National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Wilson's Creek National Battlefield Natural Resource Condition Assessment

Natural Resource Report NPS/HTLN/NRR—2011/427

ON THE COVER
Missouri State Guardsmen fighting on Bloody Hill
Scene from interpretive film

Wilson's Creek National Battlefield Natural Resource Condition Assessment

Natural Resource Report NPS/HTLN/NRR—2011/427

Gust M. Annis[1], Michael D. DeBacker[2], David D. Diamond[1], Lee F Elliott[1], Aaron J. Garringer[1], Phillip A. Hanberry[1], Kevin M. James[2], Ronnie D. Lee[1], Michael E. Morey[1], Dyanna L. Pursell[1], and Craig C. Young[2]

[1]Missouri Resource Assessment Partnership (MoRAP)
School of Natural Resources
University of Missouri
4200 New Haven Road
Columbia, MO 65201

[2]National Park Service
Heartland I&M Network
6424 West Farm Road 182
Republic, MO 65738

July 2011

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from http://science.nature.nps.gov/im/units/htln/, and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Please cite this publication as:

Annis G., M. DeBacker, D. Diamond, L. Elliott, A. Garringer, P. Hanberry, K. James, R. Lee, M. Morey, D. Pursell, and C. Young. 2011. Wilsons Creek National Battlefield natural resource condition assessment. Natural Resource Report NPS/HTLN/NRR—2011/427. National Park Service, Fort Collins, Colorado.

NPS 410/108235, July 2011

Contents

Contents (continued)

Contents (continued)

Contents (continued)

Page

Figures

Page

Figures (continued)

Page

Figures (continued)

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Tables (continued)

Page

Tables (continued)

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xvi) for more information.

Abstract

In accordance with National Park Service requirements, staff with the Missouri Resource Assessment Partnership and the Heartland Inventory and Monitoring Network conducted a natural resource condition assessment (NRCA) for Wilson's Creek National Battlefield (WICR). NRCA's are intended to provide a synthesized assessment of current conditions in the park. The NCRA for WICR builds on methods developed for a similar effort for Effigy Mounds National Monument. Basic elements of the methodology include (1) reliance on a framework of essential ecological attributes provided by the Environmental Protection Agency, (2) development of a list of resource types, indicators, and attributes for assessment, and (3) application of assessments by reporting unit, including park wide, major terrestrial landscapes types, and major streams and tributaries. Current condition was assigned to indicators based on contemporary data and management targets were defined based on best available information, which ranged from quantitative sampling data to expert opinion.

A logic model-based framework was created to evaluate each indicator for which both current data and a management target were available. The framework is hierarchical so that indicators within an attribute are evaluated as well as attributes within a resource type and/or reporting unit. A hierarchical framework allows for integrated analysis among different components of the resource types and reporting units that are found within the park. The logic-based framework was designed to address the validity of the statement "the current condition approximates the management target". For each level in the hierarchy, an assessment score is provided that corresponds to the degree that the statement is valid. A logic-based integrated analysis is not a quantitative analysis of the park resources; rather it is a method of qualitative reasoning. The framework reflects expert knowledge about the park resources and provides a formal structure of how the resource components can be arranged or summarized. This type of analysis is learning based and focused on supporting the decision making processes related to natural resource management. Result scores are on a [0 – 1] scale with zero reflecting that there is no validity to the statement while a score of one signifies that the statement is valid. In addition, scores between zero and one provide a continuum of degree of validity which allows for partial support to be recognized. Five partial support categories were created based on 0.2 breaks in scores between 0.01 and 0.99 (Figure A-A).

Figure A-A. Color coded evaluation score categories derived from rescaled evaluation scores.

Numerical evaluations of logic models provide a continuous range of results. The categorized output was used to build a dashboard for reporting to increase ease of interpretation.

WICR terrestrial communities are mainly successional and disturbance grasslands, woodlands, and glades. Integrated evaluation of the assessment hierarchy illustrates those attributes for which the current condition approximates the management target for each terrestrial reporting unit (Figure A-B).

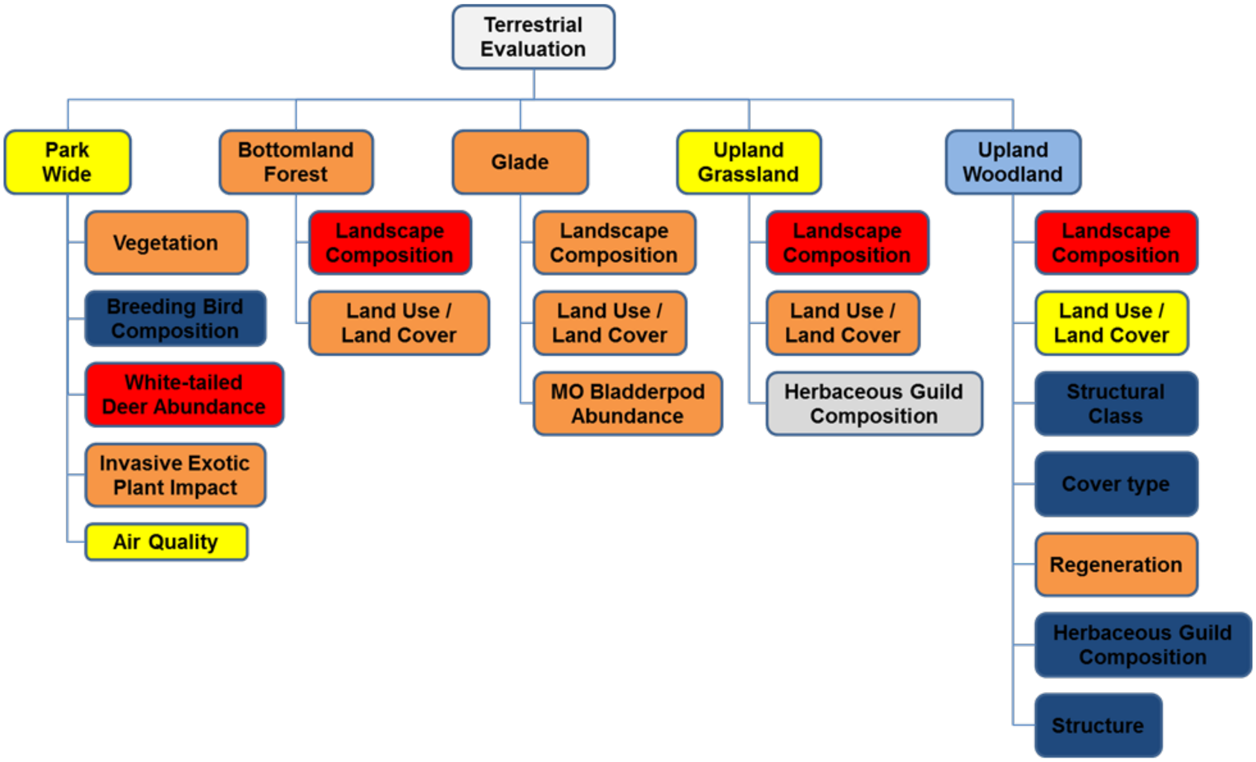

Figure A-B. Color coded evaluation results for each terrestrial reporting unit and its associated resource type and/or attributes.

Glades may represent the most important terrestrial natural community within the park, and they harbor several populations of the Federal endangered Missouri bladderpod (*Lesqurella filiformis*). Control of eastern redcedar (*Juniperus virginiana*) is a primary concern in these areas. Landscape composition in terms of small patch size and a large number of patches is a concern throughout the park. Natural succession may improve these attributes, and may also result in improvements in woodland quality without much active management. Invasive and exotic species are relatively abundant, with species such as tall fescue (*Schedonorus phoenix*), sericea lespedeza (*Lespedeza cuneata*), and smooth sumac (*Rhus glabra*) common in grasslands, and Japanese honeysuckle (*Lonicera japonica*), Osage orange (*Malcura pomifera*), and multiflora rose (*Rosa multiflora*) common in woodlands. White-tailed deer (*Odocoileus virginianus*) numbers appear high, and this may result in suppression of palatable plant species, including oaks. Finally, a diversity of habitats, including grassland, shrubland/brush, edges, and woodland has led to a good diversity of breeding birds within the park. Maintenance of this habitat diversity may be measured by maintenance of representative breeding bird species such as the Indigo bunting (*Passerina cyanea*), Eastern Towhee (*Pipilo erythrophthalmus*), and the Dickcissel (*Spiza americana*).

The largest stream, Wilson's Creek, is heavily impacted by urbanization and a waste water treatment plant in Springfield upstream in the watershed, and is listed as an impaired stream by the state Department of Natural Resources. Nonetheless, aquatic communities are generally in better condition based on analyses of indicators than terrestrial communities (Figure A-C).

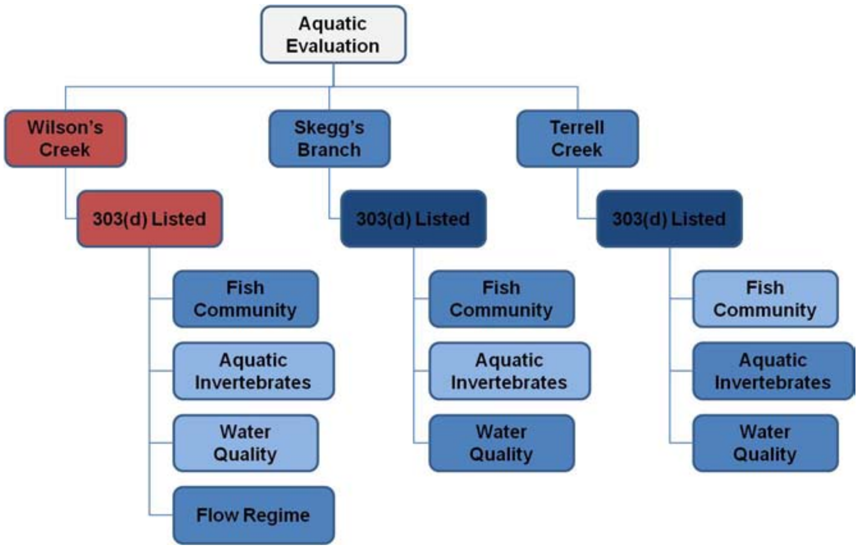

Figure A-C. Color coded evaluation results for each aquatic reporting unit and its associated resource types.

Skegg's Branch, a tributary to Wilson's Creek, has headwaters just south and west of the city of Republic, but most of the watershed is not urbanized. A second tributary, Terrell Creek, also flows mainly through a rural landscape and much of the base flow originates from Double Spring located within park boundaries. The upstream threats influence the water quality, physical habitat, and flow regime of the stream resources which in turn impact the biota. Wilson's Creek, though certainly the most threatened and degraded stream on the park, may benefit from having tributaries that are in better condition which can serve as refuges or re-colonization pools for fauna during times of reduced water quality.

Acknowledgements

All members of the condition assessment team (Table 3-1) made valuable contributions to the document, often by authoring sections within their area of expertise. Dyan Pursell deserves kudos for her development and attribution of the land cover map. Jeff Albright has provided valuable support throughout the project. Funding was provided by the Water Resources Division of the NPS Natural Resource Stewardship and Science.

Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xvi) for more information.

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and associated indicators in national park units, hereafter "parks". For these indicator-level analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The indicators targeted for evaluation depend on a park's resource setting, status of stewardship planning and science in recommending priority indicators for that park, and availability of useful data and qualified expertise to assess current conditions for each of the indicators included on the list of potential study indicators.

NRCAs represent a relatively new approach to assessing and reporting park resource conditions. They are meant to complement, but not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope[1]
- employ hierarchical indicator frameworks[2]
- identify or develop reference conditions/values to compare current condition data against, and to help in the development of management target conditions[3,4]
- emphasize spatial evaluation and GIS (map) products[5]
- should strive to provide a meaningful summary of overall findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

Although current condition reporting relative to reference conditions and values is the primary objective, NRCAs are encouraged to also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences (threats and stressors) are

[1] However, number and breadth of study indicators will vary by park

[2] Frameworks help guide indicator selection and subsequent reporting of condition findings

3 NRCAs must consider ecologically-based reference conditions, must also consider applicable legal/regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or multiple types of reference conditions/values

[4] Reference values can be single-point values or ranges, represent conditions to be achieved or threshold "triggers" to avoid, and can be expressed in semi-quantitative to highly quantitative terms; in many cases they are identified as best professional judgment estimates or interim values

[5] As appropriate and possible, NRCAs describe condition gradients or differences across the park for each study indicator and develop GIS coverages and maps that depict those differences

[6] In addition to reporting indicator-level findings, investigators are asked to take a bigger picture view and summarize key findings by park areas; each park identifies the reporting areas to be used for this purpose

also considered. They can include historic resource conditions or land uses or activities as well as park or surrounding watershed and landscape-scale condition influences.

For this type of resource assessment, credibility derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and express “level of confidence” in at least qualitative terms. Input and review from park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist identification and selection of study indicators; 2) to recommend or comment on data sets, methods, and reference conditions and values proposed for use in the study; 3) to help provide a multi-disciplinary review and accuracy check for draft study findings and products; and 4) to assist the spatial delineation of resources within the park boundary and surrounding area of interest.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for a park’s monitoring “vital signs”. They can also bring in additional (non NPS) data relevant to understanding current conditions for those vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change impacts on park natural resources is not a priority objective for NRCAs. However, the existing condition analyses and data sets developed in an NRCA should be directly useful in subsequent climate change studies and planning efforts.

NRCAs do not establish desired future conditions for study indicators. Management target ranges are suggested only as a necessary means of providing condition assessments. Decisions about desired future conditions must be made through sanctioned park planning and management processes. The proper role for NRCAs is to provide information that will help park managers with an ongoing, longer term effort to describe and quantify their park’s desired resource conditions. In the near term, NRCA findings should be directly useful for strategic park resource planning[7] and to help parks report to government “resource condition status” measures[8].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not expected to be exhaustive. Indicators will be analyzed using rigorous and statistically repeatable methods where existing data and expertise allow. In many cases the study methods will involve an informal synthesis of existing data from diverse sources. A successful NRCA delivers science-based information that is both credible and practically useful for a variety of park decision making, planning, and partnership activities.

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy(RSS) but study scope can be tailored to also work well as a post-RSS project

[8] While reporting requirements can fluctuate over time, spatial and reference-based condition data as provided by NRCAs will help parks report to some current (and anticipated) National Park Service, Department of Interior, and Office of Management and Budget accountability measures.

Over the next several years, NPS hopes to fund an NRCA project for each of the 270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA information can be found at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

NRCA Approach for Wilson's Creek National Battlefield

Prior to beginning the NRCA for Wilson's Creek National Battlefield, (WICR) we completed a NRCA for Effigy Mounds National Monument (EFMO). As part of that study, we identified three areas of compromise in various approaches to natural resource condition assessments: breadth, rigor, and focus.

- **Breadth** reflects the amount and disparity of information considered in the assessment. A project with wide breadth would seek to examine many indicators of various types (e.g. biological, processes, landscape), and/or a broad consideration of multiple threats and stressors.

- **Rigor** reflects the effort devoted to developing reference conditions, defining stressors, or characterizing resources.

  Breadth and rigor are generally inversely related. That is, as the number of indicators increases, so does the difficulty of addressing each one rigorously.

- **Focus** reflects the distribution of effort between: 1) characterization of the resource and threat assessment, and 2) selection of indicators and determination of reference condition. Ideally projects would characterize the resource and threats, as well as select indicators and determine reference conditions.

We used these three gradients to form a three-dimensional "assessment space" as a heuristic framework for designing the WICR NRCA. One can think of assessment space as a balloon and the air inside as the funding limit. As the balloon is squeezed to expand one area, another area necessarily shrinks proportionately. This reflects the trade-off in focus, breadth and rigor given limited funding. This approach provides a range of "good models" for future assessments, the selection of which will depend on the starting point and emphases of a particular project. Combinations of breadth, rigor, and focus that are not obtainable given limited funding or not ambitious enough can be judged within the assessment space (Figure 1-1).

For the NRCA at WICR, we opted for slightly more narrow breadth but greater rigor and focus versus the early EFMO assessment. This was mainly due to lessons learned during the EFMO NRCA process in terms of limitations on availability of meaningful, spatially-specific data and in term of performing assessments at meaningful scales of resolution. The approach retains a focus on development of reference condition targets. These reference conditions allowed a hierarchical assessment of ecological attributes within reporting units using logic models (see Natural Resource Condition Assessment Terminology below). Ecological attributes were classified generally in accordance with an Environmental Protection Agency framework, while reporting units were defined based on major land and aquatic features within the park.

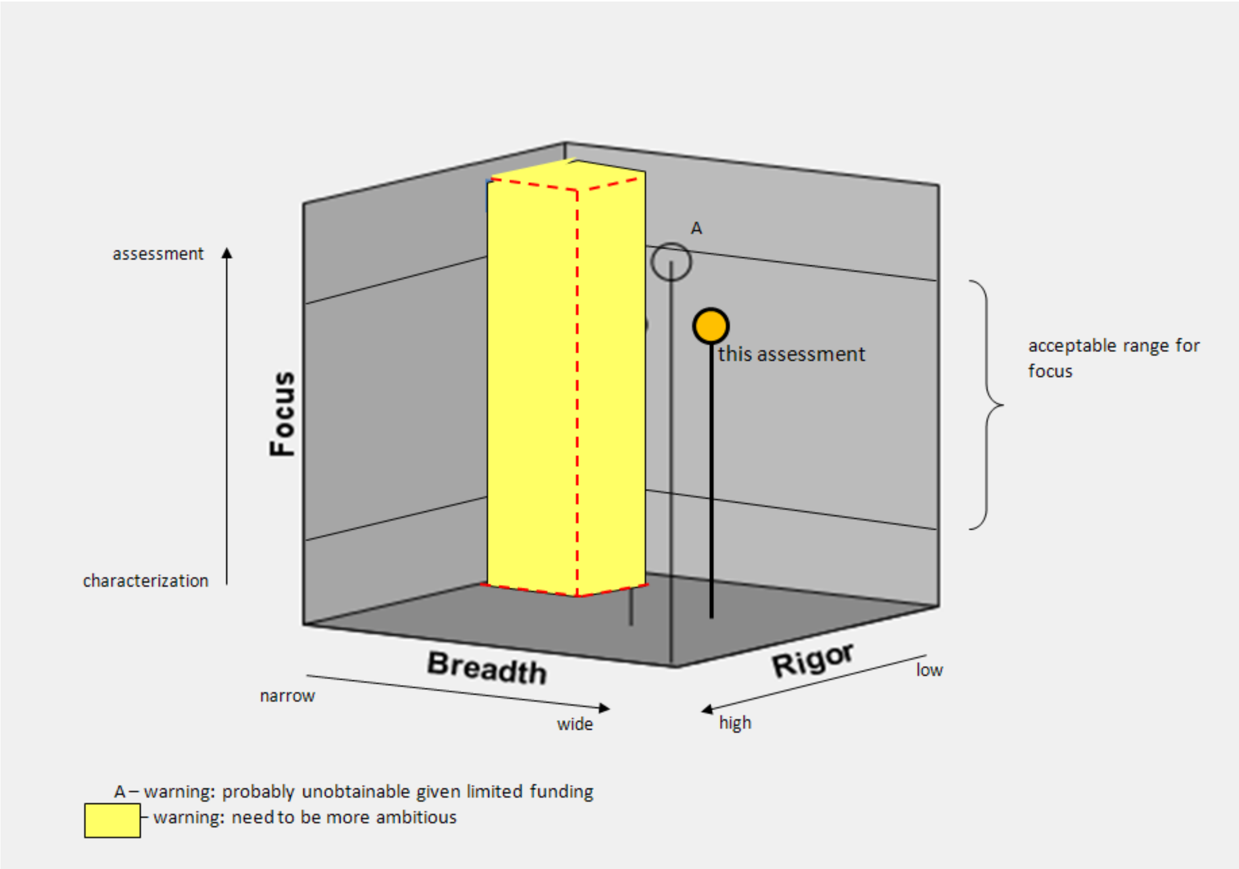

Figure 1-1. Assessment space used to design the Natural Resource Condition Assessment for Wilson's Creek National Battlefield.

Natural Resource Condition Assessment Terminology

This NRCA uses several terms in a very specific way, and these terms are critical for understanding the NRCA. While many conservation planning efforts use the same or similar terminology, we have defined several terms of importance here for reference while using the NRCA.

- Reporting Unit – A spatially defined area which serves as the unit of analysis for a natural resource condition assessment (NRCA). Natural, cultural, or management-based criteria may be used to define reporting units. The number of reporting units must be reasonable in order to limit the complexity of the NRCA.

- Resource Type – A natural resource that is of interest to park managers and that can be assessed based on attributes and indicators (see “attribute” and “indicator” below). Resource types are generally spatially nested within reporting units and are the subjects of analysis in a natural resource condition assessment (NRCA).

- Attribute – A category of interest in an ecological system. Intended as a generic term, attributes are generally non-spatial ecological categories that describe natural resources and may be assessed using one or many indicators (see “indicator” below).

- Indicator – Indicators are variables of interest in an ecological system that can be characterized with a single, direct measurement. They are the finest level of detail at which data are collected.

- Current Condition – The current measurement of an indicator. (To assess the current condition of attributes, we use logical operators to synthesize multiple indicators; see Chapter 6.)

- Management Target – Desired values for indicators derived by considering both reference conditions and practical and interpretive considerations defined by park goals. Reference conditions, in turn, are benchmark quantitative, conceptual, or descriptive values that reflect the best estimate of prevailing historic conditions.

We focus on management targets because they are often more easily defined in quantitative terms, since these are inferred both from known and surmised reference conditions, and from practical and interpretive considerations defined by park management goals. Quantifying reference conditions is often difficult or impossible due to the limited and fragmentary nature of historical data (Swetnam et al. 1999). Management targets are defined for each attribute or indicator and are summarized in Chapter 5.

Chapter 2 Park Resource Setting and Resource Stewardship Context

Park Resource Setting

Description and Characterization of Park Natural Resources

Wilson's Creek National Battlefield preserves the site of the Battle of Wilson's Creek, which was named for the stream crossing the battlefield area, about ten miles southwest of Springfield, Missouri (Figure 2-1, Figure 2-2). Union and Confederate forces fought on August 10, 1861 for control of Missouri during the first year of the Civil War. The National Park Service operates the Wilson's Creek Civil War Museum and a visitor center featuring a film, battle map presentation, and a Civil War research library. Major features include Bloody Hill, the site of the battle, a 5 mile paved interpretive road, and the restored 1852 Ray house. The Ray house, which housed the Ray family, is the only structure left intact from the time of the battle. Additionally, off the tour road, there are five walking trails and a 7 mile trail for horseback riding and hiking (NPS 2010b).

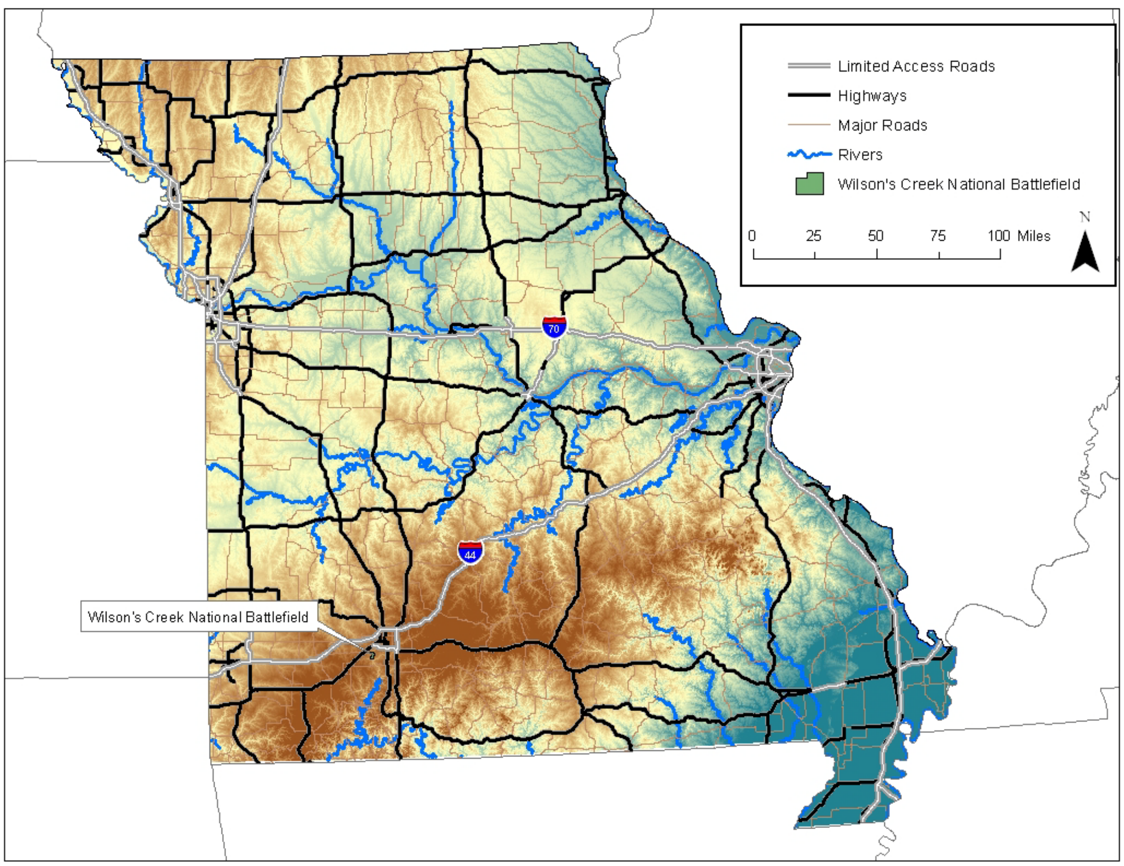

Figure 2-1. Location of Wilson's Creek National Battlefield within the state of Missouri.

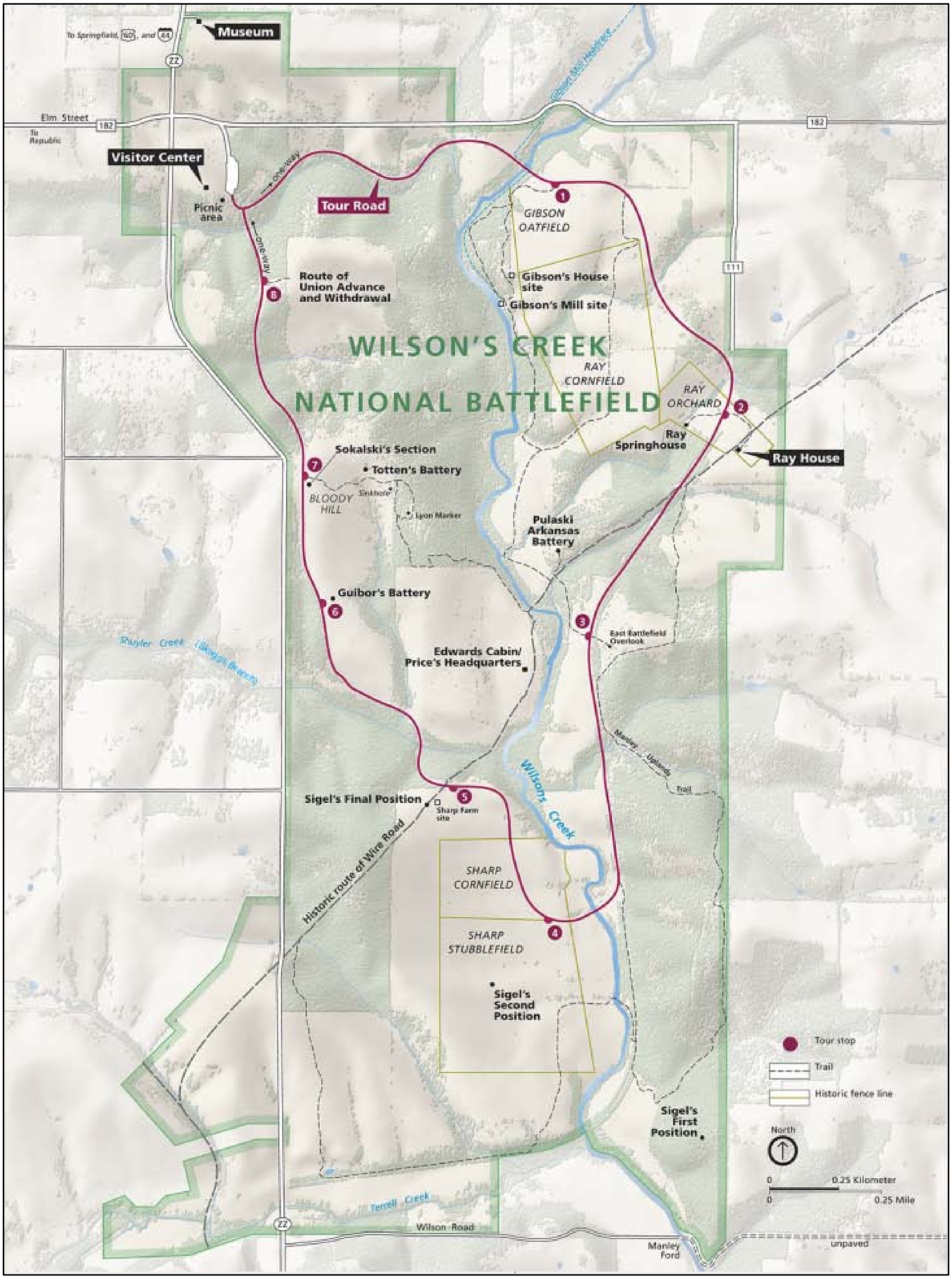

Figure 2-2. Wilson's Creek National Battlefield (NPS 2010b).

Landscape and Watershed Context and Threat Assessment

Wilson's Creek National Battlefield is on the James River Oak Savanna/Woodland land type association within the Springfield Plain Subsection of the Ozark Highlands Section (Nigh and Schroeder 2002). Historic landscapes were likely a mix of oak woodlands, savannas, and tallgrass grasslands, depending on soil depth and water holding capacity and on fire frequency. Fire frequency was in turn governed by both larger scale (e.g. roughness, the presence of streams) and more local conditions (e.g. the presence of shallow soils with exposed bedrock). Prevailing vegetation patterns probably varied with time and chance events, so a given site might have been more or less wooded at any given point in time. Some shallow soil glades are present and these often support eastern redcedar co-dominated woodlands or shrublands on the modern landscape. The modern landscape is characterized by tame tall fescue (*Schedonorus phoenix*) pastures that have resulted from succession of old fields or heavy grazing by domestic livestock following land clearing. Successional woodlands, often associated with rougher topography, stream floodplains, or upland riparian zones, are also present.

The area near WICR is under intense development pressure from the growth of the Springfield metropolitan area. In the core city area, urban land cover increased from 36,996 acres in 1972 to 103,567 acres in 2000, or 273% (Figure 2-3; Diamond and Blodgett 2003.). A buffered road network provides an index to immediate threat of development, and shows urban encroachment threats, especially from northeast of the park (Figure 2-4).

Watershed health indices consider human threats such as land use and pollution discharges as influences on key aquatic indicators (Joubert and Loomis 2005). Knowing the suite of potential threats and those that are most pervasive on the landscape helps resource managers regulate human impacts on the environment by allowing managers to target specific threats at specific locations.

The watershed threats assessment relies on data developed by the Missouri Resource Assessment partnership (MoRAP) for the EPA and Missouri DNR (see Annis et al. 2010). The data suite consists of approximately 36 datasets considered potential threats to aquatic ecological integrity from human activities. Figure 2-5 and Figure 2-6 show the land cover and selected threats within the Wilson’s Creek 10-digit watershed and surrounding James River Watershed. The complete list of the threats considered and their data sources are listed in Table 2-1. These data were used to create a human threat index (HTI) that helps to “score” every stream segment with regard to the full complement of threat data used by considering both local and upstream character (Figure 2-7). Larger HTI values indicate more potential threat. It should be noted that each potential human threat does not necessarily impact aquatic resources at all times, but each one does have the potential to impact aquatic resources at any given time. While the HTI is designed for larger spatial scales, it may still be used as a screening tool to gauge the vulnerability of watersheds to impairment (Joubert and Loomis 2005) and the degree and causes of impairment of streams and rivers in WICR.

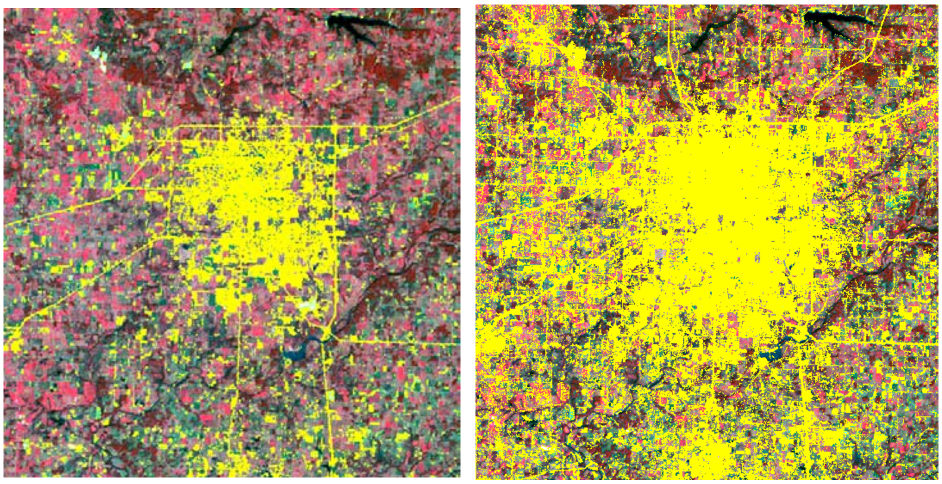

Figure 2-3. Urban development of the Springfield area, fewer than 10 miles northeast of Wilson's Creek National Battlefield, shows a 273% increase, or 66,571 acres between 1972 and 2000.

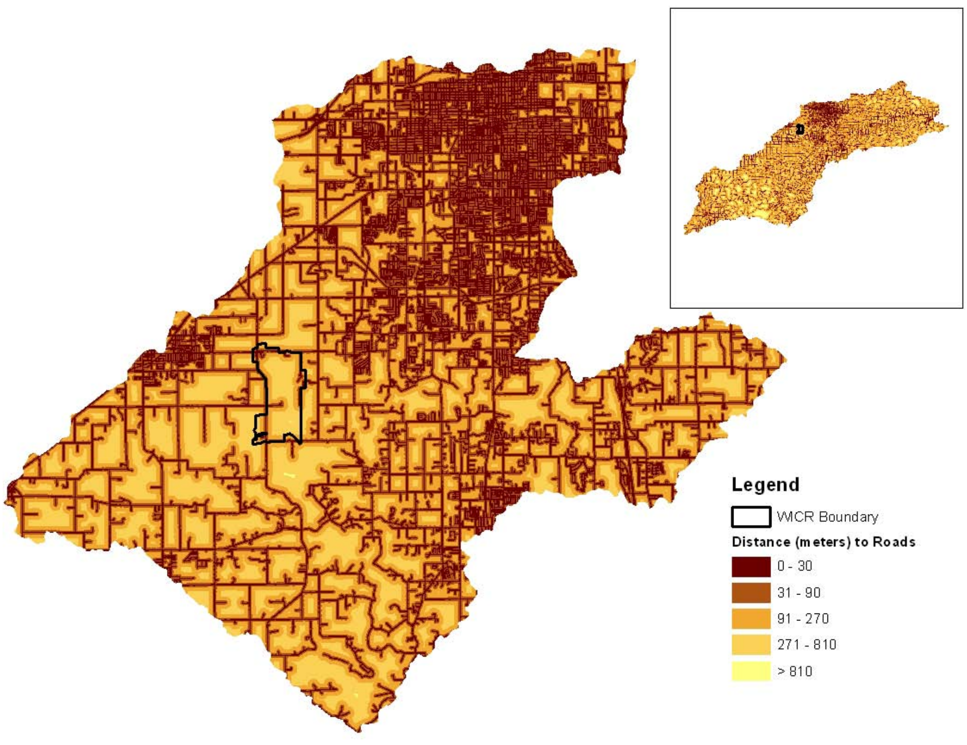

Figure 2-4. A buffered road network provides a visual index to development threats in the region around Wilson's Creek National Battlefield.

Climate

In the Ozark Highlands, winter snowfall averages 10 inches with normal January low/high temperatures of 12/24^{o} F and 100 days below freezing (McNab and Avers 1994, Missouri Climate Center 2010). July average high temperatures are between 87-90^{o} F, with a yearly range of 40-50 days above 90^{o} F (Missouri Climate Center 2010). The growing season lasts between 180-200 days and average annual precipitation ranges from 40-48 inches (McNab and Avers 1994).

Landform History

Wilson's Creek National Battlefield topography consists of rolling hills with steep slopes along water courses. The highest elevation of the battlefield is 1250 feet, at several locations. Soils are deep, stony, and cherty silt loam or shallow with a great limestone fraction (Busch 1976). The Springfield Plateau is primarily underlain with Mississippian and Pennsylvanian age rocks, which also underlie the northern edge of the Ozarks along the Missouri River. The distributional limit of many species characteristic of the Ozarks correspond with the Mississippian-age geologic formations, separating younger Pennsylvanian formations that dominate the Central Plains from the older Ordovician formations that are the primary type found in the central Ozarks. The sedimentary rock of this subregion is dominated by cherty limestone and dolomite, with smaller contributions of sandstone and shale. The geology in the region consists of limestone, dolomite, sandstone, chert, shale, and rhyolite with numerous karst formations, such as sinkholes, springs, seeps, and losing streams. Potential vegetation within the Springfield plateau features a mixture of tallgrass prairie, deciduous woodland and forest, and savanna. As such, the region forms a transition zone between prairies to the north, mountainous areas to the south, and deciduous forests to the east (Chapman et al. 2002).

Cultural History

The Battle of Wilson's Creek, also known as the Battle of Oak Hills, was fought near Springfield, Missouri on August 10, 1861 between Union and Confederate forces over control of Missouri. At the beginning of the war, Missouri was neutral, and the Missouri General Assembly created the Missouri State Guard for defense. The governor, Claiborne Fox Jackson, sided with the Confederacy, and appointed Sterling Price as general of the Missouri State Guard. After several skirmishes with Brigadier General Nathaniel Lyon, originally commander of the U.S. arsenal of St. Louis, Governor Jackson retreated to southwest Missouri, 75 miles from Springfield, with the State Guard, about 5200 soldiers. By the end of July, Brigadier Generals Ben McCulloch and N. Bart Pearce, with Confederate troops, joined Governor Jackson and Major General Price, raising the coalition forces to over 12,000. Meanwhile, Unionist General Nathaniel Lyon moved about 6,000 soldiers to Springfield. Both armies marched from their camps, the Confederates on July 31 and the Union soldiers on August 1. The armies fought briefly at Dug Springs, Missouri on August 2, when General Lyon realized he was outnumbered and retreated back to Springfield. Confederate General McCulloch followed and by August 6, was encamped at Wilson's Creek, ten miles southwest of the city (NPS 2010b).

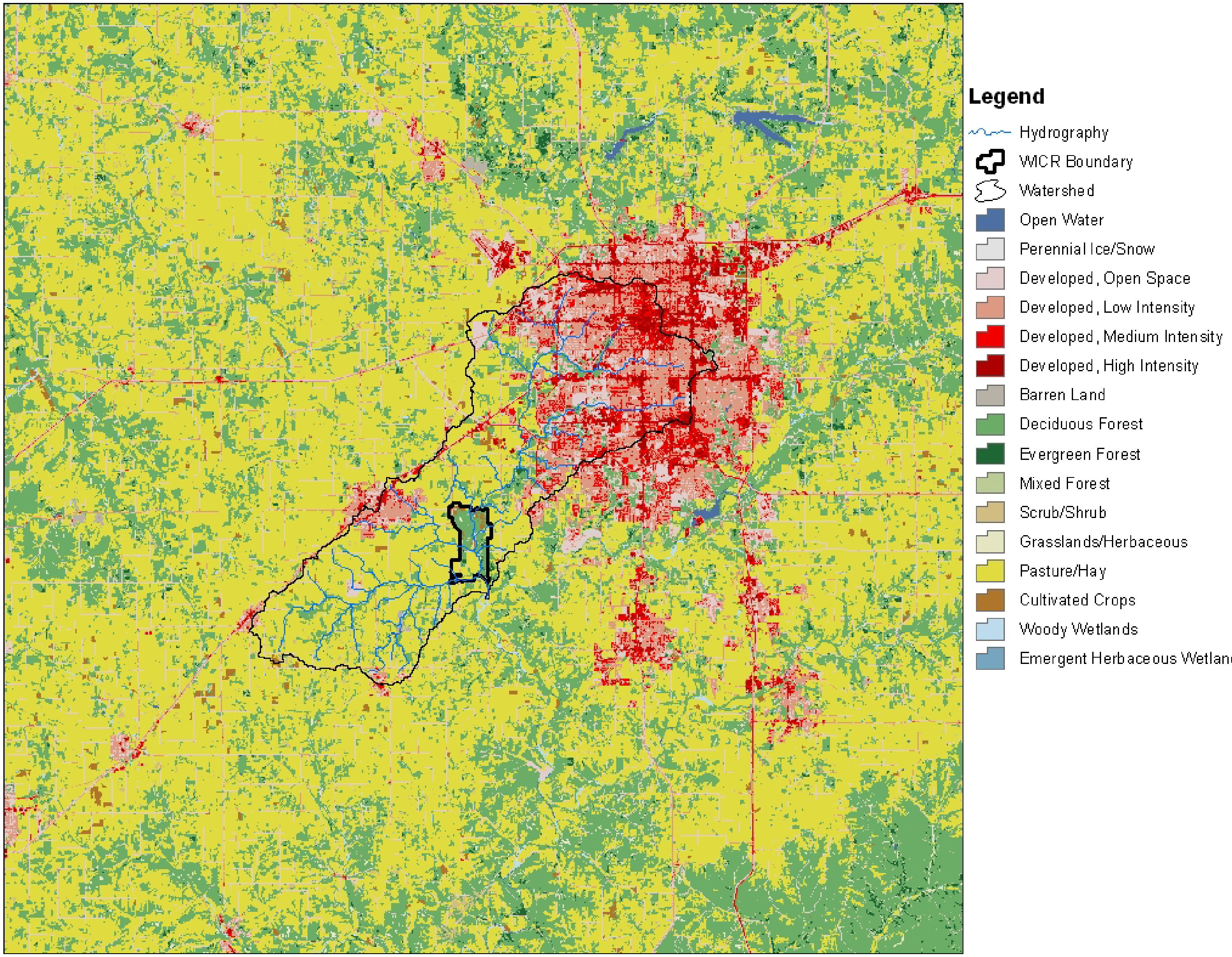

Figure 2-5. Land cover within and surrounding the watershed of Wilson's Creek National Battlefield based on the 2001 NLCD.

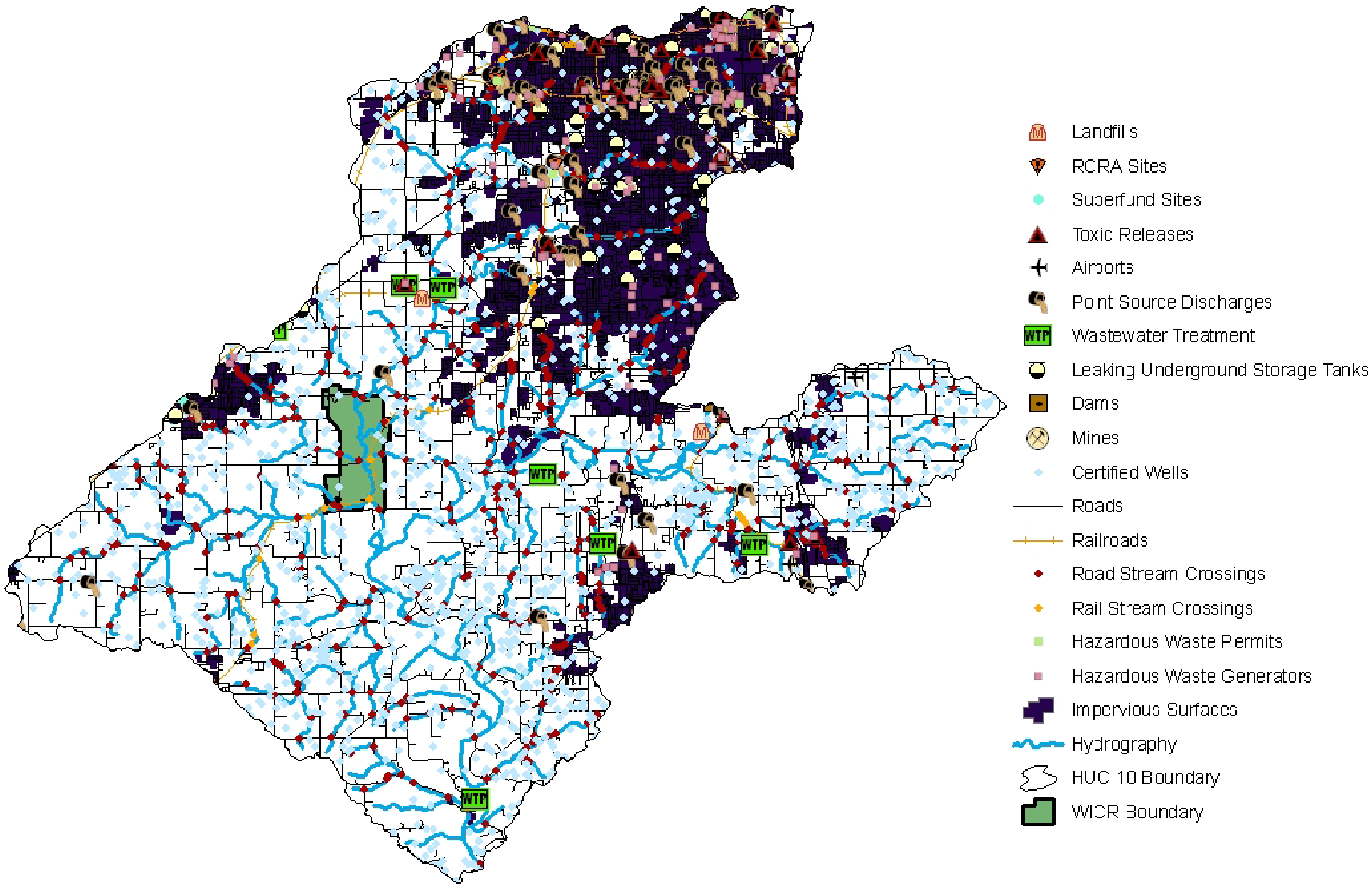

Figure 2-6. Location of potential threats in Wilson's Creek 10-digit watershed.

Table 2-1. List of all potential human threats considered and the data source for each threat.

Potential Threats	Source
Impervious Surfaces	2001 NLCD
Cropland	2001 NLCD
Pasture/Hay	2001 NLCD
Impervious in stream buffer	2001 NLCD
Cropland in stream buffer	2001 NLCD
Pasture/Hay in stream buffer	2001 NLCD
Water Wells	MoDNR Wellhead Information Management System
Major Impoundments	1:100,000 NHDPlus, 1:24,000 NWI, and modified 1:100,000 NHD
Headwater Impoundments	Elevation Derivatives for National Applications, NLCD, NWI, and modified 1:100,000 NHD
Distance downstream to lakes	1:100,000 NHDPlus, 1:24,000 NWI, and modified 1:100,000 NHD
Fragmentation of streams	1:100,000 NHDPlus, 1:24,000 NWI, and modified 1:100,000 NHD
Road Length	TIGER/line roads file
Road/Stream Crossings	TIGER/line roads file and modified 1:100,000 NHD
Railroad Length	TIGER/line rail file
Rail/Stream Crossings	TIGER/line rail file and modified 1:100,000 NHD
Pipelines (crude oil)	EPA Region 7
Pipelines (liquid fuels)	EPA Region 7
Pipelines (gases)	EPA Region 7
Powerlines	Geocomm Data Clearinghouse
Crop Pesticides	NLCD and US Agricultural Census data
Population Density	U.S. Census Bureau
Livestock Sales	Dunn and Bradstreet 2003
Ditch/Channelized Streams	1:24,000 NHD, NWI, and modified 1:100,000 NHD
Airports	GDT Dynamap/2000
Dams	National Inventory of Dams 1993-1994
Military sites	Bureau of Transportation Statistics-1998-2001
Coal Mines	EPA Basins 2001
Lead Mines	EPA Basins Version 3.0
Other Mines	Minerals Information Team
Oil and Gas Wells	MoDNR (Provisional Data)
Leaking Underground Storage Tanks	MoDNR - Air and Land
Superfund Sites	EPA Geodata dataset
Toxic Release Sites	EPA Geodata dataset
Wastewater Treatment Facilities	EPA National Pollutant Discharge Elimination System/ Permit Compliance System
Confined Animal Feeding Operations	Subset of NPDES dataset from MoDNR
Landfills	EPA Basins 2001
NPDES	MoDNR, Missouri NPDES Operating Permits
RCRIS	EPA Geodata dataset
Hazardous Waste Generators	MoDNR - Air and Land
Hazardous Waste Permits	MoDNR - Air and Land

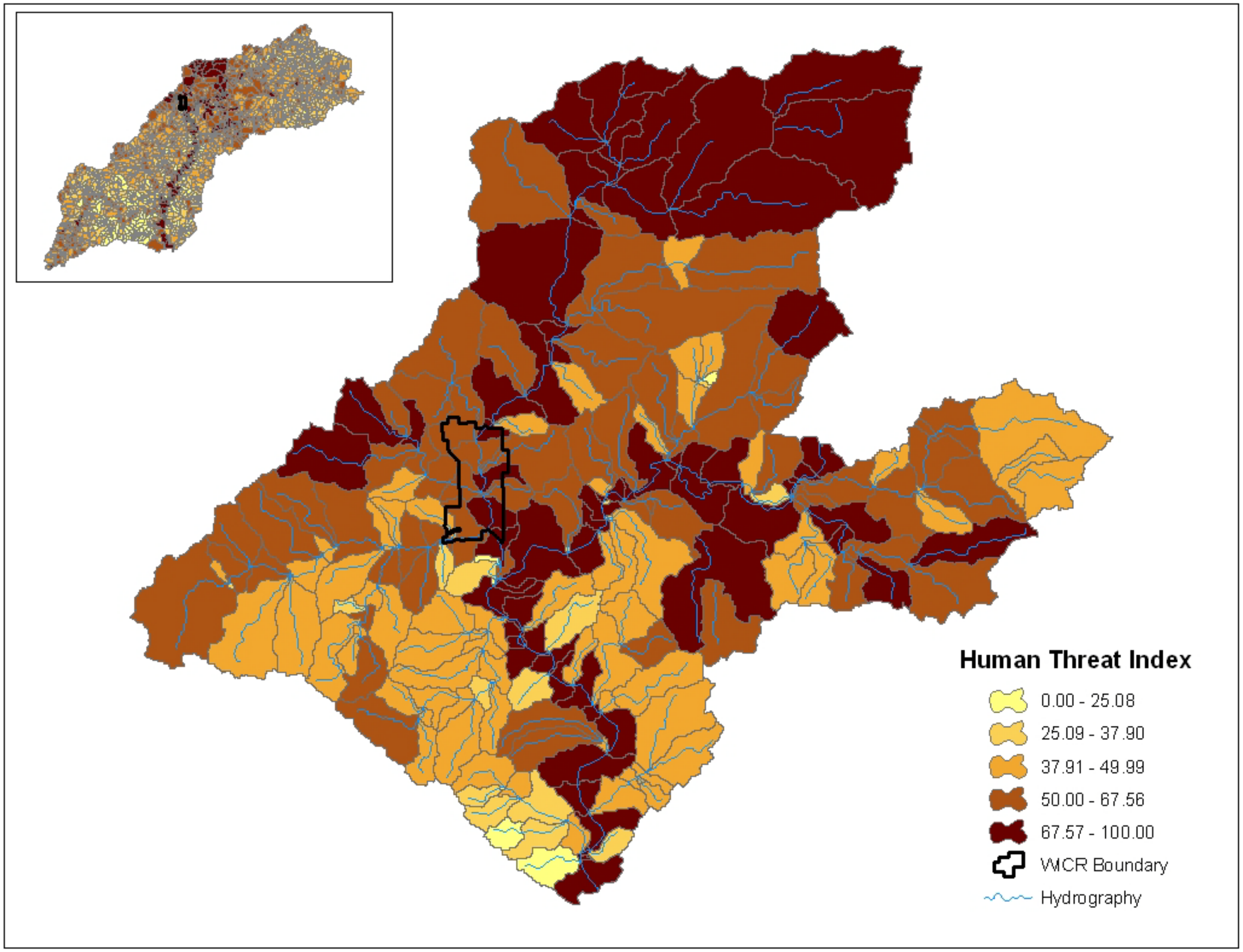

Figure 2-7. Human Threat Index for the HUC 10 encompassing Wilson's Creek National Battlefield with the HUC 8 inset.

Lyon launched a surprise attack on the Confederate camp on August 10, leaving about 1000 men to supervise supplies and a retreat. The main body under Lyon struck from the north while a smaller force of 1200, under Colonel Franz Sigel, attacked from the south at about 5:00 a.m. Surprised, the Confederates moved back to Bloody Hill, where they stabilized their position. The battle continued for five hours. Meanwhile, the Confederates routed Colonel Sigel's column, as the Union soldiers thought Confederate General McCulloch's approaching lines were Union reinforcements and did not realize they were hostile. On Oak or Bloody Hill, at about 9:30 a.m., General Lyon was killed and Major Samuel Sturgis took over command. At 11 a.m., both forces withdrew, and with ammunition low, Sturgis retreated to Springfield rather than face a fourth Confederate attack. Although Confederate troops had control of the battlefield, they were not able to pursue the Union forces. Casualties were equal, about 1,320 Union and 1,220 Confederate lives (Elkins 2007, NPS 2010b).

The Battle of Wilson's Creek gave the Confederates control of southwestern Missouri. However, Missouri formed a Union government at the end of July, during the campaign leading up to the battle. As a separate Confederate state government was not accepted, the state remained in the Union throughout the war. For the next three and a half years, the state was the scene of small scale guerrilla warfare, by bushwhackers outside of the military chain of command (NPS 2010b).

Natural Communities

Wilson's Creek National Battlefield is at the ecotone of eastern deciduous forest and western prairie. Historically, the landscape was a mixture of oak woodland, savanna, and tallgrass prairie, with small areas of steep slope woodlands and glades. Denser and more mesic forests were present along riparian areas and on steep, protected slopes (Sasseen 2003). By 1861, farmers had developed land for cultivation, and after the battle, until the National Battlefield was created in 1960, agricultural use, overgrazing by cattle, and fire suppression resulted in almost complete loss of savanna, replacement of native vegetation with exotic grasses such as tall fescue, and denser forests with considerable shrub presence. Eastern redcedar (*Juniperus virginiana*) additionally has invaded into old fields and pastures, as well as fire-suppressed woodlands (NPS 2004b)

The park contains both exotic species and rare native species. Exotic species are a pressing issue, as 500 acres are filled with exotic plant species such as common mullein (*Verbascum thapsus*), honey locust (*Gleditsia triacanthos*), musk thistle (*Carduus nutans*), and tall fescue (*Schedonorus phoenix*). Three species of brome (*Bromus* spp.), and Chinese bushclover (*Lespedeza cuneata*) are invading the habitat of the Missouri bladderpod (*Lesquerella filiformis).* Missouri bladderpod is a federally endangered plant found in limestone glades and outcrops of four Missouri counties and two counties in Arkansas. Bloody Hill Glade contains one of the largest protected populations, while four smaller populations are present on other glades within the park. In addition, there are five plants that are state imperiled or critically imperiled in Missouri: greenthread (*Thelesperma filifolium* var. *filifolium)*, buffalograss (*Buchloe dactyloides*), blue gramma grass (*Bouteloua gracilis*), royal catchfly (*Silene regia*), and false gaura (*Stenosiphon linifolius*; NPS 2004b). There also is a colony of federally endangered gray bats, discovered during a cave inventory in 1996. Similarly, the grotto salamander (*Typhlotriton spelaeus*), a species of concern to the state, was documented during cave research in 1985. Bald eagles (*Haliaeetus leucocephalus*) are migrants and occasionally are winter residents (Gale et al. 2004).

Water quality is a continuing concern at Wilson's Creek. Water quality has been very poor due to Springfield's southwest wastewater treatment plant, agricultural and storm water runoff, and nearby development. Macro-invertebrate sampling demonstrates a decline of pollution-sensitive species and dominance of pollution-tolerant species (Bowles 2010). Communities in Wilson's Creek are impoverished, but there is one fish species of interest, the Ozark sculpin, (*Cottus hypselurus*) due to its limited range and specific habitat requirements (Peterson and Justus 2005b).

Aquatic Resources In and Near Wilson's Creek National Battlefield

Wilson's Creek National Battlefield contains three streams, Wilson's Creek, Terrell Creek, and Skegg's Branch (Figure 2-2). Wilson's Creek, which originates in Springfield, Missouri, is located in Greene and Christian County and is the main stream flowing through the park. Wilson's Creek is one of largest tributaries of the James River. Wilson's Creek has a drainage area above the park of 58.3 square miles and average annual flow rates generally are 90.9 cubic feet per second, as measured by a gauge (07052160) near Wilson's Creek Battlefield (USGS 2010).

In 1959, a wastewater treatment facility was constructed on Wilson's Creek to help process wastewater from Springfield. The plant initially had a flow capacity of 12 million gallons per day. The facility has since undergone two major upgrades in 1978 and 1993. In 1978 the plant was upgraded to increase flow capacity to 30 million gallons per day and increase the overall level of water treatment. Following these upgrades, Berkas (1980, 1982) reported improvements downstream for dissolved oxygen concentrations. Further expansion and major improvements were completed in 1993 with the addition of a second treatment train. In 2001, improvements were further expanded to include biological and chemical removal of phosphorus that reduced phosphorus discharge by 40%. Currently the wastewater treatment facility is capable of continually treating 42.5 million gallons per day and 90 million gallons per day for shorter periods. The average daily flow from Springfield at this time is approximately 35 million gallons per day. The wastewater treatment facility removes approximately 70,000 pounds of pollutants from the wastewater per day before it is discharged. However, even with the removal of those pollutants, Wilson's Creek remains a distressed stream.

Wilson's Creek has poor water quality and is classified as a 303(d) stream (Missouri Department of Natural Resources 2009). Sampling has shown water toxicity from unknown pollutants and bacteria, due to drainage from the city of Springfield (Missouri Department of Natural Resources 2009). Toxicity comes from point sources such as the wastewater treatment facility and nonpoint sources such as urban stormwater (Richards and Johnson 2002). Studies since 1968 (Harvey and Skelton 1968, Kerr 1969, Emmett et al. 1978, Richards and Johnson 2002) have shown that effluent from the wastewater treatment facility and urban runoff during storms release inorganic chemicals and nutrients into Wilson's Creek. The impact of the resulting dissolved oxygen depletion has reduced animal populations, but overall the extent of damage is presently unknown. Bowles (2010) reported that even with stream degradation, invertebrate populations have not decreased from the levels recorded in earlier surveys by Harris et al. (1991) and Peitz and Cribbs (2005).

