National Park Service
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Natural Resource Stewardship and Science

George Washington Carver National Monument Natural Resource Condition Assessment

Natural Resource Report NPS/HTLN/NRR—2011/425

ON THE COVER
Boyhood statue of George Washington Carver.
Photograph courtesy of George Washing Carver National Monument

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Natural Resource Report NPS/HTLN/NRR—2011/425

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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 George Washington Carver National Monument (GWCA). NRCA's are intended to provide a synthesized assessment of current conditions in the park. The NCRA for GWCA 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 (Fig. A-B).

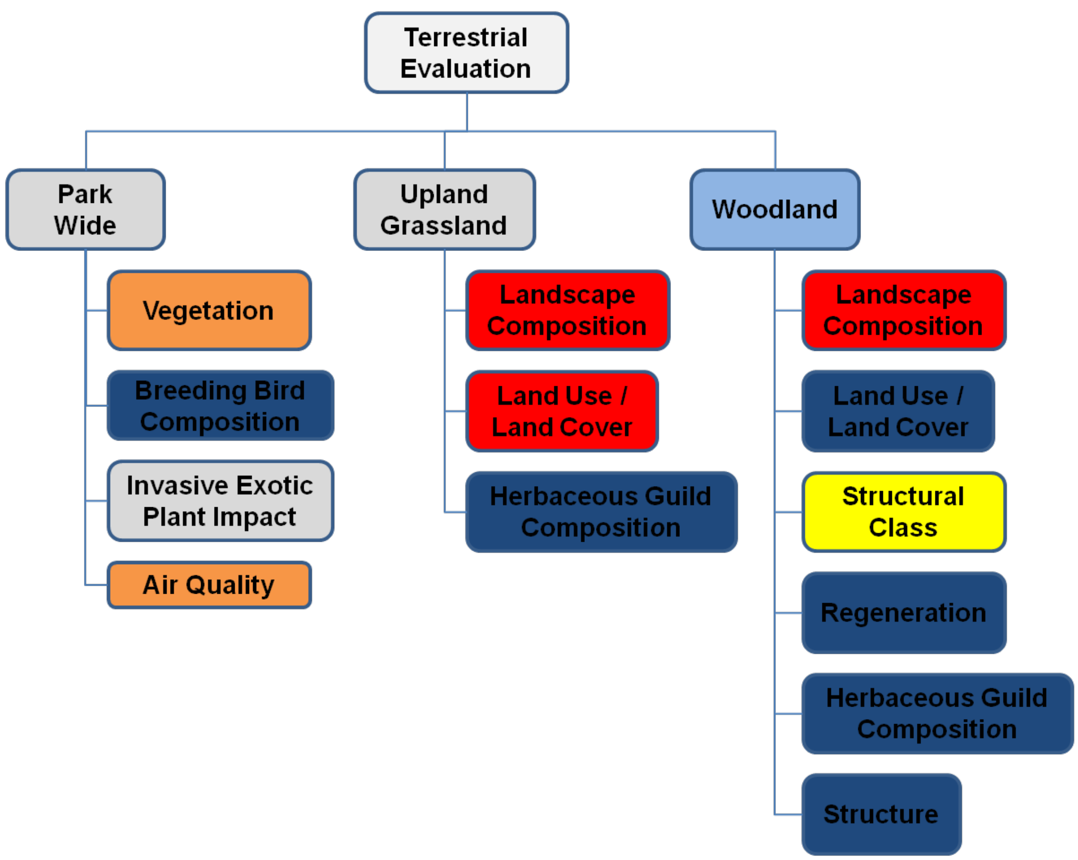

Figure A-B. Color coded evaluation results for each terrestrial reporting unit and its associated resource type and/or attributes.

Terrestrial communities at GWCA consist mainly of restored grasslands on former croplands and woodlands, mainly near upland drainage ways. Past and on-going efforts at prairie restoration have resulted in the re-establishment of many native grasses and forbs, and with continued effort these grasslands could add significant local or regional natural resource value. However, invasive species such as tall fescue (*Schedonorus phoenix*), smooth sumac (*Rhus glabra*), and multiflora rose (*Rosa multiflora*) are common. Habitat diversity within the park supports breeding bird species that require grassland, shrubland/edge, and woodland with understory habitats. Maintenance of this diversity would help populations of at least three species of continental concern that are fairly common breeding birds within park, including the Dickcissel (*Spiza americana*), Indigo Bunting (*Passerina cyanea*), and Carolina Wren (*Thryothorus ludovicianus*).

Floodplains generally support immature forests, and Japanese honeysuckle (*Lonicera japonica*) is a common invasive understory vine that may inhibit natural succession in these woodlands by preventing tree recruitment in light gaps. Upland streams, including Harkins Branch, Williams Branch, and Carver Branch, are shaded by the woodlands.

These support fairly high quality, diverse fish communities. The diversity of native fish species that are sensitive to poor water quality, such as darters, including the rare Arkansas darter (*Etheostoma cragini*), sculpins, and madtoms is generally high. Only a small segment of Harkins Branch is contained within the park, and this stream has greater discharge and somewhat higher bank instability than the others on the park.

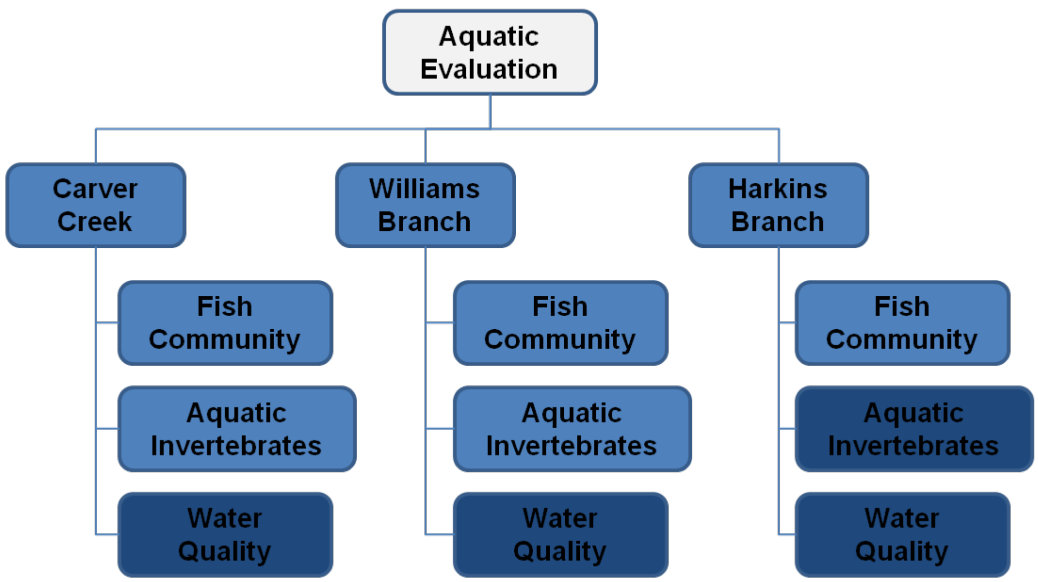

Figure A-C. Color coded evaluation results for each aquatic reporting unit and its associated resource types.

Acknowledgements

All members of the condition assessment team (Table 3-1) made valuable contributions to the document, and authored sections of the report within their area of expertise. Jim Heaney and Lana Henry of George Washington Carver National Memorial provided excellent support and input into the project. 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 conditions for study indicators. Decisions about desired conditions must be made through sanctioned park planning and management processes. Management target ranges are suggested only as a necessary means of providing condition assessments. 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.

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[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 George Washington Carver National Monument

Prior to beginning the NRCA for George Washington Carver National Monument (GWCA) 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 (NRCAs): 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 GWCA 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).

We designed this assessment to be fairly narrow in breadth (i.e. a limited number of indicators), but very rigorous (i.e. a lot of effort quantifying current and target conditions). 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.

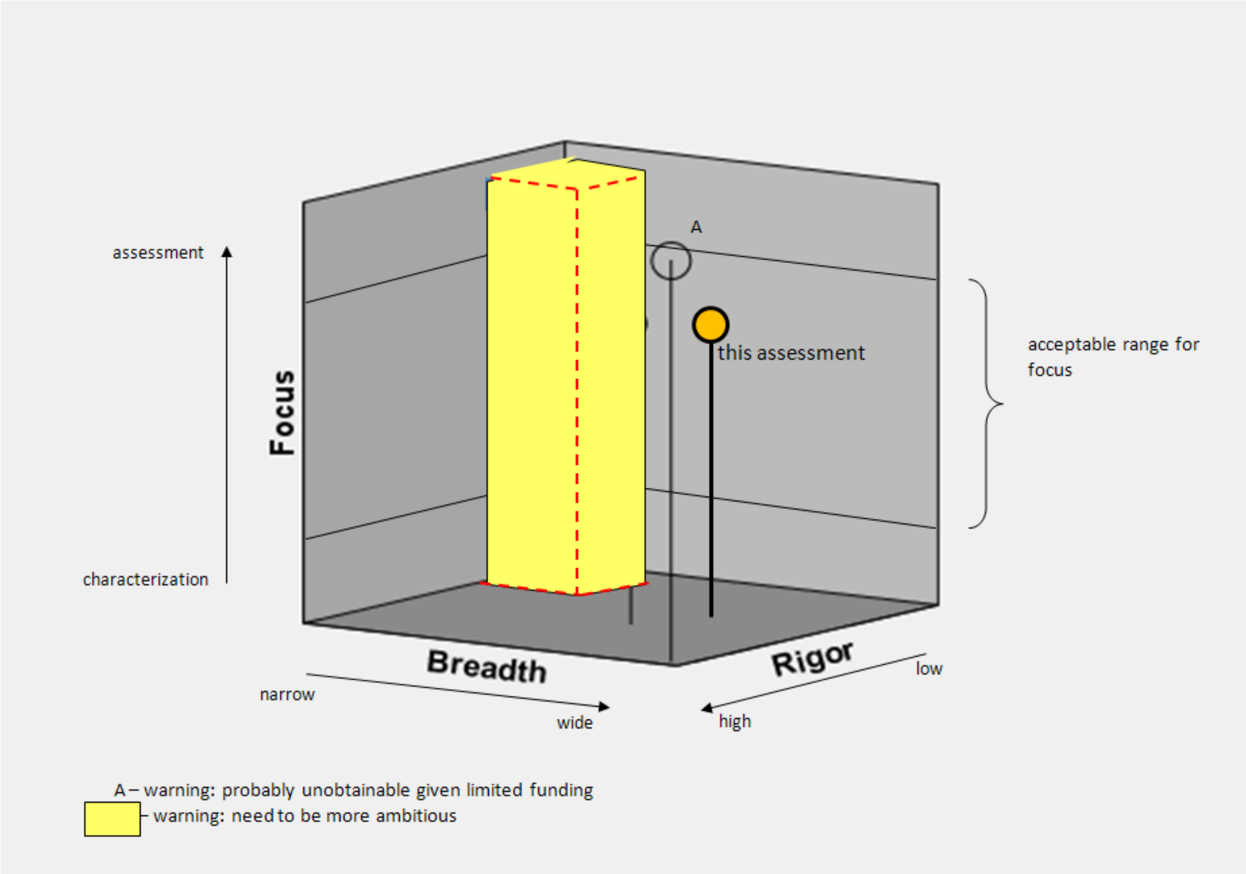

Figure 1-1. Assessment space used to design the Natural Resource Condition Assessment for George Washington National Monument.

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 future values for indicators derived by considering both reference conditions and practical and interpretive considerations defined by park goals. Reference conditions are benchmark quantitative, conceptual, or descriptive values that reflect the best estimated 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 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

The monument is located near Diamond, MO (Figure 2-1, Figure 2-2) and consists of the original 240 acre Moses Carver homestead. According to the Springs of Genius study (Harrinton et al. 1999) by the 1860-1870s "the conversion of prairie to agricultural purposes would have been nearly complete……by the late 1870s there was probably very little uncompromised prairie left on the Carver farm. At least 100 acres had been developed as fields. The remaining open land was probably intensely grazed. … What prairie remained on the Carver farm would most likely have been restricted to fence rows, hedges and patches of marginal land used for pasture and hay production. These remnants would be significantly different from pre-settlement prairie, but because the composition of the pre-settlement prairie is unknown, the full extent of the changes cannot be determined."

In 1985, NPS began a prairie restoration program on two patches totaling six acres of rocky land believed to be unplowed prairie remnant. As mowing and grazing contracts with local farmers ended, additional acres were incorporated as restored prairie units. The program's goal is to recreate a high quality pre-settlement prairie with high wildlife habitat value.

The questions of prairie plantings and proposed native plantings in the woodlands remain difficult. From a historical perspective, there was probably very little high quality prairie or woodland left on the farm during George Washington Carver's lifetime. As an adult, Carver did, however, recall wandering in the local woods, collecting and nurturing "floral beauties" as a boy. He practiced a wide array of domestic stills and crafts, learning the medicinal and economic uses of the wild resources of the farm and surrounding region. Throughout his life, Carver was a passionate naturalist, wondering daily in search of interesting botanical and geological finds. In his work, he displayed an unending interest in the potential economic and nutritional benefits of the South's native vegetation. Enhancing and interpretive part of the monument's woodland and prairie communities could offer significant insight into the development and achievements of George Washington Carver.

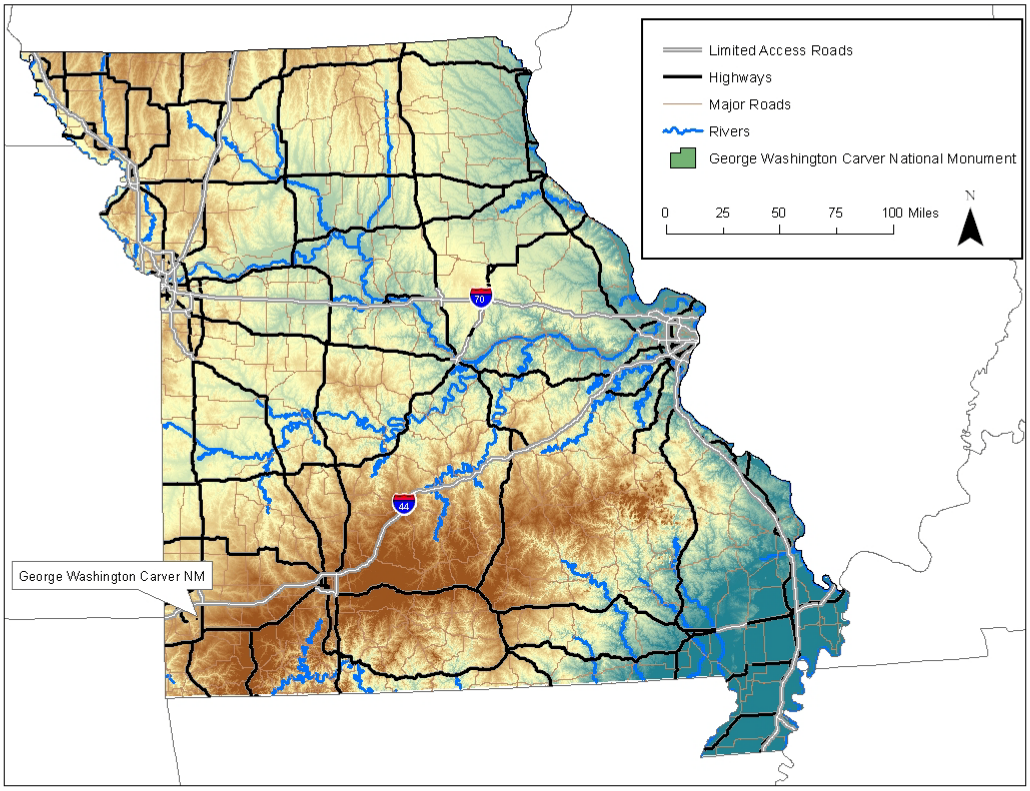

Figure 2-1. Location of George Washington Carver National Monument within the state of Missouri.

Figure 2-2. George Washington Carver National Monument.

Landscape and Watershed Context and Threat Assessment

George Washington Carver National Monument is on the Spring River Prairie/Savanna Dissected Plain land type association of the Springfield Plain Subsection of the Ozark Highlands Section (Nigh and Schroeder 2002). Historic landscapes were likely a mix of prairies and oak savannas 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 steep-sided drainages or 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 open or wooded at any given point in time. Relatively deeply-entrenched drainages punctuate an otherwise generally gently rolling landscape. The modern landscape is characterized by tame tall fescue pastures that have resulted from succession of old fields or heavy grazing by domestic livestock following land clearing for row crop agriculture. Successional woodlands, often associated with rougher topography, stream floodplains, or upland riparian zones, are also present, together with small remnants of unbroken prairie sod. The modern landscape is largely rural, and the largest nearby city, Joplin, is 10 km to the northwest and poses only moderate threat from urban expansion (Figure 2-3).

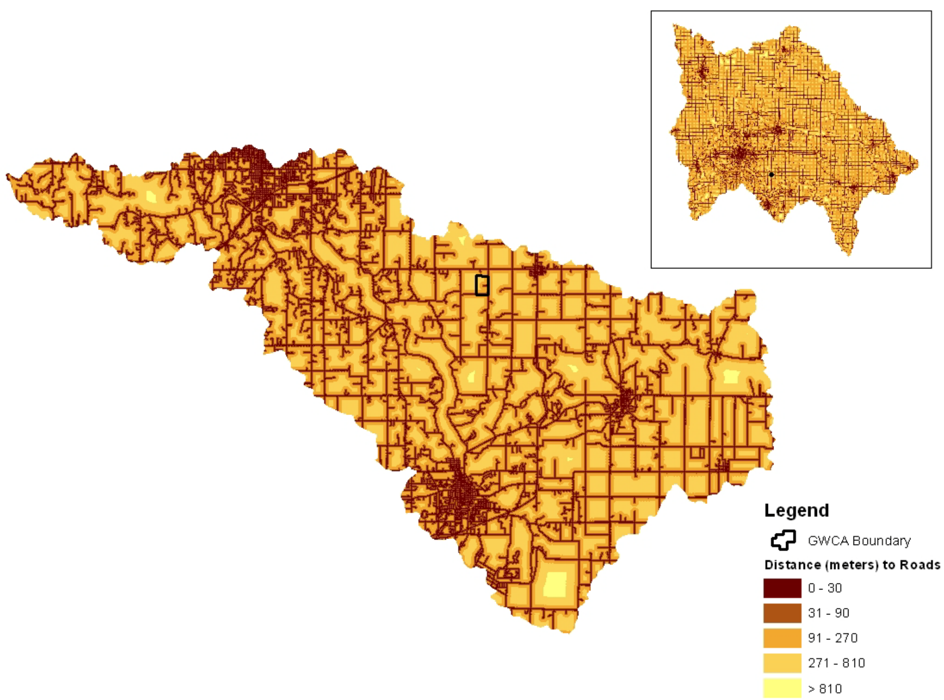

Figure 2-3. A buffered road network provides a visual index to development threats in the region around George Washington Carver National Monument.

Considering human threats such as land use and pollution discharges as indicators of watershed health provides context for understanding the condition of 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. It is noted that the Diamond Seed Company used a methyl mercury fungicide to treat seeds between 1963 and 1971. Dye traces in a nearby loosing stream indicate that runoff from the facility may have appeared in Carver Spring (Aley and Aley 1988).

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 2-4 and Figure 2-5 show the land cover and selected threats within the GWCA watersheds. The complete list of the threats considered and their data sources are listed in Table 2-1. This data was 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 2-6).

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 to streams and rivers in GWCA.

Climate

In the Ozark Highlands, winter snowfall averages 10 inches with normal January low/high temperatures of 12/24°F with 100 days below freezing (McNab and Avers 1994, Missouri Climate Center 2010). July average high temperatures are between 87-90°F, with a yearly range of 40-50 days above 90°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).

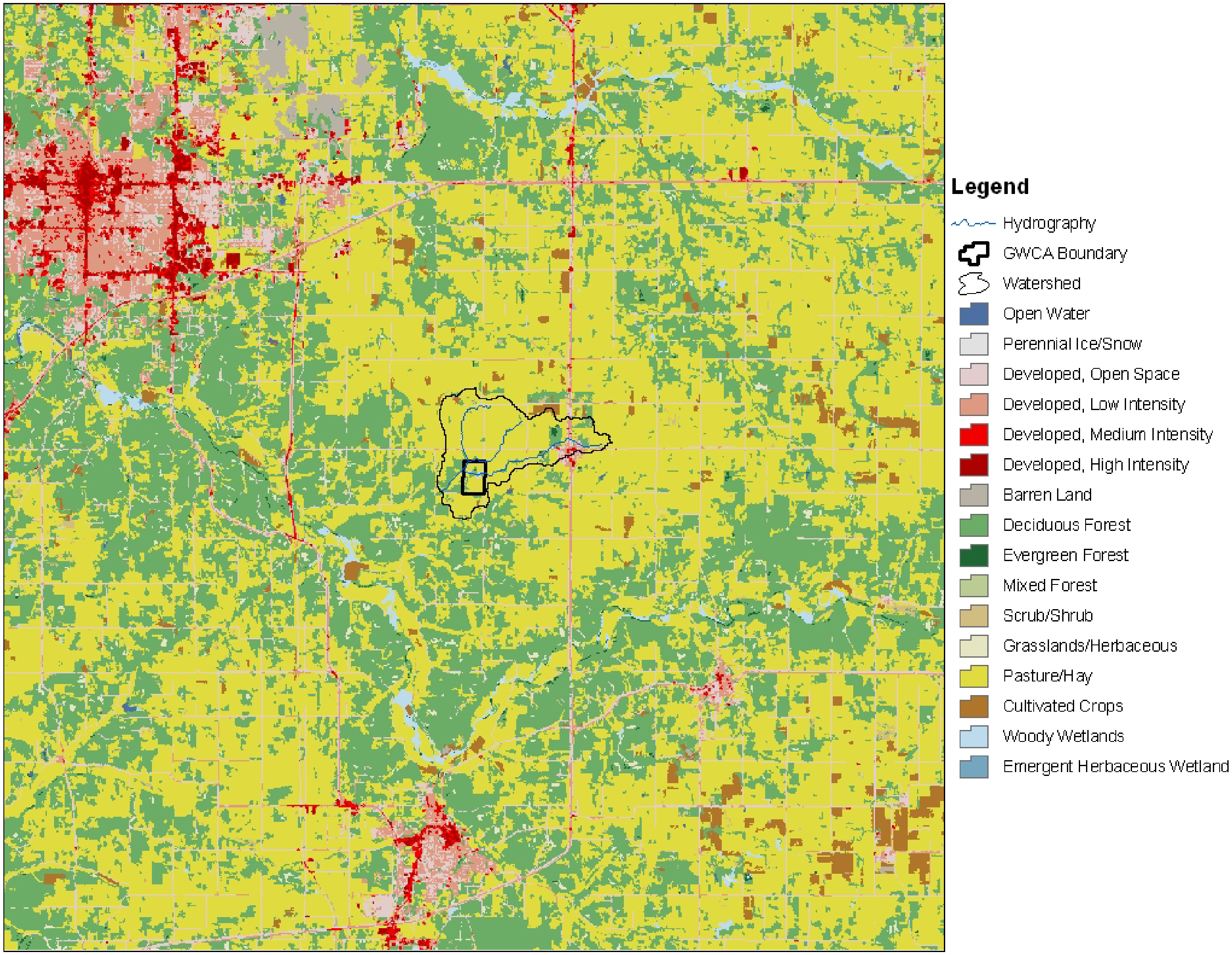

Figure 2-4. Land cover within and surrounding the watershed of George Washington Carver National Monument based on the 2001 NLCD.

Figure 2-5. Location of potential threats in George Washington Carver 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

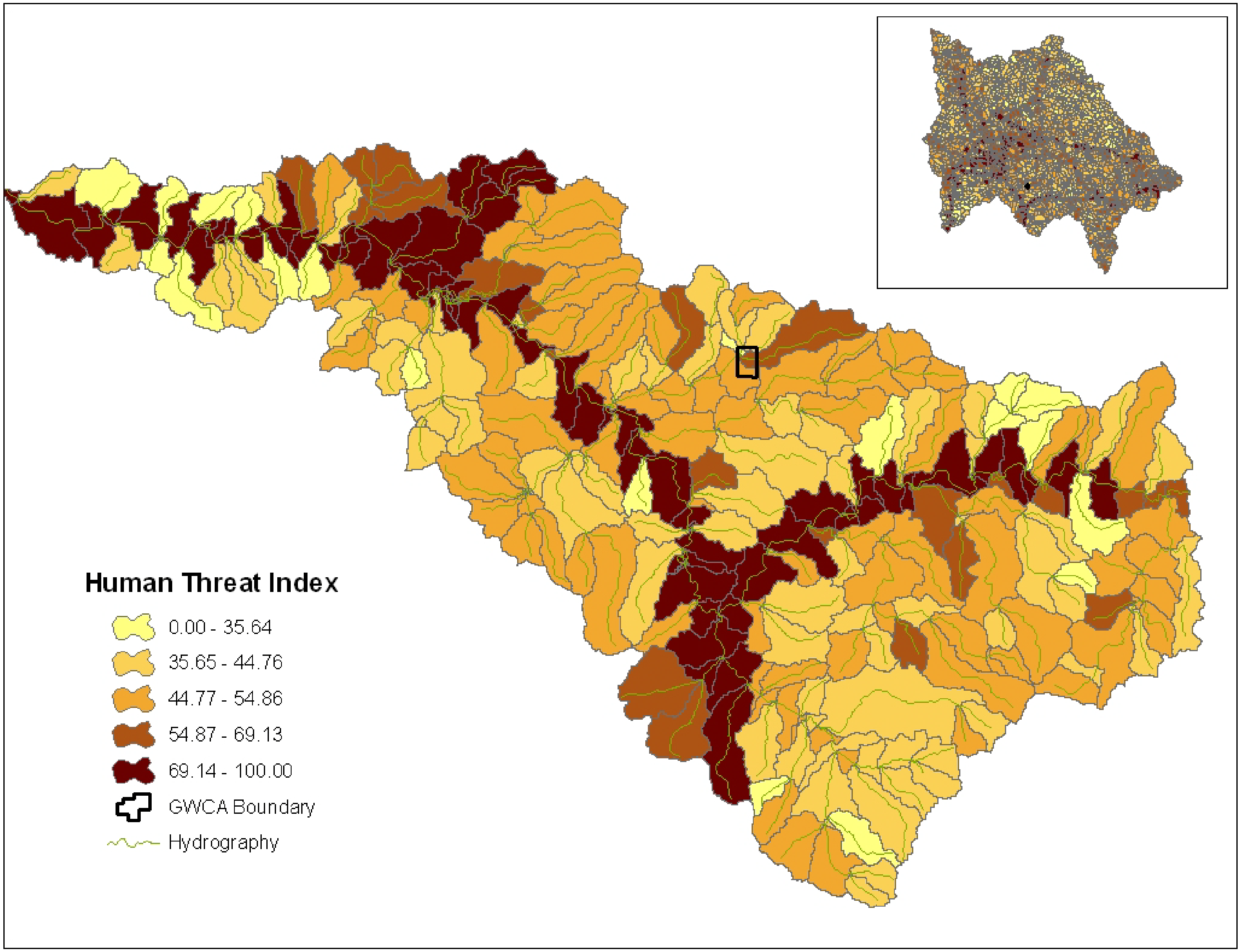

Figure 2-6. Human Threat Index for the 10 digit hydrologic unit encompassing George Washington Carver National Monument with the 8 digit hydrologic unit inset.

Landform History

George Washington Carver National Monument is in the Springfield Plateau physiographic section of the Ozark Plateaus in southwestern Missouri (Bottomley 2000). Topography consists of gently rolling uplands, heavily dissected by stream channels. Elevation ranges from about 1,000-1,800 feet. 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 forest, and savannah. 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

Although George Washington Carver only spent around 10 years on the Carver farm, the Moses Carver family and land greatly influenced his life (Dilebo 1972, Toogood 1973). The monument memorializes the life of George Washington Carver and preserves the setting of the Moses Carver farm where George spent his formative years. According to the park's Cultural Landscape Inventory, interpretation at the park relates features of the park in a commemorative nature, relative to its period of installation. It was acknowledged early on that the structural elements of the landscape had changed a great deal since Carver's boyhood years. Research showed that only the Moses Carver Family Cemetery actually dated to the boyhood period. An associated structure, the Moses Carver Late Period Dwelling – which George is known to have visited later in life – is also extant.

With few historic structures and little documentation to work with, the NPS early on decided to focus on the vegetative surroundings that would have been present during Carver's boyhood period given how influential the environment, both natural and agricultural, was to him. This setting also had to be co-sympathetic with any constructed amenities that would be added to the landscape for interpretive or commemorative purposes. To help visitors understand Carver and experience nature the way he experienced it from childhood into adulthood, one of the first amenities to the site was a nature trail developed in order to provide visitors an opportunity to experience nature within the setting. One of the unique aspects of the monument's development is how it slowly evolved and revealed itself as the place of solitude, reflection, and learning it has become.

The Carvers settled the farm in the 1830s, and purchased George Washington Carver's mother in 1855 (Toogood 1973). George Washington Carver was born into slavery during the Civil War. He and his mother were abducted by raiders soon after his birth. Moses Carver was only able to recover George Washington Carver (Dilebo 1972). As a child, Carver was allowed time to develop as a naturalist and observer. In addition, he learned good farming practices and thriftiness from the Carvers. George Washington Carver moved away around 1877 to pursue an education from schools that allowed blacks. Eventually, he earned a B.S. in 1894 and an M.S. in agriculture in 1896 from Iowa State University. During 1896, Booker T. Washington, founder of the Tuskegee Institute in Alabama, hired Carver as the school's director of agriculture. George Washington Carver lived there until his death in January 1943(Dilebo 1972, Toogood 1973).

George Washington Carver recognized, partially due to his experience on the Carver farm, that poor land use, due to widespread cotton monocultures across the South, was causing soil erosion and depletion of fertility, and ultimately, cotton crops were contributing to poverty (Dilebo 1972, Burchard 2005). Therefore, Carver worked to restore soil, and resolve associated economic and social issues, through improved agricultural practices. He encouraged use of organic mulches and compost to reduce erosion and restore topsoil, as he believed commercial fertilizers were not viable for long-term soil enrichment. He launched crop rotation, alternating cotton crops with soil-enriching crops, such as sweet potatoes, pecans, and most importantly, nitrogen-fixing legumes including peanuts and soy beans. He then created markets for these products, by developing hundreds of new uses, from food products to dyes (Burchard 2005).

Carver concentrated on sustainable agriculture as a means to a self-sufficient and healthy existence. Although he supported the farm-grown plastic and biofuels movement promoted by Henry Ford and others, and eventually suppressed by the oil industry, he found factories to be far removed from the farmer's lifestyle. Instead, Carver focused on practices and products that were immediately useful and economical for farmers, rather than commercial or industrial operations. He educated the public about soil and forest conservation, organic farming, growing a variety of crops locally, eating a nutritional diet based on whole grains and vegetables, and using homemade nontoxic products. Remarkably, Carver was able to overcome slavery, prejudice, and poverty, while remaining indifferent to personal fame and fortune, in his dedication to improve the world (Burchard 2005).

Carver's work was progressive, and as relevant today as it was in the past. His philosophy that living gently on the land, through nourishment of soil, crops, resources, and species, is the only way to sustain economic prosperity, could heal prevalent environmental and social problems. Currently, erosion and loss of soil fertility, monocultures, soil compaction, abandonment of crop rotation and cover crops, dependence on commercial fertilizers and pesticides, unrestrained water use, as well as rapid loss of species and habitat, greenhouse gases, ozone depletion, pollution, exotic species, desertification, not to mention, the associated loss of human livelihoods, demands the involvement and guidance of people like George Washington Carver.

Natural Communities

George Washington Carver National Monument currently contains a variety of habitats including restored tallgrass prairie, fescue and disturbance grasslands, young woodlands, and three small streams (James and Rowell 2009, Jones 2004, Sasseen 2005). A man-made pond and a small garden plot also add diversity to the park. The southwestern corner of the park contains remediated mine tailings and highly disturbed woodlands and grasslands. Jones (2004) subjectively noted that woodlands in the northwest corner are in better condition that other woodlands, and surmised that about 120 acres of the park has had some level of restoration, though records are not entirely complete.

The historic landscape may have consisted almost entirely of tallgrass prairie or open savanna, with wetter prairies occurring along upland drainage ways. However, drainages may have been wooded (Nigh and Schroeder 2002). Jones (2004) also noted that some areas within the resorted prairie were wetter than others, and soils grouped into historic site types also suggested some variation in the original prairies (Nigh and Schroeder 2002). Burfield and Nilon (2009) suggested that as much as 111 acres of the original Moses Carver land was unplowed prairie during George Washington Carver's early years on the farm, but that essentially all of the area of the park was plowed in the early 1900's.

Aquatic Resources In and Near George Washington Carver National Monument

There are three small streams that flow through George Washington Carver National Monument and two spring branches that are completely contained within the park. Carver Branch, Harkins Branch, and Williams Branch are all tributaries to Shoal Creek. Carver Branch is classified as a losing stream by the state of Missouri. Williams Spring is inundated by Williams Pond. Carver Spring consists of a very short spring branch that flows into Carver Branch. Stream condition in GWCA is generally good, though there may be mild impairment from threats outside of the park boundaries (Bowles 2009).

Pooled data from 2003, 2006, 2007, and 2010 document 22 fish species known to GWCA. These species generally were typical of small headwater streams, including southern redbelly dace (*Phoxinus erythrogaster*), central stoneroller (*Campostoma anomalum*), and green sunfish (*Lepomis cyanellus*; Justus and Peterson 2005a). However, the Arkansas darter (*Etheostoma cragini*) is a species of conservation concern (Missouri Natural Heritage Program 2010). The grass carp is an introduced species, and potentially detrimental to native species.

Wildlife

Fauna of George Washington Carver National Monument are typical of old fields and disturbed woodlands in the Ozark Highlands. Birds are a major visitor attraction, and are the best studied of the park’s vertebrates. Forty-nine species of birds were recorded during site visits in May of 2008 (Peitz 2009). The most common and widely distributed species was the Dickcissel (*Spiza americana*). The blue jay (*Cyanocitta cristata*), northern cardinal (*Cardinalis cardinalis*), northern mockingbird (*Minus polyglottos*), American robin (*Turdus migratorius*), American crow (*Corvus brachyrhynchos*), downy woodpecker (*Picoides pubescens*), and tufted titmouse (*Baeolophus bicolor*) are seen in the forest, developed areas, and forest edges. Common mammals include the opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), prairie vole (*Microtus ochrogaster*), and hispid cotton rat (*Sigmodon hispidus*; Robbins 2005). The herpetofauna community is typical for disturbed prairies with some common deciduous forest species. Common species include the American bull frog (*Rana catesbeiana*), southern leopard frog (*Rana sphenocephala*), ringneck snake (*Diadophis punctatus*), and three-toed box turtle (*Terrapene carolina triunguis*).

Resource Stewardship Context

Park Enabling Legislation

George Washington Carver National Monument was established to memorialize the birthplace and childhood of Dr. George Washington Carver and to preserve the setting of the Moses Carver farm. The monument was founded in 1943, however after World War II ended, issues including inflation and unwillingness of the owner to sell, delayed dedication until 1953 (Ortega 1976).

The following purpose statements are developed from the enabling legislation (from NPS 1997):

- Memorialize the life of George Washington Carver as a distinguished African American, scientist, educator, humanitarian, Christian, artist, and musician.
- Preserve the setting of the Moses Carver farm and birthplace of George Washington Carver.
- Interpret the life, accomplishments, and contributions of George Washington Carver, using a museum, wayside exhibits, and other interpretive strategies.

Fundamental Resources and Values

The following significance statements "capture the essence of the monuments importance…" (NPS 1997)

- George Washington Carver National Monument is significant because it was the birthplace and home where Carver spent his formative years that set him on the road to becoming one of this nation's most distinguished scientists and humanitarian.
- Although born a slave and orphaned as a baby, his early years were spent in a nurturing atmosphere with his adoptive white parents in an agrarian setting. Here he was given the opportunity to pursue his curiosity about the world around him.

Other Important Resources and Values

The NPS is legislatively-mandated to preserve the site of the birthplace of George Washington Carver and the Moses Carver farm. The park's legislation directs the monument to be a memorial to Carver's entire life, not just his boyhood. According to the General Management Plan (NPS 1997), within the setting of the Moses Carver farm and birthplace of Carver, the public will have an opportunity to learn about the life, accomplishments, and contributions of the distinguished African American scientist, educator, humanitarian, Christian, artist, and musician. Natural and cultural resources will serve as symbols of significant events and influences on the character and life of this great American. The interpretative program will enable people to use tangible resources to consider the abstract implications of the Carver story. The landscape and visitor facilities will support a memorial-like atmosphere, providing opportunities for the public to spend time reflecting upon their lives and experiences, and those of George Washington Carver.

George Washington Carver Monument works with its partners, including the Carver Birthplace District Association, Iowa State University, Tuskegee University, Newton County 4-H, University of Missouri, and the Northwest Newton County Conservation Opportunity Area, to develop interactive educational opportunities promoting stewardship of natural and cultural resources through web sites, interpretive facilities, an updated interpretative film, and a master repository of materials related to George Washington Carver. Future goals, in cooperation with educators, will be to provide knowledge about national parks**,** conservation, environmental leadership, and cultural and social issues, for students of all ages. In particular, the monument hopes to continue George Washington Carver's vision of the connection between humans and nature. Online learning will encourage environmental awareness, while on-site programs will demonstrate environmental practices and show how to incorporate practices into daily lives. The National Monument grounds can supply both agricultural demonstration plots of Carver's work as well as visitor involvement in inventory of species and communities. A further objective includes creating a master repository for information related to Carver.

