.6	10.2	12.8	15.3	17.9	20.4	23.0	25.5
Grassed Waterways	2.5	5.1	7.6	10.2	12.8	15.3	17.9	20.4	23.0	25.5
Grade Stabilization Structure	2.9	5.7	8.6	11.4	14.3	17.1	19.9	22.8	25.6	28.5
Cover Crop and No Till	2.4	4.8	7.3	9.7	12.2	14.6	17.0	19.5	21.9	24.2
Water and Sediment Control Basin	2.8	5.6	8.4	11.2	14.0	16.8	19.6	22.4	25.2	28.1
Land Retirement	3.5	7.1	10.6	14.1	17.7	21.2	24.7	28.2	31.8	35.4
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Forage and Biomass Planting	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0
Alternative Water	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	6.9
Winter Feeding Facilities	1.7	3.5	5.2	6.9	8.7	10.4	12.1	13.8	15.6	17.3
Critical Area Planting	1.1	2.1	3.2	4.3	5.4	6.4	7.5	8.6	9.6	10.7
Access Control	1.4	2.7	4.1	5.5	6.9	8.2	9.6	11.0	12.3	13.7
Prescribed Grazing, Alternative Water, and Heavy Use Protection	2.8	5.7	8.5	11.4	14.3	17.1	20.0	22.8	25.7	28.5
Grade Stabilization Structure	3.6	7.2	10.8	14.4	18.0	21.6	25.2	28.8	32.4	36.0
Livestock Exclusion, Alternative Water, Heavy Use Protection	2.4	4.9	7.3	9.7	12.2	14.6	17.0	19.4	21.9	24.3

Table 24. Phosphorus load reduction results for Middle Apple Creek watershed

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	1.0	1.4	1.9	2.4	2.8	3.3	3.7	4.2	4.8
Field Borders	3.4	6.8	10.2	13.6	17.0	20.4	23.8	27.2	30.6	33.9
Grassed Waterways	3.4	6.9	10.3	13.8	17.3	20.7	24.2	27.6	31.1	34.5
Grade Stabilization Structure	3.9	7.7	11.6	15.4	19.3	23.1	26.9	30.8	34.6	38.5
Cover Crop and No Till	4.0	8.0	12.0	15.9	19.9	23.9	27.8	31.8	35.8	39.9
Water and Sediment Control Basin	4.2	8.5	12.7	16.9	21.2	25.4	29.6	33.8	38.1	42.3
Land Retirement	4.7	9.5	14.2	18.9	23.7	28.4	33.1	37.8	42.6	47.3
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Forage and Biomass Planting	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
Alternative Water	0.5	0.9	1.4	1.9	2.4	2.8	3.3	3.8	4.2	4.6
Winter Feeding Facilities	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0
Critical Area Planting	1.0	1.9	2.9	3.9	4.9	5.8	6.8	7.8	8.7	9.7
Access Control	1.4	2.9	4.3	5.7	7.2	8.6	10.0	11.4	12.9	14.4
Prescribed Grazing, Alternative Water, and Heavy Use Protection	1.7	3.3	5.0	6.6	8.3	9.9	11.5	13.2	14.8	16.6
Grade Stabilization Structure	2.2	4.5	6.7	9.0	11.3	13.5	15.8	18.0	20.3	22.4
Livestock Exclusion, Alternative Water, Heavy Use Protection	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	19.9

Table 25. Sediment load reduction results for Middle Apple Creek watershed

List of Practices	Sediment load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	4.9
Field Borders	3.2	6.4	9.6	12.8	16.0	19.2	22.4	25.6	28.8	32.0
Grassed Waterways	3.2	6.4	9.6	12.8	16.0	19.2	22.4	25.6	28.8	32.0
Grade Stabilization Structure	3.7	7.4	11.1	14.8	18.5	22.2	25.9	29.6	33.3	37.0
Cover Crop and No Till	3.9	7.8	11.7	15.6	19.5	23.4	27.3	31.2	35.1	39.1
Water and Sediment Control Basin	4.2	8.5	12.7	17.0	21.3	25.5	29.8	34.0	38.3	42.4
Land Retirement	4.7	9.4	14.0	18.7	23.4	28.0	32.7	37.3	42.0	46.8
Pastureland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Forage and Biomass Planting	0	0	0	0	0	0	0	0	0	0
Alternative Water	0.4	0.8	1.1	1.5	1.9	2.2	2.6	2.9	3.3	3.8
Winter Feeding Facilities	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.1
Critical Area Planting	0.9	1.7	2.6	3.4	4.3	5.1	5.9	6.8	7.6	8.5
Access Control	1.3	2.5	3.8	5.0	6.3	7.5	8.7	10.0	11.2	12.6
Prescribed Grazing, Alternative Water, and Heavy Use Protection	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	12.9
Grade Stabilization Structure	1.5	3.0	4.6	6.1	7.7	9.2	10.7	12.3	13.8	15.2
Livestock Exclusion, Alternative Water, Heavy Use Protection	1.6	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.1

Table 26. Management unit priority ranking for the Upper and Middle Apple Creek watershed

Watershed ID	Total Ad (ac)	Crop Acres	Pasture Acres	Annual Yield N-lb/ac/yr	Annual Yield Sed-T/ac/yr	Priority Rank
15	2,834	1,390	1,019	10.87	1.72	1
6	2,815	582	1,394	12.66	2.05	2
24	2,243	330	926	12.11	2.10	3
28	1,930	370	1,108	12.32	2.04	4
3	3,255	1,250	1,057	11.10	1.80	5
10	3,779	977	2,131	12.06	1.76	5
27	1,563	161	848	11.03	1.77	7
12	2,517	591	1,125	10.95	1.70	8
9	2,770	517	1,452	11.29	1.65	8
22	2,557	899	1,181	10.89	1.68	10
21	2,282	248	1,223	10.50	1.67	11
5	3,402	777	1,403	10.50	1.64	12
14	3,864	1,493	1,251	10.23	1.74	13
11	3,414	830	1,566	10.46	1.54	14
7	3,624	792	1,670	10.43	1.49	15
20	3,041	602	1,406	10.12	1.54	16
23	2,690	296	1,194	9.32	1.54	17
17	2,476	526	1,340	10.31	1.35	18
13	3,186	632	1,780	10.38	1.34	18
4	2,002	474	902	9.74	1.36	20
2	2,596	440	944	9.11	1.47	21
8	2,856	514	1,050	9.07	1.37	22
26	3,111	103	1,756	9.43	1.29	22
18	2,433	367	1,120	9.39	1.26	24
1	3,489	716	1,256	8.26	1.28	25
16	3,420	412	1,736	8.82	1.08	25
25	3,043	263	1,354	8.73	1.16	27
19	3,388	753	1,634	8.76	1.06	28

Table 27. Summary of vulnerable acres for the Upper and Middle Apple Creek watersheds

Vulnerability Rank	Land Use and Conditions	Acres (%)
Highest	Cropland on soils with EI ≥8 and slope ≥8% Pasture on Hydrologic Soil Group D and slope >4% Pasture on Hydrologic Soil Group C and slope >6%	33,277 (40.9%)
High	Cropland on soils with EI ≥8 and slope <8% Pasture on Hydrologic Soil Group D and slope ≤4% Pasture on Hydrologic Soil Group C and slope ≤6% Pasture on Hydrologic Soil Group B and slope >6%	15,899 (19.5%)
Moderate	Remaining Pasture Remaining Cropland	5,653 (7.0%)
Low	Forest	21,382 (26.3%)
N/A	Urban Water and Wetlands	5,123 (6.3%)
	Total	81,334 (100%)

Table 28. Ranked conservation practices by most benefit per acres treated

Rank	BMPs in Upper Apple Creek watershed for **nitrogen reduction**	BMPs in Middle Apple Creek watershed for **sediment reduction**
1	PASTURELAND - Grade Stabilization Structure	CROPLAND - Land Retirement
2	PASTURELAND - Prescribed Grazing, Alternative Water, and Heavy Use Protection	CROPLAND - Water and Sediment Control Basin
3	PASTURELAND - Livestock Exclusion, Alternative Water, Heavy Use Protection	CROPLAND - Cover Crop and No Till
4	CROPLAND - Land Retirement	CROPLAND - Grade Stabilization Structure
5	PASTURELAND - Winter Feeding Facilities	CROPLAND - Field Borders
6	CROPLAND - Grade Stabilization Structure	CROPLAND - Grassed Waterways
7	CROPLAND - Water and Sediment Control Basin	PASTURELAND - Livestock Exclusion, Alternative Water, Heavy Use Protection
8	PASTURELAND - Access Control	PASTURELAND - Grade Stabilization Structure
9	CROPLAND - Grassed Waterways	PASTURELAND - Prescribed Grazing, Alternative Water, and Heavy Use Protection
10	CROPLAND - Field Borders	PASTURELAND - Access Control
11	CROPLAND - Cover Crop and No Till	PASTURELAND - Critical Area Planting
12	PASTURELAND - Critical Area Planting	PASTURELAND - Winter Feeding Facilities
13	PASTURELAND - Alternative Water	CROPLAND - Cover Crop
14	PASTURELAND - Forage and Biomass Planting	PASTURELAND - Alternative Water
15	CROPLAND - Cover Crop	PASTURELAND - Forage and Biomass Planting

FIGURES

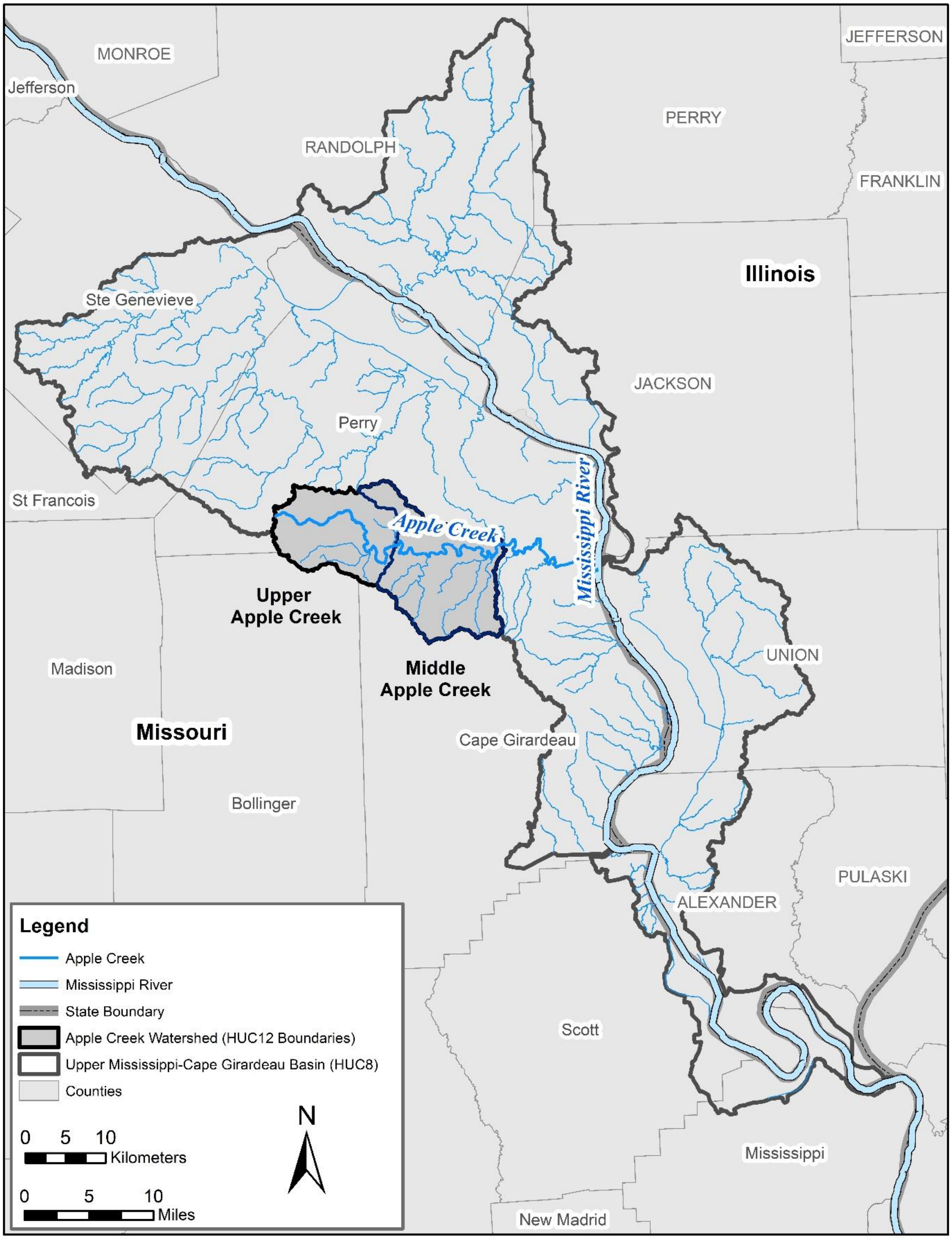


Figure 1. Upper Mississippi- Cape Girardeau watershed in southeast Missouri and southwest Illinois.

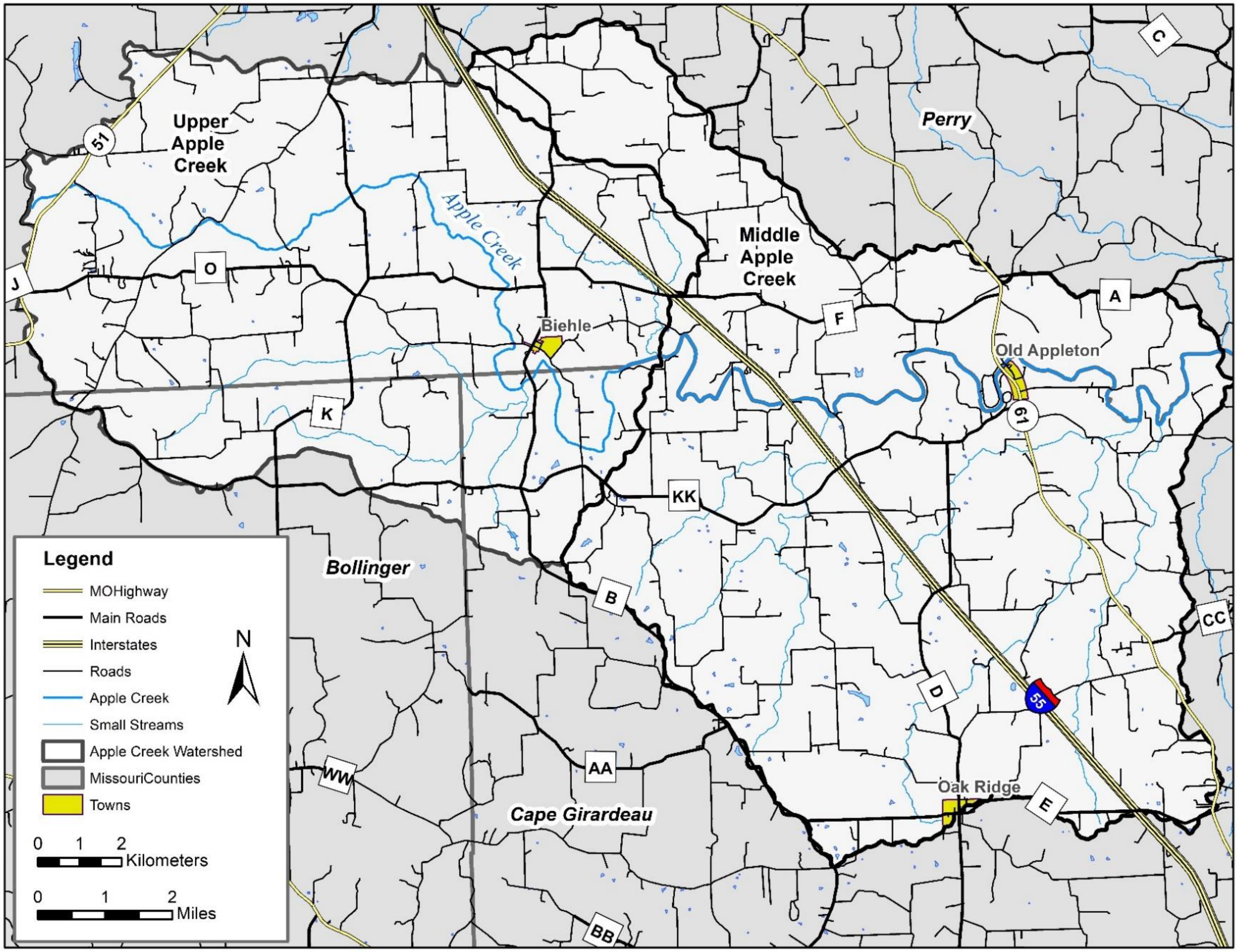


Figure 2. The Upper Apple Creek and Middle Apple Creek Watersheds.