Wildlife

Fauna of WICR are typical of old fields and disturbed woodlands and forests in the eastern Ozark Highlands. Forty-seven species of birds were recorded at Wilson's Creek National Battlefield during site visits in May 2008. The most common and widely distributed species was the Indigo bunting (*Passerina cyanea*). The Northern cardinal (*Cardinalis cardinalis*) and Blue-gray gnatcatcher (*Polioptila caerulea*) occurred frequently as well. Partners in Flight, a coalition of agencies and individuals whose mission is to conserve North America's declining bird populations, classify ten species found at WICR as species of continental importance. Two grassland obligate species were recorded, the Dickcissel (*Spiza Americana*) and the Eastern meadowlark (*Sturnella magna*). No woodland obligates were reported. Grasslands, deciduous woodlands, and shrub habitat dominate at WICR.

An inventory of the presence/absence of mammals at Wilson's Creek National Battlefield was conducted in June 2004. An initial expected species list suggested 37 terrestrial species as present or probably present at the park. Seven species of mammals were added to the list, two were excluded, and five species have a questionable status at the park. One species is considered extirpated. After revising the list, the inventory documented 21 of 37 (57 %) terrestrial species listed as either present or probably present.

No state or federally listed species were observed. Five of the undocumented species are small carnivores and may be present occasionally or in small numbers although the spotted skunk is presently listed as endangered in the state and has recently experienced a significant decline in numbers. Three species are aquatic and should be present in Wilson's Creek. The other five species are rodents and all of these species have been documented in similar habitats in southwest Missouri. The black bear has been documented in nearby areas, and the mountain lion has been reported from the Battlefield, but the sightings have not been confirmed from physical evidence.

Resource Stewardship Context

Park Enabling Legislation

Wilson's Creek, near Springfield in southwestern Missouri, was established as Wilson's Creek National Battlefield Park on April 22, 1960, and became a National Battlefield in 1970, with 1750 acres (Busch 1976, NPS 2010b). The park contains significant natural resources in rare native species, but also is managing against the invasion of many exotic species, poor water quality, and degraded habitat for native vegetation (Sasseen 2003, Bowles 2010). Management goals include restoring the landscape to historical battle-era conditions of oak savanna and agricultural fields, to enhance visualization of tactics and troop movements through the area (NPS 2010b).

Fundamental Resources and Values

Wilson's Creek National Battlefield Park's mission is to illustrate the Battle at Wilson's Creek, through collaborative partnerships such as Wilson's Creek National Battlefield Foundation. The park will continue to protect the site and historical structures, create educational programs, and connect people to nature, history, and culture. Furthermore, the park intends to restore the battlefield to the historical landscape of the 1860s, which will help provide appreciation of battle strategies and troop movements through the area (NPS 2007c).

WICR supports examples of both aquatic and terrestrial Ozark Highlands natural communities. Management and restoration of these resources includes re-vegetation of oak woodland and savanna, native grass seeding to recover grasslands and open spaces, and reduction of eastern redcedar, mesic tree species, and shrubs through regular prescribed burns in forest, grassland, and glades (NPS 2004b).

Desired Conditions for Natural Resources

Desired conditions are qualitative descriptions of the integrity and character for a set of resources and values, including visitor experiences, which the NPS has committed to achieve and maintain. Area-specific desired conditions include these qualitative descriptions as well as guidance on visitor experience opportunities and appropriate kinds and levels of management, development, and access for each area of the park. The desired conditions for natural resources at WICR are:

- Cultural landscape inventories are conducted to identify landscapes potentially eligible for listing in the national register, and to assist in future management decisions for landscapes and associated resources, both cultural and natural. A Cultural Landscape Report (CLR; NPS 2004c) clearly identifies the landscape characteristics and associated features, values, and associations that make a landscape historically significant. The content of a CLR provides the basis for making sound decisions about management, treatment, and use. The management of cultural landscapes focuses on preserving the landscape’s physical attributes, biotic systems, and use when that use contributes to its historical significance.

- The National Park Service actively seeks to understand and preserve the soil resources, and to prevent, to the extent possible, the unnatural erosion, physical removal, or contamination of the soil, or its contamination of other resources. Natural soil resources and processes function in as natural a condition as possible, except where special considerations are allowable under policy. When soil excavation is an unavoidable part of an approved facility development project, the National Park Service will minimize soil excavation, erosion, and offsite soil migration during and after the activity.

- Surface water and groundwater are protected, and water quality meets or exceeds all applicable water quality standards. NPS and NPS-permitted programs and facilities are maintained and operated to avoid pollution of surface water and groundwater.

- Natural floodplain values are preserved or restored. Long-term and short-term environmental effects associated with the occupancy and modifications of floodplains are avoided.

- The National Park Service will maintain, as part of the natural ecosystem, all native plants and animals.

- Populations of native plant and animal species function in as natural a condition as possible except where special considerations are warranted. Native species populations that have been severely reduced in or extirpated from the battlefield are restored where feasible and sustainable. The management of exotic plant and animal species, including eradication, will be conducted wherever such species threaten national monument resources or public health and when control is prudent and feasible. Federal and state-listed threatened and endangered species and their habitats are protected and sustained. Native threatened and endangered species populations that have been severely reduced in or extirpated from the national monument are restored where feasible and sustainable.

- Cultural and natural resources are conserved "unimpaired" for the enjoyment of future generations. Visitors have opportunities for forms of enjoyment that are uniquely suited and appropriate to the superlative natural and cultural resources found in the national monument. No activities occur that would cause derogation of the values and purposes for which the park has been established. For all zones, units, or other management divisions in the monument, the types and levels of visitor use are consistent with the desired resource and visitor experience conditions prescribed for those areas. NPS staff will identify implementation commitments for user capacities for all areas of the national monument.

Park staff at WICR actively work to preserve and manage cultural and natural resources. The CLR outlines historic and existing conditions and management issues (NPS 2004c). Interpretation of the battlefield and restoration of natural resources are primary considerations. Natural resource management and restoration is balanced with the need to provide for accurate interpretation of conditions at the time of the battle, including the maintenance of viewsheds and historic structures and selected cropland areas. Therefore, WICR seeks to contribute toward the conservation and restoration of streams, glades, upland grasslands, savannas and woodlands, and floodplain forests concomitant with interpretation of conditions at the time of the battle.

Chapter 3 Study Approach

Preliminary Scoping

Scientists from the Missouri Resource Assessment Partnership (MoRAP), NPS Heartland Inventory and Monitoring Network (HTLN), and park managers from Wilson's Creek National Battlefield (WICR) comprised the assessment team (Table 3-1). We used the U.S. Environmental Protection Agency's Scientific Advisory Board's Ecological Framework for Assessing and Reporting on Ecological Condition (SAB framework, EPA 2002) to guide the NRCA. The breadth and logical organization of indicators led us to adopt the framework to select and organize indicators for Wilson's Creek. With the SAB Framework as a guide, the assessment team collectively agreed on the most important resource types, attributes, and indicators for inclusion in the NRCA. We reviewed management plans and natural resource studies to ensure that the selected indicators complimented these efforts.

Table 3-2. Team members for the Wilson's Creek Battlefield Natural Resource Condition Assessment.

Name	Affiliation
Gust Annis	Missouri Resource Assessment Partnership
David Bowles	NPS, Heartland Inventory and Monitoring Network
Mike DeBacker	NPS, Heartland Inventory and Monitoring Network
David Diamond	Missouri Resource Assessment Partnership
Hope Dodd	NPS, Heartland Inventory and Monitoring Network
Lee Elliott	Missouri Resource Assessment Partnership
Jennifer Haack	NPS, Heartland Inventory and Monitoring Network
Phillip Hanberry	Missouri Resource Assessment Partnership
Ted Hillmer	NPS, Wilson's Creek National Battlefield
Kevin James	NPS, Heartland Inventory and Monitoring Network
Ronnie Lea	Missouri Resource Assessment Partnership
Sherry Leis	NPS, Fire Management Program
David Peitz	NPS Heartland Inventory and Monitoring Network
Dyan Pursell	Missouri Resource Assessment Partnership
Gareth Rowell	NPS Heartland Inventory and Monitoring Network
Gary Sullivan	NPS, Wilson's Creek National Battlefield
Diane True	Missouri Resource Assessment Partnership
Craig Young	NPS, Heartland Inventory and Monitoring Network

Assessment Framework Used in the Study

The SAB framework provided a hierarchical checklist of essential ecological attributes (EEAs), categories/subcategories, and indicators that should be considered when evaluating the health of ecological systems (EPA 2002, Table 3-2). The conceptual EEAs include three ecological attributes that are primarily patterns—landscape condition, biotic condition, and chemical/physical characteristics—and three that are primarily processes—hydrology/geomorphology, ecological processes, and natural disturbance. The hierarchical organization of the EEAs was developed from a conceptual model of ecological structure, composition, and function at a variety of scales (EPA 2002).

In some assessments, indicators of ecological condition are included with indicators of stressors (e.g., road density) (EPA 2002). In the NRCA, we focused on indicators of condition given the one-to-many relationship between stressors and condition (EPA 2002, Figure 3-1). The watershed stressor assessment may be used in parallel with the condition indicators to begin to understand the relationship between anthropogenic activities and the condition of park resources.

Table 3-3. Six essential attributes and sub-categories defined by the Environmental Protection Agency's Framework for Assessing and Reporting Ecological Condition (2002).

Landscape Condition
- Extent of Ecological System/Habitat Types
- Landscape Composition
- Landscape Pattern and Structure

Biotic Condition
- Ecosystems and Communities
  - Community Extent
  - Community Composition
  - Trophic Structure
  - Community Dynamics
  - Physical Structure
- Species and Populations
  - Population Size
  - Genetic Diversity
  - Population Structure
  - Population Dynamics
  - Habitat Suitability
- Organism Condition
  - Physiological Status
  - Symptoms of Disease or Trauma
  - Signs of disease

Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)
- Nutrient Concentrations
  - Nitrogen
  - Phosphorus
  - Other Nutrients
- Trace Inorganic and Organic Chemicals
  - Metals
  - Other Trace Elements
  - Organic Compounds
- Other Chemical Parameters
  - pH
  - Dissolved Oxygen
  - Salinity
  - Organic Matter
  - Other
- Physical Parameters

Ecological Processes
- Energy Flow
  - Primary Production
  - Net Ecosystem Production
  - Growth Efficiency
- Material Flow
  - Organic Carbon Cycling
  - Nitrogen and Phosphorus Cycling
  - Other Nutrient Cycling

Hydrology and Geomorphology
- Surface and Groundwater flows
  - Pattern of Surface Flows
  - Hydrodynamics
  - Pattern of Groundwater Flows
  - Salinity Patterns
  - Water Storage
- Dynamic Structural Characteristics
  - Channel/Shoreline Morphology, Complexity
  - Extent/Distribution of Connected Floodplain
  - Aquatic Physical Habitat Complexity
- Sediment and Material Transport
  - Sediment Supply/Movement
  - Particle Size Distribution Patterns
  - Other Material Flux

Natural Disturbance Regimes
- Frequency
- Intensity
- Extent
- Duration

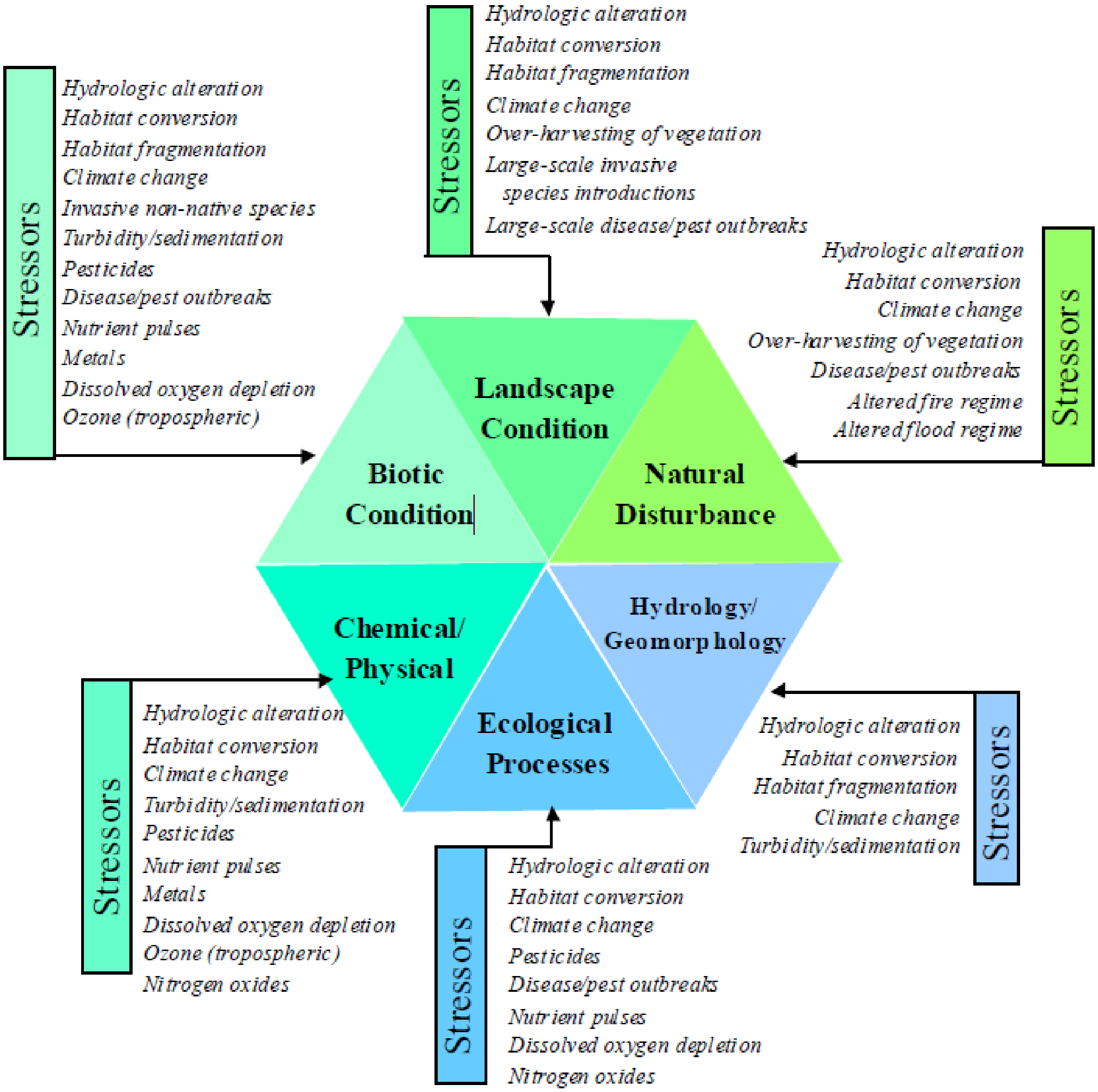

Figure 3-8. Schematic showing the one-to-many relationship between essential ecological attributes and stressors in the Environmental Protection Agency's Framework for Assessing and Reporting Ecological Condition (EPA 2002).

Resource Types, Attributes and Indicators

For WICR, we attempted to identify ecological indicators by attribute and resource type that reflect the quality or condition of park resources. In addition, the indicators are generally selected such that they are practically measurable. Thus, each resource type may have a unique suite of attributes and indicators. Also, each reporting unit may have different attributes and indicators.

Landscape Condition

Landscape Composition

Landscape patch indicators may provide a measure of habitat quality. For example, a change in the extent and composition of natural habitat patches (i.e., vegetation condition) or a change in connectivity between habitat patches (i.e., vegetation patterns) may affect the probability of local extinction, loss of diversity of native species, and regional persistence of species (EPA 2002). Consequently, managing entire landscapes, not just individual habitat types, may be required to maintain native plant and animal diversity (Liu and Taylor 2002). To evaluate landscape condition we used two simple, basic indicators: patch count and mean patch size. Non-natural fragmentation on the landscape is evidenced by an increase in the number of patches of a given vegetation type coupled with a decrease in mean patch size.

Land Use/Land Cover

Land use and land cover are indications of the overall degree of disturbance of the landscape. Prevailing dominant land cover (e.g. grassland, deciduous forest) can be defined by site type (e.g. dry upland, floodplain) within a landscape (Nigh and Schroeder 2002, Nelson 2005). Land cover types that were not historically present on a given site type may indicate past or on-going disturbance. For example, grasslands or shrublands on site types that were historically forested often indicate past or on-going cultivation or mowing; evergreen juniper woodlands or shrublands on deciduous forest site types indicate past cultivation or the absence of the historical fire regime.

Biotic Condition

Biodiversity, defined as the variety and variability among living organisms and the environments in which they occur, is recognized at genetic, population, species, community, and ecosystem levels of biological organization (U.S. Congress 1987, Noss 1990). As a result, the SAB framework characterized biotic condition at various levels as measures of composition and structure that relate directly to functional integrity (EPA 2002). Because environmental factors and human activities affect taxonomic groups differently, each group provides a different view on ecosystem health or condition (Kirkpatrick and Brown 1994, Noss 2004, Diamond et al. 2005).

For this reason, a variety of attributes and indicators represented biotic composition. For the terrestrial environment, these included the breeding bird community composition, abundance of deer, rare species, invasive/exotic plant species, and composition of plant communities in terms of structure and species dominance. These elements are important indicators for unique reasons.

Bird species distribution and abundance are tightly linked to habitat type and workers have identified species of concern via analysis of datasets collected nationwide (Canterbury et al. 2000, see http://www.partnersinflight.org/). Management activities aimed at specific bird species or guilds impact entire ecosystems. Moreover, birds enjoy a tremendous following among the public (Peitz 2009).

White-tailed deer (*Odocoileus virginianus*) are viewed as a valuable park natural resource with considerable interest from visitors. Since European settlement, populations have fluctuated greatly. They are recognized as keystone herbivores that impact the composition and structure of ecosystems across the nation (Waller and Alverson 1997).

Rare species are most subject to possible extinction and are often among the most sensitive indicators of changes in environmental conditions and land management (Noss 1990). At WICR, the primary focus has been on the Missouri bladderpod (*Lesqurella filiformis*), a winter annual that is sensitive to increases in the density of woody species, especially eastern redcedar. At least two aquatic or semi-aquatic cave-associated species, the grotto salamander (*Typhlotriton spelaeus*) and bristly crayfish (*Cambarus setosus*), are also present and are sensitive to changes in water quality.

Invasive and exotic species are recognized as among the most significant threats to global biodiversity (see Mooney and Hobbs 2000). Finally, plant communities have been altered or eliminated across vast areas of the modern landscape, and dominant cover types and their structural characteristics explain recent disturbance history (Oliver and Larson 1996). Monitoring of structure and recruitment can also predict future composition (Collins 2000, Eyre 1980).

Fish community composition was a focus for assessment of lotic environments, because many species are considered intolerant of habitat alterations (Karr 1981, Robison and Buchanan 1988, Pflieger, 1997, Barbour et al. 1999) and their assemblages can serve as a useful tool to assess changes in water and habitat quality (Hoefs and Boyle 1990, Justus and Peterson 2005a, 2005b, Peitz 2005, Petersen and Justus 2005a, 2005b). Accordingly, the composition and abundance of fish populations historically have been used to assess the biological integrity of streams (Barbour et al. 1999; Moulton et al. 2002). Moreover, the intrinsic value of fish to the public as environmental indicators and as a recreational opportunity makes the status of fish diversity a valuable interpretive topic for parks.

Aquatic invertebrates are often used to detect changes in the integrity of aquatic ecosystems over time and can be used as a surrogate for water quality conditions (Bowles 2010). This indicator seeks to determine the condition of the aquatic macroinvertebrate community using seven common invertebrate metrics.

Chemical and Physical Characteristics

Water quality

Water temperature: Water temperature affects biological and chemical characteristics of streams (Binkley and Brown 1993). For example, temperature changes can shift the structure of aquatic communities (Karr and Schlosser 1978, Matthews 1987). Temperature increases can limit residence to those species able to tolerate increased temperatures (Karr and Schlosser 1978). Sowa and Rabeni (1995) found temperature to be an important factor determining the distribution and abundance of smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*) in Missouri and suggested that elevated stream temperatures would allow largemouth bass to replace resident smallmouth bass populations. Reduced temperatures in streams during the winter can cause severe metabolic stress on fish (Cunjak 1988), while extreme temperature fluctuations can lead to direct thermal shock of eggs and fry as well as cause changes in reproductive behavior (Shuter et al. 1980).

Specific conductance: Specific conductance (SC) is a measure of the ability of water to conduct an electrical current. Conductivity increases with an increasing amount and mobility of ions. These ions, the byproduct of the breakdown of larger compounds, conduct electricity because they are negatively or positively charged when dissolved in water. Therefore, SC is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution.

Dissolved oxygen: An adequate supply of dissolved oxygen (DO) is a basic requirement for healthy aquatic ecosystems. While some aquatic organisms are adapted to low oxygen conditions, most species require DO levels greater than 5 or 6 mg/L. Larval and juvenile fish often require even higher concentrations of dissolved oxygen. DO levels fluctuate in the water column under natural conditions, but severe depletion usually results from introduction of large quantities of biodegradable organic materials into surface waters or during prolonged periods of hot weather that reduce the oxygen retention capacity of water.

pH: The pH of water is the standard measure of the concentration of hydrogen ions. A pH value of 7 represents a neutral condition. A low pH value (less than 5) indicates acidic conditions; a high pH (greater than 9) indicates alkaline conditions. Acidic and alkaline waters may limit many biological processes, such as reproduction, in freshwater ecosystems. Acidic conditions may result in increased ability of toxics that are normally bound to sediments.

Turbidity/Suspended sediments: Sediment additions affect primary production through reduced light penetration and increased scour of periphyton from streambed substrates during periods of high flow (Alabaster and Lloyd 1982, Newcombe and MacDonald 1991). Reductions in primary production can lead to subsequent reductions in secondary production since many invertebrates, primarily grazers, depend on periphyton for food (Newcombe and MacDonald 1991). Sediment increases also degrade fish spawning areas, which may lead to behavioral changes in spawning, increased egg mortality, or decreased larval growth and development (Rabeni 1993). These direct effects on fish populations may eventually reduce fish diversity (Berkman and Rabeni 1987). Similar to temperature, species inhabiting Ozark streams are typically adapted to crystal clear waters with minimal suspended sediments, even during elevated discharges (Smale and Rabeni 1991). Watersheds contributing flow to WICR streams are vulnerable to increased sedimentation and runoff from land use activities including urban development, grazing, deforestation, riparian zone clearing in tributaries, and road building.

Air quality

Given that NPS air quality monitoring programs have shown that air pollutants are transported long distances and have been detected at all NPS monitoring sites (NPS 2002), we included ozone and atmospheric deposition as indicators in the NRCA. Air pollution affects natural and cultural resources throughout much of the park system through visibility reduction, biological and human health effects, and degradation of historic structures and artifacts. The NPS generally considers stable or improving air quality as signs of success, but also strives to comply with national air quality standards (NPS 2007a). See: (http://www.nature.nps.gov/air/permits/aris/networks/htln.cfm) for more information about air quality monitoring. Ozone, sulfur dioxide, and dry deposition are collected by the Clean Air Status and Trends (*CASTNet*) network. Ozone is also monitored with passive samplers and portable continuous analyzers. Wet Deposition is monitored through cooperation with National Atmospheric Deposition Program/National Trends Network (*NADP/NTN*).

Ozone: Ozone is a very widespread air pollutant in urban and rural areas that at high concentrations is harmful to human health and damaging to vegetation (NPS 2010a). Ozone affects plants through diffusion into leaf stomata (Hogsett and Anderson 1998) and may cause foliar injury and reduced growth in some sensitive plant species (NPS 2002). Ozone is formed in the atmosphere when pollutants, especially nitrogen oxides (NO_x) and volatile organic compounds (VOC_S), react with sunlight. Anthropogenic sources of NO_x and VOC_S are emitted from industrial facilities, electric utilities, vehicle exhaust, and chemical solvents. Human health effects associated with ozone include reduced lung function, irritated throat and airways, increased susceptibility to respiratory infection, and aggravation of lung diseases.

Atmospheric deposition: Atmospheric deposition refers to the process in which airborne chemicals, including pollutants, are deposited to the earth. Atmospheric deposition includes wet deposition in rain or snow, occult deposition in cloud or fog, and dry deposition from settling, impaction, and adsorption (NPS 2007b). Atmospheric deposition of sulfur and nitrogen compounds can cause significant ecosystem effects such as acidification or eutrophication of soil and water (NPS 2007a). Acidification of soils, lakes, and streams can result in changes in community structure, biodiversity, reproduction, and decomposition. Documented impacts in some parks include stressed trees, acidified streams, and reduction in species of fish and other aquatic life in affected waters (NPS 2002).

Although nitrogen is an essential plant nutrient, increased levels of atmospheric nitrogen deposition can stress ecosystems. Excess nitrogen acts as fertilizer, favoring some types of plants and leaving others at a competitive disadvantage. This creates an imbalance in natural ecosystems, and long–term effects of these changes may include shifts in types of plant and animal species, increase in insect and disease outbreaks, and disruption of ecosystem processes such as nutrient cycling, and changes in fire frequency. Wet deposition occurs when pollutants are deposited in combination with precipitation, predominantly by rain and snow, but also by clouds and fog.

Hydrology and Geomorphology

The hydrology and geomorphology of ecological systems reflect the dynamic interplay of water flow and landforms. In river systems, for example, water flow patterns and the physical interaction among a river, its riverbed, and the surrounding land determines whether a diverse array of natural habitats and native species are maintained. Characteristics included in this category include channel morphology and shoreline characteristics, channel complexity, distribution and extent of connected floodplain, and aquatic physical habitat complexity.

Water Flow

The timing, magnitude, and variability of surface and groundwater flows control the transport of nutrients, salts, contaminants, and sediments, while also determining the inundation period of aquatic and wetland habitats. Water flow and sediment movement controls structural characteristics in streambeds, banks, and riparian wetlands. Native species have adapted accordingly; for example, many anadromous fish require clean gravels for spawning, and invertebrates choose particular particle sizes for attachment or burrowing. Disturbances in stream flow (i.e., severe fluctuations in flow resulting from floods, drought, or hydrological alteration) are important abiotic factors structuring fish and invertebrate communities (Starrett 1951, Schlosser 1985, Coon 1987, Bain et al. 1988, Resh et al. 1988, Schlosser and Ebel 1989, Schlosser 1990, Poff et al. 1997).

Natural Disturbance Regime

All ecological systems are dynamic, due in part to discrete and recurrent disturbances that may be physical, chemical, or biological in nature. Examples of natural disturbances include wind and ice storms, wildfires, floods, drought, insect outbreaks, microbial or disease epidemics, invasions of nonnative species, volcanic eruptions, earthquakes and avalanches. The frequency, intensity, extent, and duration of the events taken together are referred to as the “disturbance regime.”

Wildland fire is a natural disturbance process that has great potential to change park landscapes. Many plants and animals cannot survive without the cycles of fire to which they are adapted. National Park Service policy stresses managing rather than simply suppressing fire, which requires planning for its eventuality and promoting the use of fire as a land management tool. Natural fires have been all but eliminated from WICR and surrounding areas, even though most ecologists assert that burning promoted dominance of fire-tolerant species and kept pre-European glades, grasslands, and savannas more open than second growth woodlands in the modern landscape.

Chapter 4 Study Methods

In this chapter we describe the specific methods, data sets, and information resources used to evaluate individual attributes and indicators. Appendix C provides a summary of references for current condition and target condition for each attribute/indicator.

Landscape Condition

Landscape Composition and Land Use/Land Cover

A fine-resolution current vegetation map formed the basis for calculation of landscape condition metrics such as patch count and mean patch size, which are associated with landscape composition, and area of natural or semi-natural, successional, and cultural types. These variables were summarized by reporting unit, including park-wide, bottomland forest, glade, upland grassland, and upland woodland.

The current vegetation classification was produced by considering land cover and ecological site type. Land cover was coded by hand on-screen to 6 m resolution image objects generated using e-Cognition software from merged leaf-on and leaf-off air photos (Table 4-1, Figure 4-1). Abiotic site type was defined by merging similar ecological land types, which in turn were generated from digital county soil survey map unit polygons. In addition, we identified steep slopes (>20%) using 10 m resolution digital elevation models. Finally, current vegetation was assigned to each combination of land cover and abiotic site type (Figure 4-2).

Table 4-4. Land cover classes assigned to image objects for Wilson's Creek National Battlefield.

Land Cover Classes
Impervious
Low Intensity Urban
Barren or Sparsely Vegetated
Cropland
Grassland
Deciduous Forest
Evergreen Forest
Mixed Forest
Deciduous Woody/Herbaceous
Evergreen Woody/Herbaceous
Mixed Woody/Herbaceous
Open Water

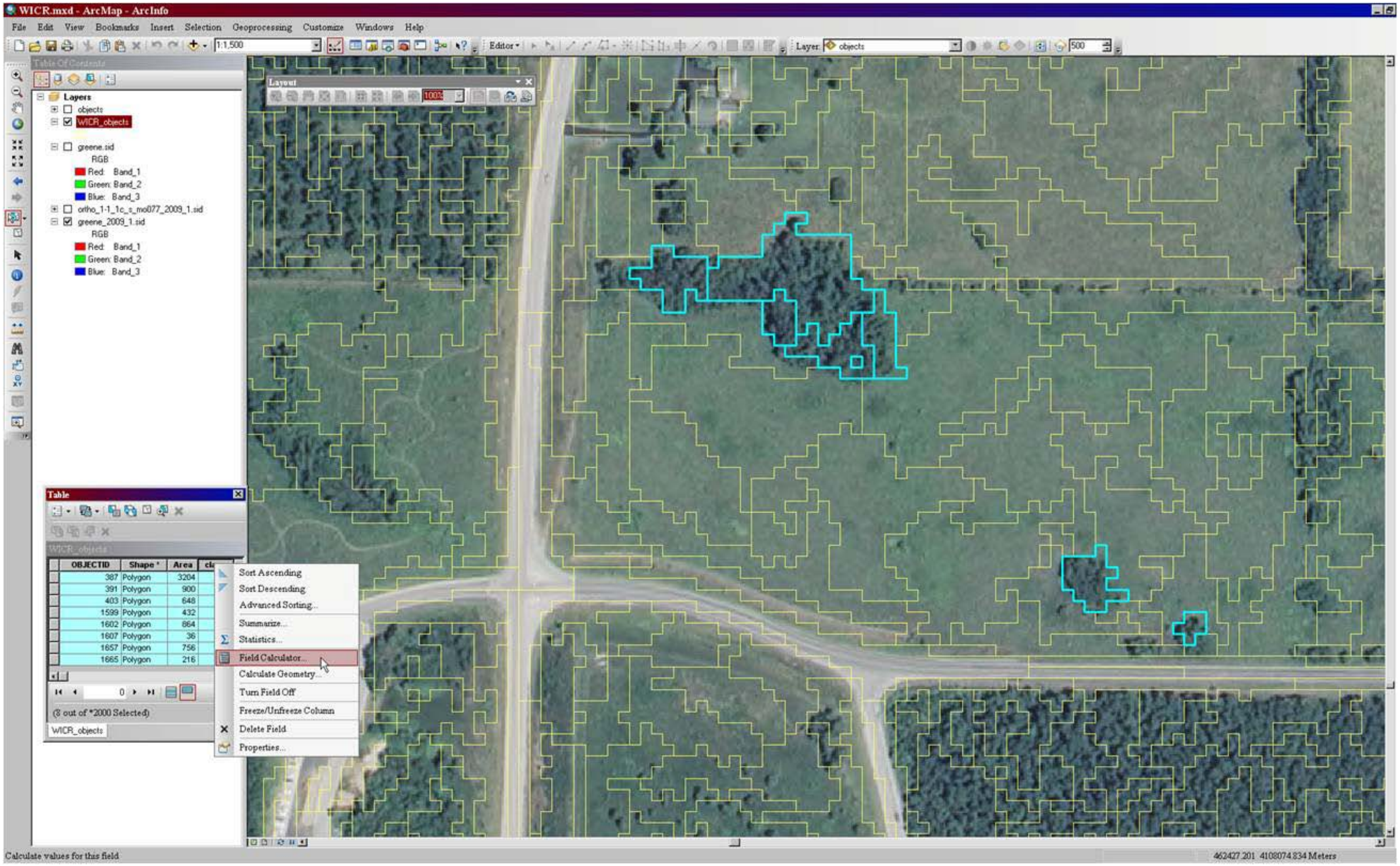

Figure 4-9. Process for assigning land cover classification to 6 m resolution image objects on-screen.

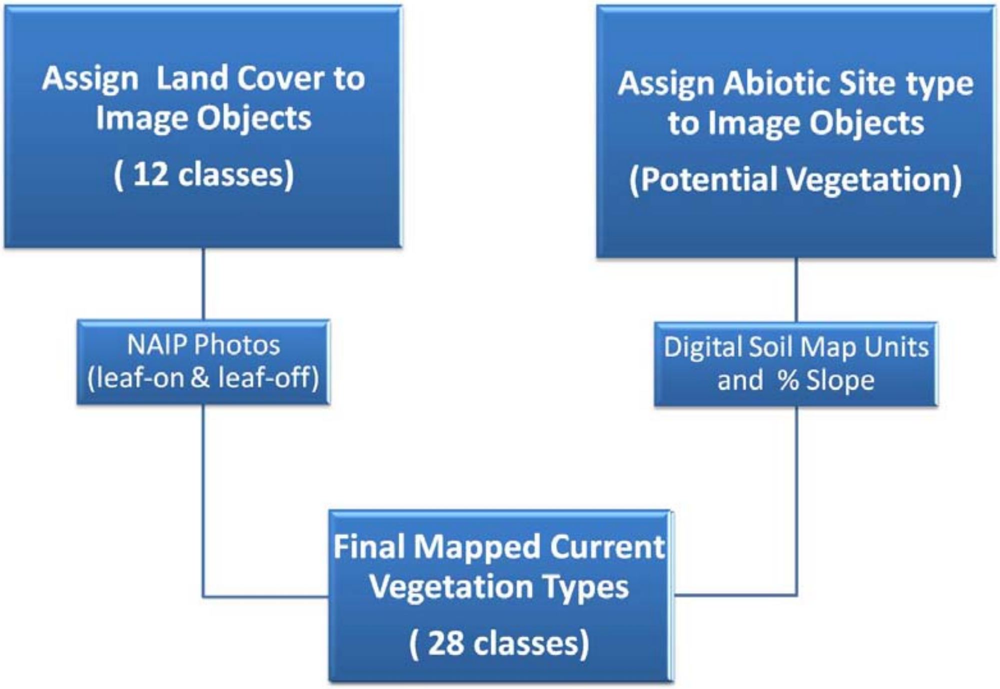

Figure 4-10. Current vegetation was assigned to image objects based on ecological site type (site potential) and current land cover.

Biotic Condition

Bird Community Composition

Breeding birds are monitored at WICR to track changes in bird community composition and abundance, and their response to changes in habitat structure and other habitat variables related to management activities. The initial breeding bird survey was done at WICR in May of 2008 (Peitz 2009). Breeding birds and their habitat were sampled at 36 permanent sites arranged in a systematic grid of 400 X 400 m. Variable circular plot methodology was used, wherein all birds seen or heard at plots during 5-min sampling periods were recorded along with their corresponding distance from the observer (Peitz et al. 2008). Birds were recorded during a period when it was light enough to observe birds to four hours after sunrise for a total of approximately 12 hours over the three days of surveys.

Quantitative bird habitat data were collected following Peitz (2008) at each listening station. Habitat data include abiotic measures (e.g. slope and aspect) and biotic measures (e.g. vegetation structure, foliar cover of six plant guilds, horizontal vegetation cover, and ground cover). We used Partners in Flight (1991) to identified species of continental importance. We used the initial survey as a baseline with the management goal of retaining the current number of species, particularly grassland obligates and species of continental importance.

White-tailed Deer

Populations of white-tailed deer are monitored each year during the winter at WIRC using spotlight surveys from the 7.90 km tour road (Peitz et al. 2007). Surveys are conducted using two 1,000,000 candlepower spotlights from a vehicle moving no more than 16 km/hr. All deer seen along the survey route are counted and their location recorded using GPS. Deer counts are made by two observers, one seated on the left and the other on the right side of the vehicle. Distances from the stopped survey vehicle to all deer are determined by a rangefinder or, for deer < 20 m from the vehicle, by visual estimates. Deer are usually observed in groups, in which case distance is taken or estimated to the center most deer in the group. In order to map locations of deer, the direction and angle of all deer or deer groups from the survey vehicle are recorded as well.

Weather permitting, deer counts are made once a week for six consecutive weeks beginning in January. Three replicate counts are made during each evening of the survey. The maximum evening count among the three replicates is averaged across sample evenings to calculate an index of relative deer density. Counting deer along the road corridor yields an index of relative deer abundance, which is correlated with the absolute abundance of deer on the battlefield. The ecological carrying capacity for deer is considered to be 8 individuals/km^2.

Rare Species: Missouri Bladderpod (Lesquerella filiformis)

The Missouri bladderpod is listed as a threatened plant under the Endangered Species Act. Monitoring of the Missouri bladderpod at seven glades or glade-like sites at WICR is on-going and consists of annual estimated counts of individual plants,(Young et al. 2006, 2008, 2009). The number of plants within a grid of 5 X 5 meter plots or 15 X 15 meter plots is estimated using density classes: 0 = no plants, 1 = 1-9 plants, 2 = 1-49 plants, 3 = 50-99 plants, 4 = 100-499 plants, 5 = 500-999 plants, and 6 = >1000 plants. Up to six workers, working independently, make visual estimates. Workers calibrate estimates against complete counts for the population in Bloody Hill Glade.Monitoring is conducted between mid-April and early Mayduring peak flowering.

Invasive Exotic Plants

The Heartland Network Inventory and Monitoring Program tracks invasive species in a systematic way at WICR. During surveys, observers search for plants designated as invasive and included on either the early-detection or park-established watch list These lists include plant species that may colonize tha park and plants that have colonized the park, respectively. Observers survey 173 transects which are 200 m long, unless intersected by the park boundary, and 3 to 12 m wide. (Presence of target species was noted and cover estimated by cover class using a cover-class scale: =0, 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, 7= >1000m^2

Plant Community Structure and Composition

Three plant communities are tracked by the HTLN at WICR, including glades, upland oak/hickory woodlands, and tallgrass prairie/savanna restoration types. These communities are sampled using a set of ten nested circular plots along two, 50 m parallel lines that are 20 m apart. Five sets of nested circular plots are located along each of the two lines, or ten sets of nested plots. Four plot sizes, 10 square meters, 1 square meter, 0.1 square meter, and 0.01 square meter, are sampled. Data collected vary by plot size, and summary statistics on species richness and diversity, the ratio of exotics to native species, species abundance and frequency, woody species density and basal area, overstory canopy cover, and ground cover are calculated (James et al. 2009).

In addition, plant communities have been sampled in conjunction with breeding bird surveys at 35, 50-meter radius plots (Peitz et al. 2008; see Bird Community Composition, above). Overall habitat type (e.g. woodland, shrub, field/prairie, etc.) was estimated by cover class within the plot. Within 5 meter subplots, canopy cover, height, and basal area were estimated by life form (e.g. hardwood, conifer), as was vegetation density at different height intervals and stems per hectare of trees by family. Finally, ground and foliar cover (<1.5 m tall) was estimated within 10 meter square sample plots by plant guild, including warm- and cool-season grasses, forbs, moss and lichens, shrubs and vines, tree seedlings, and total foliar cover.

Management targets for vegetation composition such as canopy cover, basal area, and density were taken from literature on similar communities (see references by reporting unit, Chapter 5). These values generally represent a fairly wide range, since natural communities are quite variable over time and space based both on disturbance regimes and abiotic site type.

Fish Community Composition

For aquatic ecosystems fish data are often the most readily available source of aquatic community data. This indicator seeks to examine the condition of the fish community by using five common indicators of fish community condition and by comparing an observed community to a modeled baseline community within WICR. These comparisons give a measure of "fish faunal intactness" using a taxon with a relatively long historical record.

Actual fish collection data for Wilson's Creek within the WICR boundary was acquired from several sources for different years. Collections made via seining in January and February 1984 came from Donegan (1984); collections via electrofishing and seining made in October 1988 and July 1989 were from Hoefs and Boyle (1990); electrofishing collections from July 2003 were from Petersen and Justus (2005b) (Figure 4-3); and more recent collections from May 2007 via electrofishing were from unpublished Heartland Network data (Figure 4-4). Data for Skegg's Branch within the WICR boundary came from two sources including both the Petersen and Justus (2005b) and unpublished 2007 Heartland Network described above. The only collection data available for Terrell Creek within WICR was the unpublished 2007 Heartland Network data.

We developed current conditions from Dodd (unpublished data). Five metrics were used to assess the current condition for the three watershed based reporting units (Wilson's Creek, Skegg's Branch, and Terrell Creek). These included a fish Index of Biotic Integrity (IBI), Simpson's Diversity Index, and the composition of sucker, sunfish, and benthic (darters, sculpins, madtoms) species. The IBI was used to give an overall rating of the stream quality based on characteristics (i.e. metrics) of the fish community. The Simpson's Index uses species richness and abundance to estimate the diversity of the fish community and decreases with increasing diversity (0 = completely diverse; 1 = no diversity). The percentage of sucker and sunfish were used to assess the streams because similar metrics are used in the IBI as well as other warm water IBIs in the Midwest (Karr 1981, Fausch et al. 1984, Karr et al. 1986) and can be used to make comparisons with adjacent warm water streams. It should be noted that for the analyses in this report the sunfish composition was computed by excluding bluegill and green sunfish (very tolerant species). Benthic species (darters, sculpins, and madtoms) represent species that are intolerant to human disturbance and are therefore a good indicator of stream health.

Because there is limited information published on fish communities in watersheds close to WICR, we used the mean from data collected in 2006 and 2007 as the management target. The reference condition used for the sucker, sunfish, and benthic species metrics was generally computed using the mean plus one standard deviation. The reference condition for the Simpson's Diversity Index was computed using the mean from 2006 and 2007 minus one standard deviation because this index has an inverse relationship with diversity. The fish index of biotic integrity including the management target and reference condition was developed for the Ozark Highlands by Dauwalter et al. (2003).

We also used fish species models developed for the Missouri Aquatic Gap Project to predict expected fish community composition in WICR streams. The Aquatic Gap predictive models for fish were developed using 3,723 community samples across Missouri ranging in date from 1900 through 1999. These species collections were joined to stream segments with information about stream size, gradient, temperature, and flow regime. Each fish species was modeled individually. The actual models were constructed using decision tree analysis and the final results were applied to individual stream segments meeting the model parameters within the range of each species. A final 'hyperdistribution' database file was created by combining all the individual models into a single file. This database provides a list of all fish predicted to occur in each stream segment across Missouri. Counting the number of fish predicted to occur in each stream segment allows the creation of richness maps. The models assumed that most of the species predicted to occur at a site could be collected if sampling took place during multiple seasons over multiple years on relatively undisturbed sites (Sowa et al. 2005). If sampling is more limited than this or the ecosystem is impaired a smaller percentage of the predicted species would be expected to be found. This data was used to establish baseline conditions inside of WICR.

Ideally, the present day fish community would be compared to the community that existed before degradation or to the community in a comparable reference stream. Lacking this information we compared the present day community to our modeled baseline. The Jaccard Index of Similarity is one method for comparing the community composition between two datasets. The Jaccard Similarity Index is computed by dividing the intersection, or overlap, of two datasets by the union of the same two data sets and then multiplying the result by 100 to give a percentage of faunal similarity. Two data sets are considered more similar as Jaccard Similarity values approach 100%. We compared data collected in 1984-1989 and 2003 – 2007 to Missouri Aquatic Gap Project fish species models which served as a baseline with which to compare.

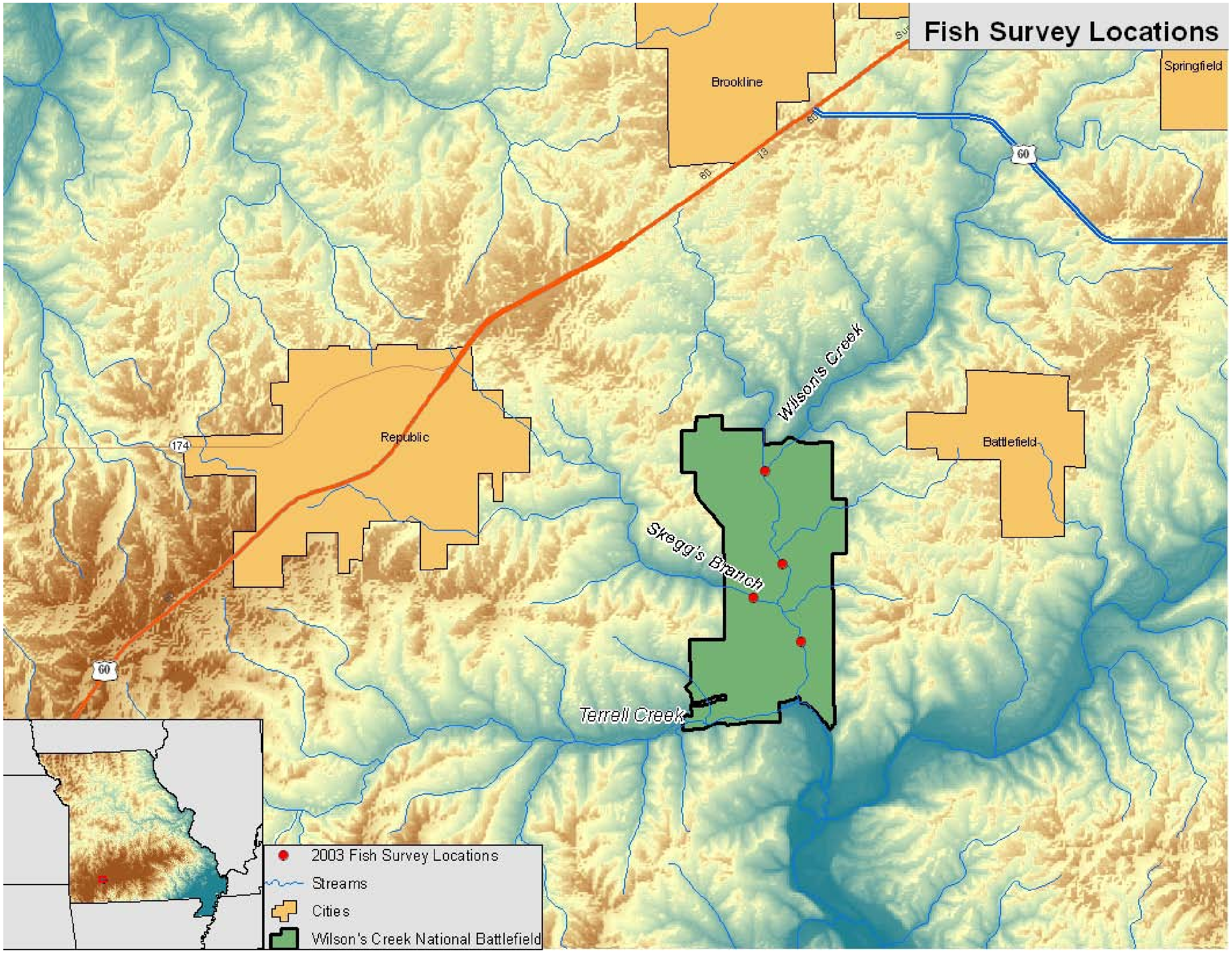

Figure 4-11. Fish survey locations during 2003 for Wilson's Creek and Skegg's Branch (Peterson and Justus 2005b).

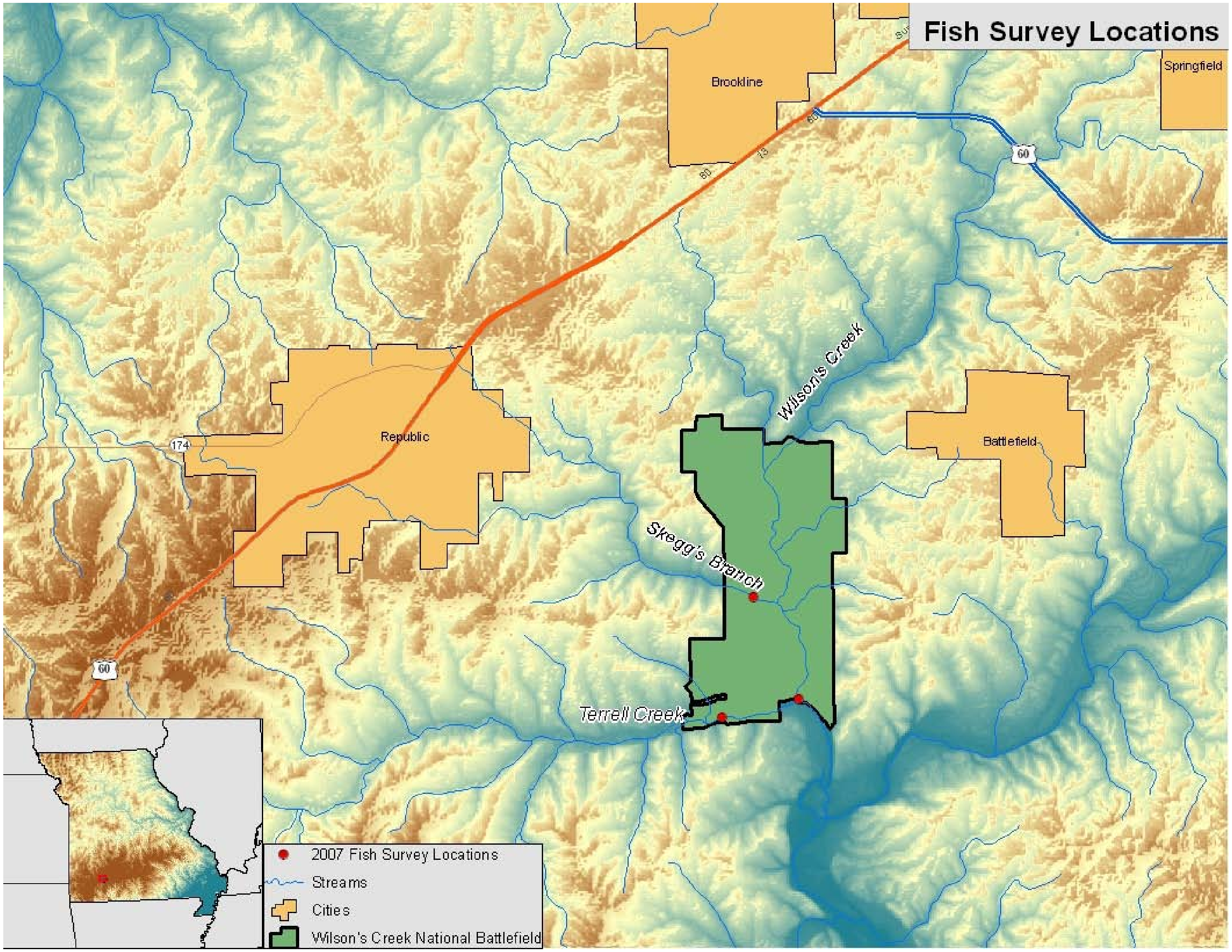

Figure 4-12. Fish survey locations for Wilson's Creek, Skegg's Branch, and Terrell Creek during 2007.

Aquatic Invertebrate Community
All aquatic invertebrate collection data for streams within WICR were acquired using a Surber stream bottom sampler. For Wilson's Creek and Skegg's branch data were available from 1988-2007. Collections made in 1988-2004 consisted of five replicate samples conducted at three monitoring sites (two in Wilson's Creek and one in Skegg's Branch). Collections made in 2005-2007 consisted of sampling three successive riffles with three benthic invertebrate samples collected at each riffle which resulted in a total of nine samples per stream (Figure 4-5; Bowles 2010). Terrell Creek had data available for 2006 and 2007. The Terrell Creek data also consisted of sampling three successive riffles with three benthic invertebrate samples collected at each riffle which resulted in a total of nine samples per stream.

Seven metrics were used to assess the current condition and establish reference conditions for the three watersheds based assessment units (Wilson's Creek, Skegg's Branch, and Terrell Creek). These included Family Richness, Taxa (genus) Richness, EPT Richness, EPT Ratio, Shannon Index (Genus), Shannon Evenness Index, and the Hilsenhoff Biotic Index. The management target and reference conditions were derived from Rabeni at al. (1997).

- Family Richness and Genus Richness reflect the health of the community through a measure of the number of families or genera present. Generally, the total number increases with improving water quality and habitat conditions.

- EPT Richness is the total number of Ephemeroptera/Plecoptera/Trichoptera taxa present. EPT richness generally declines as the aquatic community is degraded.

- EPT Ratio or EPC/C ratio is the total number of Ephemeroptera/Plecoptera/Trichoptera individuals divided by the total number of Chironomidae individuals. Good water quality is generally represented with EPT ratios greater than 0.75.

- Shannon Index (Genus) takes into account both richness and evenness. The Shannon Index decreases with increasing impairment.

- The Shannon Evenness Index is lower if a stream may have been subjected to disturbance and is populated by fewer, pollution tolerant genera. As values approach 1 the observed diversity approaches perfect evenness.

- Hilsenhoff Biotic Index (HBI) uses tolerance values to weight abundance for an estimate of pollution. The HBI increases with increasing pollution.

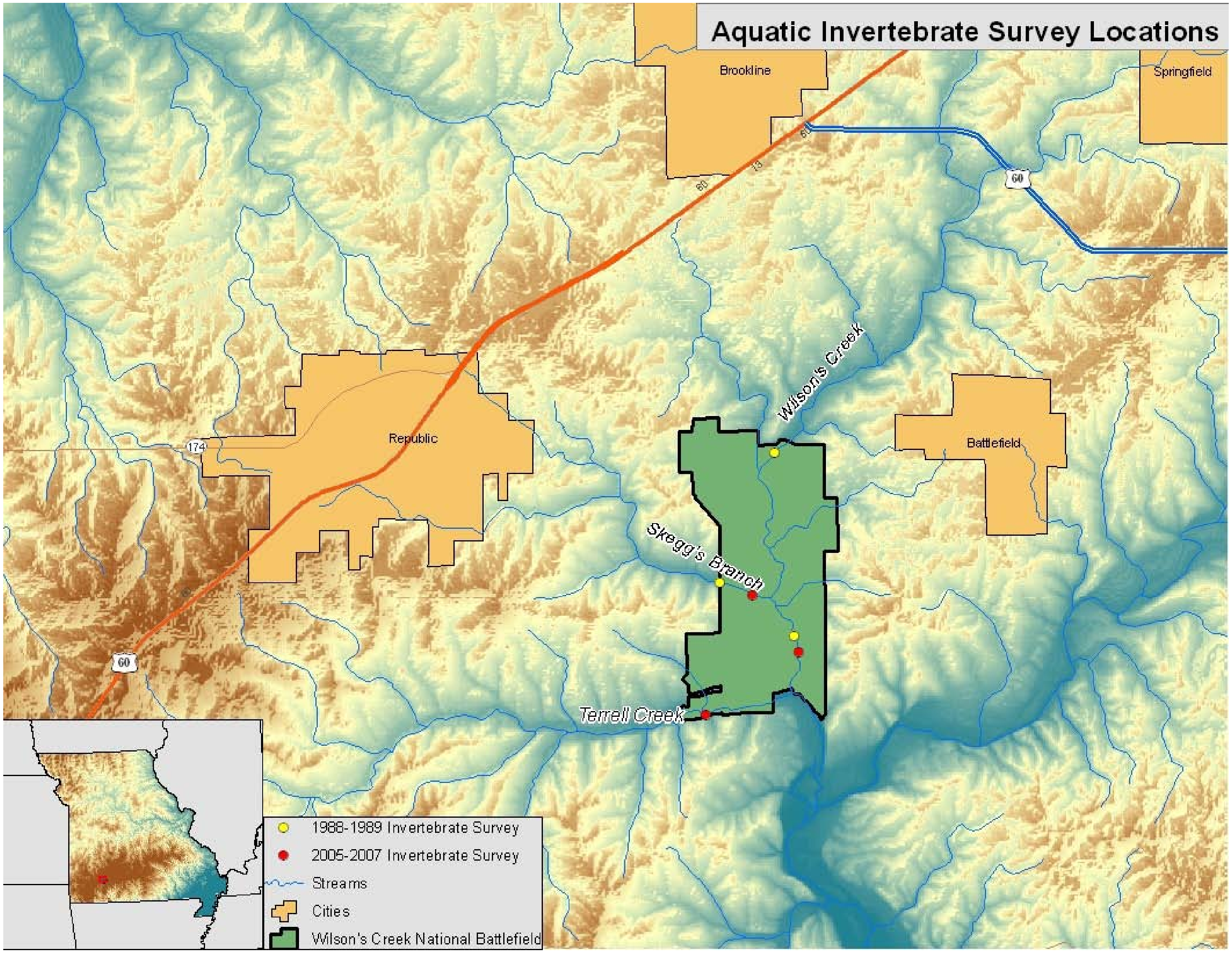

Figure 4-13. Invertebrate survey locations for Wilson's Creek, Skegg's Branch, and Terrell Creek during 1988-1989 (Harris et al. 1991) and 2005-2007 (Bowles 2010).

Chemical and Physical Characteristics

Water Quality

Temperature, Specific Conductance, Dissolved Oxygen, pH, and Turbidity,:
Data for water quality were available and reported on for temperature, specific conductance, dissolved oxygen, pH, and turbidity. Additional information is reported from a variety of literature sources.

The analytical data presented in this report were collected from several different time periods by various sources. Data from 1979 and 1999-2006 were acquired from the USGS gauging station 07052160 (Wilson's Creek near Battlefield). Data from 1989 were taken from Harris et al. (1991). Data from 2005-2007 was from Bowles (2010). When two datasets had overlapping years (i.e. 2005 and 2006) the data presented are the average from the two sources. It should be noted that Bowles (2010) points out that the data from 2005-2007 should not be used as an analytical tool. NPS established management targets based on Brown and Czarnecki (undated).

Air Quality

Air quality is an important environmental issue facing most National Parks. Data collected through the NPS air quality programs show that park units are not islands isolated from urban, agricultural, and industrial pollutants. Manmade and natural air pollutants are transported long distances and have been detected at all NPS monitoring sites (NPS 2002). Air pollution affects natural and cultural resources throughout much of the park system through visibility reduction, biological and human health effects, and degradation of historic structures and artifacts.

The National Park Service is interested in achieving the best possible air quality in its parks because air quality impacts ecological health, scenic views, human health, and visitor enjoyment. The NPS generally considers stable or improving air quality as signs of success, but also strives to comply with national air quality standards with the ultimate goal clean clear air in national parks (NPS 2007a). It is important to note that stable trends are not necessarily indicative of good air quality if an area is already experiencing poor quality air.

