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

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

Cane Creek Watershed (HUC-071401070404)
Dry Creek Watershed (HUC-071401070406)

FINAL REPORT

Deliverable # 4 – Inventory of the Watershed
Deliverable # 5 – Resource Analysis of the Watershed
Deliverable # 6 –Identification of Conservation Needs on Susceptible Acres

Prepared by:
Tyler Pursley, Graduate Assistant, OEWRI
Marc R. Owen, M.S., Assistant Director, OEWRI
Triston Rice, Graduate Assistant, OEWRI
Robert T. Pavlowsky, Ph.D., Director, OEWRI

Completed for:
Steve G. Hefner, Water Quality Conservationist, State FTS Staff
Natural Resources Conservation Service
United States Department of Agriculture
Parkade Center, Suite 250
601 Business Loop 70 West
Columbia, MO 65203-2546
Office: 573-876-9399

October 1, 2020

OEWRI EDR-20-006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SCOPE AND OBJECTIVES

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

The Missouri State Office of the NRCS contracted the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University (MSU) to perform a watershed assessment study for two HUC-12 watersheds, Cane Creek (HUC-12# 071401070404) and Dry Creek (HUC-12# 071401070406), located within the larger Whitewater watershed (HUC-8# 07140107) in southeast Missouri. These watersheds are in both the Salem Plateau subdivision of the Ozark Plateau and the Mississippi Alluvial Plain (Figure 8, Norman 1994). Both Cane and Dry Creek are tributaries of the Castor River Diversion Channel. The Castor River Diversion Channel was built in the early 1900s with the primary objective to divert the flows of the Castor and Whitewater Rivers to limit runoff into the Mississippi Alluvial Plain, allowing for agricultural production (Miller and Vandike, 1997). The Castor River upstream of the two study watersheds is listed under the Missouri Department of Natural Resources (MDNR) Section 303(d) list of impaired waters for *E. Coli* pollution. Furthermore, the Castor River Diversion Channel, downstream of the two study watersheds, is on the MDNR 303(d) list for high mercury levels in fish tissue to the point it flows into the Mississippi River just downstream of Cape Girardeau, Missouri (MDNR, 2018A).

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 Cane and Dry Creek watersheds are located within the larger Whitewater Watershed (HUC-8# 07140107) of southeast Missouri (Figure 1). Cane Creek (15,474 acres) is located completely within Bollinger County, Missouri and the majority of Dry Creek (26,150 acres) is within Bollinger County with a small section in Cape Girardeau County, Missouri (Figure 2). Both are within the larger Castor River-Castor River Diversion Channel HUC-10 Watershed (#0714010706). Both watersheds flow into the Castor River Diversion Channel (occasionally referred to as the Headwater Diversion Channel), which directly enters the Mississippi River, approximately 27 miles (45 km) to the east. There are no cities or towns within either watershed. However, Marble Hill is approximately 1.4 miles (2.3 km) north of Dry Creek and has a population of about 1,500 people, and Zalma is approximately 5.8 miles (11.5 km) west of Cane Creek and has a population of about 122. Both towns are within the larger Whitewater Watershed

Climate

Southeast Missouri has a warm and temperate continental climate with hot summers and moderate winters (Peel et al. 2007). Over the 30 years from 1989-2018, the average annual rainfall at Marble Hill, Missouri ranged from 37.0-68.4 inches with an average of 51.7 inches per year (Table 1). The highest monthly rainfall totals (>5 inches) occur during the spring months of April and May, with generally less precipitation (<4 inches) during the fall and late winter months (Figure 3A). From 1989 to 2018, average annual temperature ranged from 54.3-59.9°F with an average of 57.0°F (Table 1). Over that period, average monthly temperatures range from about 34°F in January to near 78°F in July (Figure 3B). Over the last 30 years, the overall average annual precipitation was around 50 inches per year for the majority of that time (Figure 4A). The exception would be a period with relatively high average annual rainfall from 2009-present, where the five-year moving average was near 55 inches per year. Average annual temperature has varied two degrees since 1989, increasing over the last 30 years, with the lowest average annual temperature seen in 1989 (54.3°F). Annual temperatures showed a relative decrease in the 5-year moving average around 1997, 2004, and 2011 (Figure 4B).

Solar radiation and evaporation trends are similar to temperature trends for Marble Hill. From 2000-2018, average daily solar radiation by month ranged from about 6.3 MJ/m^2 in December up to around 21.8 MJ/m^2 in June with an average of 14.3 MJ/m^2 (Figure 5A). From 2011 to 2018, monthly average daily estimated evaporation ranged from around 0.03 inches in December to about 0.20 inches in June with an average of 0.11 inches over the entire year (Figure 5B).

Geology, Topography, and Geomorphology

The geology of these two watersheds are split by the Ozark Escarpment, which separates the Ozark Plateau of the Ozark Highlands, and the Southeastern Lowlands of the Mississippi Embayment (Miller and Vandike 1997). A majority of both the Cane and Dry Creek watersheds are in the Inner Ozark Border Subsection of the Ozark Plateau Province of the Interior Highlands, with small portions in the Black River Alluvial Plain Subsection in the Mississippi Alluvial Basin of the Coastal Plain Province (Nigh and Schroeder 2002). The Inner Ozark Border Subsection is characterized by moderate to steeply rolling dissected plains underlain by Ordovician-age limestone and dolomite with loess mantled ridges (Nigh and Schroeder 2002). Bedrock is frequently exposed in streams due to deep entrenchment near the Mississippi River Floodplain. The lowlands of the Mississippi Alluvial Basin are covered by alluvium resulting from St. Francis, Mississippi, and Ohio River deposits ranging from 50 to 250 feet above bedrock (Vandike 1995, Miller and Vandike 1997). The Black River Alluvial Plain Subsection is characterized as the remnant alluvial plain of the ancient Mississippi River and makes up 15.7% (6,533 acres) of the Cane and Dry Creek watersheds. The slopes in this subsection are significantly lower than the Ozark Border Subsection, typically sloping southward at a rate of 1-1.5 feet per mile (Nigh and Schroeder 2002).

Relief is higher in the Ozark Border Subsection (150-250 ft) compared to the Black River Alluvial Plain Subsection (10-25 ft), with elevations within both watersheds ranging between 326.7 to 787.8 feet (Nigh and Schroeder 2002) (Figure 6A). Stream channels are typically comprised of gravel and sand, sometimes containing silt closer to the Mississippi River (Nigh and Schroeder 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 Cane and Dry Creek for drainage areas less than 400 mi^2 (USDA 2018a) (Figure 7).

On the Mississippi Alluvial Plain, large-scale drainage projects that effectively moved water off of the landscape were accomplished by the construction of a series of connected channelized ditches (Nigh and Schroeder 2002). It is well known that channelized streams adjust to higher slopes and increased stream power by incision and channel widening processes (Simon and Rinaldi 2000). However, over time, aggradation starts to occur, and the stream begins to meander within the constructed banks to create low, bankfull benches where vegetation can start to establish and help stabilize the channel (Figure 8).

Landscape and Soils

The Whitewater watershed is within two Major Land Resource Areas (MLRA), the Ozark Highlands and the Southern Mississippi River Alluvium (USDA 2006). The Ozark Highlands consist of highly dissected steeply rolling hills with narrow gravelly valleys and the Southern Mississippi River Alluvium consist of very gently undulating alluvial plains, backswamps, oxbows, natural levees, and terraces (USDA 2006). Soils in the Ozarks sections of these watersheds are formed in thin loess deposits over dolomite residuum, with backslopes formed in very cherty dolomite residuum (Nigh and Schroeder 2002). LiDAR derived slope shows that a majority of the land has slopes ranging from 3-24% (Figure 9). Land with slopes <3% are primarily within the alluvial floodplain of the four major streams, or within the larger Mississippi Alluvial Plain. High valley slopes (>24%) are found along the hillslopes in the Ozarks sections of these two watersheds.

Alfisols are the soil order most abundant in both the Cane and Dry Creek watersheds (75.9% and 71.5% respectively), with entisols (8.5% and 8.9%) and inceptisols (3.3% and 4.2%) primarily in the valley bottoms (Figure 10). Cane Creek has a larger amount of ultisols (7.4%) than does Dry Creek (0.2%) (Table 2). The concentration of ultisols is located in the upper section of the Cane Creek watershed (Figure 10). Soils in the two watersheds generally exhibit low infiltration rates, with approximately 75% of soils in both Cane and Dry Creek watersheds being either type C (slow) or C/D (slow/very slow) in the Hydrologic Soil Group classification (Table 2, Figure 11) (USDA 2009). The middle portion of both watersheds and the uplands of Dry Creek typically have C type soils (Figure 11). Whereas Cane Creek has somewhat more soils classified as Group B (13.3%) than Dry Creek (7.8%) (Table 2). Group B soils are typically located along valley bottoms in both watersheds and the upper section of Cane Creek (Figure 11). The Mississippi Alluvial Plain consists of the majority of C/D soil types in both Cane Creek (5.3%) and Dry Creek (5.6%) watersheds (Figure 11).

The USDA Land Capability Classification was also used to classify and describe suitability to grow field crops (USDA 2018B). Land Capability within the two watersheds range from Class 2-7, distinguished by subclasses of (e) erosion, (w) water, and (s) shallow, droughty, or stony (Table 2). Erosion (e) is the major limiting factor, accounting for approximately 56% of land in both watersheds (Table 2). Water (w) was the next most limiting (~24% in both), found near the valley bottoms and lower sloped areas (Figure 12). Cane Creek has more shallow (s), droughty, or stony soil limitations (14%) than Dry Creek (7%), which is mostly located in the uppermost portion of the Cane Creek watershed (Figure 12). Type 7e soils, which have very severe limitations that make them unsuited to cultivation and that restrict their use, are the majority of soils within both Cane Creek (29.4%) and Dry Creek (29.4%) and are found primarily in the forested hillslopes in the middle portion of both watersheds (Figure 12) (USDA 2018).

A majority of soils in both Cane and Dry Creek featured K-Factors less than 0.2 (35.1% and 40.4% respectively) and are found predominantly in forested areas (Table 2, Figure 13). Approximately 25% of soils have a K-factors of 0.2-0.4 in both watersheds, which are found within valley bottoms and the Mississippi Alluvial Plain (Table 2, Figure 13). Soils with a K-factor from 0.4-0.5 also have similar percentages (~28%) in both Cane Creek and Dry Creek and are found most often in areas of agriculture, or grass and pastureland (Table 2, Figure 13, and Figure 14). Overall, soils in both watersheds have similar runoff and erosion potential. A complete list of soil series found within the watersheds is available in Appendix A.

Hydrology and Drainage Network

The main channels of Cane and Dry Creek generally flow northwest to southeast and all drain into the Castor River Diversion channel, which flows to the Mississippi River approximately 27 miles (45 km) to the east. The Castor River Diversion Channel was constructed in the early 1900s, diverting the flows of the Castor and Whitewater rivers to channelize runoff in the Mississippi Alluvial Plain, allowing for agricultural production (Miller and Vandike 1997). This diversion channel drastically altered the hydrology and drainage characteristics in the southeast lowlands of Missouri, converting the land from densely vegetated swampland to highly channelized and productive cropland (Vandike 1995). The Cane Creek Watershed has only one main channel, whereas the Dry Creek Watershed has four; Dry Creek, Malone Creek, Gizzard Creek, and the Castor River Diversion Channel (Figure 2). There are a total of 180.4 miles of mapped streams within the two watersheds, with only 10.3 miles classified as permanent flow (Table 3). Both watersheds have relatively small percentages of permanent flow, however, Dry Creek has more (9.0 mi) than Cane Creek (1.2 mi). Of the 9 miles of permanent flow in the Dry Creek Watershed, 8.5 miles are the Castor River Diversion Channel. There are a total of 180.1 acres of lakes and ponds within the three watersheds. There are no major water users within either study watershed.

Land Use and Land Cover

Land use for the watersheds was determined using the 2014-2018 National Agricultural Statistics Service (NASS) Crop Database. Crop classes were combined to look at the overall representation of land use in the watershed. In general, the Cane Creek watershed is mainly forest land, while the Dry Creek watershed has a significantly higher percentage of crop and pasture land (Table 4). In both watersheds, agricultural land use is focused primarily on the Mississippi Alluvial Plain, with small portions of mixed land use in valley margins and the upper portion of the Dry Creek watershed (Figure 14).

Cane Creek's largest land use is forest at about 71% (Table 4). The next highest land uses in 2018 were grass and pastureland (14%) and row crops (7.5%) (Table 4). In contrast, Dry Creek had significantly less forest with only 39%, with relatively higher percentages of row crops (25%) and grass/pasture land (18%) (Table 4). Both Cane and Dry Creek watersheds are seeing noticeable increases in row crops (16 & 12%) and decreases in grass/pasture land (-15 & -23%) (Table 4). Most of the row crops for both watersheds are located in the Mississippi Alluvial Plain and throughout the main valley bottoms (Figure 14). As of 2018, the majority of the row crops are soybeans, with small sections growing corn or double cropping winter wheat with soybeans (Figure 14).

Previous Work and Other Available Data

TMDLs and Management Plans

Currently, there are no Total Maximum Daily Loads (TMDL) for streams within either watershed in this study. However, portions of the Castor River (7.5 mi) and Castor River Diversion Channel (20.3 mi) outside of the two watersheds, but within the Whitewater watershed, are on the 303(d) impaired streams list for E. Coli (Castor River) from rural nonpoint sources and mercury in fish tissue (Castor River Diversion Channel) from atmospheric deposition (MDNR 2018A, MDNR 2018B).

Surface and Ground Water Monitoring Stations

There are no United States Geological Survey (USGS) gaging stations within the two watersheds. The closest gaging station near Zalma, MO is approximately 10 miles upstream on the Castor River (USGS Gaging Station # 07021000). 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 be able to estimate runoff from different size watersheds within the study area (Figure 15). A list of the USGS gaging stations used in this study can be found in Appendix B. If resources became available to install one gaging station within each watershed, possible locations would be on Cane Creek at Hwy 51 (UTM Zone 15N Northing: 4,117,881.62 Easting: 769,554.99), Dry Creek at Hwy 91(UTM Zone 15N Northing: 4,118,069.18 Easting: 771,189.44), and/or on The Diversion Channel at State Hwy "N" (UTM Zone 15N Northing: 4,122,324.30 Easting: 779,625.30). Additionally, there is a ground water monitoring station in Delta, approximately 5 miles southeast and outside of the Dry Creek watershed (Site Number: 371125089445301). This well has been operating since 1956 and data from this station shows an overall decline of about 3 feet in ground water levels in this area and becoming more variable since 2000 (Figure 16).

Water Quality Sampling Data

There are no water quality monitoring sites available in either of the watersheds for this project. However, three sites within the larger Whitewater watershed and one more outside of the Whitewater watershed (but downstream of Cane and Dry Creek) were used to obtain relevant water quality monitoring data. Three of the sites were selected because of their location on the Castor River (upstream) and Castor River Diversion Channel (downstream). Site 2288/6.6 is upstream of 2196/15.3 and 2196/.09 (Figure 17). One site is located on Lower Whitewater Creek, approximately 15 miles north of Cane and Dry Creek, yet still in the larger Whitewater watershed (Figure 18). These four sites have from 4 to 172 samples collected and analyzed for nutrients and sediment from 1974 to 2018 (Table 6). Three of the four samples were collected by the U.S. Geologic Survey and one for the Missouri Department of Natural Resources. There are no permitted point sources or animal feeding operations within the two watersheds.

Biological Monitoring Data

There is no biological monitoring data available within the two study watersheds. However, one biological assessment was completed on the Little Whitewater Creek within the Whitewater Watershed. This biological assessment concluded that there are no major water quality problems and that this stream is able to fully support healthy macroinvertebrate communities (MDNR, 2015).

Summary

The purpose of this report is to provide the information necessary to describe and study two HUC-12 watersheds within the Whitewater River watershed for the Mississippi River Healthy Watershed Initiative (MRBI), Cane Creek (071401070404) and Dry Creek (071401070406). The purpose of the full watershed assessment is to provide NRCS field staff with the necessary information to identify locations within the watershed where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. Therefore, this first phase of the project provides a general description of the watershed and inventories the data that will be used in subsequent phases of the project. Information collected for the initial phase of the project provides the geographical, physical, hydrological, and water quality attributes of the watershed along with documentation of available data sources (Table 7).

RESOURCE ANALYSIS OF THE WATERSHED

The resource analysis of the watershed will include evaluation of water quality data within the watershed, observed channel conditions from both historical aerial photography and a field-based visual assessment, and water quality modeling results. 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 Cane and Dry Creek water quality by looking at both the range of mean concentrations and variability among sites. There are no water quality monitoring sites available in either of the watersheds for this project, however, there are four sites within the larger Whitewater watershed. Three of the sites are located on the Castor River Diversion Channel with site 2288/6.6 upstream, and both 2196/15.3 and 2196/.09 downstream of Dry and Cane Creek (Figure 17). The other site is located along Little Whitewater Creek in Bollinger County and likely best represents similar water quality conditions to the upland and hillslope streams within the Dry and Cane Creek Watersheds. All water quality data was downloaded from the MDNR Water Quality Assessment System website.

Overall, water quality conditions are worse downstream of the study watersheds than upstream, suggesting nonpoint agricultural runoff from these watersheds may be contributing to higher nutrient and sediment loads to the Mississippi River from the Castor River Diversion Channel. At the upstream site, average concentrations of TP ranged from 0.027-0.126 mg/L, TN ranged from 0.31-1.24 mg/L, and TSS concentrations ranged from 5.0-43.5 mg/L (Table 8). The site located just downstream of Cane and Dry Creek was site 2196/15.3 which had the fewest number of samples collected with only 10 samples for TP and TN, and 0 for TSS. However, the site furthest downstream on the Castor River (2196/0.9) had the greatest number of samples with a total of 168 collected for TP, 163 for TN, and 172 for TSS. Here, TP ranged from 0.008-1.527 mg/L with an average of 0.126 mg/L. Concentrations of TN ranged from 0.12-49.60 mg/L with an average of 1.24 mg/L. Average sediment concentration for this site is 43.5 mg/L ranging from 0.0-2,282 mg/L. These data suggest there is a substantial increase in nutrients and sediment between the site located upstream of the study watersheds and the sites downstream. However, it is important to note the number of sites and the spatial and temporal distribution of samples in these two watersheds are very limited.

Available water quality data suggest total phosphorus concentrations meet established reference conditons for the ecoregion while total nitrogen concentrations are elevated. Ambient water quality criteria suggested reference conditions for these streams is 0.125 mg/L TP and 0.71 mg/L TN based on the 25th percentile value for streams within the Mississippi Alluvial Plain region (USEPA 2001). This sample set shows that on average the Castor River Diversion Channel sites have mean TP concentrations at or below the regional reference condition. However, the average TN concentrations for the two sites along the Castor River Diversion Channel below the study watersheds are nearly two times higher than the reference condition. These data suggest conservation practices that can reduce nitrogen in runoff can be an important component in improving and protecting water quality from agricultural runoff directly connected to the Mississippi River and the Gulf of Mexico.

Channel Stability and Riparian Corridor Assessment

<u>Aerial Photo Methods</u>

Aerial photographs from 1996 and 2015 were obtained from the Missouri Spatial Data Information Service (MSDIS) online data server which came already rectified (Table 9). The error involved in the transformation was quantified using point-to-point error analysis. A total of 10 locations on both sets of aerials were evaluated for the point-to-point errors within each of the 12-digit HUC watershed boundary. Overall, mean point-to-point errors ranged from 3.3-22.5 ft for both watersheds (Table 10). Streams channels for each year were digitized to identify and measure changes over time. Both bank lines were digitized for the main stem and larger tributaries. However, since many of these channels were small and some of the channel banks were 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).

<u>Channel Classification</u>

Tributary channels and the main stem of the Cane and Dry Creek watersheds were further classified by identifying historical channel changes through the interpretation of aerial photos between 1996 and 2015. Channels were first characterized as “modified” or “natural”. Modified channels were then classified as either “channelized” or “dammed/ponded”. Natural channels were classified as “stable” or “active”. Active channels were identified by assessing planform changes since 1996 by overlay analysis of the digitized channel error buffer. This buffer is based on the mean point-to-point error for each watershed to account for biases attributed to rectification (Martin and Pavlowsky 2011). Active reaches were identified as areas where the error 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).

Cane Creek - Channel classification analysis on the Cane Creek watershed shows the majority of streams are stable, but there are still a relatively high number of active reaches within the watershed. Of the total 128.2 stream miles in the watershed, 67.9 miles (53%) were stable. A total of 22.9 mi (18%) of streams were classified as active using these methods, with active reaches found predominantly along the main stem in the middle portion of the watershed. Modified (Channelized or Dammed/Ponded) streams made up a combined 17.6 miles (14%) of the total stream network. Of the remaining stream miles, 19.2 miles (15%) were not visible on both sets of aerials (Table 11). Many of the channelized reaches were located along the main stem of Cane Creek (Figure 20). Most dammed/ponded streams were located in either headwater streams or tributaries that were otherwise stable, or not visible.

Dry Creek – Channel classification results for the Dry Creek watershed show there was a lower number of active reaches and a higher percentage of modified channels within the watershed compare to Cane Creek. Of the 165.7 total stream miles within the watershed, 49.1 mi (29%) were classified as channelized or dam/ponded (Table 11). Nearly all of the visible stream network in the lowlands near the outlet of the watershed have been channelized (Figure 20). There were 73.6 miles (44%) of stream channels classified as stable and only 12.1 miles (7%) classified as active. Most active sites were again located along the main stem, near channelized reaches, or near agricultural fields. The relatively low percentage of active channels in the watersheds suggests it is possible that channel incision and widening may be a more dominant mechanism for adjustment in these streams, and this effect cannot be determined through aerial photo analysis at this scale (Simon and Rinaldi 2000). However, it is also important to note that streams appear largely stable throughout most of the watersheds beyond the Mississippi River lowlands. 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). This suggests there are possible sources of erosion in the channelized reaches of both watersheds that cannot be accounted for in this method.

Riparian Corridor Analysis

The presence of a healthy riparian corridor can provide resistance to erosion during floods and filter runoff water moving from the uplands to the stream (Rosgen 1996, Montgomery and

MacDonald 2002, USDA 2003). The riparian corridors for the two watersheds in this study were evaluated by creating a buffer around the 2015 digitized stream layer and overlaying that layer on the 2015 aerial imagery. 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.

Cane Creek – The majority of the riparian corridors along streams in the Cane Creek watershed were classified as good and streams with poor corridors were found mostly along the main stem and toward the flatter lowland area in the lower portion of the watershed. Within the Cane Creek watershed, 79.8 (62%) of the total 128.2 miles of the streams were classified as having a good riparian corridor (Table 12). A total of 21.7 miles of stream (17%) were classified as having moderate riparian corridor and 26.7 stream miles (21%) classified as having poor riparian corridor. Typically, poor and moderate riparian corridors were located along the main stem of Cane Creek toward the lower portion of the watershed that has higher amounts of crop and pasture land (Figure 21).