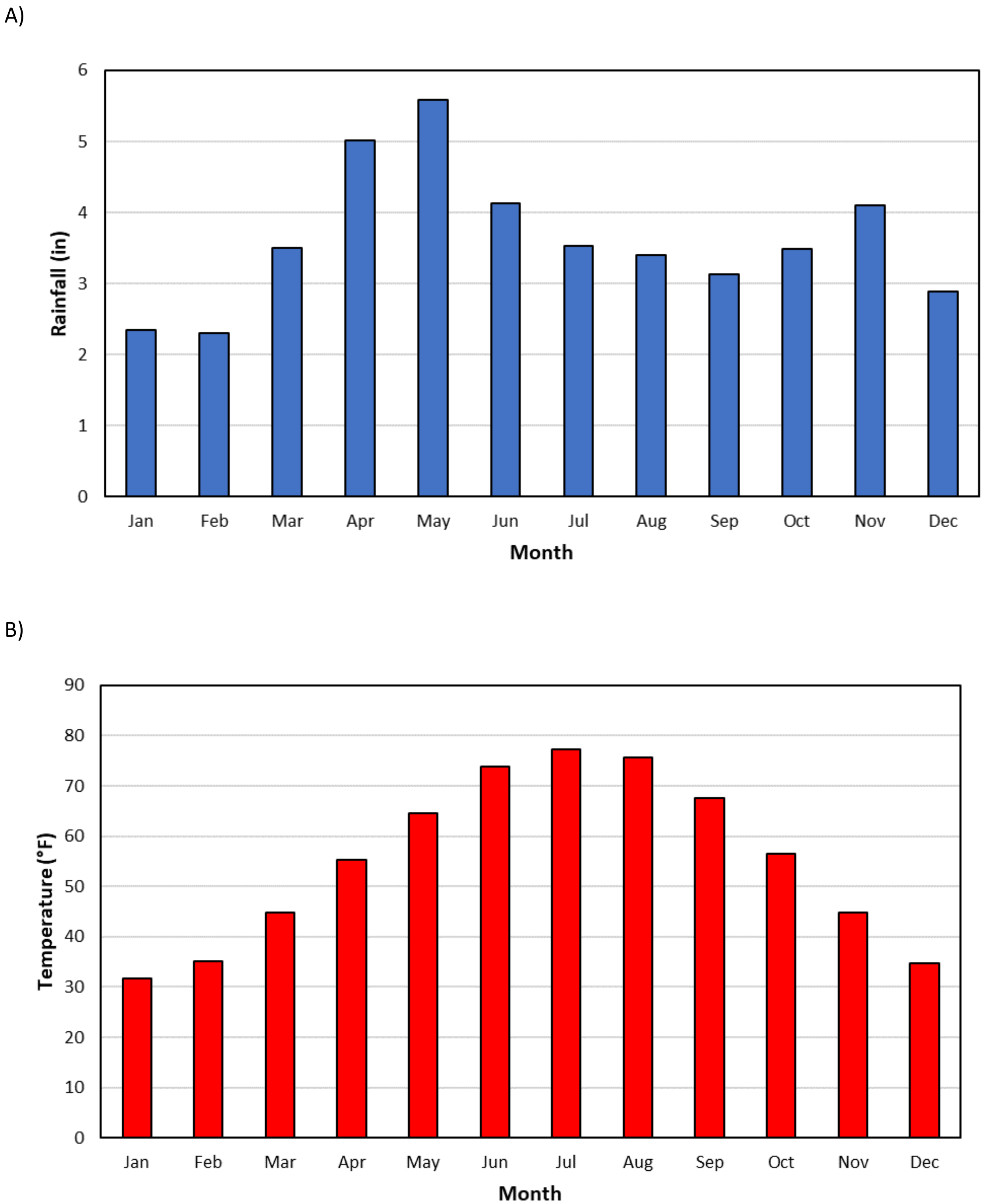
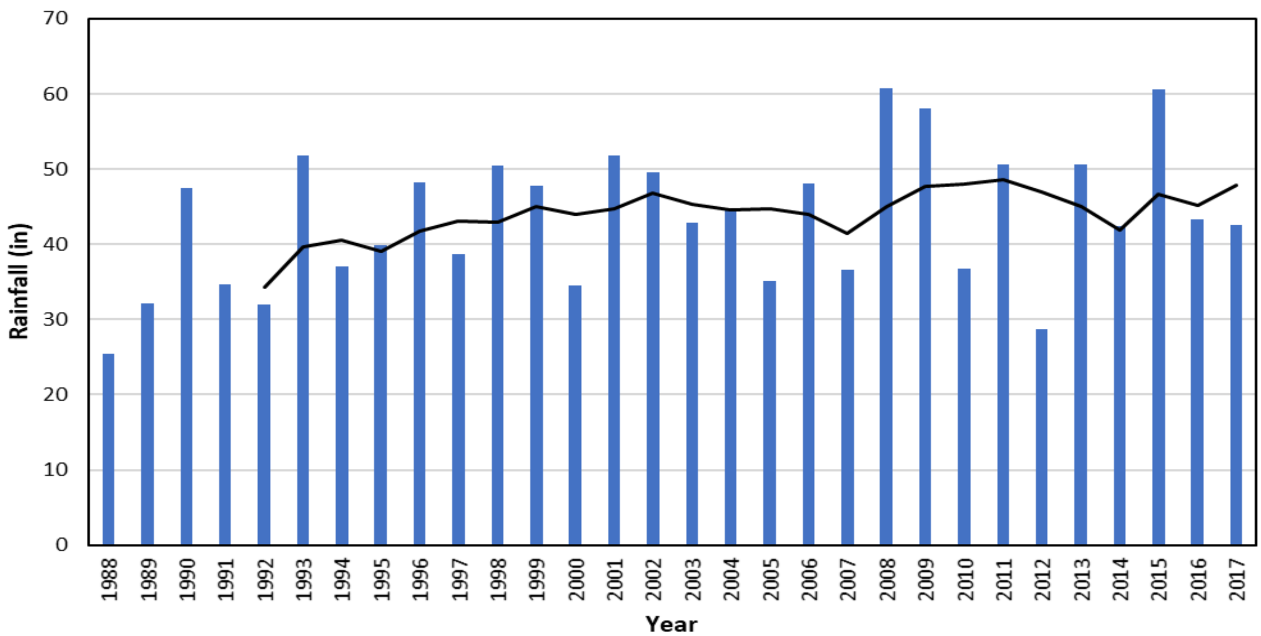


Figure 3. Mean monthly A) rainfall and B) temperature from 1988-2016 for Perryville, Missouri.

A)



B)

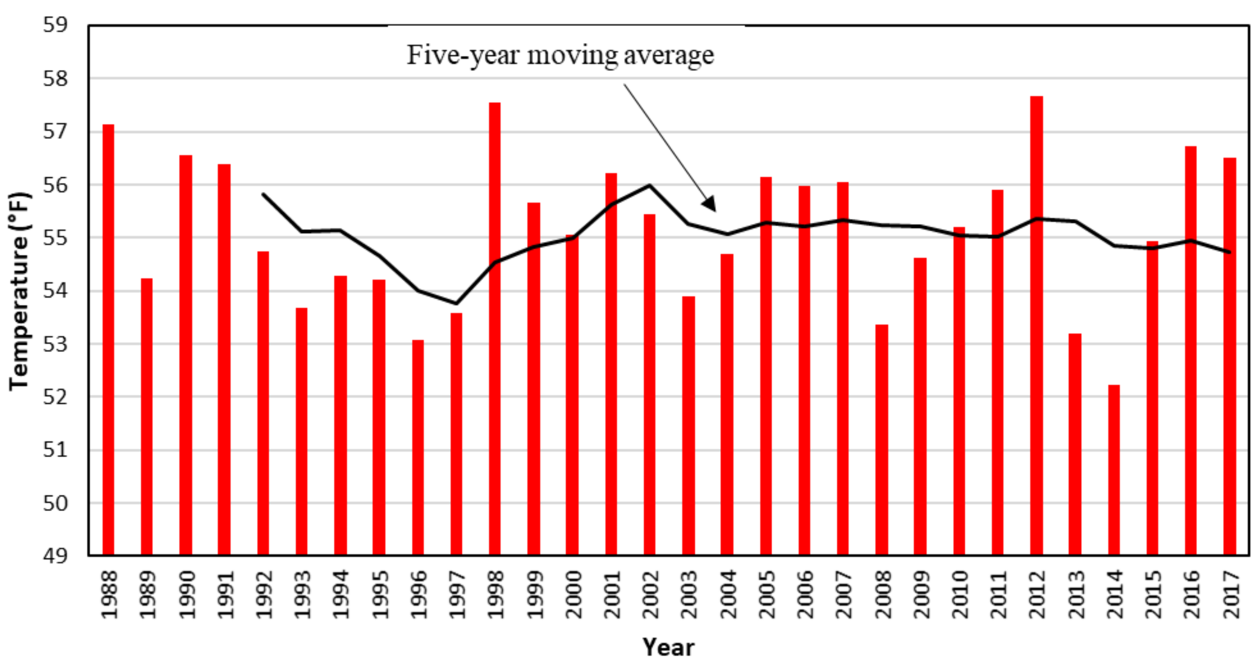
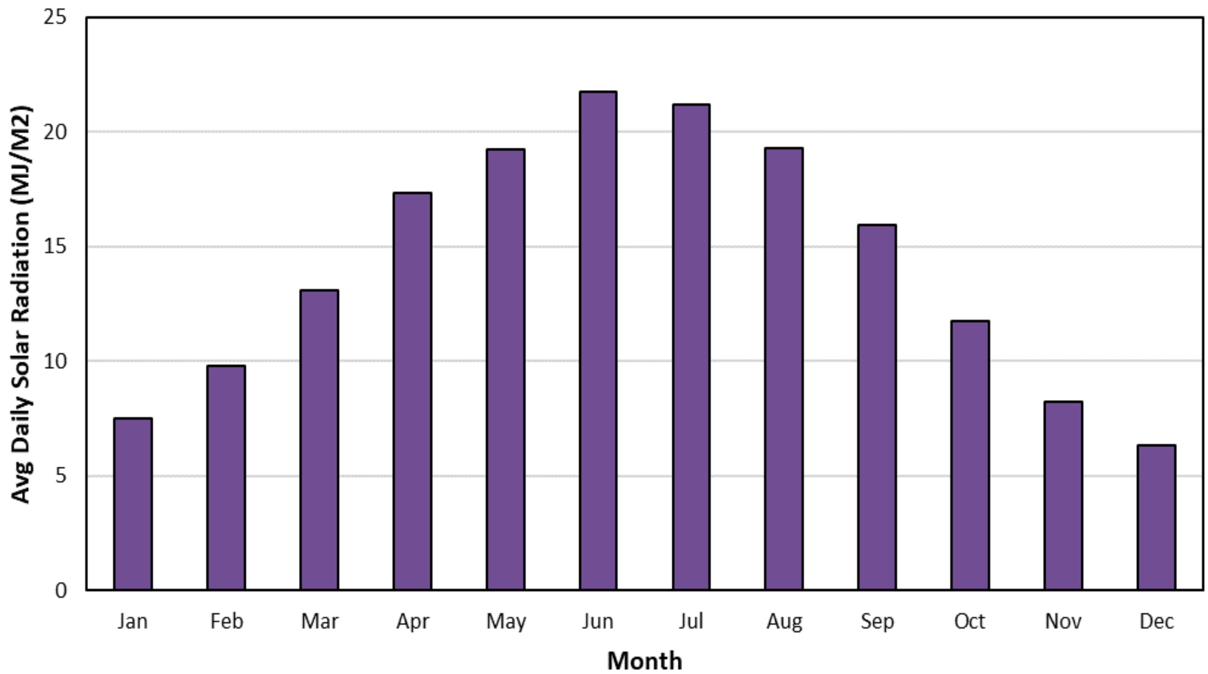


Figure 4. A) Annual total rainfall and B) average annual temperature from 1988-2017 for Perryville, Missouri.

A)



B)

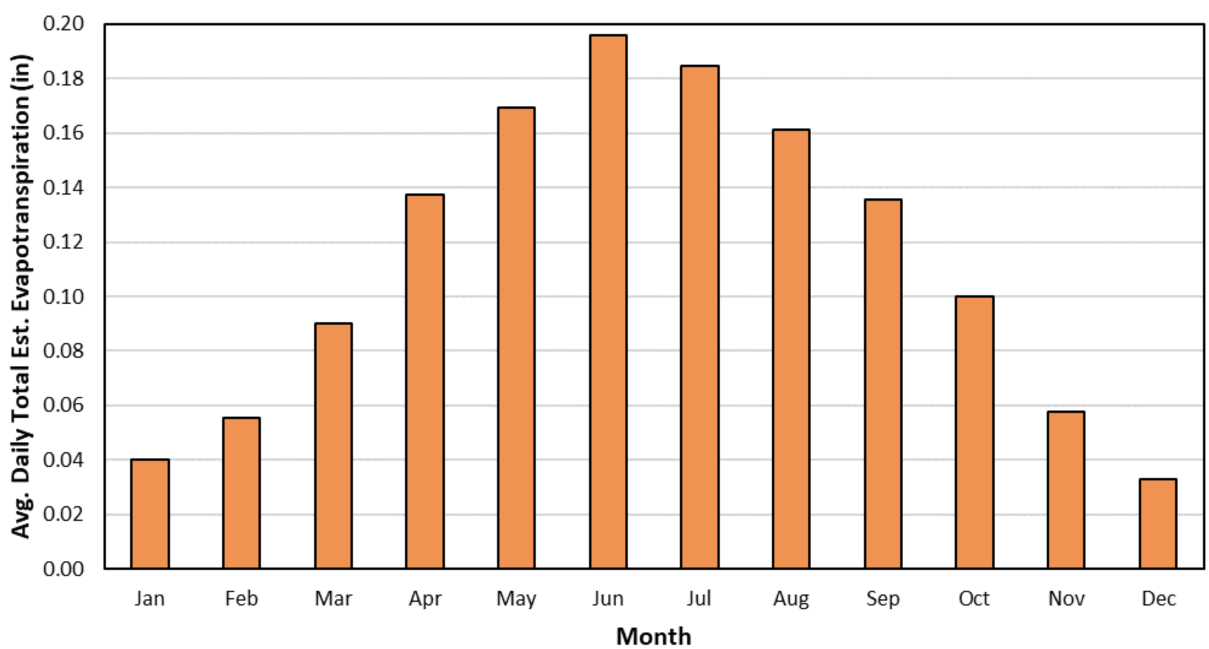


Figure 5. Average daily A) solar radiation (200-2017) for Delta, Missouri and B) estimated evapotranspiration (2000-2017) for Portageville, Missouri.

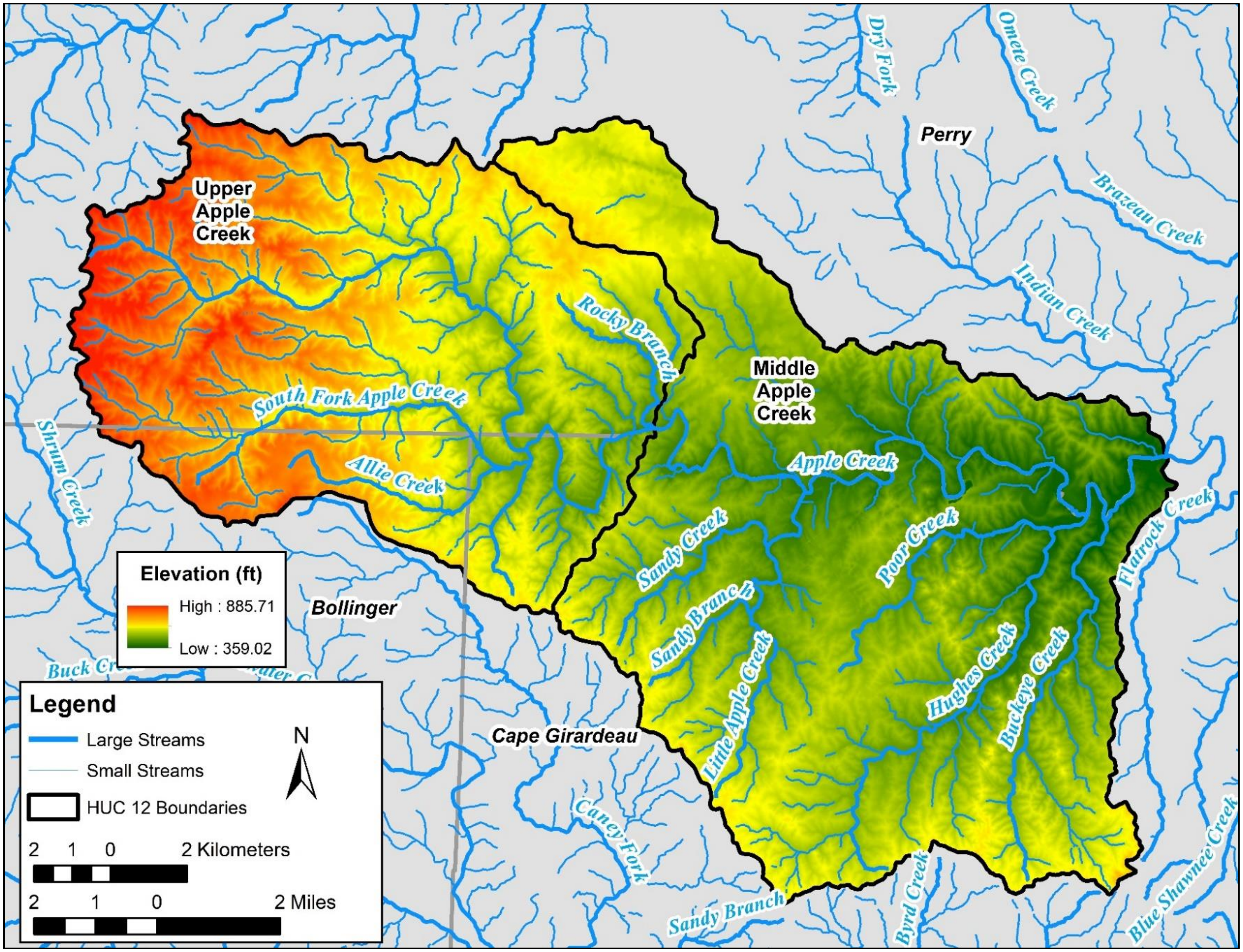


Figure 6. DEM elevations within the watershed.

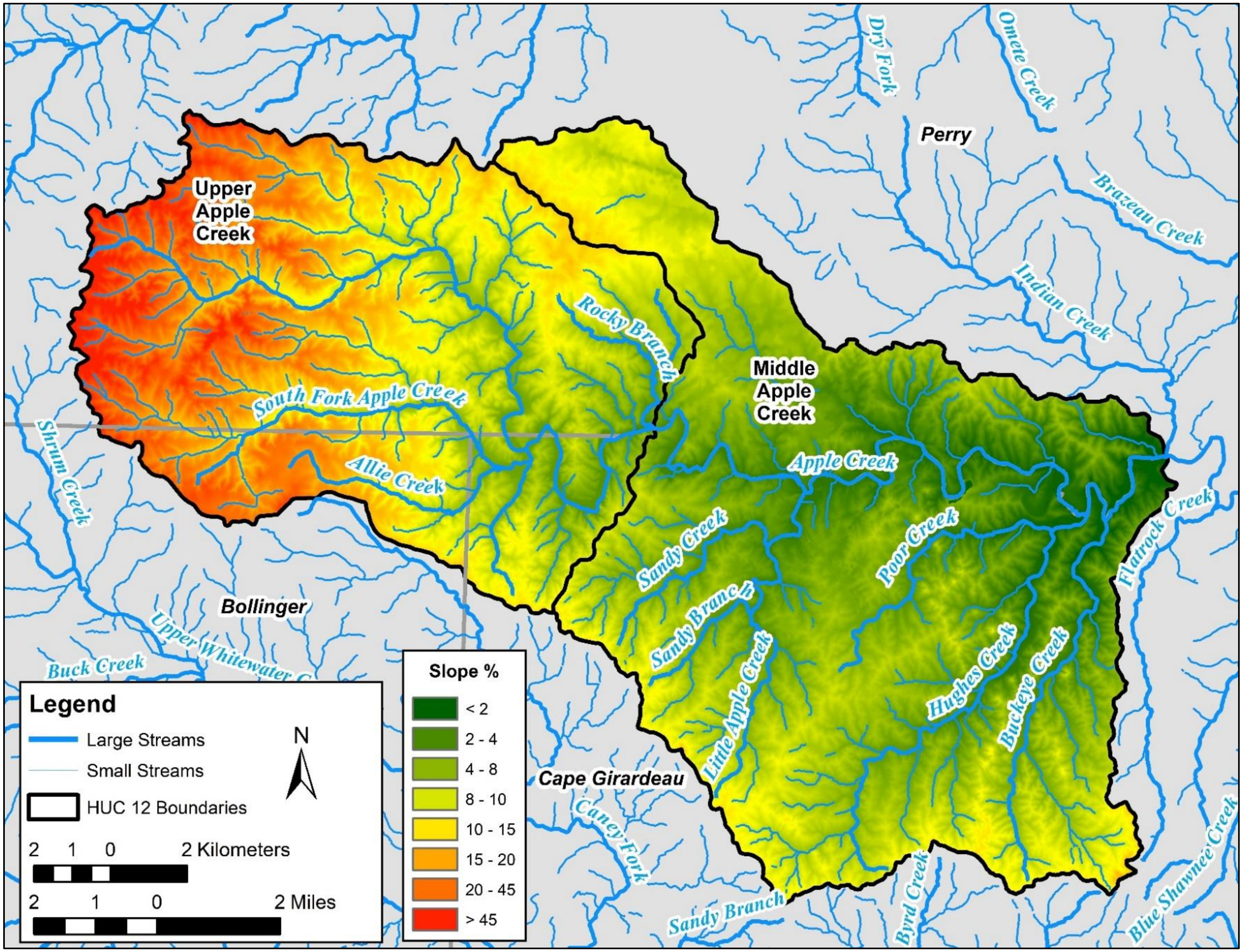


Figure 7. DEM based slope classification across the watershed.