Ozone
We used data from NPS's Air Resources Division available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm. These ozone values represent estimates for WICR based on interpolations calculated as a 5-year average concentration. Ozone concentrations were measured as the 4^{th} highest 8-hour average and expressed as parts per billion (ppb), which allowed comparison to the ozone standard of 75 ppb established by EPA in March 2008. A rating of poor was assigned to concentrations greater than or equal to the standard ($\geq$ 76 ppb). A fair rating was assigned to concentrations greater than 80% of the standard (61 to 75 ppb). A good rating was assigned to concentrations less than 80% of the standard (less than or equal to 60 ppb).

Wet Deposition
We used data from NPS's Air Resources Division available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm. Deposition estimates represent

estimates for WICR based on interpolations calculated as a 5-year average concentration. We established a condition rating using thresholds for N (total inorganic nitrogen from ammonium and nitrate ions in wet deposition) and S (total sulfur from sulfate ions in wet deposition) as described by NPS. Estimates for natural background wet deposition rates for either N or S are 0.13 kg/ha/yr in the Western United States and 0.25 kg/ha/yr in the Eastern United States (NPS 2007a). Nutrient sensitive ecosystems respond to wet deposition levels of approximately 1.5 kg/ha/yr (NPS cites Fenn et al. 2003, Krupa 2003). NPS (2007a) reports that wet deposition amounts of less than 1 kg/ha/yr do not cause ecosystem harm. As a result, we assigned a rating of good for wet deposition rates less than 1 kg/ha/yr; a rating of fair for wet deposition rates of from 1 to 3 kg/ha/yr; and a rating of poor wet deposition rates greater than 3 kg/ha/yr (Table 4-2).

Table 4-5. Condition rating for wet deposition of either N or S. Source: (NPS 2007a).

Deposition Condition	Wet Deposition (kg/ha/yr)
Poor	> 3
Fair	1-3
Good	< 1

Dry Deposition

We used data from NPS's Air Resources Division available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm. Deposition estimates represent estimates for WICR based on interpolations calculated as a 5-year average concentration. We plotted combined wet and dry deposition of nitrogen and sulfur through time over the available period of record. We did not provide condition ratings for dry deposition.

Hydrology and Geomorphology

Surface Water Flow

The hydrology and geomorphology of ecological systems reflect the dynamic interplay of water flow and landforms. In river systems, for example, water flow patterns and the physical interaction among a river, its riverbed, and the surrounding land determine whether a naturally diverse array of habitats and native species are maintained.

Surface and groundwater flows determine which habitats are wet or dry, and water flow transports nutrients, salts, contaminants, and sediments. It is less widely recognized, however, that the variability of water flows (in addition to their timing and magnitude) exerts a controlling influence on the creation and succession of habitat conditions.

The monitoring station at Wilson Creek near Battlefield, Missouri (07052160) was the only relevant station available for WICR (Figure 4-6). Discharge, measured as cubic feet per second (cfs), was collected and summarized using USGS's National Hydrology Assessment Tool Software (NATHAT). The monthly discharge means (cfs) were graphed in Microsoft Excel as monthly averages. Peak flow data were also obtained from the USGS for the monitoring station, so that time period analyses could be conducted using NATHAT. Ten hydrologic indices were computed and then compared and normalized for the different time periods against the period of record (POR) (Table 4-3). Stream flow data were analyzed in NATHAT for 1969-1970, 1973-1982, and 2000-2004. These three time periods were rated based on their deviation from the baseline of the POR. To determine the rating categories, the data were normalized for every index at each monitoring station and the most recent time period was compared to the period of record. Ratings were based on deviation 1.0, either higher or lower. Thus, if an index from the most recent time period fell within 0.25 of 1.0, the rating was Good; >.25 but <.75 was Fair, and >.75 was Poor.

Table 4-6. List of hydrological indices evaluated for a water monitoring station in Wilson's Creek National Battlefield.

Index Variables	Definition
MA1	Mean daily flow (cfs) for the period of record
ML8	Mean minimum flow (cfs) for August
MH5	Mean maximum flows (cfs) for May
FL1	Low flood pulse count (#)
FH4	High flood pulse count (#)
DL3	Annual minimum of 7-day moving average flow (cfs)
DH3	Annual maximum of 7-day moving average flow (cfs)
TL1	Julian date of annual minimum
TH1	Julian date of annual maximum
RA3	Fall rate (cfs/day)

Natural Disturbance Regime

Fire Regime

Fire was the primary natural disturbance impacting the natural communities at WICR. We inferred historic fire return intervals by reporting unit (major community type) by referring to state and transition models for similar communities prepared for the LandFire project (see http://www.landfire.gov/NationalProductDescriptions13.php).

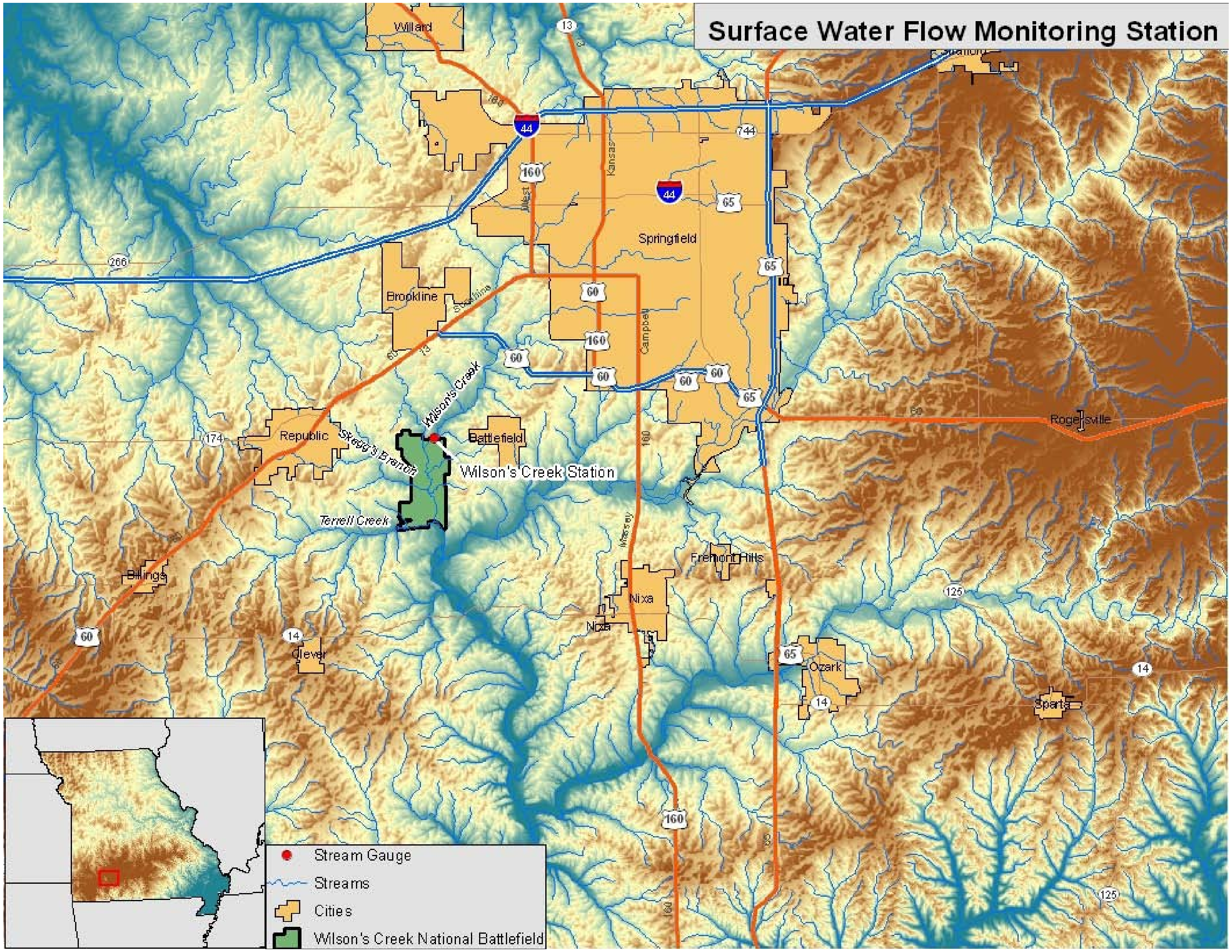

Figure 4-14. Surface water monitoring station (Wilson’s Creek near Battlefield – 07052160) on Wilson's Creek used to assess water flow in Wilson's Creek National Battlefield.

Chapter 5 Natural Resource Conditions

Reporting Units

The assessments for breeding birds, white-tailed deer, invasive exotic plants, and air quality were park-wide. For terrestrial communities, we developed reporting units based on potential vegetation and on current condition (Figure 5-1). These included bottomland forest, glade, upland grassland, and upland woodland reporting units. Potential vegetation for each terrestrial community was based on pre-european communities that were primarily associated with the reporting unit type (see Appendix D. for community descriptions). Cultural areas, including buildings, grounds, interpretive crop fields, and cemeteries were also identified and were not included for further condition assessment. Because stream character and condition can vary dramatically with drainage area (Vannote et al. 1980), we developed reporting units for Wilson's Creek, Skegg's Branch, and Terrell Creek (Figure 5-2).

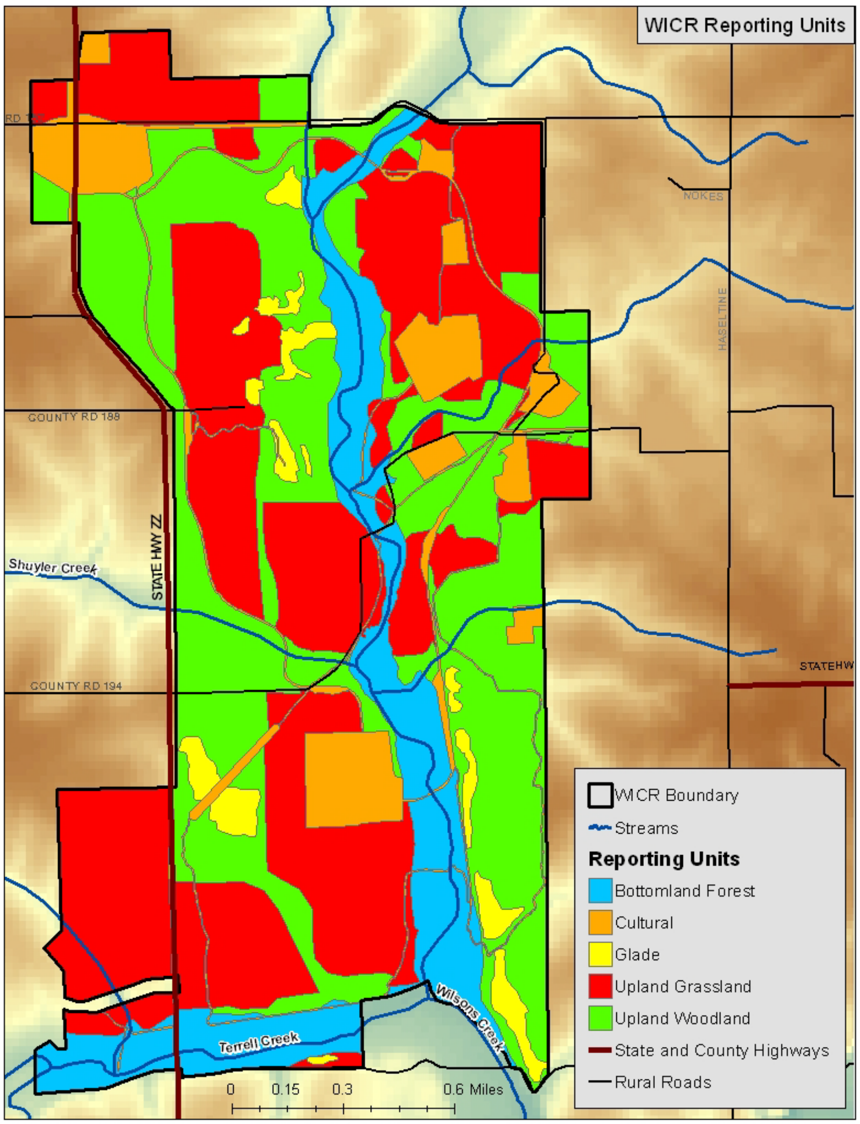

Figure 5-15. Terrestrial reporting units for Wilson's Creek National Battlefield were based on both current vegetation patterns and ecological site type (site potential).

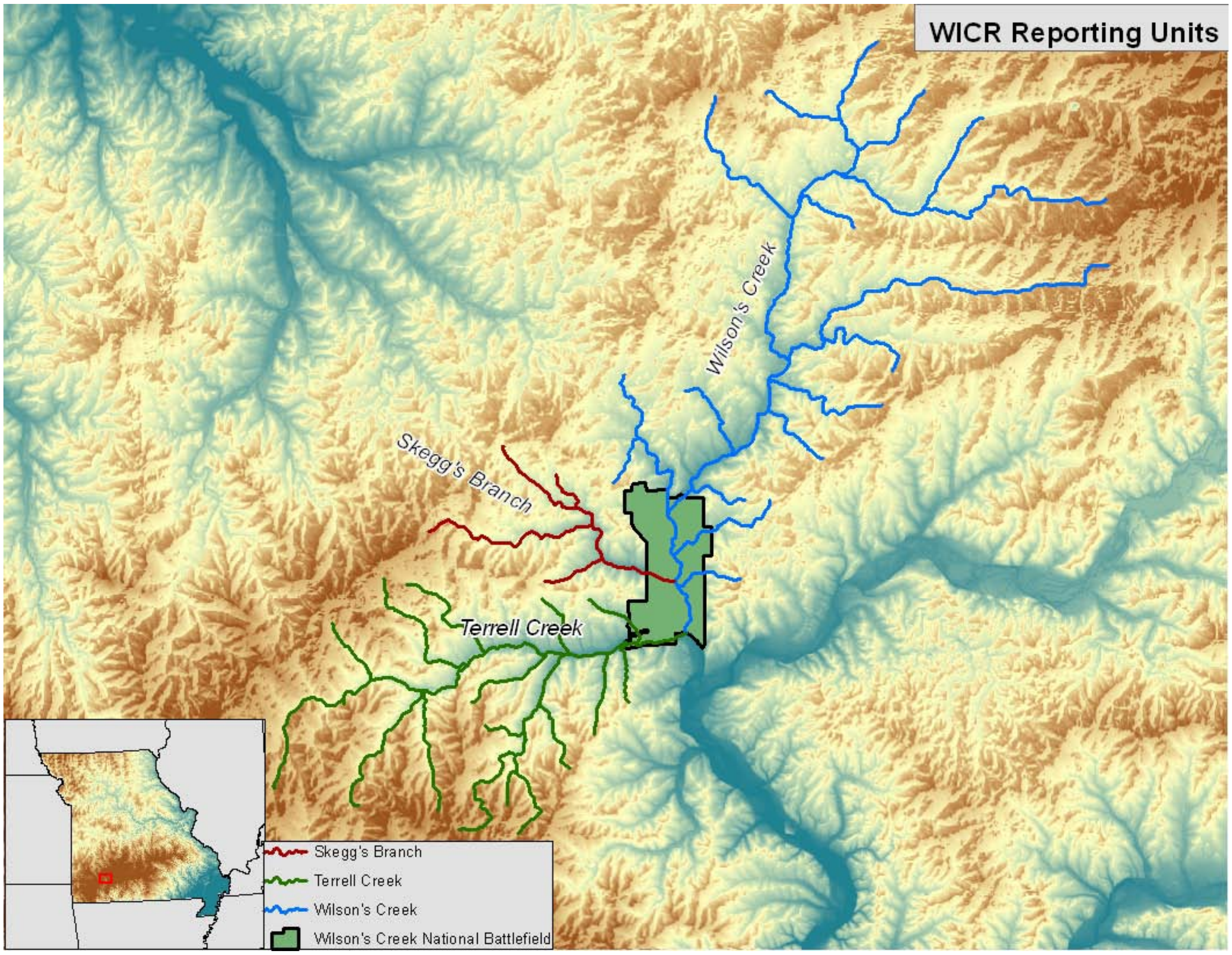

Figure 5-16. Map of stream reporting units within Wilson's Creek National Battlefield.

Condition Summaries by Reporting Units

In chapters 3 and 4, we organized the discussion of indicators and attributes used to characterize natural resources by the EPA assessment framework. In chapter five, we report the condition of natural resources by reporting unit, with a focus on indicators. Reporting units typically encompass multiple natural resources (i.e., resource types) and their related attributes/indicators. A resource type may occur in one or many reporting units, and management targets may differ for the same resource type in different reporting units (Table 5-1, Figure 5-1, Figure 5-2).

Table 5-7. Summary of natural resource condition indicators for Wilson's Creek National Battlefield. Current conditions are based on contemporary data, and management targets are based on a variety of sources, including expert judgment (see text). Indicators are presented within park reporting units (Figure 5-1, Figure 5-2) and relate to resource types and/or ecological attributes.

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
Park-wide						
	Vegetation					
		Landscape composition				
			patch count	1125 - 750	1819	2010
			mean patch size (ha)	> 1	0.4	2010
		Land use/Land cover				
			semi-natural and natural types (ha)	> 750	425	2010
			successional types (ha)	< 50	336	2010
			cultural types (ha)	≤ 40	38	2010
	Breeding bird community					
			species richness	≥ 47	47	2008
			Partners in Flight target species	≥ 10	10	2008
			number of grassland obligate species	≥ 2	2	2008
	White-tailed deer					
			index of relative abundance (individuals/km^2)	< 8	56.6	2010
	Invasive exotic plant impact					
			number of taxa	< 30	35	2006
			frequency on transects (%)	< 50	91.9	2006
			park-wide minimum cover estimate (%)	< 10	15.4	2006
	Air quality					
		Ozone				
			ozone (ppb)	≤ 60	72.2	2004 - 2008
		Atmospheric deposition				
			nitrogen (kg/ha)	< 1	12.6	2004 - 2008
			sulfur (kg/ha)	< 1	10.7	2004 - 2008
Bottomland forest						
		Landscape composition				
			patch count for forest	53 - 35	75	2010
			mean patch size for forest (ha)	> 2	0.7	2010
		Land use/Land cover				
			bottomland forest (ha)	> 90	54	2010
			successional types (ha)	< 19	59	2010

Table 5.1. Continued

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
Glade						
		Landscape composition				
			patch count for all glade types	75 - 50	79	2010
			mean patch size glade types (ha)	> 0.25	0.14	2010
		Land use/Land cover				
			glade types (ha)	> 15	10	2010
			successional types (ha)	< 10	15	2010
	Missouri Bladderpod					
		Abundance				
			Bloody Hill population size (3 yr average, count)	> 71847	5934	2010
			Wire Road population size (3 yr average, count)	> 48791	592	2010
			Terrell Creek population size (3 yr average, count)	> 14	5	2010
			Walnut Glade population size (3 yr average, count)	> 848	343	2010
			North Bloody Hill glade population size (3 yr average, count)	> 1009	128	2010
			Manley Woods glade (3 yr average, count)	> 617	252	2010
Upland grassland						
		Landscape composition				
			patch count for grassland	60 - 40	80	2010
			mean patch size for grassland (ha)	> 10	3.4	2010
		Land use/Land cover				
			restored prairie (ha)	> 250	145	2010
			successional types (ha)	< 55	161	2010
		Herbaceous guild composition				
			native grass (%)	> 60	54.4	2008
			native forbs (%)	10 - 40	27.8	2008
			native woody shrub and vine (%)	< 10	37	2008
Upland woodland						
		Landscape composition				
			patch count for woodland	188 - 125	275	2010
			mean patch size for woodland (ha)	> 2	0.8	2010
		Land use/Land cover				
			natural and semi-natural woodland (ha)	> 250	192	2010
			successional types (ha)	< 33	91	2010
		Structural class				

Table 5.1. Continued

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
			hardwood canopy cover (%)	45 - 80	72	2008
			hardwood basal area (m^2/ha)	14 - 23	15	2008
			density (stems/ha, trees > 8 cm dbh)	125 - 600	149	2008
		Cover type				
			oak species basal area (m^2/ha)	9 - 18.2	4.3	2008
			hickory and walnut species basal area (m^2/ha)	2.1 - 8	3.6	2008
		Regeneration				
			cover type small saplings (>1.5 m tall, < 2.5 cm dbh) relative density (% of stems/ha)	> 50	37	2008
			cover type large saplings (>1.5 m tall; > 2.5 and < 8 cm dbh) relative density (% of stems/ha)	> 50	19.4	2008
			total cover type sapling relative density (% of stems/ha)	> 50	21.2	2008
		Herbaceous guild composition				
			native grass (%)	10 - 80	15.4	2008
			native forbs (%)	1 - 40	15	2008
			native woody shrub (%)	15 - 50	21	2008
		Structure				
			hardwood tree height (m)	13 - 21.3	13.5	2008
Wilson's Creek						
	Water quality					
			temperature (°C)	0 - 34	18.5	2007
			specific conductance (µS/cm)	100 - 400	643.0	2007
			dissolved oxygen (mg/L)	5 - 15	9.2	2006
			pH	6.5 - 9.0	7.8	2006
			turbidity (NTU)	< 10	4.2	2007
	Surface Water Flow					
			mean daily flow (cfs) for the period of record	68.1 - 113.6	91.4	2000-2004
			mean min flow (cfs) for August	25.2 - 42.1	45	2000-2004
			mean max flows (cfs) for May	450.1 - 750	716.2	2000-2004
			low flood pulse count (#)	9.1 - 15.1	15	2000-2004
			high flood pulse count (#)	4.5 - 7.6	4.2	2000-2004
			annual min of 7-day moving average flow (cfs)	22.8 - 38.0	38.8	2000-2004
			annual max of 7-day moving average flow (cfs)	366.1 - 610.2	486.7	2000-2004
			Julian date of annual minimum	217.6 - 362.7	293.8	2000-2004
			Julian date of annual maximum	73.9 - 123.2	130	2000-2004
			fall rate (cfs/day)	17.4 - 29.1	22.9	2000-2004

Table 5.1. Continued

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
	Fish community					
		Composition				
			Simpson's diversity	≤ 0.15	0.09	2007
			sucker composition (%)	> 1.3	1.20	2007
			sunfish composition (%)	> 11	17.9	2007
			benthic species composition (%)	> 34	49.1	2007
		Condition				
			index of biotic integrity	> 60	93	2007
	Aquatic invertebrates					
		Biotic integrity				
			family richness	≥ 14.2	10.8	2007
			genus richness	> 15	14.9	2007
			EPT richness	> 4	3.8	2007
			EPT ratio	≥ 0.23	0.18	2007
			Shannon Index (Genus)	> 1.77	1.93	2007
			Shannon Evenness Index	≥ 0.9	0.72	2007
			Hilsenhoff Biotic Index	< 6.6	6.7	2007
Skegg's Branch						
	Water quality					
			temperature (°C)	0 - 34	15.3	2007
			specific conductance (μS/cm)	100 - 400	489.5	2007
			dissolved oxygen (mg/L)	5 - 15	8.8	2006
			pH	6.5 - 9.0	7.9	2006
			turbidity (NTU)	< 10	2.1	2007
	Fish community					
		Composition				
			Simpson's diversity	< 0.23	0.16	2007
			benthic species composition (%)	> 34.3	52.9	2007
		Condition				
			index of biotic integrity	> 60	73	2007
	Aquatic invertebrates					
		Biotic integrity				
			family richness	≥ 14.2	11.9	2007
			genus richness	> 15	21.7	2007
			EPT richness	> 4	3.8	2007
			EPT ratio	≥ 0.23	0.18	2007

Table 5.1. Continued

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
			Shannon Index (Genus)	> 1.77	2	2007
			Shannon Evenness Index	≥ 0.9	0.66	2007
			Hilsenhoff Biotic Index	< 6.6	5.7	2007
Terrell Creek						
	Water quality					
			temperature (^oC)	0 - 34	18.6	2007
			specific conductance (μS/cm)	100 - 400	466.9	2007
			dissolved oxygen (mg/L)	5 - 15	7.8	2007
			pH	6.5 - 9.0	7.8	2007
			turbidity (NTU)	< 10	1.5	2007
	Fish community					
		Composition				
			Simpson's diversity	< 0.44	0.73	2007
			sucker composition (%)	> 1.5	0.4	2007
			benthic species composition (%)	> 61.7	90.4	2007
		Condition				
			index of biotic integrity	> 60	61	2007
	Aquatic invertebrates					
		Biotic integrity				
			family richness	≥ 14.2	14.8	2007
			genus richness	> 15	22.4	2007
			EPT richness	> 4	4.6	2007
			EPT ratio	≥ 0.23	0.15	2007
			Shannon Index (Genus)	> 1.77	2.19	2007
			Shannon Evenness Index	≥ 0.9	0.71	2007
			Hilsenhoff Biotic Index	< 6.6	5.3	2007

Reporting Unit: Park-wide

Vegetation

Overall, WICR has 28 different current cover types, and about 425 ha (53%) are natural or semi-natural, whereas 336 ha 42% are clearly successional types. The remaining 38 ha (<5%) are cultural, including cover types such as trails and roads, buildings, interpretive croplands, and lawns (Table 5-2, Figure 5-4).

Table 5-8. Current vegetation type patch statistics and total area for Wilson's Creek National Battlefield.

Current Vegetation Class	Mean Patch Size (ha)	# of Patches	Class Area (ha)	% Class Area
Barren or Sparsely Vegetated	0.01	10	0.14	0.00%
Bottomland Oak-Hardwood Forest	0.34	188	63.94	8.00%
Bottomland Successional Deciduous Sparse Woodland and Shrubland	0.07	156	11.43	1.40%
Bottomland Successional Eastern Redcedar Sparse Woodland and Shrubland	0.02	1	0.02	0.00%
Bottomland Successional Eastern Redcedar Woodland and Forest	0.34	5	1.70	0.20%
Bottomland Successional Eastern Redcedar-Deciduous Mixed Woodland and Forest	0.11	21	2.39	0.30%
Bottomland Successional Herbaceous Vegetation	0.79	34	26.76	3.30%
Cropland	2.15	7	15.02	1.90%
Fescue Grasslands	1.27	136	173.07	21.60%
Glade/Woodland Complex (grassy)	0.02	4	0.06	0.00%
Glade/Woodland Complex (invasive eastern redcedar woodland and forest)	0.12	16	1.91	0.20%
Glade/Woodland Complex (invasive eastern redcedar-hardwood woodland and forest)	0.08	50	3.95	0.50%
Glade/Woodland Complex (sparse deciduous woodland and shrubland)	0.10	31	3.09	0.40%
Glade/Woodland Complex (sparse eastern redcedar woodland and shrubland)	0.07	8	0.53	0.10%
Open Water	0.03	39	1.20	0.20%
Prairie Restoration	0.91	173	157.50	19.70%
Trails and Roads	0.20	108	21.20	2.70%
Upland Dry Oak-Hickory Woodland and Forest	0.38	398	152.09	19.00%
Upland Mesic Oak-Hickory Woodland and Forest	0.32	15	4.78	0.60%
Upland Oak-Bluestem Flatwoods (wooded)	0.02	2	0.04	0.00%
Upland Prairie and Savanna (wooded)	0.12	58	7.22	0.90%
Upland Successional Deciduous Sparse Woodland and Shrubland	0.10	624	60.88	7.60%
Upland Successional Eastern Redcedar Sparse Woodland and Shrubland	0.08	37	3.13	0.40%
Upland Successional Eastern Redcedar Woodland and Forest	0.20	63	12.53	1.60%
Upland Successional Eastern Redcedar-Hardwood Woodland and Forest	0.35	108	38.24	4.80%
Upland Typic Slope Oak-Hardwood Woodland and Forest	0.16	150	24.73	3.10%
Upland Wet Slope and Valley Hardwood Forest	0.13	77	9.89	1.20%
Urban Low Intensity	0.06	32	2.00	0.30%

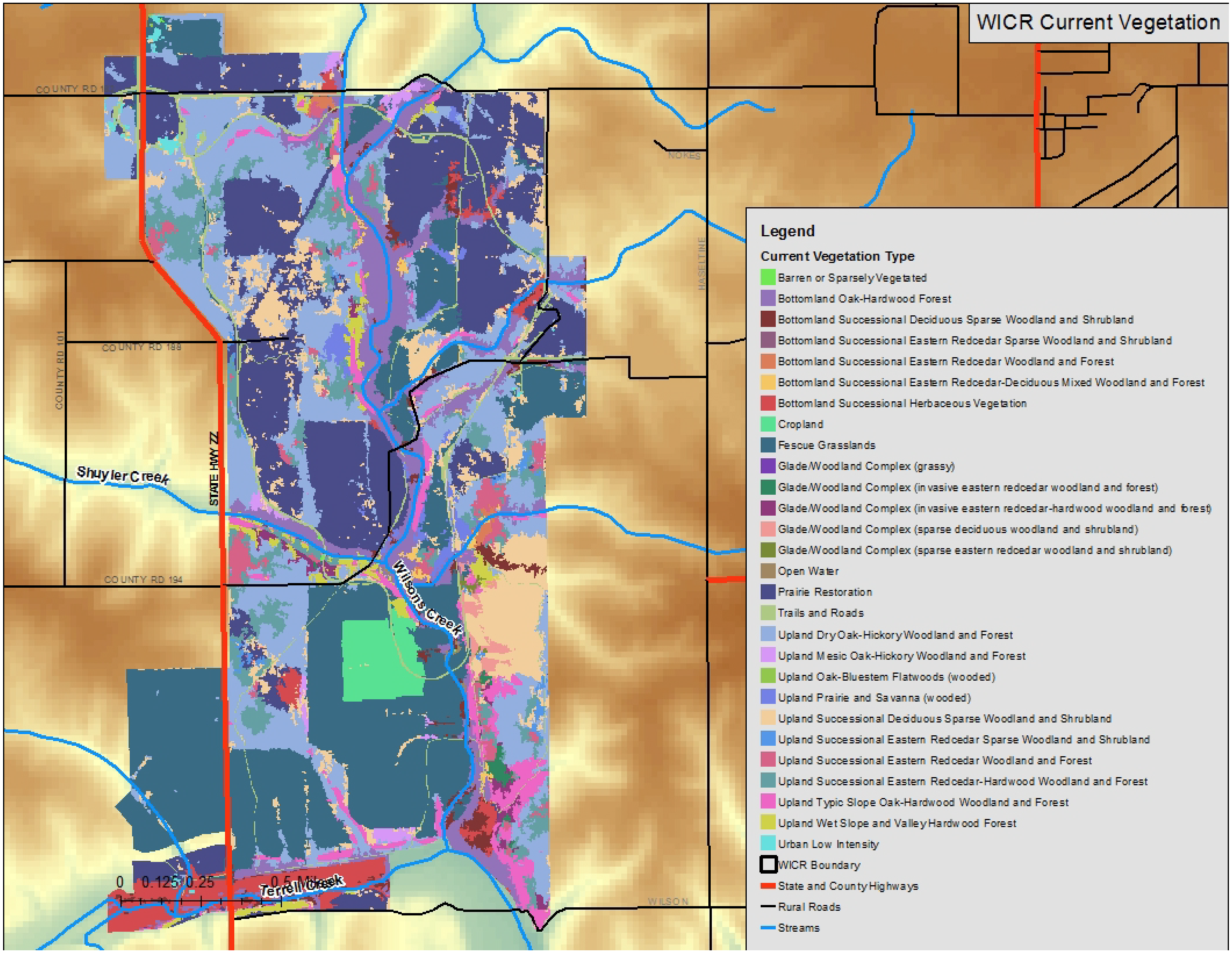

Figure 5-17. Wilson’s Creek National Battlefield current vegetation cover type.

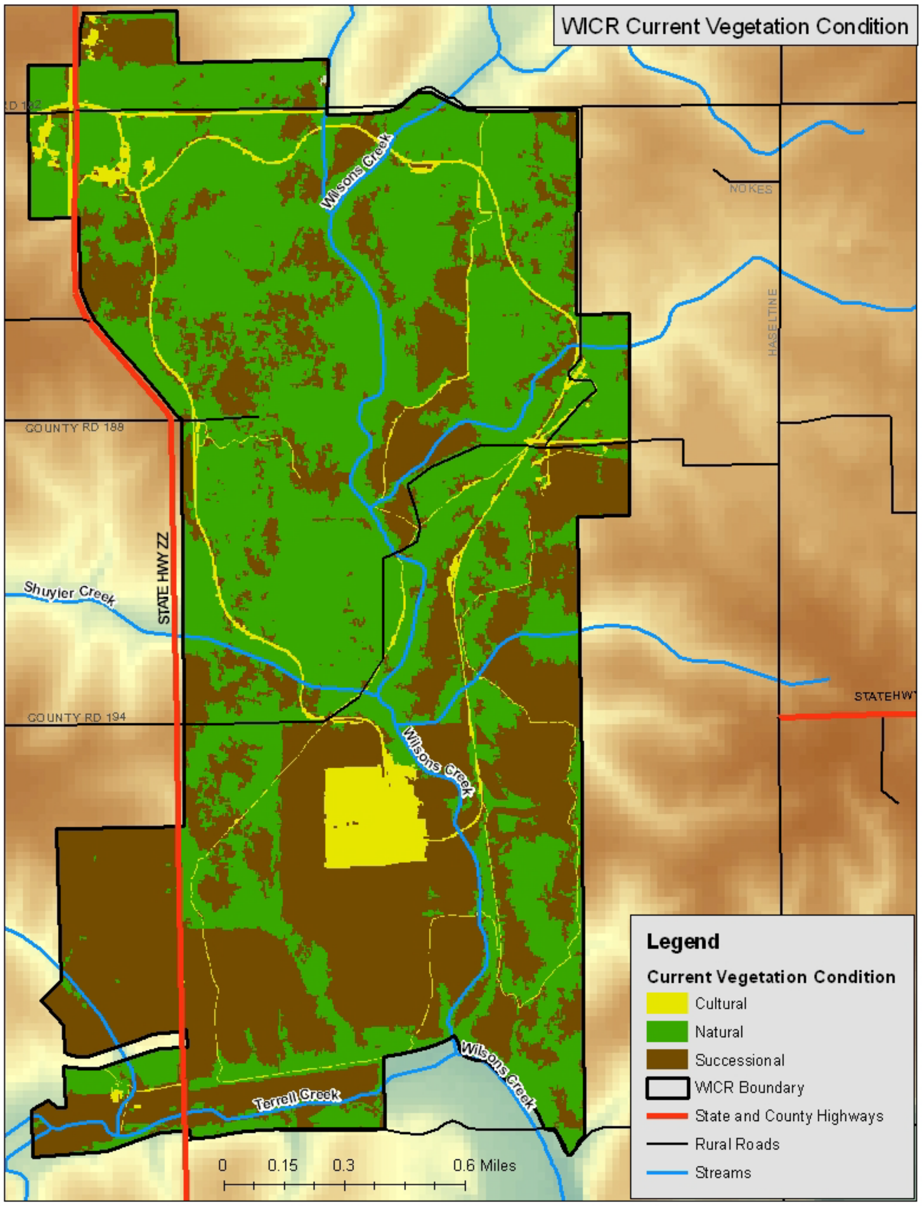

Figure 5-18. Wilson's Creek National Battlefield current vegetation condition.

Landscape Composition
There are 1819 patches of different land cover types in the park, with an average patch size of 0.44 ha. Among land cover types that cover more than 75 hectares, or slightly less than 10% of the park, grassland patches are the largest on average at 1.32 ha, and shrubland patches are among the smallest at 0.10 ha (Table 5-3). The landscape is more fragmented overall than in historic times, and management targets were established based on subjective expert opinion. These relate to reducing the number of patches and increasing mean patch size (Table 5-1).

Table 5-9. Mean patch size, number of patches, and area for major land cover types at Wilson's Creek National Battlefield.

Land Use/Land Cover Class	Mean Patch Size (ha)	# of Patches	Class Area (ha)	% Class Area
Impervious	0.20	108	21.20	2.65
Low Density Urban	0.06	32	2.00	0.25
Barren or Sparsely Vegetated	0.02	11	0.20	0.03
Cropland	2.15	7	15.02	1.88
Grassland	1.32	270	357.34	44.70
Deciduous Forest	0.65	403	262.69	32.86
Evergreen Forest	0.26	61	16.14	2.02
Mixed Forest	0.42	106	44.58	5.58
Decid. Woody/Herbaceous	0.10	741	75.41	9.43
Evergreen Woody Herbaceous	0.05	4	0.18	0.02
Mixed Woody/Herbaceous	0.09	37	3.49	0.44
Open Water	0.03	39	1.20	0.15

Land Use/Land Cover

The most abundant natural and semi-natural types include bottomland forest (64 ha), prairie restorations (157 ha), and upland dry oak-hickory forest (152 ha). Most of the successional vegetation is relatively large patches of fescue grassland. Successional eastern redcedar shrubland or woodland (57 ha) and successional deciduous sparse woodland or shrubland (60 ha) are also common. The management goals are based on expert opinion, and relate to increases in the area of semi-natural types and reduction in the area of successional types. This process will take decades of effort and is constrained by funding and by other park goals (Table 5-1).

Breeding Bird Community

Forty-seven species were recorded during surveys in 2008. The most common birds park-wide were the Indigo bunting (*Passerina cyanea*), Northern cardinal (*Cardinalis cardinalis*), and Blue-gray gnatcatcher (*Polioptila caerulea*) (Table 5-4). Ten species found at WICR are on Partners in Flight lists of birds of continental importance (Table 5-4). Two grassland obligate birds, the Dickcissel (*Spiza americana*) and the Eastern meadowlark (*Sturnella magna*), were recorded. Volunteers surveyed 33 of the 36 established plots in 2010, and observed 16 birds of continental importance to Partners in Flight, including 15 resident species (surveys from Dorothy O. Thurman, Myra Scroggs, and April McDonough, unpublished). Summer resident or resident species encountered in 2010 but not in 2008 included the Acadian Flycatcher (*Empidonax virescens*), Bell's Vireo (*Vireo bellii*), Brown Thrasher (*Toxostoma rufum*), Grasshopper Sparrow (*Ammodramus savannarum*), Louisiana Waterthrush (*Parkesia motacilla*), Prothonotary Warbler (*Protonotaria citrea*), and Red-shouldered Hawk (*Buteo lineatus*). Sample plots with the highest diversity, and highest diversity of species of importance to Partners in Flight, have been documented, and are scattered across the park.

Management targets are based on expert opinion and focus on maintenance of the current level of biodiversity. Management efforts to maintain a diversity of habitats on the park will benefit multiple species. Three species of continental importance, that are currently common at the park, have a strong habitat affinity. Two of these, the Indigo bunting and Eastern Towhee (*Pipilo erythrophthalmus*), require brushy or forest edge habitats. The Dickcissel is a grassland obligate species (Peitz 2009).

Table 5-10. Bird species recorded during breeding bird surveys in 2008 at Wilson's Creek National Battlefield (from Peitz 2009).

Common name[1]	Species name[2]	AOU code	Residency[3]
American crow	*Corvus brachyrhynchos*	AMCR	R
American goldfinch	*Carduelis tristis*	AMGO	R
Bank swallow	*Riparia riparia*	BANS	SR
Bewick's wren	*Thryomanes bewickii*	BEWR	R
Blue jay	*Cyanocitta cristata*	BLJA	R
Blue-gray gnatcatcher	*Polioptila caerulea*	BGGN	SR
Blue-winged warbler	***Vermivora pinus***	**BWWA**	**SR**
Brown thrasher	***Toxostoma rufum***	**BRTH**	**R**
Brown-headed cowbird	*Molothrus ater*	BHCO	R
Canada goose	*Branta canadensis*	CAGO	R
Carolina chickadee	*Parus carolinensis*	CACH	R
Carolina wren	***Thryothorus ludovicianus***	**CARW**	**R**
Cliff swallow[4]	*Hirundo pyrrhonota*	CLSW	SR
Cedar waxwing[4]	*Bombycilla cedrorum*	CEDW	WR
Common grackle	*Quiscalus quiscula*	COGR	R
Common yellowthroat	*Geothlypis trichas*	COYE	SR
Dickcissel	***Spiza americana***	**DICK**	**SR**
Downy woodpecker	*Picoides pubescens*	DOWO	R
Eastern (Rufous-side) towhee	***Pipilo erythrophthalmus***	**EATO**	**R**
Eastern bluebird[4]	*Sialia sialis*	EABL	R
Eastern kingbird[4]	*Tyrannus tyrannus*	EAKI	SR
Eastern meadowlark	*Sturnella magna*	EAME	R
Eastern phoebe	*Sayornis phoebe*	EAPH	R
Eastern wood-pewee	*Contopus virens*	EAWP	SR
Field sparrow	*Spizella pusilla*	FISP	R
Gray catbird	*Dumetella carolinensis*	GRCA	SR
Great blue heron	*Ardea herodias*	GBHE	R
Great crested flycatcher	*Myiarchus crinitus*	GCFL	SR
Indigo bunting	***Passerina cyanea***	**INBU**	**SR**
Kentucky warbler	***Oporornis formosus***	**KEWA**	**SR**
Northern bobwhite	*Colinus virginianus*	NOBO	R
Northern cardinal	*Cardinalis cardinalis*	NOCA	R
Northern mockingbird	*Minus polyglottos*	NOMO	R
Northern parula	*Parula americana*	NOPA	SR
Ovenbird	*Seirus aurocapillus*	OVEN	SR
Pileated woodpecker	*Dryocopus pileatus*	PIWO	R
Prairie warbler	***Dendroica discolor***	**PRAW**	**SR**

Table 5.4. Continued

Common name[1]	Species name[2]	AOU code	Residency[3]
Red-bellied woodpecker	***Melanerpes carolinus***	**RBWO**	**R**
Red-eyed vireo	*Vireo olivaceus*	REVI	SR
Red-tailed hawk	*Buteo jamaicensis*	RTHA	R
Song sparrow	*Melospiza melodia*	SOSP	R
Summer tanager	*Piranga rubra*	SUTA	SR
Turkey vulture	*Cathartes aura*	TUVU	R
(Eastern) Tufted titmouse	*Baeolophus bicolor*	ETTI	R
White-eyed vireo	***Vireo griseus***	**WEVI**	**SR**
Wild turkey	*Meleagris gallopavo*	WITU	R
Yellow-breasted chat	*Icteria virens*	YBCH	SR

[1] Bolded names are those Partners in Flight species considered of continental importance.

[2] Species names are valid and verified names taken from ITIS (Integrated Taxonomic Information System). Http://www.itis.gov/.

[3] Residency: SR = summer resident; R = year around resident; WR = winter resident; According to Stokes and Stokes (1996).

[4] Species recorded only while traveling between point transects or at other times outside of 5-min survey periods.

White-tailed Deer

From 2005 to 2010, an index of deer density dipped from just under 60 individuals/ km^2 in 2005 to 15 individuals/ km^2 in 2007, probably due to an outbreak of hemorrhagic disease. The population density has rebounded to just under 60 individual/ km^2 since 2007. At this density, the deer herd is expected to heavily browse palatable woody and herbaceous species, and hence may have an impact on development of the vegetation. Hemorrhagic disease is often related to high population densities, and might therefore be cyclic. Maintenance of the deer herd nearer to the ecological carrying capacity of about 8 individuals/km^2 (Tilghman 1989) may not be possible, but reduction in numbers would benefit the development of healthier deer herd and plant communities.

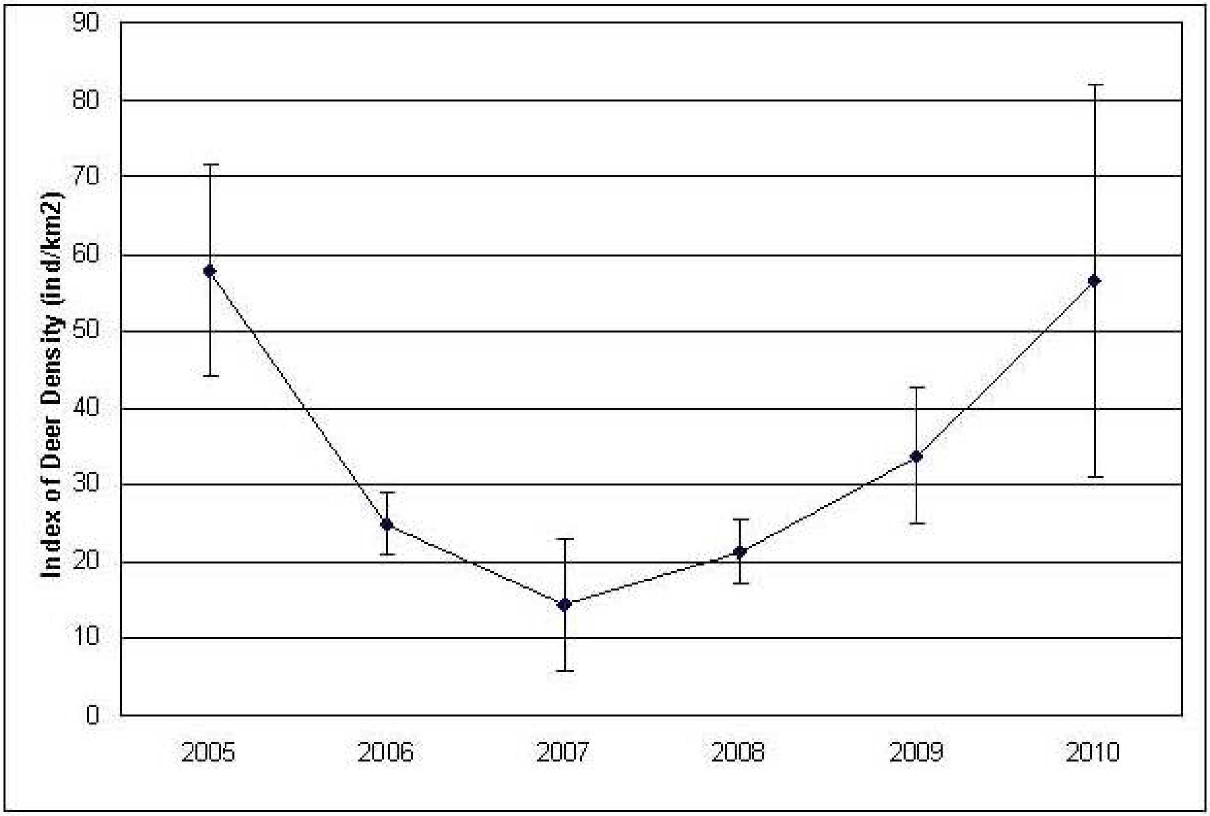

Figure 5-19. White-tailed deer population fluctuations between 2005 and 2009 at Wilson's Creek National Battlefield.

Invasive Exotic Plant Impact

Thirty-five invasive or exotic species were identified during surveys conducted in 2006, and they cover a minimum of 15.4% of the total area of the park (Table 5-5; Young et al. 2007). Management targets are based on expert opinion, and focus on reducing the numbers of invasive species in the park if possible (Table 5-1).

Table 5-11. Invasive exotic plants as Wilson's Creek National Battlefield. Management difficulty is from NatureServe (see http://www.natureserve.org/): high (H), medium (M), low (L), insignificant (I), and unknown (U).

Scientific Name	Common Name	Park-wide Cover (acres)	Frequency (percent)	Management Difficulty
Lespedeza cuneata	Sericea lespedeza	479 – 851	44.7	M/L
Bromus racemosus	Bald brome	257 – 434	34.0	U
Maclura pomifera	Osage orange	120 – 250	32.5	L
Bromus inermis	Smooth brome	63 – 105	4.0	M/L
Lonicera japonica	Japanese honeysuckle	48 – 79	37.6	H/M
Schedonorus spp.	Fescue species	9 – 25	20.8	--
Lonicera maackii	Amur honeysuckle	5 – 21	1.0	M
Rosa multiflora	Multiflora rose	6 – 17	48.2	L
Rhus glabra	Smooth sumac	2 – 6	22.8	--
Torilis spp.	Hedgeparsley species	0.6 – 2.3	25.4	--
Bromus sterilis	Poverty brome	< 1.0	11.2	U
Poa spp.	Bluegrass species (incl. Kentucky bluegrass)	< 1.0	4.1	--
Sorghum halepense	Johnsongrass	< 1.0	5.1	H/M
Dactylis glomerata	Orchardgrass	< 0.75	13.2	M/L
Elaeagnus umbellata	Autumn olive	< 0.75	3.6	L
Verbascum thapsus	Common mullein	< 0.75	15.7	L
Ailanthus altissima	Tree-of- heaven	< 0.5	2.0	M/L
Carduus nutans	Nodding plumeless thistle	< 0.5	2.0	H/M
Melilotus officinalis	Sweetclover	< 0.5	9.6	M
Morus alba	White mulberry	< 0.5	4.6	M/L
Securigera varia	Crown vetch	< 0.5	2.0	L
Celastrus orbiculatus	Oriental bittersweet	< 0.25	2.0	M
Cirsium vulgare	Bull thistle	< 0.25	1.5	M/L
Euonymus alata	Burningbush	< 0.25	3.6	L
Euonymus fortunei	Winter creeper	< 0.25	6.6	L/I
Bromus tectorum	Cheatgrass	< 0.1	1.0	H/M
Dipsacus fullonum	Fuller's teasel	< 0.1	1.0	M/L
Humulus japonicus	Japanese hop	< 0.1	1.5	--
Ligustrum vulgare	Common privet	< 0.1	1.5	H/M
Vinca minor	Common periwinkle	< 0.1	1.0	U
Arctium minus	Lesser burdock	< 0.01	0.5	M/I
Dioscorea oppositifolia	Chinese yam	< 0.01	0.5	M/I
Miscanthus sinensis	Chinese silvergrass	< 0.01	0.5	H/L
Poa compressa	Canada bluegrass	< 0.01	1.0	H/L
Potentilla recta	Sulphur cinquefoil	< 0.01	0.5	M/L

Tall fescue (*Schedonorus phoenix*), a cool-season perennial, dominates a number of relatively large grassland patches. Other invasive and exotic species common in grasslands include sericea lespedeza (*Lespedeza cuneata*), bald brome (*Bromus racemosus*), Japanese honeysuckle (*Lonicera japonica*), and smooth sumac (*Rhus glabra*). Sericea lespedeza is a relatively tall (near 1 m), warm-season perennial that competes with warm season grasses, whereas bald broom is a cool-season (winter/spring) annual. Japanese honeysuckle is a vine that remains green much of the year, from early spring through late fall and into winter, and smooth sumac is a short-lived perennial shrub or small tree. All of these species inhibit the re-establishment of native grasses and forbs, and can be managed to some extent via prescribed fire. In forests and woodlands, Japanese honeysuckle, multiflora rose (*Rosa multiflora*), and Osage orange (*Malcura pomifera*) were most common. These four species can be expected to become less frequent as woodlands mature and shading favors native species, and none are very fire-tolerant. However, both honeysuckle and rose may persist in relatively mature woodlands and forests.

<u>Cave Resources</u>

At least two caves have been reported to support populations of rare species at WICR. The Missouri state Heritage database lists records for Gray Bat (*Myotis grisescens*) and grotto salamander (*Eurycea spelacea*) from a cave on the north side of the park. Slay et al. (2004) did not find Gray bat at these caves, but did mention that the bristly cave crayfish (*Cambarus setosus*) had been documented from the south cave. Furthermore, since both caves are wet, this species along with the grotto salamander, cave isopods (*Caecidotea* sp.) and cave amphipods (*Stygobromus* sp., *Bactrurus* sp.) are likely associated with both caves. Since little is known about the fauna of these caves, specific management goals cannot be identified, although certainly human disturbance should be avoided.

<u>Air Quality</u>

Ozone Assessment

Results of the ozone assessment presented in show that ozone concentrations have declined slightly in recent years with data from most time periods rated as moderate. A number of plant species are susceptible to damage from ozone and NPS assesses the risk of ozone injury to vegetation by park. The report *Assessing the risk of foliar injury from ozone on vegetation in parks in the Heartland Network* (NPS 2004a) indicates that the risk of foliar injury to plants in WICR is low. In fact WICR is rated among the lowest risk for ozone injury to vegetation for parks across the United States (Figure 5-7). Despite being low risk for ozone injury to vegetation NPS indicates that there are from 8 to 14 ozone sensitive plant species in WICR (NPS 2001, NPS 2004a, and NPS 2006).

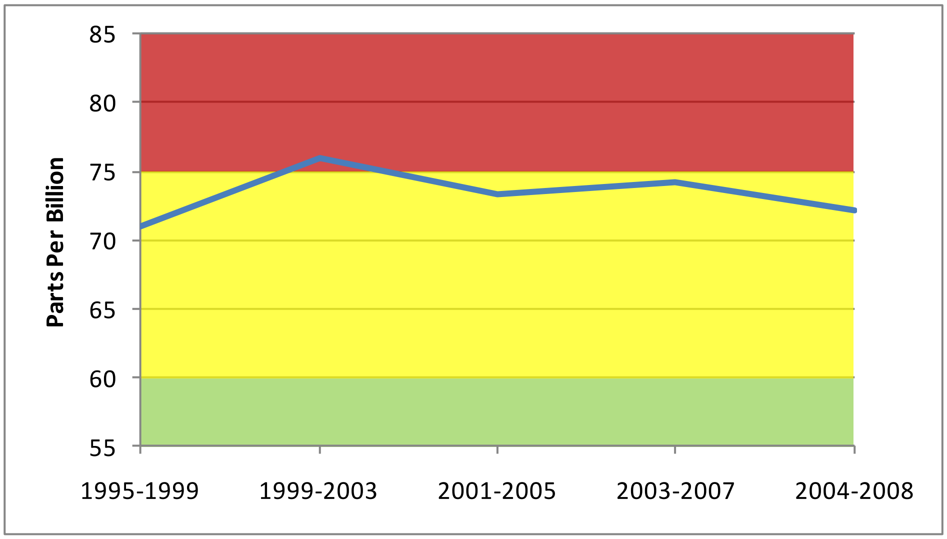

Figure 5-20. Average of fourth Maximum 8-hour Ozone levels based on five-year averages of interpolated deposition estimates (NPS 2010a). Greater than or equal to 76 ppb is considered poor, between 61-75 fair, and below 61 good (NPS 2007a).

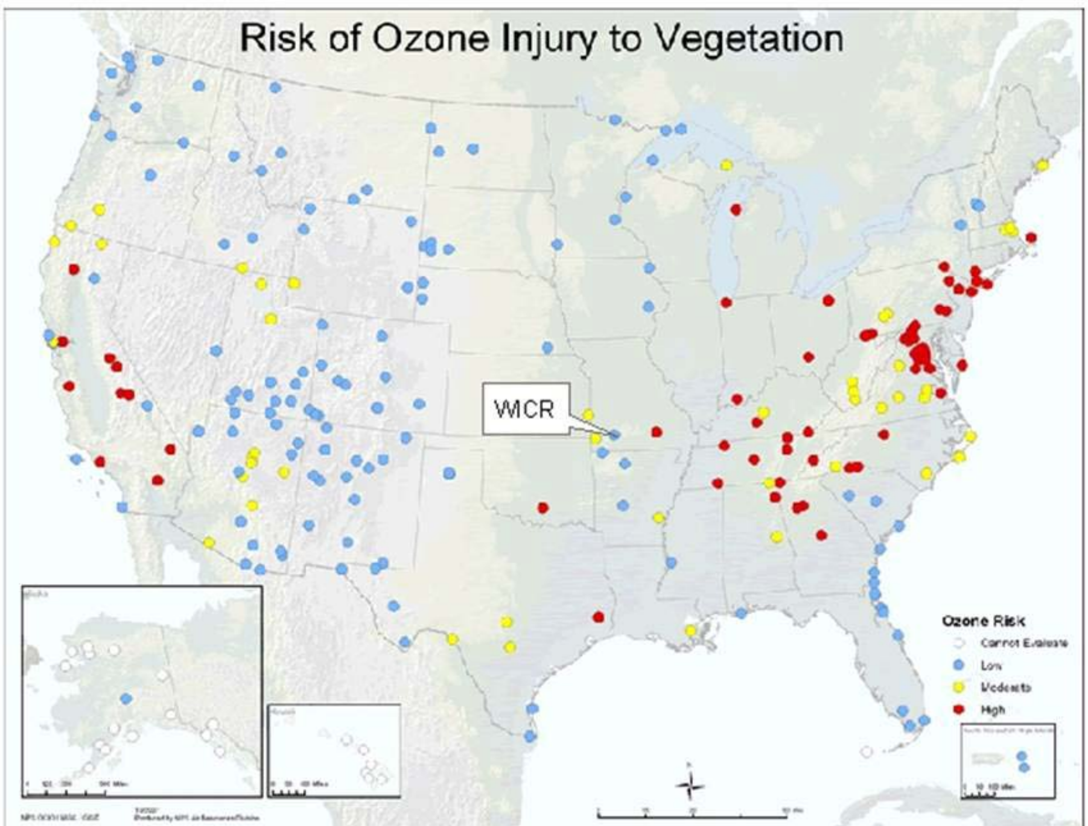

Figure 5-21. Map showing the risk of ozone injury to vegetation by park (NPS 2007d).

Atmospheric Deposition

Average interpolated estimates of wet deposition of nitrogen ranged from 12.6 to 13.6 kg/ha/yr., and estimates of wet deposition of sulfur ranged from 10.29 to 12.06 kg/ha/yr. All estimates far exceeded the threshold for "poor" of 3 kg/ha/yr. Wet deposition of from sulfates, nitrates, and ammonium account for the majority of total nitrogen and sulfur deposition.

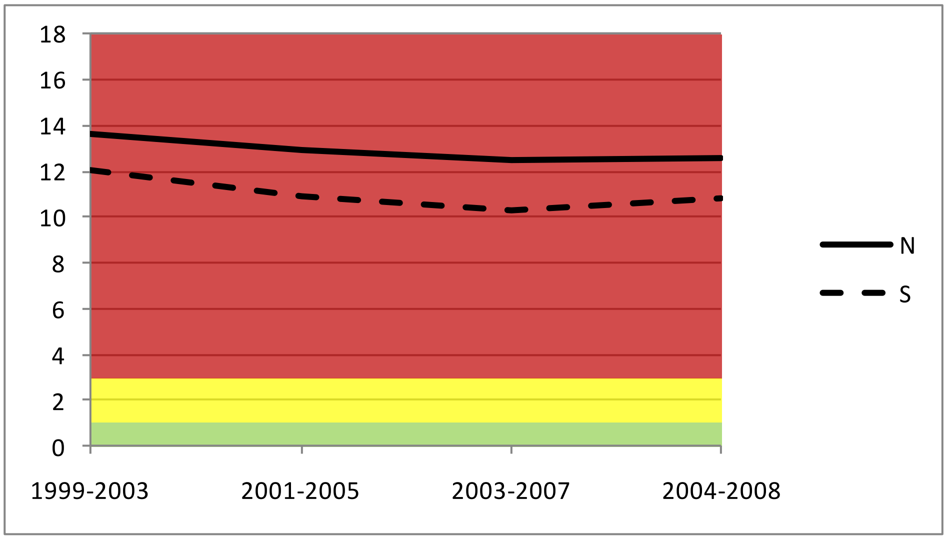

Figure 5-22. Total nitrogen and sulfur from wet deposition of sulfate (S04), nitrate (N03) and ammonium (NH4) based on five-year averages of interpolated deposition estimates (NPS 2010a) Greater than 3 ppb is considered poor, between 1 and 3 ppb fair, and below 1 ppb good.