Dry Creek – In contrast to Cane Creek, Dry Creek streams were classified as having more poor riparian corridors along streams. The poor classification makes up a total of 83.3 (50%) of the total 165.7 stream miles within the watershed (Table 12). There is a total of 32.0 mi of streams in the moderate category within the watershed. Moderate and poor riparian corridors were found primarily in the cropland areas of the Mississippi Alluvial Plain located in the lower portions of the watershed, with other major concentrations in the pasture and cropland in the headwaters and main valley floors (Figure 21). There are 32.0 mi (30%) of streams within the watershed classified as good and these reaches are typically along the first and second-order tributaries. These results suggest the Dry Creek watershed may benefit from riparian corridor enhancement, particularly in the agricultural areas of the lowlands.

<u>Visual Stream Survey Results</u>

A modified rapid visual stream survey was conducted upstream and downstream of all public road crossings within the watershed following NRCS protocols (USDA 1998). The protocol was modified by 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.

Cane Creek – For Cane Creek, the lowest scoring sites generally featured reaches that had been modified which also generally had poor riparian corridor conditions. The more unstable streams were typically in pasture areas with visible manure presence or had livestock access to the stream, poor riparian forest cover, limited canopy cover, and decreased bank stability. The main stem of Cane Creek was in relatively good condition and showed the highest scores where riparian buffers were also in good condition (Figure 22). Channel conditions in the tributaries were largely dependent on the riparian zone where there was a related decrease in canopy cover and bank stability. Examples of the sites evaluated with overall scores can be found in Appendix D. Overall, streams located on hillslopes had the highest overall scores with an average of 8.9 (good category) and sites along than valley bottom had an average score of 7.2 (fair category) (Table 13). Uplands sites had the lowest overall average score of 6.5 (fair category). Uplands and valley bottoms scored similarly on overall scores for channel condition and hydrologic alteration, but upland streams featured lower rated riparian corridors and canopy cover as well as increased bank stability. These data suggest streams located in the uplands are responding to land use management that perhaps should be a priority in this watershed.

Dry Creek – Most low scores throughout the Dry Creek watershed were related to stream alteration. Sites in the uplands and flat, lowlands generally had the lowest scores compared to hillslope and valley bottom sites (Figure 22). Hillslopes again featured the highest overall average score of 8.2 (good category) while valley bottoms sites had an average score of 6.2 (fair category) (Table 13). Upland and lowland sites in the Dry Creek watershed had the lowest average scores of 5.9 and 4.8 (poor category). This assessment suggests streams in the lowlands and uplands are responding more detrimentally to land management practices and should be a priority for implementing conservation practices.

Rainfall–Runoff Relationship

Annual and monthly runoff rates for the selected for the Dry and Cane Creek watersheds were estimated using equations developed from 21 USGS gaging stations in the region. Monthly runoff rates are important for understanding the seasonal variability and how rainfall-runoff relationships correspond to land management and annual runoff rates will be used to help validate the STEPL model hydrology results. A list of the equations used for this analysis of monthly mean discharge values can be found in Appendix E. Mean annual discharge for the Cane Creek watershed is 31.2 ft^3/s and 52.4 ft^3/s for Dry Creek (Figure 23). Total runoff volume for the Cane Creek watershed was 22,631 ac-ft and 37,969 ac-ft for the Dry Creek watershed. For both watersheds, average discharge peaks in the month of April and is the lowest in September. Average runoff as a percentage of rainfall for the Cane Creek watershed was 33.9% and 33.7% for Dry Creek. Monthly mean runoff as a percentage of rainfall is highest in the late winter and early spring and lowest in the late summer and early fall ranging from less than 10% in July and September >60% in April. The remainder of the rainfall is either lost to evapotranspiration or moved through the soil into groundwater storage through infiltration (USDA, 2009b). These estimates are comparable with existing literature that state evapotranspiration rates for Missouri range from 60–70% (Sanford and Selnick 2013).

Water Quality Modeling

<u>STEPL Model</u>

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

For this study, each watershed was modeled with inputs following methods outlined in the STEPL user's guide. Model inputs include drainage area, soil hydrologic group, land use, animal numbers, and estimates on septic systems within the watershed. Land use was derived from the 2018 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 on 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 F.

Lateral stream bank erosion was accounted for by calculating the 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. Erosional areas were identified by overlaying the bank lines from each aerial photo year. The areas between the

1996 and 2015 photos that do not overlap were considered the bank erosion polygons. Additionally, an error buffer was used for the polygons to account for the difference in photos. The area of bank erosion was then divided by the length to calculate a mean width. The mean width was then divided by the number of years between photos to establish an average annual migration rate for each bank erosion polygon. This method identified a total of 36 eroding stream banks in the Cane Creek watershed and 35 eroding stream banks in the Dry Creek watershed (Appendix G). Total eroding bank length for each watershed was 4,583 ft for Cane Creek and 5,507 ft for Dry Creek. Average weighted bank height and migration rate for Cane Creek was 6.1 ft and 0.7 ft/yr. Average weighted bank height and migration rate for Dry Creek was 6.2 ft and 1.0 ft/yr. These estimates are conservative and meant to be used as a rough estimate of the most aggressive bank erosion within each watershed to compare with other nonpoint sources. These methods also can only detect bank erosion due to lateral migration or excessive widening. More accurate bank erosion estimates and sediment budget assessments are beyond the scope of this study.

Cane Creek - Average yields for the Cane Creek watershed were 4.36 lb/ac/yr for nitrogen, 1.01 lb/ac/yr phosphorus, and 0.51 T/ac/yr of sediment (Table 14). Runoff rates were 0.88 ac-ft/ac/yr and the percentage of rainfall as runoff was 20.4% for the watershed. Modeled percent runoff is lower than the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 33.9% for the watershed. The disagreement between these two methods is about 50% relative percent difference (RPD). This is likely due to increased rainfall that is reflected in the USGS gage records but not updated in the STEPL model. This discrepancy occurred in other southeast Missouri watershed assessments where higher intensity rainfall has known to have increased since 2005 (Pavlowsky et al. 2015, Reminga et al. 2019).

Dry Creek - Average yields for the Dry Creek watershed were 7.12 lb/ac/yr for nitrogen, 1.51 lb/ac/yr phosphorus, and 0.72 T/ac/yr of sediment (Table 14). Runoff rates were 1.05 ac-ft/ac/yr and the percentage of rainfall as runoff was 24.2% for the watershed. Again, as with Cane Creek, modeled percent runoff is lower than the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 33.7% for the watershed. The disagreement between these two methods is about 32% RPD and is likely due to the increase in high rainfall intensity since 2005 in southeast Missouri.

When assessing model results by sources for the two watersheds in this study, the majority of the nutrient and sediment load is from agricultural nonpoint source pollution. However, Dry Creek is contributing substantially more nutrients and sediment from agricultural land use than Cane Creek. Model results show crop and pastureland account for 82-87% of the nutrient loads and around 81% of the sediment load in the Dry Creek watersheds (Table 15). In contrast, crop and pasture land account for 57-72% of the nutrient load and 55% of the sediment load in Cane Creek. Pastureland is the highest contributor of nitrogen in the Cane Creek watershed, but the model results show forest land is the highest contributor of phosphorus and sediment. Streambank erosion is also a significant contributor to the total sediment load of both watersheds contributing 7.8-10.6% load in these two watersheds. These results suggest implementation of conservation practices on cropland in the Dry Creek watershed should be the priority and pasture land should be the priority in the Cane Creek watershed.

Summary

The purpose of this section of the report is to provide results of the resource analysis of the watershed (Deliverable #5) for the Mississippi River Basin Healthy Watersheds Initiative (MRBI) Watershed Assessment for the Cane Creek Watershed (HUC-071401070404) and the Dry Creek Watershed (HUC-071401070406). Available water quality data was limited to areas outside of both watershed boundaries, but available data downstream indicates nutrient concentrations exceed regional ambient water quality criteria suggested reference conditions for streams in the Mississippi Alluvial Plain region. This is particularly true for nitrogen, which was around 2-times higher than the reference concentration which is directly connected to the Mississippi River.

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, while all of the streams located in the lowlands have been channelized. Due to the small size of the tributary streams within the watershed, overhead vegetation, and photo quality limitations, a complete classification of all the small tributary streams was not always possible. The riparian corridor assessment does show most poor riparian corridors are located in the lower main stem and into the lowlands while smaller streams tended to have better riparian forest cover. Streams assessed in the visual stream survey showed channels in the flatter lowlands and uplands were classified in poorer condition than streams on the hillslopes and main valley bottoms mainly due to poor riparian conditions, degraded streambanks, and livestock access to the stream. Additionally, streams draining cropland in the lowlands also did not generally have a sufficient vegetative buffer.

Water quality modeling results indicate cropland and pasture land produce the majority of the nonpoint source pollution within the Dry Creek watershed while forest land is an important overall source in the Cane Creek watershed. Model results show cropland accounts for the majority of the nutrient and sediment load in the Dry Creek watershed. Pastureland is the major contributor of nitrogen in the Cane Creek watershed, with forest being the highest contributor of phosphorus and sediment. Streambank erosion is also a contributor to the sediment load contributing 7.8-10.6% of the total sediment load in these watersheds. These data suggest implementation of conservation practices in crop and pasture land in Dry Creek watershed and pasture land in Cane Creek watershed would be beneficial in reducing the nitrogen load to the Castor River Diversion Channel that is directly connected to the Mississippi River.

IDENTIFICATION OF CONSERVATION NEEDS

Load Reduction Analysis

Load reductions for the two watersheds in this study were modeled with STEPL using established conservation practice efficiencies (Waidler et al. 2009, GSWCC 2013, Tetra Tech 2017). The efficiencies of combined practices were calculated with STEPL's BMP Calculator. A total of eleven cropland conservation practice scenarios and nine pastureland scenarios were modeled. A description of each combined conservation practice scenario with calculated efficiencies can be found in Appendix H. 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 percentages of cropland and pastureland treated in 10% increments.

Cropland practices include cover crops, no-till, water and sediment control basins, grassed waterways, field borders, and grade stabilization structures. Land retirement was also used as a scenario to show what would happen if cropland was taken out of production. For pastureland, conservation practices included in the analysis were alternative water, critical area planting, forage and biomass planting, access control, prescribed grazing, heavy use protection, and grade stabilization. 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.

Conservation practices have been implemented in each of the modeled watersheds that need to be addressed in the existing load calculations. For this, estimates of the percentage of cropland with existing conservation practices were calculated based on input from area staff. It was estimated that 15% of the cropland was using cover crop and grade stabilization structures and around 15% of the pasture in the watershed was implementing forage and biomass planting. Calculated load reductions within the STEPL model show existing nutrient and sediment reductions range from 3.6-4.3% in Cane Creek and 7.3-7.5% in the Dry Creek watershed. The resulting loads then will be reflected in the total load that takes these existing conservation practices into account.

Cane Creek - Load reduction analysis for the Cane Creek watershed shows that the most beneficial conservation practices for reduction of nitrogen would be achieved in pastureland, while phosphorus and sediment reductions are most significant with practices applied to cropland. By applying cover crop, no-till, and grassed waterways to 50% of the 1,695 acres of cropland (848 acres), the reduction for nitrogen would be 11.2%, phosphorus 12.9%, and sediment 12.7% (Tables 16-18). In contrast, if all the cropland within the watershed was taken out of production through land retirement the resulting load reduction would be 26.0% for nitrogen, 27.3% phosphorus, and 29.0% sediment. Furthermore, applying a grade stabilization structure to 50% of the 2,166 acres of pastureland (1,083 acres) within the watershed the load reduction would be an additional 16.2% for nitrogen, 10.0% for phosphorus, and 9.4% for sediment. By combining cropland and pastureland practices in this watershed these practices can substantially reduce nutrient and sediment loads in the watershed.

Dry Creek - Load reduction analysis for the Dry Creek watershed indicates that the implementation of cropland conservation practices can significantly reduce nutrient and sediment loads. For example, with the implementation of cover crops, no-till, and grassed waterways on 50% of the 9,791 acres of cropland (4,895 acres) load reduction would be 22.0% for nitrogen, 26.7% for phosphorus, and 26.3% for sediment (Tables 19-21). As a comparison, if all the cropland within the watershed was taken out of production, the resulting load reduction would be 51.0% for nitrogen, 56.2% phosphorus, and 60.1% sediment. In addition, applying grade stabilization structures to 50% of the 4,640 acres of pastureland (2,320 acres) would reduce nitrogen by 12.0%, phosphorus 7.4%, and sediment 6.7%. This analysis suggests implementation of cropland conservation practices can significantly reduce nutrient and sediment loads in this watershed with added benefit from practices implemented on pasturelands.

Resource Priorities

In the Cane and Dry Creek watersheds, the top resource priority identified is the reduction of nitrogen entering the Diversion Channel, which is a direct conduit to the Mississippi River and eventually the Gulf of Mexico. STEPL modeling results suggest higher nitrogen loads are coming from pastureland (43.2%) compared to cropland (28.3%) in the Cane Creek watershed. For the Dry Creek watershed, STEPL modeling results indicate the majority of nitrogen is coming from cropland (55.7%) and the second highest source is pastureland (32.0%). Load reduction estimates suggest implementation of conservation practices in the Cane Creek watershed should be focused on pastureland and cropland should be the focus in the Dry Creek watershed. Total amount of pastureland in each watershed is 2,166 acres in the Cane Creek watershed and 4,640 acres in the Dry Creek watershed. However, total cropland is only 1,695 acres in the Cane Creek watershed and 9,791 acres in the Dry Creek watershed. Therefore, implementing pastureland conservation practices in the Cane Creek watershed and cropland conservation practices in the Dry Creek watershed will be the most effective in reducing nitrogen loads to the Diversion Channel.

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 susceptible acres classification, and a conservation practice rating system.

Management Units

To better plan for locations to implement conservation practices, the watersheds were split into 11 smaller sub-watersheds, or management units (MUs) (Figure 24). 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, phosphorus, and sediment yields for each MU in both watersheds ranging from about 450-9,000 acres (Table 22). MUs 1 and 8 cover the portions of the two watersheds located in the Mississippi Alluvial Plain. MUs were ranked by nitrogen yields since nitrogen from agriculture is generally considered the pollutant of most concern for hypoxia in the Gulf (Burkart and James 1999). The two highest ranked MUs (#5 and #7) in terms of nitrogen yields are located in the upper Dry Creek watershed (Figure 24). This area has a relatively high intensity of agricultural land use compared to the other areas in the uplands that includes both pasture and some crops and is steeper than the portions of the watershed in the lowlands. The next highest ranked MUs for nitrogen yields are #1 and #8, which cover the portions of the two watersheds located in the Mississippi Alluvial Plain and comprised of nearly all cropland.

Susceptible Acres Classification

To identify areas with the most pollution potential within a proposed project, a susceptible acres ranking system was developed to help field staff isolate problem areas and prioritize projects within the same MU. Four risk classes were used to rank the agricultural land within the watershed based on the 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 "other".   A description of each class type is detailed below and summarized in Table 23.

Highest – For the Cane and Dry Creek watersheds, land with the highest susceptibility classification for conservation planning was identified on both crop and pasture land. Irrigated land was identified as having the highest susceptibility for potential pollution in areas where crops are grown. Additionally, pastureland with a slope of >8% that is within 850 ft of a stream was also identified as having the highest susceptibility for potential pollution. Within these two watersheds, 3,477 acres are classified in the highest priority category, or roughly 8.4% of the watershed area (Figure 25).

High – Non-irrigated cropland and pastureland with a slope of <8% that is within 850 ft of a stream will be classified in the high susceptibility category for conservation planning.   There is a total of 13,001 acres of high priority acres in these three watersheds, or about 31.2% of the total drainage area.

Moderate – All pastureland outside of the 850 ft stream buffer will be classified in the moderate susceptibility category. This totals 1,799 acres, or 4.3% of the total area of the two study watersheds.

Low - Low susceptibility acres were defined as all of the forested areas within the watershed including land adjacent to a stream with good riparian corridor. Within the two study watersheds there are 20,949 low priority acres, or 50.3% of the total area.

N/A – This category represents all urban land use and land classified as water or wetlands within the two study watersheds. This represents 2,399 acres, or 5.8% 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 Cane and Dry 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 Cane and Dry Creek watershed was based on the amount of nitrogen reduction that could be achieved by the selected conservation practices. The top two rankings in the Cane Creek watershed are pastureland conservation practices (Table 24). The top practice for reducing the nitrogen load is treating pastureland with a grade stabilization structure. The other top practice in this watershed is a prescribed grazing/alternative water system with access control, forage and biomass planting, and heavy use protection. There is a total of 2,166 acres of pastureland within the Cane Creek watershed and only 1,695 acres of cropland.

In the Dry Creek watershed, cropland conservation practices make up the top nine in the ranking (Table 24). This is a result of cropland having a relatively higher load per acre and cropland conservation practices having relatively high efficiency ratings. The top practice for nitrogen reduction is a combination of cover crop, no-till, and a grassed waterway. The second highest practice in terms of nitrogen reduction is cover crop and a grade stabilization structure. Pastureland conservation practices rank at the bottom of all practices identified in the Dry Creek watershed. The top practice for reducing the nitrogen load using a pastureland practice is installing a grade stabilization structure. Overall there are 4,640 acres of pasture land in the Dry Creek watershed versus 9,791 acres of cropland. 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 the results of a watershed assessment study of two HUC-12 watersheds directly draining into the Castor River Diversion Channel, Cane Creek (071401070404) and Dry Creek (071401070406) located in Bollinger County, Missouri. These assessments support the Mississippi River Basin Healthy Watersheds Initiative (MRBI) designed to work with landowners to implement voluntary conservation practices to reduce nutrients entering the Gulf of Mexico. The goal of the MRBI program is to improve water quality, restore wetlands, and enhance wildlife habitat while ensuring economic viability of agricultural lands in high-priority watersheds within the Mississippi River Basin (USDA, 2017). Ultimately, this watershed assessment provides NRCS field staff with the necessary information to identify locations within the study watersheds where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. The assessment included three phases, 1) resource inventory, 2) resource analysis, and 3) identification of resource needs. There are seven main conclusions for this assessment:

1) Currently, there are no Total Maximum Daily Loads (TMDL) for streams within either watershed in this study. However, portions of the Castor River (7.5 mi) and Castor River Diversion Channel (20.3 mi) outside of the two watersheds, but within the Whitewater watershed are on the 303(d) impaired streams list for E. Coli (Castor River) from rural nonpoint sources;

2)). Available water quality data was limited to areas outside of both watershed boundaries, but available data downstream indicates nutrient concentrations exceed regional ambient water quality criteria suggested reference conditions for streams in the Mississippi Alluvial Plain region. This is particularly true for nitrogen, which was around 2-times higher than the reference concentration which is directly connected to the Mississippi River;

3) Historical aerial photo analysis was used to identify potential contributions of streambank erosion to water quality problems within the study watersheds and to evaluate riparian corridor vegetation. The majority of actively eroding reaches within the watershed were located along the main stem, while all of the streams located in the lowlands have be channelized. However, streambank erosion is also a significant contributor to the total sediment load of both watersheds contributing 7.8-10.6% of the load in these two watersheds.;

4) The riparian corridor assessment does show most poor riparian corridors are located in the lower main stem and into the lowlands while smaller stream tended to have better riparian forest cover. Streams assessed in the visual stream survey showed channels in the flatter lowlands and uplands were classified in poorer condition than streams on the hillslopes and main valley bottoms mainly due to poor riparian conditions, degraded streambanks, and livestock access to the stream. Additionally, streams draining cropland in the lowlands also did not generally have a sufficient vegetative buffer;

5) Water quality modeling results indicate cropland and pasture land produce the majority of the nonpoint source pollution within the Dry Creek watershed while forest land is an important overall source in the Cane Creek watershed. Model results show cropland accounts for the majority of the nutrient and sediment load in the Dry Creek watershed. Pastureland is the major contributor of nitrogen in the Cane Creek watershed, with forest being the highest contributor of phosphorus and sediment. Streambank erosion is also a contributor to the sediment load contributing 7.8-10.6% of the total sediment load in these watersheds. These data suggest implementation of conservation practices in crop and pasture land in Dry Creek watershed and pasture land in Cane Creek watershed would be beneficial in reducing the nitrogen load to the Castor River Diversion Channel that is directly connected to the Mississippi River;

6) Modeling results also indicate existing conservation practices, such as existing grade stabilization structures and cover crops, are responsible for slightly reducing the exiting nitrogen loads within the watershed. Load reduction analysis suggests and that additional conservation practices on cropland can significantly reduce loads with the implementation on

both crop and pasture land up to and exceeding 40% in Cane Creek and 68% in the Dry Creek watershed; and

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

REFERENCES

Burkart, M.R. and D.E. James (1999) Agricultural-Nitrogen Contributions to Hypoxia in the Gulf of Mexico. J. Environ. Qual. 28:850-859.

GSWCC (2013) Best Management Practices for Georgia Agriculture, Conservation Practices to Protect Surface Water Quality, Second Edition. The Georgia Soil and Water Conservation Commission.

Martin, D.J. and R.T. Pavlowsky (2011) Spatial Patterns of Channel Instability along an Ozark River, Southwest Missouri. Physical Geography Vol. 32, 445-468.

MDNR (2018A) 2018 Section 303(d) Listed Waters. Clean Water Commission Approved 1-4-2018. Missouri Department of Natural Resources.

MDNR (2018B) 2018 Section 303(d) Listed Waters TMDL Prioritization and Development Schedule. Missouri Department of Natural Resources.

MDNR (2015) Biological Assessment and Habitat Study Little Whitewater Creek Bollinger and Cape Girardeau Counties Fall 2014 – Spring 2015. Water Pollution Control Branch, Water Protection Program, Department of Environmental Quality, Missouri Department of Natural Resources.

Miller, D. E., and Vandike, J. E. (1997) Missouri State Water Plan Series Volume 2, Groundwater Resources of Missouri, Missouri Department of Natural Resources, Division of Geology and Land Survey. Water Resources Report 227 p.

Montgomery D.R. and L.H. MacDonald (2002) Diagnostic approach to stream channel assessment and monitoring. Journal of the American Water Resources Association, Vol. 38, 1-16.

Nigh, T. A., and W. A. Schroeder (2002) Atlas of Missouri Ecoregions. Missouri Department of Conservation.

Norman, D. E., (1994) Headwater diversion channel: Watershed inventory and assessment. Missouri Department of Conservation.

Pavlowsky, R.T., M.R. Owen, and R.A. Bradley (2016) Historical Rainfall Analysis for the Big Barren Creek Watershed, Southeast Missouri (1955-2015). Ozarks Environmental and Water Resources Institute, Missouri State University, OEWRI EDR-16-001, March 23, 2016.

Peel, M. C., B. L. Finlayson, and T. A. McMahon (2007) Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences Discussions, European Geosciences Union 1633-1644.

Reminga, K.N., G.F. Roman, K.A. Coonen, M.R. Owen, H.R. Adams, and R.T. Pavlowsky (2019). Mississippi River Basin Healthy Watershed Initiative (MRBI) Watershed Assessment for: Upper Apple Creek Watershed (HUC12# 071401050401) and Middle Apple Creek Watershed (HUC12# 071401050403). Final Report. Ozarks Environmental and Water Resources Institute, Missouri State University, OEWRI EDR-19-004, October 9, 2019.