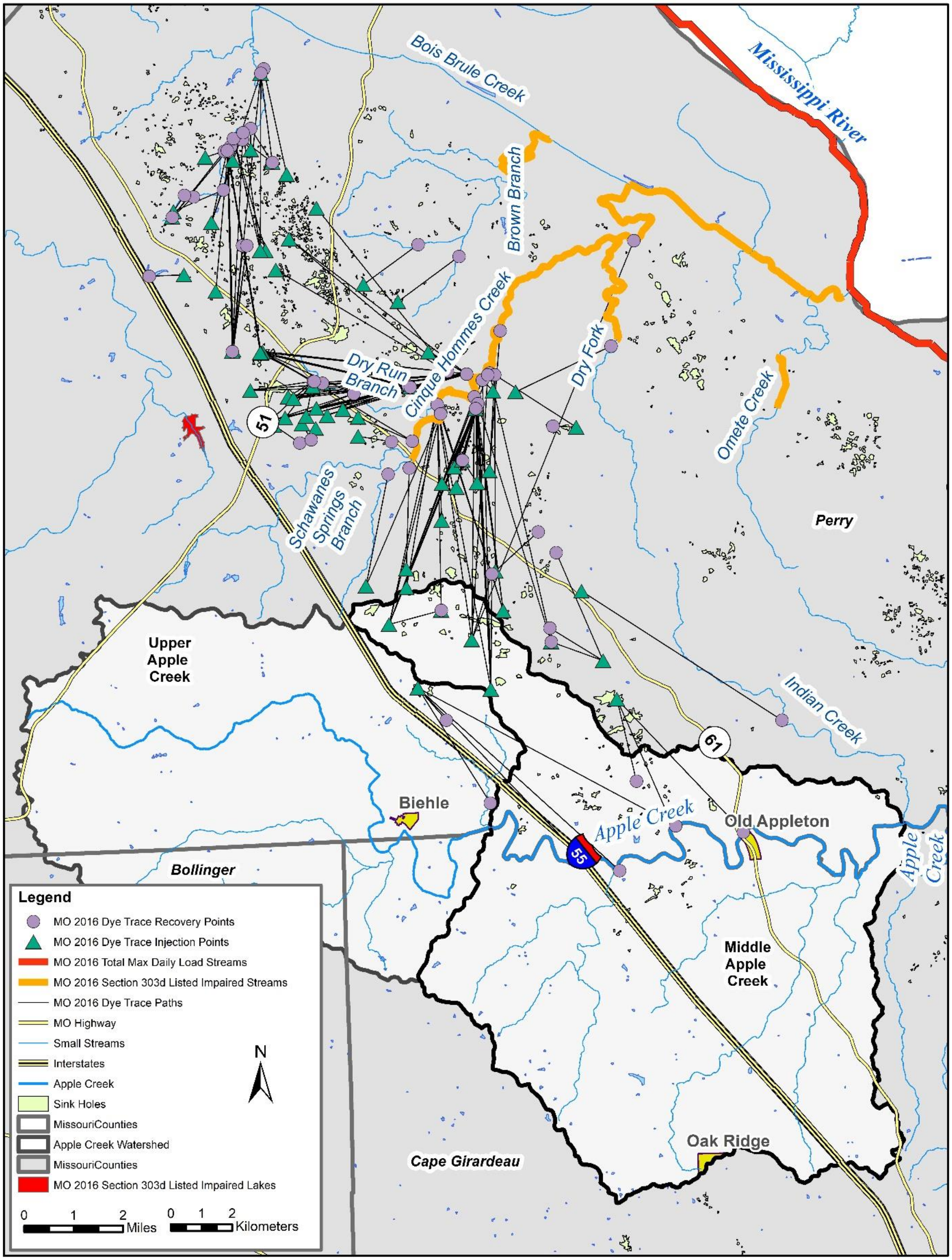


Figure 8. Dye tracing paths in the Perry County Karst Plain.

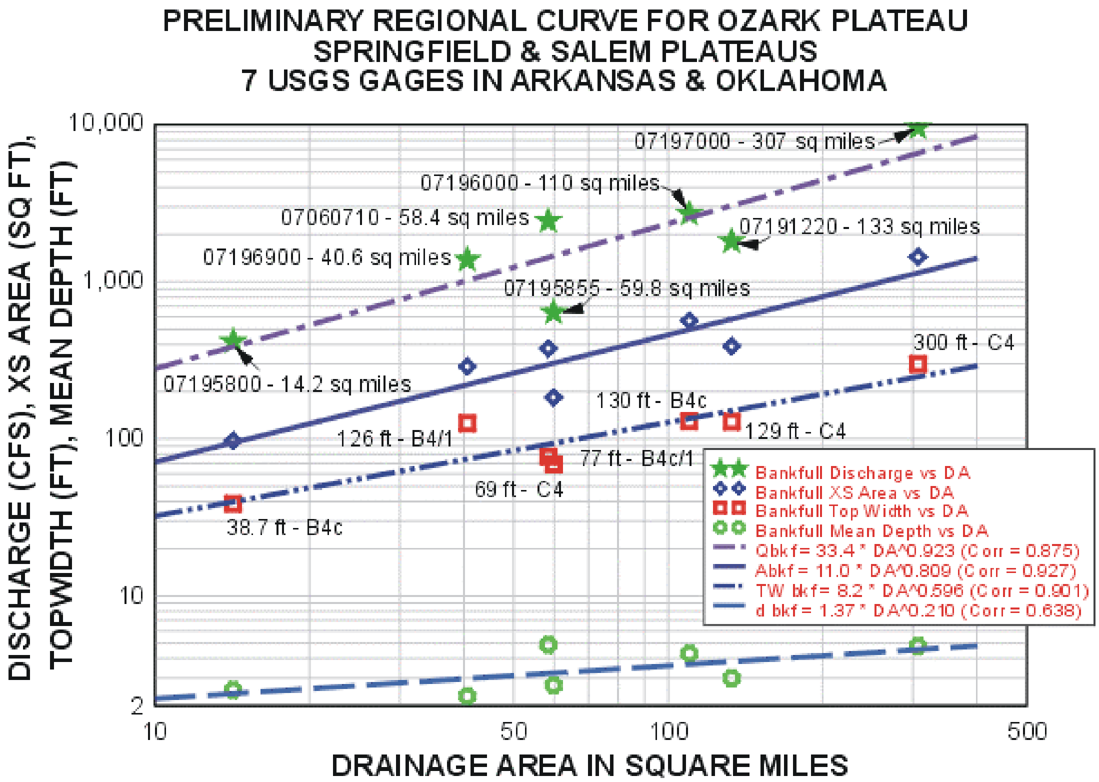


Figure 9. Regional channel geometry curves for A) Springfield and Salem Plateaus and B) Osage Plains. Source: NRCS-National Water Management Center.

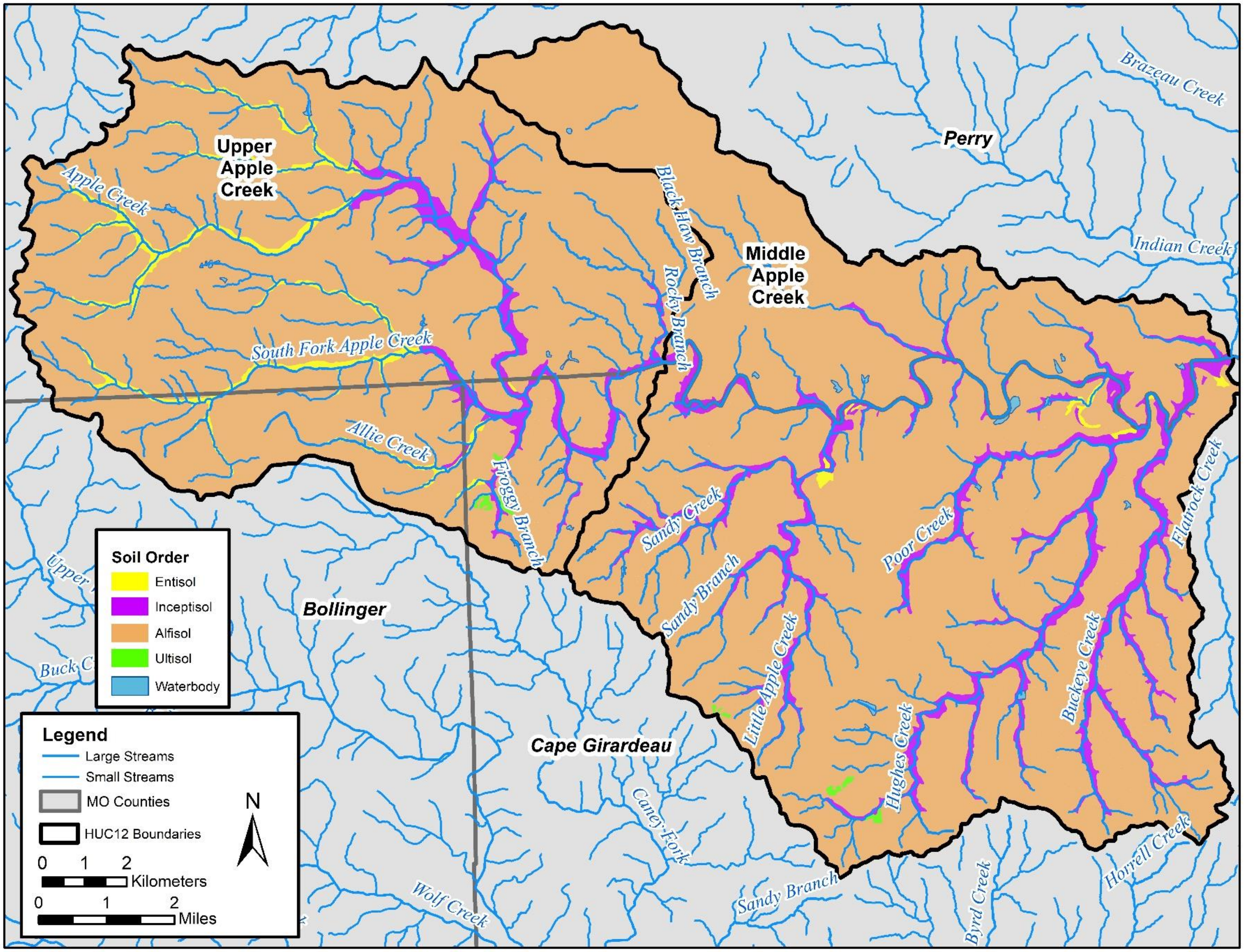


Figure 10. Soil series classified by order.

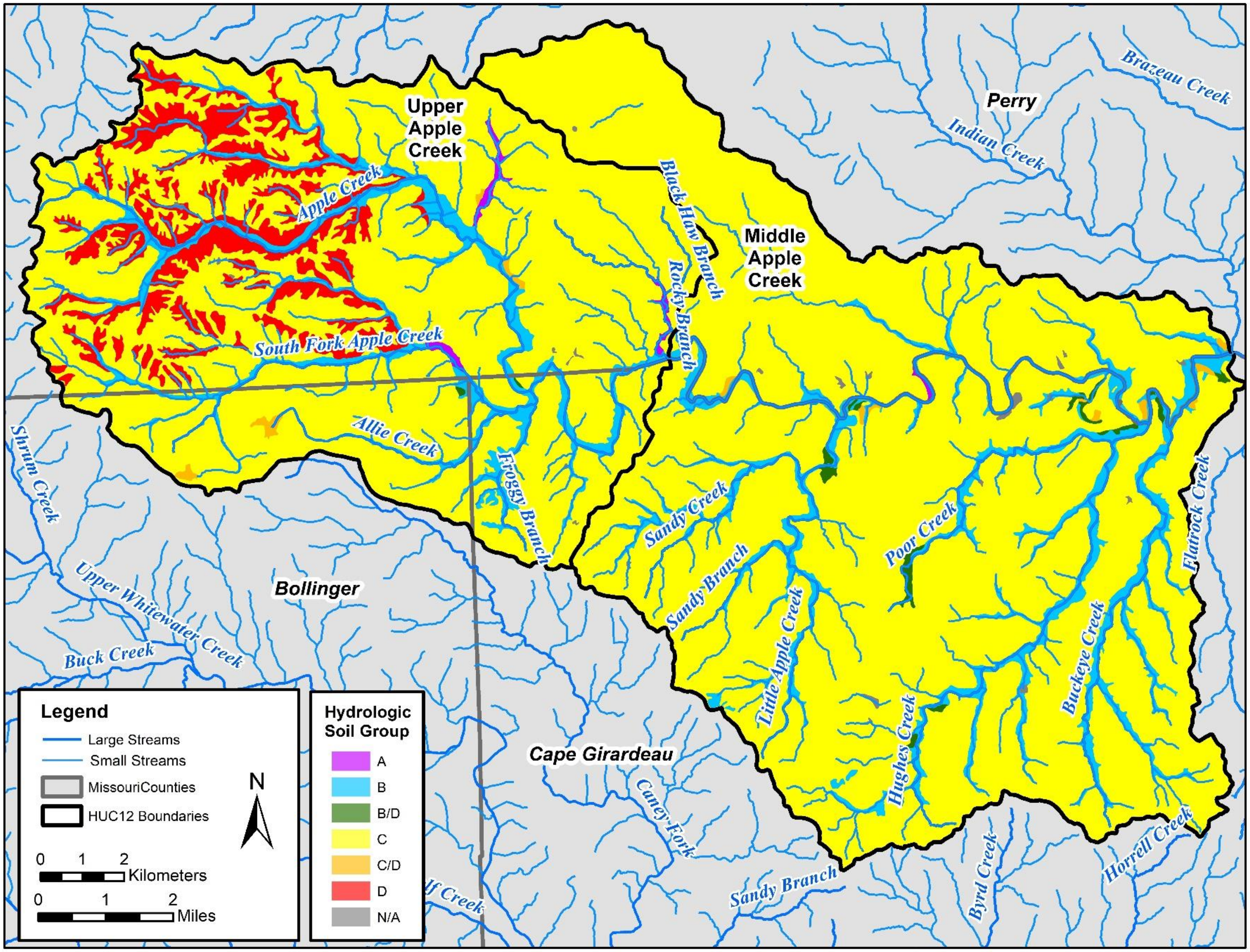


Figure 11. Soil series classified by hydrologic soil group.

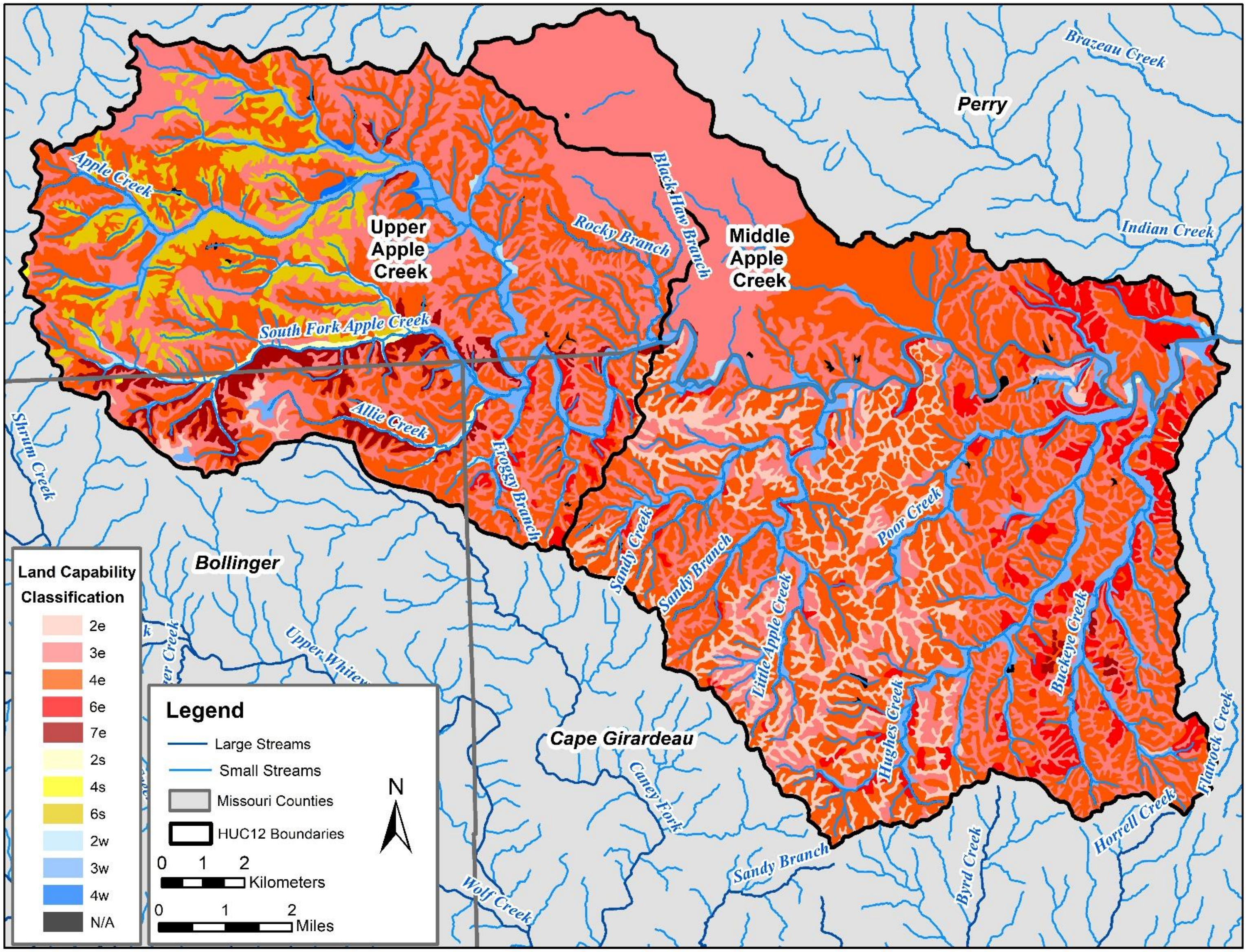


Figure 12. Soil series classified by land capability classification.