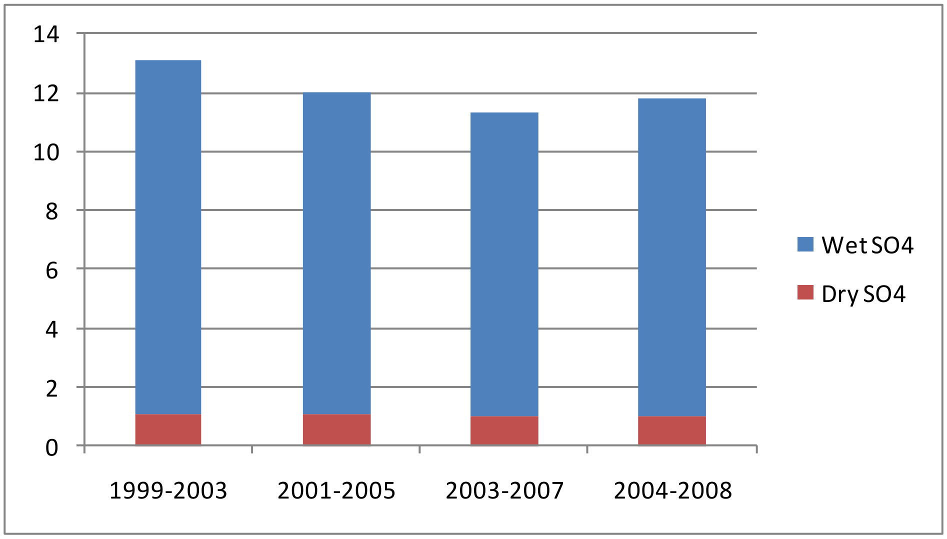

Figure 5-23. Total wet and dry sulfur deposition based on five-year averages of interpolated deposition estimates (NPS 2010a).

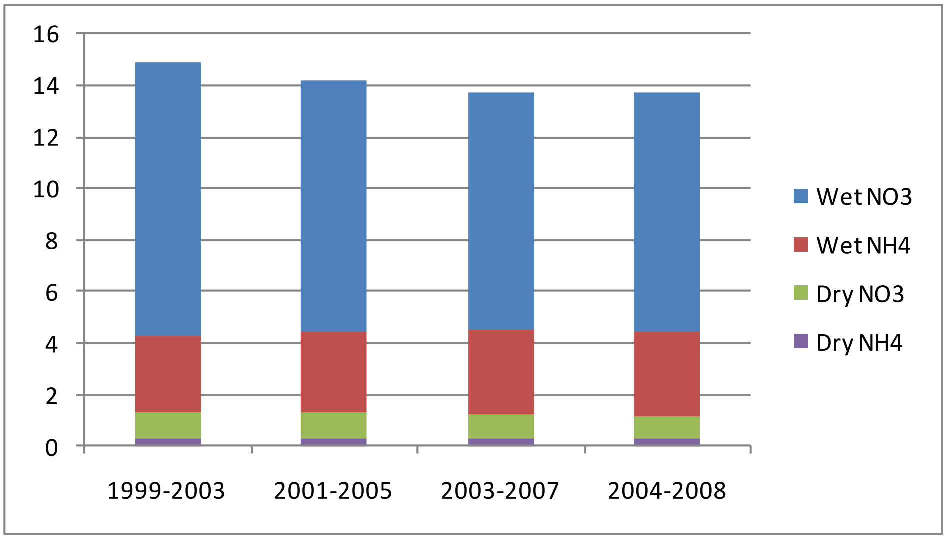

Figure 5-24. Total wet and dry nitrogen deposition based on five-year averages of interpolated deposition estimates (NPS 2010a).

Reporting Unit: Bottomland Forest

Bottomlands of WICR contain more area of successional types (55 ha) than natural forest types (52 ha). Essentially all of the woodlands are young and disturbed. Most of the successional vegetation consists of fescue grassland or other successional herbaceous vegetation (45 ha). Mean patch size for forest is 0.68 ha in 75 patches. Management goals are based on expert judgment, and relate to conversion of existing successional types to semi-natural types.

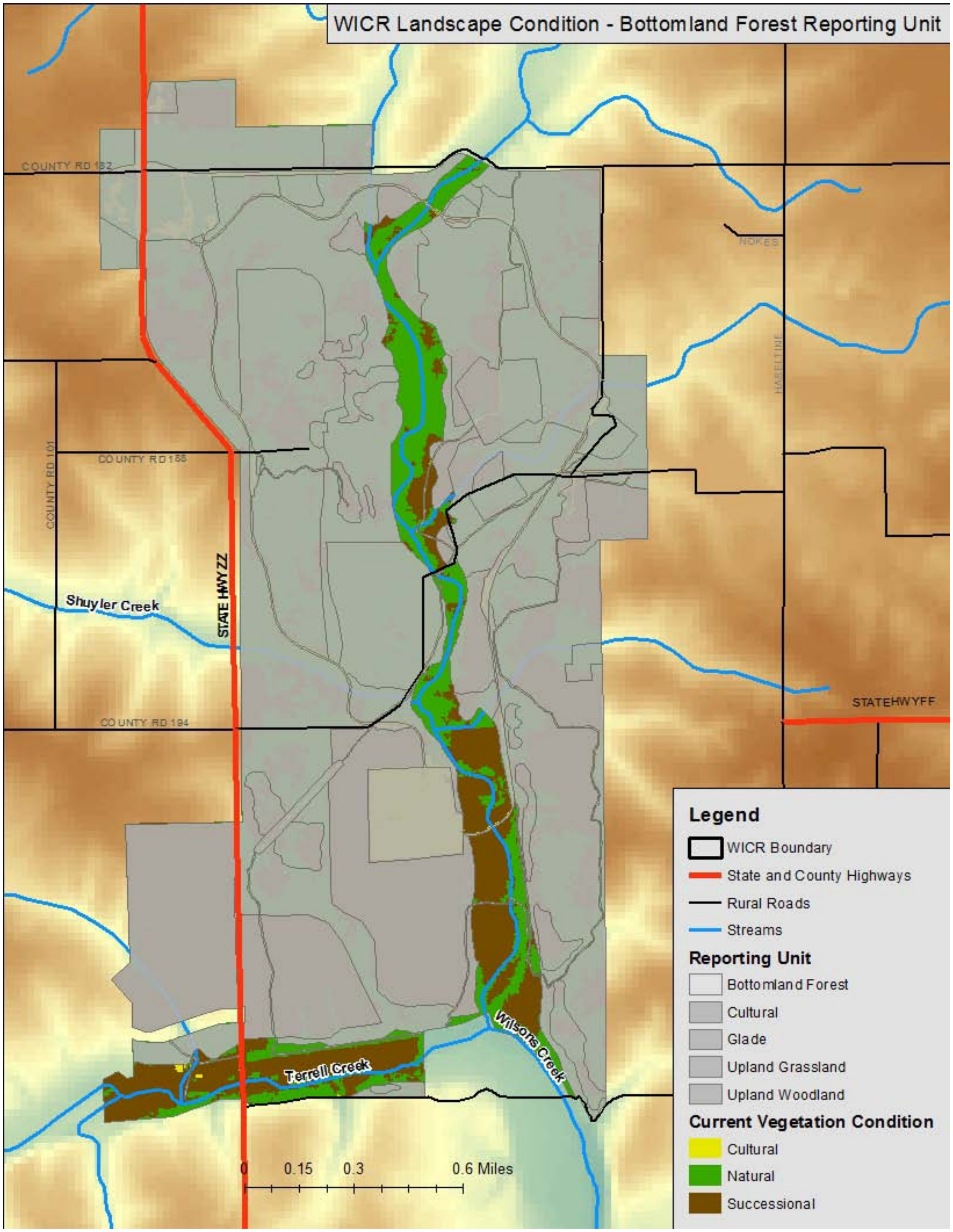

Figure 5-25. Current landscape composition for the bottomland forest reporting unit.

Reporting Unit: Glade

Glades at WICR cannot be easily circumscribed since they occupy variable habitats that can be defined either as open woodlands or glades. They cover from about 25 to 37 ha, depending on how they are circumscribed, in several relatively small patches (Figure 5-1; Young et al. 2006). For the purposes of this report, we selected a conservative approach toward circumscribing glades.

About 10 ha of the 25 ha reporting unit is in sparse woody or open habitat, whereas 15 ha is in more closed woodlands. The number of different land cover patches (79) and patch size (0.14 ha) are indicative of the inherently variable habitat, with exposed rock and thin soils alternating with deeper soils. Management goals, based on expert judgement, might include reducing the overall number of patches and patch size somewhat, but patchiness is expected within the reporting unit. The primary management focus should be on reduction in the amount of eastern redcedar (*Juniperus virginiana*) dominated or co-dominated communities, which now comprise >9 ha of the reporting unit. Herbaceous glade species, including the Missouri bladderpod (*Lesquerella filiformis*), would benefit from a more open habitat (Young et al. 2009). However, eastern redcedar is a natural component of glades, especially those associated with rim-rocks and steep slopes.

Missouri bladderpod is a rare winter annual plant that is endemic to glades, or xeric limestone prairies, of the Ozark Highlands (Young et al. 2008, 2009). The largest populations are on Bloody Hill Glade and on Wire Road GladePopulation sizes vary significantly from year to year, presumably due to precipitation and temperature variation. Young et al. (2009) found that soil depth and competition for light with Eastern redcedar and possibly other woody and herbaceous species was a primary factor limiting populations of this species to naturally open microsites on Bloody Hill Glade. Competition from herbaceous species may be relatively limited in naturally open microsites.

To define management targets for Missouri bladderpod, we compared the current size of six Missouri bladderpod populations at WICR to the population size ranges observed in each of those populations over an extended time period. The time periods varied for each population: Bloody Hill Glade (2001-2010); Manley Woods, Walnut, and Wire Road Glades (2002-2010); North Bloody Hill Glade (2003-2010); and Terrell Creek Glade (2007-2010). To account for naturally high annual variability, the current Missouri bladderpod population size was calculated as the three-year (2008-2010) average of the population size interval midpoints. A population size range, which defined management targets for each population, was based on the minimum and maximum values observed during the given time period. The end points of the range were calculated as the minimum and maximum population size interval midpoints observed with 10% of the difference between the maximum and minimum added to the minimum and subtracted from the maximum, respectively. This range effectively covers 80% of the difference between the observed minimum and maximum population sizes for each Missouri bladderpod population in the park.

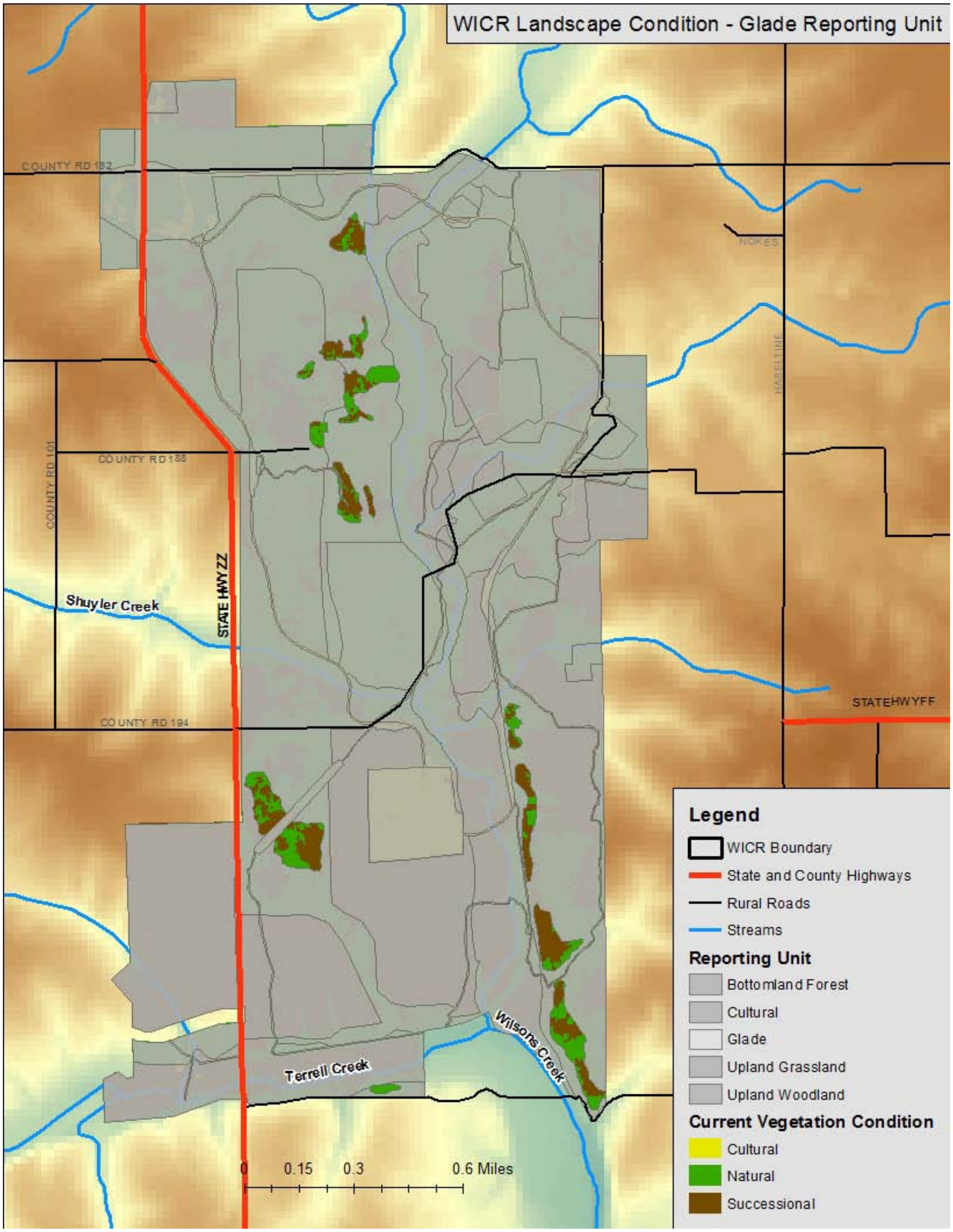

Figure 5-26. Current landscape composition for the glade reporting unit.

Reporting Unit: Upland Grassland

Upland grasslands at WICR are essentially all disturbed, but management activities have restored some compliment of native species to about 145 ha, whereas about 138 ha are successional grasslands dominated by tall fescue or other herbaceous species and low shrubs, or are other successional types (23 ha). Grassland condition is highly variable across both restorations and disturbance grasslands, and all may be more or less heavily dominated by early successional shrubs and vines such as *Rubus* spp, smooth sumac (*Rhus glabra*), *Prunus* spp., and multiflora rose (*Rosa multiflora*). Currently, based on limited sampling, average native shrub and vine cover (37%) exceeds average native grass cover (22.3%; Table 5-1) within the reporting unit.

Management goals were based on professional judgment, and relate to establishment of more prairie restorations with native warm-season grasses and forbs and fewer shrubs and vines. However, efforts along these lines may be costly, and some species, such as selected bird species, may benefit from woody-dominated patches within the recovery unit (Peitz 2009). Efforts to improve existing restored prairie may be most efficient, with some areas simply mowed to favor herbaceous species over shrubs or allowed to succeed to shrublands and woodlands to provide early successional habitat in the landscape. At best, restoration of high quality prairies will require many decades of effort (see Jordan et al. 1987).

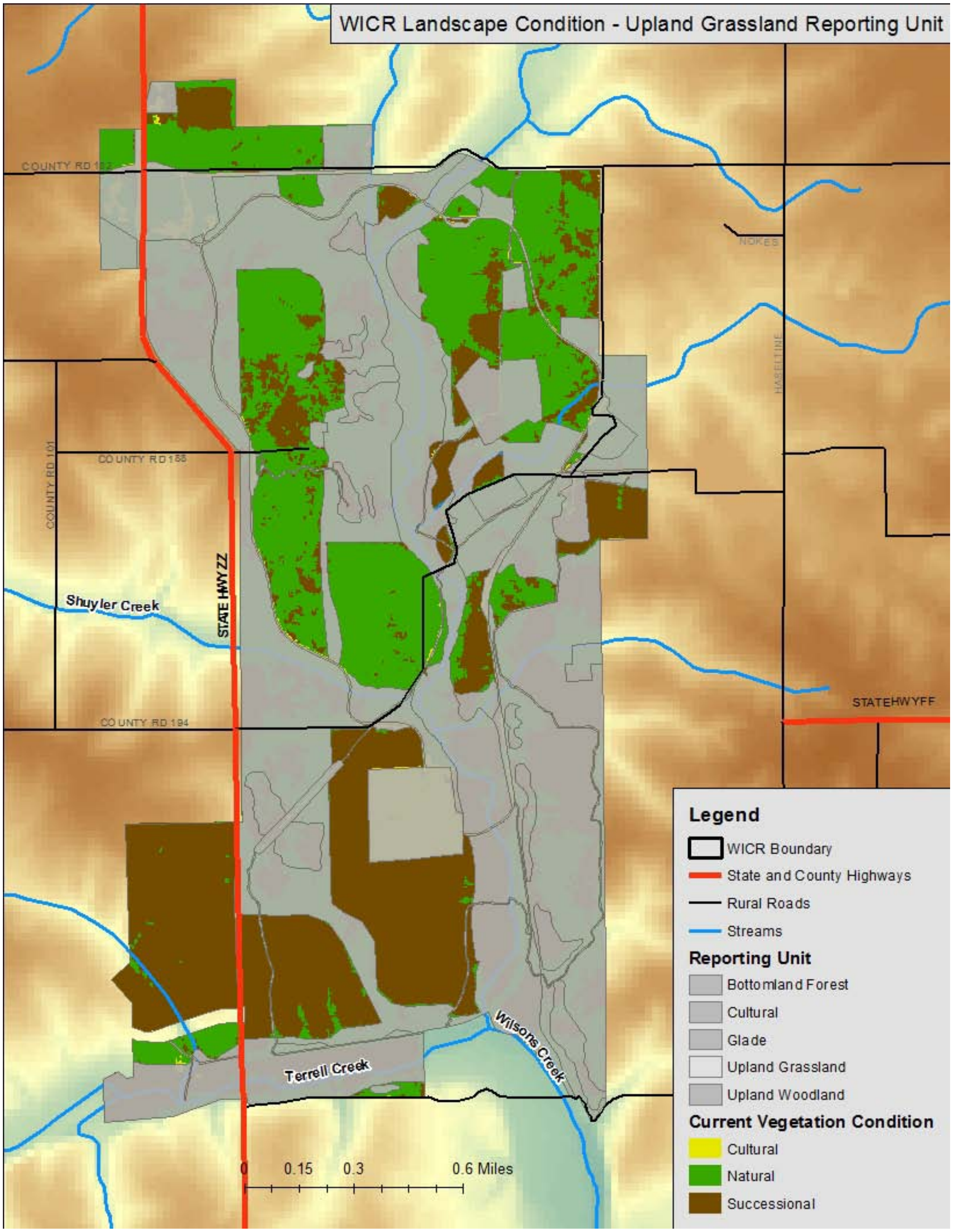

Figure 5-27. Current landscape composition for the upland grassland reporting unit.

Reporting Unit: Upland Woodland
Upland woodlands at WICR are almost all young and disturbed, but slopes tend to be in slightly better condition than flatter areas. About 192 ha represent semi-natural young woodlands and forests, whereas 91 ha are successional types, mainly eastern redcedar woodland, sparse woodland, and shrubland (46 ha), or deciduous sparse woodland or shrubland (33 ha). Mean patch size is 0.84 ha in 275 patches.

In terms of woody species structure and composition, the most striking feature is the relatively low basal area of oak species and relatively low mean hardwood tree height (Table 5-1). This is indicative of young woodlands with young trees, and with early successional species instead of oaks more dominant. Cover of large saplings is also relatively low, indicating possibly low tree recruitment, although this was not strongly indicated by the data. Finally, herbaceous flora, where present, consists of many shrubs and vines within grassy areas and relatively low cover of native grasses.

Management target numbers for vegetation structure and cover were gleaned mainly from Nelson (2005) and from Missouri forest and woodland natural community profiles posted at http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed 10/15/2010. The proportional range of cover type species composition was multiplied by the lower and upper range of total basal area to derive the management targets. Target numbers for regeneration were from Jenkins et al. (1997) and from Rice and Penfound (1955). Management goals should aim to reduce the number of successional types and allow the forests to mature. Natural succession toward older growth woodlands will proceed without a great deal of active management. For example, eastern redcedar cover will likely be reduced over time via successional processes (e.g. shading by taller deciduous trees). Lack of tree recruitment may be a management concern, especially if white-tailed deer numbers are too high over long time intervals.

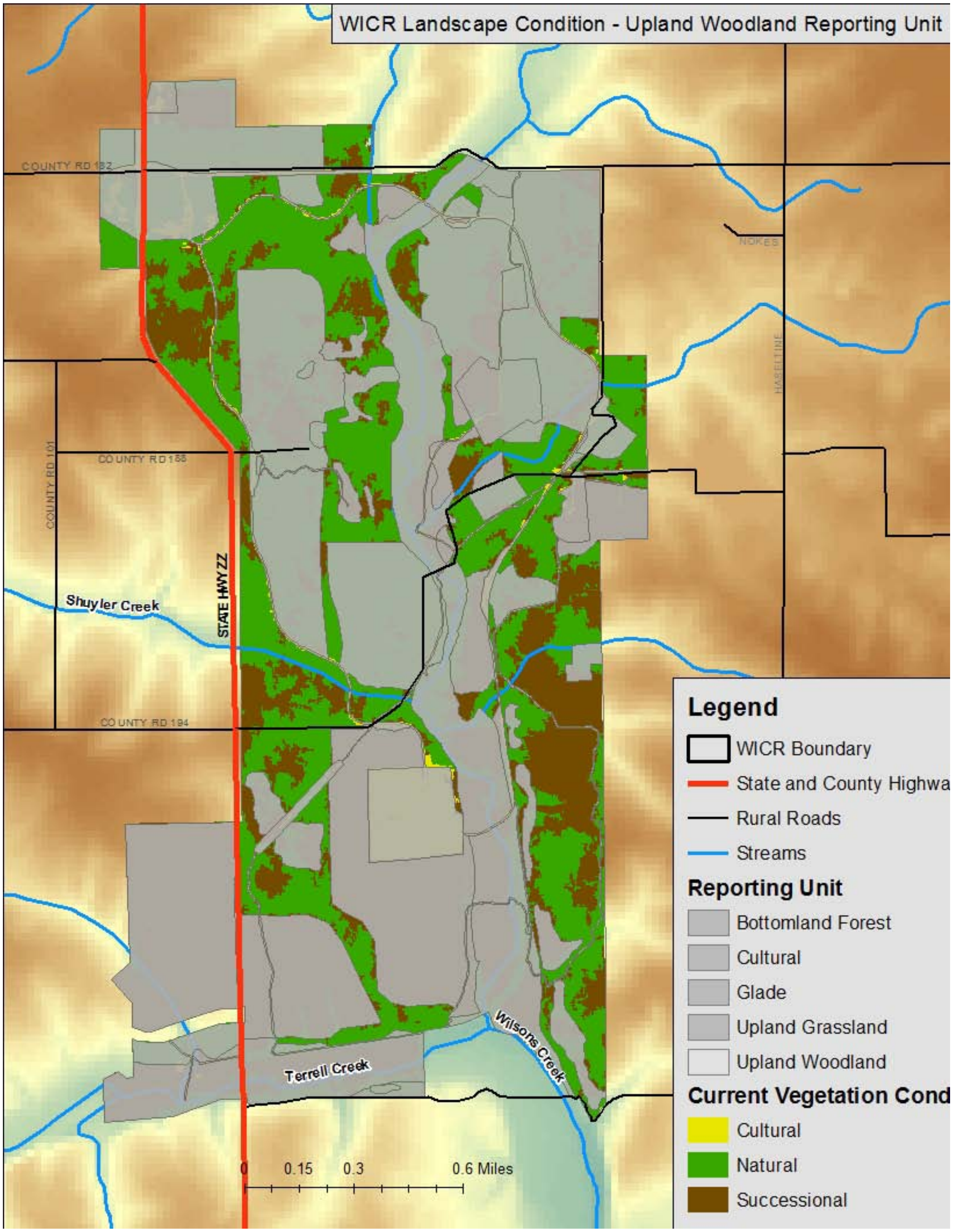

Figure 5-28. Current landscape composition for the upland woodland reporting unit.

Reporting Unit: Wilson's Creek

Aquatic Threats

Land cover and land use impact water quality and aquatic life. Watersheds with approximately 10% impervious surface typically have degraded aquatic communities (Center for Watershed Protection 2003). Wilson's Creek drains much of Springfield, Missouri which is a rapidly growing urbanized area. Based on year 2000 census data there are 101,042 people residing in the watershed (413 people per km^2). Thirty-two percent of the watershed above the park is classified as impervious surface (Figure 2-5, Figure 2-6 and Table 5-6). As such, most of the threats to aquatic resources in the park stem from impervious surface and point source discharges that originate upstream and outside of the park proper. There are two wastewater treatment facilities, 74 documented leaking underground storage tanks, and 46 hazardous waste generators in the drainage area above the park. Additionally, there are 227 road-stream crossings and 21 railroad-stream crossings. The 174 headwater impoundments have the potential to both alter flows and alter the biological integrity of streams. Cropland is not significant in the watershed, but pasture/hay makes up 41% of the watershed's land use. Although certainly not representative of all threats to aquatic systems, Table 5-6 includes the set of potential threats to aquatic ecological integrity quantified for Wilson's Creek.

Table 5-12. Quantified threats for Wilson's Creek in Wilson's Creek National Battlefield. Values are from the last stream segment downstream of the park.

Human Threat	# or amount	% or Density
Impervious Surfaces	77040000 m^2	31.50%
Cropland	2572200 m^2	1.05%
Pasture/Hay	99634500 m^2	40.74%
Airports	4	0.02 pkm^2
Roads	1116667 m	4566 pkm^2
Road/Stream Crossings	227	0.93 pkm^2
Railroads	85979 m	352 pkm^2
Railroad/Stream Crossings	21	0.09 pkm^2
Water Wells	1286	5.25 pkm^2
CERCLIS	1	0.004 pkm^2
Leaking Underground Storage Tanks	74	0.30 pkm^2
Mines (not Lead or Coal)	1	0.004 pkm^2
Pipelines	23630 m	97 pkm^2
Waste Water Treatment Facilities	2	0.008 pkm^2
Toxic Releases	10	0.04 pkm^2
RCRIS	2	0.008 pkm^2
Crop Pesticides	2127 kg	8.70 pkm^2
Landfills	1	0.004 pkm^2
Headwater Impoundments	174	0.71 pkm^2
NPDES	37	0.15 pkm^2
Livestock Sales	$220,850,000	902988 pkm^2
Channelized Stream/Ditch	9392 m	38.40 pkm^2
2000 Population	101042	413 pkm^2
Hazardous Generators	46	0.19 pkm^2
Hazardous Permits	3	0.01 pkm^2

Water Quality

Wilson's Creek is one of the largest tributaries in the James River basin and drains a large portion of the city of Springfield, Missouri. Wilson's Creek has poor water quality with 29 km classified as a 303(d) stream (Figure 5-155; Missouri Department of Natural Resources 2009). This impairment has contributed to biological impoverishment on the stream which has been attributed to non-point source pollution and urban development. A Total Maximum Daily Load (TMDL) as required by the Clean Water Act is currently under development for Wilson's Creek.

Sampling has shown water toxicity from unknown pollutants and bacteria, due to drainage from the city of Springfield (Missouri Department of Natural Resources 2009). Toxicity comes from point sources such as the wastewater treatment facility and nonpoint sources such as urban stormwater (Richards and Johnson 2002). In the past summer rainfall events, combined with wastewater effluent, severely depleted dissolved oxygen levels in Wilson's Creek (Emmett et al. 1978). Studies since 1968 (Harvey and Skelton 1968, Kerr 1969, Emmett et al. 1978, Richards and Johnson 2002) have shown that effluent from the wastewater treatment facility and urban runoff during storms release inorganic chemicals and nutrients into Wilson's Creek. The impact of the resulting dissolved oxygen depletion has reduced animal populations, but overall the extent of damage is presently unknown.

Wilson's Creek presently receives approximately 42.5 million gallons of treated sewage per day (Bowles 2010). Improvements to the wastewater treatment facility in 2001 have improved water quality in recent years. Richards and Johnson (2002) reported that contaminant concentrations are typically below their state limits for protecting aquatic life. However, fecal indicator bacteria densities can exceed the state limit for whole-body contact during base-flow conditions and can be markedly higher during storm events.

Phosphorus and nitrogen compounds in Wilson's Creek remain relatively high (Missouri Department of Natural Resources 2007) which can encourage algal growth. The water treatment plant currently reduces phosphorus discharge levels to an average of 0.5 mg/L (Bowles 2010 cite http://www.springfieldmo.gov/sanitary/phosphorus.html), however the EPA recommends that total phosphorus should not exceed 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs. Bowles (2010), citing Mueller and Helsel (1996), reports that nitrate concentrations in streams are usually less than 0.6 mg/L. The Missouri Department of Natural Resources (2007) reports that in Wilson's Creek nitrate-nitrite and total nitrogen concentrations are 1.73 mg/L and 1.93 mg/L respectively.

Bowles (2010) reported that even with stream degradation, invertebrate populations have not decreased from the levels recorded in earlier surveys by Harris et al. (1991) and Peitz and Cribbs (2005). Based on the five water quality parameters analyzed for this report, only specific conductance is rated as being off target over most of the period of record (Table 5-7). Temperature, dissolved oxygen, pH, and turbidity are all rated as being on target over their respective periods of record.

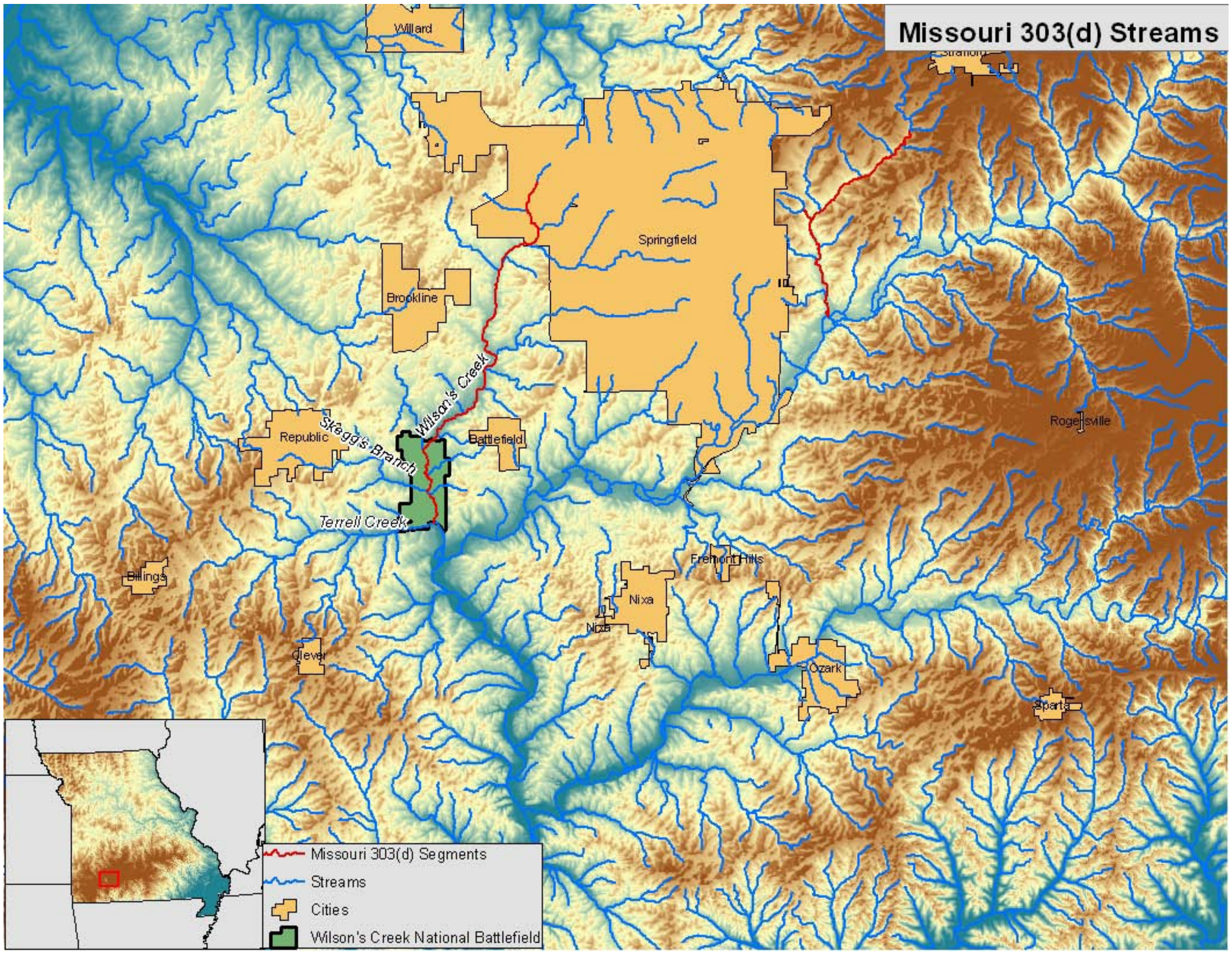

Figure 5-29. Wilson's Creek flowing through Wilson's Creek national Battlefield is classified as a 303(d) listed stream. Data source: 303(d) Listed Impaired Waters NHD Indexed Dataset Extracted on August 1, 2010 (http://www.epa.gov/waters/data/downloads.html).

Table 5-13. Water quality indicators for Wilson's Creek.

Indicator	Management Target	Mean[1,2]	Rating
Temperature (°C)			
1989	0-34 °C	22.3	On Target
1999	0-34 °C	22.4	On Target
2000	0-34 °C	14.7	On Target
2001	0-34 °C	19.5	On Target
2002	0-34 °C	17.0	On Target
2003	0-34 °C	16.2	On Target
2004	0-34 °C	23.2	On Target
2005	0-34 °C	19.8	On Target
2006	0-34 °C	21.0	On Target
2007	0-34 °C	18.5	On Target
Mean	0-34 °C	19.5	On Target
Specific Conductance (µS/cm @ 25°C)			
1979	100-400 µS/cm	320.0	On Target
1999	100-400 µS/cm	741.0	Off Target
2000	100-400 µS/cm	457.4	Off Target
2001	100-400 µS/cm	797.3	Off Target
2002	100-400 µS/cm	791.1	Off Target
2003	100-400 µS/cm	893.1	Off Target
2004	100-400 µS/cm	576.7	Off Target
2005	100-400 µS/cm	774.4	Off Target
2006	100-400 µS/cm	760.0	Off Target
2007	100-400 µS/cm	643.0	Off Target
Mean	100-400 µS/cm	675.4	Off Target
Dissolved Oxygen (mg/L)			
1999	5-15 mg/liter	7.6	On Target
2000	5-15 mg/liter	9.2	On Target
2001	5-15 mg/liter	8.9	On Target
2002	5-15 mg/liter	9.3	On Target
2003	5-15 mg/liter	9.1	On Target
2005	5-15 mg/liter	9.2	On Target
2006	5-15 mg/liter	7.9	On Target
Mean	5-15 mg/liter	8.7	On Target
pH			
1989	6.5-9.0	7.6	On Target
1999	6.5-9.0	7.4	On Target
2000	6.5-9.0	7.5	On Target
2001	6.5-9.0	7.6	On Target
2002	6.5-9.0	7.4	On Target
2003	6.5-9.0	7.3	On Target
2004	6.5-9.0	7.4	On Target
2005	6.5-9.0	7.5	On Target
2006	6.5-9.0	7.7	On Target
Mean	6.5-9.0	7.5	On Target
Turbidity (NTU)			
2006	<10 NTU	5.9	On Target
2007	<10 NTU	4.3	On Target
Mean	<10 NTU	5.1	On Target

[1] Mean from USGS stream gauge 07052160, Harris et al. (1991), Bowles (2010), and unpublished Heartland data.

[2] Years with data from more than one source were averaged.

Surface Water Flow

Storm water from urban areas is known to contribute pollutants to streams as well as increase the magnitude, duration, and frequency of storm water flows. The modified stream flows can alter the stream channel through scouring, channelization, and incision, and can modify substrate types. Wilson' Creek is generally considered to be a stream with surface water flows that are impacted by the effects of urbanization and discharges of a waste water treatment plant. The altered hydrograph for Wilson's Creek generally exhibits increased peak flows and reduced baseflows (EPA Undated). Because Wilson's Creek drains much of Springfield, it is prone to flashiness after even modest rainfall amounts (Richards and Johnson 2002).

Reviewing reveals that Wilson's Creek has high spring flows with the months of August, September and October exhibiting the lowest mean monthly flows over the available period of record. Discharge from the Springfield Southwest Waste Water Treatment Plant (WWTP), located on the confluence of Wilson Creek and South Creek, affects stream hydrology in a number of ways and increases daily average flows over all flow ranges. t is important to note that below the WWTP nearly all baseflow is provided by the plant. Low flow effects of urbanization are somewhat mitigated for areas below the WWTP because the constant discharge of the plant provides adequate flow during dryer periods (EPA Undated). Because Wilson Creek is a losing stream over much of its length comparing its lower flows to reference streams is not applicable (EPA Undated).

Because of some of the flow caveats associated with impervious surface and the WWTP, the analysis below should be interpreted with some caution as the entire period of record is impacted by both urban impervious cover and the WWTP. These analyses results report on the most recent four years of record compared to a baseline from the period of record. The baseline is not based on a natural or unaltered flow condition, but on a somewhat intermittent POR from 1969 to 2004.

Figure 5-177 and Figure 5-188 present the hydrologic index comparisons normalized to a POR baseline. Management targets and ratings were derived from Figure 5-17. Final ratings were established using the most recent period of record for the monitoring station. To determine the rating categories, the data were normalized for every index and the most recent period of record was compared to the POR. Ratings were based on deviation 1.0, either higher or lower. Thus if an index for the most recent POR fell within 0.25 of 1.0, the rating was good; >.25 but <.75 was fair, and >.75 was poor.

Recognizing that the management and ratings are based on a period of record that is influenced by the city of Springfield over the entire period, hydrologic indicators that deviate the most from the POR baseline, thereby receiving a "fair" rating, include mean minimum flow for August, high flood pulse count, annual minimum of 7-day moving average, and the Julian date of the annual maximum (Table 5-8). Assessed in this manner, 60% of the flow indicators are rated as good while the remaining 40% are rated fair.

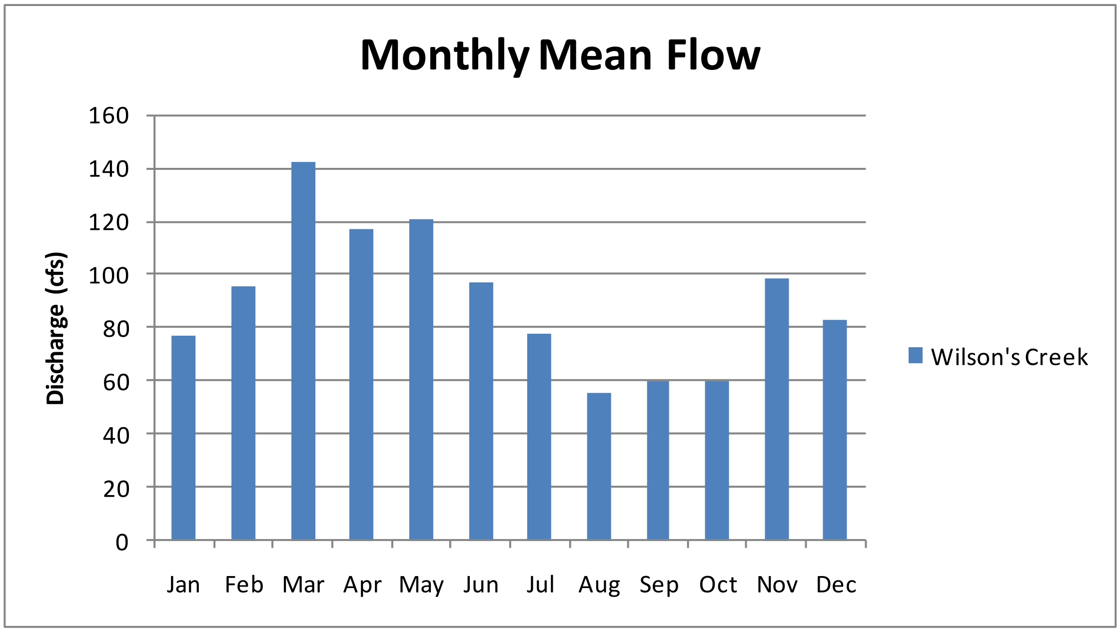

Figure 5-30. Mean monthly discharge (cubic feet per second) for monitoring station on Wilson's Creek.

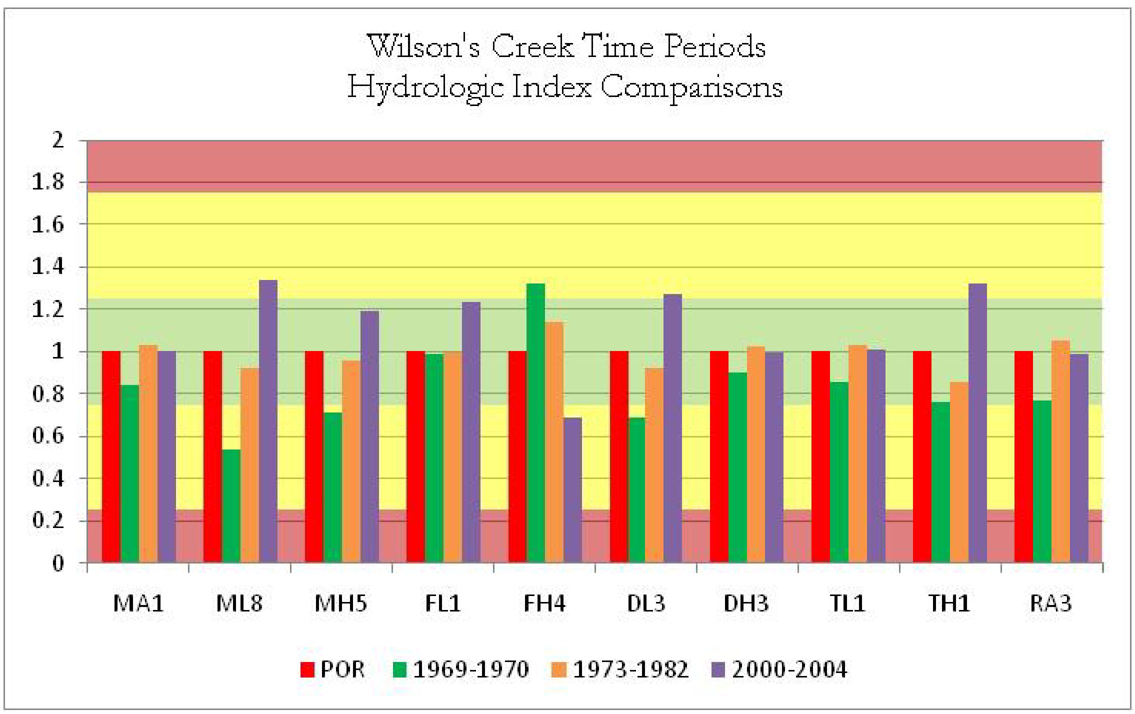

Figure 5-31. Wilson's Creek hydrologic index comparisons. Data normalized to period of record average baseline. The ratings for the park are classified into three categories, the first is Good (green) the second is Fair (yellow) and the last is Poor (red). To determine the categories, the data were normalized for every index at each monitoring station and the most recent time period was compared to the period of record. Ratings were based on deviation 1.0, either higher or lower. Thus, if an index from the most recent time period fell within 0.25 of 1.0, the rating was Good; >.25 but <.75 was Fair, and >.75 was Poor.

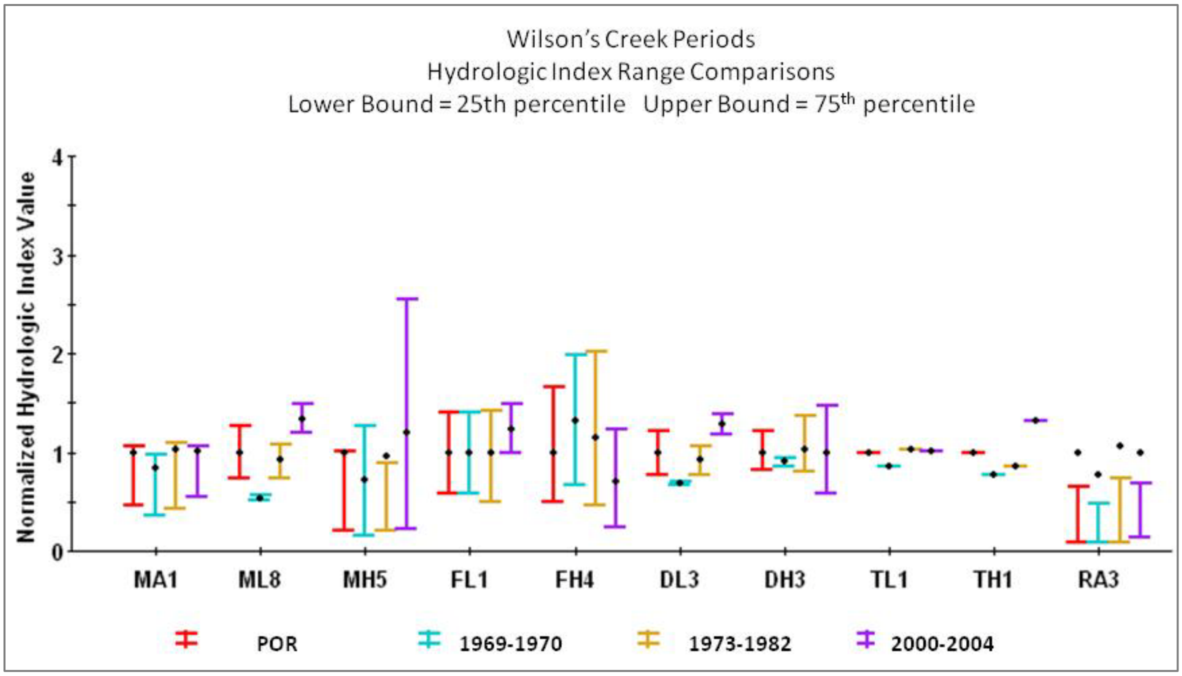

Figure 5-32. Wilson's Creek hydrologic index range comparisons. Data normalized to period of record (POR) baseline.

Table 5-14. List of hydrological indicators with normalized values, mean values, and management targets from 2000-2004 for Wilson's Creek.

Indicators	Definition	Normalized Value	Values	Management Target	Rating
MA1	Mean daily flow (cfs) for the period of record	1.006	91.3	68.1 - 113.6	On Target
ML8	Mean minimum flow (cfs) for August	1.337	45.0	25.2 - 42.1	Off Target
MH5	Mean maximum flows (cfs) for May	1.193	716.2	450.1 - 750.1	On Target
FL1	Low flood pulse count (#)	1.238	15.0	9.1 - 15.1	On Target
FH4	High flood pulse count (#)	0.693	4.2	4.5 - 7.6	Off Target
DL3	Annual minimum of 7-day moving average flow (cfs)	1.274	38.8	22.8 - 38.0	Off Target
DH3	Annual maximum of 7-day moving average flow (cfs)	0.997	486.7	366.1 - 610.2	On Target
TL1	Julian date of annual minimum	1.013	293.8	217.6 - 362.7	On Target
TH1	Julian date of annual maximum	1.32	130.0	73.9 - 123.2	Off Target
RA3	Fall rate (cfs/day)	0.987	22.9	17.4 - 29.1	On Target

Fish Community Composition and Condition

The fish species commonly collected in Wilson's Creek are fairly typical of an Ozark stream (Peterson and Justus 2005b). Collections made between 1984 and 2007 indicate that 42 fish species have been collected from the creek within WICR.

Reviewing Table 5-9 reveals that, based on data collected in 2007, only sucker composition is rated as being off target. The current IBI value of 93 is very good and is notably higher than the base management target. This implies that despite the fact the water quality in Wilson's Creek can be poor and the stream is listed as a 303(d) stream, fish are still able to utilize the available habitats when water quality conditions improve. It is important to note that for all fish community indicators other than IBI the management target and reference condition values were derived from the mean values from two years of data (2006 and 2007).

Results of the Jaccard Similarity analyses reveal that more fish species were collected from stream segments in Wilson's Creek than were modeled to occur in those same areas for any of the assessed time periods (Table 5-10 and Table 5-11). This information further supports the conclusion that the fish community in Wilson's Creek is still able to utilize the available habitat when not severely impacted by problems with water quality. The common carp is an introduced species known to inhabit Wilson's Creek.

The conservation status of a species is designated by a number from 1 to 5, preceded by a letter designating the geographic scale of the assessment (G = Global; S = State). The five point scale ranges from 1 (critically imperiled) to 5 (demonstrably secure). Additional qualifiers may be applied to the scale. The conservation status numbers designate the following (NatureServe 2008):

1= Critically imperiled

2 = imperiled

3 = Vulnerable to extirpation or extinction

4 = Apparently secure

5 = Demonstrable widespread, abundant, and secure

Determining which and how many species are secure or imperiled is important for understanding the condition of an ecosystem and for targeting conservation. No fish species collected from Wilson's Creek are designated as critically imperiled (G1) or imperiled (G2) on a global scale (Table 5-12). A single species, the Ozark chub (*Erimystax harryi*) is listed as G3G4Q with a rounded global status of G3 (NatureServe 2010). There are no S1, S2, or S3 fish species known to occur in Wilson's Creek in the park.

Table 5-15. Ratings for five fish metrics computed for Wilson's Creek.

Indicator	Management Target	Reference Condition	Current Condition	Rating
Simpson's Diversity	<0.15	0.07	0.09	On Target
Sucker Composition (%)	>1.26	1.37	1.20	Off Target
Sunfish Composition (%)	>11.03	20.7	17.87	On Target
Benthic spp. Composition (%)	>34.10	55.37	49.14	On Target
Index of Biotic Integrity (IBI)	>60	80	93	On Target

Table 5-16. Fish species observed1 and predicted2 to occur in Wilson's Creek.

Collected Not Predicted	Predicted Not Collected	Shared
Banded Darter	Brook Silverside	Banded Sculpin
Black Redhorse	Creek Chubsucker	Bigeye Shiner
Channel Catfish	Golden Shiner	Black Bullhead
Fantail Darter	Grass Pickerel	Blackspotted Topminnow
Fathead Minnow[4]		Bluegill
Gizzard Shad		Bluntnose Minnow
Golden Redhorse		Central Stoneroller
Greenside Darter		Common Carp[3]
Hornyhead Chub		Creek Chub
Largescale Stoneroller		Duskystripe Shiner
Mottled Sculpin[5]		Green Sunfish
Northern Hog Sucker		Largemouth Bass
Ozark Bass		Logperch
Ozark Chub		Longear Sunfish
Ozark Sculpin		Orangethroat Darter
Rainbow Darter		Ozark Minnow
Rosyface Shiner		Smallmouth Bass
Southern Redbelly Dace		Stippled Darter
Striped Shiner		Western Mosquitofish
Telescope Shiner		White Sucker
Yellow Bullhead		
Yoke Darter		

[1] Observed species from Donegan (1984), Hoefs and Boyle (1990), Peterson and Justus (2005b), and unpublished Heartland data.
[2] Predicted species based on Aquatic GAP species distribution models.
[3] Introduced species
[4] Likely escaped from bait bucket - recorded in 1989.
[5] Not typically found in this region - recorded in 1984, 1985, and 1989.

Table 5-17. Jaccard Similarity computed for Wilson's Creek.

Wilson's Creek	Overall	1984-1989[1]	2003-2007[2]
Total Species Collected	42	34	32
Total Species Modeled	24	24	24
Collected not Predicted	22	16	17
Predicted not Collected	4	6	9
Collected and Predicted (Shared)	20	18	15
Introduced Species	1	1	1
Jaccard Similarity[3]	44%	45%	37%
Jaccard Similarity[4]	42%	44%	38%

[1] Data from Donegan (1984) and Hoefs and Boyle (1990).
[2] Data from Peterson and Justus (2005b) and unpublished Heartland data.
[3] Jaccard Similarity computed using all species.
[4] Jaccard Similarity computed after removing introduced species.

Table 5-18. Number of globally listed fish species (G-rank) and state listed fish species (S-rank) by actual collections and models in Wilson's Creek.

	Wilson's Creek	
Rank	Collection	Model
G3G4Q	1	0
G4	3	1
G5	38	23
S4	3	0
S?	38	23
SE	1	1

Aquatic Invertebrates

Bowles (2010) provides a complete discussion of aquatic invertebrate community metrics for Wilson's Creek. As evidenced in Table B-1 the invertebrate metrics are quite variable over the years sampled. Considering trends in the data record for each metric reveals that family richness has generally declined over the POR, but data from the last three years have shown marked improvements. Trends in genus richness, EPT richness, and EPT ratio have been variable without a pronounced trend. Shannon Index and Shannon Evenness Index both exhibit improving trends while the Hilsenhoff Biotic Index has stayed very close to the management target. As discussed in Bowles (2010), despite being an impaired creek, invertebrate collections from recent years indicate that the condition of the stream has not declined compared to conditions earlier in the POR.

Reporting Unit: Skegg's Branch (Shuyler Creek)

Aquatic Threats

Skegg's Branch drains much of the city of Republic, Missouri and as such approximately 30% of the Skegg's Branch watershed is classified as impervious surface mostly in the upper portions of the watershed (Figure 2-5, Figure 2-6, and Table 5-13). Threats associated with urban areas are prominent in the upper portions of the watershed. Fifty-two percent of the watershed is represented in land cover classed as pasture/hay which is the principal land cover class below Republic, Missouri. There are four leaking underground storage tanks and 19 headwater impoundments. Table 5-13 provides a list of all potential threats that were quantified in Skegg's Branch. Based on the year 2000 population data, approximately 6,235 people live in the watershed (321 people per km^2).

Table 5-19. Quantified threats for Skegg's Branch in Wilson's Creek National Battlefield. Values are from the last stream segment before entering Wilson's Creek.

Human Threat	# or amount	% or Density
Impervious	5817600 m^2	29.93%
Cropland	160200 m^2	0.82%
Pasture/Hay	10125000 m^2	52.09%
Road/Stream Crossings	32	1.65 pkm^2
Roads	90809 m	4672 pkm^2
Railroads	1443 m	74 pkm^2
Water Wells	69	3.55 pkm^2
CERCLIS	1	0.05 pkm^3
Leaking Underground Storage Tanks	4	0.21 pkm^2
Pipelines	5367 m	276 pkm^2
Crop Pesticides	133 kg	6.83 pkm^2
Headwater Impoundments	19	0.98 pkm^2
Livestock Sales	$180,000	9261 pkm^2
2000 Population	6235	321 pkm^2
Hazardous Generators	3	0.15 pkm^2

Water Quality

Despite draining much of the city of Republic, Skegg's Branch water quality and invertebrate communities are in relatively good condition (Bowles 2010). Based on data assessed for this report, water quality in Skegg's Branch is on target for all years and all parameters except specific conductance (Table 5-14). Although rated as on target in 2005, specific conductance was off target in 2006 and 2007 which were the last two years for which data weres available. The City of Republic, Missouri in the upper portion of the Skegg's Branch watershed is presently experiencing rapid growth which raises concerns about future water quality.

Table 5-20. Water quality for Skegg's Branch.

Indicator	Management Target	Mean[1,2]	Rating
Temperature (°C)			
1989	0-34 °C	18.5	On Target
2005	0-34 °C	16.4	On Target
2006	0-34 °C	18.7	On Target
2007	0-34 °C	15.3	On Target
Mean	0-34 °C	17.2	On Target
Specific Conductance (µS/cm @ 25°C)			
2005	100-400 µS/cm	399	On Target
2006	100-400 µS/cm	495.8	Off Target
2007	100-400 µS/cm	489.5	Off Target
Mean	100-400 µS/cm	467.4	Off Target
Dissolved Oxygen (mg/L)			
2005	5-15 mg/liter	9.3	On Target
2006	5-15 mg/liter	8.8	On Target
Mean	5-15 mg/liter	9.1	On Target
pH			
1989	6.5-9.0	7.9	On Target
2005	6.5-9.0	7.4	On Target
2006	6.5-9.0	7.9	On Target
Mean	6.5-9.0	7.7	On Target
Turbidity (NTU)			
2006	<10 NTU	0.7	On Target
2007	<10 NTU	2.1	On Target
Mean	<10 NTU	1.4	On Target

[1] Mean from Harris et al. (1991), Bowles (2010), and unpublished Heartland data.
[2] Years with data from more than one source were averaged.

Fish Community Composition and Condition

Fish collections made in 2003 and 2007 document nine fish species in Skegg's Branch within WICR (Table 5-15 and Table 5-16). Fish predictive distribution models indicate that 17 fish species could be expected to occur in Skegg's Branch under relatively undisturbed conditions. The Jaccard Similarity between the observed and predicted fish communities is 30%.

Reviewing Table 5-17 reveals that of the three indicators with a condition rating all are within the established management target. Sucker composition and sunfish composition had no data and therefore could not be given a rating. No introduced species have been collected from Skegg's Branch in WICR.

No fish species collected from Skegg's Branch are designated as critically imperiled (G1) or imperiled (G2) on a global scale (Table 5-18). There are no S1, S2, or S3 fish species known to occur in Skegg's Branch within the park.

Table 5-21. Fish species observed1 and predicted2 to occur in Skegg's Branch.

Collected Not Predicted	Predicted Not Collected	Shared
Banded Sculpin	Black Bullhead	Central Stoneroller[3]
Ozark Sculpin	Bluegill	Creek Chub
Rainbow Darter	Bluntnose Minnow	Duskystripe Shiner
	Creek Chubsucker	Orangethroat Darter
	Golden Shiner	Southern Redbelly Dace
	Grass Pickerel	Stippled Darter
	Green Sunfish	
	Largemouth Bass	
	Ozark Minnow	
	Western Mosquitofish	
	White Sucker	

[1] Observed species from Peterson and Justus (2005b), and unpublished Heartland data.
[2] Predicted species based on Aquatic GAP species distribution models.
[3] Data recorded as Stoneroller sp. was assumed to be Central Stoneroller.

Table 5-22. Jaccard Similarity computed for Skegg's Branch.

Skegg's Branch	Number
Total Species Collected	9
Total Species Modeled	17
Collected not Predicted	3
Predicted not Collected	11
Collected and Predicted (Shared)	6
Introduced Species	0
Jaccard Similarity	30%

Table 5-23. Ratings for five fish metrics computed for Skegg's Branch.