Rosgen, D.L. (1996) Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Sanford W.E. and D. L. Selnick (2013) Estimation of Evapotranspiration Across the Conterminous United States Using Regression with Climate and Land-Cover Data. Journal of the American Water Resources Association Vol. 49 (1), 217-230.

Simon, A and M. Rinaldi (2000) Channel Instability in the Loess Area of the Midwestern United States. Journal of the American Water Resources Association, Vol. 36, No.1.

Tetra Tech, Inc. (2017) User's Guide Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) Version 4.4. Developed for U.S. Environmental Protection Agency by Tetra Tech Inc., Fairfax, Virginia, September 2017.

USDA (2018a) Natural Resources Conservation Service. Regional Hydraulic Geometry Curves. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/manage/hydrology/?cid=nrcs143_015052 (October 17, 2019).

USDA (2018b) National soil survey handbook, title 430-VI, Part 622. U.S. Department of Agriculture, Natural Resources Conservation Service.

USDA (2017) Mississippi River Basin Healthy Watersheds. United States Department of Agriculture. Accessed November 11, 2018. www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcseprd1410017.pdf.

USDA (2014) Riparian Forest Buffer. Natural Resource Conservation Service, United States Department of Agriculture Conservation Practice Standard. Code 391.

USDA (2009) Chapter 7, Hydrologic Soil Groups. National Resources Conservation Service, United States Department of Agriculture. Part 630 Hydrology National Engineering Handbook.

USDA (2006) Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. National Resources Conservation Service, U.S. Department of Agriculture Handbook 296.

USDA (1998) Stream Visual Assessment Protocol. National Resources Conservation Service, U. S. Department of Agriculture National Water and Climate Center Technical Note 99-1.

USEPA (2001) Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion X. U.S. Environmental Protection Agency, Office of Water, EPA 822-B-01-016, December 2001.

Vandike, J. E. (1995) Missouri State Water Plan Series Volume 1, Surface Water Resources of Missouri, Missouri Department of Natural Resources, Division of Geology and Land Survey. Water Resources Report Number 45. 122 p.

Waidler, D., M. White, E. Steglich, S. Wang, J. Williams, C.A. Jones, R. Srinivasan (2009) Conservation Practice Modeling Guide for SWAT and APEX.

TABLES

Table 1. Annual rainfall and average annual temperature for Marble Hill, MO (1989-2018).

Year	Total Rainfall (in)	Average Temperature (F^o)
1989	44.1	54.3
1990	57.1	57.8
1991	49.2	57.6
1992	44.0	56.1
1993	54.7	55.3
1994	49.4	56.3
1995	47.7	56.1
1996	50.5	55.2
1997	46.9	55.6
1998	*50.3	59.3
1999	45.2	58.0
2000	42.5	57.0
2001	46.6	57.4
2002	64.5	57.2
2003	50.1	56.2
2004	*45.6	57.1
2005	49.8	58.2
2006	54.0	57.8
2007	44.1	*58.4
2008	66.9	*55.1
2009	55.3	*54.4
2010	44.5	*57.0
2011	68.4	*57.5
2012	37.0	*59.5
2013	61.6	*56.3
2014	47.9	*55.6
2015	68.0	*58.0
2016	53.3	*59.9
2017	48.4	*58.8
2018	55.2	*57.9
n	28	30.0
Min	37.0	54.3
Mean	51.7	57.0
Max	68.4	59.9

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

Missing data were retrieved from nearby stations: *Zalma and *Cape Girardeau

Table 2. Watershed soil characteristics summary

Dry Creek									
Soil Order	**%**	**Hydrologic Soil Group**	**%**	**Soil Erosion K-Factor**	**%**	**Soil Erosion T-Factor**	**%**	**Land Capability Classification**	%
Alfisol	75.9	A	0.4	<0.2	35.1	0	0.8	2w	8.3
Entisol	8.9	B	7.8	0.2-0.3	1.0	2	0.1	3w	7.6
Ultisol	0.2	B/D	5.6	0.3-0.4	24.9	3	13.7	4w	8.9
Inceptisol	4.2	C	61.8	0.4-0.5	28.4	4	51.4	2e	0.7
Other	0.3	C/D	13.2	>0.5	0.1	5	23.4	3e	17.7
		D	0.1					4e	8
		Other	0.5					6e	0.6
								7e	29.4
								2s	2.5
								3s	0.0
								4s	4.4
								6s	0.3
								Other	1.0

Cane Creek									
Soil Order	**%**	**Hydrologic Soil Group**	**%**	**Soil Erosion K-Factor**	**%**	**Soil Erosion T-Factor**	**%**	**Land Capability Classification**	%
Alfisol	75.9	A	0.1	<0.2	40.4	0	0.8	2w	7.8
Entisol	8.5	B	13.3	0.2-0.3	1.8	3	20.6	3w	7.3
Ultisol	7.4	B/D	5.3	0.3-0.4	24.4	4	51.7	4w	8.9
Inceptisol	3.3	C	62.2	0.4-0.5	28.9	5	22.4	2e	0.7
Other	0.4	C/D	14.0	>0.5	0.0			3e	18.3
		D	0.0					4e	8.1
		Other	0.5					6e	0.4
								7e	29.4
								2s	2.6
								3s	0.5
								4s	5.9
								6s	4.7
								7s	0.1
								Other	0.9

Table 3. Drainage network summary

Water Feature	Length/Area
Total Streams	**180.4 mi**
Permanent Flow	10.3 mi
Cane Creek	1.2 mi
Dry Creek	9.0 mi
Intermittent Flow	170.1 mi
Cane Creek	69.5 mi
Dry Creek	100.6 mi
Waterbodies	
Ponds/Lakes	180.1 ac
Cane Creek	67.6 ac
Dry Creek	112.4 ac

Table 4. Generalized crop data classification from 2014-2018

Cane Creek General Land Use/Land Cover	**2014**	**2015**	**Year 2016**	**2017**	**2018**	**% Change 2014-2018**
Row Crops	6.5%	6.9%	7.5%	7.7%	7.5%	15.50
Dbl Crop	0.1%	0.1%	0.0%	0.1%	0.1%	17.86
Small Grains	0.0%	0.0%	0.0%	0.0%	0.0%	-37.87
Alfalfa and other Hay	2.6%	2.2%	3.0%	3.3%	3.1%	20.59
Fallow/Idle Cropland and Barren	0.0%	0.3%	0.1%	0.0%	0.0%	95.47
Developed Land	3.2%	3.2%	3.2%	3.2%	3.1%	-0.75
Forest	70.0%	71.9%	71.6%	71.0%	70.8%	1.15
Grass/Pasture	16.5%	14.4%	13.5%	13.6%	14.0%	-15.18
Wetlands	0.5%	0.6%	0.5%	0.6%	0.7%	30.48
Open Water	0.6%	0.5%	0.6%	0.5%	0.6%	-2.53
Dry Creek General Land Use/Land Cover	**2014**	**2015**	**Year 2016**	**2017**	**2018**	**% Change 2014-2018**
Row Crops	22.2%	23.8%	24.6%	25.5%	24.8%	11.73
Dbl Crop	1.9%	0.5%	0.5%	0.3%	1.5%	-19.78
Small Grains	0.3%	0.1%	0.7%	0.1%	0.0%	-86.74
Alfalfa and other Hay	8.7%	7.0%	9.1%	11.5%	10.8%	23.62
Fallow/Idle Cropland and Barren	0.0%	0.6%	0.3%	0.5%	0.1%	115.14
Developed Land	3.8%	4.0%	3.8%	3.8%	3.7%	-2.19
Forest	37.4%	39.7%	39.8%	38.9%	38.6%	3.27
Grass/Pasture	23.1%	21.2%	18.9%	16.9%	17.6%	-23.49
Wetlands	2.3%	2.5%	2.0%	2.1%	2.3%	-0.04
Open Water	0.3%	0.3%	0.3%	0.3%	0.3%	-2.95

Table 5. Specific crop data from 2014-2018 with percent change.

Cane Creek Class Name	**Year 2014**	**2015**	**2016**	**2017**	**2018**	**% Change 2014-2018**
Sorghum	0.2%	0.0%	0.0%	6.8%	6.6%	3136.8%
Soybeans	4.9%	5.6%	5.4%	0.0%	0.0%	-100.0%
Developed/Open Space	2.9%	2.9%	2.9%	2.8%	2.9%	-2.8%
Deciduous Forest	69.8%	71.7%	71.5%	70.9%	70.6%	1.1%
Grass/Pasture	16.5%	14.4%	13.5%	13.6%	14.0%	-15.2%
Dry Creek Class Name	**Year 2014**	**2015**	**2016**	**2017**	**2018**	**% Change 2014-2018**
Soybeans	19.5%	20.6%	19.8%	22.2%	21.9%	12.3
Other Hay/Non Alfalfa	8.7%	7.0%	9.1%	11.4%	10.8%	23.3
Developed/Open Space	3.2%	3.2%	3.1%	3.1%	3.0%	-7.1
Deciduous Forest	37.3%	39.6%	39.7%	38.9%	38.4%	3.1
Grass/Pasture	23.1%	21.2%	18.9%	16.9%	17.6%	-23.5
Woody Wetlands	2.3%	2.4%	2.0%	1.9%	2.2%	-3.9
Open Water	0.3%	0.3%	0.3%	0.3%	0.3%	-2.9

Table 6. Water quality monitoring sites with nutrient and sediment data summary.

Site ID	TP (n)	TP start date	TP end date	TP Mean (mg/L)	TN (n)	TN start date	TN end date	TN Mean (mg/L)	TSS (n)	TSS start date	TSS end date	TSS Mean (mg/L)
2288/6.6	116	11/2/1999	10/23/2018	0.045	116	11/2/1999	10/23/2018	0.31	108	11/2/1999	9/19/2018	24.38
2196/0.9	168	6/3/1999	11/9/2009	0.127	163	6/3/1999	11/9/2009	1.24	172	6/3/1999	11/9/2009	43.44
2196/15.3	10	10/23/1974	7/17/1975	0.053	10	10/23/1974	7/17/1975	1.06	NA	NA	NA	NA
2229/17.7	35	3/14/2000	3/24/2015	0.027	35	3/14/2000	3/24/2015	0.50	4	9/19/2012	3/24/2015	<5

n = sample number

TP = total phosphorus

TN = total nitrogen

TSS = total suspended sediment

602 = Long Branch Site Number

Table 7. Data and source summary with web site address

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

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

Table 8. Water quality data summary

Site	TP (mg/L)						TN (mg/L)						TSS (mg/L)					
ID	n	min	mean	max	SD	CV%	n	min	mean	max	SD	CV%	N	min	mean	max	SD	CV%
2288/6.6	116	0.020	0.045	0.4	0.052	117.2	116	0.08	0.31	1.60	0.233	75.53	108	6.0	24.38	348.0	43.91	180.1
2196/0.9	168	0.008	0.126	1.527	0.156	123.5	163	0.12	1.24	49.60	3.878	312.6	172	0.0	43.45	2282	175.2	403.3
2196/15.3	10	0.020	0.053	0.130	0.033	61.65	10	0.11	1.07	7.06	2.119	200.6	N/A	N/A	N/A	N/A	N/A	N/A
2229/17.7	35	0.010	0.027	0.240	0.049	184.4	35	0.14	0.50	1.62	0.356	71.76	4	5.0	5.0	5.0	0.0	0.0

n = sample number

TP = total phosphorus

TN = total nitrogen

TSS = total suspended sediment

N/A = not available

Table 9. 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 10. Point-to-point (PTP) errors by watershed.

Watershed	Range PTP Error (ft)	Mean PTP Error (ft)
Cane Creek	3.3 – 22.5	12.9
Dry Creek	3.6 – 20.2	11.0

Table 11. Channel Classification analysis summary

Watershed	**Total Length (mi)**	**Channelized**	**Dam/Pond**	**Stable**	**Active**	**Not Visible**
Cane Creek	128.2	13.0	4.6	67.9	22.9	19.8
		10%	4%	53%	18%	15%
Dry Creek	165.7	43.6	5.5	73.6	12.1	30.9
		26%	3%	44%	7%	19%

Table 12. Riparian corridor analysis summary

Watershed	Total Length (mi)	Good	Moderate	Poor
Cane Creek	128.2	79.8	21.7	26.7
		62%	17%	21%
Dry Creek	165.7	50.5	32.0	83.3
		30%	19%	50%

Table 13. Visual Stream Assessment Results

Cane Creek		Average Rating					
Landform	**Number of Assessments**	**Overall Score**	**Channel Condition**	**Hydrologic Alteration**	**Riparian Corridor**	**Bank Stability**	**Canopy Cover**
Hillslope	14	8.9	10.0	9.4	8.7	8.9	9.0
Upland	7	6.5	8.5	8.8	2.8	8.0	3.0
Lowland	-	-	-	-	-	-	-
Valley Bottom	41	7.2	8.6	8.6	6.4	7.0	6.9

Dry Creek		Average Rating					
Landform	**Number of Assessments**	**Overall Score**	**Channel Condition**	**Hydrologic Alteration**	**Riparian Corridor**	**Bank Stability**	**Canopy Cover**
Hillslope	26	8.2	8.8	8.7	8.2	8.0	8.0
Upland	34	5.9	7.0	6.3	5.3	6.3	4.6
Lowland	19	4.8	6.2	3.9	5.0	4.1	4.9
Valley Bottom	41	6.8	7.4	7.6	6.1	7.0	6.1

Table 14. STEPL model results

Watershed ID	Total Ad (ac)	Runoff (ac-ft)	Runoff Yield (ac-ft/ac)	% Rainfall as runoff	Annual Load			Annual Yield			Mean Concentration		
					N- lb/yr	P- lb/yr	Sed- t/yr	N- lb/ac/yr	P- lb/ac/yr	Sed- t/ac/yr	N- mg/L	P- mg/L	Sed- mg/L
Cane Creek	15,474	13,677	0.88	20.4	67,471	15,575	7,855	4.36	1.01	0.51	1.81	0.419	422
Dry Creek	26,150	27,442	1.05	24.2	186,230	39,599	18,698	7.12	1.51	0.72	2.50	0.531	501

Table 15. STEPL results by sources

Sources	N Load (lb/yr)	%	P Load (lb/yr)	%	Sediment Load (t/yr)	%
Cane Creek						
Urban	5,410	8.0	836	5.4	124	1.6
Cropland	19,062	28.3	4,752	30.5	2,398	30.5
Pastureland	29,150	43.2	4,146	26.6	1,976	25.2
Forest	12,510	18.5	5,326	34.2	2,525	32.1
Streambank	1,331	2.0	512	3.3	832	10.6
Total	67,464	100.0	15,573	100.0	7,855	100.0
Dry Creek						
Urban	10,705	5.7	1,654	4.2	246	1.3
Cropland	103,654	55.7	24,965	63.0	11,832	63.3
Pastureland	59,644	32.0	7,804	19.7	3,357	17.9
Forest	9,877	5.3	4,271	10.8	1,813	9.7
Streambank	2,322	1.3	894	2.3	1,451	7.8
Total	186,202	100.0	39,588	100.0	18,698	100.0

Table 16. Nitrogen load reduction results for the Cane Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Nitrogen 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	2.2	2.7	3.1	3.6	4.0	4.4
No-till	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.0
Cover Crop and No-till	1.6	3.1	4.7	6.3	7.9	9.4	11.0	12.6	14.1	15.7
Water and Sediment Control Basin	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.3	17.2	19.1
Cover Crop and Water and Sediment Control Basin	2.0	4.0	5.9	7.9	9.9	11.9	13.9	15.8	17.8	19.8
Grassed Waterways	1.9	3.8	5.8	7.7	9.6	11.5	13.4	15.4	17.3	19.2
Field Border	1.9	3.8	5.8	7.7	9.6	11.5	13.4	15.4	17.3	19.2
Grade Stabilization Structure	2.1	4.2	6.4	8.4	10.6	12.7	14.8	17.0	19.1	21.2
Cover crop, No-till, and Grassed Waterway	2.2	4.5	6.7	8.9	11.2	13.4	15.7	19.9	20.1	22.4
Cover Crop and Grade Stabilization Structure	2.2	4.5	6.7	7.9	11.2	13.4	15.6	17.8	20.1	22.3
Land Retirement	2.6	5.2	7.8	10.4	13.0	15.6	18.2	20.7	23.4	26.0
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Alternative Water	0.6	1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.6	6.3
Critical Area Planting	1.0	2.0	3.0	3.9	4.9	5.9	6.9	7.9	8.9	9.9
Forage and Biomass Planting	0.6	1.2	1.8	2.4	3.1	3.7	4.3	4.9	5.5	6.1
Access Control	1.3	2.5	3.8	5.1	6.3	7.6	8.9	10.1	11.4	12.7
Access Control, and Forage and Biomass Planting	1.2	2.4	3.6	4.7	5.9	7.1	8.3	9.5	10.7	11.8
Prescribed Grazing	1.7	3.4	5.1	6.8	8.5	10.2	11.8	13.5	15.2	16.9
Access Control, Forage and Biomass Planting, and Prescribed Grazing	2.2	4.4	6.5	8.7	10.9	13.1	15.2	17.4	19.6	21.8
Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	2.5	5.0	7.4	9.9	12.4	14.9	17.4	19.8	22.3	24.8
Grade Stabilization Structure	3.2	6.5	9.7	13.0	16.2	19.4	22.7	25.9	29.2	32.4

Table 17. Phosphorus load reduction results for the Cane Creek watershed.

Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Phosphorus load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.3	0.5	0.8	1.1	1.4	1.6	1.9	2.2	2.4	2.7
No-till	2.3	4.5	6.8	9.0	11.3	13.5	15.8	18.0	20.3	22.5
Cover Crop and No-till	2.3	4.6	7.0	9.3	11.6	13.9	16.3	18.6	20.9	23.2
Water and Sediment Control Basin	2.4	4.8	7.3	9.7	12.1	14.5	17.0	19.4	21.8	24.2
Cover Crop and Water and Sediment Control Basin	2.4	4.8	7.3	9.7	12.1	14.5	17.0	19.4	21.8	24.2
Grassed Waterways	2.1	4.2	6.3	8.4	10.5	12.6	14.7	16.8	18.9	21.0
Field Border	2.0	4.1	6.1	8.2	10.2	12.2	14.3	16.3	18.4	20.4
Grade Stabilization Structure	2.3	4.6	6.9	9.2	11.4	13.7	16.0	18.3	20.6	22.9
Cover crop, No-till, and Grassed Waterway	2.6	5.2	7.7	10.3	12.9	15.5	18.0	20.6	23.2	25.8
Cover Crop and Grade Stabilization Structure	2.4	4.7	7.1	9.4	11.8	14.1	16.5	18.8	21.2	23.6
Land Retirement	2.7	5.5	8.2	10.9	13.7	16.4	19.1	21.9	24.6	27.3
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Alternative Water	0.4	0.8	1.3	1.7	2.1	2.5	2.9	3.3	3.8	4.2
Critical Area Planting	0.9	1.8	2.6	3.5	4.4	5.3	6.1	7.0	7.9	8.8
Forage and Biomass Planting	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.6
Access Control	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.0
Access Control, and Forage and Biomass Planting	0.8	1.6	2.4	3.2	4.0	4.7	5.5	6.3	7.1	7.9
Prescribed Grazing	0.8	1.5	2.3	3.1	3.8	4.6	5.4	6.2	6.9	7.7
Access Control, Forage and Biomass Planting, and Prescribed Grazing	1.1	2.3	3.4	4.6	5.7	6.9	8.0	9.2	10.3	11.4
Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	1.3	2.7	4.0	5.4	6.7	8.1	9.4	10.8	12.1	13.4
Grade Stabilization Structure	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0

Table 18. Sediment load reduction results for the Cane Creek watershed.

Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Sediment load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.1
No-till	2.4	4.7	7.1	9.4	11.8	14.1	16.5	18.8	21.2	23.5
Cover Crop and No-till	2.4	4.8	7.3	9.7	12.1	14.5	16.9	19.4	21.8	24.2
Water and Sediment Control Basin	2.6	5.2	7.9	10.5	13.1	15.7	18.4	21.0	23.6	26.2
Cover Crop and Water and Sediment Control Basin	2.6	5.2	7.9	10.5	13.1	15.7	18.4	21.0	23.6	26.2
Grassed Waterways	2.0	4.0	6.0	7.9	9.9	11.9	13.9	15.9	17.9	19.8
Field Border	2.0	4.0	6.0	7.9	9.9	11.9	13.9	15.9	17.9	19.8
Grade Stabilization Structure	2.3	4.6	6.9	9.2	11.4	13.7	16.0	18.3	20.6	22.9
Cover crop, No-till, and Grassed Waterway	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4
Cover Crop and Grade Stabilization Structure	2.4	4.7	7.1	9.5	11.8	14.2	16.6	18.9	21.3	23.7
Land Retirement	2.9	5.8	8.7	11.6	14.5	17.4	20.3	23.2	26.1	29.0
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Alternative Water	0.5	0.9	1.4	1.9	2.4	2.8	3.3	3.8	4.2	4.7
Critical Area Planting	1.1	2.1	3.2	4.2	5.3	6.3	7.4	8.5	9.5	10.6
Forage and Biomass Planting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Access Control	1.6	3.1	4.7	6.2	7.8	9.4	10.9	12.5	14.0	15.6
Access Control, and Forage and Biomass Planting	0.8	1.6	2.3	3.1	3.9	4.7	5.5	6.2	7.0	7.8
Prescribed Grazing	0.8	1.7	2.5	3.4	4.2	5.0	5.9	6.7	7.5	8.4
Access Control, Forage and Biomass Planting, and Prescribed Grazing	1.2	2.4	3.6	4.7	5.9	7.1	8.3	9.5	10.7	11.8
Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	1.4	2.7	4.1	5.5	6.8	8.2	9.6	10.9	12.3	13.7
Grade Stabilization Structure	1.9	3.8	5.7	7.5	9.4	11.3	13.2	15.1	17.0	18.9

Table 19. Nitrogen load reduction results for the Dry Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Nitrogen load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9.0
No-till	2.4	4.9	7.3	9.8	12.2	14.7	17.1	19.6	22.0	24.5
Cover Crop and No-till	3.0	6.0	9.0	12.1	15.1	18.1	21.1	24.1	27.1	30.1
Water and Sediment Control Basin	3.7	7.4	11.1	14.8	18.5	22.1	25.8	29.5	33.2	36.9
Cover Crop and Water and Sediment Control Basin	3.8	7.7	11.5	15.4	19.2	23.1	26.9	30.8	34.6	38.5
Grassed Waterways	3.8	7.6	11.4	15.2	19.0	22.8	26.6	30.4	34.2	37.9
Field Border	3.8	7.6	11.4	15.2	19.0	22.8	26.6	30.4	34.2	37.9
Grade Stabilization Structure	4.2	8.3	12.5	16.7	20.9	25.0	29.2	33.4	37.6	41.7
Cover crop, No-till, and Grassed Waterway	4.4	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.5	43.9
Cover Crop and Grade Stabilization Structure	4.4	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.6	44.0
Land Retirement	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45.9	51.0
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Alternative Water	0.5	0.9	1.4	1.8	2.3	2.7	3.2	3.7	4.1	4.6
Critical Area Planting	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0
Forage and Biomass Planting	0.5	1.0	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8
Access Control	0.9	1.8	2.7	3.6	4.5	5.3	6.2	7.1	8.0	8.9
Access Control, and Forage and Biomass Planting	0.9	1.7	2.6	3.5	4.4	5.2	6.1	7.0	7.8	8.7
Prescribed Grazing	1.3	2.5	3.8	5.1	6.3	7.6	8.8	10.1	11.4	12.6
Access Control, Forage and Biomass Planting, and Prescribed Grazing	1.6	3.2	4.9	6.5	8.1	9.7	11.3	13.0	14.6	16.2
Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	1.8	3.7	5.5	7.4	9.2	11.1	12.9	14.7	16.6	18.4
Grade Stabilization Structure	2.4	4.8	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0

Table 20. Phosphorus load reduction results for the Dry Creek watershed.

Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Phosphorus load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.5
No-till	4.6	9.3	13.9	18.5	23.2	27.8	32.5	37.1	41.7	46.4
Cover Crop and No-till	4.8	9.6	14.3	19.1	23.9	28.7	33.5	38.2	43.0	47.8
Water and Sediment Control Basin	5.0	9.9	14.9	19.9	24.8	29.8	34.7	39.7	44.7	49.6
Cover Crop and Water and Sediment Control Basin	5.0	9.9	14.9	19.9	24.8	29.8	34.7	39.7	44.7	49.6
Grassed Waterways	4.4	8.7	13.1	17.4	21.8	26.2	30.5	34.9	39.2	43.6
Field Border	4.2	8.5	12.7	16.9	21.1	25.4	29.6	33.8	38.1	42.3
Grade Stabilization Structure	4.7	9.5	14.2	18.9	23.6	28.4	33.1	37.8	42.6	47.3
Cover crop, No-till, and Grassed Waterway	5.3	10.7	16.0	21.3	26.7	32.0	37.3	42.7	48.0	53.3
Cover Crop and Grade Stabilization Structure	4.9	9.7	14.6	19.5	24.3	29.2	34.1	38.9	43.8	48.6
Land Retirement	5.6	11.2	16.9	22.5	28.1	33.7	39.3	44.9	50.6	56.2
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Alternative Water	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
Critical Area Planting	0.6	1.2	1.9	2.5	3.1	3.7	4.4	5.0	5.6	6.2
Forage and Biomass Planting	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4
Access Control	0.9	1.9	2.8	3.7	4.6	5.6	6.5	7.4	8.4	9.3
Access Control, and Forage and Biomass Planting	0.6	1.2	1.7	2.3	2.9	3.5	4.1	4.7	5.2	5.8
Prescribed Grazing	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.5	5.0	5.6
Access Control, Forage and Biomass Planting, and Prescribed Grazing	0.8	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.4
Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	1.0	2.0	3.0	3.9	4.9	5.9	6.9	7.9	8.9	9.8
Grade Stabilization Structure	1.5	3.0	4.4	5.9	7.4	8.9	10.3	11.8	13.3	14.8

Table 21. Sediment load reduction results for the Dry Creek watershed.

Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Sediment load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.6	1.3	1.9	2.5	3.2	3.8	4.4	5.1	5.7	6.3
No-till	1.3	9.7	14.6	19.5	24.4	29.2	34.1	39.0	43.8	48.7
Cover Crop and No-till	5.0	10.0	15.1	20.1	25.1	30.1	35.1	40.1	45.2	50.2
Water and Sediment Control Basin	5.4	10.9	16.3	21.8	27.2	32.7	38.1	43.5	49.0	54.4
Cover Crop and Water and Sediment Control Basin	5.4	10.9	16.3	21.8	27.2	32.7	38.1	43.5	49.0	54.4
Grassed Waterways	4.1	8.2	12.3	16.5	20.6	24.7	28.8	32.9	37.0	41.1
Field Border	4.1	8.2	12.3	16.5	20.6	24.7	28.8	32.9	37.0	41.1
Grade Stabilization Structure	4.7	9.5	14.2	19.0	23.7	28.5	33.2	38.0	42.7	47.5
Cover crop, No-till, and Grassed Waterway	5.3	10.5	15.8	21.1	26.3	31.6	36.9	42.1	47.4	52.6
Cover Crop and Grade Stabilization Structure	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1	49.0
Land Retirement	6.0	12.0	18.0	24.0	30.1	36.1	42.1	48.1	54.1	60.1
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Alternative Water	0.3	0.7	1.0	1.3	1.7	2.0	2.4	2.7	3.0	3.4
Critical Area Planting	0.8	1.5	2.3	3.0	3.8	4.5	5.3	6.0	6.8	7.5
Forage and Biomass Planting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Access Control	1.1	2.2	3.3	4.5	5.6	6.7	7.8	8.9	10.0	11.1
Access Control, and Forage and Biomass Planting	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.5	5.0	5.6
Prescribed Grazing	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0
Access Control, Forage and Biomass Planting, and Prescribed Grazing	0.8	1.7	2.5	3.4	4.2	5.1	5.9	6.8	7.6	8.5
Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	1.0	2.0	2.9	3.9	4.9	5.9	6.8	7.8	8.8	9.8
Grade Stabilization Structure	1.3	2.7	4.0	5.4	6.7	8.1	9.4	10.8	12.1	13.5

Table 22. Annual nutrient and sediment yields and MU ranking by nitrogen yield.

Watershed ID	Total Ad (ac)	Crop Acres	Pasture Acres	Annual Yield N-lb/ac/yr	Annual Yield P-lb/ac/yr	Annual Yield Sed-T/ac/yr	Priority Rank
5	2,329.74	1,058.33	711.64	10.43	2.37	1.33	1
7	3,183.31	1,000.19	1,256.14	8.91	1.69	0.81	2
8	453.79	263.6	86.75	7.13	1.34	0.51	3
1	9,083.44	5,734.00	725.32	6.04	1.19	0.39	4
9	2,967.84	811.52	568.46	5.66	1.18	0.53	5
6	3,234.29	450.22	782.7	5.62	1.17	0.58	6
3	3,301.32	620.01	546.55	5.61	1.35	0.73	7
4	2,437.89	571	276.37	4.95	1.18	0.58	8
2	2,607.10	368.24	349.32	4.86	1.25	0.69	9
10	8,415.28	517.96	1,202.85	3.41	0.76	0.35	10
11	3,651.57	103.76	309.51	2.11	0.61	0.36	11

Table 23. Summary of susceptibility classification for the two study watersheds.

Susceptible Acres Rank	**Land Use and Conditions**	Cane Creek Acres (%)	Dry Creek Acres (%)
Highest	Irrigated Cropland and Pasture on slope >8% and within 850 ft of stream	667 (4.3%)	2,810 (10.7%)
High	Non-irrigated Cropland Pasture on slope <8% and within 850 ft of stream	2,735 (17.7%)	10,266 (39.3%)
Moderate	All other pasture	452 (2.9%)	1,347 (5.1%)
Low	Forest	10,908 (70.5%)	10,041 (38.4%)
N/A	Urban, Water, and Wetlands	712 (4.6%)	1,687 (6.4%)
	Total	15,474 (100%)	26,150 (100%)

Table 24. Ranked conservation practices by largest nitrogen load reduction.

Rank	Conservation Practices for Cane Creek **Nitrogen Reduction**	Conservation Practices for Dry Creek **Nitrogen Reduction**
1	PASTURE - Grade Stabilization Structure	CROPLAND - Cover crop, No-till, and Grassed Waterway
2	PASTURE - Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	CROPLAND - Cover Crop and Grade Stabilization Structure
3	CROPLAND - Cover crop, No-till, and Grassed Waterway	CROPLAND - Grade Stabilization Structure
4	CROPLAND - Cover Crop and Grade Stabilization Structure	CROPLAND - Cover Crop and Water and Sediment Control Basin
5	PASTURE - Access Control, Forage and Biomass Planting, and Prescribed Grazing	CROPLAND - Grassed Waterways
6	CROPLAND - Grade Stabilization Structure	CROPLAND - Field Border
7	CROPLAND - Cover Crop and Water and Sediment Control Basin	CROPLAND - Water and Sediment Control Basin
8	CROPLAND - Grassed Waterways	CROPLAND - Cover Crop and No-till
9	CROPLAND - Field Border	CROPLAND - No-till
10	CROPLAND - Water and Sediment Control Basin	PASTURE - Grade Stabilization Structure
11	PASTURE - Prescribed Grazing	PASTURE - Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing
12	CROPLAND - Cover Crop and No-till	PASTURE - Access Control, Forage and Biomass Planting, and Prescribed Grazing
13	CROPLAND - No-till	PASTURE - Prescribed Grazing
14	PASTURE - Access Control	CROPLAND - Cover Crop
15	PASTURE - Access Control, and Forage and Biomass Planting	PASTURE - Access Control
16	PASTURE - Critical Area Planting	PASTURE - Access Control, and Forage and Biomass Planting
17	PASTURE - Alternative Water	PASTURE - Critical Area Planting
18	PASTURE - Forage and Biomass Planting	PASTURE - Alternative Water
19	CROPLAND - Cover Crop	PASTURE - Forage and Biomass Planting

FIGURES

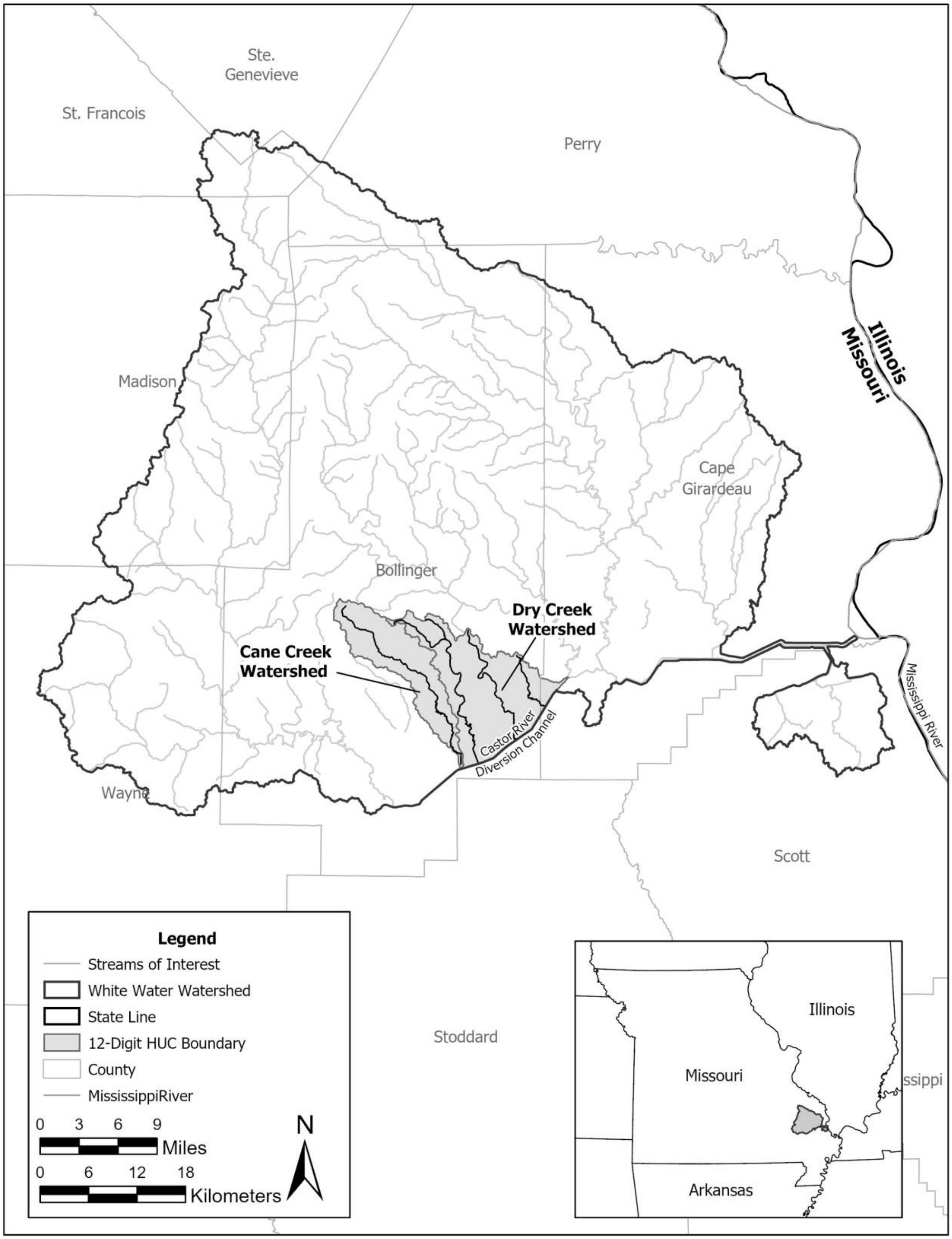


Figure 1. White Water watershed in Southeast Missouri.

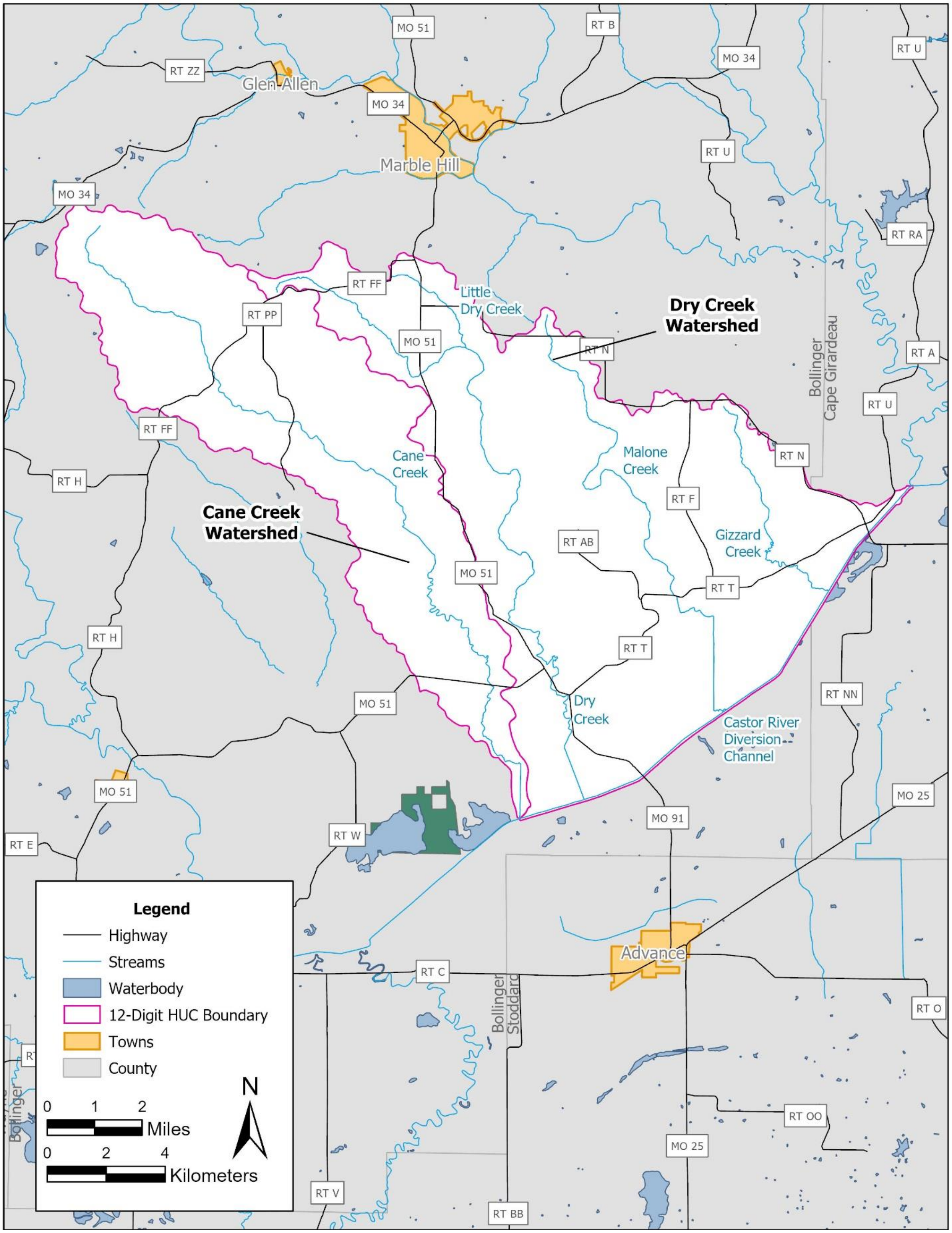


Figure 2. The Cane Creek, and Dry Creek watersheds.

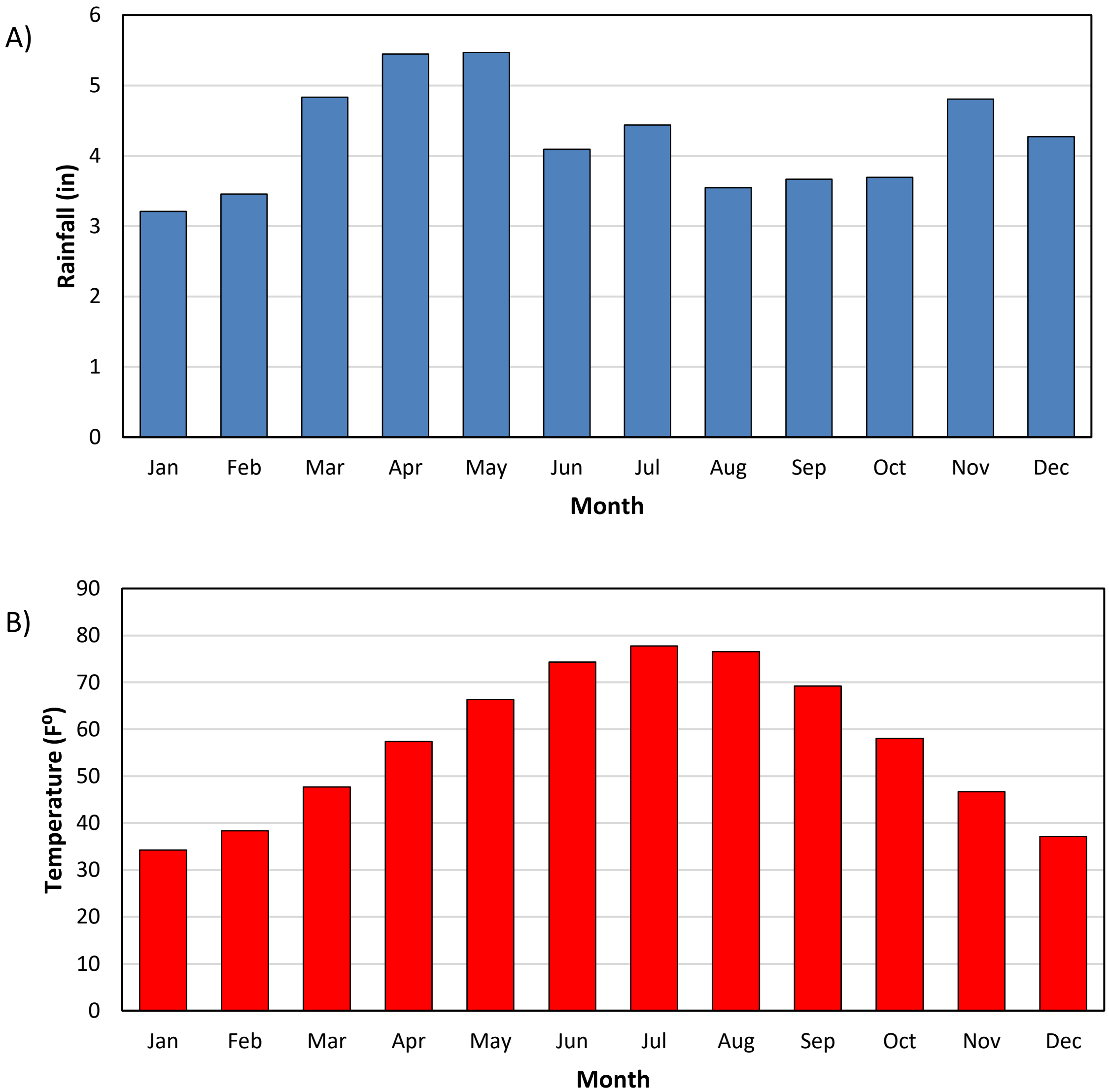
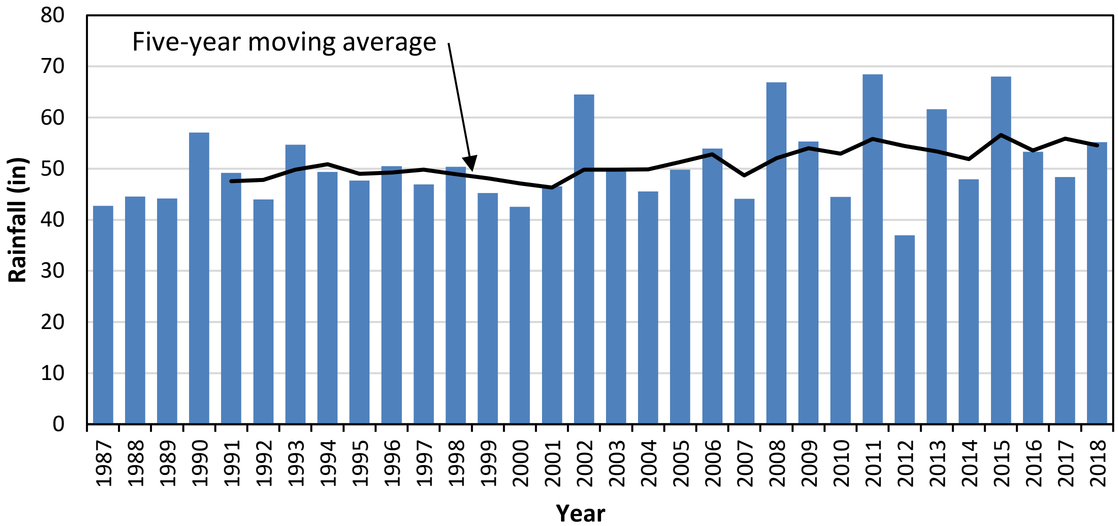


Figure 3. Mean monthly A) rainfall and B) temperature from 1989-2019 for Marble Hill, MO.



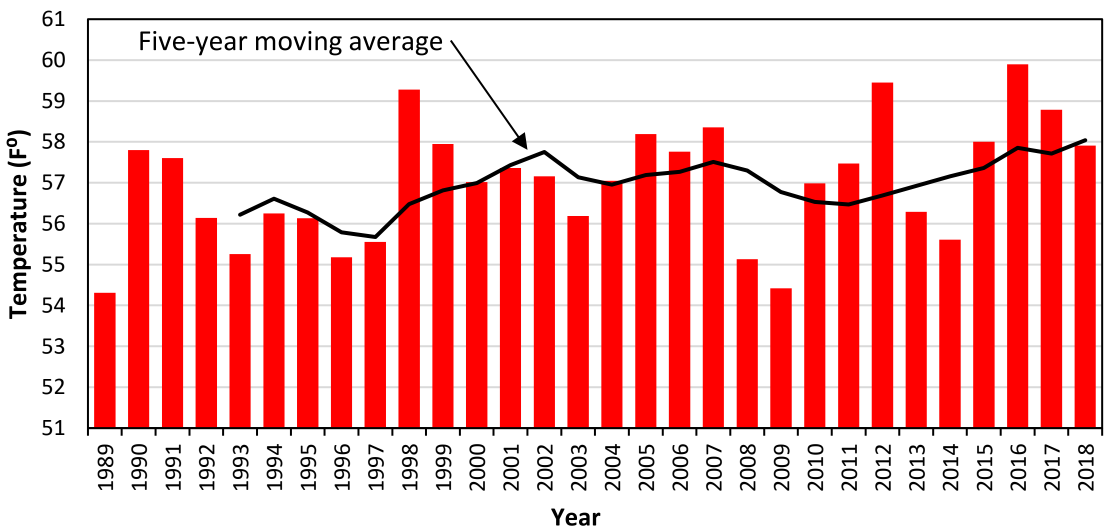


Figure 4. A) Annual total rainfall and B) average annual temperature from 1989-2018 for Marble Hill, MO.

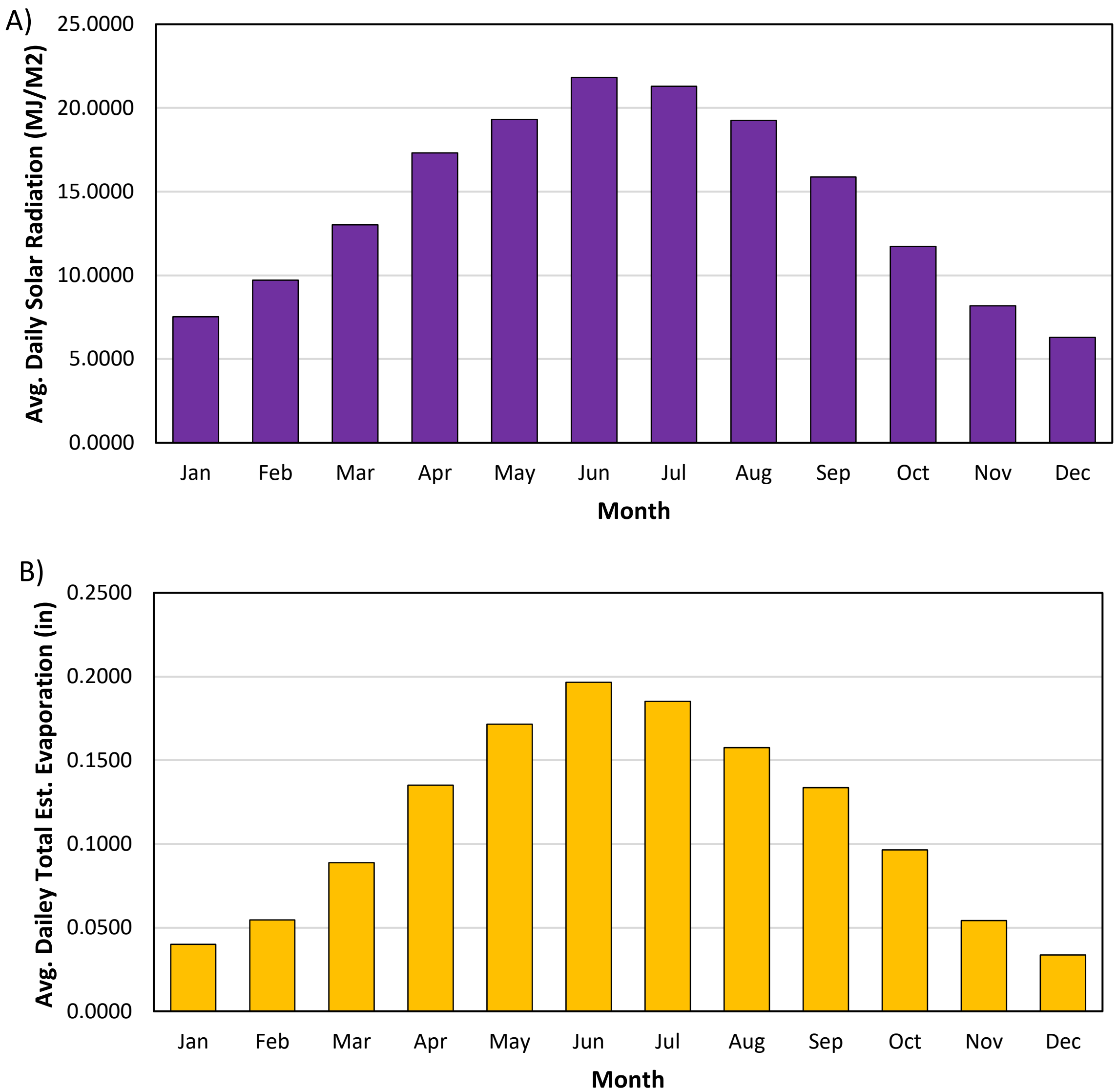


Figure 5. Average daily A) solar radiation (2000-2018) for Delta, Cape Girardeau County MO and B) estimated evaporation (2011-2018) for Portageville, Pemiscot County MO.

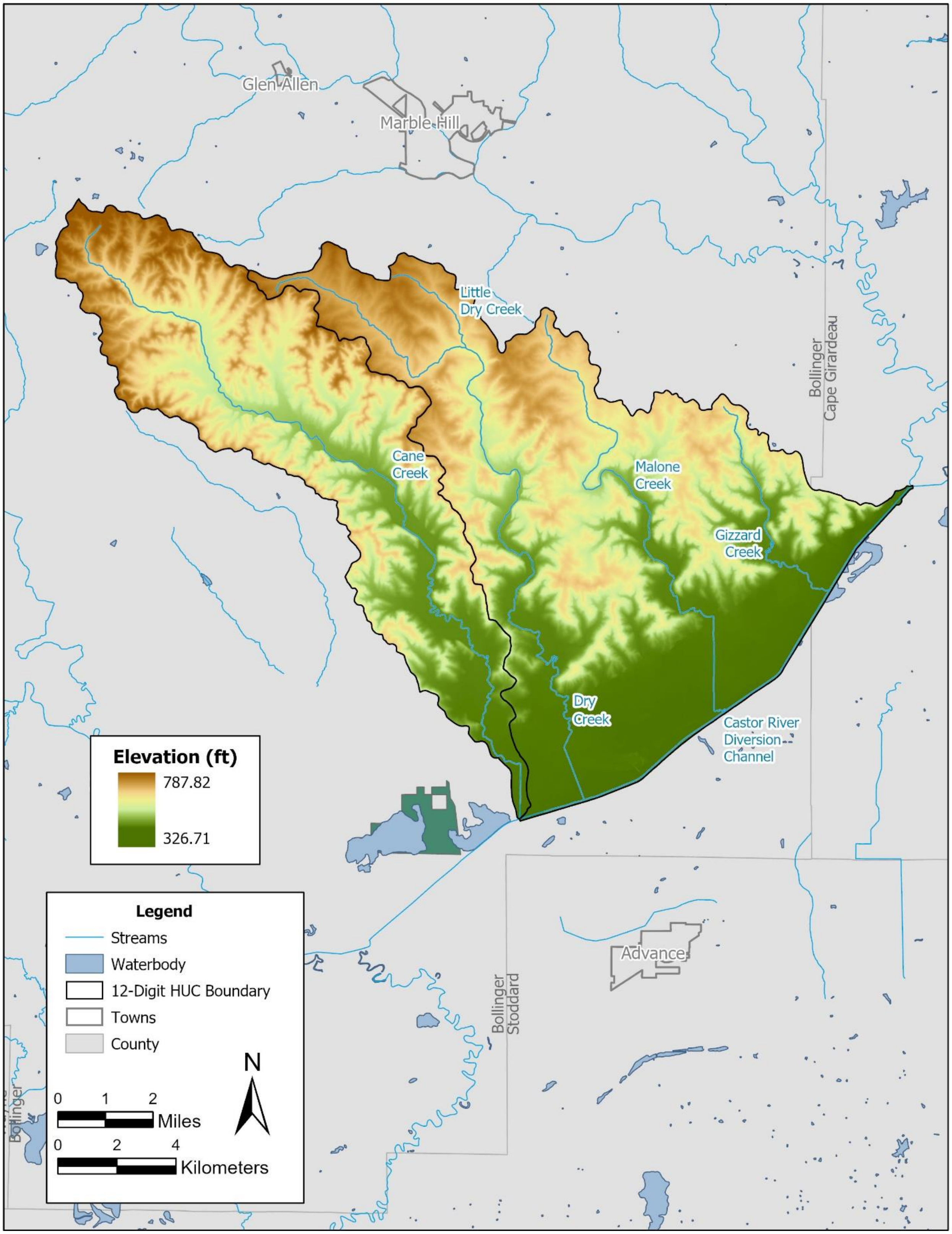


Figure 6. LiDAR elevations within the watershed (ft)

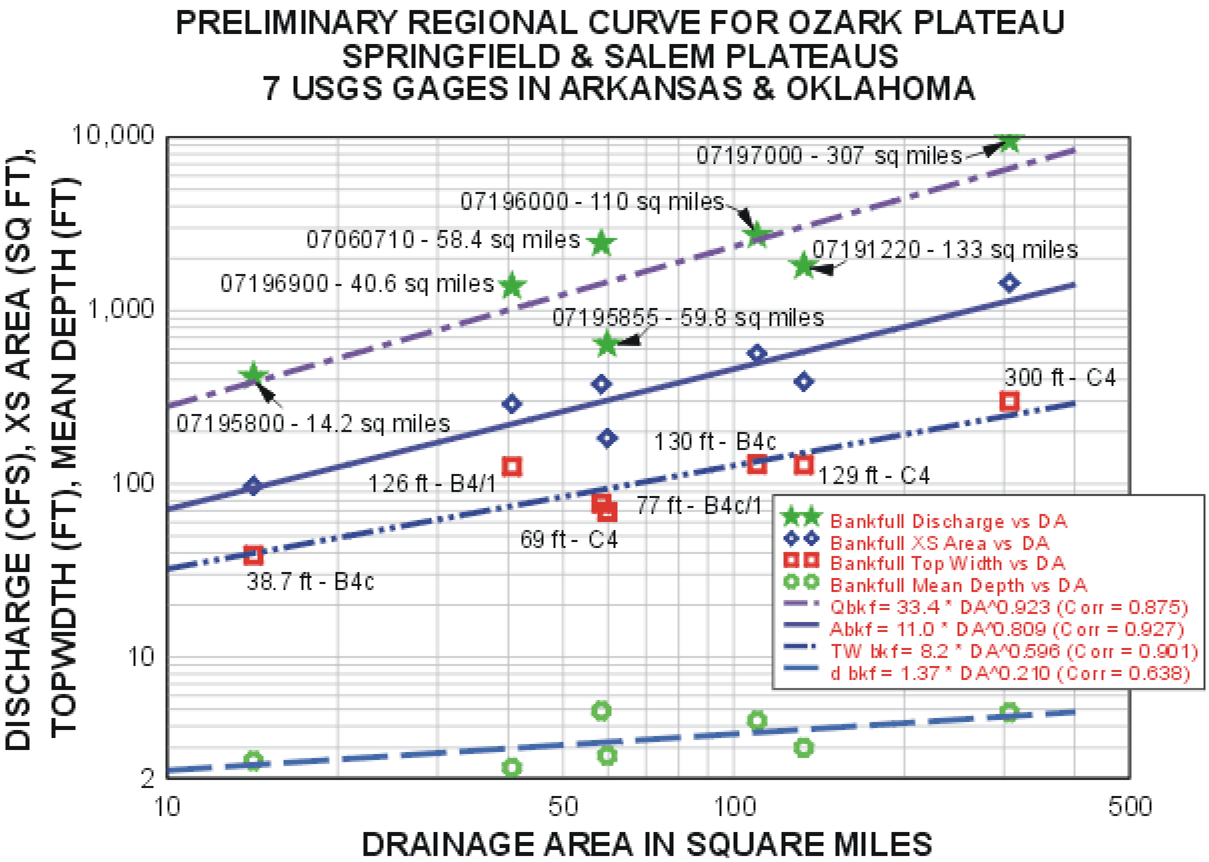


Figure 7. Regional Channel geometry curves for Springfield and Salem Plateaus. Source: NRCS-National Water Management Center.

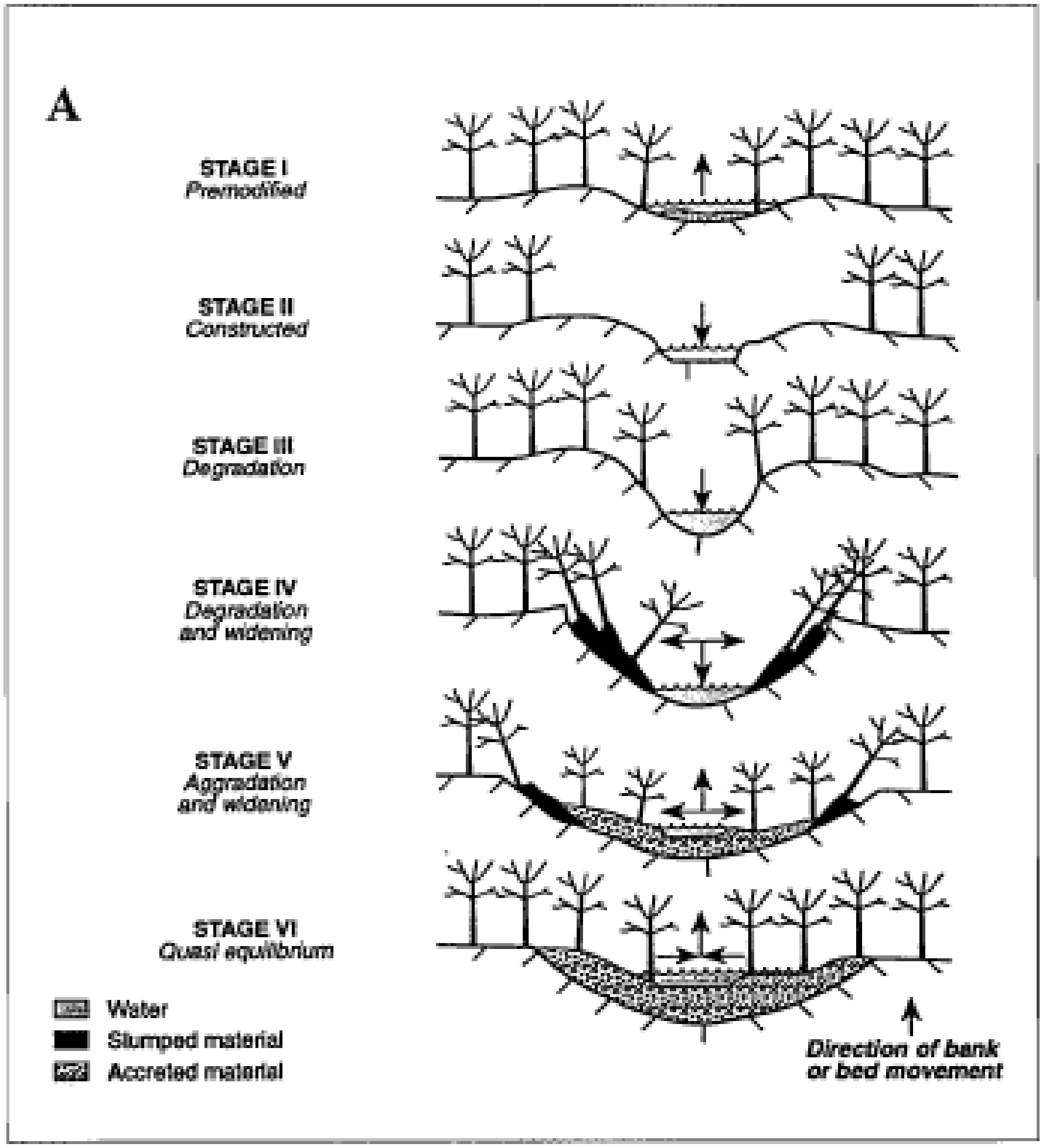


Figure 8. Six Stage Channel Evolution Model for Disturbed Alluvial Channels (Simon and Rinaldi 2000).

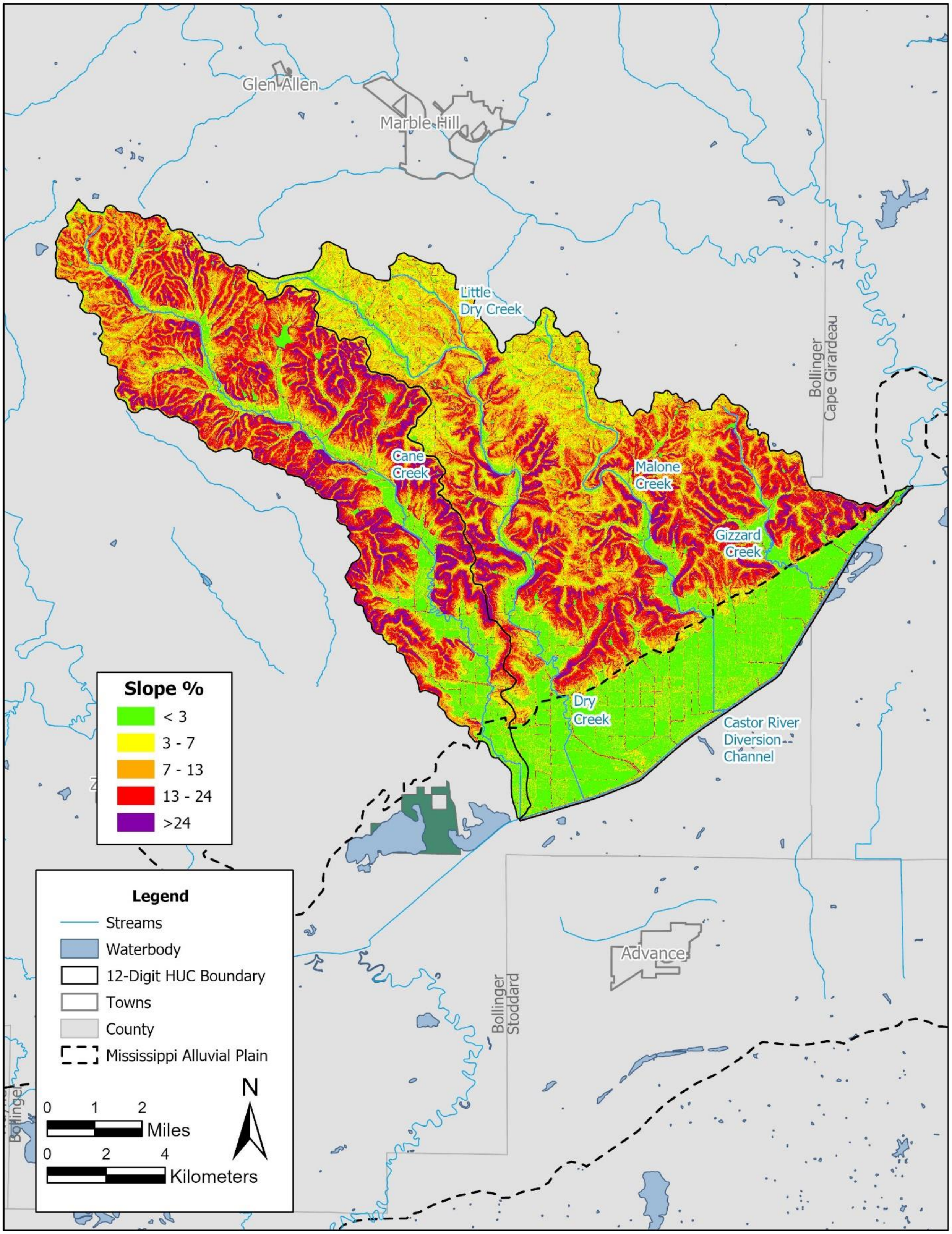


Figure 9. LiDAR based slope classification across the watershed.

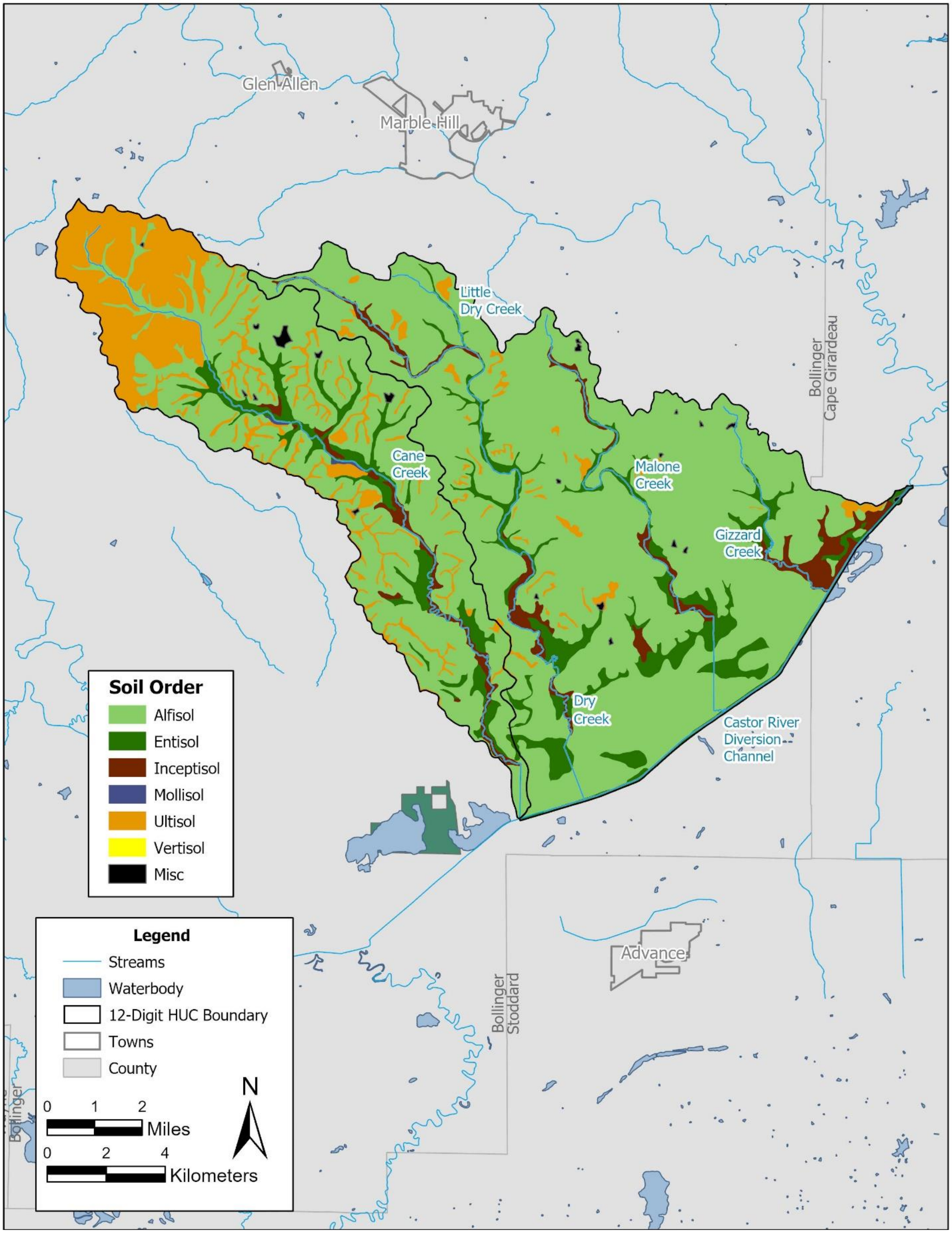


Figure 10. Soil series classified by order.

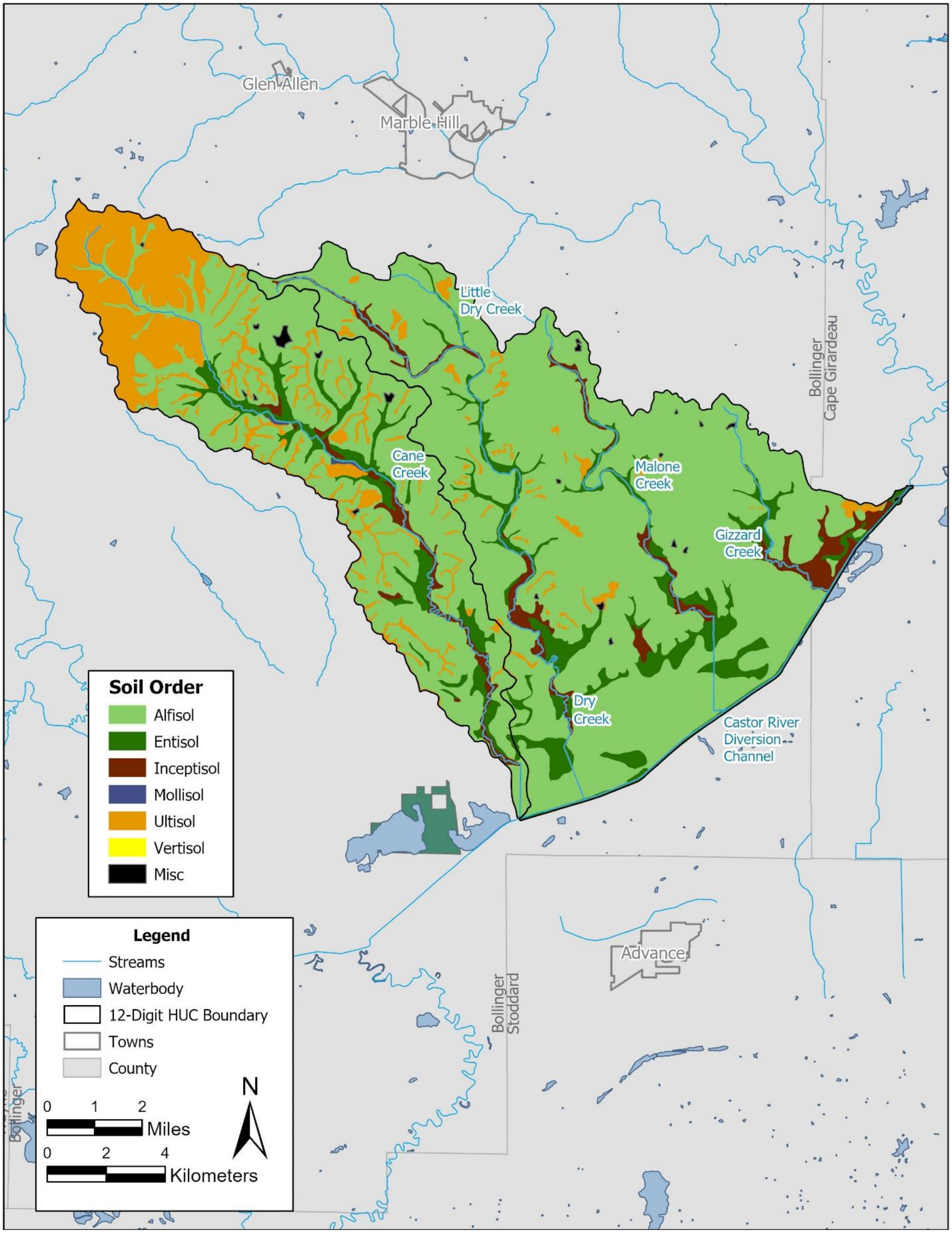


Figure 11. Soil series classified by hydrologic soil group.

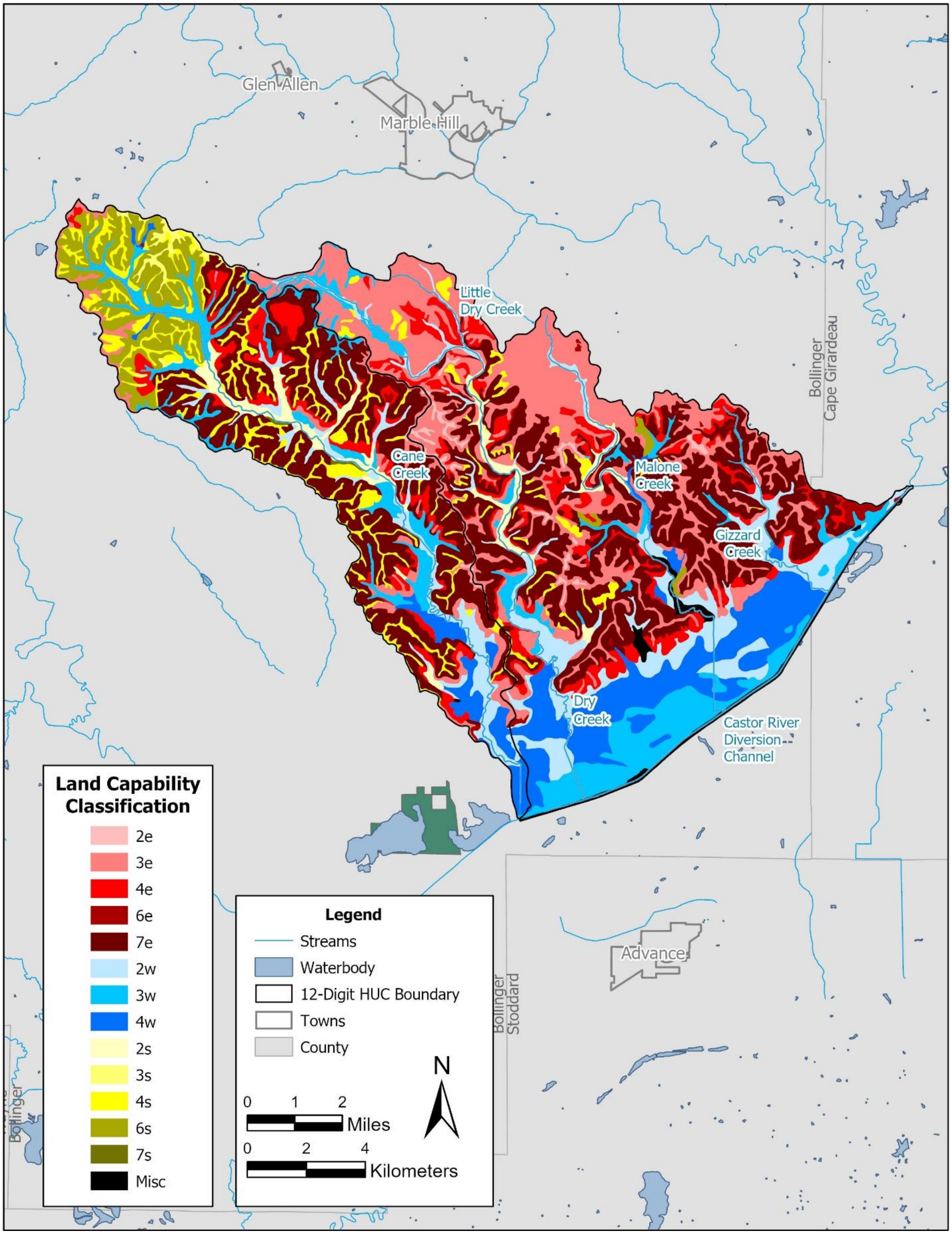


Figure 12. Soil series classified by land capability classification.

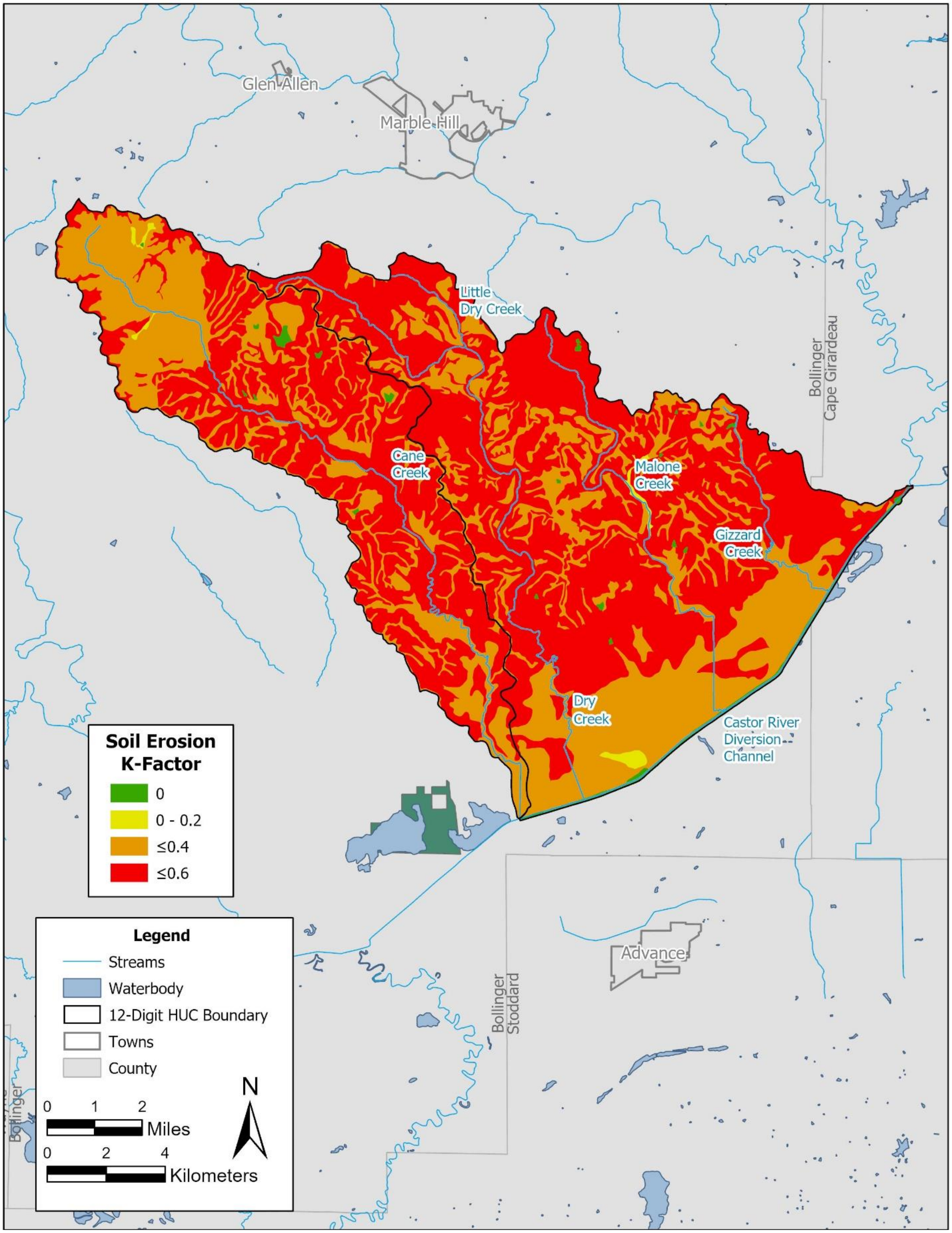


Figure 13. Soil series classified by soil erosion K-factor.

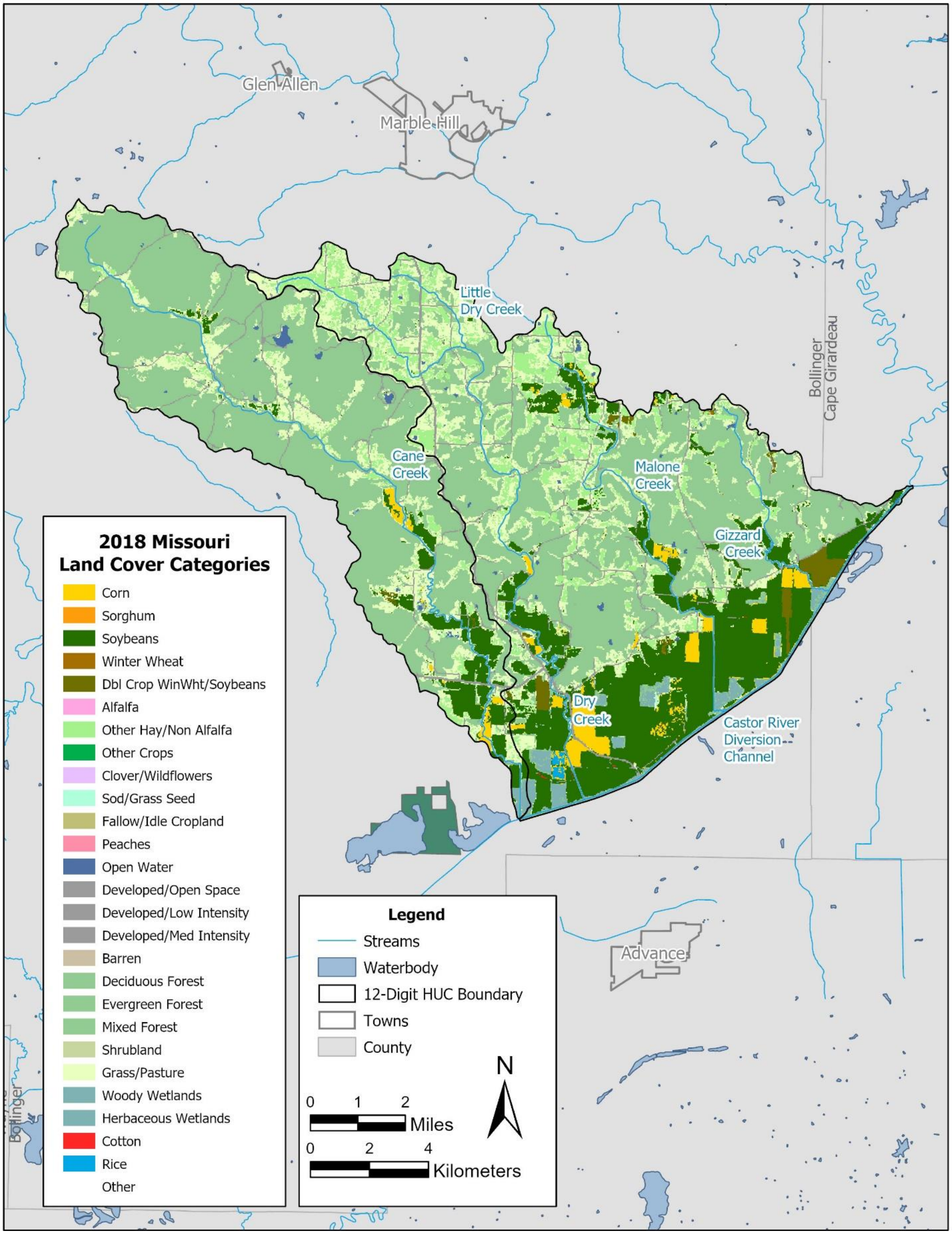


Figure 14. 2018 crop data from the NASS.

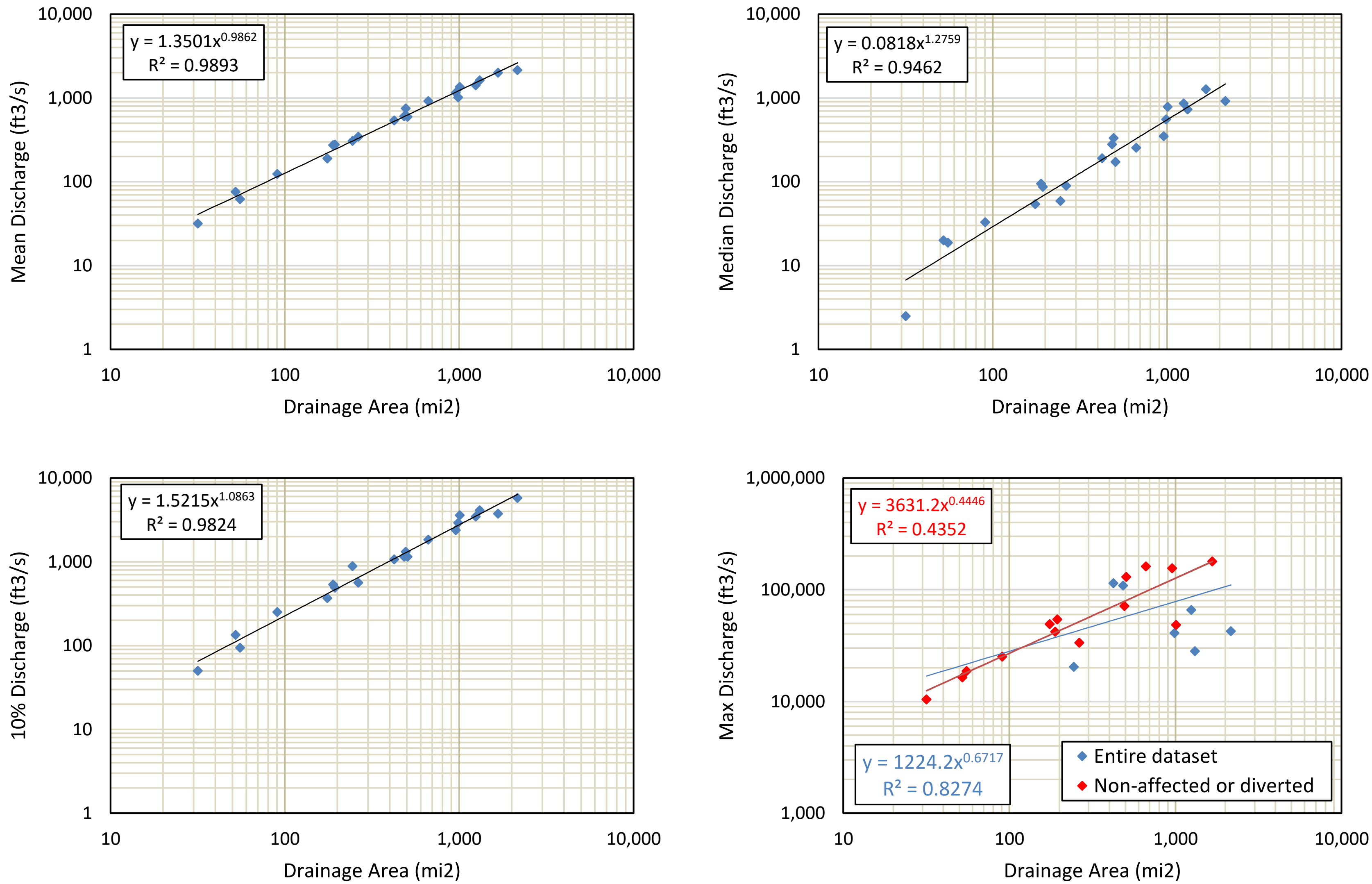


Figure 15. Drainage area and discharge relationships for 21 USGS gaging stations near the study watershed.

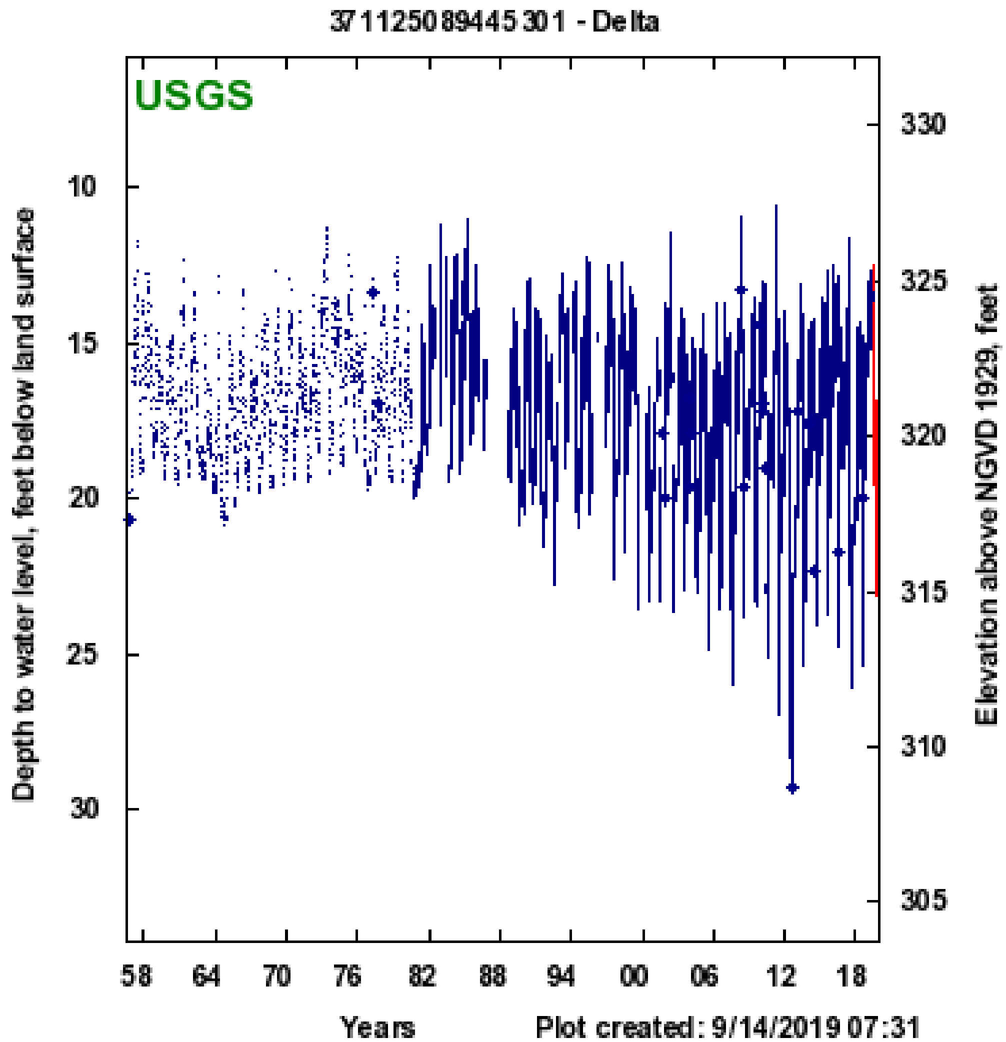


Figure 16. Groundwater level change for Delta (1958-2018).