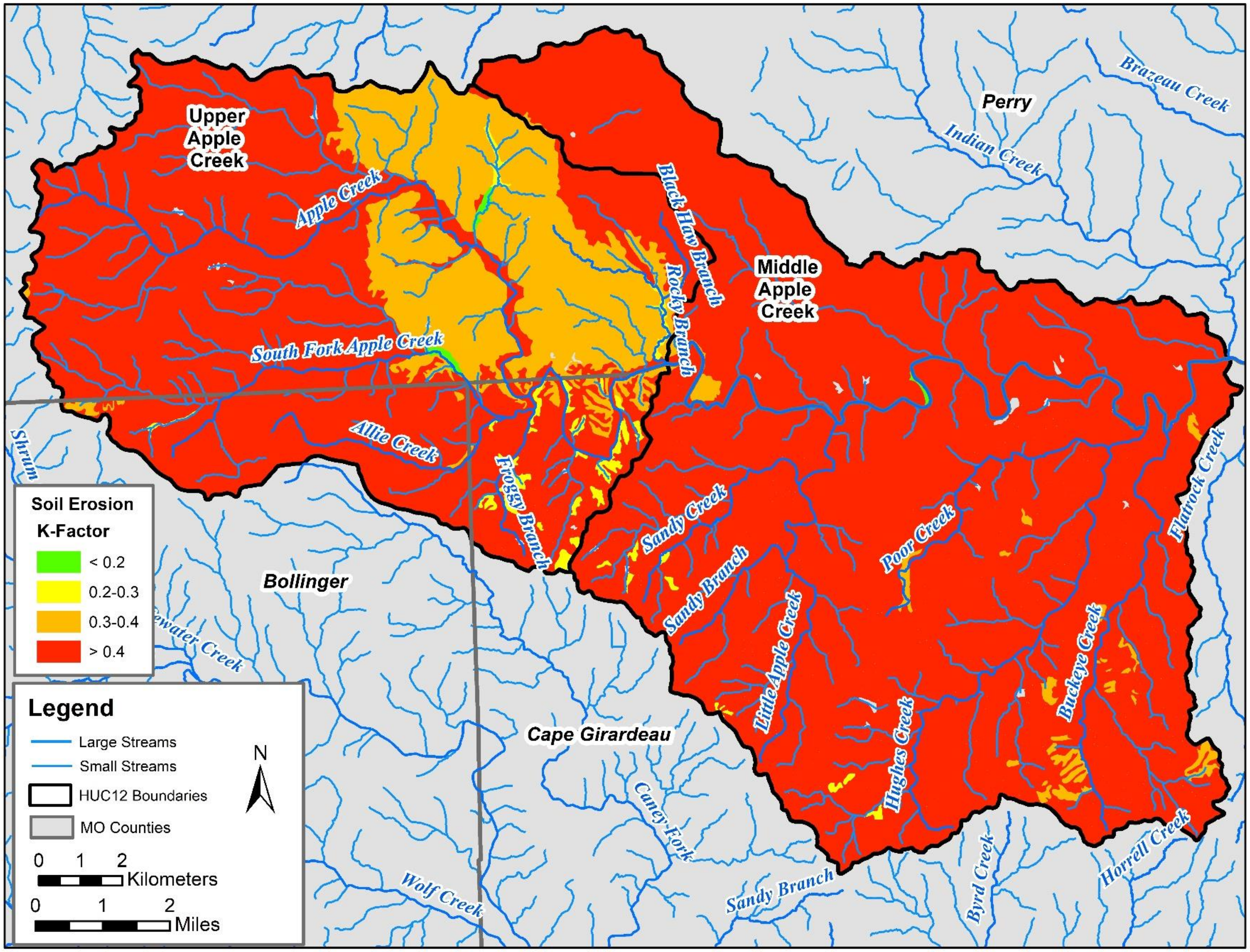


Figure 13. Soil series classified by soil erosion K-factor.

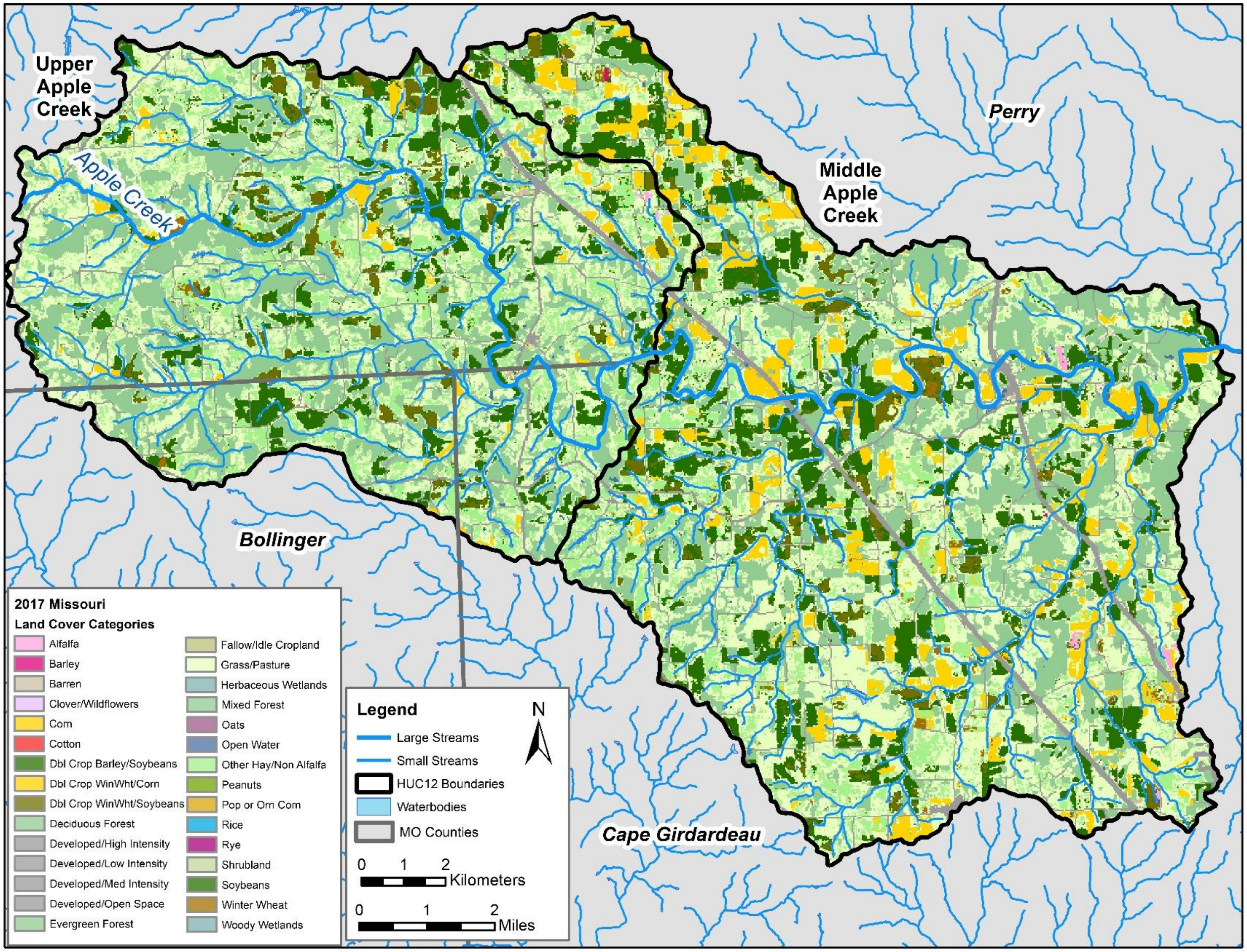


Figure 14. 2017 crop data from the NASS.

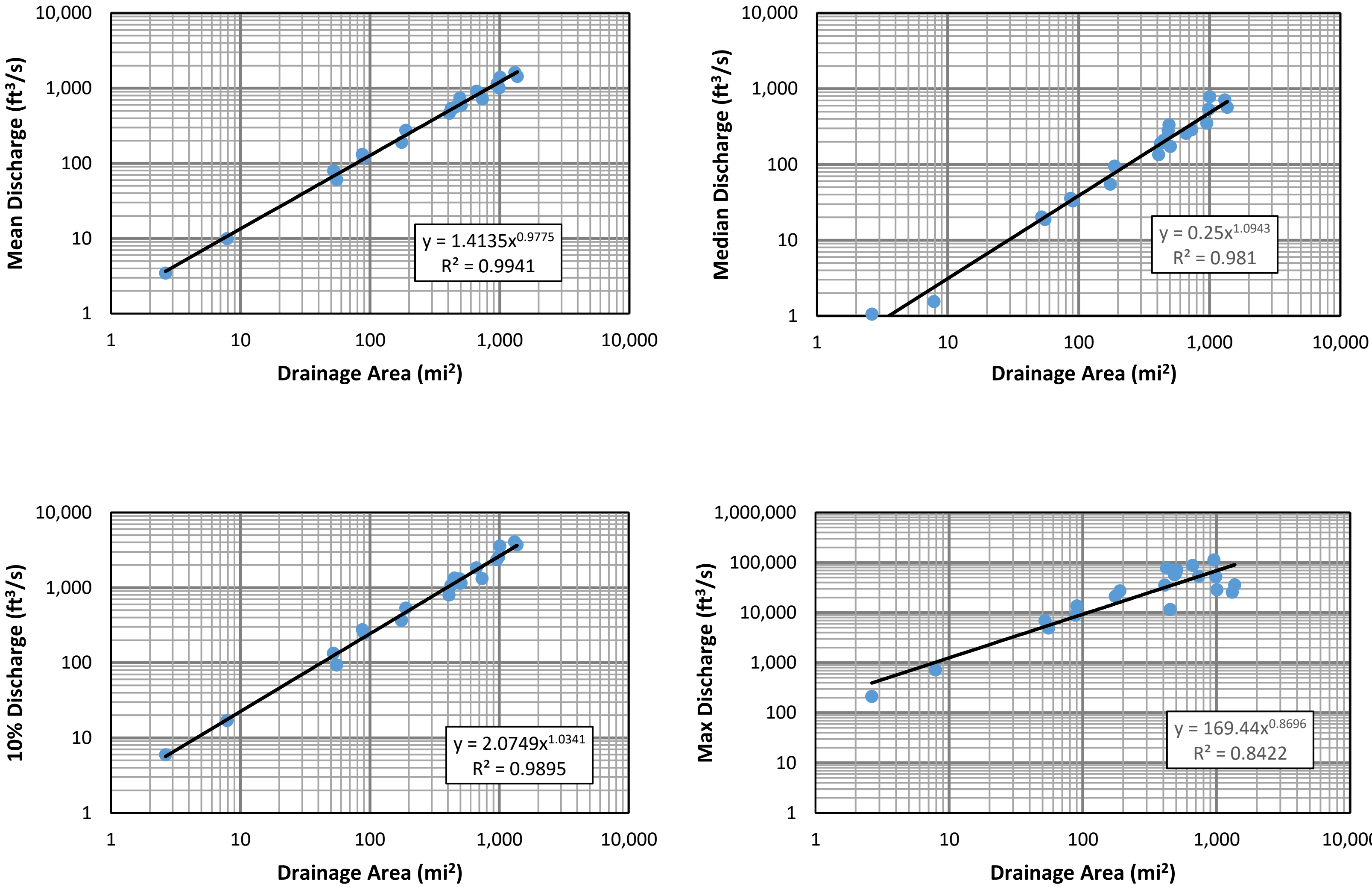


Figure 15. Drainage area and discharge relationships for 21 USGS gaging stations near the study watershed.

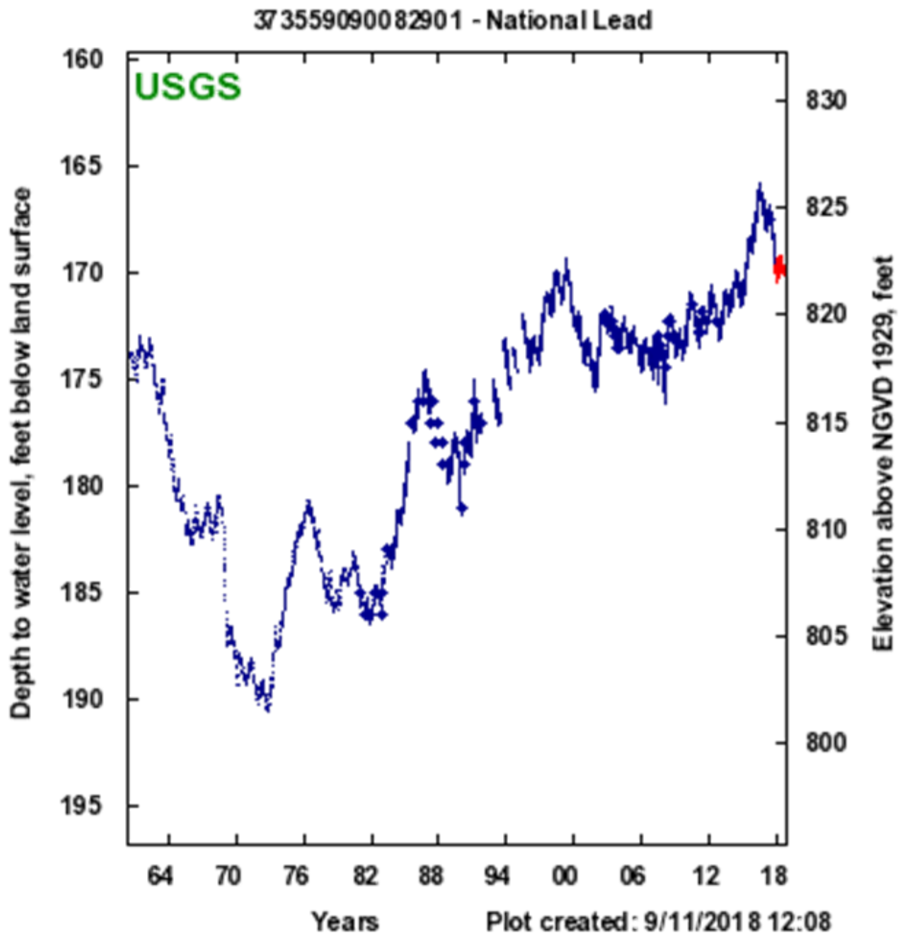


Figure 16. Ground water level change for Perry County, Missouri (1960-2018).

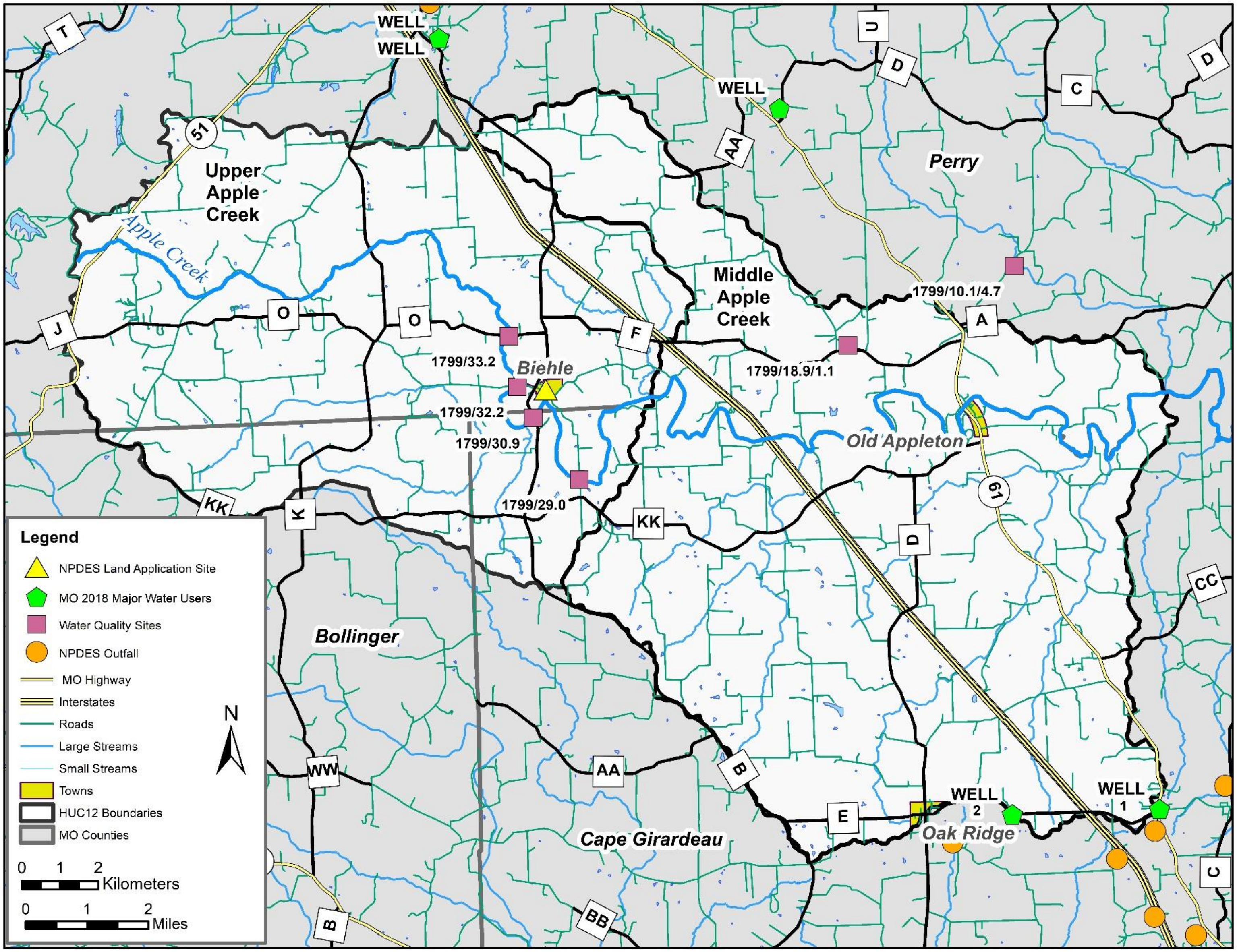


Figure 17. Permitted point sources and water quality monitoring station locations.