Indicator	Management Target	Reference Condition	Current Condition	Rating
Simpson's Diversity	<0.24	0.13	0.16	On Target
Sucker Composition (%)	N/A	N/A	0.00	N/A
Sunfish Composition (%)	N/A	N/A	0.00	N/A
Benthic spp. Composition (%)	>34.3	60.64	52.92	On Target
Index of Biotic Integrity (IBI)	>60	80	73	On Target

Table 5-24. Number of globally listed fish species (G-rank) and state listed fish species (S-rank) by actual collections and models for Skegg's Branch.

	Skegg's Branch	
Rank	Collection	Model
G3G4Q	0	0
G4	2	1
G5	7	16
S4	0	0
S?	9	17
SE	0	0

Aquatic Invertebrates

As reported by Bowles (2010) the aquatic invertebrate metrics presented in Table B-2 do not definitively point to impairment. Looking at trends in the data reveal that genus richness has improved over the last three years. EPT richness is too variable to draw any firm conclusions, however consistently declining EPT ratios indicate that the more pollution tolerant Chironomidae make up an increasingly large portion of the benthic community (Bowles 2010). Both the Shannon Index and Shannon Evenness Index are variable, but have stable to slightly increasing linear trends. The Shannon Evenness Index is however off target for the entire period of record (POR). The Hilsenhoff Biotic Index trend is variable, but within the management target for the entire POR. As Bowles (2010) suggests the condition of the invertebrate communities in Skegg's Branch are not obviously degraded, but conditions should continue to be monitored due to continued development in the watershed.

Reporting Unit: Terrell Creek

Aquatic Threats

Unlike Wilson's Creek and Skegg's Branch, Terrell Creek does not drain an urban area and as such has a very small amount of impervious surface in the watershed (Figure 2-5, Figure 2-6, Figure 2-7 and Table 5-19). Most of the Terrell Creek watershed is comprised of Pasture/Hay land use (73%). Cropland is not a significant land use in the watershed. There are 219 water wells and 72 headwater impoundments in the drainage. Based on the year 2000 census data, 2,215 people reside in the watershed (31 people per km^2). Table 5-19 provides a complete list of the potential threats quantified in the Terrell Creek watershed.

Table 5-25. Quantified threats for Terrell Creek in Wilson's Creek National Battlefield. Values are from the last stream segment before entering Wilson's Creek.

Human Threat	# or amount	% or Density
Impervious	1221300 m^2	1.73%
Cropland	488700 m^2	0.69%
Pasture/Hay	51690600 m^2	73.16%
Road/Stream Crossings	48	0.68 pkm^2
Roads	121619 m	1721 pkm^2
Railroad/Stream Crossings	6	0.08 pkm^2
Railroads	10532 m	149 pkm^2
Water Wells	218	3.09 pkm^2
Other Mines (not lead or coal)	1	0.01 pkm^2
Pipelines	9208 m	130 pkm^2
Crop Pesticides	398 kg	5.63 pkm^2
Headwater Impoundments	72	1.02 pkm^2
NPDES	4	0.06 pkm^2
Livestock Sales	$330,000	4670 pkm^2
Leaking Underground Storage Tanks	1	0.01 pkm^2
2000 Population	2215	31 pkm^2

Water Quality

Water quality in Terrell Creek is generally good with most of the watershed draining undeveloped rural areas and, as importantly, much of the stream flow comes from Double Spring located within the boundaries of WICR (Bowles 2010). All indicators except specific conductance are rated as on target for the available POR (Table 5-20).

Table 5-26. Water quality indicators for Terrell Creek.

Indicator	Management Target	Mean[1,2]	Rating
Temperature (°C)			
2006	0-34 °C	16.3	On Target
2007	0-34 °C	14.8	On Target
2008	0-34 °C	13.6	On Target
Mean	0-34 °C	14.9	On Target
Specific Conductance (µS/cm @ 25°C)			
2006	100-400 µS/cm	471.7	Off Target
2007	100-400 µS/cm	472.3	Off Target
2008	100-400 µS/cm	375.2	On Target
Mean	100-400 µS/cm	439.7	Off Target
Dissolved Oxygen (mg/L)			
2006	5-15 mg/liter	9.0	On Target
2007	5-15 mg/liter	7.2	On Target
2008	5-15 mg/liter	11.3	On Target
Mean	5-15 mg/liter	8.9	On Target
pH			
2006	6.5-9.0	7.4	On Target
2007	6.5-9.0	7.8	On Target
2008	6.5-9.0	7.9	On Target
Mean	6.5-9.0	7.7	On Target
Turbidity (NTU)			
2006	<10 NTU	2.7	On Target
2007	<10 NTU	1.1	On Target
Mean	<10 NTU	1.9	On Target

[1] Mean from Bowles (2010) and unpublished Heartland data.
[2] Years with data from more than one source were averaged.

Fish Community Composition and Condition

Terrell Creek fish community collections within WICR from 2007 documented eleven species of fish (Table 5-21 and Table 5-22). Fish species predictive distribution models from the Missouri Aquatic Gap Project indicate that as many as 25 species could inhabit the creek within WICR. Jaccard Similarity between the observed and predicted fish communities is 39%.

In 2007, Simpson's Diversity and sucker composition were outside of the management target (Table 5-23). Although less than the generally accepted reference condition of >80, the fish IBI of 61 for Terrell Creek is still considered good (Dauwalter et al. 2003). It should be noted though that Terrell Creek has the lowest computed fish IBI (based on data from 2007) of the three streams considered in the WICR analyses.

No fish species collected from Terrell Creek are designated as critically imperiled (G1) or imperiled (G2) on a global scale (Table 5-24). There are no S1, S2, or S3 fish species known to occur in Terrell Creek within the park.

Table 5-27. Fish species observed1 and predicted2 to occur in Terrell Creek.

Collected Not Predicted	Predicted Not Collected	Shared
Blackspotted Topminnow	Black Bullhead	Banded Sculpin
	Bluegill	Central Stoneroller
	Creek Chubsucker	Creek Chub
	Grass Pickerel	Duskystripe Shiner
	Green Sunfish	Largescale Stoneroller
	Hornyhead Chub	Orangethroat Darter
	Largemouth Bass	Ozark Sculpin
	Northern Hogsucker	Southern Redbelly Dace
	Ozark Bass	Stippled Darter
	Ozark Minnow	White Sucker
	Rainbow Darter	
	Rainbow Trout[3]	
	Slender Madtom	
	Striped Shiner	
	Telescope Shiner	

[1] Observed data from unpublished Heartland data.
[2] Predicted species based on Aquatic GAP species distribution models.
[3] Introduced species

Table 5-28. Jaccard Similarity computed for Terrell Creek.

Terrell Creek	Number
Total Species Collected	11
Total Species Modeled	25
Collected not Predicted	1
Predicted not Collected	15
Collected and Predicted (Shared)	10
Introduced Species	1
Jaccard Similarity[1]	39%
Jaccard Similarity[2]	40%

[1] Jaccard Similarity computed using all species.
[2] Jaccard Similarity computed after removing introduced species.

Table 5-29. Ratings for five fish metrics computed for Terrell Creek.

Indicator	Management Target	Reference Condition	Current Condition	Rating
Simpson's Diversity	<0.50	0.16	0.73	Off Target
Sucker Composition (%)	>1.53	3.09	0.42	Off Target
Sunfish Composition (%)	N/A	N/A	0.00	N/A
Benthic spp. Composition (%)	>61.64	61.65	90.36	On Target
Index of Biotic Integrity (IBI)	>60	80	61	On Target

Table 5-30. Number of globally listed fish species (G-rank) and state listed fish species (S-rank) by actual collections and models for Terrell Creek.

	Terrell Creek	
Rank	Collection	Model
G3G4Q	0	0
G4	2	2
G5	9	23
S4	0	1
S?	11	23
SE	0	1

Aquatic Invertebrates

The relatively short two year data record for aquatic invertebrates in Terrell Creek make assessments of the resource condition difficult (Table B-3). As evidenced in the table, data from 2007 indicated a reduction in community condition for every indicator considered. However, as (Bowles 2010) indicates, the data suggest that the communities and therefore the water quality conditions are generally good. The Terrell Creek watershed is mostly rural with a majority of stream flow coming from a spring within WICR. Higher richness and diversity values for Terrell Creek compared to Wilson's Creek or Skegg's Branch may be due to the substantial spring flow inputs.

Chapter 6 Integrated Evaluation and Discussion

Logic-based Evaluation

Bringing together many metrics from numerous natural systems with the intention of assessing the condition of the park natural resources yields an impressive amount of information to interpret. To facilitate the interpretation of the condition assessment, a logic-based evaluation was undertaken. Integrating multiple evaluations into a single model requires an ecological understanding of the relationships among all of the model components. The ecological relationships are reflected in the logical connections used to create a unified framework.

A logic model-based framework was created to evaluate each indicator for which both current data and a management target were available. This type of framework is focused on the logical relationship of components within and among reporting units as presented in the previous chapter. The framework is hierarchical so that indicators within an attribute are evaluated as well as attributes within a resource type and/or reporting unit. A hierarchical framework allows for integrated analysis among different components of the resource types and reporting units that are found within the park. The logic-based framework was designed to address the validity of the statement "the current condition approximates the management target". If the statement is valid, then there is full support for the current condition approximating the management target. For each level in the hierarchy, an assessment score is provided that corresponds to the degree that the statement is valid. Result scores are on a [0 – 1] scale with zero reflecting that there is no validity (i.e. no support) to the statement while a score of one signifies that the statement is valid (i.e. full support). In addition, scores between zero and one provide a continuum of degree of validity which allows for partial support to be recognized. Evaluation scoring is based on fuzzy logic sets in which all degrees of support, not just binary "yes/no", are reported. Here each level in the hierarchy can be presented individually or as a partial assessment for all reporting units.

A logic-based integrated analysis is not a quantitative analysis of the park resources; rather it is a method of qualitative reasoning. The framework reflects expert knowledge about the park resources and provides a formal structure of how the resource components can be arranged or summarized. Such a method represents only one interpretation of the relationships within and among levels of the hierarchical framework. The core of the logic model evaluation is the knowledge base. Here we refer to a knowledge base as a formal and logical representation of best available information. Integrating data from many different attributes into a single knowledge base allows for a transparent synthesis and evaluation of park resources. This type of analysis is learning based and focused on supporting the decision making processes related to natural resource management.

Methods

The Natural Resource Condition Assessment per the national guidance represents the most up-to-date knowledge base of the parks resources. The logic model for evaluating all reporting units and associated resource types was graphically designed with NetWeaver Developer software (Rules of Thumb, Inc., North East, PA). This software uses a logic engine, similar to a database engine found in relational database software, to run the analysis. The knowledge base reflects the relationships between reporting units, resource types, attributes and indicators as presented in earlier chapters and tables included therein.

Hierarchical framework

Components of the knowledge base have been arranged into a hierarchical framework. Topics within each level of the hierarchy are joined together by logical operators. These operators form a logic model upon which the knowledge base is evaluated. The complete logic model for evaluating the current condition of resource types represents one possible logical interpretation of attributes and indicators. The reporting unit and all lower levels in the hierarchy can be modified to include new management objectives or logical relationships. The flexibility of the model means that any topic can be removed or added and most importantly, reference conditions can be updated throughout the adaptive management process.

The hierarchical framework reflects the nested arrangement of both spatially delineated areas within the park boundary (i.e. reporting unit) and assessment metrics (i.e. attributes and indicators) arranged within natural resource types in those areas (Figure 6-1).

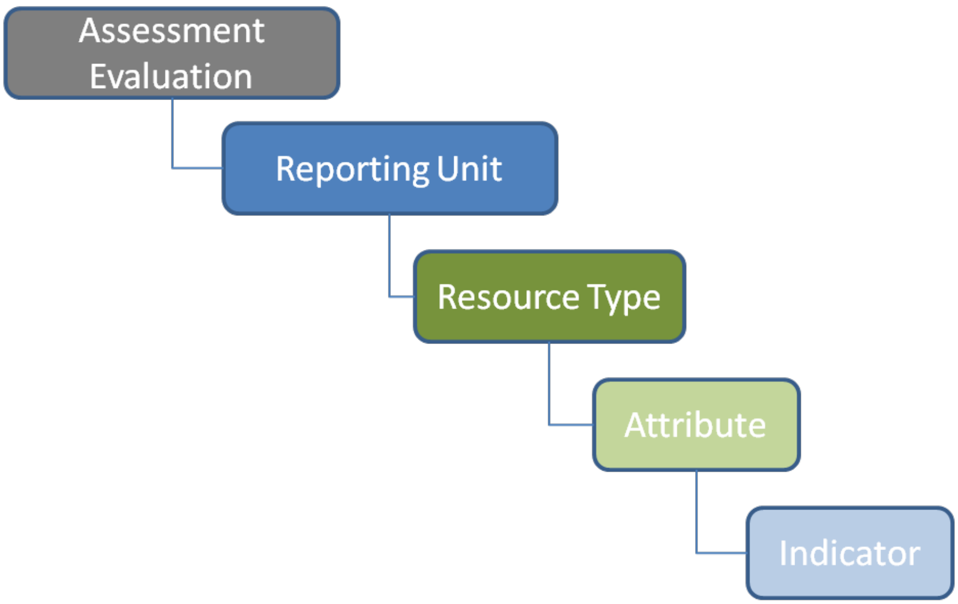

Figure 6-1. Hierarchical framework used in the integrated analysis of the Natural Resource Condition Assessment.

Applying the hierarchical arrangement (Fig. 6.1) to the NRCA creates a framework that illustrates the relationships of all reporting units to their resource types, attributes and indicators (Figs. 6.2 and 6.3). All topics in the logic-model correspond to the NRCA. Each node or level in the hierarchy represents the relationship of attributes and/or indicators within a resource type or reporting unit.

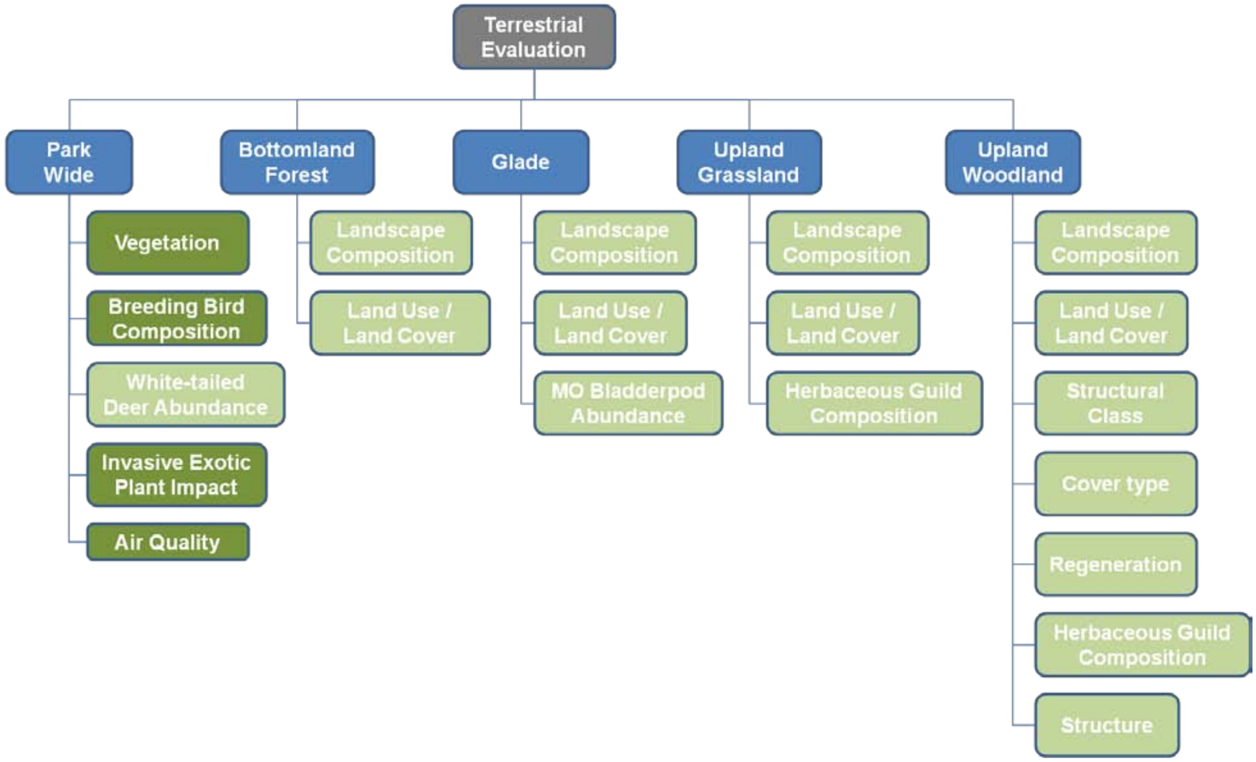

Figure 6-2. Higher levels of the model framework that reflect logical relationship of resource type (dark green) within reporting unit (blue) for the terrestrial assessment. Attributes are labeled light green.

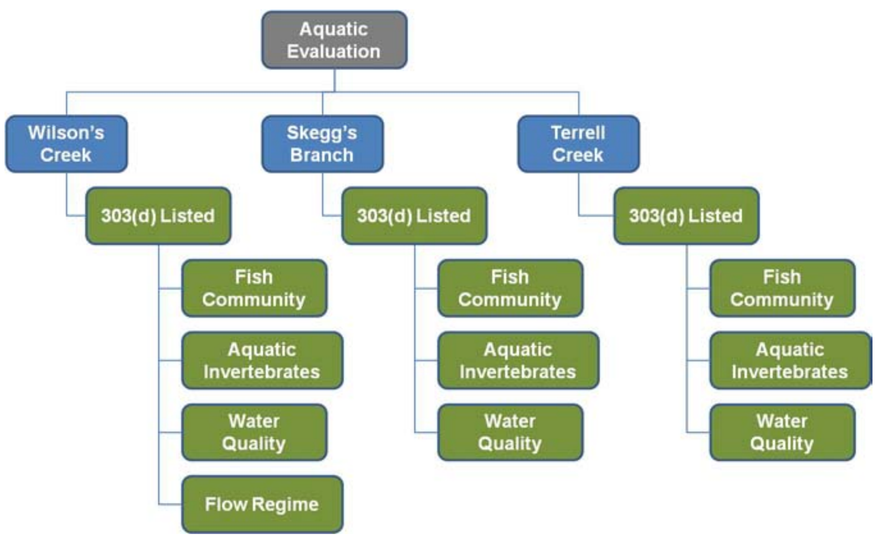

Figure 6-3. Higher levels of the model framework that reflect logical relationship of resource types within reporting unit (blue) for the aquatic assessment.

Logical operators

Indicators, attributes and resource types are evaluated at their next higher level in the model according to logical operators. These operators reflect the logical relationship within levels and how each topic contributes to the evaluation of the resource condition. Nearly all model topics are joined by the *union* operator. Topics related by a *union* incrementally contribute to the overall evaluation of the next higher level of the model. All metrics connected by a union operator contribute equally to the evaluation. Here the assumption is that each topic in the knowledge base contributes equally to the ability of the current condition to approximate the management target.

In a single case, indicators are related by an *and* operator. This type of operator requires that all indicators must be fully supported in order for the overall attribute evaluation to be supported. The landscape composition indicators are joined by the *and* operator. Therefore for current landscape condition to approximate the management target both patch count and mean patch size must be fully supported. If either indicator is not fully satisfied, then the landscape composition attribute will evaluate to no support.

For each aquatic reporting unit, the overall evaluation is conditional upon the stream being listed as a 303(d) stream. If the stream is listed, then the overall current condition does not approximate the management condition. If the stream is not listed, then the reporting unit is evaluated according to the other resource types.

Management target range

For each indicator within the hierarchical knowledge base an assessment is performed to determine how closely the current condition (input) coincides with the range of management targets (no support and full support columns in Table 6-1). Again, level of support reflects the degree to which the evaluation statement is valid. This target range was derived from management targets presented at the indicator level in Table 5-1. Converting management targets into a range of values from which the degree of support for the evaluation statement can be assessed is the basis of the integrated analysis. A conservative approach was used to develop the evaluation range of values from the initial management targets in chapter 5. Full support for the evaluation statement corresponds to the management target value(s) in Table 5-1. For those indicators with a management target greater than (>) or equal to (≥) a target number in Table 5-1, the "no support" management target value was set to 50% less than the stated target. This resulted in a range of values from no support (management target – 50%) to full support (management target). The opposite methodology was applied to those indicators with management target less than (<) or equal to (≤) a target number in Table 5-1, the "no support" management target value was set to 50% more than the stated target. For these indicators the target range is from no support (management target + 50%) to full support (management target). In some cases the management target is a range of values (i.e. pH). Therefore full support corresponds to any value within the management target range presented in Table 5-1. No support values are derived from ± 50% of the range of full support values. For example, the range of full support for pH is 6.5 – 9.0, which is a spread of 2.5. Half of this spread (1.3) was subtracted from 6.5 and added to 9.0 to provide no support values of ≤ 5.2 or ≥ 10.3. This method was used in order to provide the most information as to how closely the current condition approximates the management target when the statement is not supported. The type of management target range is indicative of the type of evaluation ramp function used in the assessment.

Evaluation ramp

For each topic in the model (from reporting unit to resource type and down to indicator) there is an evaluation statement. The statement defines what is being evaluated at that level in the model (e.g. mean patch size or total area occupied by a community type) and always reflects the degree of validity for the statement. Full support (strength of evidence = 1.0) for the statement that mean patch size approximates the management target in the upland grassland community is determined by comparing the current input value against the management target (Figure 6-4). The management target range is the evaluation ramp function in NetWeaver. The ramp function indicates that a mean patch size of 10 ha or greater provides full support for the statement while a mean patch size of 5 ha or smaller provides no support (zero strength of evidence) for the condition being valid. This is the most common evaluation ramp function used in the analysis. All indicators with a target composed of a range between two values have this type of ramp function and subsequent analysis is similar to mean patch size (Figure 6-4).

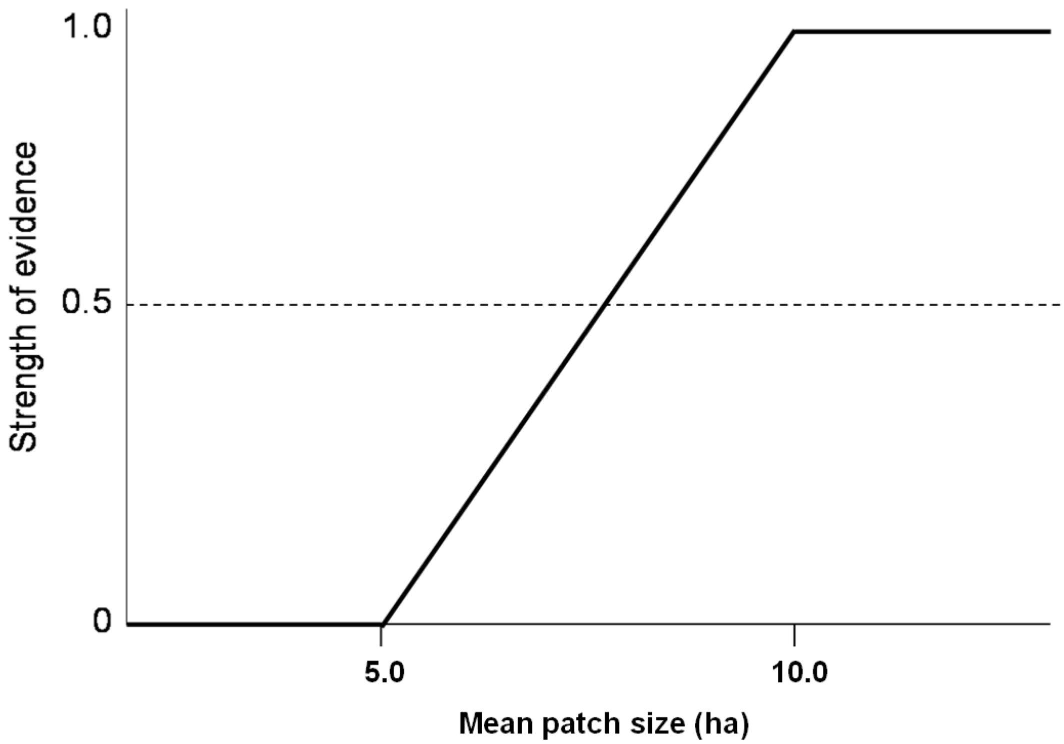

Figure 6-4. NetWeaver ramp function used to evaluate mean patch size in the upland grassland reporting unit of Wilson's Creek National Battlefield, Missouri.

Ramp functions reflect the type of evaluation required to assess the specific indicator and are based on ecological understanding of the underlying data being evaluated. For certain aspects of water quality too much or too little of a condition may not be appropriate for the community (Figure 6-5). A middle range of pH best reflects a valid pH condition for all three streams within the park.

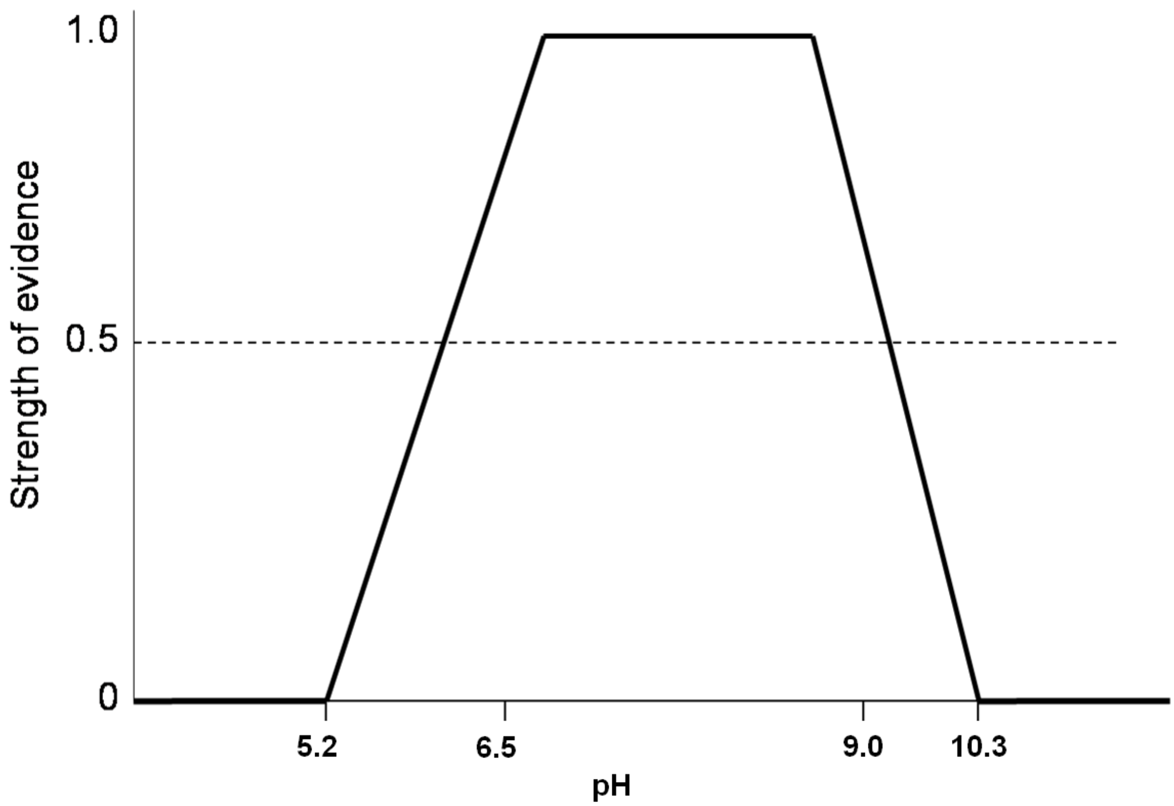

Figure 6-5. NetWeaver ramp function used to evaluate pH for all three aquatic reporting unit's of Wilson's Creek National Battlefield, Missouri.

Indicators with management targets and associated ramp functions similar to pH (Figure 6-5) represent the idea that more is not always better. For these indicators, an optimum range of values have been identified. Therefore full support (strength of evidence = 1.0) is achieved when the input value is between 6.5 and 9.0. No support (strength of evidence = 0) reflects any input value ≤ 5.2 or ≥ 10.3. Input values for pH between 5.2 and 6.5 or between 9.0 and 10.3 evaluate to partial support for the current condition of pH approximating the management target.

Evaluation output

Evaluation results obtained from NetWeaver are rescaled to [0 -1] to facilitate interpretation. The continuous normalized scores have been divided into seven color coded categories that reflect the degree to which the current condition approximates the management target (Figure 6-6). No support (output score = 0) is red while full support (output score = 1) is dark blue. Five partial support categories were created based on 0.2 breaks in scores between 0.01 and 0.99.

Figure 6-6. Color coded evaluation score categories derived from rescaled NetWeaver evaluation scores.

Numerical evaluations of fuzzy logic models provide a continuous range of results. The categorized output can be used to build dashboard reporting to increase ease of interpretation. The logic model, as implemented in NetWeaver, is focused on interpretation rather than prediction of the current conditions.

Results

The results of the integrated analysis reflect the evaluation of validity of the statement: "the current condition approximates the management target". The direct evaluation of current conditions is performed at the indicator level only. Above this level, evaluation scores are a function of the direct evaluation score below and the logical operator linking the indicators. Together, scores are passed upward in the hierarchy which allows for the evaluation of attributes, resource types and reporting units indirectly. As the NetWeaver output scores approach 1.0 the degree of support for the validity of the statement increases while scores closer to zero point to less support for the current condition approximating the management target. Even though this is not a quantitative analysis of indicators, it is a qualitative evaluation of the best available knowledge as identified by the Natural Resource Condition Assessment.

Results are presented and summarized to the reporting unit. Evaluation scores are presented for each level of the hierarchy up to the reporting unit level of the framework (Figure 6-7, Figure 6-8).

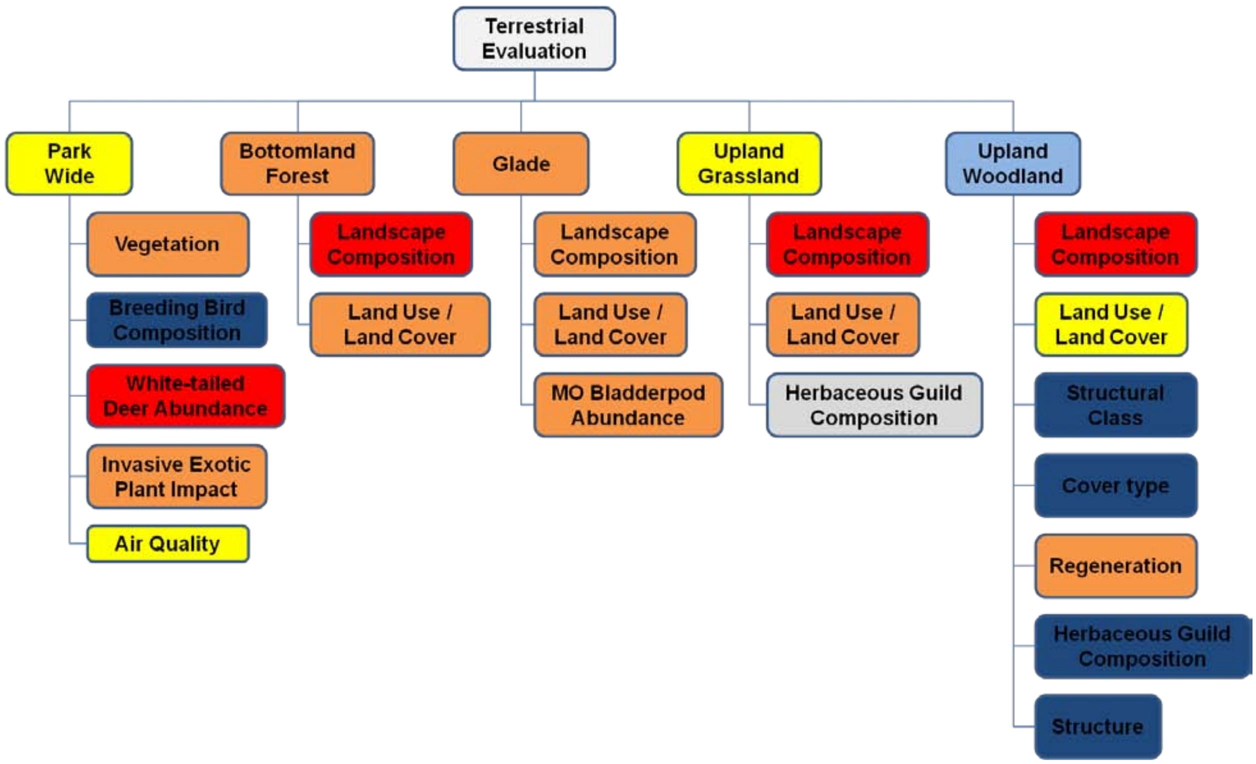

Figure 6-7. Color coded evaluation results for each terrestrial reporting unit and its associated resource type and/or attributes.

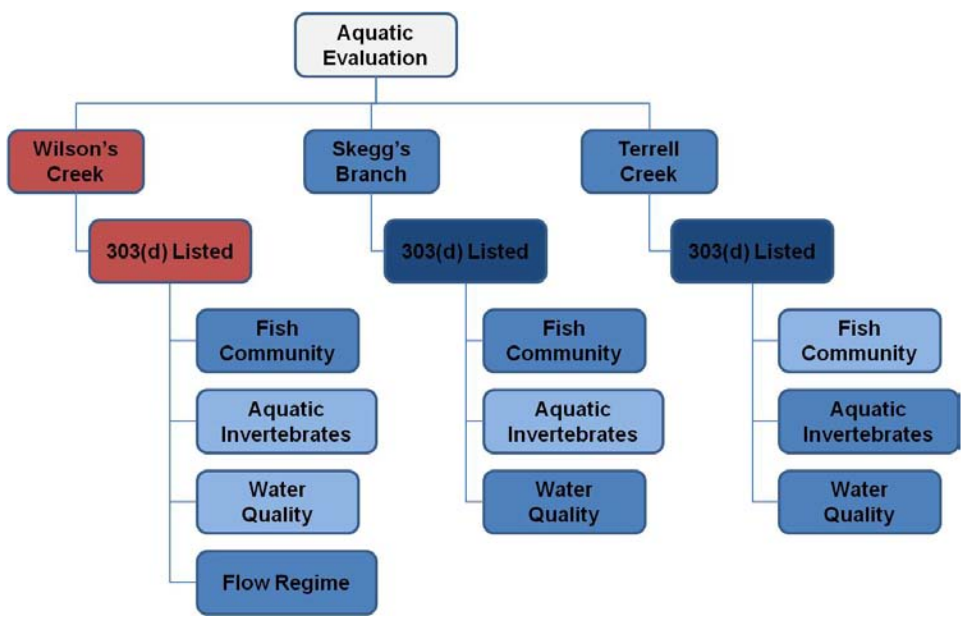

Figure 6-8. Color coded evaluation results for each aquatic reporting unit and its associated resource types.

Reporting unit: Park Wide

Overall support for the park wide reporting unit is moderately low (output score = 0.31). The number of community patches throughout the park was too high while their mean patch size was too small, which resulted in no support (output score = 0) for landscape composition at the park wide scale (Table 6-1). This reflects a fragmented landscape composed of numerous small patches. There was moderate support (output score = 0.4) for the composition of those patches, primarily because of the amount of cultural land cover type in the park. However the amount of semi-natural or natural community types was low while there was a large amount of successional community types detected at the park wide scale.

The overabundance of deer in the park was offset by the number of breeding birds observed. Invasive exotic plants, while low in number of species detected (output score = .67) were observed in a both greater frequency and abundance as measured by foliar cover than their minimum management targets.

Air quality, while beyond the scope of the park boundary, had low support for approximating the management target. Atmospheric deposition did not provide any support while the amount of ozone detected was greater than the management target.

Table 6-1. Rescaled NetWeaver output scores for the integrated analysis of the park wide reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Park-wide							0.31
	Vegetation						0.2
		Landscape composition					0
			patch count	≥ 1313 or ≤ 562	1125 - 750	1819	0
			mean patch size (ha)	0.5	1	0.4	0
		Land use/Land cover					0.4
			semi-natural and natural types (ha)	350	750	425	0.19
			successioanal types (ha)	75	50	336	0
			cultural types (ha)	60	40	38	1
	Breeding bird community						1
			species richness	24	47	47	1
			Partners in Flight target species	5	10	10	1
			number of grassland obligate species	1	2	2	1
	White-tailed deer						
			index of relative abundance (individuals/km^2)	12	8	56.6	0
	Invasive exotic plant impact						0.22
			number of taxa	45	30	35	0.67
			frequency on transects (%)	75	50	91.9	0
			park-wide min cover estimate (%)	15	10	15.4	0
	Air quality						0.12
		Ozone					
			ozone (ppb)	75	60	72.2	0.24
		Atmoshperic deposition					0
			nitrogen (kg/ha/yr)	3	1	12.6	0
			sulfur (kg/ha/yr)	3	1	10.7	0

Reporting unit: Bottomland Forest

The bottomland forest reporting unit was evaluated according to the spatial arrangement and composition of patches within the delineated area of the community only (Table 6-2**)**. Within the forest, there were too many small patches (landscape composition output score = 0). Furthermore, the bottomland forest was composed by nearly equal amounts of bottomland forest and successional types.

Table 6-2. Rescaled NetWeaver output scores for the integrated analysis of the bottomland forest reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Bottomland forest							0.05
		Landscape composition					0
			patch count for forest	≥ 62 or ≤ 26	53 - 35	75	0
			mean patch size for forest (ha)	1	2	0.7	0
		Land use/Land cover					0.1
			bottomland forest (ha)	45	90	54	0.2
			successional types (ha)	29	19	59	0

Reporting unit: Glade

Glades are not only a unique type scattered throughout the park they have special management concerns as indicated by their reporting unit designation. The number of glade patches nearly approximates the management target (output score = .69, Table 6-3). However the mean patch size of glade patches is small, resulting in low support for the evaluation statement (output score = .08). For those glade areas, a greater amount of successional community types were detected than glade community types (land use/land cover output score = .17).

Missouri bladderpod populations are associated with a number of glades in the park. Their abundance serves as an indicator of glade condition. The management target range for each population was based on 80% of the minimum-maximum population size range over a ten year period (2001-2010) for that population. Overall support for abundance within each population approximating the management target is low (output score = 0.1).

Table 6-3. Rescaled NetWeaver output scores for the integrated analysis of the glade reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Glade							0.12
		Landscape composition					0.11
			patch count for all glade types	≥ 88 or ≤ 38	75 - 50	79	0.69
			mean patch size glade types (ha)	0.13	0.25	0.14	0.08
		Land use/Land cover					0.17
			glade types (ha)	7.5	15	10	0.33
			successional types (ha)	15	10	15	0
	Missouri Bladderpod						
		Abundance					0.1
			Bloody Hill population size (count)	11470	71847	5934	0
			Wire Road population size (count)	5527	48791	592	0
			Terrell Creek population size (count)	9	14	5	0
			Walnut Glade population size (count)	130	848	343	0.3
			North Bloody Hill glade population size (count)	117	1009	128	0.01
			Manley Woods glade population size (count)	121	617	252	0.26

Reporting unit: Upland Grassland

Overall support for the upland grassland reporting unit approximating the management target was low (output score = .09, Table 6-4). Again, this community type consisted of too many patches that were on average too small. Furthermore, most of the area within the reporting unit was currently classified as successional type rather than restored prairie type. However, there was high support for native grass abundance (output score = .81) and moderate support for native forb abundance (output score = .59). This support was offset within the herbaceous guild composition attribute by the large abundance of native woody shrub and vine guild (no support). The current input values for herbaceous guild composition indicators were based on a small sample area relative to the extent of the reporting unit. The monitoring sites from which the input values were compiled were considered to be representative of the larger prairie restoration areas within the park.

Table 6-4. Rescaled NetWeaver output scores for the integrated analysis of the upland grassland reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Upland grassland							0.09
		Landscape composition					0
			patch count for grassland	≥ 70 or ≤ 30	60 - 40	80	0
			mean patch size for grassland (ha)	5	10	3.4	0
		Land use/Land cover					0.08
			restored prairie (ha)	125	250	145	0.16
			successional types (ha)	83	55	161	0
		Herbaceous guild composition					0.19
			native grass (%)	30	60	54.4	0.81
			native forbs (%)	10	40	27.8	0.59
			native woody shrub and vine (%)	15	10	37	0

Reporting unit: Upland Woodland

Overall support for the upland woodland reporting unit is low (output score = .16, Table 6-5). Of all of the indicators within this reporting unit, hardwood canopy cover is the closest to approximating the management target (output score = .77). Of the hardwoods in the canopy, there is low support for their height approximating the management target (output score = .06). Moderate support was found for both the area occupied by natural and semi-natural woodland and the relative density of small saplings. However the reporting unit still consists of too many patches that are on average too small. Of note is the lack of support for oak and low support for hickory and walnut species basal area. These three genera make up the overstory composition cover type for the reporting unit. There is low support for the evaluation statement for the understory attributes (regeneration and herbaceous guild composition).

Table 6-5. Rescaled NetWeaver output scores for the integrated analysis of the upland woodland reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Upland woodland							0.16
		Landscape composition					0
			patch count for woodland	≥ 220 or ≤ 93	188 - 125	275	0
			mean patch size for woodland (ha)	1	2	0.8	0
		Land use/Land cover					0.27
			natural and semi-natural woodland (ha)	125	250	192	0.54
			successional types (ha)	50	33	91	0
		Structural class					0.31
			hardwood canopy cover (%)	45	80	72	0.77
			hardwood basal area (m^2/ha)	14	23	15	0.11
			density (stems/ha, trees > 8 cm dbh)	125	600	149	0.05
		Cover type					0.13
			oak species basal area (m^2/ha)	9	18.2	4.3	0
			hickory and walnut species basal area (m^2/ha)	2.1	8	3.6	0.25
		Regeneration					0.16
			cover type small saplings (>1.5 m tall, < 2.5 cm dbh) relative density (% of stems/ha)	25	50	37	0.48
			cover type large saplings (>1.5 m tall; > 2.5 and < 8 cm dbh) relative density (% of stems/ha)	25	50	19.4	0
			total cover type sapling relative density (% of stems/ha)	25	50	21.2	0
		Herbaceous guild composition					0.2
			native grass (%)	10	80	15.4	0.08
			native forbs (%)	1	40	15	0.36
			native woody shrub (%)	15	50	21	0.17
		Structure					
			hardwood tree height (m)	13	21.3	13.5	0.06

Reporting unit: Wilson's Creek

Since Wilson's Creek is a 303(d) listed stream, overall support for reporting unit was low (output score = 0, Table 6-6). However, for each of the other four resource types output scores ranged from .76 (aquatic invertebrates) to .91 (fish community and flow regime). Current water quality and flow regime for Wilson's Creek nearly match the management targets. Overall high output scores in the hierarchy reflect moderate or better support for most lower levels in the reporting unit logic model. Even though Wilson's Creek is an impaired stream, resources within the creek were still evaluated and found to be close to approximating management conditions.

Table 6-6. Rescaled NetWeaver output scores for the integrated analysis of the Wilson's Creek reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Wilson's creek							0
	303(d) listed			0	1	0	0
	Water quality						0.8
			temperature (°C)	≤ -17 or ≥ 51	0 - 34	18.5	1
			specific conductance (μS/cm)	0 or ≥ 550	100 - 400	643	0
			dissolved oxygen (mg/L)	0 or ≥ 20	5 - 15	9.2	1
			pH	≤ 5.2 or ≥ 10.3	6.5 - 9.0	7.8	1
			turbidity (NTU)	15	10	4.2	1
	Surface Water Flow						0.91
			mean daily flow (cfs) for the period of record	≤ 45.3 or ≥ 136.4	68.1 - 113.6	91.4	1
			mean min flow (cfs) for August	≤ 16.7 or ≥ 50.6	25.2 - 42.1	45	0.66
			mean max flows (cfs) for May	≤ 300.1 or ≥ 900	450.1 - 750	716.2	1
			low flood pulse count (#)	≤ 6.1 or ≥ 18.1	9.1 - 15.1	15	1
			high flood pulse count (#)	≤ 2.9 or ≥ 9.2	4.5 - 7.6	4.2	0.81
			annual min of 7-day moving average flow (cfs)	≤ 15.2 or ≥ 45.6	22.8 - 38.0	38.8	0.9
			annual max of 7-day moving average flow (cfs)	≤ 244 or ≥ 732.3	366.1 - 610.2	486.7	1
			Julian date of annual minimum	≤ 145 or ≥ 435.3	217.6 - 362.7	293.8	1
			Julian date of annual maximum	≤ 49.2 or ≥ 147.9	73.9 - 123.2	130	0.72
			fall rate (cfs/day)	≤ 11.5 or ≥ 35	17.4 - 29.1	22.9	1
	Fish community						0.91
		Composition					0.81
			Simpson's diversity	0.23	0.15	0.09	0.57
			sucker composition (%)	1	1.3	1.2	0.81
			sunfish composition (%)	1.4	11	17.9	1
			benthic species composition (%)	13	34	49.1	1
		Condition					
			index of biotic integrity	30	60	93	1
	Aquatic invertebrates						
		Biotic integrity					0.76
			family richness	7.1	14.2	10.8	0.5
			genus richness	7.5	15	14.9	1
			EPT richness	2	4	3.8	0.9
			EPT ratio	0.14	0.23	0.18	0.45
			Shannon Index (Genus)	0.89	1.77	1.93	1
			Shannon Evenness Index	0.54	0.9	0.72	0.5

Reporting unit: Skegg's Branch

Overall support for the entire Skegg's Branch reporting unit was high (output score = .92, Table 6-7). Skegg's Branch is not an impaired listed stream, therefore all resource scores contributed to the overall evaluation score of the reporting unit. There was full support for the fish community resource type (output score = 1). Overall water quality was similar to Wilson's Creek with an output score of .88. All indicators of biotic integrity had at least moderate support for the evaluation statement, with EPT ratio having the lowest output score of .45.

Table 6-7. Rescaled NetWeaver output scores for the integrated analysis of Skegg's Branch reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Skegg's branch							0.92
	303(d) listed			0	1	1	1
	Water quality						0.88
			temperature (°C)	≤ -17 or ≥ 51	0 - 34	15.3	1
			specific conductance (µS/cm)	0 or ≥ 550	100 - 400	489.5	0.4
			dissolved oxygen (mg/L)	0 or ≥ 20	5 - 15	8.8	1
			pH	≤ 5.2 or ≥ 10.3	6.5 - 9.0	7.9	1
			turbidity (NTU)	15	10	2.1	1
	Fish community						1
		Composition					1
			Simpson's diversity	0.33	0.23	0.16	1
			benthic species composition (%)	8	34.3	52.9	1
		Condition					
			index of biotic integrity	30	60	73	1
	Aquatic invertebrates						
		Biotic integrity					0.79
			family richness	7.1	14.2	11.9	0.68
			genus richness	7.5	15	21.7	1
			EPT richness	2	4	3.8	0.89
			EPT ratio	0.14	0.23	0.18	0.45
			Shannon Index (Genus)	0.89	1.77	2	1
			Shannon Evenness Index	0.54	0.83	0.66	0.49

Reporting unit: Terrell Creek

The overall assessment for Terrell Creek reporting unit is similar to the other aquatic reporting units in the park (output score = .87, Table 6-8). Terrell Creek is not an impaired listed stream, therefore all resource scores contributed to the overall evaluation score of the reporting unit. There is high support for current water quality condition approximating the management targets (output score .91) with specific conductance being the only indicator without full support. Even though overall fish community support is high, Simpson's diversity measure and sucker composition have low support (output scores of .24 and .23, respectively). The overall biotic integrity of Terrell Creek is a bit higher than both Wilson's creek and Skegg's branch, with an output score of .83.

Table 6-8. Rescaled NetWeaver output scores for the integrated analysis of the Terrell Creek reporting unit of Wilson's Creek National Battlefield, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Terrell creek							0.87
	303(d) listed			0	1	1	1
	Water quality						0.91
			temperature (oC)	≤ -17 or ≥ 51	0 - 34	18.6	1
			specific conductance (µS/cm)	0 or ≥ 550	100 - 400	466.9	0.6
			dissolved oxygen (mg/L)	0 or ≥ 20	5 - 15	7.8	1
			pH	≤ 5.2 or ≥ 10.3	6.5 - 9.0	7.8	1
			turbidity (NTU)	15	10	1.5	1
	Fish community						0.75
		Composition					0.49
			Simpson's diversity	0.82	0.44	0.73	0.24
			sucker composition (%)	0.1	1.5	0.4	0.23
			benthic species composition (%)	21	61.7	90.4	1
		Condition					
			index of biotic integrity	30	60	61	1
	Aquatic invertebrates						
		Biotic integrity					0.83
			family richness	7.1	14.2	14.8	1
			genus richness	7.5	15	22.4	1
			EPT richness	2	4	4.6	1
			EPT ratio	0.13	0.19	0.15	0.33
			Shannon Index (Genus)	0.89	1.77	2.19	1
			Shannon Evenness Index	0.54	0.89	0.71	0.49

Overall, the integrated analysis for reporting units in the NRCA show terrestrial systems that currently do not reflect management targets and aquatic systems that nearly approximate the management targets. Although landscape composition at the park wide scale is supported, the spatial arrangement of patches within specific community types is lacking.

Discussion

The integrated analysis provides one way to evaluate a large number of NRCA components in a simplified manner. The logic-based evaluation achieves this level of simplification by first arranging all of the variables into a hierarchical framework which represents their ecological relationships. Secondly, this analysis makes the assumption that all variables within each level of the hierarchy contribute equally to the overall evaluation. Building off quantitative measures and expert reasoning that were employed in the NRCA to develop reference conditions, a qualitative evaluation of how closely the current condition approximates the management target was undertaken. Here the emphasis is on the evaluation statement, or the idea of how closely the current condition approximates the management target, and the logical relationship among the variables. The strength of this analysis is that it provides formal structure to a multi-faceted natural resource so that an orderly interpretation of the entire knowledge base can be performed. Ultimately it allows numerous components from multiple systems to be evaluated in a way that creates the foundation for future decision making processes. It is important to remember that the logic model represents only one of many different examples of the ecological relationships within the natural system. However, due to the modular nature of designing logic models within NetWeaver and the transparency of the logical relationships, it is easy to iterate on various logical relationships such that all aspects of the natural resources are best evaluated.

Color coded output categories allow for quick interpretation of the framework. Looking at specific output scores provides greater detail for understanding the degree of departure for support for the evaluation statement. Together, these two types of reporting evaluation results can be used to direct decision making priorities or taken as input for decision making software.

Glades and slope woodlands at Wilson's Creek National Battlefield represent the most significant terrestrial natural communities. Glades support populations of the rare Missouri Bladderpod (*Lesquerella filiformis)* along with other species of interest such as slender sandwort (*Arenaria patula*), green milkweed (*Asclepias viridiflora*), and downy gentian (*Gentiana puberula*). This habitat is naturally patchy with areas of deeper soils alternating with shallow soils and exposed rock across small areas.

Woodlands at WICR are mainly early successional and disturbance types, but slope woodlands are generally in better condition than upland woodlands. They are usually dominated by oaks (*Quercus* spp.) and hickories (*Carya* spp.). Oaks and hickories also dominate some upland areas but are interspersed with more disturbed woodlands with species such as eastern redcedar, Osage orange, hackberry (*Celtis* spp.), and honey locust (*Gleditsia triacanthos*). Bottomland woodlands are generally dominated by early successional species such as hackberry (*Celtis occidentalis*), ash (*Fraxinus* spp.), and American elm (*Ulmus americana*). Grasslands are generally in poor condition. Areas where restoration efforts have been made do have a compliment of native grasses, but many areas are still invaded by species such as smooth sumac (*Rhus glabra*), blackberries (*Rhus* spp.), multiflora rose (*Rosa multiflora*), *Prunus* spp., and Japanese honeysuckle (*Lonicera japonica*). Grasslands where restoration has not been applied may be dominated by tall fescue (*Schedonordus phoenix*) or by a variety of annual cool season grasses and forbs together with the shrubs and vines mentioned above.

Natural resource management options are limited in such a disturbed landscape. Where funds and time are limited, focus on a few areas may be warranted. Eastern redcedar (*Juniperus virginiana*) reduction in glades may promote higher populations of glade-associated herbaceous species, including Missouri bladderpod. Increasing native grass and forb diversity in grasslands that already have a compliment of native species may increase the population of grassland endemic birds of interest. Early successional shrublands may also provide valuable habitat to wildlife species, including selected bird species, both in the winter and summer seasons. In this regard, creation of a patchwork of grassland and shrubland habitats, possibly by mowing different areas in different years, may be beneficial. Tall fescue grasslands that are very regularly mowed offer little value to native wildlife. Disturbance woodlands on better soils with eastern redcedar and other early successional species may be replaced over decades with woodlands that contain a higher compliment of desirable species without much active management. Likewise, existing bottomland and slope woodlands may become more valuable old-growth communities in time. Some bird species benefit from larger patches of woodland, which creates woodland interior habitat. Overall, however, breeding bird diversity is good because of the diversity of grassland, shrubland, edge, and woodland habitats on the park.

The aquatic resources of both Wilson's Creek and Skeggs Branch are impacted by upstream urbanization from Springfield and Republic respectively. Terrell Creek is less threatened overall with most of the upstream watershed comprised of pasture/hay land use. These upstream threats influence the water quality, physical habitat, and flow regime of the stream resources which in turn impact the biota. Wilson's Creek, though certainly the most threatened and degraded stream on the park, may benefit from having tributaries that are in better condition which can serve as refuges or re-colonization pools for fauna during times of reduced water quality.

The results of Chapter 6's aquatic assessment of Wilson's Creek should be interpreted with some caution and it is important to note that the assessment relies on a limited number of indicators based on data from a single year. Chapter 5 provides additional information which should be interpreted in conjunction with the results of the NetWeaver assessments. Water quality issues, especially in Wilson's Creek, have been well documented and it has been listed as a 303(d) stream by the Missouri Department of Natural Resources for failure to meet clean water standards under the federal Clean Water Act. Phosphorus, nitrogen, and fecal bacteria levels are often high. Most of the threats to Wilson's Creek are related to the urban influence of the city of Springfield and the wastewater treatment facility located upstream from WICR.

The numbers of options to park managers for improving water quality and other aquatic indicators in streams flowing through WICR are limited because most sources of degradation originate upstream outside of the park boundaries. As Bowles (2010) points out, maintaining and widening riparian buffers along the streams in WICR will help to protect aquatic life and in-stream habitat from localized chemical runoff and sedimentation. Maintaining the riparian buffers with native trees and grasses in conjunction with limiting impervious surfaces in the park will help stabilize the riparian zones and in-stream habitat.

Literature Cited

Alabaster, J.S., and R. Lloyd. 1982. Water quality criteria for freshwater fish. Butterworth Publisher, London, UK.

Annis, G.M., S.P. Sowa, D.D. Diamond, M.D. Combes, K.E. Doisy, A.J. Garringer, and P. Hanberry. 2010. Developing synoptic human threat indices for assessing the ecological integrity of freshwater ecosystems in EPA Region 7. Final Report, EPA Project CD-98768101-0, Columbia, Missouri.

Bain, M.B., J.T. Finn, and H.E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69: 382-392.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrate, and fish, 2nd edition. EPA 841-B-99-002, U.S. Environmental Protection Agency, Washington, D.C.

Berkas, W.R. 1982. Streamflow and water quality conditions, Wilson’s Creek and James River, Springfield area, Missouri. Water-Resources Investigations 82-26. U.S. Geological Survey, Rolla, Missouri.

Berkas, W.R. 1980. Effects of urban runoff and wastewater effluent on Wilson’s Creek and James River near Springfield, Missouri. Water-Resources Investigations 80-27. U.S. Geological Survey, Rolla, Missouri.

Berkman, H.E., and C.F. Rabeni. 1987. Effect of siltation on stream fish communities. Environmental Biology of Fishes 18:285-294.

Binkley, D., and T.C. Brown. 1993. Forest practices as nonpoint sources of pollution in North America. Water Resources Bulletin 29:729-740.

Bowles, D.E. 2010. Aquatic invertebrate monitoring at Wilson’s Creek National Battlefield: 2005-2007 trend report. Natural Resource Technical Report NPS/HTLN/NRTR-2010/287. National Park Service, Fort Collins, CO.

Brown, D., and J. Czarnezki. Undated. Missouri streams fact sheet-chemical monitoring. Missouri Department of Conservation, Jefferson City, Missouri.

Busch, T.P. 1976. National Register of Historic Places nomination form for Wilson’s Creek National Battlefield. < http://pdfhost.focus.nps.gov/docs/NRHP/Text/66000113.pdf>. Accessed 1 February 2010.

Canterbury, G.E., T.E. Martin, D.R. Petit, L.J. Petit, and D.F. Bradford. 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology 14:544-558.

Center for Watershed Protection. 2003. Impacts of impervious cover on aquatic systems. Center for Watershed Protection, Ellicott City, Maryland.

Chapman, S.S., J.M. Omernik, G.E. Griffith, W.A. Schroeder, T.A. Nigh, and T.F. Wilton. 2002. Ecoregions of Iowa and Missouri. U.S. Geological Survey, Reston, Virginia.

Collins, S.L. 2000. Disturbance frequency and community stability in native tallgrass prairie. The American Naturalist 155:311-325.

Coon, T.G. 1987. Interaction of disturbances in tallgrass prairie: a field experiment. Ecology 68:1243-1250.

Cunjak, R.A. 1988. Physiological consequences of overwintering: the cost of acclimatization? Canadian Journal of Fisheries and Aquatic Sciences 45:443-452.

Dauwalter, D.C., E.J. Pert, and W.E. Keith. 2003. An index of biotic integrity for fish assemblages in Ozark Highland streams of Arkansas. Southeastern Naturalist 2:447-468.

Diamond, D.D., and C. Blodgett. 2003. Urban remote sensing for land use change and impacts. Final Report, US EPA, Office of Research and Development, Las Vegas, Nevada.

Diamond, D.D., C.D. True, S.P. Sowa, W.E. Foster, and K.B. Jones. 2005. Influence of targets and assessment region size on perceived conservation priorities. Environmental Management 35:130-137.

Donegan, D.S. 1984. Wilsons Creek fish species diversity. National Park Service, Republic, Missouri.

Elkins, K. 2007. The battle: A brief account of the battle of Wilson's Creek, its significance, and the Civil War in Missouri. National Park Service, Republic, Missouri.

Emmett, L.F., J. Skelton, R.R. Luckey, D.E. Miller, T.L. Thompson, and J.W. Whitfield. 1978. Water resources and geology of the Springfield area, Missouri. Water Resources Report 34. Missouri Department of Natural Resources, Rolla, Missouri.

Environmental Protection Agency (EPA). Undated. Wilson and Jordan Creeks (MO_2375 and 3374) Christian and Greene Counties, Missouri: Total Maximum Daily Load. Draft Report, EPA Region 7, Kansas City, Missouri.