The staff at GWCA have incorporated prairie restoration and the maintenance of a small garden plot into management of the park (see review in Burfield and Nilon 2009, Jones 1995). Other aspects of the natural environment are interpreted as having influenced the young George Washington Carver, including the presence of wildflowers, fruit and nut trees, and the Carver Spring. Natural resource management therefore emphasizes maintenance and restoration of native flora and fauna

Plant Community Restoration

Restoration of native prairie recognizes the importance of the natural environment on George Washington Carver as a boy. Other aspects of the natural environment are interpreted as having influenced the young George Washington Carver, including the presence of wildflowers, fruit and nut trees, and the Carver Spring. Natural resource management therefore emphasizes maintenance and restoration of native flora and fauna

Approximately 80 acres (32 ha) of GWCA were farmed in the last 30 years under a variety of special use permits. These areas are currently undergoing restoration to native prairie. Management activities including seeding, planting, mowing, haying, and prescribed burning are used as restoration treatments. In recent years, restoration activities have consisted mainly of mowing, haying and prescribed burning. GWCA has conducted 17 prescribed burns between 1982 and 2008.

While prairie vegetation has been established, exotic plant species have also become established and may impede successful prairie restoration. Management objectives include restoring prairie through planting native species, removing invasive species, prescribed burning, and monitoring species abundance and richness. The restoration results will be compared with a reference site, Diamond Grove Prairie, which is a privately-owned prairie near GWCA.

The springs, creeks and adjacent forest also were a curiosity to George Washington Carver. GWCA's riparian forest canopies have closed in recent years. Management objectives include restoring woodlands and savannah through selectively removing trees to increase canopy openness and increase understory growth, controlling invasive species, and potentially introducing prescribed fire.

Invasive, Exotic Plant Management

The invasive Japanese honeysuckle (*Lonicera japonica*), tartarian honeysuckle (*Lonicera tartarica*) are abundant in the woodlands; while Johnson grass (*Sorghum halepense*), crown vetch (*Securigera varia*), and lespedza (*Lespedeza cuneata*) have colonized prairies at GWCA. The high abundance of thistles (*Cirsium* spp.) on adjacent lands is also a potential problem. Extensive grazing on surrounding farms invites exotic species establishment and growth. GWCA staff are writing a Fire Management Plan to use prescribed burning for control of exotic plant species. Prescribed fire will ideally provide a viable native seed bed and reduce the number of exotic plant species and encroaching native woody plants such as sumac (*Rhus spp*.), blackberries (*Rubus spp*.), woody briars (*Smilax spp.*), and grape vine (*Vitus* spp.), which are also invading restored prairies.

<u>Wildlife Management</u>
Aquatic habitats are an important part of the natural and cultural interpretive programs at the park. Two springs, a small spring-fed pond, and three streams that flow through the park (two of which originate off park grounds) are home to several species of reptiles and amphibians. Plant and animal life within these waters are of great interest to visitors and are excellent education tools for park interpreters. Park waters are influenced by adjacent land use such as agriculture and pasture. Because of the role water plays in the life cycle of many reptiles and amphibians, these species are good indicators of water quality. Amphibians are of particular interest due to their sensitivity to pollutants.

Desired Conditions for Natural Resources
The Long Range Interpretive Plan for GWCA (2007) provides some direction with regards to the natural resources and their use in interpreting the life of George Washington Carver. According to the plan, natural resources will serve as symbols of significant events and influences on the character and life of George Washington Carver. The landscape will support a memorial-like atmosphere, providing opportunities for the public to spend time reflecting upon their lives and experiences, and those of George Washington Carver.

Woodlands, savannahs, prairie, and streams will be managed to help visitors understand that GWC discovered beauty in nature, communed with the Creator through nature, and gained inspiration for artistic creations through nature. Visitors will forge connections between the natural environment of George's formative years on the farm, the curiosity and creativity it inspired, and the rejuvenation it provided to him throughout his life. The woodlands, savannahs, and prairie, and streams will provide opportunities for visitors to gain inspiration and serenity from the natural environment – and reflect upon Carver gaining inspiration from the natural environment.

Woodlands, savannahs, and prairie will be managed to provide visitor's the opportunity to understand George's excitement about plants and talent for caring for plants – which began on the Moses Carver farm. "Day after day I spent in the woods alone in order to collect my floral beauties and put them in my little garden I had hidden in brush not far from the house, as it was considered foolishness in that neighborhood to waste time with flowers." George Washington Carver, 1897

Natural resources will be managed in a manner which helps visitors realize that, fundamentally, George Washington Carver was a conservationist -- envisioning all things in nature as useful.

Other desired conditions for natural resources at GWCA are:

- Manage cultural and natural resources to memorialize Carver's life in a dignified and inspirational setting

- Interpret how the boyhood farm and surrounding area influenced Carver as an adult.

- Manage the park's resources so they can be used to help interpret how the boyhood farm and surrounding area influenced Carver as an adult.

- To preserve the agrarian setting.

- 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 national monument 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.

- 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.

- George Washington Carver was a soil conservationist, conducting scientific research to improve soil conservation and farming methods across the South. The management of soil resources aims 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.

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 George Washington Carver National Monument (GWCA) 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 GWCA. 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 also reviewed management plans and natural resource studies to ensure that the selected indicators complimented these efforts.

Table 3-1. Team members for the George Washington Carver National Monument 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
Jim Heaney	George Washington Carver National Monument
Lana Henry	George Washington Carver National Monument
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
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 3-2. 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

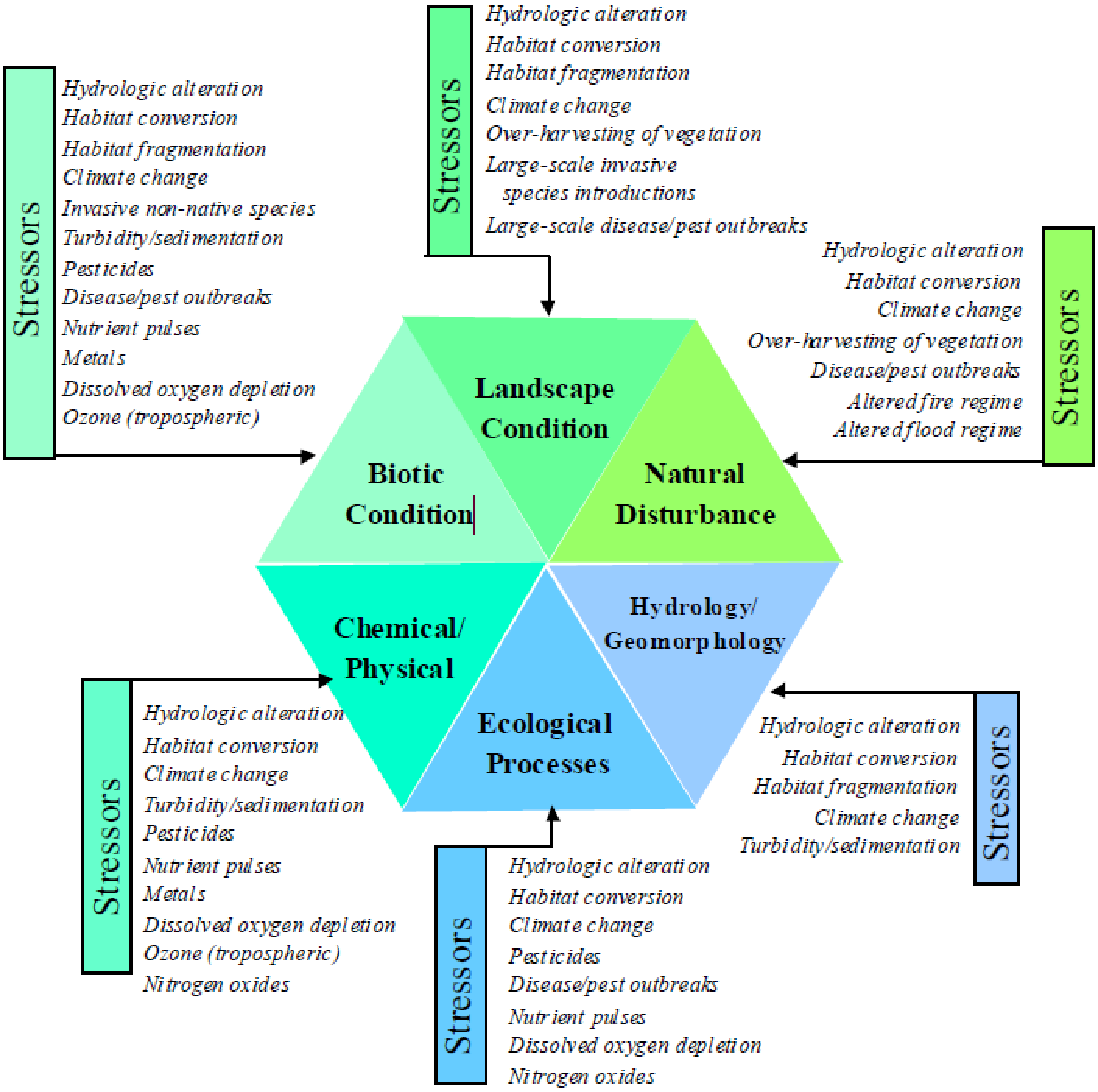

Figure 3-1. Schematic showing the one-to-many relationship between essential ecological attributes and stressors in the Environmental Protection Agency's Framework for Assessing and Reporting Ecological Condition (EPA 2002).

Resource Types, Attributes and Indicators

For GWCA, 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 and can be impacted by reasonable levels of management effort. 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

<u>Landscape Composition</u>
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.

<u>Land Use/Land Cover</u>
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, dense woodlands on site types that were historically forested often indicate past cultivation, overgrazing, a reduction in ground fire frequency, or a combination of these human-associated disturbance factors.

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, 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 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).

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).

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 2009). 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). Such 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. Additionally, 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 lability 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 GWCA 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 is affecting 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: 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 2010). 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. The NPS monitors wet deposition through the National Atmospheric Deposition Program (NADP) and is the only component monitored extensively across the United States. Dry deposition of particles and gases occurs by complex processes such as settling, impaction, and adsorption. Dry deposition is monitored through the Clean Air Status and Trends Network (CASTNet).

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 determine 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 native 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 GWCA and surrounding areas. Most ecologists assert that burning promoted dominance of fire-tolerant species and kept pre-European grasslands and savannas more open than second growth woodlands in the modern landscape.

Chapter 4 Study Methods

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.

The current vegetation classification was produced by considering land cover and ecological site type. Land cover was coded by hand on-screen to 2 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. Finally, conceptual current vegetation was assigned to each combination of land cover and abiotic site type (Figure 4-2).

Table 4-1. Land cover classes assigned to image objects for George Washington Carver National Monument.

Land Cover Classes
Impervious
Low Density Urban
Barren or Sparsely Vegetated
Grassland
Deciduous Forest
Deciduous Woody/Herbaceous
Open Water

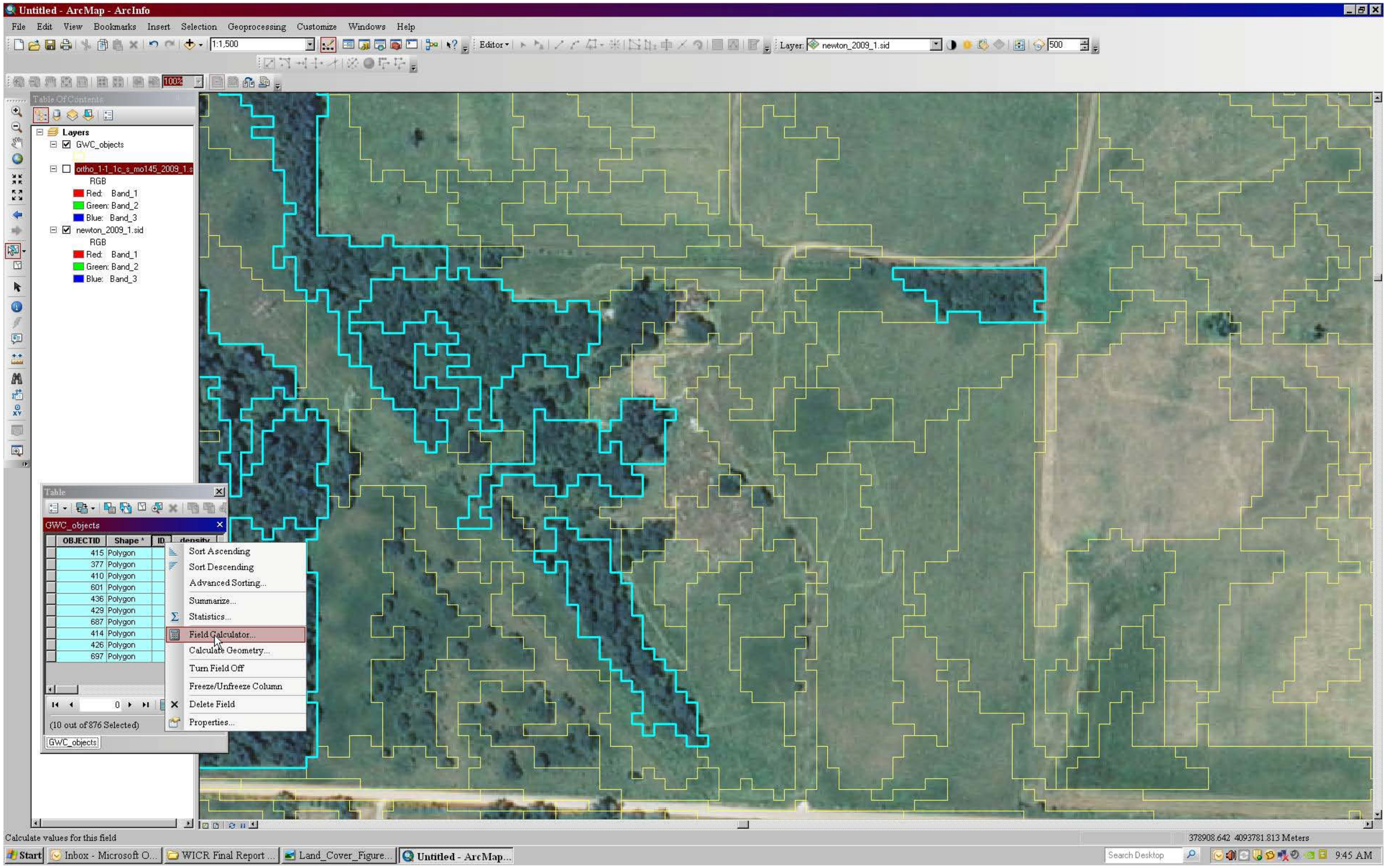

Figure 4-1. Process for assigning land cover classification to image objects on-screen.

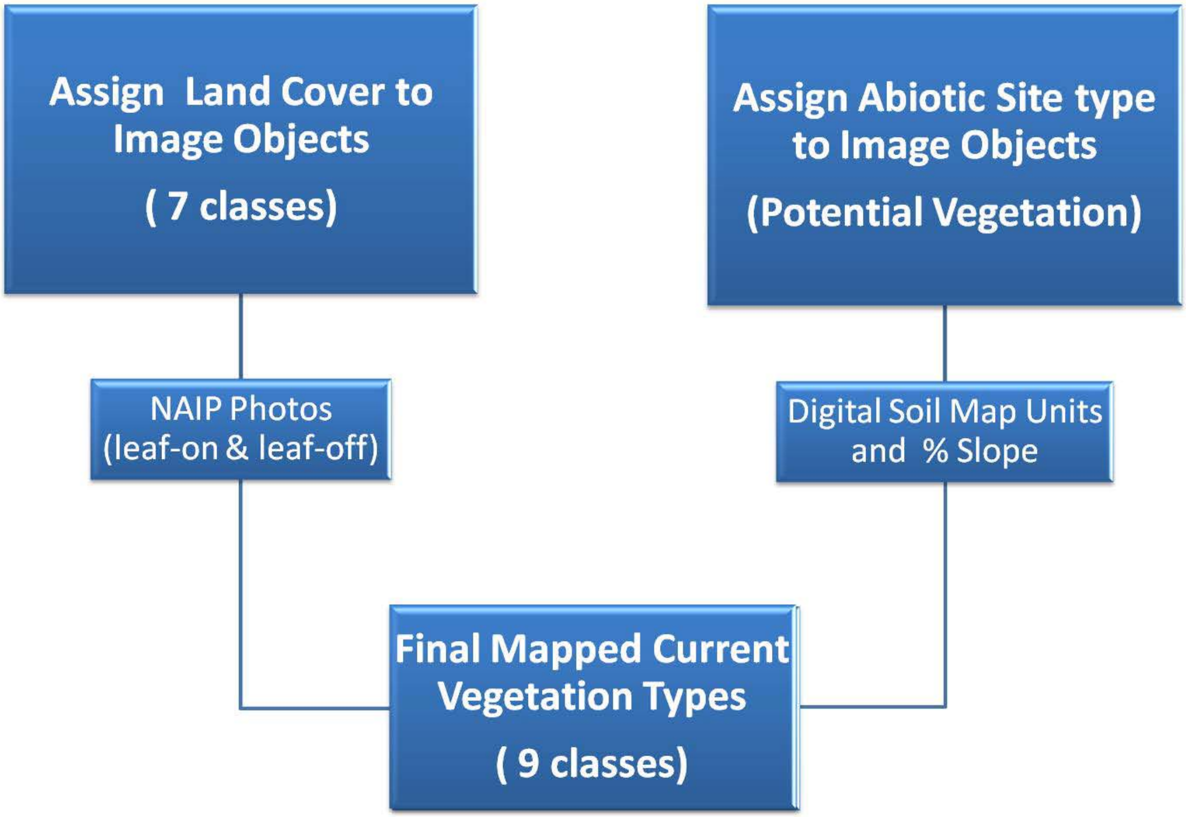

Figure 4-2. Current vegetation was assigned to image objects based on ecological site type (site potential) and current land cover.

Biotic Condition

Bird Community Composition

Breeding birds are monitored at GWCA 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. An intensive breeding bird survey was done at GWCA in the summer of 2008 using standardized protocol (Peitz et al. 2008, Peitz 2009). Breeding birds and their habitat were sampled at 70 permanent sites arranged in a systematic grid of 100 X 100 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.

Invasive Exotic Plants

Invasive and exotic plants are recognized by the NPS as a threat to native biodiversity across the nation. In response, the Heartland Network Inventory and Monitoring Program tracks invasive species in a systematic way at GWCA. A park-based watch list of possible invasive exotic species has been generated, and data were collected from a 6-m belt within 97 units (Cribbs et al. 2007). The units consisted of a grid modified by vegetation cover type (e.g. units consisted either of grassland or forest, not a mixture of both). Presence of target species was noted and cover estimated by cover class.

Plant Community Structure and Composition

Woodlands and upland grasslands are tracked by the Heartland Inventory and Monitoring Network at GWCA. 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 are sampled in conjunction with breeding bird surveys at 38, 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 1.78 meter 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. 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 using five common indicators of fish community condition and by comparing an observed community to a modeled baseline community within GWCA. These comparisons give a measure of “fish faunal intactness” using a taxon with a relatively long historical record.

Actual fish collection data for streams within GWCA was collected by seining and backpack-electrofishing using direct current during July 2003 (Figure 4-3; Justus and Petersen 2005a); and more recently from 2006, 2007, and 2010 via electrofishing by the Heartland network (Figure 4-4; Dodd et al. 2011).

We developed current conditions from Dodd et al. (2011). Five metrics were used to assess the current condition and establish reference conditions for the three watershed based reporting units (Carver Branch, Williams Branch, and Harkins Branch). 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 GWCA we used the mean values from data collected in 2006 and 2007 as the management target. The reference condition used for the sucker, sunfish, and benthic species metrics was 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 IBI 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 GWCA 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 help establish baseline conditions inside of GWCA.

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 pooled data collected in 2003, 2006, 2007 and 2010 to Missouri Aquatic Gap Project fish species models which served as a baseline with which to compare.

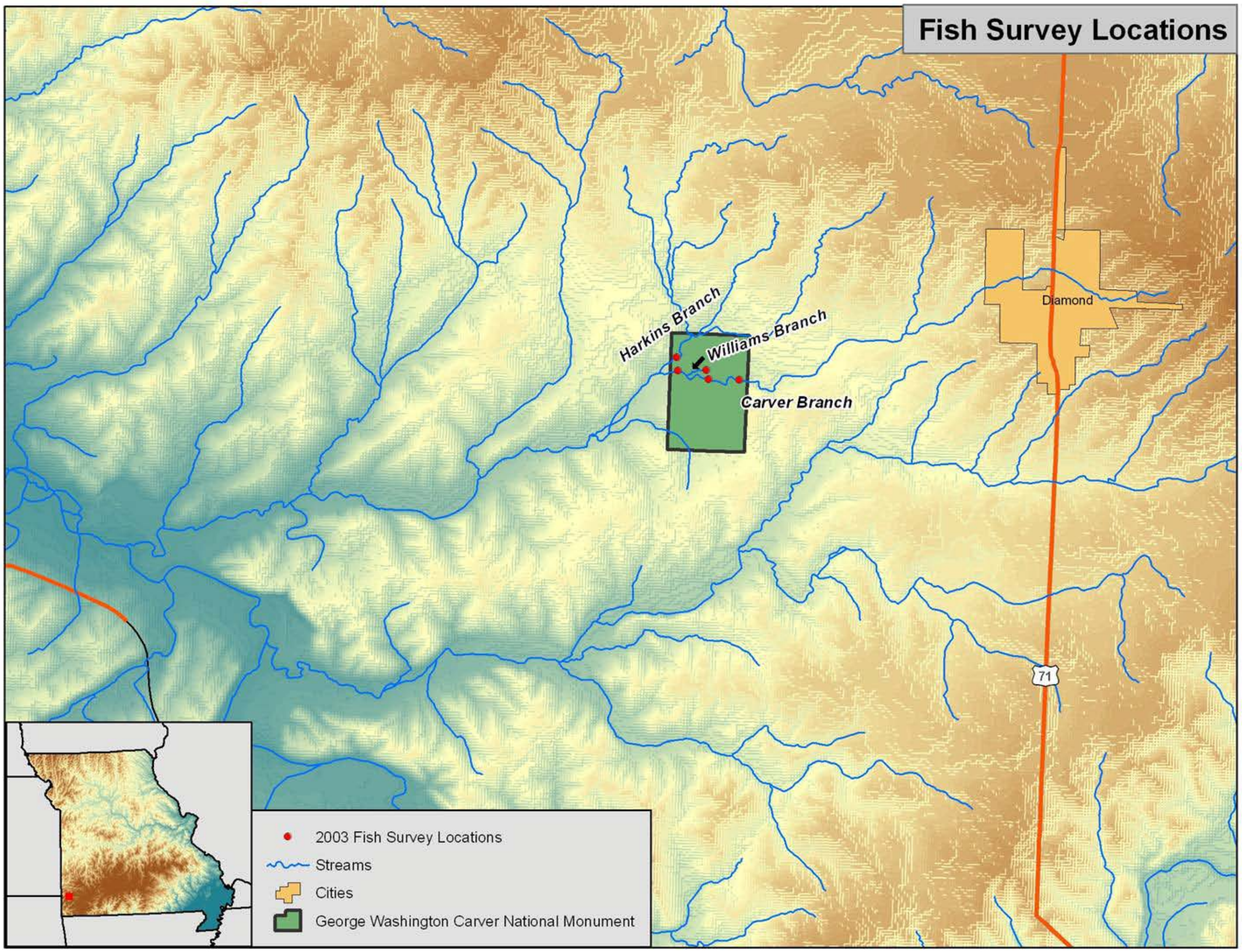

Figure 4-3. Fish survey locations during 2003 for Carver Branch, Harkins Branch, and Williams Branch (Justus and Peterson 2005a).

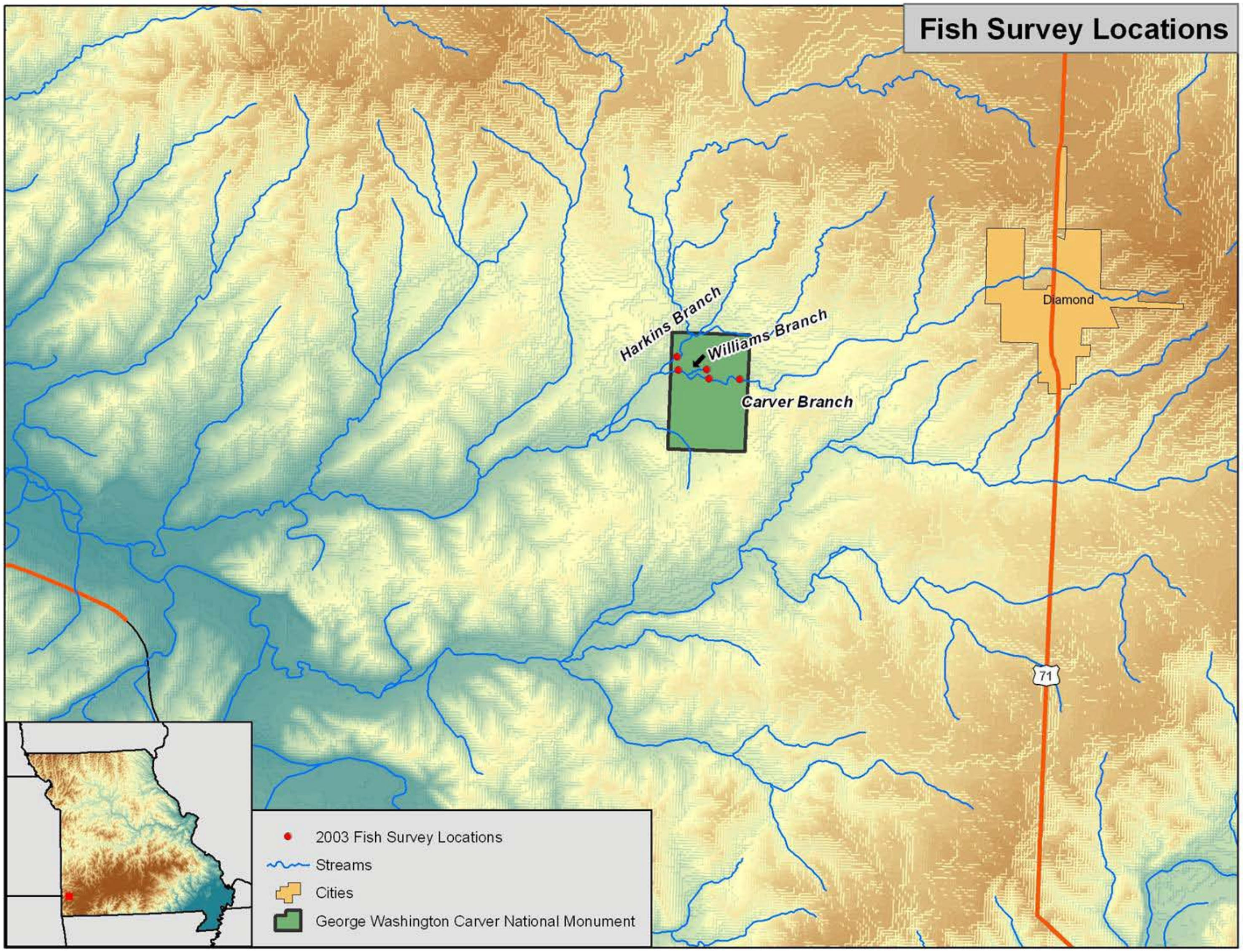

Figure 4-4. Fish survey locations during 2006, 2007, and 2010 for Carver Branch, Harkins Branch, and Williams Branch.

Aquatic Invertebrate Community

Aquatic invertebrate collection data for streams within GWCA were acquired using a Surber stream bottom sampler. Generally, data was available for 2005-2007 with one or two additional years of earlier data for some indicators. Collections made in 2005-2007 consisted of sampling three successive riffles with three benthic invertebrate samples collected at each riffle following Bowles et al. (2008), Monitoring Protocol for Aquatic Invertebrates of Small Streams in the Heartland Inventory and Monitoring Network (Figure 4-5).

Seven metrics were used to assess the current condition and establish reference conditions for the three watershed based assessment units (Carver Branch, Williams Branch, and Harkins Branch). 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.
- With the Shannon Evenness Index lower evenness indicates 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.

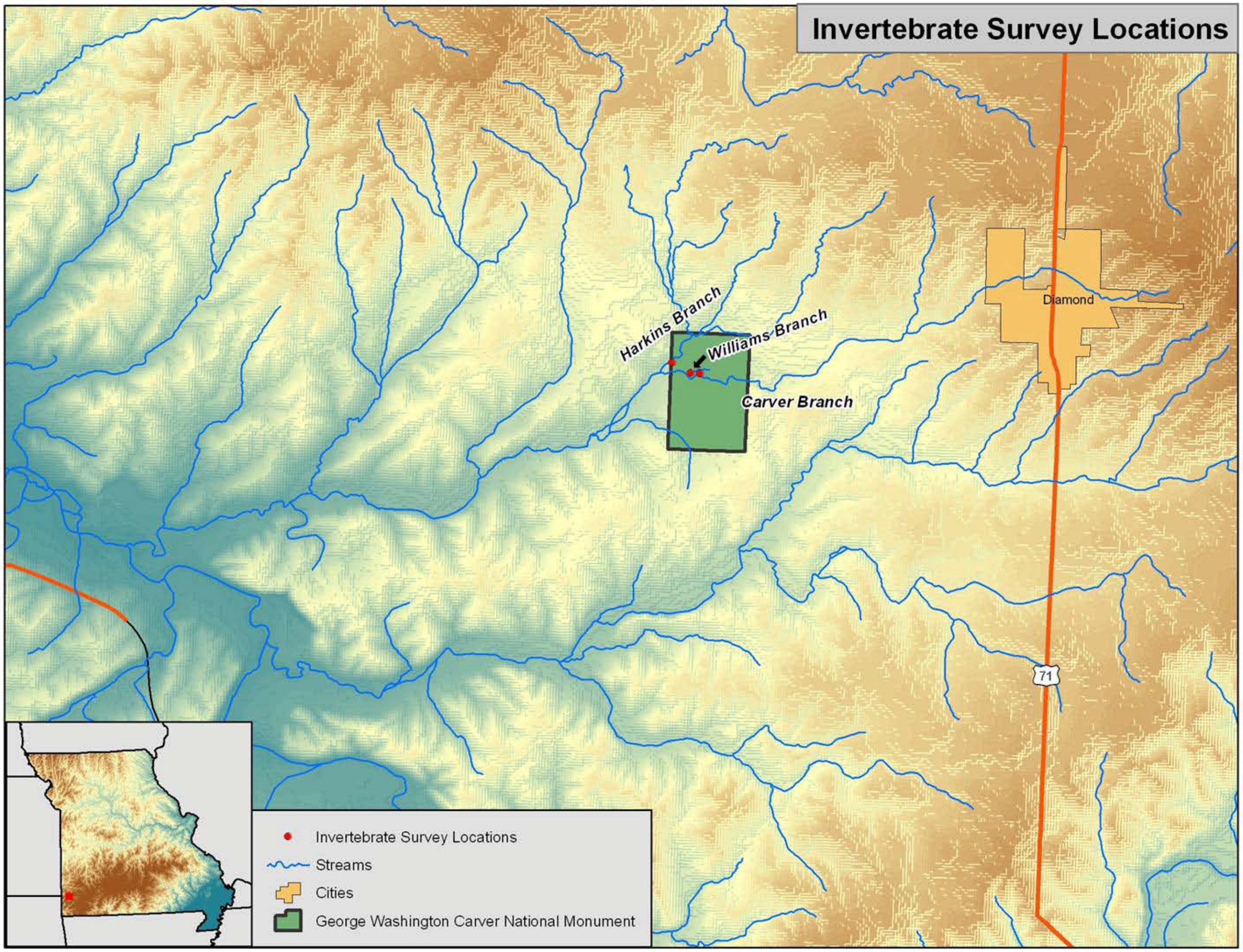

Figure 4-5. Invertebrate survey locations for Carver Branch, Harkins Branch, and Williams Branch during 2005-2007 (Bowles 2009).

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. Water quality information is based on Core 5 indicators for 2006, 2007, and 2010 taken from Dodd et al. (2011). Dodd et al. (2011) reports that data collected in 2006, 2007, and 2010 were collected continuously with data loggers. It should be noted that stream discharge was higher in 2007 than in 2006 or 2010. 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 is affecting 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 GWCA based on interpolations calculated as a 5-year average concentration. Ozone concentrations were measured as the 4th 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 (≥ 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 GWCA 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 4-2. 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

<u>Dry Deposition</u>
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 GWCA 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.

Because of a lack of available data this indicator was not included in the analysis.

Natural Disturbance Regime

Fire Regime

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

Chapter 5 Natural Resource Conditions

Reporting Units

For terrestrial communities, we developed reporting units that included the whole park, plus sub-divisions based on potential vegetation and on current condition (Figure 5-1). These included park-wide, upland grassland, woodland, and persimmon grove. 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). The persimmon grove reporting unit is conceptual, and is an area of cultural importance to George Washington Carver during the time he spent on the Carver farm. Cultural areas such as buildings, parking lots, and associated lawns and grounds were also identified and separated from areas that will be managed for more natural or semi-natural vegetation.

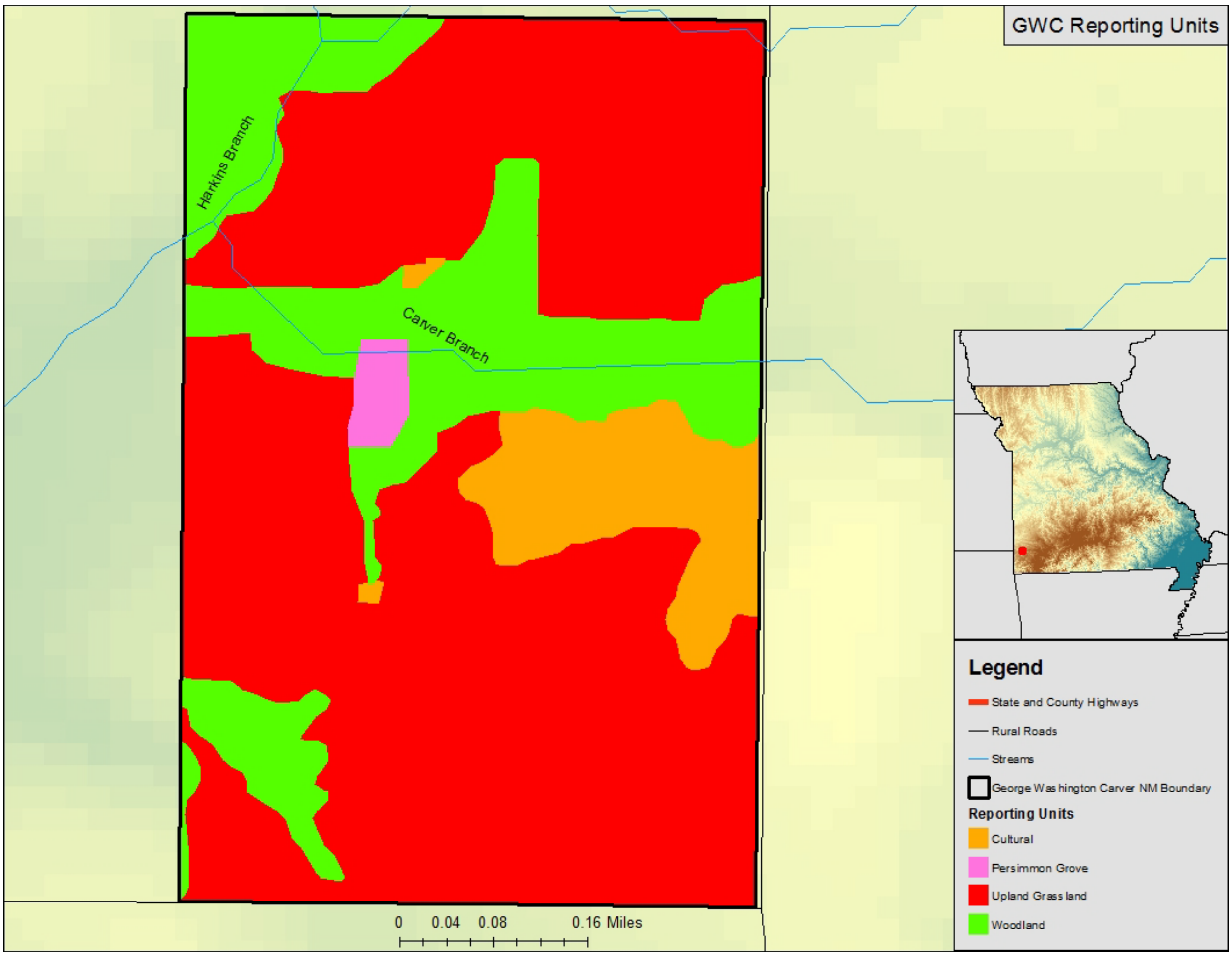

Figure 5-1. Terrestrial reporting units for George Washington Carver National Monument were based on both current vegetation patterns and ecological site type (site potential). The Persimmon Grove reporting unit is essentially continuous with the Woodland Reporting unit, but has cultural significance.

Because stream character and condition can vary dramatically with drainage area (Vannote et al. 1980), we developed reporting units for Harkins Branch, Williams Branch, and Carver Branch

(Figure 5-2). Air quality, which is largely reflective of global or regional processes, was reported at the park-wide scale.

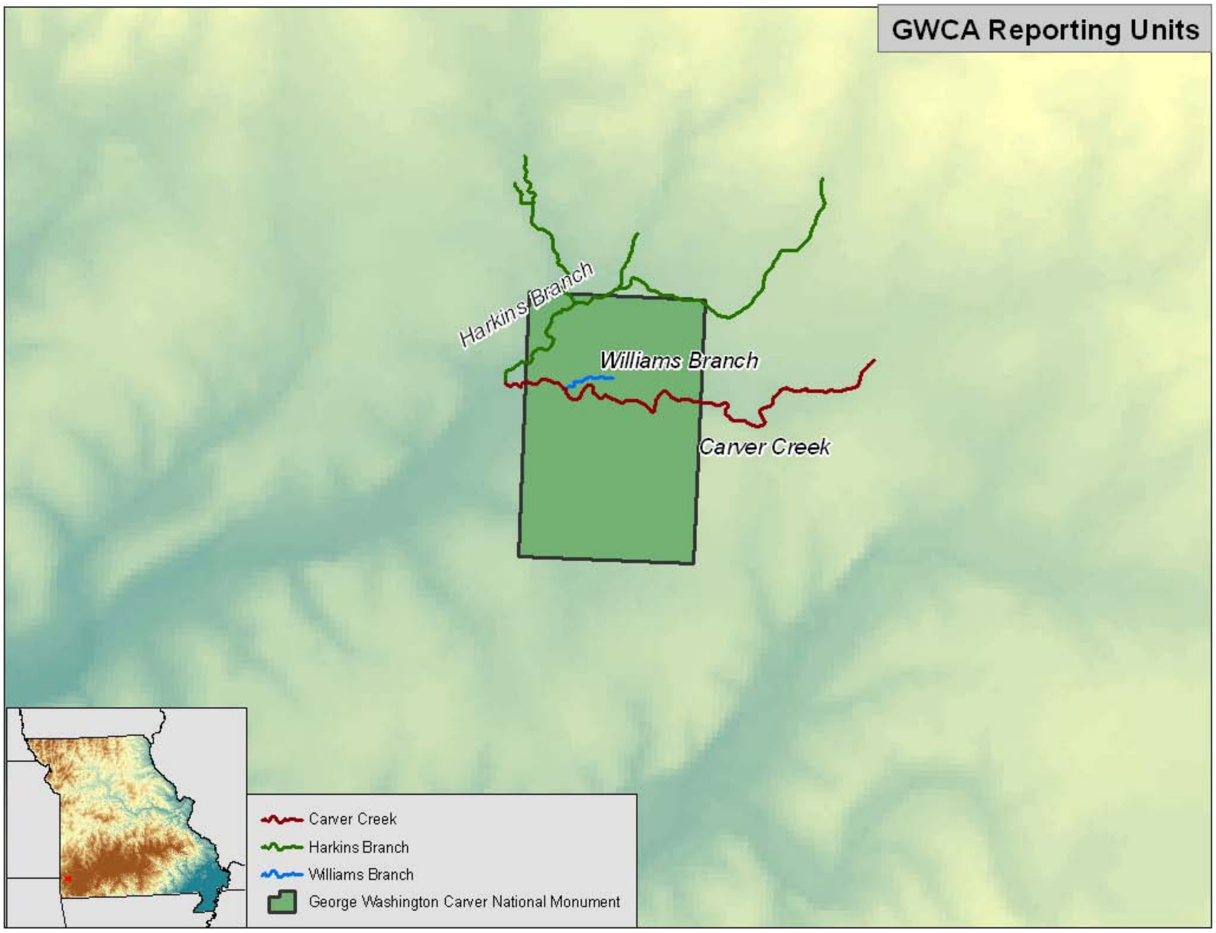

Figure 5-2. Map of stream reporting units within George Washington Carver National Monument.

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, however, the management targets may differ for the same resource type in different reporting units. Table 5-1 summarizes resource types and their indicators/attributes by reporting units.

Table 5-1. Summary of natural resource condition indicators for George Washington Carver National Monument. Current conditions and management targets are based on a variety of sources, including field data, literature, and expert judgment. (App. B summarizes how current condition and target values were determined.) Indicator(s) characterize resource types and their attributes within reporting units.

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
Park-wide						
	Vegetation					
		Landscape composition				
			patch count	< 50	105	2010
			mean patch size (ha)	> 3	1.09	2010
		Land use/Land cover				
			semi-natural and natural types (ha)	> 75	25	2010
			successional types (ha)	< 18	68	2010
			cultural types (ha)	≤ 3	3	2010
	Breeding bird community					
			species richness	≥ 47	47	2008
			Partners in Flight target species	≥ 6	6	2008
			number of grassland obligate species	≥ 3	3	2008
	Invasive exotic plant impact					
			number of taxa	< 30	35	2006
			frequency on transects (%)	< 50	91.9	2006
			park-wide minimum cover estimate (%)	< 10	9.0	2006
	Air quality					
		Ozone				
			ozone (ppb)	≤ 60	72.9	2003 - 2007
		Atmospheric deposition				
			nitrogen (kg/ha/yr)	≤ 1	13.03	2003 - 2007
			sulfur (kg/ha/yr)	≤ 1	10.6	2003 - 2007
Upland grassland						
		Landscape composition				
			patch count for grassland	< 10	0	2010
			mean patch size for grassland (ha)	> 5	0	2010
		Land use/Land cover				
			prairie (ha)	> 55	0	2010
			successional types (ha)	< 15	65	2010
		Diversity				
			native species richness	≥ 71	74	2008
			total species richness	≥ 135	143	2008
		Herbaceous guild composition				
			native grass (%)	> 30 5	47.2	2008
			native forbs (%)	> 17 5	37.6	2008
			native woody shrub and vine (%)	< 41.8	22.4	2008
Woodland						
		Landscape composition				
			patch count for woodland	< 10	18	2010
			mean patch size for woodland (ha)	> 2	1.1	2010
		Land use/Land cover				
			natural and semi-natural woodland (ha)	≥ 20	20	2010
			successional types (ha)	< 1	0.9	2010
		Structural class				
			hardwood canopy cover (%)	> 50	85	2008
			hardwood basal area (m^2/ha)	14 - 25	7.5	2008

Table 5.1. Continued

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
			density (stems/ha, trees > 8 cm dbh)	125 - 600	111	2008
		Regeneration				
			Total hackberry relative density (% of stems/ha, < 8 cm dbh)	< 50	41	2008
		Herbaceous guild composition				
			native grass (%)	10 - 70	13	2008
			native forbs (%)	1 - 45	18	2008
			native woody shrub (%)	20 - 50	20	2008
		Structure				
			hardwood tree height (m)	9 - 22	18.6	2008
Carver Branch						
	Water quality					
			temperature (°C)	0 - 34	15.3	2010
			specific conductance (µS/cm)	100 - 400	282.1	2010
			dissolved oxygen (mg/L)	5 - 15	7.9	2010
			pH	6.5 - 9.0	7.4	2010
			turbidity (NTU)	< 10	2.2	2010
	Fish community					
		Composition				
			Simpson's Diversity	≤ 0.49	0.97	2010
			sucker composition (%)	> 52	0.50	2010
			benthic species composition (%)	> 13.4	19.8	2010
		Condition				
			Index of Biotic Integrity	> 60	55	2010
	Aquatic invertebrates					
		Biotic integrity				
			family richness	≥ 14 2	16.0	2007
			genus richness	> 15	17.6	2007
			EPT richness	> 4	6.9	2007
			EPT ratio	≥ 0.85	0.68	2007
			Shannon Index (Genus)	> 1.77	2.26	2007
			Shannon Evenness Index	≥ 0.75	0.79	2007
			Hilsenhoff Biotic Index	< 6.6	4.6	2007
Williams branch						
	Water quality					
			temperature (°C)	0 - 34	17.1	2010
			specific conductance (µS/cm)	100 - 400	228.0	2010
			dissolved oxygen (mg/L)	5 - 15	10.8	2010
			pH	6.5 - 9.0	7.8	2010
			turbidity (NTU)	< 10	3.0	2010
	Fish community					
		Composition				
			Simpson's Diversity	< 0.34	0.21	2010
			benthic species composition (%)	> 74.4	80.7	2010
		Condition				
			Index of Biotic Integrity	> 60	81	2010
	Aquatic invertebrates					
		Biotic integrity				
			family richness	≥ 14 2	14	2007
			genus richness	> 15	15.4	2007
			EPT richness	> 4	6	2007
			EPT ratio	≥ 0.85	0.68	2007

Table 5.1. Continued

Reporting Unit	Resource Type	Attribute	Indicator	Management Target	Current Condition	Current Year
			Shannon Index (Genus)	> 1.77	2.03	2007
			Shannon Evenness Index	≥ 0.75	0.79	2007
			Hilsenhoff Biotic Index	< 6.6	4.4	2007
Harkins branch						
	Water quality					
			temperature (^{o}C)	0 - 34	17.3	2010
			specific conductance (μS/cm)	100 - 400	214.3	2010
			dissolved oxygen (mg/L)	5 - 15	7.3	2010
			pH	6.5 - 9.0	7.1	2010
			turbidity (NTU)	< 10	3.6	2010
	Fish community					
		Composition				
			Simpson's Diversity	< 0.27	0.15	2010
			benthic species composition (%)	> 18 3	33.1	2010
		Condition				
			Index of Biotic Integrity	> 60	52	2010
	Aquatic invertebrates					
		Biotic integrity				
			family richness	≥ 14 2	15.1	2007
			genus richness	> 15	16.1	2007
			EPT richness	> 4	7.6	2007
			EPT ratio	≥ 0.99	0.79	2007
			Shannon Index (Genus)	> 1.77	2.27	2007
			Shannon Evenness Index	≥ 0.75	0.83	2007
			Hilsenhoff Biotic Index	< 6.6	4.3	2007

Reporting Unit: Park-wide

Vegetation

Overall, GWCA has ten different current conceptual cover types, and about 22 ha (23%) are natural or semi-natural, whereas 65 ha (68%) are successional types. The remaining 9 ha (9%) are cultural cover types, including cover such as buildings, lawns, roads, and parking lots (Table 5-2, Figure 5-4). Wooded types are considered semi-natural and grassy types successional for this summary, but this distinction is somewhat misleading, since essentially the entire park is in some stage of disturbance and recovery from past land use, mainly row crop agriculture. Finally, current cover types are conceptual in nature, and are not based on field sampling. Current vegetation will be classified and mapped by NPS under a separate project.

Table 5-2. Current (conceptual) vegetation type distribution.

Current Vegetation Class	Mean Patch Size (ha)	# of Patches	Class Area (ha)	% Class Area
Barren or Sparsely Vegetated	0.07	1	0.07	0.08
Bottomland Oak-Hardwood Forest	1.12	11	12.36	12.89
Bottomland Successional Deciduous Sparse Woodland and Shrubland	0.07	2	0.14	0.14
Bottomland Successional Herbaceous Vegetation	0.47	12	5.63	5.87
Open Water	0.31	1	0.31	0.32
Trails and Roads	0.10	13	1.27	1.32
Upland Prairie and Savanna (wooded)	0.27	45	12.28	12.80
Upland Successional Deciduous Sparse Woodland and Shrubland	0.11	17	1.85	1.93
Upland Successional and Disturbance Grassland	4.03	15	60.50	63.08
Urban Low Intensity	0.17	9	1.50	1.57

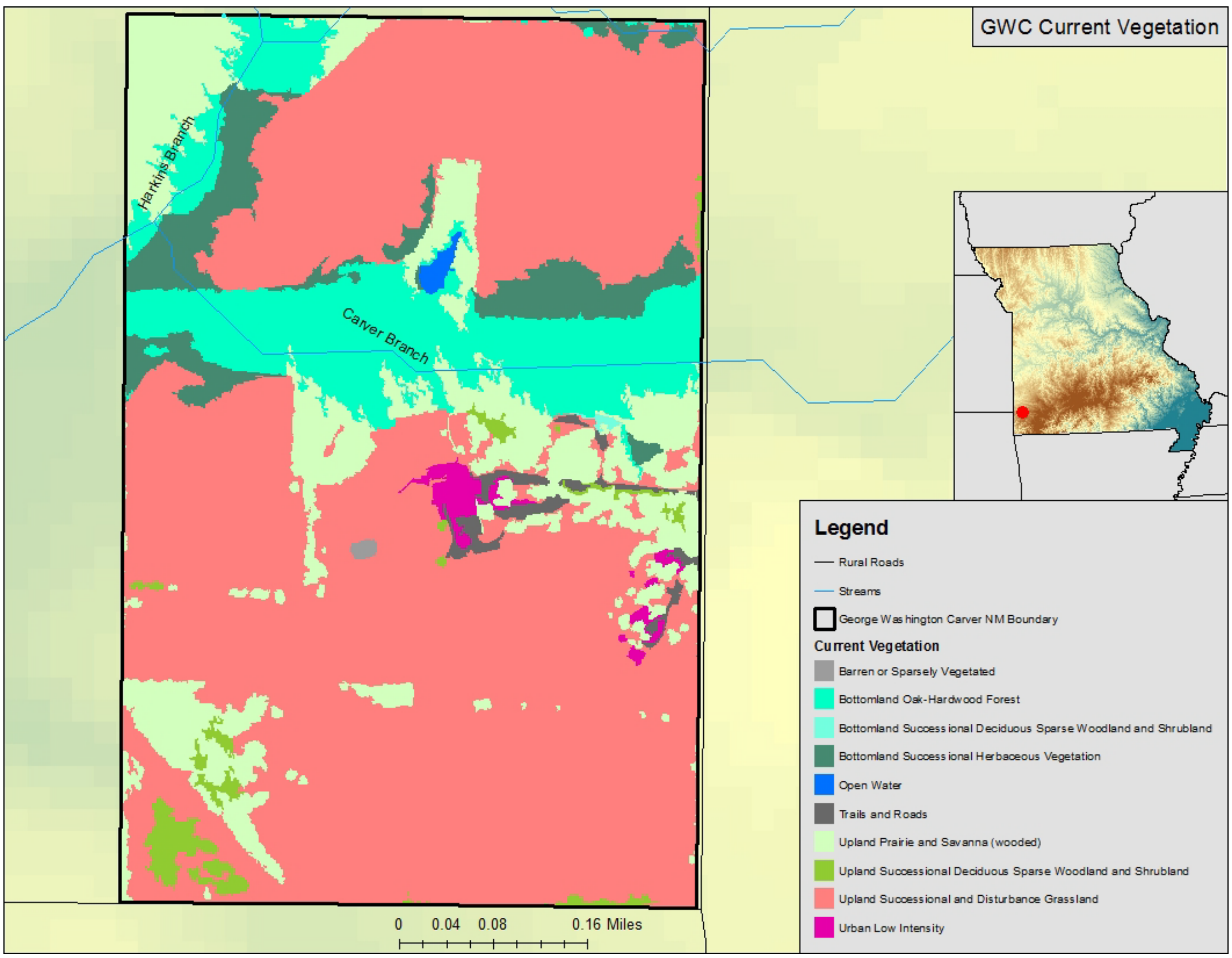

Figure 5-3. George Washington Carver National Monument current (conceptual) vegetation cover types.

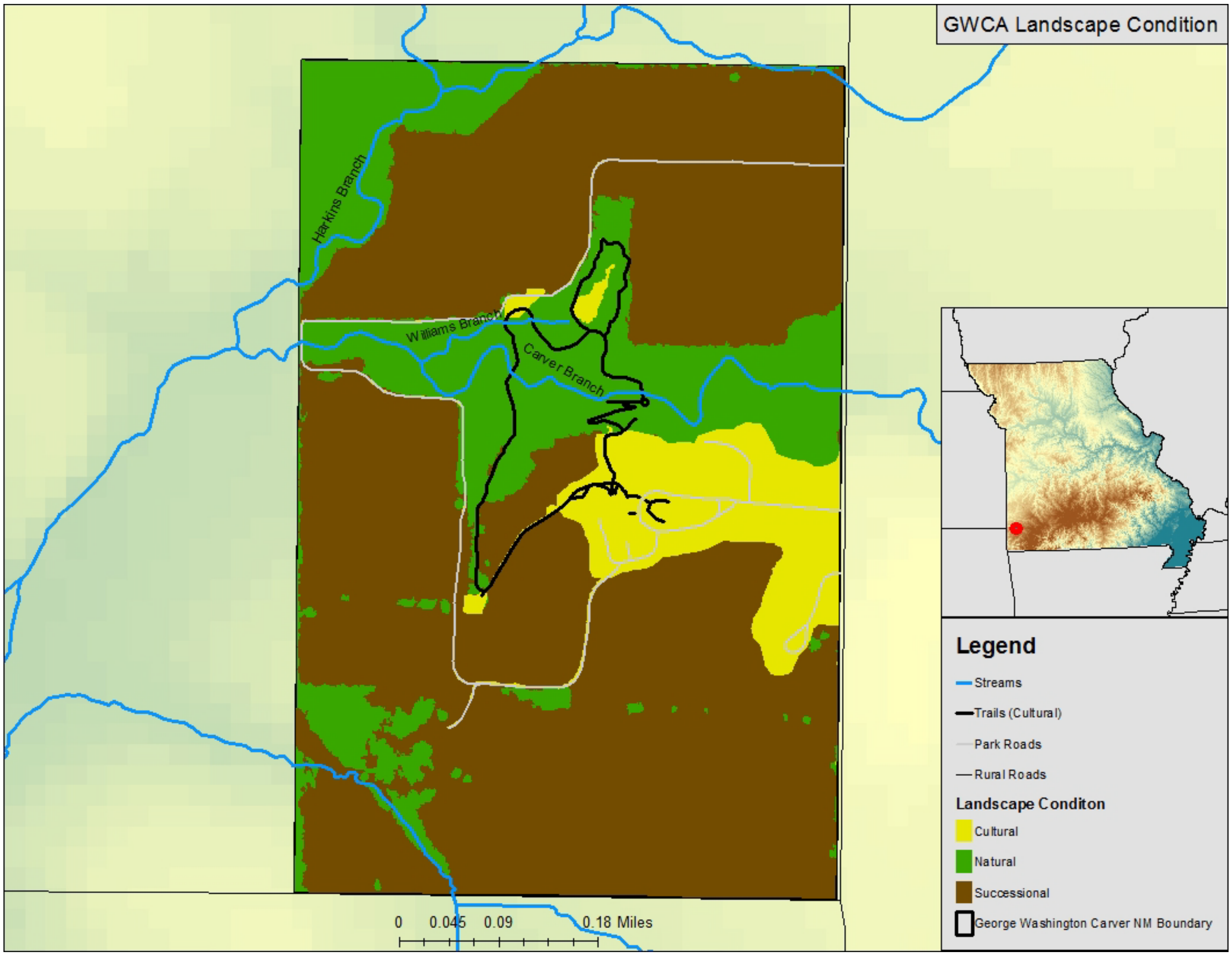

Figure 5-4. George Washington Carver National Monument current landscape condition.

Landscape Composition

There are 105 patches of different land cover types in the park, with an average patch size of 0.90 ha. Grassland patches are the larger on average (3.48 ha) than deciduous forest (0.57 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 5-3. Mean patch size, number of patches, and area for major land cover types at George Washington Carver National Monument.

Land Use/Land Cover Class	Mean Patch Size (ha)	# of Patches	Class Area (ha)	% Class Area
Impervious	0.10	13	1.27	1.32
Low Density Urban	0.17	9	1.50	1.56
Barren or Sparsely Vegetated	0.07	1	0.07	0.07
Grassland	3.48	19	66.13	68.95
Deciduous Forest	0.57	43	24.64	25.69
Decid. Woody/Herbaceous	0.10	19	1.99	2.07
Open Water	0.31	1	0.31	0.32

Land Use/Land Cover

Grasslands occupy 66 ha of the park and were designated as successional, while deciduous woodlands and forests occupied 25 ha and were designated as semi-natural (Table 5-3). All other land cover types occupied no more than two hectares of the park. Successional sparse woodland and shrubland occupies only about 2 ha, but may be important for birds of concern such as the Indigo bunting (see Breeding Birds, below). 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, in this case low quality grasslands.

Breeding Bird Community

Forty-nine species were recorded during the 2008 survey, and the most common bird was the Dickcissel (*Spiza Americana*; Peitz 2009). The Brown-headed cowbird (*Molothrus ater*), Indigo bunting (*Passerina cyanea*), Carolina wren (*Thryothorus ludovicianus*), and Northern cardinal (*Cardinalis cardinalis*) were moderately abundant (Table 5-4).

Table 5-4. Bird species recorded during breeding bird surveys in 2008 at George Washington Carver National Monument (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
American robin	*Turdus migratorius*	AMRO	R
American woodcock	*Scolopax minor*	AMWO	SR
Barn swallow	*Hirundo rustica*	BARS	SR
Belted kingfisher[4]	*Ceryle alcyon*	BEKI	R
Blue jay	*Cyanocitta cristata*	BLJA	R
Blue-gray gnatcatcher	*Polioptila caerulea*	BGGN	SR
Brown thrasher	***Toxostoma rufum***	**BRTH**	**R**
Brown-headed cowbird	*Molothrus ater*	BHCO	R
Carolina chickadee	*Parus carolinensis*	CACH	R
Carolina wren	***Thryothorus ludovicianus***	**CARW**	**R**
Chipping sparrow	*Spizella passerina*	CHSP	SR
Common nighthawk	*Chordeiles minor*	CONI	SR
Common yellowthroat	*Geothlypis trichas*	COYE	SR
Dickcissel	***Spiza americana***	**DICK**	**SR**
Downy woodpecker	*Picoides pubescens*	DOWO	R
Eastern bluebird	*Sialia sialis*	EABL	R
Eastern kingbird	*Tyrannus tyrannus*	EAKI	SR
Eastern meadowlark	*Sturnella magna*	EAME	R
Eastern phoebe	*Sayornis phoebe*	EAPH	R
Eastern wood-pewee	*Contopus virens*	EAWP	SR

Common name[1]	Species name[2]	AOU code	Residency[3]
Field sparrow	*Spizella pusilla*	FISP	R
Grasshopper sparrow	*Ammodramus savannarum*	GRSP	SR
Great blue heron[4]	*Ardea herodias*	GBHE	R
Great crested flycatcher	*Myiarchus crinitus*	GCFL	SR
House sparrow	*Passer domesticus*	HOSP	R
Indigo bunting	***Passerina cyanea***	**INBU**	**SR**
Kentucky warbler	***Oporornis formosus***	**KEWA**	**SR**
Killdeer	*Charadrius vociferous*	KILL	R
Lark sparrow	*Chondestes grammacus*	LASP	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
Pileated woodpecker	*Dryocopus pileatus*	PIWO	R
Purple martin	*Progne subis*	PUMA	SR
Red-bellied woodpecker	***Melanerpes carolinus***	**RBWO**	**R**
Red-eyed vireo	*Vireo olivaceus*	REVI	SR
Red-shouldered hawk	*Buteo lineatus*	RSHA	R
Red-tailed hawk	*Buteo jamaicensis*	RTHA	R
Ruby-throated hummingbird	*Archilochus colubris*	RTHU	SR
Scissor-tailed flycatcher[4]	*Tyrannus forficatus*	STFL	SR
Song sparrow	*Melospiza melodia*	SOSP	WR
Summer tanager	*Piranga rubra*	SUTA	SR
Turkey vulture	*Cathartes aura*	TUVU	R
(Eastern) Tufted titmouse	*Baeolophus bicolor*	ETTI	R
Yellow-billed cuckoo	*Coccyzus americanus*	YBCU	SR
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.

Six species found at GWCA are on Partners in Flight lists of birds of concern (see Peitz 2009; Table 5-4). Three grassland obligate birds, the Dickcissel, Eastern meadowlark (*Sturnella magna*), and grasshopper sparrow (*Ammodramus savannarum*), were recorded at the park. No forest obligate species were recorded, and hence most of the species within the park do well in fragmented habitat. Management targets are based on expert opinion and focus on maintenance of the current level of biodiversity, including overall richness, species of concern, and grassland obligate species. The three most frequent species of concern and their habitats include the Dickcissel (tallgrass prairie or weedy fields), Indigo bunting (brush and low trees of overgrown fields), and Carolina wren (woodland understory). These habitats may deserve special attention in terms of vegetation management on the park. However, management of specific plots may not be practical since an action designed to benefit one species may harm another, and thus management within the context of communities may be most practical. In this regard, maintenance of tallgrass prairie across relatively large areas, some shrubby vegetation in different patches, and understory within woodlands, would benefit grassland obligates and all three species of concern.

Invasive Exotic Plant Impact

Twenty-five invasive or exotic species were identified during surveys conducted in 2006, and they cover a minimum of 8.9% of the total area of the park (Table 5-5, Cribbs et al. 2007). Management targets are based on expert opinion, and focus on reducing, or not allowing further expansion, numbers and cover within the park if possible.

Table 5-5. Invasive exotic plants at George Washington Carver National Monument. Management difficulty codes are 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
Lonicera japonica	Japanese honeysuckle	18.9 - 47.2	27.80%	HM
Bromus racemosus	Bald brome	7.3 - 27.5	33.00%	----
Schedonorus phoenix	Tall fescue	5.0 - 15.0	20.60%	----
Maclura pomifera	Osage orange	3.3 - 12.3	19.60%	L
Poa spp.	Bluegrass species	1.6 - 7.7	7.20%	----
Rosa multiflora	Multiflora rose	1.5 - 5.9	37.10%	L
Rhus glabra	Smooth sumac	1.4 - 3.8	19.60%	----
Bromus inermis	Smooth brome	1.3 -3.8	21.60%	ML
Sorghum halepense	Johnsongrass	1.0 - 4.0	28.90%	HM
Lespedeza cuneata	Sericea lespedeza	0.7 - 2.8	35.10%	ML
Securigera varia	Crownvetch	0.6 - 1.2	1.00%	L
Torilis japonica	Erect hegeparsley	0.6 - 1.2	1.00%	----
Bromus sterilis	Poverty brome	<0.75	9.30%	U
Euonymus fortunei	Winter creeper	< 0.50	13.40%	LI
Ligustrum vulgare	Common privet	< 0.5	14.40%	HM
Dactylis glomerata	Orchardgrass	< 0.25	13.40%	ML
Melilotus officinalis	Sweetclover	< 0.25	5.20%	M
Morus alba	White mulberry	< 0.25	9.30%	ML
Glechoma hederacea	Ground ivy	< 0.1	2.10%	U
Verbascum thapsus	Common mullein	< 0.1	6.20%	L
Celastrus orbiculatus	Oriental bittersweet	< 0.01	2.10%	M
Lonicera maackii	Amur honeysuckle	< 0.01	1.00%	M
Potentilla recta	Sulphur cinquefoil	< 0.01	5.20%	ML
Arctium minus	Lesser burdock	< 0.001	1.00%	MI
Euonymus alatus	Burning bush	< 0.001	1.00%	L

In grasslands, tall fescue (*Schedonorus phoenix*), a cool-season perennial, and bald brome (*Bromus racemosus*), a cool-season annual, both cover at least two hectares, but their distribution is patchy. Smooth sumac (*Rhus glabra*) is a common native invasive shrub in the grasslands. In woodlands, Japanese honeysuckle (*Lonicera japonica*), a perennial vine, forms the dominant ground cover across most of the park, at least 8 hectares, and is difficult to control. Osage orange (*Malcura pomifera*) is a common invasive tree, particularly in the woodlands on the northwest side of the park. Multiflora rose (*Rosa multiflora*) is common in both woodland and grassland habitats on the park.

Air Quality

Ozone Assessment

Results of the ozone assessment presented in (Figure 5-5) show that ozone concentrations have declined slightly in recent years with data for most of the available period of record rated as high risk.

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 2004) indicates that the risk of foliar injury to plants in GWCA is moderate (Figure 5-6). NPS indicates that there are from 8 to 20 ozone sensitive plant species in GWCA (NPS 2001, NPS 2004, and NPS 2006).

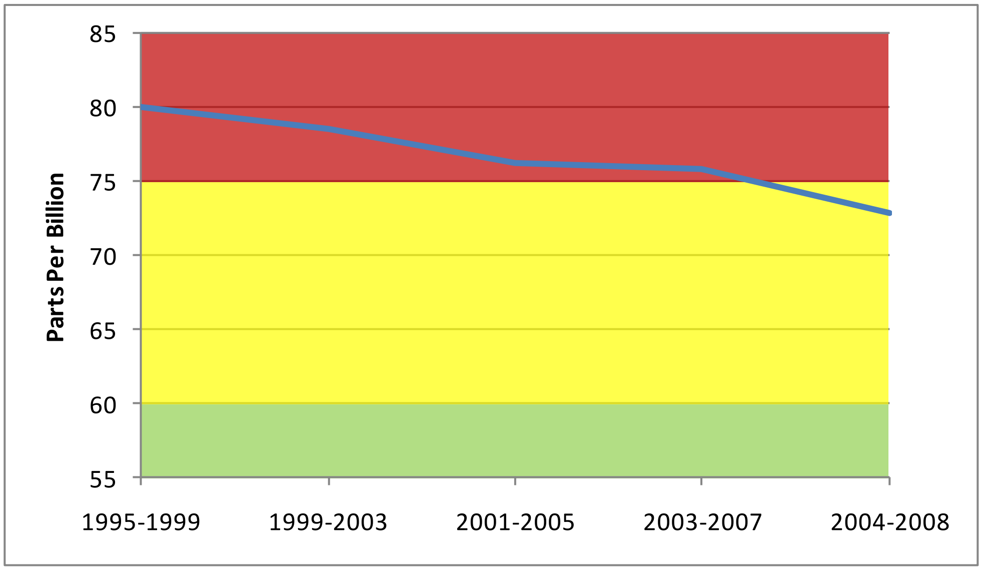

Figure 5-5. Average of fourth Maximum 8-hour Ozone levels based on five-year averages of interpolated deposition estimates (NPS 2010). Greater than or equal to 76 ppb is considered poor, between 61-75 fair, and below 61 good (NPS 2007a).

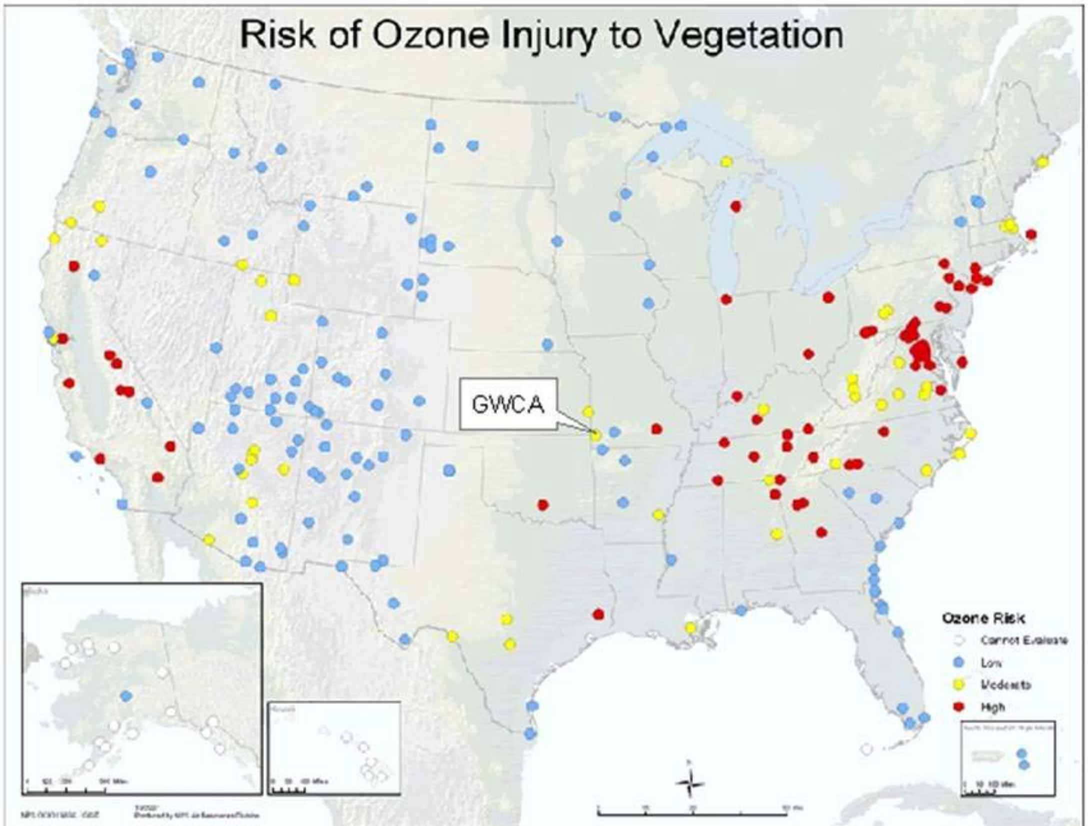

Figure 5-6. Map showing the risk of ozone injury to vegetation by park (NPS 2007d).

Atmospheric Deposition

Average interpolated estimates of wet deposition for nitrogen ranged from 13.02 to 14.89 kg/ha/yr., and estimates of wet deposition of sulfur ranged from 10.6 to 12.7 kg/ha/yr. All estimates far exceeded the threshold of 3 kg/ha/yr(Figure 5-7). Wet deposition from sulfates, nitrates, and ammonium account for a majority of total sulfur and nitrogen deposition (Figure 5-8, Figure 5-9).

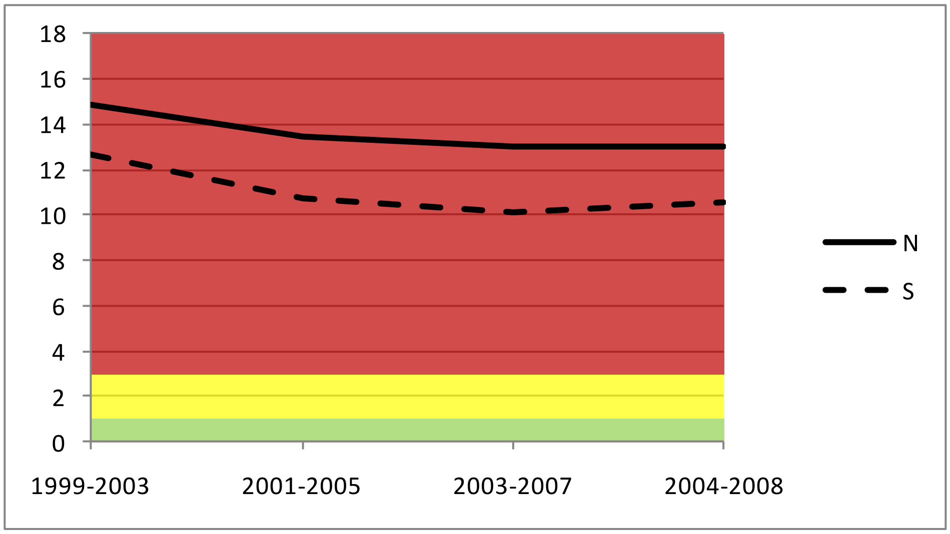

Figure 5-7. Total nitrogen and sulfur from wet deposition of sulfate (S04), nitrate (N03), and ammonium (NH4) based on five-year averages of interpolated deposition estimates (NPS 2010). Greater than 3 ppb is considered poor, between 1 and 3 ppb fair, and below 1 ppb good.

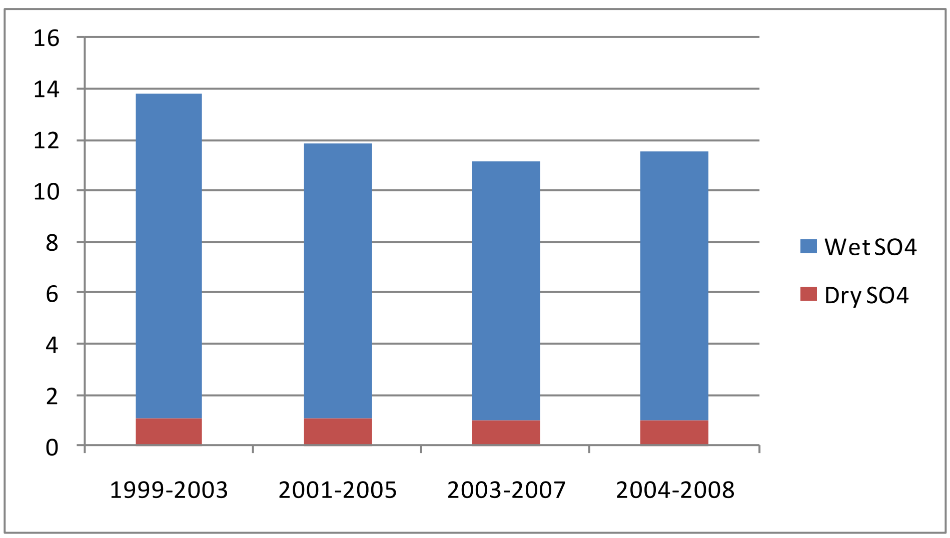

Figure 5-8. Total wet and dry sulfate deposition based on five-year averages of interpolated deposition estimates (NPS 2010).

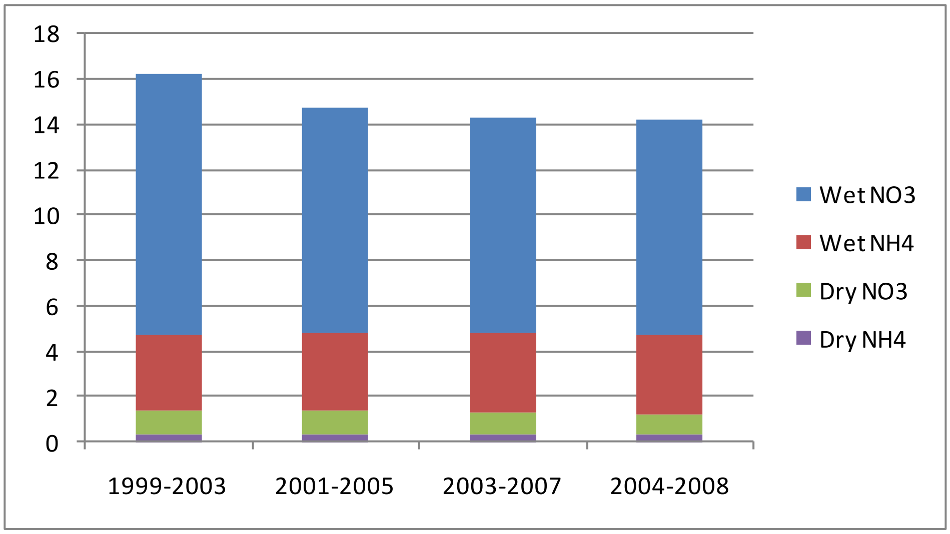

Figure 5-9. Total wet and dry nitrogen deposition based on five-year averages of interpolated deposition estimates (NPS 2010).

Reporting Unit: Persimmon Grove

The persimmon grove reporting unit is conceptual and is a subset of the main woodland reporting unit (Figure 5-4, 5-10). The current vegetation of this reporting unit is not different from the adjacent woodland. In terms of patch count, patch size, and overall cover, management goals do not differ from current conditions. For interpretive purposes, management goals in the future might include re-establishment of persimmons, which are rare or may be absent in the current forest, along with other native fruit and nut trees that may have inspired George Washington Carver's interest in natural history and agronomy.

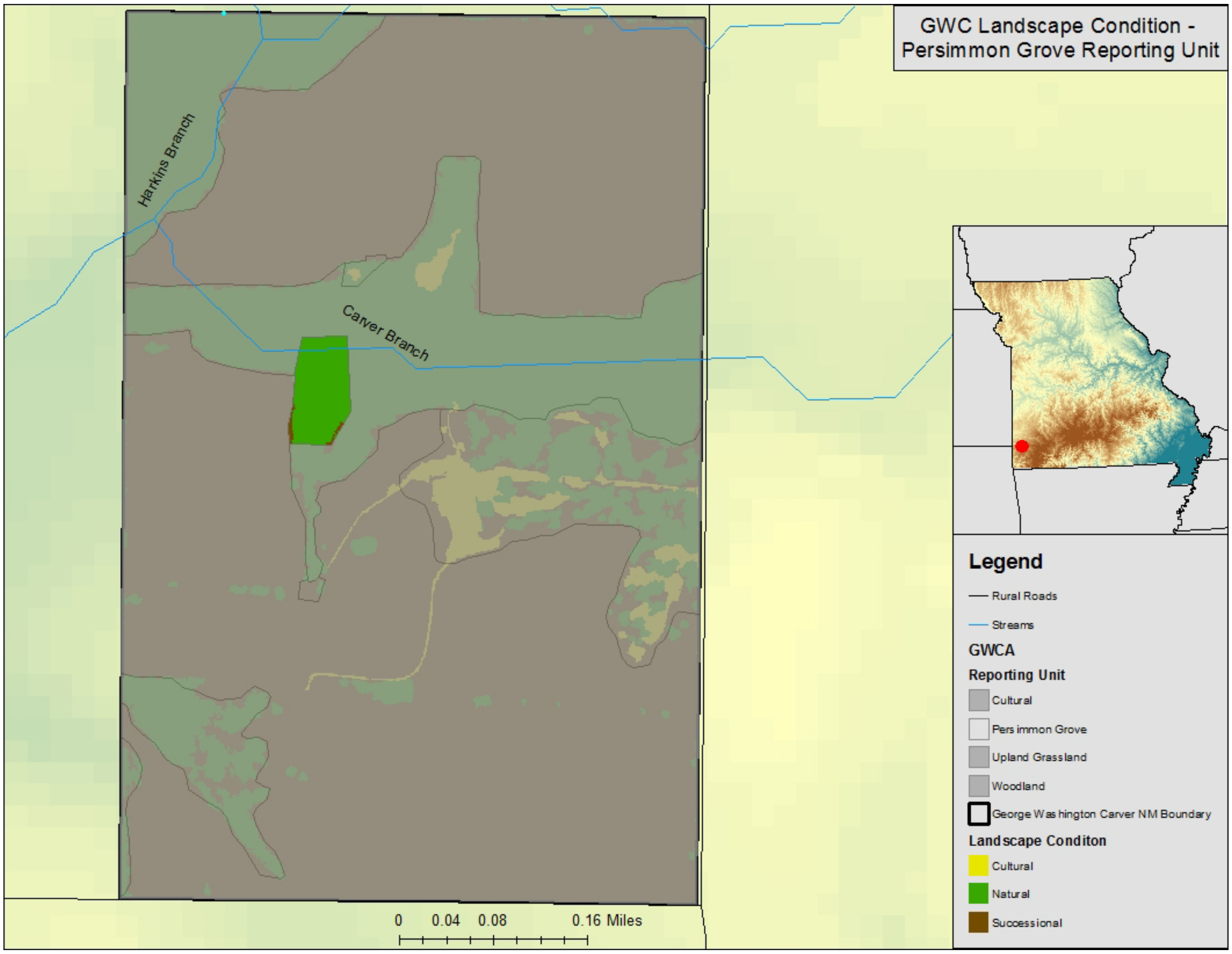

Figure 5-10. Current landscape composition for the persimmon grove reporting unit.

Reporting Unit: Upland Grassland

Grasslands at GWCA are in various states of restoration, but the spatial extent and type of past restoration efforts have not been well-documented. Some areas are dominated by tall grasses such as Indiangrass (*Sorghastrum nutans*) and big bluestem (*Andropogon gerardii*), whereas others are dominated by tall fescue (*Schedonorus phoenix*), but again the differences among patches are not well mapped. Overall, we designated all grasslands as successional (Figure 5-11), although some areas are in much more natural condition than others, and they do contain a reasonable compliment of native grasses and forbs (Table 5-1; Jones 2004).

Management goals are from the professional judgment that the region was once tallgrass prairie, and therefore the desire for improvement in grassland condition to a "semi-natural" rather than "successional" state. For areas that are in poor condition, this process will require continuous effort over decades. Fescue grassland patches that are currently within and adjacent to sparse woodlands and shrublands on the southwest side of the park might reasonably be left to succeed to shrubby vegetation that favors some target breeding birds of concern (see Breeding Birds, above).

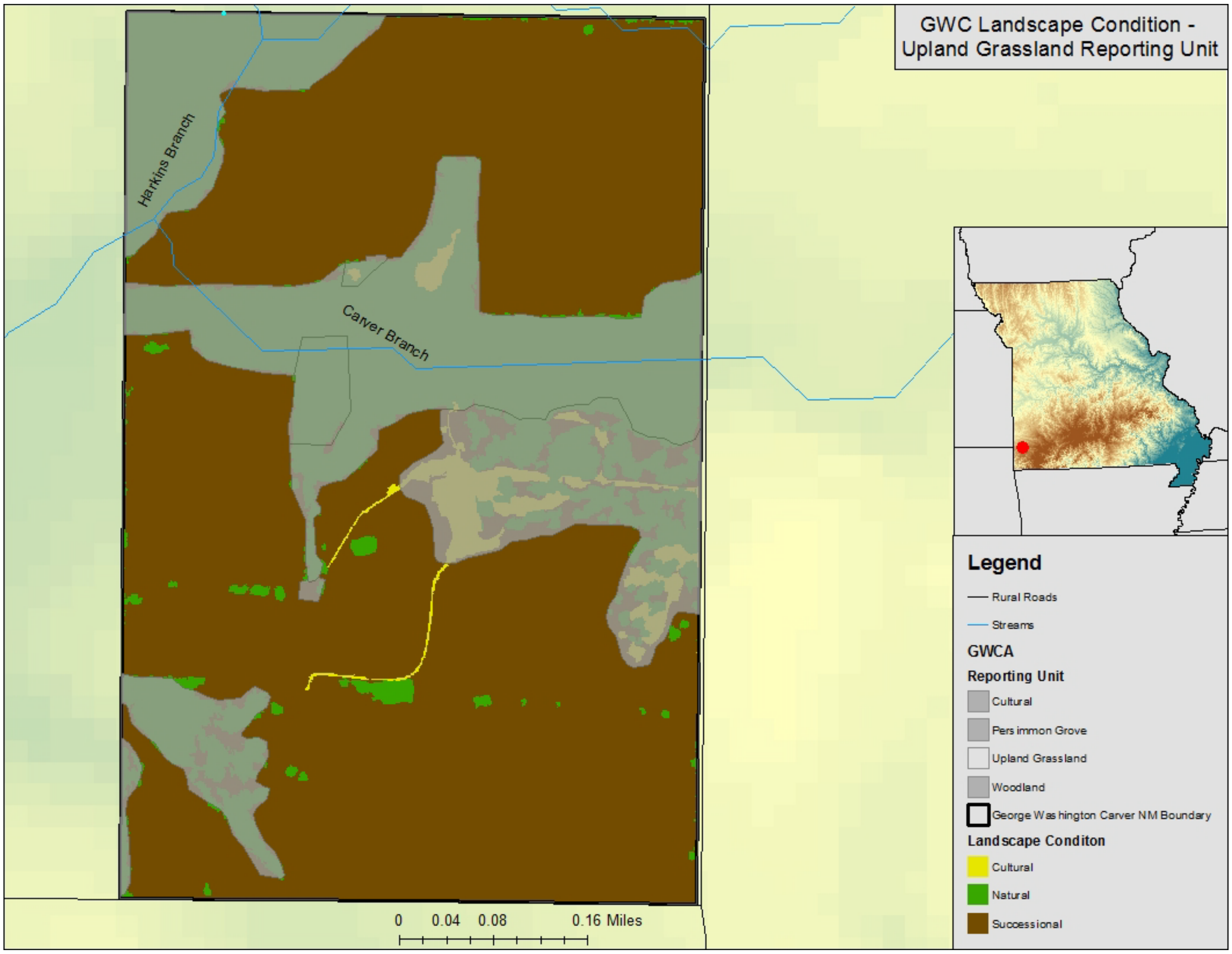

Figure 5-11. Current landscape composition for the upland grassland reporting unit.

Reporting Unit: Woodland

Woodlands at GWCA are generally young, semi-natural types and are mainly associated with upland drainages (Figure 5-12). Hackberry (*Celtic occidentalis*) and American elm (*Ulmus americana*), both generally early successional species, are dominant throughout the park (NPS Unpublished, Undated). Some sites do contain later successional species such as black walnut (*Juglans nigra*) and overcup oak (*Quercus macrocarpa*). Recruitment of the early successional hackberry (*Celtis occidentalis*) is less than the management target of 50% of overall sapling density (see Table 5-1). Overall structure (e.g. height, canopy cover) is generally within the range expected for these types of woodlands. Sapling density is generally low, which is expected in young woodland.

Overall, woodland patch size is smaller and number of patches larger than management targets, which were arrived at subjectively based on professional judgment. Management targets for other structural characteristics such as height, basal area, hardwood canopy cover, and density are based on professional judgment informed by data from similar communities described mainly by Nelson (2005) and Missouri forest and woodland natural community profiles posted at http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed 10/15/2010. Target numbers for regeneration were from Jenkins et al. (1997) and from Rice and Penfound (1955). Woodlands might be expected to continue to improve in overall composition over time, although the pervasive presence of Japanese honeysuckle (*Lonicera japonica*) in the ground cover layer may tend to limit recruitment of desirable trees into light gaps when they appear.

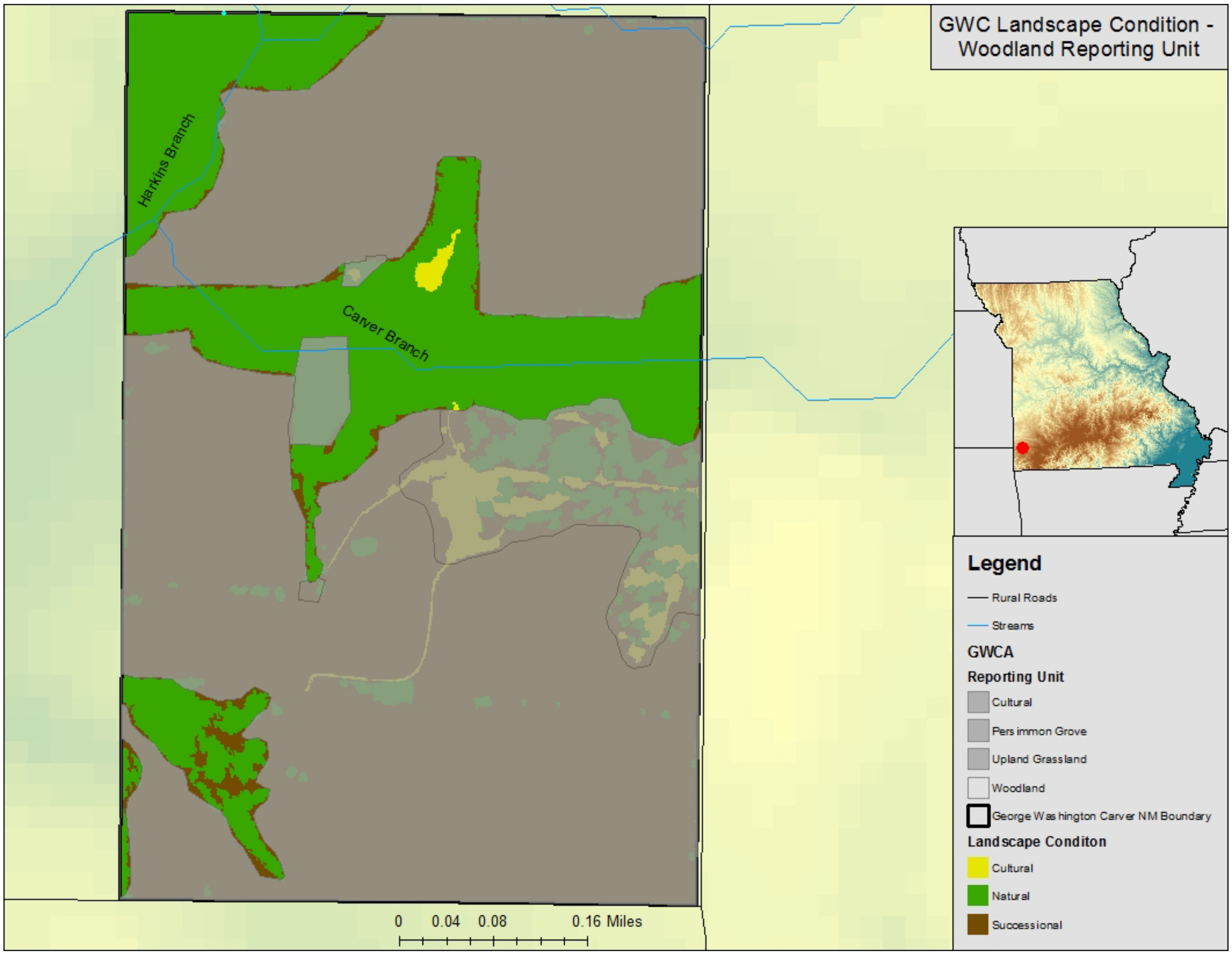

Figure 5-12. Current landscape composition for the woodland reporting unit.

Reporting Unit: Carver Branch

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). Carver Branch drains much of the city of Diamond, Missouri which had a population of 808 people in 2000. Based on year 2000 census data there are approximately 683 people residing in the Carver Branch watershed (44 people per km^2). Seventy-eight percent of the watershed above the park is classified as pasture/hay, while only 1.6% and 1.1% of the area is classified as impervious surface and cropland respectively (Figure 2-1, Table 5-6). There is one known leaking underground tank and one waste water treatment facility in the watershed. Although certainly not representative of all threats to aquatic systems, Table 2-1 includes the set of potential threats to aquatic ecological integrity quantified for Carver Branch.

Table 5-6. Quantified threats for Carver Branch in George Washington Carver National Monument. Values are from the last stream segment downstream of the park.

Human Threat	# or amount	% or Density
Impervious Surfaces	251100 m^2	1.62%
Cropland	171000 m^2	1.11%
Pasture/Hay	12052800 m^2	77.93%
Road/Stream Crossings	15	0.97 pkm^2
Roads	26743 m	1729 pkm^2
Water Wells	22	1.42 pkm^2
Leaking Underground Storage Tanks	1	0.06 pkm^2
Pipelines	5400 m	349 pkm^2
Waste Water Treatment Facilities	1	0.06 pkm^2
Crop Pesticides	38.36 kg	2.48 pkm^2
Headwater Impoundments	7	0.45 pkm^2
NPDES	1	0.06 pkm^2
2000 Population	683	44.19 pkm^2

Water Quality

Based on the Core 5 water quality measurements assessed for this report, only pH from 2007 is rated as being off target (Table 5-7). Temperature, specific conductance, dissolved oxygen, and turbidity are all rated as on target over their respective periods of record. Generally, the parameters measured are fairly typical for regional streams and do not suggest impairment (Bowles 2009 cites Brown and Czarnezki undated). Dodd et al. (2011) suggests that the higher turbidity in 2007 occurred during the nighttime hours and may be due to terrestrial animal activity in the stream or along the bank. Any additional growth or development in the city of Diamond, Missouri could potentially impact water quality in Carver Branch.

Table 5-7. Water quality indicators for Carver Branch.

Indicator	Management Target	Mean[1]	Rating
Temperature (°C)			
2006	0-34 °C	18.2	On Target
2007	0-34 °C	16.0	On Target
2010	0-34 °C	15.3	On Target
Mean	0-34 °C	16.5	On Target
Specific Conductance (µS/cm @ 25°C)			
2006	100-400 µS/cm	331.5	On Target
2007	100-400 µS/cm	215.3	On Target
2010	100-400 µS/cm	282.1	On Target
Mean	100-400 µS/cm	276.3	On Target
Dissolved Oxygen (mg/L)			
2006	5-15 mg/liter	7.6	On Target
2007	5-15 mg/liter	7.6	On Target
2010	5-15 mg/liter	7.9	On Target
Mean	5-15 mg/liter	7.7	On Target
pH			
2006	6.5-9.0	7.2	On Target
2007	6.5-9.0	9.8	Off Target
2010	6.5-9.0	7.4	On Target
Mean	6.5-9.0	8.1	On Target
Turbidity (NTU)			
2006	<10 NTU	1.1	On Target
2007	<10 NTU	9.3	On Target
2010	<10 NTU	2.2	On Target
Mean	<10 NTU	4.2	On Target

[1] Mean from Dodd et al. (2011).

Fish Community Composition and Condition

Justus and Petersen (2005a) report that the fish collected from sites in George Washington Carver National Monument are typical of small headwater streams. Collections made during 2010 record 12 species from Carver Branch, while pooling data collected in 2003, 2006, 2007, and 2010 document 17 species occurring in the creek within GWCA. Two species of potential interest in Carver Branch are the cardinal shiner (*Luxilus cardinalis*) and the stippled darter (*Etheostoma punctulatim*) because they are endemic to the Ozark Plateau; however they are fairly common in certain parts of the Ozark Plateau (Justus and Peterson 2005a). In addition, the Arkansas darter is a species that is at risk of extirpation throughout its range (Dodd et al. 2011).

Reviewing Table 5-8 reveals that, based on data collected in 2010 the IBI of 55 is off target despite being on target during 2006 and 2007. Benthic species composition is the only indicator rated as being on target for 2010. Sunfish composition could not be computed for analyses.

Although the bluntnose minnow has not been collected in Carver Branch, predictive models indicate that this species could be expected to occur under relatively undisturbed conditions. The Jaccard Similarity between the observed and predicted fish communities is 72% indicating that species present may be very similar to the potential community (Table 5-9, Table 5-10).

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 Carver Branch are designated as critically imperiled (G1) or imperiled (G2) on a global scale (Table 5-11). In addition, there are no S1 or S2 fish species known to occur in Carver Branch in the park. A single species, the Arkansas darter (*Etheostoma cragini*) is listed as G3 and S3.

Table 5-8. Ratings for five fish metrics computed for Carver Branch.

Indicator	Management Target	Reference Condition	Current Condition[1]	Rating
Simpson's Diversity				
2006	≤0.49	0 38	0.41	Off Target
2007	≤0.49	0 38	0.56	Off Target
2010	≤0.49	0 38	0.97	Off Target
Mean	≤0.49	0 38	0.65	Off Target
Sucker Composition (%)				
2006	>0.52	0.63	0.45	Off Target
2007	>0.52	0.63	0.60	On Target
2010	>0.52	0.63	0.50	Off Target
Mean	>0.52	0.63	0.52	Off Target
Sunfish Composition (%)				
2006	N/A	N/A	0.00	N/A
2007	N/A	N/A	0.00	N/A
2010	N/A	N/A	0.00	N/A
Mean	N/A	N/A	0.00	N/A
Benthic spp. Composition (%)				
2006	>13.4	13.74	13.65	On Target
2007	>13.4	13.74	13.20	Off Target
2010	>13.4	13.74	19.80	On Target
Mean	>13.4	13.74	15.55	On Target
Index of Biotic Integrity (IBI)				
2006	>60	80	63	On Target
2007	>60	80	68	On Target
2010	>60	80	55	Off Target
Mean	>60	80	62	On Target

[1] Current condition from Dodd et al. (2011).

Table 5-9. Fish species observed[1] and predicted[2] to occur in Carver Branch.

Collected Not Predicted	Predicted Not Collected	Shared
Banded Sculpin	Bluntnose Minnow	Arkansas Darter
Duskystripe Shiner		Bluegill
Rainbow Darter		Cardinal Shiner
Slender Madtom		Central Stoneroller[3]
		Creek Chub
		Fantail Darter
		Green Sunfish
		Largemouth Bass
		Orangethroat Darter
		Southern Redbelly Dace
		Stippled Darter
		Western Mosquitofish
		White Sucker

[1] Observed species from Justus and Peterson (2005a) and Dodd et al. (2011).

[2] Predicted species based on Aquatic GAP species distribution models.

[3] Data recorded as Stoneroller sp. was assumed to be Central Stoneroller.

Table 5-10. Jaccard Similarity computed for Carver Branch.

Carver Branch	Number
Total Species Collected	17
Total Species Modeled	14
Collected not Predicted	4
Predicted not Collected	1
Collected and Predicted (Shared)	13
Introduced Species	0
Jaccard Similarity	72%

Table 5-11. Number of globally listed fish species (G-rank) and state listed fish species (S-rank) by actual collections and models in Carver Branch.

	Carver Branch	
Rank	Collection	Model
G3	1	1
G4	2	2
G5	14	11
S3	1	1
S?	16	13

Aquatic Invertebrates

The seven aquatic invertebrate community indicators assessed for this report indicate that aquatic invertebrate communities are in generally good condition. Family richness ranged between 14.2 and 16 over the four years of data assessed for this report, all of which are at or above the management target value (Table 5-12). Genus richness values have generally increased over the last three years. EPT richness has remained constant at 6.9 for 2006 and 2007, though is somewhat lower than previous years. The EPT ratio, Shannon Index, Shannon Evenness Index have all increased over the latest three years of available data indicating stable to improving conditions, although the EPT ratio is off target for the available period of record (POR). The Hilsenhoff Biotic Index values have been variable over the available POR. It should be noted, however, that Bowles (2009) caution against using these data for trend assessments.

Table 5-12. Aquatic invertebrate indicators for Carver Branch.

Indicator	Management Target	Reference Condition	Mean[1]	Rating
Family Richness				
1996	≥14 2	14.2	14.6	On Target
2005	≥14 2	14.2	14.2	On Target
2006	≥14 2	14.2	15.3	On Target
2007	≥14 2	14.2	16.0	On Target
Mean	≥14 2	14.2	15.0	On Target
Genus Richness				
1989	>15	26.2	33.0	On Target
2005	>15	26.2	15.9	On Target
2006	>15	26.2	17.0	On Target
2007	>15	26.2	17.6	On Target
Mean	>15	26.2	20.9	On Target
EPT Richness				
1989	>4	7.8	11.0	On Target
2005	>4	7.8	7.4	On Target
2006	>4	7.8	6.9	On Target
2007	>4	7.8	6.9	On Target
Mean	>4	7.8	8.1	On Target
EPT Ratio				
1996	≥0.85	N/A	0.48	Off Target
2005	≥0.85	N/A	0.38	Off Target
2006	≥0.85	N/A	0.48	Off Target
2007	≥0.85	N/A	0.68	Off Target
Mean	≥0.85	N/A	0.51	Off Target
Shannon Index				
1989	>1.77	2.39	2.14	On Target
1996	>1.77	2.39	1.84	On Target
2005	>1.77	2.39	1.74	Off Target
2006	>1.77	2.39	2.11	On Target
2007	>1.77	2.39	2.26	On Target
Mean	>1.77	2.39	2.02	On Target
Shannon Evenness Index				
2005	≥0.75	N/A	0.64	Off Target
2006	≥0.75	N/A	0.74	Off Target
2007	≥0.75	N/A	0.79	On Target
Mean	≥0.75	N/A	0.72	Off Target
Hilsenhoff Biotic Index				
1996	<6.6	<4.3	4.75	On Target
2005	<6.6	<4.3	5.23	On Target
2006	<6.6	<4.3	4.23	On Target
2007	<6.6	<4.3	4.62	On Target
Mean	<6.6	<4.3	4.71	On Target

[1] Mean from Harris et al. (1991) and Bowles (2009).

Reporting Unit: Williams Branch

<u>Aquatic Threats</u>

Because of the mapping scale, threats in Williams Branch were not directly assessed. However, because Williams Branch is entirely within the boundary of GWCA threats to this stream are likely minimal.

Water Quality

Based on the Core 5 water quality measurements analyzed for this report only pH for a single year (2007) is rated as being off target. This is likely due to the fact that Williams Branch is entirely within the boundary of GWCA, and is therefore relatively undisturbed (Table 5-13).

Table 5-13. Water quality indicators for Williams Branch.

Indicator	Management Target	Mean[1]	Rating
Temperature (C)			
2006	0-34 °C	21.2	On Target
2007	0-34 °C	14.7	On Target
2010	0-34 °C	17.1	On Target
Mean	0-34 °C	17.7	On Target
Specific Conductance (µS/cm @ 25 C)			
2006	100-400 µS/cm	256.6	On Target
2007	100-400 µS/cm	178.8	On Target
2010	100-400 µS/cm	228.0	On Target
Mean	100-400 µS/cm	221.1	On Target
Dissolved Oxygen (mg/L)			
2006	5-15 mg/liter	8.6	On Target
2007	5-15 mg/liter	7.9	On Target
2010	5-15 mg/liter	10.8	On Target
Mean	5-15 mg/liter	9.1	On Target
pH			
2006	6.5-9.0	7.9	On Target
2007	6.5-9.0	9.4	Off Target
2010	6.5-9.0	7.8	On Target
Mean	6.5-9.0	8.4	On Target
Turbidity (NTU)			
2006	<10 NTU	4.3	On Target
2007	<10 NTU	5.0	On Target
2010	<10 NTU	3.0	On Target
Mean	<10 NTU	4.1	On Target

[1] Mean from Dodd et al. (2011).

Fish Community Composition and Condition

Because of the mapping scale, predicted fish communities were not available for Williams Branch.

Collections made during 2010 record nine species from Williams Branch. Pooled collections from 2003, 2006, 2007, and 2010 document a total of fourteen species as present in Williams Branch within GWCA (see Table 5-14 for species list).

Reviewing Table 5-15 reveals that the observed IBI of 81 is very good and above the commonly accepted reference condition value of 80. Both Simpson's Diversity and benthic species composition are rated as being on target for 2010. Sucker and sunfish composition had no data and therefore could not be given a rating. A species of interest is the stippled darter (*Etheostoma punctulatim*) because it is endemic to the Ozark Plateau; however they are fairly common in certain parts of the Ozark Plateau (Justus and Peterson 2005a). Another species of interest may be the Arkansas darter which is at risk of extirpation throughout its range (Dodd et al. 2011). No introduced species were reported from Williams Branch in 2007.

No fish species collected from Williams Branch are designated as critically imperiled (G1) or imperiled (G2) on a global scale or state scale (Table 5-16). The Arkansas darter (*Etheostoma cragini*) is listed as G3 and S3.

Table 5-14. Fish species observed[1] in Williams Branch.

Collected Species
Arkansas Darter
Banded Sculpin
Central Stoneroller
Creek Chub
Fantail Darter
Green Sunfish
Largemouth Bass
Orangethroat Darter
Rainbow Darter
Slender Madtom
Southern Redbelly Dace
Stippled Darter
Western Mosquitofish
White Sucker

[1] Observed species from Justus and Peterson (2005a) and Dodd et al. (2011).

Table 5-15. Ratings for five fish metrics computed for Williams Branch.

Indicator	Management Target	Mean[1]	Rating
Temperature (C)			
2006	0-34 °C	21.2	On Target
2007	0-34 °C	14.7	On Target
2010	0-34 °C	17.1	On Target
Mean	0-34 °C	17.7	On Target
Specific Conductance (µS/cm @ 25 C)			
2006	100-400 µS/cm	256.6	On Target
2007	100-400 µS/cm	178.8	On Target
2010	100-400 µS/cm	228.0	On Target
Mean	100-400 µS/cm	221.1	On Target
Dissolved Oxygen (mg/L)			
2006	5-15 mg/liter	8.6	On Target
2007	5-15 mg/liter	7.9	On Target
2010	5-15 mg/liter	10.8	On Target
Mean	5-15 mg/liter	9.1	On Target
pH			
2006	6.5-9.0	7.9	On Target
2007	6.5-9.0	9.4	Off Target
2010	6.5-9.0	7.8	On Target
Mean	6.5-9.0	8.4	On Target
Turbidity (NTU)			
2006	<10 NTU	4.3	On Target
2007	<10 NTU	5.0	On Target
2010	<10 NTU	3.0	On Target
Mean	<10 NTU	4.1	On Target

[1] Mean from Dodd et al. (2011).

Table 5-16. Number of globally listed fish species (G-rank) and state listed fish species (S-rank) by actual collections in Williams Branch.

Rank	Williams Branch Collection
G3	1
G4	1
G5	12
S3	1
S?	13

Aquatic Invertebrates

The Williams Branch aquatic invertebrate community is in generally good condition. Family richness in Williams Branch is on target for 2006, but off for both 2005 and 2007. Genus richness is on target for the last two years for which data is available. EPT richness increased progressively from 2005 – 2007 as did the EPT ratio, though the EPA Ratio is off target for the entire POR. Both the Shannon Index and the Shannon Evenness Index remained fairly high and constant from 2005 – 2007 indicating stable conditions and minimal disturbance. The mean Hilsenhoff Biotic Index scores were below 5.0 for both 2006 and 2007 which indicates that the taxa represented were only moderately tolerant of pollution (Table 5-17).

Table 5-17. Aquatic invertebrate indicators for Williams Branch.

Indicator	Management Target	Reference Condition	Mean[1]	Rating
Family Richness				
2005	≥14 2	14.2	11.8	Off Target
2006	≥14 2	14.2	15.3	On Target
2007	≥14 2	14.2	14.0	Off Target
Mean	≥14 2	14.2	13.7	Off Target
Genus Richness				
1989	>15	26.2	37.0	On Target
2005	>15	26.2	13.9	Off Target
2006	>15	26.2	17.0	On Target
2007	>15	26.2	15.4	On Target
Mean	>15	26.2	20.8	On Target
EPT Richness				
1989	>4	7.8	15.0	On Target
2005	>4	7.8	5.3	On Target
2006	>4	7.8	5.9	On Target
2007	>4	7.8	6.0	On Target
Mean	>4	7.8	8.1	On Target
EPT Ratio				
2005	≥0.85	N/A	0.48	Off Target
2006	≥0.85	N/A	0.52	Off Target
2007	≥0.85	N/A	0.68	Off Target
Mean	≥0.85	N/A	0.56	Off Target
Shannon Index				
1989	>1.77	2.39	2.29	On Target
2005	>1.77	2.39	1.80	On Target
2006	>1.77	2.39	2.04	On Target
2007	>1.77	2.39	2.03	On Target
Mean	>1.77	2.39	2.04	On Target
Shannon Evenness Index				
2005	≥0.75	N/A	0.74	Off Target
2006	≥0.75	N/A	0.72	Off Target
2007	≥0.75	N/A	0.79	On Target
Mean	≥0.75	N/A	0.75	Off Target
Hilsenhoff Biotic Index				
2005	<6.6	<4.3	5.54	On Target
2006	<6.6	<4.3	4.30	On Target
2007	<6.6	<4.3	4.44	On Target
Mean	<6.6	<4.3	4.76	On Target

[1] Mean from Bowles (2009).

Reporting Unit: Harkins Branch

Aquatic Threats

Unlike Carver Branch, Harkins Branch does is not influenced by urban areas and, as such, has a low population density and relatively limited threats. The dominant land use in the watershed is pasture/hay which comprises approximately 90% of the area (Table 5-18).

Table 5-18. Quantified threats for Harkins Branch in George Washington Carver National Monument. Values are from the last stream segment before entering Carver Branch.

Human Threat	# or amount	% or Density
Cropland	54900 m^2	0.81%
Pasture/Hay	6081300 m^2	89.93%
Road/Stream Crossings	4	0.59 pkm^2
Roads	7626 m	1128 pkm^2
Water Wells	7	1.04 pkm^2
Pipelines	5400 m	799 pkm^2
Crop Pesticides	13 kg	1.92 pkm^2
Headwater Impoundments	1	0.15 pkm^2
2000 Population	38	5.64 pkm^2

Water Quality

The Core 5 water quality indicators for Harkins Branch all fall within the management target for the three years for which data was available, thus water quality can be interpreted as being generally good (Table 5-19).

Table 5-19. Water quality indicators for Harkins Branch.

Indicator	Management Target	Mean[1]	Rating
Temperature (C)			
2006	0-34 °C	20.3	On Target
2007	0-34 °C	16.1	On Target
2010	0-34 °C	17.3	On Target
Mean	0-34 °C	17.9	On Target
Specific Conductance (µS/cm @ 25 C)			
2006	100-400 µS/cm	296.4	On Target
2007	100-400 µS/cm	164.0	On Target
2010	100-400 µS/cm	214.5	On Target
Mean	100-400 µS/cm	225.0	On Target
Dissolved Oxygen (mg/L)			
2006	5-15 mg/liter	5.9	On Target
2007	5-15 mg/liter	9.8	On Target
2010	5-15 mg/liter	7.3	On Target
Mean	5-15 mg/liter	7.7	On Target
pH			
2006	6.5-9.0	7.2	On Target
2007	6.5-9.0	6.6	On Target
2010	6.5-9.0	7.1	On Target
Mean	6.5-9.0	7.0	On Target
Turbidity (NTU)			
2006	<10 NTU	0.7	On Target
2007	<10 NTU	5.2	On Target
2010	<10 NTU	3.6	On Target
Mean	<10 NTU	3.2	On Target

[1] Mean from Dodd et al. (2011).

Fish Community

Collections during 2010 document 14 fish species in Harkins Branch within GWCA, while pooled collections from 2003, 2006, 2007, and 2010 record 18 species as being present. Predictive models place thirteen fish species in Harkins Branch within GWCA adding three fish that have not been documented in recent collections. The Jaccard Similarity between the observed and collected fish species is only 48%, however collections record eight additional fish that the models do not place in the stream (Table 5-20, Table 5-21). This further supports evidence in Dodd et al. (2011) that the fish communities within Harkins Branch are generally diverse and healthy.

Table 5-20. Fish species observed[1] and predicted[2] to occur in Harkins Branch.

Collected Not Predicted[3]	Predicted Not Collected	Shared
Banded Sculpin	Bluntnose Minnow	Arkansas Darter
Black Bullhead	Largemouth Bass	Bluegill
Duskystripe Shiner	Orangespotted Sunfish	Cardinal Shiner
Rainbow Darter		Central Stoneroller[4]
Slender Madtom		Creek Chub
Southern Redbelly Dace		Fantail Darter
Stippled Darter		Green Sunfish
Stonecat		Orangethroat Darter
		Western Mosquitofish
		White Sucker

[1] Observed species from Justus and Peterson (2005a) and Dodd et al. (2011).

[2] Predicted species based on Aquatic GAP species distribution models.

[3] Species class Non-carp minnow species were removed from HTLN collection because they were not comparable.

[4] Data recorded as Stoneroller sp. was assumed to be Central Stoneroller.

Table 5-21. Jaccard Similarity computed for Harkins Branch.

Harkins Branch	Number
Total Species Collected[1]	18
Total Species Modeled	13
Collected not Predicted	8
Predicted not Collected	3
Collected and Predicted (Shared)	10
Introduced Species	0
Jaccard Similarity	48%

[1] Species class Non-carp minnow species were removed from HTLN collection because they were not comparable.

Reviewing Table 5-22 reveals that Simpson's Diversity and benthic species composition are both rated as being on target in 2007 and 2010. It is interesting to note, however, that the IBI has declined over the three years for which data was available and in 2010 received a rating of off target. Sucker and sunfish composition had no data and therefore could not be given a rating. No introduced species have been collected from Harkin's Branch in GWCA.

As with Carver Branch, the cardinal shiner (*Luxilus cardinalis*) and the stippled darter (*Etheostoma punctulatim*) may be of special interest because they are endemic to the Ozark Plateau; (Justus and Peterson 2005a). In addition, the Arkansas darter which is a species that is at risk of extirpation throughout its range is present in Harkins Branch (Dodd et al. 2011). No fish species collected from Harkin's Branch are designated as critically imperiled (G1) or imperiled (G2) on a global scale nor are there any S1 or S2 fish species known to occur in Harkin's Branch within the park (Table 5-23).

Table 5-22. Ratings for five fish metrics computed for Harkins Branch within GWCA.

Indicator	Management Target	Reference Condition	Current Condition	Rating
Simpson's Diversity				
2006	<0.27	0 13	0.38	Off Target
2007	<0.27	0 13	0.17	On Target
2010	<0.27	0 13	0.15	On Target
Mean	<0.27	0 13	0.23	On Target
Sucker Composition (%)				
2006	N/A	N/A	0.00	N/A
2007	N/A	N/A	0.00	N/A
2010	N/A	N/A	0.00	N/A
Mean	N/A	N/A	0.00	N/A
Sunfish Composition (%)				
2006	N/A	N/A	0.00	N/A
2007	N/A	N/A	0.00	N/A
2010	N/A	N/A	0.00	N/A
Mean	N/A	N/A	0.00	N/A
Benthic spp. Composition (%)				
2006	>18.3	29.34	10.55	Off Target
2007	>18.3	29.34	26.10	On Target
2010	>18.3	29.34	33.10	On Target
Mean	>18.3	29.34	23.25	On Target
Index of Biotic Integrity (IBI)				
2006	>60	80	73	On Target
2007	>60	80	67	On Target
2010	>60	80	52	Off Target
Mean	>60	80	64	On Target

[1] Current condition from Dodd et al. (2011).

Table 5-23. Number of globally listed fish species (G-rank) and state listed fish species (S-rank) by actual collections and models in Harkins Branch.

	Harkins Branch	
Rank	Collection	Model
G3	1	1
G4	2	1
G5	15	11
S3	1	1
S?	17	12

<u>Aquatic Invertebrates</u>

Family richness increases progressively from 2005 thorough 2007 and received a rating of on target for 2007, likewise genus richness was on target for the last two years of the POR (Table 5-24). EPT richness, Shannon Index, and the Hilsenhoff Biotic Index were rated as being on target for all years in which data was available. The relatively high Shannon Evenness Index scores suggest minimal disturbance while the relatively low Hilsenhoff Biotic Index scores indicate that the taxa represented in the samples are only moderately tollerant of pollution (Bowles 2009).

Table 5-24. Aquatic invertebrate indicators for Harkins Branch.

Indicator	Management Target	Reference Condition	Mean[1]	Rating
Family Richness				
1996	≥14 2	14.2	17.8	On Target
2005	≥14 2	14.2	10.6	Off Target
2006	≥14 2	14.2	14.0	Off Target
2007	≥14 2	14.2	15.1	On Target
Mean	≥14 2	14.2	14.4	On Target
Genus Richness				
2005	>15	26.2	12.1	Off Target
2006	>15	26.2	15.1	On Target
2007	>15	26.2	16.1	On Target
Mean	>15	26.2	14.4	Off Target
EPT Richness				
2005	>4	7.8	6.4	On Target
2006	>4	7.8	7.3	On Target
2007	>4	7.8	7.6	On Target
Mean	>4	7.8	7.1	On Target
EPT Ratio				
1996	≥0 99	N/A	0.51	Off Target
2005	≥0 99	N/A	0.51	Off Target
2006	≥0 99	N/A	0.65	Off Target
2007	≥0 99	N/A	0.79	Off Target
Mean	≥0 99	N/A	0.62	Off Target
Shannon Index				
1996	>1.77	2.39	2.03	On Target
2005	>1.77	2.39	1.88	On Target
2006	>1.77	2.39	1.99	On Target
2007	>1.77	2.39	2.27	On Target
Mean	>1.77	2.39	2.04	On Target
Shannon Evenness Index				
2005	≥0.75	N/A	0.74	Off Target
2006	≥0.75	N/A	0.74	Off Target
2007	≥0.75	N/A	0.83	On Target
Mean	≥0.75	N/A	0.77	On Target
Hilsenhoff Biotic Index				
1996	<6.6	<4.3	4.87	On Target
2005	<6.6	<4.3	5.04	On Target
2006	<6.6	<4.3	4.82	On Target
2007	<6.6	<4.3	4.30	On Target
Mean	<6.6	<4.3	4.76	On Target

[1] Mean from Bowles (2009).

Chapter 6 Integrated Evaluation and Discussion

Logic-based Evaluation

Bringing together lots of 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).

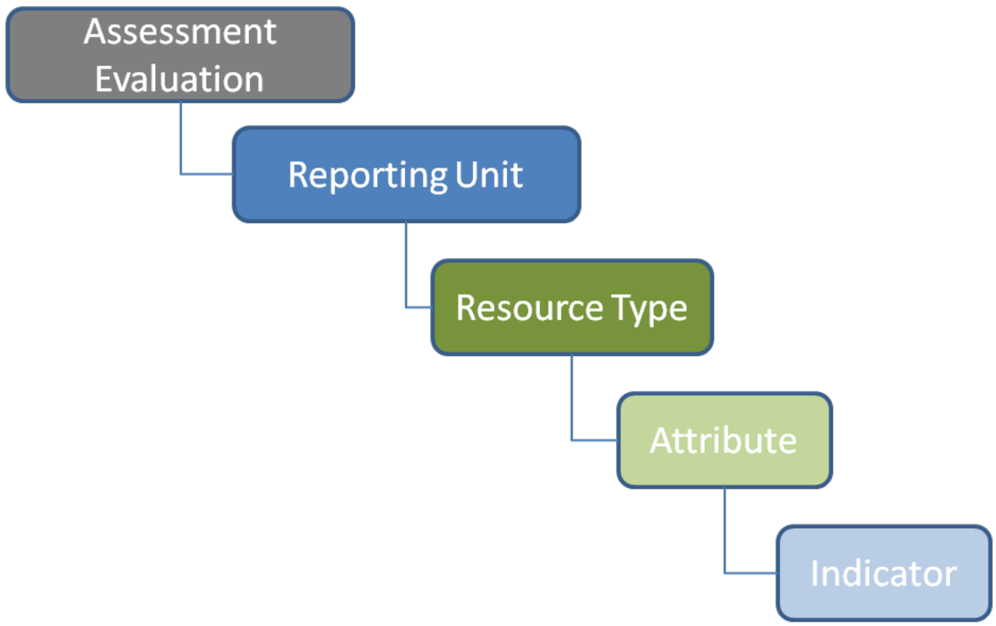

Figure 6-1. Hierarchical framework used in the integrated analysis of the Natural Resource Condition Assessment.

Applying the hierarchical arrangement (Figure 6-1) to the NRCA creates a framework that illustrates the relationships of all reporting units to their resource types, attributes and indicators (Figure 6-2, Figure 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.

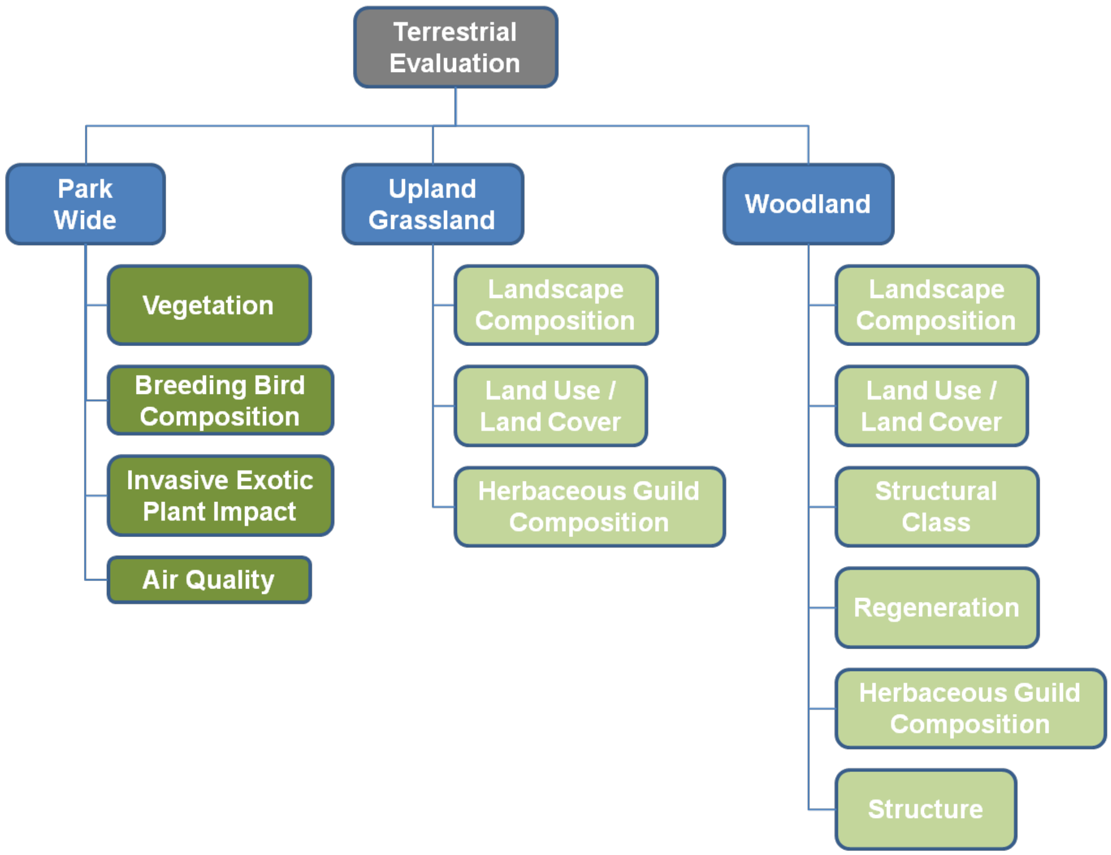

Figure 6-2. Higher levels of the model framework that reflect logical relationship of resource type (dark green) within reporting unit (blue) for the terrestrial assessment. Attributes are labeled light green.

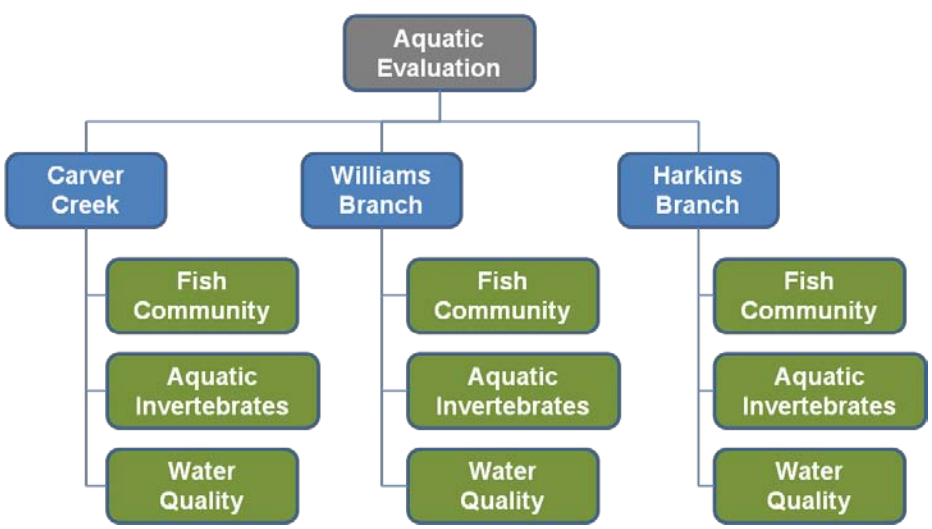

Figure 6-3. Higher levels of the model framework that reflect logical relationship of resource types within reporting unit (blue) for the aquatic assessment.

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.

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 5 ha or greater provides full support for the statement while a mean patch size of 2.5 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 6-1).

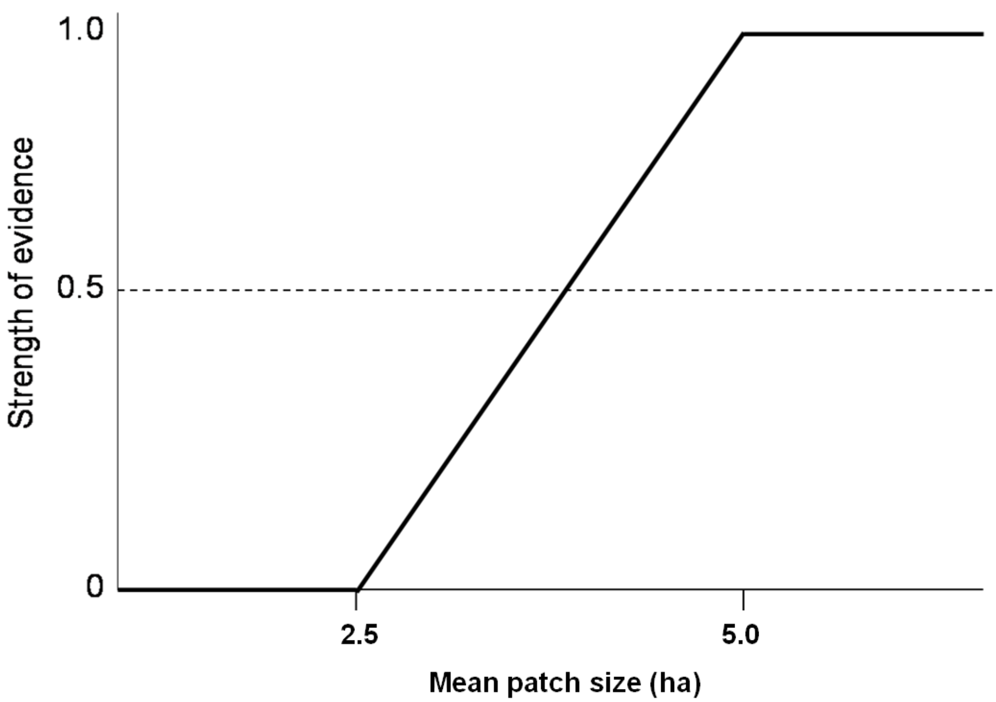

Figure 6-4. NetWeaver ramp function used to evaluate mean patch size in the upland grassland reporting unit of George Washington Carver National Monument, Missouri.

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.

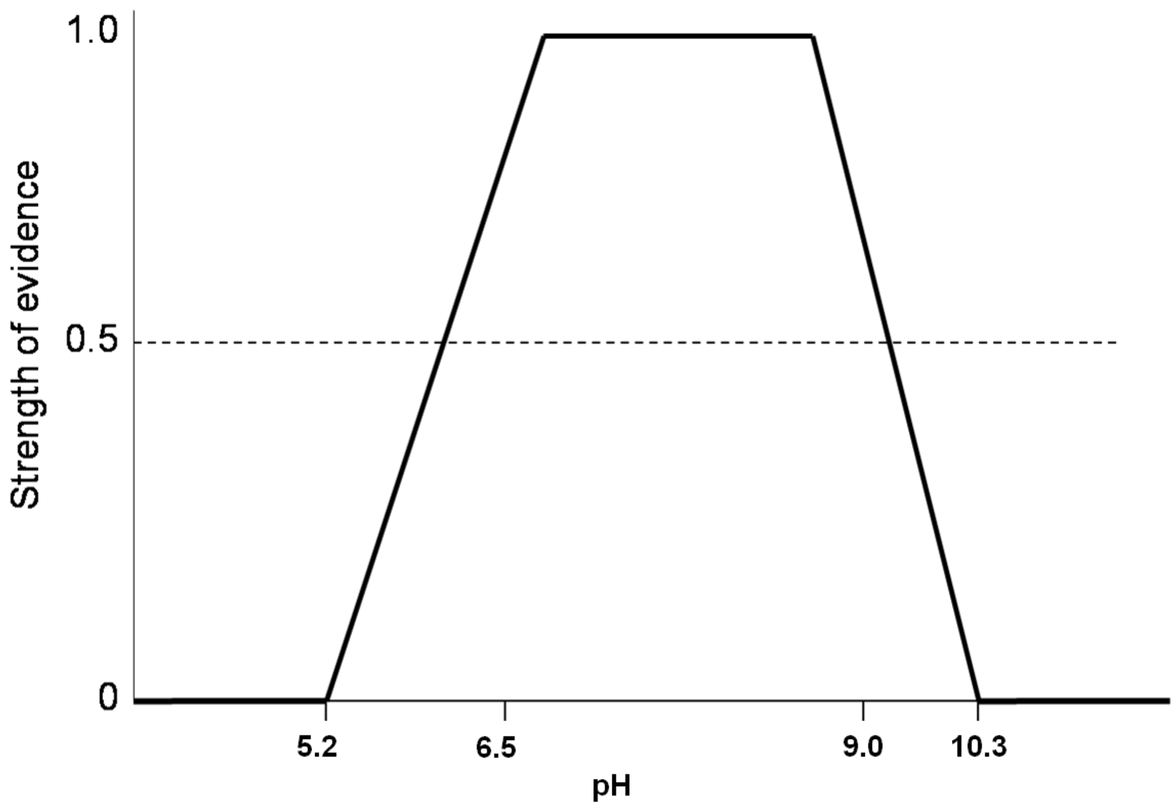

Figure 6-5. NetWeaver ramp function used to evaluate pH for all three aquatic reporting unit's of George Washington Carver National Monument, Missouri.

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. The Persimmon Grove reporting unit was treated as part of the Woodland 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).

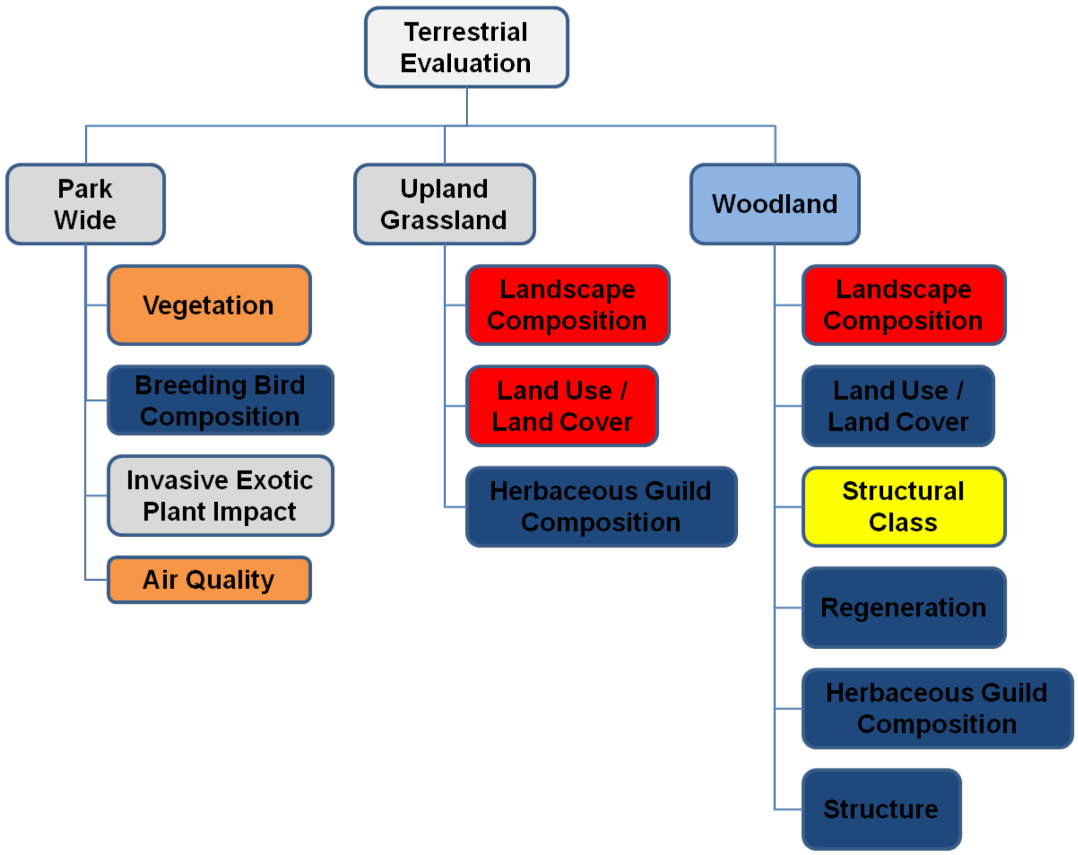

Figure 6-7. Color coded evaluation results for each terrestrial reporting unit and its associated resource type and/or attributes.

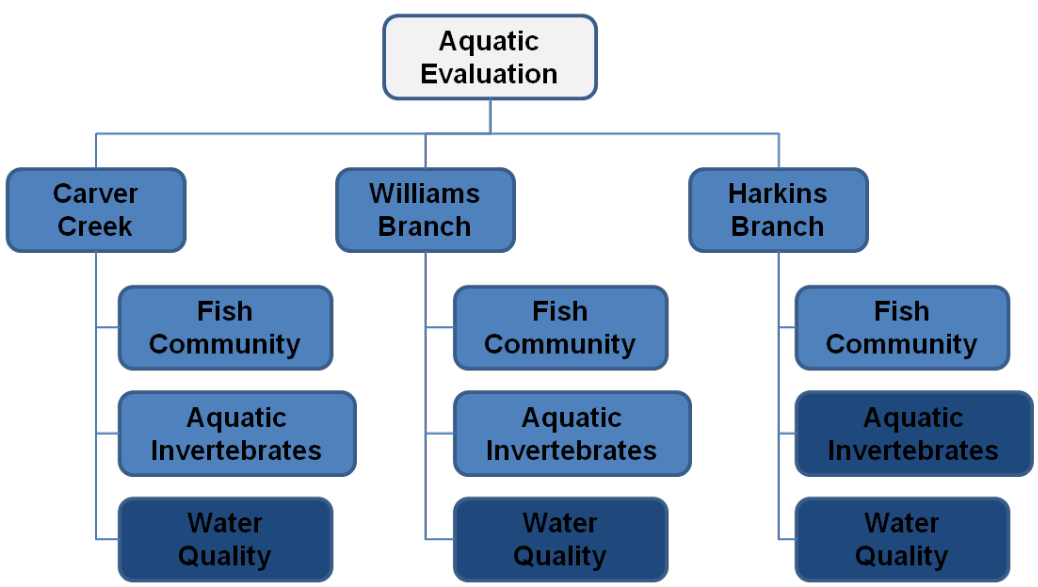

Figure 6-8. Color coded evaluation results for each aquatic reporting unit and its associated resource types.

Reporting unit: Park Wide

Overall support for the park wide reporting unit is moderate (output score = 0.44). 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).

Table 6-1. Rescaled NetWeaver output scores for the integrated analysis of the park wide reporting unit of George Washington Carver National Monument, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Park-wide							0.44
	Vegetation						0.17
		Landscape composition					0
			patch count	75	50	105	0
			mean patch size (ha)	1.5	3	1.09	0
		Land use/Land cover					0.33
			semi-natural and natural types (ha)	36	75	25	0
			successional types (ha)	27	18	68	0
			cultural types (ha)	4.5	3	3	1
	Breeding bird community						1
			species richness	24	47	47	1
			Partners in Flight target species	3	6	6	1
			number of grassland obligate species	2	3	3	1
	Invasive exotic plant impact						0.56
			number of taxa	45	30	35	0.67
			frequency on transects (%)	75	50	91.9	0
			park-wide minimum cover estimate (%)	15	10	9.0	1
	Air quality						0.01
		Ozone					
			ozone (ppb)	76.0	60	72.9	0.19
		Atmospheric deposition					0
			nitrogen (kg/ha/yr)	3.0	1	13	0
			sulfur (kg/ha/yr)	3.0	1	10.6	0

This reflects a fragmented landscape composed of numerous small patches. There was moderate support (output score = 0.33) for the composition of those patches, primarily because of the amount of cultural land cover type in the park. Park wide, the landscape is dominated by successional community types rather than natural or semi-natural types.

Across the park, there was full support for the breeding bird indicators approximating the management targets. The number of grassland obligate species, target species of concern, and overall species richness all had output scores = 1.

Invasive exotic plants, while low in abundance as measured by foliar cover (output score = 1) were high in number of taxa (output score = 0). The low abundance of a high number of invasive plants, coupled with their low frequency across the park results in an overall moderate support for the impact of invasive exotic plants approximating the management target.

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 nearly greater than the management target.

Reporting unit: Upland Grassland

Overall support for the upland grassland reporting unit approximating the management target was moderate (output score = .5, Table 6-2). This reporting unit was split between no support for the spatial arrangement and composition of grassland patches and full support for the plant community composition as measured by native guild abundance and species diversity. The decision to describe the grassland areas as a successional community type rather than a semi-natural type is reflected in the overall score for the land use/land cover attribute.

Table 6-2. Rescaled NetWeaver output scores for the integrated analysis of the upland grassland reporting unit of George Washington Carver National Monument, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Upland grassland							0.5
		Landscape composition					0
			patch count for grassland	15	10	0	0
			mean patch size for grassland (ha)	2.5	5	0	0
		Land use/Land cover					0
			prairie (ha)	27.5	55	0	0
			successional types (ha)	22.5	15	65	0
		Diversity					1
			native species richness	36	71	74	1
			total species richness	68	135	143	1
		Herbaceous guild composition					1
			native grass (%)	15.3	30.5	47.2	1
			native forbs (%)	8.8	17.5	37.6	1
			native woody shrub and vine (%)	62.7	41.8	22.4	1

Reporting unit: Woodland

Overall support for the woodland reporting unit is moderately high (output score = .72, Table 6-3). Although the landscape composition is fully supported for the reporting unit and the canopy height and cover of the woodland is good, the woodland composition and structure reflects a successional woodland community recovering from stand level disturbances. The abundance of native guilds in the understory approximates the management targets. Furthermore, the relative density of hackberry in the regeneration layer (stems < 8.0 cm dbh) is less than the management target. The high degree of support for the area occupied by natural woodland and low support for the overstory structural indicators may be an artifact of breeding bird monitoring sites from which the current values were derived.

Table 6-3. Rescaled NetWeaver output scores for the integrated analysis of the woodland reporting unit of George Washington Carver National Monument, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Woodland							0.72
		Landscape composition					0
			patch count for woodland	15	10	18	0
			mean patch size for woodland (ha)	1	2	1.1	0
		Land use/Land cover					1
			natural and semi-natural woodland (ha)	10	20	20	1
			successional types (ha)	2	1	0.9	1
		Structural class					0.33
			hardwood canopy cover (%)	25	50	85	1
			hardwood basal area (m^2/ha)	14	25	7.5	0
			density (stems/ha, trees > 8 cm dbh)	125	600	111	0
		Regeneration					0
			total hackberry relative density (% of stems/ha, < 8 cm dbh)	75	50	41	1
		Herbaceous guild composition					1
			native grass (%)	≤ 5 or ≥ 85	10 - 70	13	1
			native forbs (%)	< 1 or ≥ 67	1 - 45	18	1
			native woody shrub (%)	≤ 5 or ≥ 65	20 - 50	20	1
		Structure					
			hardwood tree height (m)	≤ 2.5 or ≥ 28.5	9 - 22	18.6	1

Reporting unit: Carver Branch

Overall support for Carver Branch reporting unit was high (output score = .94, Table 6-4). For each of the three resource types output scores ranged from 1 (water quality) to .9 (fish community). Overall high output scores in the hierarchy reflect moderate or better support for most lower levels in the reporting unit logic model. Only three indicators did not have full support for the evaluation statement (sucker species composition, IBI, and EPT ratio).

Table 6-4. Rescaled NetWeaver output scores for the integrated analysis of the Carver Branch reporting unit of George Washington Carver National Monument, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Carver Branch							0.94
	Water quality						1
			temperature (°C)	≤ -17 or ≥ 51	0 - 34	15.3	1
			specific conductance (μS/cm)	0 or ≥ 550	100 - 400	282.1	1
			dissolved oxygen (mg/L)	0 or ≥ 20	5 - 15	7.9	1
			pH	≤ 5.2 or ≥ 10.3	6.5 - 9.0	7.4	1
			turbidity (NTU)	15	10	2.2	1
	Fish community						0.90
		Composition					0.97
			Simpson's diversity	0.25	0.49	0.97	1
			sucker composition (%)	0.26	0.52	0.50	0.92
			benthic species composition (%)	6.7	13.4	19.8	1
		Condition					
			index of biotic integrity	30	60	55	0.83
	Aquatic invertebrates						0.93
		Biotic integrity					
			family richness	7.1	14.2	16.0	1
			genus richness	7.5	15	17.6	1
			EPT richness	2	4	6.9	1
			EPT ratio	0.51	0.85	0.68	0.5
			Shannon Index (Genus)	0.89	1.77	2.26	1
			Shannon Evenness Index	0.5	0.75	0.79	1
			Hilsenhoff Biotic Index	9.9	6.6	4.6	1

Reporting unit: Williams Branch

Overall support for the Williams Branch reporting unit was high (output score = .97, Table 6-5). There was a full support for the fish community resource type (output score = 1). Overall water quality was similar to Carver Branch with an output score of 1. As with Carver Branch, all aquatic invertebrate indicators were fully supported except for EPT ratio (moderate support with output score = .5).

Table 6-5. Rescaled NetWeaver output scores for the integrated analysis of Williams Branch reporting unit of George Washington Carver National Monument, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Williams Branch							0.97
	Water quality						1
			temperature (°C)	≤ -17 or ≥ 51	0 - 34	17.1	1
			specific conductance (µS/cm)	0 or ≥ 550	100 - 400	228.0	1
			dissolved oxygen (mg/L)	0 or ≥ 20	5 - 15	10.8	1
			pH	≤ 5.2 or ≥ 10.3	6.5 - 9.0	7.8	1
			turbidity (NTU)	15	10	3.0	1
	Fish community						1
		Composition					1
			Simpson's diversity	0.51	0 34	0.21	1
			benthic species composition (%)	37.2	74.4	80.7	1
		Condition					
			index of biotic integrity	30	60	81	1
	Aquatic invertebrates						0.92
		Biotic integrity					
			family richness	7.1	14.2	14	1
			genus richness	7.5	15	15.4	1
			EPT richness	2	4	6	1
			EPT ratio	0.51	0.85	0.68	0.5
			Shannon Index (Genus)	0.89	1.77	2.03	1
			Shannon Evenness Index	0.5	0.75	0.79	1
			Hilsenhoff Biotic Index	9.9	6.6	4.4	1

Reporting unit: Harkins Branch

Output for Harkins Branch was similar to both Carver Branch and Williams Branch. The overall score for the reporting unit was .96 (Table 6-6). As with the other aquatic reporting units, water quality was fully supported while aquatic invertebrates was fully satisfied as well. The Index of Biotic Integrity was lowest among all three reporting units in Harkins Branch (output score = .73).

Table 6-6. Rescaled NetWeaver output scores for the integrated analysis of the Harkins Branch reporting unit of George Washington Carver National Monument, Missouri.

Reporting Unit	Resource Type	Attribute	Indicator	No Support	Full Support	Input	Score
Harkins Branch							0.96
	Water quality						1
			temperature (°C)	≤ -17 or ≥ 51	0 - 34	17.3	1
			specific conductance (µS/cm)	0 or ≥ 550	100 - 400	214.5	1
			dissolved oxygen (mg/L)	0 or ≥ 20	5 - 15	7.3	1
			pH	≤ 5.2 or ≥ 10.3	6.5 - 9.0	7.1	1
			turbidity (NTU)	15	10	3.6	1
	Fish community						0.87
		Composition					1
			Simpson's diversity	0.41	0.27	0.15	1
			benthic species composition (%)	9 2	18.3	33.1	1
		Condition					
			index of biotic integrity	30	60	52	0.73
	Aquatic invertebrates						1
		Biotic integrity					
			family richness	7 1	14.2	15.1	1
			genus richness	7 5	15	16.1	1
			EPT richness	2	4	7.6	1
			EPT ratio	0 59	0.79	0.79	1
			Shannon Index (Genus)	0.89	1.77	2.27	1
			Shannon Evenness Index	0 5	0.75	0.83	1
			Hilsenhoff Biotic Index	9 9	6.6	4.3	1

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. The lack of designated semi-natural or natural grasslands and overstory composition of the woodlands are the two biggest factors affecting the terrestrial reporting units in the monument.

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.

Terrestrial communities at George Washington Carver National Monument have developed mainly from former croplands. Some of the current woodlands were likely too wet or steep to be converted to crop production, or were kept as pasture land for other reasons. Since native species were apparently never eliminated from the woodlands, they are designated as semi-natural, whereas grasslands, where the native flora and fauna was essentially entirely eliminated by row crop production, are called successional.

National Park Service staff have re-established some compliment of native grasses and forbs across much of the park. Despite a history of crop production, the remnants of mima mounds, common on native prairies such as Diamond Prairie nearby, are still evident in grasslands across much of the park. Also, three grassland obligate bird species nest in the park. Continued grassland restoration efforts seem warranted, and these will likely result in restored prairies of local or regional significance. However, progress may be slow.

Young woodlands occur mainly along upland drainage ways or in areas where mining activity has left highly disturbed soils. These areas may mature over time if Japanese honeysuckle (*Lonicera japonica*) does not restrict recruitment of oaks and hickories into the canopy. Since woodland patches are small, the management of this and other invasive species in the future seems doable given reasonable funding and effort.

The park holds enough habitat diversity to support breeding bird species that use grassland, woodland edge, and woodland habitats with dense understory. Management in favor of shrubland or edge type habitat on old mined lands in the southwest part of the park might be advised to provide this bird habitat as well. Also, grassland mowing patterns that promote some shrub composition in some areas or years would add to the overall habitat diversity of the park.

Three small streams flow through GWCA, and the floodplains are generally wooded. Harkins Branch in the north is larger in terms of discharge, and Williams Branch flows into Carver Branch, with which it shares a floodplain, in the central part of the park. Although the watersheds of these streams exist in a generally agricultural landscape, the water quality and physical habitat is generally good. Diversity of darter, sculpin, and madtom species is generally high, and the Arkansas darter (*Etheostoma cragini*), a rare species, is present. Harkins Branch shows greater stream bank instability than the other two streams, and only a small segment is contained within the park, so impacts from off-site may be a concern. Likewise, a spring on

Carver Branch that tends to mitigate impacts from seasonal or annual variations in precipitation and temperature is likely fed from areas off the park, so land use changes in nearby may impact this resource.

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

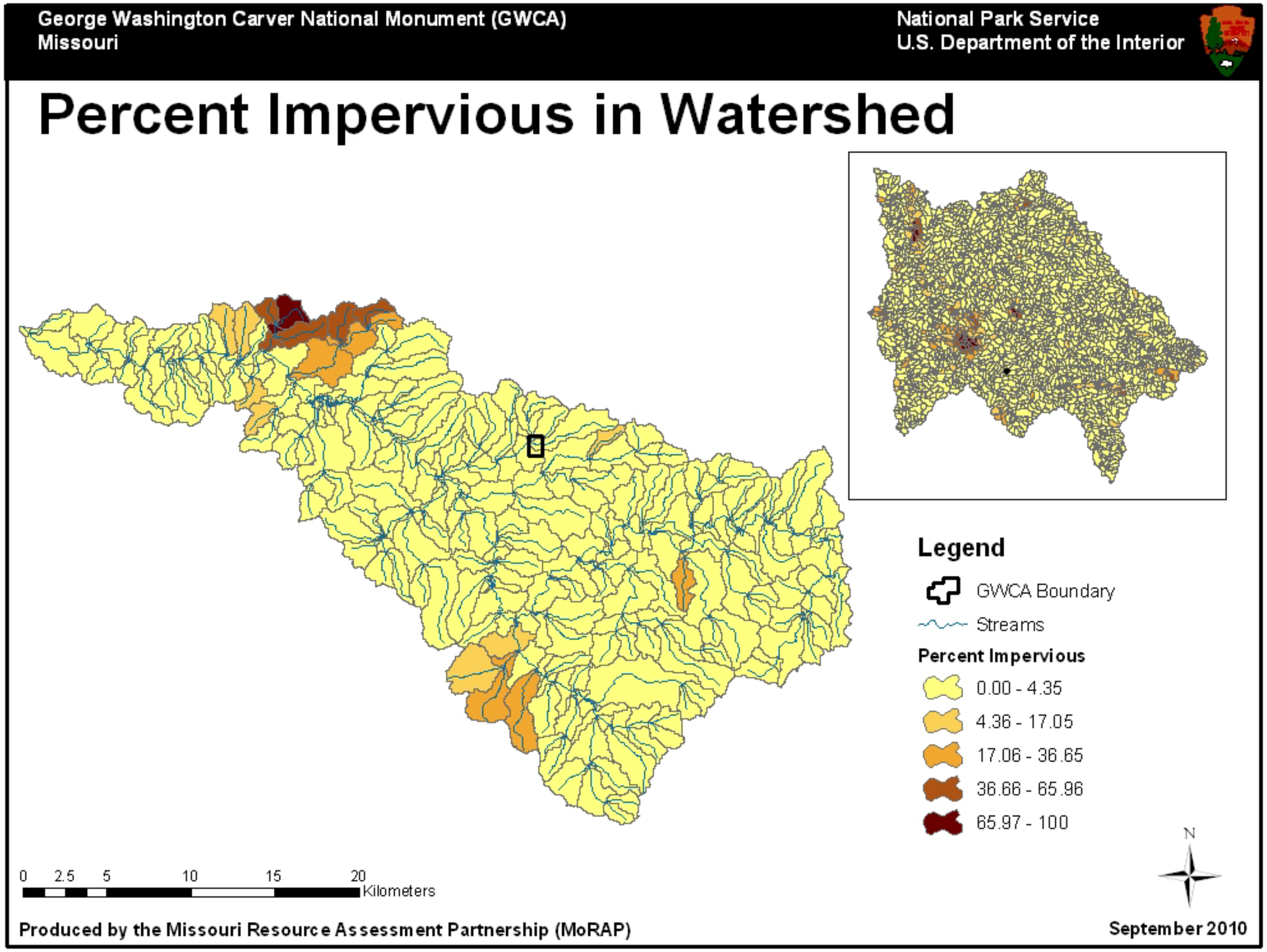

Figure A-1. Percentage of impervious surfaces above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

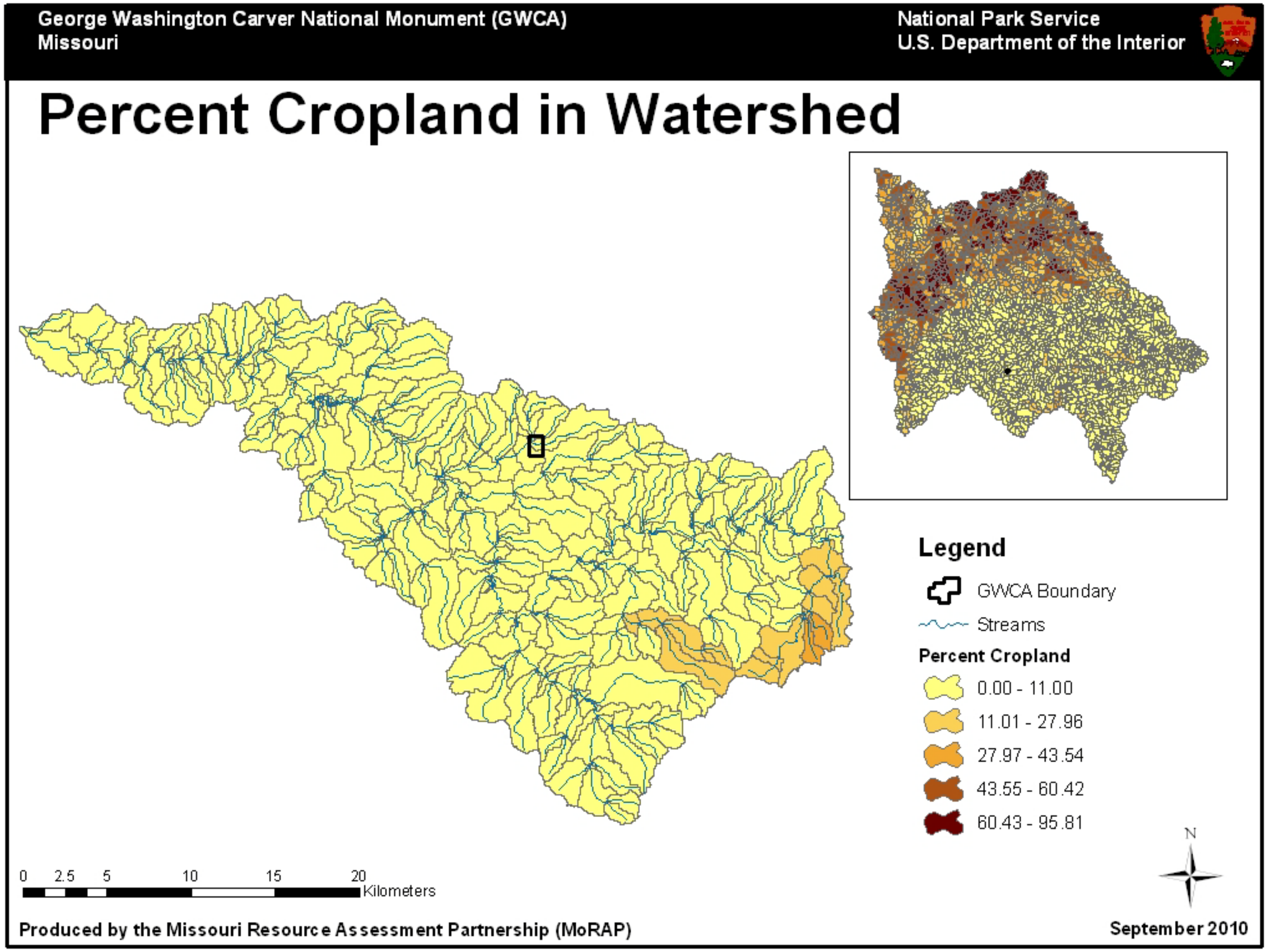

Figure A-2. Percentage of cropland above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

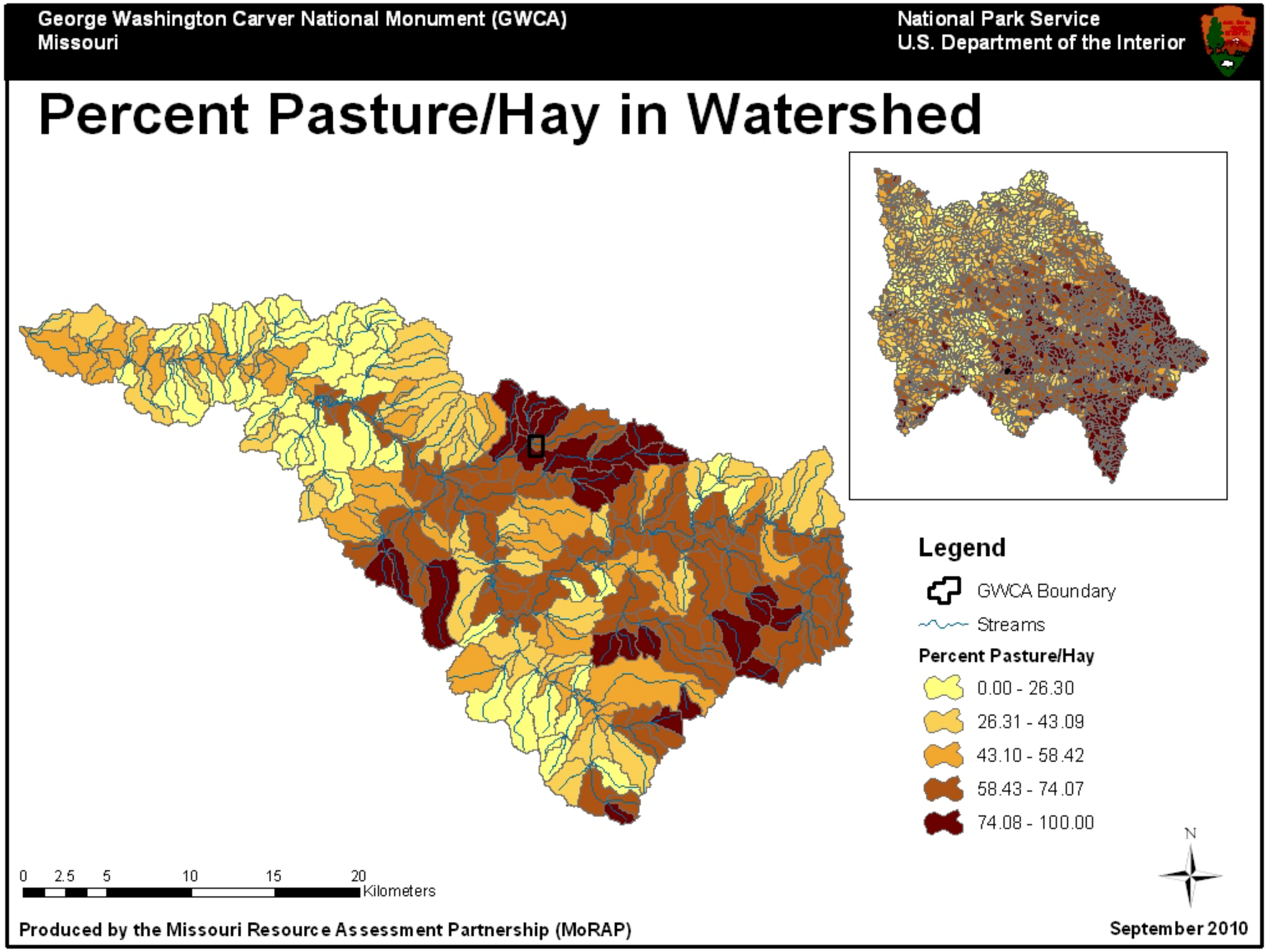

Figure A-3. Percentage of pasture/hay above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

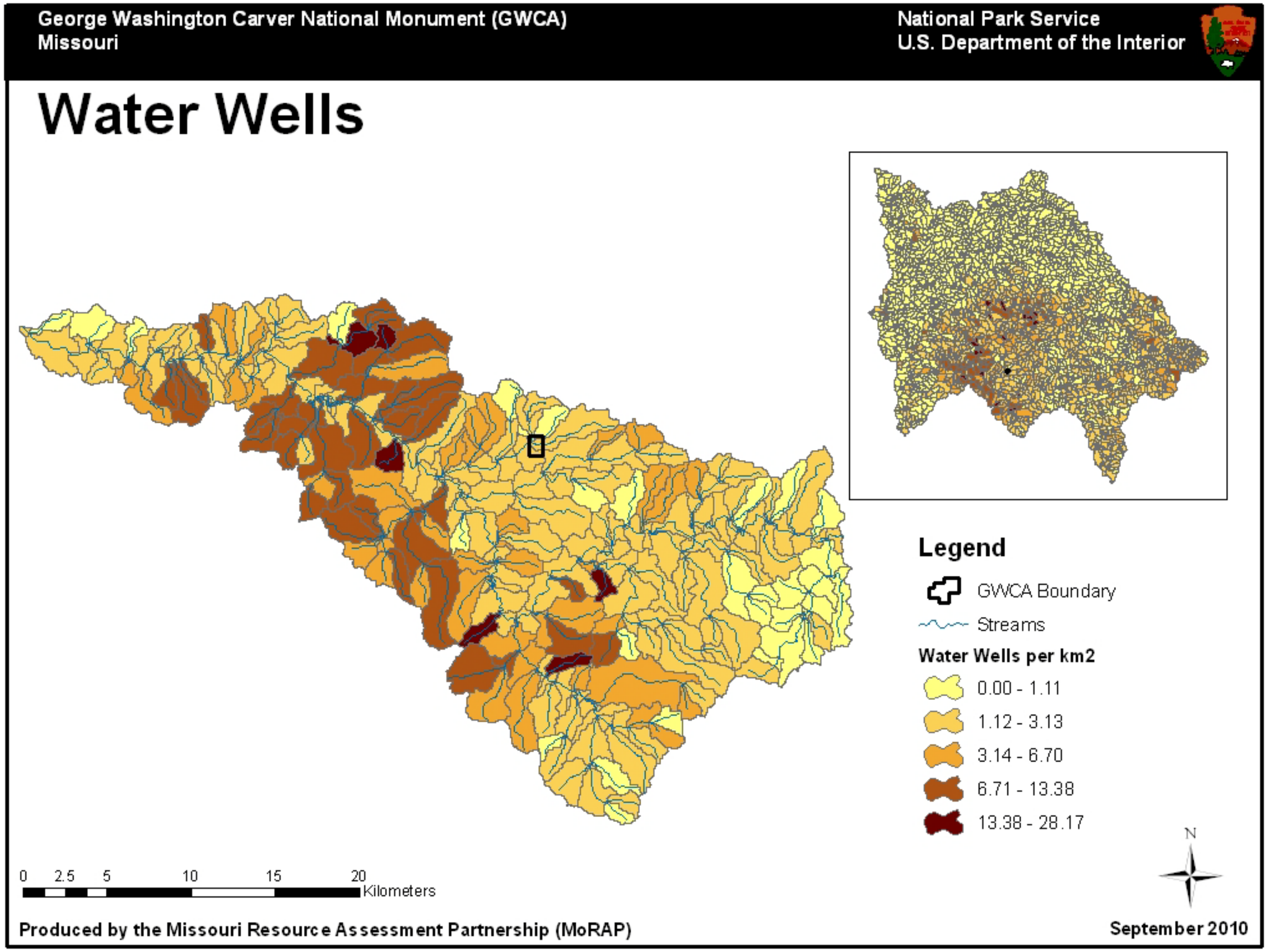

Figure A-4. Density of water wells above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

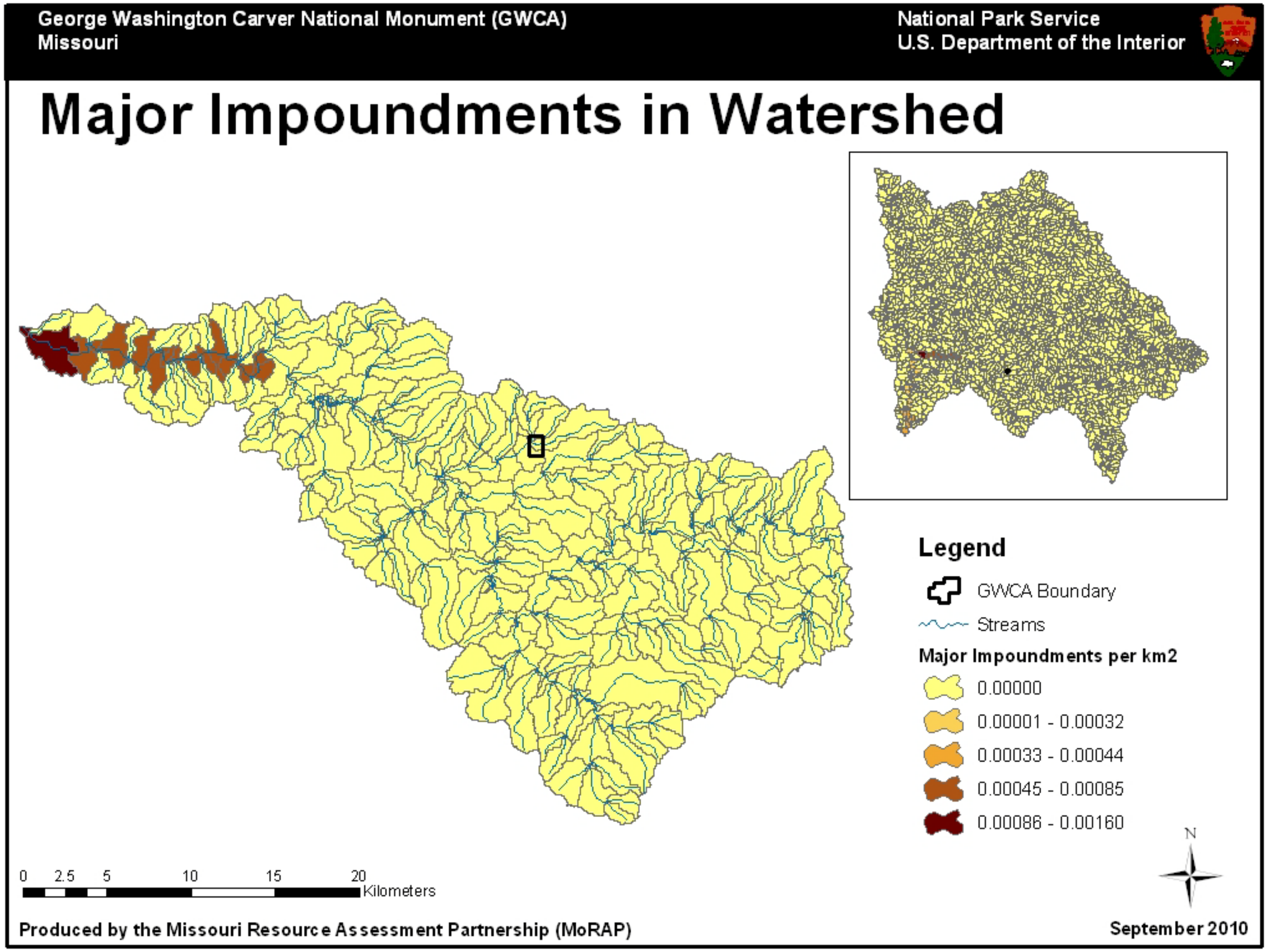

Figure A-5. Density of major impoundments above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

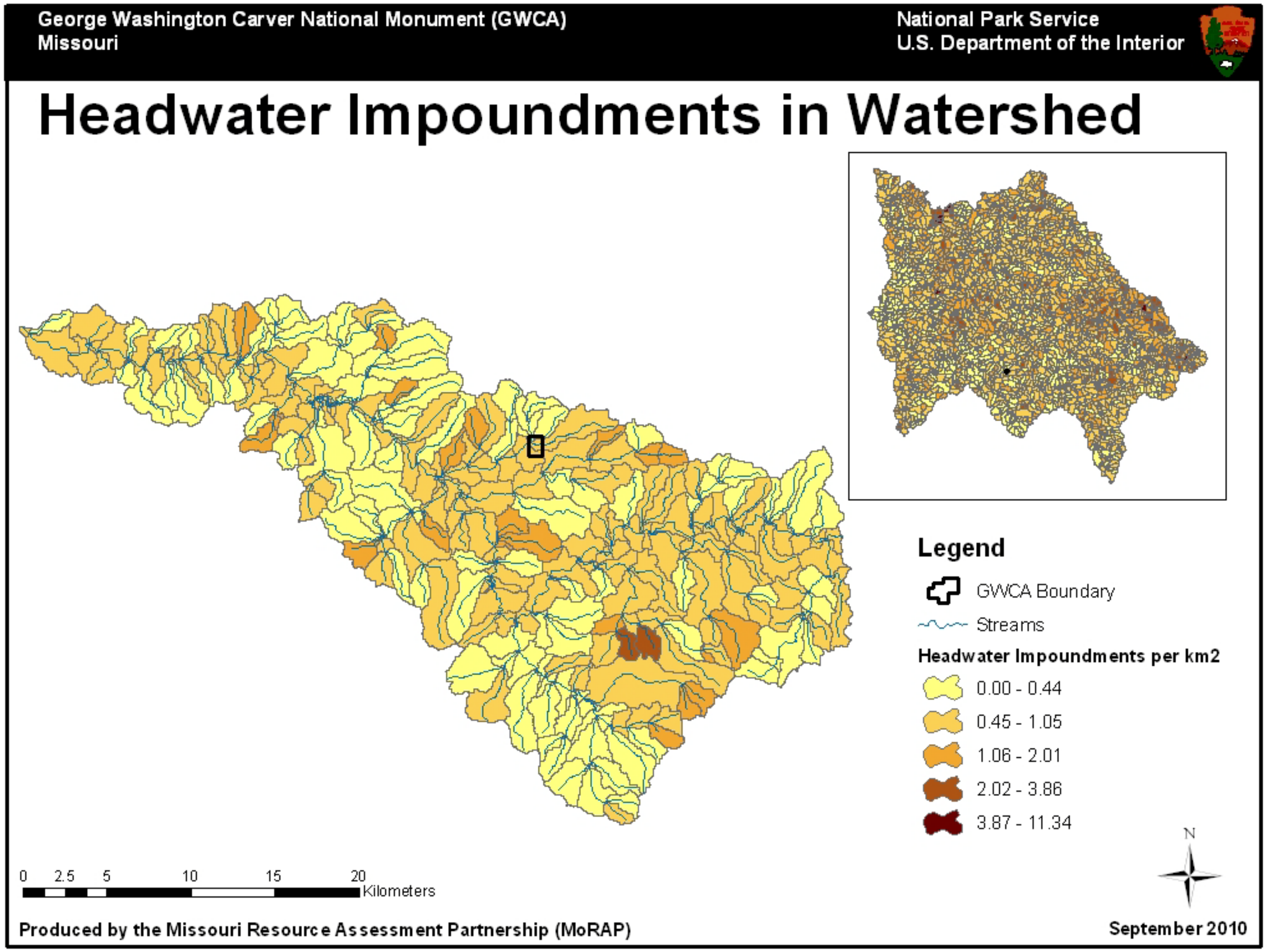

Figure A-6. Density of headwater impoundments above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

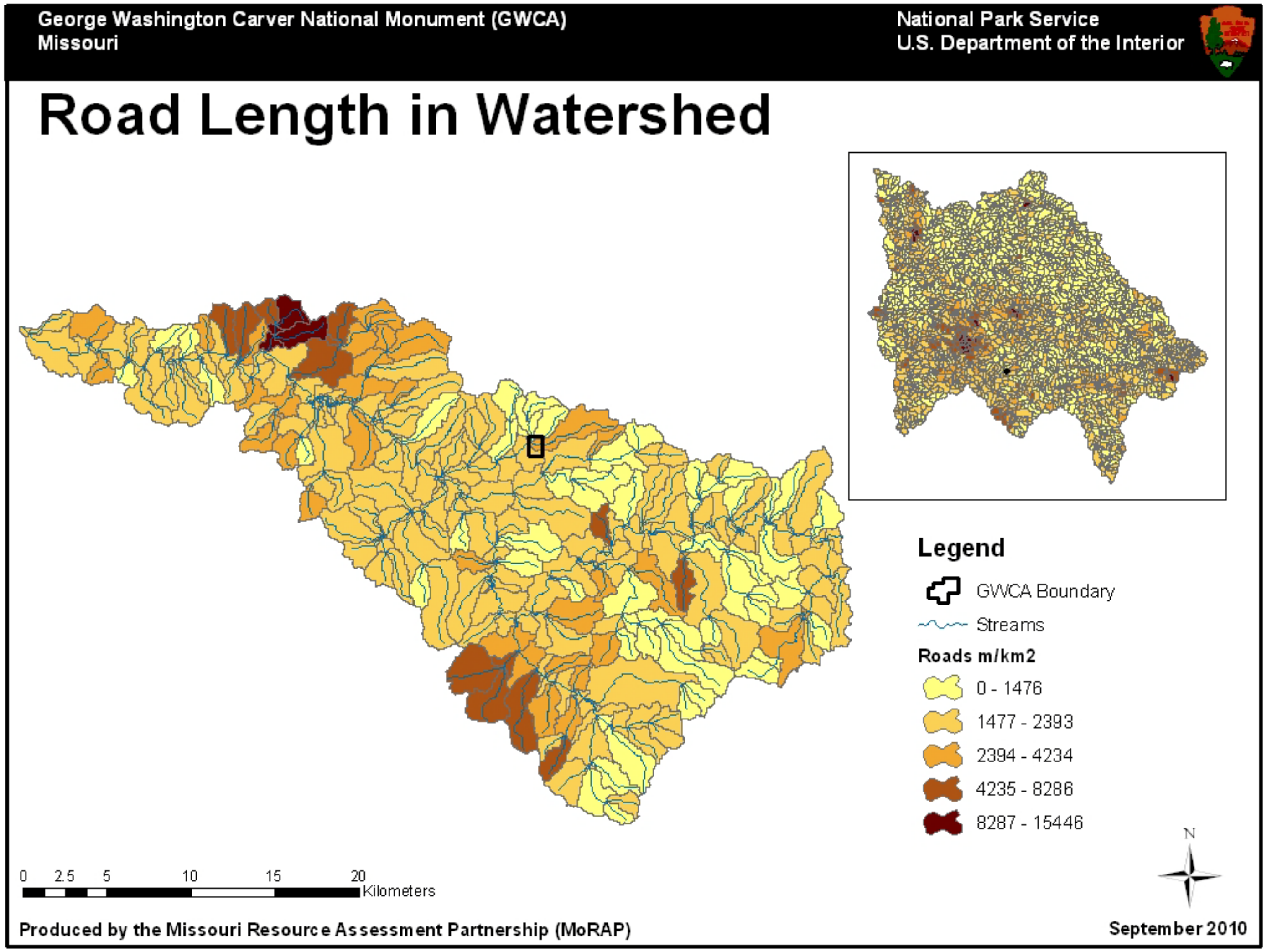

Figure A-7. Length of roads above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

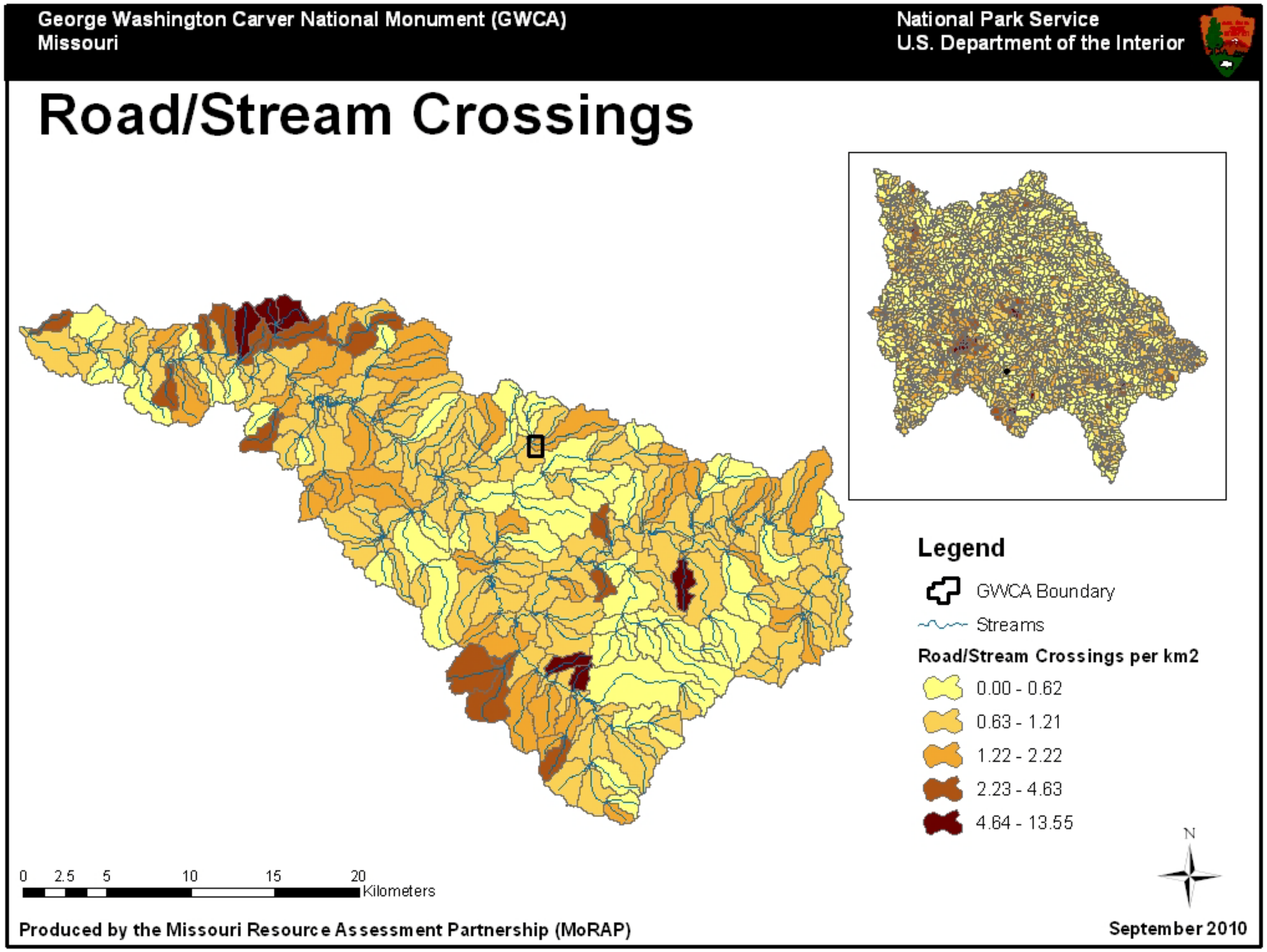

Figure A-8. Density of road/stream crossings above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

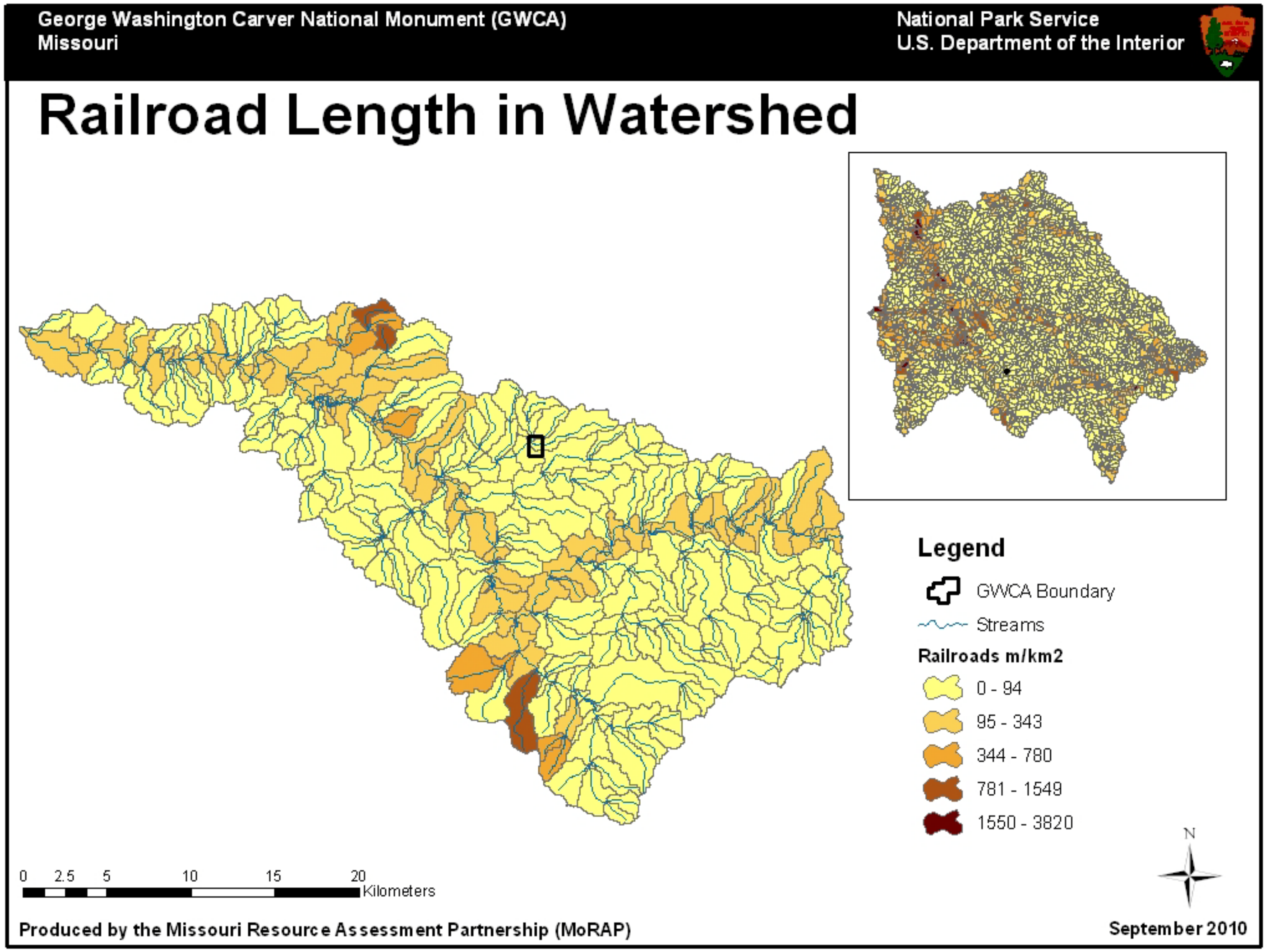

Figure A-9. Length of railroads above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

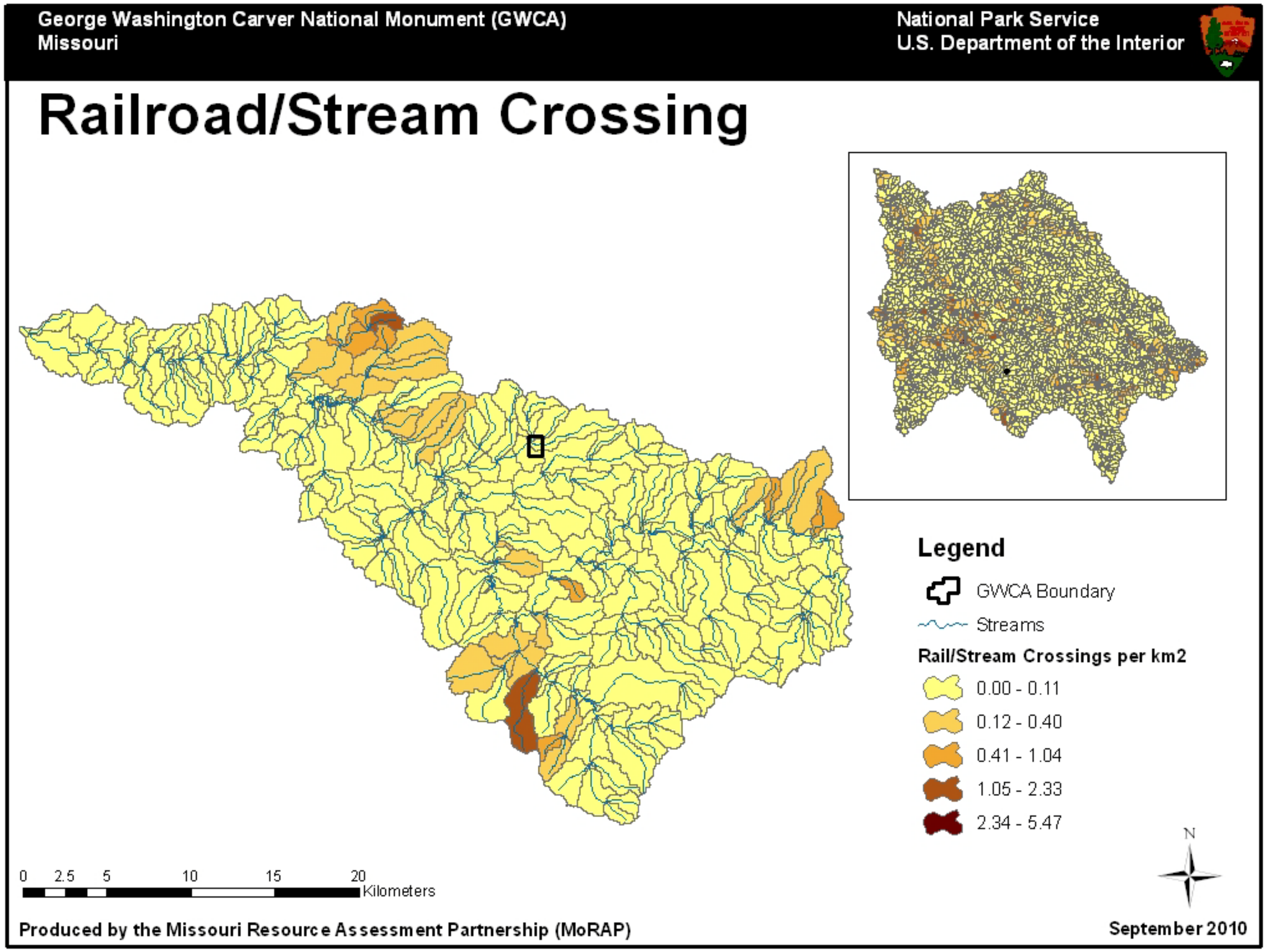

Figure A-10. Density of railroad/stream crossings above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

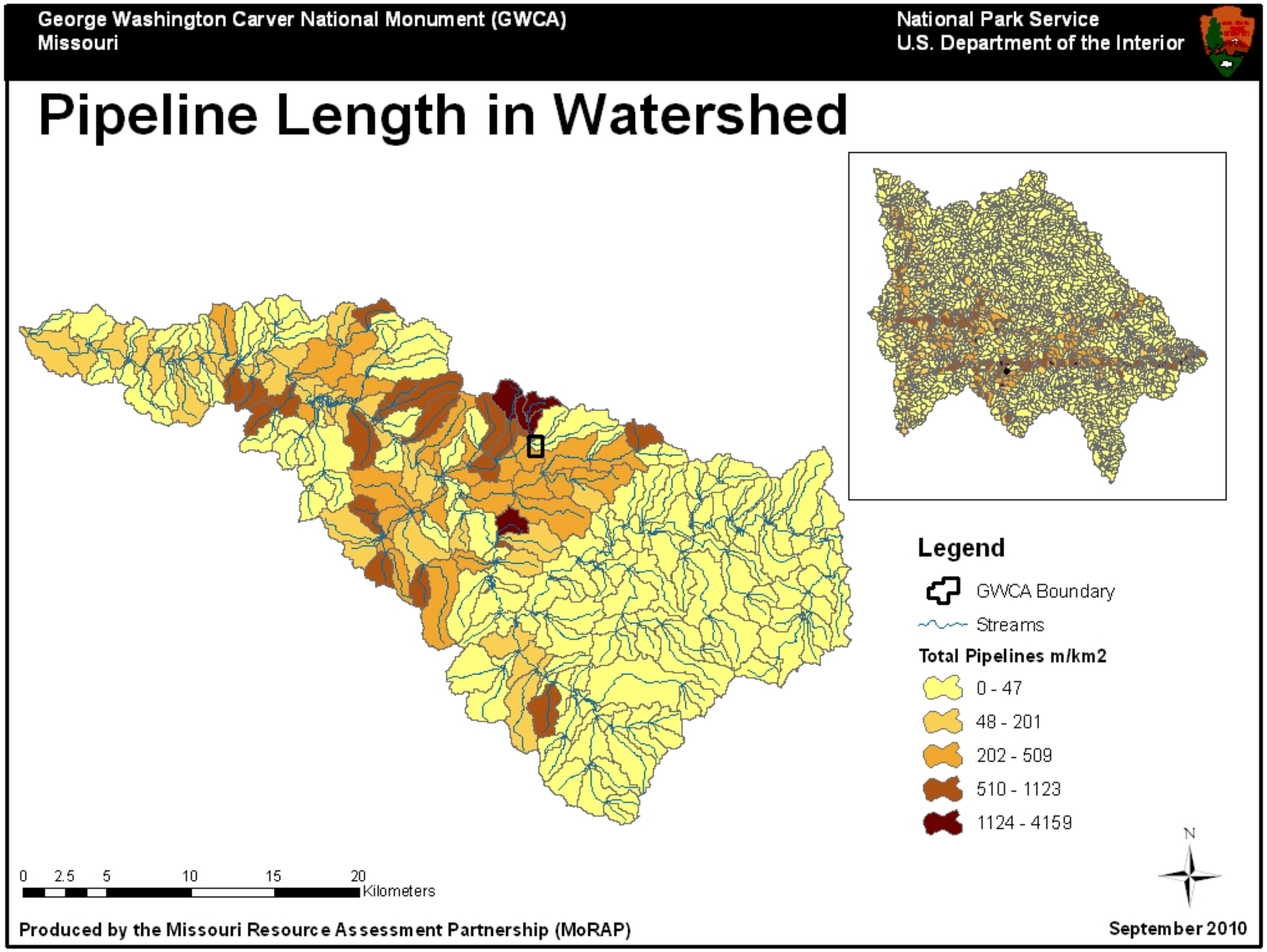

Figure A-11. Length of pipelines above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

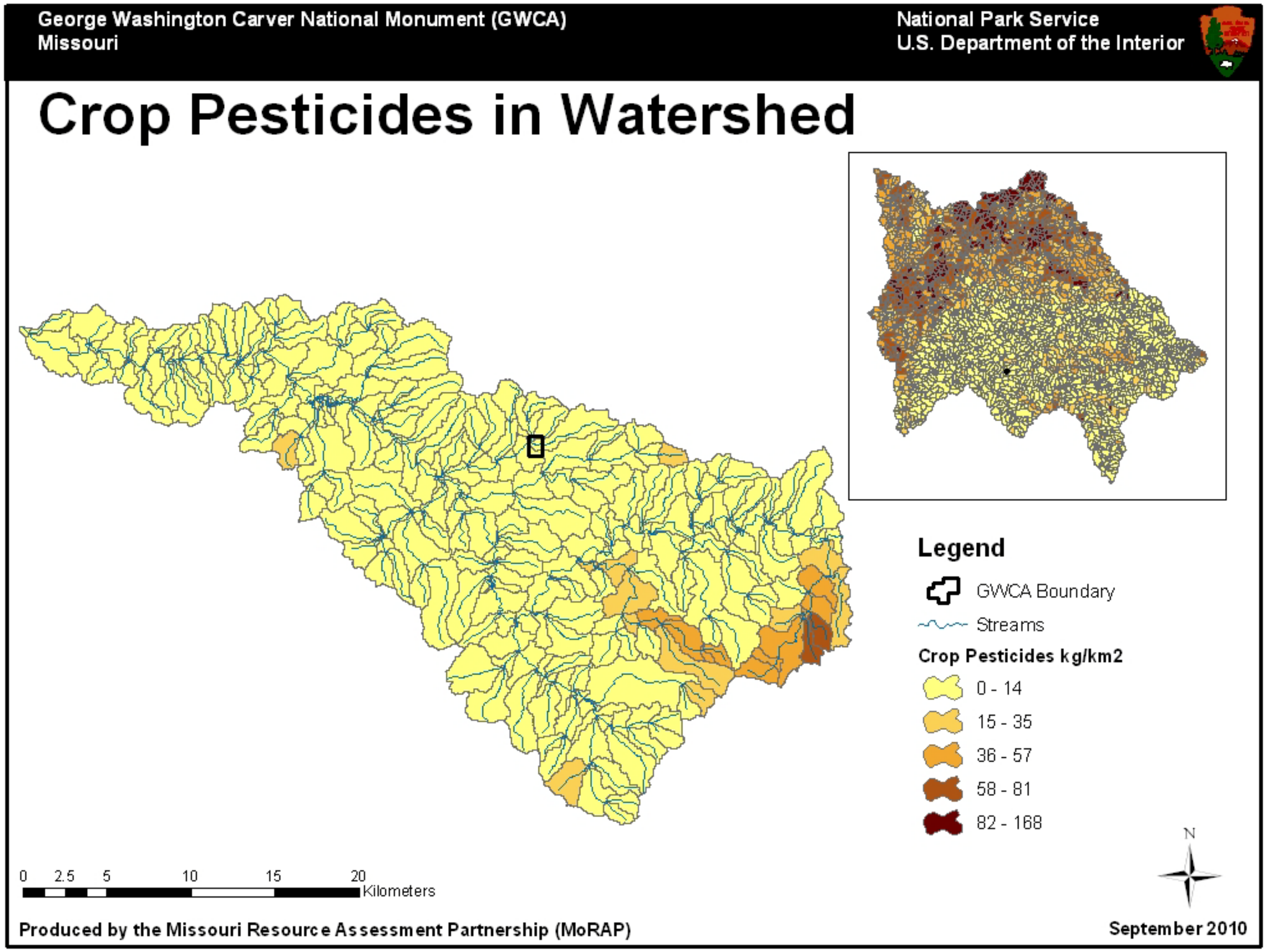

Figure A-12. Density of crop pesticides above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

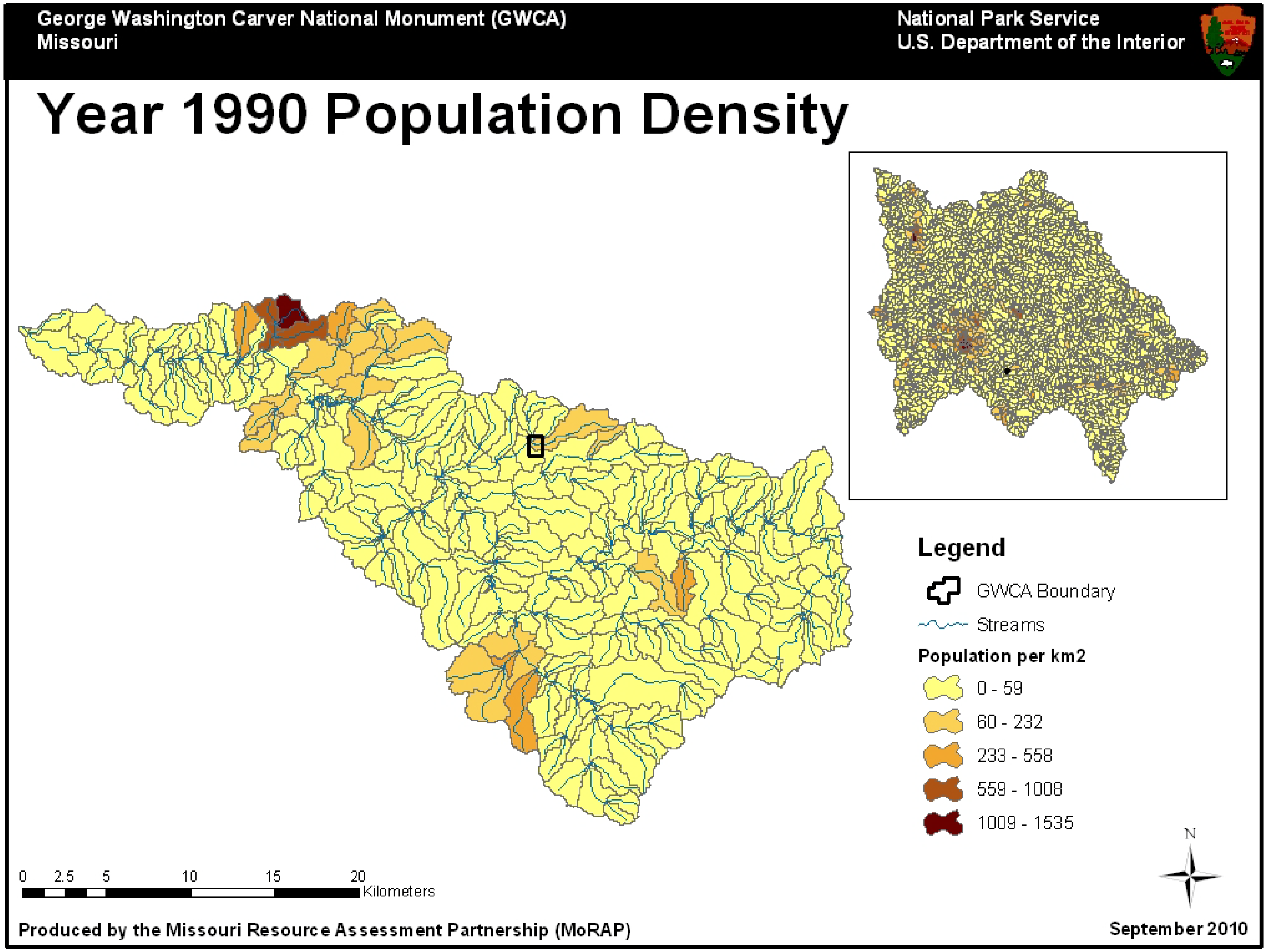

Figure A-13. Density of population in 1990 above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

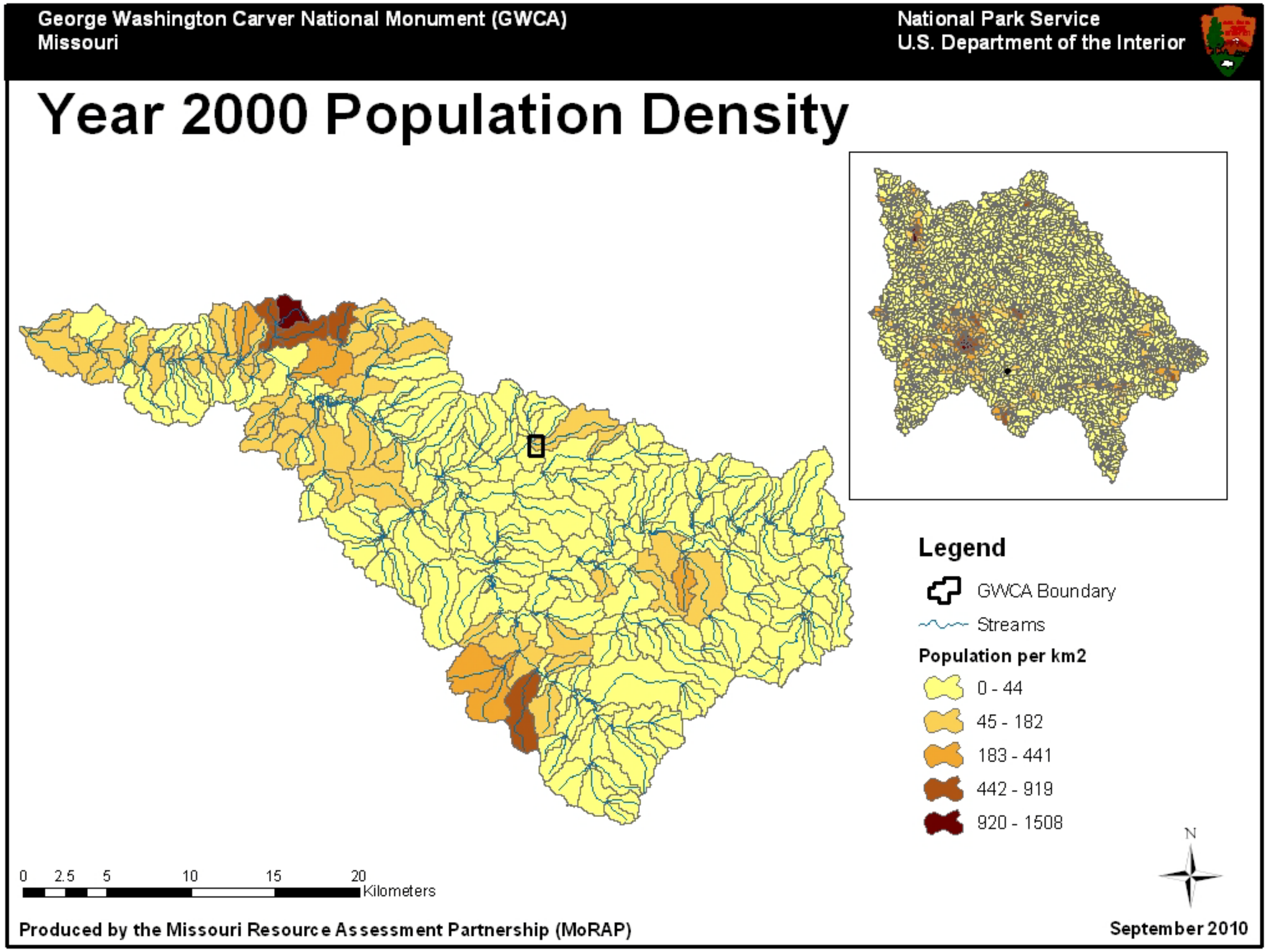

Figure A-14. Density of population in 2000 above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

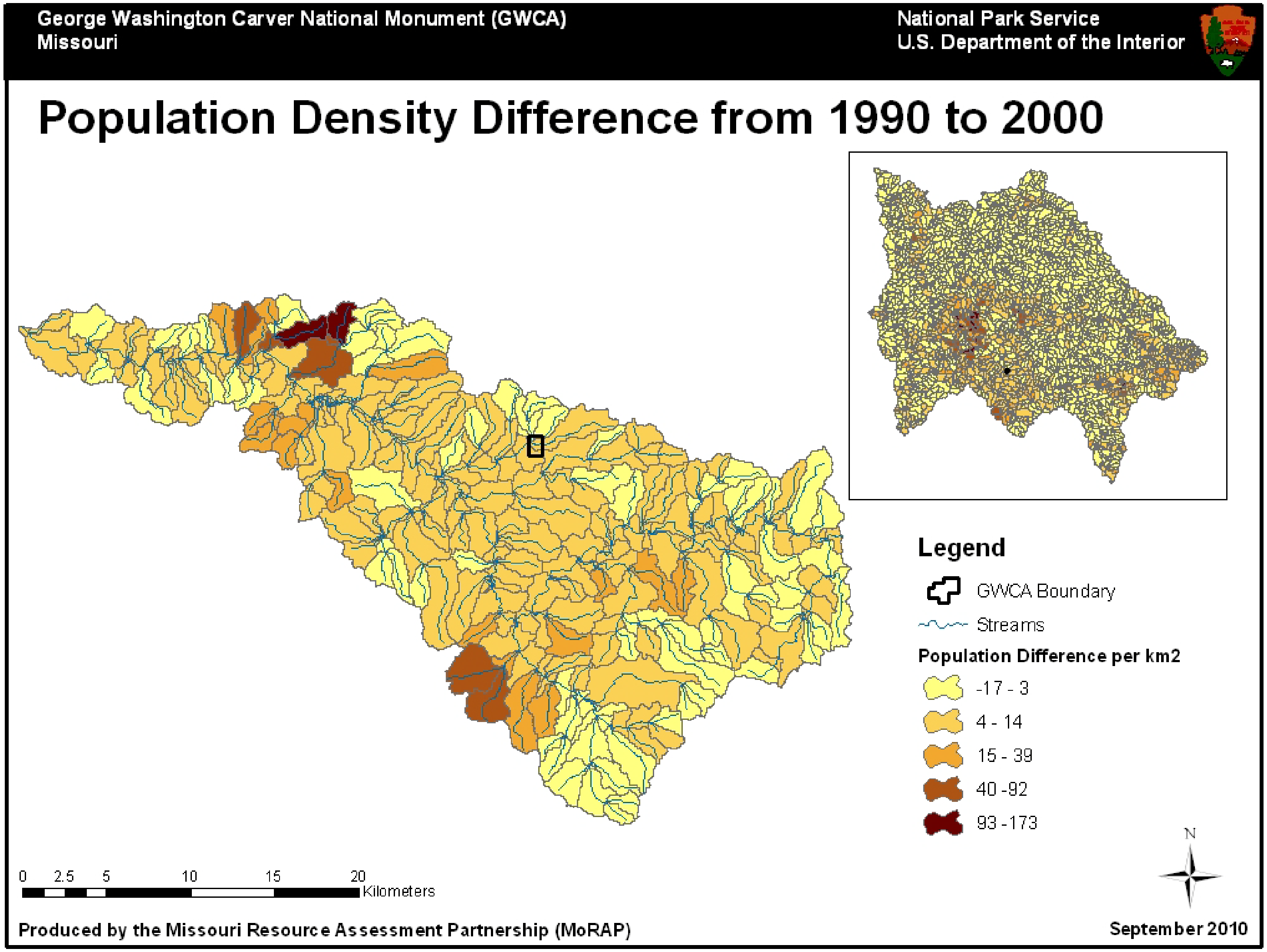

Figure A-15. Change in population density from 1990 to 2000 above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

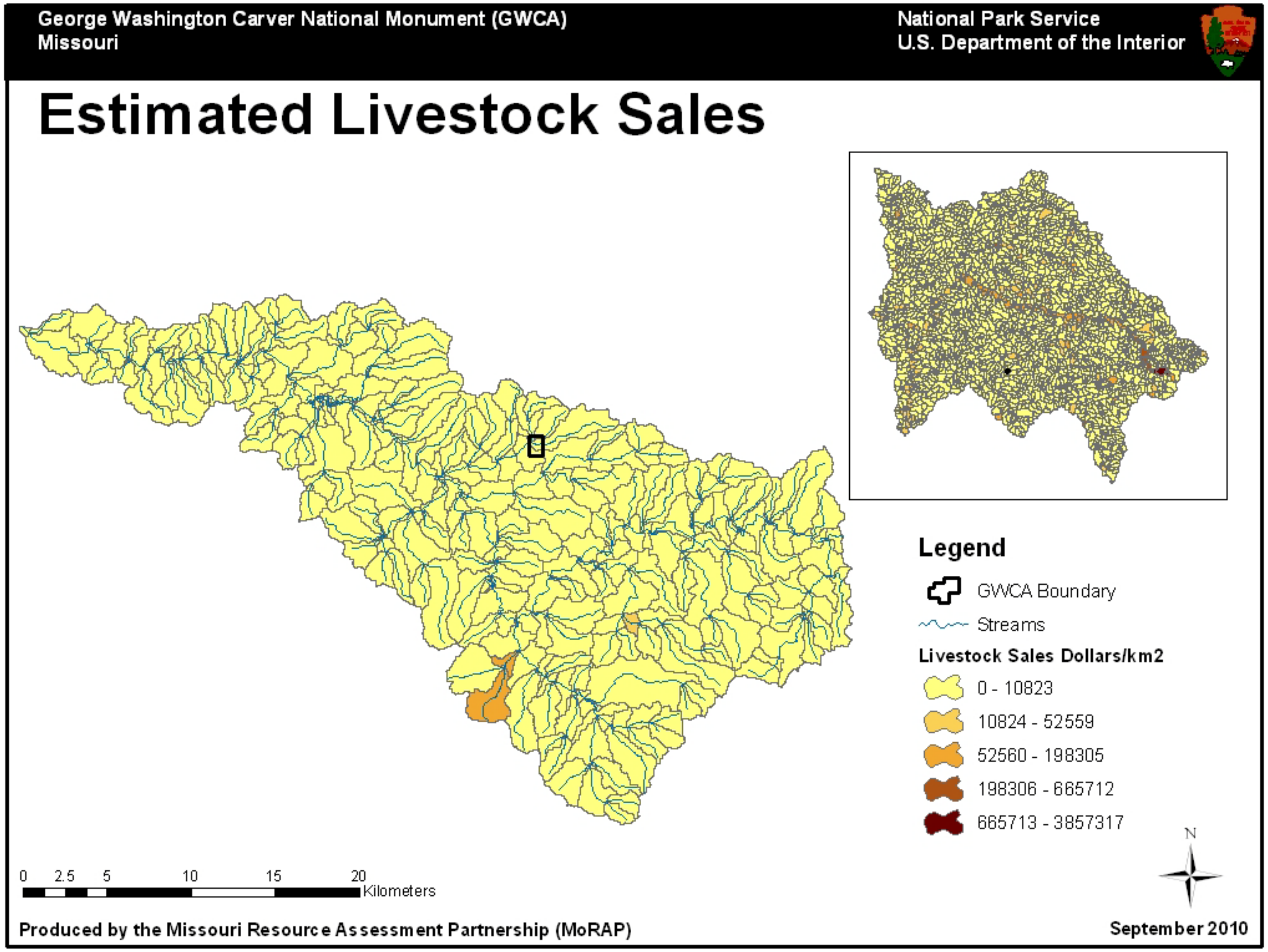

Figure A-16. Amount of livestock sales above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

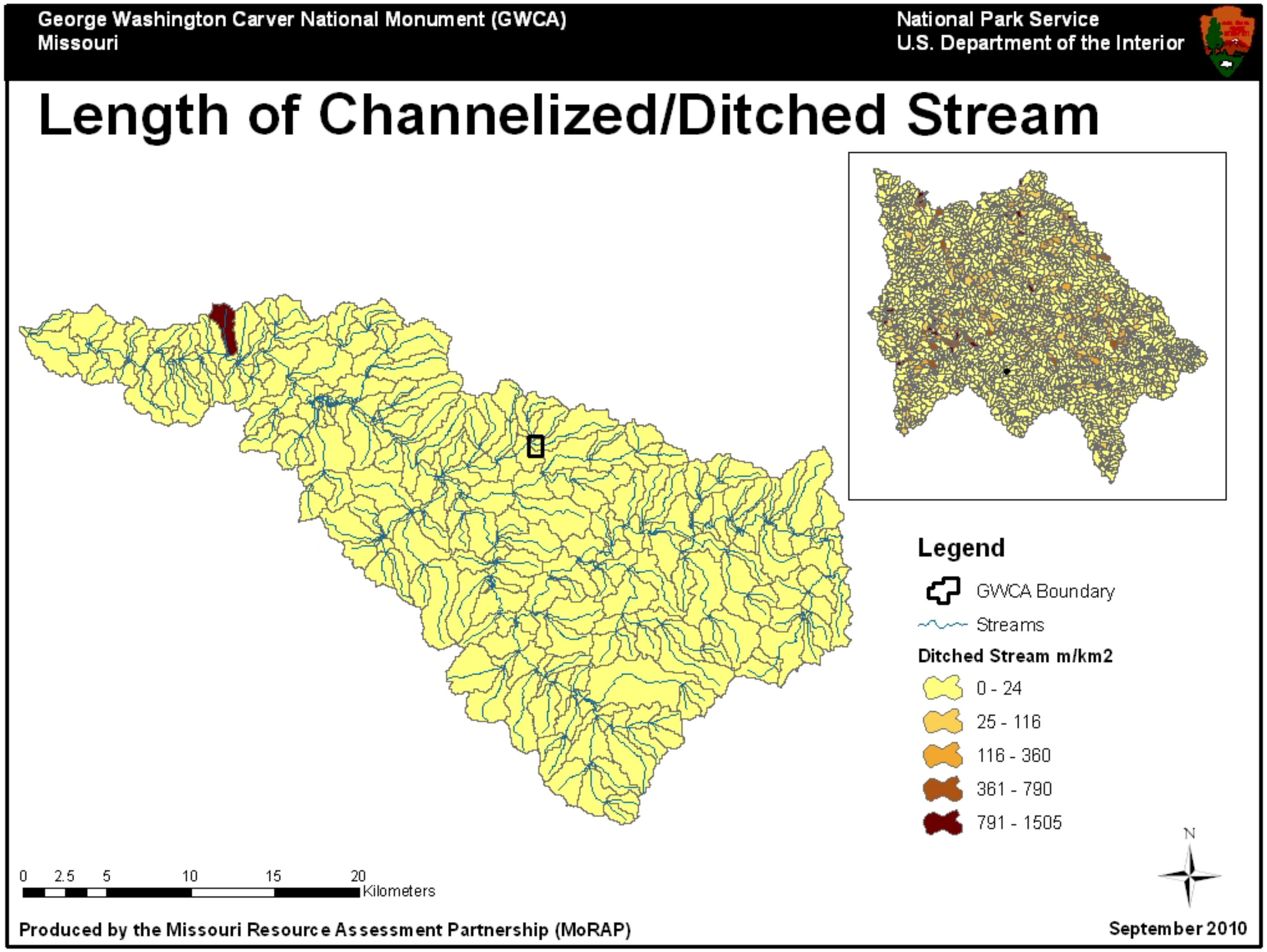

Figure A-17. Length of channelized/ditched streams above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

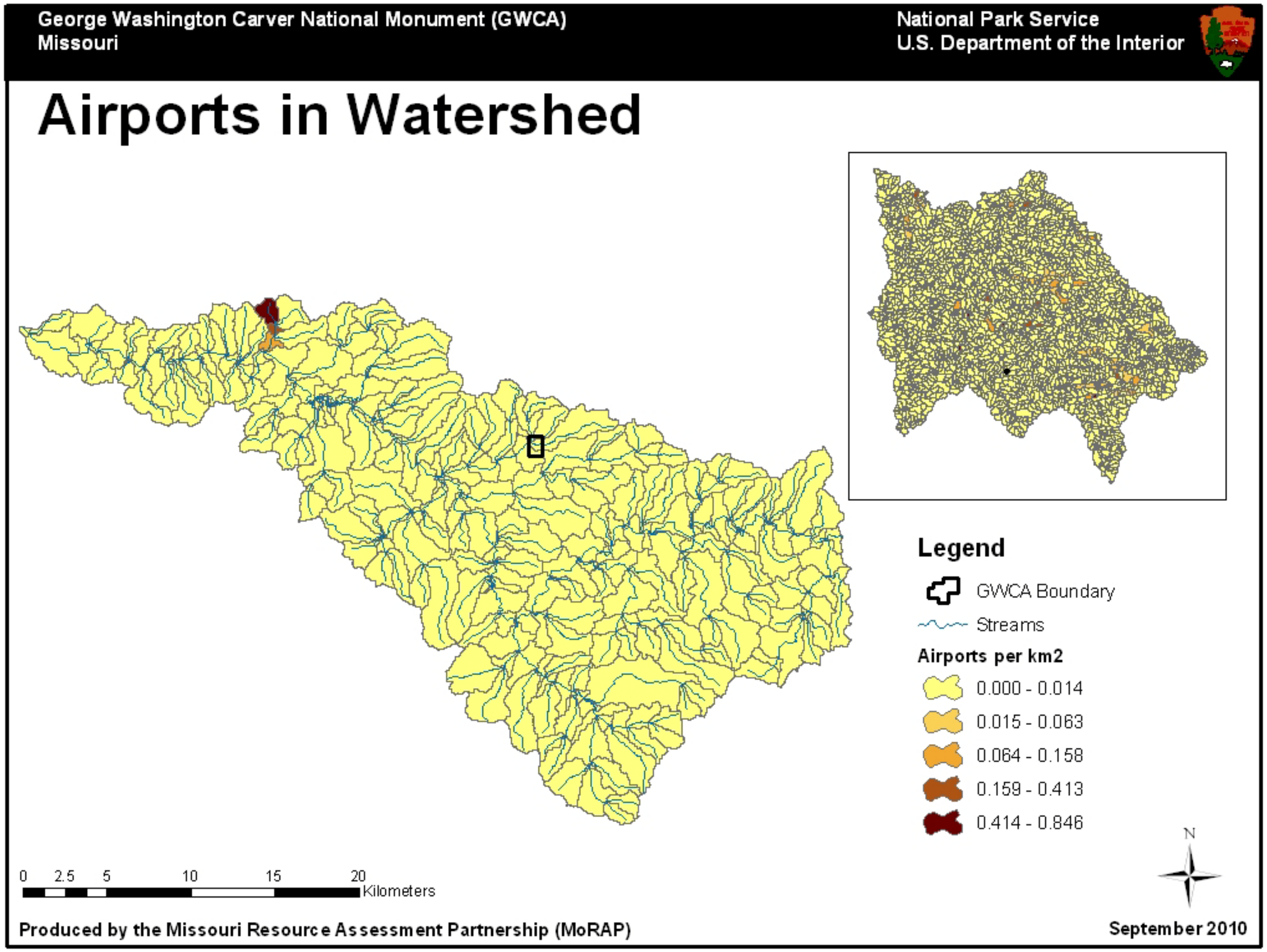

Figure A-18. Density of airports above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

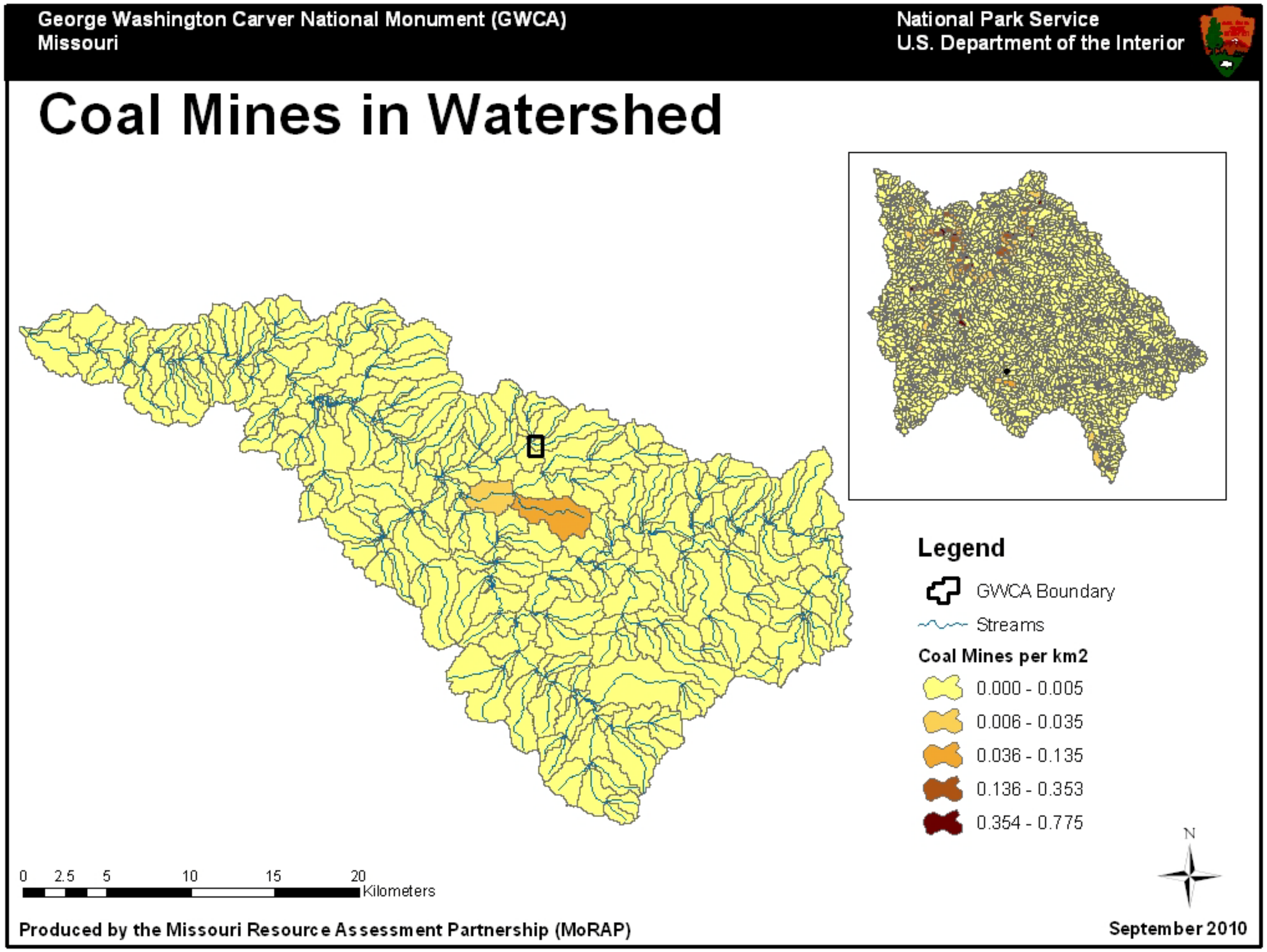

Figure A-19. Density of coal mines above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

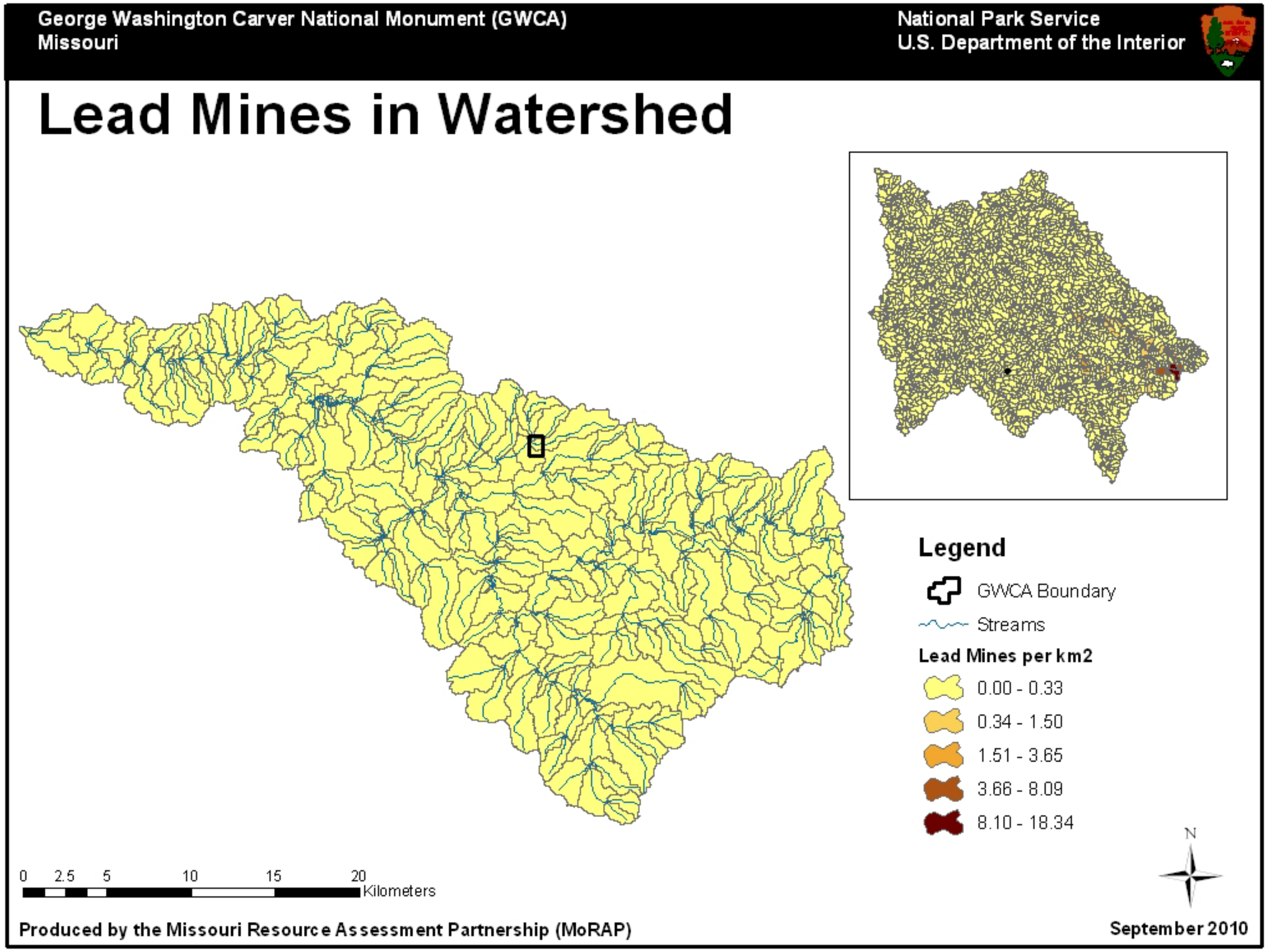

Figure A-20. Density of lead mines above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

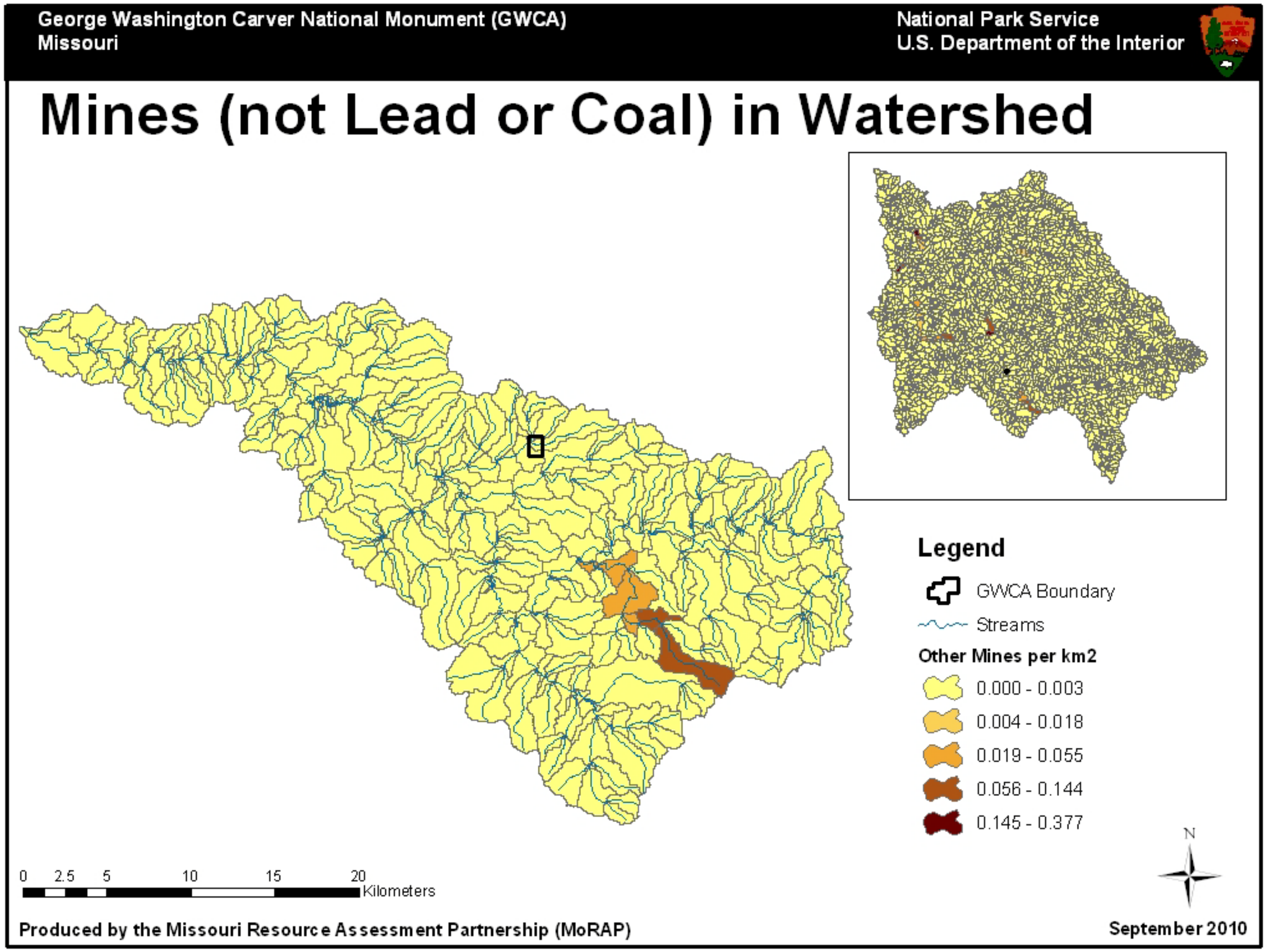

Figure A-21. Density of other mines above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

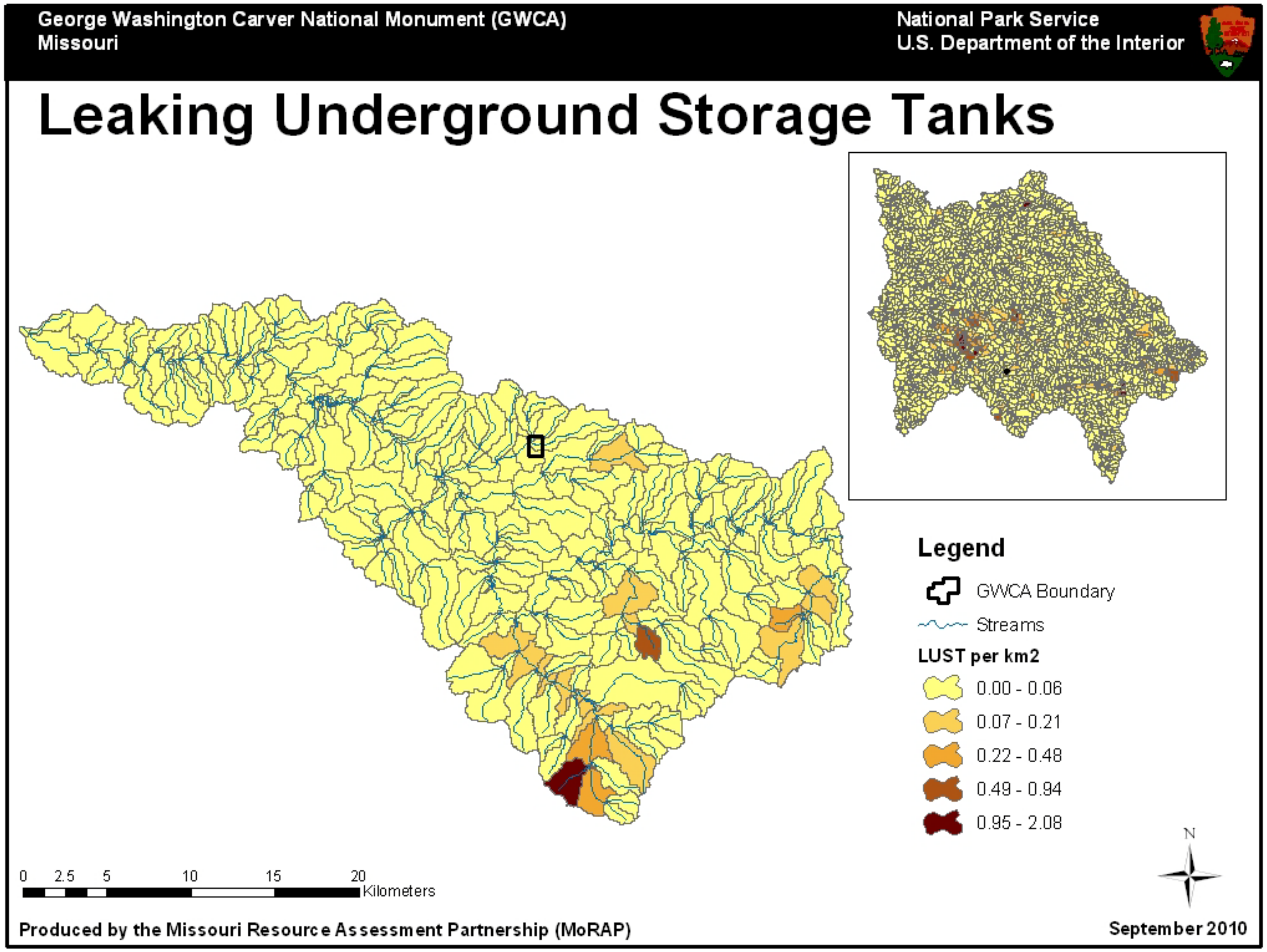

Figure A-22. Density of leaking underground storage tanks above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

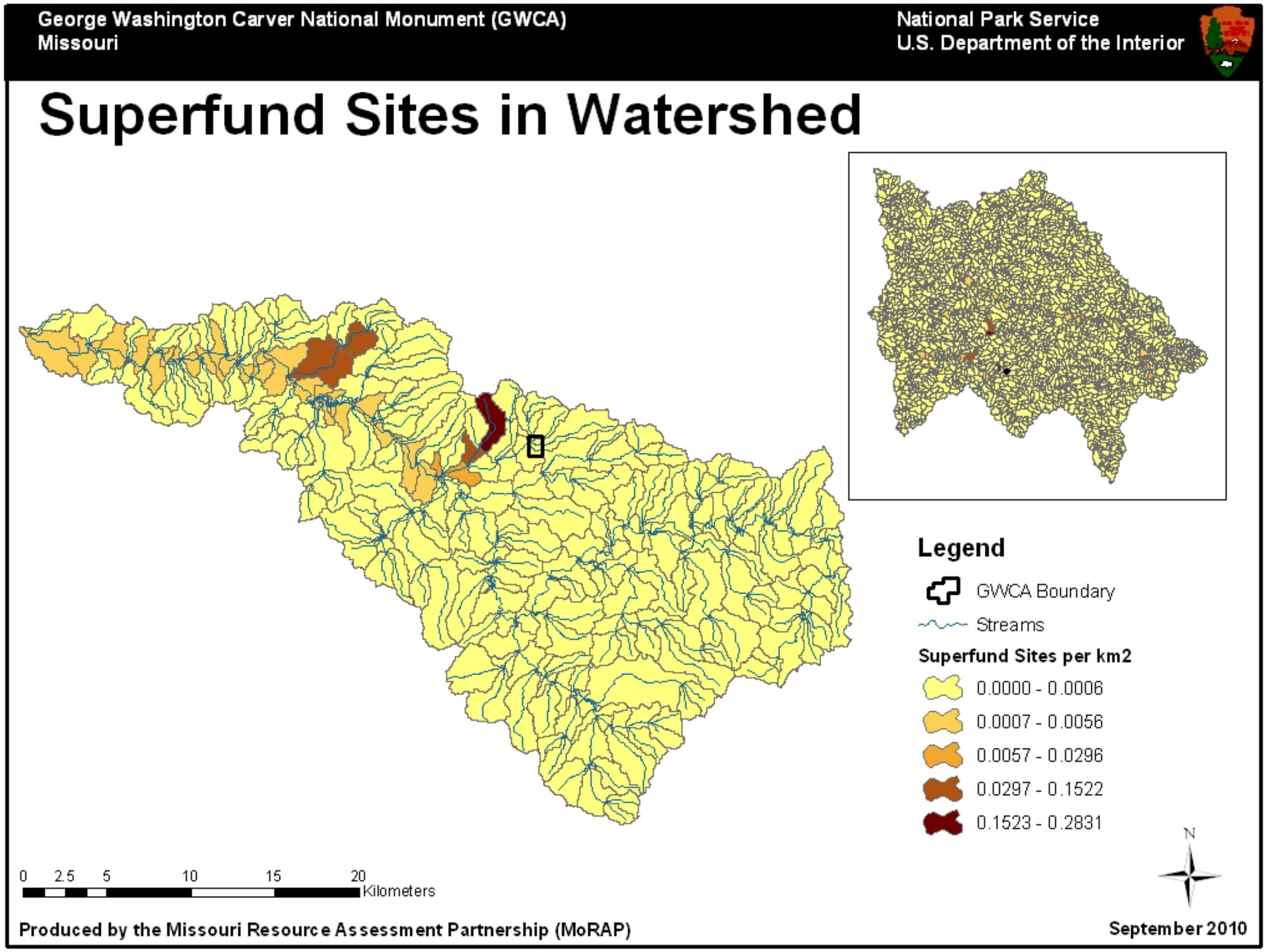

Figure A-23. Density of superfund sites above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

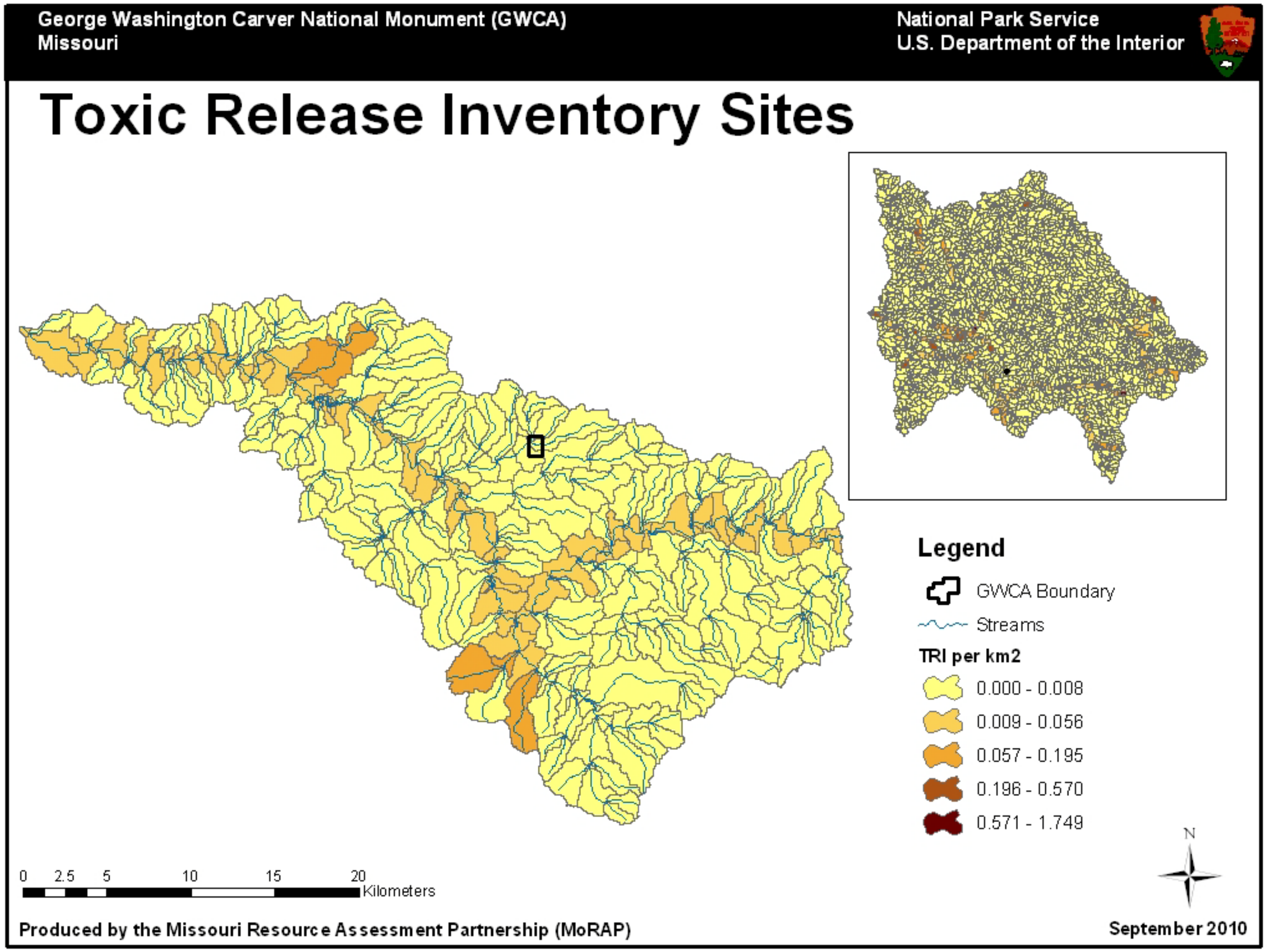

Figure A-24. Density of toxic release inventory sites above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

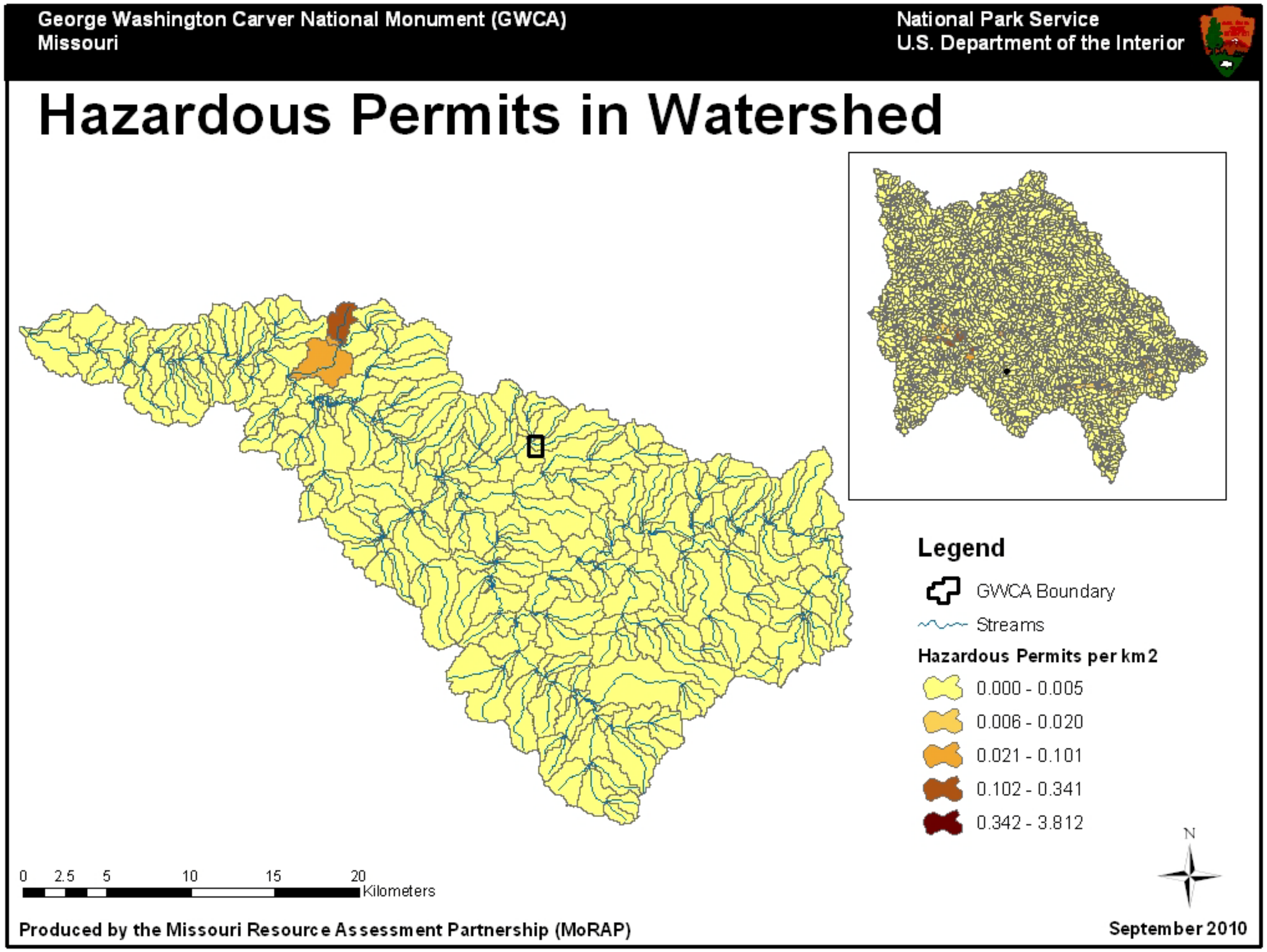

Figure A-25. Density of hazardous permits above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

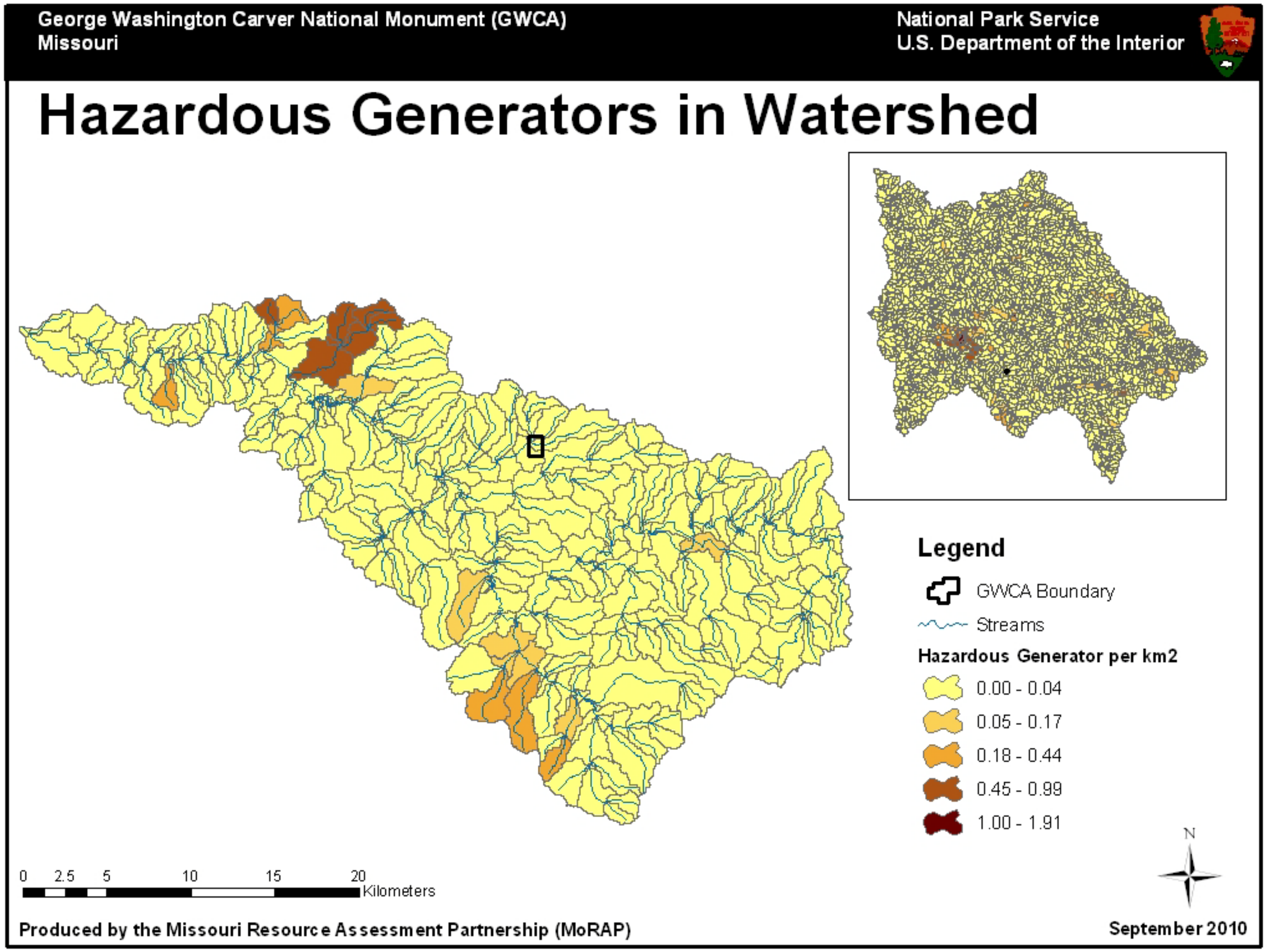

Figure A-26. Density of hazardous generators above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

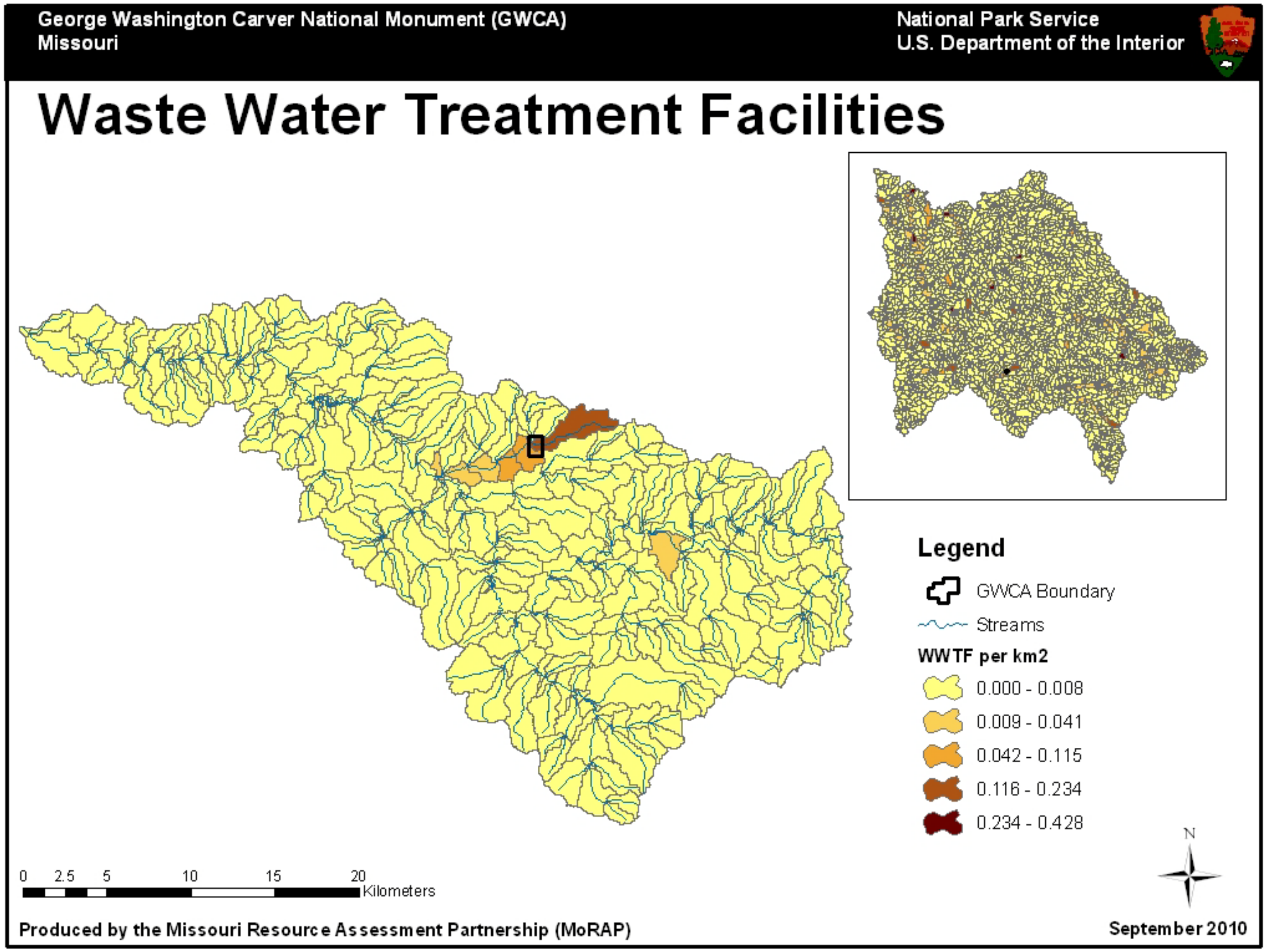

Figure A-27. Density of waste water treatment facilities above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

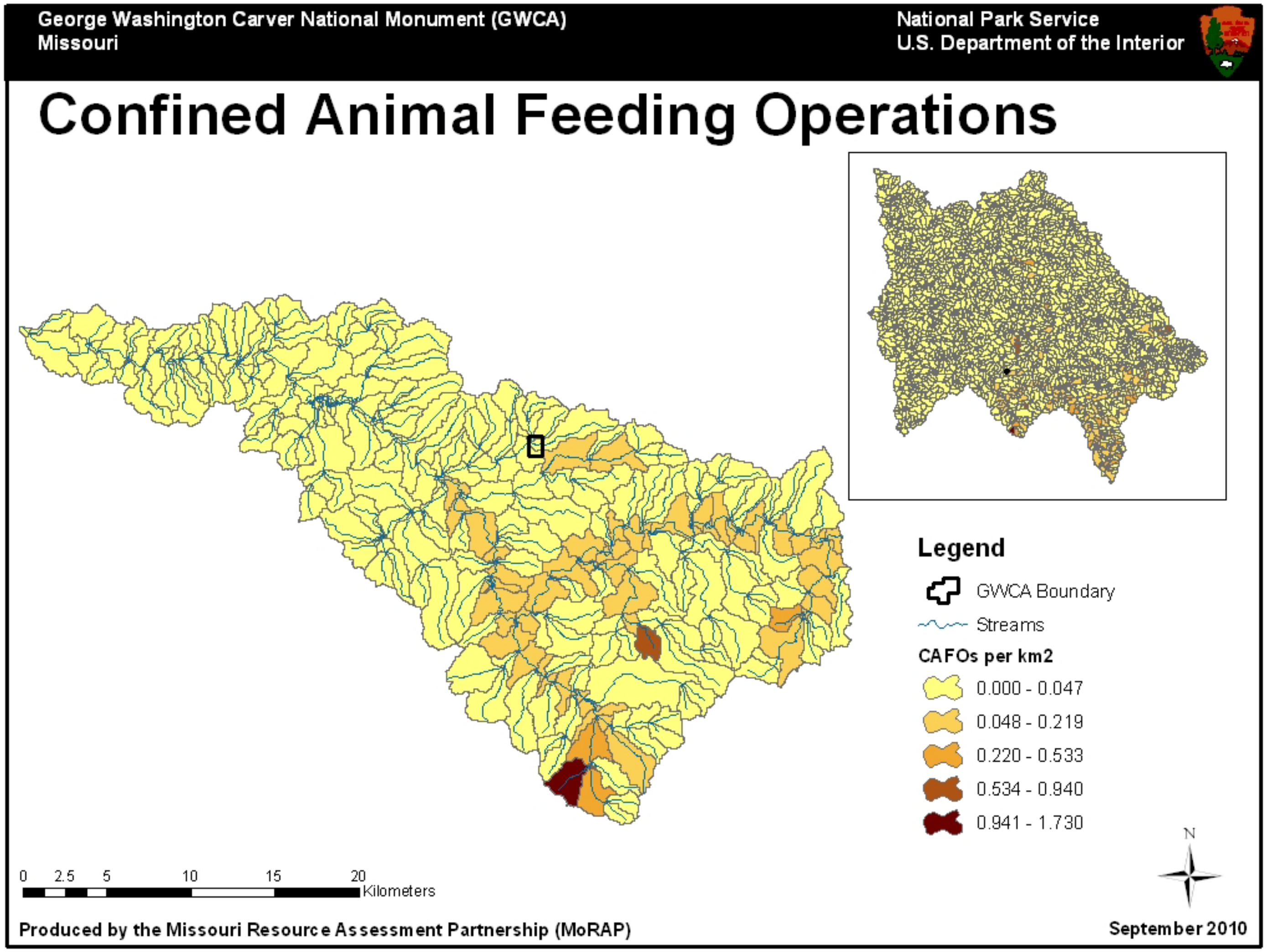

Figure A-28. Density of confined animal feeding operations above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

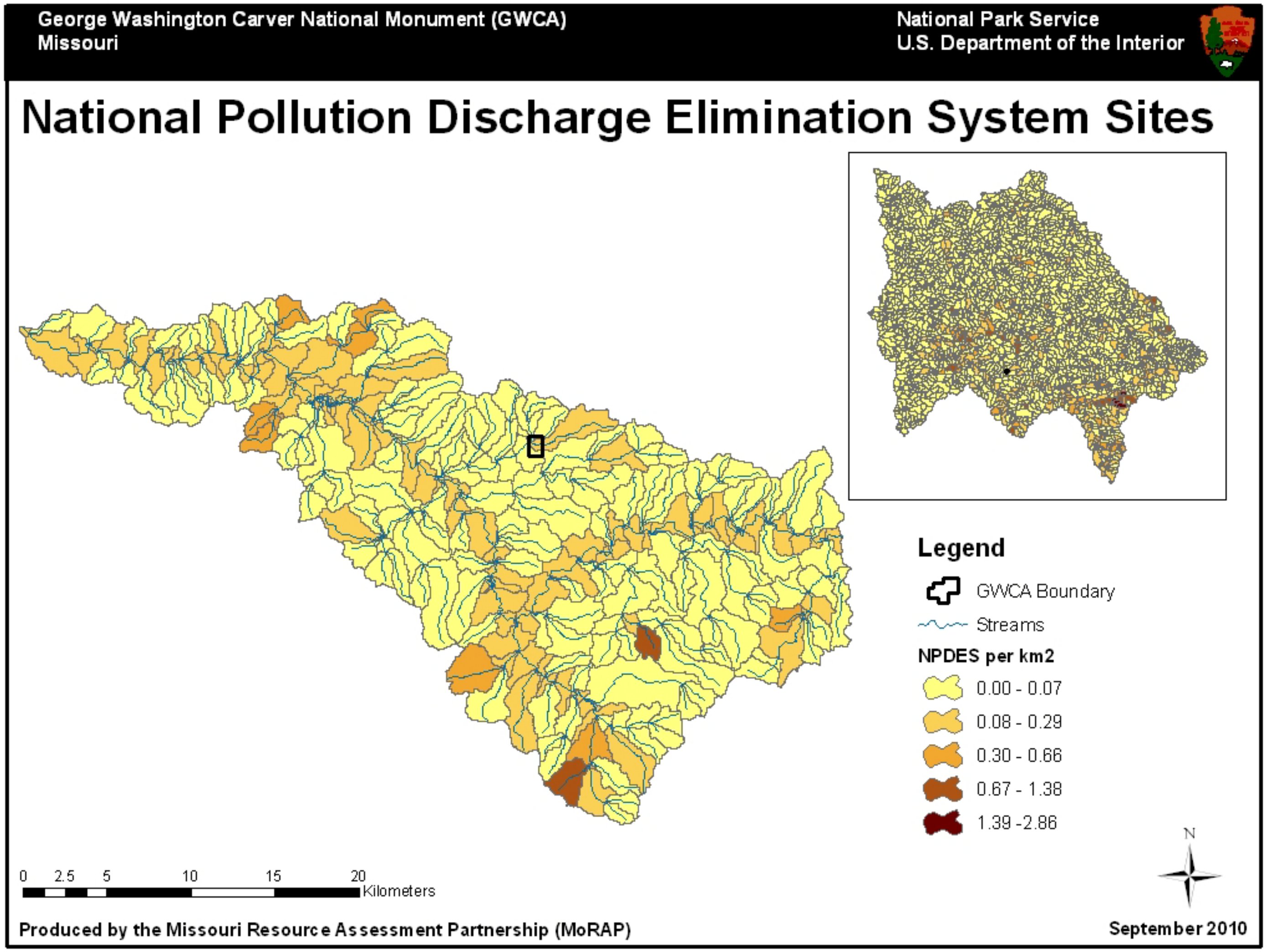

Figure A-29. Density of National Pollution Discharge Elimination System (NPDES) sites above every stream segment in the HUC 10 and HUC 8 (inset) for GWCA.

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

Reporting Unit / **Resource Type** / **Attribute**	**Current Condition**	**Reference/Target Condition**
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 George Washington Carver National Monument, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/193. National Park Service, Fort Collins, Colorado.	Targets represent 2008 baseline data collection. The goal is to maintain or enhance the breeding bird community.
Invasive exotic plant impact	Cr bbs, J.T., C.C. Young, J.L. Haack, and H.J. Etheridge. 2007. Invasive exotic plant monitoring at George Washington Carver National Monument: Year 1 (2006). Natural Resource Technical Report NPS/HTLN/NRTR—2007/017. 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.cfm	NPS (2007a) reports that wet deposition amounts of less than 1 kg/ha/yr do not cause ecosystem harm.
Upland grassland		
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.

Reporting Unit / Resource Type	Attribute	Current Condition	Reference/Target Condition
Woodland	Diversity and herbacous guild composition	James, K.M. and G.A. Rowell. 2009. Plant Community Monitoring Baseline Report, George Washington Carver National Monument. Natural Resource Technical Report NPS/HTLN/NRTR—2009/190. National Park Service, Fort Collins, Colorado. Habitat data from Peitz, D.G. 2009. Bird monitoring at George Washington Carver National Monument, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/193. National Park Service, Fort Collins, Colorado.	Professional judgement was used to set targets for a "semi-natural" prairie condition as opposed to the current successional state. Professional Judgement was informed by community descriptions in Appendix C.
	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 George Washington Carver National Monument, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/193. 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 C, 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	Current Condition	Reference/Target Condition
Regeneration	Habitat data from Peitz, D.G. 2009. Bird monitoring at George Washington Carver National Monument, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/193. 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 C, 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.
Herbacous guild composition	Habitat data from Peitz, D.G. 2009. Bird monitoring at George Washington Carver National Monument, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/193. 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). Total woody cover (understory) from Missouri Forest and Woodland Natural Community Profiles (http://mdc4.mdc.mo.gov/Documents/17524.doc, accessed: 10/15/2010).
Structure	Habitat data from Peitz, D.G. 2009. Bird monitoring at George Washington Carver National Monument, Missouri 2008 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/193. 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).

Reporting Unit / Resource Type / Attribute	Current Condition	Reference/Target Condition
Carver Creek, Williams Branch and Harkins Branch		
Water quality (medians)	Dodd, H.R., D.E. Bowles, and S.K. Mueller, and M.K. Clark. 2011. Fish community monitoring at George Washington Carver: 2006-2007, 2010 status report. Natural Resource Data Series NPS/HTLN/NRDS—2011/124. 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
Fish community		
Composition	Dodd, H.R., D.E. Bowles, and S.K. Mueller, and M.K. Clark. 2011. Fish community monitoring at George Washington Carver: 2006-2007, 2010 status report. Natural Resource Data Series NPS/HTLN/NRDS—2011/124. National Park Service, Fort Collins, Colorado.	Current data is compared to baseline data collected in 2006/2007 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	Dodd, H.R., D.E. Bowles, and S.K. Mueller, and M.K. Clark. 2011. Fish community monitoring at George Washington Carver: 2006-2007, 2010 status report. Natural Resource Data Series NPS/HTLN/NRDS—2011/124. 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. 2009. Aquatic invertebrate monitoring at George Washington Carver National Monument, 2005-2007 Report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/243. 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.

Appendix C Descriptions of Pre-European Vegetation Communities for George Washington Carver National Monument, Missouri

Descriptions of Pre-European Vegetation Communities for George Washington Carver National Monument, Missouri

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

Primarily associated with the Upland Grassland Reporting Unit
Dominant Species: big bluestem/prairie cordgrass-switchgrass
General Historical Vegetation: mesic tallgrass prairie
Ecological Land Types: Wet-Mesic Footslope/High Terrace Prairies; Wet-Mesic Low Floodplain Prairies
Ecological System: Southeastern Great Plains Tallgrass Prairie
Description: Herbaceous cover of this community is high (>80%) and woody cover is low (generally <10%). The herbaceous layer is dominated by tallgrass species such as *Andropogon gerardii* (big bluestem), *Panicum virgatum* (switchgrass), and *Spartina pectinata* (prairie cordgrass) and may be 4 to 7 feet tall. Graminoids such as *Tripsacum dactyloides* (eastern gamagrass), *Carex crus-corvi* (ravenfoot sedge), *Carex stipata* (awlfruit sedge), and *Carex oklahomensis* (Oklahoma sedge) may be conspicuous. Forbs and sedges form a sublayer of the herbaceous canopy and may include species such as *Helianthus grosseserratus* (sawtooth sunflower), *Eryngium yuccifolium* (rattlesnake master), *Potentilla simplex* (common cinquefoil), *Arnoglossum plantagineum* (groovestem Indian plantain), *Pediularis canadensis* (Canadian lousewort), *Lilium michiganense* (Michigan lily), *Veronicastrum virginicum* (Culver's root), *Lysimachia lanceolata* (lanceleaf loosestrife), *Liatris pycnostachya* (common water hemlock), *Teucrium canadense* (Canada germander), and *Eupatorium perfoliatum* (common boneset).

Primarily associated with the 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 Grassland Reporting Unit
Dominant Species: little bluestem/prairie dropseed-big bluestem
General Historical Vegetation: bluestem prairie
Ecological Land Type: Chert Upland Prairie
Ecological System: Southeastern Great Plains Tallgrass Prairie
Description: This community is characterized by a grass and forb cover of greater than 85%, reaching a height of 3 to 6 feet tall. Woody cover is low (generally <10%). Grasses dominate this community with species such as *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (yellow Indiangrass), *Andropogon gerardii* (big bluestem), and *Sporobolus heterolepis* (prairie dropseed) dominant among the grasses. Other graminoid species that may be present to co-dominant include *Danthonia spicata* (poverty grass), *Dichanthelium acuminatum* (tapered rosette grass), *Dichanthelium oligosanthes* var. *scribnerianum* (Scribner's panic grass), *Isolepis carinatus* (keeled bulrush), *Fimbristylis puberula* (hairy fimbry), *Carex meadii* (Mead's sedge), and *Andropogon virginicus* (broomsedge). Forbs are generally present in this community, usually having a cover of <40%. Forb species characteristic of this community may include *Callihroe digitata* (fringed poppy mallow), *Silene regia* (royal catchfly), *Vernonia arkansana* (Arkansas ironweed), *Silphium laciniatum* (compass plant), *Echinacea pallida* (pale purple coneflower), *Pycnanthemum tenuifolium* (slender mountain mint), *Tephrosia virginiana* (goat's rue), *Coreopsis palmata* (finger coreopsis), *Comandra umbellata* (bastard toadflax), and *Helianthus mollis* (ashy sunflower) among many others. Shrubs that may be encountered include *Rubus* spp. (blackberry), *Rhus copallinum* (shining sumac), and *Rosa carolina* (pasture rose), but cover for these species should be low.

Primarily associated with the Upland Grassland Reporting Unit
Dominant Species: post oak/chinquapin oak-bluestem
General Historical Vegetation: post oak-bluestem prairie or savanna
Ecological Land Type: Loess Over Residuum Upland Prairies and Savannas
Ecological System: Ozark-Ouachita Dry Oak Woodland
Description: Overstory canopy consists of trees 30 to 60 feet tall, with a canopy cover less than 30%, and trees may have been nearly absent across large patches (>50 ha) of the landscape. Dominant overstory canopy species include *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), *Quercus velutina* (black oak), and *Carya texana* (black hickory). On more alkaline soils (loess over limestone/dolomite), species such as *Quercus muehlenbergii* (chinquapin oak), *Fraxinus americana* (white ash), and *Juniperus virginiana* (easter redcedar) are more common. The shrub layer is generally sparse (<25%) with species such as *Amorpha canescens* (lead plant), *Ceanothus americanus* (New Jersey tea), and *Rosa carolina* (pasture rose). Shrubs on more alkaline sites may include *Rhus aromatica* (fragrant sumac), and *Frangula*

caroliniana (Carolina buckthorn). The herbaceous layer is variable, depending on local overstory canopy conditions (70 to 100% cover). The herbaceous layer is consistent with the description for **Chert Upland Prairie** and includes species such as *Andropogon gerardii* (big bluestem), *Sorghastrum nutans* (yellow Indiangrass), and *Schizachyrium scoparium* (little bluestem). Forbs encountered in this community include species such as *Liatris squarrosa* (scaly blazing star), *Liatris aspera* (tall blazing star), *Helianthus occidentalis* (fewleaf sunflower), *Cunila origanoides* (common dittany), and other species of the surrounding prairie.

Primarily associated with the Woodland 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 *Ulmus americana* (American elm), with *Quercus alba* (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) also present. 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).

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