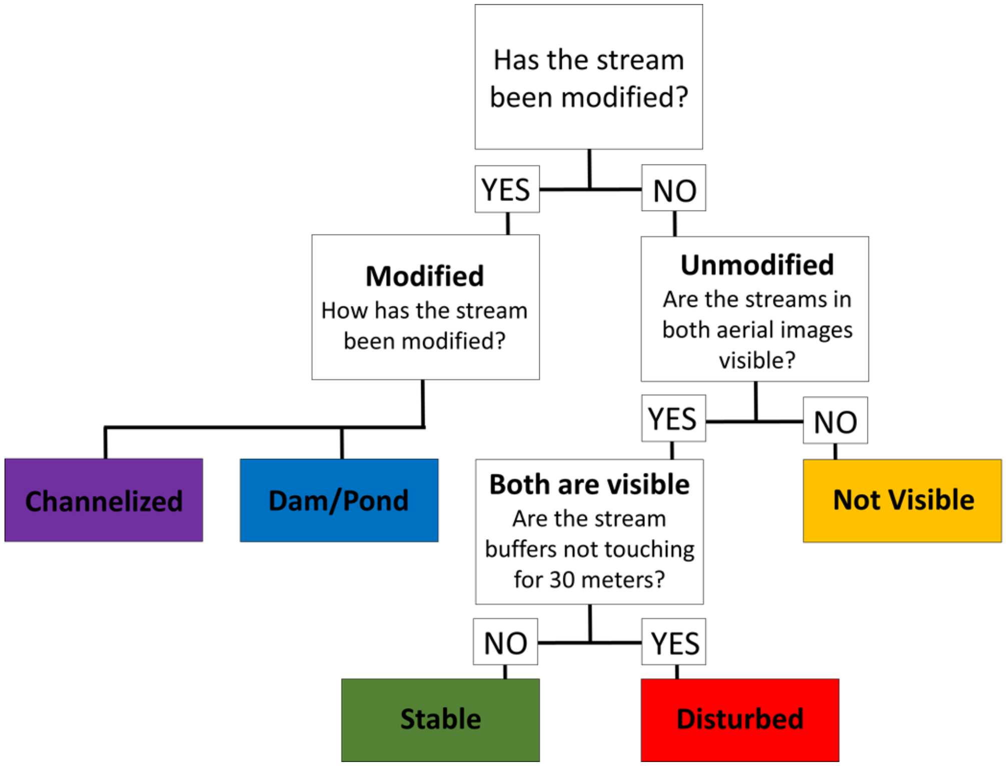


Figure 18. Flow chart showing decision tree for classifying stream channels from aerial photo analysis.

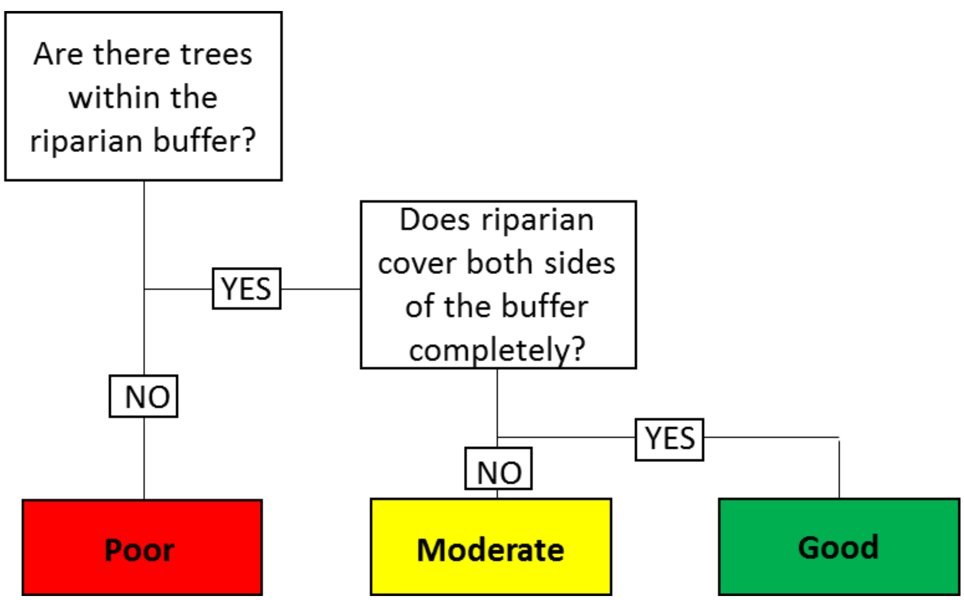


Figure 19. Flow chart showing decision tree for riparian corridor assessment from aerial photo analysis.

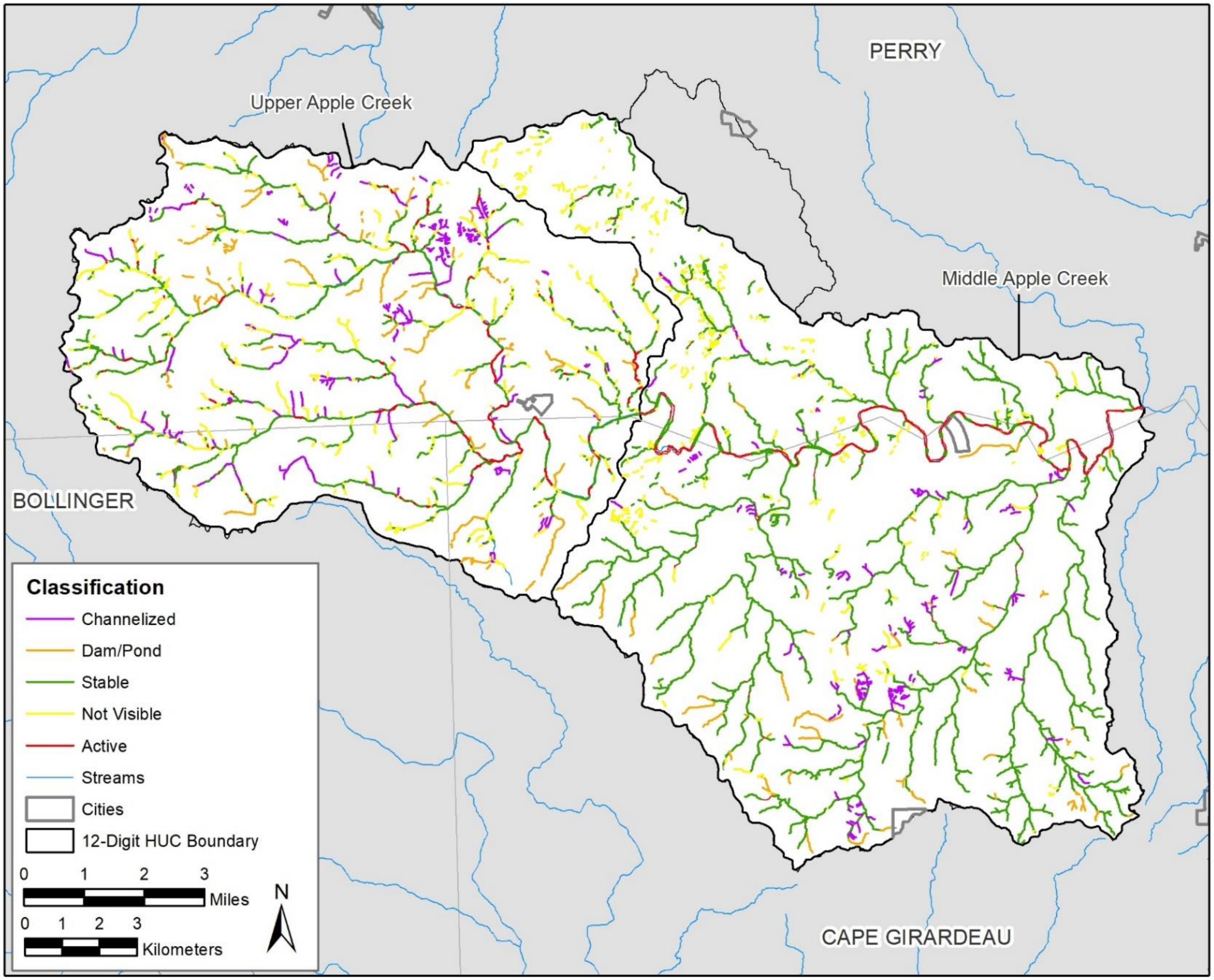


Figure 20. Channel stability classification.

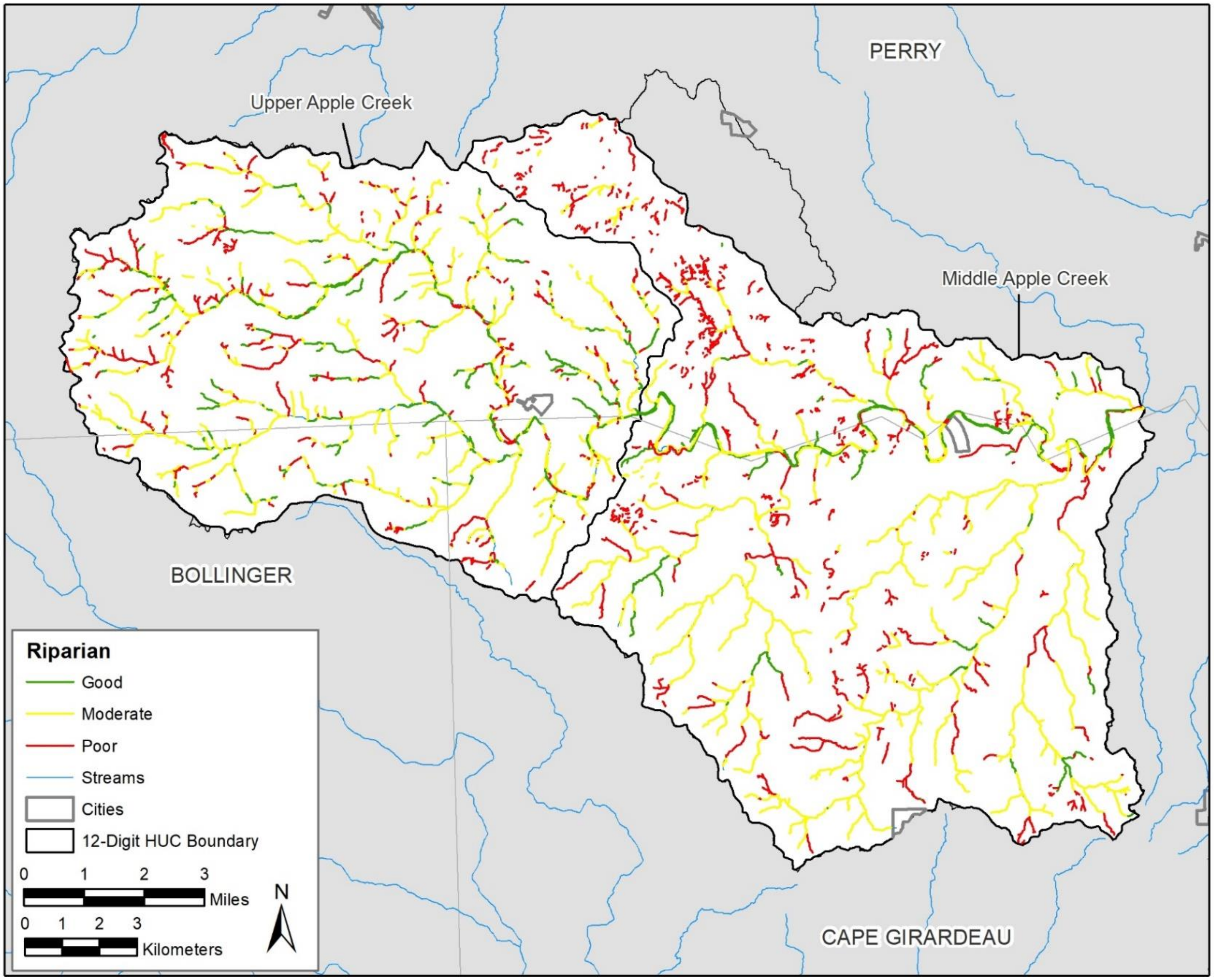


Figure 21. Riparian corridor classification.

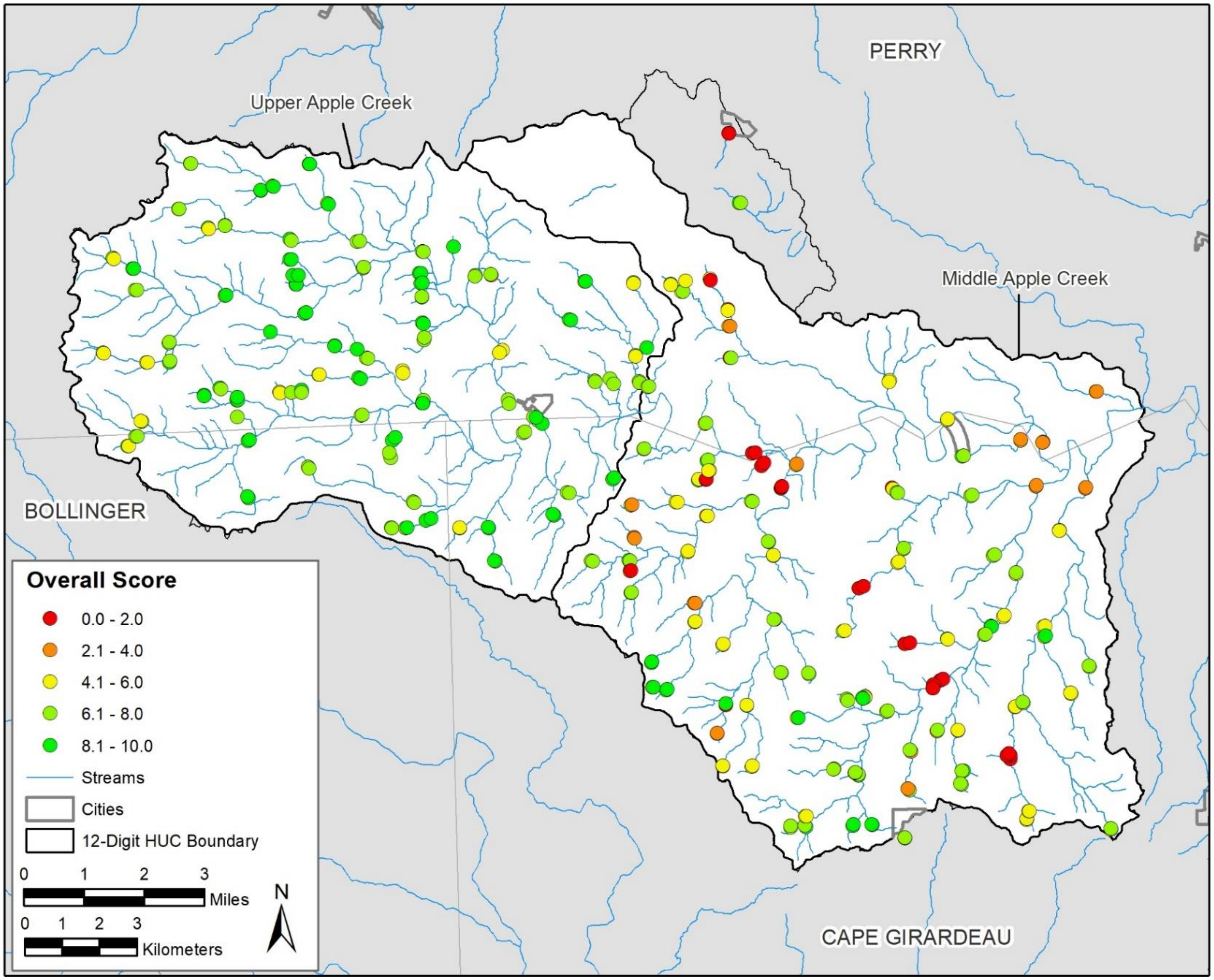
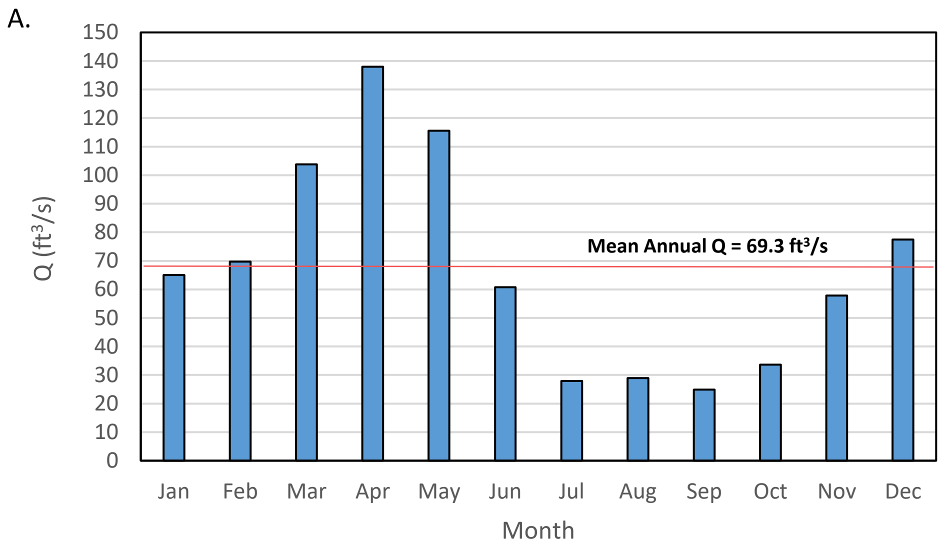


Figure 22. Visual stream assessment results.



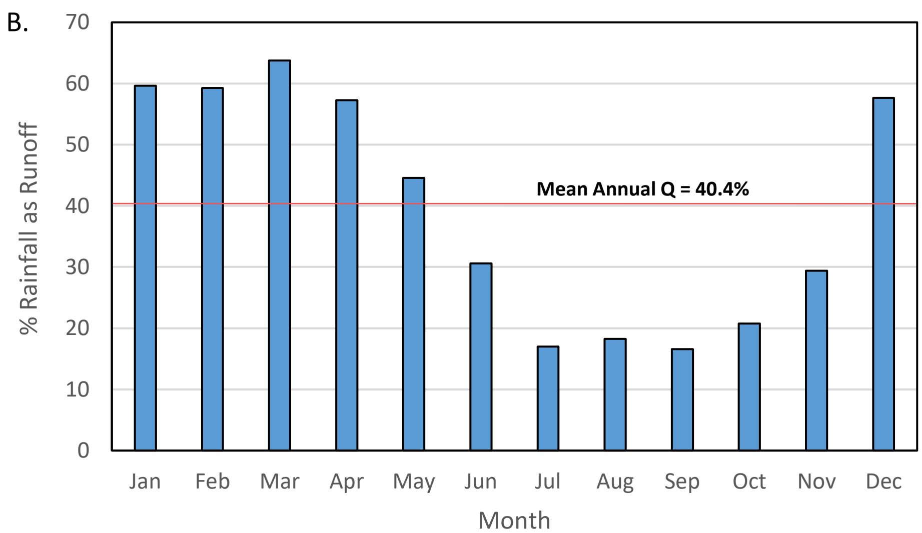


Figure 23. Mean monthly discharge A) and monthly runoff percentage B) for the Upper Apple Creek watershed

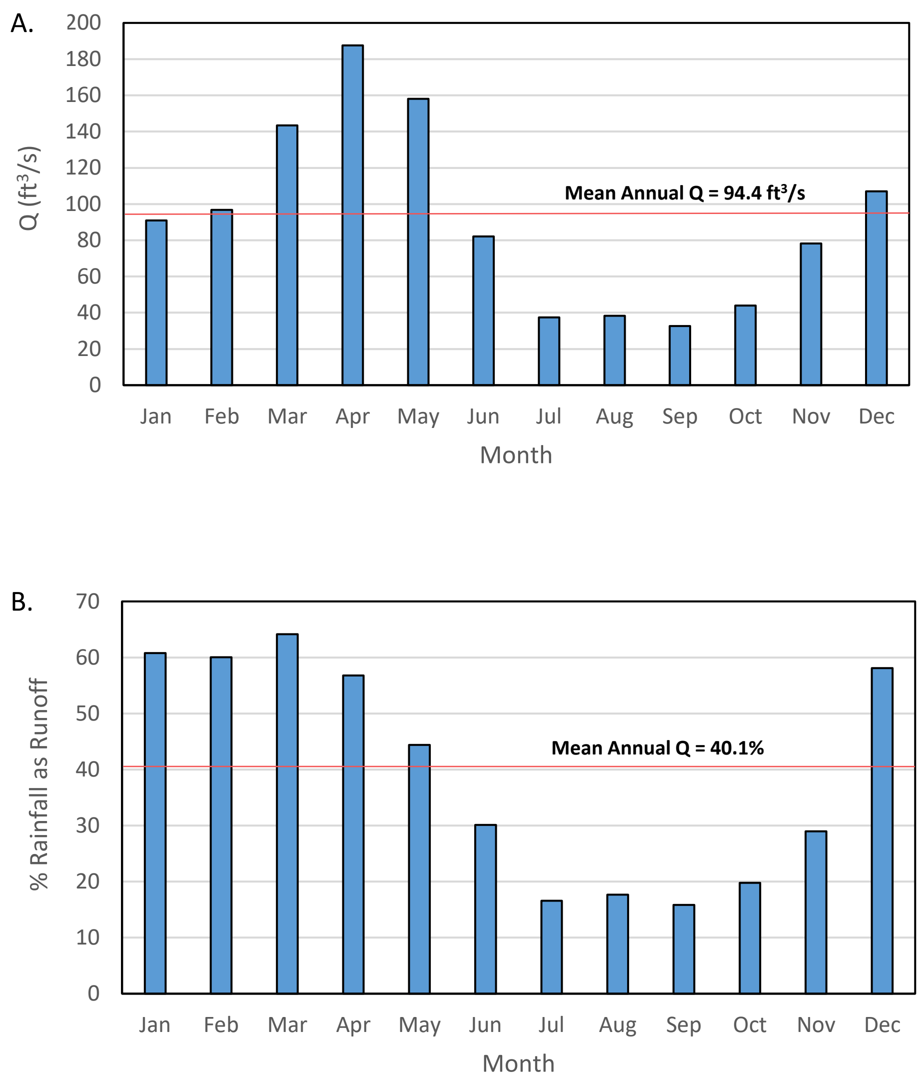


Figure 24. Mean monthly discharge A) and monthly runoff percentage B) for the Middle Apple Creek watershed

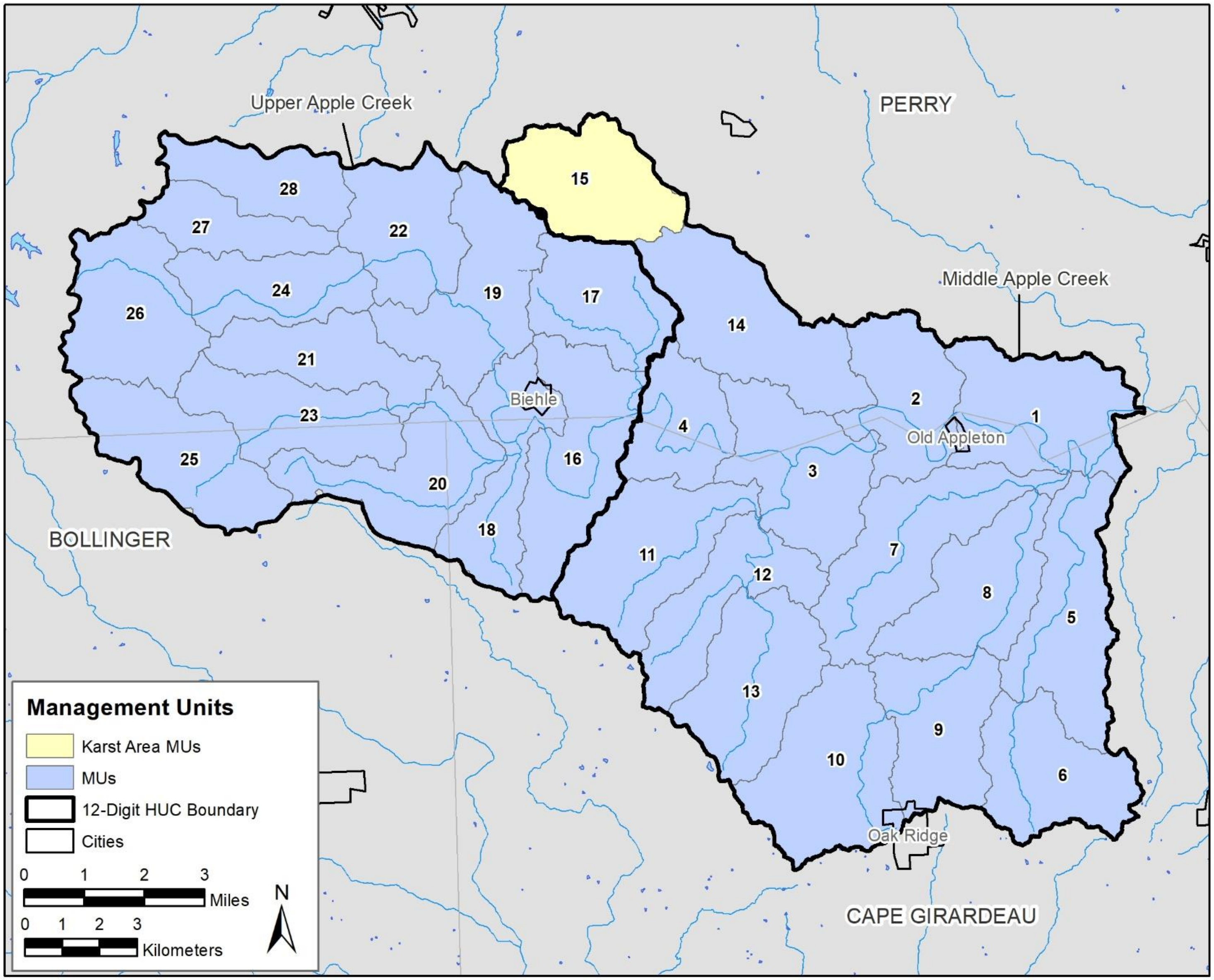


Figure 25. Management unit zones

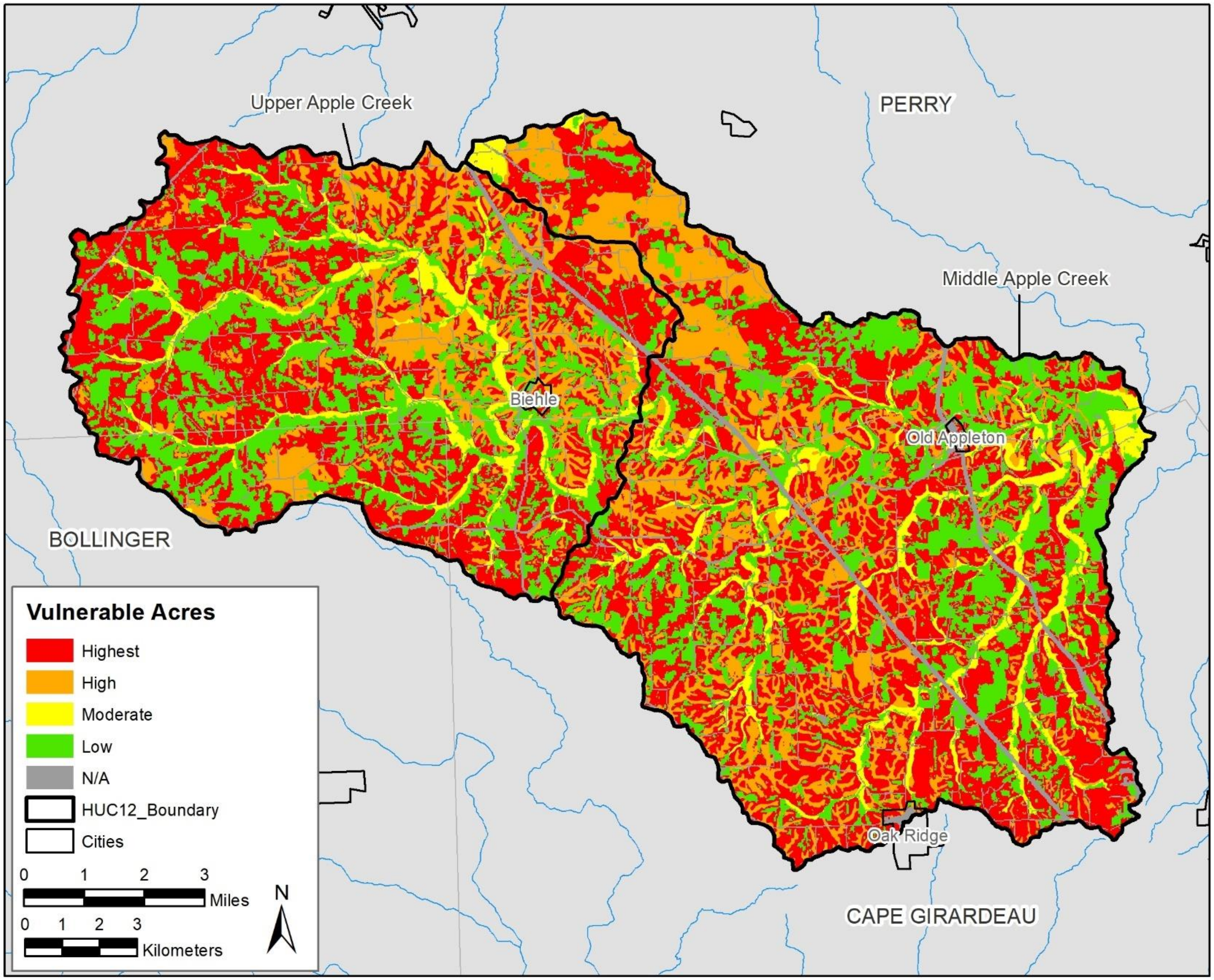


Figure 26. Vulnerable acres within both watersheds.

APPENDICES

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

MU #	Acres	% Area	Map Unit Name and Description	Soil Order	Landform	Kf factor	Land Capability Classification	Hydrologic Soil Group
60001	8,230	10.1	Menfro silt loam,5 to 9 percent slopes,eroded	alfisol	uplands	0.49	3e	C
60003	312.2	0.4	Menfro silt loam, 9 to 14 percent slopes, eroded	alfisol	uplands	0.43	4e	C
60024	1,911	2.3	Menfro silt loam,3 to 9 percent slopes,eroded	alfisol	uplands	0.49	3e	C
60033	279.8	0.3	Wrengart silt loam,5 to 9 percent slopes,eroded	alfisol	uplands	0.49	3e	C
60037	4,416	5.4	Wrengart silt loam,8 to 15 percent slopes,eroded	alfisol	uplands	0.43	4e	C
60045	1,266	1.6	Minnith silt loam,8 to 15 percent slopes,eroded	alfisol	uplands	0.49	4e	C
60046	7.3	0.0	Minnith silt loam,15 to 30 percent slopes,	alfisol	uplands	0.49	6s	C
60131	427.5	0.5	Holstein loam,14 to 20 percent slopes,	alfisol	uplands	0.28	6e	C
60137	57.6	0.1	Iva silt loam, 1 to 5 percent slopes	alfisol	uplands/terraces	0.43	2e	C/D
60151	407.3	0.5	Pevely-Minnith complex,15 to 35 percent slopes,	alfisol	uplands/hillslopes	0.37	7e	C
60164	437.6	0.5	Menfro silt loam, 14 to 35 percent slopes, eroded	alfisol	uplands	0.37	6e	C
60165	4,739	5.8	Menfro silt loam, 2 to 5 percent slopes	alfisol	uplands	0.43	2e	C
60169	3,732	4.6	Menfro silt loam, 9 to 14 percent slopes	alfisol	uplands	0.43	4e	C
60172	3,657	4.5	Menfro silt loam, karst, 2 to 9 percent slopes, eroded	alfisol	uplands	0.49	3e	C
60173	3,962	4.9	Menfro silt loam, karst,2 to 14 percent slopes,eroded	alfisol	uplands	0.49	3e	C
60177	0.1	0.0	Menfro silt loam, karst, 9 to 35 percent slopes, eroded	alfisol	uplands	0.49	3e	C
60179	2,579	3.2	Menfro-Bucklick silt loams, 14 to 20 percent slopes	alfisol	uplands	0.43	6e	C
60180	7,111	8.7	Menfro-Bucklick silt loams, 9 to 14 percent slopes	alfisol	uplands	0.43	4e	C
60181	1,577	1.9	Menfro-Bucklick silt loams, 9 to 14 percent slopes, eroded	alfisol	uplands	0.43	4e	C
60182	1,400	1.7	Menfro-Bucklick silt loams, karst, 5 to 20 percent slopes	alfisol	uplands	0.43	4e	C
60183	2,522	3.1	Menfro-Caneyville silt loams, karst, 5 to 20 percent slopes, eroded	alfisol	uplands	0.43	4e	C
60185	107.8	0.1	Menfro-Clarksville complex, 20 to 60 percent slopes	alfisol	uplands	0.43	7e	C
60187	51.9	0.1	Menfro-Holstein silt loams, 14 to 20 percent slopes	alfisol	uplands	0.43	6e	C
60188	3,481	4.3	Menfro-Holstein silt loams, 9 to 14 percent slopes	alfisol	uplands	0.43	4e	C
60192	3,948	4.8	Minnith silt loam, 3 to 8 percent slopes	alfisol	uplands	0.37	3e	C
60194	4,589	5.6	Minnith-Pevely complex, 8 to 15 percent slopes, eroded	alfisol	uplands	0.37	4e	C
60260	648.9	0.8	Weller silt loam,5 to 9 percent slopes,	alfisol	uplands/high stream benches	0.49	3e	D
64001	86.3	0.1	Freeburg silt loam, 0 to 3 percent slopes, rarely flooded	alfisol	high floodplains/ terraces	0.43	2w	C/D
66005	80.1	0.1	Deible silt loam,0 to 2 percent slopes,rarely flooded	alfisol	terraces	0.55	4w	D
66014	3,646	4.5	Haymond silt loam, 0 to 3 percent slopes, frequently flooded	Inceptisol	floodplains	0.43	3w	B
66024	60.2	0.1	Wilbur silt loam, 0 to 2 percent slopes, frequently flooded	Inceptisol	floodplains	0.43	3w	B/D
66054	132.5	0.2	Wakeland silt loam, 0 to 2 percent slopes, frequently flooded	Entisol	floodplains	0.43	3w	B/D
66087	416.9	0.5	Elsah silt loam,0 to 3 percent slopes,frequently flooded	Entisol	floodplains	0.43	3w	B
67000	368.7	0.5	Elsah silt loam,1 to 3 percent slopes,frequently flooded	Entisol	floodplains	0.43	3w	B
67001	1,867	2.3	Haymond silt loam, 1 to 3 percent slopes, frequently flooded	Inceptisol	floodplains	0.43	3w	B
67008	74.1	0.1	Wilbur silt loam, 1 to 3 percent slopes, frequently flooded	Inceptisol	floodplains	0.37	3w	B/D
73100	196.1	0.2	Wrengart silt loam,2 to 5 percent slopes,	alfisol	uplands	0.49	2e	C

MU #	Acres	% Area	Map Unit Name and Description	Soil Order	Landform	Kf factor	Land Capability Classification	Hydrologic Soil Group
73101	4,793	5.9	Wrengart silt loam,5 to 9 percent slopes,	alfisol	uplands	0.49	3e	C
73156	8.3	0.0	Alred-Gepp complex,8 to 15 percent slopes,stony	alfisol	uplands	0.32	4s	C
73210	3,462	4.3	Goss very cobbly silt loam,15 to 50 percent slopes,extremely stony	alfisol	uplands	0.49	6s	D
73264	1,245	1.5	Alred-Wrengart complex,15 to 35 percent slopes,rocky, very stony	alfisol	uplands	0.43	7e	C
73266	52.6	0.1	Hildebrecht silt loam,8 to 15 percent slopes,eroded	alfisol	uplands	0.32	4e	C
73270	1,561	1.9	Wrengart silt loam,9 to 14 percent slopes,moderately eroded	alfisol	uplands	0.43	4e	C
73456	14.3	0.0	Hildebrecht silt loam,8 to 15 percent slopes,	alfisol	uplands	0.37	4s	C
73495	102.2	0.1	Poynor gravelly silt loam, 15 to 35 percent slopes	ultisol	uplands	0.28	6e	B
73567	6.6	0.0	Peridge silt loam,15 to 20 percent slopes,	alfisol	uplands	0.49	6e	B
73568	11.0	0.0	Peridge silt loam,3 to 8 percent slopes,	alfisol	uplands	0.49	3e	B
73569	71.3	0.1	Peridge silt loam, 8 to 15 percent slopes	alfisol	uplands	0.49	4e	B
73605	78.5	0.1	Ogborn silt loam,1 to 5 percent slopes,	alfisol	uplands	0.43	3w	C/D
74679	8.5	0.0	Higdon silt loam,0 to 2 percent slopes,rarely flooded	alfisol	terraces	0.37	3w	B/D
75381	3.8	0.0	Bearthicket silt loam, 0 to 2 percent slopes, rarely flooded	alfisol	floodplains/terraces	0.43	2s	B
75451	14.6	0.0	Gladden silt loam,0 to 3 percent slopes,occasionally flooded	Inceptisol	flooplains	0.32	2w	B
75452	123.6	0.2	Gladden fine sandy loam, 0 to 3 percent slopes, frequently flooded	Inceptisol	flooplains	0.17	3w	A
75468	270.1	0.3	Elsah silt loam,0 to 3 percent slopes,occasionally flooded	Entisol	floodplains	0.43	2s	B
76012	370.5	0.5	Elsah silt loam,1 to 3 percent slopes,occasionally flooded	Entisol	floodplains	0.43	2w	B
76051	26.4	0.0	Tilk-Secesh complex, 1 to 3 percent slopes,occasionally flooded	Alfisol	floodplains/terraces/alluvial fans	0.28	3w	B
76052	132.1	0.2	Gladden fine sandy loam,1 to 3 percent slopes,frequently flooded	Inceptisol	floodplains	0.20	3w	A
99000	30.0	0.0	Pits, Quarry	N/A	N/A	N/A	N/A	N/A
99001	250.0	0.3	Water	N/A	N/A	N/A	N/A	N/A
99003	2.7	0.0	Miscellaneous Water	N/A	N/A	N/A	N/A	N/A
99010	8.1	0.0	Pits-Dumps complex	N/A	N/A	N/A	N/A	N/A

Appendix B. USGS gaging stations near the watershed.

USGS Gage ID	Station Name	Stream	Start Year	Years of Record	Ad (mi^2)	Elev. (ft)	Flow Exceedence (ft3/s)				
							90%	50%	10%	Max	Mean
7010208	Martigney Creek near Arnold, MO	Martigney Creek	1997	21	2.6	407.3	0.41	1.06	6.00	213.0	3.47
7019317	Mattese Creek near Mattese, MO	Mattese Creek	1996	22	7.9	422.0	0.02	1.54	17.02	723.0	9.96
7017200	Big River at Irondale, MO	Big River	1965	53	175	753.3	10.0	54.9	367.0	21,300	191.1
7021000	Castor River at Zalma, MO	Castor River	1920	89	423	350.5	62.0	191.0	1,077	78,000	537.8
7062500	Black River at Leeper, MO	Black River	1921	83	987	416.5	250.0	535.0	2,570	52,900	1,010
7061500	Black River near Annapolis, MO	Black River	1939	79	484	569.7	123.0	280.0	1,150	57,300	606.4
7018100	Big River near Richwoods, MO	Big River	1949	67	735	523.0	103.0	288.0	1,330	53,600	725.0
7037500	St. Francis River near Patterson, MO	St. Francis River	1921	96	956	370.5	57.0	350.0	2,370	113,000	1,159
7035800	St. Francis River near Mill Creek, MO	St. Francis River	1987	29	505	556.3	15.0	173.5	1,150	72,000	590.6
7036100	St. Francis River near Saco, MO	St. Francis River	1983	28	664	472.0	31.2	258.0	1,834	88,600	915.2
7043500	Little River Ditch No. 1 near Morehouse, MO	Little River	1945	69	450	280.8	73.5	209.0	1,350	11,700	556.4
7039500	St. Francis River at Wappapello, MO	St. Francis River	1940	70	1,311	314.6	54.0	710.0	4,070	25,600	1,622
7035000	Little St. Francis River at Fredericktown, MO	Little St. Francis River	1939	30	90.5	678.6	2.9	33.0	247.3	13,800	121.5
7061270	East Fork Black River near Lesterville, MO	East Fork Black River	2001	16	52.2	825.3	3.9	20.2	134.4	6,960	79.3
7020550	South Fork Saline Creek near Perryville, MO	South Fork Saline Creek	1998	17	55.3	445.0	7.4	18.7	94.0	4,940	60.7
7061600	Black River below Annapolis, MO	Black River	2006	12	493	555.3	170.0	335.5	1,313	59,700	743.2
7040000	St. Francis River at Fisk, MO	St. Francis River	1927	28	1,370	N/A	145.0	570.0	3,710	36,000	1,436
7062575	Black River above Williamsville, MO	Black River	2008	10	1,007	406.7	396.0	789.0	3,590	28,700	1,407
7061290	E. Fk. Black R. bl Lower Taum Sauk Reservoir	Black River	2008	10	87.3	725.0	5.8	35.6	277.0	8,970	131.8
7037300	Big Creek at Sam A Baker State Park, MO	Big Creek	2005	13	189	406.2	28.7	95.4	535.0	27,500	276.2
7017610	Big River below Bonne Terre, MO	Big River	2011	7	409	628.0	46.5	135.0	801.4	35,700	462.4

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 of VSA survey in the Upper Apple Creek watershed

Site # 3: Downstream

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

Overall Score 4.7

Site # 4: Upstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	5
Bank stability	9
Canopy cover	4
Manure presence	3

Overall Score 6.8

Site # 16: Downstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	4
Bank stability	6
Canopy cover	3
Manure presence	

Overall Score 6.6

Site # 23: Downstream

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

Overall Score

8.6

Site # 36: Upstream

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

Overall Score

9.8

Site # 39 : Upstream

Channel condition	3
Hydrologic alteration	10
Riparian zone	6
Bank stability	10
Canopy cover	1
Manure presence	5

Overall Score

5.8

Site # 44: Upstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	5
Bank stability	8
Canopy cover	3
Manure presence	5

Overall Score 6.8

Site # 52: Upstream

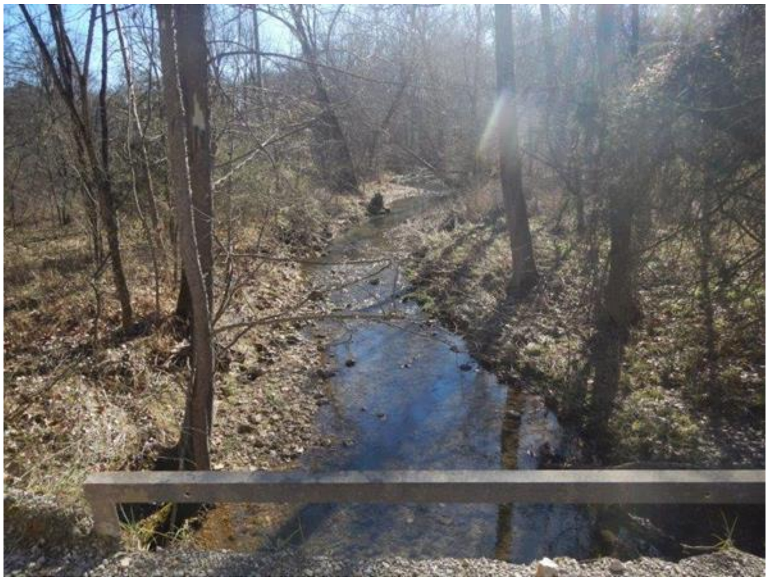
Channel condition	10
Hydrologic alteration	9
Riparian zone	9
Bank stability	8
Canopy cover	10
Manure presence	

Overall Score 9.2

Site # 55: Downstream

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

Overall Score 10.0



Site # 62: Downstream

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

Overall Score 9.4

Site # 65: Upstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	1
Bank stability	3
Canopy cover	7
Manure presence	

Overall Score 6.2

Site # 67: Downstream

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

Overall Score 5.8

Site # 70: Downstream

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

Overall Score

9.2

Site # 72: Upstream

Channel condition	10
Hydrologic alteration	8
Riparian zone	5
Bank stability	4
Canopy cover	6
Manure presence	5

Overall Score

6.3

Site # 72: Downstream

Channel condition	10
Hydrologic alteration	8
Riparian zone	8
Bank stability	6
Canopy cover	7
Manure presence	5

Overall Score

7.3

Site # 76: Downstream

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

Overall Score

7.0

Site # 77: Downstream

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

Overall Score

6.2

Site # 83: Downstream

Channel condition	10
Hydrologic alteration	7
Riparian zone	8
Bank stability	3
Canopy cover	10
Manure presence	

Overall Score

7.6

Site # 90: Downstream

Channel condition	10
Hydrologic alteration	7
Riparian zone	6
Bank stability	3
Canopy cover	4
Manure presence	4

Overall Score

5.7

Site # 96: Downstream

Channel condition	10
Hydrologic alteration	10
Riparian zone	1
Bank stability	8
Canopy cover	1
Manure presence	5

Overall Score

5.8

Appendix E. Examples of the VSA survey results from the Middle Apple Creek watershed

MAC Site # 33: Upstream

Channel condition	3
Hydrologic alteration	6
Riparian zone	4
Bank stability	2
Canopy cover	1
Manure presence	5

Overall Score

3.5

MAC Site #104: Upstream

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

Overall Score

9.2

MAC Site # 137: Upstream

Channel condition	1
Hydrologic alteration	1
Riparian zone	2
Bank stability	1
Canopy cover	1
Manure presence	5

Overall Score

1.8

MAC Site # 86: Upstream

Channel condition	9
Hydrologic alteration	8
Riparian zone	3
Bank stability	10
Canopy cover	3
Manure presence	5

Overall Score

6.3

MAC Site # 38: Upstream

Channel condition	7
Hydrologic alteration	7
Riparian zone	1
Bank stability	3
Canopy cover	1
Manure presence	0

Overall Score

3.8

MAC Site # 24: Upstream

Channel condition	10
Hydrologic alteration	9
Riparian zone	7
Bank stability	8
Canopy cover	3
Manure presence	0

Overall Score

7.4

MAC Site # 74: Upstream

Channel condition	6
Hydrologic alteration	3
Riparian zone	1
Bank stability	3
Canopy cover	1
Manure presence	5

Overall Score

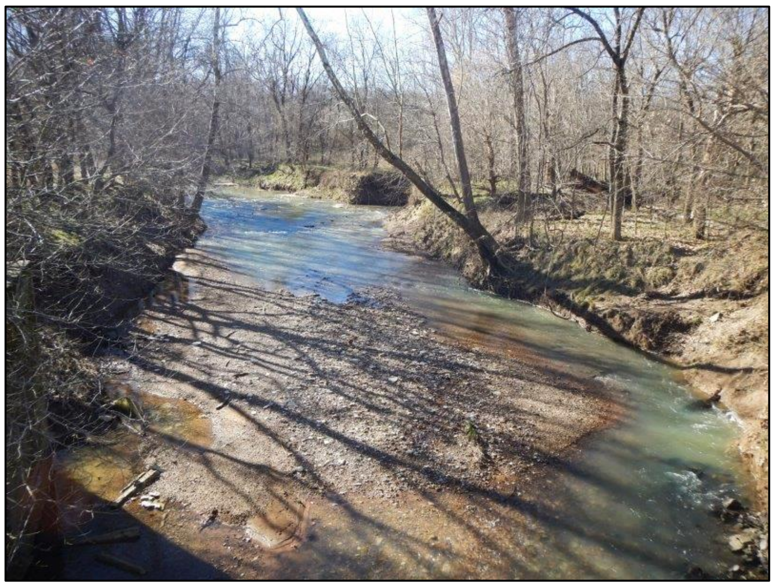
3.2

MAC Site # 4: Upstream

Channel condition	4
Hydrologic alteration	4
Riparian zone	5
Bank stability	4
Canopy cover	4
Manure presence	0

Overall Score

3.5



MAC Site # 75: Upstream

Channel condition	10
Hydrologic alteration	8
Riparian zone	3
Bank stability	8
Canopy cover	7
Manure presence	0

Overall Score

7.2

MAC Site # 109: Downstream

Channel condition	7
Hydrologic alteration	7
Riparian zone	8
Bank stability	1
Canopy cover	9
Manure presence	0

Overall Score

6.4

MAC Site # 50: Downstream

Channel condition	7
Hydrologic alteration	9
Riparian zone	1
Bank stability	6
Canopy cover	1
Manure presence	3

Overall Score

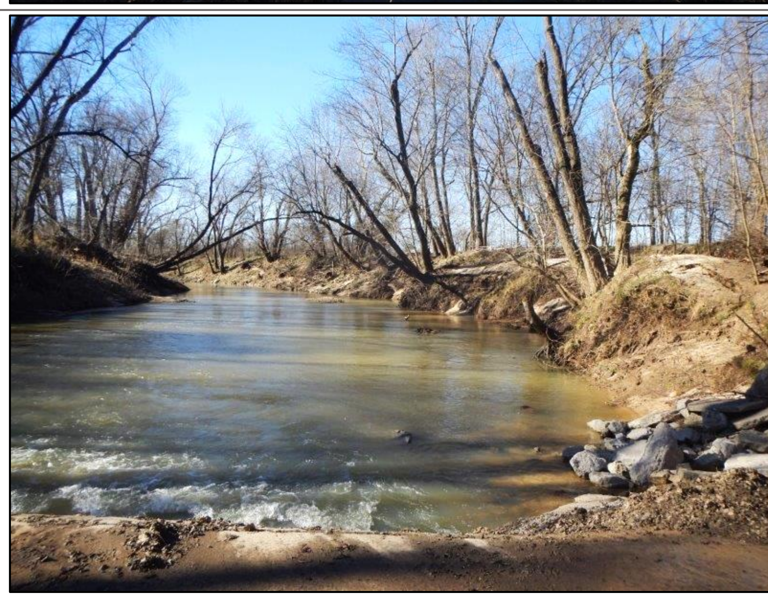
4.5

MAC Site # 2: Downstream

Channel condition	8
Hydrologic alteration	2
Riparian zone	3
Bank stability	2
Canopy cover	3
Manure presence	0

Overall Score

3.0



MAC Site # 128: Downstream

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

Overall Score

5.3

MAC Site # 92: Downstream

Channel condition	3
Hydrologic alteration	8
Riparian zone	1
Bank stability	5
Canopy cover	1
Manure presence	0

Overall Score

3.6

MAC Site # 7: Upstream

Channel condition	9
Hydrologic alteration	5
Riparian zone	2
Bank stability	9
Canopy cover	1
Manure presence	5

Overall Score

5.2

MAC Site # 3: Downstream

Channel condition	5
Hydrologic alteration	3
Riparian zone	3
Bank stability	5
Canopy cover	3
Manure presence	0

Overall Score 3.2

MAC Site # 68: Upstream

Channel condition	7
Hydrologic alteration	8
Riparian zone	1
Bank stability	4
Canopy cover	1
Manure presence	5

Overall Score 4.3

MAC Site # 13: Downstream

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

Overall Score 10.0

MAC Site # 114: Upstream

Channel condition	1
Hydrologic alteration	6
Riparian zone	1
Bank stability	7
Canopy cover	1
Manure presence	0

Overall Score

3.2

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

Model	R2	b0	b1	Upper Apple Creek Q (m3/s)	Middle Apple Creek Q (m3/s)	Upper Apple Creek Q (ft3/s)	Middle Apple Creek Q (ft3/s)
Mean Annual Q	0.99	0.01579	0.97754	1.96	2.67	69.26	94.35
Jan Mean Q	0.99	0.00986	1.06029	1.84	2.58	65.06	90.97
Feb Mean Q	0.99	0.01164	1.04055	1.97	2.74	69.70	96.86
March Mean Q	0.99	0.01911	1.02099	2.94	4.06	103.85	143.42
April Mean Q	0.97	0.03218	0.97292	3.91	5.31	137.96	187.65
May Mean Q	0.99	0.02504	0.98798	3.27	4.47	115.62	158.02
June Mean Q	0.96	0.01593	0.94940	1.72	2.32	60.80	82.09
July Mean Q	0.91	0.00841	0.92113	0.79	1.06	27.92	37.36
Aug Mean Q	0.94	0.01020	0.88900	0.82	1.08	28.90	38.28
Sept Mean Q	0.91	0.01028	0.85733	0.71	0.93	24.92	32.68
Oct Mean Q	0.93	0.01440	0.84956	0.95	1.24	33.61	43.96
Nov Mean Q	0.96	0.01479	0.95424	1.64	2.21	57.82	78.18
Dec Mean Q	0.99	0.01410	1.02300	2.19	3.03	77.41	106.97

* Power function equation $y = b_0 (x)^{b1}$
Where: y = mean monthly discharge in m^3/s
X = drainage area in km^2

Upper Apple Creek drainage area = 138.8 km^2
Middle Apple Creek drainage area = 190.4 km^2

Appendix G. STEPL model inputs for the Upper and Middle Apple Creek watersheds

Watershed	Total Ad (ac)	HSG	Land Use (ac)					# of Animals		# Septic Systems
			Urban	Cropland	Pastureland	Forest	Other	Beef Cattle	Swine (Hog)	
Upper Apple Creek	34,291	C	1,852	5,370	16,959	10,000	110	6,784	780	346
Middle Apple Creek	47,043	C	3,013	12,225	20,281	11,384	141	8,112	586	577

Appendix H. Bank erosion Upper Apple Creek

Reach ID	Length (ft)	Height (ft)	Area (ft²)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
1	947	10.8	33,661	35.6	1.9
2	855	11.5	54,216	63.4	3.3
3	637	13.1	22,977	36.1	1.9
4	632	10.2	16,994	26.9	1.4
5	621	9.5	46,469	74.8	3.9
6	601	10.8	79,754	132.7	7.0
7	528	8.2	24,068	45.6	2.4
8	469	9.5	8,873	18.9	1.0
9	440	12.1	47,036	106.9	5.6
10	436	7.5	7,041	16.2	0.9
11	433	6.9	6,033	13.9	0.7
12	419	9.5	24,548	58.5	3.1
13	418	8.5	33,742	80.7	4.2
14	370	9.5	14,262	38.5	2.0
15	369	10.8	9,093	24.6	1.3
16	366	11.5	24,015	65.7	3.5
17	354	12.5	8,039	22.7	1.2
18	335	9.8	9,486	28.3	1.5
19	328	10.2	16,394	50.0	2.6
20	299	8.2	13,770	46.0	2.4
21	289	8.2	7,310	25.3	1.3
22	281	6.6	3,047	10.9	0.6
23	280	8.9	12,062	43.1	2.3
24	279	2.6	8,303	29.8	1.6
25	267	11.5	21,430	80.1	4.2
26	234	10.5	12,863	55.0	2.9
27	231	11.2	8,713	37.7	2.0
28	229	7.9	12,690	55.4	2.9
29	228	8.9	4,586	20.1	1.1
30	221	8.5	2,042	9.2	0.5
31	221	3.0	2,335	10.6	0.6
32	204	10.5	4,403	21.6	1.1
33	197	8.9	1,711	8.7	0.5
34	193	3.0	4,240	22.0	1.2
35	190	7.2	7,075	37.2	2.0
36	157	12.8	1,786	11.3	0.6
37	121	10.2	1,136	9.4	0.5
38	113	7.5	1,316	11.6	0.6
39	621	7.9	63,298	102.0	5.4
40	468	6.2	26,067	55.7	2.9
41	458	9.5	30,045	65.6	3.5
42	425	8.9	14,912	35.1	1.8
43	379	9.8	14,483	38.2	2.0
44	350	9.5	7,714	22.0	1.2
45	350	8.9	15,599	44.6	2.3
46	349	1.0	7,019	20.1	1.1
47	341	11.5	17,062	50.0	2.6
48	336	9.5	8,821	26.2	1.4
49	332	8.5	8,031	24.2	1.3
50	325	9.2	14,856	45.7	2.4
51	308	8.9	9,110	29.5	1.6
52	306	9.2	6,706	21.9	1.2
53	299	9.5	6,053	20.2	1.1
54	298	12.1	9,683	32.5	1.7
55	298	5.6	6,278	21.1	1.1
56	294	12.5	11,279	38.4	2.0
57	289	8.2	6,932	24.0	1.3
58	283	8.2	5,564	19.6	1.0
59	278	3.6	7,128	25.7	1.4
60	270	9.8	4,885	18.1	1.0
61	263	8.2	3,966	15.1	0.8

Reach ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
62	258	4.6	27,934	108.4	5.7
63	257	4.3	6,700	26.1	1.4
64	241	7.5	5,388	22.3	1.2
65	236	4.9	5,332	22.6	1.2
66	236	1.6	8,134	34.5	1.8
67	233	6.6	5,313	22.8	1.2
68	232	11.8	6,780	29.3	1.5
69	230	11.5	4,089	17.8	0.9
70	224	6.9	3,881	17.3	0.9
71	221	5.9	10,899	49.3	2.6
72	218	3.6	7,843	36.0	1.9
73	216	2.6	11,817	54.7	2.9
74	213	9.2	3,813	17.9	0.9
75	210	5.9	3,741	17.8	0.9
76	209	9.5	4,788	22.9	1.2
77	198	4.9	1,040	5.2	0.3
78	197	5.6	6,244	31.6	1.7
79	196	13.1	5,141	26.2	1.4
80	194	9.8	4,207	21.7	1.1
81	191	7.2	776	4.1	0.2
82	190	9.8	1,506	7.9	0.4
83	190	3.6	9,196	48.4	2.5
84	188	10.2	1,587	8.4	0.4
85	182	10.8	4,121	22.6	1.2
86	181	5.6	3,498	19.4	1.0
87	180	9.2	715	4.0	0.2
88	178	5.2	2,432	13.7	0.7
89	175	6.9	5,497	31.4	1.7
90	170	11.8	3,730	22.0	1.2
91	163	4.3	2,553	15.7	0.8
92	160	0.3	2,623	16.4	0.9
93	160	8.2	1,847	11.5	0.6
94	159	11.8	8,823	55.6	2.9
95	158	8.2	2,562	16.2	0.9
96	158	7.9	2,544	16.1	0.8
97	154	3.3	2,056	13.3	0.7
98	154	6.6	2,450	16.0	0.8
99	143	6.6	1,389	9.7	0.5
100	142	1.3	3,032	21.4	1.1
101	140	6.9	1,787	12.7	0.7
102	138	11.5	1,125	8.2	0.4
103	134	9.8	1,947	14.5	0.8
104	134	7.2	2,820	21.1	1.1
105	130	3.9	3,103	23.9	1.3
106	128	2.6	1,951	15.2	0.8
107	124	8.2	778	6.3	0.3
108	124	4.3	2,244	18.1	1.0
109	123	4.6	4,815	39.1	2.1
110	122	11.8	1,551	12.7	0.7
111	120	3.6	1,292	10.8	0.6
112	117	3.3	1,360	11.6	0.6
113	116	4.9	668	5.8	0.3
114	116	3.9	1,179	10.2	0.5
115	115	3.3	724	6.3	0.3
116	112	4.3	1,130	10.1	0.5
117	112	3.6	1,578	14.1	0.7
118	111	3.6	1,281	11.6	0.6
119	110	5.6	4,248	38.6	2.0
120	109	6.6	2,462	22.6	1.2
121	108	3.9	1,423	13.1	0.7
122	103	11.2	967	9.4	0.5
123	103	4.9	1,332	13.0	0.7
124	102	3.9	801	7.9	0.4

Reach ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
125	102	8.5	706	6.9	0.4
126	102	6.2	939	9.2	0.5
127	101	1.0	426	4.2	0.2
128	101	6.9	924	9.1	0.5
129	99	9.5	516	5.2	0.3
130	99	5.2	790	8.0	0.4
131	99	11.5	1,852	18.7	1.0
132	99	2.0	1,766	17.9	0.9
133	98	4.3	898	9.2	0.5
134	97	10.2	1,093	11.3	0.6
135	96	6.2	814	8.5	0.4
136	94	2.3	1,102	11.7	0.6
137	93	6.9	1,669	18.0	0.9
138	91	4.6	970	10.6	0.6
139	91	5.2	1,306	14.3	0.8
140	90	8.9	754	8.3	0.4
141	90	3.9	779	8.7	0.5
142	90	8.5	874	9.7	0.5
143	89	3.0	529	5.9	0.3
144	87	3.3	1,653	19.0	1.0
145	86	5.6	504	5.8	0.3
146	86	2.0	1,014	11.7	0.6
147	86	4.9	1,123	13.1	0.7
148	85	5.9	484	5.7	0.3
149	81	3.3	1,192	14.6	0.8
150	78	4.6	703	9.0	0.5
151	77	5.2	1,347	17.5	0.9
152	76	8.9	449	5.9	0.3
153	75	8.2	668	8.9	0.5
154	75	8.2	790	10.6	0.6
155	73	4.6	882	12.0	0.6
156	72	6.2	682	9.4	0.5
157	72	11.5	664	9.2	0.5
158	72	3.6	505	7.0	0.4
159	68	14.8	558	8.2	0.4
160	67	3.0	2,077	31.0	1.6
161	67	5.9	190	2.8	0.1
162	67	5.6	371	5.6	0.3
163	66	9.2	389	5.9	0.3
164	66	8.5	328	5.0	0.3
165	66	4.6	665	10.1	0.5
166	63	8.5	463	7.3	0.4
167	63	3.9	140	2.2	0.1
168	62	3.9	322	5.2	0.3
169	62	3.6	269	4.4	0.2
170	60	2.6	387	6.5	0.3
171	60	9.2	1,105	18.6	1.0
172	58	4.3	229	3.9	0.2
173	58	6.2	456	7.9	0.4
174	57	5.6	440	7.7	0.4
175	57	6.6	293	5.2	0.3
176	56	1.6	2,220	39.3	2.1
177	56	7.5	431	7.7	0.4
178	56	1.6	556	10.0	0.5
179	55	4.9	579	10.6	0.6
180	54	8.2	206	3.8	0.2
181	54	2.0	569	10.5	0.6
182	54	4.9	481	8.9	0.5
183	53	8.5	319	6.0	0.3
184	52	4.9	468	9.1	0.5
185	48	3.6	528	11.0	0.6
186	48	7.5	291	6.1	0.3
187	46	5.2	254	5.5	0.3

Reach ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
188	45	4.9	378	8.3	0.4
189	45	9.2	776	17.1	0.9
190	45	7.9	244	5.4	0.3
191	45	10.5	103	2.3	0.1
192	42	5.6	397	9.4	0.5
193	42	6.6	176	4.2	0.2
194	42	5.6	481	11.5	0.6
195	41	7.2	134	3.3	0.2
196	41	6.2	1,044	25.6	1.3
197	41	11.5	386	9.5	0.5
198	40	11.5	150	3.7	0.2
199	40	3.6	705	17.6	0.9
200	40	6.6	269	6.7	0.4
201	40	4.3	234	5.9	0.3
202	39	4.6	252	6.5	0.3
203	39	5.6	796	20.5	1.1
204	38	7.5	259	6.7	0.4
205	38	4.9	322	8.4	0.4
206	36	7.2	515	14.2	0.7
207	36	4.9	201	5.6	0.3
208	35	2.3	433	12.3	0.6
209	35	3.9	319	9.0	0.5
210	34	3.9	448	13.1	0.7
211	33	5.2	338	10.2	0.5
212	33	8.2	81	2.4	0.1
213	32	6.6	134	4.2	0.2
214	32	3.9	558	17.6	0.9
215	31	3.3	304	9.8	0.5
216	31	4.6	323	10.5	0.6
217	30	5.2	243	8.1	0.4
218	29	6.2	274	9.3	0.5
219	29	2.6	146	5.0	0.3
220	29	5.6	205	7.1	0.4
221	28	3.6	267	9.5	0.5
222	28	6.9	196	7.0	0.4
223	28	3.9	111	4.0	0.2
224	14	3.6	45	3.2	0.2
225	13	2.3	130	10.2	0.5
Average	170	6.8	5,426	20.3	1.1

Appendix I. Bank erosion in Middle Apple Creek

Reach ID	Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
1	24.3	13.1	90	3.7	0.19
2	287.7	13.1	4,418	15.4	0.81
3	202.6	14.8	15,951	78.7	4.14
4	113.5	11.5	4,013	35.4	1.86
5	231.5	14.8	3,066	13.2	0.70
6	308.5	9.8	26,700	86.5	4.55
7	256.6	14.8	11,957	46.6	2.45
8	1,544.0	12.3	11,448	7.4	0.39
9	106.6	13.1	267	2.5	0.13
10	140.1	8.2	564	4.0	0.21
11	364.2	14.8	10,639	29.2	1.54
12	693.8	13.1	25,498	36.8	1.93
13	112.9	13.1	734	6.5	0.34
14	293.2	11.5	20,411	69.6	3.66
15	211.8	11.5	2,184	10.3	0.54
16	695.2	8.2	12,754	18.3	0.97
17	793.5	8.2	6,959	8.8	0.46
18	265.0	13.1	7,219	27.2	1.43
19	269.7	14.8	17,127	63.5	3.34
20	206.4	13.1	1,448	7.0	0.37
21	180.5	14.8	617	3.4	0.18
22	45.5	13.1	92	2.0	0.11
23	636.6	6.6	21,973	34.5	1.82
24	154.0	16.4	780	5.1	0.27
25	40.8	8.2	354	8.7	0.46
26	509.3	11.5	5,588	11.0	0.58
27	1,150.9	11.5	37,154	32.3	1.70
28	164.7	11.5	2,425	14.7	0.77
29	71.5	8.2	768	10.7	0.57
30	346.8	8.2	7,703	22.2	1.17
31	44.8	13.8	96	2.2	0.11
32	95.9	9.8	73	0.8	0.04
33	22.5	7.5	69	3.1	0.16
34	67.2	9.8	989	14.7	0.77
35	59.4	14.1	422	7.1	0.37
36	367.7	11.3	5,929	16.1	0.85
37	491.8	9.8	2,055	4.2	0.22
38	38.6	11.5	54	1.4	0.07
39	72.9	11.5	301	4.1	0.22
40	25.6	11.5	25	1.0	0.05
41	300.9	10.2	7,902	26.3	1.38
42	369.9	13.1	8,919	24.1	1.27
43	346.8	10.2	9,621	27.7	1.46
44	422.8	8.5	13,516	32.0	1.68
45	662.8	13.1	3,786	5.7	0.30
46	241.7	8.2	3,422	14.2	0.74
47	280.2	12.5	3,903	13.9	0.73
48	497.2	13.1	6,077	12.2	0.64
49	31.3	8.2	68	2.2	0.11
50	445.5	14.1	15,515	34.8	1.83
51	678.1	9.8	45,896	67.7	3.56
52	100.4	10.9	2,153	21.4	1.13
53	73.8	11.5	264	3.6	0.19
54	58.2	12.3	192	3.3	0.17
55	235.4	13.1	4,519	19.2	1.01
56	61.7	13.1	38	0.6	0.03
57	815.3	16.4	18,608	22.8	1.20
58	266.3	13.1	1,869	7.0	0.37
59	241.3	13.1	549	2.3	0.12
60	189.6	9.8	1,879	9.9	0.52
61	825.0	13.8	49,859	60.4	3.18
62	167.5	13.1	2,364	14.1	0.74

Reach ID	Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
63	489.2	14.8	8,229	16.8	0.89
64	67.7	13.1	177	2.6	0.14
65	47.9	9.8	468	9.8	0.51
66	771.8	13.1	13,786	17.9	0.94
67	130.2	14.8	2,643	20.3	1.07
68	1,284.0	13.1	56,416	43.9	2.31
69	86.7	14.8	1,042	12.0	0.63
70	23.6	10.2	200	8.5	0.45
71	76.1	14.8	553	7.3	0.38
72	326.5	9.0	5,777	17.7	0.93
73	258.5	14.8	2,127	8.2	0.43
74	127.0	4.6	5,075	39.9	2.10
75	669.9	11.5	11,805	17.6	0.93
76	27.2	10.9	131	4.8	0.25
77	815.3	14.8	8,797	10.8	0.57
78	174.2	13.1	2,117	12.1	0.64
79	2,342.6	10.9	249,141	106.4	5.60
80	373.0	11.5	2,127	5.7	0.30
81	809.7	9.8	52,884	65.3	3.44
82	100.4	13.1	284	2.8	0.15
83	1,353.0	10.7	12,070	8.9	0.47
84	320.0	9.8	15,672	49.0	2.58
85	49.5	13.8	259	5.2	0.27
86	273.8	14.8	2,951	10.8	0.57
87	378.3	14.1	15,887	42.0	2.21
88	671.6	7.0	9,368	13.9	0.73
89	1,159.4	11.9	15,402	13.3	0.70
90	82.9	14.8	312	3.8	0.20
91	135.9	14.8	1,313	9.7	0.51
92	285.1	3.3	2,821	9.9	0.52
93	476.5	11.5	7,484	15.7	0.83
94	662.8	7.2	16,839	25.4	1.34
95	151.1	13.1	9,906	65.6	3.45
96	205.2	14.8	2,925	14.3	0.75
97	297.6	14.8	8,813	29.6	1.56
98	2,136.7	16.2	85,844	40.2	2.11
99	99.3	13.1	446	4.5	0.24
100	1,119.9	14.8	14,684	13.1	0.69
101	298.2	13.1	8,040	27.0	1.42
102	71.9	13.1	588	8.2	0.43
103	186.4	8.2	2,406	12.9	0.68
104	699.7	7.6	4,328	6.2	0.33
105	134.8	13.1	1,227	9.1	0.48
106	279.3	13.1	2,888	10.3	0.54
107	1,007.7	12.6	19,143	19.0	1.00
108	129.0	4.1	1,882	14.6	0.77
109	158.2	8.2	1,021	6.5	0.34
110	1,254.5	9.8	53,047	42.3	2.23
111	275.0	13.1	5,634	20.5	1.08
112	112.2	6.2	336	3.0	0.16
113	78.6	9.8	1,293	16.4	0.87
114	240.5	5.7	5,726	23.8	1.25
115	62.7	13.1	167	2.7	0.14
116	65.4	14.8	330	5.0	0.27
117	611.5	9.8	14,928	24.4	1.28
118	676.6	11.5	14,466	21.4	1.13
119	3,260.8	13.8	218,023	66.9	3.52
120	296.3	14.8	6,276	21.2	1.11
121	114.8	16.4	468	4.1	0.21
122	128.3	16.4	1,040	8.1	0.43
123	321.8	11.5	2,078	6.5	0.34
124	880.9	16.4	10,888	12.4	0.65
125	71.9	9.8	237	3.3	0.17

Reach ID	Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
126	185.3	11.1	1,328	7.2	0.38
127	953.7	6.6	11,464	12.0	0.63
128	457.7	11.5	9,233	20.2	1.06
129	160.5	11.5	1,382	8.6	0.45
130	25.1	13.1	32	1.3	0.07
131	708.3	13.1	9,039	12.8	0.67
132	36.3	13.1	64	1.8	0.09
133	795.3	8.2	7,908	9.9	0.52
134	16.4	6.6	48	3.0	0.16
135	396.7	11.5	4,346	11.0	0.58
136	349.1	14.8	3,923	11.2	0.59
137	96.8	4.1	156	1.6	0.08
138	1,669.0	12.0	48,669	29.2	1.53
139	298.9	11.8	7,868	26.3	1.39
140	223.7	13.1	878	3.9	0.21
141	450.0	11.5	1,413	3.1	0.17
142	594.5	13.1	9,249	15.6	0.82
143	25.9	12.8	28	1.1	0.06
144	529.9	6.9	6,975	13.2	0.69
145	37.7	12.8	37	1.0	0.05
146	149.9	13.1	595	4.0	0.21
147	193.3	16.4	3,536	18.3	0.96
148	201.8	3.3	2,884	14.3	0.75
149	381.8	14.8	8,614	22.6	1.19
150	452.4	16.4	6,924	15.3	0.81
151	298.5	18.6	3,277	11.0	0.58
152	33.8	1.6	119	3.5	0.19
153	33.1	1.6	329	9.9	0.52
154	180.5	10.5	1,544	8.6	0.45
155	196.9	11.5	4,160	21.1	1.11
156	363.5	19.7	7,746	21.3	1.12
157	1,033.1	5.7	24,997	24.2	1.27
158	49.6	19.7	31	0.6	0.03
159	240.5	13.1	3,155	13.1	0.69
160	363.0	9.8	2,660	7.3	0.39
161	415.0	14.8	14,001	33.7	1.78
162	128.0	1.3	867	6.8	0.36
163	20.8	14.8	71	3.4	0.18
164	295.9	11.5	3,380	11.4	0.60
165	4,716.5	14.1	289,799	61.4	3.23
166	1,470.5	11.5	86,378	58.7	3.09
167	102.1	16.4	1,350	13.2	0.70
168	96.4	1.1	264	2.7	0.14
169	104.3	9.8	393	3.8	0.20
170	239.2	9.8	2,552	10.7	0.56
171	2,212.3	15.6	59,168	26.7	1.41
172	451.4	18.0	8,743	19.4	1.02
173	439.0	15.7	4,804	10.9	0.58
174	176.5	13.1	6,771	38.4	2.02
175	417.3	12.7	13,992	33.5	1.76
176	1,029.2	13.1	20,402	19.8	1.04
177	480.1	13.1	6,527	13.6	0.72
178	16.4	16.4	91	5.6	0.29
179	92.5	16.4	1,034	11.2	0.59
180	437.6	17.7	6,084	13.9	0.73
181	125.0	14.8	3,795	30.4	1.60
182	1,744.1	13.7	27,073	15.5	0.82
183	105.8	11.5	278	2.6	0.14
184	105.4	9.8	215	2.0	0.11
185	33.1	9.8	84	2.5	0.13
186	818.9	9.8	21,497	26.3	1.38
187	53.6	9.8	169	3.1	0.17
Average	**416.1**	**11.8**	**12,136**	**17.5**	**0.92**

Appendix J. 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
Field Borders	0.700	0.700	0.650
Grassed Waterway	0.700	0.750	0.650
Grade Stabilization Structure	0.750	0.750	0.750
Cover Crop and No-Till	0.397	0.709	0.793
Water and Sediment Control Basin	0.550	0.685	0.860
Land Retirement	0.898	0.808	0.950
Pasture Land			
Forage and Biomass Planting	0.181	0.150	0.000
Alternative Water	0.133	0.115	0.187
Winter Feeding Facilities	0.350	0.400	0.400
Critical Area Planting	0.175	0.200	0.420
Access Control	0.203	0.304	0.620
Prescribed Grazing, Alternative Water, and Heavy Use Protection	0.581	0.448	0.638
Grade Stabilization Structure	0.750	0.750	0.750
Livestock Exclusion, Alternative Water, and Heavy Use Protection	0.435	0.503	0.794

Appendix K. New regression equations from selected USGS gaging stations in SE, Missouri and SW Illinois.

Station	Ad (mi2)	Mean Q (ft3/s)
Rayse Creek near Waltonville, IL	88.0	94.70
South Fork Saline Creek near Perryville, MO	55.3	60.71
Crab Orchard Creek near Marion, IL	31.7	31.90
Mattese Creek near Mattese, MO	7.88	9.96
Martigney Creek near Arnold, MO	2.64	3.47