Environmental Protection Agency (EPA). 2002. A framework for assessing and reporting on ecological condition: Executive summary. <http://www.epa.gov/sab/pdf/epec02009a.pdf>. Accessed 25 January 2011.

Eyre, F.H. 1980. Forest Cover Types of the United States and Canada. Society of American Foresters, Washington, D.C.

Fausch, K.D., J.R. Karr, P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Transactions of the American Fisheries Society 113:39-55.

Fenn, M.E., J.S. Baron, E.B. Allen, H.M. Rueth, K.R. Nydick, W.D. Bowman, J.O. Sickman, T. Meixner, D.W. Johnson, and P. Neitlich. 2003. Ecological effects of nitrogen deposition in the Western United States. BioScience 53: 404-420.

Gale, C., R. Shaw, and G. Sullivan. 2004. Fire management plan for Wilson's Creek National Battlefield. National Park Service, Republic, Missouri.

Harris, M.A., B.C. Kondratieff, and T.P. Boyle. 1991. Invertebrate assemblages and water quality in six National Park units in the Great Plains. National Park Service, Water Resources Division, Fort Collins, Colorado.

Harvey, E.J., and J. Skelton. 1968. Hydrology study of a waste-disposal problem in karst area at Springfield, Missouri. Professional Paper 600-C. U.S. Geological Survey, Reston, Virginia.

Hoefs, N.J., and T.P. Boyle. 1990. Fish community survey, Wilson's Creek, MO. Water Resource Division, Applied Research Branch, National Park Service, Colorado State University, Fort Collins, Colorado.

Hogsett, W.E., and C.P. Anderson. 1998. Ecological effects of tropospheric ozone: a U.S. perspective – past, present, and future. Pages 419-437 *in* T. Schneider, editor. Air Pollution in the 21st Century, Priority Issues and Policy. Studies in Environmental Science 72, Elsevier, Amsterdam, Netherlands.

James, K.M., M.D. DeBacker, G.A. Rowell, J.L. Haack, and L.W. Morrison. 2009. Vegetation community monitoring protocol for the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR-2009/141. National Park Service, Fort Collins, Colorado.

James, K.M., and M.M. Guck. 2010. Logic-based approach to evaluating plant communities at Effigy Mounds National Monument, Iowa. Natural Resource Report NPS/HTLN/NRR-2010/181. National Park Service, Fort Collins, Colorado.

Jenkins, S.E., R. Guyette, and A.J. Rebertus. 1997. Vegetation -site relationships and fire history of savanna-glade-woodland mosaic in the Ozarks. Pages 184-201 i*n* S.G. Pallardy, R.A. Cecich, H.E. Garrett, P.S. Johnson, editors. Proceedings of 11th Central Hardwood Forest Conference. General Technical Report NC-188. U. S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Jordan, W.R.,III, M.E. Gilpin, and J.D. Aber. 1987. Restoration ecology: A synthetic approach to ecological research. Cambridge University Press, Cambridge, UK.

Joubert, L., and G. Loomis. 2005. Chepachet Village decentralized wastewater demonstration project. University of Rhode Island, College of the Environment and Life Sciences, Kingston, Rhode Island.

Justus, B.G., and J.C. Peterson. 2005a. The fishes of George Washington Carver National Monument, Missouri, 2003. Scientific Investigations Report 2005-5128. National Park Service, U.S. Geological Survey, Reston, Virginia.

Justus, B.G., and J.C. Peterson. 2005b. The fishes of Pea Ridge National Military Park, Arkansas, 2003. Scientific Investigations Report 2005-5129. National Park Service, U.S. Geological Survey, Reston, Virginia.

Karr J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Karr, J.R., K.D. Gausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running water: A method and its rationale. Special Publication 5. Illinois Natural History Survey, Champaign, Illinois.

Karr J.R., and I.J. Schlosser. 1978. Water resources and the land-water interface. Science 201: 229-234.

Kerr, R.S. 1969. James River-Wilsons Creek study. U.S. Department of Interior, Federal Water Pollution Control Administration, Ada, Oklahoma.

Kirkpatrick, J.B., and M.J. Brown. 1994. A comparison of direct and environmental domain approaches to planning reservation of forest higher plant communities and species in Tasmania. Conservation Biology 8:217-224.

Krupa, S.V. 2003. Effects of atmospheric ammonia (NH_3) on terrestrial vegetation: a review. Environmental Pollution 124: 179-221.

Liu, J., and W.W. Taylor, editors. 2002. Integrating landscape ecology into natural resource management. Cambridge University Press, Cambridge, UK.

Matthews, W.J. 1987. Physicochemical tolerance and selectivity of stream fishes as related to their geographic ranges and local distributions. Pages 111-120 *in* J.W. Matthews. and D.C. Heins, editors. Community and Evolutionary Ecology of North American Stream Fishes. University of Oklahoma Press, Norman, Oklahoma.

McNab, W.H., and E.A. Avers. 1994. Ecological Subregions of the United States. U.S. Forest Service, Washington D.C.

Missouri Climate Center. 2010. Climate of Missouri. <http://climate.missouri.edu/climate.php>. Accessed 14 October 2010.

Missouri Department of Natural Resources. 2009. Proposed Missouri 2008 Section 303(d) list as approved by the Missouri Clean Water Commission, May 6, 2009.

<http://www.dnr.mo.gov/env/wpp/waterquality/303d/50609cwc-approvedlist.pdf>. Accessed 11 October 2010.

Missouri Department of Natural Resources. 2007. Springfield urban streams, Clear Creek, Jordan Creek, Wilson Creek, and Galloway Creek, Greene County. Biological Assessment Report. Missouri Department of Natural Resources, Jefferson City, Missouri.

Mooney, H.A., and R.J. Hobbs. 2000. Invasive species in a changing world. Island Press, Washington, D.C.

Moulton, S.R., III, J.G. Kennen, R.M. Goldstein, and J.A. Hambrook. 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program. Open-file Report 02-150, U.S. Geological Survey, Reston, Virginia.

Mueller, D.K., and D.R. Helsel. 1996. Nutrients in the Nation's waters-too much of a good thing? U.S. Geological Survey Circular 1136. <http://pubs.usgs.gov/circ/circ1136>. Accessed 16 November 2010.

National Park Service (NPS). 2010a. Air quality estimates for the Inventory and Monitoring Program. <http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm>. Accessed 7 February 2011.

National Park Service (NPS). 2010b. Wilson's Creek National Battlefield. <http://www.nps.gov/wicr/>. Accessed 1 February 2010.

National Park Service (NPS). 2007a. 2006 Annual performance and progress report: Air quality in National Parks; Final October 2007. National Park Service Air Resource Division, U.S. Department of Interior, Washington, D.C.

National Park Service (NPS). 2007b. Ecological effects of air pollution. <http://www.nature.nps.gov/air/AQBasics/ecologic.cfm>. Accessed 21 September 2010.

National Park Service (NPS). 2007c. First annual centennial strategy for Wilson's Creek National Battlefield. National Park Service, Washington, D.C.

National Park Service (NPS). 2007d. Ozone risk assessment map. <http://www.nature.nps.gov/air/permits/aris/networks/ozoneriskassessmentmap.cfm>. Accessed 8 October 2010.

National Park Service (NPS). 2006. Ozone sensitive plant species, by park. <http://www.nature.nps.gov/air/permits/aris/docs/Ozone_Sensitive_ByPark_3600.pdf>. Accessed 16 November 2010.

National Park Service (NPS). 2004a. Assessing the risk of foliar injury from ozone on vegetation in parks in the Heartland Network. <http://www.nature.nps.gov/Pubs/pdf/03Risk/htlnO3RiskOct04.pdf>. Accessed 16 November 2010.

National Park Service (NPS). 2004b. Environmental assessment Wilson's Creek National Battlefield fire management plan. National Park Service, Republic, Missouri.

National Park Service (NPS). 2004c. Wilson's Creek National Battlefield: Cultural Landscape Report. National Park Service, Republic, Missouri.

National Park Service (NPS). 2002. Air quality in the National Parks, 2nd edition. National Park Service, Air Resource Division, U.S. Department of Interior, Washington, D.C.

National Park Service (NPS). 2001. Air quality monitoring considerations for the Heartland Network. <http://www.nature.nps.gov/air/permits/aris/networks/docs/htlnAirQualitySummary.pdf>. Accessed 16 November 2010.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life. Version 7.1. NatureServe, Arlington, Virginia. <http://www.natureserve.org/explorer>. Accessed 16 November 2010.

NatureServe. 2008. <http://www.natureserve.org/explorer/ranking.htm#interpret>. Accessed 11 October 2010.

Nelson, P.W. 2005. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, Jefferson City, Missouri.

Newcombe, C.P., and D.D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11:72-82.

Nigh, T.A., and W.A. Schroeder. 2002. Atlas of Missouri ecoregions. Missouri Department of Conservation, Columbia, Missouri.

Noss, R.F. 2004. Conservation targets and information needs for regional conservation planning. Natural Areas Journal 24:223-231.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-354.

Oliver, C.D., and B.C. Larson. 1996. Forest Stand Dynamics, updated edition. John Wiley and Sons, Inc., New York, New York.

Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri. 2008 Status Report. Natural Resource Technical Report NPS/HTLN/NRTR-2009/195. National Park Service, Fort Collins, Colorado.

Peitz, D.G. 2006. White-tailed deer monitoring at Wilson's Creek National Battlefield, Missouri: 2005-2006 status report. Natural Resource Technical Report NPS/HTLN/NRTR-2006/016. National Park Service, Fort Collins, Colorado.

Peitz, D.G. 2005. Fish community monitoring in prairie park streams with emphasis on Topeka Shiner (*Notropis Topeka*): summary report 2001-2004. National Park Service, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program, Wilson's Creek National Battlefield, Republic, Missouri.

Peitz, D.G., and J.T. Cribbs. 2005. Bio-monitoring of water quality using aquatic invertebrates and in-stream habitat and riparian condition assessments: Status report for Wilson's Creek and Skegg's Branch, Wilson's Creek National Battlefield, Missouri 1988-2004. National Park Service, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program, Republic, Missouri.

Peitz, D.G., J.T. Cribbs, J.L. Haack, G.A. Rowell, L.W. Morrison, and M.D. DeBacker. 2007. White-tailed deer monitoring protocol for the Heartland Network Inventory and Monitoring Program. Natural Resource Report NPS/HTLN/NRR—2007/014. National Park service, Fort Collins, Colorado.

Peitz, D.G., G.A. Rowell, J.L. Haack, K.M. James, L.W. Morrison, and M.D. DeBacker. 2008. Breeding bird monitoring protocol for the Heartland Network Inventory and Monitoring Program. Natural Resource Report NPS/HTLN/NRR-2008/044. National Park Service, Fort Collins, Colorado.

Peterson, J.C., and B.G. Justus. 2005a. The fishes of Hot Springs National Park, Arkansas, 2003. Scientific Investigations Report 2005-5126. National Park Service, U.S. Geological Survey, Reston, Virginia.

Peterson, J.C., and B.G. Justus. 2005b. The fishes of Wilson's Creek National Battlefield, Missouri, 2003. Scientific Investigations Report 2005-5127. National Park Service, U.S. Geological Survey, Reston, Virginia.

Pflieger, W.L. 1997. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime. Bioscience 47:769-784.

Rabeni, C.F. 1993. Warmwater streams. Pages 427-443 *in* C.C. Kohler and W.A. Hubert, editors. Inland Fisheries Management in North America. American Fisheries Society, Bethesda, Maryland.

Rabeni, C.F., R.J. Sarver, N. Wang, G.S. Wallace, M. Weiland, and J.T. Peterson. 1997. Development of regionally-based biological criteria for Missouri streams. Final Report, Missouri Department of Natural Resources, Jefferson City, Missouri.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.R. Reice, A.L. Sheldon, J.B. Wallace, and R.C. Wissmar. 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7:433-455.

Rice, E.L., and W.T. Penfound. 1955. An evaluation of the variable-radius and paired-tree methods in the Blackjack-Post Oak forest. Ecology 36:315-320.

Richards, J.M., and B.T. Johnson. 2002. Water quality, selected chemical characteristics, and toxicity of base flow and urban stormwater in Pearson Creek and Wilsons Creek Basins, Greene County, Missouri, August 1999 to August 2000. Water Resources Investigations Report 4124. U.S. Geological Survey, Reston, Virginia.

Robison, H.W., and T.M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, Arkansas.

Sasseen, A.N. 2003. Monitoring summary and tornado damage assessment for Manley Woods Wilson's Creek National Battlefield. National Park Service, Prairie Cluster Prototype Long-Term Ecological Monitoring Program, Republic, Missouri.

Schlosser, I.J. 1990. Environmental variation, life history attributes, and community structure in stream fishes: Implications for environmental management and assessment. Environmental Management 14:621-628.

Schlosser, I.J. 1985. Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology 66:1484-1490.

Schlosser, I.J., and K.K. Ebel. 1989. Effects of flow regime and cyprinid predation on a headwater stream. Ecological Monographs 59:41-57.

Shuter, B.J., J.A. MacLean, F.E.J. Fry, and H. A. Regier. 1980. Stochastic simulation of temperature effects on first-year survival of smallmouth bass. Transactions of the American Fisheries Society 109:1-34.

Slay, M.E., C.J. Bitting, J.D. Wilhide. 2004. A bat inventory at Buffalo National River, Pea Ridge National Military Park, and Wilson's Creek National Battlefield. National Park Service, Heartland Inventory and Monitoring Network, Republic, Missouri.

Smale, M.A., and C.F. Rabeni. 1991. The effects of special area land treatment (SALT) agricultural practices on the biological health of headwater streams. Missouri Department of Natural Resources, Jefferson City, Missouri.

Sowa, S.P., D.D. Diamond, R. Abbitt, G. Annis, T. Gordon, M.E. Morey, G.R. Sorensen, and D. True. 2005. A gap analysis for riverine ecosystems of Missouri. U.S. Geological Survey, National Gap Analysis Program, Columbia, Missouri.

Sowa, S.P., and C.F. Rabeni. 1995. Regional evaluation of the relation of habitat to distribution and abundance of smallmouth bass and largemouth bass in Missouri streams. Transactions of the American Fisheries Society 124:240-251.

Starrett, W.C. 1951. Some factors affecting the abundance of minnows in the Des Moines River, Iowa. Ecology 32:13-24.

Swetnam, T.W., C.D. Allen, and J.L. Betancourt. 1999. Applied historical ecology: Using the past to manage for the future. Ecological Applications 9:1189-1206.

Tilghman, N.G. 1989. Impacts of White-tailed Deer on forest regeneration in northwestern Pennsylvania. J. Wildlife Management 53(3):524-532.

U.S. Congress. 1987. Technologies to maintain biological diversity. Office of Technology Assessment, U.S. Government Printing Office, Washington, D.C.

U.S. Geological Survey (USGS). 2010. National Water Information System: Mapper. <http://wdr.water.usgs.gov/nwisgmap/>. Accessed 21 September 2010.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Gushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Waller, D.M., and W.S. Alverson. 1997. The white-tailed deer: a keystone herbivore. Wildlife Society Bulletin 25:217-226.

Young, C.C., J.L. Haack, and H.J. Etheridge. 2007. Invasive exotic plant monitoring at Wilson's Creek National Battlefield: Year 1 (2006). Natural Resource Technical Report NPS/HTLN/NRTR—2007/013. National Park Service, Fort Collins, Colorado.

Young, C.C., L.W. Morrison, and H.J. Etheridge. 2006. Missouri bladderpod population size and initial habitat assessment for the Bloody Hill glade population at Wilson's Creek National Battlefield. Natural Resource Technical Report NPS/HTLN/NRTR-2006/017. National Park Service, Fort Collins, Colorado.

Young, C.C., L.W. Morrison, and J.L. Haack. 2009. Habitat relationships and management implications for *Lesquerella filiformis* Rollins (Missouri bladderpod) on a xeric limestone prairie. Journal of the Torrey Botanical Survey 136:233-241.

Young, C.C., L.W. Morrison, M.I. Kelrick, and M.D. DeBacker. 2008. Monitoring *Lesqurella filiformis* Rollins (Missouri bladderpod): application and evaluation of a grid-based survey approach. Natural Areas Journal 50:417-425.

Appendix A Data Source and Maps for All Potential Threats Included in the Human Threat Index

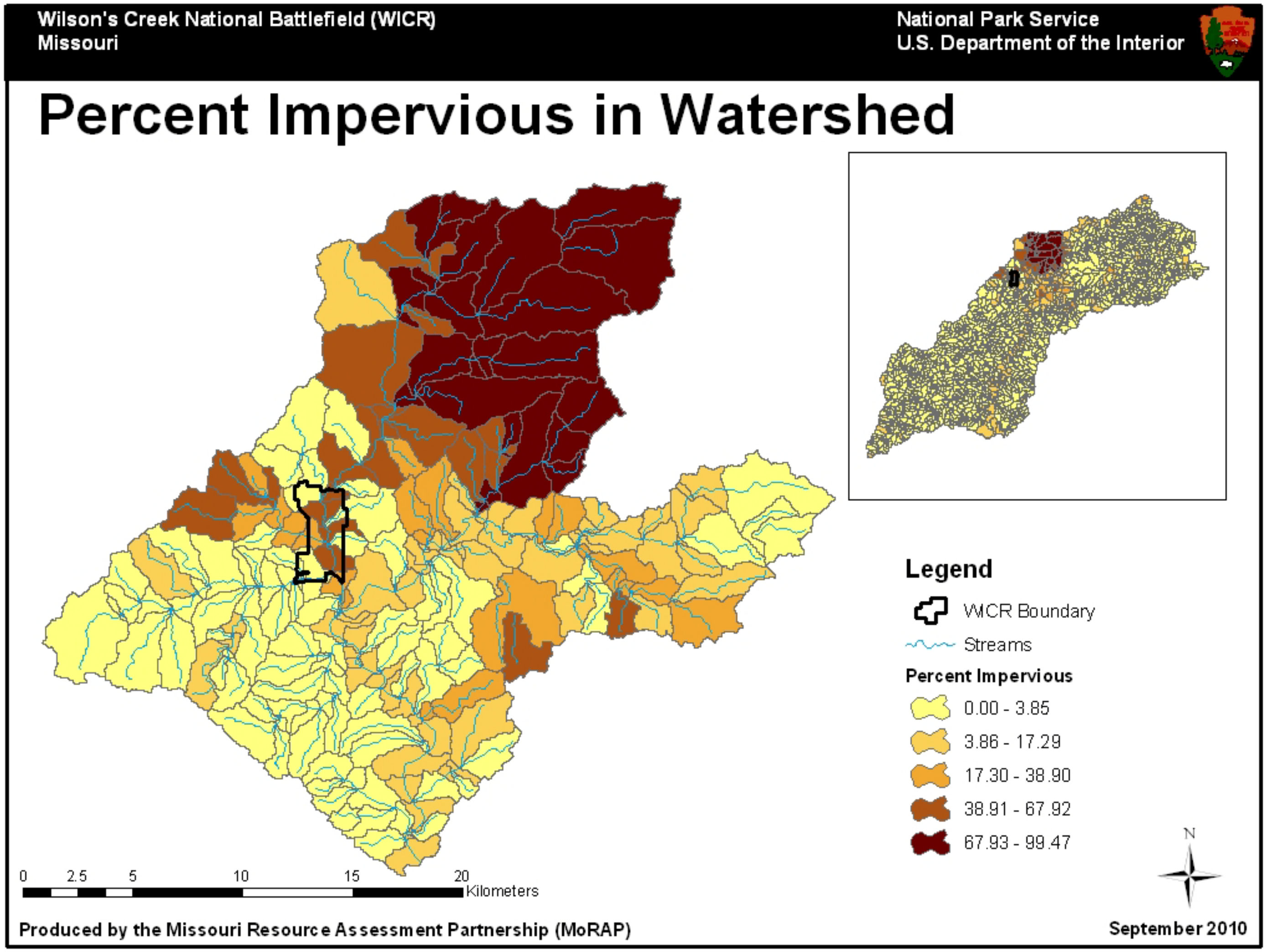

Figure A-9. Percentage of impervious surfaces above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

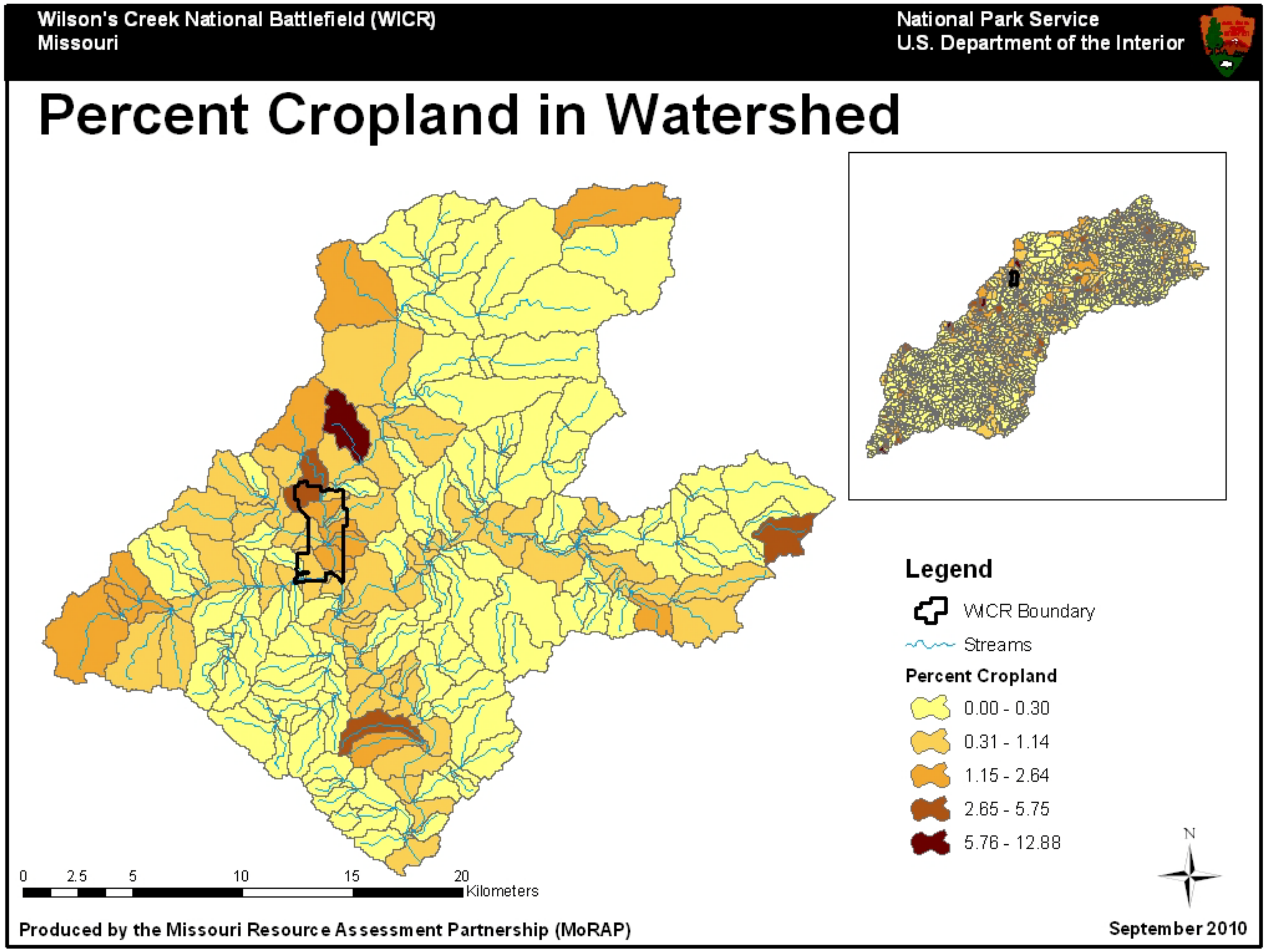

Figure A-10. Percentage of cropland above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

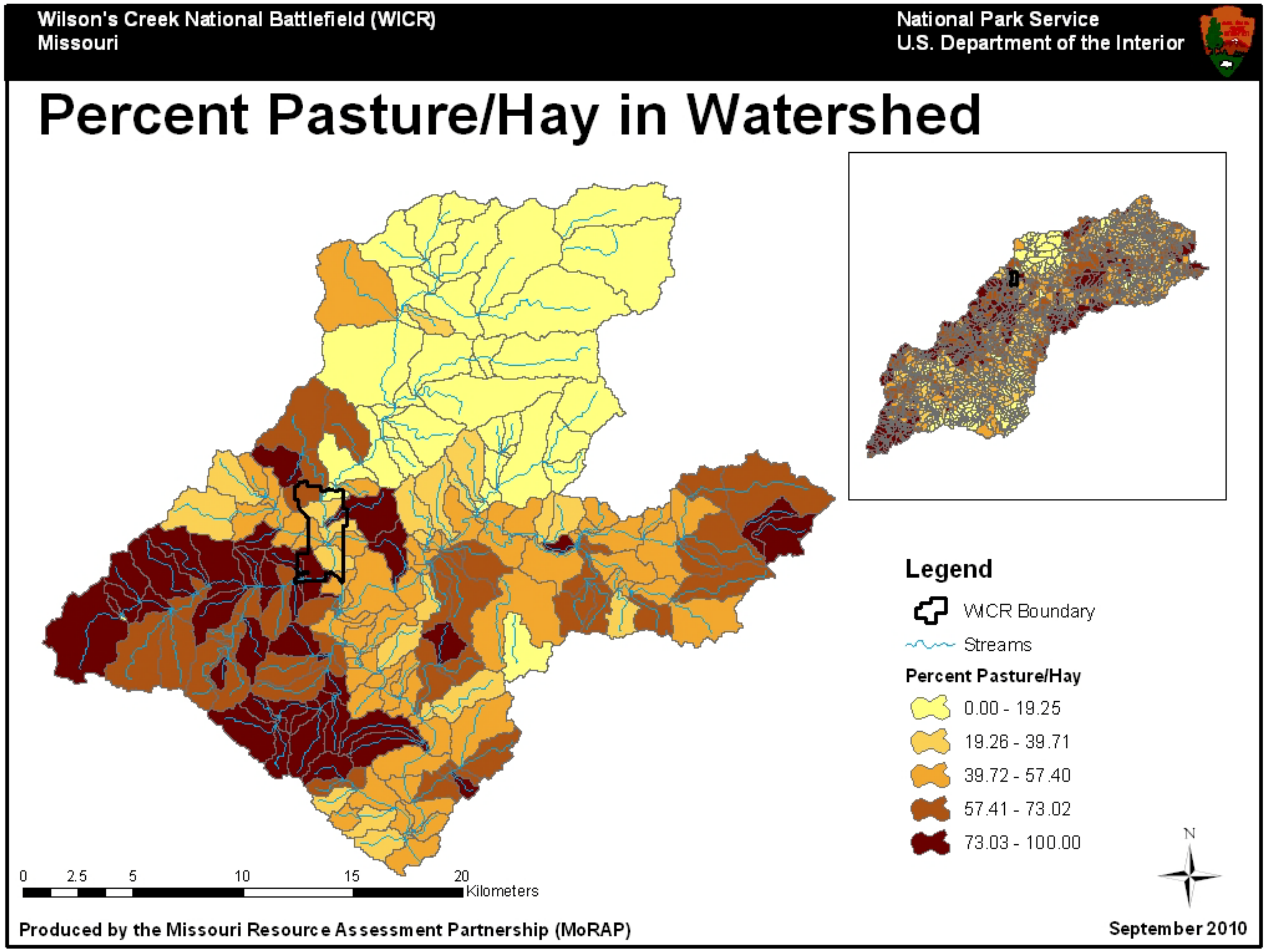

Figure A-11. Percentage of pasture/hay above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

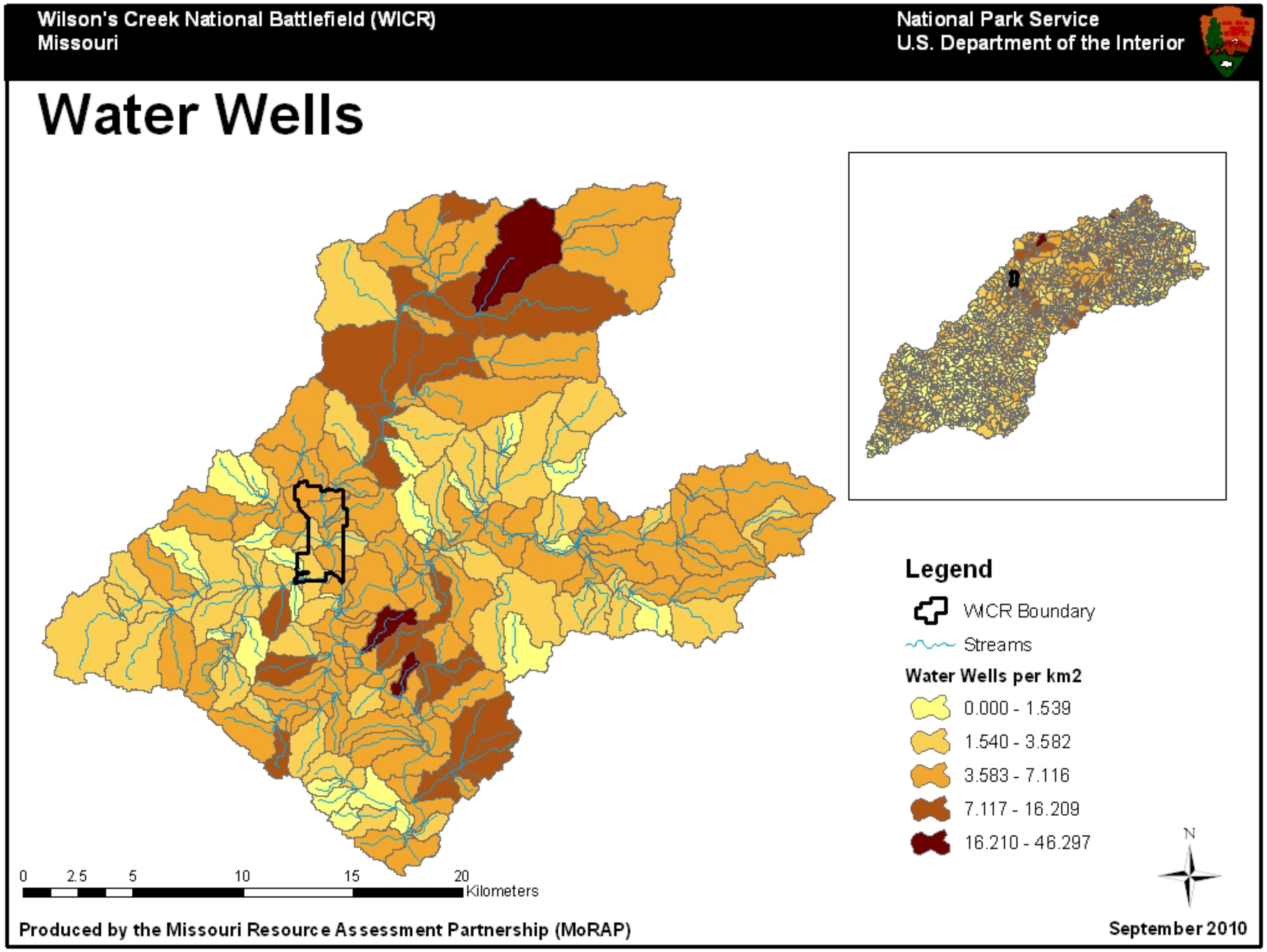

Figure A-12. Density of water wells above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

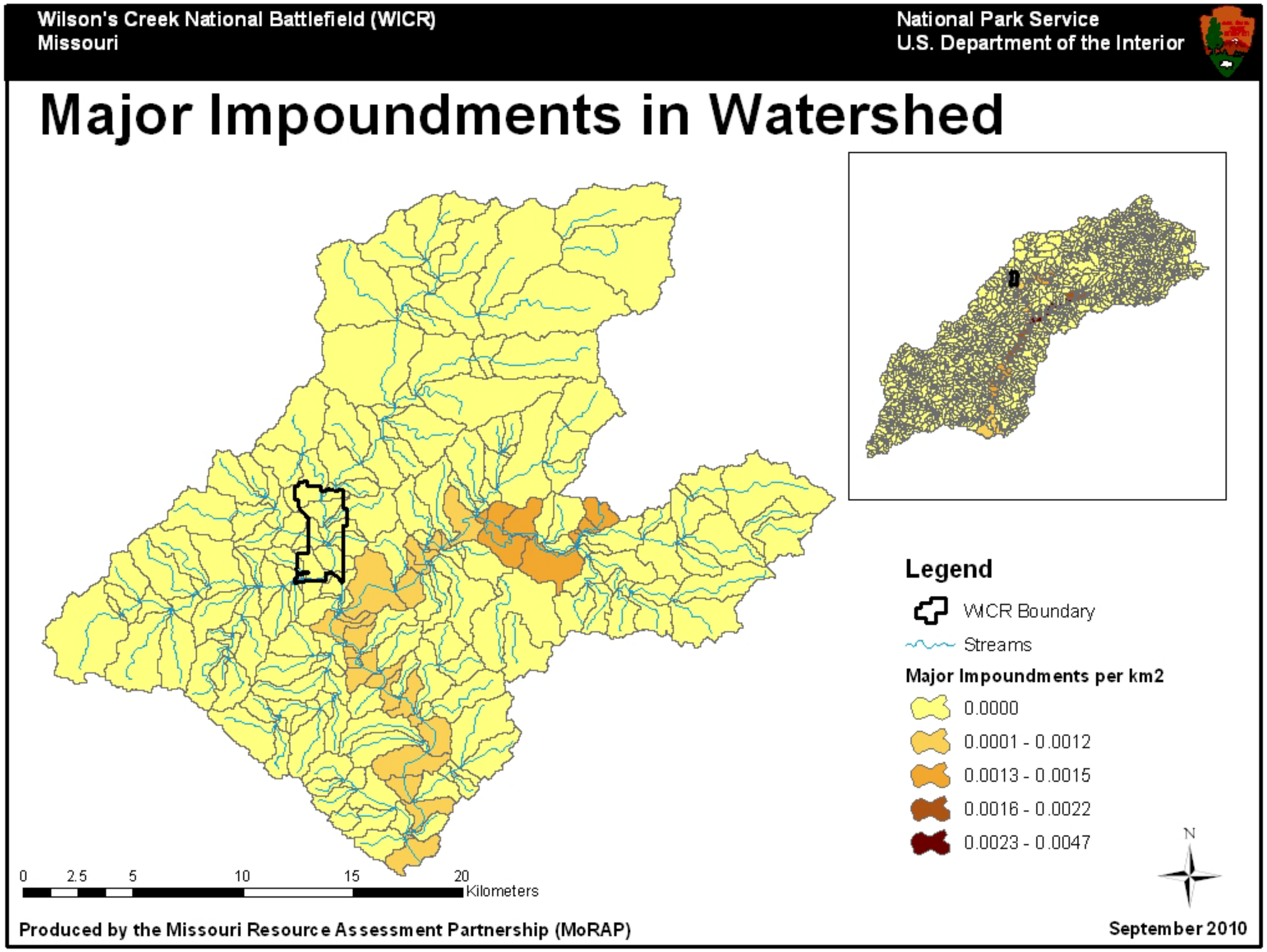

Figure A-13. Density of major impoundments above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

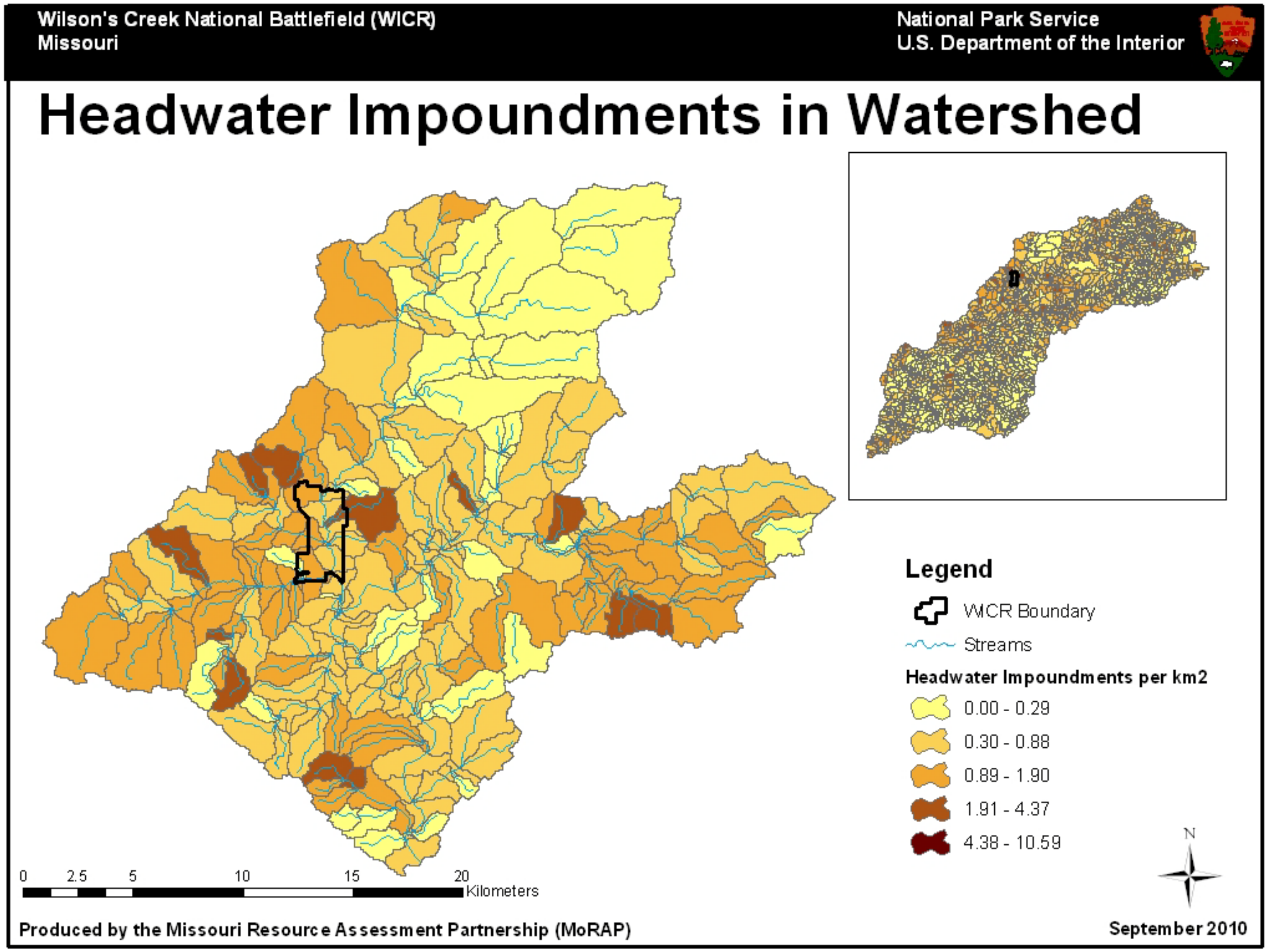

Figure A-14. Density of headwater impoundments above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

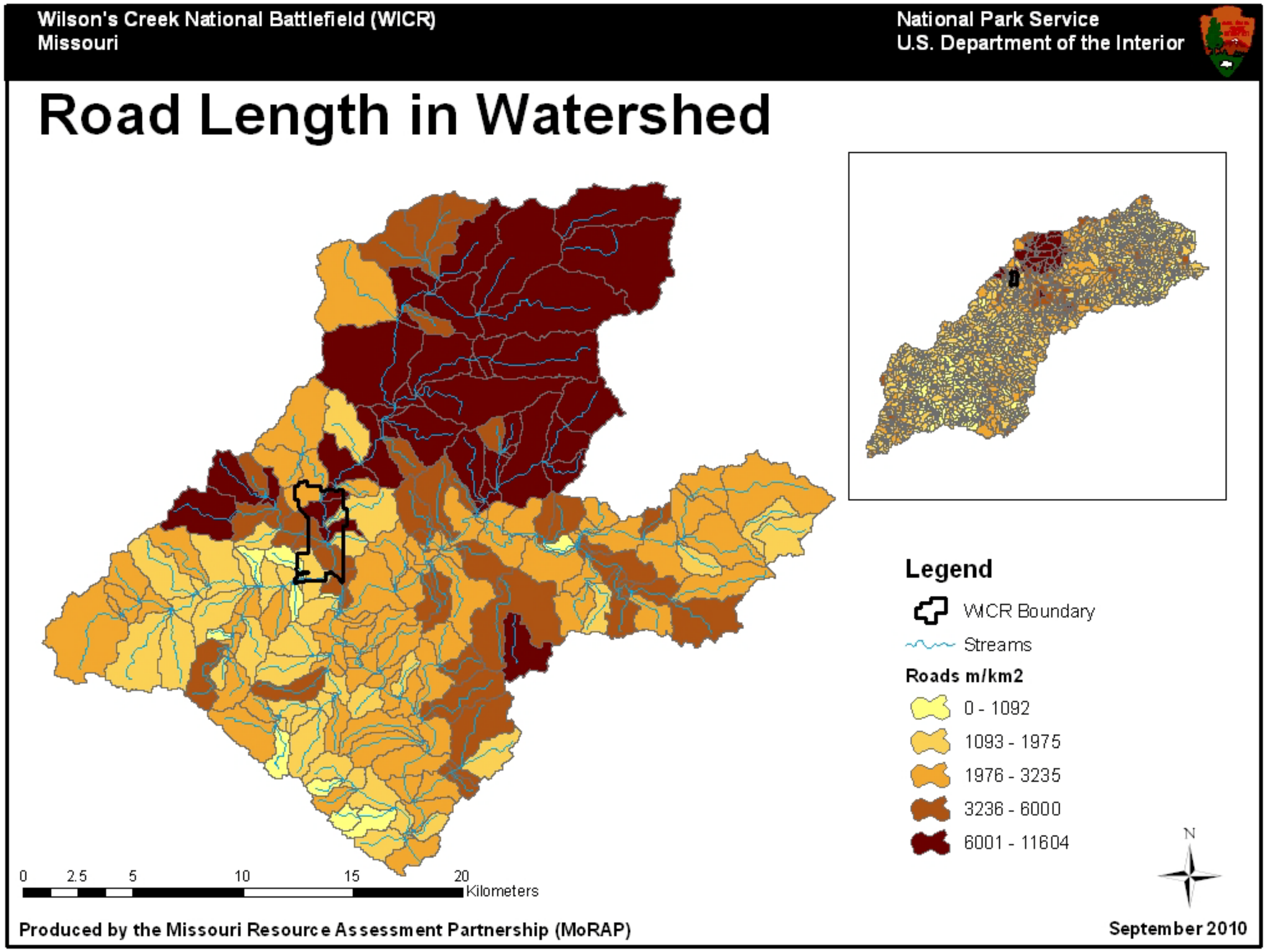

Figure A-15. Length of roads above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

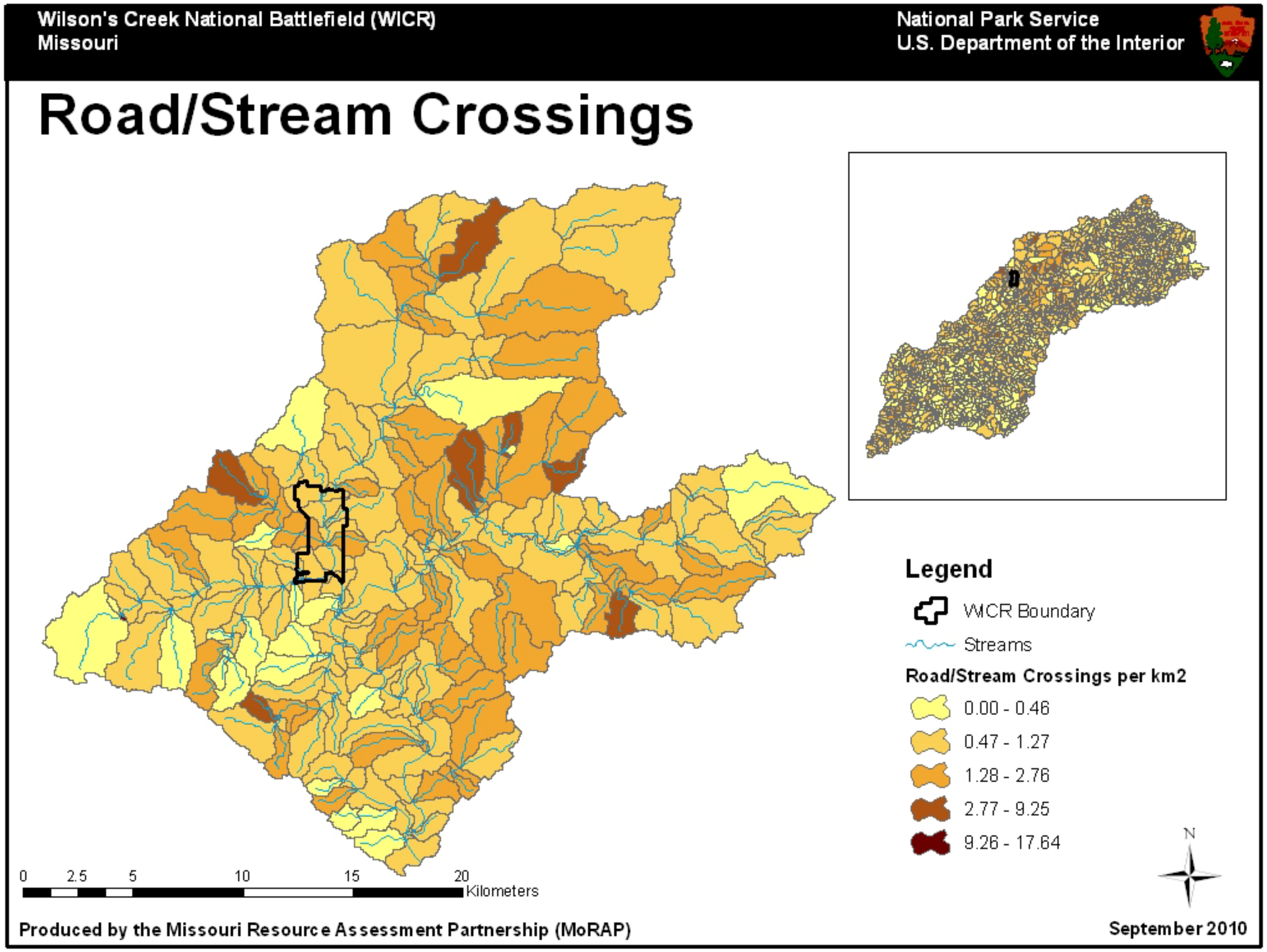

Figure A-16. Density of road/stream crossings above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

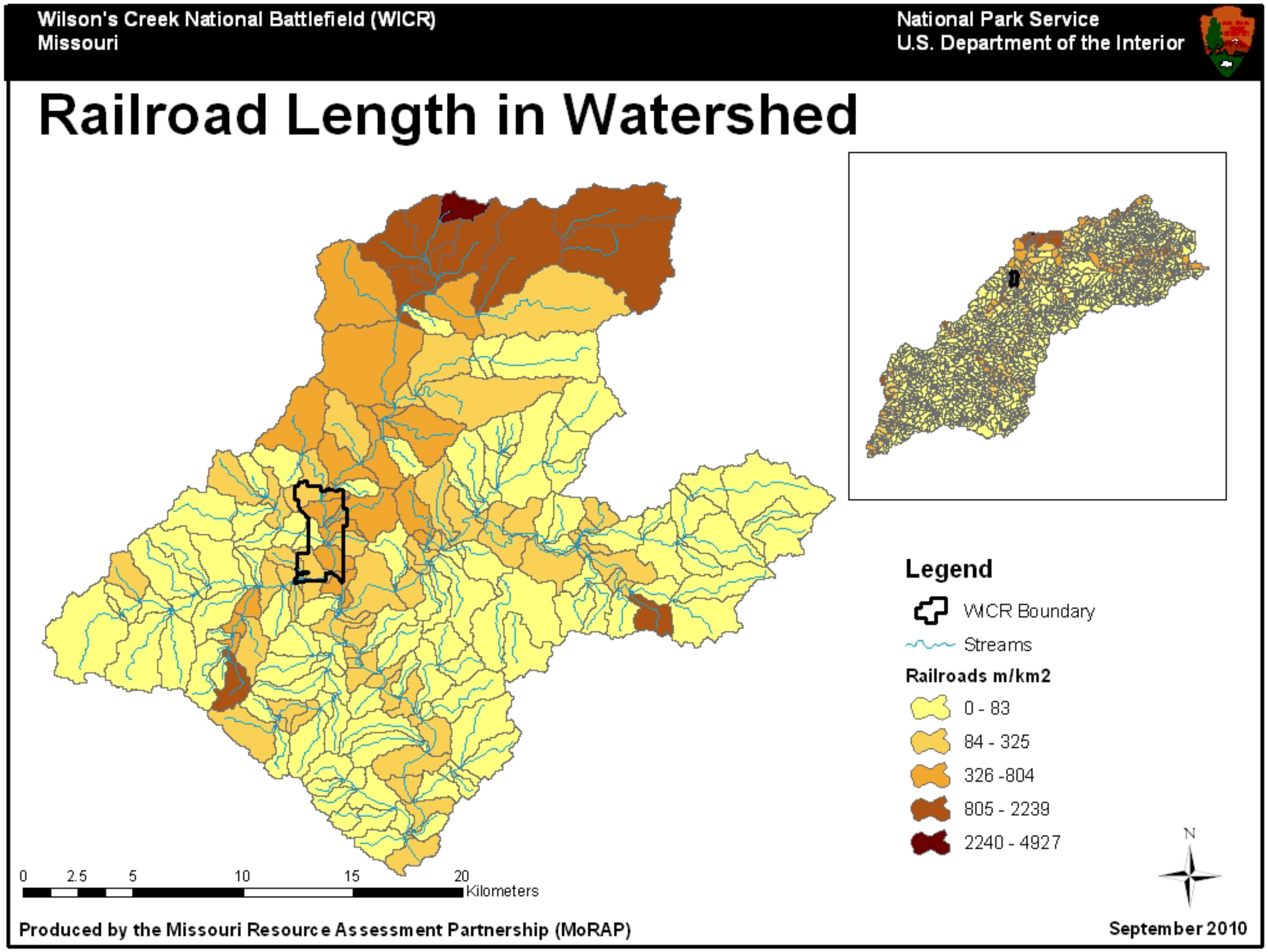

Figure A-17. Length of railroads above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

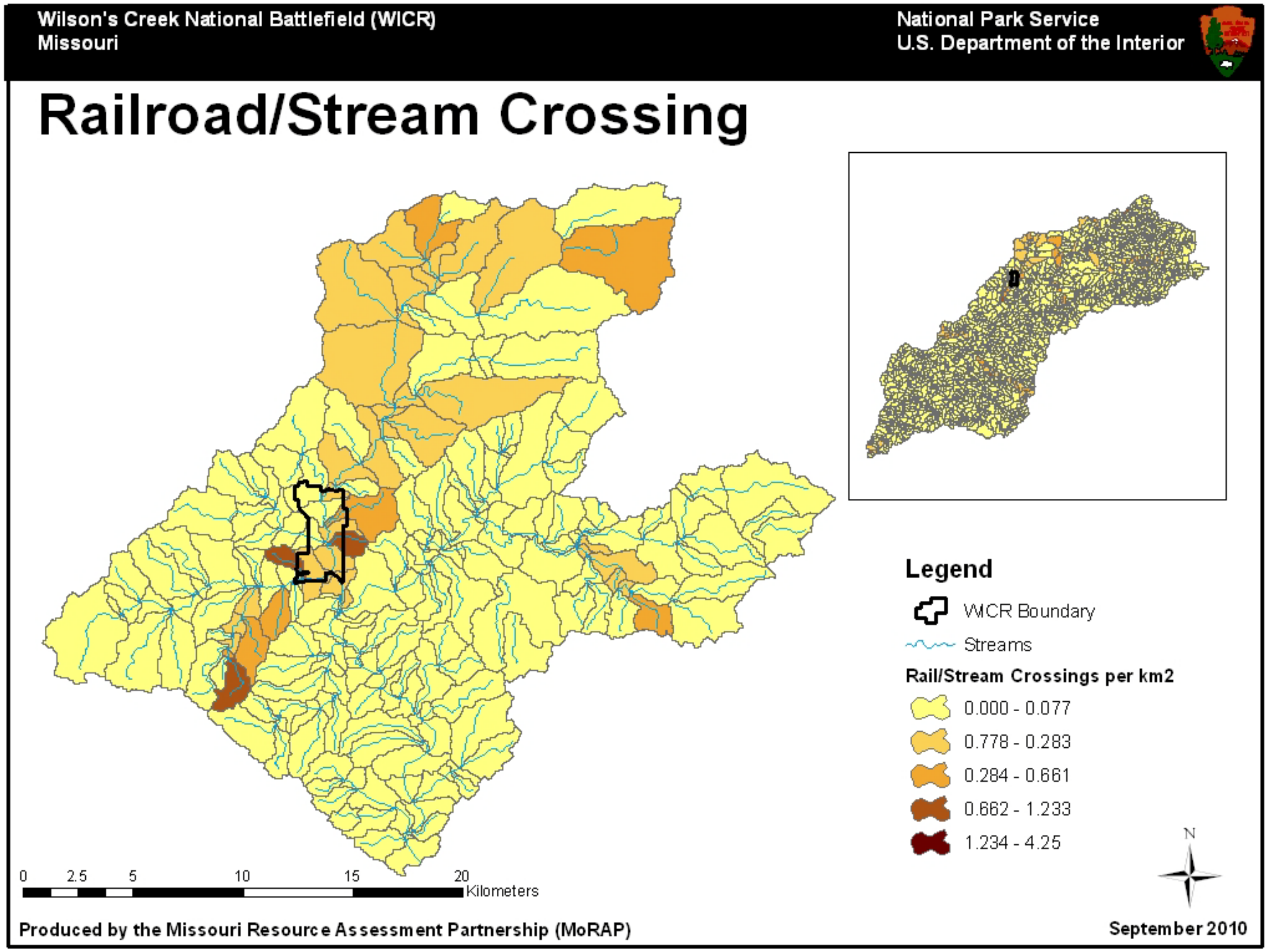

Figure A-18. Density of railroad/stream crossings above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

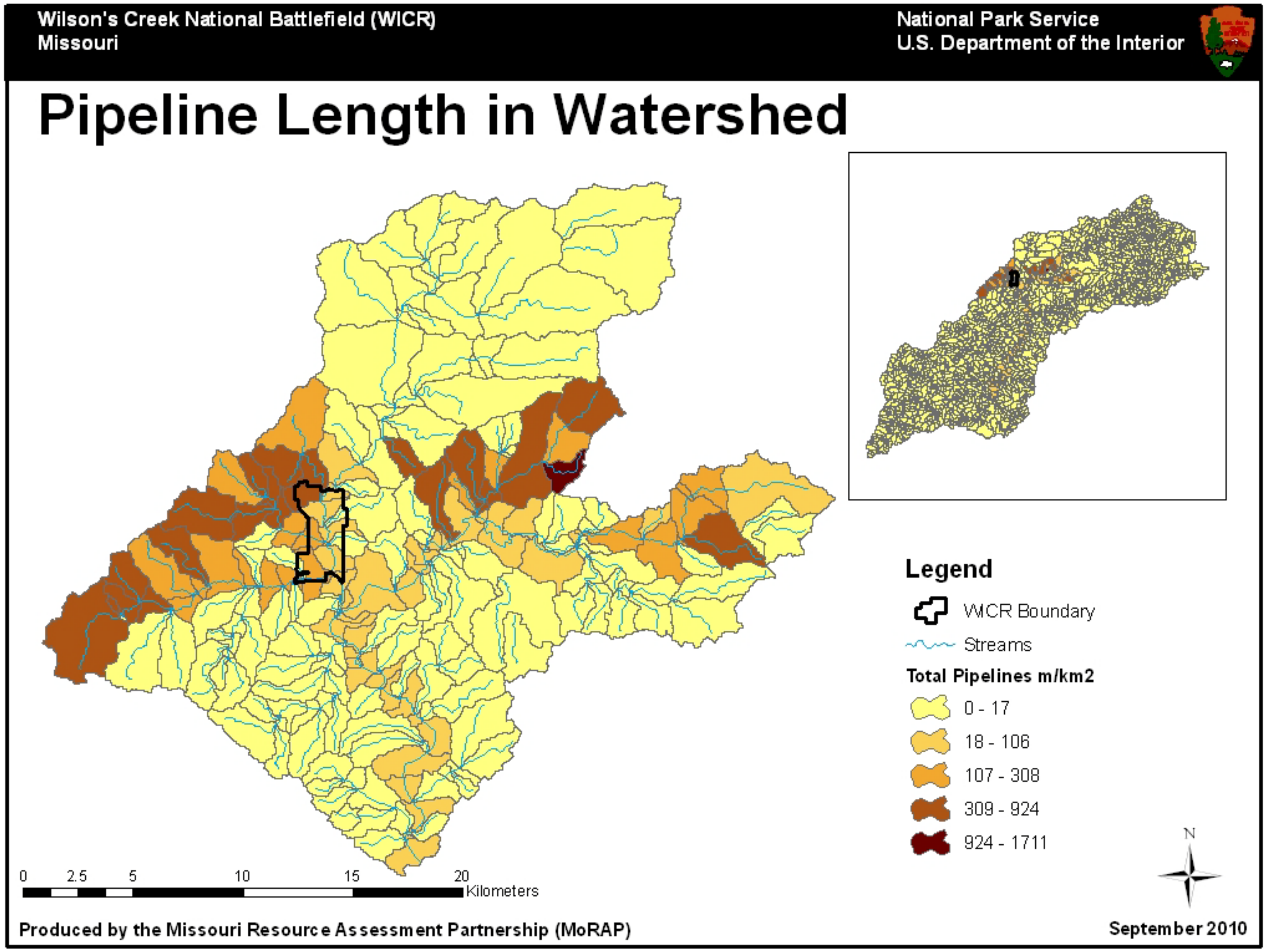

Figure A-19. Length of pipelines above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