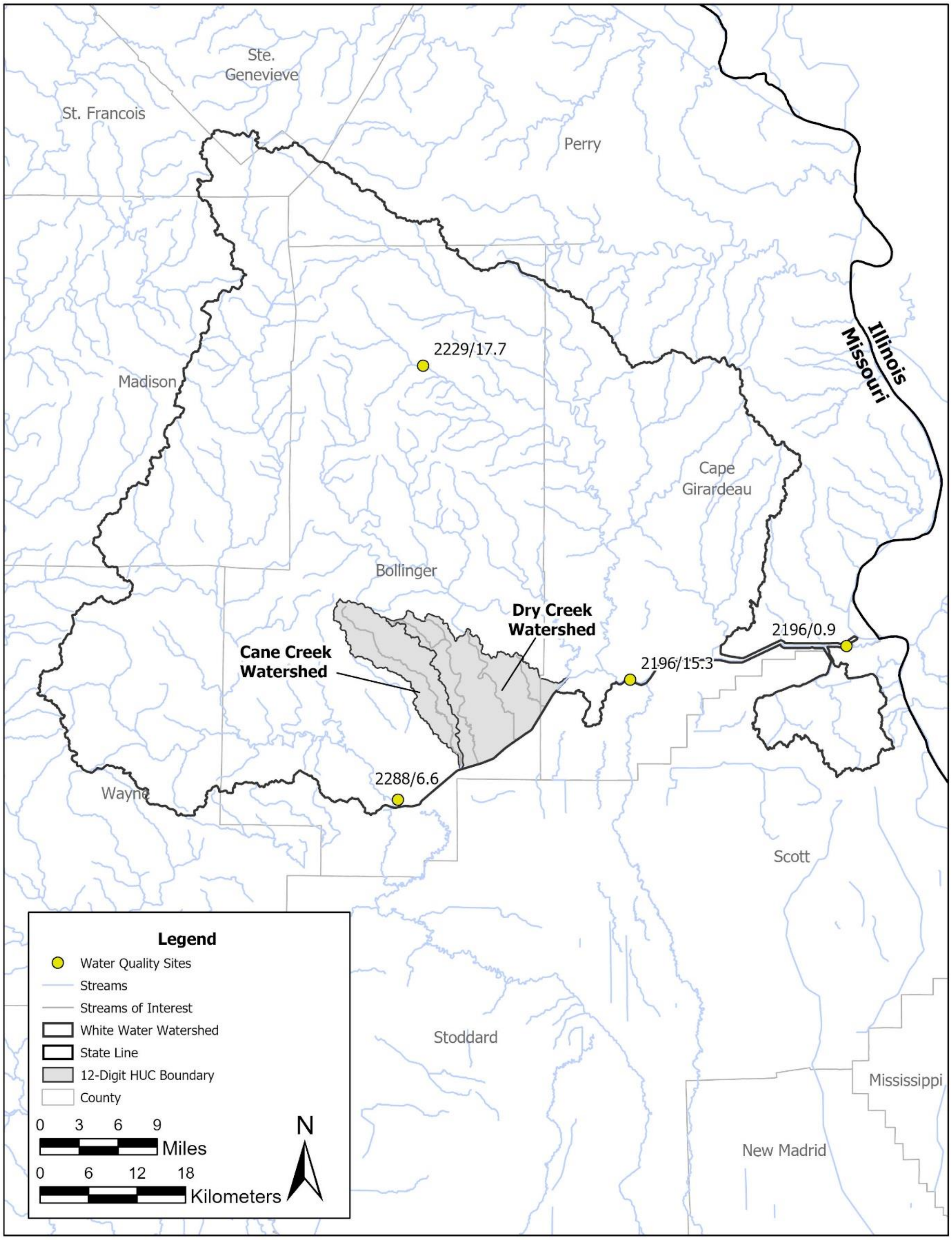


Figure 17. Water quality monitoring station locations.

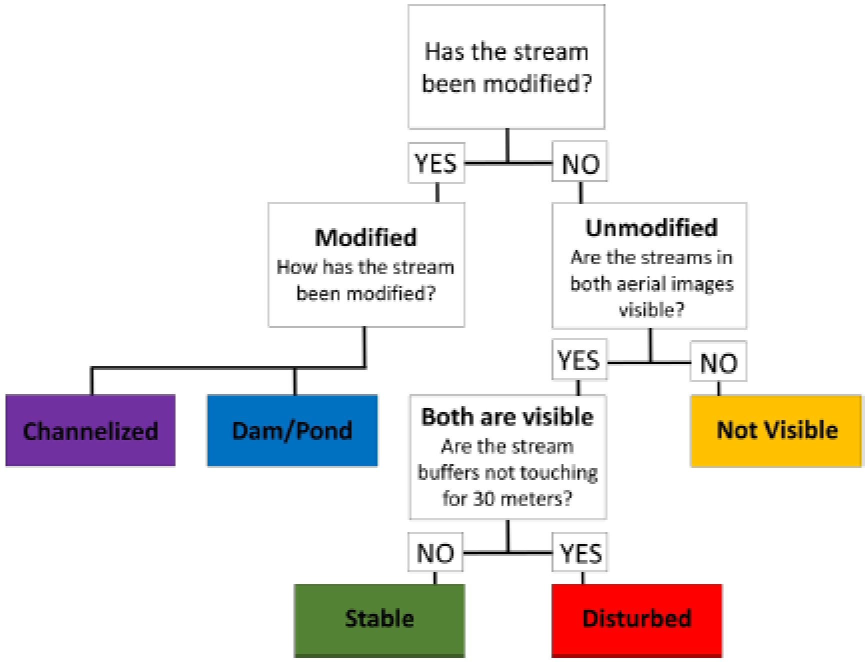


Figure 18. Flow chart showing decision tree for classifying stream channels from aerials.

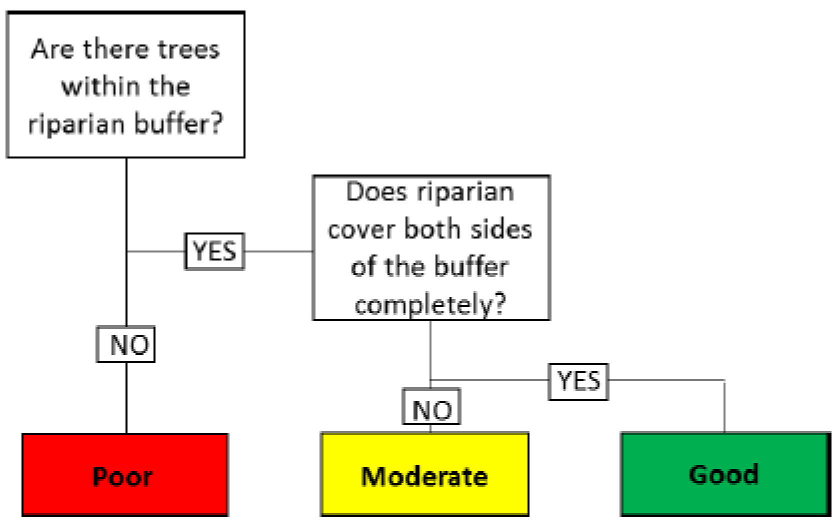


Figure 19. Flow chart showing decision tree for riparian corridor assessment from aerials.

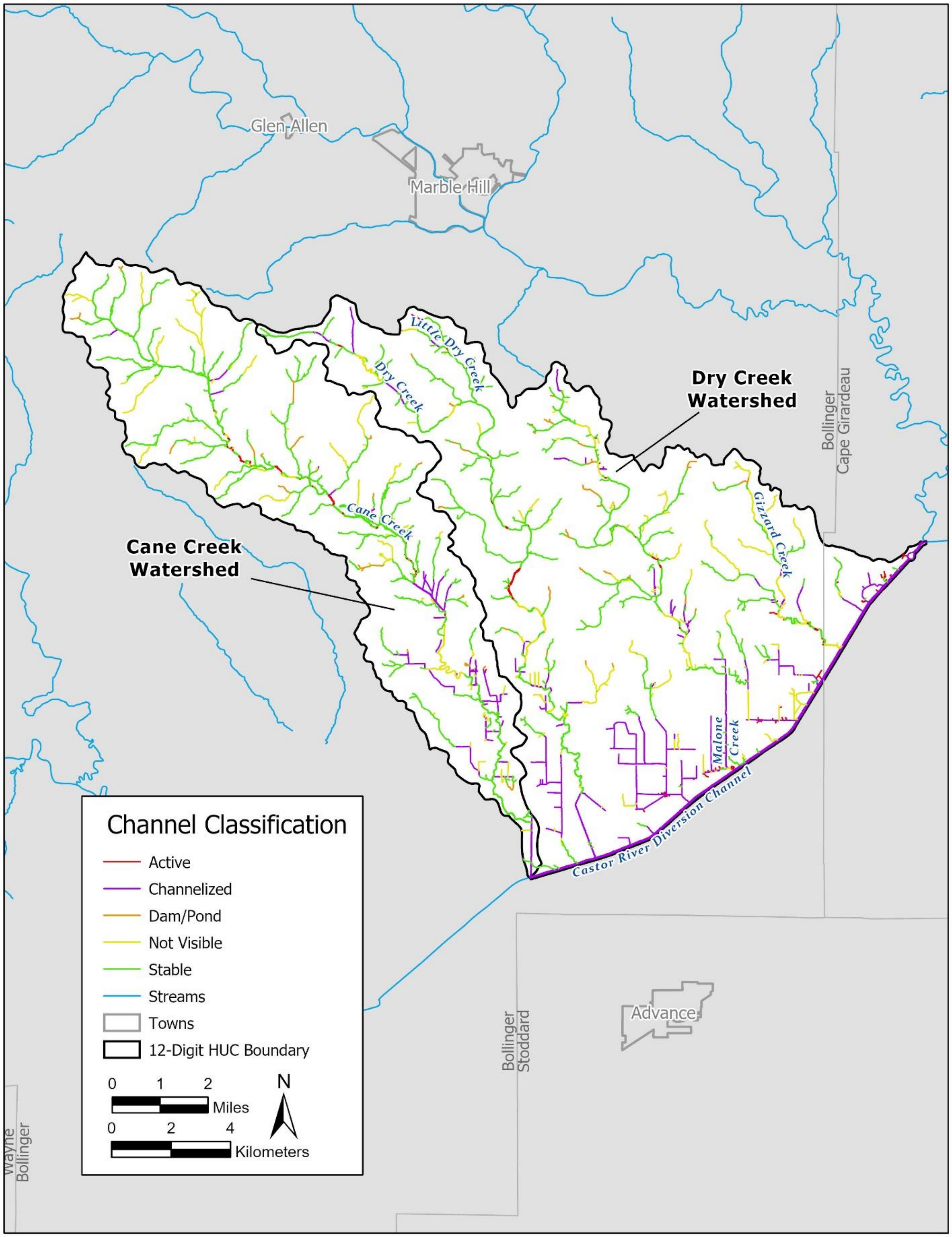


Figure 20. Channel stability classification.

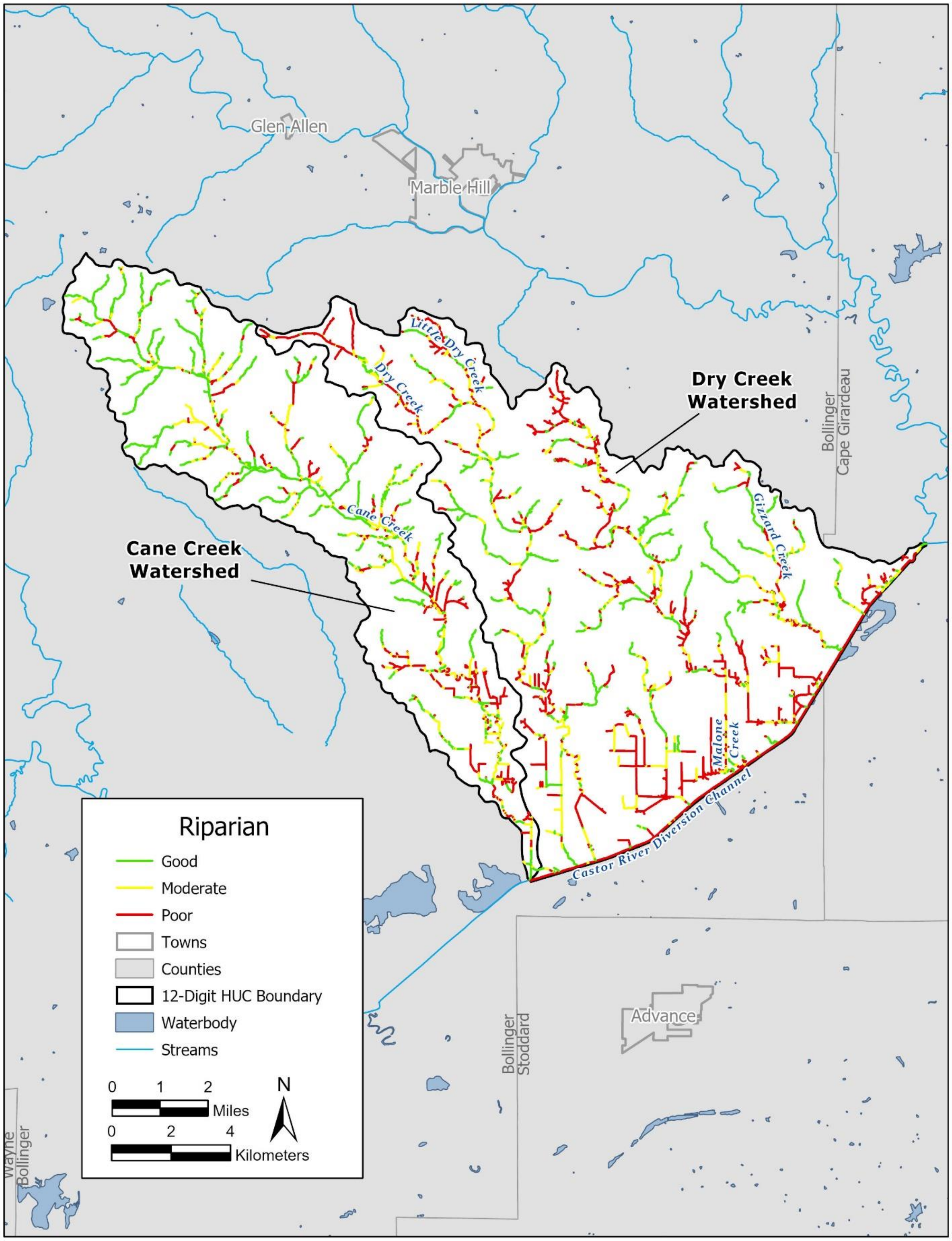


Figure 21. Riparian corridor classification

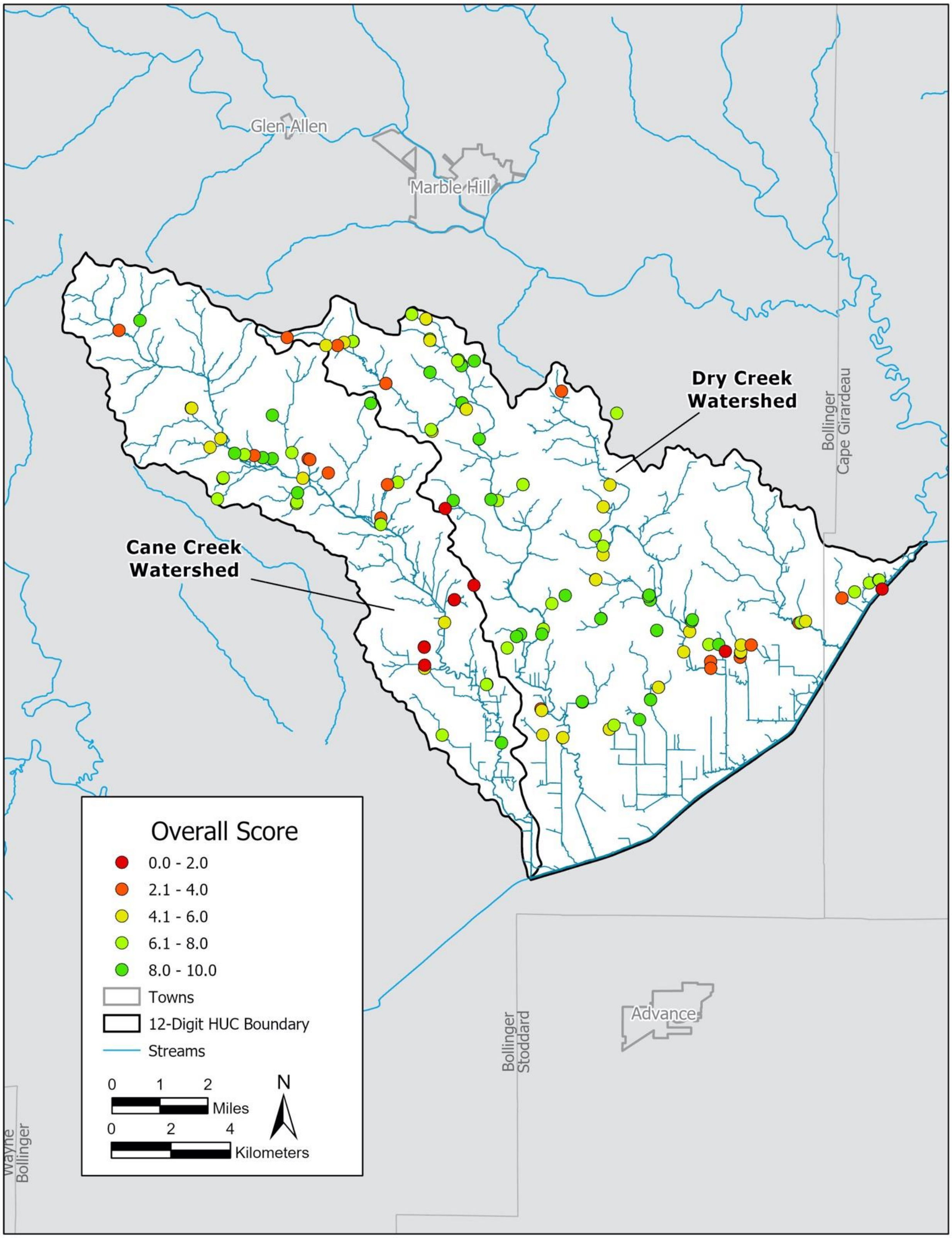


Figure 22. Visual stream assessment results

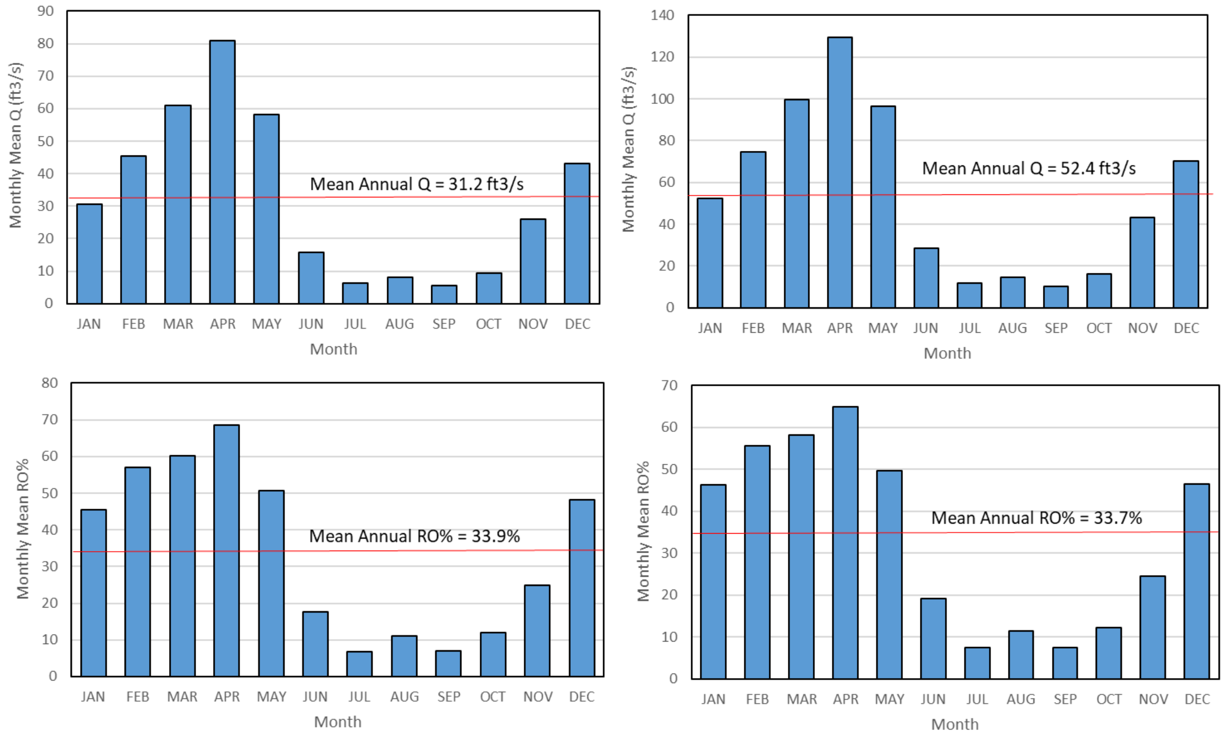


Figure 23. Mean monthly discharge and runoff percentage for the Cane Creek and Dry Creek watersheds

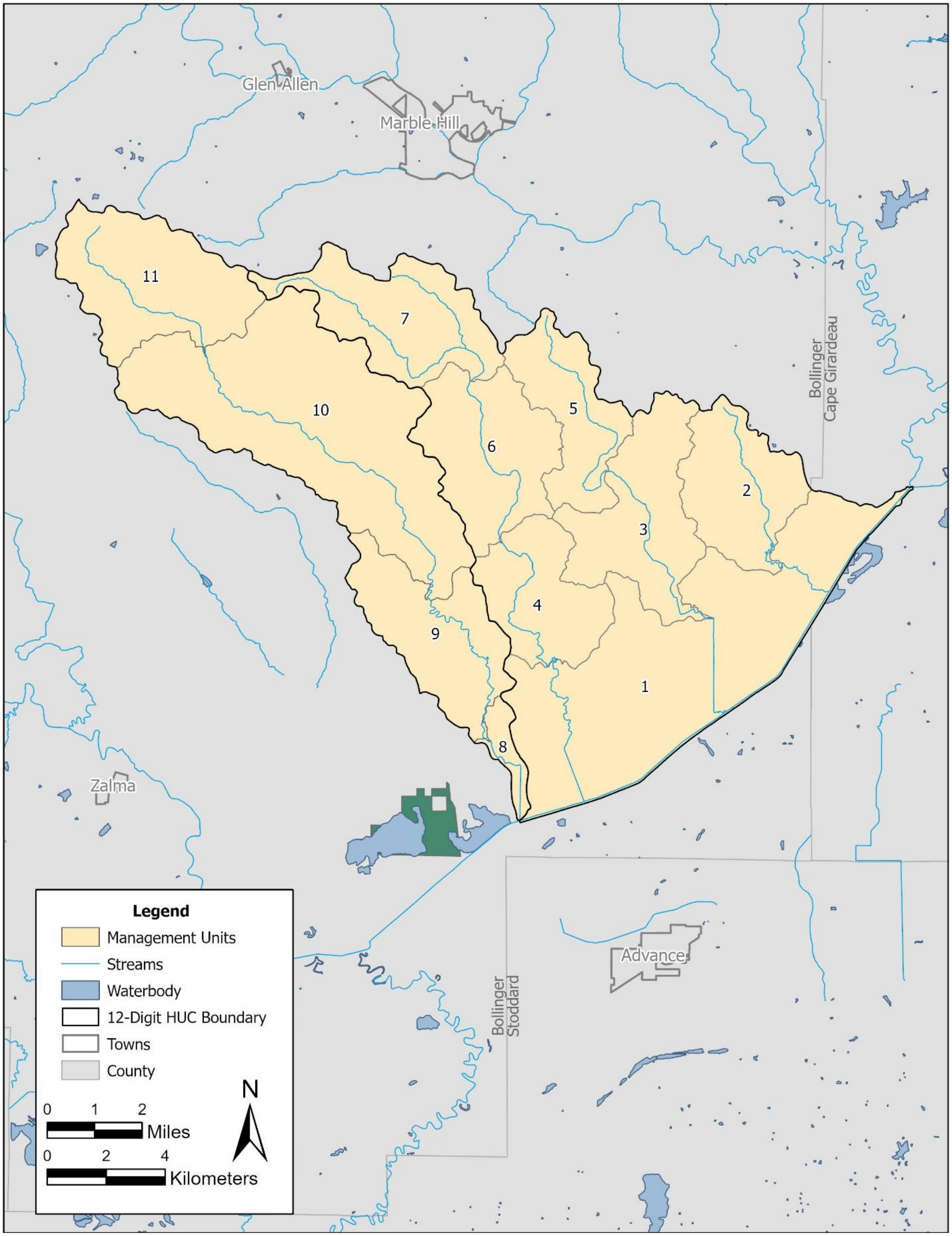


Figure 24. Management units within the two study watersheds.

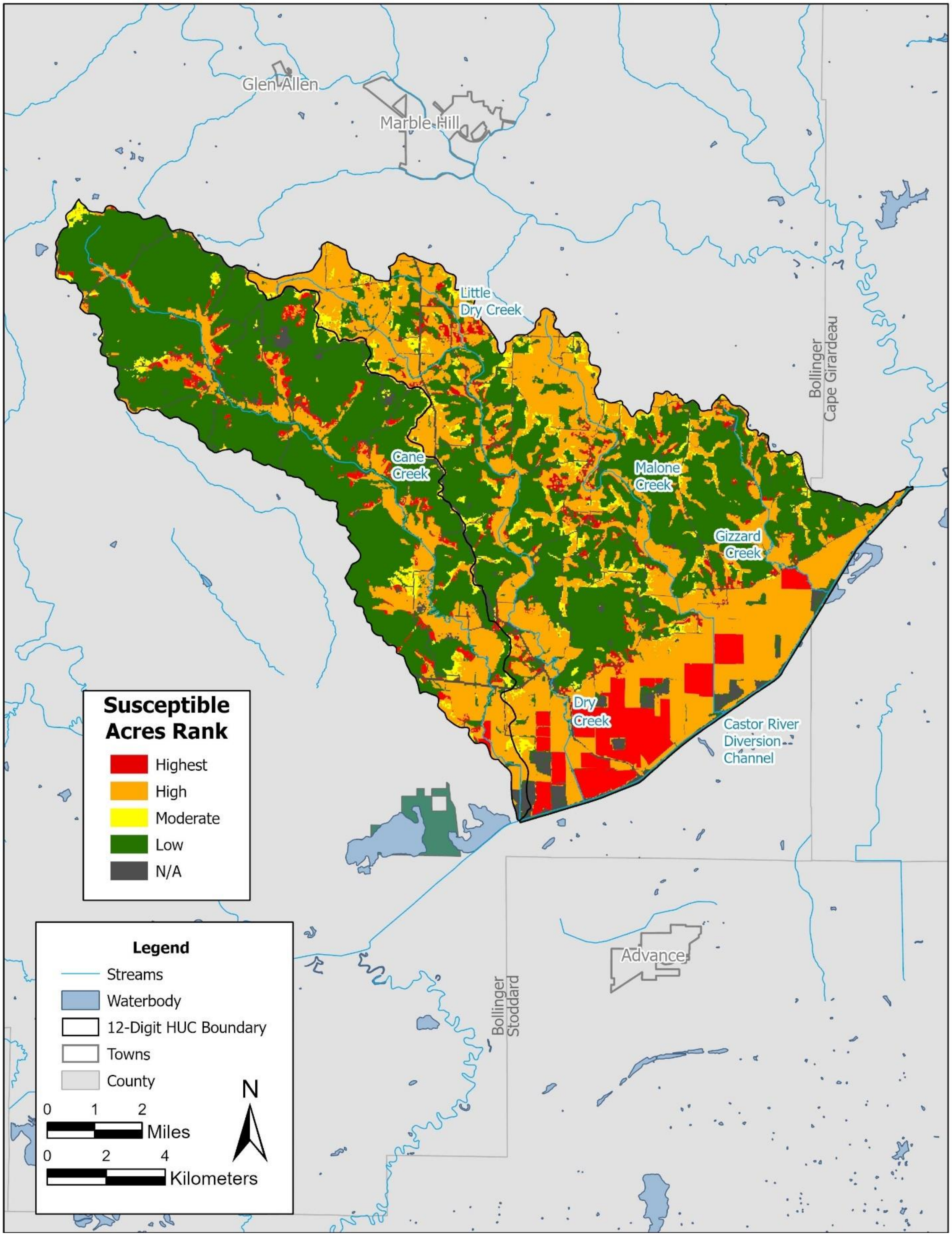


Figure 25. Distribution of susceptible acres classification within the two study watersheds.

APPENDICES

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

MU#	Acres	% Area	Series Name	Hydrologic Soil Group	Landform	K Factor	T Factor	Soil Order	Land Capability Classification	Slope % Range
60033	3,954	9.5%	Wrengart silt loam	C	Upland	0.49	4	Alfisol	3e	6
60033	7	0.0%	Wrengart silt loam	C	Upland	0.49	4	Alfisol	3e	6
60045	9	0.0%	Minnith silt loam	C	Upland	0.49	5	Alfisol	4e	12
60046	90	0.2%	Minnith silt loam	C	Upland	0.49	5	Alfisol	6s	25
66024	239	0.6%	Wilbur silt loam	B/D	Floodplain	0.43	5	Inceptisol	3w	1
66054	4	0.0%	Wakeland silt loam	B/D	Floodplain	0.43	5	Entisol	3w	1
66054	285	0.7%	Wakeland silt loam	B/D	Floodplain	0.43	5	Entisol	3w	1
66055	461	1.1%	Haymond silt loam	B	Floodplain	0.43	5	Inceptisol	2w	1
67001	75	0.2%	Haymond silt loam	B	Floodplain	0.43	5	Inceptisol	3w	2
67004	100	0.2%	Haymond silt loam	B	Floodplain	0.43	5	Inceptisol	2w	1
73100	298	0.7%	Wrengart silt loam	C	Upland	0.49	4	Alfisol	2e	4
73101	1,498	3.6%	Wrengart silt loam	C	Upland	0.49	4	Alfisol	3e	7
73139	409	1.0%	Poynor-Clarksvilles-Scholten complex	B	Upland	NA	3	Ultisol	4s	12
73140	1,942	4.7%	Clarksville-Scholten complex	B	Upland	NA	3	Ultisol	6s	30
73151	29	0.1%	Caneyville-Gasconade-Bucklick complex	C	Upland	NA	2	Alfisol	6s	20
73156	1,813	4.4%	Alred-Gepp complex	C	Upland	NA	4	Alfisol	4s	12
73157	225	0.5%	Captina silt loam	C/D	Upland	0.43	3	Ultisol	3e	5
73264	12,227	29.4%	Alred-Wrengart complex	C	Upland	NA	4	Alfisol	7e	25
73264	189	0.5%	Alred-Wrengart complex	C	Upland	NA	4	Alfisol	7e	25
73265	189	0.5%	Captina-Scholten complex	C	Upland	0.43	3	Ultisol	3s	6
73266	2,063	5.0%	Hildebrecht silt loam	C	Upland	0.32	3	Alfisol	4e	12
73267	130	0.3%	Yelton-Scholten complex	C	Upland	0.43	3	Ultisol	4s	12
73269	28	0.1%	Brussels-Gasconade-Rock outcrop complex	C	Upland	NA	5	Mollisol	7s	53
73270	1,261	3.0%	Wrengart silt loam	C	Upland	0.43	3	Alfisol	4e	12
73270	53	0.1%	Wrengart silt loam	C	Upland	0.43	3	Alfisol	4e	12
73272	408	1.0%	Hildebrecht silt loam	C/D	Upland	0.37	3	Alfisol	3w	5
73343	18	0.0%	Captina silt loam	D	Upland	0.43	3	Ultisol	3e	6
73344	28	0.1%	Captina silt loam	C	Upland	0.43	3	Ultisol	4e	12
73346	1,797	4.3%	Hildebrecht silt loam	C	Upland	0.32	3	Alfisol	3e	6

73495	63	0.2%	Poynor gravelly silt loam	B	Upland	NA	3	Ultisol	6e	17
73567	46	0.1%	Peridge silt loam	B	Upland	0.49	5	Alfisol	6e	6
73568	4	0.0%	Peridge silt loam	B	Upland	0.49	4	Alfisol	3e	12
73569	8	0.0%	Peridge silt loam	B	Upland	0.49	5	Alfisol	4e	0.5
73605	102	0.2%	Ogborn silt loam	C/D	Upland	0.43	3	Alfisol	3w	4
74644	25	0.1%	Deible silt loam	D	Stream Terrace	0.55	3	Alfisol	3w	2
74646	26	0.1%	Cornwall silt loam	C	Stream Terrace	0.43	4	Ultisol	3s	6
74649	112	0.3%	Aslinger-Waben complex	C/D	Stream Terrace	0.37	4	Ultisol	4s	9
74679	66	0.2%	Higdon silt loam	B/D	Stream Terrace	0.37	5	Alfisol	3w	1
74698	34	0.1%	Baylock silt loam	B/D	Stream Terrace	0.32	5	Alfisol	3w	2
74699	125	0.3%	Baylock silt loam	B/D	Stream Terrace	0.32	5	Alfisol	3w	2
75381	64	0.2%	Bearthicket silt loam	B	Stream Terrace	0.43	5	Alfisol	2s	1
75395	101	0.2%	Jamesfin silt loam	B	Floodpain	0.49	5	Inceptisol	2w	1
75408	17	0.0%	Secesh silt loam	B	Floodpain	0.37	4	Alfisol	3s	1
75417	46	0.1%	Relfe-Sandbur complex	A	Floodpain	0.17	5	Entisol	4w	1
75428	47	0.1%	Tilk-corwall-poynor complex	A	Floodpain	0.17	5	Alfisol	4w	3
75429	367	0.9%	Tilk-Secesh complex	B	Floodpain	0.28	5	Alfisol	3w	1
75430	87	0.2%	Wideman fine sandy loam	A	Floodpain	0.17	5	Entisol	3w	2
75468	1,025	2.5%	Elsah silt loam	B	Floodpain	0.43	4	Entisol	2s	2
76012	517	1.2%	Elsah silt loam	B	Floodpain	0.43	4	Entisol	2w	2
76044	17	0.0%	Relfe-Sandbur complex	A	Floodpain	0.17	5	Entisol	4w	2
76051	396	1.0%	Tilk-Secesh complex	B	Floodpain	0.28	5	Alfisol	3w	1
82007	171	0.4%	Bosket laom	B	Stream Terrace	0.37	5	Alfisol	3w	2
82077	17	0.0%	Dundee silt loam	C/D	Stream Terrace	0.43	5	Alfisol	3w	2
82079	184	0.4%	Oaklimeter silt loam	C	Stream Terrace	0.37	5	Inceptisol	NA	0.5
86000	17	0.0%	Dubbs silt loam	B	Floodplain	0.49	5	Alfisol	2w	0.2
86001	2,637	6.3%	Calhoun silt loam	C/D	Floodplain	0.37	5	Alfisol	4w	0.2
86001	41	0.1%	Calhoun silt loam	C/D	Floodplain	0.37	5	Alfisol	4w	0.5
86002	1,770	4.3%	Falaya silt loam	B/D	Floodplain	0.49	5	Entisol	2w	0.5
86002	78	0.2%	Falaya silt loam	B/D	Floodplain	0.49	5	Entisol	2w	0.5
86003	1,010	2.4%	Amagon silt loam	C/D	Floodplain	0.37	5	Alfisol	4w	0.5
86004	1,333	3.2%	Forestdale silty clay loam	C/D	Floodplain	0.32	5	Alfisol	3w	0.5
86006	90	0.2%	Adler silt loam	C	Floodplain	0.37	5	Inceptisol	2w	0.5
86016	7	0.0%	Commerce silty clay loam	C/D	Floodplain	0.37	5	Inceptisol	2w	0.5
86038	63	0.2%	Mhoon silt loam	B/D	Floodplain	0.43	5	Inceptisol	3w	0.5

86039	36	0.1%	Mhoon silt loam	B/D	Floodplain	0.43	5	Inceptisol	3w	0.5
86056	0	0.0%	Sharkey silty clay	D	Floodplain	0.24	5	Vertisol	4w	0.5
86074	6	0.0%	Adler silt loam	C	Floodplain	0.37	5	Inceptisol	NA	0.5
86118	401	1.0%	Oaklimeter silt loam	C	Floodplain	0.37	5	Inceptisol	2w	0.5
86118	67	0.2%	Oaklimeter silt loam	C	Floodplain	0.37	5	Inceptisol	2w	0.5
90000	109	0.3%	Memphis silt Loam	B	Upland	0.43	5	Alfisol	3e	6
90001	33	0.1%	Memphis silt Loam	B	Upland	0.43	4	Alfisol	6e	12
99001	121	0.3%	Water	B	NA	NA	NA	NA	6e	NA
99001	9	0.0%	Water	B	NA	NA	NA	NA	NA	NA
99038	227	0.5%	Levees-Borrow pits complex	NA	Levee	NA	NA	Entisol	NA	13
99038	65	0.2%	Levees-Borrow pits complex	NA	Levee	NA	NA	Entisol	NA	13

Appendix B. USGS gaging stations near the watershed.

USGS Gage ID	Station Name	Stream	Start Year	Years of Record	Ad (mi2)	Elevation (ft)	90%	50%	10%	Max	Mean
7062575	Black River above Williamsville, MO	Black River	2008	11	1,007	407	396	787	3,590	48,400	1,362
7061600	Black River below Annapolis, MO	Black River	2006	13	493	555	170	333	1,310	71,200	756
7037300	Big Creek at Sam A Baker State Park, MO	Big Creek	2006	13	189	406	29	95	535	42,100	276
7020550	South Fork Saline Creek near Perryville, MO	South Fork Saline Creek	1998	21	55	445	7	19	94	18,700	62
7037500	St. Francis River near Patterson, MO	St. Francis River	1921	98	956	370	57	350	2,370	155,000	1,162
7036100	St. Francis River near Saco, MO	St. Francis River	1983	36	664	472	31	256	1,830	161,000	924
7035800	St. Francis River near Mill Creek, MO	St. Francis River	1987	32	505	556	15	173	1,148	130,000	598
7035000	Little St. Francis River at Fredericktown, MO	Little St. Francis River	1983	36	91	679	3	33	251	25,100	124
7039500	St. Francis River at Wappapello, MO	St. Francis River	1942	77	1,311	315	52	730	4,100	28,100	1,629
7062500	Black River at Leeper, MO	Black River	1949	70	987	417	252	557	2,912	40,900	1,019
7061500	Black River near Annapolis, MO	Black River	1939	80	484	570	123	280	1,150	109,000	607
7063000	Black River at Poplar Bluff, MO	Black River	1949	70	1,245	317	401	864	3,460	65,600	1,417
7021000	Castor River at Zalma, MO	Castor River	1920	99	423	350	62	191	1,070	114,000	539
5599490	Big Muddy Creek at RTE 127 at Murphysboro, IL	Big Muddy River	1971	47	2,159	336	104	920	5,742	42,400	2,163
7017260	Big River below Desloge	Big River	1988	31	264	650	36	90	561	33,500	345
7017200	Big River at Irondale, MO	Big River	1965	54	175	753	10	54	367	49,100	190
7061270	East Fork Black River nr Lesterville, MO	East Fork Black River	2002	17	52	825	4	20	134	16,400	76
7068510	Little Black River below Fairdealing, MO	Little Black River	1980	39	194	294	40	87	490	54,200	279
3612000	Cache River at Forman, IL	Cache River	1923	96	244	308	2	59	882	20,400	308
7067000	Current River at Van Buren, MO	Current River	1921	98	1,667	443	710	1,270	3,730	179,000	2,012
5597500	Crap Orchard Creek near Marion, IL	Crab Orchard Creek	1952	67	32	416	0	3	50	10,400	32

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 of Cane and Dry Creek Watersheds.

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

Overall Score 9.6

Channel condition	10
Hydrologic alteration	10
Riparian zone	1
Bank stability	10
Canopy cover	1
Manure presence	2

Overall Score 5.7

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

Overall Score 8.4

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

Overall Score
4.0

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

Overall Score
10.0

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

Overall Score
5.8

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

Overall Score
10

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

Overall Score
5.5

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

Overall Score
8.3

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

Overall Score
3.6

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

Overall Score
9.2

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

Overall Score
1.8

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

Month	R^2	b_0	b_1	Cane Creek Ad = 24.2 mi^2 Q (ft^3/s)	Dry Creek Ad = 40.9 mi^2 Q (ft^3/s)
Jan.	0.98	1.1511	1.0299	30.6	52.6
Feb.	0.99	2.2108	0.9486	45.4	74.6
March	0.99	3.0973	0.9355	61.0	99.6
April	0.97	4.6064	0.8993	80.8	129.5
May	0.97	2.7036	0.9634	58.2	96.4
June	0.97	0.4144	1.141	15.7	28.6
July	0.94	0.1355	1.203	6.3	11.8
Aug.	0.89	0.2607	1.0825	8.2	14.5
Sept.	0.93	0.1467	1.1413	5.6	10.1
Oct.	0.91	0.3342	1.0431	9.3	16.0
Nov.	0.94	1.1807	0.9702	26.0	43.2
Dec.	0.97	2.2024	0.9337	43.1	70.4

Equation: $y=b_0x\hat{}b_1$
Where: y = mean monthly discharge (ft^3/s)
x = drainage area (mi^2)

Appendix F. STEPL model inputs for the Cane and Dry Creek Watersheds.

Watershed	Total Ad (ac)	HSG	Land Use (ac)					Beef Cattle	# Septic Systems
			Urban	Cropland	Pastureland	Forest	Water		
Cane Creek	15,474	C	515	1,695	2,166	10,901	196	610	72
Dry Creek	26,150	C	1,019	9,791	4,640	10,034	666	1,779	281

Appendix G. Eroding streambank inputs into STEPL for the Cane and Dry Creek Watersheds

Cane Creek Watershed

Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
76	6.6	819	10.8	0.57
51	5.9	351	6.9	0.36
121	6.2	493	4.1	0.21
35	6.6	65	1.9	0.10
44	6.9	73	1.7	0.09
80	3.6	338	4.2	0.22
106	5.2	746	7.0	0.37
128	3.6	1,455	11.4	0.60
267	4.3	1,824	6.8	0.36
27	4.9	61	2.2	0.12
151	2.6	2,342	15.5	0.81
219	5.6	2,767	12.6	0.66
166	7.2	3,445	20.8	1.09
148	6.6	1,924	13.0	0.68
249	6.2	3,448	13.9	0.73
516	5.9	7,373	14.3	0.75
188	3.3	2,638	14.0	0.74
158	6.6	917	5.8	0.31
19	5.2	17	0.9	0.05
50	5.6	171	3.4	0.18
74	3.3	335	4.5	0.24
67	3.6	343	5.1	0.27
375	6.2	7,858	20.9	1.10
32	3.6	28	0.9	0.05
85	2.6	355	4.2	0.22
39	3.9	67	1.7	0.09
42	4.6	116	2.7	0.14
29	4.3	63	2.2	0.12
121	5.2	626	5.2	0.27
114	3.9	860	7.5	0.40
221	6.6	3,975	18.0	0.95
158	7.9	1,355	8.6	0.45
74	8.5	695	9.4	0.50
131	7.2	1,211	9.2	0.48
117	8.2	867	7.4	0.39
105	4.6	394	3.8	0.57

Total Length = 4,583 ft
Weighted mean height = 6.1 ft
Weighted mean rate = 0.7 ft/yr

Dry Creek Watershed

Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
72	2.6	642	8.9	0.47
52	5.6	149	2.8	0.15
191	5.9	2,171	11.4	0.60
175	7.5	1,614	9.2	0.48
278	5.6	2,608	9.4	0.49
165	6.9	1,372	8.3	0.44
73	7.2	353	4.9	0.26
230	7.5	6,306	27.4	1.44
274	7.9	4,304	15.7	0.83
161	4.9	1,681	10.4	0.55
25	8.2	67	2.7	0.14
84	4.6	262	3.1	0.17
169	8.2	1,302	7.7	0.41
108	5.9	825	7.6	0.40
16	3.3	24	1.6	0.08
471	5.2	9,693	20.6	1.08
631	4.9	16,594	26.3	1.38
173	4.9	2,255	13.0	0.69
138	3.9	2,401	17.4	0.92
257	8.2	6,366	24.8	1.30
39	1.6	21	0.5	0.03
128	6.6	838	6.6	0.34
317	6.6	5,954	18.8	0.99
79	3.0	695	8.8	0.46
30	5.2	117	3.9	0.21
59	8.5	465	7.9	0.42
52	4.9	96	1.8	0.10
254	3.0	4,951	19.5	1.02
112	3.3	918	8.2	0.43
30	2.3	74	2.4	0.13
337	4.9	7,283	21.6	1.14
20	4.9	42	2.1	0.11
59	6.9	188	3.2	0.17
124	6.9	920	7.4	0.39
123	7.5	1,433	11.6	0.61

Total Length = 5,507 ft
Weighted mean height =6.2 ft
Weighted mean rate = 1.0 ft/yr

Appendix H. 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
No-till	0.250	0.687	0.770
Cover Crop and No-till	0.397	0.709	0.793
Water and Sediment Control Basin	0.550	0.685	0.860
Cover Crop and Water and Sediment Control Basin	0.594	0.685	0.860
Grassed Waterways	0.700	0.750	0.650
Field Border	0.700	0.700	0.650
Grade Stabilization Structure	0.750	0.750	0.750
Cover crop, No-till, and Grassed Waterway	0.765	0.866	0.832
Cover Crop and Grade Stabilization Structure	0.799	0.767	0.775
Land Retirement	0.898	0.808	0.950
Pastureland			
Alternative Water	0.133	0.115	0.187
Critical Area Planting	0.175	0.200	0.420
Forage and Biomass Planting	0.181	0.150	0.000
Access Control	0.203	0.304	0.620
Access Control, and Forage and Biomass Planting	0.264	0.279	0.310
Prescribed Grazing	0.408	0.227	0.333
Access Control, Forage and Biomass Planting, and Prescribed Grazing	0.513	0.371	0.471
Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	0.582	0.449	0.544
Grade Stabilization Structure	0.750	0.750	0.750