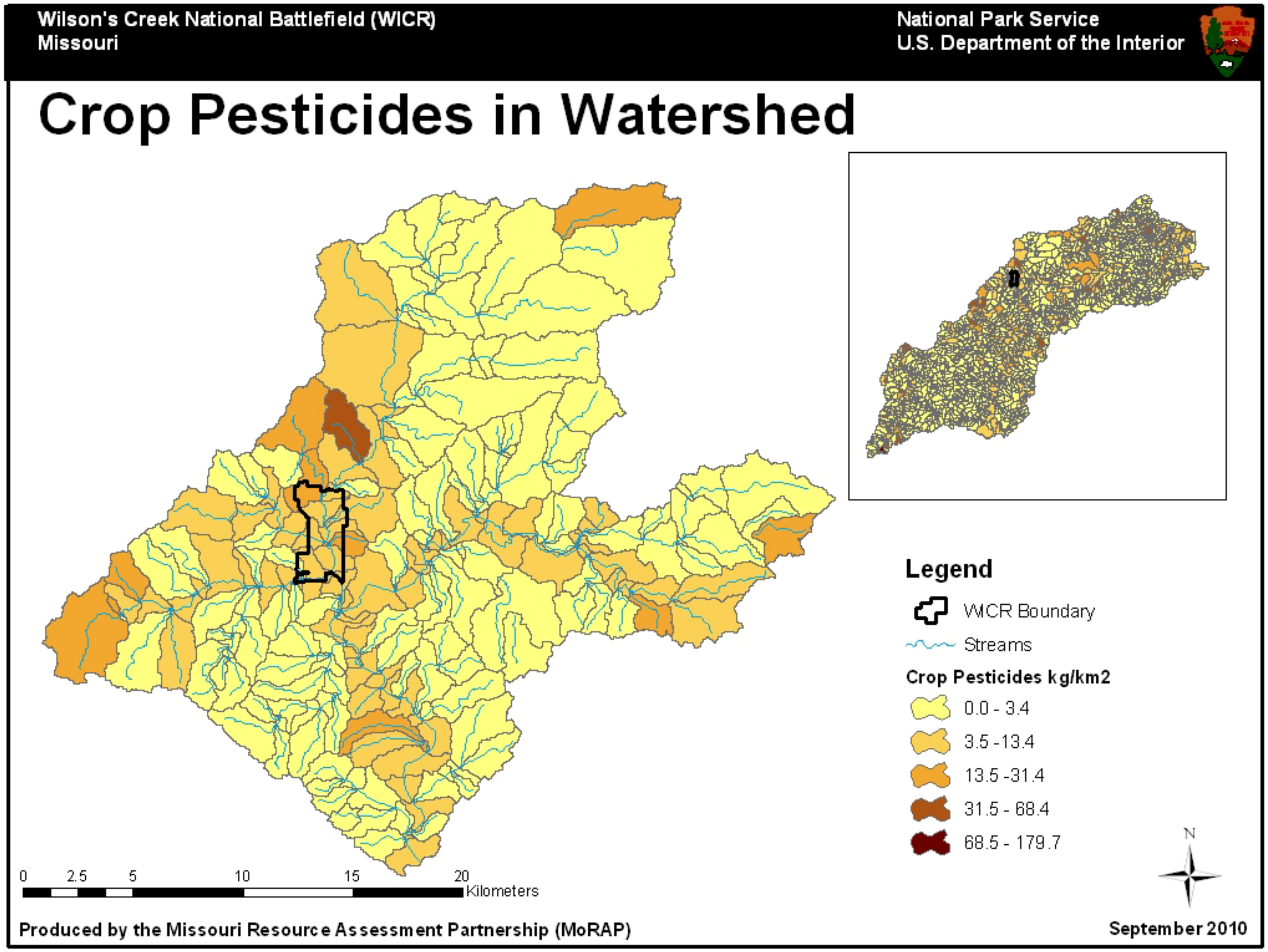

Figure A-20. Application rates of crop pesticides above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

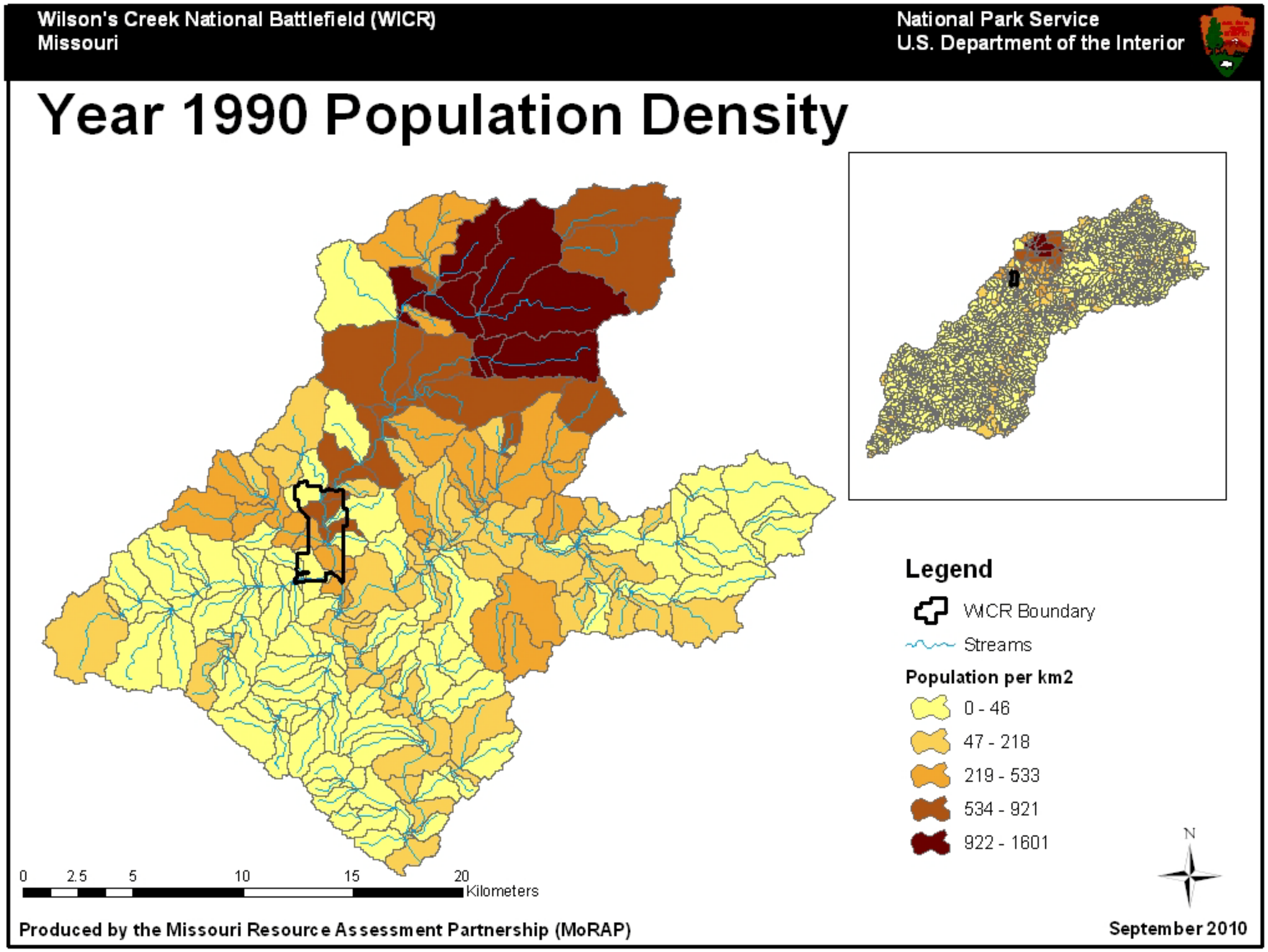

Figure A-21. Density of population in 1990 above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

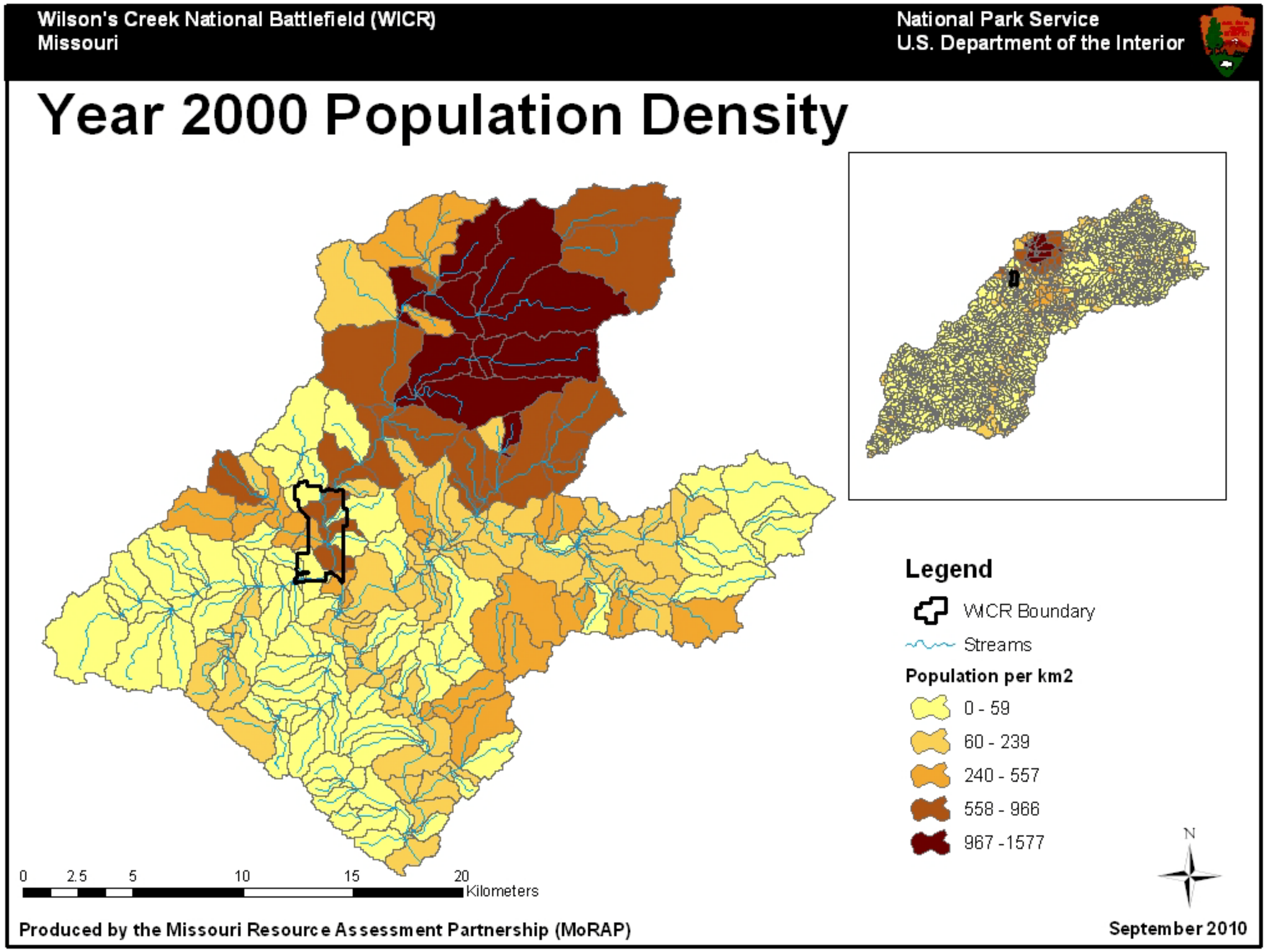

Figure A-22. Density of population in 2000 above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

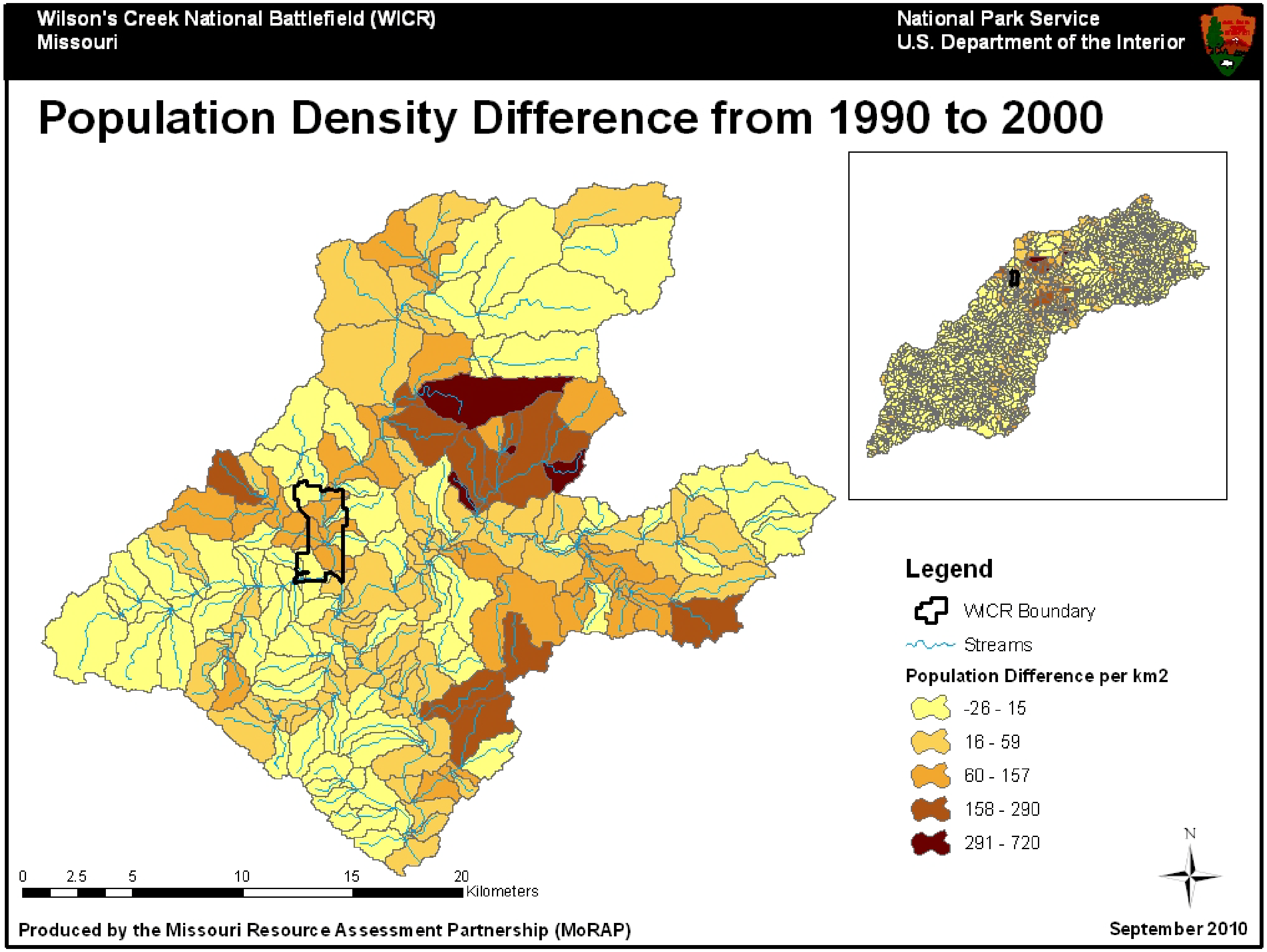

Figure A-23. Change in population density from 1990 to 2000 above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

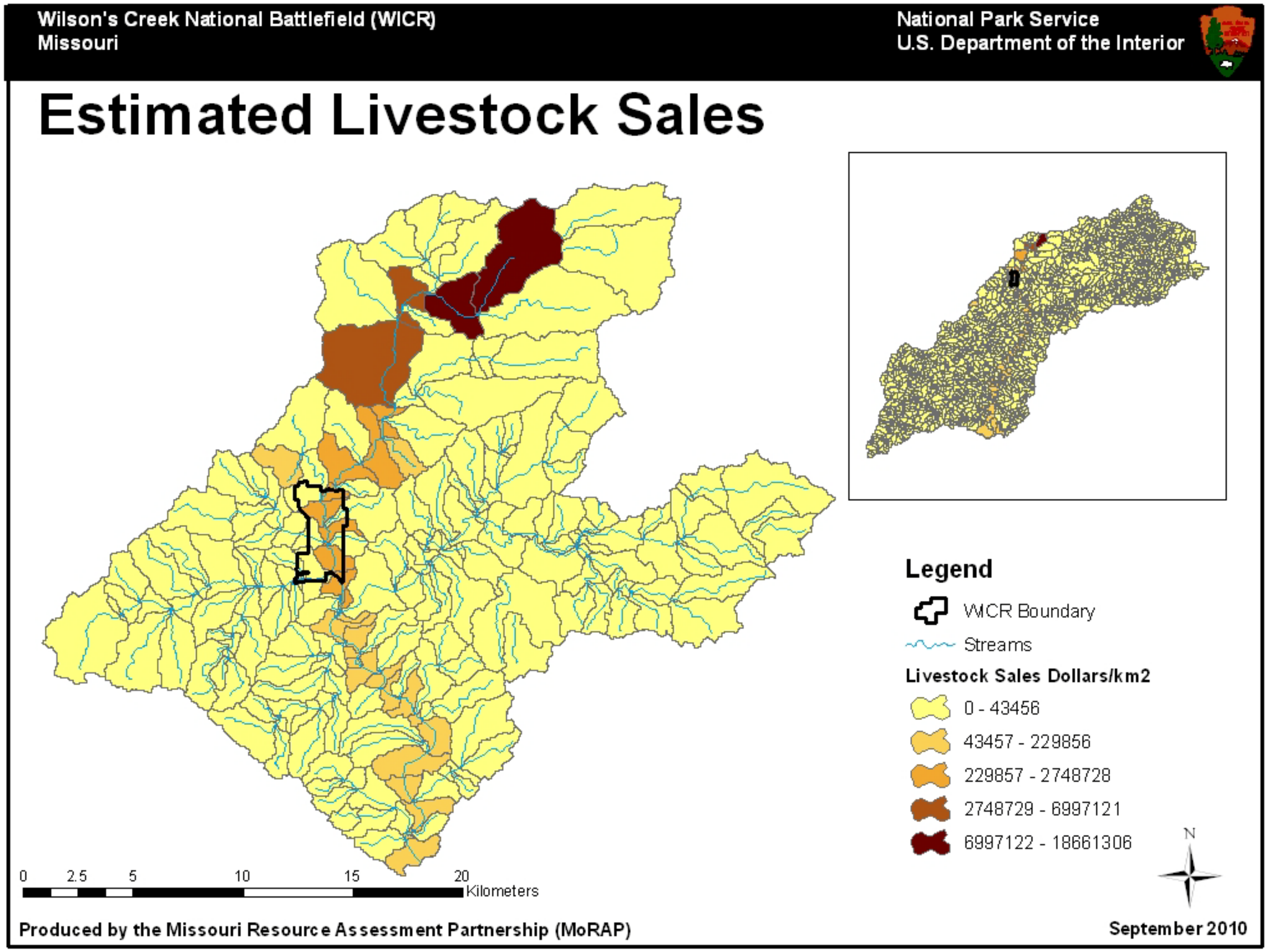

Figure A-24. Amount of livestock sales above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

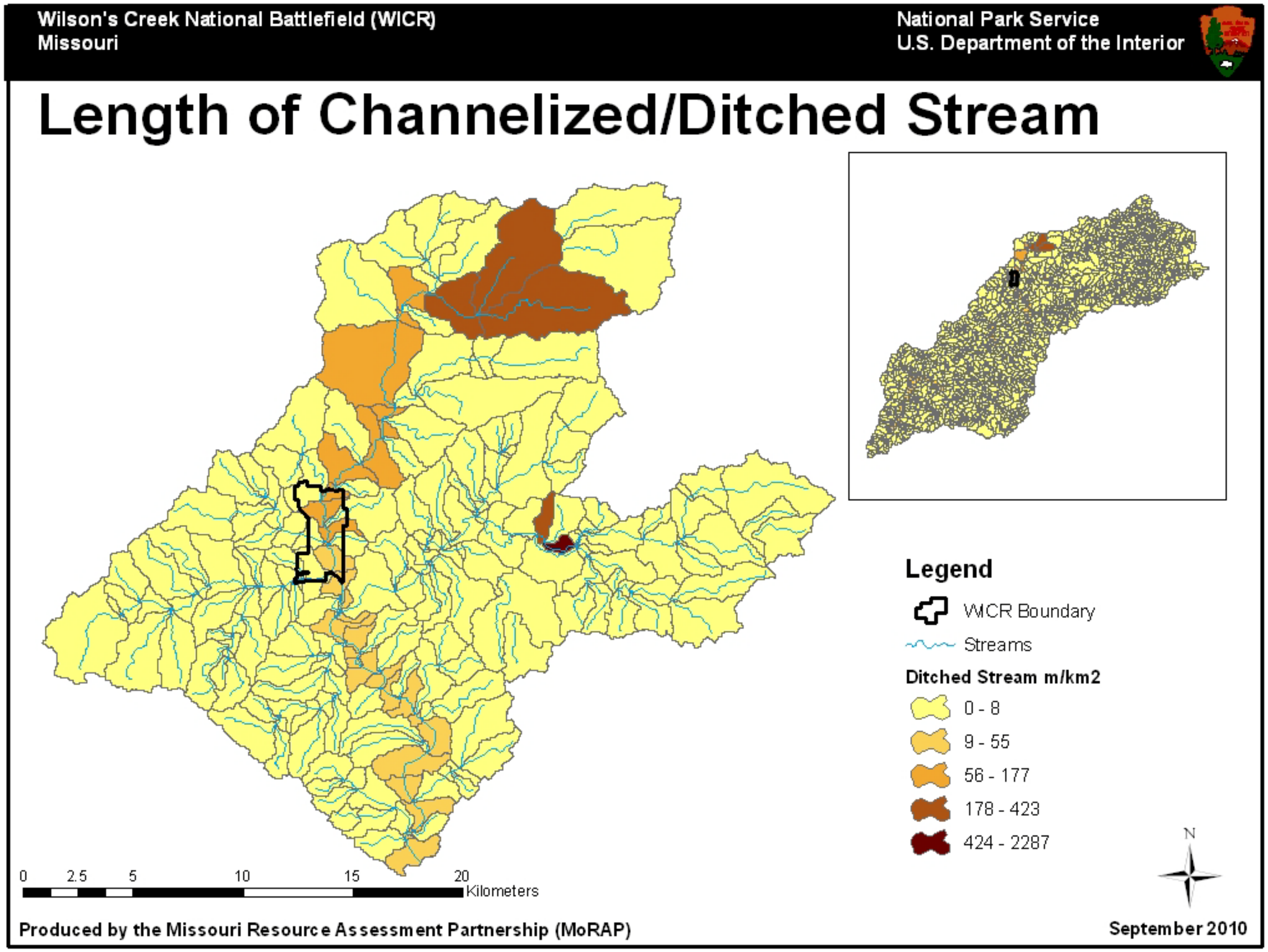

Figure A-25. Length of channelized/ditched streams above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

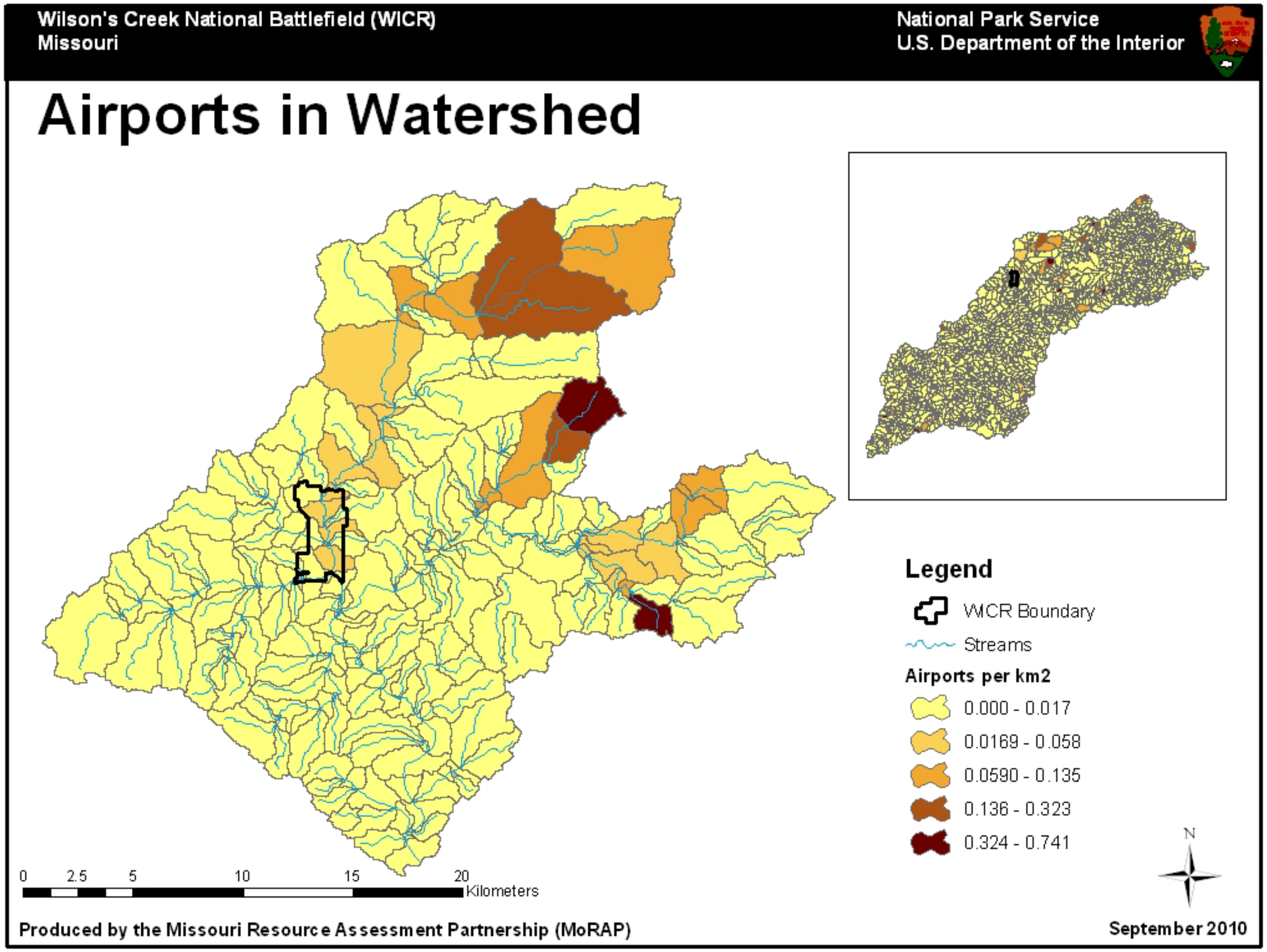

Figure A-26. Density of airports above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

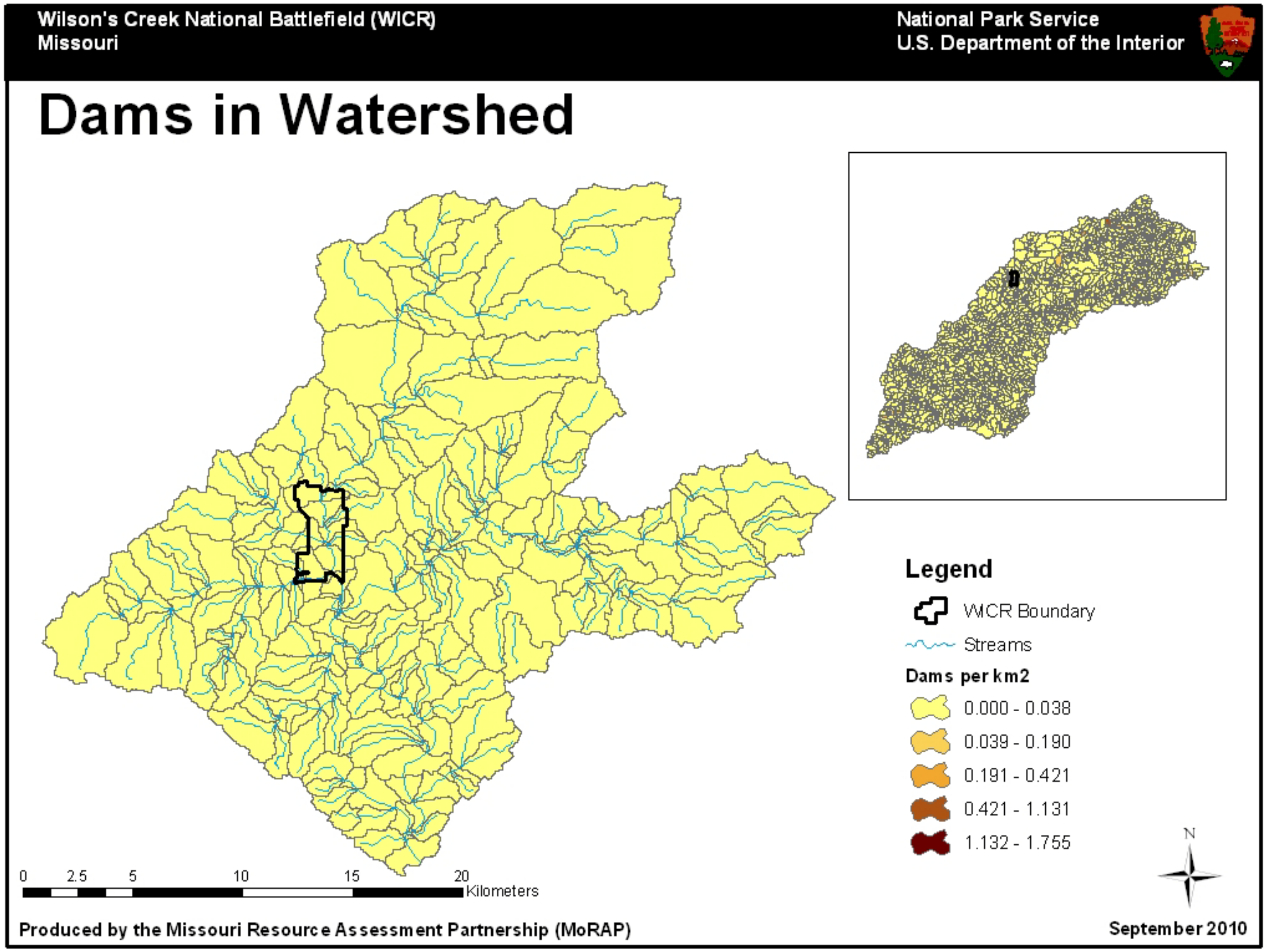

Figure A-27. Density of dams above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

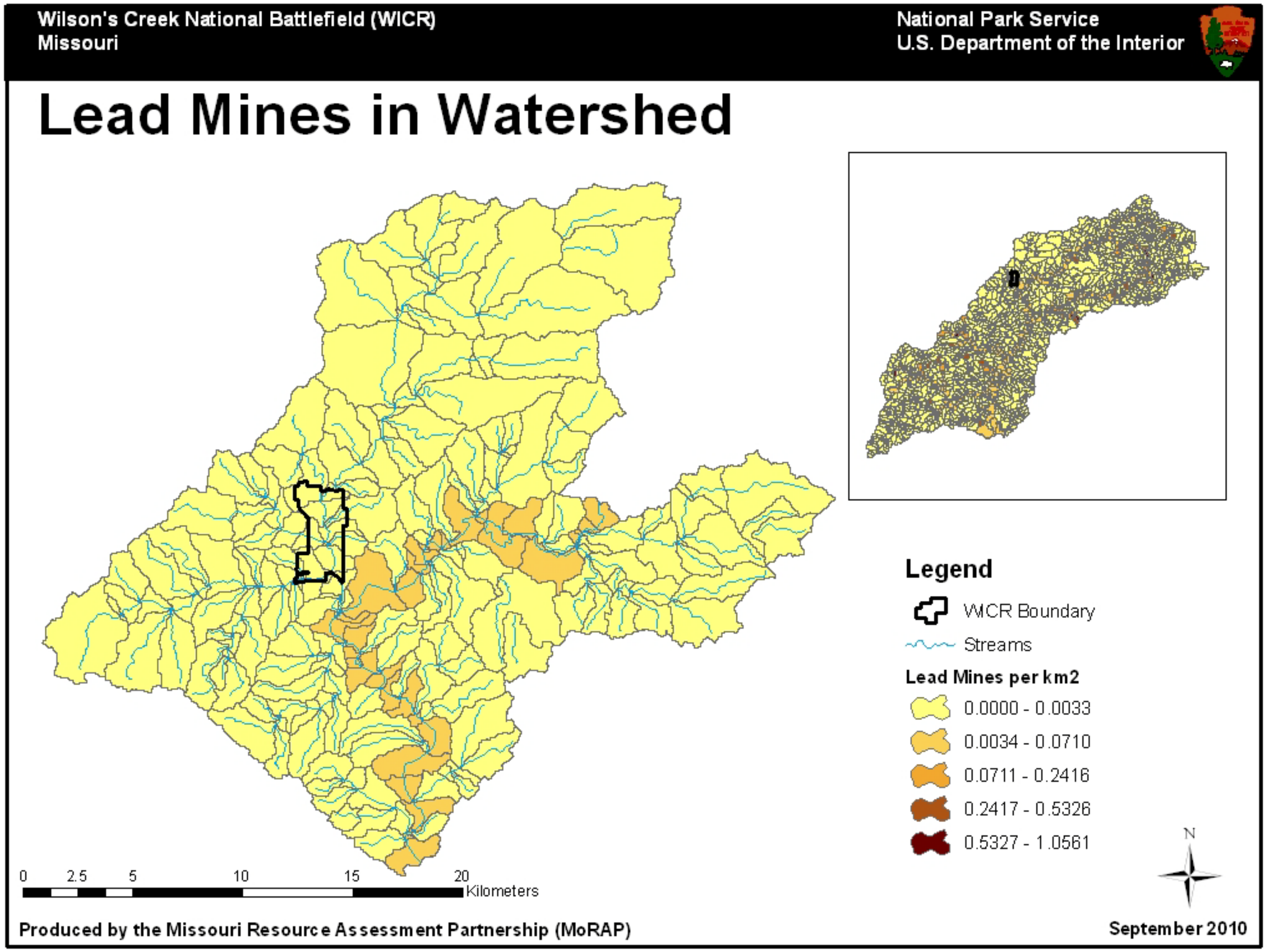

Figure A-28. Density of lead mines above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

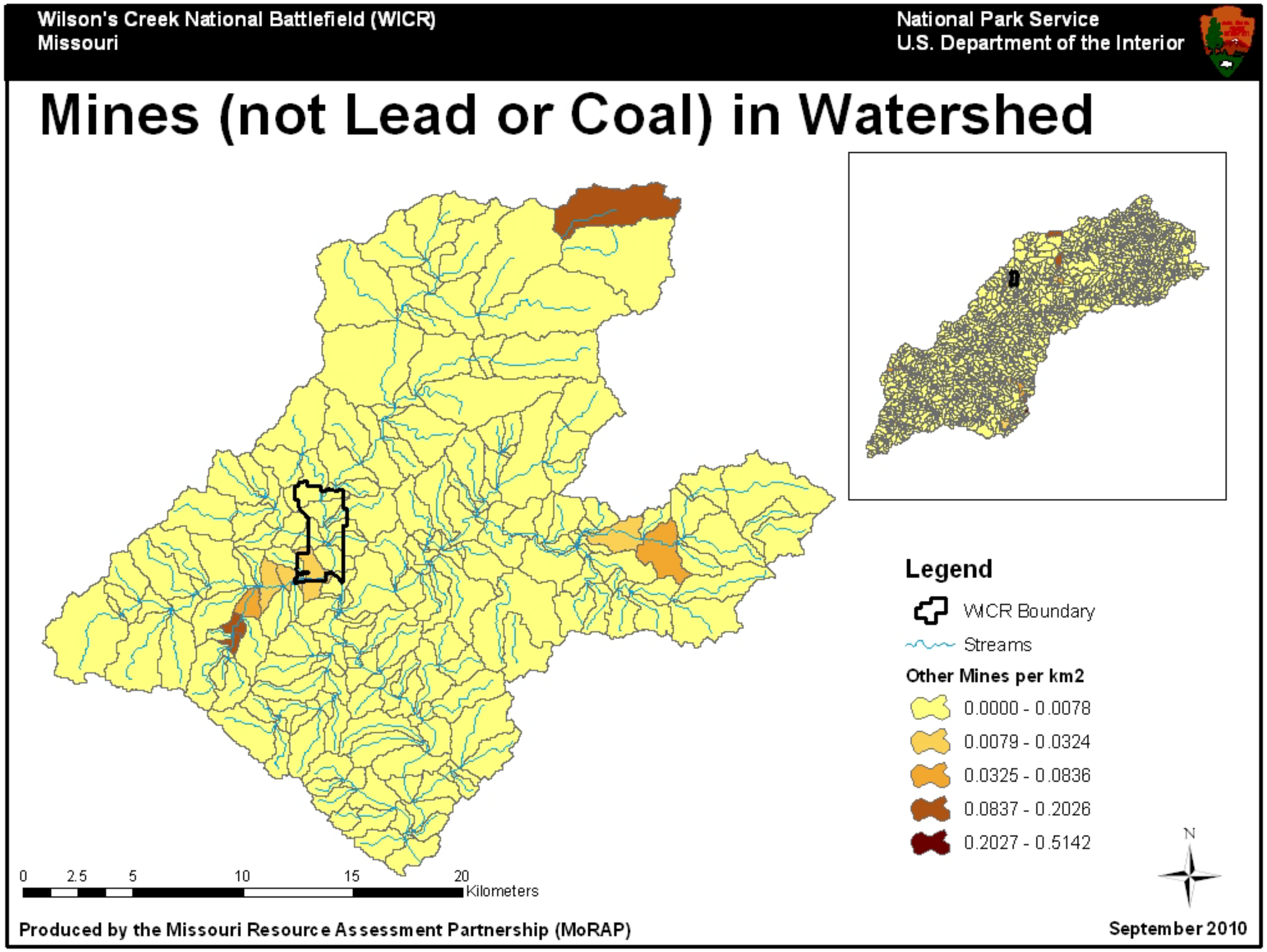

Figure A-29. Density of other mines above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

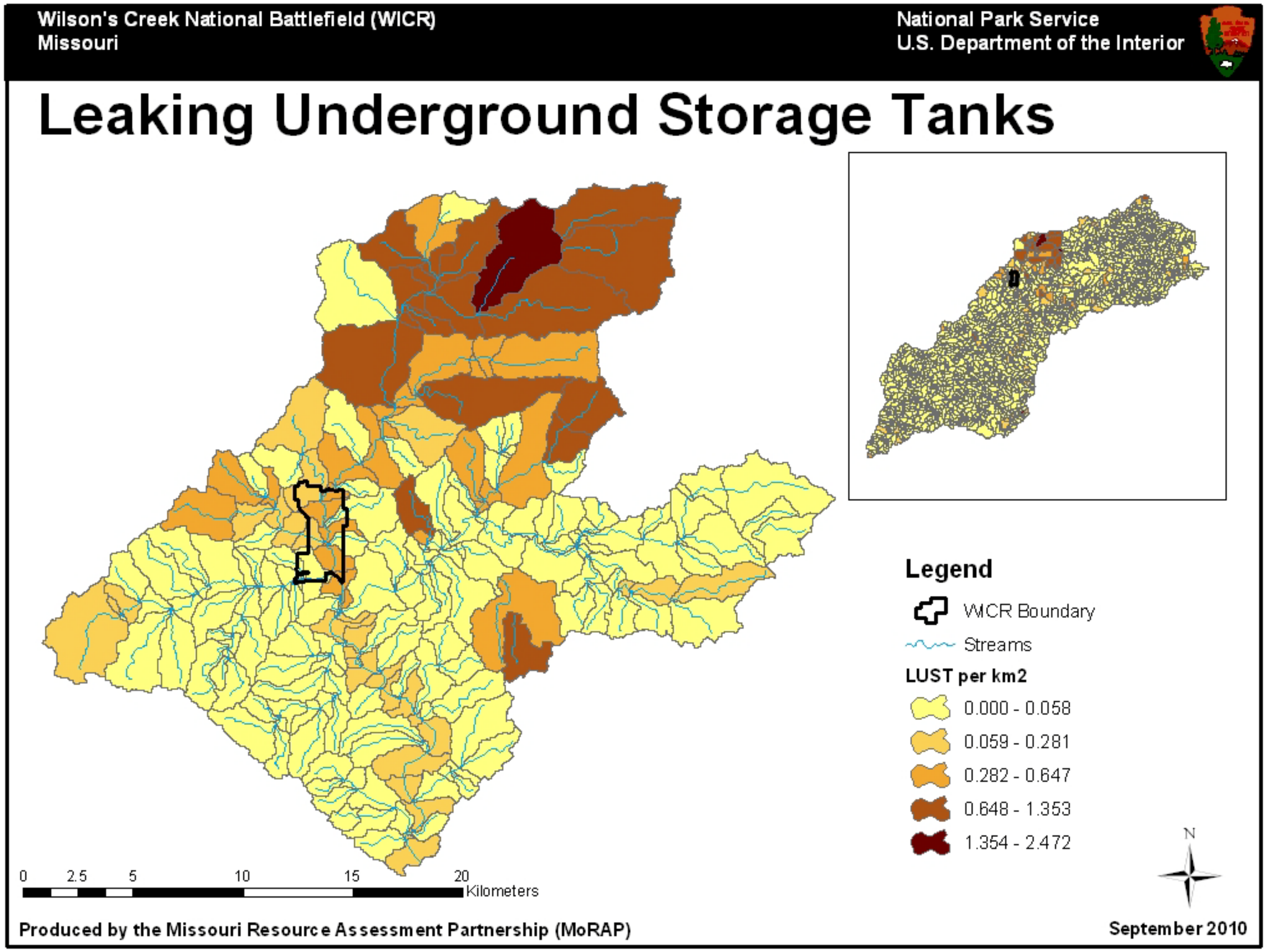

Figure A-30. Density of leaking underground storage tanks above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

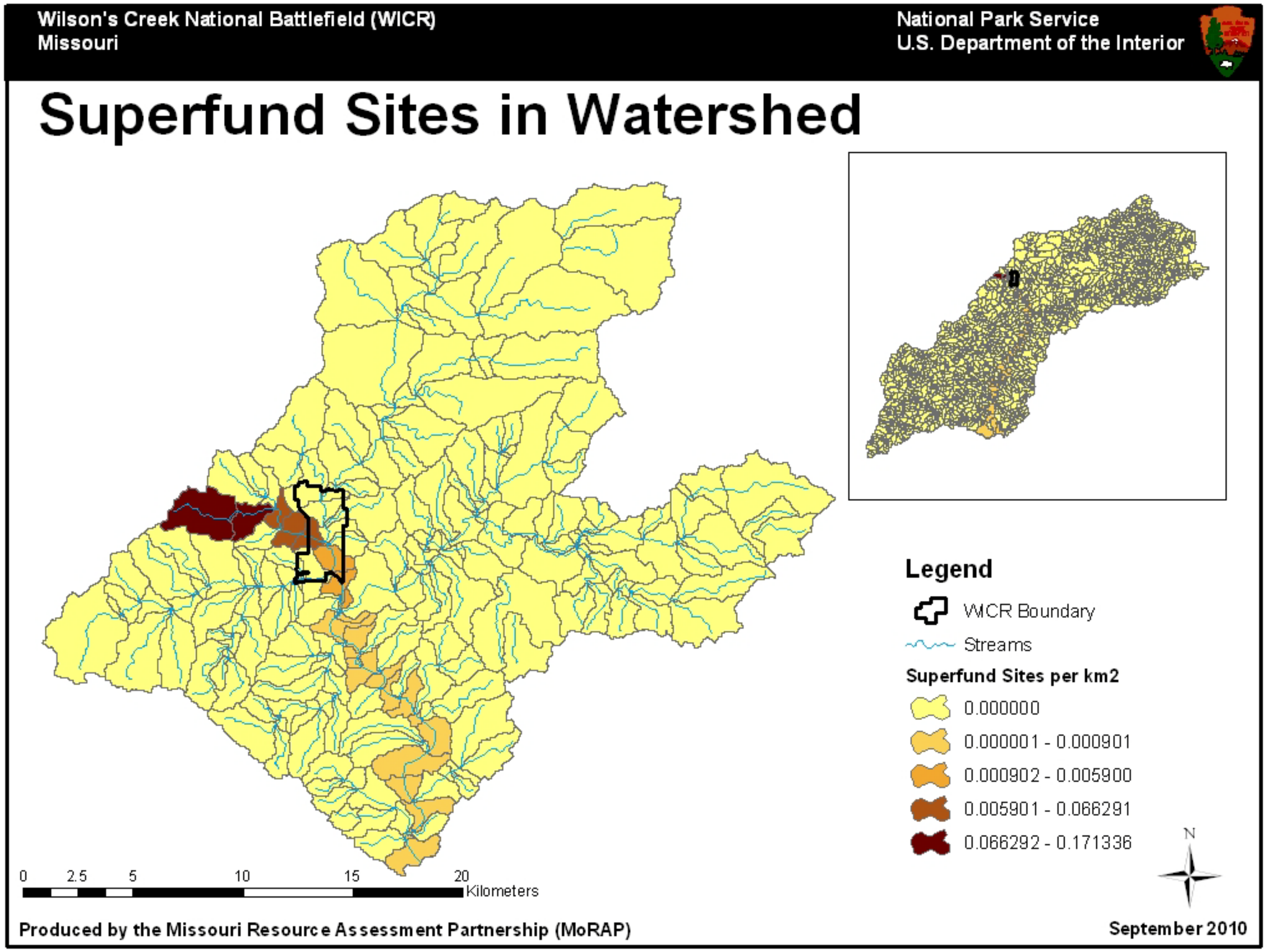

Figure A-31. Density of superfund sites above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

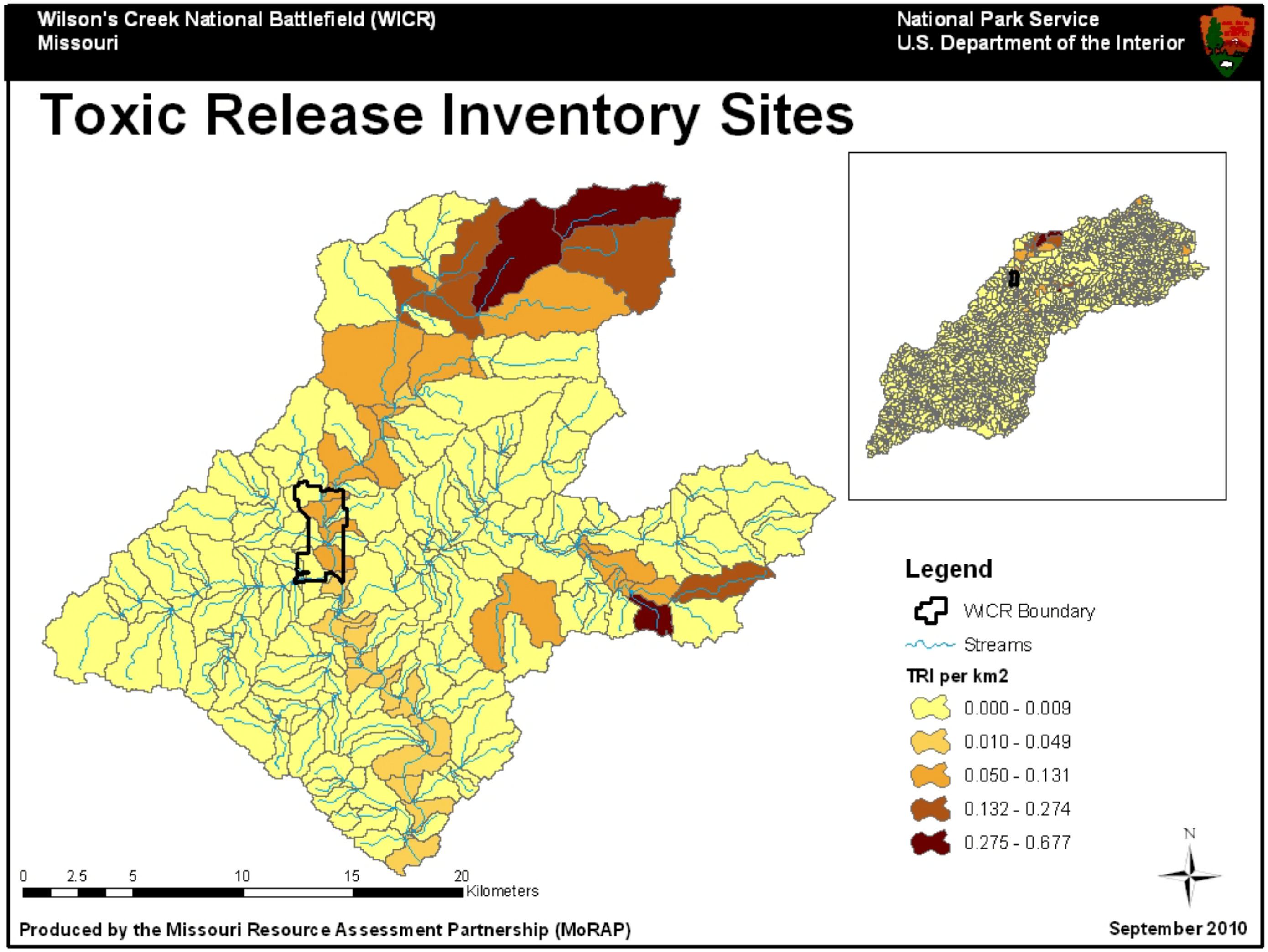

Figure A-32. Density of toxic release inventory sites above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

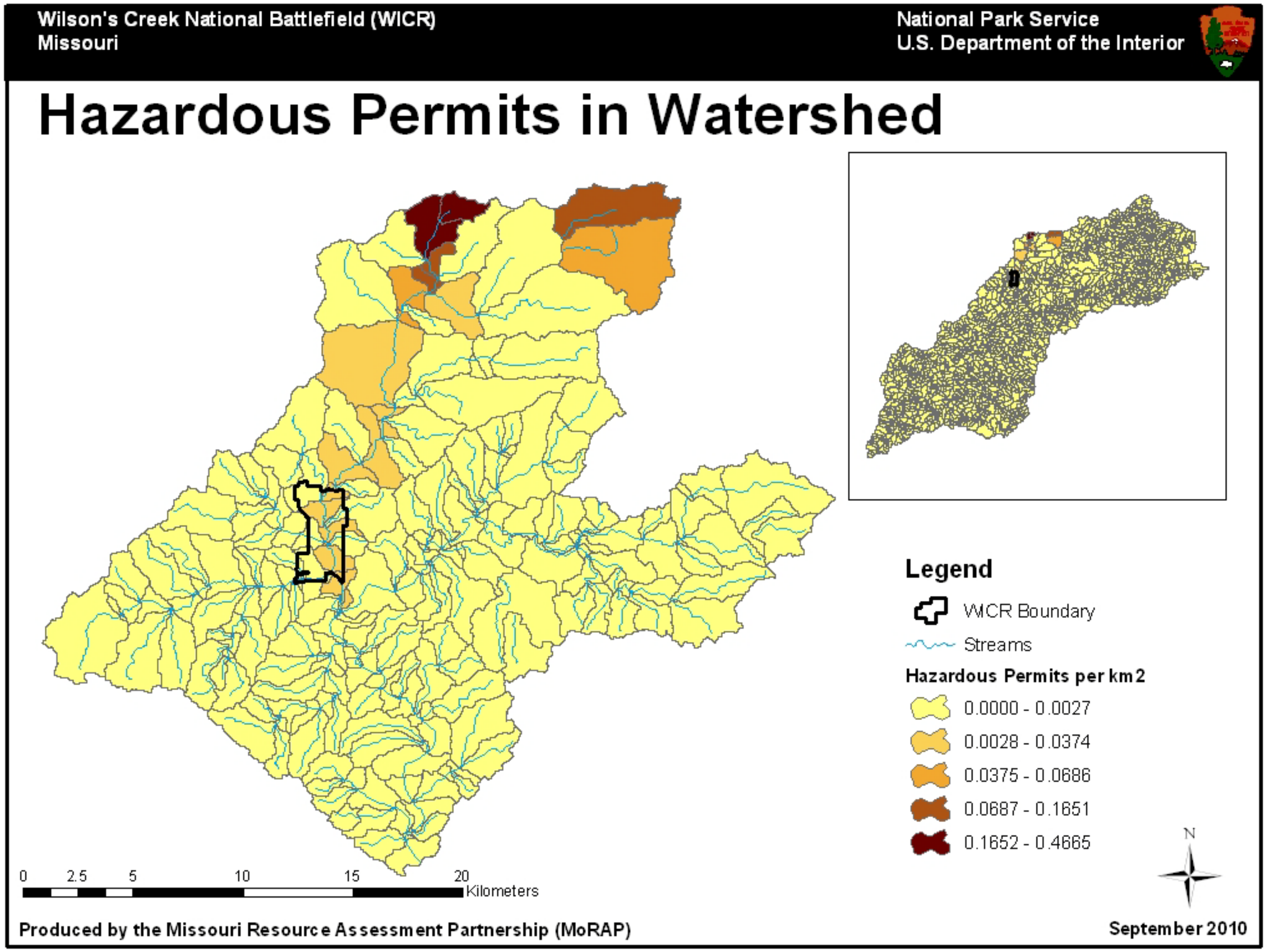

Figure A-33. Density of hazardous permits above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

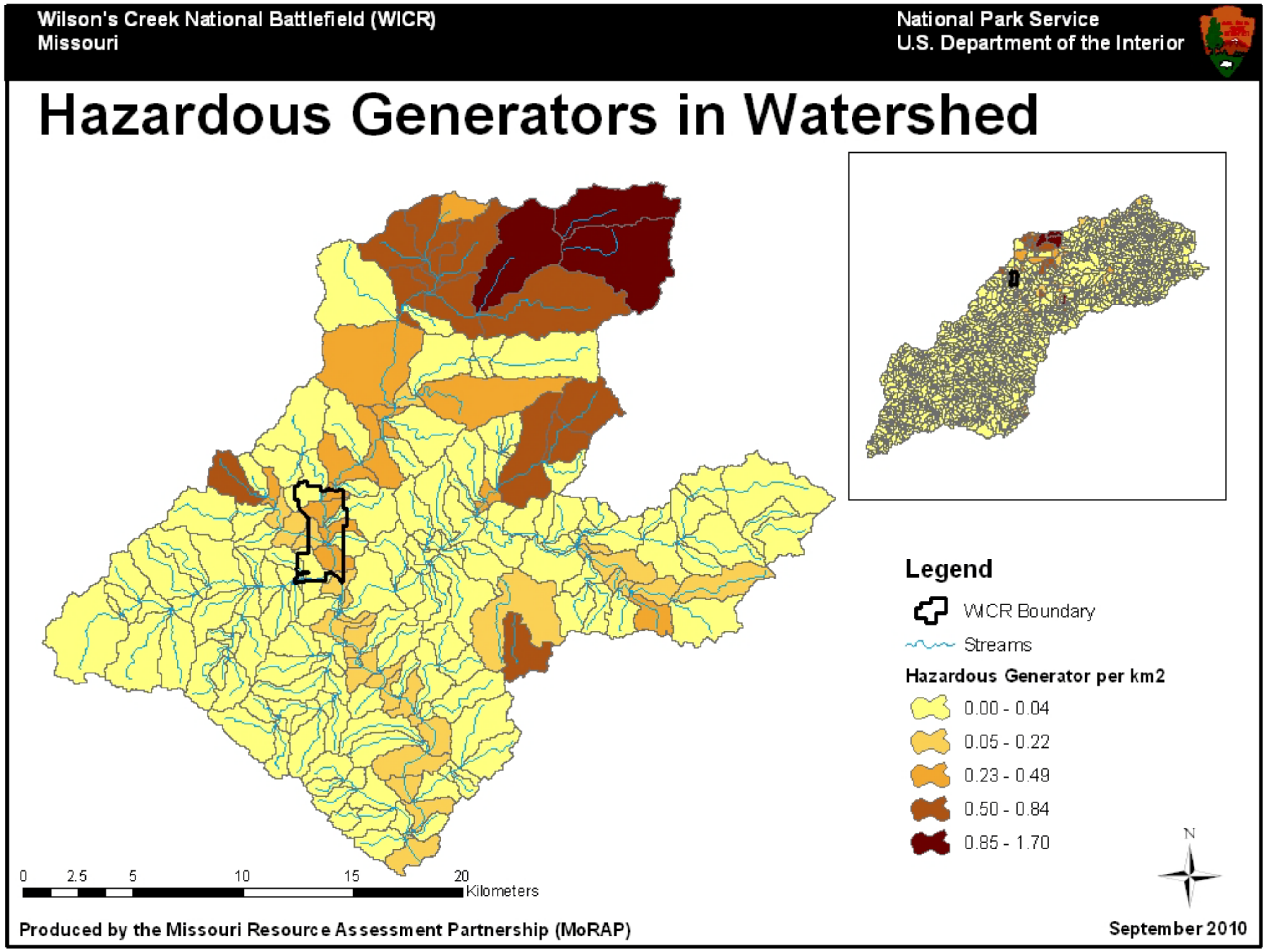

Figure A-34. Density of hazardous generators above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

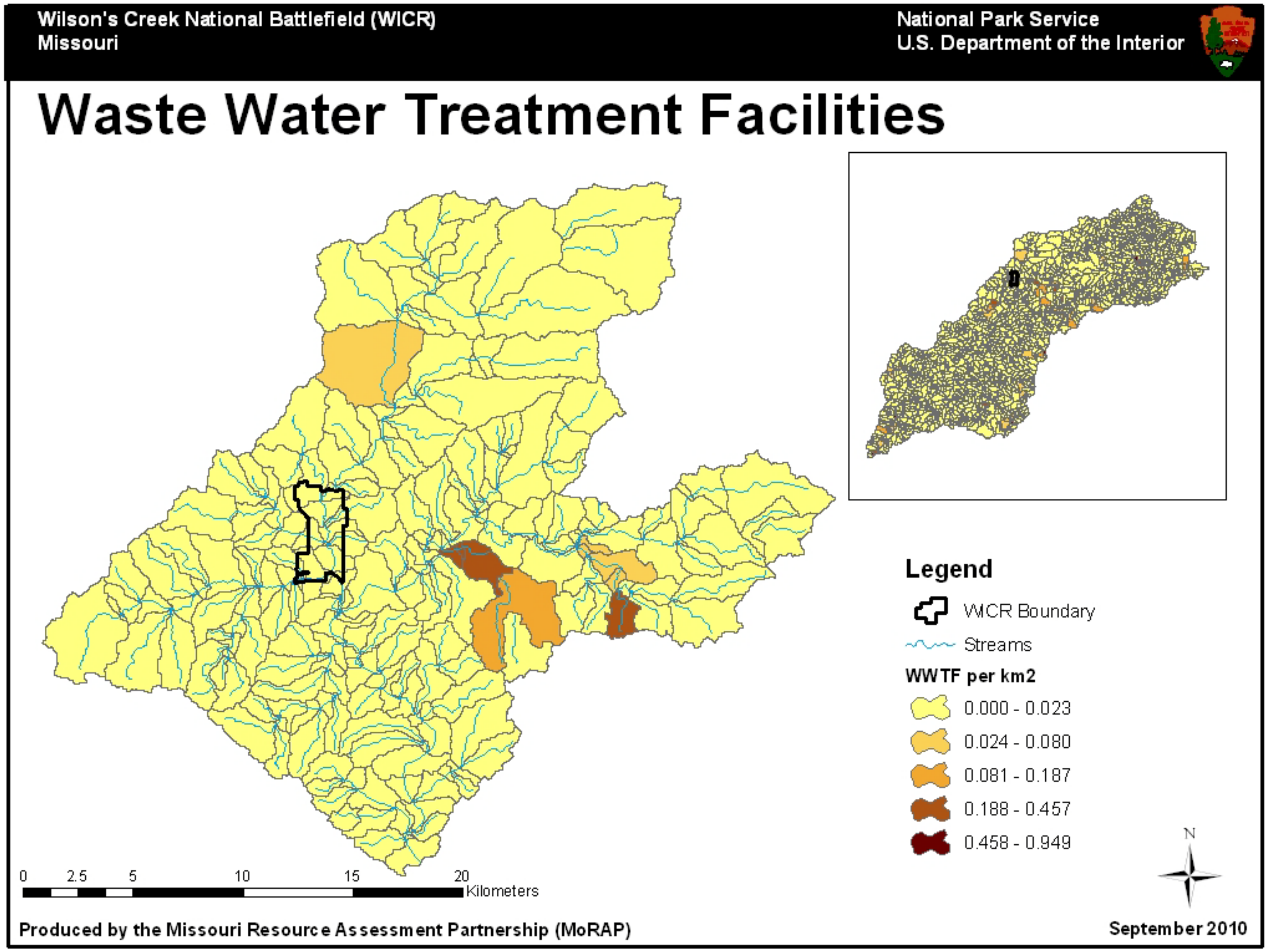

Figure A-35. Density of waste water treatment facilities above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

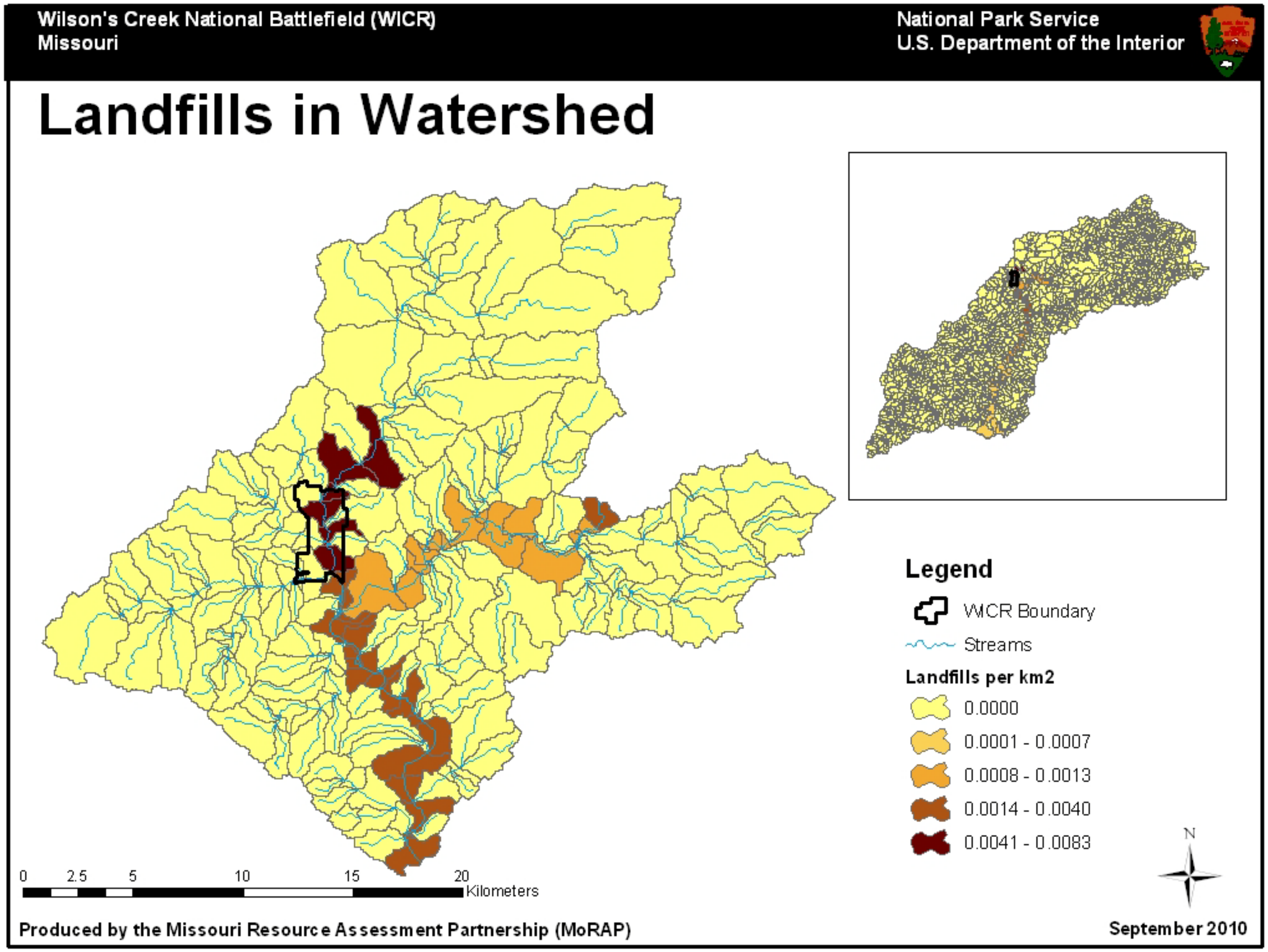

Figure A-36. Density of landfills above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

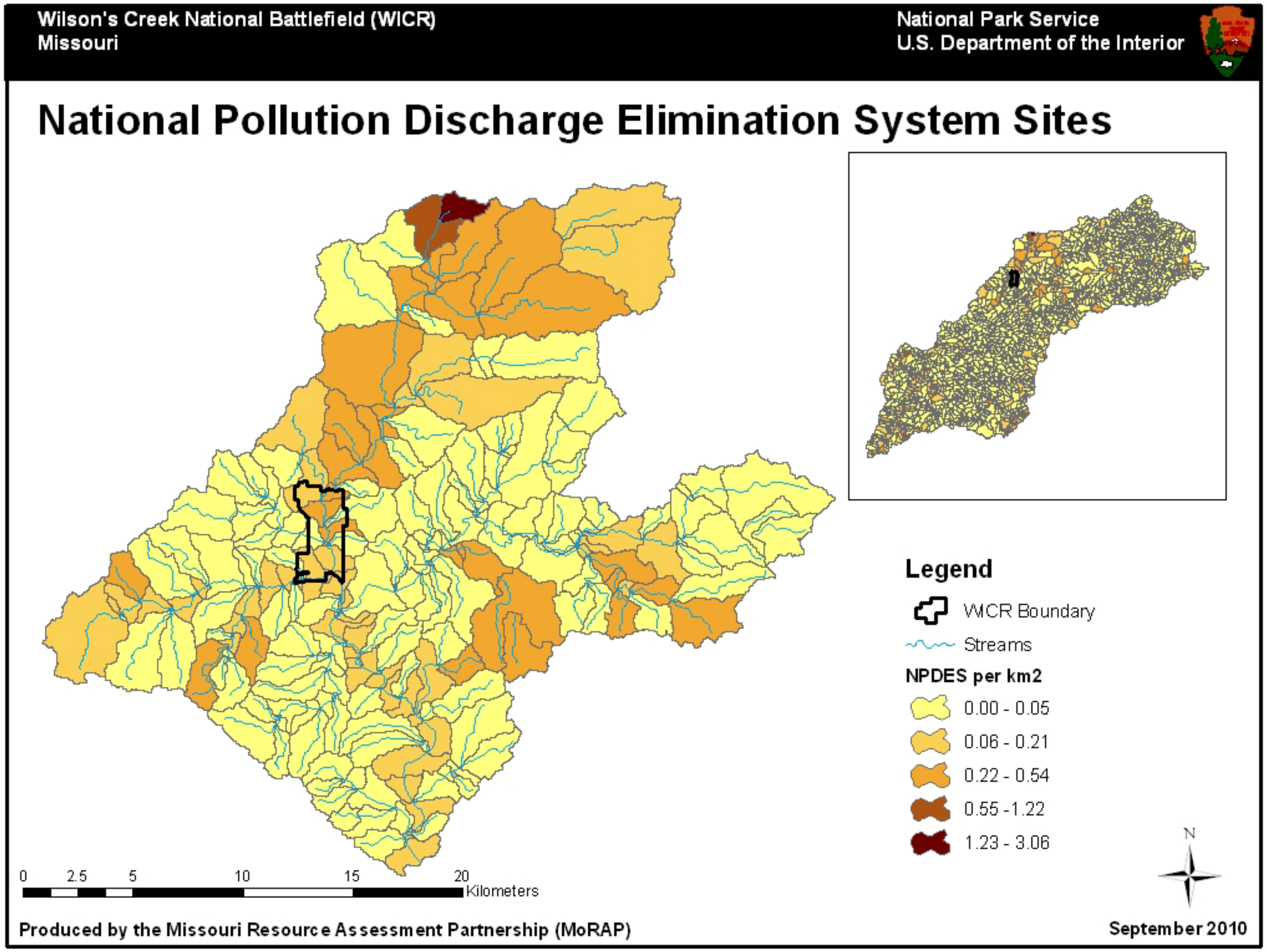

Figure A-37. Density of National Pollution Discharge Elimination System (NPDES) sites above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

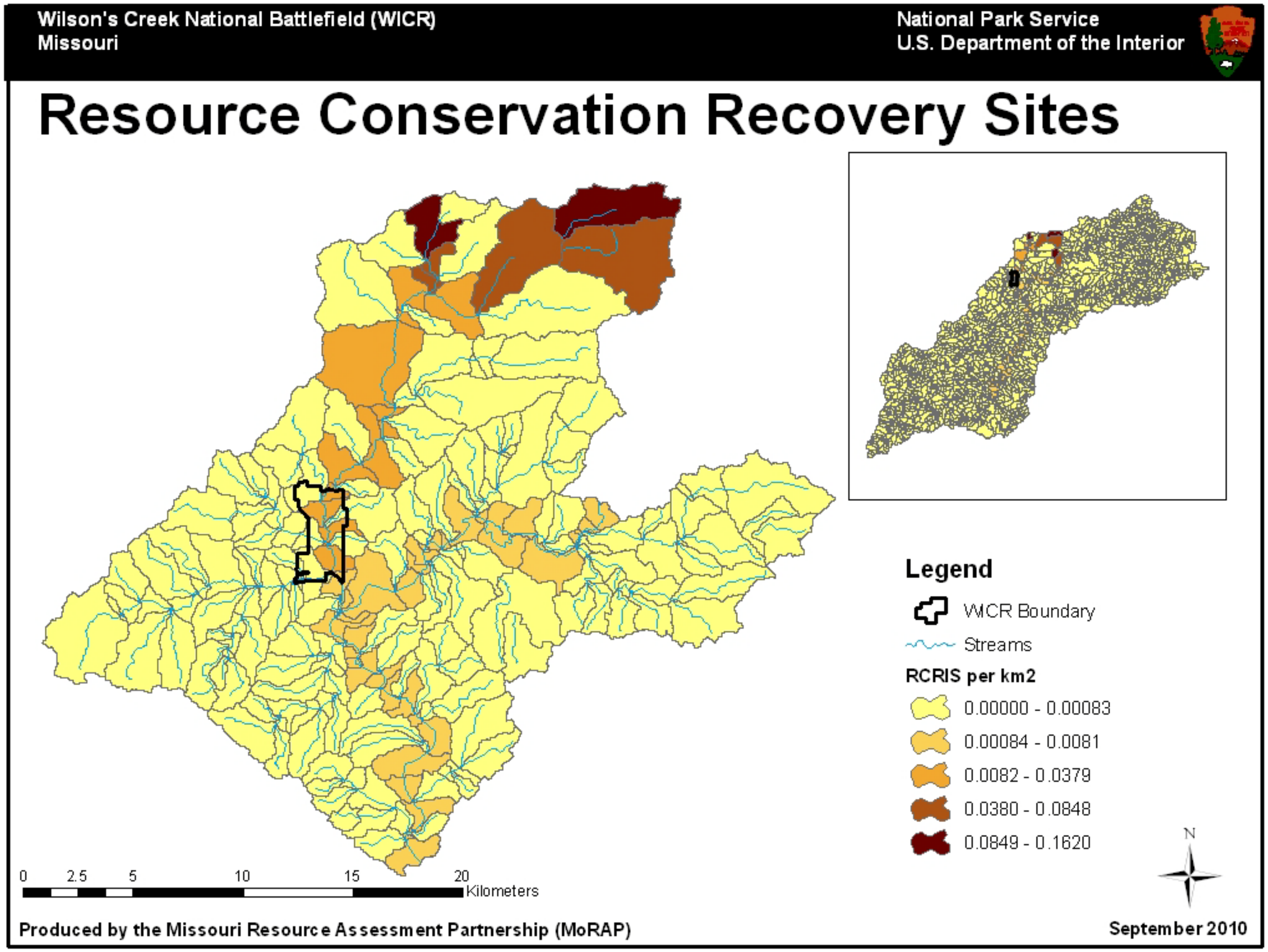

Figure A-38. Density of Resource Conservation Recovery sites above every stream segment in the HUC 10 and HUC 8 (inset) for WICR.

Appendix B Aquatic Invertebrate Indicators.

Table B-1. Aquatic invertebrate indicators for Wilson's Creek.

Indicator	Management Target	Reference Condition	Mean[1]	Rating
Family Richness				
1988	>14.1	14.2	10.0	Off Target
1989	>14.1	14.2	12.5	Off Target
1990	>14.1	14.2	9.6	Off Target
1996	>14.1	14.2	10.8	Off Target
1997	>14.1	14.2	12.2	Off Target
1998	>14.1	14.2	11.8	Off Target
1999	>14.1	14.2	8.9	Off Target
2000	>14.1	14.2	5.8	Off Target
2001	>14.1	14.2	8.6	Off Target
2002	>14.1	14.2	8.5	Off Target
2003	>14.1	14.2	7.7	Off Target
2004	>14.1	14.2	7.2	Off Target
2005	>14.1	14.2	10.0	Off Target
2006	>14.1	14.2	9.5	Off Target
2007	>14.1	14.2	10.8	Off Target
Mean	>14.1	14.2	9.6	Off Target
Genus Richness				
1988	>15	26.2	12.0	Off Target
1989	>15	26.2	16.4	On Target
1990	>15	26.2	13.6	Off Target
1996	>15	26.2	21.0	On Target
1997	>15	26.2	18.8	On Target
1998	>15	26.2	18.5	On Target
1999	>15	26.2	14.5	Off Target
2000	>15	26.2	10.3	Off Target
2001	>15	26.2	14.6	Off Target
2002	>15	26.2	13.4	Off Target
2003	>15	26.2	12.6	Off Target
2004	>15	26.2	9.9	Off Target
2005	>15	26.2	17.6	On Target
2006	>15	26.2	13.6	Off Target
2007	>15	26.2	14.9	Off Target
Mean	>15	26.2	14.8	Off Target
EPT Richness				
1988	>4	7.8	3.9	Off Target
1989	>4	7.8	3.1	Off Target
1990	>4	7.8	1.4	Off Target
1996	>4	7.8	5.2	On Target
1997	>4	7.8	4.6	On Target
1998	>4	7.8	5.7	On Target
1999	>4	7.8	3.1	Off Target
2000	>4	7.8	2.5	Off Target
2001	>4	7.8	4.6	On Target
2002	>4	7.8	3.8	Off Target
2003	>4	7.8	3.8	Off Target
2004	>4	7.8	1.9	Off Target
2005	>4	7.8	3.6	Off Target
2006	>4	7.8	2.5	Off Target
2007	>4	7.8	3.8	Off Target
Mean	>4	7.8	3.6	Off Target
EPT Ratio				
1988	>0.22	N/A	0.61	On Target

Table B-1. Continued

Indicator	Management Target	Reference Condition	Mean[1]	Rating
1989	>0.22	N/A	0.26	On Target
1990	>0.22	N/A	0.01	Off Target
1996	>0.22	N/A	0.27	On Target
1997	>0.22	N/A	0.25	On Target
1998	>0.22	N/A	0.56	On Target
1999	>0.22	N/A	0.37	On Target
2000	>0.22	N/A	0.11	Off Target
2001	>0.22	N/A	0.39	On Target
2002	>0.22	N/A	0.28	On Target
2003	>0.22	N/A	0.37	On Target
2004	>0.22	N/A	0.33	On Target
2005	>0.22	N/A	0.29	On Target
2006	>0.22	N/A	0.57	On Target
2007	>0.22	N/A	0.18	Off Target
Mean	>0.22	N/A	0.32	On Target
Shannon Index (Genus)				
1988	>1.77	2.39	1.12	Off Target
1989	>1.77	2.39	0.22	Off Target
1990	>1.77	2.39	1.14	Off Target
1996	>1.77	2.39	0.90	Off Target
1997	>1.77	2.39	1.76	Off Target
1998	>1.77	2.39	1.09	Off Target
1999	>1.77	2.39	1.64	Off Target
2000	>1.77	2.39	1.44	Off Target
2001	>1.77	2.39	1.45	Off Target
2002	>1.77	2.39	1.35	Off Target
2003	>1.77	2.39	1.88	On Target
2004	>1.77	2.39	1.49	Off Target
2005	>1.77	2.39	1.94	On Target
2006	>1.77	2.39	2.03	On Target
2007	>1.77	2.39	1.93	On Target
Mean	>1.77	2.39	1.43	Off Target
Shannon Evenness Index				
1988	>0.8	N/A	0.49	Off Target
1989	>0.8	N/A	0.12	Off Target
1990	>0.8	N/A	0.57	Off Target
1996	>0.8	N/A	0.46	Off Target
1997	>0.8	N/A	0.69	Off Target
1998	>0.8	N/A	0.56	Off Target
1999	>0.8	N/A	0.70	Off Target
2000	>0.8	N/A	0.66	Off Target
2001	>0.8	N/A	0.67	Off Target
2002	>0.8	N/A	0.63	Off Target
2003	>0.8	N/A	0.76	Off Target
2004	>0.8	N/A	0.62	Off Target
2005	>0.8	N/A	0.71	Off Target
2006	>0.8	N/A	0.77	Off Target
2007	>0.8	N/A	0.72	Off Target
Mean	>0.8	N/A	0.61	Off Target
Hilsenhoff Biotic Index				
1988	<6.6	<4.3	5.33	On Target
1989	<6.6	<4.3	5.61	On Target
1990	<6.6	<4.3	6.61	Off Target
1996	<6.6	<4.3	5.85	On Target
1997	<6.6	<4.3	5.94	On Target

Table B-1. Continued

Indicator	Management Target	Reference Condition	Mean[1]	Rating
1998	<6.6	<4.3	5.50	On Target
1999	<6.6	<4.3	6.17	On Target
2000	<6.6	<4.3	6.61	Off Target
2001	<6.6	<4.3	5.77	On Target
2002	<6.6	<4.3	5.87	On Target
2003	<6.6	<4.3	5.83	On Target
2004	<6.6	<4.3	5.24	On Target
2005	<6.6	<4.3	5.98	On Target
2006	<6.6	<4.3	5.37	On Target
2007	<6.6	<4.3	6.72	Off Target
Mean	<6.6	<4.3	5.89	On Target

[1] Mean from Bowles (2010).

Table B-2. Aquatic invertebrate indicators for Skegg's Branch.

Indicator	Management Target	Reference Condition	Mean[1]	Rating
Family Richness				
1988	>14.1	14.2	12.0	Off Target
1989	>14.1	14.2	17.3	On Target
1990	>14.1	14.2	17.0	On Target
1997	>14.1	14.2	17.3	On Target
1999	>14.1	14.2	12.5	Off Target
2001	>14.1	14.2	10.9	Off Target
2002	>14.1	14.2	8.0	Off Target
2003	>14.1	14.2	8.2	Off Target
2004	>14.1	14.2	8.7	Off Target
2005	>14.1	14.2	9.8	Off Target
2006	>14.1	14.2	11.0	Off Target
2007	>14.1	14.2	11.9	Off Target
Mean	>14.1	14.2	12.1	Off Target
Genus Richness				
1988	>15	26.2	14.0	Off Target
1989	>15	26.2	23.5	On Target
1990	>15	26.2	23.8	On Target
1997	>15	26.2	25.8	On Target
1999	>15	26.2	20.0	On Target
2001	>15	26.2	18.7	On Target
2002	>15	26.2	15.7	On Target
2003	>15	26.2	14.0	Off Target
2004	>15	26.2	11.9	Off Target
2005	>15	26.2	18.6	On Target
2006	>15	26.2	20.0	On Target
2007	>15	26.2	21.7	On Target
Mean	>15	26.2	19.0	On Target
EPT Richness				
1988	>4	7.8	3.8	Off Target
1989	>4	7.8	6.2	On Target
1990	>4	7.8	5.6	On Target
1997	>4	7.8	5.1	On Target
1999	>4	7.8	2.8	Off Target
2001	>4	7.8	4.9	On Target
2002	>4	7.8	2.8	Off Target
2003	>4	7.8	4.4	On Target
2004	>4	7.8	2.5	Off Target
2005	>4	7.8	3.0	Off Target
2006	>4	7.8	3.9	Off Target
2007	>4	7.8	3.8	Off Target
Mean	>4	7.8	4.1	On Target
EPT Ratio				
1988	>0.22	N/A	0.72	On Target
1989	>0.22	N/A	0.55	On Target
1990	>0.22	N/A	0.58	On Target
1997	>0.22	N/A	0.27	On Target
1999	>0.22	N/A	0.29	On Target
2001	>0.22	N/A	0.45	On Target
2002	>0.22	N/A	0.33	On Target
2003	>0.22	N/A	0.45	On Target
2004	>0.22	N/A	0.44	On Target
2005	>0.22	N/A	0.36	On Target

Table B-2. Continued

Indicator	Management Target	Reference Condition	Mean[1]	Rating
2006	>0.22	N/A	0.28	On Target
2007	>0.22	N/A	0.18	Off Target
Mean	>0.22	N/A	0.41	On Target
Shannon Index (Genus)				
1989	>1.77	2.39	1.90	On Target
1990	>1.77	2.39	1.73	Off Target
1997	>1.77	2.39	1.86	On Target
1999	>1.77	2.39	1.63	Off Target
2001	>1.77	2.39	1.73	Off Target
2002	>1.77	2.39	1.33	Off Target
2003	>1.77	2.39	1.27	Off Target
2004	>1.77	2.39	1.95	On Target
2005	>1.77	2.39	1.59	Off Target
2006	>1.77	2.39	2.34	On Target
2007	>1.77	2.39	2.00	On Target
Mean	>1.77	2.39	1.76	Off Target
Shannon Evenness Index				
1989	>0.8	N/A	0.67	Off Target
1990	>0.8	N/A	0.63	Off Target
1997	>0.8	N/A	0.65	Off Target
1999	>0.8	N/A	0.74	Off Target
2001	>0.8	N/A	0.72	Off Target
2002	>0.8	N/A	0.67	Off Target
2003	>0.8	N/A	0.66	Off Target
2004	>0.8	N/A	0.80	Off Target
2005	>0.8	N/A	0.69	Off Target
2006	>0.8	N/A	0.77	Off Target
2007	>0.8	N/A	0.66	Off Target
Mean	>0.8	N/A	0.70	Off Target
Hilsenhoff Biotic Index				
1988	<6.6	<4.3	5.81	On Target
1989	<6.6	<4.3	5.69	On Target
1990	<6.6	<4.3	5.70	On Target
1997	<6.6	<4.3	6.12	On Target
1999	<6.6	<4.3	5.50	On Target
2001	<6.6	<4.3	5.21	On Target
2002	<6.6	<4.3	5.41	On Target
2003	<6.6	<4.3	6.24	On Target
2004	<6.6	<4.3	4.95	On Target
2005	<6.6	<4.3	4.39	On Target
2006	<6.6	<4.3	5.49	On Target
2007	<6.6	<4.3	5.72	On Target
Mean	<6.6	<4.3	5.52	On Target

[1] Mean from Bowles (2010).

Table B-3. Aquatic invertebrate indicators for Terrell Creek.

Indicator	Management Target	Reference Condition	Mean[1]	Rating
Family Richness				
2006	>14.1	14.2	15.9	On Target
2007	>14.1	14.2	14.8	On Target
Mean	>14.1	14.2	15.3	On Target
Genus Richness				
2006	>15	26.2	25.4	On Target
2007	>15	26.2	22.4	On Target
Mean	>15	26.2	23.9	On Target
EPT Richness				
2006	>4	7.8	7.8	On Target
2007	>4	7.8	4.6	On Target
Mean	>4	7.8	6.2	On Target
EPT Ratio				
2006	>0.18	N/A	0.43	On Target
2007	>0.18	N/A	0.15	Off Target
Mean	>0.18	N/A	0.29	On Target
Shannon Index (Genus)				
2006	>1.77	2.39	2.69	On Target
2007	>1.77	2.39	2.19	On Target
Mean	>1.77	2.39	2.44	On Target
Shannon Evenness Index				
2006	>0.8	N/A	0.83	On Target
2007	>0.8	N/A	0.71	Off Target
Mean	>0.8	N/A	0.77	Off Target
Hilsenhoff Biotic Index				
2006	<6.6	<4.3	5.00	On Target
2007	<6.6	<4.3	5.30	On Target
Mean	<6.6	<4.3	5.15	On Target

[1] Mean from Bowles (2010).

Appendix C Summary of Information Sources for Current and Reference Conditions for Each Attribute/Indicator

Reporting Unit	Resource Type	Attribute	Data/Information Sources	Reference/Target Conditions
Park-wide				
	Vegetation			
		Landscape composition	Vegetation cover types were mapped from high resolution aerial imagary, potential vegetation, and soil map units	Targets based on professional judgement. Generally fewer patches of larger size are desirable.
		Land use/Land cover	Vegetation cover types were assigned to three classes: natural, successional, and cultural	Targets based on professional judgement with the goal of increasing the area of natural vegetation while decreasing successional vegetation.
	Breeding bird community		Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/195. National Park Service, Fort Collins, Colorado.	Targets represent 2008 baseline data collection. The goal is to maintain or enhance the breeding bird community.
	White-tailed deer		http://science.nature.nps.gov/im/units/htln/library/Wildlife/Deer/WICR_Deer_2005_2010_r.pdf	Peer reviewed literature reports that the ecological carrying capacity for deer is 8 indifividuals/km^2 Tilghman, Nancy G. 1989. Impacts of White-tailed Deer on forest regeneration in northwestern Pennsylvania. J. Wildlife Management 53(3):524-532.
	Invasive exotic plant impact		Young, C.C., J.L. Haack, and H.J. Etheridge. 2007. Invasive exotic plant monitoring at Wilson's Creek National Battlefield: Year 1 (2006). Natural Resource Technical Report NPS/HTLN/NRTR—2007/013 National Park Service, Fort Collins, Colorado.	Targets are based on professional judgement, and focus on reducing, or not allowing further expansions, in the numbers and foliar cover of invasive plant speices within the park.
	Air quality			
		Ozone	Five-year average of the annual 4th-highest 8-hour ozone concentration from interpolated data between 2004 - 2008. See:http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm	EPA standard of < 75ppb established in 2008
		Atmoshperic deposition	Five-year average concentration from interpolated data between 2004 - 2008. See:http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.c	NPS (2007a) reports that wet deposition amounts of less than 1 kg/ha/yr do not cause ecosystem harm.

Reporting Unit Resource Type Attribute	Data/Information Sources	Reference/Target Conditions
Upland woodland reporting unit		
Landscape Composition	Vegetation cover types were mapped from high resolution aerial imagary, potential vegetation, and soil map units	Targets based on professional judgement. Generally fewer patches of larger size are desirable.
Land Use/Land Cover	Vegetation cover types were assigned to three classes: natural, successional, and cultural	Targets based on professional judgement with the goal of increasing the area of natural vegetation while decreasing successional vegetation.
Structural class	Habitat data from Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/195. National Park Service, Fort Collins, Colorado.	Professional judgement was used to set targets for the woodland. Professional Judgement was informed by community descriptions in Appendix D, and: Canopy cover and basal area from Nelson (2005) and Missouri Forest and Woodland Natural Community Profiles (http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed: 10/15/2010). Stem density range of values from Jenkins, S.E., R. Guyette, and A.J. Rebertus. 1997. Vegetation-site relationships and fire history of savanna-glade-woodland mosaic in the Ozarks. Pages 184-201 in S.G. Pallardy, R.A. Cecich, H.E. Garrett, and P.S. Johnson, editors. Proceedings of 11th Central Hardwood Forest Conference. General Technical Report NC-188. U. S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Reporting Unit

Resource Type

Attribute	Data/Information Sources	Reference/Target Conditions
Cover type	Habitat data from Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/195. National Park Service, Fort Collins, Colorado.	The lower limit of oak composition was multiplied by the lower limit of total basal area. The upper limit of oak composition was multiplied by the uppder limit of total basal. Proportional range of oak species composition (0.65-0.80) and range of total basal area for the reporting unit from Nelson (2005) and Missouri Forest and Woodland Natural Community Profiles (http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed: 10/15/2010).
		The lower limit of hickory and walnut composition was multiplied by the lower limit of total basal area. The upper limit of hickory and walnut composition was multiplied by the uppder limit of total basal. Proportional range of hickory and walnut species composition (0.15-0.30) and range of total basal area for the reporting unit from Nelson (2005) and Missouri Forest and Woodland Natural Community Profiles (http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed: 10/15/2010).
Regeneration	Habitat data from Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/195. National Park Service, Fort Collins, Colorado.	Professional judgement was used to set targets for the woodland. Professional Judgement was informed by community descriptions in Appendix D, and: Jenkins, S.E., R. Guyette, and A.J. Rebertus. 1997. Vegetation-site relationships and fire history of savanna-glade-woodland mosaic in the Ozarks. Pages 184-201 in S.G. Pallardy, R.A. Cecich, H.E. Garrett, and P.S. Johnson, editors. Proceedings of 11th Central Hardwood Forest Conference. General Technical Report NC-188. U. S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Reporting Unit / **Resource Type** / **Attribute**	**Data/Information Sources**	**Reference/Target Conditions**
Herbacous guild composition	Habitat data from Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/195. National Park Service, Fort Collins, Colorado.	Cover of native grass and forbs from Nelson (2005) and Missouri Forest and Woodland Natural Community Profiles (http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed: 10/15/2010) weighted by areal extent of type, and professional judgement. Total woody cover (understory) from Missouri Forest and Woodland Natural Community Profiles (http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed: 10/15/2010) weighted by areal extent of type.
Structure	Habitat data from Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/195. National Park Service, Fort Collins, Colorado.	Height of canopy from Nelson (2005) and Missouri Forest and Woodland Natural Community Profiles (http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed: 10/15/2010). Weighted by areal extent of different woodland types. To be measured as average over all upland woodlands.
Bottomland forest		
Landscape Composition	Vegetation cover types were mapped from high resolution aerial imagary, potential vegetation, and soil map units	Targets based on professional judgement. Generally fewer patches of larger size are desirable.
Land Use/Land Cover	Vegetation cover types were assigned to three classes: natural, successional, and cultural	Targets based on professional judgement with the goal of increasing the area of natural vegetation while decreasing successional vegetation.
Upland grassland (restored priairie) reporting unit		
Landscape Composition	Vegetation cover types were mapped from high resolution aerial imagary, potential vegetation, and soil map units	Targets based on professional judgement. Generally fewer patches of larger size are desirable.
Land Use/Land Cover	Vegetation cover types were assigned to three classes: natural, successional, and cultural	Targets based on professional judgement with the goal of increasing the area of restorede prairie with native warm-season grasses and forbs and fewer shrubs and vines.

Reporting Unit	Resource Type	Attribute	Data/Information Sources	Reference/Target Conditions
		Diversity and herbacous guild composition	2008 unpublished data following - James, K. M., M. D. DeBacker, G. A. Rowell, J. L. Haack and L. W. Morrison. 2009. Vegetation community monitoring protocol for the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR — 2009/141. National Park Service, Fort Collins, Colorado. Habitat data from Peitz, D.G. 2009. Bird monitoring at Wilson's Creek National Battlefield, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/195. National Park Service, Fort Collins, Colorado.	Professional judgement was used to set targets for the upland grasslands with the goal of increasing the cover of native warm-season grasses and forbs, and decreasing the cover of shrubs and vines. Professional Judgement was informed by community descriptions in Appendix D.
Glade reporting unit				
		Landscape Composition	Vegetation cover types were mapped from high resolution aerial imagary, potential vegetation, and soil map units	Targets based on professional judgement. Generally fewer patches of larger size are desirable.
		Land Use/Land Cover	Vegetation cover types were assigned to three classes: natural, successional, and cultural	Targets based on professional judgement with the goal reducing the overall number of patches and patch size somewhat, but patchiness is expected within the reporting unit; and to reduce the foliar cover or red cedar
		Missouri Bladderpod	2010 unpublished monitoring data following - Young, C.C., M.I. Kelrick, L.W. Morrison, M.D. DeBacker, J.L. Haack, and G.A. Rowell. 2008. Missouri Bladderpod Monitoring Protocol for Wilson's Creek National Battlefield. Natural Resource Report NPS/MWR/HTLN/NRR—2008/043. National Park Service, Fort Collins, Colorado.	To define management targets for Missouri bladderpod, we compared the current size of six Missouri bladderpod populations to the population size ranges observed in each of those populations over an extended time period. To account for naturally high annual variability, the current Missouri bladderpod population size was calculated as the three-year (2008-2010) average of the population size interval midpoints. A population size range, which defined management targets for each population, was based on the minimum and maximum values observed during the given time period.

Reporting Unit / Resource Type / Attribute	Data/Information Sources	Reference/Target Conditions
Wilson's Creek, Skeggs Branch, and Terrell Creek		
Fish community		
Composition	2007 unpublished data following - Dodd, H.R., D.G Peitz, G.A. Rowell, D.E. Bowles, and L.M. Morrison. 2008. Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR - 2008/052. National Park Service, Fort Collins, Colorado.	2007 data serves as baseline with the goal to maintain or improve the fish community. Sowa, S.P., D.D. Diamond, R. Abbitt, G. Annis, T. Gordon, M.E. Morey, G.R. Sorensen, and D. True. 2005. A gap analysis for riverine ecosystems of Missouri. U.S. Geological Survey, National Gap Analysis Program, Columbia, Missouri.
Condition	2007 unpublished data following - Dodd, H.R., D.G Peitz, G.A. Rowell, D.E. Bowles, and L.M. Morrison. 2008. Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR - 2008/052. National Park Service, Fort Collins, Colorado.	Reference condition is based on peer reviewed index in: Dauwalter, D.C., E.J. Pert, and W.E. Keith. 2003. An index of biotic integrity for fish assemblages in Ozark Highland streams of Arkansas. Southeastern Naturalist 2:447-468.
Aquatic invertebrates	Bowles D. E. 2010. Aquatic invertebrate monitoring at Wilson’s Creek National Battlefield: 2005-2007 trend report. Natural Resource Technical Report NPS/HTLN/NRTR—2010/287. National Park Service, Fort Collins, Colorado.	Reference condition is based on peer reviewed index in: Rabeni, C.F., R.J. Sarver, N. Wang, G.S. Wallace, M. Weiland, and J.T. Peterson. 1997. Development of regionally-based biological criteria for Missouri streams. Final Report, Missouri Department of Natural Resources, Jefferson City, Missouri.
Water quality (medians)	Bowles D. E. 2010. Aquatic invertebrate monitoring at Wilson’s Creek National Battlefield: 2005-2007 trend report. Natural Resource Technical Report NPS/HTLN/NRTR—2010/287. National Park Service, Fort Collins, Colorado.	Reference conditions based on State of Missouri recommendations in: Brown, D., and J. Czarnezki. Undated. Missouri streams fact sheet-chemical monitoring. Missouri Department of Conservation, Jefferson City, Missouri. http://www.mostreamteam.org/Documents/Fact%20Sheets/17767.pdf
Flow Regime (Wilson's Creek only)	Current condition is value based upon the entire period of record (POR) for stream gauge on Wilson's Creek (Wilson's Creek near Battlefield - 07052160). Management target was based on standard deviation from the POR value for that index. Management Target were based on deviation 25th and 75th percentiles of the POR.	Management target was based on standard deviation from the POR value for that index. Management Target were based on deviation 25th and 75th percentiles of the POR.

Appendix D Descriptions of Pre-European Vegetation Communities for Wilson's Creek National Battlefield, Missouri

Descriptions of Pre-European Vegetation Communities for Wilson's Creek National Battlefield, Missouri

Lee F. Elliott, Missouri Resource Assessment Partnership
27 April 2010

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: black oak/post oak-hickory
General Historical Vegetation: dry-mesic slope forest
Ecological Land Type: Slope forest (>20% slopes)
Ecological System: Ozark-Ouachita Dry-Mesic Hardwood forest
Description: Woodlands over cherty substrates are dominated by *Quercus velutina* (black oak), *Quercus alba* (white oak), *Quercus stellata* (post oak), and *Carya alba* (mockernut hickory). The canopy is relatively closed (canopy cover of 70 to 100%) at a height of 30 to 90 feet, with a basal area between 60 and 100 sq. ft./acre. Sites over limestone substrate may have *Quercus muehlenbergii* (chinquapin oak) and *Fraxinus quadrangulata* (blue ash) or *Fraxinus americana* (white ash) as codominants. The shrub canopy has a cover of 10 to 40%, with species such as *Rhus aromatica* (fragrant sumac), *Vaccinium* spp. (blueberries), *Parthenocissus quinquefolia* (Virginia creeper), and *Ceanothus americana* (New Jersey tea). Species such as *Sideroxylon lanuginosum* (gum bumelia), *Juniperus virginiana* (eastern redcedar) and *Frangula caroliniana* (Carolina buckthorn) are more likely to be encountered on limestone substrates. Herbaceous cover may range from 40 to 80% cover with species such as *Schizachyrium scoparium* (little bluestem), *Andropogon gerardii* (big bluestem), *Bouteloua curtipendula* (sideoats grama), *Sorghastrum nutans* (yellow Indiangrass), *Dalea* spp. (prairie clovers), *Desmodium* spp. (ticktrefoils), *Lespedeza* spp. (lespedezas), *Dichanthelium* spp. (panic grasses), and *Helianthus hirsutus* (hairy sunflower). On sites with limestone substrate, species such as *Muhlenbergia sobolifera* (rock muhly), *Taenidia integerrima* (yellow pimpernel), *Lithospermum canescens* (hoary puccoon), *Astragalus distortus* (Ozark milkvetch), and *Astragalus crassicarpus* var. *trichocalyx* (groundplum milkvetch) are more commonly encountered.

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: black oak/post oak-hickory
General Historical Vegetation: dry-mesic slope woodland (acidic)
Ecological Land Type: Alfic Chert Exposed Backslope Woodlands AND Limestone/Dolomite Exposed Backslope Glade/Woodland Complex
Ecological System: Ozark-Ouachita Dry Oak Woodland
Description: The woodland communities of this complex tend to occur on deeper soils and the glade communities are more likely to occur on thin-soiled sites over limestone or dolomite. The glade community will be described separately. Woodlands over cherty substrates are dominated by *Quercus alba* (white oak), *Quercus stellata* (post oak), and *Quercus velutina* (black oak), and *Carya alba* (mockernut hickory). The canopy is relatively open (canopy cover of 60 to 80%) at a

height of 20 to 70 feet, with a basal area between 50 and 90 sq. ft./acre. Sites over limestone substrate may have *Quercus muehlenbergii* (chinquapin oak) and *Fraxinus quadrangulata* (blue ash) or *Fraxinus americana* (white ash) as codominants. The shrub canopy has a cover of 10 to 40%, with species such as *Rhus aromatica* (fragrant sumac), *Vaccinium* spp. (blueberries), *Parthenocissus quinquefolia* (Virginia creeper), and *Ceanothus americana* (New Jersey tea). Species such as *Sideroxylon lanuginosum* (gum bumelia), *Juniperus virginiana* (eastern redcedar) and *Frangula caroliniana* (Carolina buckthorn) are more likely to be encountered on limestone substrates. Herbaceous cover may range from 50 to 100% cover with species such as *Schizachyrium scoparium* (little bluestem), *Andropogon gerardii* (big bluestem), *Bouteloua curtipendula* (sideoats grama), *Sorghastrum nutans* (yellow Indiangrass), *Dalea* spp. (prairie clovers), *Desmodium* spp. (ticktrefoils), *Lespedeza* spp. (lespedezas), *Dichanthelium* spp. (panic grasses), and *Helianthus hirsutus* (hairy sunflower). On sites with limestone substrate, species such as *Muhlenbergia sobolifera* (rock muhly), *Taenidia integerrima* (yellow pimpernel), *Lithospermum canescens* (hoary puccoon), *Astragalus distortus* (Ozark milkvetch), and *Astragalus crassicarpus* var. *trichocalyx* (groundplum milkvetch) are more commonly encountered.

Primarily associated with the Glade Reporting Unit
Dominant Species: little bluestem/sideoats grama-blackjack oak
General Historical Vegetation: open herbaceous glade/woodland complex
Ecological Land Type: Limestone/Dolomite Upland Glade/Woodland Complex AND Limestone/Dolomite Upland Post Oak Woodlands
Ecological Systems: Central Interior Highlands Calcareous Glade and Barrens; Ozark-Ouachita Dry Oak Woodlands
Description: The glades portion of this glade/woodland complex is dominated by perennial and annual forbs, grasses and sedges with woody cover often stunted and gnarled. Overstory canopy cover is generally less than 30%, with low basal areas (often less than 50 sq. ft./acre). Species of the limited overstory may include *Quercus muehlenbergii* (chinquapin oak), *Quercus stellata* (post oak), *Carya texana* (black hickory), and *Juniperus virginiana* (eastern redcedar). Shrub species such as *Sideroxylon lanuginosum* (gum bumelia), *Rhus aromatica* (fragrant sumac), and *Frangula caroliniana* (Carolina buckthorn) may be present but typically have little overall canopy cover (less than 20%). The cover of herbaceous vegetation is variable, depending on soil depth. On deep-soiled sites, *Schizachyrium scoparium* (little bluestem) and *Bouteloua curtipendula* (sideoats grama) dominate the site. Conspicuous forbs such as *Rudbeckia missouriensis* (Missouri orange coneflower), *Silphium terebinthinaceum* (prairie dock), *Symphyotrichum sericeum* (western silver aster), *Psoralidium tenuiflorum* (slimflower scurfpea), *Heliotropium tenellum* (pasture heliotrope) and numerous other species are common. On sites with shallower soils, *Croton monanthogynus* (prairie tea), *Ophioglossum engelmannii* (limestone addertongue), *Sedum pulchellum* (widowscross), *Sporobolus neglectus* (puffsheath dropseed), *Sporobolus vaginiflorus* (poverty dropseed), and lichens are more likely to be encountered. The woodlands portion of the complex is open (30 to 60% cover) and short (20 to 50 feet in height), but may have a basal area between 30 and 60 sq. ft./acre. Dominant overstory species include species similar to those of the glade portion. *Fraxinus quadrangulata* (blue ash) and/or *Fraxinus americana* (white ash) may also be present. Shrub cover is less than 30% with similar species to those found in the glade. Herbaceous cover may be patchy to continuous (30 to 90% cover) and

consists of forbs and grasses similar to those found on deep-soiled sites of the glades. Other species that might be encountered in the woodlands include *Lithospermum canescens* (hoary puccoon), *Arnoglossum plantagineum* (groovestem Indian plantain), *Astragalus distortus* (Ozark milkvetch), *Astragalus crassicarpus* var. *trichocalyx* (groundplum milkvetch), and numerous other species.

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: post oak-bluestem
General Historical Vegetation: flatwoods
Ecological Land Type: Loess Fragipan Upland Flatwoods
Ecological System: Ozark-Ouachita Dry Oak Woodland
Description: This open woodland is characterized by a subsurface soil layer of reduced permeability leading to brief periods of flooding during rainy periods, followed by extended dry periods. The overstory is often open (cover between 30 and 80%), relatively short (30 to 50 feet in height), and with a basal area between 30 and 70 sq. ft/acre. The overstory is typically dominated by *Quercus stellata* (post oak), though *Quercus marilandica* (blackjack oak) and *Carya texana* (black hickory) may also be present. The shrub/understory is poorly developed (less than 40% cover) and contains species such as *Rubus* spp. (blackberries) and *Toxicodendron radicans* (eastern poison ivy). The herbaceous canopy may be dense and dominated by grasses and sedges, particularly *Schizachyrium scoparium* (little bluestem). *Cinna arundinacea* (sweet woodreed), *Carex* spp. (sedges), *Juncus interior* (inland rush), and *Symphyotrichum patens* (late purple aster) are among the many other species that may be present.

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: post oak/black oak-blackjack oak
General Historical Vegetation: dry oak woodland
Ecological Land Type: Ultic Chert Upland Mixed Oak Woodlands
Ecological System: Ozark-Ouachita Dry Oak Woodland
Description: Open to relatively closed-canopy woodland (30 to 80 % canopy cover, to a height of 35 to 50 feet) dominated by *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), and *Quercus velutina* (black oak). Basal area for these woodlands is typically between 30 and 70 sq. ft./acre. *Carya texana* (black hickory) may also be a conspicuous to co-dominant canopy species. The shrub and woody understory layers generally has a canopy cover less than 40% and may include species such as *Vaccinium arboreum* (farkleberry), *Vaccinium pallidum* (lowbush blueberry), *Rhus aromatica* (fragrant sumac), *Sassafras albidum* (sassafras), *Ulmus alata* (winged elm), *Viburnum rufidulum* (rusty blackhaw), and *Ceanothus americanus* (New Jersey tea). The herbaceous layer may be open to closed (60 to 100% cover). If open, lichens may be a conspicuous element of the ground flora. Herbaceous species common to the community include *Schizachyrium scoparium* (little bluestem), *Andropogon gerardii* (big bluestem, *Lespedeza hirta* (hairy lespedeza), *Lespedeza violacea* (violet lespedeza), *Lespedeza procumbens* (trailing lespedeza), *Dichanthelium acuminatum* (tapered rosette grass), *Dichanthelium sphaerocarpon* (roundseed panicgrass), *Dichanthelium linearifolium* (slimleaf panicgrass), *Parthenium integrifolium* (wild quinine), *Tephrosia virginiana* (goat's rue), *Dalea* spp. (prairie clovers), *Desmodium* spp. (ticktrefoils), *Solidago* spp. (goldenrods), *Symphyotrichum* spp. (asters), and *Liatris* spp. (blazingstars) among others.

Primarily associated with the Bottomland Forest Reporting Unit
Dominant Species: red oak/sugar maple-bitternut hickory
General Historical Vegetation: floodplain forest
Ecological Land Type: Mesic High Floodplain Forest
Ecological System: Ozark-Ouachita Mesic Hardwood Forest
Description: These forests have an almost closed canopy (80 to 100% canopy closure) to a height of 80 to 120 feet and a basal area from 80 to 110 sq. ft./acre. The overstory canopy is dominated by a variety of species including *Quercus rubra* (northern red oak), *Acer saccharum* (sugar maple), *Quercus alba* (white oak), *Juglans major* (black walnut), *Ulmus americana* (American elm), and *Carya cordiformis* (bitternut hickory). Other canopy species include *Tilia americana* (American basswood), *Ulmus rubra* (slippery elm), *Quercus shumardii* (Shumard's oak), *Fraxinus americana* (white ash), and *Gymnocladus dioicus* (Kentucky coffeetree). An understory (to a height of 5 to 25 feet) of saplings of the overstory as well as *Asimina triloba* (pawpaw), *Aesculus glabra* (Ohio buckey), *Carpinus caroliniana* (American hornbeam), and *Diospyros virginiana* (common persimmon) is present. Shrubs are also present with a cover from 30 to 60% and include species such as *Lindera benzoin* (spicebush), *Staphylea trifolia* (American bladdernut), *Corylus americana* (American hazelnut), *Campsis radicans* (trumpet creeper), and *Toxicodendron radicans* (eastern poison ivy). The herbaceous layer is diverse, with a canopy cover between 30 and 70%. Various species may be encountered in the herbaceous layer, including *Laportea canadensis* (Canadian woodnettle), *Carex* spp. (sedges), *Asarum canadense* (Canadian wildginger), *Hydrophyllum virginianum* (eastern waterleaf), *Enemion biternatum* (eastern false rue anemone), *Arisaema dracontium* (green dragon), *Trillium* spp. (trilliums), and numerous other species.

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: red oak/sugar maple-bitternut hickory
General Historical Vegetation: mesic upland forest
Ecological Land Type: Mesic Footslope/High Terrace Forests
Ecological System: Ozark-Ouachita Mesic Hardwood Forest
Description: These forests have an almost closed canopy (90 to 100% canopy closure) to a height of 80 to 120 feet and a basal area from 90 to 120 sq. ft./acre. The overstory canopy is dominated by a variety of species including *Quercus rubra* (northern red oak), *Acer saccharum* (sugar maple), *Quercus alba* (white oak), *Carya cordiformis* (bitternut hickory), and *Carya ovata* (shagbark hickory). Other canopy species include *Tilia americana* (American basswood), *Juglans nigra* (black walnut), and *Gymnocladus dioicus* (Kentucky coffeetree). An understory (to a height of 5 to 25 feet) of saplings of the overstory as well as *Asimina triloba* (pawpaw), *Aesculus glabra* (Ohio buckey), *Ulmus rubra* (slippery elm), *Carpinus caroliniana* (American hornbeam), and *Diospyros virginiana* (common persimmon) is present. Shrubs are also present with a cover from 30 to 60% and include species such as *Lindera benzoin* (spicebush), *Staphylea trifolia* (American bladdernut), *Corylus americana* (American hazelnut), and *Toxicodendron radicans* (eastern poison ivy). The herbaceous layer is diverse, with a canopy cover between 30 and 70%. Various species may be encountered in the herbaceous layer, including *Laportea canadensis* (Canadian woodnettle), *Erigenia bulbosa* (harbinger of spring), *Cardamine concatenata* (cutleaf toothwart), *Erythronium albidum* (white fawnlily), *Enemion biternatum*

(eastern false rue anemone), *Arisaema dracontium* (green dragon), *Trillium* spp. (trilliums), numerous ferns, and numerous other species.

Primarily associated with the Upland Woodland and Upland Grassland Reporting Units
Dominant Species: white oak/black oak-hickory
General Historical Vegetation: dry-mesic oak woodland
Ecological Land Type: Alfic Chert Upland Woodlands AND Ultic Chert Upland Mixed Oak Woodland
Ecological System: Ozark-Ouachita Dry-Mesic Oak Forest
Description: This open to closed woodland (50 to 80% canopy cover) may have a canopy reaching to 50 to 80 feet in height and a basal area between 80 and 100 sq. ft./acre. Dominant species of the overstory are *Quercus alba* (white oak), *Quercus velutina* (black oak), and *Carya alba* (mockernut hickory). The cover of the sapling/shrub layer varies from 20 to 40% cover and is often dominated by species such as *Rhus aromatica* (fragrant sumac), *Vaccinium pallidum* (lowbush blueberry), *Parthenocissus quinquefolia* (Virginia creeper), and *Vaccinium arboreum* (farkleberry). Other shrub species that may be present include *Ceanothus americanus* (New Jersey tea), *Vitis aestivalis* (summer grape), and *Amorpha canescens* (leadplant). The herbaceous layer has a cover from 60 to 90% and often contains more forbs than the drier post oak woodlands. Species dominant in the herbaceous layer may include *Schizachyrium scoparium* (little bluestem), *Andropogon gerardii* (big bluestem), *Desmodium nudiflorum* (nakedflower ticktrefoil), *Desmodium marilandicum* (smooth small-leaf ticktrefoil), *Desmodium glutinosum* (pointedleaf ticktrefoil), and *Amphicarpaea bracteata* (American hogpeanut). *Monarda bradburiana* (eastern beebalm), *Helianthus hirsutus* (hairy sunflower), *Solidago ulmifolia* (elm-leaved goldenrod), *Silene virginica* (fire pink), *Maianthemum racemosum* (feathery false lily of the valley), and *Geranium maculatum* (spotted geranium) may also be common.

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: white oak/blackoak-hickory/dogwood
General Historical Vegetation: dry-mesic slope forest (acidic)
Ecological Land Type: Alfic Chert Protected Backslope Forests AND Limestone/Dolomite Protected Backslope Glade/Woodland Complex
Ecological System: Ozark-Ouachita Dry-Mesic Oak Forest
Description: This forest and woodland is dominated by *Quercus alba* (white oak), *Quercus velutina* (black oak), and *Carya alba* (mockernut hickory) with a relatively closed canopy (greater than 70% canopy closure), reaching heights of 60 to 80 feet, with a basal area of between 80 and 100 sq. ft./acre. Other canopy species that may be encountered include *Quercus rubra* (northern red oak), *Quercus stellata* (post oak), and *Carya ovata* (shagbark hickory). The understory and shrub layer is patchy with cover between 20 and 60% and containing species from the overstory as well as *Cornus florida* (flowering dogwood), *Corylus americanus* (American hazelnut), *Ostrya virginiana* (hophornbeam), *Rhus aromatica* (fragrant sumac), *Parthenocissus quinquefolia* (Virginia creeper), and *Vitis* spp. (grapes). The herbaceous layer is generally less than 40% cover and contains species such as *Schizachyrium scoparium* (little bluestem), *Amphicarpaea bracteata* (American hogpeanut), *Desmodium nudiflorum* (nakedleaf ticktrefoil), *Desmodium glutinosum* (pointedleaf ticktrefoil), *Geranium maculatum* (spotted geranium), and *Maianthemum racemosum* (feathery false lily of the valley).

Primarily associated with the Bottomland Forest Reporting Unit
Dominant Species: white oak/bur oak-pecan
General Historical Vegetation: floodplain forest (small drainages)
Ecological Land Type: Mesic Upland Drainageway Woodlands AND Dry-Mesic Upland Drainageway Woodlands
Ecological System: North-Central Interior Floodplain
Description: These woodlands have relatively closed canopies (80 to 100% canopy cover) to a height sometimes exceeding 70 feet, with basal areas of overstory species around 80 to 110 sq. ft./acre. Dominant species include *Quercus macrocarpa* (bur oak), *Carya illinoinensis* (pecan), *Carya laciniosa* (shellbark hickory), and *Quercus alba* (white oak), with white oak becoming more dominant at higher landscape positions. Stands may have significant cover of *Fraxinus pennsylvanica* (green ash), *Celtis laevigata* (sugarberry), *Gleditsia triacanthos* (honeylocust), and *Platanus occidentalis* (American sycamore), especially along stream margins. A subcanopy of *Morus rubra* (red mulberry), *Acer negundo* (boxelder), and *Acer rubrum* (red maple) may commonly be encountered. Shrubs cover is variable (30 to 60% canopy cover) with saplings of the canopy and subcanopy species and other species including *Ilex decidua* (possumhaw), *Diospyros virginiana* (common persimmon), *Corylus americana* (American hazelnut), *Toxicodendron radicans* (poison ivy), *Campsis radicans* (trumpet creeper), and *Crataegus* spp. (hawthorns). The herbaceous layer is typically open (20 to 50% cover) and may include species such as *Elymus virginicus* (Virginia wildrye), *Chasmanthium latifolium* (Indian woodoats), *Cinna arundinacea* (sweet woodreed), *Diarrhena americana* (American beakgrain), *Packera obovata* (roughleaf ragwort), *Impatiens capensis* (jewelweed), and *Campanulastrum americanum* (American bellflower).

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: white oak/bur oak-pecan
General Historical Vegetation: mesic slope forest
Ecological Land Type: Dry-Mesic Footslope/High Terrace Forests AND Dry-Mesic Upland Drainageway Woodlands
Ecological System: Ozark-Ouachita Dry-Mesic Oak Forest
Description: This mesic woodland or forest has a relatively closed canopy (70 to 80% canopy cover) to a height of 60 to 90 feet, with basal area ranging from 50 to 100 sq. ft./acre. On better drained terraces and footslopes, the dominant species of the canopy includes *Quercus alba* (white oak) and *Quercus rubra* (northern red oak). Other overstory species commonly encountered include *Carya ovata* (shagbark hickory), *Carya alba* (mockernut hickory), *Ulmus americana* (American elm), and *Nyssa sylvatica* (blackgum). The shrub and understory layer is typically not well-developed (0 to 30% canopy cover) and contains species such as *Lindera benzoin* (spicebush), *Carpinus caroliniana* (American hornbeam), *Corylus caroliniana* (American hazelnut), and *Parthenocissus quinquefolia* (Virginia creeper). Forbs, sedges, and grasses contribute to a variable herbaceous cover (30 to 70% cover) with species such as *Elymus virginicus* (Virginia wildrye), *Carex amphibola* (eastern narrowleaf sedge), *Elephantopus carolinianus* (Carolina elephantsfoot), *Chasmanthium latifolium* (Indian woodoats), *Campanulastrum americanum* (American bellflower), and *Desmodium* spp. (tick trefoils). Lower

landscape positions that may be subject to periodic but brief flooding may have *Carya illinoinensis* (pecan), *Quercus macrocarpa* (bur oak), *Carya cordiformis* (bitternut hickory), and *Quercus shumardii* (Shumard's oak). Such sites may also have *Acer negundo* (boxelder), *Acer saccharinum* (silver maple), and *Fraxinus pennsylvanica* (green ash) in the overstory.

Primarily associated with the Upland Woodland Reporting Unit
Dominant Species: white oak/red oak-black oak/sugar maple
General Historical Vegetation: mesic slope forest
Ecological Land Type: Very Mesic Slope Forest
Ecological System: Ozark-Ouachita Mesic Hardwood Forest
Description: This forest has a relatively closed canopy (70 to 100% canopy cover) with canopies reaching to 100 feet in height and basal areas ranging from 80 to 100 sq. ft./acre. Dominant species include *Quercus alba* (white oak), *Quercus rubra* (northern red oak), *Acer saccharum* (sugar maple), *Quercus velutina* (black oak), *Carya ovata* (shagbark hickory) and *Carya cordiformis* (bitternut hickory). Other canopy species include *Quercus muehlenbergii* (chinquapin oak), *Carya alba* (mockernut hickory), and *Quercus shumardii* (Shumard's oak). The understory and shrub canopy varies from 30 to 60% and contains saplings of the overstory species in addition to such species as *Cercis canadensis* (eastern redbud), *Asimina triloba* (pawpaw), *Lindera benzoin* (spicebush), *Corylus americana* (American hazelnut), *Carpinus caroliniana* (American hornbeam), and *Cornus florida* (flowering dogwood). The herbaceous layer is variable (from 30 to 60% cover) and contains numerous forbs, along with grass such as *Elymus virginicus* (Virginia wildrye) and *Chasmanthium latifolium* (Indian woodoats), and *Carex* spp. (sedges).

Primary References:

Nelson, P. W., et al. 2005. The Terrestrial Natural Communities of Missouri, Revised ed. The Missouri Natural Areas Committee. Jefferson City, Missouri. 550 pp.

Nigh, T. A. and W. A. Schroeder. 2002. Atlas of Missouri Ecoregions. Missouri Department of Conservation. 212 pp.

Natureserve. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, VA. U. S.A. http://www.natureserve.org/explorer. (Accessed: 1 April 2010)

Missouri Resource Assessment Partnership. 2010. MoRAP Project: Ecological Classification for Missouri. http://www.cerc.usgs.gov/MoRAP/Assets/UploadedFiles/Projects/ecs/EcologicalClassificationSystemPoster.pdf

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 410/108235, July 2011

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov