National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment
Richmond National Battlefield Park, Virginia

Natural Resource Report NPS/NER/NRR—2012/548

ON THE COVER
All images are from Richmond National Battlefield Park. Clockwise from left, a warm-season grass meadow at Gaines' Mill, marbled salamander (*Ambystoma opacum*), and prescribed fire activity for grassland/cultural meadow management.
Photographs by: Kristen Allen, Richmond National Battlefield Park.

Natural Resource Condition Assessment Richmond National Battlefield Park, Virginia

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

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM).

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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.16) for more information.

Executive Summary

The goal of this assessment is to provide an overview of natural resource condition status to allow Richmond National Battlefield Park (NBP) to effectively manage National Park Service (NPS) trust resources through Resource Stewardship Strategies (RSS) and General Management Plans. An ancillary benefit is that it will aid the park in meeting government reporting requirements, such as the land health goals under the Government Performance Results Act (GPRA).

This assessment is based on existing data and information from natural resource managers at Richmond NBP and the Mid-Atlantic Inventory and Monitoring Network. A natural resource assessment should provide a concise, understandable, and accurate summary of the condition of the ecological system. Reporting on this ecological condition will provide for better decision-making at the park level. Thus, collaborating with decision-makers was an important part of this project.

The natural resources evaluated in this assessment were landscape dynamics, vegetation communities, wetland and riparian resources, biological integrity, water resources, and park-wide resources such as soils, air quality, visitor use, viewscape, and soundscape. Precise measurements and objective analysis are preferred for assessing the condition of natural resources. Wherever possible, we used quantitative data and established thresholds, but in some cases only qualitative measures were available to rate important categories. Rather than remove these categories all together, we simply reported on the type of data that was available and the methods used to compare these data to a desired condition. In all cases, straightforward tables, charts, maps, and geospatial data are provided to summarize findings.

Based on available data, the majority of resources at Richmond NBP appear to be in good condition. One exception is the amount of exotic plant species detected at established forest monitoring plots. Recent and consistent water quality data within the park is the most striking data gap. Though data were not available for this assessment, MIDN I&M network began monthly water quality monitoring in 2010. Current data gaps also include soil chemistry and acidity, impact of visitor use on natural resources, and population trends of faunal species. The MIDN network began assessing forest soil chemistry and acidity in the forest vegetation monitoring plots in 2011, although data was not available for this assessement.

In-park threats and stressors include habitat degradation by exotic plant species. Outside park stressors include high density residential and commercial development, industrial and agricultural runoff, and concerns regarding air quality, particularly atmospheric deposition.

Acknowledgments

This project would not have been possible without the help of personnel from Richmond National Battlefield Park, NPS Northeast Region, Mid-Atlantic Network, Natural Resource Program Center, and various departments at Virginia Tech. We would like to thank the following people for their contribution to this assessment effort:

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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.

Abbreviations

AQI	Air Quality Index
BBS	Breeding Bird Survey
BDC	Beaver Dam Creek
BOD	Biological Oxygen Demand
C-CAP	Coastal Change Analysis Program
CB	Chickahominy Bluff
CH	Cold Harbor
CM	Chimborazo Medical Museum
DCR	Department of Conservation and Recreation
DEM	Digital Elevation Model
DEQ	Department of Environmental Quality
DNH	Department of Natural Heritage
DNR	Department of Natural Resources
DO	Dissolved Oxygen
DB	Drewry's Bluff (Fort Darling)
DRG	Digital Raster Graphic
EPA	Environmental Protection Agency
EPD	Environmental Protection Division
ESRI	Environmental Systems Research Institute
FH	Fort Harrison
GM	Gaines' Mill
GAP	Gap Analysis Program
GDD	Growing Degree Days
GeoMAC	Geospatial Multi-Agency Coordination Group
GIS	Geographic Information System
GMP	General Management Plan
GPRA	Government Performance Results Act
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
I&M	Inventory and Monitoring
MH	Malvern Hill
MIDN	Mid-Atlantic Network
NAIP	National Agriculture Imagery Program
NBP	National Battlefield Park
NESDIS	National Environmental Satellite, Data, and Information Service
NHD	National Hydrologic Data
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NTCHS	National Technical Committee for Hydric Soils
NWI	National Wetlands Inventory
PAHs	Polycyclic Aromatic Hydrocarbons
PB	Parker's Battery

PPM	Parts per million
RICH	Richmond National Battlefield Park
RSS	Resource Stewardship Strategies
SCP	Southern Coastal Plain
SERCC	Southeast Regional Climate Center
SGCN	Species of Greatest Conservation Need
SSURGO	Soil Survey Geographic
TC	Totopotomoy Creek
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA	Virginia
VaFWIS	Virginia Fish and Wildlife Information Service
VBMP	Virginia Base Mapping Program
VDGIF	Virginia Department of Game and Inland Fisheries
VSCI	Virginia Stream Condition Index

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 for more information.

1.0 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, 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 logical reference conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the

[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

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

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")

[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products

[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status, per se, for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings 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 describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist in selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

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 some of a park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

> Important NRCA Success Factors …
>
> Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline
>
> Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)
>
> Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures.[8]

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

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

Resource Stewardship Planning and Science

Richmond NBP is part of the NPS Mid-Atlantic Network Inventory and Monitoring (I&M) Program. The Inventory and Monitoring program was established in 1992 to complete biological inventories for all parks with significant natural resources and establish ongoing monitoring programs in select parks. In 1998, the program grew and 32 networks were established to investigate "long-term trends in the condition of National Park System resources" (National Park Service 2009a). The Mid-Atlantic Network has completed basic inventories of major vertebrate taxa and plant communities. In consultation with park staff and their Science Advisory board, the Mid-Atlantic Network chose 43 "vital signs" as indicators of overall health of park resources (Comiskey and Callahan 2008). The 43 vital signs were ranked and 20 are being implemented in a priority order, beginning with 16 that will be implemented in the next three to five years. These vital signs are:

Air and Climate
- Ozone
- Wet and dry deposition
- Visibility and particulate matter
- Air contaminants (mercury)
- Weather and Climate

[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 accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget

Geology and Soils

- Stream / river channel characteristics
- Soil structure and composition

Water

- Stream and river water dynamics
- Water chemistry
- Aquatic macroinvertebrates

Biological Integrity

- Invasive exotic plants
- Native forest pests
- Exotic diseases / pathogens – plants
- Forest plant communities
- White tailed deer (herbivory)
- Breeding birds

Study Approach

Richmond NBP personnel, NPS Northeast Region scientists, and Mid-Atlantic Inventory and Monitoring Network scientists were involved at the early stages of this assessment. A preliminary scoping meeting took place at Richmond NBP on March 17, 2010. At this meeting, we introduced the Natural Resource Condition Assessment program as a whole. The main portion of the meeting was dedicated to the discussion of significant natural resources, threats and stressors to the resources, ongoing programs, issues, conflicts, concerns, and specific indicators and measures of natural resource health (i.e. I&M vital signs). We followed this with a discussion of regional setting and study areas (spatial levels, hydrologic units, and ecological communities). Ideas and discussions from this meeting were then further refined and shared via e-mail. We integrated comments and began analysis and report formulation. A draft report was available in July. Input from reviews by NPS staff will be integrated into a final draft.

The National Park Service (NPS) monitors their natural resources using an ecological monitoring framework that has been widely used among other agencies (Fancy et al. 2009). There are six basic level 1 categories: 1) air and climate; 2) geology and soils; 3) water; 4) biological integrity; 5) human use; and 6) ecosystem pattern and processes. We found the NPS categories to be uncomplicated and intuitive. This framework is also familiar to NPS personnel and will allow the users to compare current vital sign monitoring plans to this assessment. We have organized this assessment by ecosystem resource to be most useful for park personnel.

Each section contains a brief description of the resources, past and current inventory and monitoring efforts, and threats and stressors. We identified the major threats and stressors in each section to help guide us in developing a framework and choosing appropriate indicators for the assessment. For each category assessed, we identified indicators and measures from our preliminary scoping meeting with NPS personnel and follow-up communication.

The current value of each measure was recorded and compared to documented reference values. Reference values were obtained from the NPS, federal standards (e.g. EPA, USGS), state standards (e.g. VA DEQ, DNR), primary research, or our scoping meeting (Table 1). These

Table 1. Data sources for indicators and measures.

Level 1 Category	Attribute	Vital Sign/Indicator	Data Source
Landscape Dynamics			
	Land Cover	Percent forested riparian buffer within park	NPS vegetation map (Patterson 2008), RICH data
		Percent total forest cover within park	RICH data
		Natural vegetation within park comparison to other conservation areas within subbasin	2001 NLCD (USGS 2001)
	Land Use	Impervious surface within park	2001 NLCD
		Housing density	NPScape
		Converted land cover	NPScape
		Population density	NPScape
Vegetation Communities			
	Forest Health	Species Composition	MIDN I&M data
		Land cover	Patterson 2008; 2001 NLCD (USGS 2001)
		Key forest bird species	Bradshaw (2007)
		Native forest pests	MIDN I&M data
		Invasive exotic plants	MIDN I&M data, RICH data (2005), Forder (2011)
		Soil structure and composition	Ecological Integrity Reporting SOP NETN (Version 3.09)
		White-tailed deer density	RICH data
	Grassland Integrity	Species Composition	Forder (2011)
		Proportion of plot cover	Forder (2011)
		Species count	Forder (2011)
		Key grassland bird species	Bradshaw (2007)
		Soil structure and composition	Ecological Integrity Reporting SOP NETN (Version 3.09)
Wetland/Riparian Resources			
		Extent of wetlands	2001 NLCD (USGS 2001)
		Surrounding land use index	2002 NPS vegetation map; 2001 NLCD (USGS 2001); Faber-Langendoen (2009)
		Landscape connectivity	2002 NPS vegetation map; 2001 NLCD (USGS 2001); Faber-Langendoen (2009)
		Buffer index	2002 NPS vegetation map; 2001 NLCD (USGS 2001); Faber-Langendoen (2009)
Air and Climate			
Air Quality	Ozone	8-hour average O_3 concentration	Clean Air Status and Trends Network (CASTNet) and Gaseous Pollutant Monitoring (GPMN); NPS (2009)
	Atmospheric Deposition	Sulfur deposition	National Atmospheric Deposition Program (NADP)
		Nitrogen deposition	NADP (University of Illinois at Urbana-Champaign 2009); NPS (2009)
	Visibility	Haze index (deciviews)	Interagency Monitoring of Protected Visual Environments (IMPROVE) (Colorado State University 2009); NPS (2009)
	Mercury	Total mercury in precipitation	Mercury Deposition Network (MDN), a NADP Network (NADP 2009)

Level 1 Category	Attribute	Vital Sign/Indicator	Data Source
Water			
Hydrology	Hydrology	Flow	USGS (2009c)
Water Quality	Stream Condition	Dissolved oxygen	RICH data, USGS (2009c), VA DEQ (2008, 2009)
		pH	RICH data, USGS (2009c), VA DEQ (2008, 2009)
		Temperature	RICH data, USGS (2009c), VA DEQ (2008, 2009)
		Bacterial (fecal coliform)	RICH data, USGS (2009c), VA DEQ (2008, 2009)
		Bacterial (E. coli)	RICH data, USGS (2009c), VA DEQ (2008, 2009)
		Conductivity	RICH data, USGS (2009c), VA DEQ (2008, 2009)
		Turbidity	RICH data, USGS (2009c), VA DEQ (2008, 2009)
	Macroinvertebrates	CPMI	RICH data (2003-2009)
Biological Integrity			
Focal Taxa	Fish	Jaccard's Index of Similarity	RICH species list (NPS 2010), Atkinson (2008)
	Amphibians	Jaccard's Index of Similarity	RICH species list (NPS 2010), reference list from Mitchell (2007)
	Reptiles	Jaccard's Index of Similarity	RICH species list, reference list from Mitchell (2007)
	Birds	Jaccard's Index of Similarity	RICH species list (NPS 2010), BBS data for Coastal Plain (USGS 2009b)
		Community trends	BBS data for Coastal Plain
	Mammals	Jaccard's Index of Similarity	RICH species list (NPS 2010), reference list from Barry and Sareen (2008)

values were then used in determining the overall condition status for the category) by assigning a midpoint to each indicator based on the condition status rating. The midpoints were then averaged to provide an overall condition status for each level 1 category. Summary tables are provided at the conclusion of each chapter.

In addition, we provided a data quality rating based on three categories, *thematic*, *spatial*, and *temporal* (). We gave *thematic* a 1 or 0 (yes or no) based on whether these data were from the best available source. Ratings for thematic data varied by each case and are explained in the corresponding section. *Spatial* received a 1 or 0 based on the spatial proximity of these data (in-park data or out-of-park data). We also gave *temporal* a 1 or 0 based on how recently these data were acquired. *Temporal* was somewhat dependent on data type, but generally, if the data were from the last five years, they received a 1. The data quality values were averaged, and an overall rating is given for the data quality (good = 2.67 to 3; fair = 1.34 to 2.66; and poor = 0 to 1.33). We provide access to these scores in spreadsheets to view calculations, update data, and modify importance ratings as management goals change. Data quality tables for each resource are listed in Appendix A.

2.0 Park Resource Setting

Richmond NBP is located in central Virginia, approximately 161 km (100 mi) south of Washington D.C. Richmond National Battlefield Park (NBP) consists of over 2,300 ac divided among 13 separate park units within the City of Richmond, and three surrounding counties (Henrico, Hanover, and Chesterfield). These units fall near the divide between Coastal Plain and Piedmont of Virginia and are bounded by the Pamunkey River, James River, and Middle Chickahominy River watersheds.

Richmond NBP is one of five parks of the National Park System commemorating and preserving battlefields of the 1864-1865 United States Civil War campaigns in Virginia. The park protects and interprets resources associated with the siege of Richmond, the Confederate capital during the Civil War, and the many Civil War battles fought in the vicinity of Richmond, Virginia.

The Chimborazo Park unit contains a visitor center and administrative offices and is the only park owned unit within the city of Richmond. The remaining units lie north, east, and south of the city, in Henrico, Hanover, and Chesterfield counties. Lands surrounding park boundaries are primarily residential developments, industrial, rural homes and farmland. In 2009, over 134,000 people visited Richmond NBP (National Park Service 2009b).

Richmond NBP was established during Franklin D. Roosevelt's administration on March 2, 1936. The park's many units protect Civil War battlefield sites around Richmond, Virginia, the Confederate capital city.

The park commemorates four major actions of the U.S. Civil War:

1. the 1862 Seven Days Campaign, June 26 – July 1, 1862 encompassing Beaver Dam Creek, Gaines' Mill, Glendale (Frayser's Farm) and Malvern Hill;
2. a portion of the 1864 Overland Campaign, May 28 – June 13, 1864, including Totopotomoy Creek and Cold Harbor;
3. May 15, 1862 naval action at Drewry's Bluff;
4. and actions along the Richmond-Petersburg front, September 29, 1864 -April 2, 1865, encompassing Fort Harrison, New Market Heights, Deep Bottom and Parker's Battery (National Park Service 2010).

Regional Land Use History

Chesterfield County

In 1831 the first railroad in Virginia, called the Chesterfield Railroad, was built allowing the transport of coal from mines near Falling Creek to the head of the of navigation of the James River. Further rail lines in the Richmond and Danville areas played key roles during the Civil War (Chesterfield County 2010). Tobacco was first cultivated in America in Chesterfield County in 1612. The estimated 2008 population of Chesterfield County was 311,000, a growth of over 53,000 since 2000 (U.S. Census Bureau 2009). According to the Virginia Department of Forestry in 2006, 53% of Chesterfield County was considered forested. Between 1957 and 2006, there was a 24% decline in forestland in the County. Pocahontas State Park, Presquille National

Wildlife Refuge, and County parks and conservation areas are the primary government landowners.

Hanover County

In 2009, Hanover County's population was estimated to be 99,933. Forty percent of the county is designated as a Rural Conservation Area. In addition, Hanover has 34 nationally registered historic sites. The county's comprehensive plan predicts an average annual growth rate of 1.5-2.5% through 2027 (Hanover County 2010). From 2000 to 2009, the county grew by approximately 15.8%, from a population of 86,320 to 99,933.

Henrico County

Most of the land in Henrico County is classified as vacant which includes agricultural use. The amount of land classified as vacant has been decreasing: at the end of 1990, sixty-one percent (61%) of the county was classified as vacant; by the end of 2006, this figure stood at fifty-one percent (51%). Vacant land includes areas in flood plain, wetlands, and other sensitive land. Not all vacant land can be developed. The second largest land use category, by acreage, is single-family residential (Henrico County 2009). Henrico County has an average annual population increase of about 2%. From 2000 to 2009, the county grew by approximately 13%, from a population of 262,210to 296,415.

Study Areas

Based on input from NPS personnel, we chose to assess the condition of each individual unit (see Table 2). Where data was available, measures and indicators were used for specific units within Richmond NBP. A brief description of each unit follows:

Table 2. Units of Richmond National Battlefield Park.

Unit	Acres	Watershed
Beaver Dam Creek	271.19	Middle Chickahominy River
Chickahominy Bluff	38.88	Middle Chickahominy River
Chimborazo	6.02	James River - Falling Creek
Cold Harbor	184.00	Middle Chickahominy River
Drewry's Bluff	36.29	James River - Falling Creek
Fort Harrison	322.04	James River - Falling Creek
Gaines' Mill	60.35	Middle Chickahominy River
Garthright House	2.09	Middle Chickahominy River
Malvern Hill	1062.76	James River - Falling Creek
Parker's Battery	10.09	James River - Falling Creek
Totopotomoy Creek (Rural Point)	143.80	Middle Chickahominy River
Turkey Hill	174.72	Middle Chickahominy River

Totopotomoy Creek (Rural Point)

Totopotomoy Creek consists of 143 ac, with approximately 25 ac in an agriculture lease (Figure 1). A house dating back to the 1720's is on the property along with a plant nursery that dates back to the 1920's. The unit is bounded by a housing development to the east and Totopomoy Creek to the south and west. It contains a large powerline right of way adjacent to the creek and is managed in meadow vegetation by Dominion Virginia Power.

Figure 1. Totopotomoy Creek aerial view (NAIP 2009).

Chickahominy Bluff (CB)

Chickahominy Bluff (38.8 ac) is a primarily forested area (Figure 2).The northern half of this unit is dominated by a forested wetland, with species including cypress, maple, blackgum, and scattered upper canopy loblolly pines. Residential developments surround this property. Chickahominy Bluff contains the highest point of all units (52 m) (Patterson 2008). Encroaching development is the largest threat to the persistence of biodiversity at this site (Patterson). Chickahominy Bluffs, along with Beaver Dam Creek, contain the forested areas of most concern at Richmond NBP.

Figure 2. Chickahominy Bluff aerial view (NAIP 2009).

Beaver Dam Creek (BDC)

This larger unit (271 ac) is dominated by emergent wetlands and is mostly inaccessible (Figure 3). Atkinson (2008) found a diverse fish community in Beaver Dam Creek. This unit is threatened by encroaching exotics and dense residential development. Along with Chickahominy Bluffs, Beaver Dam Creek contain the forested areas of most concern at RICH (Patterson 2008). Beaver Dam Creek harbors an excellent nontidal wetland, with both emergent and forested components. Although small, this habitat is critical to many species (Bradshaw 2007).

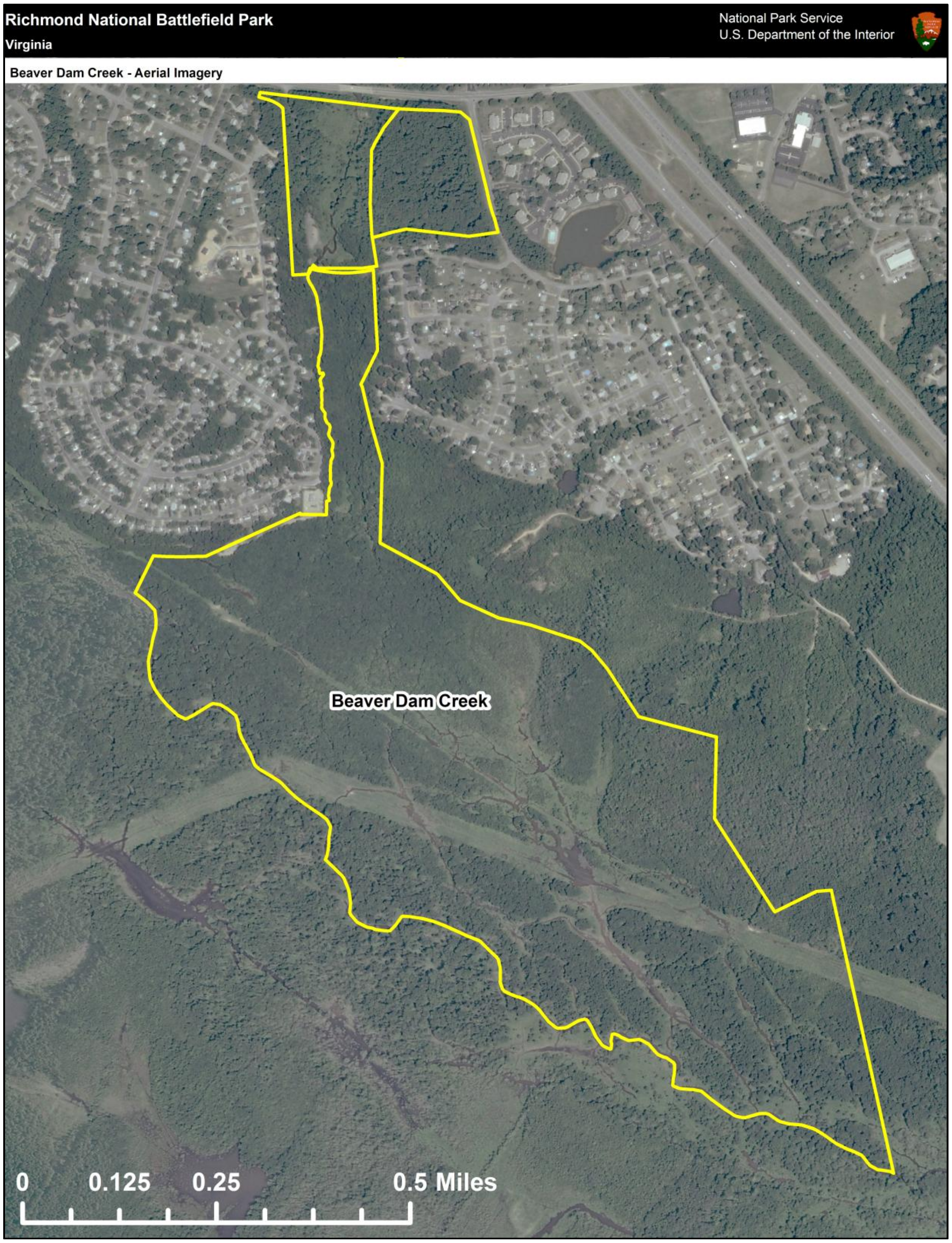

Figure 3. Beaver Dam Creek aerial view (NAIP 2009).

Gaines' Mill (GM)

This 60-ac unit is mostly comprised of older mixed forest with meadows and is bounded by agriculture fields to the north (Figure 4). The upland forest is a mixture of mature oaks, beech, and tulip poplar with mature loblolly pines on the higher slopes (Bradshaw 2007). The stream that runs along the northern border of this unit creates approximately two acres of wetland habitat. Agriculture runoff nearby has been found to impact the stream.

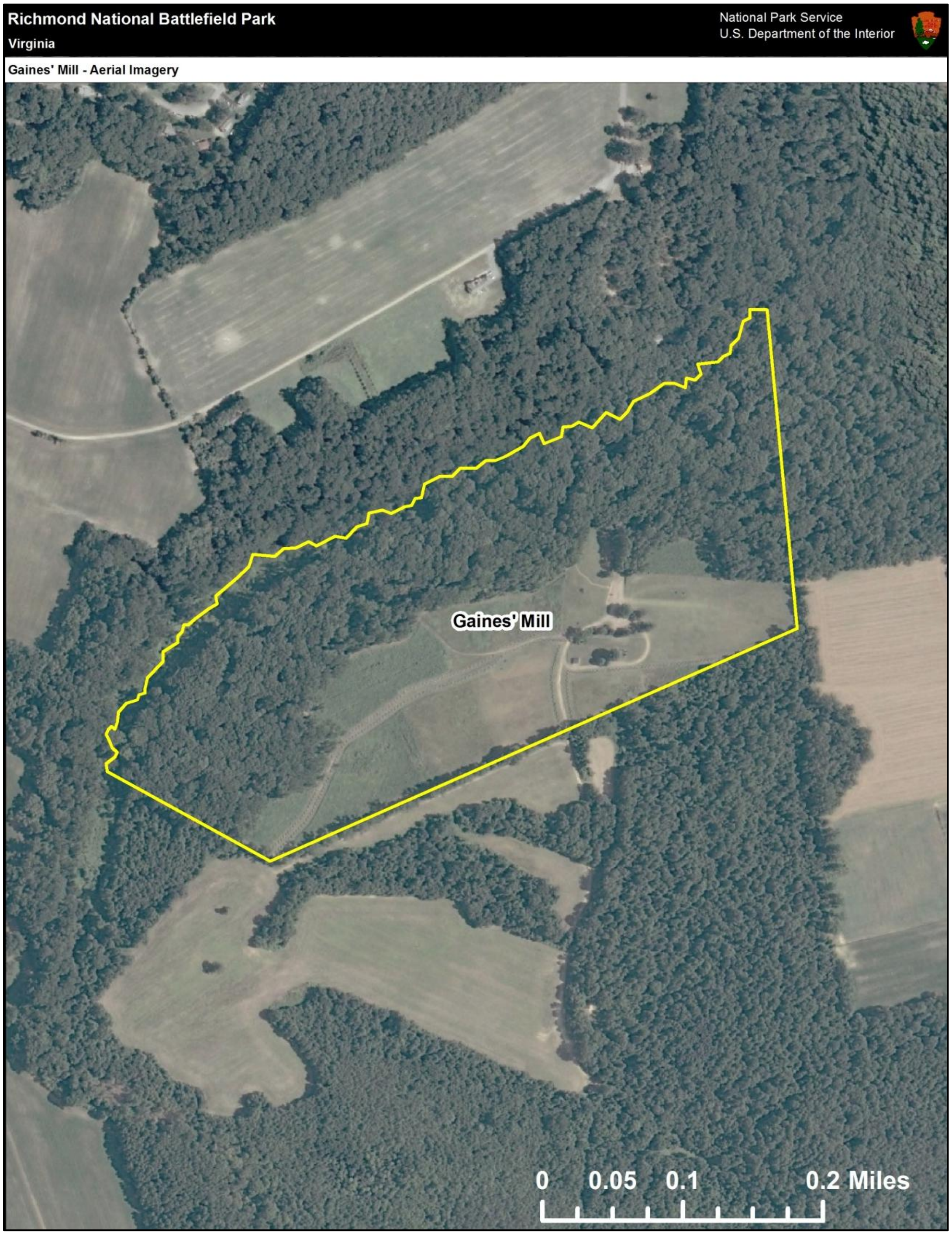

Figure 4. Gaines' Mill aerial view (NAIP 2009).

Cold Harbor (CH)

Cold Harbor is comprised of grasslands, mixed forest, and wetlands. Cold Harbor contains a nearly unspoiled creek where bacteria were found to be higher entering the park than when leaving the park. Park personnel conduct prescribed burns on approximately 30 ac. The majority of Coastal Plain Mixed Oak/Heath Forest (a state listed community) found on the park is mapped at the Cold Harbor unit. Prescribed fire is used as a management tool to enhance this rare community (Figure 5).

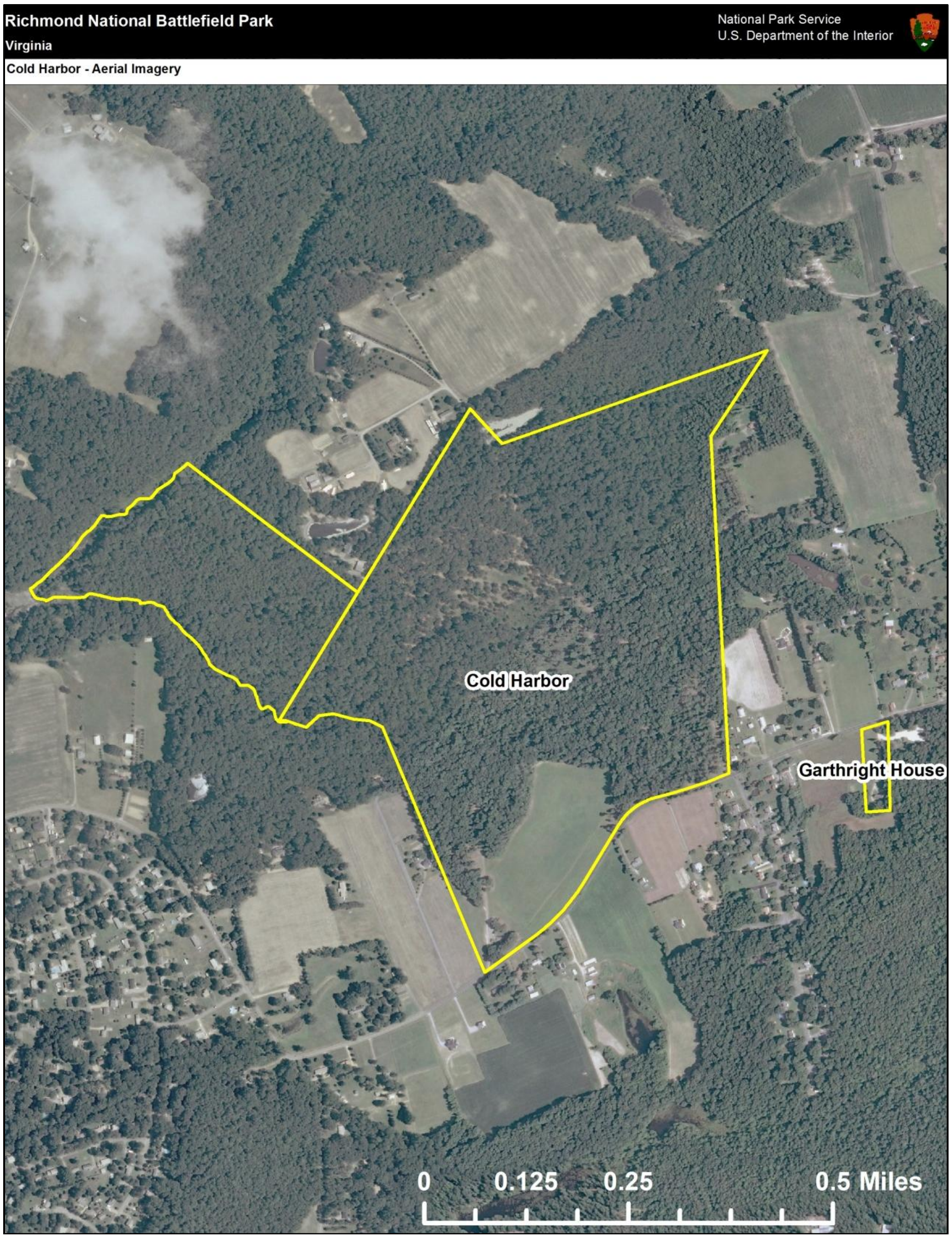

Figure 5. Cold Harbor aerial view (NAIP 2009).

Turkey Hill (TH)

Turkey Hill is undeveloped and inaccessible to visitors (Figure 6). Wetlands and riparian forests comprise the majority of the 175 acres; a portion of the Chickahominy River flows through the unit.

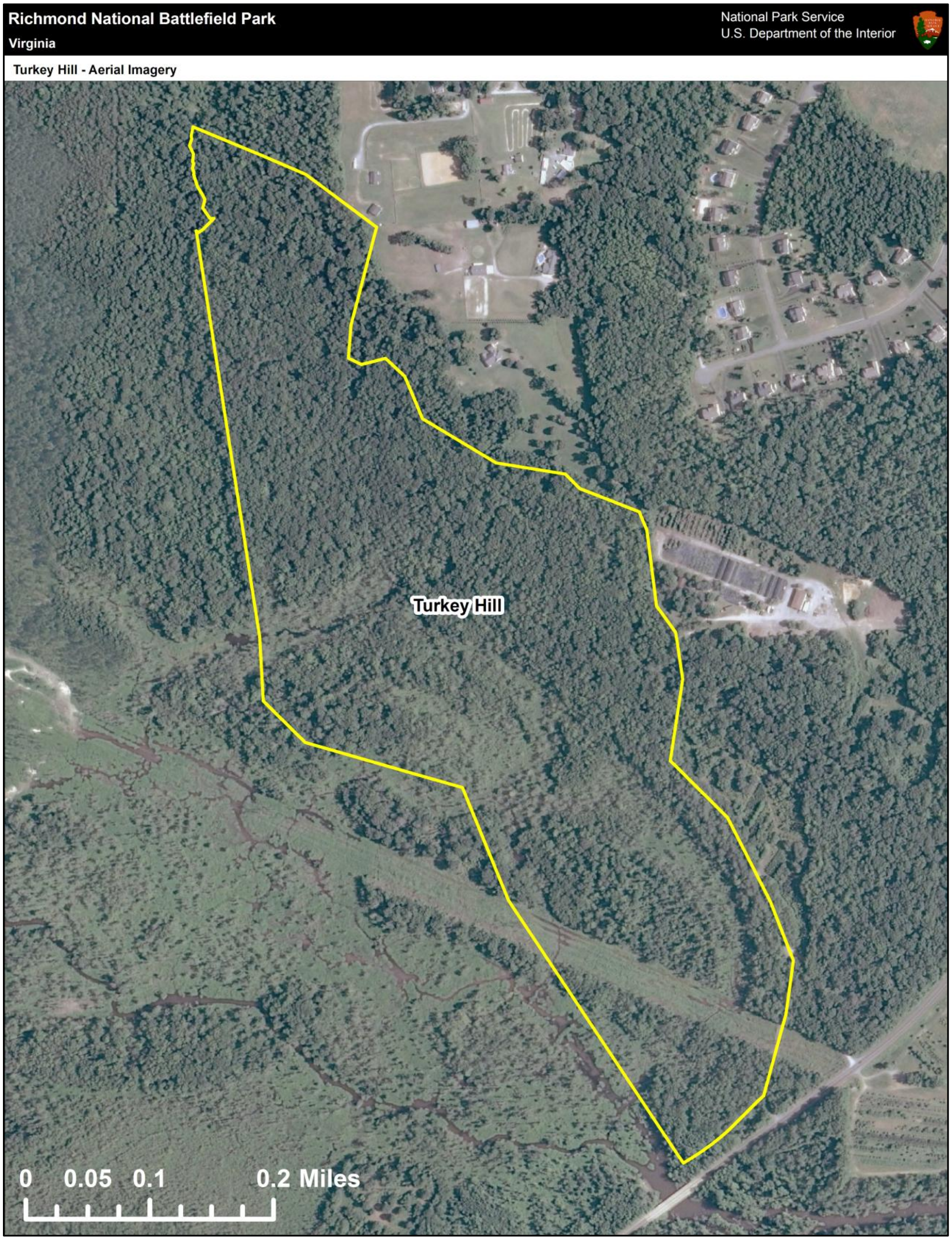

Figure 6. Turkey Hill aerial view (NAIP 2009).

Malvern Hill (MH)

Malvern Hill is the largest unit at Richmond NBP covering over 1,000 ac (Figure 7). It is the only unit with open water (9.9 ac) and contains approximately 124 ac of forested wetlands in combination with a few hundred acres of land in agriculture leases. Richmond NBP staff conduct prescribed burns on about 60 ac of meadow/field habitat to promote native, warm-season grasses. There are approximately 74 ac of mature, mast-producing hardwoods, segregated into three components by two state secondary roads.

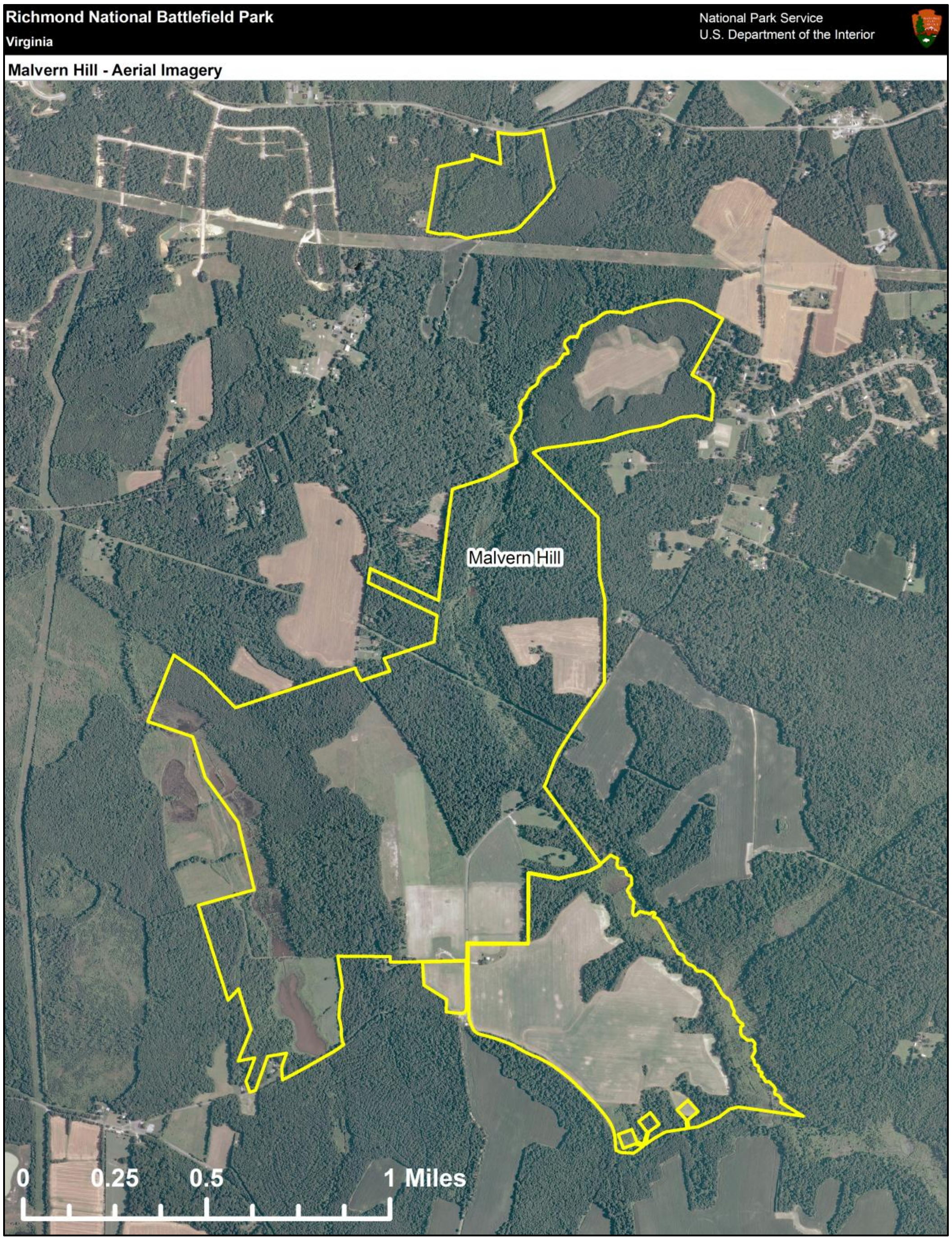

Figure 7. Malvern Hill aerial view (NAIP 2009).

Fort Harrison (FH)

Fort Harrison is a narrow corridor on either side of a historical road that links a number of Civil War forts (Figure 8). The road winds through low density residential, agricultural, and mixed forest land. Wetlands comprise approximately 7.7 ac (2.2% of 316 ac) of this unit. Beaver monitoring occurs here to protect the earthworks. A visitor center, picnic area, and offices are located within the central forested area (Bradshaw 2007).

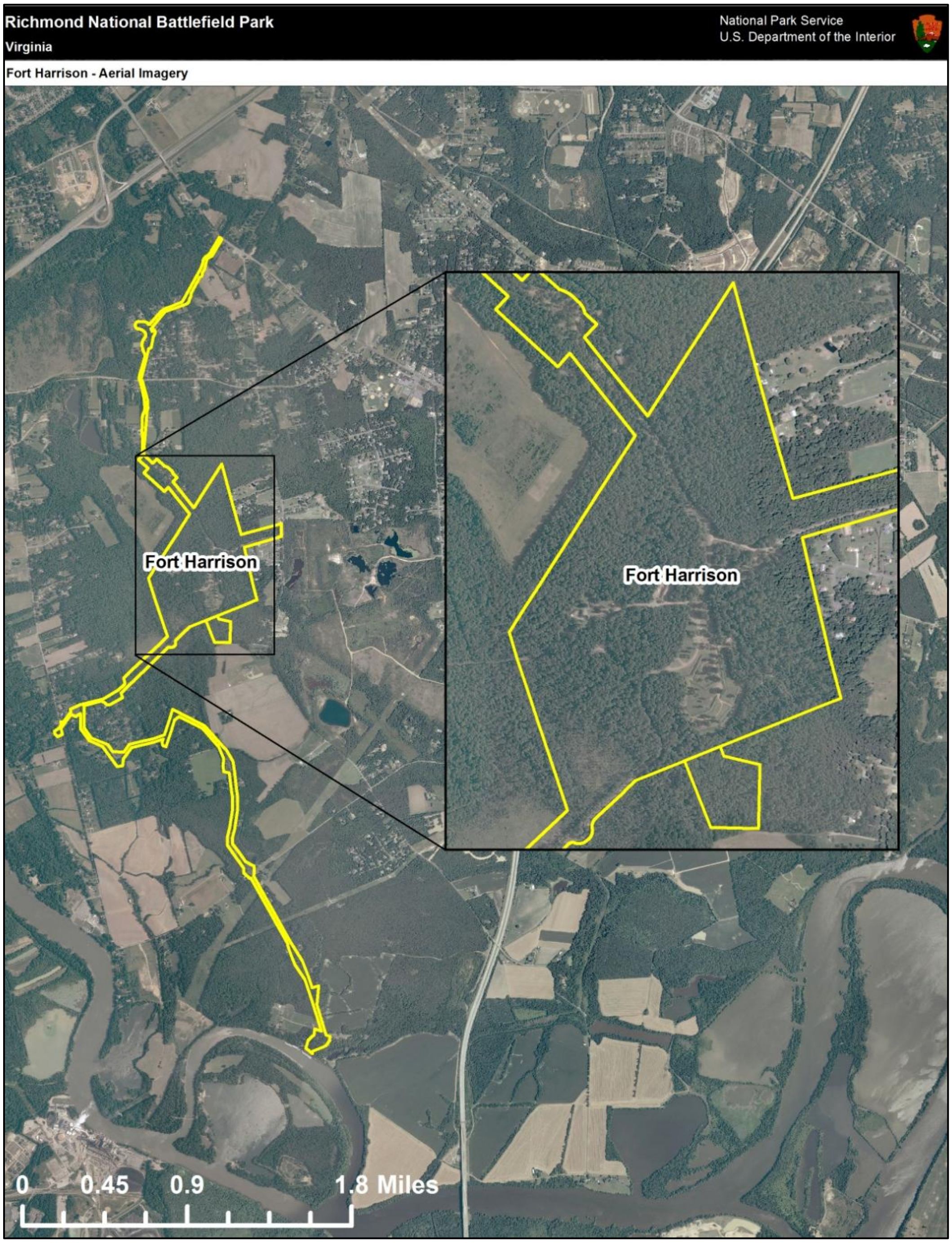

Figure 8. Fort Harrison aerial view (NAIP 2009).

Parker's Battery (PB)

Parker's Battery is a small (10 ac) unit with a small block of upland, mixed forest (Figure 9). Little natural habitat surrounds this unit. A small, 2.5 ac grassland is a product of a utility line that runs the western border of the unit.

Figure 9. Parker's Battery aerial view (NAIP 2009).

Drewry's Bluff (Fort Darling) (DB)

Drewry's Bluff sits atop a high bluff along the James River (Figure 10). The majority of this unit (24.7 ac) is a good example of a mature hardwood forest located on the James River. Additionally, there is 2.5 ac of forested wetlands (Bradshaw 2007). Potential development on the opposite side of the river threatens the viewshed along the border with the James River. I-95 borders a portion of this 36 ac unit.

Figure 10. Drewry's Bluff aerial view (NAIP 2009).

Chimborazo Medical Museum (CM)

The Chimborazo Park unit contains a visitor center and administrative offices and is the only park owned unit within the City of Richmond (Figures 11 and 12). The property is mainly mowed lawn with scattered trees (6 ac). The Chimborazo Medical museum contains exhibits on medical equipment and hospital life, including information on the men and women who staffed Chimborazo hospital. The main visitor center, the Civil War Visitor Center at Tredegar Iron Works for Richmond NBP has three floors of exhibits and artifacts on display. Cold Harbor, Fort Harrison, and Glendale/Malvern Hill visitors' centers also have exhibits on display.

Figure 11. Chimborazo Medical Museum aerial view (NAIP 2009).

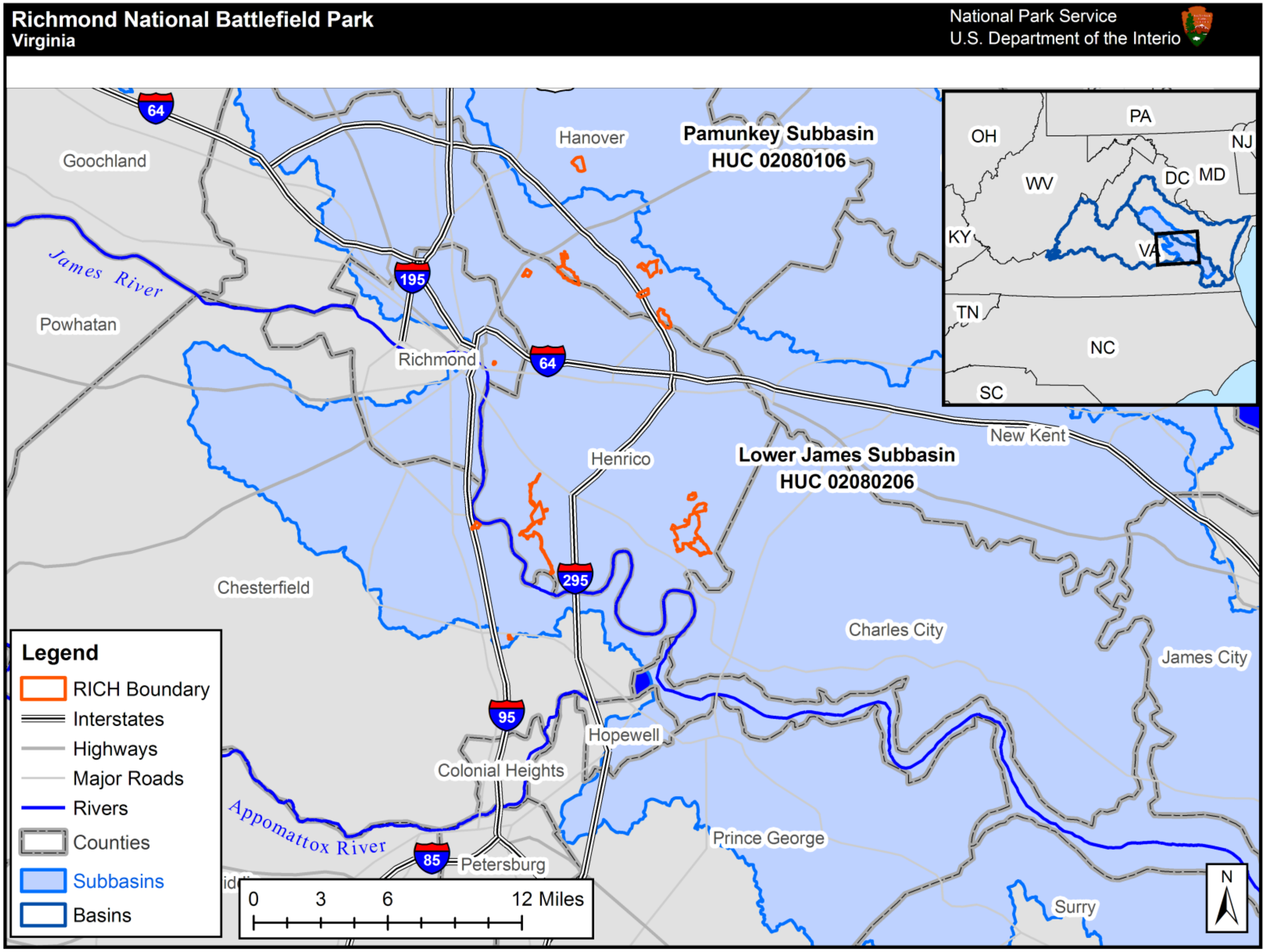

Figure 12. The location of Richmond National Battlefield Park.

Climate

The climate at Richmond NBP is characterized by warm, humid summers and mild winters. The average annual temperature in Richmond is 58.8 degrees Fahrenheit (°F). The coldest month on record is January, with an average high temperature of 35.2°F (Table 3; Figure 13). The warmest month is usually August, with average temperatures of 79.9°F (Knight et al. 2010). The lowest and highest recorded temperatures were -8°F in 1979 and 105°F recorded in 1977. In 2009, the average annual departure from the normal temperature was 1.1°F (Table 4).

Annual rainfall in Richmond averages 43.9 in, while annual snowfall averages 8.4 in (Knight et al. 2010) (Table 5). Major storms do not seem to be of great concern for this area of Virginia but thunderstorms producing high winds and flashfloods are not uncommon. The state of Virginia averages one tropical storm or its remnants per year, and averages one hurricane every 2.3 years (Roth & Cobb 2001). Tornadoes are not common in the area. From 1950-2000, Chesterfield County experienced 17 tornadoes; Henrico County recorded 10 tornadoes; and Hanover County, four tornadoes (NOAA 2001).

Table 3. Status of 2009 temperature indicators compared to the 30-year normal (1971-2000) at the Richmond (KRIC) weather observing station (Knight et al. 2010).

Temperature Indicator	Richmond, VA 2009	Richmond, VA 1971-2000
Average Annual Temperature	58.8°F	57.7°F
Average Annual Maximum Temperature	68.8°F	67.9°F
Summer Maximum (highest temperature)	98°F	98.8°F
Hot Days (days with T max ≥ 90°F)	33	41
Average Annual Minimum Temperature	48.8°F	47.5°F
Winter Minimum (lowest temperature)	4°F	6.6°F
Cold Days (days with T max ≤ 32°F)	4	7
Sub-freezing Nights (days with T min ≤ 32°F)	76	81
Cold Winter Nights (days with T min ≤ 0°F)	0	0
Growing Season Length (days between last spring 32°F and first fall 32°F)	251	209

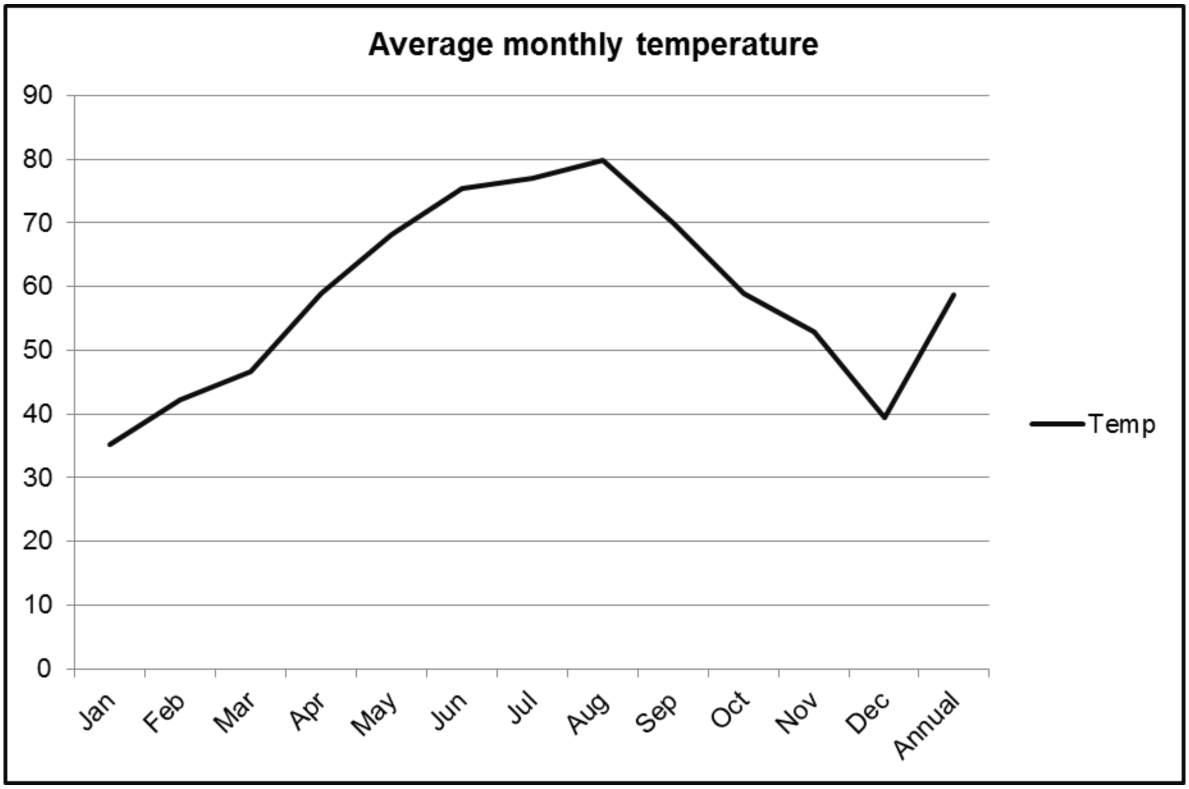

Figure 13. Summary of 2009 monthly average temperatures Richmond, VA (Knight et al. 2010).

Table 4. Summary of 2009 departure from normal temperature based on 30-year normal (1971–2000) for Richmond, VA (Knight et al. 2010).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Richmond	-1.2	2.7	-1.0	1.8	2.8	2.0	-0.9	3.6	0.1	0.7	4.0	-1.0	1.1

Table 5. Status of 2009 precipitation indicators compared to the 30-year normal (1971-2000) at the Richmond (KRIC) weather observing station (Knight et al. 2010).

Precipitation Indicator	Richmond, VA 2009	Richmond, VA 1971-2000
Annual Precipitation	48.4 in	43.9 in
Autumn (Oct-Dec) Precipitation	21.4 in	9.8 in
Heavy Rain (days with ≥ 1.0 in rain)	12	10
Extreme Rain (days with ≥ 2.0 in rain)	1	2
Micro-drought (strings of 7+ days without rain)	9	9
Annual Snowfall	14.0 in	8.4 in
Snow (days with ≥ 0.1 in snow)	5	5
Moderate Snow (days with ≥ 2.0 in snow)	3	1
Heavy Snow (days with ≥ 5.0 in snow)	1	1

Geology and Landforms

Richmond NBP is uniquely located within the Fall Line, where the Piedmont Plateau and Atlantic Coastal Plain provinces meet. This allows for Richmond NBP to host not only gently rolling hills characterized with metaphoric rocks and highly weathered soil, but also flat topography with soft, sedimentary rocks. Not many bedrock exposures are seen within the park property; the oldest rocks found are 300 Ma Petersburg Granite. Faults within the park have an effect on the landscape of Richmond NBP. Though not well exposed, faults contribute to Central Virginia's complex, ancient geologic history. As one of the larger military parks in the national park system, Richmond NBP protects essential geologic formations that form Virginia's natural history (Thornberry-Ehrlich 2005).

Surface Water and Wetlands

The James is the largest and most prominent river influencing Richmond NBP. Feeding into the Chesapeake Bay and originating in the mountains of western Virginia, the James River spans almost the entire state. Other park units contain smaller streams that ultimately serve as tributaries to the James River. Beaver Dam Creek, Boatswain Creek, and Bloody Run, all located in the park's northern most units, empty into the Chickahominy River, which in turn, empties into the James River. The Beaver Dam Creek unit consists primarily of a wide wetland area bordering the creek, although a small percentage of the surrounding floodplain is forested (National Park Service 2010).

The park tests water quality across many sites. However, the results are closely tied to upstream conditions which are often not under the park's control. Therefore, water quality in these systems is often affected by land use and management at their headwaters. Because the health of the park's aquatic communities depends heavily on water quality, conditions are monitored throughout its many units. The park has incorporated many techniques to preserve water quality including the use of buffer zones near wetlands and waterways as well as the careful assessment of activity that could potentially impact park aquatic resources (National Park Service 2010). More information on park unit wetlands and water quality can be found in Sections 5.0 and 7.0 respectively.

Flora and Fauna

For park managers to effectively maintain biological diversity and ecological health within their parks, they must have a basic knowledge of what natural resources exist in parks, as well as an understanding of the factors that may support and threaten them. One of the first goals of the I&M Program has been to establish baseline biological inventories for vascular plants and vertebrates in order to provide a reliable account of species at each park, with the inventory and monitoring results to be used as a fundamental tool for future park management.

Preliminary inventories for mammals, birds, reptiles, amphibians, fish, and vegetation have been completed for Richmond NBP (Atkinson 2008; Mitchell 2007; Bradshaw 2007; Barry and Sareen 2008). Documented at Richmond NBP are 154 species of birds, 24 amphibians, 24 reptiles, 23 mammals, and 30 fish species. Additionally, 654 species of trees, shrubs, and herbaceous plants occur in the park (NPS 2010). Several Virginia Species of Greatest Conservation Need have been documented including: 31 birds, five reptiles, and four fish. Six natural communities (Chapter 4.0) as defined in the Natural Communities of Virginia were identified by Patterson (2008) at Richmond NBP.

3.0 Landscape Dynamics

The Mid-Atlantic region of the eastern United States is developing rapidly, and many parks in the Mid-Atlantic Network (MIDN) are now facing pressure from adjacent suburban development. The resulting effects of population growth include land use change, increased pollution, increased resource extraction, habitat fragmentation, and increased distribution of exotic and invasive species (Wagner et al. 2006). The primary stressors listed in the MIDN vital signs report that have the greatest affect on terrestrial ecosystems are: climate change, atmospheric pollution, biotic change, and land use change (Comiskey and Callahan 2008). Such changes can result in numerous negative impacts on our federal and state protected lands.

Richmond NBP consists of many non-contiguous units surrounded by various degrees of human development and is faced with a variety of environmental issues. Combined, the eleven units have over 40 miles of edge (Courtenay 2010). Water quality and invasive species are important management concerns monitored and managed by the park. Whenever possible, the park uses natural buffer zones, native species plantings, and other preemptive management techniques to protect from encroaching threats and stressors. The park's management goal is to create a native species rich environment, and minimize the threat of invasives, while restoring important cultural landscapes to their historic conditions (National Park Service 2010).

In 2010, an assessment of green infrastructure at Richmond NBP was conducted. Green infrastructure is the interconnected network of natural areas, such as greenways, wetlands, parks, and preserves. Green spaces manage stormwater, reduce flooding, and improve water quality. As an important part of conservation planning, green infrastructure characterizes core (large sections of habitat) and corridor (connections among the section) areas of forest as the two most important qualities for conservation. The greater Richmond metropolitan area is comprised primarily of non-forested area (48.38%). Urban areas and farms break up core areas, creating a large amount of edge (25.06%). Richmond NBP has a similar amount of edge (26.28%), however it is comprised of only 16.96% non-forest and 50.52% core (Courtenay 2010) (Figure 14). Chickahominy Bluff, Beaver Dam Creek, and Turkey Hill have the highest percentage of core habitat of all the units. Parker’s Battery and Chimborazo have no core habitat as there is no surrounding forested habitat.

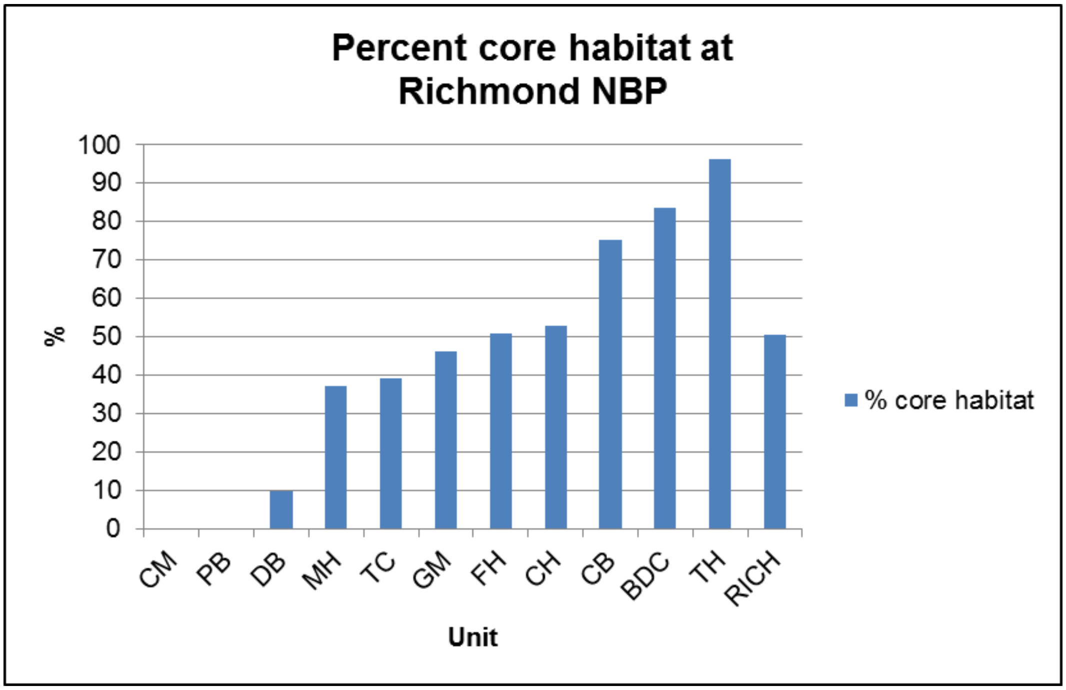

Figure 14. Percent core habitat at Richmond NBP (Courtenay 2010)

Land Cover Change

Land cover change is an on-going issue across the country and often serves as a primary threat to other natural resources. Increased vehicular traffic, noise and emissions could degrade the overall visitor experience of the park. Increasing the amount of impervious surfaces in and around the park also has direct consequences to the park's water quality, fisheries, and wildlife.

Some of the most immediate and potentially severe threats to biotic diversity are related to changes in land cover and wildlife habitat. The *Virginia* Comprehensive Wildlife Conservation Strategy External Steering Committee identified the following critical issues regarding land use changes for the next ten years (Virginia Department of Game and Inland Fisheries 2005):

- Habitat loss, fragmentation, and isolation
- Poor land-use decision-making
- Integration of economic development and sound conservation
- Sprawl
- Decline of agriculture
- Riparian development
- Lack of land conservation
- Inadequate land use planning
- Predation, due to high mesocarnivore populations

Figures 15-18 show land cover change from 1992-2001 (NPScape). Total change in natural land cover is perhaps the simplest indicator of biotic integrity (O'Neill et al. 1997). Calculating the percent of natural land cover remaining in an area provides a general indication as to the overall landscape condition surrounding protected areas and offers insight into potential threats (i.e., how much land has been converted and where is it located in relation to the park boundary) as well as opportunities (i.e., connectivity of natural cover). Calculating the proportion of converted (agriculture and urban) land, also known as the U-index (O'Neill et al. 1988), can be used to measure general land use pressure by humans (Svancara and Story 2009). We also examined the change in land cover within the overall watersheds containing Richmond NBP for 1996, 2001, and 2005 (see Appendix C).

Human Population

Encroachment of human population and development is arguably the most important threat or stressor the park must consider. Development may lead to increasing point and non-point source pollution, affecting air and water quality. Increased vehicle emissions can occur as more people move to the area. In-park biological integrity may also be stressed from these outside influences. Although seemingly intuitive, several studies have quantitatively researched the relationship between human population and the degradation of the world's natural resources (Jones and Clark 1987, Forester and Machlist 1996, McKinney 2001, Parks and Harcourt 2002, Cardillo et al. 2004). In a 2001 study, nonnative plant and fish diversity were negatively correlated with human population (McKinney 2001). Parks and Harcourt (2002) found that the probability of species extinction around western U.S. National Parks was significantly correlated with the surrounding human population density.

We examined three factors to assess human effects in the Richmond NBP area. Population change and population density were obtained through census data from the U.S. Census Bureau and ESRI. The third factor we examined was relative impervious surfaces within Richmond NBP boundaries.

Richmond NBP is part of the Richmond, VA Metropolitan Statistical Area (MSA), which contains portions of 17 counties with a 2008 population estimate of 1,233,035 people. The population changed from 1,100,200 in 2000 to 1,233,035 in 2008, a 12.1 percent change. The population is projected to be 1,483,015 in 2020, a 34.8 percent change between 2000 and 2020. The Richmond MSA is ranked the 43rd highest population out of 366 MSAs nationwide. The total population for Richmond City in 2000 was 197,945, while the 2009 total was 204,451. Figures 19 and 20 illustrate the population change in each watershed and in the portion of each county that sits within the watershed study areas surrounding Richmond NBP. Population data and trends were obtained from the ESRI Maps and Data website (ESRI 2009).

Along with population change, a good indicator of human effects on natural resources is population density. The Richmond MSA had a population density of 276.9 people/square km in 2000 (Figure 21). Henrico and Chesterfield Counties have the highest population density of the counties in the study areas where portions of the county have 1,000 or more people/square mile.

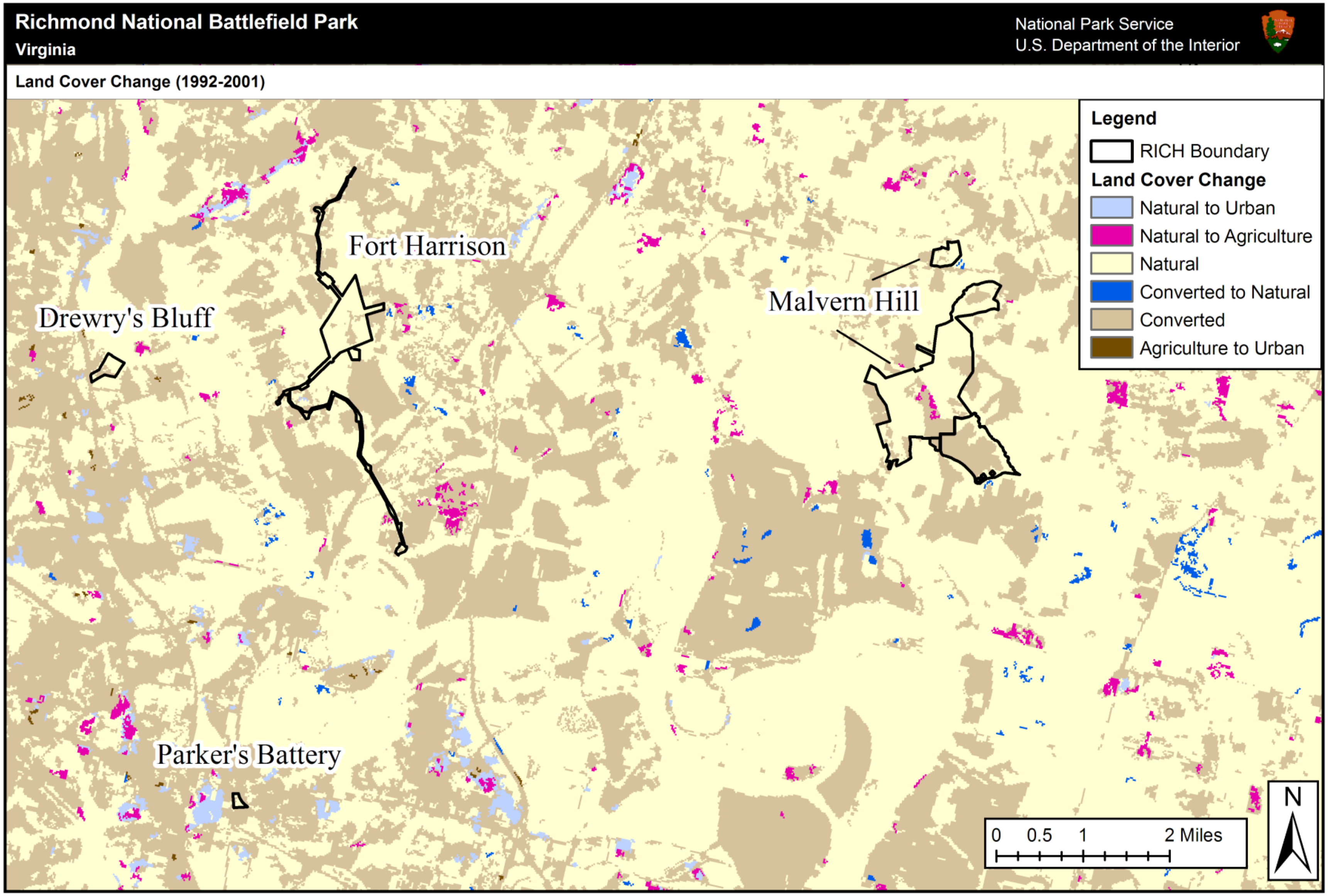

Figure 15. Land cover change for Drewry's Bluff, Parker's Battery, Fort Harrison, Malvern Hill, and surrounding areas (1992-2001) (NPScape).

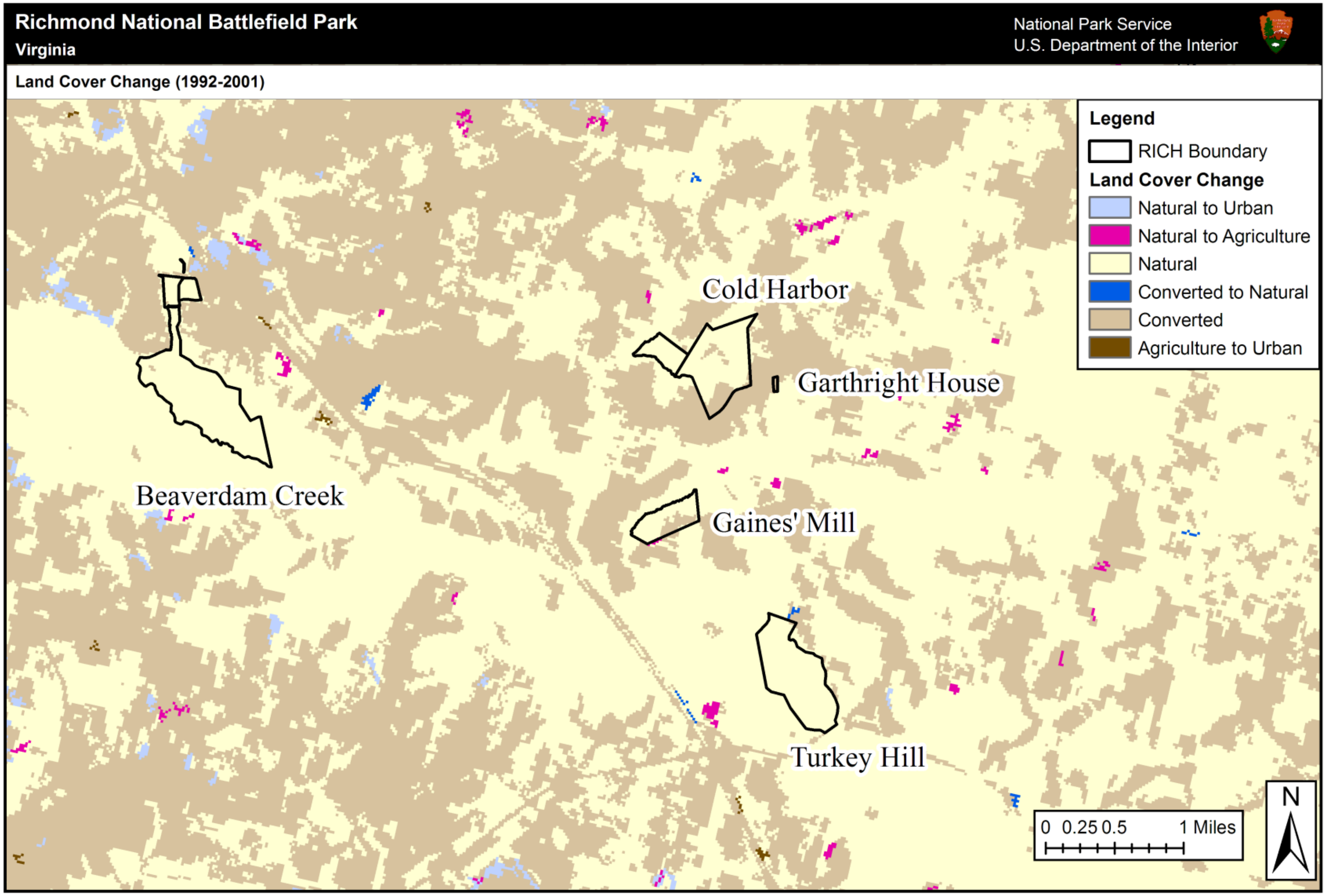

Figure 16. Land cover change for Beaver Dam Creek, Cold Harbor, Gaines' Mill, Turkey Hill, and surrounding areas (1992-2001) (NPScape).

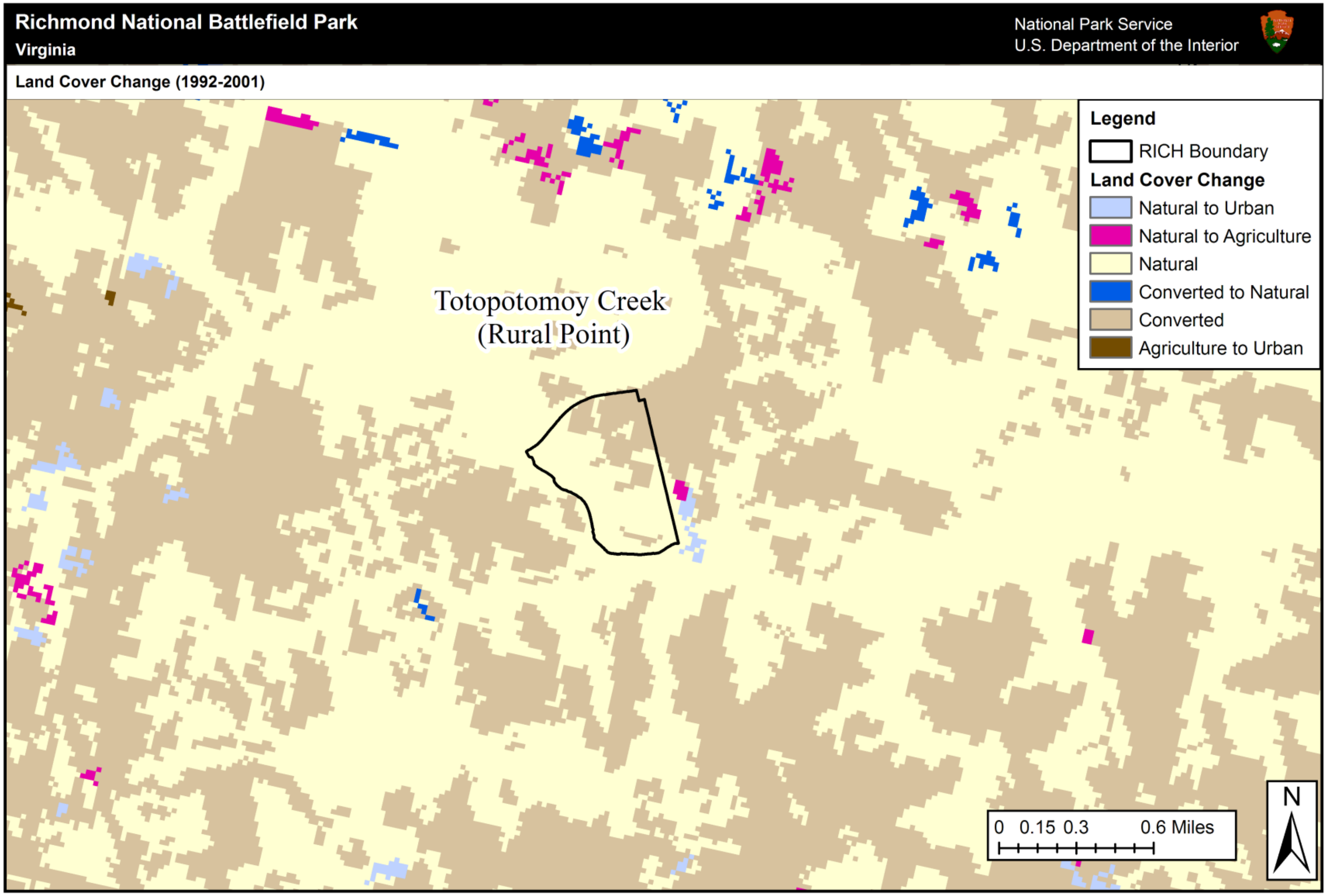

Figure 17. Land cover change for Totopotomoy Creek (Rural Point) and surrounding areas (1992-2001) (NPScape).

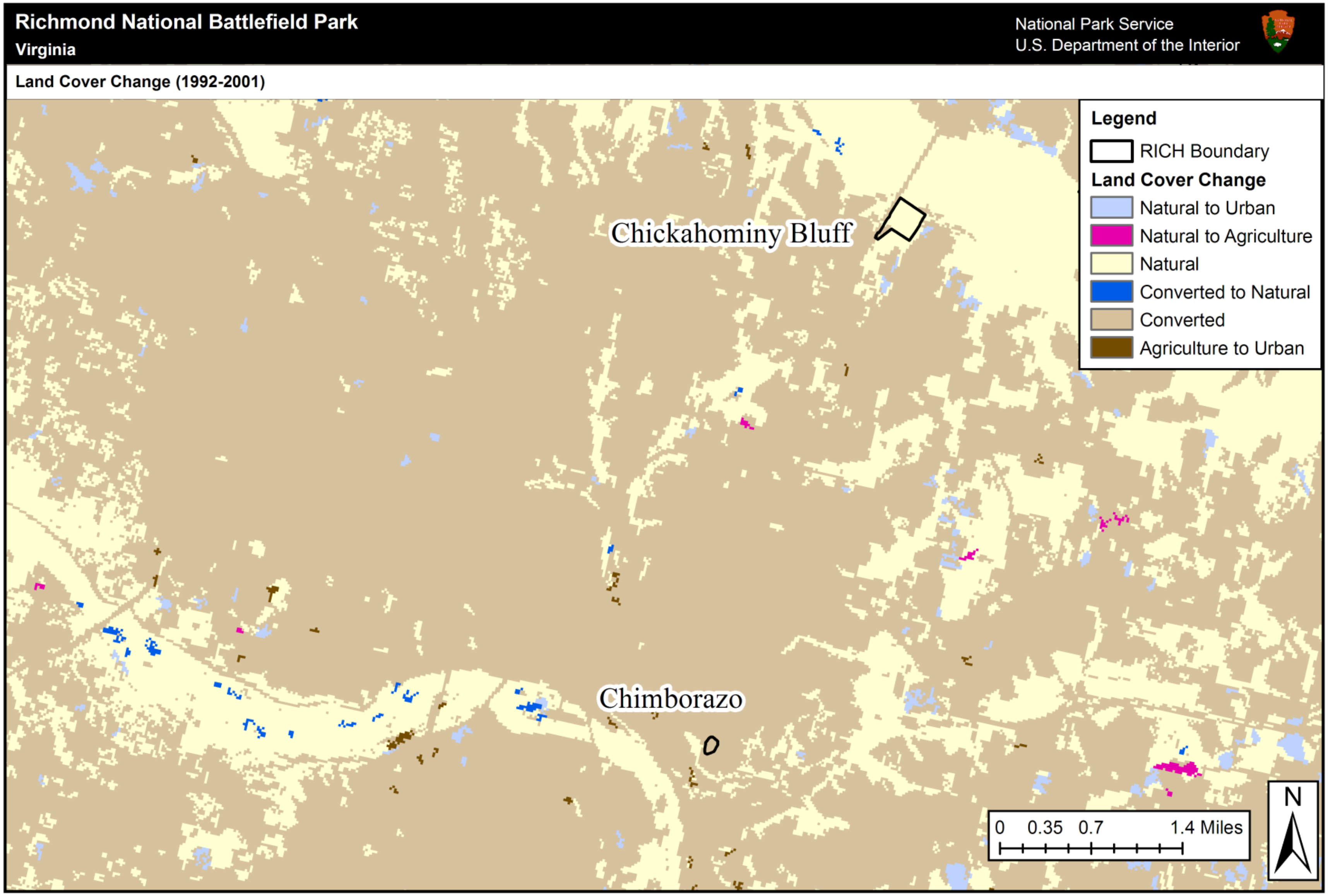

Figure 18. Land cover change for Chickahominy Bluff, Chimborazo, and surrounding areas (1992-2001) (NPScape).

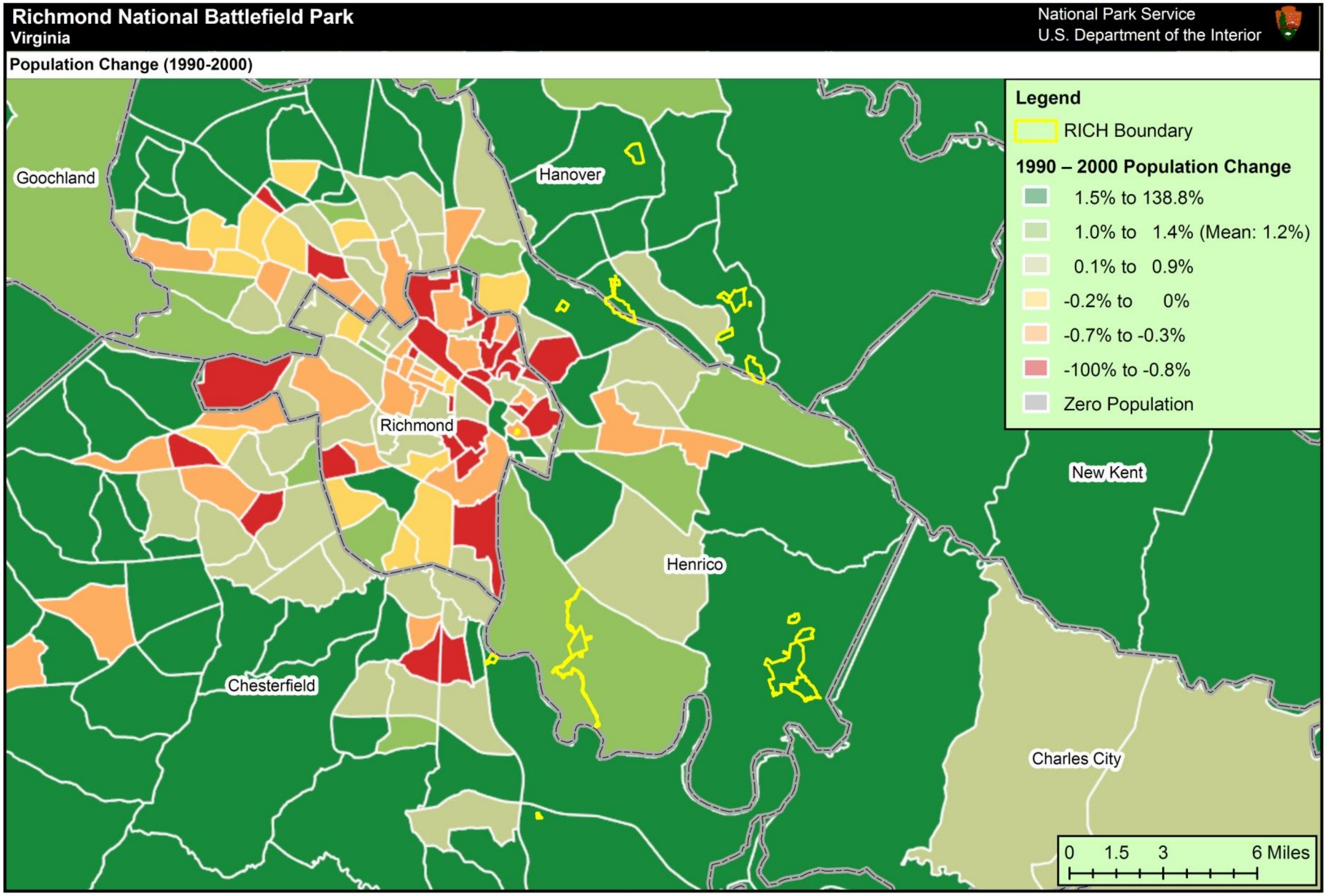

Figure 19. Human population change in areas containing Richmond National Battlefield Park (RICH) from 1990 to 2000 (ESRI 2009).

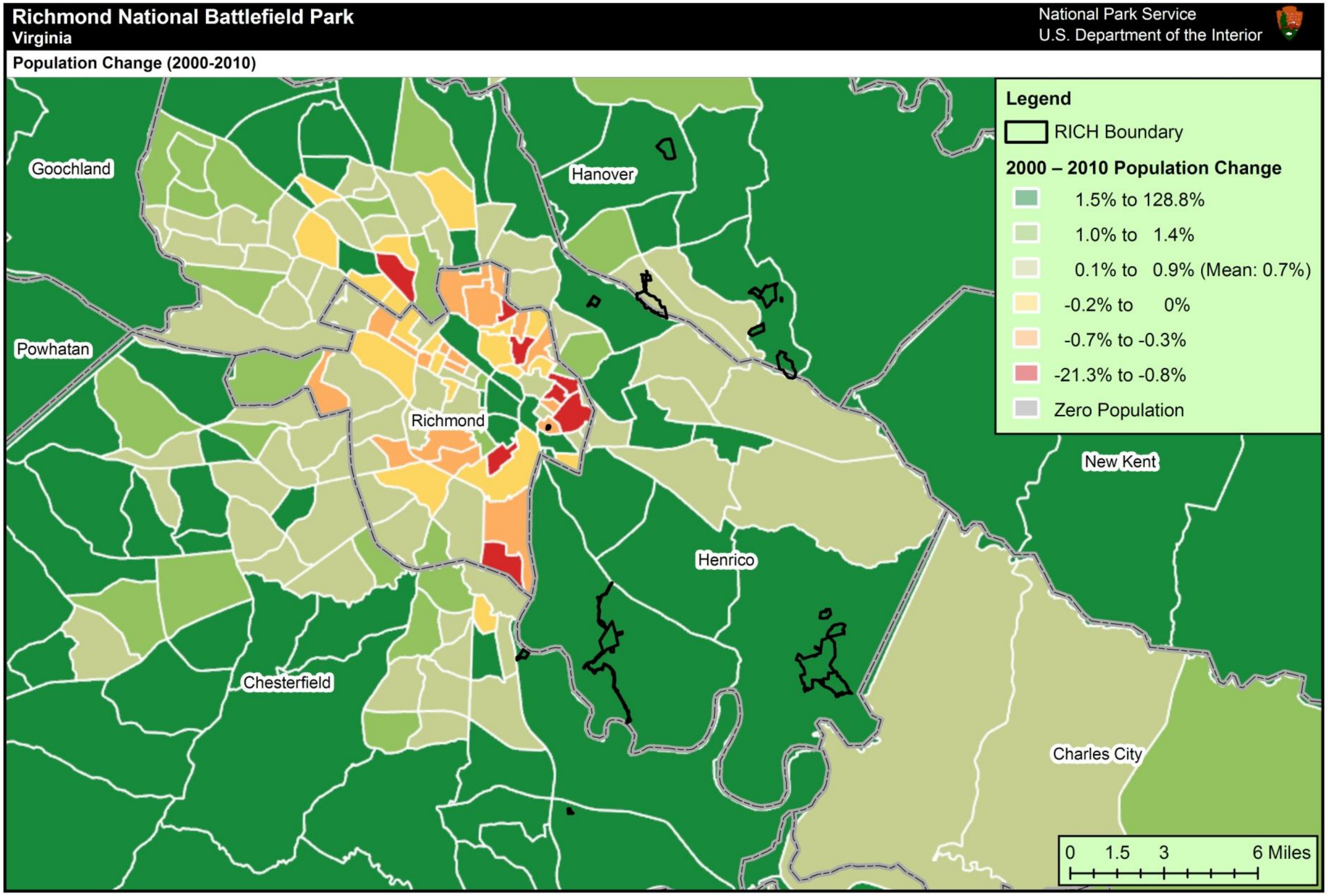

Figure 20. Human population change in areas containing Richmond National Battlefield Park (RICH) from 2000 to 2010 (ESRI 2009).

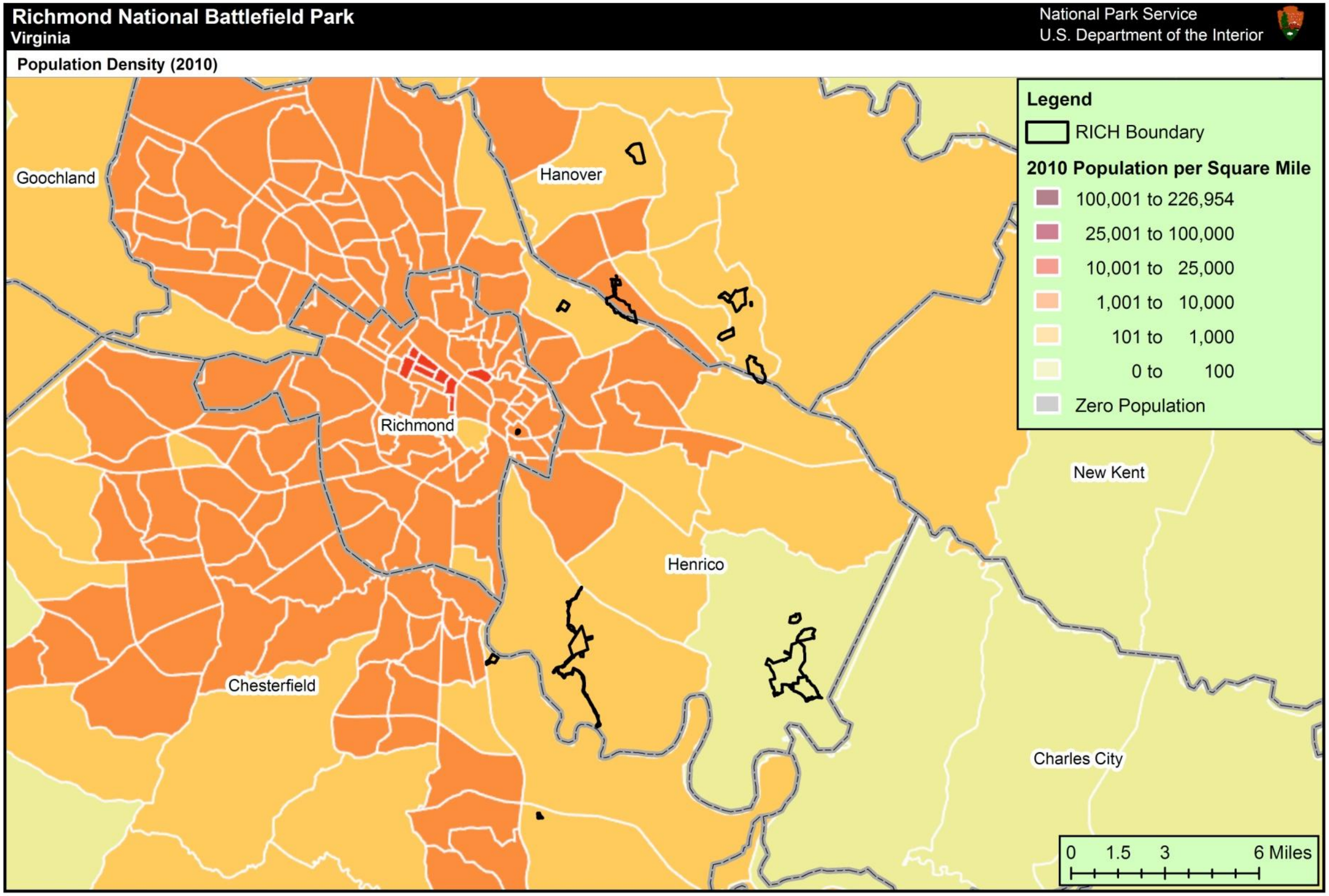

Figure 21. Human population density (2010) in areas containing Richmond National Battlefield Park (RICH) (U.S. Census Bureau 2009a).

Impervious Surface

Impervious surfaces within the park give a useful measure of environmental condition, as they can have a direct impact on overall hydrology and water quality (Schueler 2000, Hurd and Civco 2004). The average amount of impervious surface for all units within Richmond NBP is 1.1% (Figure 22).

From the 2001 NLCD (EPA 2008), the watersheds where the park is located contain 95,898 ac (25.4%) of impervious surface. Increased impervious surface leads to degradations in water quality, hydrology, habitat structure, and aquatic biodiversity (Schueler 2000, Hurd and Civco 2004). In a review of eighteen studies relating stream quality to urbanization, Schueler (2000) suggests using three management categories (Table 6) to group streams by percent impervious surface. Sensitive streams are generally characterized by stable channels, good water quality, and good to excellent stream biodiversity. Schueler recommends watersheds containing streams with the "sensitive" classification should protect biodiversity and channel stability with watershed-wide impervious cover limits and site impervious cover limits. Impacted streams will often have unstable channels, fair water quality, and fair to good stream biodiversity. Management objectives for "impacted" watersheds include maintaining critical elements of stream quality by instituting site impervious cover limits. Non-supporting streams will have highly unstable channels, fair to poor water quality, and poor stream biodiversity. It is recommended that downstream pollutant loads should be minimized for non-supporting streams, while additional infill and redevelopment is encouraged (Schueler 2000).

Development and Agriculture

Development and agriculture are issues extremely relevant to the park, especially for water quality issues. Land development and urbanization can have dramatic impacts on the interplay between infiltration and runoff. Drewry's Bluff contains a small unamed tributary of the James River that drains a neighboring asphalt plant before it reaches an old, leaching county industrial landfill (Figure 23).

As land is developed and covered with impervious surfaces like roofs, roads, and parking lots, infiltration capacity of large areas can be lowered to zero with runoff rates dramatically increased. Changes in runoff rates can also come as the result of other development activities including vegetation clearing, soil compaction, altered drainage patterns, ditching, and channelization on remaining soil-covered lands, shifting what historically may have been a predominately subsurface flow pattern to a predominantly surface flow pattern (Booth and Jackson 1997). This can profoundly alter the magnitude, intensity, and duration of water discharges associated with precipitation events and result in the delivery of sediment and excess nutrient loads and pollutants into surface water systems by many orders of magnitude (Wolman and Schick 1967). There are obvious issues associated with surrounding development air quality, noise pollution, and habitat fragmentation. Figure 24 shows erosion effects at a nearby agricultural field draining into Western Run at Malvern Hill.

Table 6. Schueler (2000) related percent impervious cover to management category.

Impervious Cover	Management Category
1 to 10% impervious	Sensitive streams
11 to 25% impervious	Impacted streams
26 to 100% impervious	Non-supporting streams

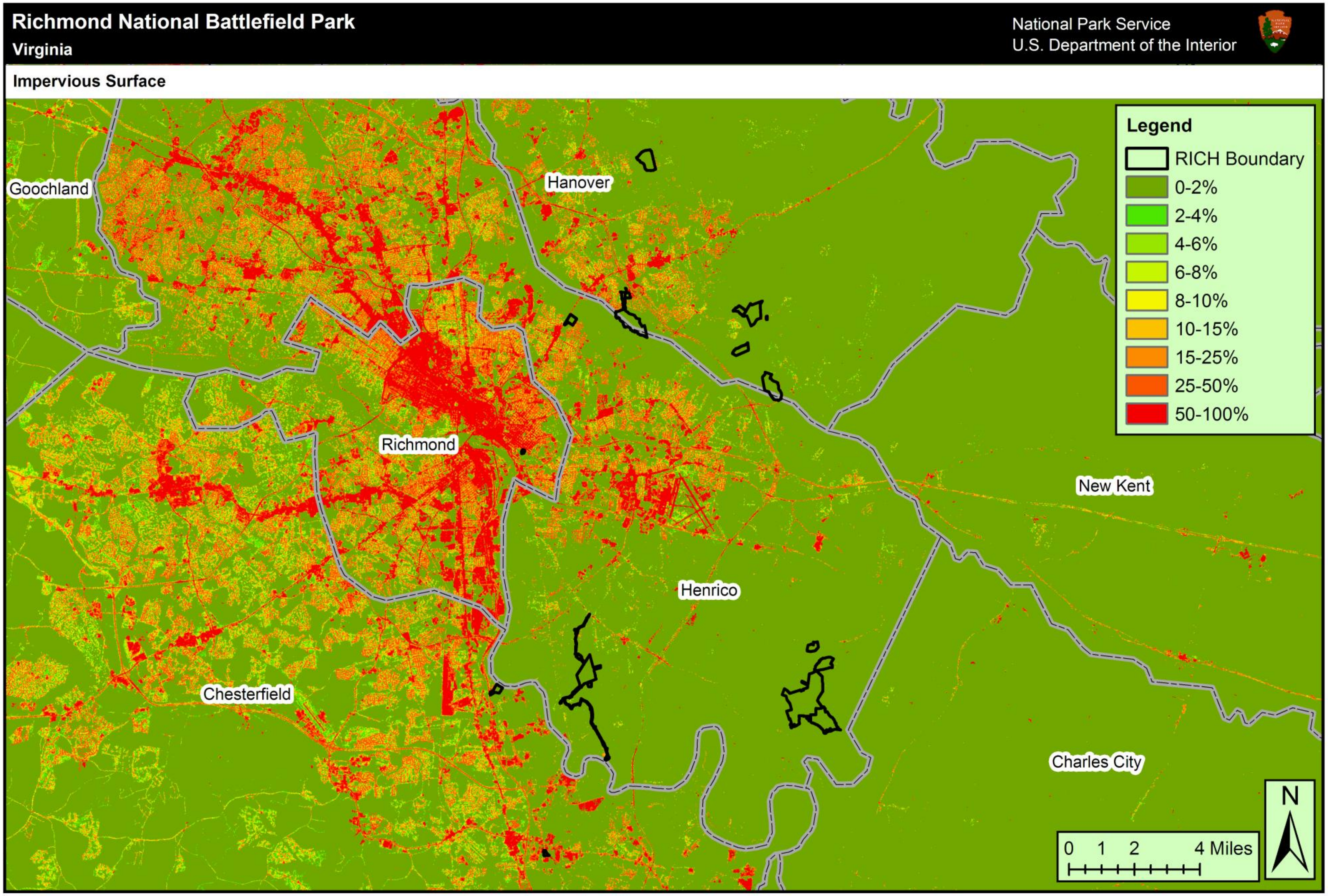

Figure 22. Impervious surface for Richmond NBP (NPScape).

Figure 23. Park stream with latex release from bordering asphalt plant (Drewry's Bluff). November 2007.

Figure 24. Erosion from adjacent agricultural field draining into Western Run, Malvern Hill. November 2007.

Cold Harbor, Gaines' Mill, and Malvern Hill contain most of the headwaters of their streams, though agriculture surrounds them. Recently, bacterial impairments were discovered at these units, most likely a result of the agriculture use. A major stressor at Chickahominy Bluff, Beaver Dam Creek, and Totopotomoy Creek is intense upstream urban and suburban development. Additionally, Chickahominy Bluff experiences extreme sediment deposition at due to development on the only greenspace upstream. These streams are commonly flashy and have many stormwater inputs draining roads, neighborhoods, parking lots, and strip malls.

Additionally, land development that encroaches on the riparian areas can have consequential influences on the physical properties of the water and the way it moves through surface water systems (see Figure 25). Current (2010) and projected (2030 and 2090) housing density for the areas surrounding the units at Richmond NBP can be seen in Figures 26-28 (NPScape). Development can reduce the potential for woody material to be introduced into the stream channel that could otherwise serve as a stabilizing element to dissipate flow energy and help protect from stream bank erosion (Booth et al. 1996) (Figure 29). If established deep-rooted vegetation is replaced by shallow-rooted grasses or ornamentals (or not replaced at all), inherent stream bank stability and resistance to channel widening is lost (Booth and Jackson 1994). Reduction of a stream's overhead canopy directly affects water temperature and the amount of leaf litter that enters the aquatic food chain (Booth and Jackson 1997). Loss of vegetation also means reduced filtering of pollutants and nutrients, causing negative effects to water quality. Additional threats to water quality include municipal and industrial wastewater discharges, mining and quarrying operations, agricultural runoff from crop fields, and cattle and recreational uses.

Figure 25. Noname Creek runs adjacent to a closed county landfill and into the James River at Drewry's Bluff. Photo by Rick Webb, December 2008.

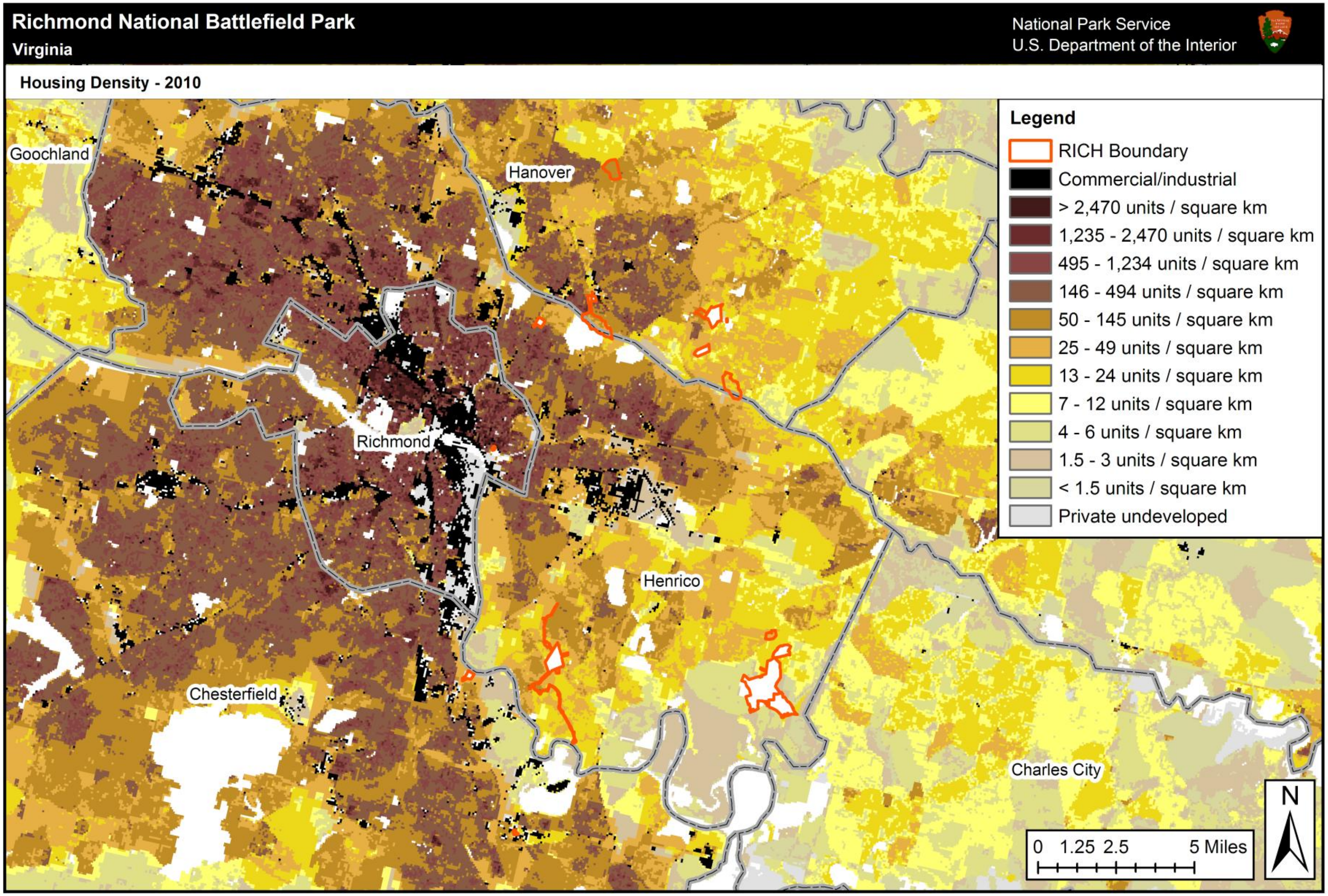

Figure 26. Housing density surrounding Richmond NBP (2010).

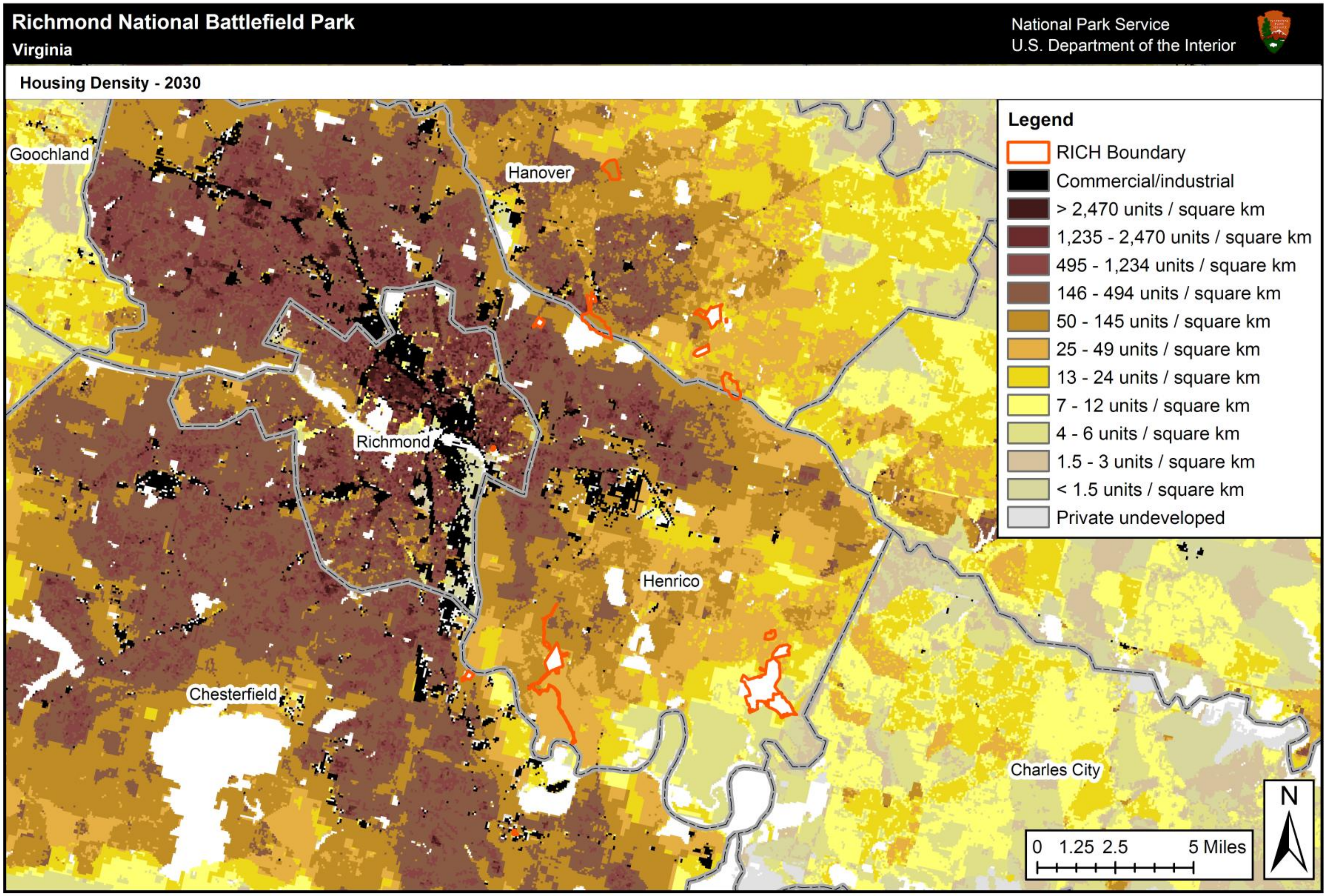

Figure 27. Housing density surrounding Richmond NBP (2030).

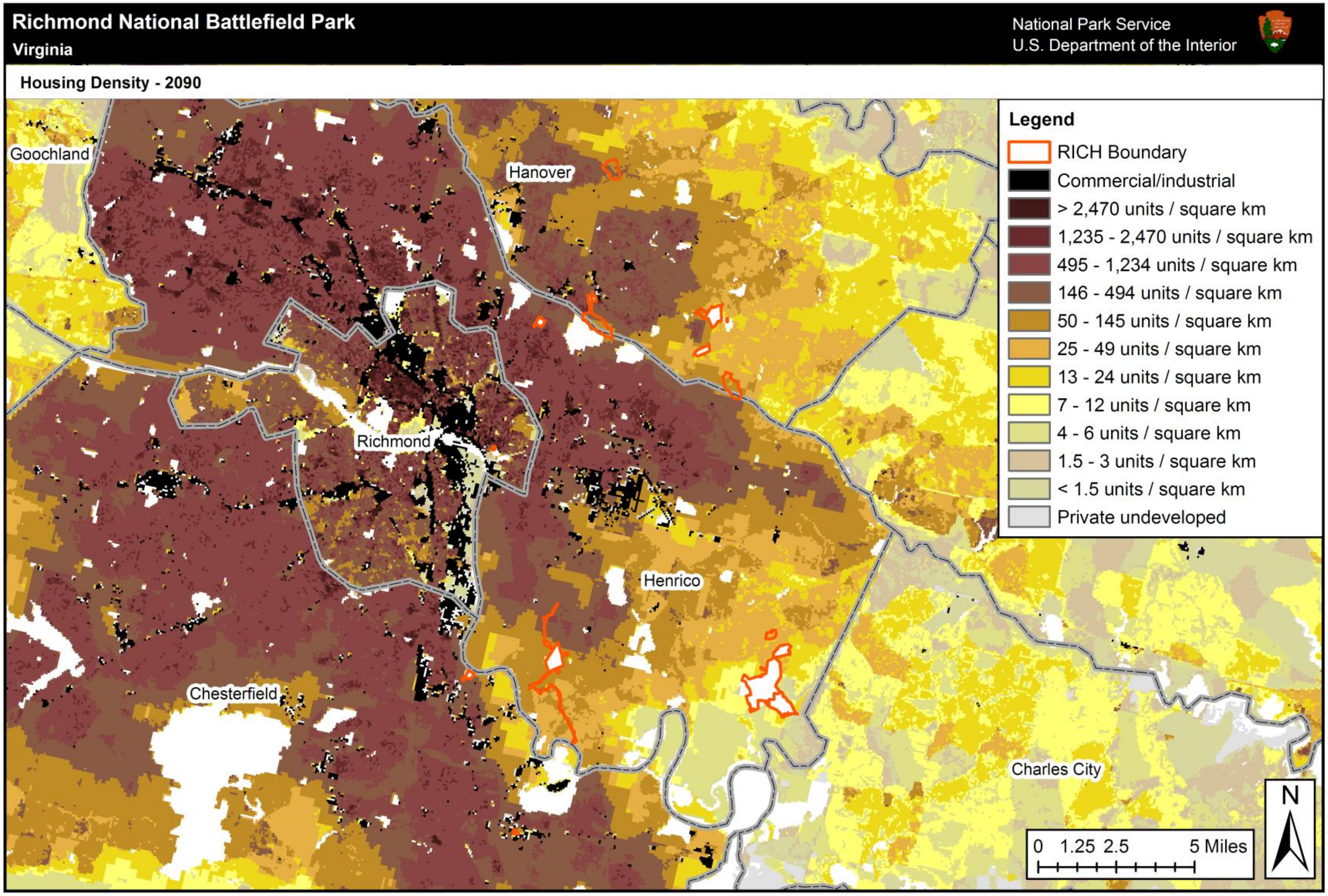

Figure 28. Housing density surrounding Richmond NBP (2090).

Figure 29. Portion of park stream with extreme bank erosion due to the periodic release of a neighboring asphalt plant's retention pond (Drewry's Bluff). August 2001.

Wildfire and Fuel

Fire exclusion practices have drastically changed the natural fire processes across the United States (Lear and Waldrop 1998, U.S. Geological Survey 2000) (Figure 30). However, prescribed fires are now being used more actively in regenerating oak (Brose et al. 1998) and pine (Lear and Waldrop 1998) stands within the eastern United States. Wildfires have not been an imminent concern for Richmond NBP. There have been 23 fires recorded at Richmond NBP since 1994 (Table 7).

According to a simulated historical fire severity model (USDA Forest Service 2006), low severity fires accounted for essentially all fire occurrences at Richmond NBP. Mixed and replacement severity fires accounted for a small and relatively insignificant percentage of fires at Richmond NBP. Low severity fires cause less than 25% average replacement of dominant biomass, mixed severity fires cause between 25 and 75% replacement, and replacement severity fires cause greater than 75% average replacement of dominant biomass. Approximately 38% of Richmond NBP is in the Fire Regime Condition Class III, meaning there is high departure from historic vegetation. These data are intended to be used at a landscape scale (USDA Forest Service 2006), so caution should be taken with analysis of these data at a more detailed scale within Richmond NBP boundaries.

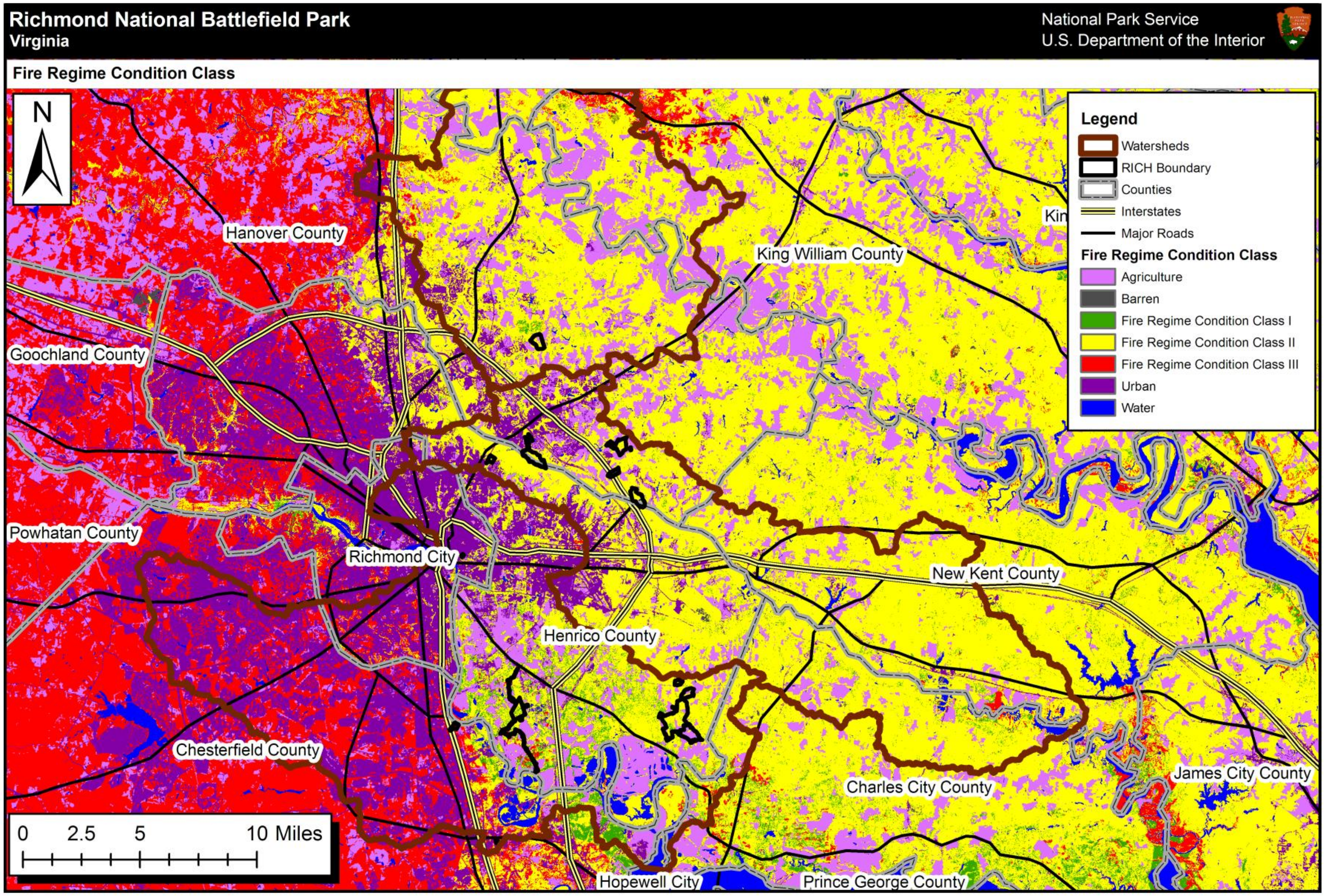

Figure 30. Departure between current vegetation condition and reference vegetation condition according to LANDFIRE (USDA Forest Service 2006) in the region of Richmond National Battlefield Park (RICH). Fire Regime Condition Class I is low departure from historic vegetation; Condition Class II is moderate departure from historic vegetation; and Condition Class III is high departure from historic vegetation.

Table 7. Prescribed and wildfires reported at Richmond NBP (RICH 2010).

Fire ID	Year	Fire Name	Date	Acres	Unit
VA-RICH-1994-156	1994	Fort Harrison Quarters	12/24/1994	3.0	FH
VA-RICH-1996-082	1996	Drewry's Trail	04/24/1996	0.0	DB
VA-RICH-1996-210	1996	Millrace Apts.	11/30/1996	0.0	GM
VA-RICH-1997-050	1997	Chickahominy	04/19/1997	0.0	CB
VA-RICH-1997-049	1997	Cold Harbor RX	04/16/1997	0.0	CH
VA-RICH-1997-094	1997	Malvern Field	07/09/1997	30.0	MH
VA-RICH-1998-123	1998	Drewry's Obs. Platform	08/28/1998	0.0	DB
VA-RICH-1999-264	1999	Lewellyn Lightning Strike	08/01/1999	0.0	MH
VA-RICH-2000-0002	2000	Cooper	10/30/2000	0.0	FH
VA-RICH-2000	2000	Fort Harrison RX	03/15/2000	0.3	FH
VA-RICH-	2002	Gaines' Mill RX	03/01/2002	1.3	GM
VA-RICH-2002-150	2002	Drewry's Trail 2	08/11/2002	0.3	DB
VA-RICH-2002-024	2002	Fort Harrison Ranger Office	02/01/2002	0.3	FH
VA-RICH-2004	2004	Cold Harbor RX 2	03/01/2004	27.6	CH
VA-RICH-2005	2005	Cold Harbor RX 3	03/22/2005	21.0	CH
VA-RICH-2005	2005	Fort Harrison RX 2	not given	0.8	FH
VA-RIP-0506	2005	West House Barn	09/19/2005	1.0	MH
VA-RIP-06015	2006	Malvern Hill Rx 06	04/05/2006	41.0	MH
VA-RIP-0702	2007	Malvern Hill Rx 07	03/30/2007	41.0	MH
VA-RIP-08002	2008	Malvern Hill Rx 08	03/13/2008	0.0	MH
VA-RIP-0908	2009	Fort Darling Fire	04/05/2009	10.5	DB
VA-RIP-0907	2009	Malvern Hill 09	03/24/2009	42.0	MH
VA-RIP-0906	2009	Cold Harbor 09	03/24/2009	28.0	CH

Fuel types (Figure 31) and fuel loads are existing threats that should be monitored at Richmond NBP. As dead and dry plant materials build up, the risk of more catastrophic fire events increases (U.S. Geological Survey 2000). Richmond NBP has relatively high connectivity to neighboring forests, which should be considered when assessing overall fire risk. Two hazard fuel surveys were conducted in 1993 and 2005. Both found very small areas of increased fire risk due to fuel jackpots. In such cases, the park worked to remove them when they were in areas of infrastructure.

Condition Status Summary for Landscape Dynamics

Encroachment of human population, increased traffic, vehicle emissions, and other industrial development near the park are arguably the most important and constant threats and stressors the park must consider. Development may lead to increasing point and non-point source pollution, affecting air and water quality. In-park biological integrity may also be stressed from these outside influences. The small amount of unnatural habitat within the park is small (mostly at Chimborazo). The park amount of impervious surface was well under the reference value of 10% (1.1%).

Richmond NBP has a large percentage of edge habitat (26.28%), yet it is comprised of 50.52% core habitat (Courtenay 2010). Several of the units are connected to the Chickahominy River corridor which is likely to remain core habitat. Each park unit showed overall fragmentation with no corridors connecting the park units. Core areas allow for habitat development, while corridors allow for the movement of plant and animal species, improving habitat health and genetic diversity (Courtenay 2010). Ecological networks within Richmond NBP are especially important because, in such a fragmented cultural landscape, they may provide one of the few opportunities for corridors, connectivity, and wildlife movement in the area. Courtenay (2010) found Beaver Dam Creek, Chickahominy Bluff, Cold Harbor, Gaines' Mill, and Turkey Hill have the highest potential for creating connecting core forest areas near the Chickahominy River. Malvern Hill has relatively low core habitat for its size; although it is located near large core areas and could potentially be connected to Turkey Hill, Gaines' Mill, and Cold Harbor. If not protected, the surrounding land near units such as Malvern Hill, may be zoned for development in the near future.

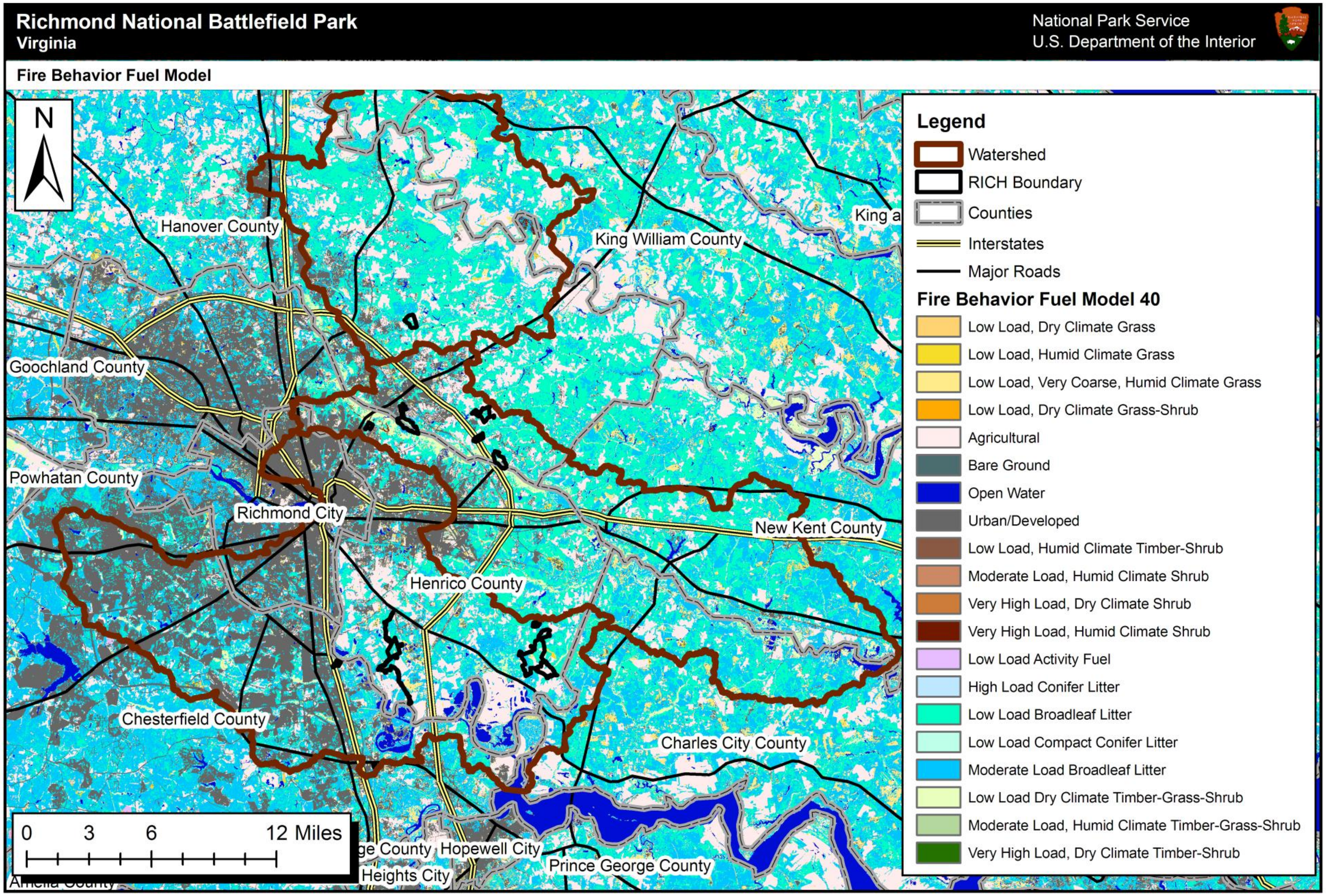

Figure 31. Wildfire fuel types according to LANDFIRE (USDA Forest Service 2006) in the region of Richmond National Battlefield Park (RICH).

4.0 Vegetation Communities

Significant land cover classes at Richmond NBP are the upland forests, meadows/fields, riparian forests, and wetlands. These systems have sustained substantial losses in the eastern United States and Virginia. The latest vegetation mapping effort at Richmond NBP took place in April, May and July 2002, July 2003, June and July 2004, July and September 2005, and April 2006 (Patterson 2008).

We chose appropriate indicators and measures from the broad-scale park assessment to also assess the condition of each ecological community within the park (see Table 8 – data sources). The communities were identified in our scoping meeting using the Richmond NBP vegetation map as a guide. The important communities we identified were: 1) upland forest; 2) riparian forest; 3) wetland/stream; and 4) meadow/field. We calculated the relative acres and percentage of communities using an altered form of the Richmond NBP vegetation map. The Richmond NBP vegetation map was altered by assigning a simplified ecological community to each of the polygons. We dissolved polygons based on the ecological community and combined (union) the ecological communities with the authorized boundary. We performed several operations in ArcGIS Toolbox (ESRI 2006) to simplify and repair geometry. The resulting ecological community maps are shown in Figures 32-35. Vegetation communities were calculated by unit and can be seen in Table 9. Relative percentages of communities are also listed. Figure 36 provides an image of typical forested area within the Cold Harber unit and one of the unique plant species found there-in.

Ecologically Critical Areas and Other Unique Natural Resources

Six natural communities (Figures 37-40) as defined in the Natural Communities of Virginia were identified by Patterson (2008) at Richmond NBP these are (http://www.dcr.virginia.gov/natural_heritage/nctoc.shtml):

1. Acidic Oak - Hickory Forest
2. Coastal Plain/Piedmont Acidic Seepage Swamp
3. Coastal Plain/Piedmont Small-Stream Floodplain Forest
4. Coastal Plain Mixed Oak/Heath Forest
5. Mesic Mixed Hardwood Forest
6. Non-Riverine Saturated Forest

In addition, there are three Virginia Natural Heritage exemplary natural communities at Richmond NBP: Coastal Plain/Piedmont Acidic Seepage Swamp, Mesic Mixed Hardwood Forest, and Coastal Plain/Piedmont Swamp Forest. Although the other five natural communities in the park do not meet the criteria to be an exemplary natural community, they should be protected (Patterson 2008). Although maps were not available at the time of this assessment, it should be noted that two examplary communities were recently identified at Turkey Hill (Mesic Mixed Hardwood Forest and Coastal Plain/Piedmont Swamp Forest).

Table 8. Data sources used for measures of vegetation communities for Richmond NBP.

Indicator	Measure	Data Source(s)
Forest Condition	Land cover	Patterson (2008)
	Native forest pests	MIDN I&M data (2010)
	Key forest bird species	Bradshaw (2007)
	Invasive exotic plants	MIDN I&M data (2010)
	White-tailed deer density	Prowatzke (2011), Horsley et al. (2003)
Grassland/Meadow Condition	Relative cover native plant species	RICH (2005), RICH (2010b), Forder (2011), Latham (2009)
	% woody species	Forder (2011)
	Key grassland bird species	Bradshaw (2007)

Table 9. Ecological communities for the units comprising Richmond NBP.

Unit	Built-up Land	% Built-up Land	Meadow	% Meadow	Riparian Forest	% Riparian Forest	Upland Forest	% Upland Forest	Wetland	% Wetland	River/ Stream	% River/ Stream
Beaver Dam Creek	1.6	0.6	0	0	53.4	19.7	26.6	9.8	186.5	68.8	3.1	1.1
Chickahominy Bluff	5.2	13.3	0	0	11.7	30.0	22.0	56.6	0	0	0	0
Chimborazo	6.0	100.0	0	0	0	0	0	0	0	0	0	0
Cold Harbor	10.2	5.6	15.3	8.4	1.7	0.9	142.2	78.0	12.8	7.0	0	0
Drewry's Bluff	2.3	6.5	7.6	21.1	0	0	26.0	72.4	0.0	0	0	0
Fort Harrison	56.4	17.8	0.5	0.1	34.9	11.0	217.3	68.6	7.7	2.4	0	0
Gaines' Mill	2.0	3.3	13.0	21.5	0.7	1.1	42.7	70.7	2.1	3.5	0	0
Garthright House	2.1	100.0	0	0	0.0	0	0	0	0	0	0	0
Malvern Hill	144.5	13.6	170.8	16.1	82.8	7.8	549.7	51.7	114.9	10.8	0	0
Parker's Battery	1.8	17.8	0	0	0.0	0	8.3	82.2	0	0	0	0
Totopotomoy Creek (Rural Point)	51.7	36.0	0	0	16.4	11.4	66.7	46.4	8.9	6.2	0	0
Turkey Hill	0	0	0	0	62.2	35.6	64.1	36.7	38.9	22.3	9.5	5.4

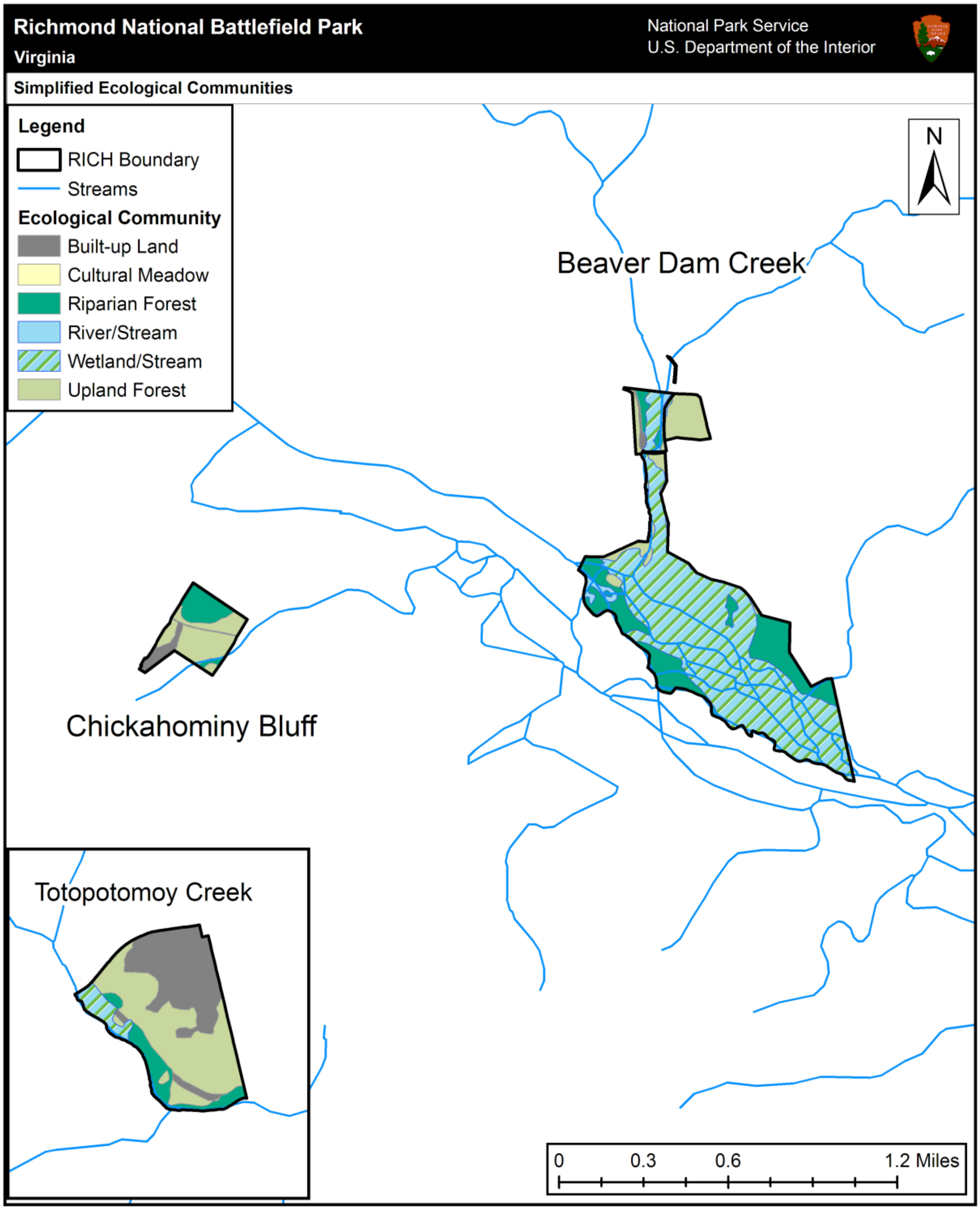

Figure 32. Richmond National Battlefield Park (RICH) simplified land cover (RICH 2010a).

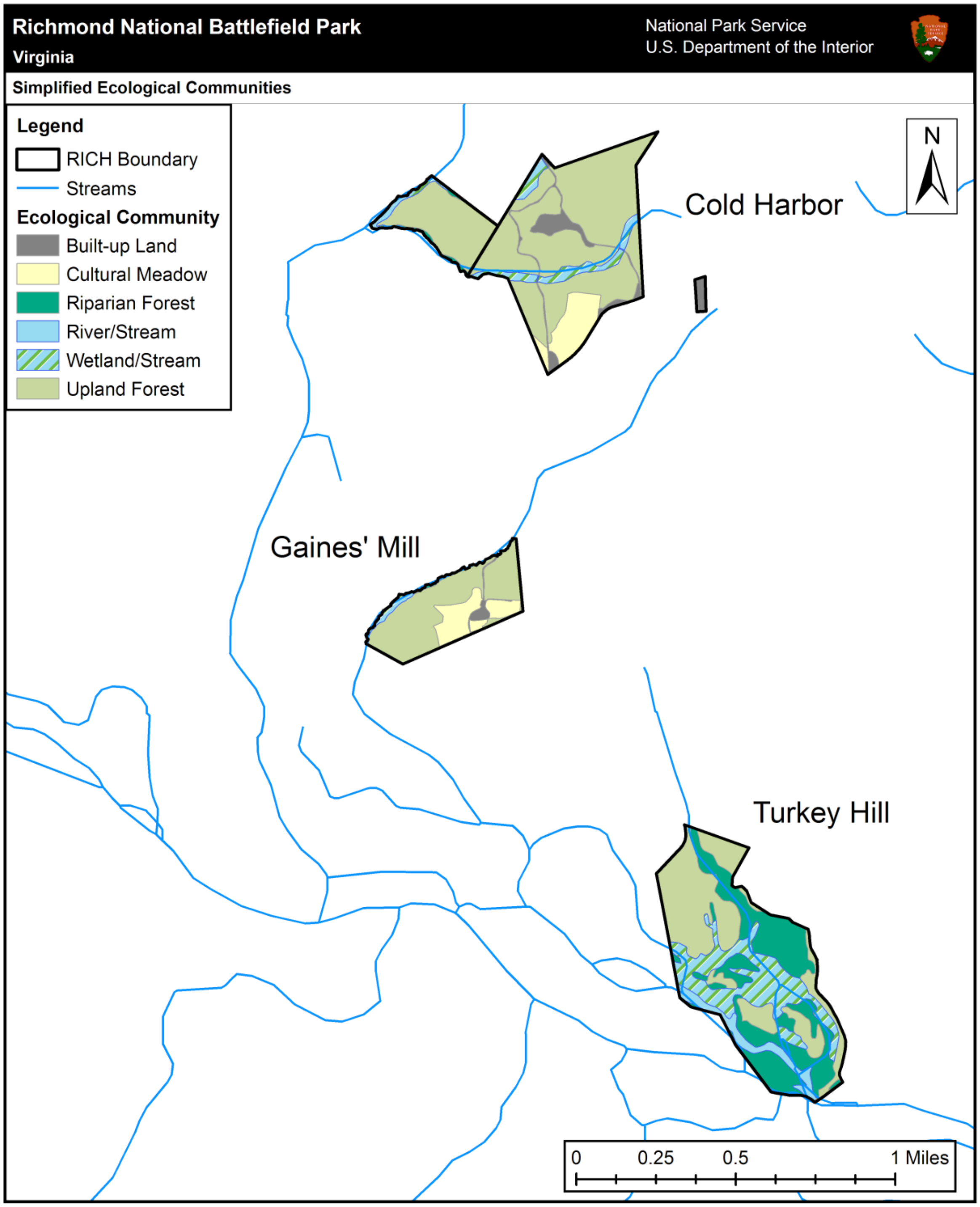

Figure 33. Richmond National Battlefield Park (RICH) simplified land cover (RICH 2010a).

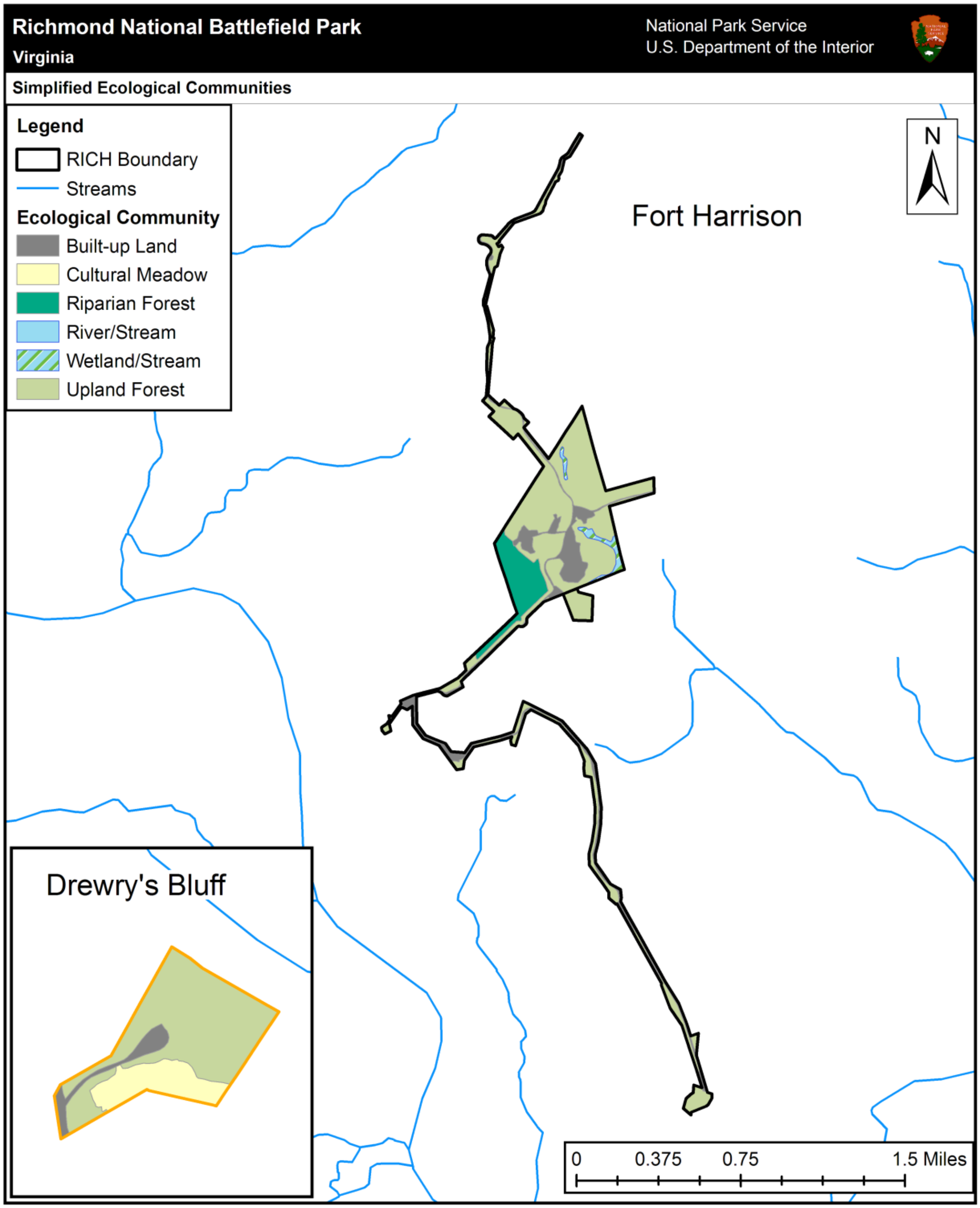

Figure 34. Richmond National Battlefield Park (RICH) simplified land cover (RICH 2010a).

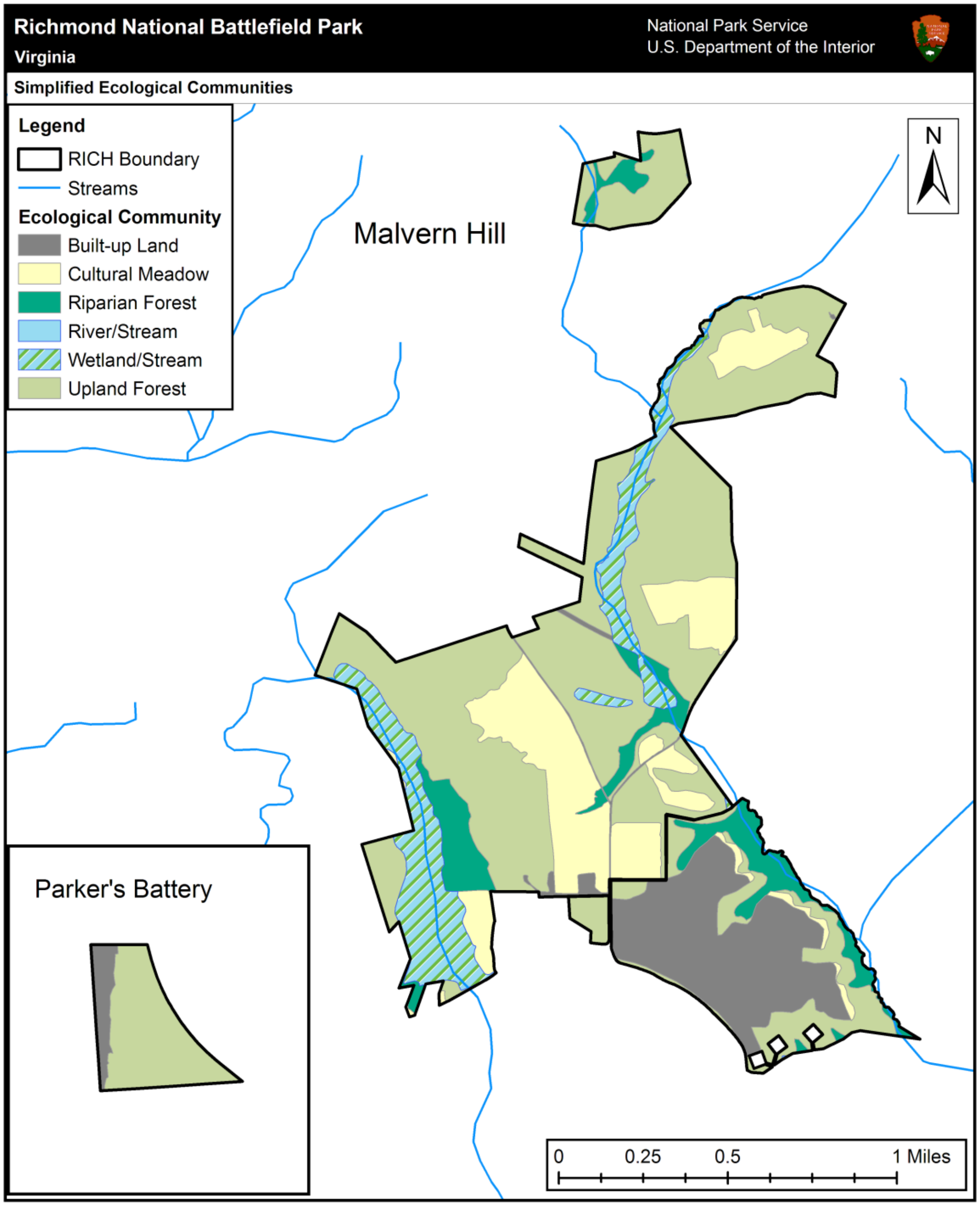

Figure 35. Richmond National Battlefield Park (RICH) simplified land cover (RICH 2010a).

Figure 36. Lupine (*Lupinus perennis)*, Cold Harbor (April 2008).

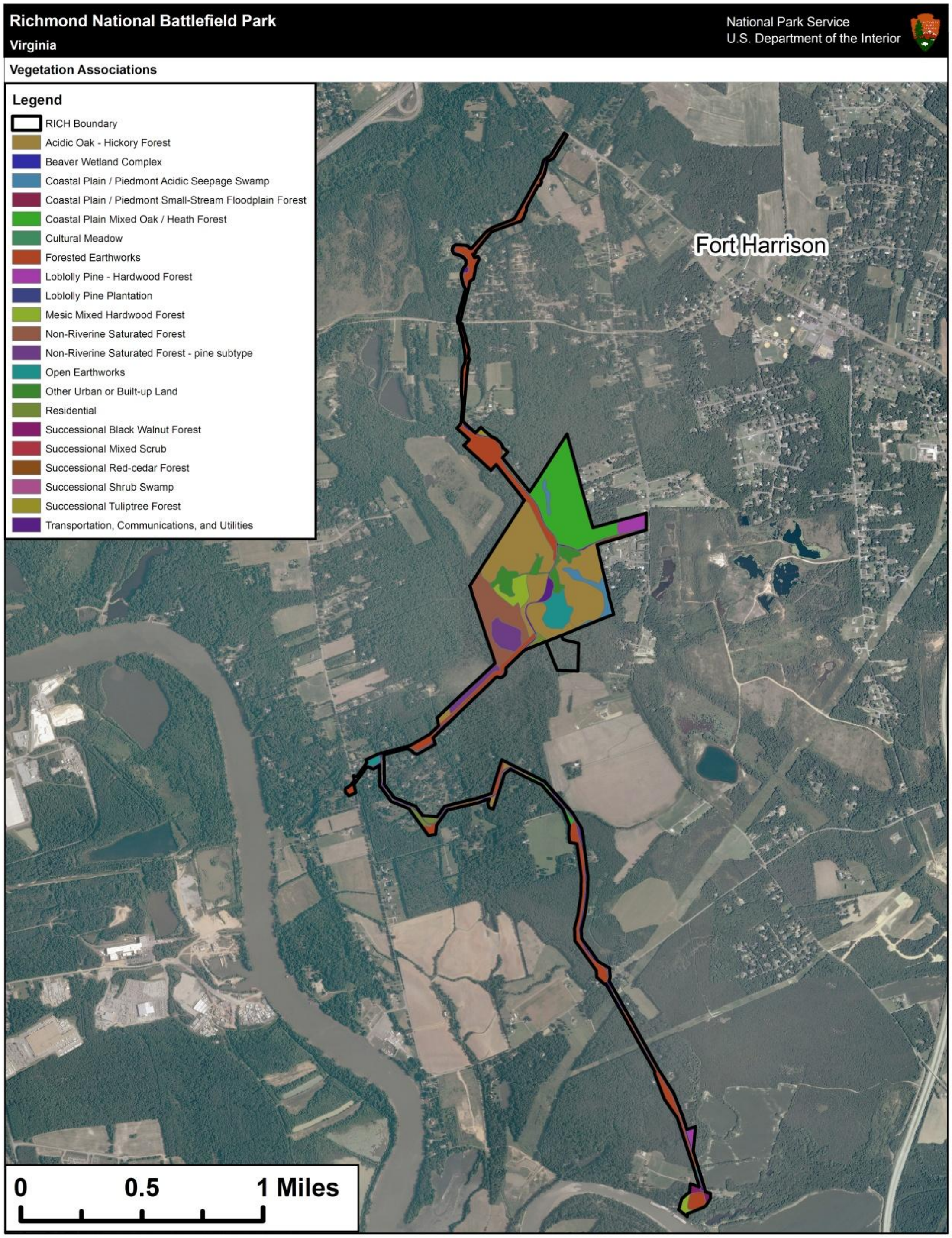

Figure 37. Vegetation associations for Fort Harrison (Patterson 2008).

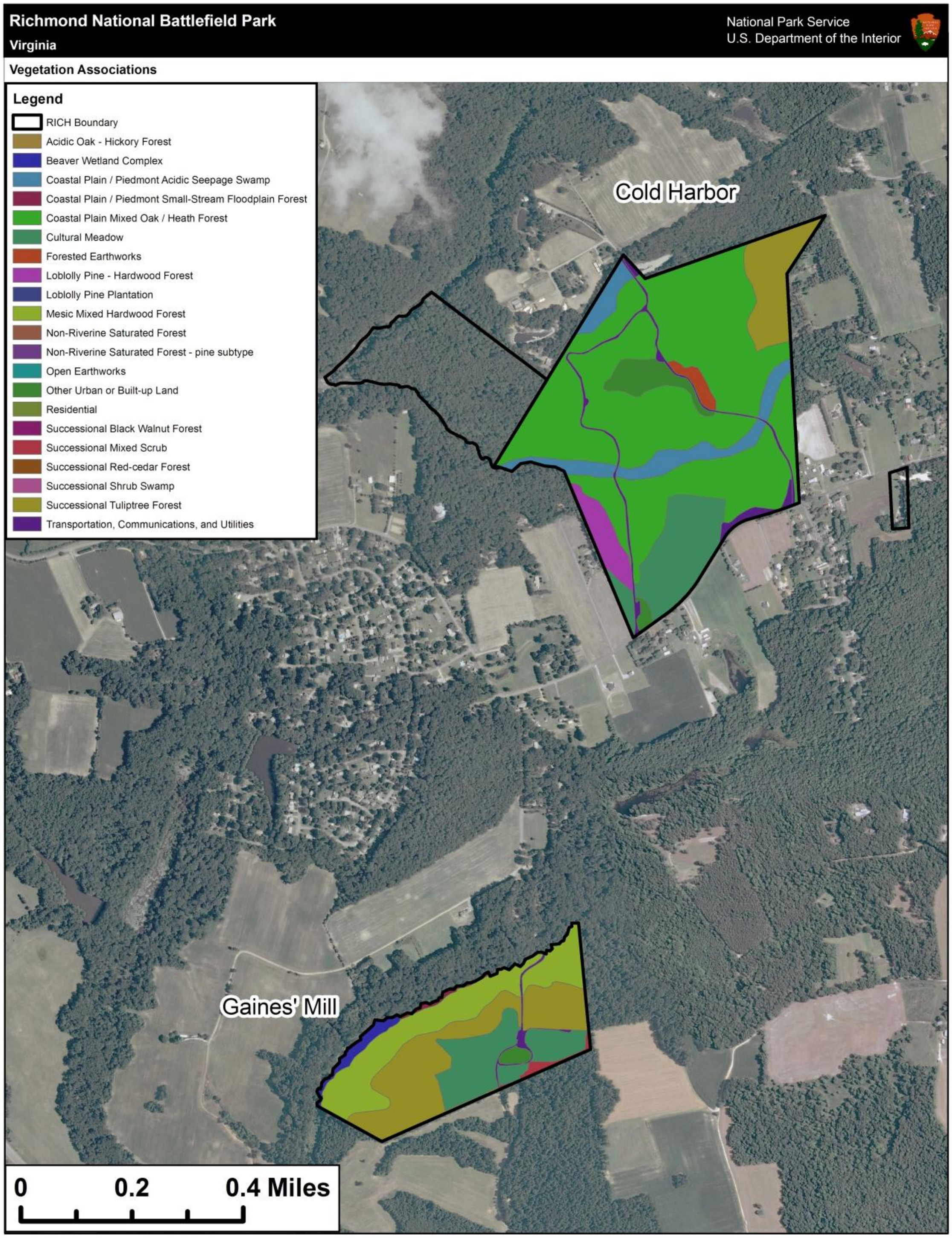

Figure 38. Vegetation associations for Cold Harbor and Gaines' Mill (Patterson 2008).

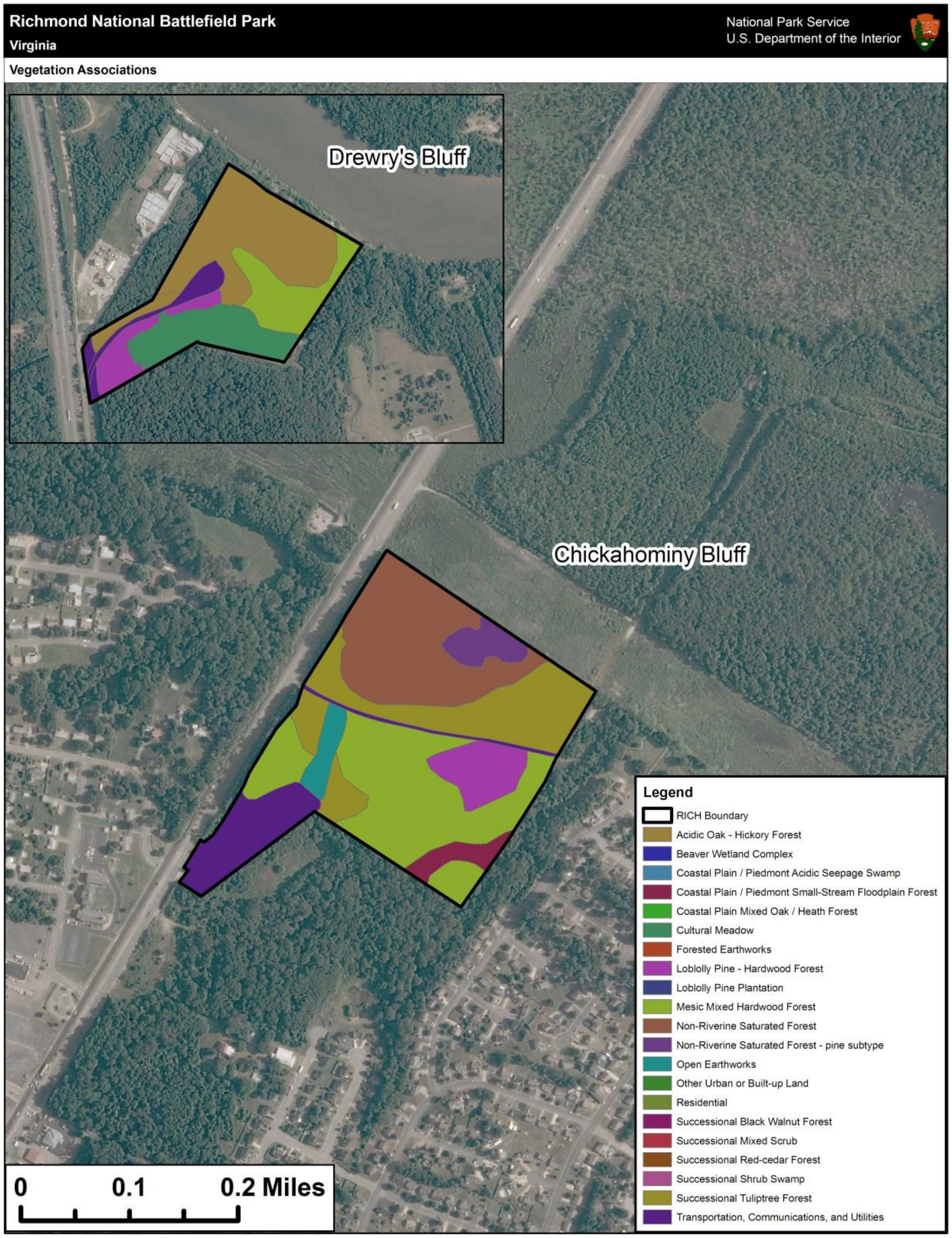

Figure 39. Vegetation associations for Drewry's Bluff and Chickahominy Bluff (Patterson 2008).

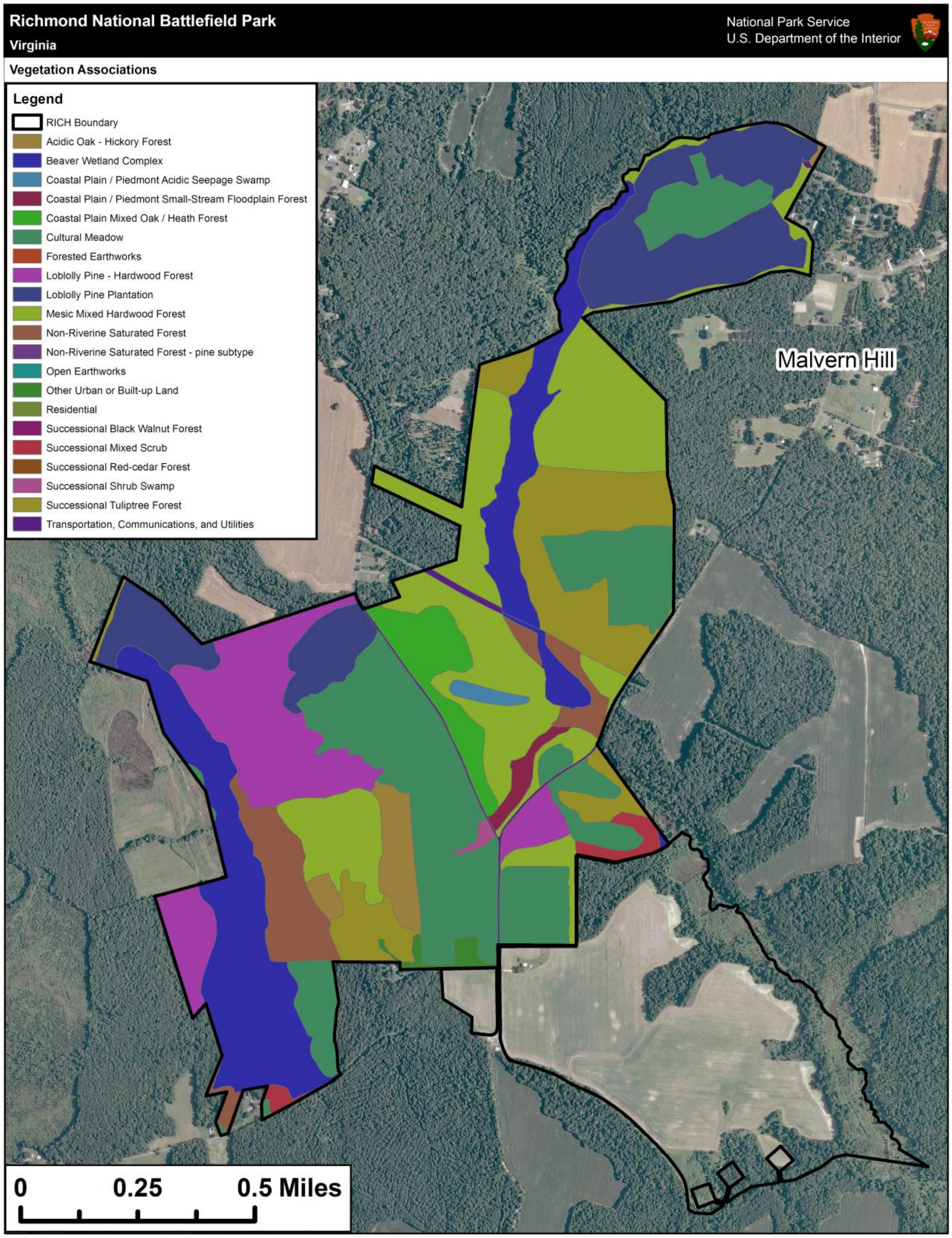

Figure 40. Vegetation associations for Malvern Hill (Patterson 2008).

Nonnative and Invasive Plants

Invasive plants are introduced species that can thrive in areas beyond their natural range of dispersal. These plants are characteristically adaptable, aggressive, and have a high reproductive capacity (USDA National Agricultural Library 2011). A nonnative plant species are found growing outside its natural range and are sometimes referred to as exotic.

Per discussions with park personnel, the plant species currently the most prevalent at Richmond NBP are Japanese honeysuckle (*Lonicera japonica*) and Nepalese browntop (*Microstegium vimineum*). Patterson (2008) found that forested wetlands had the highest cover by invasive, nonnative species while meadows and early successional classes had the highest diversity of nonnative plant species. Other invasive nonnative species noted during this survey included tree of heaven (*Ailanthus altissima*), Chinese privet (*Ligustrum sinense*), and wartremoving herb (*Murdannia keisak*), English ivy (*Hedera helix*), Princesstree (*Paulownia tomentosa*), and oriental ladysthumb (*Polygonum caespitosum* var. *longisetum)*. Of the 654 plant species recorded on Richmond NBP, 21% (n=140) are nonnative. Data from Richmond NBP (Table 10 and Figures 41-49) show that every unit surveyed (Turkey Hill and Chimborazo not surveyed) is impacted by invasive, nonnative plant species. A complete data summary of the native and nonnative species can be found in Appendix D.

Table 10. Acres impacted by invasive, nonnative plant species for Richmond NBP by unit (data from RICH (2005).

Unit	< 25%	25-50%	51-75%	> 75%
Totopotomoy Creek (Rural Point)	102.6	54.7	63.5	25.1
Chickahominy Bluff	52.9	12.4	32	12.3
Beaver Dam Creek	5.4	10.2	3.5	17.6
Gaines' Mill	59.5	3.5	1.5	0
Cold Harbor	11.5	0.03	0	0
Malvern Hill	64.8	77.2	238.5	329.4
Fort Harrison	26	11.9	17.1	3.9
Parker's Battery	0.3	0.4	0.02	0
Drewry's Bluff (Fort Darling)	1.8	0.19	12.6	8.2
Garthright House	0	0.2	0	0
Park-wide	324.8	170.8	368.7	396.6

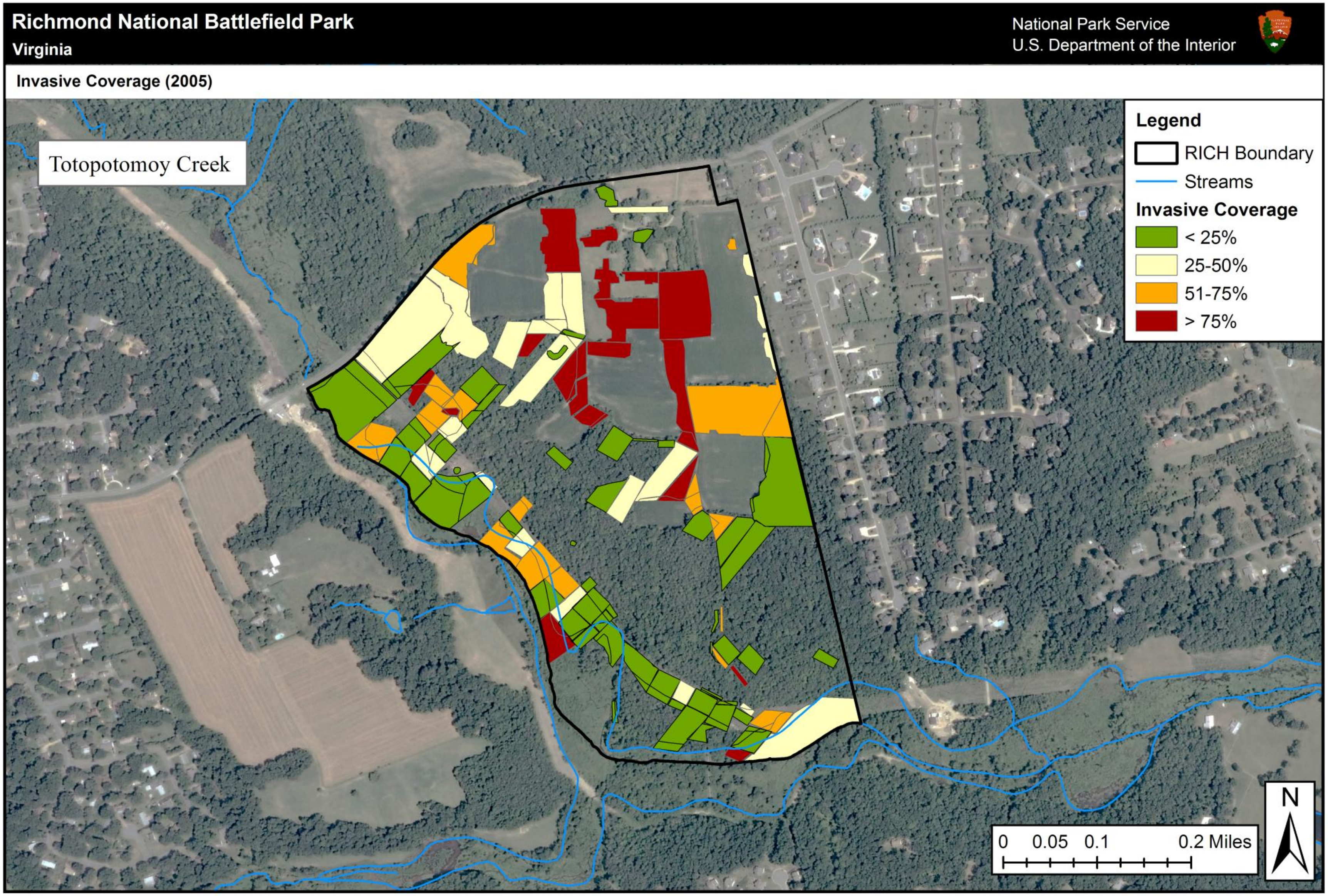

Figure 41. Invasive plant cover for Totopotomoy Creek (RICH 2005).

Figure 42. Invasive plant cover for Chickahominy Bluff (RICH 2005).

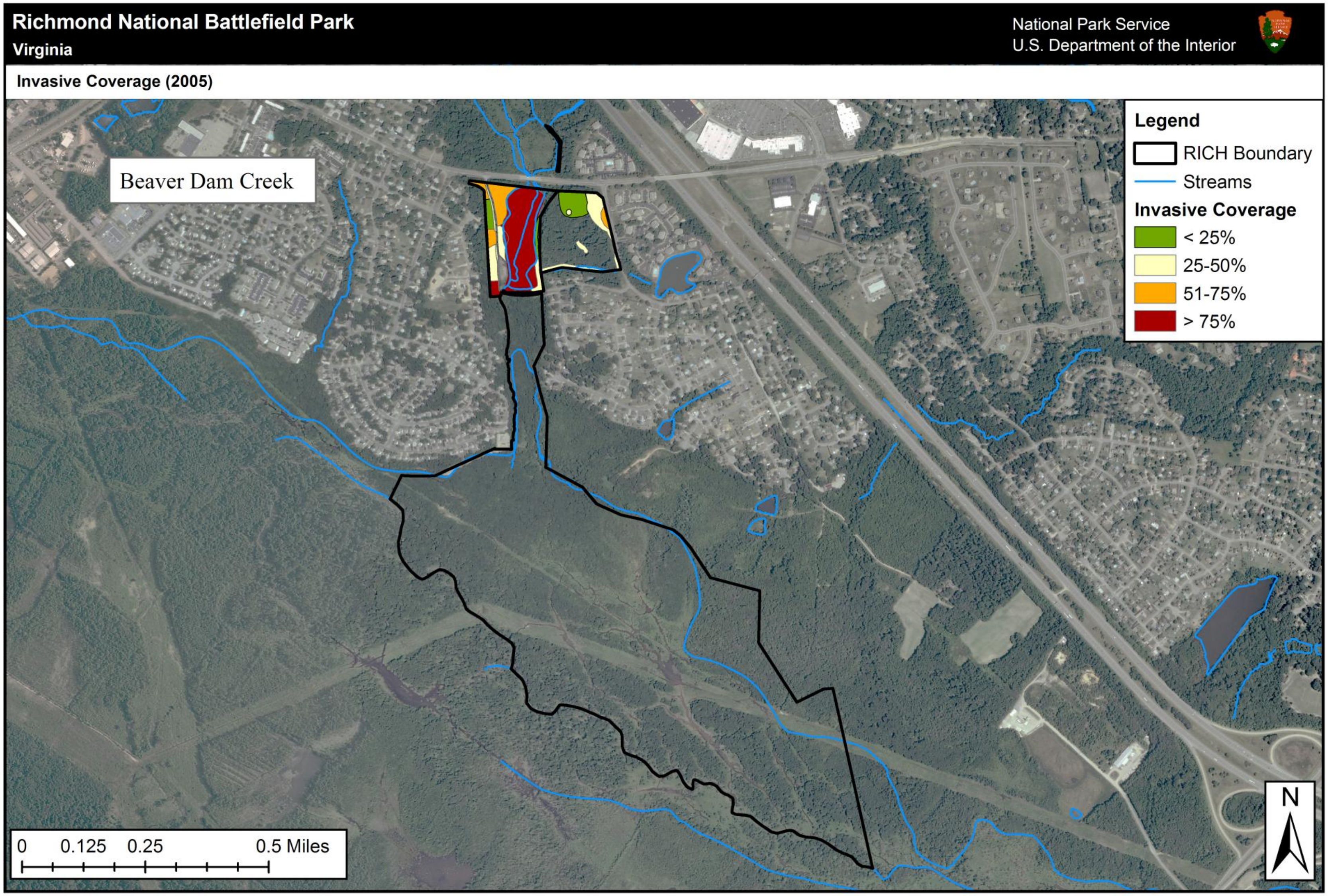

Figure 43. Invasive plant cover for Beaver Dam Creek (RICH 2005).

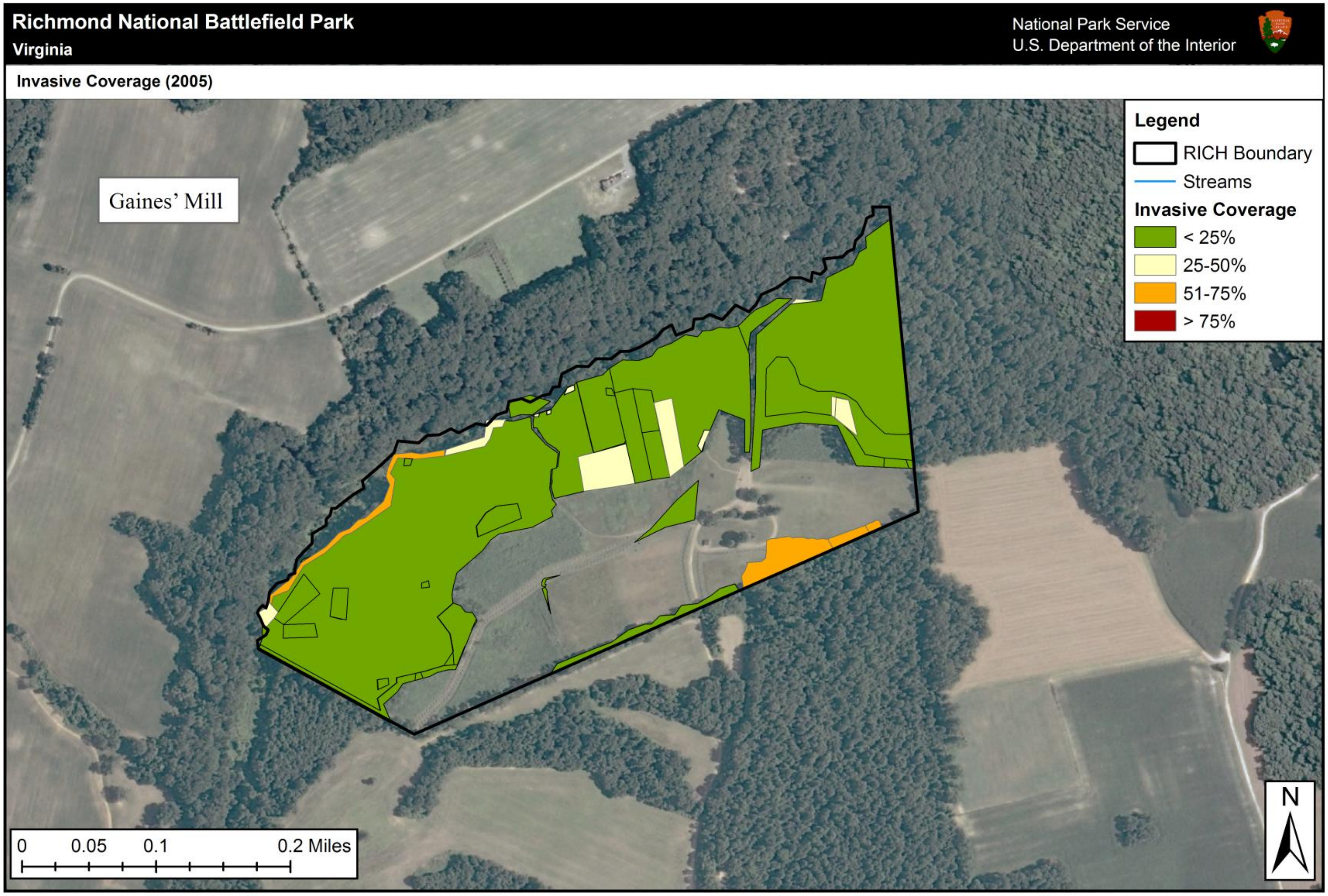

Figure 44. Invasive plant cover for Gaines' Mill (RICH 2005).

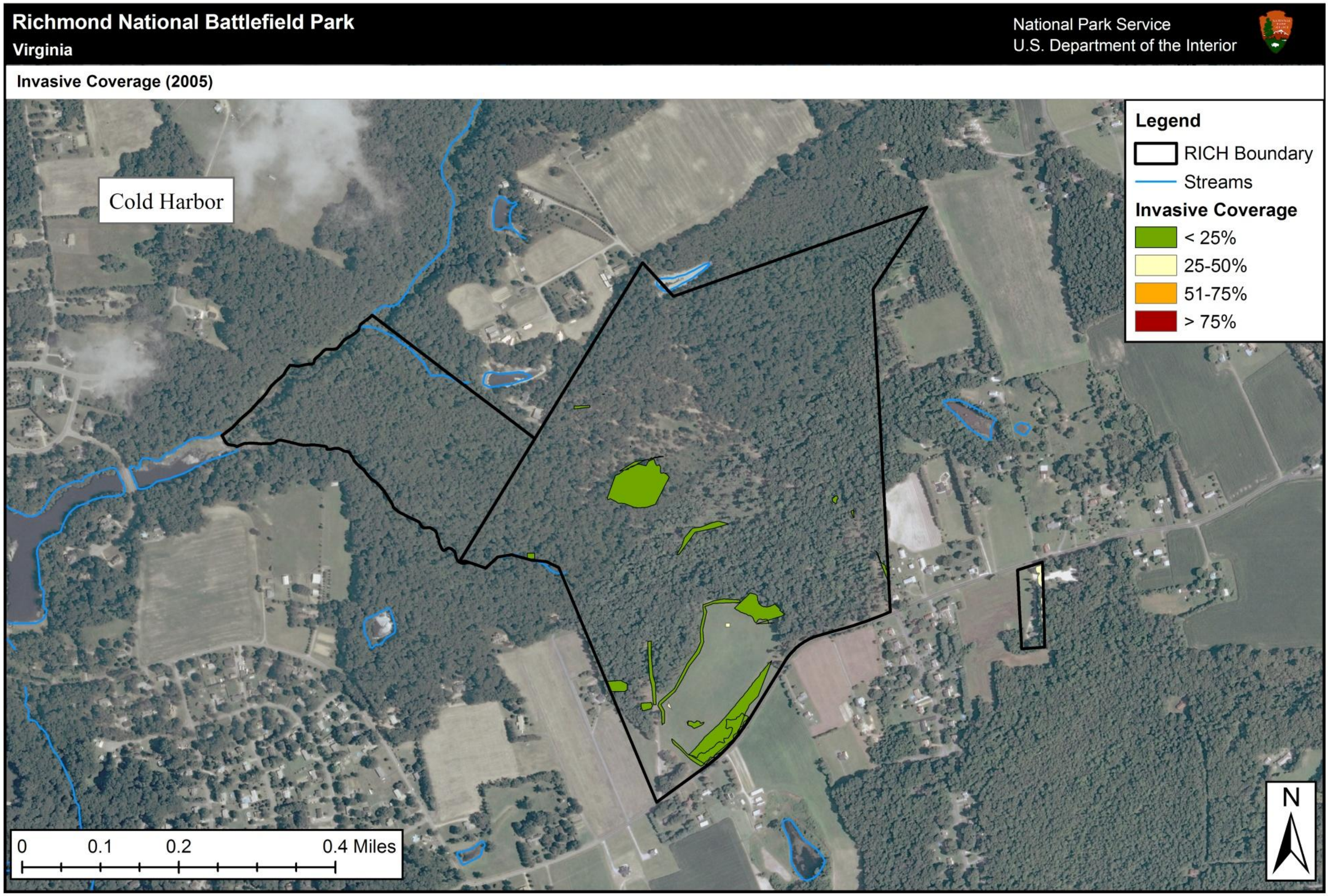

Figure 45. Invasive plant cover for Cold Harbor (RICH 2005).

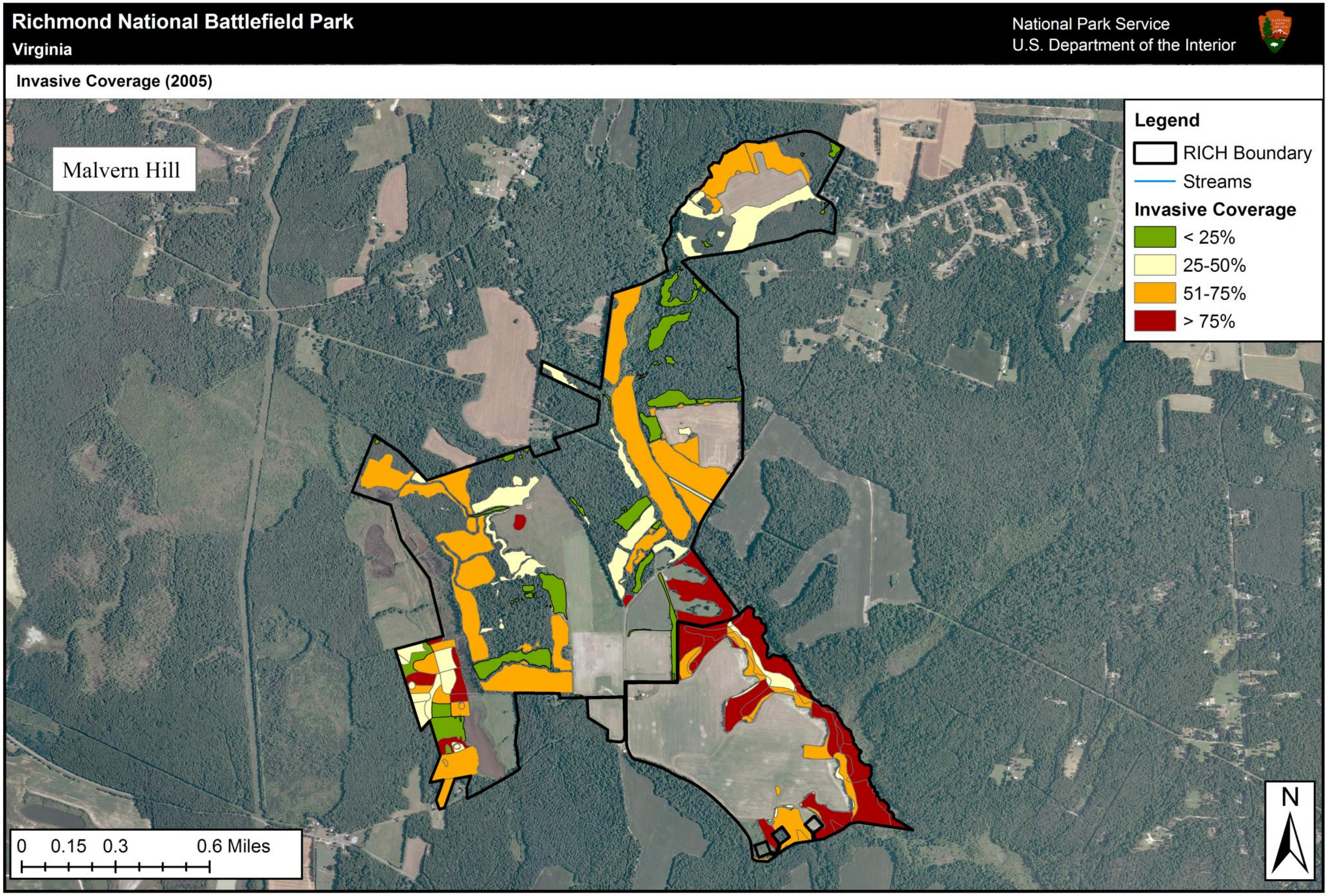

Figure 46. Invasive plant cover for Malvern Hill (RICH 2005).

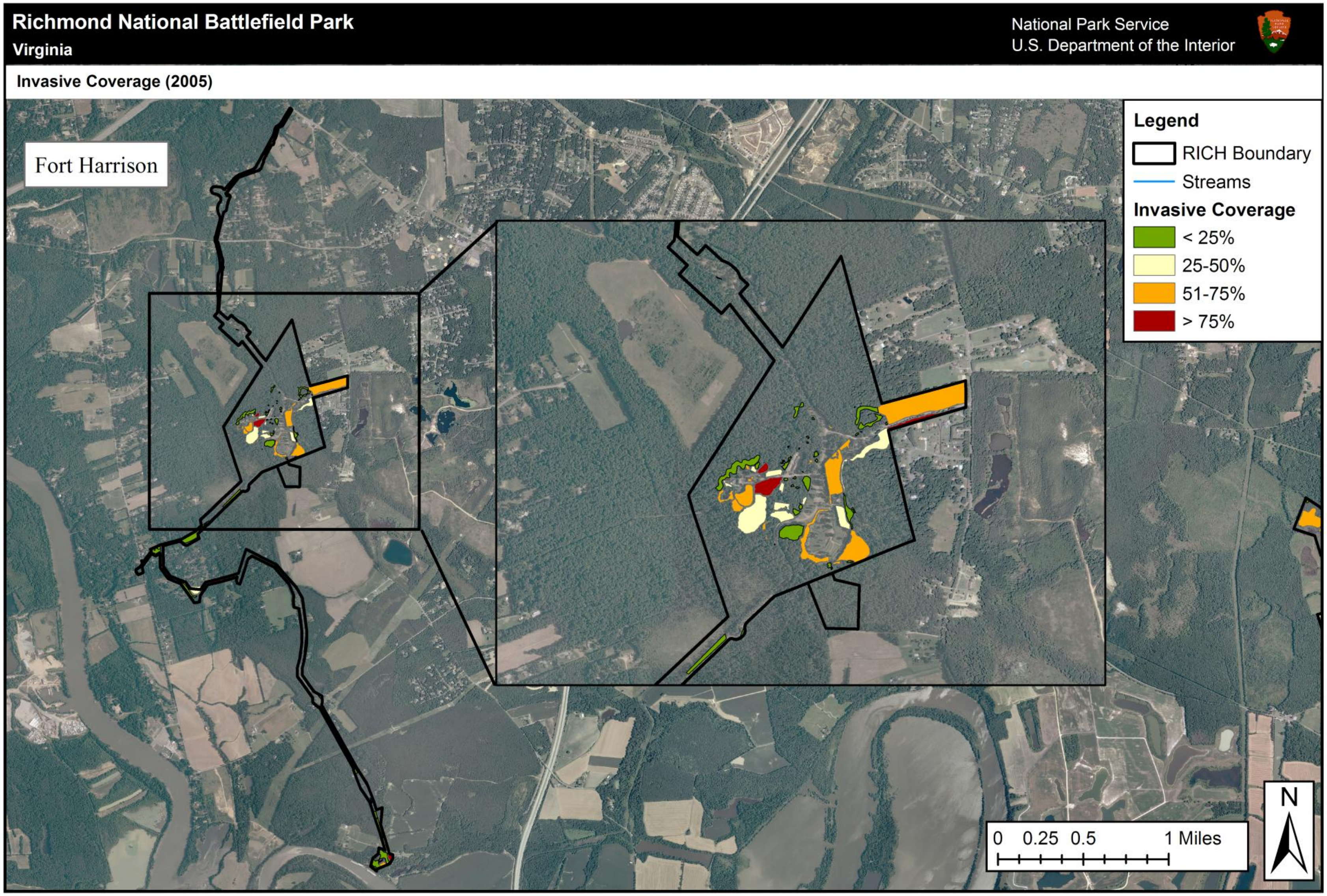

Figure 47. Invasive plant cover for Fort Harrison (RICH 2005).

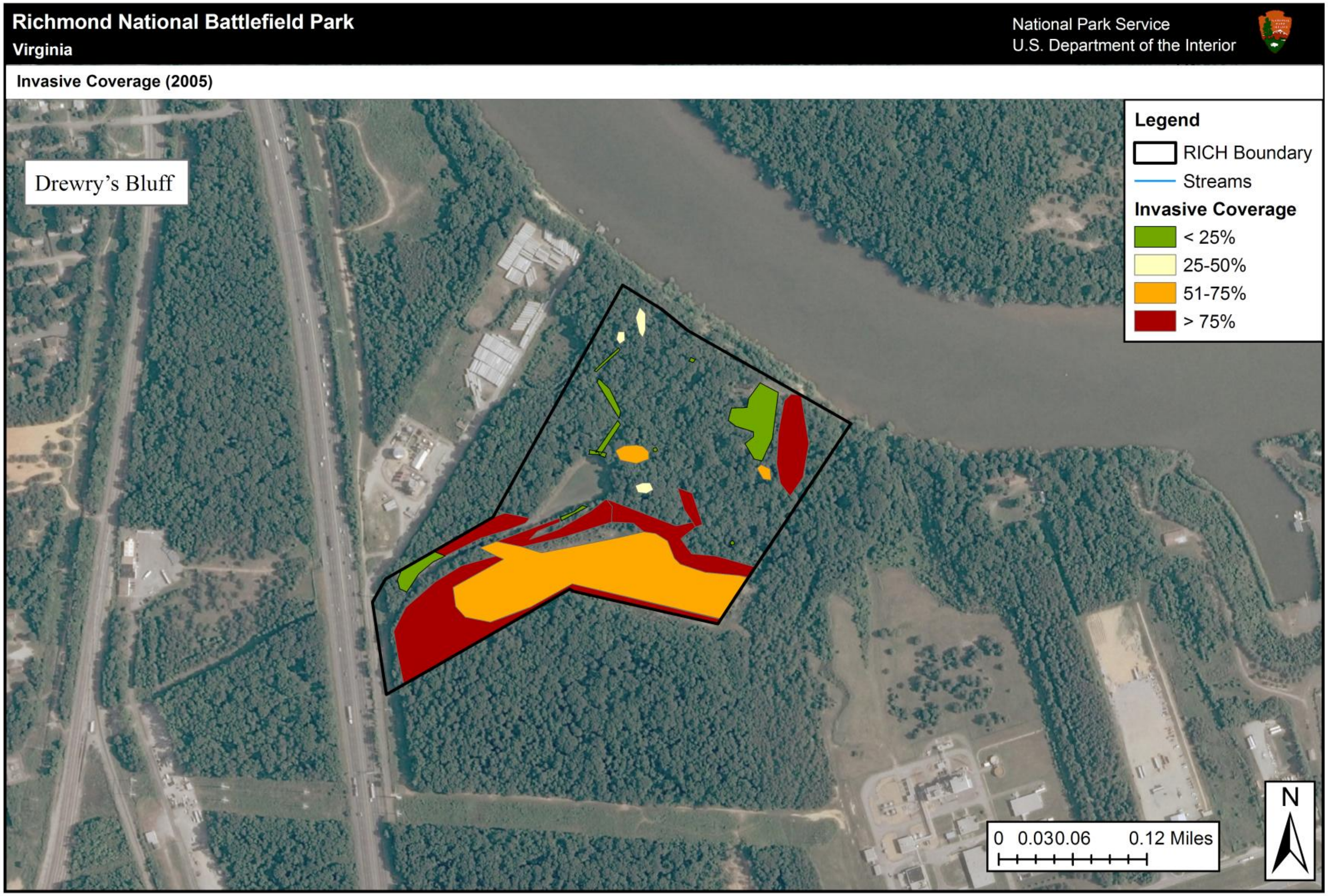

Figure 48. Invasive plant cover for Drewry's Bluff (RICH 2005).

Figure 49. Invasive plant cover for Parker's Battery (RICH 2005).

Forest Condition

MIDN I&M funded vital signs that are presently monitored at Richmond NBP include invasive exotic plants, native forest pests, exotic diseases/pathogens – plants, forest plant communities, and white-tailed deer (herbivory) (Comiskey and Callahan 2008). Metrics used to assess the forest condition at Richmond NBP include land cover, native forest pests, indicator species, invasive exotic plants, and white-tailed deer density. MIDN I&M forest monitoring objectives are to:

1. Determine the status of and trends in forest structure, composition, and dynamics of canopy and understory woody species.
2. Determine the status of and trends in the density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse.
3. Detect and monitor the presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests.
4. Determine the status of and trends in forest coarse woody debris and the availability of snags.
5. Determine the status of and trends in soil Ca:Al and C:N ratios to assess the extent of base cation depletion, increased aluminum availability, and/or nitrogen saturation impacting MIDN forest soils.

<u>Land Cover</u>

Upland forests at Richmond NBP consist of 1165.8 ac of deciduous forest and 263.9 ac of riparian forest (Table 11). Upland forest and riparian forest land cover classes were used to calculate total forest cover for each unit at Richmond NBP. We considered > 59% forest cover as "good" and < 30% as "poor" reference value based on research from Gardner et al. (1987). Only one unit rates as poor for the amount of forest cover, Beaver Dam Creek (Table 11). This is simply due to the fact that the majority (68.8%) of Beaver Dam Creek is a large wetland complex.

Table 11. Forest cover for Richmond NBP units.

Unit	Forest Cover (ac)	Forest Cover (%)	Rating
Beaver Dam Creek	80.1	29.5	Poor
Chickahominy Bluff	33.7	86.7	Good
Chimborazo	n/a	n/a	n/a
Cold Harbor	143.9	79.0	Good
Drewry's Bluff	26.0	72.4	Good
Fort Harrison	252.3	79.6	Good
Gaines' Mill	43.3	71.8	Good
Garthright House	n/a	n/a	n/a
Malvern Hill	632.6	59.5	Good
Parker's Battery	8.3	82.2	Good
Totopotomoy Creek	83.1	57.9	Good
Turkey Hill	126.3	72.3	Good

Native Forest Pests

Forest pests are listed as a MIDN Vital Sign (Comiskey and Callahan 2008). From 2007- 2009 no forest pests were observed at Richmond NBP. Forest health plots are sampled park-wide. Forest pests of concern include gypsy moth, and hemlock wooly adelgid.

Indicator species

Indicator species can be used to assess the condition of the environment and to monitor trends in condition over time. We assume that more species presence indicate a better forest condition. They can provide early warning signs of changes in the environment, and, at times, can be used to diagnose the cause of an environmental problem. Specific bird species can be a good indicator of the ecological condition of the forests. The wood thrush is an abundant breeder and the ovenbird is a common breeder at the park. The wood thrush prefers moist deciduous forests with dense and well developed understory, and is a good indicator of upland forest. The ovenbird is a good indicator of closed-canopy, mature forests with a sparse understory. The wood thrush, Kentucky warbler, scarlet tanager, yellow-throated vireo, pileated woodpecker, and red-eyed vireo were chosen as indicators of forest condition (See 6.0 Biological Integrity for more information).

Species composition

Forest structure and composition are important measures of forest condition and health. Monitoring trends of these metrics will help natural resource managers identify stressors that may degrade forest function. Declines in seedling and sapling densities could indicate a reduced capacity of the forest to regenerate and/or high white-tailed deer density. Outside park stressors such as acid deposition can alter soil chemistry, disrupting nutrient cycles. Increased habitat fragmentation and development surrounding Richmond NBP can weaken the ecological integrity of the forests.

Table 12 shows the average stocking density for the established monitoring plots by unit. One year of data was collected at each of the 32 plots. Trends and desired conditions can be determined and evaluated in the future. Beaver Dam Creek and Malvern Hill have the highest average number of trees/ha; Gaines' Mill has the lowest. Totopotomoy Creek and Cold Harbor have the highest average number of saplings/ha and stocking/ha; Fort Harrison and Chickahominy Bluff have the lowest (Figures 50-52).

Table 12. Average trees, saplings, and stocking/ha for MIDN I&M forest monitoring plots by unit.

Unit	# of Plots	Average Trees/ha	Average Saplings/ha	Average Stocking/ha
Malvern Hill	16	647	1375	33073
Beaver Dam Creek	1	850*	1294*	44167*
Chickahominy Bluff	1	475*	1059*	1667*
Cold Harbor	2	375	1647	86667
Fort Harrison	4	513	1265	6042
Gaines' Mill	1	275*	1294*	18333*
Totopotomoy Creek	2	513	2294	74583
Turkey Hill	5	585	1459	18667

*For data with only one sample plot no average value was calculated.

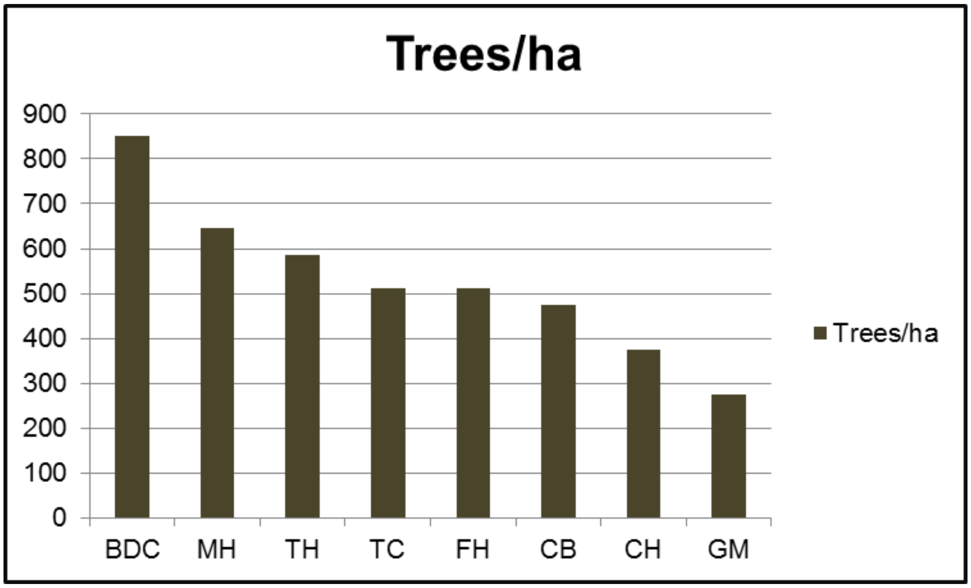

Figure 50. Average trees/ha by unit for MIDN I&M forest monitoring plots.

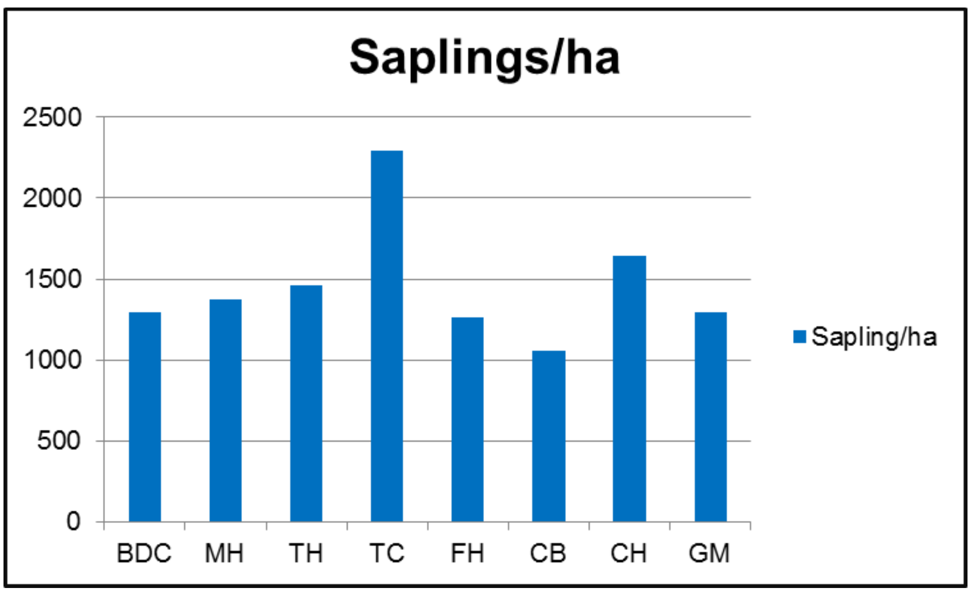

Figure 51. Average saplings/ha by unit for MIDN I&M forest monitoring plots.

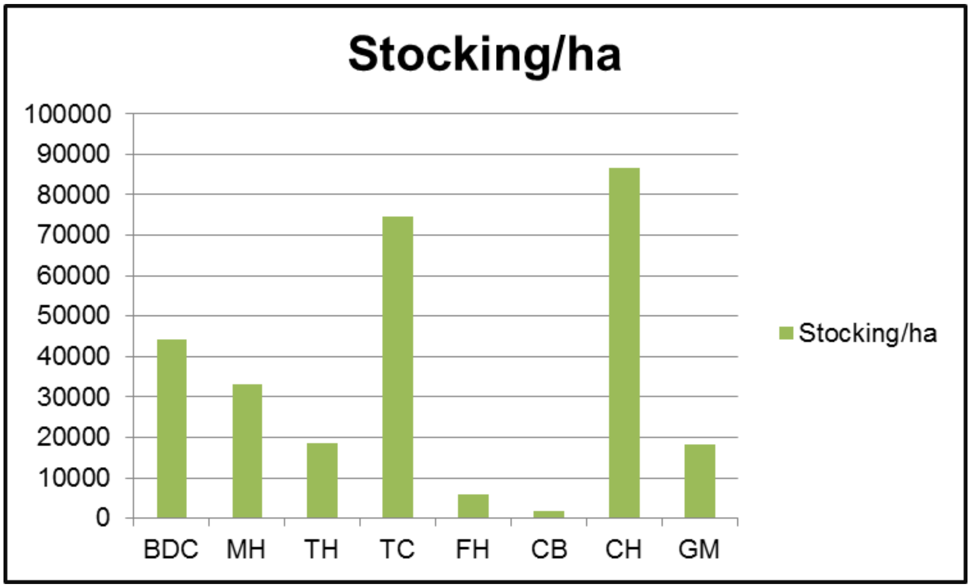

Figure 52. Average stocking/ha by unit for MIDN I&M forest monitoring plots.

In July 2011, the MIDN Inventory and Monitoring Program published the first report in their series of network wide vegetation monitoring reports. This document will provide additional analysis and summary statistics on forest structure and composition of canopy and understory species; density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse; invasive exotic plants, exotic plant diseases and pathogens, forest pests, soil fertility, and soil acidity within the forest vegetation plots of Richmond NBP (Comiskey and Wakamiya 2011).

Invasive Exotic Plants

Invasive species, particularly those that are exotic, have the potential to degrade native species and their habitat. They occupy habitat niches that would otherwise support native species, thereby degrading native species communities. Forest monitoring plots were established in 2007 on seven units: Fort Harrison (n=4), Chickahominy Bluff (n=1), Beaver Dam Creek (n=1), Malvern Hill (n=16), Cold Harbor (n=2), Gaines' Mill (n=1), Turkey Hill (n=5), and Totopotomoy Creek (n=2). Figures 53-57 show established monitoring plots at each of the aforementioned units. Each year, eight plots were established for exotic plant surveys, resulting in a total of 32 plots. Exotic species have been identified on many of the plots for the past four years (Table 13). Each plot has been surveyed once and trends can be established in the future. In 2010, four out of the eight plots surveyed had exotic species.

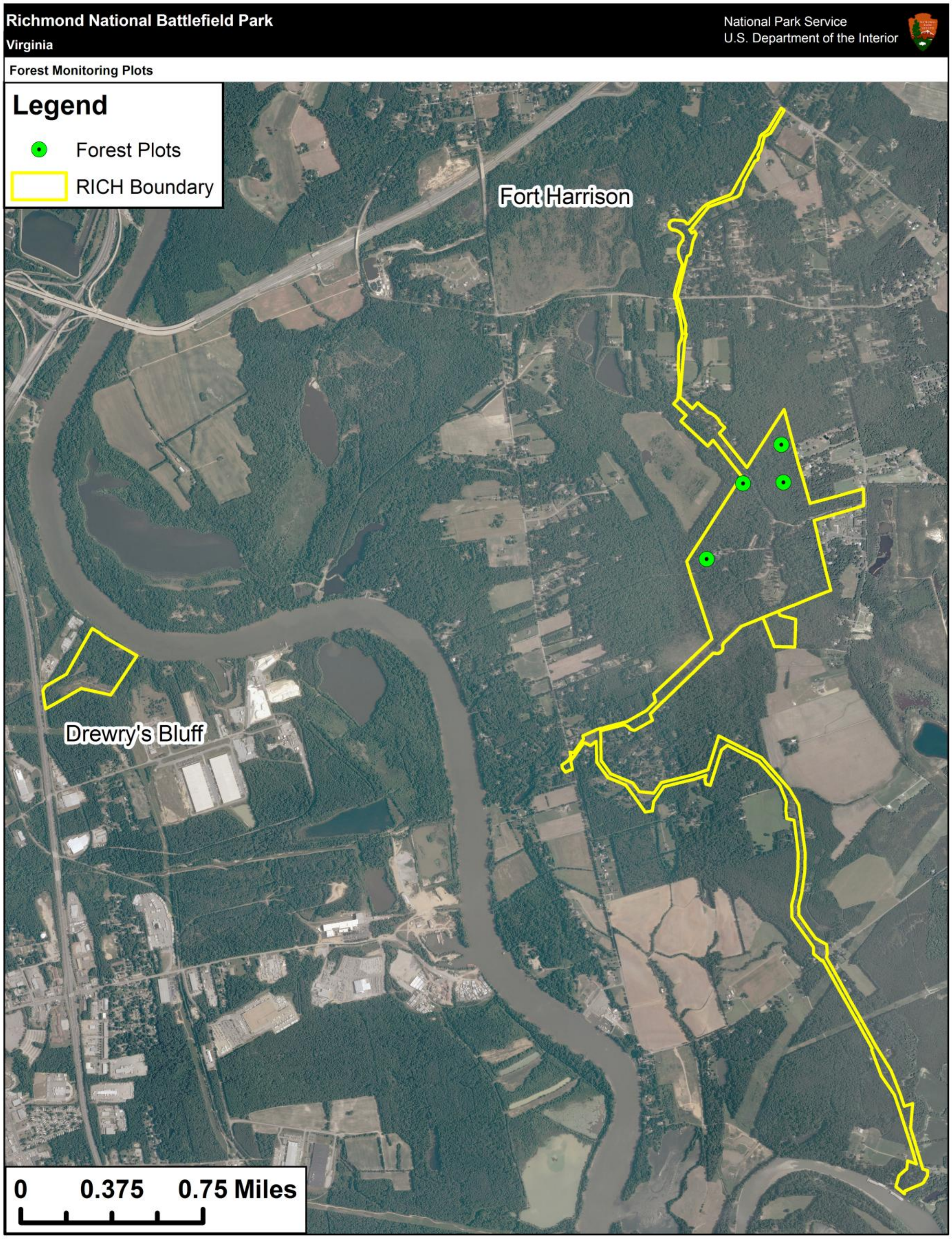

Figure 53. MIDN I&M forest monitoring plots at Fort Harrison.

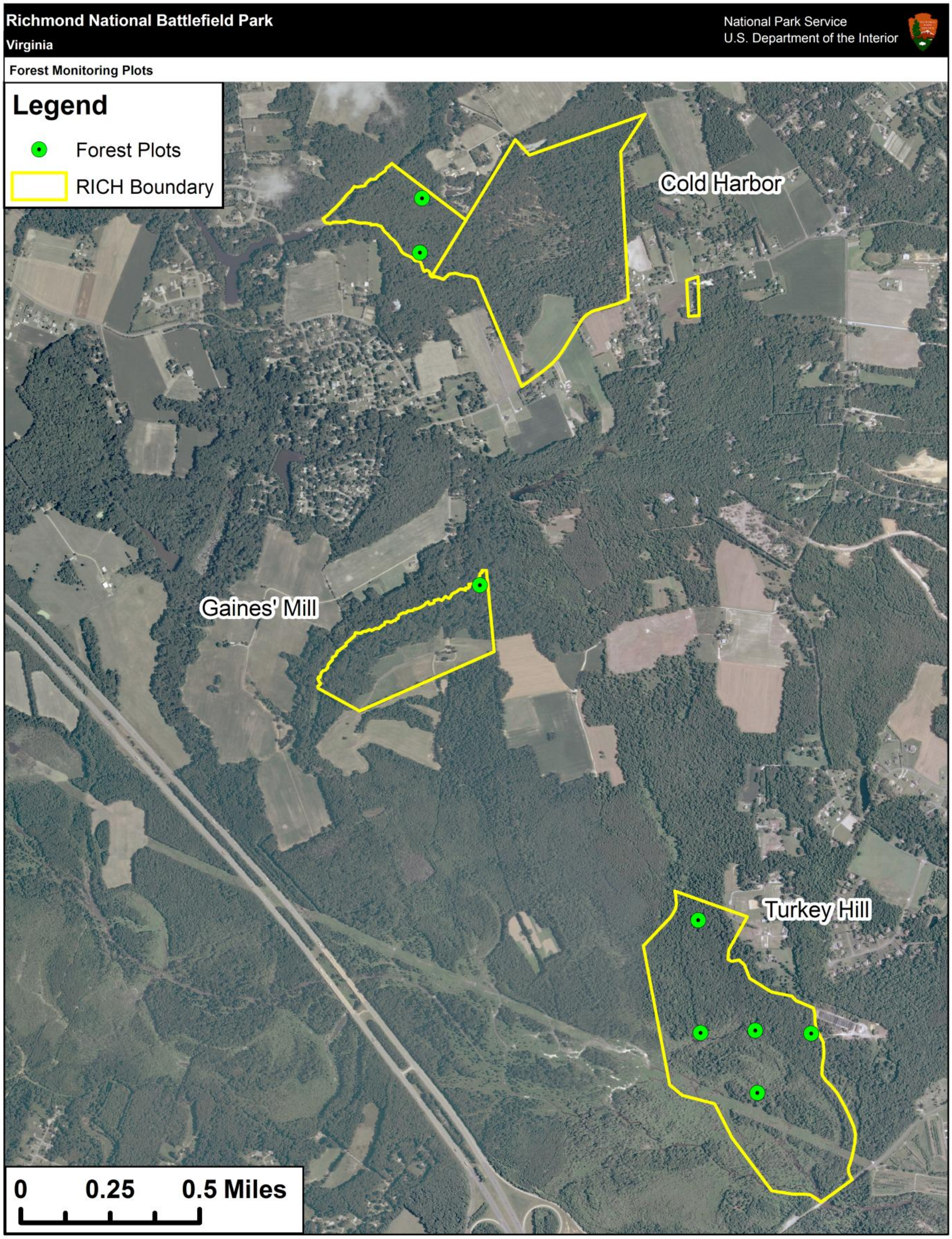

Figure 54. MIDN I&M forest monitoring plots for Cold Harbor, Gaines' Mill, and Turkey Hill.

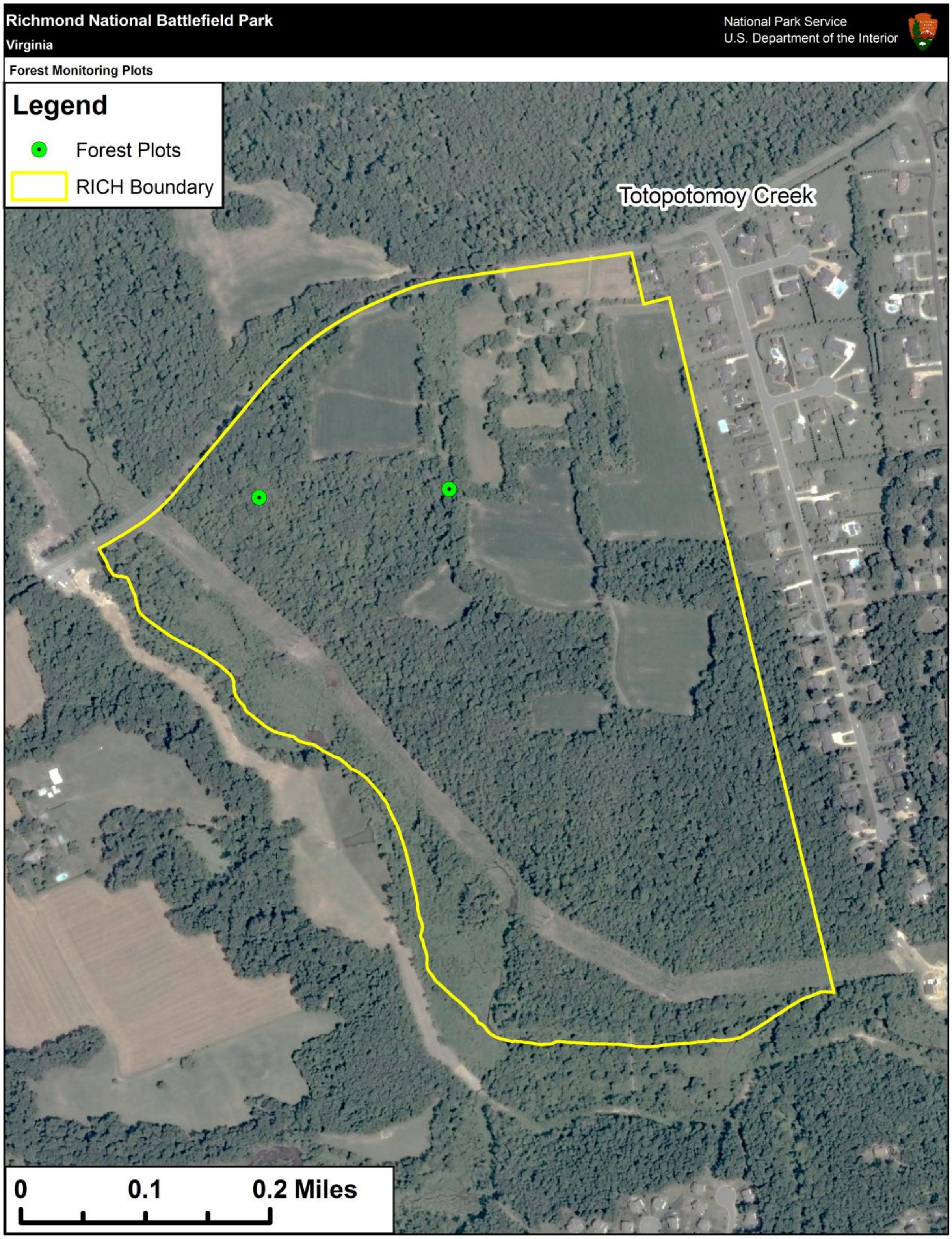

Figure 55. MIDN I&M forest monitoring plots for Totopotomoy Creek.

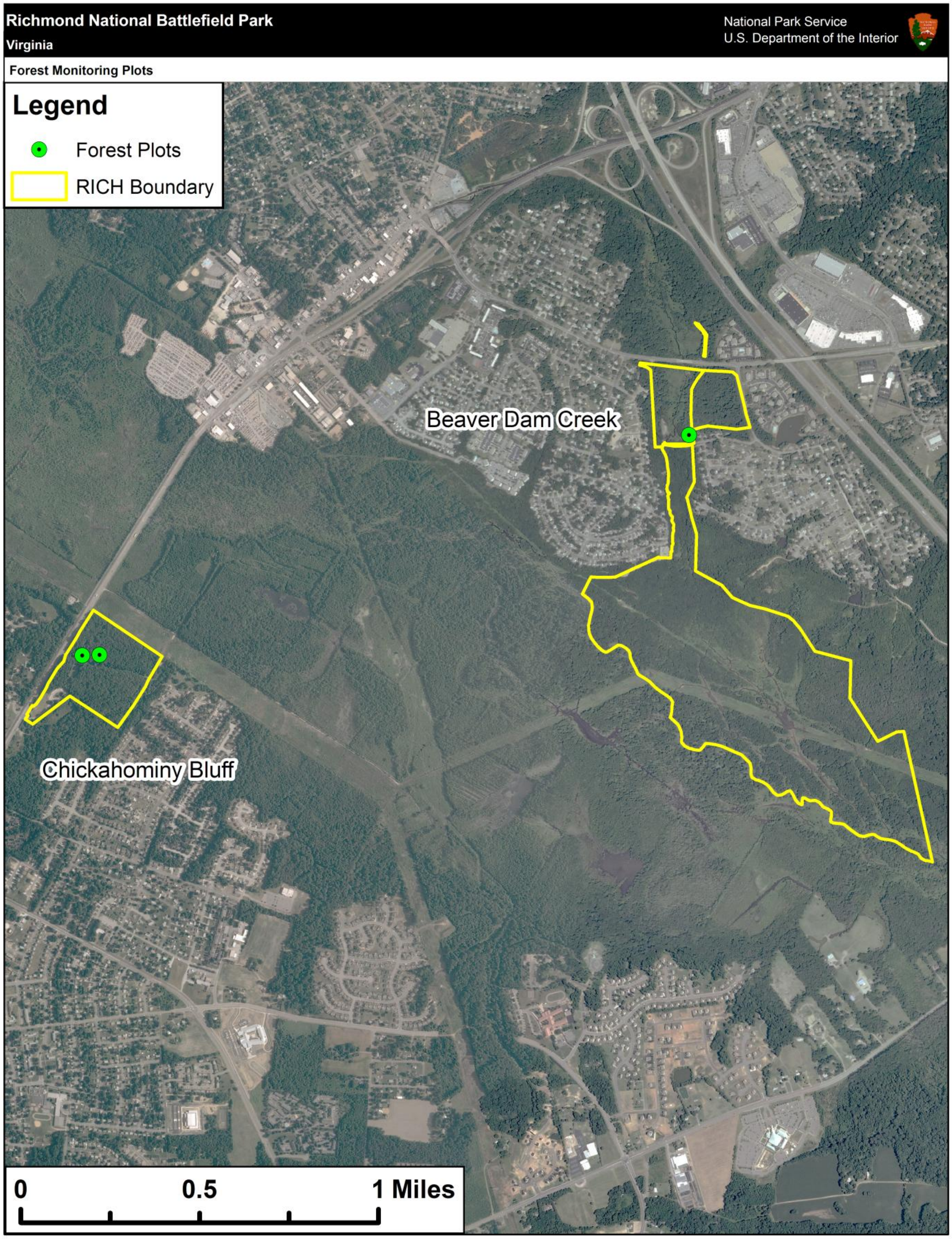

Figure 56. MIDN I&M forest monitoring plots for Chickahominy Bluff and Beaver Dam Creek.

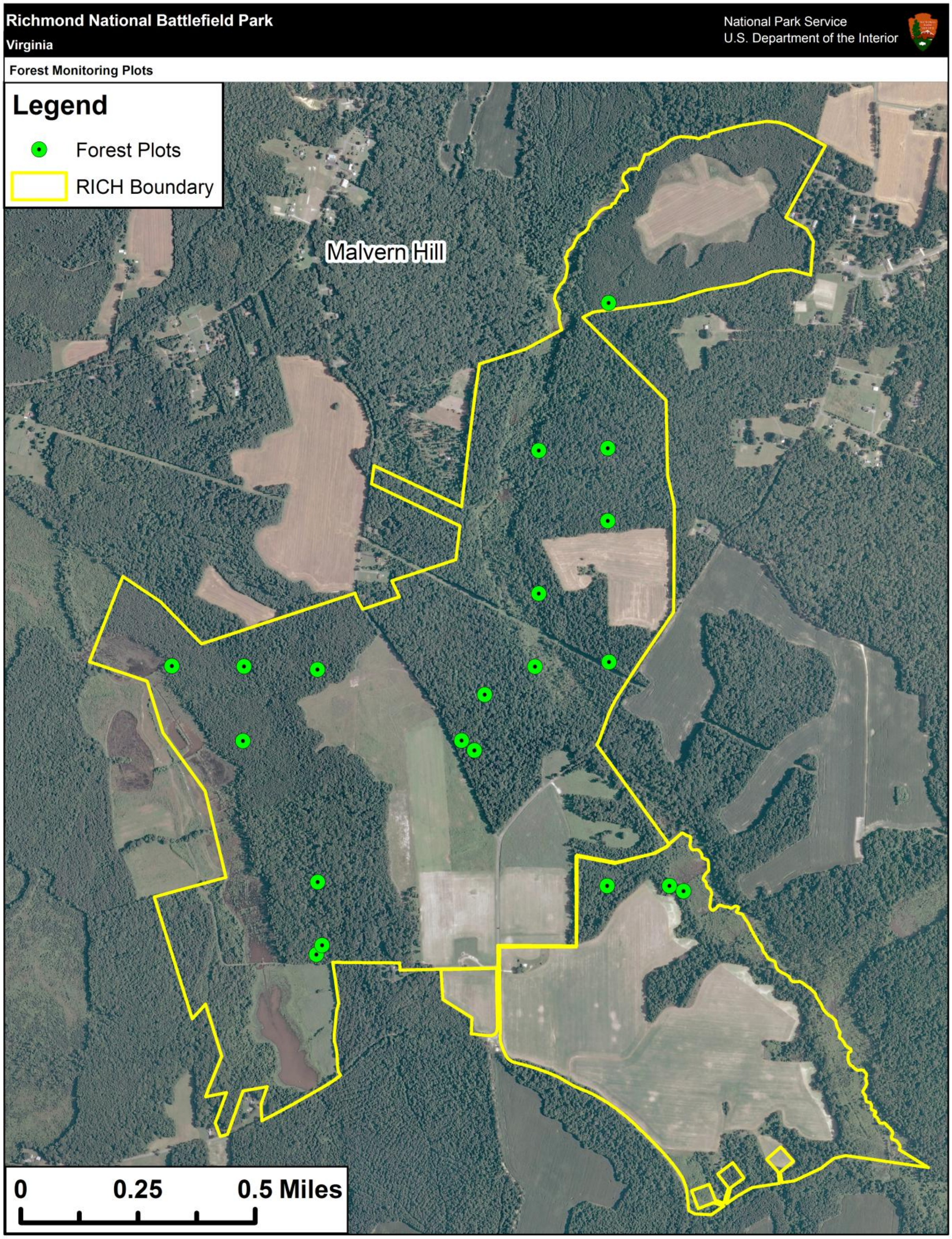

Figure 57. MIDN I&M forest monitoring plots for Malvern Hill.

Table 13. Preliminary results (2007-2010) from forest monitoring plots (number of exotic species/plot/year/unit).

Unit	Year	Plot Number	# Exotic Species
Beaver Dam Creek	2008	148	5
Chickahominy Bluff	2010	309	4
Cold Harbor	2007	20	0
	2009	203	0
Fort Harrison	2008	154	0
	2010	303	0
	2010	304	0
	2010	311	0
Gaines' Mill	2008	153	0
Malvern Hill	2007	15	4
	2007	16	2
	2007	63	2
	2007	64	2
	2007	72	3
	2008	129	2
	2008	131	3
	2008	133	0
	2008	134	0
	2009	226	0
	2009	230	1
	2009	233	1
	2009	238	4
	2010	306	3
	2010	314	1
	2010	317	0
Turkey Hill	2007	19	0
	2007	73	0
	2009	207	2
	2009	219	2
	2010	307	1
Totopotomoy Creek	2008	155	1
	2009	215	7

White-tailed Deer Density

Currently, deer herbivory is monitored on Malvern Hill with population counts and deer exclosures to obtain more detailed data on deer herbivory impacts. . Overabundant deer populations have detrimental impacts on the ecosystem. High deer browse pressure can potentially increase nonnative plant species and eliminate habitat for native faunal species. Richmond NBP is isolated from nearby conservations lands, as a result, deer seek refuge on the park where hunting is not allowed. To sustain a healthy forest ecosystem, which includes the ability of forests to regenerate, white-tailed deer management is important. Per discussion with Richmond NBP personnel, the reference value of 8 deer/km^2 (or 3 deer/mi^2) was chosen for the park (Horsley et al. 2003). As shown in Table 14, the reference value has not been met since monitoring began in 2005.

Table 14. Deer density at Malvern Hill (numbers in deer/mi^2).

Basic Statistics	2005	2006	2007	2008	2009	2010
Mean	29	20	n/a	44	n/a	50
Lower bound[1]	20	11	n/a	31	n/a	37
Upper bound	40	38	n/a	61	n/a	67

[1] Bounds refer to a 95% confidence interval.

Prescribed Fire in Forest Ecosystems

Prescribed fire is an important habitat management tool used in both the forests and grasslands at Richmond NBP. Prescribed fire is used to reduce brushy fuels, open up and maintain vistas, and maintain the sandy oak/pine forest and acidic seepage swamp communities, two forest communities that are well adapted to fire. The Cold Harbor 20 ac burn unit was treated in 1998, 2004, 2005, and 2009 (Figures 58 and 59). Mechanical and chemical treatments have also taken place in the unit to thin an extremely dense shrub layer that resulted from the 1998 burn and made burning difficult at the site. Management objectives were to: 1) have a > 50% reduction in pole size tree density after four burns (Table 15); 2) increase native grasses by > 75% after four burns; and maintain a Civil War era open forested stand (Forder 2011). After the third burn treatment objectives were met for the Cold Harbor unit. Observers noted an increase in grasses and sedge species which indicates management is working to achieve the desired objectives.

Figure 58. Recent burn Cold Harbor (May 2005).

Table 15. Cold Harbor tree summary (Forder 2011).

Plot	Monitoring Status	Trees/acre	Basal Area (sq ft/acre)
1	Pre-treatment	768.9	100.5
	Treatment 1 Yr 1	299.5	no data
	Treatment 2 Yr 1	275.2	86.4
	Treatment 3 Yr 1	186.2	95.9
	Treatment 2 Yr 2	242.8	90.3
	Treatment 3 Yr 2	186.2	98.4
2	Pre-treatment	101.2	96.7
	Treatment 1 Yr 1	68.8	no data
	Treatment 2 Yr 1	60.7	74.7
	Treatment 3 Yr 1	121.4	157.9
	Treatment 2 Yr 2	60.7	77.4
	Treatment 3 Yr 2	72.8	80.0

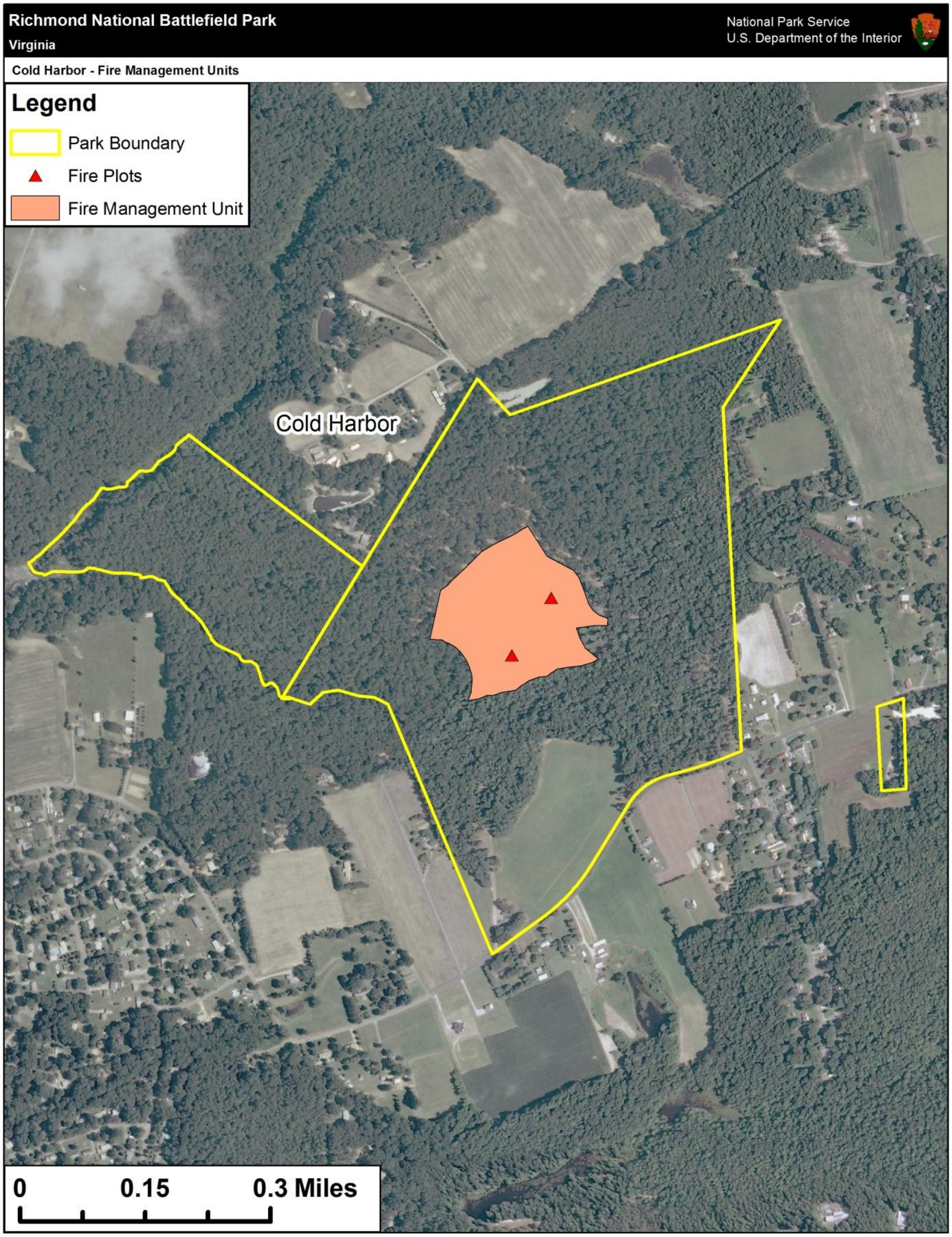

Figure 59. Fire management units and fire monitoring plots at Cold Harbor.

Grassland/Meadow Condition

Native grasslands have been altered to a greater degree than any other biome in North America (North American Bird Conservation Initiative U.S. Committee 2009). Declines in grassland birds have been attributed to conversion of grasslands to cropland, increasingly intensive agricultural practices, and commercial and residential development. Grassland birds are among the fastest and most consistently declining birds in North America; 48% are of conservation concern and 55% are showing significant declines (North American Bird Conservation Initiative U.S. Committee 2009). Most grassland species in the United States both breed and winter in grasslands, which makes it easier to determine the causes of these declines (Browder et al. 2002).

At Richmond NBP grassland habitats are maintained as part of the cultural landscape. Managers use prescribed fire to maintain the cultural landscape as well as to promote native vegetative cover (see Figures 60 and 61 for photographs showing park specific examples).

Wolter et al (2008) states the minimum size for a productive grassland is 20 ac, with 100 ac or larger being optimum. The grasslands of the eastern United States have been converted to other uses and are divided among many owners with different management objectives. This results in patches smaller than the ideal size for many grassland birds. There are patches of grassland/cultural meadow on five units at Richmond NBP; however only Malvern Hill and Cold Harbor have patches > 10 ac (Table 16). The average patch size of each of those five units is below the optimum size. Due to cultural resource needs, it is likely impossible for patch size to increase at most of these units. It is important, however, to conserve and enhance the existing grassland habitat at the park. Managers at Richmond NBP are converting the majority of grassland habitat to native, warm-season grasses.

<u>Prescribed fire in Grassland Ecosystems</u>

Prescribed fire effects monitoring began in 2005 at Malvern Hill. There are 13 monitoring plots located in a complex of seven fields. Objectives for management were to: 1) reduce percent cover of woody species to < 25%; 2) reduce percent cover of nonnative grasses and forbs to < 25%; and 3) increase percent cover of native grasses and forbs (meadow specialist species) to >75% (Forder 2011). In 2010, all objectives were met with the exception of maintaining nonnative grass cover < 25% in the cool season grass fields (Figures 62-65). In the fall of 2010, 18 ac were also treated with herbicide to allow native warm-season grasses to germinate at a faster rate. In addition to creating habitat preferred my many species of birds and small mammals, an added benefit of prescribed fire operations is a reduction of maintenance effort and mowing. Figures 66 and 67 display preliminary results for Gaines' Mill, which is also managed for native warm season grasses by annual bushogging only, Figure 68 displays the fire management units and plots at Malvern Hill.

Table 16. Park unit grassland patches greater than 10 ac.

Number of Patches	Malvern Hill Acres	Cold Harbor Acres
1	10.2	13.8
2	11.3	
3	16.0	
4	18.2	
5	27.6	
6	77.5	

Figure 60. Malvern Hill meadow (October 2007).

Figure 61. Gaines' Mill meadow (September 2006).

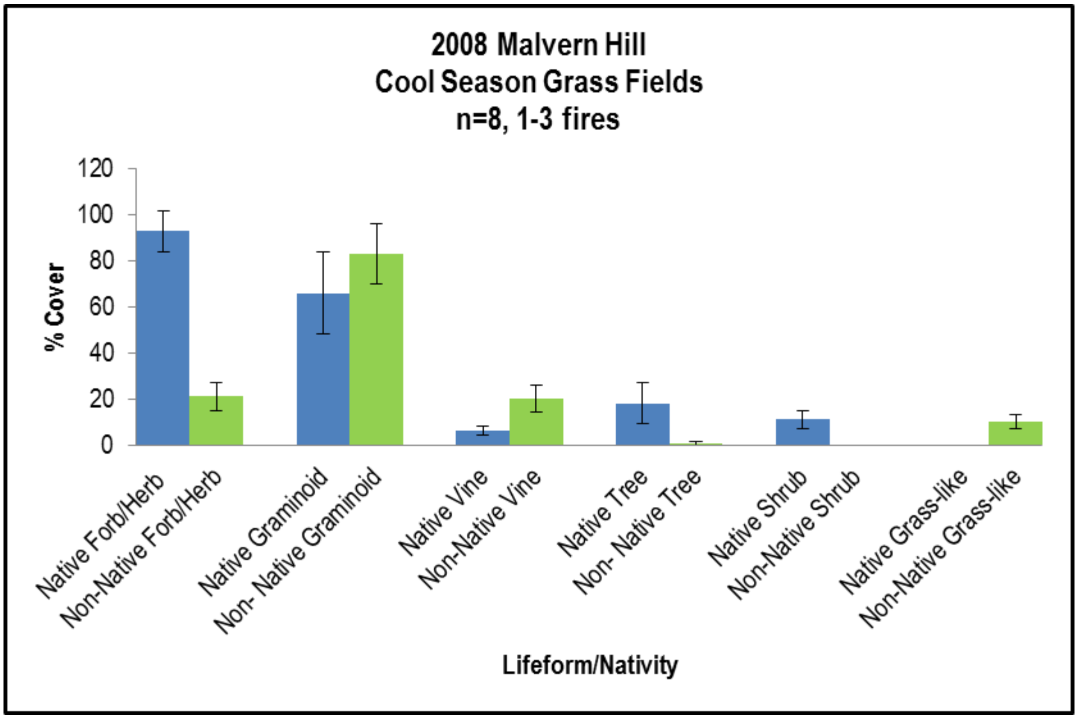

Figure 62. 2008 percent cover of native and nonnative species, cold-season grass fields (Forder 2011).

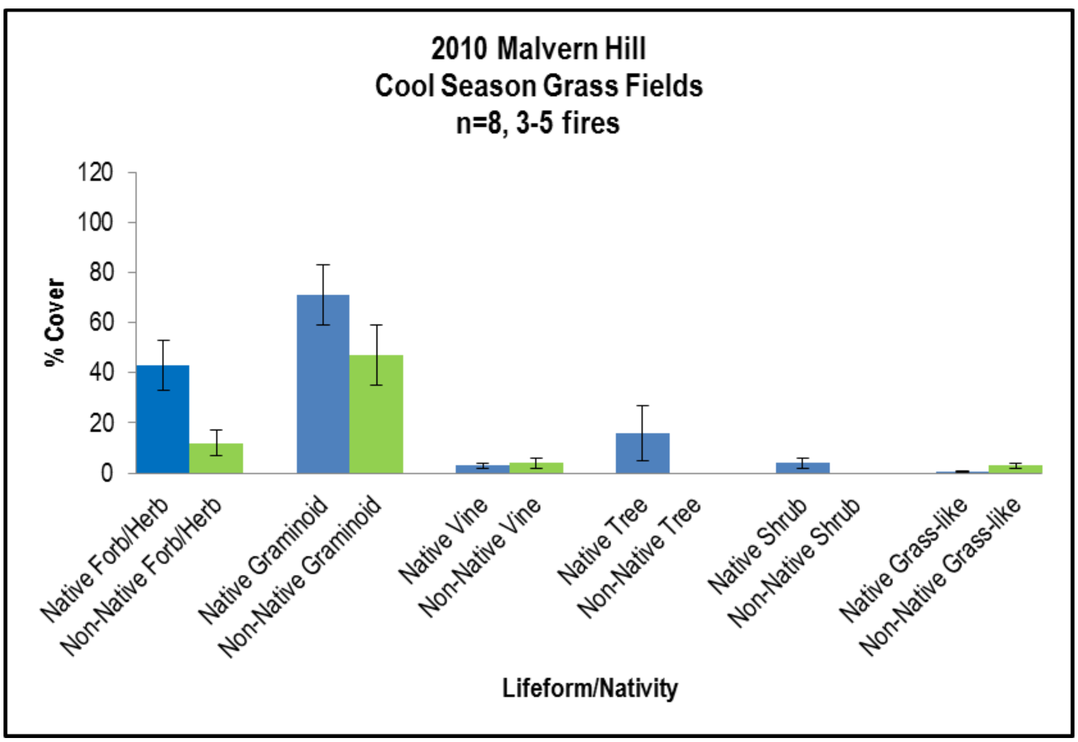

Figure 63. 2010 percent cover native and nonnative species, cold-season grass fields (Forder 2011).

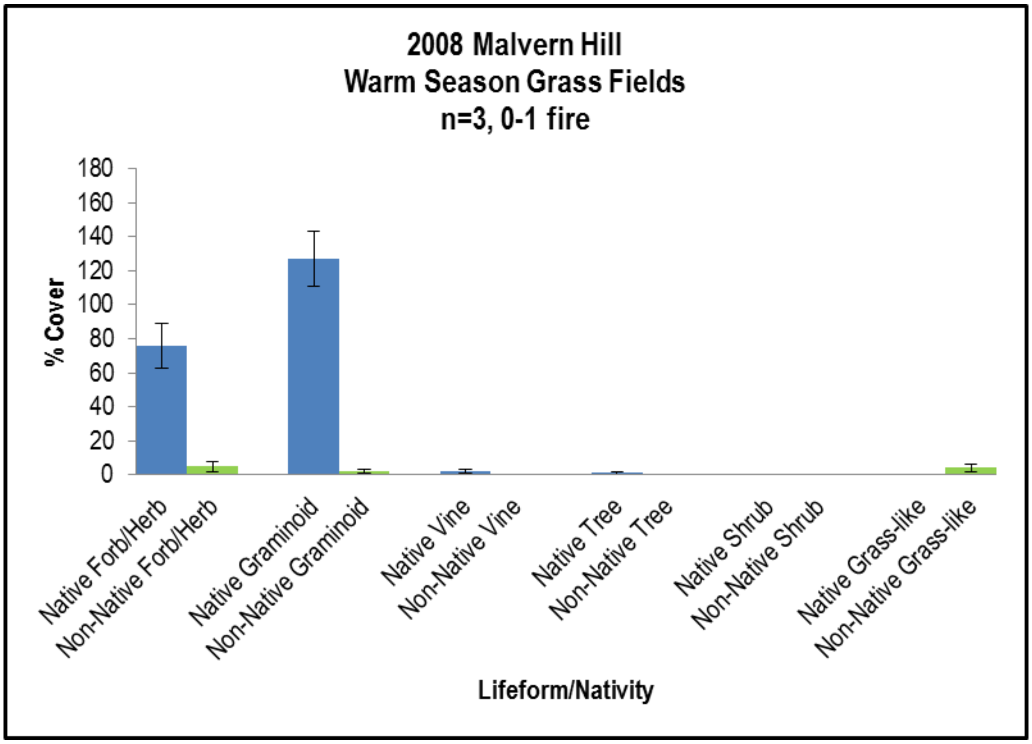

Figure 64. 2008 percent cover native and nonnative species, warm-season grass fields (Forder 2011).

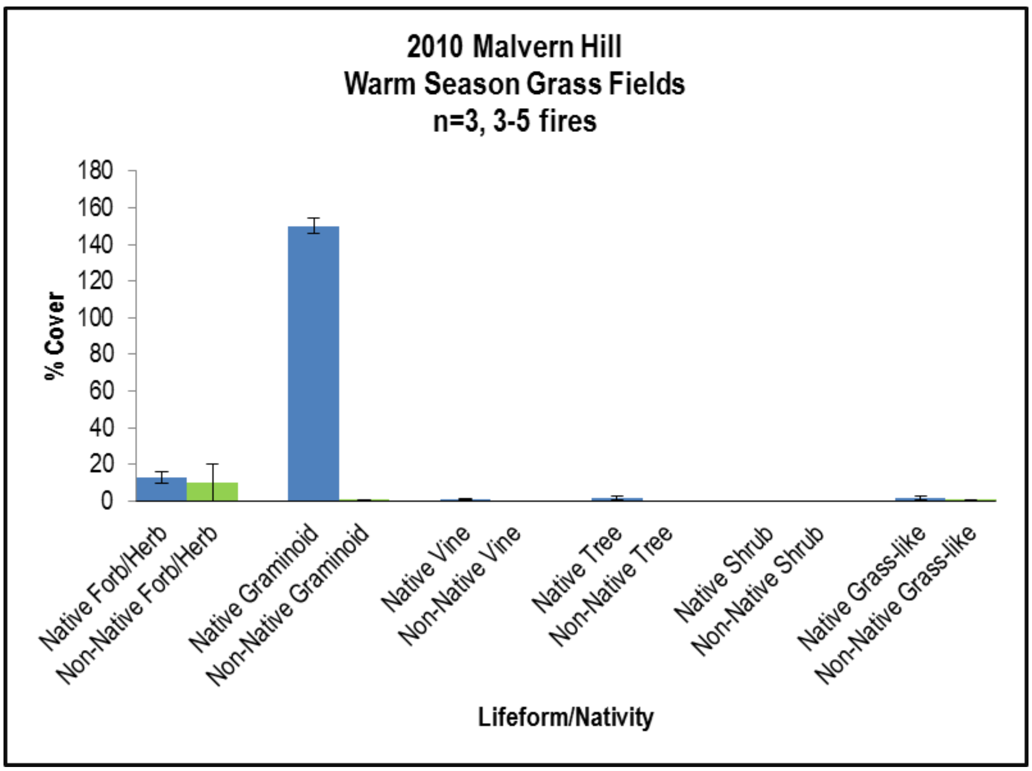

Figure 65. 2010 percent cover native and nonnative species, warm-season grass fields (Forder 2011).

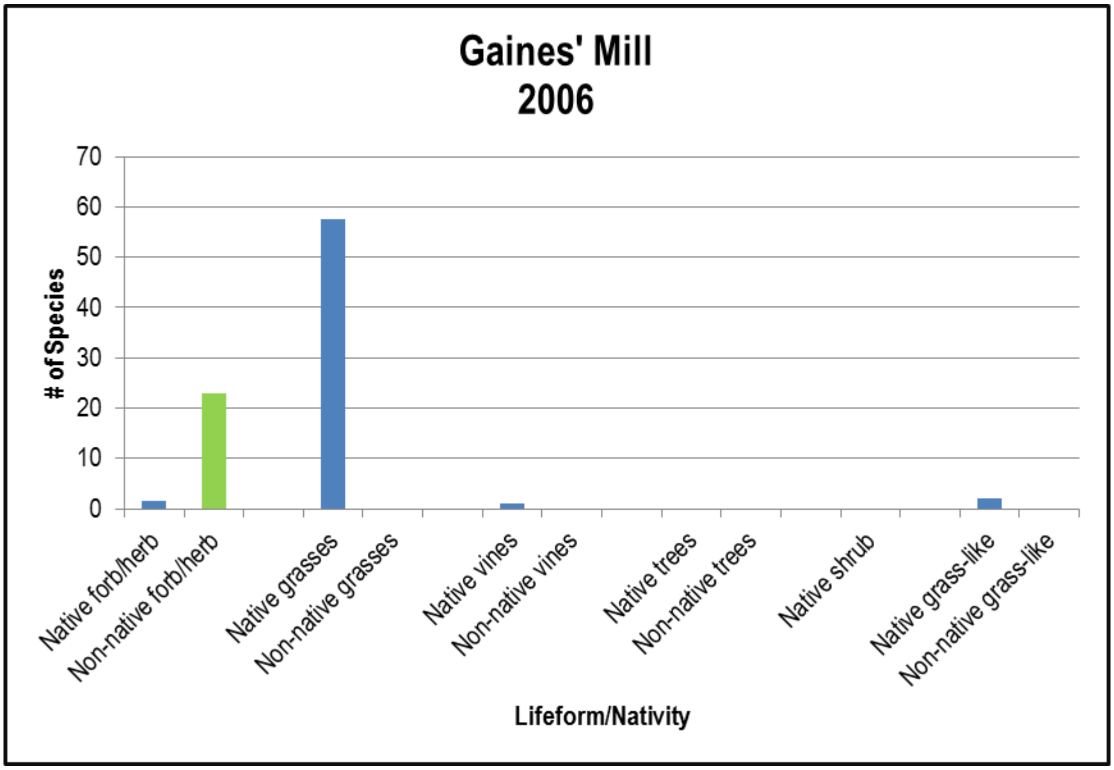

Figure 66. 2006 percent cover native and nonnative species, Gaines' Mill fields (RICH 2010b).

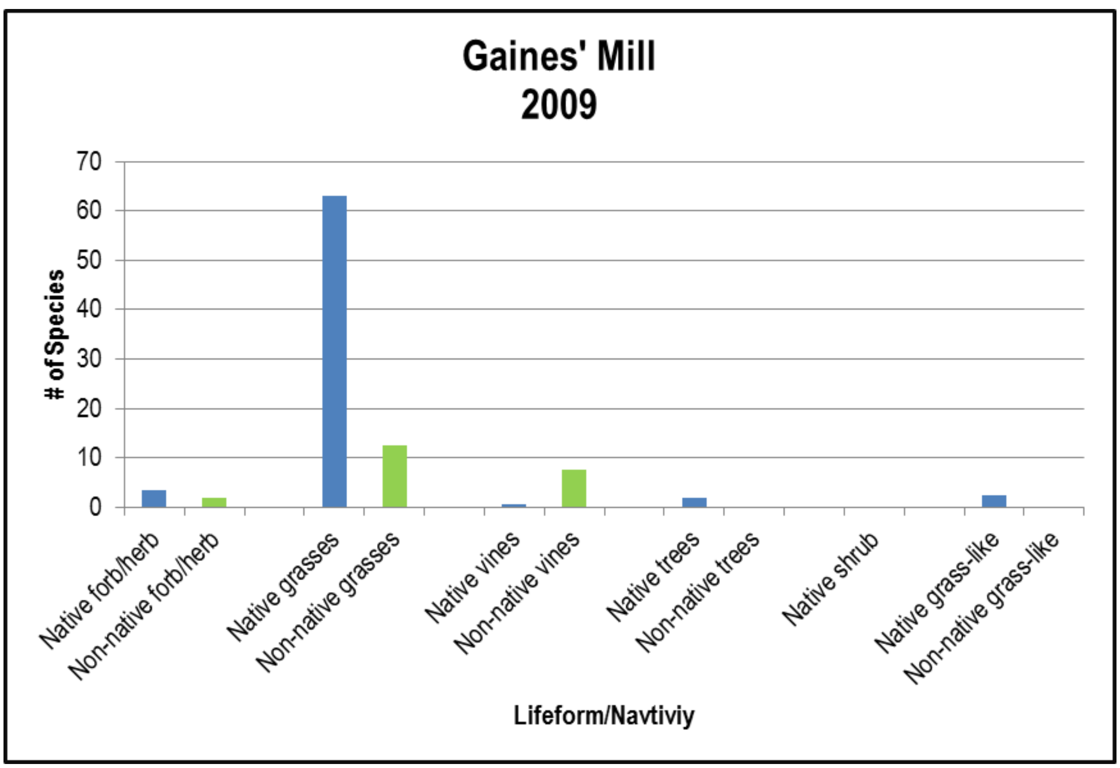

Figure 67. 2009 percent cover native and nonnative species, Gaines' Mill fields (RICH 2010b).

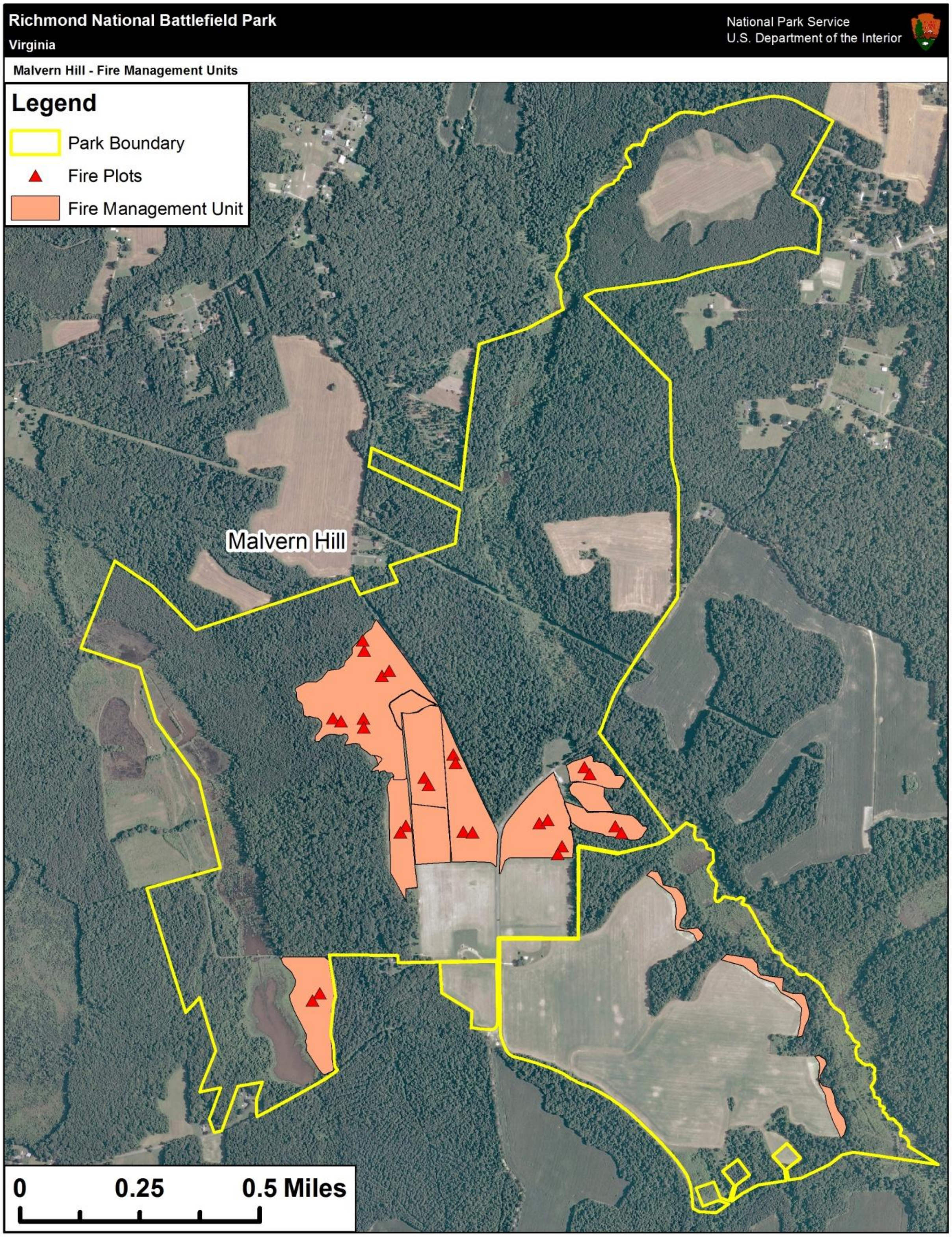

Figure 68. Fire management units and fire monitoring plots at Malvern Hill.

Condition Status Summary for Vegetation Communities

Forest cover at all the units is rated as good (see Table 17 summary). No forest pests were detected since monitoring efforts began in 2007. Four years of white-tailed deer density surveys indicate an increasing population trend. Increasing development outside park boundaries may increase the number of deer utilizing habitats at Richmond NBP. Hunting is prohibited in all National Parks in Virginia. Therefore, it is not clear what options managers have at Richmond NBP to control potential future negative impacts of high deer density on native vegetation communities. Although data were not available for this assessment, deer browse is currently monitored at the park to determine impacts of deer on native vegetation communities.

Managing grasslands for native warm-season grasses can have a great benefit the overall quality of habitats for faunal species and ecological integrity of the park. To manage for grassland bird species, larger tracts of grassland habitat should be kept intact. Prescribed fire objectives at Malvern Hill were met with the exception of maintaining nonnative grass cover < 25% percent in the cool season grass fields. For Cold Harbor, after three burns objectives have been met as well. As prescribed fire operations continue in the future, trends can be assessed and goals and objectives re-evaluated.

Data gaps for this assessment include soil quality for both forests and grasslands as well as the desired species composition for the tree, sapling, and seedling layers. Trend data is nonexistent for most metrics, with one exception of white-tailed deer density.

Table 17. Vegetation communities condition summary.

Category	Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition	Trend
Forest Condition	Land cover	Percent total forest cover within park	> 59% = Good 31-58% = Fair < 30% = Poor	See **Error! Reference source not found.** for unit ratings	The amount of forested habitat within the park should remain stable.
	Native forest pests	# species present % infestation by habitat	Park will not be negatively impacted by forest pests	0 forest pests detected (Good)	
	Indicator species	Key forest bird species	Population and/or presence of indicator species remain stable over time.	6 out of 6 species known to be present (Good)	Insufficient data to evaluate trends. Key species = Wood thrush, Kentucky warbler, scarlet tanager, yellow-throated vireo, pileated woodpecker, red-eyed vireo
	Species Composition	Species composition for the tree, sapling, and seedling layers	TBD	See **Error! Reference source not found.** for unit numbers	Trends can be evaluated in the future.
	Invasive exotic plants	Average # exotic species /forest plot	Average of < 0.5 invasive exotic species/plot = Good Average of 0.5 to < 3.5 invasive exotic species/plot = Fair Average of 3.5 or more key invasive exotic species/ plot = Poor	Average 1.1 exotic species in 2010 or 50% of plots surveyed (Fair)	Insufficient data to evaluate trends.
	White-tailed deer density	Deer Population Density	< 8 /km2 = Good > 8 /km2 = Significant Concern	50 deer/mi^2 (129/km^2) (Significant Concern)	Increasing trend. Reference condition has not been met since monitoring began in 2005.
	Soil Quality	Acid Stress (average Ca:Al ratio); (proportion of plots below 1.00)	Soil Ca:Al ratio > 4 = Good Soil Ca:Al ratio 1-4 = Fair Soil Ca:Al ratio < 1 = Poor	Unknown- Data Gap	
		Nitrogen Saturation (average C:N ratio); (proportion of plots below 20.0)	Soil C:N ratio > 25 = Good Soil C:N ratio 20-25 =Fair Soil C:N ratio < 20 = Poor	Unknown- Data Gap	

Category	Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition	Trend
Grassland Integrity	Relative plot cover (%)	Grassland/meadow specialists vs. nonnatives	Percent cover of woody species < 25% Percent cover of nonnatives grasses and forbs < 25% Percent cover of “meadow specialists” native grasses and forbs > 75%	All objectives were met in 2010 with the exception of maintaining nonnative grass cover < 25% in cool season grass fields.	
		Grassland acreage within park	The amount of native grassland habitat within the park should remain stable.	207.1 ac	
	Woody species	Relative cover	Percent cover of woody species < 25%	16% (2010) (Good)	Malvern Hill only
	Key grassland bird species	Population and/or presence of indicator species.	Population and/or presence of indicator species remain stable over time.	4 out of 4 species known to be present (Good)	Insufficient data to evaluate trends. Key species = grasshopper sparrow, eastern meadowlark, northern bobwhite quail, Savannah sparrow
	Soil Quality	Acid Stress (average Ca:Al ratio); (proportion of plots below 1.00)	Soil Ca:Al ratio > 4 = Good Soil Ca:Al ratio 1-4 = Fair Soil Ca:Al ratio < 1 = Poor	Unknown- Data Gap	
		Nitrogen Saturation (average C:N ratio); (proportion of plots below 20.0)	Soil C:N ratio > 25 = Good Soil C:N ratio 20-25 = Fair Soil C:N ratio < 20 = Poor	Unknown- Data Gap	

5.0 Wetland/Riparian Resources

Riparian forests are subjected to many disturbances from timber harvesting, livestock grazing, and recreational development. Because of these competing uses, riparian forests have declined from historic levels and are now greatly reduced in area and connectivity. Riparian buffer strips are used extensively all over the world to control sedimentation, remove excess nutrients from surface runoff, ameliorate surface water temperature flux, and provide habitat and migration corridors for flora and fauna. Streams are physically linked via the riparian zone to their watersheds, and riparian areas are considered critical components of streams. In riparian zones, vegetation type and coverage also influence water quantity and quality. When riparian structure and function are diminished, the changes are reflected in both aquatic and riparian flora and fauna (Bryce et al. 2002).

Patterson (2008) identified several isolated headwater wetlands totaling 22.4 ac in Cold Harbor, Malvern Hill, and Fort Harrison and mapped them as Coastal Plain/Piedmont Acidic Seepage Swamp. Coastal Plain/Piedmont Acidic Seepage Swamp is an uncommon wetland habitat in the eastern United States. Small areas totaling 10 ac at Beaver Dam Creek, Chickahominy Bluff, Malvern Hill, and Watt House are mapped as Coastal Plain/Piedmont Small-Stream Floodplain Forest. These rare wetland habitats can be negatively impacted by beaver activity. Natural resource managers at Richmond NBP currently monitor beaver activity at all park units with the exception of Parkers Battery and Drewry's Bluff which do not have suitable habitat for beavers. Figure 69 shows a typical wetland from the Turkey Hill management unit.

Wetland Integrity

Landscape connectivity, buffer index, and surrounding land use index are measures used to assess the wetland communities at Richmond NBP. Measures used to assess the wetland communities at Richmond NBP were adapted from Faber-Langendoen (2009). Appendix E details the methods and datasets used for our analyses. Wetland integrity was rated using three metrics: 1) landscape connectivity, 2) buffer index, and 3) surrounding land use.

Landscape connectivity is a measure of the percent of unfragmented landscape within a 500 m buffer adjacent to non-riverine wetlands, upstream and downstream from riverine wetlands. For riverine types, it is a measure of the degree to which the riverine corridor above and below a floodplain area exhibits connectivity with adjacent natural systems. Connectivity for riverine types averaged 87.1% across all units. Average connectivity for non-riverine types at Richmond NBP scored 69.5%. Both are categorized as “variegated” and ranked as “good.”

Buffer index condition (Figures 70-73) is the overall area and condition of the buffer immediately surrounding a wetland. To establish this, we: 1) identified and classified vegetated, non-anthropogenic land cover, 2) determined the percentage of the wetland perimeter adjacent to this vegetation, non-anthropogenic cover, and 3) determined the average width of the identified buffer, corrected for slope. The total area (park-wide) of non-anthropogenic cover within the wetland buffer is 13947460.9 m^2 or 3446.492 acres.

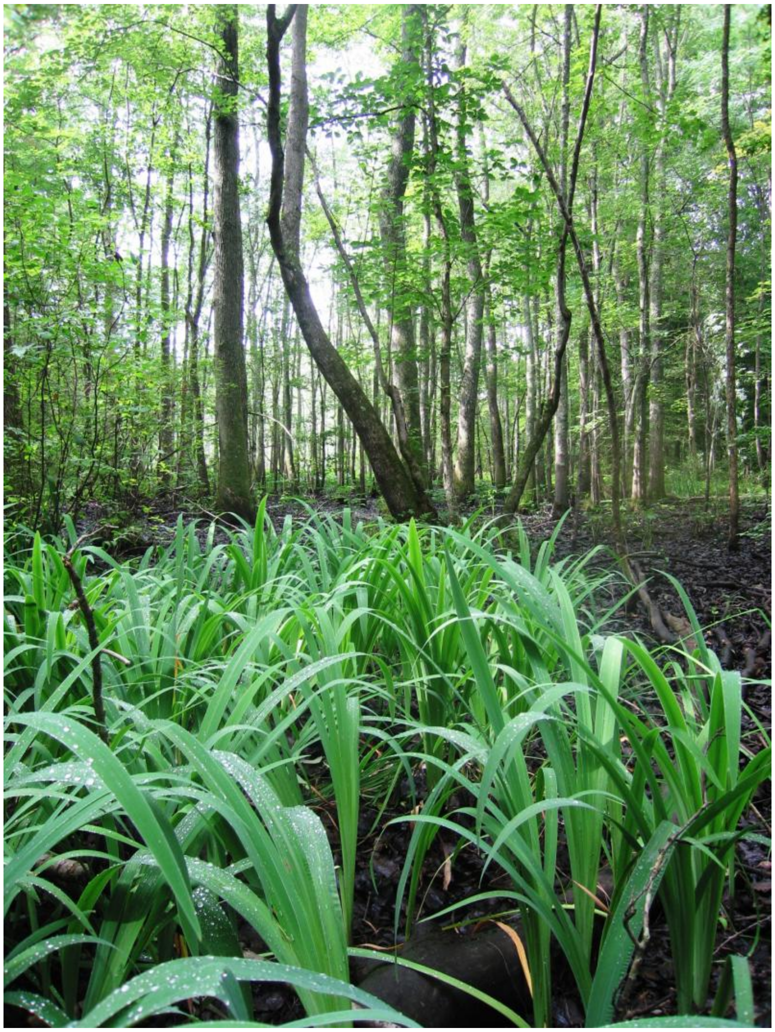

Figure 69. Wetland community at Turkey Hill (June 2010).

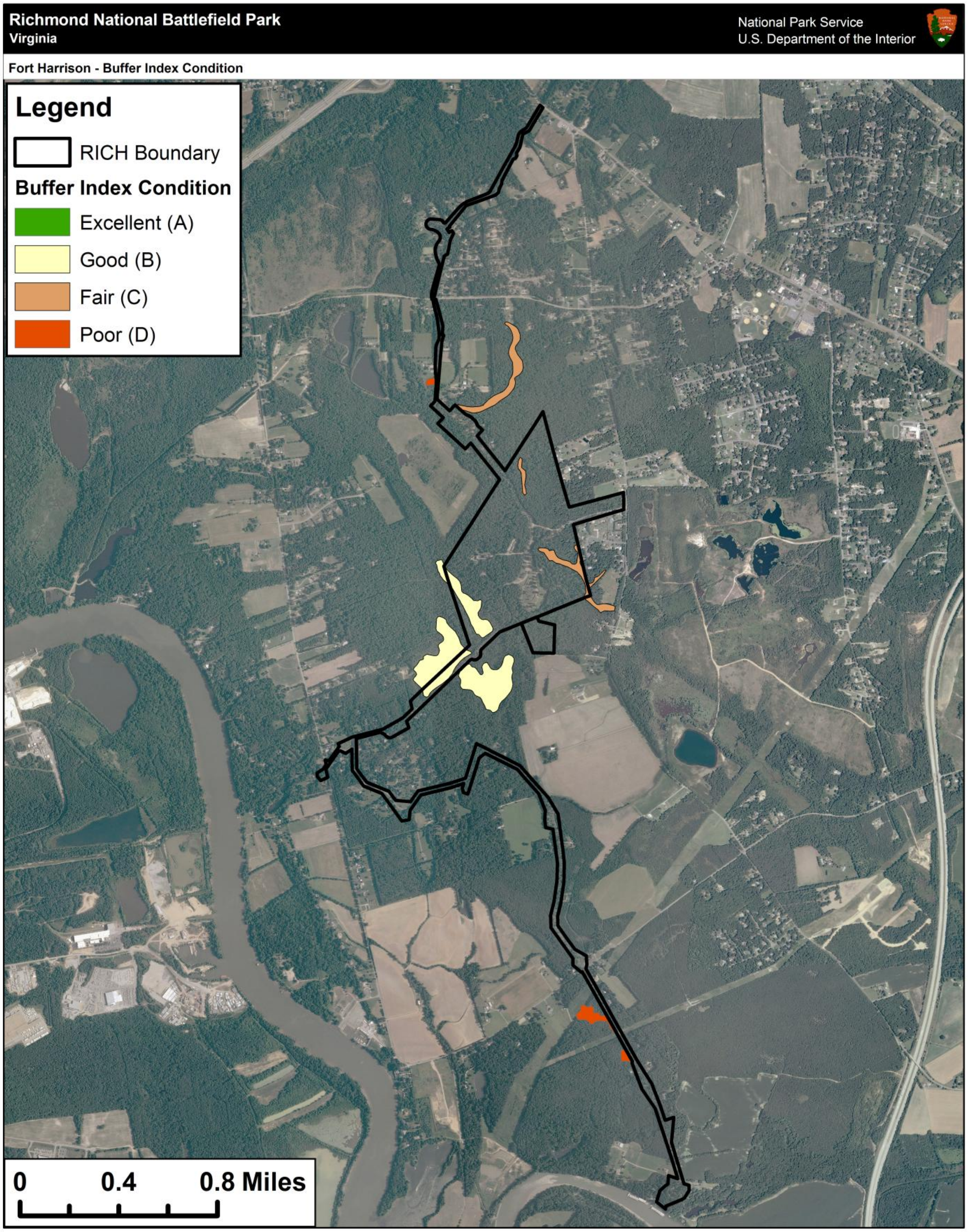

Figure 70. Wetland buffer index condition of buffers immediately surrounding wetlands at Fort Harrison.

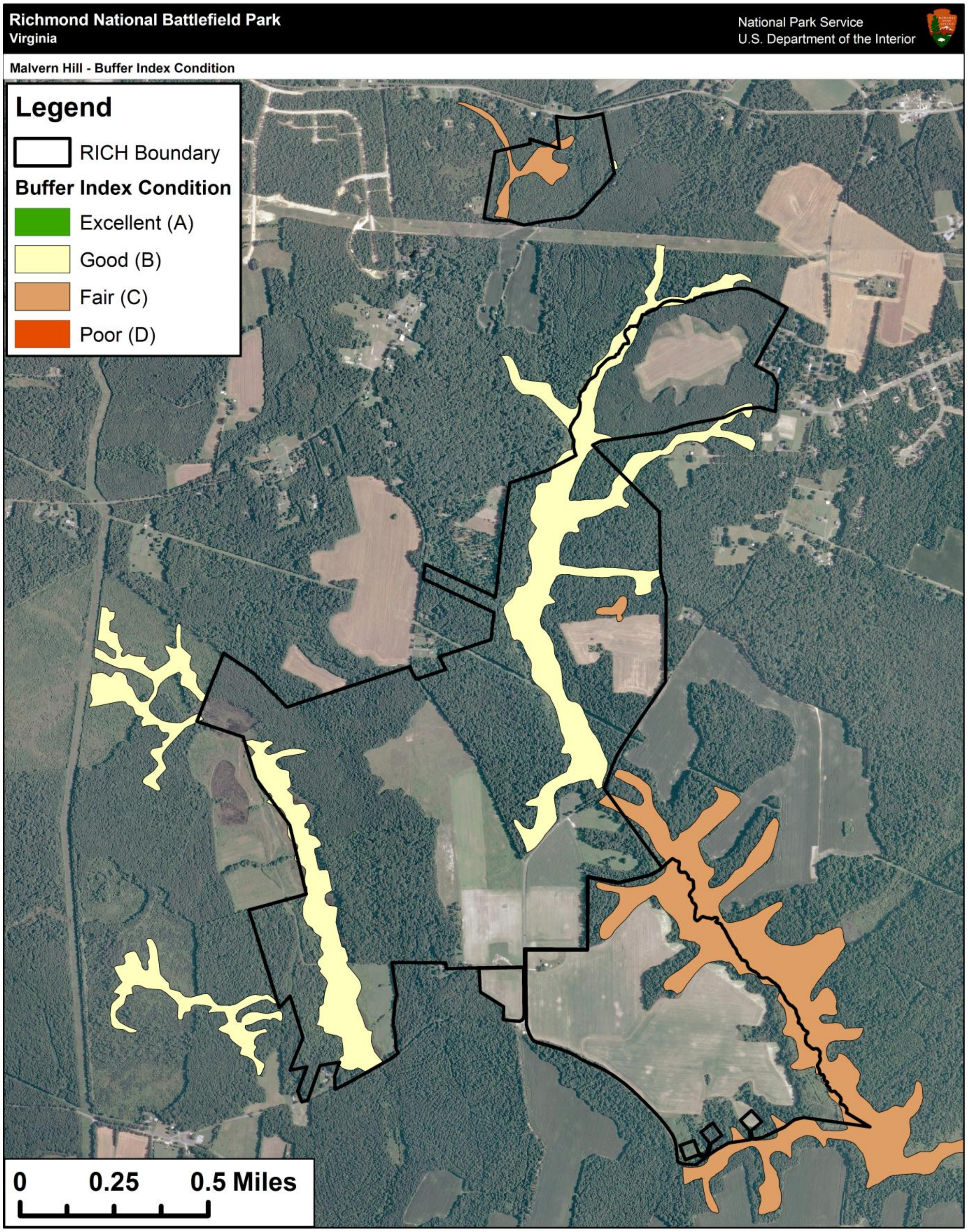

Figure 71. Wetland buffer index condition of buffers immediately surrounding wetlands at Malvern Hill.

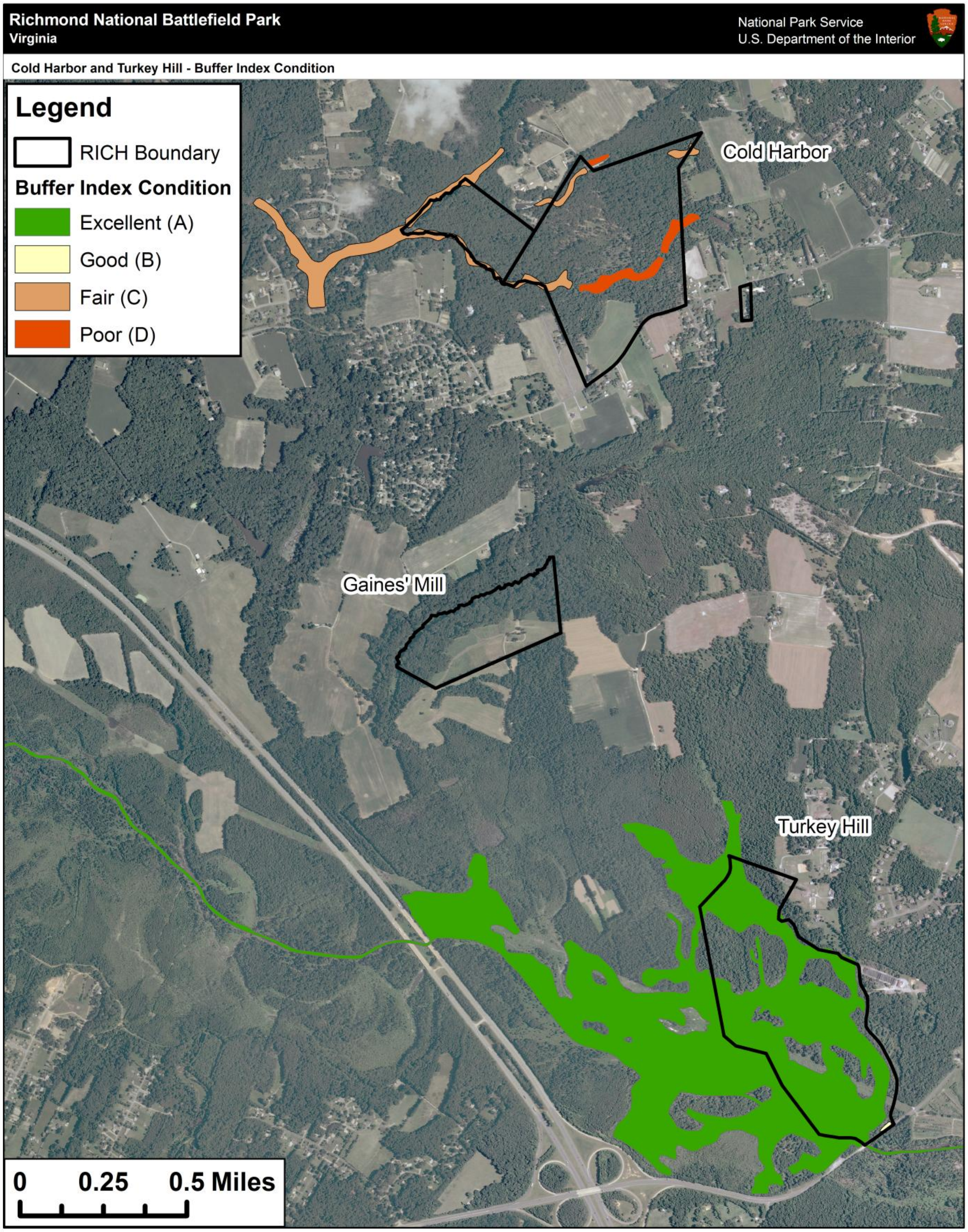

Figure 72. Wetland buffer index condition of buffers immediately surrounding wetlands at Cold Harbor and Turkey Hill.

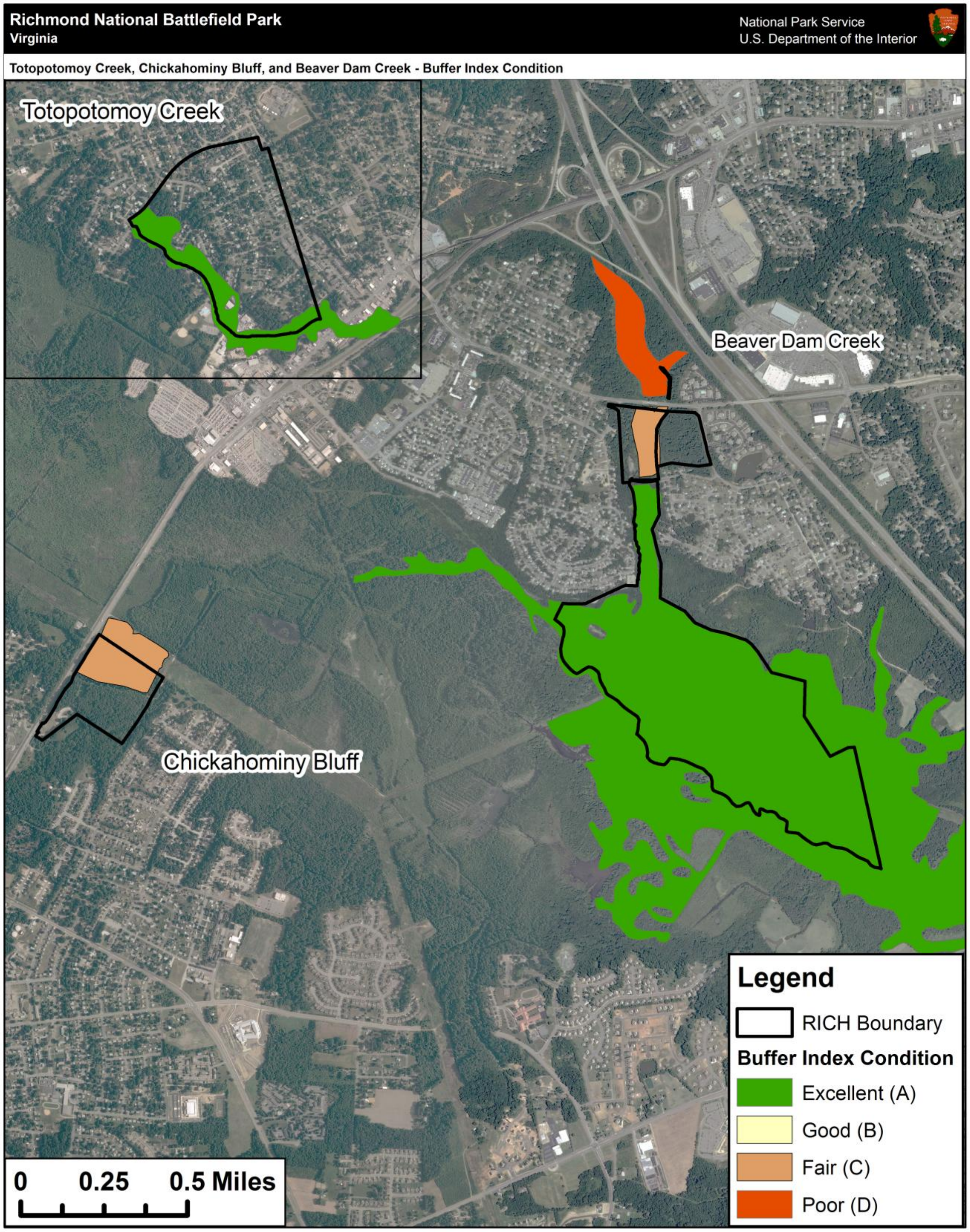

Figure 73. Wetland buffer index condition of buffers immediately surrounding wetlands at Totopotomoy Creek, Chickahominy Bluff, and Beaver Dam Creek.

Good quality wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland. Percent of wetland buffer area that is non-anthropogenic cover was averaged 65.3%. Surrounding land use is a measure of the intensity of human dominated land uses within a specific landscape area. We used these three steps to analyze surrounding land use: 1) buffered the park boundary to landscape area as delineated by the 8-digit Hydrologic Unit Code (HUC), 2) ranked land cover by human impact, and 3) in a GIS ran analysis of land cover within the watershed. Each land use type occurring in the landscape area is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target system.

Condition Status Summary for Wetland/Riparian Resources

Overall, the condition of the wetlands at Richmond NBP is rated as excellent. The average score for wetlands at Richmond NBP is 0.83. Average buffer width, length, and surrounding land use index all scored as excellent. Turkey Hill and Beaver Dam Creek had the highest rated buffer condition. Condition status summaries for the wetlands can be viewed in Table 18.

Table 18. Wetland/Riparian resources condition status summary.

MIDN Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition	Trends
Extent of wetlands	Area of wetlands present	Wetland areas of the park are dominated by native plant species and the extent of wetlands remains stable or increases over time.	BDC= 186.5 ac CH = 12.8 ac FH = 7.7 ac GM =2.1 ac MH = 114.9 ac TH = 38.9 ac TC = 8.9 ac	Trends can be evaluated in the future.
Surrounding land use index	A measure of the intensity of human dominated land uses within a specific landscape area (such as a catchment) from the center of the occurrence. Each land use type occurring in the landscape area is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target system.	Excellent = 1.0–0.95 Good = 0.80–0.95 Fair = 0.4–0.8 Poor = < 0.4	0.83 (Excellent)	
Landscape connectivity	Non-riverine: Percent of wetland buffer area that is adjacent non-anthropogenic cover. Riverine: Percent of wetland buffer area that is adjacent non-anthropogenic cover.	Excellent = Intact, 90–100% natural habitat around wetland Good = Variegated, 60–90% natural habitat Fair = Fragmented, 20–60% natural habitat Poor = Relictual, < 20% natural habitat	69.5% (Good) 87.1% (Good)	
Buffer index	An index of the overall area and condition of the buffer immediately surrounding the wetland, using 3 measures: (1) Percent of Wetland with Buffer, (2) Average Buffer Width (with slope correction), and (3) Buffer Condition. Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	See Appendix F.	Average length = 83.9% (Excellent) Average width = 299 m (Excellent) Condition = 65.3 % (Good)	

6.0 Biological Integrity

Ideally, an assessment of the biotic communities at Richmond NBP would consist of the complete range of plants and animals known to occur within the park as well as the full suite of species found on pristine tracts of similar habitat in the same landscape over several years. Species absences or species located that were not part of that suite of native species would represent decreases in biotic integrity from the reference scenario. Such a complete assessment is beyond the scope of this project. We can, however, use existing datasets for a few of these taxa to permit some insight as to the likely state of biotic communities at Richmond NBP. There have been a few investigations of animals and plants at Richmond NBP over the past 10 years (Table 19). We use the term “biological integrity” as defined by Frey (1977) and Karr and Dudley (1981) as “The capability of supporting and maintaining a balanced, integrated, adapted community of organisms having a species composition, diversity, and functional organization comparable to the natural habitats of the region.”

In addition to the baseline MIDN I&M surveys conducted, ongoing monitoring at Richmond NBP include: stream macroinvertebrates, beaver activity, invasive species, meadow birds, meadow vegetation, and white-tailed deer. The park began monitoring birds, reptiles, and amphibians at the Malvern Hill unit starting in 2010. In addition to the surveys in Table 19, the Virginia Natural Heritage Program conducted surveys of rare, threatened and endangered plants and animals at Cold Harbor, Malvern Hill, and Totopotomoy Creek.

These studies have been synthesized into a species information database by the NPS (Certified Organisms: NPSpecies 2009). We utilized expected species lists presented in initial MIDN Inventory and Monitoring (I&M) reports. For an urban park such as Richmond NBP, it is especially difficult to find additional reference datasets. We elected to focus on those communities for which the most defensible information was available Table 20. We also looked to the existing NPS I&M Vital Signs Program for the MIDN to provide some guidance as to which species communities were considered important enough for future monitoring efforts (Figures 74-78).

Natural resources significant to legal mandates/policy at Richmond NBP are wetlands, water quality, state-listed species, and exotic species. Natural resources significant for other reasons are unique vegetation communities and grassland habitat. The MIDN program has proposed 15 Vital Signs for monitoring, five of which are related to biological integrity. MIDN I&M funded vital signs monitored within long-term forest health plots at Richmond NBP include: invasive exotic plants, native forest pests, exotic diseases/pathogens–plants, forest plant communities, and white-tailed deer (herbivory) (Comiskey and Callahan 2008).

Table 19. Past and current inventory and monitoring programs at Richmond NBP.

Community Target for Survey	Year Data Collected	Unit(s)[1]	Citation
Fish	2002, 2003	BDC, CH, GM, MH	Atkinson (2008)
Amphibians and Reptiles	2002-2004	GM, CH, BDC, CB, MH, FH,DB,PB,TC	Mitchell (2007)
Birds	2003, 2004	BC, CB, CH, DB, FH, GM, MH, PB,TC	Bradshaw (2007)
Mammals	2003, 2004	BDC, CB, CH, DB, FH, GM, MH, PB	Barry and Sareen (2008)
White-tailed deer	Began 2006	MH	Ongoing, Malvern Hill
Invasive species monitoring	Every five years, beginning 2001	All	Ongoing, Park-wide
Beaver monitoring	Began 2004	CH, MH, GM, FH, BDC	Ongoing
Meadow vegetation monitoring	Began 2005	CH, MH	Ongoing, every fall
Fire monitoring	Began 2005	CH, MH	Ongoing, every fall
Meadow birds	Began winter 2010	MH	Ongoing, quarterly

[1]Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 20. Data sources used for measures of biological integrity within Richmond NBP.

Indicator	Measure	Data Source
Fish	Jaccard's Index of Similarity, species richness, IBI	RICH species list, NatureServe watershed reference list, Atkinson (2008)
Amphibians	Jaccard's Index of Similarity, species richness	RICH species list, reference list from Mitchell (2006)
Reptiles	Jaccard's Index of Similarity, species richness	RICH species list, reference list from Mitchell (2007)
Birds	Jaccard's Index of Similarity, species richness	RICH species list, Bradshaw (2007), BBS reference list
	Community trends	BBS data for Upper Coastal Plain
Mammals	Jaccard's Index of Similarity, species richness	RICH species list, reference list from Barry and Sareen (2008), RICH data
Invasive Species	Percent invasive/ exotic species	RICH data (2005)

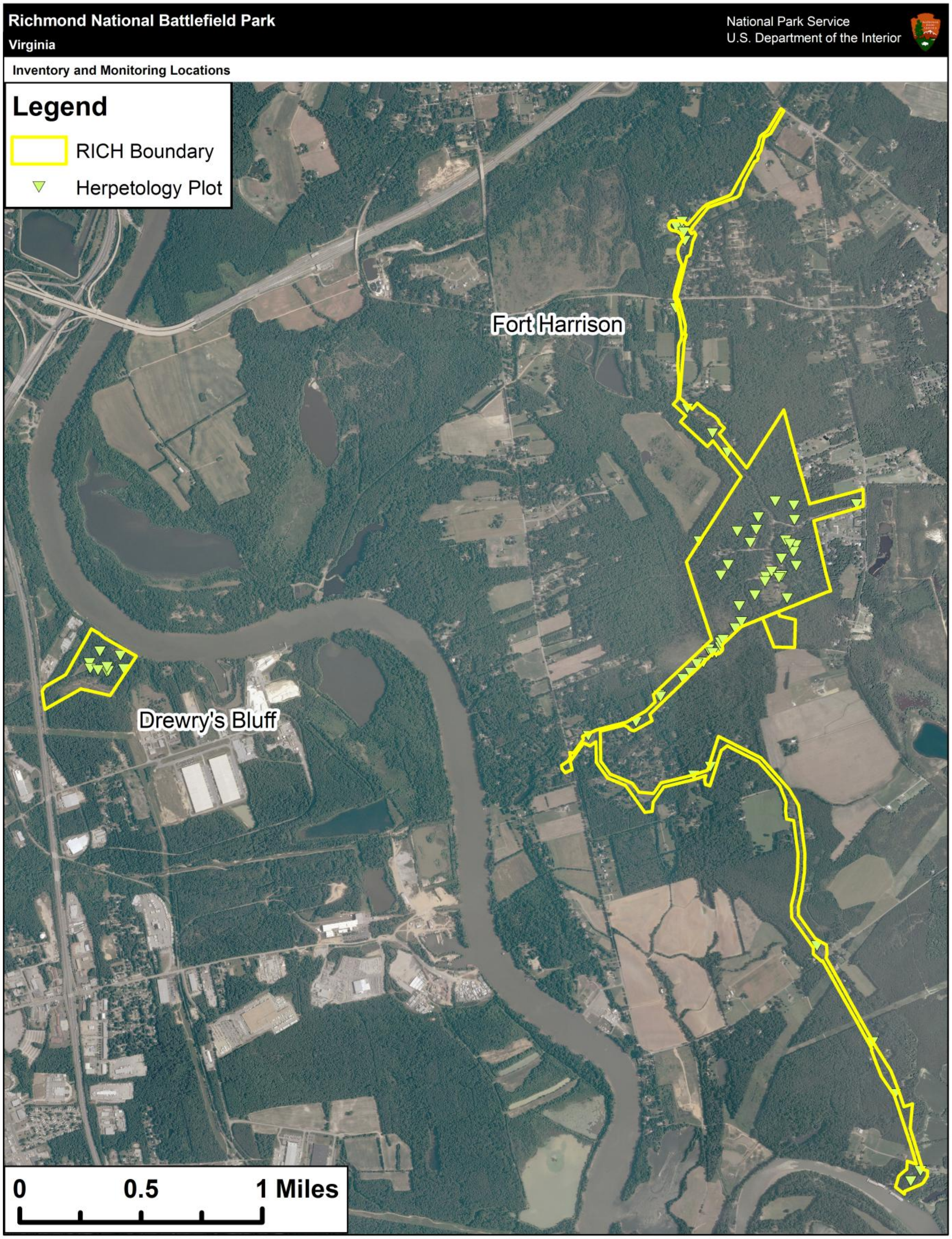

Figure 74. Inventory and monitoring locations for Fort Harrison and Drewry's Bluff.

Figure 75. Inventory and monitoring locations for Beaver Dam Creek and Chickahominy Bluff.

Figure 76. Inventory and monitoring locations for Parker's Battery.

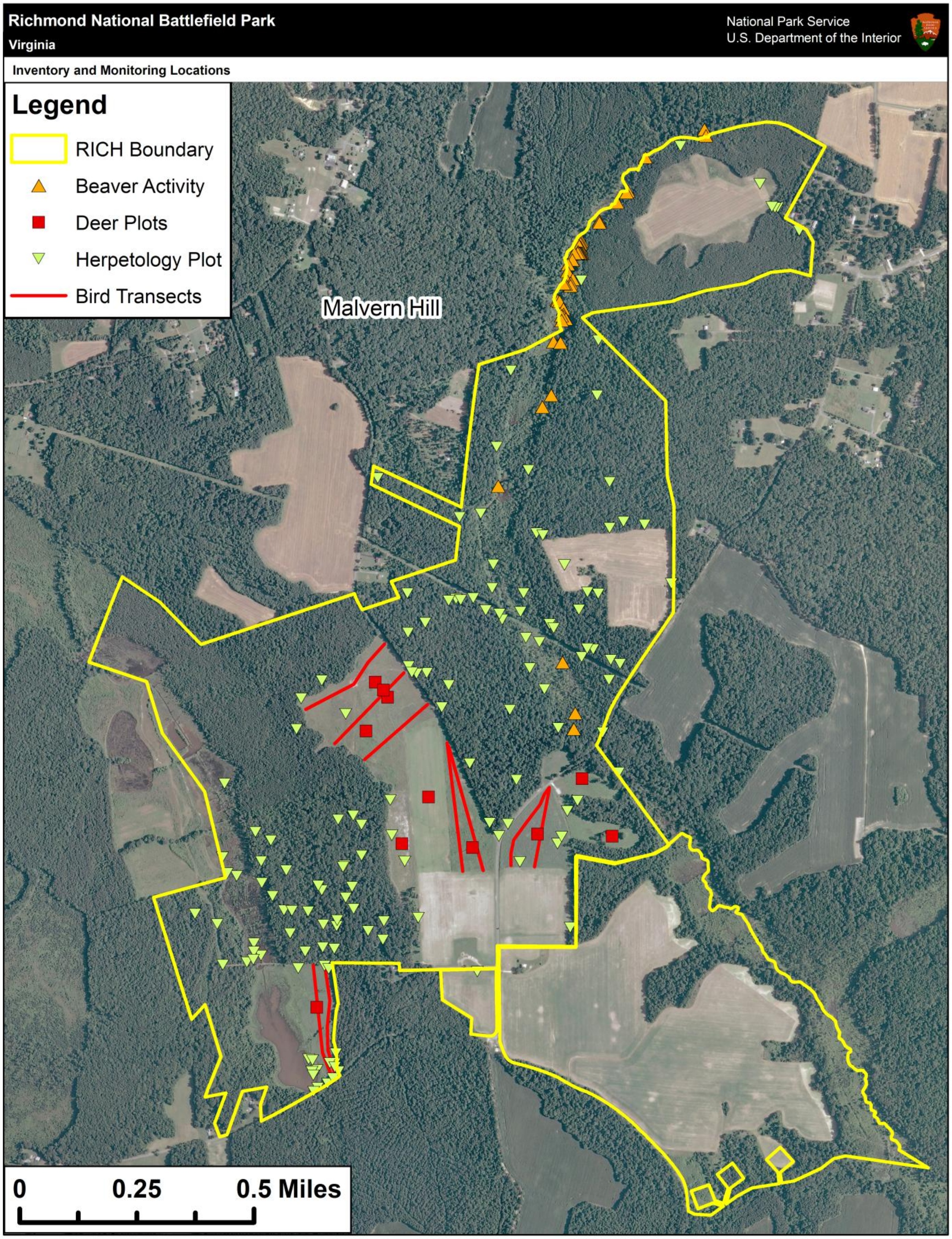

Figure 77. Inventory and monitoring locations for Malvern Hill.

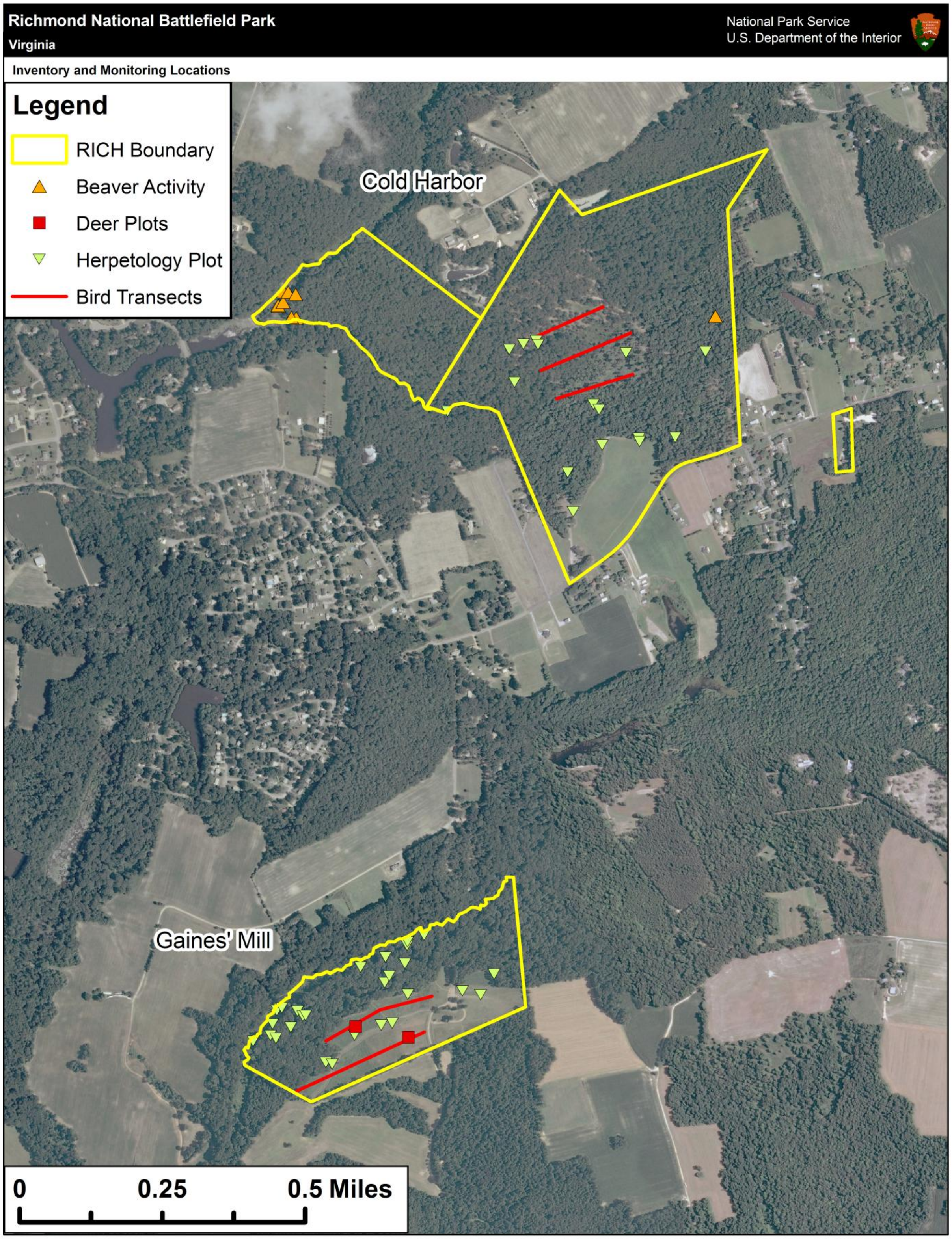

Figure 78. Inventory and monitoring locations for Cold Harbor, Gaines' Mill, and Turkey Hill.

To determine quantitative measures of biotic condition, we used the Jaccard Index of Similarity for comparisons with other species lists for the state of Virginia. The Jaccard Index of Similarity is a simple method for comparing species diversity between two different samples or communities (Krebs 1999). We used inventory and monitoring reports to examine expected and observed species lists where given. The value is calculated by dividing the number of species found in both samples (a) by the number found in only one sample or the other (b, c):

$S_j = a / (a+b+c)$.

Per discussion with NPS personnel, we gave a 'good' condition status to those indicators with a Jaccard's Index of Similarity ≥ 0.50, and a 'fair' condition status to those ≥ 0.25. Scores < 0.25 were given a 'poor' condition status. These values can be updated and refined in subsequent years as more information becomes available.

Fish Communities

Fish were inventoried at Richmond NBP in 2002 and 2003. Atkinson (2008) sampled sites along Beaver Dam Creek (Beaver Dam Creek Unit), Bloody Run (Cold Harbor Unit), Boatswain Creek (Gaines' Mill Unit), Crewes Channel (Malvern Hill Unit), and Western Run (Malvern Hill Unit). Our assessment was completed using the fish species documented during this effort (see Appendices F and G for abbreviations and species lists).

There are 30 fish species that utilize Richmond NBP habitats for some period of their annual or seasonal life requisites. The Atkinson (2008) study found the greatest diversity of fish in Beaver Dam Creek (Table 21). Findings of interest during this study include the ironcolor shiner (*Notropis chalybaeus*), gizzard shad (*Dorosoma cepedianum*), bluehead chub (*Nocomis leptocephalus*), least brook lamprey (*Lampetra aepyptera*) (see Figure 79), and swamp darter (*Etheostoma fusiforme).* Atkinson (2008) did not list species expected to occur at the various units of Richmond NBP.

One method to determine biotic integrity of the fish assemblage at Richmond NBP is to use an Index of Biotic Integrity (IBI). The IBI is a tool to evaluate the integrity of surface waters used nationwide. The index is designed to evaluate changes in fish assemblages over time using species composition, richness, and ecological factors (Karr and Dudley 1981). These two characteristics can be broken down into seven categories: species richness, species composition, presence of indicator species, trophic function, fish abundance, reproductive function, and condition (Grabarkiewicz and Davis 2008).

Table 21. IBI metrics for fish species detected during baseline surveys by Atkinson (2008).

Year	2002					2003	
Unit	BDC	GM	CH	MH (Western Run)	MH (Crewes Channel)	BDC[1]	MH (Crewes Channel)
Species richness	17	10	3	13	10	25	7
# individuals	208	651	9	210	296	491	207
# darter species	1	0	0	0	0	2	0
# sucker species	1	0	0	1	0	1	0
# sunfish species	4	4	0	3	6	8	5
% green sunfish	--	--	--	--	--	--	0.5
# intolerant species	1	0	0	0	0	1	0

[1] Sample period for Beaver Dam Creek consisted of two survey days (all others were based on one survey day).

Figure 79. Least brook lampreys, Cold Harbor (April 2005).

Metrics used to calculate IBI can include: total number of species, number of darter species, number of sunfish species, number of sucker species, number of intolerant species, percentage of green sunfish, percentage omnivores, percentage insectivorous cyprinids, percentage top carnivores, number of individuals, percentage hybrids, and indication of disease (Grabarkiewicz and Davis 2008). We chose the following metrics: total number of species, number of darter species, number of sunfish species, number of sucker species, and number of intolerant species to evaluate the fish community at Richmond NBP (Table 21).

Total number of fish species is the total number of fish species identified from a sample collection. A reduction of taxonomic richness may indicate a pollution problem (e.g., organic enrichment, toxicity) and/or physical habitat loss.

Fish species with the least tolerance to environmental change are typically the first to disappear when water quality degrades. Fish species are broadly categorized as intolerant, intermediate, or tolerant to environmental stressors. A total of nine sunfish species, two darters, and one species of sucker were observed during the two year survey effort by Atkinson. The majority of fish species documented during these surveys are classified as 'intermediate." The ironcolor shiner was the only intolerant species documented.

Darters, sunfish, and suckers are generally intolerant of environmental disturbances such as siltation, pollutants, and habitat disturbance. Sunfish are more tolerant and usually persist after darters disappear. Darters are the most imperiled group of North American fishes, with one-third of all darter species in some degree of population decline (Grabarkiewicz and Davis 2008).

Beaver Dam Creek had the highest documented species richness; Cold Harbor had the lowest. Beaver Dam Creek was the only unit to have darter, sucker, and sunfish species. Malvern Hill (Crewes Channel) and Gaines' Mill only had sunfish species observed.

Amphibian Communities

Amphibians are good indicators of habitat quality and change due to their sensitivity to pollutants and environmental stressors. Habitat loss, environmental contaminants, and invasive species directly affect salamander and other amphibian populations. Vegetation along streams is important for the survival of many amphibian species because of the shade it provides. When the vegetation is gone, eggs may be exposed to lethal amounts of ultraviolet radiation. Additionally, salamanders can be negatively impacted by various introduced species such as bullfrogs and species of predatory fish (Kiesecker and Blaustein 1998). Amphibians are of particular interest in biotic condition analyses due to their sensitivity to their surrounding environment. Recent declines in amphibian reproduction elsewhere in the region make them of further interest as part of this assessment.

Amphibians were recently inventoried at Richmond NBP along with reptiles (Mitchell 2007). Mitchell (2007) employed a variety of survey methods aimed at compiling the most comprehensive list of amphibians present at the park. Our assessment was completed using the amphibian species documented during this effort (see Appendix H).

A total of 24 species of amphibians (14 anurans, 10 salamanders) were observed for Richmond NBP as part of the Mitchell's (2007) survey. This study suggests that four additional amphibian species (two anuran, two salamanders) have ranges coincident with Richmond NBP, but were not observed: squirrel treefrog *(Hyla squirella),* Brimley's chorus frog *(Pseudacris brimleyi),* four-toed salamander *(Hemidactylium scutatum),* and eastern mud salamander *(Pseudotriton montanus)*. The absence of these species is presumably due to a lack of required habitat, precipitation patterns during the survey period, and low encounter rates with very secretive species. The Jaccard Similarity Index between the observed species and the potential assemblage is 0.88 for the entire park (Table 22). Cold Harbor, Malvern Hill, and Fort Harrison had the highest percentage of expected species observed.

Table 22. Expected, observed, and Jaccard Index of Similarity for amphibian species at Richmond NBP (Mitchell 2007).

Metric	GM	CH	BDC	CB	MH	FH	DB	PB
# expected	24	25	19	12	27	27	20	7
# observed	8	10	5	8	18	17	5	1
Jaccard Index of Similarity	0.33	0.40	0.26	0.67	0.67	0.63	0.25	0.14

Reptile Communities

We completed a community composition analysis for reptiles similar to our methods for amphibians listed above. Reptiles were surveyed from 2002 to 2004 (Mitchell 2007) along with amphibians using similar methods (see Appendix I for detailed species lists).

The Mitchell survey detected a total of 20 reptiles at Richmond NBP (eight turtle species, three lizard species, and nine snake species). The survey suggests the potential for 12 additional species with overlapping ranges (although habitat may not be found at the park). Species expected to occur during the Mitchell survey, but not observed include: eastern six-lined racerunner (*Cnemidophorus sexlineatus*), southeastern five-lined skink (*Eumeces inexpectatus*), broad-headed skink (*Eumeces laticeps*), slender glass lizard (*Ophisaurus attenuatus*), scarlet snake (*Cemophora coccinea*), eastern hog-nosed snake (*Heterodon platirhinos*), and mole kingsnake (*Lampropeltis calligaster*).

This yields a Jaccard Similarity Index of 0.63 for the entire park (Table 23). The NPSCertified species list contains four species that were not detected during the Mitchell survey, but have been identified by NPS staff: eastern hog-nosed snake (*Heterodon platirhinos*), milk snake (*Lampropeltis triangulum triangulum*), red-bellied snake (*Storeria occipitomaculata*), and southeastern five-lined skink (*Eumeces inexpectatus*).

Table 23. Expected, observed, and Jaccard Index of Similarity for reptile species at Richmond NBP (Mitchell 2007).

Metric	GM	CH	BDC	CB	MH	FH	DB	PB
# expected	28	28	18	12	32	31	19	6
# observed	8	5	6	5	18	12	4	1
Jaccard Index of Similarity	0.29	0.189	0.33	0.42	0.56	0.39	0.21	0.17

Avian Communities

Browder et al. (2002) state numerous reasons why birds are good indicators for monitoring habitat change: 1) individual bird species are associated with particular habitats; 2) changes in species composition and abundance can be evident relatively quickly after a disturbance; 3) systematic and extensive bird surveys are currently conducted across the United States and southern Canada (Audubon Breeding Bird Survey, Christmas Bird Count, etc); 4) groups of bird species can be used to develop associations with habitats that are predictive of the relative level of anthropogenic disturbance; and 5) birds are important to a large segment of the public, so the public may relate to concerns about changes in bird communities better than to those of other taxa, such as plants or invertebrates.

Birds were inventoried at Richmond NBP in 2003-2004 (Bradshaw 2007). The survey documented 151 species that utilize Richmond NBP habitats for some period of their annual or seasonal life requisites (see Appendix J for detailed species lists). However, the certified species list from Richmond NBP, list three rare species not documented during the Bradshaw survey, (brown pelican (*Pelecanus occidentalis*), golden eagle (*Aquila chrysaetos*), and northern saw-whet owl (*Aegolius acadicus*)). The two lists combined confirm 154 birds at Richmond NBP (NPS 2010). Bradshaw found a high percentage of species observed to be edge species or species that utilize small woodlots such as northern cardinal, tufted titmouse, Carolina chickadee, and American robin. This is due to the fact that Richmond NBP is comprised mostly of small, fragmented habitats. Our assessment was completed using the bird species documented during Bradshaw's effort.

The Bradshaw (2007) study suggests that four additional bird species (two native and two non—native) have breeding ranges coincident with Richmond NBP but were not observed during the survey period (whip-poor-will (*Caprimulgus vociferous)*, chuck-will's-widow (*Caprimulgus carolinensis*), rock pigeon (*Columba livia*), and house sparrow (*Passer domesticus*)). The Jaccard Similarity Index between the observed species and the potential assemblage for all of Richmond NBP units for the breeding season is 0.95. The worm-eating warbler (*Helmitheros vermivorus*) was the only species detected (at Malvern Hill only) that was not expected.

The migratory expected species list included 28 species. Four species were expected but not observed (common tern (*Sterna hirundo)*, willow flycatcher (*Empidonax traillii)*, orange-crowned warbler (*Vermivora celata)*, and bobolink (*Dolichonyx oryzivorus*). Also, four species were detected but not expected (black-necked stilt (*Himantopus mexicanus)*, Caspian tern (*Sterna caspia)*, Tennessee warbler (*Vermivora peregrina)*, and bay-breasted warbler (*Dendroica castanea*). This gives a Jaccard Similarity Index of 0.71. No species were observed that were not expected for the winter season. Three expected species, northern shoveler (*Anas clypeata)*, American coot (*Fulica Americana)*, and American pipit (*Anthus rubescens)*, were not encountered (Jaccard Similarity Index 0.89).

Table 24 shows expected and observed species for the units surveyed during this effort. Malvern Hill had the highest percentage of expected species observed; Parker's Battery had the lowest.

Table 24. Jaccard Index of Similarity for expected (n=98) and observed avian species observed at Richmond NBP (Bradshaw 2007) the breeding season.

Metric	GM	CH	BDC	CB	MH	FH	DB	PB
# observed	87	76	64	58	145	94	72	34
Jaccard Index of Similarity	0.70	0.61	0.51	0.47	0.95	0.76	0.59	0.28

Another means for assessing the biotic condition of the birds at Richmond NBP was to examine the population trends for each species. From a management perspective, Richmond NBP would like to see each species either at, or moving towards, population levels desired for management. These levels will differ depending on the status of the species. For example, we assume that rare species populations would be desirable if their numbers were increasing. The opposite would be true of exotic or nuisance species.

We elected to first compare this suite of species to that of known breeders from the surrounding landscape. The reference list of breeding birds was synthesized from data compiled as part of the ongoing USGS Breeding Bird Survey (BBS) effort (U.S. Geological Survey 2008). The bird community at Richmond NBP is reported to contain 90 species listed as "breeder" or "resident."

Using the BBS data for the Upper Coastal Plain region, we were able to establish observation trends for 72 species known to breed at Richmond NBP. These species are associated with all vegetation communities found at Richmond NBP.

We calculated trends for two periods. The first period was for the entire survey period (1966 – 2007). The second period was for the last 28 years only (1980 – 2007). Comparisons between these periods will allow us to determine if any significant trends changed more recently. We categorized trends as "acceptable" or "unacceptable" by using a simple management matrix for each class of species in the set (Table 25). These three classes were: species of "concern," "nuisance," or "breeder/resident." These values were used to determine the overall management acceptability of population trends for the bird community.

Table 25. Management matrix used to categorize trend combinations.

		Management Evaluation		
Period 1 1966 – 2007	**Period 2 1980 – 2007**	**SGCN**	**Nuisance / Nonnative**	**Other breeders / residents**
increasing	increasing	acceptable	unacceptable	acceptable
decreasing	increasing	acceptable	unacceptable	acceptable
not significant	increasing	acceptable	unacceptable	acceptable
increasing	decreasing	unacceptable	acceptable	unacceptable
decreasing	decreasing	unacceptable	acceptable	unacceptable
not significant	decreasing	unacceptable	acceptable	unacceptable
increasing	not significant	unacceptable	unacceptable	acceptable
decreasing	not significant	unacceptable	acceptable	unacceptable
not significant	not significant	unacceptable	unacceptable	acceptable

Thirty-six of the 73 (49%) species were deemed "acceptable." Twenty-two Species of Greatest Conservation Need (SGCN) from the VA Wildlife Action Plan (VDGIF 2005) were deemed "unacceptable" based on their observed trends; two were deemed "acceptable" (northern harrier and yellow-breasted chat). For example, the grasshopper sparrow is a Virginia SGCN. The population trends for both Period 1 and 2 are decreasing (Figures 80 and 81). Therefore, this trend is "unacceptable." The European starling (classified as nuisance/nonnative species) has a decreasing trend for Period 1 and a not significant (or stable) trend for Period 2 (Figures 82 and 83). For this reason, we gave the European starling an "acceptable" rating.

This result suggests that many breeding birds in the landscape surrounding, and perhaps including Richmond NBP, are experiencing significant long and/or short-term declines. It is important to note that this does not provide any evidence that these species are stable or unstable as there are no long-term data on breeding bird observations at Richmond NBP.

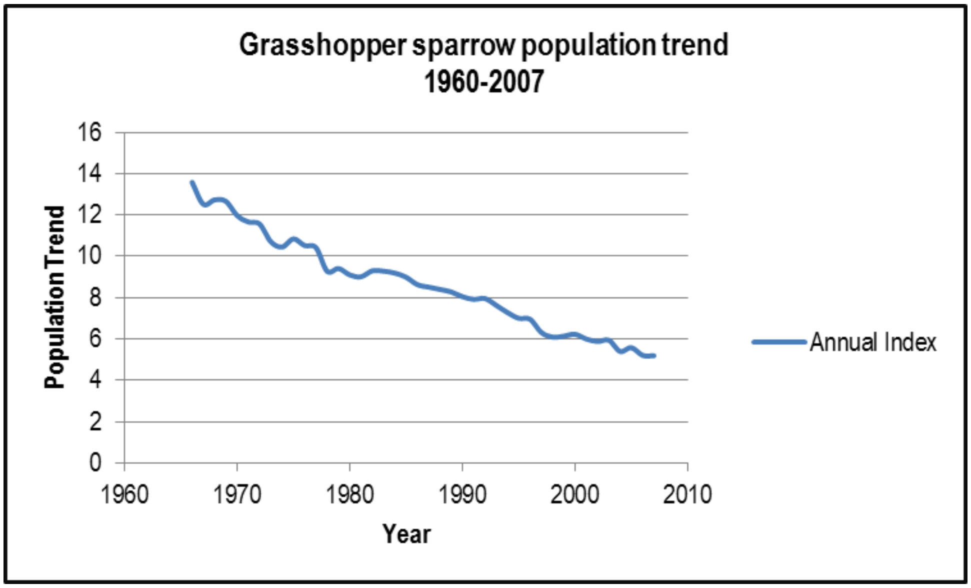

Figure 80. Grasshopper sparrow population trend for Virginia (1960-2007) (USGS 2009b).

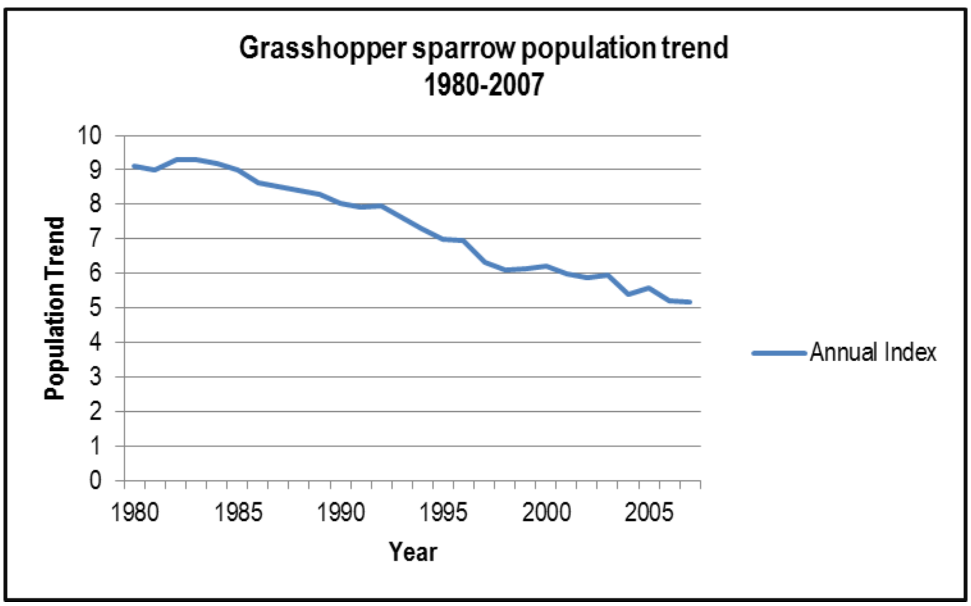

Figure 81. Grasshopper sparrow population trend for Virginia (1980-2007) (USGS 2009b).

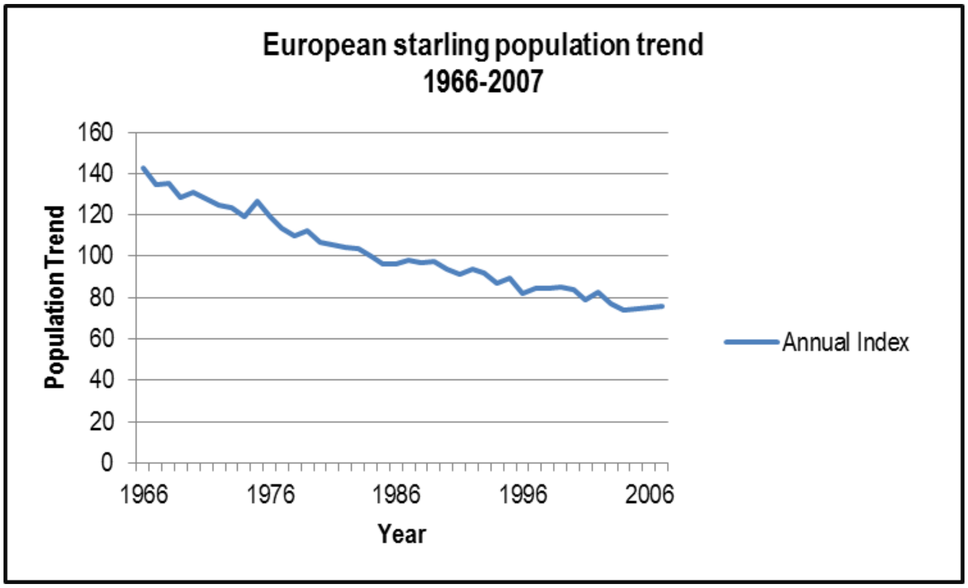

Figure 82. European starling population trend for Virginia (1966-2007) (USGS 2009b).

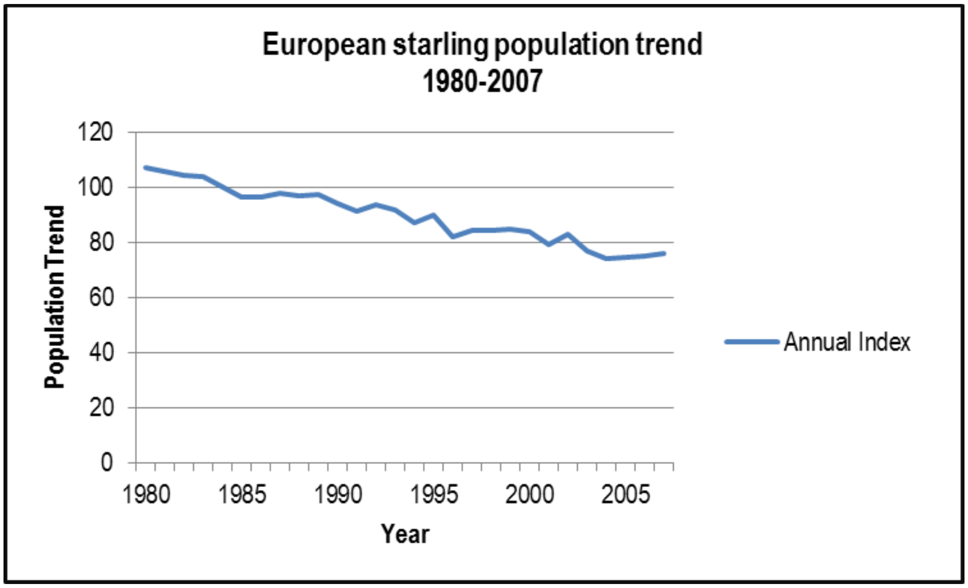

Figure 83. European starling population trend for Virginia (1980-2007) (USGS 2009b).

Mammal Communities

Mammals were inventoried at Richmond NBP in 2003 and 2004 (Barry and Sareen 2008). Barry and Sareen employed a variety of survey methods aimed at compiling the most comprehensive list of mammals present at the park. Our assessment was completed using the mammal species documented during this effort (see Appendix K).

Mammals were analyzed on a park-wide basis, as a complete species list, both expected and observed. There were 23 species documented (bats were not surveyed) at Richmond NBP during the Barry and Sareen survey. This study suggests that 15 additional mammal species have ranges coincident with Richmond NBP, but were not observed. These species are: North American least shrew (*Cryptotis parva*), American pygmy shrew (*Sorex hoyi*), southeastern shrew (*Sorex longirostris*), star-nosed mole (*Condylura cristata*), golden mouse (*Ochrotomys nuttalli*), common muskrat (*Ondatra zibethicus*), hispid cotton rat (*Sigmodon hispidus*), brown rat (*Rattus norvegicus*), eastern fox squirrel (*Sciurus niger*), red squirrel (*Tamiasciurus hudsonicus*), meadow jumping mouse (*Zapus hudsonius*), coyote (*Canis latrans*), domestic dog (*Canis lupus*), bobcat (*Lynx rufus*), and long-tailed weasel (*Mustela frenata*). The Jaccard Similarity Index between the observed species and the potential assemblage is 0.61. Complete data for individual units were not available for this analysis.

Nonnative Species

We used information from Richmond NBP to assess the status and percentage of invasive species within the park boundaries (Table 26). These data are based on initial I&M baseline inventory data and varies from seven to nine years old. Appendices K-O list all nonnative species documented on Richmond NBP.

Table 26. Proportion of invasive species by taxa and study area at Richmond NBP (park-wide).

Taxonomic Group	# Native species	# Nonnative species	% Nonnative
Fish	25	5	17
Amphibians	23	0	--
Reptiles	24	0	--
Birds	134	3	2
Mammals	20	3	13

Species of Greatest Conservation Need (SGCN)

There are 41 species of greatest conservation need documented at Richmond NBP (Table 27). This is 15% of the total number of high priority faunal species identified for the state of Virginia (Virginia Department of Game and Inland Fisheries (VDGIF) 2005). There are 32 high priority birds found at the park (Table 28), 33% of the 96 species identified for the state of Virginia. Appendix O contains a complete species lists with associated state and global ranks and federal and state status.

Table 27. Total number of species documented at Richmond NBP, number of Species of Greatest Conservation Need (SGCN) from the VA Wildlife Action Plan (VDGIF 2005), and % of SGCN Virginia that are found at the park.

Taxonomic Group	# SGCN TOTAL IN VA	# SGCN at RICH	# Species Documented[1]	% SGCN at RICH
Park-wide				
Birds	96	32	137	33
Amphibians	32	0	23	--
Reptiles	28	5	24	18
Mammals	24	0	23	--
Fish	96	4	30	4

[1]Including nonnative species.

Table 28. Species of Greatest Conservation Need and distribution at Richmond NBP.

Common Name	VA SGCN	Distribution at RICH
Bird		
American black duck	Tier II	MH
American woodcock	Tier IV	FH, MH
bald eagle	Tier II	CB, MH
black-and-white warbler	Tier IV	BDC,CB, CH, DB, FH, GM, MH, PB
brown creeper	Tier IV	All units
brown thrasher	Tier IV	MH, FH, DB, CB, PB
chimney swift	Tier IV	BDC, CH, FH, GM, MH
eastern kingbird	Tier IV	CH, FH, GM, MH
eastern meadowlark	Tier IV	CH, GM, MH
eastern towhee	Tier IV	BDC,CB, CH, DB, FH, GM, MH, PB
eastern wood-pewee	Tier IV	All units except BDC
field sparrow	Tier IV	CH, DB, FH, GM, MH, PB
grasshopper sparrow	Tier IV	CH, DB, MH
gray catbird	Tier IV	BDC, DB, GM, MH
green heron	Tier IV	BDC
Kentucky warbler	Tier IV	CB, GM, MH
Louisiana waterthrush	Tier IV	DB, FH, GM, MH
northern bobwhite	Tier IV	FH, MH
northern harrier	Tier III	BDC, MH
northern parula	Tier IV	All except PB
northern rough-winged swallow	Tier IV	BDC, MH, PB
northern saw-whet owl	Tier II	Unknown
ovenbird	Tier IV	CB, CH, DB, FH, GM, MH
prairie warbler	Tier IV	FH, GM, MH
prothonotary warbler	Tier IV	BDC, FH, GM, MH
scarlet tanager	Tier IV	BDC, CB, CH, DB, FH, GM, MH
wood thrush	Tier IV	CB, CH, DB, FH, GM, MH
worm-eating warbler	Tier IV	MH
yellow warbler	Tier IV	BDC, FH, MH
yellow-billed cuckoo	Tier IV	CB, CH, DB, FH, GM, MH
yellow-breasted chat	Tier IV	FH, GM, MH
yellow-throated vireo	Tier IV	CB, CH, DB, FH, GM, MH
Fish		
American eel	Tier IV	BDC, MH
least brook lamprey	Tier IV	BDC, MH, CH

Common Name	VA SGCN	Distribution at RICH
ironcolor shiner	Tier IV	BDC
Reptile		
common slider	Tier IV	MH
eastern box turtle	Tier III	GM, CH, CB, MH, FH, DB
eastern hog-nosed snake	Tier IV	expected (GM, CH, MH, FH, DB)
eastern kingsnake	Tier III	CB, MH
spotted turtle	Tier III	MH

Condition Status Summary for Biological Integrity

It is clear that future surveys are needed to assess the biological integrity of the units at Richmond NBP (see Tables 29-37 for summaries). An assessment based on baseline surveys conducted over five years old is not preferred. Surveys currently underway should also address abundance, population trends, and threats which, over time, will provide better information to complete biotic community assessments.

The species richness found at Richmond NBP appears to be good, given the many challenges to natural resources conservation in a multi-unit cultural park. Due to the fragmented nature of Richmond NBP, the surrounding urbanized landscape, the size of appropriate habitat, and barriers to dispersal, diversity of many faunal groups is likely low (Bradshaw 2007). In addition to evaluating habitats within the park, habitats can be evaluated in relation to the surrounding landscape, as a loss of habitat outside the park will most likely impact species within the park. Species richness was highest at the larger park units. Malvern Hill, Fort Harrison, Beaver Dam Creek, and Turkey Hill provide the best habitat for a variety of faunal groups largely due to the large acreage they contain.

Understanding the threats to the faunal species at Richmond NBP is imperative. Other threats and stressors such as development and nonnative/exotic plant species appear to have a larger negative impact on native fauna. Other threats to species at Richmond NBP likely include mortality from vehicular traffic (Barry and Sareen 2008), human disturbance, pollution from surrounding properties, and habitat loss or alteration due to human population growth in the surrounding communities. The decline of some species appears to be part of a larger regional decline affecting many of the urbanized areas of the Mid-Atlantic region.

Table 29. Biological integrity condition status summary for all units at Richmond NBP.

Vital Sign / Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Fish communities	Species richness	Populations will remain stable or increase over time.	30 fish species documented at the park	Future faunal surveys will be beneficial to monitor relative abundances and diversity of native species over time. Insufficient data to evaluate trends.
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	154 bird species documented at the park	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	Breeding = 0.95 (Good) Migratory = 0.71 (Good) Winter = 0.89 (Good)	
	Population trends (regional)	Each species either at, or moving towards, population levels desired for management.	49% of species rated 'acceptable'	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	23 amphibian species documented at the park	Insufficient data to evaluate trends. Change in species richness can be evaluated as more data is collected.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.88 (Good)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	24 species of reptile documented at the park	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.63 (Good)	
Mammal communities	Species richness	The existing richness and abundance mammal communities in the park will remain stable or increase over time.	22 species of mammal documented at the park	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.61 (Good)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	40 SGCN	Insufficient data to evaluate trends.

[1]Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 30. Biological integrity condition status summary for Beaver Dam Creek.

Vital Sign / Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends (s)
Fish communities	Species richness	Populations will remain stable or increase over time.	26 fish species documented at the unit	Future faunal surveys will be beneficial to monitor relative abundances and diversity of native species over time. Insufficient data to evaluate trends.
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	64 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.51 (Good)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	5 amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.26 (Fair)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	6 species of reptile documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.33 (Fair)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	14 SGCN	Insufficient data to evaluate trends.

[1]Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 31. Biological integrity condition status summary for Chickahominy Bluff.

Vital Sign / Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends(s)
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	58 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.47 (Fair)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	8 amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.67 (Good)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	5 species of reptile documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.42 (Fair)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	15 SGCN	Insufficient data to evaluate trends.

[1]Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 32. Biological integrity condition status summary for Cold Harbor.

Vital Sign / Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends (s)
Fish communities	Species richness	Populations will remain stable or increase over time.	3 fish species documented at the unit	Future faunal surveys will be beneficial to monitor relative abundances and diversity of native species over time. Insufficient data to evaluate trends.
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	76 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.61 (Good)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	10 amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.40 (Fair)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	5 species of reptile documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.18 (Poor)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	16 SGCN	Insufficient data to evaluate trends.

[1]Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 33. Biological integrity condition status summary for Drewry's Bluff.

Vital Sign / Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends (s)
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	72 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.59 (Good)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	5 amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.25 (Fair)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	4 species of reptile documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.21 (Poor)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	14 SGCN	Insufficient data to evaluate trends.

[1]Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 34. Biological integrity condition status summary for Fort Harrison.

Vital Sign/Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends (s)
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	94 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.76 (Good)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	17 amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.63 (Good)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	12 species of reptile documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.39 (Fair)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	22 SGCN	Insufficient data to evaluate trends.

1Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery

Table 35. Biological integrity condition status summary for Gaines' Mill.

Vital Sign / Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends(s)
Fish communities	Species richness	Populations will remain stable or increase over time.	10 fish species documented at the unit	Future faunal surveys will be beneficial to monitor relative abundances and diversity of native species over time. Insufficient data to evaluate trends.
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	87 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.70 (Good)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	8amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.33 (Fair)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	8 species of reptile documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.29 (Fair)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	21 SGCN	Insufficient data to evaluate trends.

1Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 36. Biological integrity condition status summary for Malvern Hill.

Vital Sign / Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends(s)
Fish communities	Species richness	Populations will remain stable or increase over time.	13fish species documented (Western Run) 12 fish species documented (Crewes Channel)	Future faunal surveys will be beneficial to monitor relative abundances and diversity of native species over time. Insufficient data to evaluate trends.
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	145 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.95 (Good)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	18 amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.67 (Good)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	18 species of reptile documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.56 (Good)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	36 SGCN	Insufficient data to evaluate trends.

1Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

Table 37. Biological integrity condition status summary for Parker's Battery.

Vital Sign / Indicator	Measure	Threshold Criteria	Current Condition[1]	Trends (s)
Bird Communities	Species richness and abundance of breeding birds	The existing richness and abundance of obligate grassland and forest breeding bird communities in the park will remain stable or increase over time.	34 bird species documented at the unit	Insufficient data to evaluate trends at RICH.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.28 (Fair)	
Amphibian communities	Species richness	The existing richness of amphibian communities in the park will remain stable or increase over time.	1 amphibian species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.14 (Poor)	
Reptile communities	Species richness	The existing richness and abundance of reptile communities in the park will remain stable or increase over time.	1 reptile species documented at the unit	Insufficient data to evaluate trends.
	Reference species list Jaccard's Index of Similarity	≥ 0.50 = Good ≥ 0.25 = Fair < 0.25 = Poor	0.17 (Poor)	
State SGCN	Species presence/absence	The existing number and population of state-listed SGCN will remain stable or increase over time.	7 SGCN	Insufficient data to evaluate trends.

1Park unit abbreviations: BDC = Beaver Dam Creek, CB = Chickahominy Bluff, CH = Cold Harbor, DB = Drewry's Bluff, FH = Fort Harrison, GM = Gaines' Mill, MH = Malvern Hill, PB = Parker's Battery, CM = Chimborazo, TC = Totopotomoy Creek

7.0 Water Resources

Hydrology

Hydrology involves the study of water and how it moves across the earth's surface, through the soil and underlying rock, the atmosphere, and vegetation. One way to monitor water as it moves through the hydrologic system is to monitor the flow and discharge rates of streams in an area. The flow of a stream is a measure of the rate at which water moves through the stream channel. The term discharge can refer to the total outflow of a water course or drainage basin. These terms are sometimes used interchangeably as indicators of the amount of water (by rate or volume respectively) moving through a system. Flow rates are inherently variable and unique to each surface water system so there is not one standard measure of a "good" flow, but changes in flow outside of normal ranges can be an indicator of changes in the system.

The USGS rates current discharge by comparing the values to the actual flow. Actual flow is the natural flow of a stream or river (average annual water flow at a given point without any human influence) minus the reduction of flow due to upstream withdrawals. Using this comparison, the USGS gives stream flow conditions a rating of excellent, good, fair, or poor. If the flow rate is within 2% of the actual flow it is rated excellent, within 5% it is considered good, within 8% fair, and outside of 8% it is rated poor. The good, fair, poor ranking are an assessment of the ability to make flow estimation for a given location and it is not a rating of the health of the flow. Because there is no other standard available to rate the stream flow, this was used to evaluate hydrology at Richmond NBP.

The units of Richmond NBP are located on either side of the fall line separating the Virginia Piedmont from the coastal plain. This is significant when evaluating hydrology since these two physiographic provinces have very different geology types which affect the movement of water.

The western most units of Richmond NBP, and most of the Piedmont Physiographic Province, is underlain by dense, almost impermeable bedrock that yields water primarily from secondary porosity and permeability provided by fractures. The bedrock is partly covered by glacial deposits of unconsolidated weathered rock material, alluvium, and soil called regolith. The region is primarily underlain by bedrock aquifers classified as crystalline-rock and undifferentiated sedimentary-rock aquifers. Water in crystalline-rock aquifers is present in fractures in the rock and in the weathered material that overlies the rock (U.S. Geological Survey 2009a). On the eastern side of the fall line, where the majority of the units at Richmond NBP lie, is the beginning of the Northern Atlantic Coastal Plain Physiographic Province. This area is underlain by lenses and layers of clay, silt, and sand, with minor amounts of lignite, gravel, and limestone deposited on irregular crystalline-rock surface, warped by tectonic forces. The aquifers in the region are composed of sand, gravel, and limestone and are separated by the less permeable silt, clay, and silty or clayey soils. Water still moves through these confining units, particularly in thin spots, or where they contain more sand (U.S. Geological Survey 2009a).

Permeability refers to the rate at which water is able to flow through a soil, which affects the amount of infiltration. Infiltration capacity is the amount of precipitation that can be absorbed into the soil. Infiltration of precipitation is a critical source of water for plant growth and biotic development of the land. This process also moves many materials in and out of the soil and drives important physical and chemical processes, as well as providing the primary source for stream and groundwater recharge by through-flow. Any precipitation that cannot be brought into the soil through infiltration will result in direct runoff. This balance between infiltration and runoff plays a very important role in the hydrologic cycle.

Groundwater recharge is highly variable because it is determined by local and regional precipitation and runoff, which are highly variable and are influenced by topographic relief, and the capacity of the land surface to accept infiltrating water on a watershed level. Almost all recharge in the Piedmont is from precipitation that enters the aquifers through the porous regolith. Most of the recharge takes place in inter-stream areas, where water moves laterally through the regolith and discharges to a nearby stream or depression during or shortly after a precipitation event. Some of the water, however, moves downward through the regolith until it reaches the bedrock where it enters through fractures or solution openings (U.S. Geological Survey 2009a).

In the Coastal Plain groundwater recharge undergoes a similar process, and it is also heavily influenced by precipitation and runoff. After a precipitation event, water sometimes percolates through the soil and enters one of the aquifers closer to the surface, for example the surficial aquifer. Aquifers in this region are vertically separated by areas of clayey or silty confining units that retard the vertical flow of ground water. Water that is not confined to the aquifer or discharged into streams may move through thin or more permeable areas of the confining units into adjacent aquifers. The water may actually move through multiple aquifers, making them to some extent hydraulically interconnected. Other aquifers in the area may be closely tied to streams, where water may move in via precipitation and discharge into a stream in some cases over just a few miles. The North Atlantic Coastal Plain is made up of six of these aquifers, each having specific characteristics, depths, and geographic regions (U.S. Geological Survey 2009a).

Streamflow (Discharge)

We found a limited amount of stream flow data (U.S. Geological Survey 2009c) from streams or rivers flowing through Richmond NBP. No stations were available inside park boundaries, however the Chickahominy River and Totopotomoy Creek, had data available a few miles downstream of where they exit the park. This Chickahominy River station lies within the Lower James River Subbasin, in the Chickahominy River watershed, and is located near Providence Forge, VA. Existing data from this stations is reported from 1942-2009. The Totopotomoy Creek station is located in the Pamunky River Subbasin (HUC 02080106) near Studley, VA. No stations were available in the James River/Falling Creek watershed.

Monthly stream flow over the last 30 years is shown in Figure 84. Additional information on how stream flow varies throughout the year can be seen in Figure 85. Although these data are taken from outside of Richmond NBP, it may provide useful information on monthly variation of stream flow in the park. In contrast to precipitation, the lowest stream flows are in the summer, July having the lowest flow of any other month. Interestingly, July receives more rainfall than any other month on average (SERCC 2009). Based on this information, it seems evaporation and transpiration play a significant role in the stream flow dynamics throughout the year. This may be directly influenced by the amount of impermeable surfaces.

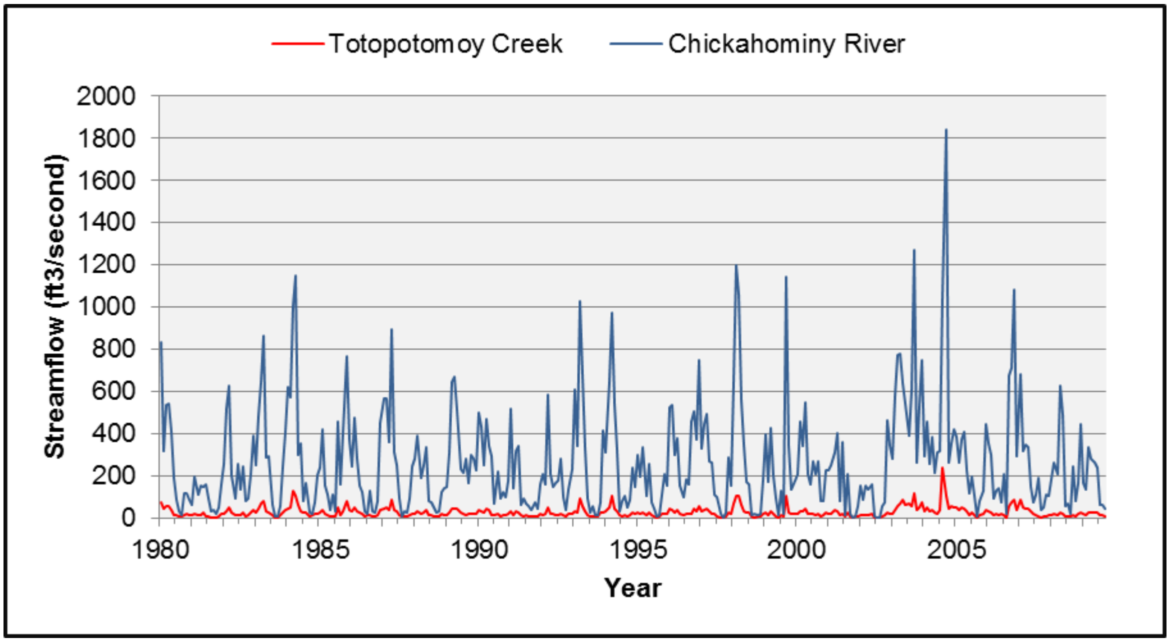

Figure 84. Monthly variation of stream flow in the Chickahominy River, near Providence Forge, VA and the Totopotomoy Creek, near Studley, VA. Each point represents a monthly average, and all 12 months are represented for each year shown.

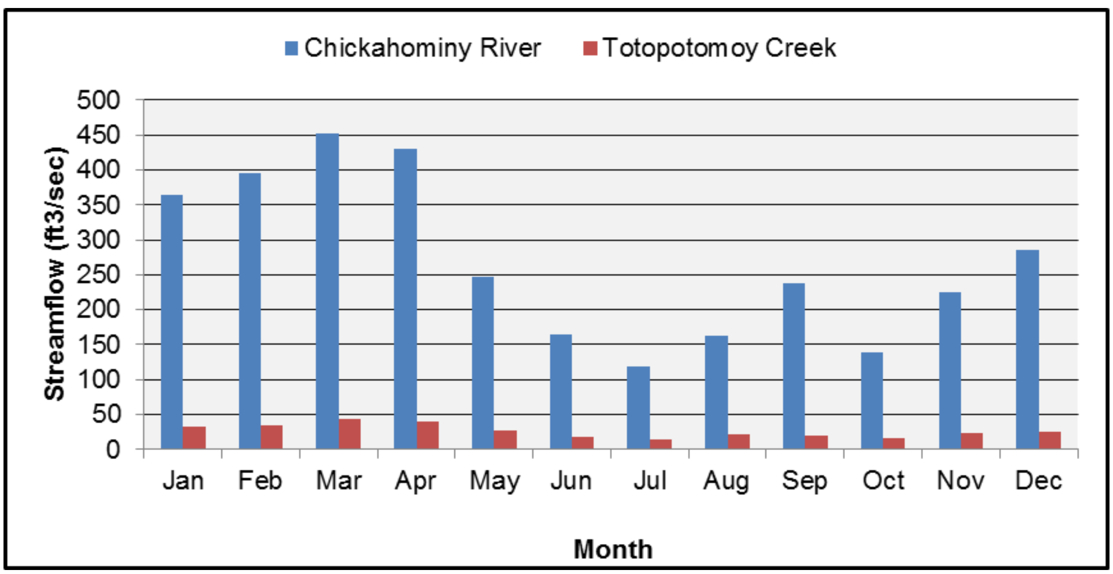

Figure 85. Average monthly discharge at Station 02042500 Chickahominy River, near Providence Forge, VA.

Standards used by USGS cannot be applied to streams at Richmond NBP because the natural flow (average annual water flow at a given point without any human influence) and actual flow (the natural flow of a stream or river minus the reduction of flow due to upstream withdrawals) data are unavailable. However, the USGS provided ratings for the hydrology at Chickahominy River without data for the natural or actual flow. USGS stream flow ratings were not available at the Totopotomoy Creek station. Stream flow was rated for the Chickahominy River based solely on the USGS ratings comparing the current flow (flow at a given time) to actual flow (rated excellent, good, fair, or poor). Based on 73 observations since 2000, 34% were rated good, 56% were rated fair, and 10% were rated poor. Based on ratings given by the USGS alone, discharge at Richmond NBP was rated fair since over half of all ratings were given the fair rating by the USGS. The validity of these ratings is unknown since “actual flow” is unclear. This was the only information available rating stream flow in the area.

Water Quality

Water quality standards consist of statements that describe water quality requirements. They also contain numeric limits for some specific physical, chemical, biological, or radiological characteristics of water. These statements and numeric limits describe water quality necessary to meet and maintain uses such as swimming and other water-based recreation, public water supply, and the propagation and growth of aquatic life.

Standards include general and specific descriptions, because not all requirements for water quality protection can be numerically defined. The standards are intended to reflect current understanding and incorporate changes in law, technology and information available to the Water Board and DEQ.

The units of Richmond NBP all fall in the Lower James River Subbasin (HUC 02080601), with exception to the Totopotomoy Creek unit located in the Pamunkey River Subbasin (HUC 02080106). Water quality data was collected within the James River/ Falling Creek (HUC 0208020601) and Chickahominy River (HUC 0208020605) watersheds, illustrated in Figure 86. Water quality monitoring stations were selected based upon proximity to park units and availability of useful data. If the stations were not inside, or in close proximity to park units they were not considered. Each park unit with water quality data available was evaluated separately. One unit, Totopotomoy Creek, did not have sufficient data available to evaluate water quality. Fort Harrison, Malvern Hill, Drewry’s Bluff, Chickahominy Bluff, Beaver Dam Creek, Cold Harbor, Gaines’ Mill, and Turkey Hill had sufficient data to rate some of the water quality parameters. Data sources for the water quality measures are found in Table 38. Locations of the monitoring stations are provided in Table 39 and Figures 87-91. The vast majority of the stations are taken within park units, but a few VA DEQ sites are taken just outside park boundaries, particularly two at Fort Harrison. These stations were used to address the conditions of the James River which borders the southern tip of Fort Harrison.

A few major waterbodies in the area include Beaver Dam Creek, Bloody Run, Boatswain Creek, Chickahominy River, Crewe’s Channel, James River, McDowell Creek, Powhite Creek, and Western Run.

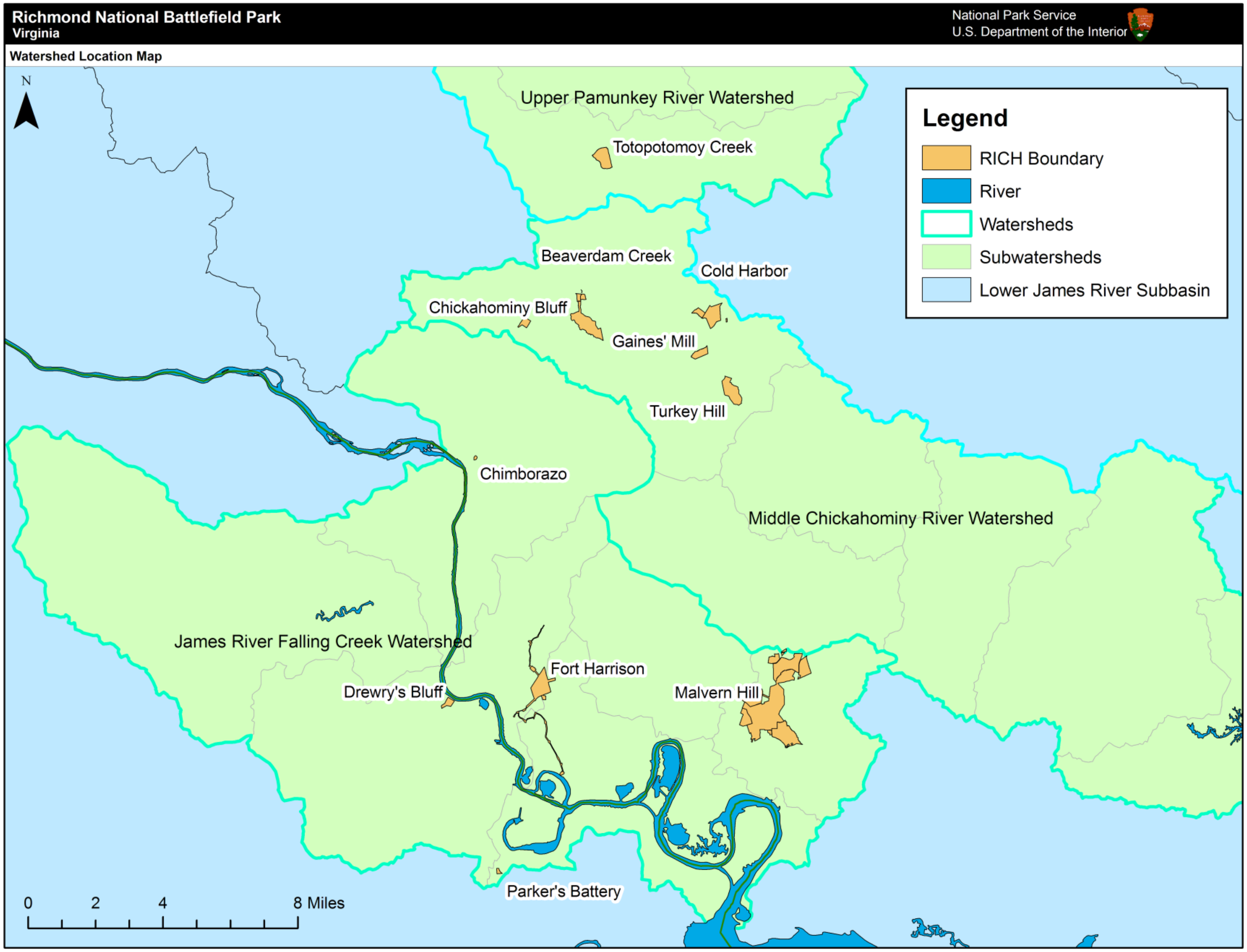

Figure 86. RICH units location in James River/Falling Creek, Middle Chickahominy River, and Upper Pamunkey River watersheds (RICH 2010c).

Table 38. Data sources used for measures of water quality for Richmond NBP.

Indicator	Measure	Data Source(s)
Hydrology	Flow	USGS (2009c)
Stream Condition	Dissolved Oxygen	RICH data, USGS (2009c), VA DEQ (2008, 2009)
	pH	RICH data, USGS (2009c), VA DEQ (2008, 2009)
	Temperature	RICH data, USGS (2009c), VA DEQ (2008, 2009)
	Bacterial (Fecal Coliform)	USGS (2009c), VA DEQ (2008, 2009)
	Bacterial (*E. coli*)	USGS
	Conductivity	RICH data, USGS (2009c), VA DEQ (2008, 2009)
	Macroinvertebrates	RICH data

Table 39. Water quality monitoring stations in the Lower James River Subbasin (HUC 02080206).

Site	Agency	Latitude	Longitude	Datum
Beaver Dam Creek				
BDC1	NPS	37.59515	77.3589	NAD83
Chickahominy Bluff				
CB1	NPS	37.58353	77.3873	NAD83
CB2	NPS			
0204243350	USGS	37.58361	77.38806	NAD83
Cold Harbor				
CH1	NPS	37.59167	77.2823	NAD83
CH2	NPS	37.58912	77.2919	NAD83
0204243610	USGS	37.59167	77.2825	NAD27
0204243650	USGS	37.58925	77.29201	NAD83
Drewry's Bluff (Fort Darling)				
DB1	NPS	37.4222	77.4243	NAD83
DB2	NPS	37.42181	77.4238	NAD83
DB3	NPS	37.42054	77.4227	NAD83
DB4	NPS	37.42026	77.422	NAD83
DB5	NPS	37.42067	77.4211	NAD83
DB6	NPS	37.4213	77.4205	NAD83
0203853010	USGS	37.42222	77.42472	NAD27
0203853030	USGS	37.42139	77.42389	NAD27
0203853050	USGS	37.42028	77.42167	NAD27
Fort Harrison				
FH1	NPS	37.42314	-77.3771	NAD83
FH2	NPS	37.42877	-77.3754	NAD83
0203854210	USGS	37.42291	77.37695	NAD83
2-JMS096.22	DEQ	37.38972	77.36278	NAD83
2-FOM003.60	DEQ	37.38194	77.37694	NAD83
Gaines' Mill				
GM1	NPS	37.57729	77.289	NAD83
GM2	NPS	37.57259	77.2972	NAD83
0204243830	USGS	37.57276	77.29704	NAD83
0204243790	USGS	37.57722	77.28917	NAD27
Malvern Hill				
MH1	NPS	37.41991	77.2453	NAD83
MH2	NPS	37.43828	77.2423	NAD83
MH3	NPS	37.42213	77.2648	NAD83
MH4	NPS	37.4087	77.2559	NAD83
MH5	NPS	n/a	n/a	n/a
0203874250	USGS	37.43806	77.24389	NAD83
0203874275	USGS	37.41944	77.24528	NAD83
0203874770	USGS	37.42111	77.26306	NAD27
0203874785	USGS	37.40869	77.25595	NAD83
Turkey Hill				
2-CHK055.04	DEQ	37.55194	77.27139	NAD83

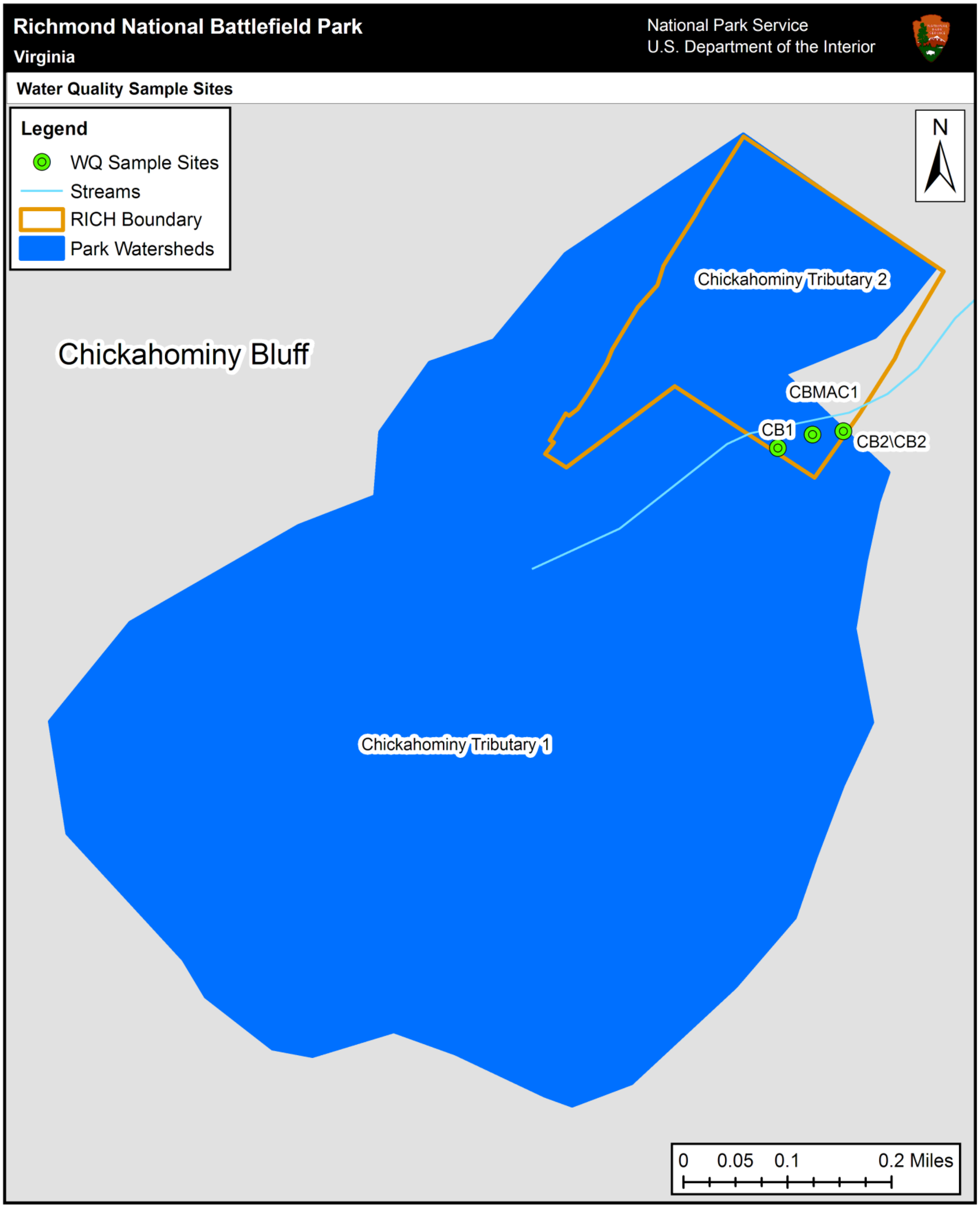

Figure 87. Location of water quality monitoring stations at Chickahominy Bluff (RICH 2010c).

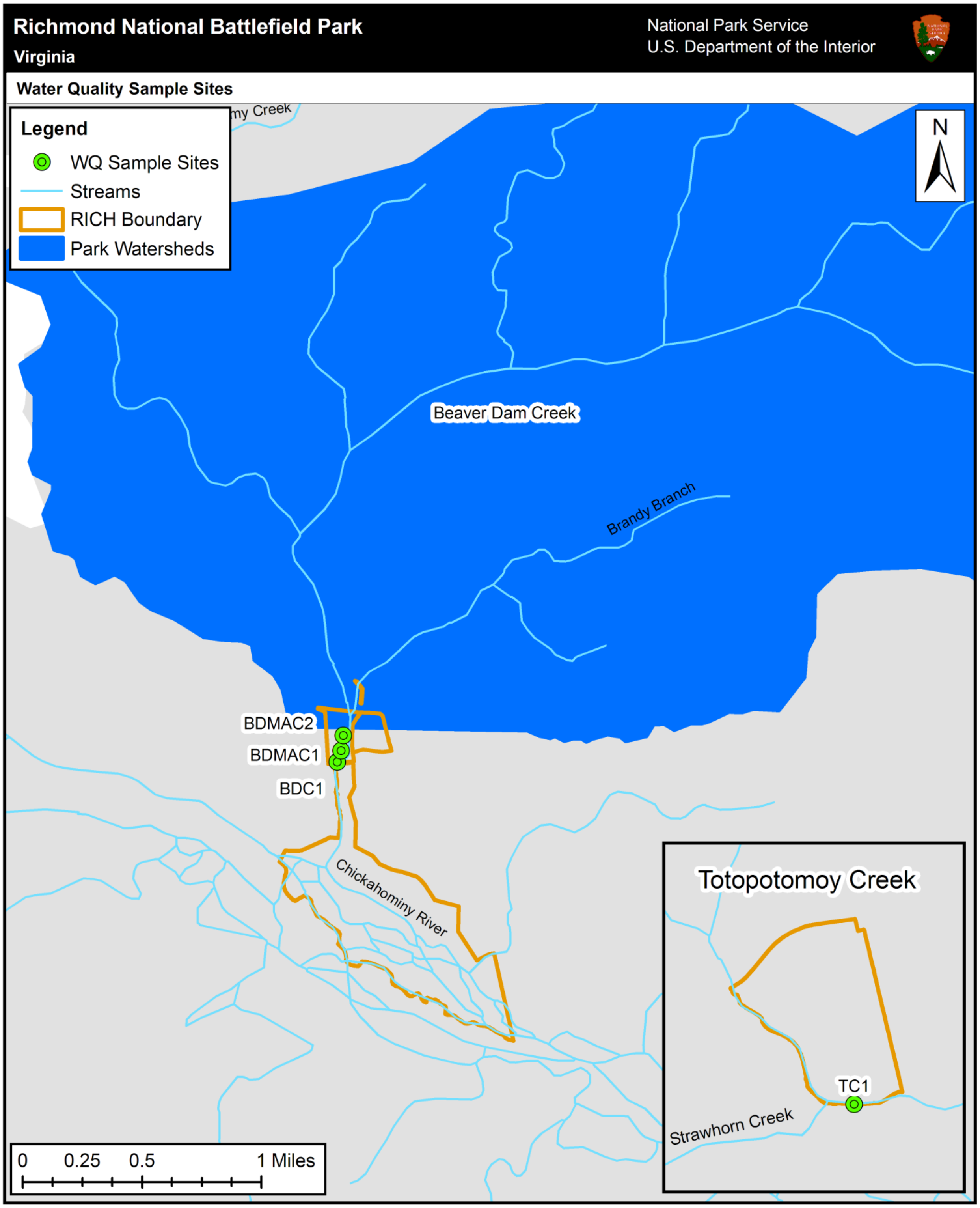

Figure 88. Location of water quality monitoring stations at Beaver Dam Creek and Totopotomoy Creek (RICH 2010c).

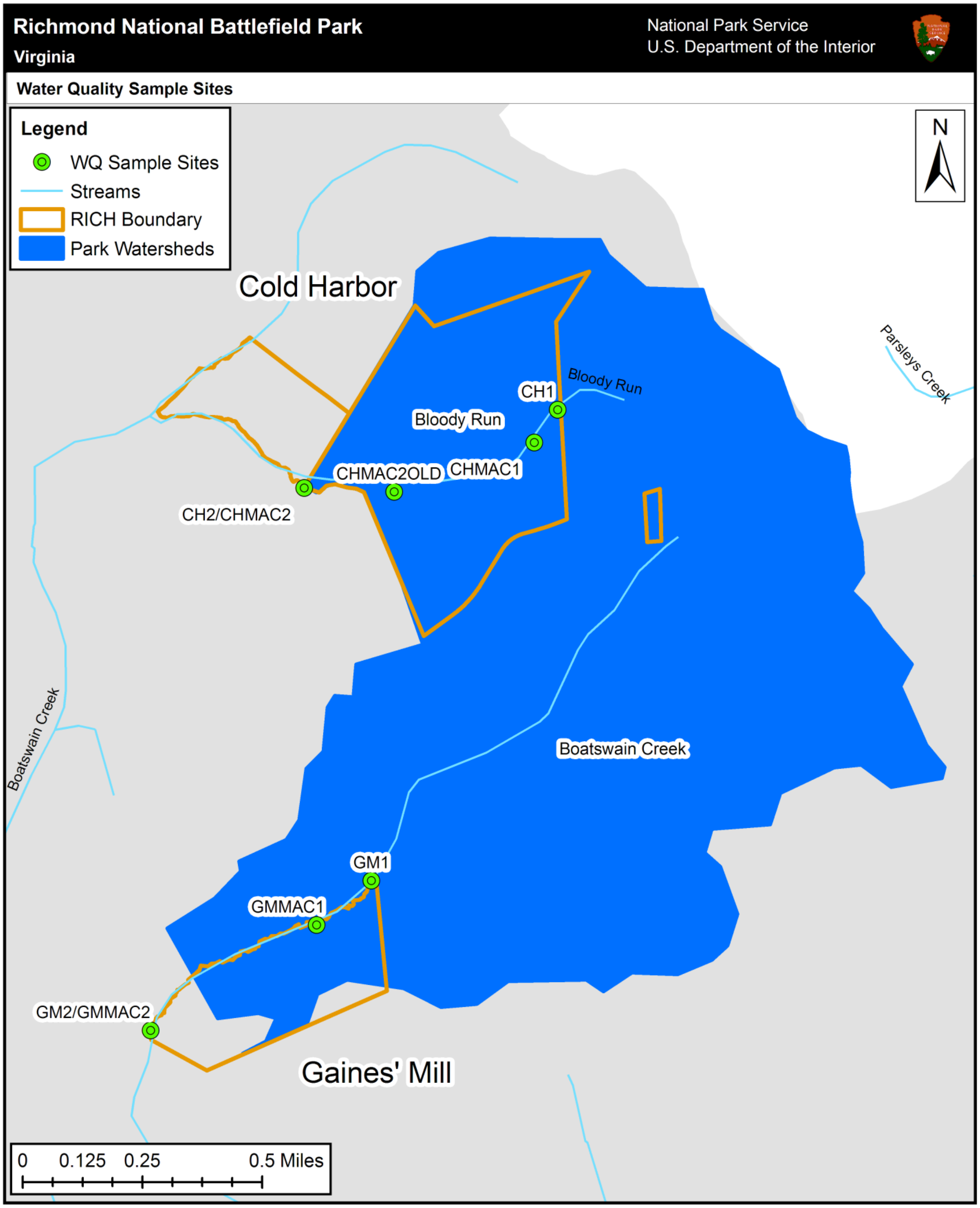

Figure 89. Location of water quality monitoring stations at Cold Harbor and Gaines' Mill (RICH 2010c).

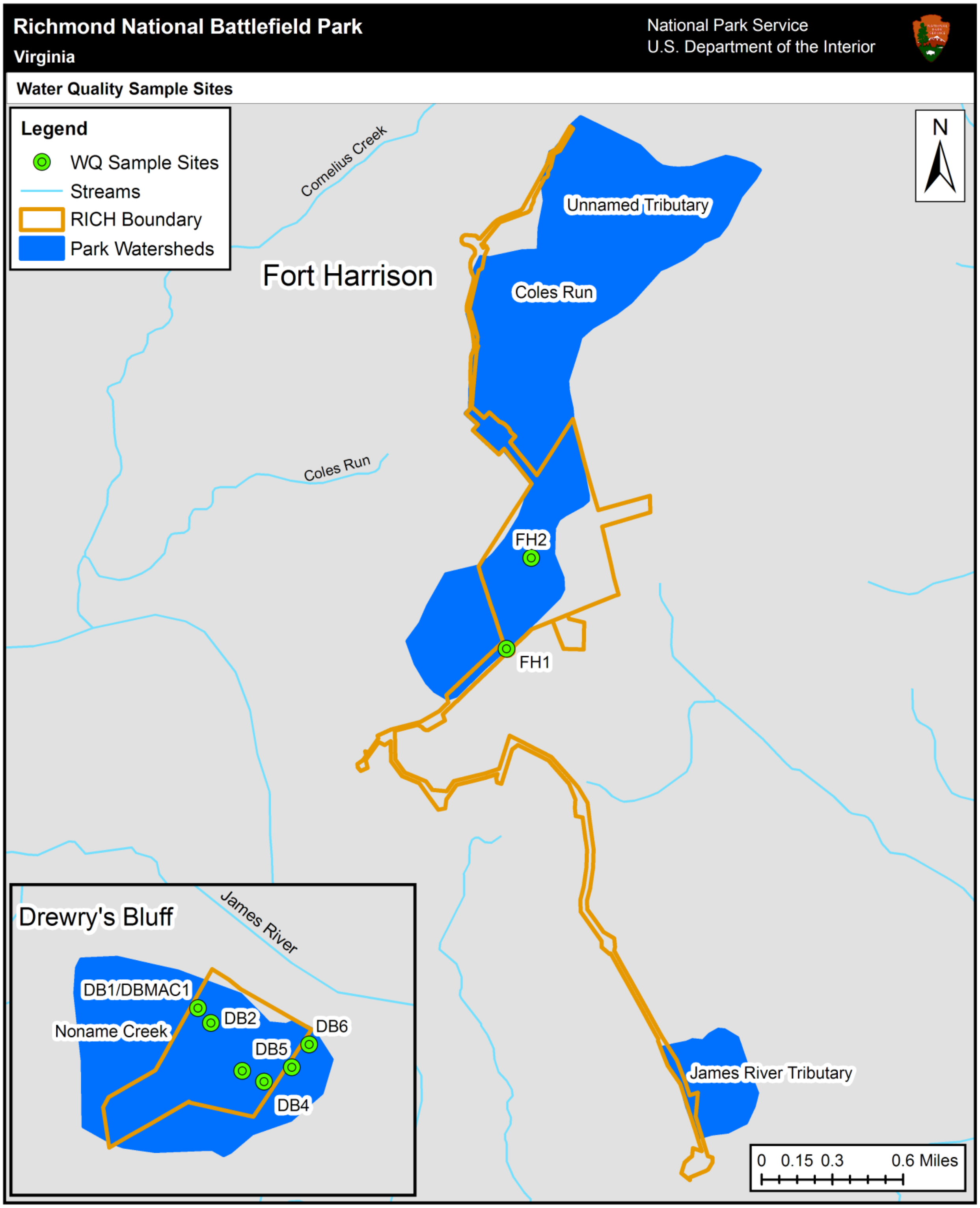

Figure 90. Location of water quality monitoring stations at Fort Harrison and Drewry's Bluff (RICH 2010c).

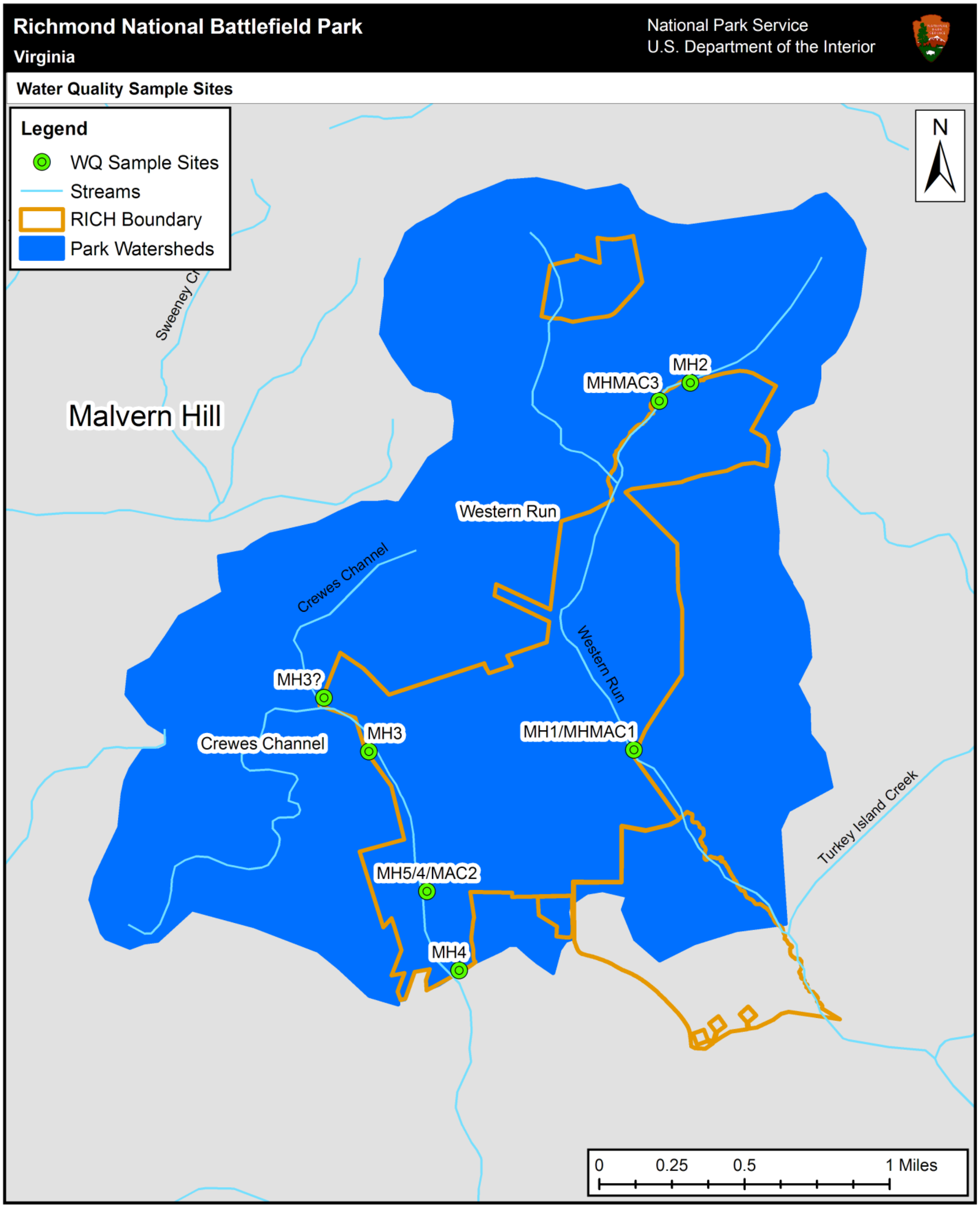

Figure 91. Location of water quality monitoring stations at Malvern Hill (RICH 2010c).

Dissolved Oxygen

Dissolved oxygen (DO) is a relative measure of volume of oxygen, O_2, dissolved in water, and is often measured in mg/l. It is considered relative because temperature, pressure, and salinity affect the capacity of water to hold oxygen. Both high (i.e. supersaturation) and low DO concentrations can be harmful in aquatic systems, though low DO concentrations are more common. Low DO concentrations may result from excess organic matter in aquatic systems, as aerobic (oxygen-consuming) decomposition breaks down organic material. Low DO levels are most prevalent during the warm summer months when water temperatures rise and mixing of the water column is reduced.

The addition of excess nutrients from allochthonous inputs (coming from outside the aquatic system) can greatly affect DO levels. Nutrients can increase the biological oxygen demand (BOD) and therefore lower DO concentrations in water. This process occurs because nutrients can stimulate the growth of algae and other aquatic plants, which eventually die. Once dead, this organic material is decomposed by oxygen-consuming processes, resulting in low DO. Nutrients often enter aquatic systems from agricultural runoff, storm water runoff, waste-water treatment plants, and septic systems (U.S. Environmental Protection Agency 2008e). According to the U.S. EPA, nutrient pollution, especially from nitrogen and phosphorus, has consistently ranked as one of the top causes of water degradation in the U.S. (U.S. EPA 2008d).

Virginia water quality standards list criteria for DO in surface water systems in the state based on the classification category of the water body. Standards for Class VI waters (natural trout waters) are the most restrictive allowing for a minimum level of 6.0 mg/L and daily average not below 7.0 mg/L. Richmond NBP is considered to be in Class III waters specified as Non-Tidal Waters and Piedmont Zones. The Virginia water quality standards state that Class III waters shall not fall below a minimum of 4.0 mg/L and a daily average not below 5.0 mg/L (Table 40). Several of the streams at Richmond NBP fall in the VII category.

Table 40. Dissolved oxygen water quality standards from 9 VAC 25-260 Virginia Water Quality Standards.

Class	Description of Class	Dissolved Oxygen (mg/L)	pH	Maximum Temperature (ºC)
I	Open Ocean	Minimum of 5.0	6.0 – 9.0	-
II	Tidal Waters	Minimum of 4.0, Daily Avg. 5.0	6.0 – 9.0	-
III	Non-Tidal Coastal Waters and Piedmont Zones	Minimum of 4.0, Daily Avg. 5.0	6.0 – 9.0	32
IV	Mountainous Zones Waters	Minimum of 4.0, Daily Avg. 5.0	6.0 – 9.0	31
V	Stockable Trout Waters	Minimum of 5.0, Daily Avg. 6.0	6.0 – 9.0	21
VI	Natural Trout Waters	Minimum of 6.0, Daily Avg. 7.0	6.0 – 9.0	20
VII	Swamp Waters	*	4.3 – 9.0	*

*This classification recognizes that the natural quality of these waters may fall outside of the ranges for DO and pH set forth above as water quality criteria; therefore, on a case-by-case basis, criteria for specific Class VII waters can be developed which reflect the natural quality of the waterbody. Virginia Pollutant Discharge Elimination System limitations in Class VII waters shall meet pH of 6.0 – 9.0.

Dissolved oxygen data was taken from 36 stations in the Lower James River Subbasin (HUC 02080206), with stations occurring in eight different park units. Of the 258 samples taken throughout the park units, 56 fell below the VA Standard of 4mg/L for a single sample minimum (21.7%). The percentages of dissolved oxygen samples above the VA state standards ranged from 69% (Fort Harrison) to 94% (Gaines' Mill) in individual park units. Overall, five of the park units received good ratings, and three received fair ratings (units with more than 75% of values passing the standard received good, and those between 50-75% received a fair rating).

Averages reported by the DEQ and USGS are not true daily averages but rather the average of all available data at each station since 2000. Data from the NPS was averaged by day, and then by station. Detailed information on dissolved oxygen in the subbasin is available in Table 41. Data quality scores varied by unit, Appendix A lists data quality scores for DO by unit.

Section 303(d) of the Clean Water Act requires Virginia (and all states) to submit a list of water bodies in the state that do not meet water quality standards. The Virginia DEQ develops and submits this report to the U.S. Environmental Protection Agency every even-numbered year. The Final 2008 305(b)/303(d) Water Quality Assessment Integrated Report (VADEQ 2008) lists 94 sections of a waterbodies in the Lower James River Subbasin (HUC 02080206) as impaired due to low DO levels, more than any other cause of impairment.

pH

pH measures the relative amount of free hydrogen and hydroxyl ions in a solution, determining how acidic or basic (alkaline) a solution is. The pH values are expressed from 0-14, lower values being more acidic (more free hydrogen ions), higher values more alkaline (more free hydroxyl ions). A pH of 7 is considered neutral. pH is measured on a logarithmic scale, every unit represents a tenfold change. For example, a pH of 4 is ten times more acidic than a pH of 5, and one-hundred times more acidic than a pH of 6. Most aquatic organisms prefer a pH between 6.5-8, a pH outside this range can stress the physiological systems of organisms and reduce reproduction (U.S. Environmental Protection Agency 2006). The solubility of heavy metals and biological availability of nutrients is also affected by different pH levels. In the lower pH range heavy metals tend to be more soluble, increasing their toxicity. pH can also change the form of phosphorus and its availability to aquatic organisms.

Virginia water quality standards list acceptable pH levels as 6.0-9.0 for all classes except for swamp waters where natural levels may be more acidic. Section 9 VAC 25-260-50 of the 2008 Virginia Water Quality Standards lists the pH numeric criteria for all waters other than swamp waters as 6.0-9.0. Of the 274 observations available inside and in close proximity to park units, 115 fell outside the acceptable range of 6.0-9.0 (41.9%). The pH values throughout the park units varied significantly, ranging from 3.8 to 8.5. Overall, waters tended to be acidic, with only one station averaging values over a neutral pH of 7. All observations falling outside of the target range fell below a pH of 6.0. In individual park units, percentages of pH reading falling in the acceptable range of 6.0-9.0 varied from 24% (Cold Harbor) to 100% (Turkey Hill). Refer to Table 42 for details. Data quality scores varied by unit, Appendix A lists those quality scores for pH by unit.

Table 41. Dissolved Oxygen values for the James River Subbasin from 2000-2009. Data represent all stations available within and close proximity to park units.

Site	Observations	# Under Standard	Maximum (mg/L)	Mean (mg/L)	Minimum (mg/L)	Date Range (mo/yr)
Beaver Dam Creek (83% acceptable values)						
BDC1	12	2	15.6	7.89	1.6	12/01-03/09
Chickahominy Bluff (90% acceptable values)						
CB1	12	1	21.1	9.86	3	12/01-03/09
CB2	5	1	12.6	7.75	3.9	12/02-11/07
0204243350	4	0	10.6	9.1	7.4	08/01-04/02
Cold Harbor (73% acceptable values)						
CH1	8	4	6.5	3.9	1.4	12/01-11/07
CH2	11	1	21.5	8.2	1.7	07/02-03/09
0204243610	5	3	4.5	3.3	0.8	08/01-08/09
0204243650	6	0	10.3	7.5	5.6	08/01-08/09
Drewry's Bluff (Fort Darling) (70% acceptable values)						
DB1	10	3	11.5	6.9	0.4	12/01-03/09
DB2	9	1	10.3	7.6	2.7	12/01-03/09
DB3	7	2	10.9	7.1	2.6	12/01-02/06
DB4	7	4	10.3	5	1.7	12/01-02/06
DB5	7	2	21.3	8.8	3.4	12/01-02/06
DB6	8	2	14.23	7.6	3.3	12/01-02/06
0203853010	4	2	10.2	5.3	0.3	08/01-04/02
0203853030	4	2	8.6	4.85	0.3	08/01-04/02
0203853050	4	0	7.9	6.5	4	08/01-04/02
Fort Harrison (69% acceptable values)						
FH1	8	4	7.2	4.7	1.4	12/01-11/07
FH2	5	3	7.2	3.6	0.6	12/02-11/04
0203854210	4	4	0.9	0.5	0.3	08/01-04/02
2-JMS096.22	11	0	9.9	8.3	6.3	05/00-10/00
2-FOM003.60	8	0	12.8	9.5	6.6	01/00-03/01
Gaines' Mill (94% acceptable values)						
GM1	11	1	11.9	8.3	2.8	12/01-03/09
GM2	9	1	19.8	7.9	1.9	07/02-11/07
0204243830	6	0	11.4	6.8	4	08/01-08/09
0204243790	6	0	11.6	9	7.6	08/01-08/09
Malvern Hill (79% acceptable values)						
MH1	11	2	10.2	7.3	0.1	12/01-3/09
MH2	7	3	7.29	4.5	0.7	12/02-11/07
MH3	8	3	13.1	5.6	1.6	12/01-11/07
MH4	5	0	8.4	7.5	4.4	07/02-11/07
MH5	2	0	7.8	7.5	7.1	01/04-03/04
0203874250	5	1	9.3	6.6	3.6	08/01-08/09
0203874275	6	0	11.6	8	6.4	08/01-08/09
0203874770	4	1	10.5	6.3	2.2	08/01-04/02
0203874785	4	1	8.6	6.5	3.3	08/01-04/02
Turkey Hill (87% acceptable values)						
2-CHK055.04	15	2	12.6	7.7	2.7	01/00-04/01

Table 42. pH values for the James River Subbasin from 2000-2009. Data represents all water quality monitoring stations within five miles of park units with available data.

Station	Observations	# outside Standard	Maximum	Median	Minimum	Date Range (mo/yr)
Beaver Dam Creek (93% acceptable values)						
BDC1	14	1	8.54	6.56	5.48	12/01-11/09
Chickahominy Bluff (83% acceptable values)						
CB1	14	2	8.24	6.43	4.65	12/01-11/09
CB2	6	1	8.5	6.24	5.44	12/02-07/09
204243350	4	1	6.5	6.15	5.8	08/01-04/02
Cold Harbor						
CH1	9	n/a	8.56	6.18	3.81	12/01-07/09
CH2	13	n/a	8.03	5.73	4.78	07/02-12/09
204243610	6	n/a	5.9	5.7	4.8	08/01-08/09
204243650	6	n/a	5.9	5.35	4.7	08/01-08/09
Drewry's Bluff (Fort Darling) (55% acceptable values)						
DB1	12	6	8.28	5.99	4.76	12/01-12/09
DB2	10	4	8.19	6.17	4.49	12/01-03/09
DB3	7	4	8.18	5.95	4.63	12/01-02/06
DB4	7	4	8.13	5.98	4.69	12/01-02/06
DB5	7	3	7.9	6.32	4.53	12/01-02/06
DB6	8	3	7.27	6.43	4.52	12/01-02/06
203853010	4	2	9	5.9	5.5	08/01-04/02
203853030	4	2	6.5	5.95	5.8	08/01-04/02
203853050	4	0	6.6	6.2	6.1	08/01-04/02
Fort Harrison (51% acceptable values)						
FH1	8	6	8.29	5.29	4.34	12/01-11/07
FH2	5	4	8.18	4.72	4.16	12/02-11/04
203854210	4	4	5.3	4.75	4.5	08/01-04/02
2-JMS096.22	12	0	8.3	7.6	7.2	05/00-10/00
2-FOM003.60	8	4	6.6	5.8	5.4	01/00-03/01
Gaines' Mill (50% acceptable values)						
GM1	11	6	8.19	5.88	4.56	12/01-03/09
GM2	9	5	7.99	5.96	3.76	07/02-11/07
204243830	6	3	6.3	6	5.3	08/01-08/09
204243790	6	2	6.8	6.25	5.4	08/01-08/09
Malvern Hill (60% acceptable values)						
MH1	13	2	7.23	6.36	5.52	12/01-12/09
MH2	7	5	6.84	5.8	3.27	12/02-11/07
MH3	8	4	6.99	6.15	3.25	12/01-11/07
MH4	5	1	7.09	6.76	3.16	07/02-11/07
MH5	2	0	6.91	6.73	6.54	01/04-03/04
203874250	6	1	6.6	6.15	5.3	08/01-08/09
203874275	6	2	6.7	6.4	5.5	08/01-08/09
203874770	4	4	5.7	5.15	4.9	08/01-04/02
203874785	4	3	6.5	5.8	5.6	08/01-04/02
Turkey Hill (100% acceptable values)						
2-CHK055.04	15	0	6.9	6.6	6	01/00-04/01

Units with ≤ 50% passing the standard were considered poor, 50-75% as fair, and > 75% as good. Since a large percentage of the values fell below a pH of 6.0, two of the eight park units received a poor rating (Cold Harbor and Gaines' Mill). Of the remaining units, three were rated as fair (Drewry's Bluff, Fort Harrison, and Malvern Hill) and three as good (Beaver Dam Creek, Chickahominy Bluff, and Turkey Hill).

Temperature

All aquatic organisms have optimal temperature ranges in which to live. An organism outside its optimal temperature range can become stressed or die. Biological and chemical processes are also temperature dependant. DO and conductivity are directly affected by temperature change (colder water can hold more DO and is less conductive). Concrete, buildings, and paved surfaces pose barriers to rainwater stopping it from entering the soil below. In addition to collecting wastes, the water draining off hot pavement (particularly in the summer) has a higher temperature than water entering a stream through groundwater.

Virginia water quality standards list criteria for temperature in surface water systems in the state based on the classification category of the water body. Standards for Class IV are the most restrictive allowing for a maximum of 20ºC for natural trout waters since trout are very sensitive to warm waters. Richmond NBP lies in the Non-tidal Coastal Waters and Piedmont Zone (Class III Waters) where the standard is a maximum of 32ºC (Table 40). The standards also specify that any rise above natural temperatures shall not exceed 3ºC (standards for hourly temperature change for natural trout waters are more restrictive).

The temperature of Non-tidal Coastal and Piedmont Zone waters shall not exceed 32ºC due to effluents according to Section 9 VAC 25-260-50 of the 2008 Virginia Water Quality Standards. Of the 261 temperatures taken from all 36 stations throughout Richmond NBP, none exceeded the standard of 32ºC. The maximum temperature recorded was 31.24ºC (at Malvern Hill) on 7/8/2002, and the minimum was 1.4 (at Turkey Hill) on 2/3/2000. The temperature data available over the last ten years is summarized in Table 43.

The maximum temperatures in Table 43 only represent the highest temperatures from available data. More consistent data during the summer months would likely show higher values. Although they may not represent the highest temperatures in this date range, it is the best data available. From this data, the temperature was rated as good in the eight park units with data available because all values fell below the state standard of 32ºC. Data quality scores varied by unit, Appendix A lists data quality scores for temperature by unit.

Table 43. Temperature values for the James River Subbasin from 2000-2009. Data represents all water quality monitoring stations within five miles of park units with available data.

Station	Observations	# over Standard	Maximum Temperature (ºC)	Date	Minimum Temperature (ºC)	Date
Beaver Dam Creek (100% acceptable values)						
BDC1	12	0	24.9	08/11/2003	5.01	12/18/2002
Chickahominy Bluff (100% acceptable values)						
CB1	13	0	27.96	07/03/2002	3.79	12/03/2008
CB2	6	0	22.05	08/13/2003	5.84	12/18/2002
204243350	4	0	25.4	08/20/2001	8.9	01/25/2002
Cold Harbor (100% acceptable values)						
CH1	8	0	23.95	08/11/2003	8.41	12/17/2002
CH2	11	0	23.03	07/03/2002	5.42	12/17/2002
204243610	6	0	24.1	08/11/2009	8	01/22/2002
204243650	6	0	22.9	08/11/2009	5.4	01/22/2002
Drewry's Bluff (Fort Darling) (100% acceptable values)						
DB1	11	0	20.74	07/08/2002	6.28	12/18/2002
DB2	9	0	22.52	08/13/2003	5.26	12/18/2002
DB3	6	0	19.39	08/13/2003	7.17	12/18/2002
DB4	7	0	20.89	07/08/2002	8.35	12/18/2002
DB5	7	0	20.38	08/13/2003	8.06	12/18/2002
DB6	8	0	20.87	08/13/2003	6.36	12/19/2002
203853010	4	0	21.2	08/23/2001	10.9	01/31/2002
203853030	4	0	21.1	08/23/2001	11.7	01/31/2002
203853050	4	0	20.9	08/23/2001	12.3	01/31/2002
Fort Harrison (100% acceptable values)						
FH1	7	0	30.61	07/03/2002	6.74	11/29/2007
FH2	4	0	22.54	08/13/2003	6.04	12/19/2002
203854210	4	0	22.7	08/22/2001	9.4	01/22/2002
2-JMS096.22	12	0	31	08/07/2000	18.4	05/01/2000
2-FOM003.60	8	0	23.8	07/19/2000	2.9	01/24/2001
Gaines' Mill (100% acceptable values)						
GM1	11	0	23.03	08/11/2003	4.04	12/03/2008
GM2	8	0	27.45	07/03/2002	4.8	12/17/2002
204243830	6	0	26	08/11/2009	5.2	01/23/2002
204243790	6	0	25.9	08/11/2009	5.7	01/23/2002
Malvern Hill (100% acceptable values)						
MH1	13	0	23.09	08/12/2003	4.52	11/30/2007
MH2	6	0	21.9	08/12/2003	5.32	01/07/2004
MH3	8	0	26.59	08/12/2003	3.15	01/07/2004
MH4	5	0	31.24	07/08/2002	5.21	01/07/2004
MH5	2	0	13.03	03/09/2004	5.11	01/07/2004
203874250	6	0	19.3	08/11/2009	8.8	01/18/2002
203874275	6	0	23.3	08/13/2009	3.2	01/16/2002
203874770	4	0	22.1	08/24/2001	6.2	01/17/2002
203874785	4	0	25.8	08/24/2001	5.7	01/17/2002
Turkey Hill (100% acceptable values)						
2-CHK055.04	15	0	27.8	08/08/2000	1.43	02/03/2000

Bacterial Contamination (Fecal Coliform: E. Coli and Enterococci)

Fecal coliform bacteria (which includes both *E. coli* and enterococci) contamination is the most common form of bacterial contamination in many water bodies. Its presence in aquatic environments is a human health hazard and may indicate the presence of other dangerous pathogens as well. Fecal coliform bacteria often enter waterways through the direct discharge of untreated (or insufficiently treated) human waste and agricultural and municipal runoff.

There are two basic methods for testing water for bacteria: the membrane filter method and multiple-tube fermentation method. The membrane filter method involves filtering samples through various pore sizes, followed by the incubation of the filtered material on a nutrient medium. The number of bacterial colonies are counted and stored as CFUs (colony forming units). The multiple tube fermentation method uses a specified amount of the sample, and a nutrient broth, and is then incubated. The amount of gas or turbidity in the water is used to determine the most-probable-number (MPN) of the bacteria.

In 1986, the EPA published Ambient Water Quality Criteria for Bacteria-1986 (U.S. Environmental Protection Agency 1986). Before the publication of this document, EPA recommended the use of fecal coliform as an indicator organism to protect people from gastrointestinal illness in recreational waters and recommended numeric criteria for fecal coliform upon which many state standards (including Virginia) were based. However, in EPA epidemiological studies, *E. coli* and enterococci were found to exhibit the strongest correlation to swimming-associated gastroenteritis. *E. coli* were related to swimming-associated gastroenteritis in freshwaters only and enterococci in both fresh and marine waters. EPA subsequently recommended the use of *E. coli* or enterococci for fresh recreational waters and enterococci for marine recreational waters because levels of enterococci more accurately predict acute gastrointestinal illness than levels of fecal coliforms. Fecal coliforms as a group were determined to be a poor indicator of the risk of digestive system illness. However, many states continue to use fecal coliforms as their primary health risk indicator. In states where water quality standards are still based on fecal coliforms as the indicator bacteria for human health, monitoring fecal coliforms are the best way to insure compliance with state water quality standards. However, to better determine the health risk from recreational water contact, results of EPA studies suggest considering switching to the *E. coli* or enterococci method for testing freshwater.

Virginia has state restrictions for *E. coli* and enterococci, but continues to regulate total fecal coliforms. Table 44 provides standards for *E. coli* and enterococci concentrations based on 9 VAC 25-260-170 Virginia Water Quality Standards. The Virginia Water Quality Standards state that "fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month, nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water."

Table 44. Maximum fecal coliform, E. coli, and enterococci bacteria standards per 100 ml of water from 9 VAC 25-260 Virginia Water Quality Standards.

Bacteria Type	Geometric Mean[1]	Single Sample Maximum[2]	Other Criteria
Fecal coliform	200	--	Not more than 10% of the total samples taken during any calendar month to exceed 400 fecal coliform bacteria
Freshwater[2] E. coli	126	235	--
Saltwater and Transition Zone[3] enterococci	35	104	--

[1] For two or more samples taken during any calendar month.
[2] No single sample maximum for enterococci and *E. coli* shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.
The EPA suggests switching from monitoring fecal coliforms to the *E. coli* or enterococci method for testing fresh water. Although there are standards for *E. coli* in Virginia, *E. coli* data are not reported as frequently as fecal coliform. For these reasons, both fecal coliform and *E. coli* have been included in this discussion. No data on bacterial contamination was available from the NPS, all data summarized in this section was collected online from the Virginia DEQ and the USGS.

E. coli

Althought no DEQ stations had E. coli records available, USGS collected limited data in August, 2009 in order to begin characterizing bacterial impairments in several park streams. Samples were taken at three park streams at the point where each stream enters and exits the park. The standard states that the geometric mean of two or more values from the same calendar month shall not exceed 126/100mL. The two records in each of the six stations were both taken in August of 2009, and the geometric mean was compared to the standard of 126/100mL. Otherwise values would be compared to the single sample maximum of 235/100mL. Only three park units had any data available regarding *E. coli* (Cold Harbor, Gaines' Mill, and Malvern Hill). Of these, only Malvern Hill received a good rating since both stations geometric mean fell below the state standard. Cold Harbor and Gaines' Mill received a poor rating because at least 50 percent of the stations at each unit exceeded the standard. More detailed information on the *E. coli* data can be found in Table 45. Data quality scores varied by unit, Appendix A lists data quality scores for bacterial contamination by unit. Sample points generally were temporally and spatially acceptable; however more data is necessary to accurately assess the condition of the park units.

It is difficult to make conclusions on *E. coli* in the watershed with these few observations alone. The VA 303(d) lists 49 waterbodies as impaired due wholly or in part to *E. coli* levels. It is the second highest cause of impairment in the Lower James River Subbasin, behind dissolved oxygen. According to the list of impaired waters in the VA 303(d), *E. coli* has been detected in Beaver Dam Creek, Boatswain Creek, Chickahominy River, Crewe's Channel, James River, and Western Run. Since *E. coli* has been shown to be a problem elsewhere in the subbasin it should be monitored more closely. It should be noted that these guidelines are based on human health impacts, not necessarily ecological impacts.

Table 45. *E. Coli* values for the James River Subbasin from 2000-2009. Data represents all water quality monitoring stations within five miles of park units with available data.

Station	Observations	Pass/Fail	Max	Geometric Mean	Min	Dates
Cold Harbor (50% acceptable values)						
204243610	2	Fail	400	368.8	340	8/11/09-8/13/09
204243650	2	Pass	130	105.1	85	8/11/09-8/13/09
Gaines' Mill (0% acceptable values)						
204243830	2	Fail	2100	1279.8	780	8/11/09-8/13/09
204243790	2	Fail	320	277.1	240	8/11/09-8/13/09
Malvern Hill (100% acceptable values)						
203874250	2	Pass	64	58.8	54	8/11/09-8/13/09
203874275	2	Pass	130	119.6	110	8/11/09-8/13/09

Fecal coliform

Fecal coliform bacteria are still widely used as an indicator of human health risk in surface waters. The Virginia water quality standard for fecal coliform states "Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water." Sufficient data is not available to compare the geometric means to the state standards within the same month. Since detailed data were not available, the standard limiting 10% of monthly samples to 400 CFU's/ 100mL was used. We reported fecal coliforms as months in which 10% of the samples pass or fail the standard of 400/ 100mL. Since no stations had more than three replicates per month; any value exceeding 400 fecal coliform bacteria /100mL would result in that month failing.

Based on all available data since 2000 either in or in close proximity to park, 9 of 76 months were in excess of the standard. Seven of the park units had information available through DEQ and USGS. Six of the park units received a good rating since over 75% of months fell below the standard. One station (Chickahominy Bluff) received a fair rating since 50-75% of months exceeded the standard. Detailed results on fecal coliform can be found in Table 46. Data quality scores varied by unit, Appendix A lists data quality scores for fecal coliform by unit. If more detailed data were available the geometric mean would have been compared to the 200 fecal coliform/100mL standard. The data were acceptable both temporally and spatially.

Although fecal coliform received a good rating in most units, bacterial contamination may still be a problem at the watershed level. Because of the specificity of the standard a less restrictive measure was used (400 fecal coliform/100mL instead of 200 fecal coliform/100mL). Although the majority of waters in this report were assessed as good, they may not pass the more restrictive standard limiting a monthly geometric mean of 200 fecal coliform/100mL. If data were sampled more often, this standard could be applied and the waters could be assessed accurately. Additional information on fecal coliform in the Lower James River Subbasin can be found in the Virginia 303(d) listing. It cites 17 waterbodies in the subbasin as having sections impaired due wholly or in part to fecal coliform levels.

Table 46. Fecal Coliform values for the James River Subbasin from 2000-2009. Data represents all water quality monitoring stations within five miles of park units with available data.

Station	Station	Observations (months)	# Exceeding Standard	Maximum #/100mL	Mean #/100mL	Minimum #/100mL
Chickahominy Bluff (75% acceptable values)						
204243350	204243350	4	1	680	341.8	67
Cold Harbor (88% acceptable values)						
204243610	204243610	4	0	95	45.5	10
204243650	204243650	4	1	570	286.8	87
Drewry's Bluff (Fort Darling) (92% acceptable values)						
203853010	203853010	4	1	950	303	28
203853030	203853030	4	0	330	92.5	3
203853050	203853050	4	0	400	117.75	3
Fort Harrison (88% acceptable values)						
203854210	203854210	4	1	510	143.8	5
2-JMS096.22	2-JMS096.22	6	1	2400	246.8	0
2-FOM003.60	2-FOM003.60	7	0	300	137.5	100
Gaines' Mill (88% acceptable values)						
204243830	204243830	4	1	1200	404.8	29
204243790	204243790	4	0	200	79.8	10
Malvern Hill (73% acceptable values)						
203874250	203874250	4	0	160	54.3	8
203874275	203874275	3	2	740	496.7	340
203874770	203874770	4	1	700	202	29
203874785	203874785	4	0	190	112.3	39
Turkey Hill (100% acceptable values)						
2-CHK055.04	2-CHK055.04	12	0	300	123.1	100

Conductivity

Electrical conductivity is a measure of water's ability to carry an electric current and is dependent on the amount of inorganic dissolved solids in the water. Distilled water has a very low specific conductance, while salt water has a high specific conductance. The conductivity provides a good estimate of dissolved metals or other substances in water. Conductivity in streams and rivers is greatly influenced by the geology of the area. A few examples of materials that can increase conductivity when dissolved in water are chloride, nitrate, sulfate and phosphate anions, or sodium, magnesium, calcium, iron and aluminum cations. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm), both are equivalent. It is affected by temperature change, with warmer water having a higher conductivity. For this reason, specific conductance is usually presented at 25ºC for consistency (USEPA 2006).

There are no state standards for conductivity, possibly due to its high variability depending on substrate. However, it is still important to monitor as an indicator of the measure of dissolved solids. Abrupt changes in conductivity may indicate that water or wastes are being diverted into the stream from a new source. Effluents and pollution can raise the conductivity of a water body. However, oil and other organic compounds do not conduct electrical current very well, and so may lower the conductivity of the water. Low-conductivity values may also indicate that the water in a stream is subject to relatively high precipitation and run-off inputs in relation to the volume of flow from groundwater inputs, and so may also be subject to more dynamic flow and temperature fluctuations. Conductivity can also indicate the degree to which a watershed's bedrock and mineral soil resists erosion. The conductivity of rivers in the United States generally range from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can range as high as 10,000 µmhos/cm (USEPA 2006).

Although these standards are useful as a reference, we will not give conductivity a rating because of its high variability. Data given is intended to be used as reference for future values. Higher conductivity readings in the future represent higher dissolved solids, which may indicate more pollutants. Conductivity values were available at all data stations listed in Table 39, and although there are no state standards in which to rate them, they are a useful way to monitor dissolved solids in waterbodies. Conductivity values throughout the park ranged significantly from 3-3900 µmhos/cm, both occurring in stations in at Drewry's Bluff.

The EPA states that: "streams supporting good mixed fisheries have a range between 150 and 500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates" (USEPA 2006). Available conductivity data from Richmond NBP seem low compared to the level recommended by the EPA, but without baseline data to determine the "natural level" of conductivity in the system, the current condition cannot be assessed; however, generally low conductivity is indicative of good quality water.

The averages for individual park units usually fell below the recommended level, but low values of conductivity simply indicate low dissolved solids. It could reflect characteristics of the substrate, or the source of water. It may indicate the stream is more "precipitation dominated," because low-conductivity streams typically have less groundwater input than high-conductivity streams (Dartmouth 2009). Due to a lack of state standards conductivity was not rated, values in Table 47 are intended to be used as reference values only. Data quality scores varied by unit, Appendix A lists data quality scores for conductivity by unit.

Macroinvertebrates

Benthic (stream-bottom dwelling) macroinvertebrate assemblages reflect a broad range of trophic levels, life cycles, and conditional tolerances and so provide valuable information for interpreting cumulative land use effects and are also well-suited for assessing site-specific impacts. Macroinvertebrate sampling is an efficient and relatively inexpensive method that is widely accepted as a means to monitor ecosystem health. Data collected can be an important component of any habitat monitoring program, identify potentially vulnerable habitat, provide a mechanism for tracking land use impact changes over time, and facilitate compliance with legal mandates including the Clean Water Act.

Macroinvertebrate assemblages are a valuable indicator of stream health at Richmond NBP. The National Park Service provided information detailing macroinvertebrate assemblages of streams at Beaver Dam Creek, Chickahominy Bluff, Cold Harbor, Drewry's Bluff, and Malvern Hill. The macroinvertebrate data used was evaluated using the Coastal Plain Macroinvertebrate Index (CPMI). The index rates macroinvertebrate diversity from poor to excellent based on a scale from 0-30. Table 48 outlines the scores for CPMI.

Macroinvertebrates were sampled by the park, using the EPA Rapid Bioassessment Protocol (Multihabitat Approach) from 2003 to 2009 at ten different sites at Richmond NBP. Since many sites were missing several years of sampling, only stations with at least four years of data, and corresponding water quality data were selected. Due to staffing limitations, the park samples half of the sites in the spring and the remaining half the following fall. Although, these two sampling times straddle two calendar years, they were combined into one year in Table 49 for simplicity. For example, 2003 includes fall 2003 data and spring 2004 data.

The index used to evaluate macroinvertebrates was the Coastal Plain Macroinvertebrate Index (CPMI). Scoring for CPMI ranges from 0 to 30 (poor (< 6), fair (6-10), good (12-20), and excellent (22-30). These values are derived from the diversity of macroinvertebrates sampled, outlined in Table 49. CPMI scores ranged from 2 to 24 at Richmond NBP. The stations with the highest and lowest CPMI scores were GM1 and DB2 respectively. Of the seven stations, five had increasing CMPI scores from the first year of sampling to the last, one stayed the same, and one decreased. Detailed results can be seen in Table 49. Based on 2009 scores, two stations received an excellent rating (GM1, BD1), two stations received good ratings, two fair ratings, and one a poor rating (DB2). For this report, individual units were rated based on their most current CPMI scores (2009). In the case of Drewry's Bluff, the 2009 scores from the two stations were averaged and compared to the standards.

The macroinvertebrate levels inside the park are not optimal, but an increasing trend may indicate improving water quality. Continued monitoring at these stations will provide valuable information on the overall health of the streams. Data quality scores varied by unit, Appendix A lists data quality scores for macroinvertebrates by unit.

Table 47. Conductivity values for the James River Subbasin from 2000-2009. Data represents all water quality monitoring stations within five miles of park units with available data.

Station	Observations	Maximum µmhos/cm	Mean µmhos/cm	Minimum µmhos/cm	Date Range
Beaver Dam Creek					
BDC1	14	139.7	102.6	71.5	12/01-11/09
Chickahominy Bluff					
CB1	14	272.2	167.9	71.3	12/01-11/09
CB2	6	243	137.4	48.3	12/02-07/09
204243350	4	172	141.5	117	08/01-04/02
Cold Harbor					
CH1	9	144.6	83.3	40.1	12/01-07/09
CH2	13	72	54.1	42	07/02-12/09
204243610	6	73	48	32	08/01-08/09
204243650	6	70	59	44	08/010-8/09
Drewry's Bluff (Fort Darling)					
DB1	12	854.2	224.5	51	12/01-12/09
DB2	10	838	264	82	12/01-03/09
DB3	7	912.3	478	261.4	12/01-02/06
DB4	7	1077.6	437.2	3	12/01-02/06
DB5	7	491.4	312	4	12/01-02/06
DB6	8	355.9	286.6	70.3	12/01-02/06
203853010	4	3900	1183.8	124	08/01-04/02
203853030	4	830	730.8	645	08/01-04/02
203853050	4	476	443	403	08/01-04/02
Fort Harrison					
FH1	8	58.3	38	30	12/01-11/07
FH2	5	60.1	42.1	21.1	12/02-11/04
203854210	4	56	45.8	35	08/01-04/02
2-JMS096.22	11	288	222.3	149	05/00-10/00
2-FOM003.60	8	72	63.5	57	01/00-03/02
Gaines' Mill					
GM1	11	70.6	53.3	42	12/01-03/09
GM2	9	87	63.9	48	07/02-11/07
204243830	6	67	58.5	50	08/01-08/09
204243790	6	66	58.2	52	08/01-08/09
Malvern Hill					
MH1	13	124.9	72.3	39.8	12/01-12/09
MH2	7	114.2	79.1	56.7	12/02-11/07
MH3	8	116.3	55.4	15	12/01-11/07
MH4	5	146.6	85	42.9	07/02-11/07
MH5	2	68	61.7	55.4	01/04-03/04
203874250	5	96	71	58	08/01-08/09
203874275	6	70	59.8	36	08/01-08/09
203874770	4	80	67.8	52	08/01-04/02
203874785	4	149	126.8	94	08/01-04/02
Turkey Hill					
2-CHK055.04	15	662	186	124	01/00-04/01

Table 48. Coastal Plain Macroinvertebrate Index (CPMI) scoring system for macroinvertebrate assemblages.

Index Metric	Score			
	6	4	2	0
Number of genera	> 25	17-25	9-16	< 9
Number of EPT[1] genera	> 9	7-9	4-6	< 4
% Ephemeroptera genera	> 29	20-29	10-19	< 10
Hilsenhoff Biotic Index	< 4.9	4.9-6.0	6.1-7.3	> 7.3
% Clingers	> 51	34-51	17-33	< 17
Total	The sum is then evaluated against the standard[2]			

[1]Ephemeroptera (mayflies), Plecoptera (Stoneflies), Tricoptera (Caddisflies)
[2]Excellent = 22-30; Good = 12-20; Fair = 6-10; Poor = < 6

Table 49. Coastal Plain Macroinvertebrate Index (CPMI) for water quality monitoring sites at Richmond NBP 2003-2008. Scores range from poor (< 6), fair (6-10), good (12-20), and excellent (22-30).

Site	2003	2004	2005	2006	2007	2008	2009	Average Score
Beaver Dam Creek								
BD 1	12	16	12	10	18	18	22	15.4
Chickahominy Bluff								
CB 1	n/a	10	8	n/a	14	10	8	10.0
Cold Harbor								
CH 2	12	n/a	20	24	24	18	20	19.7
Drewry's Bluff								
DB 1	4	4	6	6	n/a	6	8	5.7
DB 2	n/a	2	4	4	n/a	2	4	3.2
Gaines' Mill								
GM 1	8	24	24	n/a	18	24	22	20.0
Malvern Hill								
MH 1	20	n/a	20	n/a	10	16	20	17.2

Condition Status Summary for Water Resources

Overall, a lack of consistent data and irregular monitoring and reporting are the most significant impediments to a thorough assessment of water quality at Richmond NBP. Much of existing data are outdated and some of the data currently available are not easily evaluated against state or federal standards because of inconsistent measuring intervals. Available data provide some insight into water quality conditions at park units, but current and consistent data in all of the fields would provide a much more accurate representation of the current conditions at each unit. All water quality parameters would benefit from more data. *E. coli* in particular is lacking sufficient information.

Currently there is not enough long-term data available to analyze changing conditions; however the MIDN I&M network has begun a monthly water quality monitoring program in 2010. With a long-term data collection plan established, it may provide opportunities to follow trends throughout different waterbodies. Without consistent data, trends for any of the water quality parameters cannot be made. Several of the parameters, in particular temperature dependent or other seasonally variable parameters, cannot be fairly compared when taken randomly throughout the year. If reliable data stations were established and data was collected at the same time each year it would be possible to monitor how the water quality is changing over time.

The Totopotomoy Creek unit was acquired by the NPS in 2009; consequently it is lacking long term data to evaluate water quality. Some hydrology information was available online, but unlike the Chickahominy River, hydrology information it was not rated by USGS. To assess this park unit more watershed level data is needed.

Water quality is rarely an issue that belongs wholly to a single management unit, especially urbanized areas such as Richmond which are exposed to hazardous sites (a closed county landfill, and a previous latex and hydrochloric acid spill at Drewry‘s Bluff). Public outreach and engagement in local and regional water quality issues can be an important component of efforts to preserve the integrity of water systems in and around Richmond NBP. Increasing the amount of data within the park would provide much more insight into the current conditions of water within Richmond NBP. Routinely taking measurements multiple times a month during selected months would ensure values would match current state standards. They would also allow reliable trend data for different waterways. Cooperative efforts with VA SOS and other volunteers is a good way to continue to gain additional insight into conditions inside the park for relatively little expense.

Measuring conductivity overtime is an easy and accurate way to measure the level of dissolved substances. Although it cannot indicate the types of substances present, a steady increase of conductivity over a period of years is usually indicative of pollution. Also, transitioning from fecal coliform to *E. coli* is recommended by the EPA to more accurately assess human health risk in waterbodies around the park.

For each water quality measure, either the standard is met or fails to be met, which determines whether it is considered “acceptable.” Each park unit was rated for dissolved oxygen, pH, temperature, *E. coli*, fecal coliform, and macroinvertebrate CPMI based on the percentage of observations considered acceptable. Park units with > 75% of acceptable values were considered good, 51-75% were considered fair, and 0-50% were rated poor. Tables 50-57 address the water quality conditions at each park unit based on the selected parameters.

Table 50. Water quality conditions at the Beaver Dam Creek unit of Richmond NBP (Beaver Dam Creek) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	83 % of observations ≥ 4mg/L minimum (Good)	No data available
	pH	pH values fall between 6.0 and 9.0 > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	93% between a pH of 6.0 and 9.0 (Good)	No data available
	Temperature	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL	n/a	No data available
	Bacterial Contamination (Fecal Coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL	n/a	No data available
	Aquatic macroinvertebrates	CPMI scores range from Poor (< 6), Fair (6-10), Good (12-20), and Excellent (22-30)	22.0 (Good)	No data available

Table 51. Water quality conditions at the Chickahominy Bluff unit of Richmond NBP (unamed tributary of the Chickahominy River) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	90% of observations ≥ 4mg/L minimum (Good)	No data available
	pH	pH values fall between 6.0 and 9.0 > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	83% between a pH of 6.0 and 9.0 (Good)	No data available
	Temperature	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL	n/a	No data available
	Bacterial Contamination (Fecal Coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	75% of months with available data had acceptable values (Fair)	No data available
	Aquatic macroinvertebrates	CPMI scores range from Poor (< 6), Fair (6-10), Good (12-20), and Excellent (22-30)	8.0 (Fair)	No data available

Table 52. Water quality conditions at the Cold Harbor unit of Richmond NBP (Bloody Run) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	73% of observations ≥ 4mg/L minimum (Fair)	No data available
	pH	pH values fall between 6.0 and 9.0	n/a	Cold Harbor is VII standard; Lower pH is natural
	Temperature	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	50% of stations had geometric means below 126cfu/100mL (Poor)	No data available
	Bacterial Contamination (fecal coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	88% of months with available data had acceptable values (Good)	No data available
	Aquatic macroinvertebrates	CPMI scores range from Poor (< 6), Fair (6-10), Good (12-20), and Excellent (22-30)	20.0 (Good)	No data available

Table 53. Water quality conditions at the Drewry's Bluff unit of Richmond NBP (unamed tributary of the James River) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	70% of observations ≥ 4mg/L minimum (Fair)	No data available
	pH	pH values fall between 6.0 and 9.0 > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	55% between a pH of 6.0 and 9.0 (Fair)	No data available
	Temperature	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL	n/a	No data available
	Bacterial Contamination (Fecal Coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	92% of months with available data had acceptable values (Good)	No data available
	Aquatic macroinvertebrates	CPMI scores range from Poor (< 6), Fair (6-10), Good (12-20), and Excellent (22-30)	Average of two 2009 stations = 6.0 (Fair)	No data available

Table 54. Water quality conditions at the Fort Harrison unit of Richmond NBP (roadside wetland) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	69% of observations ≥ 4mg/L minimum (Fair)	No data available
	pH	pH values fall between 6.0 and 9.0 > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	51% between a pH of 6.0 and 9.0 (Fair)	No data available
	Temperature	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL	n/a	No data available
	Bacterial Contamination (Fecal Coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	88% of months with available data had acceptable values (Good)	No data available
	Aquatic macroinvertebrates	n/a	n/a	No data available

Table 55. Water quality conditions at the Gaines' Mill unit of Richmond NBP (Boatswain Creek) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	97% of observations ≥ 4mg/L minimum (Good)	No data available
	pH	pH values fall between 6.0 and 9.0 > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	50% between a pH of 6.0 and 9.0 (Poor)	No data available
	Temperature	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	0% of stations had geometric means below 126cfu/100mL (Poor)	No data available
	Bacterial Contamination (Fecal Coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	88% of months with available data had acceptable values (Good)	No data available
	Aquatic macroinvertebrates	CPMI scores range from Poor (< 6), Fair (6-10), Good (12-20), and Excellent (22-30)	22 (Good)	No data available

Table 56. Water quality conditions at the Malvern Hill unit of Richmond NBP (Western Run and Crewes' Channel) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO[*]	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	79% of observations ≥ 4mg/L minimum (Fair)	No data available
	pH[*]	pH values fall between 6.0 and 9.0 > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	60% between a pH of 6.0 and 9.0 (Fair)	No data available
	Temperature[*]	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% of stations had geometric means below 126cfu/100mL (Good)	No data available
	Bacterial Contamination (Fecal Coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	80% of months with available data had acceptable values (Good)	No data available
	Aquatic macroinvertebrates	CPMI scores range from Poor (< 6), Fair (6-10), Good (12-20), and Excellent (22-30)	20.0 (Good)	No data available

[*]Values were averaged between Crewes' Channel and Western Run (two stream systems running through Malvern Hill).

Table 57. Water quality conditions at the Turkey Hill unit of Richmond NBP (Chickahominy River) compared to Virginia state standards.

Vital Sign/Indicator	Measure	Reference Condition(s)	Current Condition[1]	Trends(s)
Water Quality	DO	DO ≥ 4mg/L > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	87% of observations ≥ 4mg/L minimum (Good)	No data available
	pH	pH values fall between 6.0 and 9.0 > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% between a pH of 6.0 and 9.0 (Good)	No data available
	Temperature	Mean annual water temperature shall not exceed 32 ºC > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% < 32 ºC (Good)	No data available No data available
	Bacterial contamination (E. coli)	Geometric mean shall not exceed 126cfu/100mL, or a single sample exceed 235cfu/100mL	n/a	No data available
	Bacterial Contamination (Fecal Coliform)	10% of samples taken within a given month shall not exceed 400 fecal coliform bacteria/100mL > 75% passing (Good) 51-75% passing (Fair) ≤ 50% passing (Poor)	100% of months with available data had acceptable values (Good)	No data available
	Aquatic macroinvertebrates	n/a	n/a	No data available

8.0 Park-wide Resources

Soils

Richmond NBP lies near the border of the Atlantic Coastal Plain province and is primarily flat terrain with elevations ranging from sea level to about 100 m (300 ft). Large streams and rivers in the Coastal Plain province include the James, York, Rappahannock, and Potomac. The Blue Ridge Mountains lie about 90 miles to the west, and the Chesapeake Bay 60 miles to the east. Elevations range from a few feet above sea level along the river to a little over 300 feet in parts of the western section of the city. Although approximately 70% of the park's acreage is forested, habitats range from open grasslands, savannah-like pinelands, many acres of riparian wetlands, and stream side communities. Erosion is of great concern along the parks many miles of historic earthworks. The long, steep slopes and infertile soils inherent to many of the park's earthworks combine to magnify their vulnerability to erosion (National Park Service 2010). Surrounding land use and development have increased runoff and sedimentation (Figure 92).

Several soil-based assessments can be assembled from current soil data using the NPS soil database and an extension that runs on ArcGIS (ESRI 2006), the USDA Natural Resource Conservation Service Soil Data Viewer (2008). The assessments we found most useful for park assessment include potential erosion hazard for off-road and off-trail traffic and flooding frequency class. Explanations from USDA Natural Resource Conservation Service Soil Data Viewer (2008) follow with more detail in Appendices L and M. Other potentially important soils information were gathered from the USDA NRCS soil characterization lab database (USDA NRCS 2009).

Figure 92. Sedimentation at Chickahominy Bluff. Portion of stream on the park is choked with sand and sediment. February 2006.

The Northern Atlantic Coastal Plain Physiographic Province is underlain by lenses and layers of clay, silt, and sand, with minor amounts of lignite, gravel, and limestone deposited on irregular crystalline-rock surface, warped by tectonic forces. The aquifers in the region are composed of sand, gravel, and limestone and are separated by the less permeable silt, clay, or clayey soils. Water still moves through these confining units, particularly in thin spots, or where they contain more sand (U.S. Geological Survey 2009a).

Soil types occurring within Richmond NBP are listed in Tables 59-60; and displayed in Figures 93-99.

Table 58. Soil types within the Upper Pamunkey watershed (Totopotomoy Creek).

Soil types	Acreage	Percent
Fluvaquents, nearly level	29.0	20.1
Kempsville-Bourne fine sandy loams, 0 to 2 percent slopes	4.7	3.3
Orangeburg-Faceville fine sandy loams, 0 to 2 percent slopes	11.8	8.2
Suffolk loamy fine sand, 2 to 7 percent slopes	52.2	36.3
Udults-Ochrepts complex, moderately steep	3.6	2.5
Udults-Ochrepts complex, sloping	15.3	10.6
Udults-Ochrepts complex, steep	27.2	18.9
Total	143.8	

Table 59. Soil types for units within the Middle Chickahominy watershed (Chickahominy Bluff, Beaver Dam Creek, Cold Harbor, Garthright House, Gaines' Mill, and Turkey Hill).

Soil types	Acreage	Percent
Altavista fine sandy loam	3.4	0.5
Augusta fine sandy loam	36.5	5.0
Bertie fine sandy loam	0.8	0.1
Caroline fine sandy loam, 15 to 25 percent slopes, eroded	0.6	0.1
Caroline-Dogue complex, 2 to 7 percent slopes, eroded	4.7	0.6
Caroline-Dogue complex, 7 to 15 percent slopes, eroded	14.5	2.0
Chewacla and Riverview soils	3.0	0.4
Fluvaquents, nearly level	236.0	32.3
Goldsboro fine sandy loam, overwash, 0 to 4 percent slopes	3.1	0.4
Kempsville fine sandy loam, flooded, 2 to 6 percent slopes	6.5	0.9
Kempsville gravelly fine sandy loam, 2 to 7 percent slopes	4.3	0.6
Kempsville gravelly fine sandy loam, 7 to 15 percent slopes	12.3	1.7
Kempsville-Bourne fine sandy loams, 2 to 7 percent slopes	4.8	0.7
Kenansville loamy sand, 2 to 7 percent slopes	8.0	1.1
Kinston silt loam	3.1	0.4
Myatt fine sandy loam	17.0	2.3
Myatt variant fine sandy loam	125.8	17.2
Norfolk fine sandy loam, 2 to 6 percent slopes	5.3	0.7
Ochrepts and Udults, steep	11.0	1.5
Orangeburg fine sandy loam, 2 to 7 percent slopes	3.0	0.4
Orangeburg-Faceville fine sandy loams, 2 to 7 percent slopes	3.6	0.5
Sassafras fine sandy loam, 2 to 6 percent slopes	3.2	0.4
Suffolk loamy fine sand, 2 to 7 percent slopes	84.5	11.6
Udults, sloping	9.4	1.3
Udults-Ochrepts complex, moderately steep	90.8	12.4
Udults-Ochrepts complex, sloping	26.6	3.6
Udults-Ochrepts complex, steep	7.9	1.1
Water	1.4	0.2
Total	731.2	

Table 60. Soils types for units within the James River/Falling Creek watershed (Chimborazo, Drewry's Bluff, Fort Harrison, Malvern Hill, and Parker's Battery).

Soils types	Acreage	Percent
Abell fine sandy loam, 2 to 6 percent slopes	4.3	0.3
Altavista fine sandy loam, 0 to 2 percent slopes	9.6	0.7
Altavista fine sandy loam, 2 to 6 percent slopes	5.5	0.4
Angie loam, 0 to 2 percent slopes	58.8	4.1
Angie loam, 2 to 6 percent slopes	2.3	0.2
Angie loam, 2 to 6 percent slopes, eroded	14.7	1.0
Angie loam, 6 to 10 percent slopes, eroded	2.4	0.2
Angie loam, concretionary subsoil variant	2.4	0.2
Atlee very fine sandy loam	25.1	1.7
Atlee-Urban land complex, 0 to 4 percent slopes	6.0	0.4
Bourne fine sandy loam, 0 to 2 percent slopes	1.7	0.1
Caroline clay loam, 2 to 10 percent slopes, severely eroded	4.2	0.3
Caroline very fine sandy loam, 10 to 15 percent slopes, eroded	4.3	0.3
Caroline very fine sandy loam, 2 to 6 percent slopes, eroded	80.5	5.6
Caroline very fine sandy loam, 6 to 10 percent slopes, eroded	17.4	1.2
Chastain silt loam	13.6	0.9
Chewacla and Riverview soils	9.4	0.7
Chewacla silt loam, clayey substratum	4.5	0.3
Coxville silt loam	1.6	0.1
Craven fine sandy loam, 2 to 6 percent slopes	0.0	0.0
Dunbar fine sandy loam, 0 to 4 percent slopes	0.2	0.0
Duplin very fine sandy loam, 2 to 6 percent slopes, eroded	18.5	1.3
Duplin very fine sandy loam, 6 to 10 percent slopes, eroded	20.4	1.4
Faceville fine sandy loam, 2 to 6 percent slopes	2.1	0.1
Gravel pit	1.3	0.1
Gritney fine sandy loam, 6 to 12 percent slopes	6.3	0.4
Kempsville fine sandy loam, 0 to 2 percent slopes	0.0	0.0
Kempsville fine sandy loam, 10 to 25 percent slopes, eroded	6.8	0.5
Kempsville fine sandy loam, 2 to 10 percent slopes, eroded	24.1	1.7
Kempsville very fine sandy loam, clayey substratum, 0 to 2 percent slopes	78.5	5.5
Kempsville very fine sandy loam, clayey substratum, 2 to 6 percent slopes	27.6	1.9
Kinston and Mantachie soils	59.4	4.1
Lenoir loam, flooded, 0 to 4 percent slopes	0.1	0.0
Lenoir silt loam	125.0	8.7
Lucy-Orangeburg loamy sands, 2 to 6 percent slopes	10.1	0.7
Lynchburg fine sandy loam	3.1	0.2
Mantachie-Chastain complex	30.5	2.1
Masada loam, 2 to 6 percent slopes	4.5	0.3
Masada loam, 6 to 12 percent slopes	2.8	0.2
Norfolk fine sandy loam, 0 to 2 percent slopes	6.3	0.4
Norfolk fine sandy loam, 2 to 6 percent slopes	27.8	1.9
Norfolk fine sandy loam, 6 to 10 percent slopes	20.0	1.4
Ochrepts and Udults, sloping	34.2	2.4
Ochrepts and Udults, steep	188.6	13.1
Pamunkey clay loam, 6 to 15 percent slopes, severely eroded	0.4	0.0
Pamunkey fine sandy loam, 0 to 2 percent slopes	3.2	0.2
Pamunkey fine sandy loam, 2 to 6 percent slopes	5.6	0.4
Pamunkey fine sandy loam, 6 to 15 percent slopes	5.0	0.3
Rains very fine sandy loam	1.3	0.1
Roanoke silt loam	70.2	4.9
Ruston fine sandy loam, 0 to 2 percent slopes	12.4	0.9
Ruston fine sandy loam, 2 to 6 percent slopes	25.2	1.8
Ruston fine sandy loam, 6 to 10 percent slopes eroded	2.6	0.2
Sassafras fine sandy loam, 0 to 2 percent slopes	3.1	0.2
Sassafras fine sandy loam, 2 to 6 percent slopes	76.5	5.3
State fine sandy loam, clayey substratum, 0 to 2 percent slopes	0.0	0.0
State fine sandy loam, clayey substratum, 2 to 6 percent slopes	78.2	5.4
State fine sandy loam, clayey substratum, 6 to 10 percent slopes, eroded	0.5	0.0

Soils types	Acreage	Percent
Tetotum loam, clayey substratum, 2 to 6 percent slopes	4.9	0.3
Turbeville fine sandy loam, 0 to 2 percent slopes	13.7	1.0
Turbeville fine sandy loam, 2 to 6 percent slopes	98.0	6.8
Turbeville fine sandy loam, 6 to 10 percent slopes, eroded	60.9	4.2
Turbeville gravelly fine sandy loam, 2 to 6 percent slopes	5.8	0.4
Turbeville gravelly fine sandy loam, 6 to 10 percent slopes	2.8	0.2
Total	1437.0	

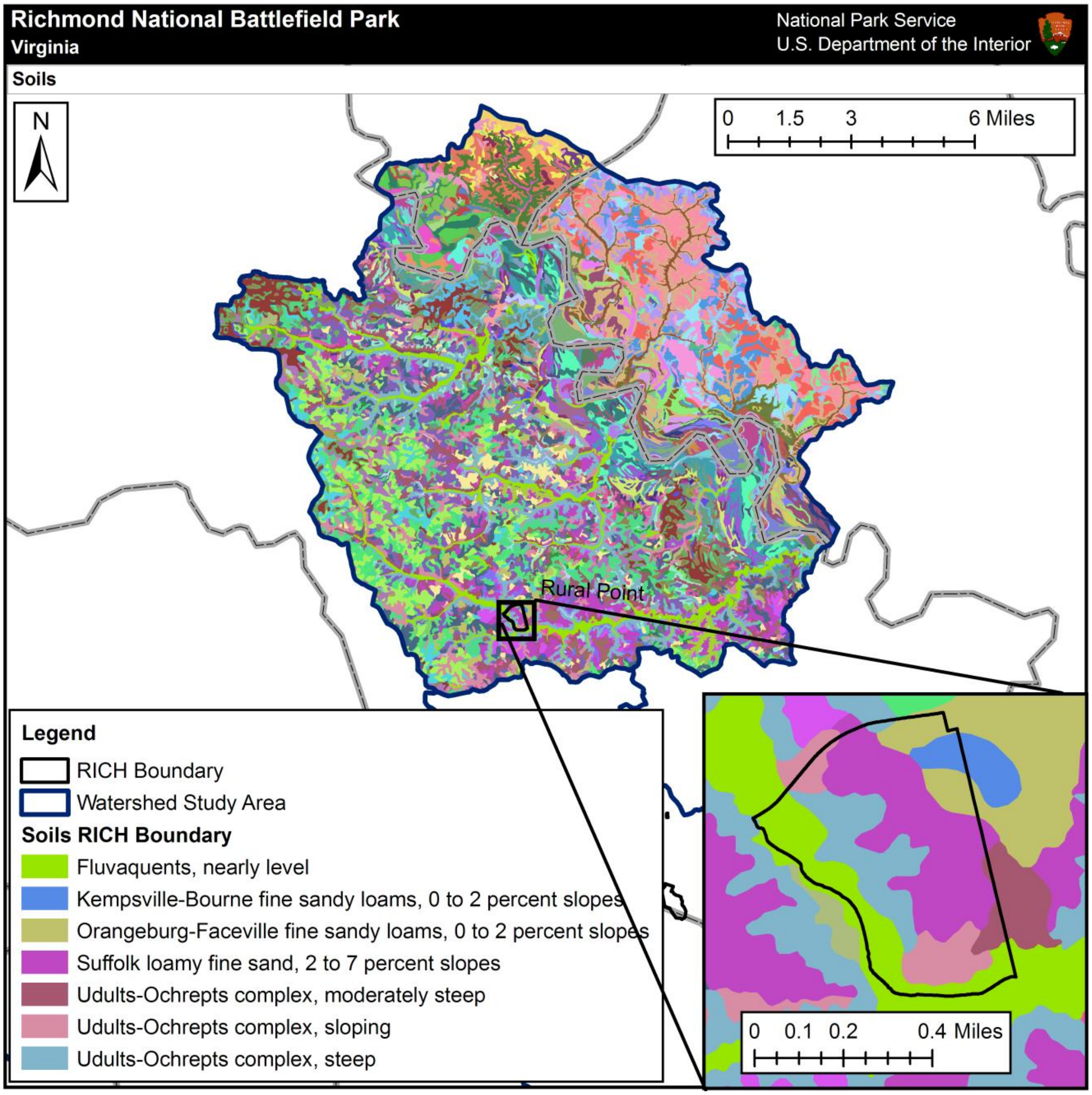

Figure 93. Soil types within Totopotomoy Creek (Rural Point). Soil types for the entire watershed study area are shown but are not contained in the legend.

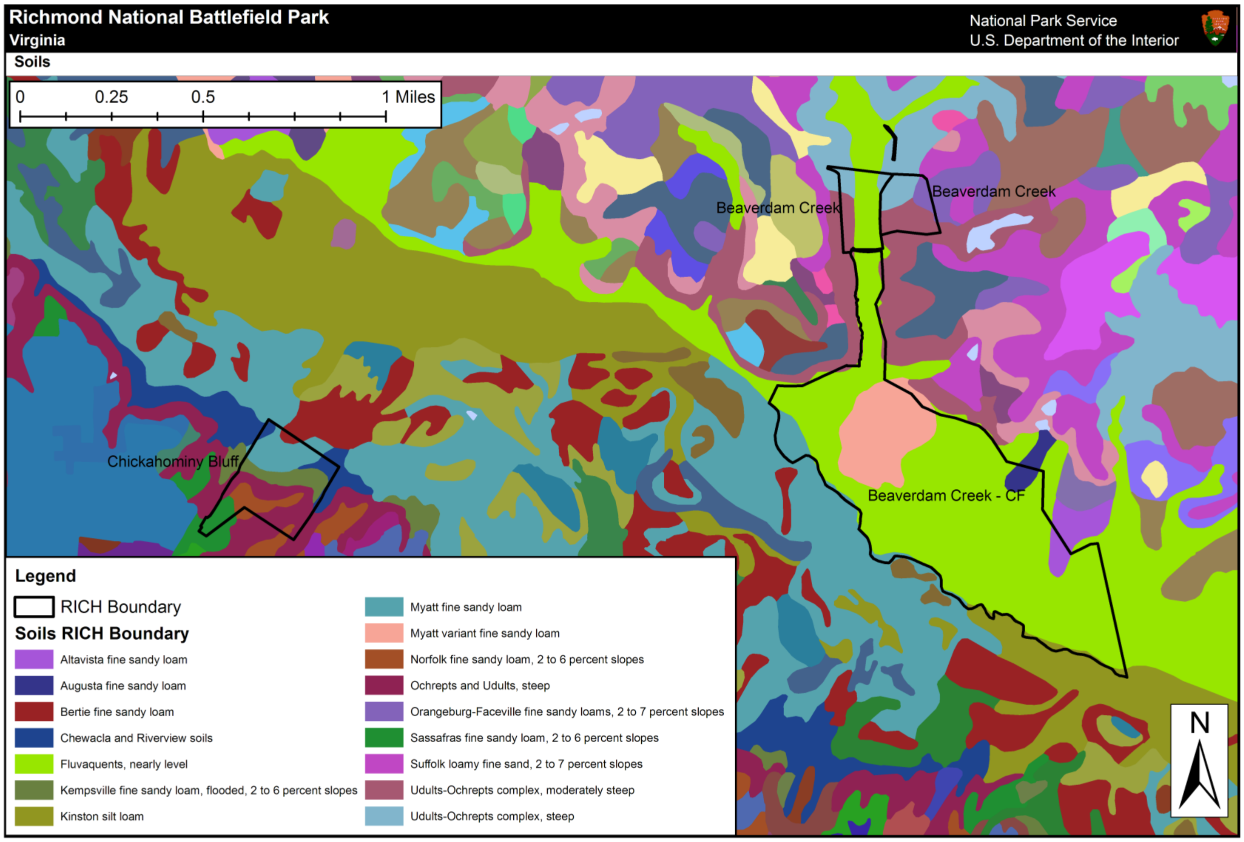

Figure 94. Soil types within Chickahominy Bluff and Beaver Dam Creek. Soil types for the entire watershed study area are shown but are not contained in the legend.

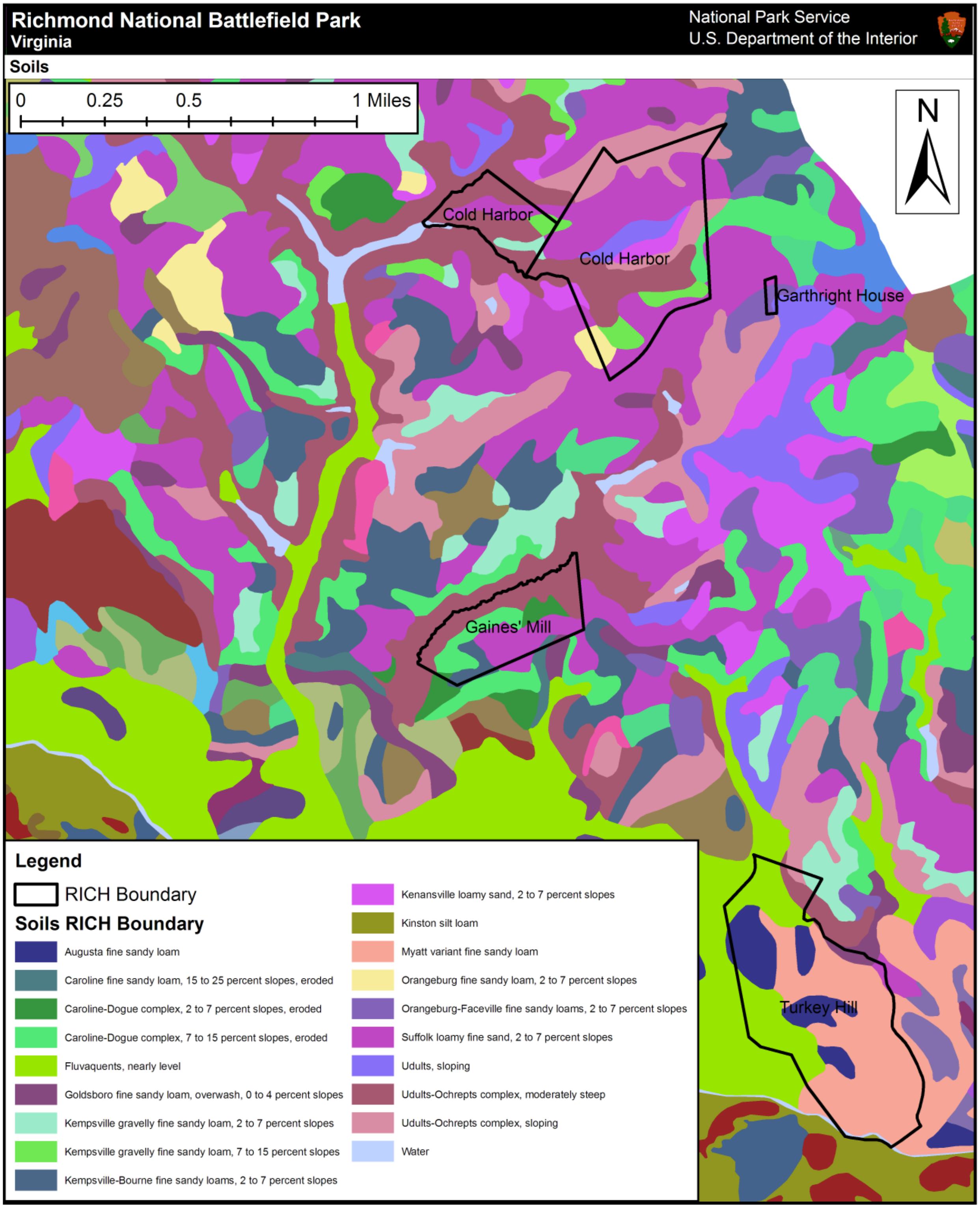

Figure 95. Soil types within Cold Harbor and Gaines' Mill. Soil types for the entire watershed study area are shown but are not contained in the legend.

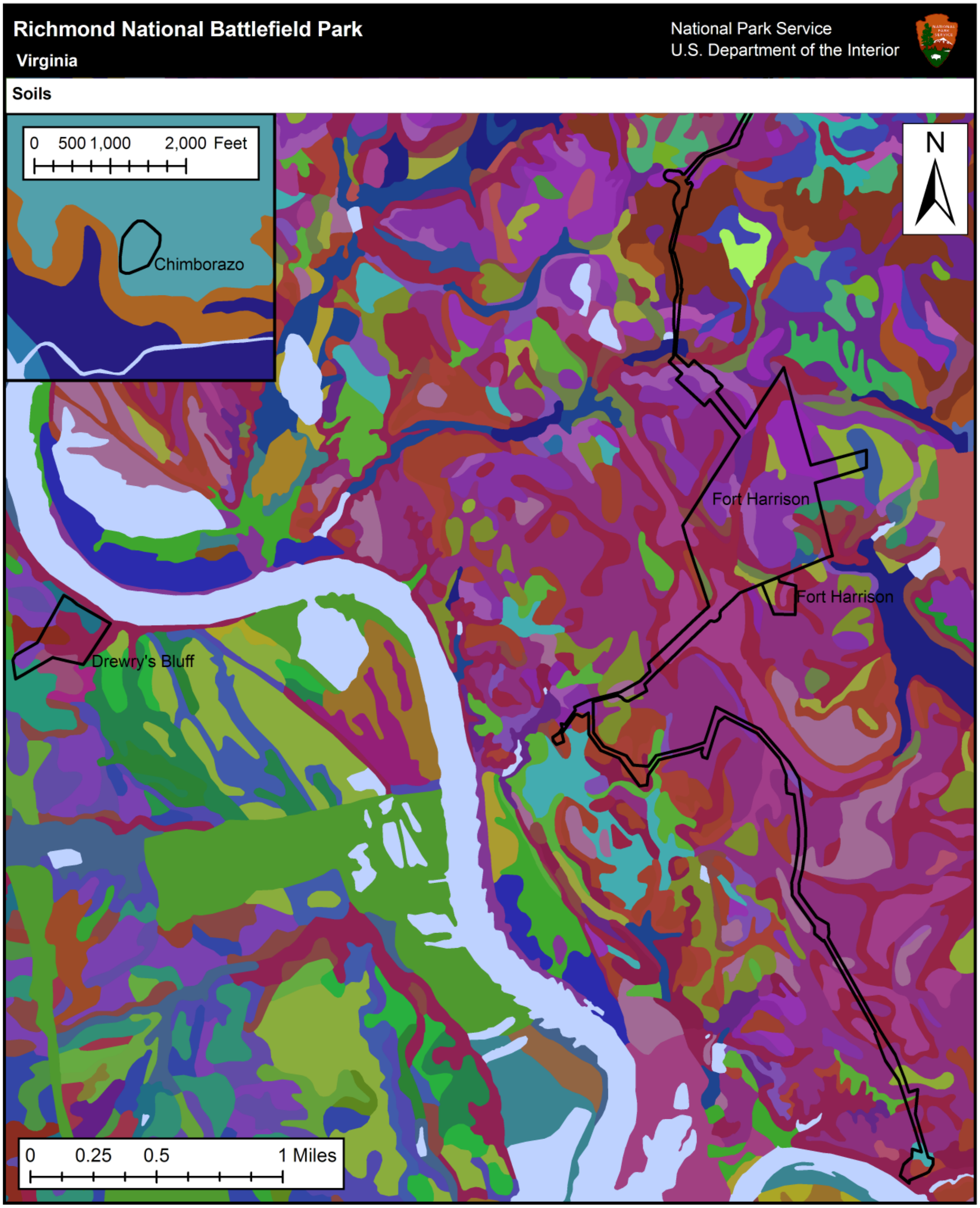

Figure 96. Soil types within Drewry's Bluff and Fort Harrison. Soil types for the entire watershed study area are shown but are not contained in the legend.

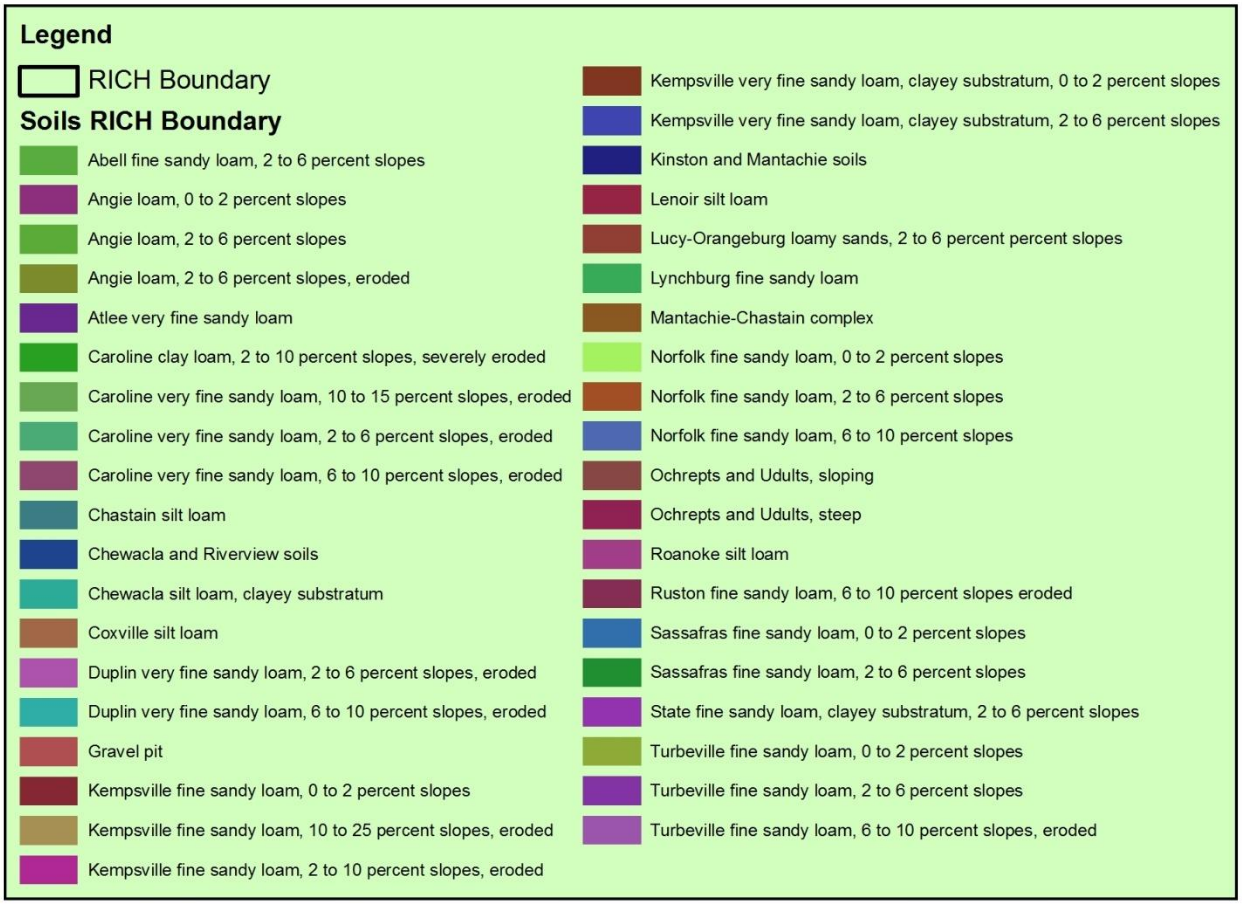

Figure 97. Legend for soil types within Drewry's Bluff and Fort Harrison. Soil types for the entire watershed study area are shown but are not contained in the legend.

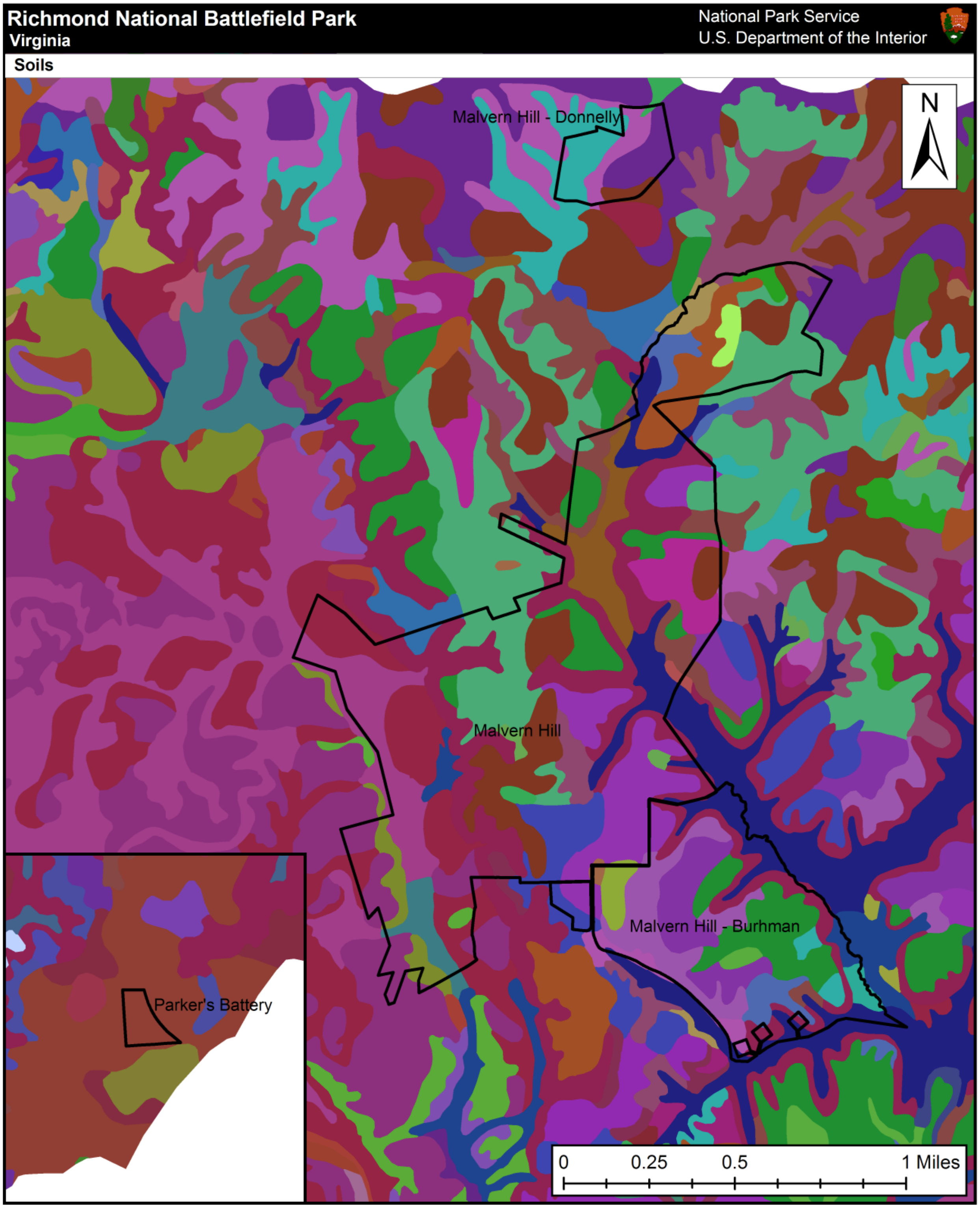

Figure 98. Soil types within Malvern Hill and Parker's Battery. Soil types for the entire watershed study area are shown but are not contained in the legend.

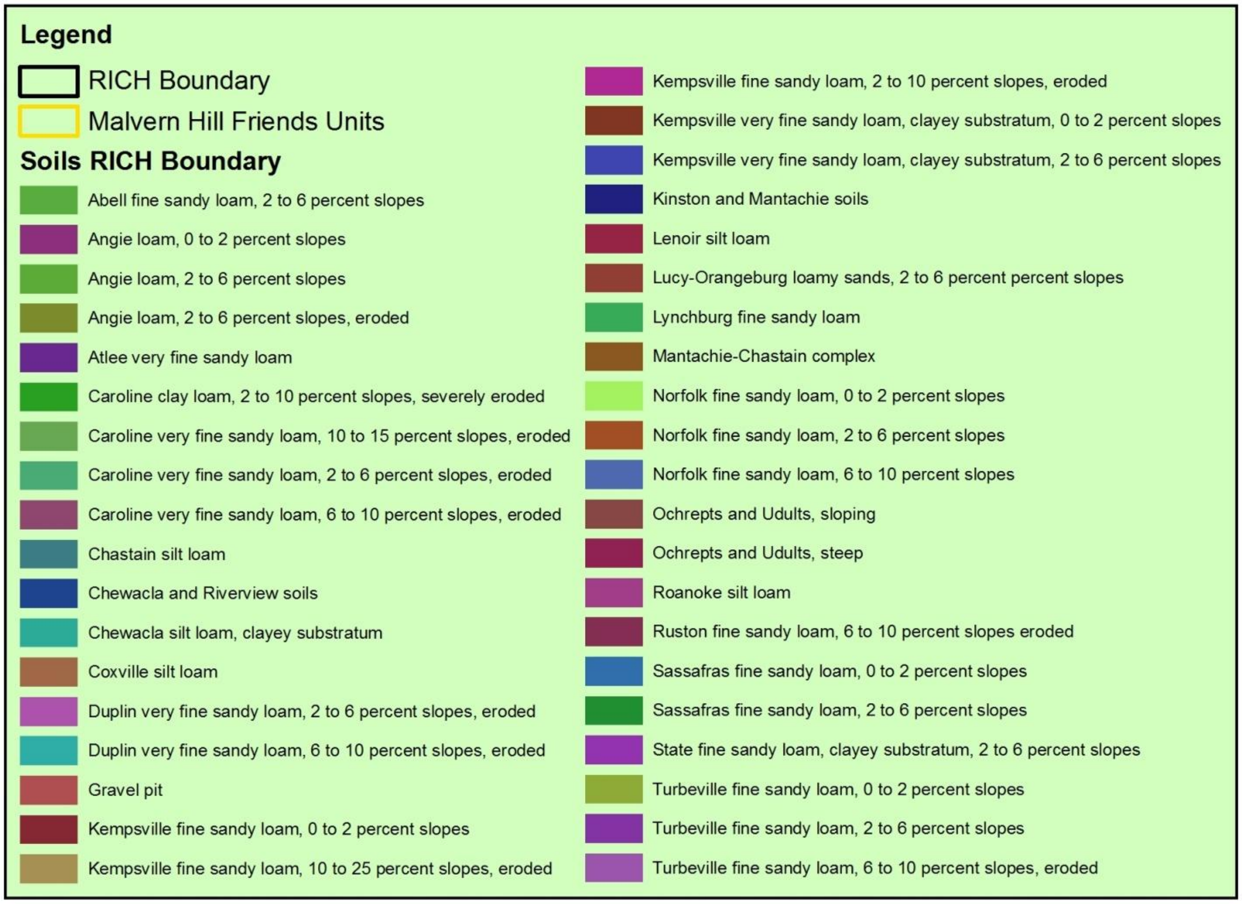

Figure 99. Legend for soil types within Malvern Hill and Parker's Battery. Soil types for the entire watershed study area are shown but are not contained in the legend.

Potential Erosion Hazard

Ratings indicate the hazard or risk of soil loss from off-road and off-trail areas after disturbance activities that expose the soil surface, and are based on slope and soil erodibility factor K. The soil loss is caused by sheet, rill or gully erosion in off-road or off-trail areas where 50 to 75 percent of the surface has been exposed by logging, grazing, mining, or other kinds of disturbance.

The hazard is described as "slight," "moderate," "severe," or "very severe." Ratings of soils found in the park of "slight" indicates that erosion is unlikely under ordinary climatic conditions; while soil rating of "moderate" indicates that some erosion is likely and that erosion-control measures may be needed (USDA Natural Resource Conservation Service 2008).

Another measure of the erosion potential of a soil is the hydrologic soil group (USDA Natural Resource Conservation Service 2008). Hydrologic soil groups are based on estimates of runoff potential. The dominant soils in each map unit are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The soils in the United States are assigned to four groups (A, B, C, and D). The groups found in the park are defined as follows:

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission. This is a measure of how rapidly the upper 50 cm of the soil become saturated during extremely heavy rainfall events, causing accelerated erosion.

Natural drainage class refers to the frequency and duration of wet periods under conditions similar to those under which the soil developed. Alteration of the water regime by man, either through drainage or irrigation, is not a consideration unless the alterations have significantly changed the morphology of the soil. The classes for soils found in the park or discussed under hydrologic soil groups B and C include:

Well drained. Water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons. The soils are mainly free of or deep to soil features that are related to wetness.

Moderately well drained. Water is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence commonly is moderately deep and transitory through permanent. They commonly have a moderately low or lower saturated hydraulic conductivity in a layer within the upper 1 m, periodically receive high rainfall, or both.

Hydric soils are soils found mostly in wetlands and former wetlands that show morphology formed under frequent, long-duration flooding, or long-term saturation and reduction conditions in the near surface, favoring the growth of hydrophytic vegetation. Hydric soils are explained in detail by the USDA NRCS (2008).

The potential erosion hazards for each watershed study area are listed in Tables 61-63; and displayed in Figures 100-104. The majority of Richmond NBP is listed as having ‘slight’ erosion potential. All areas with slopes of 15% or higher have moderate erosion potential as well.

Table 61. Potential erosion hazard comparison for Upper Pamunkey watershed (Totopotomoy Creek).

Potential Erosion	RICH Acres	% of RICH
Not rated	0	0
Slight	113	79
Moderate	30.8	21
Severe	0	0
Very Severe	0	0
Total	143.8	

Table 62. Potential erosion hazard comparison for units within the Middle Chickahominy watershed (Chickahominy Bluff, Beaver Dam Creek, Cold Harbor, Garthright House, Gaines' Mill, and Turkey Hill).

Potential Erosion	RICH Acres	% of RICH
Not rated	1.4	1.4
Slight	604.9	82.7
Moderate	124.9	17.1
Severe	0	--
Very Severe	0	--
Total	731.2	

Table 63. Potential erosion hazard comparison for units within the James River/Falling Creek watershed (Chimborazo, Drewry's Bluff, Fort Harrison, Malvern Hill, and Parker's Battery).

Potential Erosion	RICH Acres	% of RICH
Not rated	1.3	0.1
Slight	1236.0	86.0
Moderate	199.7	13.9
Severe	0	--
Very Severe	0	--
Total	1437.0	

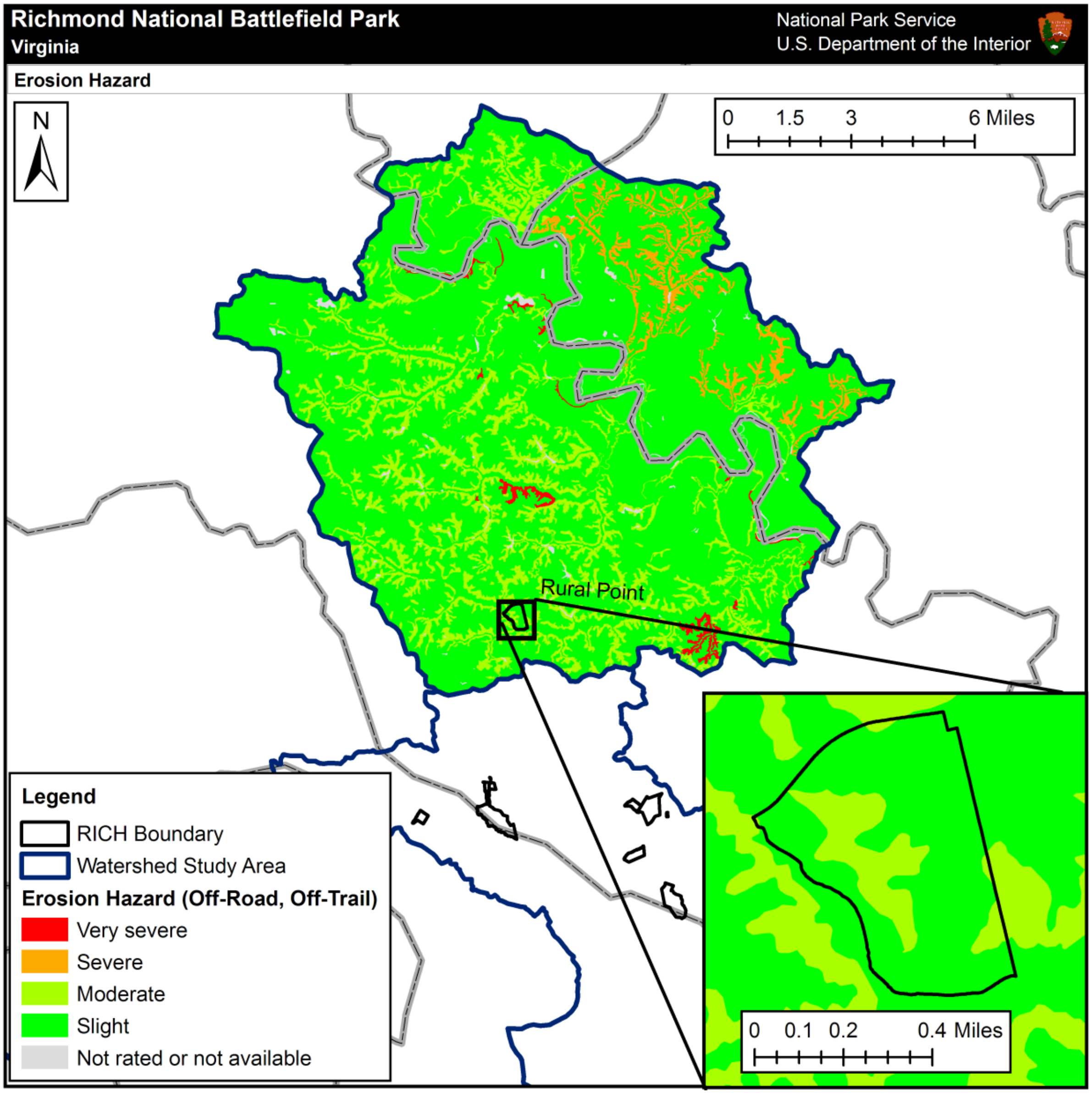

Figure 100. Potential erosion hazard (off-road, off-trail) according to soil characteristics in the watershed study area and at Totopotomoy Creek.

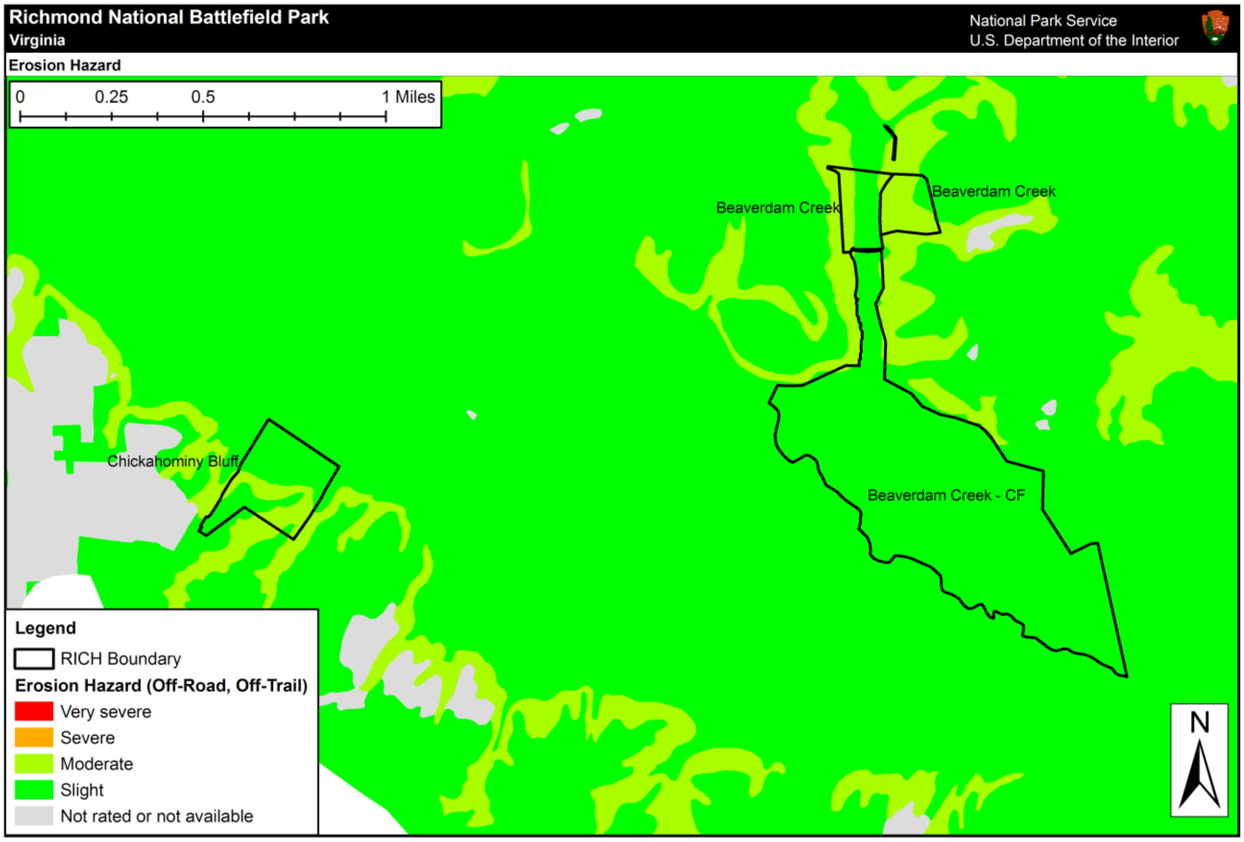

Figure 101. Potential erosion hazard (off-road, off- trail) according to soil characteristics for Chickahominy Bluff and Beaver Dam Creek.

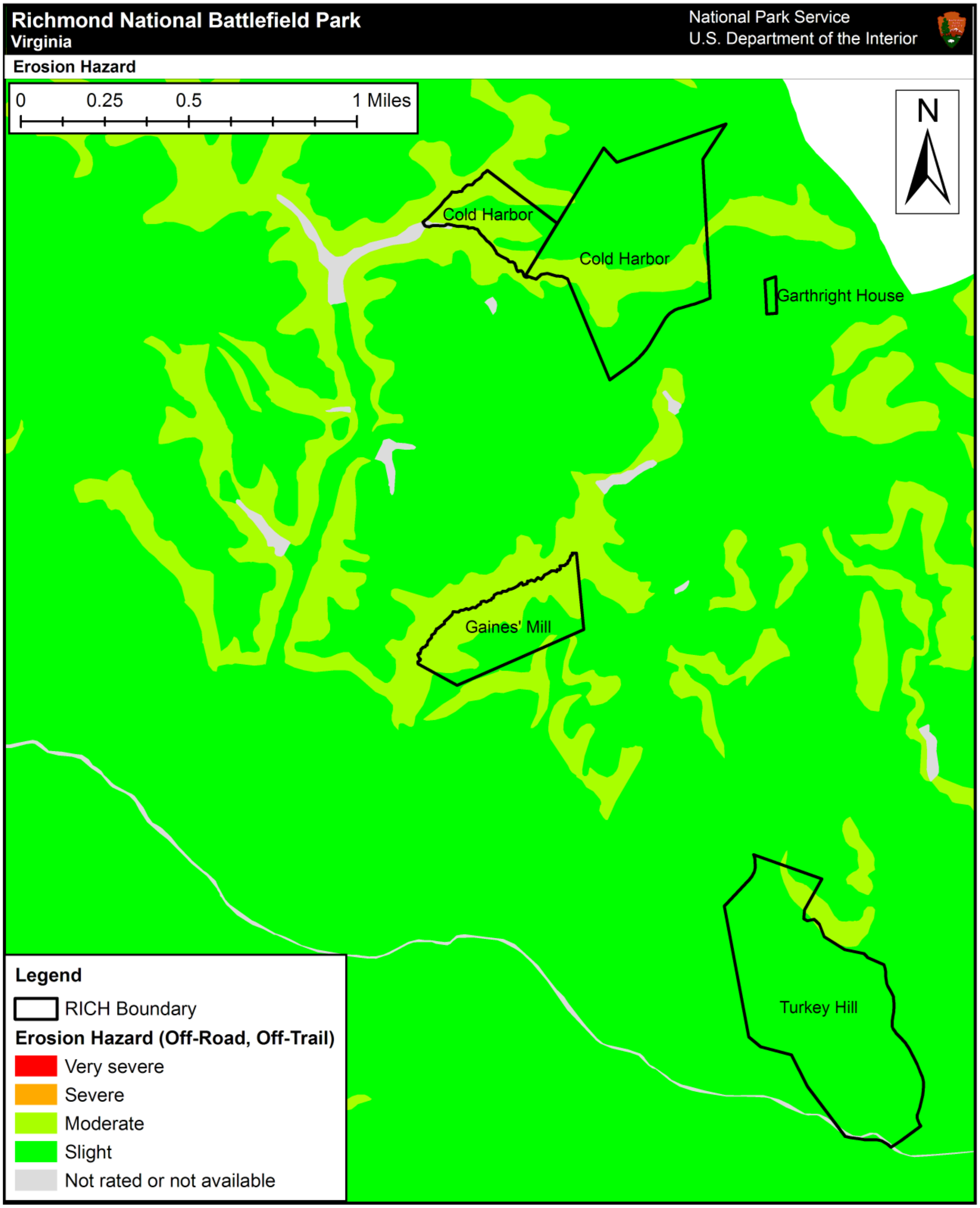

Figure 102. Potential erosion hazard (off-road, off- trail) according to soil characteristics for Cold Harbor, Garthright House, Gaines' Mill, and Turkey Hill.

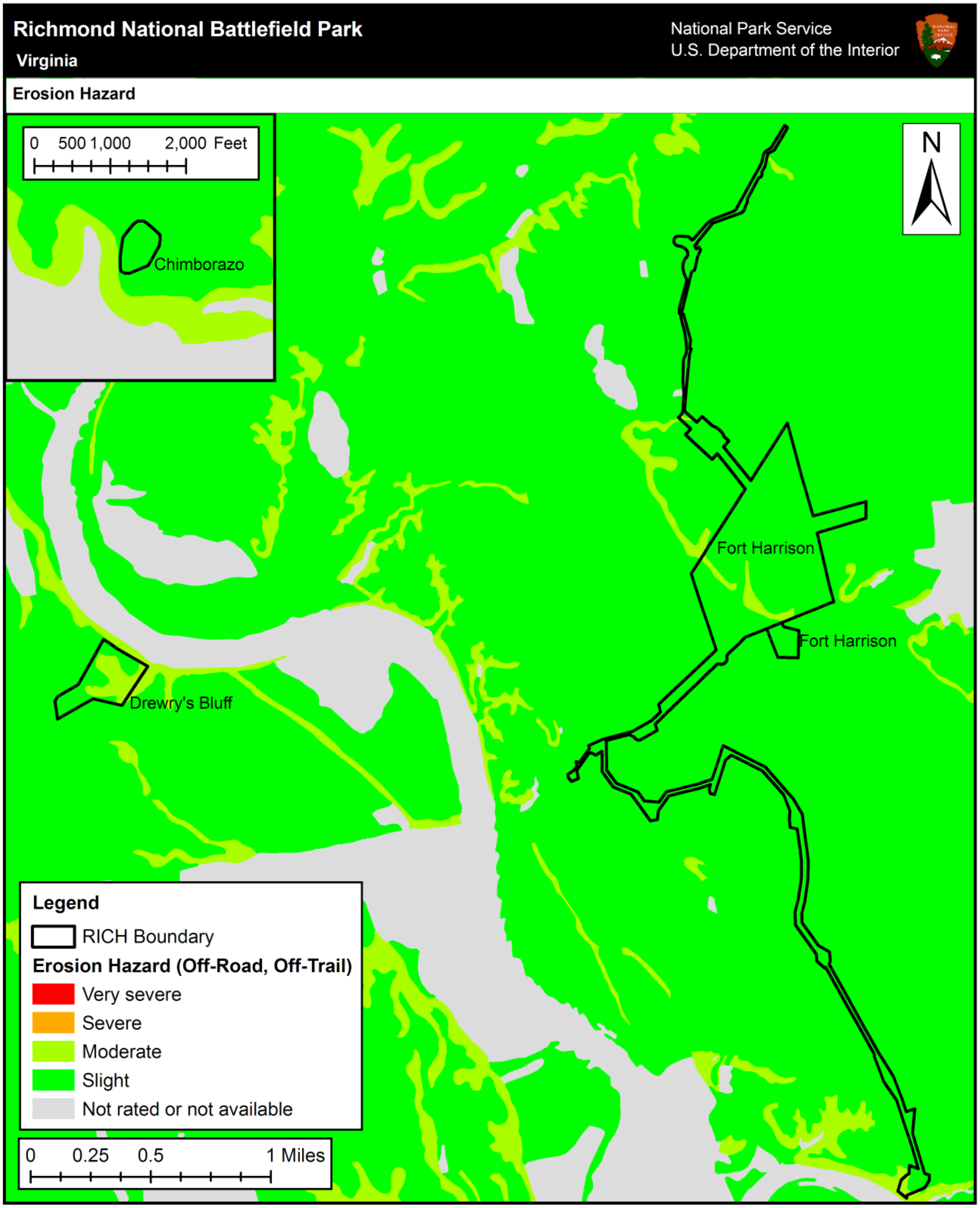

Figure 103. Potential erosion hazard (off-road, off- trail) according to soil characteristics for Drewry's Bluff and Fort Harrison.

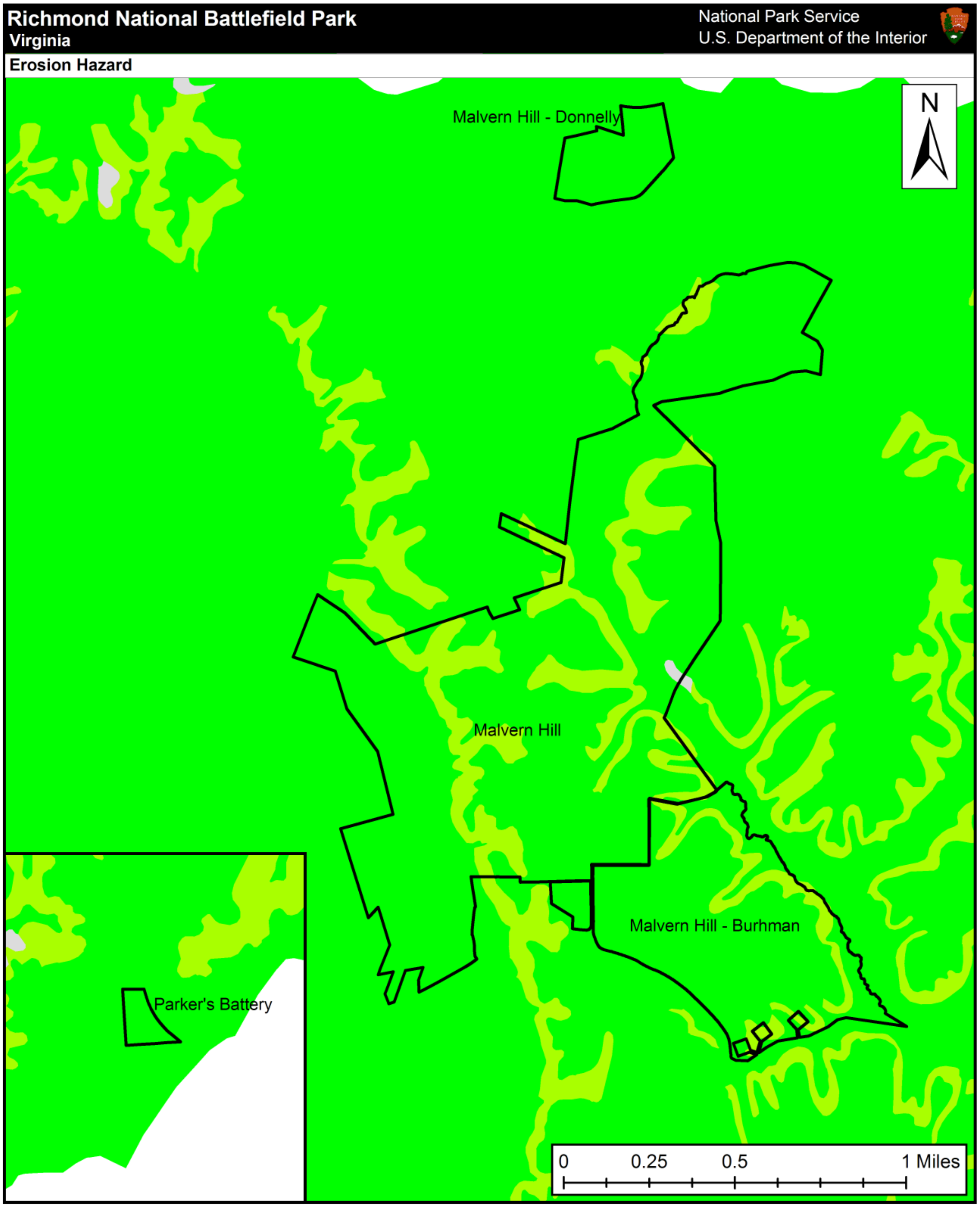

Figure 104. Potential erosion hazard (off-road, off- trail) according to soil characteristics for Malvern Hill and Parker's Battery.

Flooding Frequency Class

Flooding is the temporary inundation of an area caused by overflowing streams, by runoff from adjacent slopes, or by tides. Water standing for short periods after rainfall or snowmelt is not considered flooding, and water standing in swamps and marshes is considered ponding rather than flooding. Flooding frequency is displayed in Tables 64-66 and displayed in Figures105-109.

Flooding frequency class is the number of times flooding occurs over a period of time and is expressed as a class. Flooding Frequency Classes are based on the interpretation of soil properties and other evidence gathered during soil survey field work. The classes are “none,” “very rare,” “rare,” “occasional,” “frequent,” and “very frequent” (USDA Natural Resource Conservation Service 2008). “Occasional” flooding is expected infrequently under usual weather conditions, with a 5 to 50 percent chance of flooding in any year or 5 to 50 times in 100 years. Flooding duration and monthly occurrence are also important factors explained in detail by USDA NRCS (2008).

The majority of the soils in the Upper Pamunkey and Middle Chickahominy park units are rated as having ‘frequent’ flooding frequency (80% and 52.6% respectively). The majority of the soils in the watershed study areas are rated as having a flooding frequency of ‘none.’ Only 21% of the units in the James River/Falling Creek study area are listed as having ‘frequent’ flooding frequency.

Table 64. Flooding frequency comparison for Upper Pamunkey watershed (Totopotomoy Creek).

Flooding Frequency	RICH Acres	% of RICH
Not rated	0	0
None	114.8	20
Rare	0	0
Very rare	--	--
Occasional	0	0
Frequent	29.0	80
Very frequent	0	0
Total	143.8	

Table 65. Flooding frequency comparison for units within the Middle Chickahominy watershed (Chickahominy Bluff, Beaver Dam Creek, Cold Harbor, Garthright House, Gaines' Mill, and Turkey Hill).

Flooding Frequency	RICH Acres	% of RICH
Not rated	0	--
None	299.1	40.9
Rare	0	--
Very rare	0	--
Occasional	47.2	6.5
Frequent	384.9	52.6
Very frequent	0	--
Total	731.2	

Table 66. Flooding frequency comparison for units within the James River/Falling Creek watershed (Chimborazo, Drewry's Bluff, Fort Harrison, Malvern Hill, and Parker's Battery).

Flooding Frequency	RICH Acres	% of RICH
Not rated	0	--
None	1048.6	73.0
Rare	0	--
Occasional	72.8	5.1
Frequent	314.0	21.9
Very frequent	1.6	0.1
Total	1437.0	

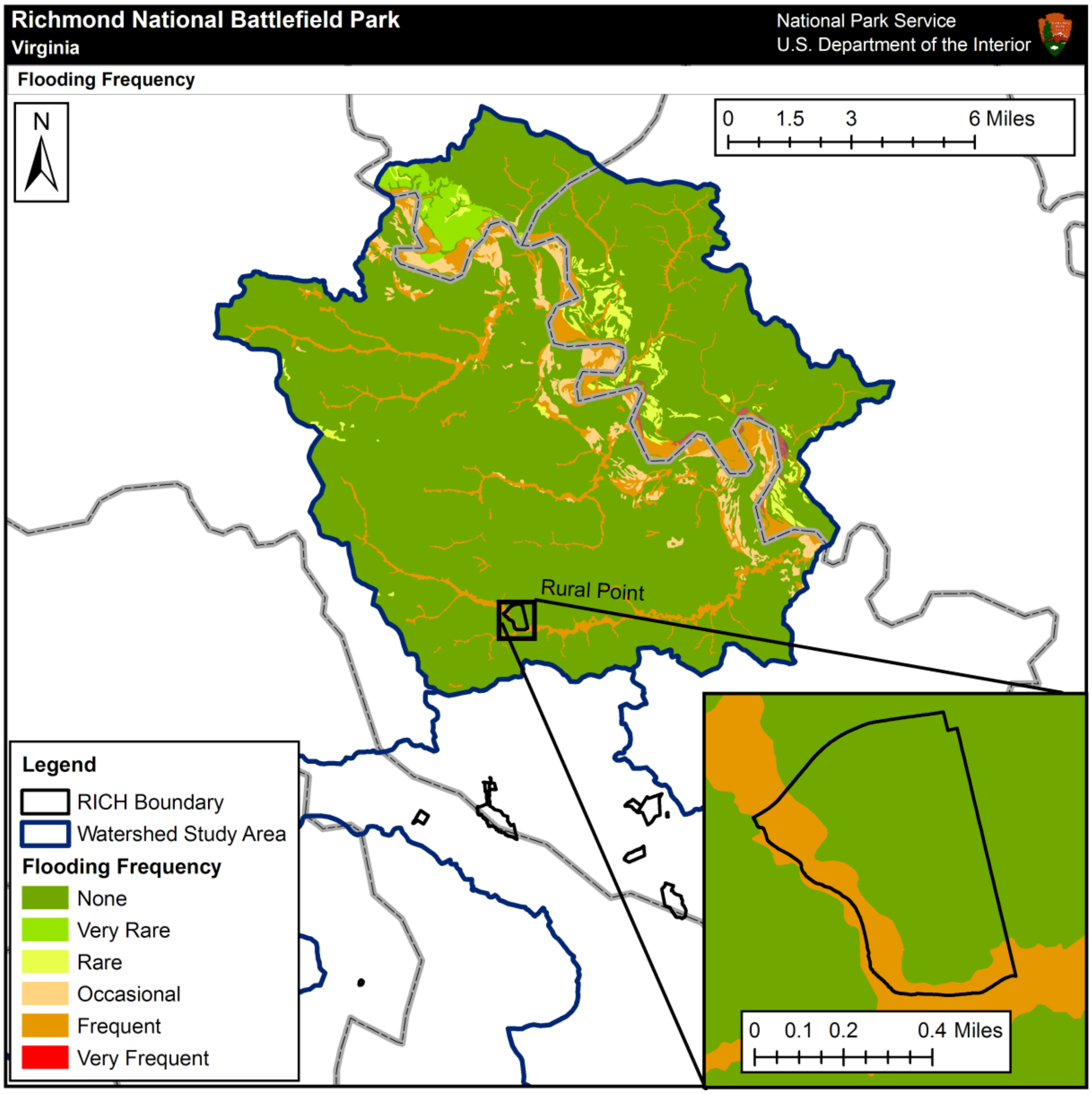

Figure 105. Flooding frequencies according to soil characteristics in the watershed study area and at Totopotomoy Creek (Rural Point).

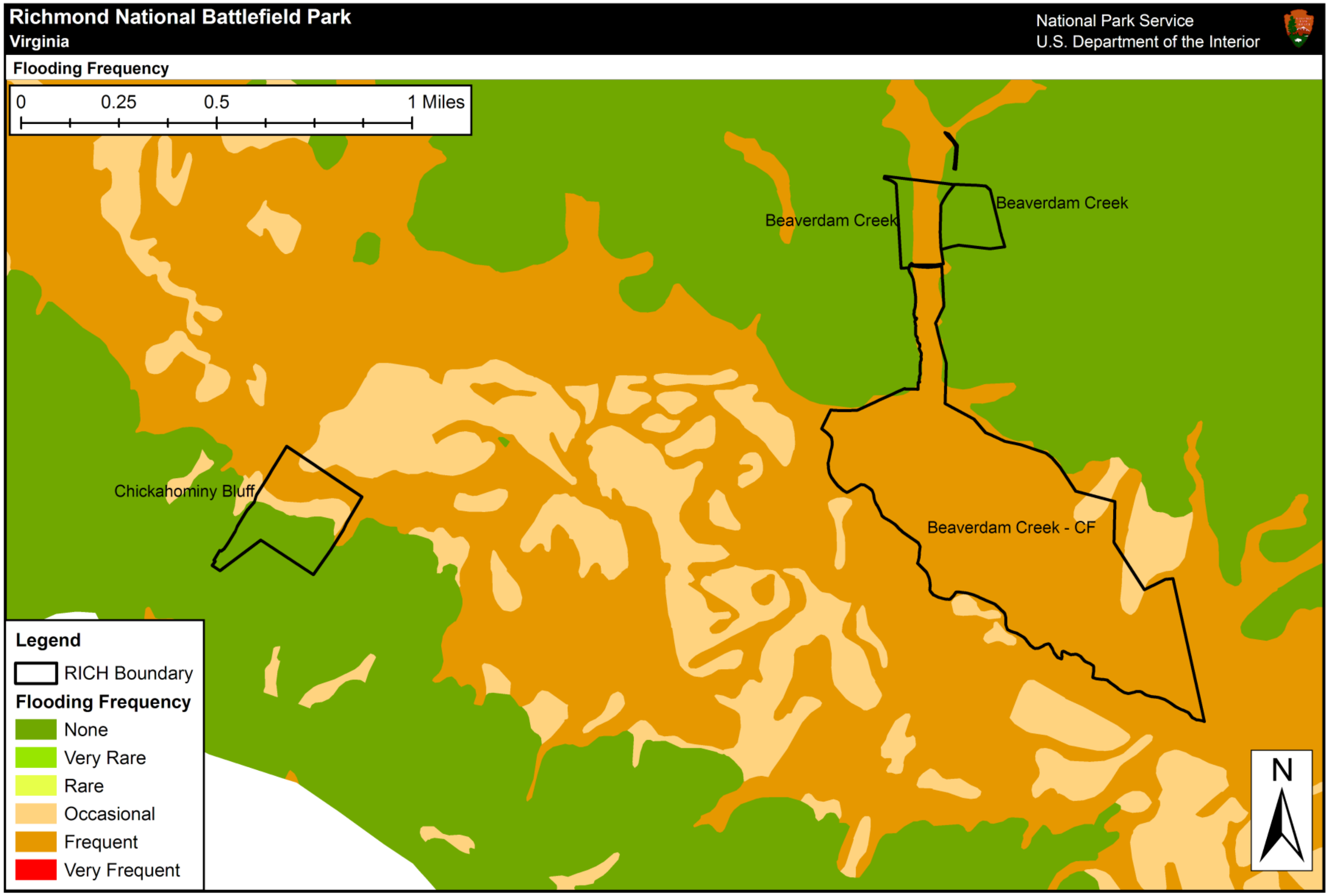

Figure 106. Flooding frequencies according to soil characteristics at Chickahominy Bluff and Beaver Dam Creek.

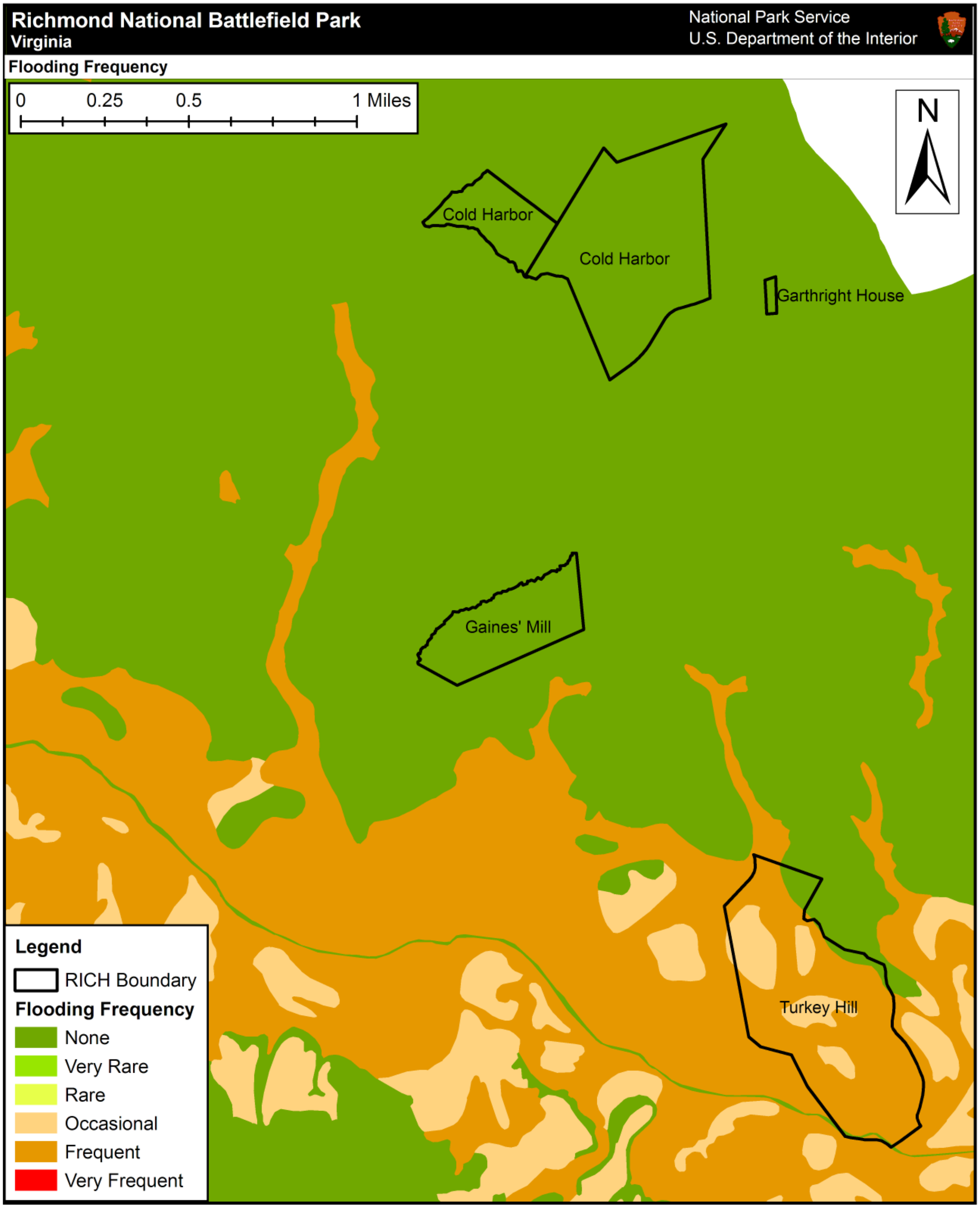

Figure 107. Flooding frequencies according to soil characteristics at Cold Harbor, Garthright House, Gaines' Mill, and Turkey Hill.

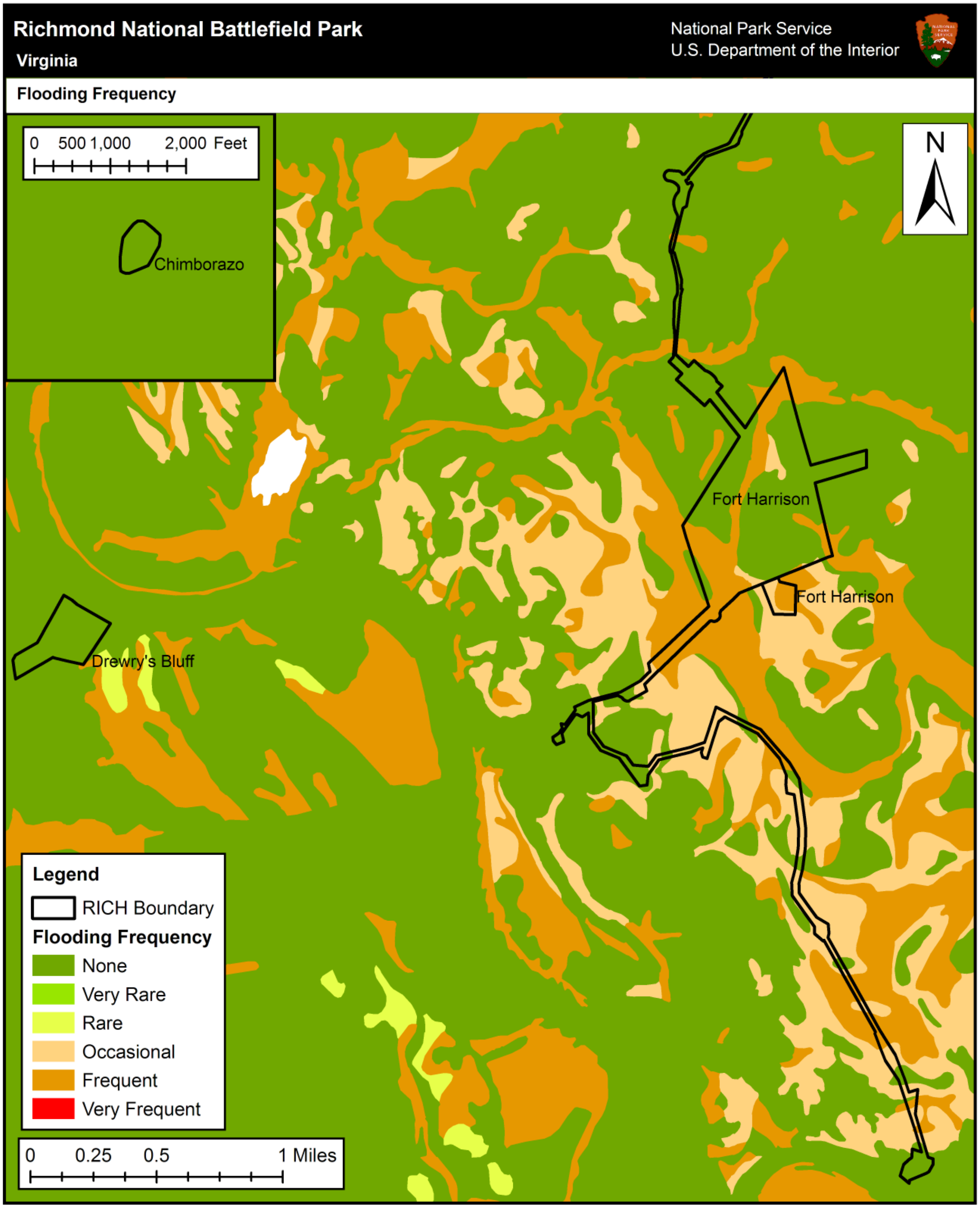

Figure 108. Flooding frequencies according to soil characteristics for Drewry's Bluff, Fort Harrison, and Chimborazo.

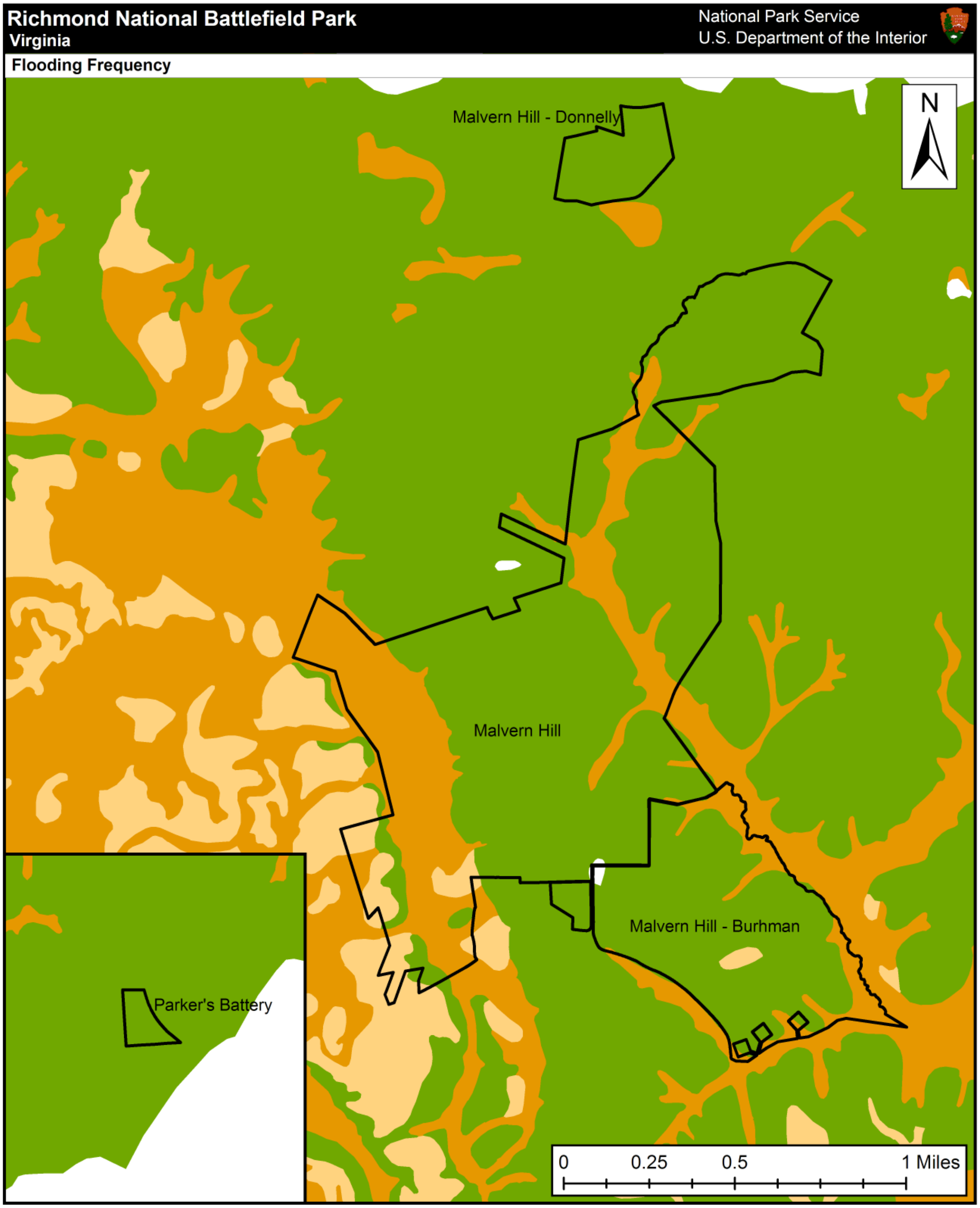

Figure 109. Flooding frequencies according to soil characteristics for Malvern Hill and Parker's Battery.

Soil Acidity and Chemistry

Soil acidity, pH, aluminum saturation, cation exchange capacity, and base saturation values are useful values to examine. Soil acidity is determined largely by soil composition and chemical reactions. The development or accumulation of soil acidity usually parallels the weathering sequence in which aluminum (Al) is released and accumulates in the soil, mainly as exchangeable Al^{3+} when soil pH < 5.5. pH is a measure of the reaction of the soil. Since the availability of most plant-essential elements depend on soil pH, it is also an indicator of the relative availability of plant nutrients (McLean 1982).

Extractable acidity at pH 8.2 is a good measure of the "potential" acidity. High values of potential acidity indicate a possible lowering of the soil pH as weathering and leaching continue. The KCl-extractable Al is more related to the immediate lime requirement and existing cation exchange capacity (CEC) of the soil. Aluminum saturation increases at pH values of 4.5 or less, and is an indication of the percent of the effective CEC that is due to the presence of aluminum. Aluminum is not considered an essential nutrient. The primary concern with Al is the possible toxic effects at high concentrations, especially in strongly acid subsoils (below pH 5.0). Plant sensitivity to Al is usually accentuated in soils low in Ca. Al toxicity reduces rooting depth and degree of root branching into the subsoil which is usually more apparent during stress periods, e.g., drought.

The effective CEC in acid soils is the measure of the total quantity of negative charges per unit weight of the material, measured as the sum of extractable bases plus KCl-extractable Al. The lower the effective CEC, the less able the soil to adsorb added lime and nutrients. Base saturation is the ratio of the quantity of extractable Ca^{2+}, Mg^{2+}, and K^{+} ions attached to soil particles compared to the cation exchange capacity of the soil. Base saturation is expressed as a percentage of available exchange sites occupied (USDA Natural Resource Conservation Service 1995).

Without actual values from the park, we cannot determine the needs or the hazards of the potential/actual acidity and liming needs. However, samples can be obtained and the status can be determined and compared to these measured values for interpretation purposes. A recommendation for liming and fertilization accompanies the soil nutrient sample results obtained from the Virginia Cooperative Extension Nutrient Analysis Lab at Virginia Tech in Blacksburg, VA. Sampling can be conducted sequentially to follow the progress in raising the soil pH in the major rooting zone to between 5.5 and 5.8. A higher pH in this range indicates essential soil nutrients are soluble and most available to plants.

Air Quality

Air quality directly impacts health, visibility, vegetation, surface waters, soils, and wildlife. The risk of foliar injury on vegetation is increased with high levels of ozone (Kohut 2007). Threats to the park's air quality include point sources, such as power plants and large industrial facilities located upwind. Emissions from such sources can travel hundreds of kilometers and influence the park's air quality. Additionally, development near the park could lead to an increase in vehicle traffic and its associated emissions that could impact the park's air quality. Additional air quality and climate data and information from the Air Resource Division (ARD) can be found in Appendices N and Oof this report.

In addition to human health, air pollution has also been shown to impact ecological health at National Park Service sites (National Park Service 2004, 2007). The NPS ARD has developed methods and reference values to evaluate air quality conditions important for natural resource planning and management (National Park Service 2007). The ARD approach to air quality assessment includes standard reference values for ozone, atmospheric (wet) deposition in the form of nitrogen and sulfur, and visibility. Based on certain criteria, these categories are given a score of “good,” “moderate,” or “significant concern.” We added total mercury as a recommended measurement based on NPS Northeast Region findings (National Park Service 2004).

Although Richmond NBP does not have air quality monitoring stations on-site, the ARD interpolates data from all available monitors in the region into 5-year averages (see Figure 110 for a map showing the nearest air quality monitoring stations). This document utilizes the most recent data interpolations from the 2004 – 2008 period. The NPS I&M Program is currently finalizing risk assessments to evaluate the threats from nitrogen deposition, acidic deposition, and mercury. These assessments will be available online in mid-2011 on the NPS ARD website (http://www.nature.nps.gov/air/) and will assist managers in determining what park resources are at risk from air pollution, and what type of air quality monitoring might be needed.

Ozone (O_3)

The ARD criterion for ozone utilizes the newly revised 2008 national standard for ozone air quality as a baseline. The national standard requires that the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 75 parts per billion (ppb) (U.S. Environmental Protection Agency 2009). In assessing air quality within national parks, the ARD recommends that if the interpolated 5-year average of the fourth-highest daily maximum 8-hour average ozone concentrations is greater than or equal to 76 ppb, then ozone is classified as a “significant concern” in the park. If the interpolated 5-year average is between 61 ppb and 75 ppb, concentrations greater than 80-percent of the national standard, then the park is classified as “moderate.” To receive a “good” ozone rating, a park must have a 5-year average ozone concentration less than 61 ppb (concentrations less than 80-percent of the national standard).

Ozone is formed when other pollutants, primarily nitrogen oxides and volatile organic compounds, react in the atmosphere in the presence of sunlight, usually during the warm summer months. Ozone causes considerable damage to vegetation throughout the world, including agricultural crops and native plants in natural ecosystems. The EPA has established an ozone standard to protect human health. EPA has adopted an identical standard to protect public

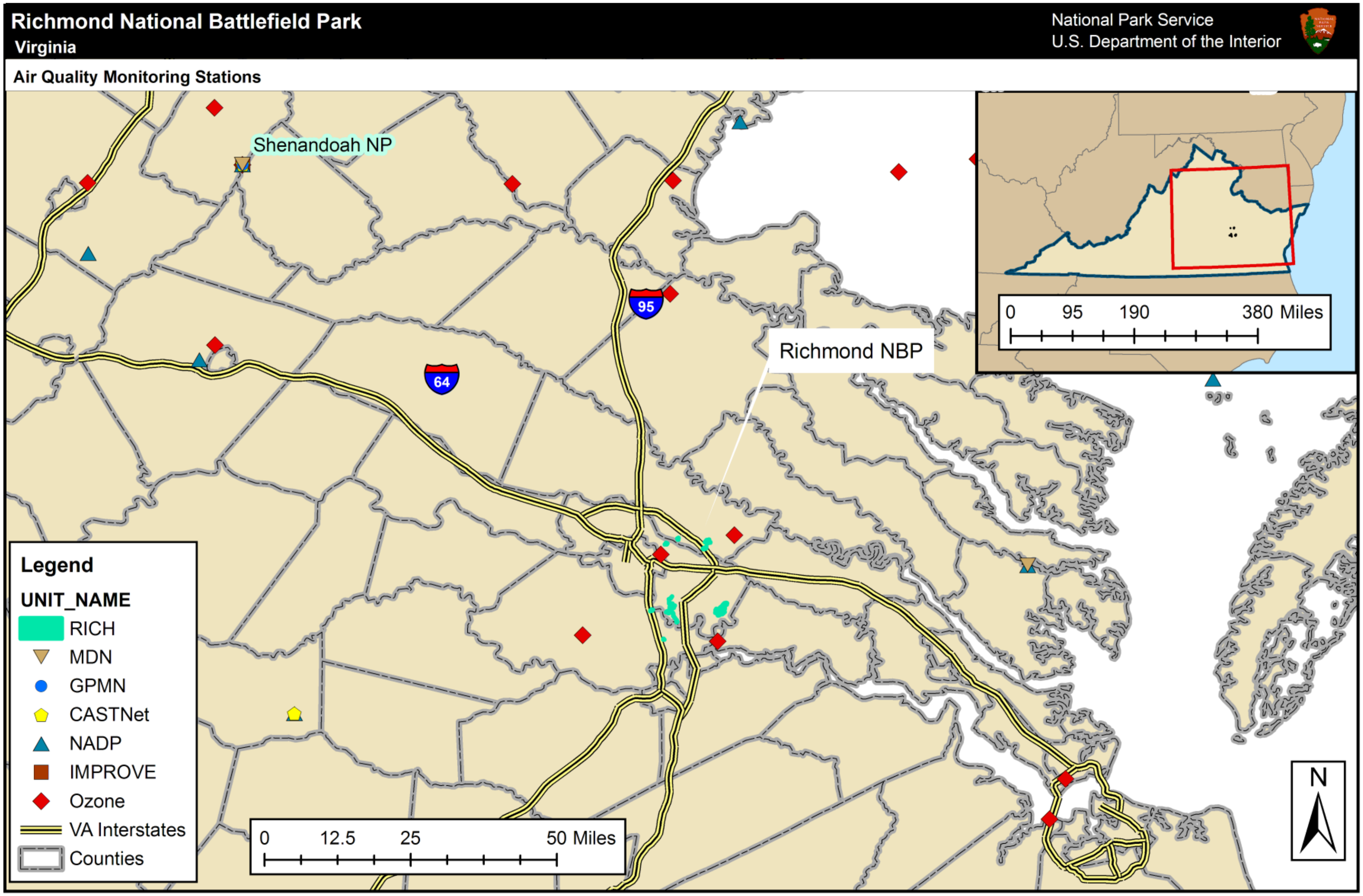

Figure 110. Air quality monitoring stations for Richmond NBP. Gaseous Pollutant Monitoring Network (GPMN), Clean Air Status and Trends Network (CASTNet), National Atmospheric Deposition Program (NADP), Mercury Deposition Network (MDN), and Interagency Monitoring of Protected Visual Environments (IMPROVE) are all represented.

welfare, including plants, from ozone effects. However, there is evidence to suggest that this standard, based on human health effects, is not protective of very sensitive plant species.

The 5-year (2003 – 2007) average ozone concentrations were 79.5 ppb, earning the parks a poor ozone condition status rating (NPS 2009) (Table 67). The 2004 vegetation risk assessment indicated that the park is at moderate risk for plant injury, and the ARD consequently maintained the original ozone air quality condition status of "moderate."

Table 67. Air Resources Division ozone air quality condition classifications and corresponding condition status for this assessment.

Current Condition Ozone Concentration (ppb)	Condition Status
≥ 76	Poor
61 – 75	Fair
≤ 60	Good

[1]The Air Resources Division ozone air quality condition classifications are as follows: significant concern, moderate concern, and good condition.

Atmospheric Deposition

Atmospheric deposition is the process by which airborne pollutants are deposited to the earth. These pollutants include, but are not limited to, sulfur dioxide, nitrogen oxides, ammonia, and mercury. Total deposition consists of both wet and dry components. Wet deposition occurs when pollutants are deposited in combination with precipitation, predominantly by rain and snow, but also by clouds and fog.

Sulfur dioxide (SO_2) originates mostly from coal combustion and causes respiratory irritation. It also contributes to acid rain and particle formation. The reference value for acceptable SO_2 is set by the National Ambient Air Quality standards (NAAQS) at 0.033ppm for the annual arithmetic mean (U.S. Environmental Protection Agency 2008b).

Nitrogen dioxide (NO_2) is a brownish gas that is generated during high-temperature combustion. It is a member of a family of chemicals called nitrogen oxides, or NO_x. Major sources of NO_x include coal-fired power plants, industrial boilers, and motor vehicles. Like ozone, it causes respiratory irritation. It is also important because it can react to form ozone and particles, contribute to acid rain, deposit into waterbodies and upset the nutrient balance, and degrade visibility. The reference value for acceptable NO_2 is set by the National Ambient Air Quality standards (NAAQS) at 0.053ppm for an 8-hour average, not to be exceeded more than once per year (U.S. Environmental Protection Agency 2008b).

Atmospheric deposition at Richmond NBP is classified as a "significant concern" or "poor" condition status rating (Table 68). The total wet nitrogen deposition at Richmond NBP is estimated at 4.19 kg/ha/yr, and the total estimated wet sulfur deposition is 5.20 kg/ha/yr (NPS 2009). There is no current information to indicate whether ecosystems at Richmond NBP are sensitive to nitrogen or sulfur deposition, but deposition is elevated. Nitrogen deposition, in particular, may affect the integrity of vegetation communities at Richmond NBP because excess nitrogen has been found to encourage growth of invasive plant species at the expense of native species.

Table 68. Air Resources Division wet deposition condition classifications and corresponding condition status for this assessment. The wet deposition values refer to either nitrogen or sulfur individually, not the sum of the two.

Current Condition Wet Deposition (kg/ha/yr)	Condition Status[1]
> 3	Poor
1 – 3	Fair
< 1	Good

[1]Air Resources Division wet deposition condition classifications are as follows: significant concern, moderate concern, and good condition.

Visibility

The enjoyment and appreciation of the unique features of our national parks are linked to one's ability to see clearly through the atmosphere. Small particles suspended in the atmosphere, mostly as a result of human-caused air pollution, often create haze that lessens the visitor's national park experience. The visibility condition status rating at Richmond NBP is classified as a “significant concern” or “poor” because the current visibility is 13.1 deciviews (dv) above estimated natural conditions (National Park Service Air Resource Division 2009).

Parks with a visibility condition estimate of less than two dv above estimated natural conditions receive a “good” visibility condition classification. Those parks with visibility condition estimates between two and eight dv above natural conditions are classified as “moderate,” and parks with visibility condition estimates greater than eight dv above natural conditions are classified as a “significant concern.” While the dv ranges for each category are somewhat subjective, they reflect as nearly as possible the variation in visibility conditions across the visibility monitoring network.

As illustrated in Table 69, parks with a visibility condition estimate of less than two dv above estimated natural conditions receive a “good” visibility condition classification. Those parks with visibility condition estimates between two and eight dv above natural conditions are classified as “moderate,” and parks with visibility condition estimates greater than eight dv above natural conditions are classified as a “significant concern.” While the dv ranges for each category are somewhat subjective, they reflect as nearly as possible the variation in visibility conditions across the visibility monitoring network.

Table 69. Air Resources Division visibility condition classifications and corresponding condition status for this assessment.

Visibility Condition - Current Status Relative to Natural Background (dv)[1]	Condition Status[2]
> 8	Poor
2 – 8	Fair
< 2	Good

[1]This is based on the deviation of the current Group 50 visibility conditions from the estimated Group 50 natural background conditions, where Group 50 is defined as the mean of the visibility observations falling within the range from the 40th through the 60th percentiles.
[2]Air Resources Division visibility condition classifications are as follows: significant concern, moderate concern, and good condition.

Mercury

Total mercury is another specific wet-deposition category that has broad environmental implications and has been shown to be an important measurement to consider in the NPS Mid-Atlantic Network (National Park Service 2004). The Mercury Deposition Network (MDN) is a special NADP Network and has been measuring total mercury in precipitation since 1996, currently at more than 100 sites (National Atmospheric Deposition Program 2009). Mercury persists in the environment, accumulates in the food chain, and is a neurotoxin. This indicator is especially important measurement of fish and wetland-feeding species (i.e. loons, pelicans, eagles, and otters) health. Mercury is also of great concern to human health, especially pregnant women (National Atmospheric Deposition Program 2009).

If Richmond NBP measures mercury levels in the future, a recommended reference value for mercury concentrations in rain and snow is 2-3 ng/L (Meili et al. 2003). This is based on an estimate of natural background mercury concentrations in precipitation (i.e. levels estimated to occur in the absence of anthropogenic influences). This value is not specifically linked to effects in biota in the park, as those reactions are much more complex and ecosystem specific. More site specific information would need to be identified and evaluated to address ecosystem risk or effects from current mercury input levels at Richmond NBP. In areas with high mercury methylating potential, even low concentrations or deposition may cause significant and harmful ecosystem effects.

Due to the difficulty in rating mercury levels at the park level, mercury was not included in the overall rating of air quality in this assessment. There are a variety of factors that make it difficult to rate mercury concentrations or deposition in parks. It is much more difficult to set target values for mercury deposition rates, as deposition rates are highly influenced by precipitation amounts.

Concentrations in rainwater for the state of Virginia range from 8.0 to 8.9 ng/L (National Atmospheric Deposition Program 2009). A 2004 report (National Park Service 2004) found that wet mercury deposition is higher in the eastern U.S. than in the western U.S. No specific mercury data was reported for the closest MDN site in Shenandoah NP, although it was stated that this site has been operating since 2002 so trends could not be calculated. Additionally, monitoring may not be adequate for Richmond NBP because the Shenandoah NP MDN monitoring location is approximately 160 kilometers away (National Park Service 2004). A complete summary of the air quality condition assessment is contained within Table 70.

Table 70. Current air quality values compared to reference values at Richmond NBP for natural resource management and planning.

MIDN Vital Sign / Indicator	Threshold Criteria	Current Condition	Comments
Ozone concentration (ppb)	< 60 ppb = Good 61-75 ppb = Fair > 76 ppb = Poor	79.5 ppb (Poor)	For the period 1996 – 2005, ozone concentrations, nitrogen and sulfur deposition, and visibility in the Mid-Atlantic appear to remain relatively unchanged.
Wet Deposition (kg/ha/yr)	< 1 kg/ha/yr = Good 1 – 3 kg/ha/yr = Fair > 3 kg/ha/yr = Poor	Sulfur: 5.2 kg/ha/yr (Poor) Nitrogen: 4.2 kg/ha/yr (Poor)	
Visibility Condition – Current Status Relative to Natural Background (dv)	< 2 = Good 2-8 = Fair > 8 = Poor	13.1 dv (Poor)	
Mercury deposition	Mercury concentrations in rain and snow is 2-3 ng/L	Unknown	If Richmond NBP measures mercury levels in the future, a recommended reference value for mercury concentrations in rain and snow is 2-3 ng/L (Meili et al. 2003).

Visitor and Recreation Use

The National Park Service was established to provide for its visitors. The NPS mission is to "preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations." In fact, the top guiding principle to accomplish this mission is excellent service for park visitors and partners (National Park Service 2008b). Visitors are no doubt the primary reason the NPS exists and continues to be an important part of this country.

Visitor and recreation use, however, has been shown to negatively affect the other half of the NPS mission, which is to protect natural and cultural resources. Several studies have shown a negative correlation between outdoor recreation and the various natural resources covered in this assessment (Taylor and Knight 2003, Wood et al. 2006, Park et al. 2008). As visitation to parks increases, these two parts of the mission often work against each other.

The number of visitors per year at Richmond NBP increased steadily from 1944 to 1971 where it peaked at approximately 481,300 visitors (National Park Service 2009b). The next 15 years dropped down to around 300,000 visitors per year until it peaked again in 1991 at 475,786 visitors. In 1993 the number of visitors dropped steeply to under 100,000 visitors per year, and stayed fairly consistent since (Figure 111). Visitation to Richmond NBP appears to coincide with the seasons, with peaks occurring in the spring and summer months, particularly April-July (Figure 112). Richmond NBP ranked 205th out of 360 in most visited National Parks in 2008 (National Park Service 2009b).

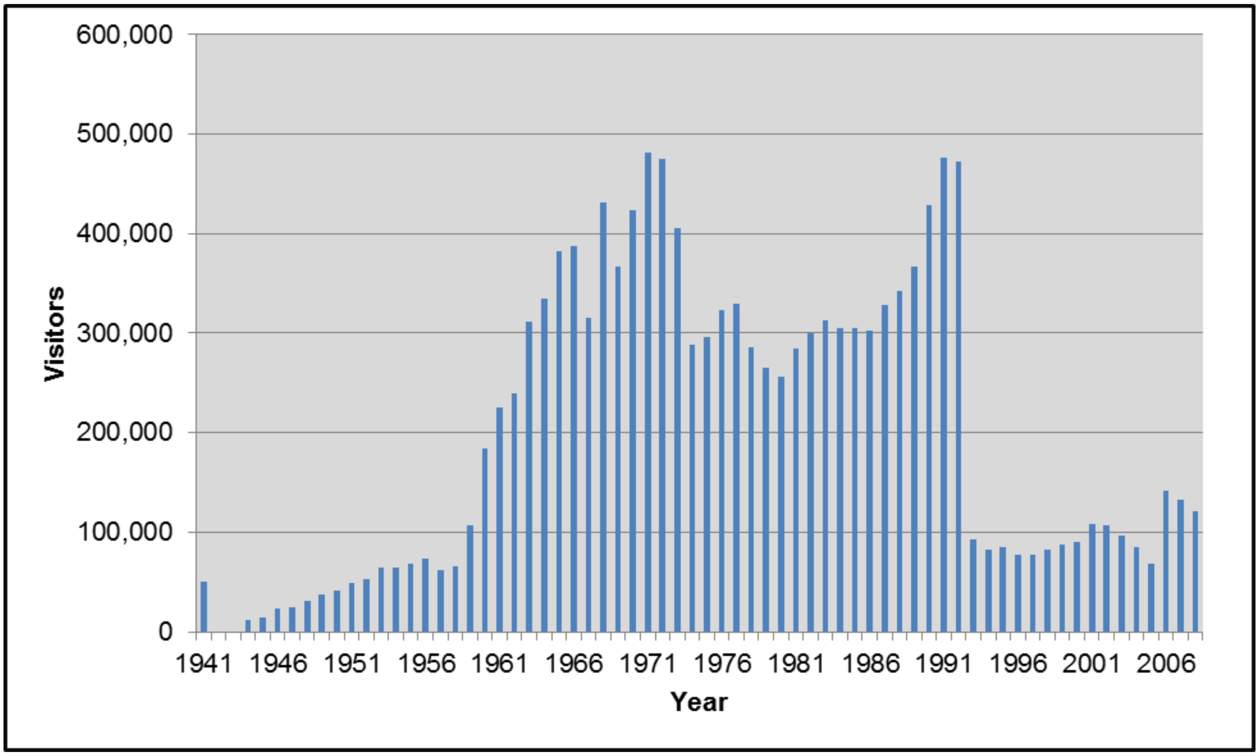

Figure 111. Number of visitors per year to Richmond NBP (1941 to 2008).

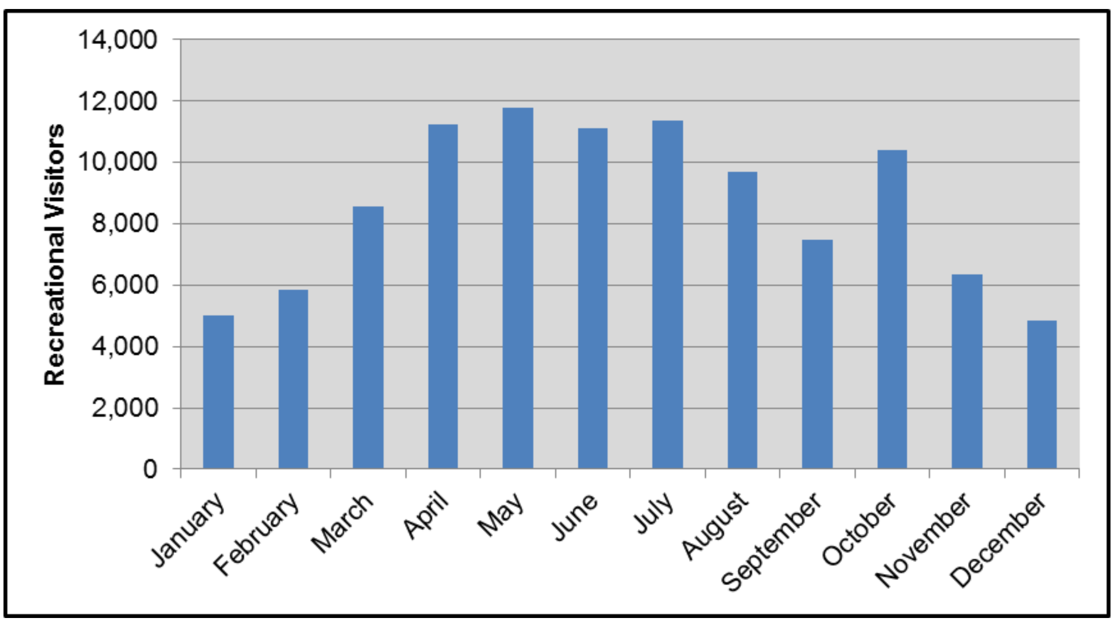

Figure 112. Average monthly visitors to Richmond NBP (1999 – 2008).

Richmond NBP for a thirty year stretch had over 250,000 visitors annually, from 1963 to 1992. The recreational visitors reached over 400,000 for eight of those years. Since 1992 however the park has only had more than 100,000 visitors five times, averaging fewer than 96,000 from 1993 to 2008. It is unclear why the number of recreational visitors decreased so steeply after the high levels in 1992 and remained so low since. The park is attempting to raise visitation levels with implementing the 2007 Richmond NBP Centennial Strategic plan. This document sets a series of goals to accomplish in the next 10 years relating to stewardship, environment, recreation, education, and professionalism. A few of the more pertinent goals are increasing visitation by 10% through collaboration with state and local tourism agencies, increasing the amount of school children attending special programs, and establishing and maintaining new trails. The park already has different education programs and activities for visitors posted on the Richmond NBP website which may attract repeat visitors. Visitors spend an average of 0.54 hours at each unit (Table 71).

Table 71. Average time spent at popular destinations of Richmond NBP (National Park Service 2009b).

Location	Average Length of Stay (1995- present)
Chimborazo Visitor Center	0.50 hours
Fort Harrison	0.75 hours
Fort Brady	0.40 hours
Cold Harbor	0.75 hours
Fort Darling	0.50 hours
Chickahominy Bluff	0.40 hours
Malvern Hill	0.25 hours
Parker's Battery	1.0 hour
Gaines' Mill	0.33 hours

Viewscape

It is important for visitors to experience Richmond NBP in its historical context. Unobstructed views and concealing sounds of modern life are important factors for visitors to have an enjoyable experience. Specifically for cultural parks, open areas were historic battles took place are significant areas to protect. Richmond NBP is facing expanding developments along park boundaries and/or in the viewshed.

For this assessment, observation points were analyzed in a GIS and 360 degree views of the surrounding landscape were examined. We buffered the provided Richmond NBP viewshed observer points to 50-mile radius. A viewshed analysis was completed over a curved surface for the 50-mile buffer area using park observer points and 10-meter National Elevation Dataset (NED). The Richmond NBP vegetation map was merged with the surrounding NLCD land cover map. We then calculated the percentage of raster cells visible from park observer points that are anthropogenic cover types. The final result show only 6% of viewshed is anthropogenic cover (Figure 113). The results of this study can be used to consider boundary adjustments for planning in the GMP for the most heavily visited areas of the park.

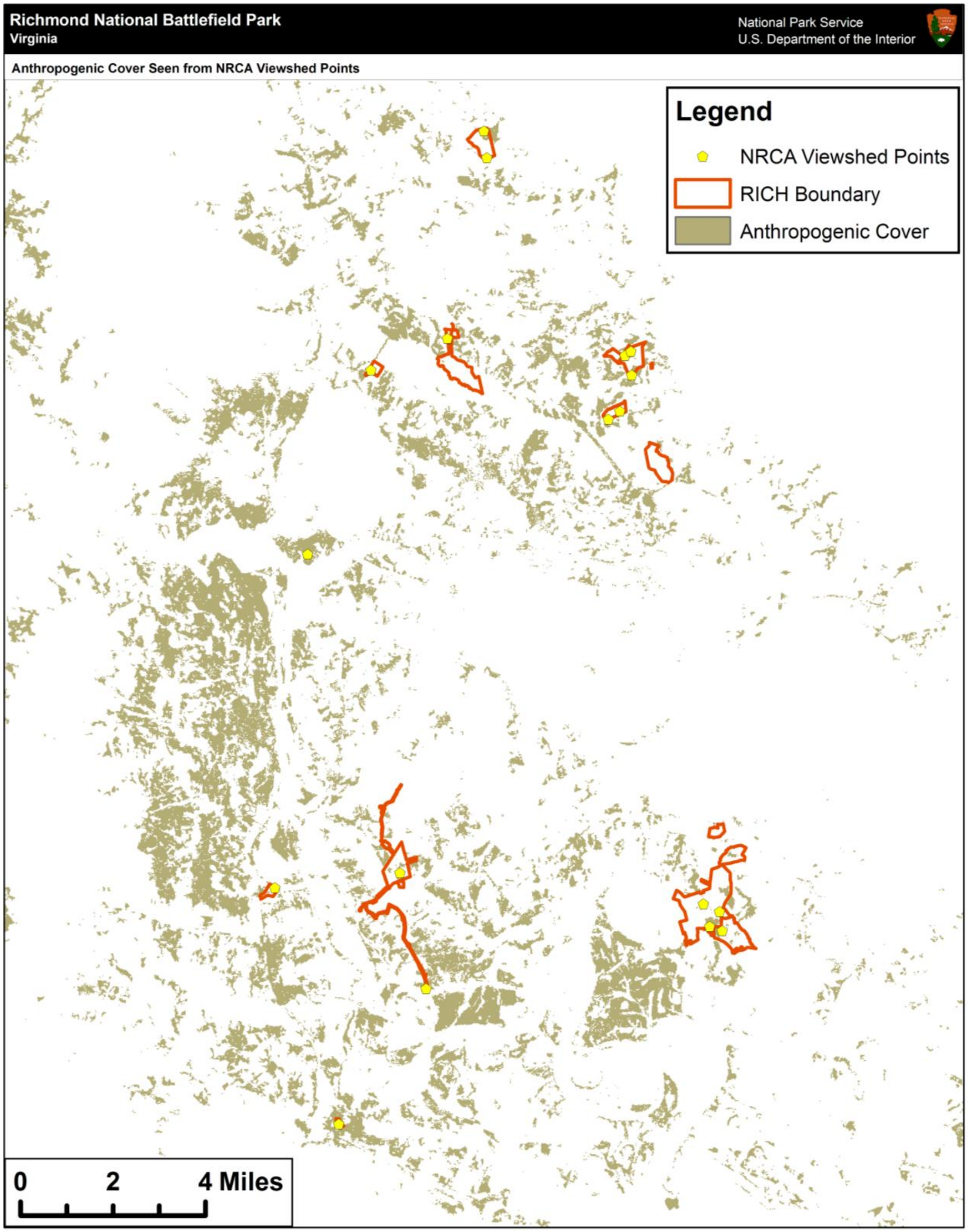

Figure 113. Anthropogenic cover seen from NRCA viewshed points.

Soundscape

The National Park Service aims to preserve and/or restore the natural resources within parks; this also includes the soundscape. Culturally appropriate sounds are important elements of the national park experience and are even more so in cultural parks. While natural and culturally relevant sounds enhance visitors' experience, sounds associated with modern day life are usually unwanted, uncharacteristic, and inappropriate can interfere with the visitors' experience. Visitors commonly notice many noises such as aircraft, cell phones, vehicles, and noises associated with park operations. In recent years, the number of airplanes and helicopters flying over national park units has increased dramatically (http://www.nature.nps.gov/naturalsounds/).

The configuration of Richmond NBP, with scattered units in a highly urbanized area, makes managing for noise very difficult. Future acoustical monitoring for baseline conditions can be useful to park managers at Richmond NBP. Managers can identify specific issues related to each unit and establish acceptable levels and impacts. Areas of the park where unnatural sound has a higher probability of impacting visitors should be noted. Frequencies, magnitudes, and durations will vary throughout the units and it is important to note if those areas are also popularly visited areas.

Condition Status Summary for Park-wide Resources

Trends cannot be evaluated from the interpolated 5-year averages utilized by the ARD. However, the NPS ARD evaluates 10-year trends in air quality for parks with on-site or nearby monitoring. Maps in the most recently available progress report show trends in ozone, deposition, and visibility that can be used to discern regional trends (National Park Service 2007). For the period 1996 – 2005, ozone concentrations, nitrogen and sulfur deposition, and visibility in the Mid-Atlantic appear to remain relatively unchanged. From the environmental and natural resource management perspective, air quality at Richmond NBP is poor overall (National Park Service 2008a). Wet Deposition and visibility both ranked as poor. A 2004 risk assessment determined that the ozone threat to vegetation at Richmond NBP is moderate. Risk of plant injury is moderate because the soil moisture values that prevail during periods of high ozone exposure are frequently not sufficient to limit stomatal uptake of ozone (National Park Service 2004).

The NPS I&M Program is currently conducting risk assessments to evaluate the threats from several sources. The assessments will evaluate nitrogen deposition (complete in late 2009), acidic deposition from nitrogen and sulfur (complete in 2010), and mercury deposition (complete in 2010) in national parks. These I&M assessments will be available on the NPS ARD website and will assist managers in determining what park resources are at risk from air pollution, and what type of air quality monitoring might be needed.

Trends for soils, soundscape, and visitor use (as it relates to natural resources) could not be evaluated due to lack of long-term data or data relevant to natural resources and these metrics were assessed as "unknown."

9.0 Natural Resource Condition Assessment Summary

Based upon available data, most of the natural resources at Richmond NBP appear to be in good condition. Despite the level of urbanization and the threats and stressors resulting from it, the natural resources found within the units of the Richmond NBP are considerable. The majority of the park land is forested and provides benefits as wildlife habitat, water quality, and erosion control. Encroachment of development, increased traffic, vehicle emissions, and other industrial development near the park are arguably the most important and constant threats and stressors the park must consider. Development may lead to increasing point and non-point source pollution, affecting air and water quality. In-park biological integrity may also be stressed from these outside influences.

The proportion of non-natural vegetation within the park is low. The amount of forest cover is also rated as good for all units evaluated. No forest pests have been detected at the park since monitoring began in 2007. However, nonnative exotic plant species have been found at the majority of forest monitoring plots. Managers are currently managing cool-season grasslands with prescribed fire to promote native, warm-season grasses. Additional treatment and data are needed to determine if desired condition for grasslands have been met. An increasing trend in white-tailed deer density was one of the few trends that could be evaluated for this assessment.

Over 50% of the species expected to be found at Richmond NBP were observed during initial MIDN I&M surveys. Larger units such as Malvern Hill, Fort Harrison, Beaver Dam Creek, and Turkey Hill had the highest species richness. However, the assessment of faunal species is based on data greater than five years old.

Wetland and riparian areas were rated as good. Most wetland buffers were rated as good and exhibit connectivity with adjacent natural systems. However, dated information and irregular monitoring were significant impediments to a thorough assessment of water quality in and around Richmond NBP. Air quality was rated poor; though air quality and water quality are generally areas outside of the park's control.

Trend data was lacking for this assessment for the majority of metrics. Future MIDN I&M programs will focus on establishing trends for water quality, forest pests, exotic plant species, and faunal communities. Richmond NBP certainly faces many natural resource management challenges as a fragmented park in an urban landscape. This makes the protected habitats within the units an important refuge for a variety of faunal species. Richmond NBP also contains three Virginia Natural Heritage exemplary natural communities. Though these areas are small they are ecologically important and should be managed with care.

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Appendix A. Data quality.

We provide a data quality rating based on three categories, *thematic*, *spatial*, and *temporal* (Table A-1). We gave *thematic* a 1 or 0 (yes or no) based on whether these data were from the best available source. Ratings for thematic data varied by each case and are explained in the corresponding section. *Spatial* received a 1 or 0 based on the spatial proximity of these data (in-park data or out-of-park data). We also gave *temporal* a 1 or 0 based on how recently these data were acquired. *Temporal* was somewhat dependent on data type, but generally, if the data were from the last five years, they received a 1. The data quality values were averaged, and an overall rating is given for the data quality (good = 2.67 to 3; fair = 1.34 to 2.66; and poor = 0 to 1.33).

These indicators and measures were selected among the recommendations made by Fancy et al. (2009), the MIDN vital signs (Comiskey and Callahan 2008), preliminary scoping meeting with NPS personnel, and follow-up communication.

Table A-1. Data quality was rated based on *thematic* (1 = best source; 0 = not the best source), s*patial* (1 = inside park boundary; 0 = outside park boundary), and *temporal* (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	**Spatial**	**Temporal**
Indicator A	*Measure A*	1	0	0
		1 out of 3		
Indicator B	*Measure B*	1	1	0
		2 out of 3		
Indicator C	*Measure C*	1	1	1
		3 out of 3		
Average		1	0.7	0.3
Sum of Average		2 out of 3		

Table A-2. Condition status scoring system for Richmond NBP Natural Resource Assessment.

Condition Status	Range	Condition Score
Good	0.67 – 1.00	0.84
Fair	0.34 – 0.66	0.5
Poor	0.00 – 0.33	0.17

The following are data quality scores for measures assessed in the NRCA:

Table A-3. Biological integrity condition status data summary for all units at Richmond NBP. Data quality was rated based on *thematic* (1 = best source; 0 = not the best source), *spatial* (1 = inside park boundary; 0 = outside park boundary), and *temporal* (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Fish	Jaccard's Index of Similarity	1	1	0
		2 out of 3		
Amphibians	Jaccard's Index of Similarity	1	1	0
		2 out of 3		
Reptiles	Jaccard's Index of Similarity	1	1	0
		2 out of 3		
Birds	Jaccard's Index of Similarity	1	1	0
		2 out of 3		
	BBS community trends	1	0	1
		2 out of 3		
Mammals	Jaccard's Index of Similarity	1	1	0
		2 out of 3		
Biological Integrity Average		1.97 out of 3		

Table A-4. Water resources condition status summary for the Beaver Dam Creek unit of Richmond NBP. Data quality was rated based on *thematic* (1 = best source; 0 = not the best source), *spatial* (1 = within the park boundary; 0 = outside park boundary), and *temporal* (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	1
		3 out of 3		
	pH	1	1	1
		3 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	N/A		
	Fecal Coliform	N/A		
Macroinvertebrates	CPMI	1	1	1
		3 out of 3		
Water Resources Average		2.75 out of 3		

Table A-5. Water resources condition status summary for the Chickahominy Bluff unit of Richmond NBP. Data quality was rated based on *thematic* (1 = best source; 0 = not the best source), *spatial* (1 = within the park boundary; 0 = outside park boundary), and *temporal* (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	1
		3 out of 3		
	pH	1	1	1
		3 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	N/A		
	Fecal Coliform	0	1	1
		2 out of 3		
Macroinvertebrates	CPMI	1	1	1
		3 out of 3		
Water Resources Average		2.6 out of 3		

Table A-6. Water resources condition status summary for the Cold Harbor unit of Richmond NBP. Data quality was rated based on thematic (1 = best source; 0 = not the best source), spatial (1 = within the park boundary; 0 = outside park boundary), and temporal (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	1
		3 out of 3		
	pH	1	1	1
		3 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	0	1	1
		2 out of 3		
	Fecal Coliform	0	1	1
		2 out of 3		
Macroinvertebrates	CPMI	1	1	1
		3 out of 3		
Water Resources Average		2.5 out of 3		

Table A-7. Water resources condition status summary for the Drewry's Bluff unit of Richmond NBP. Data quality was rated based on thematic (1 = best source; 0 = not the best source), spatial (1 = within the park boundary; 0 = outside park boundary), and temporal (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	1
		3 out of 3		
	pH	1	1	0
		2 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	N/A		
	Fecal Coliform	0	1	1
		2 out of 3		
Macroinvertebrates	CPMI	1	1	1
		3 out of 3		
Water Resources Average		2.4 out of 3		

Table A-8. Water resources condition status summary for the Fort Harrison unit of Richmond NBP. Data quality was rated based on thematic (1 = best source; 0 = not the best source), spatial (1 = within the park boundary; 0 = outside park boundary), and temporal (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	0
		2 out of 3		
	pH	1	1	0
		2 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	N/A		
	Fecal Coliform	0	1	1
		2 out of 3		
Macroinvertebrates	CPMI	N/A		
Water Resources Average		2.0 out of 3		

Table A-9. Water resources condition status summary for the Gaines' Mill unit of Richmond NBP. Data quality was rated based on thematic (1 = best source; 0 = not the best source), spatial (1 = within the park boundary; 0 = outside park boundary), and temporal (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	1
		3 out of 3		
	pH	1	1	1
		3 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	0	1	1
		2 out of 3		
	Fecal Coliform	0	1	1
		2 out of 3		
Macroinvertebrates	CPMI	1	1	1
		3 out of 3		
Water Resources Average		2.5 out of 3		

Table A-10. Water resources condition status summary for the Malvern Hill unit of Richmond NBP. Data quality was rated based on thematic (1 = best source; 0 = not the best source), spatial (1 = within the park boundary; 0 = outside park boundary), and temporal (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	1
		3 out of 3		
	pH	1	1	1
		3 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	0	1	1
		2 out of 3		
	Fecal Coliform	0	1	1
		2 out of 3		
Macroinvertebrates	CPMI	1	1	1
		3 out of 3		
Water Resources Average		2.5 out of 3		

Table A-11. Water resources condition status summary for the Turkey Hill unit of Richmond NBP. Data quality was rated based on thematic (1 = best source; 0 = not the best source), spatial (1 = within the park boundary; 0 = outside park boundary), and temporal (1 = recent; 0 = older than 5 years). The colors green, yellow, and red refer to good, fair, and poor scores respectively.

Indicator	Measure	Data Quality		
		Thematic	Spatial	Temporal
Stream Condition	Dissolved Oxygen	1	1	0
		2 out of 3		
	pH	1	1	0
		2 out of 3		
	Temperature	1	1	0
		2 out of 3		
	E. coli	N/A		
	Fecal Coliform	0	1	1
		2 out of 3		
Macroinvertebrates	CPMI	N/A		
Water Resources Average		2.0 out of 3		

Appendix B. Land cover calculation methods.

We used “Extract by Mask” in ArcToolbox (ESRI 2006) to clip each land cover dataset to the study areas. In some cases we performed grid reclassification and relabeling of class name to simplify and to make the raster files that were produced more useable.

NOAA Coastal Change Analysis Program Classification Scheme (National Oceanic and Atmospheric Administration 2008):

Uplands

Consisting of areas above sea level where saturated soils and standing water are absent. Also, the hydrologic regime is not sufficiently wet to support vegetation associated with wetlands. Upland features are divided into classes such as High, Medium, Low Intensity Development, Cultivated land, Grassland, Pasture/ Hay, Barren land, Scrub/Shrub, Dwarf Shrub, Deciduous, Evergreen and Mixed Forest.

2- *Developed, High Intensity* – Includes highly developed areas where people reside or work in high numbers. Impervious surfaces account for 80 to 100 percent of the total cover.

Characteristic land cover features: Large commercial/industrial complexes and associated parking, commercial strip development, large barns, hangars, interstate highways, and runways.

3- *Developed, Medium Intensity* – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover.

Characteristic land cover features: Small buildings such as single family housing units, farm outbuildings, and large sheds.

4- *Developed, Low Intensity* – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 21 to 49 percent of total cover.

Characteristic land cover features: Same as Medium Intensity Developed with the addition of streets and roads with associated trees and grasses. If roads or portions of roads are present in the imagery they are represented as this class in the final land cover product.

5- *Developed, Open Space* – Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover.

Characteristic land cover features: Parks, lawns, athletic fields, golf courses, and natural grasses occurring around airports and industrial sites.

6- *Cultivated Crops* – Areas used for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

Characteristic land cover features: Crops (corn, soybeans, vegetables, tobacco, and cotton), orchards, nurseries, and vineyards.

7- ***Pasture/Hay*** – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

Characteristic land cover features: Crops such as alfalfa, hay, and winter wheat.

8- ***Grassland/Herbaceous*** – Areas dominated by graminoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Characteristic land cover features: Prairies, meadows, fallow fields, clear-cuts with natural grasses, and undeveloped lands with naturally occurring grasses.

9- ***Deciduous Forest*** – Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

Characteristic species: Maples (*Acer*), Hickory (*Carya*), Oaks (*Quercus*), and Aspen (*Populus tremuloides*).

10- ***Evergreen Forest*** – Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

Characteristic species: Longleaf pine (*Pinus palustris*), slash pine (*Pinus ellioti*), shortleaf pine (*Pinus echinta*), loblolly pine (*Pinus taeda*), and other southern yellow (*Picea*); various spruces and balsam fir (*Abies balsamea*); white pine (*Pinus strobus*), red pine (*Pinus resinosa*), and jack pine (*Pinus banksiana*); hemlock (*Tsuga canadensis*); and such western species as Douglas-fir (*Pseudotsuga menziesii*), redwood (*Sequoia sempervirens*), ponderosa pine (*Pinus monticola*), Sitka spruce (*Picea sitchensis*), Engelmann spruce (*Picea engelmanni*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*).

11- ***Mixed Forest*** – Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

Characteristic species: Those listed in 9 and 10.

12- ***Scrub/Shrub*** – Areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

Characteristic species: Those listed in 9 and 10 as well as chaparral species such as chamise (*Adenostoma fasciculatum*), chaparral honeysuckle (*Lonicera interrupta*), scrub oak (*Quercus beberidifolia*), sagebrush (*Artemisia tridentate*), and manzanita (*Arctostaphylos spp.*).

Wetlands

Areas dominated by saturated soils and often standing water. Wetlands vegetation is adapted to withstand long-term immersion and saturated, oxygen-depleted soils. These are divided into two salinity regimes: Palustrine for freshwater wetlands and Estuarine for saltwater wetlands. These are further divided into Forested, Shrub/Scrub, and Emergent wetlands. Unconsolidated Shores are also included as wetlands.

13- *Palustrine Forested Wetland* – Includes all tidal and nontidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.

Characteristic species: Tupelo (Nyssa spp.), Cottonwoods (*Populus deltoids*), Bald cypress (*Taxodium distichum*), American elm (*Ulmus americana*), Ash (*Fraxinus spp.*), and tamarack (Larix spp.).

14- *Palustrine Scrub/Shrub Wetland* – Includes all tidal and non tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. The species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions (Cowardin et al. 1979).

Characteristic species: Alders (*Alnus spp*.), willows (*Salix spp*.), buttonbush (*Cephalanthus occidentalis*), red osier dogwood *(Cornus stolonifera*), honeycup (*Zenobia pulverenta*), spirea (*Spiraea douglassii*), bog birch (*Betula pumila*), and young trees such as red maple (*Acer rubrum*) and black spruce (*Picea mariana*).

15- *Palustrine Emergent Wetland (Persistent)* – Includes all tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Plants generally remain standing until the next growing season. Total vegetation cover is greater than 80 percent.

Characteristic species: Cattails (*Typha spp*.), sedges (*Carex spp.*), bulrushes (*Scirpus spp.*), rushes (*Juncus spp*.), saw grass (*Cladium jamaicaense*), and reed (*Phragmites australis*).

16- *Estuarine Forested Wetland* – Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

Characteristic species: Red Mangrove (*Rhizophora mangle*), Black Mangrove (*Avicennia germinans*) and White Mangrove (*Languncularia racemosa*)

17- *Estuarine Scrub / Shrub Wetland* – Includes all tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

Characteristic species: Sea-myrtle (*Baccharis halimifolia*) and marsh elder (*Iva frutescens*).

18- *Estuarine Emergent Wetland* – Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Perennial plants usually dominate these wetlands. Total vegetation cover is greater than 80 percent.

Characteristic species: Cordgrass (*Spartina spp.*), needlerush (*Juncus roemerianus*), narrow leaved cattail (*Typha angustifolia*), southern wild rice (*Zizaniopsis miliacea*), common pickleweed (*Salicornia virginica*), sea blite (*Suaeda californica*), and arrow grass (*Triglochin martimum*).

19- *Unconsolidated Shore* – Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class.

Characteristic land cover features: Beaches, bars, and flats.

20- *Barren Land* – (rock/sand/clay) Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.

Characteristic land cover features: Quarries, strip mines, gravel pits, dunes, beaches above the high-water line, sandy areas other than beaches, deserts and arid riverbeds, and exposed rock.

21- *Open Water* – All areas of open water, generally with less than 25 percent cover of vegetation or soil.

Characteristic land cover features: Lakes, rivers, reservoirs, streams, ponds, and ocean.

Table B-1. Vegetation and land cover crosswalk (reclassifications) for C-CAP land cover and Richmond NBP vegetation map.

Vegetation Reclassification	C-CAP Class	Local Name (Vegetation Map)	Ecological Community
Natural Vegetation	Deciduous Forest	Acidic Oak - Hickory Forest	Upland Forest
		Coastal Plain Mixed Oak / Heath Forest	Upland Forest
		Forested Earthworks	Upland Forest
		Mesic Mixed Hardwood Forest	Upland Forest
		Successional Black Walnut Forest	Upland Forest
		Successional Tuliptree Forest	Upland Forest
	Estuarine Emergent Wetland		
	Estuarine Forest Wetland		
	Estuarine Shrub/Scrub Wetland		
	Evergreen Forest	Loblolly Pine Plantation	Upland Forest
		Successional Red-cedar Forest	Upland Forest
	Grassland		
	Mixed Forest	Loblolly Pine - Hardwood Forest	Upland Forest
	Palustrine Emergent Wetland	Beaver Wetland Complex	Wetland
		Coastal Plain / Piedmont Acidic Seepage Swamp	Wetland
	Palustrine Forested Wetland	Coastal Plain / Piedmont Small-Stream Floodplain Forest	Riparian Forest
		Non-Riverine Saturated Forest	Riparian Forest
		Non-Riverine Saturated Forest - pine subtype	Riparian Forest
	Palustrine Shrub/Scrub Wetland	Successional Shrub Swamp	Riparian Forest
	Shrub/Scrub	Successional Mixed Scrub	Upland Forest
Semi-natural Vegetation	Cultivated		
	Pasture/Hay	Cultural Meadow	Meadow/Field
	Developed Open Space		
Unnatural Vegetation	High Intensity Developed		
	Low Intensity Developed	Transportation, Communications, and Utilities	Built-up Land
		Open Earthworks	Built-up Land
		Residential	Built-up Land
	Medium Intensity Developed	Other Urban or Built-up Land	Built-up Land
Other	Bare Land		
	Unconsolidated Shore		
	Water		

Appendix C. Watershed level maps.

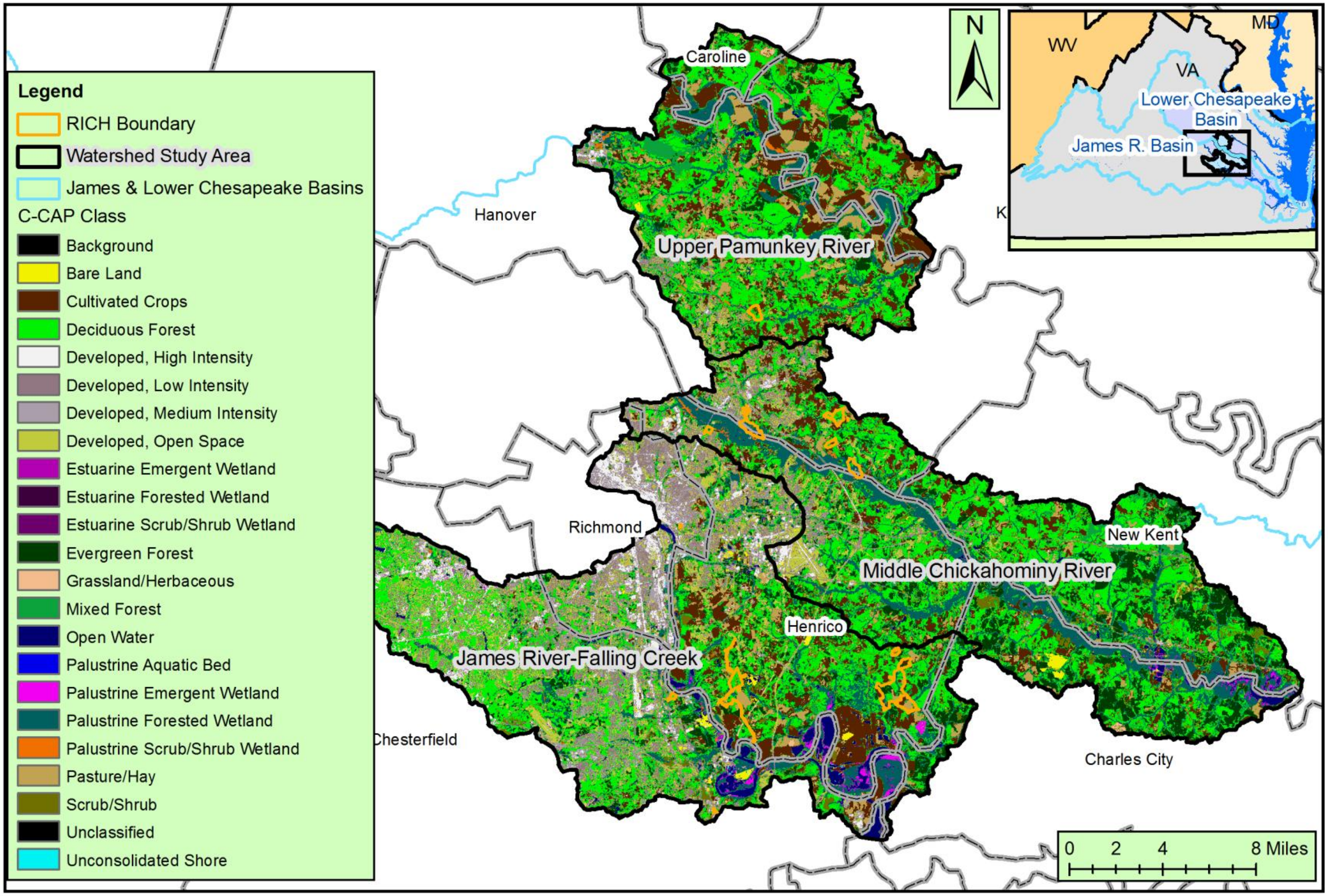

Figure C-1. 1996 Land cover (C-CAP) within the Richmond NBP (RICH) watershed study area and park detail.

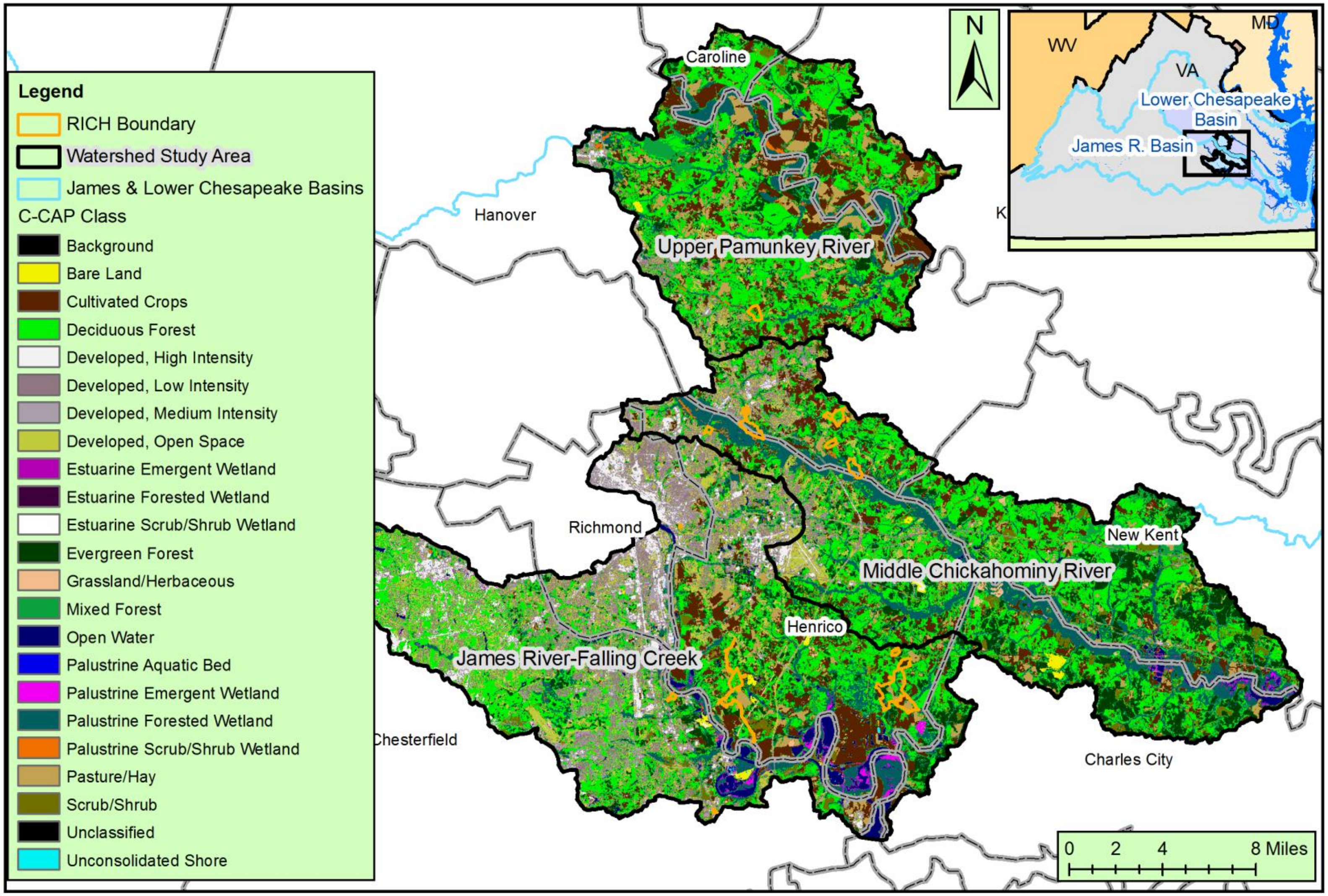

Figure C-2. 2001 Land cover (C-CAP) within the Richmond NBP (RICH) watershed study area.

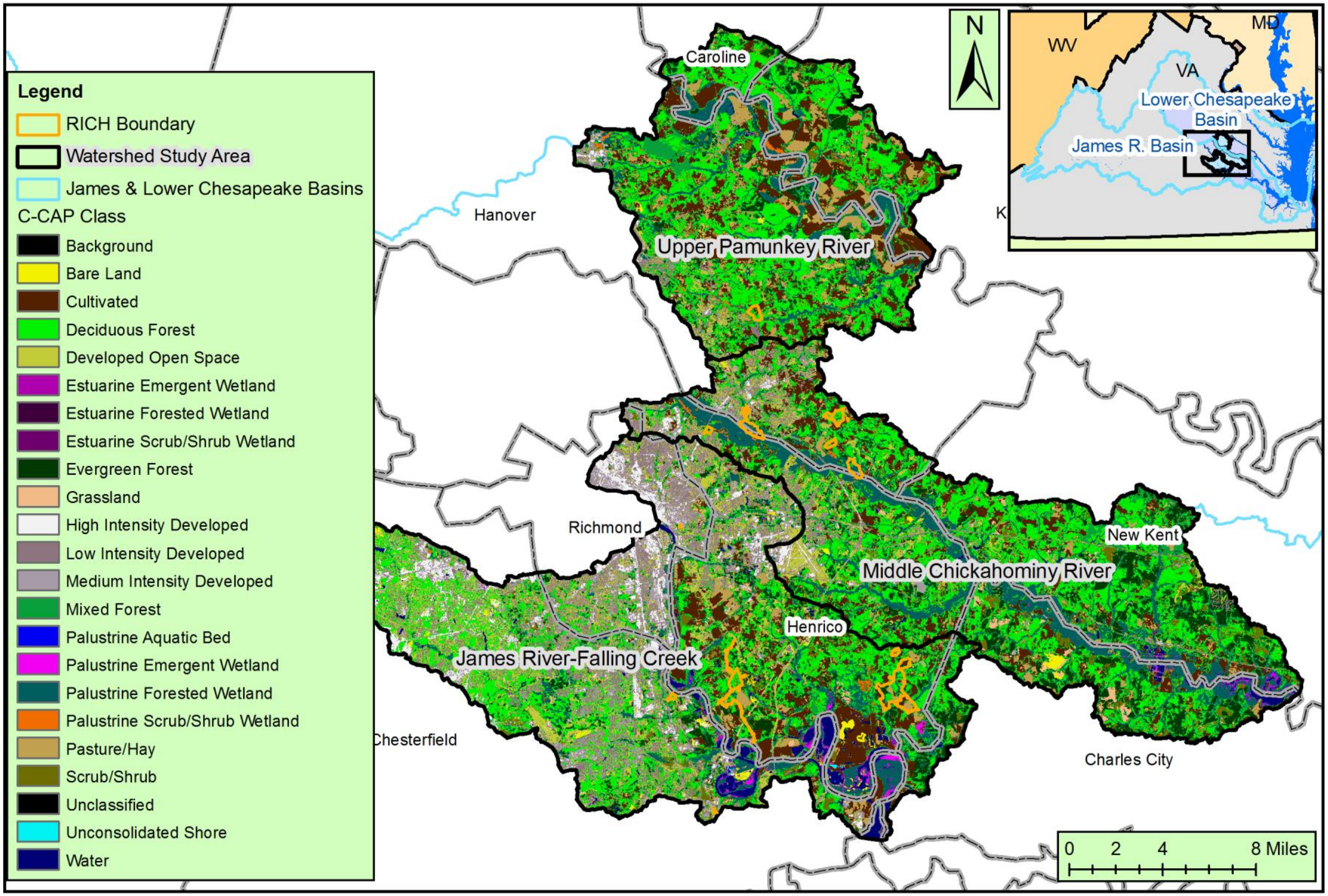

Figure C-3. 2005 Land cover (C-CAP) within the Richmond NBP (RICH) watershed study area and park detail.

Appendix D. Native (n=619) and nonnative (n=174) plant species, Richmond National Battlefield Park. These species have been cross referenced to the Virginia Department of Conservation and Recreation's Division of Natural Heritage rare plant list (Virginia Department of Conservation and Recreation Division of Natural Heritage 2007). See reference for Appendix F for explanation of abbreviations.

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Abutilon theophrasti	Probably Present	n/a	Nonnative					
Acalypha gracilens	Present in Park	Unknown	Native					
Acalypha rhomboidea	Present in Park	Unknown	Native					
Acer negundo	Present in Park	Unknown	Native					
Acer rubrum	Present in Park	Unknown	Native					
Acer saccharinum	Present in Park	Unknown	Native					
Achillea millefolium	Present in Park	Unknown	Native					
Agalinis purpurea	Probably Present	n/a	Native					
Agrimonia parviflora	Probably Present	n/a	Native					
Agrostis capillaris	Present in Park	Unknown	Nonnative					
Agrostis hyemalis	Present in Park	Unknown	Native					
Agrostis perennans	Present in Park	Unknown	Native					
Agrostis stolonifera	Present in Park	Unknown	Nonnative					
Ailanthus altissima	Present in Park	Unknown	Nonnative					
Aira caryophyllea	Present in Park	Unknown	Nonnative					
Albizia julibrissin	Present in Park	Unknown	Nonnative					
Alisma subcordatum	Probably Present	n/a	Native					
Alliaria petiolata	Present in Park	Unknown	Nonnative					
Allium vineale	Present in Park	Unknown	Nonnative					
Alnus serrulata	Present in Park	Unknown	Native					
Alopecurus carolinianus	Present in Park	Unknown	Native					
Amaranthus hybridus	Present in Park	Unknown	Nonnative					
Ambrosia artemisiifolia	Present in Park	Unknown	Native					
Amelanchier arborea	Present in Park	Unknown	Native					
Amelanchier stolonifera	Present in Park	Unknown	Native					
Amphicarpaea bracteata	Present in Park	Unknown	Native					
Anagallis arvensis	Present in Park	Unknown	Nonnative					
Andropogon gerardii	Present in Park	Unknown	Native					
Andropogon ternarius	Present in Park	Unknown	Native					
Andropogon virginicus	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Antennaria plantaginifolia	Present in Park	Unknown	Native					
Anthemis cotula	Present in Park	Unknown	Nonnative					
Anthoxanthum odoratum	Present in Park	Unknown	Nonnative					
Aphanes microcarpa	Present in Park	Unknown	Nonnative					
Apios americana	Present in Park	Unknown	Native					
Aplectrum hyemale	Probably Present	n/a	Native					
Apocynum cannabinum	Present in Park	Unknown	Native					
Arabidopsis thaliana	Present in Park	Unknown	Nonnative					
Arabis laevigata	Present in Park	Unknown	Native					
Aralia spinosa	Present in Park	Unknown	Native					
Arctium minus	Present in Park	Unknown	Nonnative					
Arisaema triphyllum	Present in Park	Unknown	Native					
Aristida dichotoma	Present in Park	Unknown	Native					
Aristida dichotoma var. *curtissii*	Present in Park	Unknown	Native					
Aristida longispica	Present in Park	Unknown	Native					
Aristida oligantha	Present in Park	Unknown	Native					
Aristolochia serpentaria	Present in Park	Unknown	Native					
Arnica acaulis	Probably Present	n/a	Native					
Arnoglossum atriplicifolium	Probably Present	n/a	Native					
Artemisia vulgaris var. *vulgaris*	Present in Park	Unknown	Nonnative					
Asclepias amplexicaulis	Probably Present	n/a	Native					
Asclepias incarnata	Probably Present	n/a	Native					
Asclepias syriaca	Probably Present	n/a	Native					
Asclepias tuberosa	Probably Present	n/a	Native					
Asclepias verticillata	Present in Park	Unknown	Native					
Asclepias viridiflora	Present in Park	Unknown	Native					
Asimina triloba	Present in Park	Unknown	Native					
Asparagus officinalis	Present in Park	Unknown	Nonnative					
Asplenium platyneuron	Present in Park	Unknown	Native					
Athyrium filix-femina	Present in Park	Unknown	Native					
Athyrium filix-femina ssp. *asplenioides*	Present in Park	Unknown	Native					
Aureolaria virginica	Present in Park	Unknown	Native					
Baptisia tinctoria	Present in Park	Unknown	Native					
Barbarea verna	Present in Park	Unknown	Nonnative					
Bartonia virginica	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Berberis julianiae	Probably Present	n/a	Nonnative					
Berberis thunbergii	Present in Park	Unknown	Nonnative					
Betula nigra	Present in Park	Unknown	Native					
Bidens aristosa	Present in Park	Unknown	Native					
Bidens bipinnata	Present in Park	Unknown	Native					
Bidens discoidea	Probably Present	n/a	Native					
Bidens frondosa	Present in Park	Unknown	Native					
Bignonia capreolata	Present in Park	Unknown	Native					
Boehmeria cylindrica	Present in Park	Unknown	Native					
Botrychium dissectum	Present in Park	Unknown	Native					
Botrychium virginianum	Present in Park	Unknown	Native					
Brassica napus	Present in Park	Unknown	Nonnative					
Bromus arvensis	Present in Park	Unknown	Nonnative					
Bromus inermis	Present in Park	Unknown	Nonnative					
Bromus racemosus	Present in Park	Unknown	Nonnative					
Broussonetia papyrifera	Present in Park	Unknown	Nonnative					
Buglossoides arvensis	Present in Park	Unknown	Nonnative					
Bulbostylis capillaris	Present in Park	Unknown	Native					
Buxus sempervirens	Probably Present	n/a	Nonnative					
Calamintha nepeta ssp. *nepeta*	Present in Park	Unknown	Nonnative					
Calepina irregularis	Present in Park	Unknown	Nonnative					
Callitriche heterophylla ssp. *heterophylla*	Present in Park	Unknown	Native					
Calystegia sepium	Probably Present	n/a	Unknown					
Campsis radicans	Present in Park	Unknown	Native					
Capsella bursa-pastoris	Present in Park	Unknown	Nonnative					
Cardamine concatenata	Present in Park	Unknown	Native					
Cardamine hirsuta	Present in Park	Unknown	Nonnative					
Carex abscondita	Present in Park	Unknown	Native					
Carex alata	Present in Park	Unknown	Native					
Carex albicans	Present in Park	Unknown	Native					
Carex albicans var. *albicans*	Present in Park	Unknown	Native					
Carex albolutescens	Present in Park	Unknown	Native					
Carex annectens	Present in Park	Unknown	Native					
Carex atlantica ssp. *atlantica*	Present in Park	Unknown	Native					
Carex atlantica ssp. *capillacea*	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Carex blanda	Present in Park	Unknown	Native					
Carex caroliniana	Present in Park	Unknown	Native					
Carex cephalophora	Present in Park	Unknown	Native					
Carex collinsii	Present in Park	Unknown	Native					
Carex communis	Present in Park	Unknown	Native					
Carex complanata	Present in Park	Unknown	Native					
Carex crebriflora	Present in Park	Unknown	Native					
Carex crinita	Present in Park	Unknown	Native					
Carex debilis	Present in Park	Unknown	Native					
Carex digitalis	Present in Park	Unknown	Native					
Carex festucacea	Present in Park	Unknown	Native					
Carex flaccosperma	Present in Park	Unknown	Native					
Carex folliculata	Present in Park	Unknown	Native					
Carex frankii	Probably Present	n/a	Native					
Carex gracilescens	Present in Park	Unknown	Native					
Carex hirsutella	Present in Park	Unknown	Native					
Carex intumescens	Present in Park	Unknown	Native					
Carex laevivaginata	Present in Park	Unknown	Native					
Carex laxiculmis var. *laxiculmis*	Present in Park	Unknown	Native					
Carex leavenworthii	Present in Park	Unknown	Native					
Carex lonchocarpa	Present in Park	Unknown	Native					
Carex lupulina	Present in Park	Unknown	Native					
Carex lurida	Present in Park	Unknown	Native					
Carex nigromarginata	Present in Park	Unknown	Native					
Carex normalis	Present in Park	Unknown	Native					
Carex oligocarpa	Present in Park	Unknown	Native					
Carex pensylvanica	Present in Park	Unknown	Native					
Carex radiata	Present in Park	Unknown	Native					
Carex rosea	Present in Park	Unknown	Native					
Carex seorsa	Present in Park	Unknown	Native					
Carex stipata	Present in Park	Unknown	Native					
Carex stricta	Present in Park	Unknown	Native					
Carex swanii	Present in Park	Unknown	Native					
Carex tribuloides	Present in Park	Unknown	Native					
Carex typhina	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Carex vulpinoidea	Present in Park	Unknown	Native					
Carex willdenowii	Present in Park	Unknown	Native					
Carpinus caroliniana	Present in Park	Unknown	Native					
Carya glabra	Present in Park	Unknown	Native					
Carya ovalis	Present in Park	Unknown	Native					
Carya pallida	Present in Park	Unknown	Native					
Carya tomentosa	Present in Park	Unknown	Native					
Castanea dentata	Present in Park	Unknown	Native					
Castanea pumila var. *pumila*	Present in Park	Unknown	Native					
Catalpa speciosa	Probably Present	n/a	Nonnative					
Ceanothus americanus	Present in Park	Unknown	Native					
Celastrus orbiculatus	Present in Park	Unknown	Nonnative					
Celtis occidentalis	Present in Park	Unknown	Native					
Cenchrus longispinus	Probably Present	n/a	Native					
Centaurea cyanus	Present in Park	Unknown	Nonnative					
Cephalanthus occidentalis	Present in Park	Unknown	Native					
Cerastium fontanum ssp. *vulgare*	Present in Park	Unknown	Nonnative					
Cerastium glomeratum	Present in Park	Unknown	Nonnative					
Cercis canadensis var. canadensis	Present in Park	Unknown	Native					
Chaerophyllum procumbens	Present in Park	Unknown	Native					
Chaerophyllum tainturieri	Present in Park	Unknown	Native					
Chamaecrista fasciculata var. *fasciculata*	Present in Park	Unknown	Native					
Chamaecrista nictitans ssp. nictitans var. *nictitans*	Present in Park	Unknown	Native					
Chamaesyce maculata	Present in Park	Unknown	Native					
Chamaesyce nutans	Present in Park	Unknown	Native					
Chasmanthium laxum	Present in Park	Unknown	Native					
Chelone glabra	Present in Park	Unknown	Native					
Chenopodium album	Present in Park	Unknown	Nonnative					
Chenopodium ambrosioides var. *ambrosioides*	Present in Park	Unknown	Nonnative					
Chimaphila maculata	Present in Park	Unknown	Native					
Chimaphila umbellata	Present in Park	Unknown	Native					
Chionanthus virginicus	Present in Park	Unknown	Native					
Chrysopsis mariana	Present in Park	Unknown	Native					
Cichorium intybus	Present in Park	Unknown	Nonnative					
Cicuta maculata var. *maculata*	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Cinna arundinacea	Present in Park	Unknown	Native					
Circaea lutetiana ssp. *canadensis*	Present in Park	Unknown	Native					
Cirsium discolor	Probably Present	n/a	Native					
Cirsium pumilum	Probably Present	n/a	Native					
Cirsium vulgare	Present in Park	Unknown	Nonnative					
Claytonia virginica	Probably Present	n/a	Native					
Clematis ochroleuca	Present in Park	Unknown	Native					
Clematis virginiana	Probably Present	n/a	Native					
Clethra alnifolia	Present in Park	Unknown	Native					
Clitoria mariana	Present in Park	Unknown	Native					
Commelina communis	Present in Park	Unknown	Nonnative					
Commelina diffusa var. *diffusa*	Present in Park	Unknown	Nonnative					
Commelina virginica	Present in Park	Unknown	Native					
Conyza canadensis	Present in Park	Unknown	Native					
Coreopsis lanceolata	Present in Park	Unknown	Native					
Coreopsis verticillata	Probably Present	n/a	Native					
Cornus amomum	Present in Park	Unknown	Native					
Cornus florida	Present in Park	Unknown	Native					
Cornus foemina	Present in Park	Unknown	Native					
Coronopus didymus	Present in Park	Unknown	Nonnative					
Corylus americana	Present in Park	Unknown	Native					
Crataegus uniflora	Present in Park	Unknown	Native					
Crotalaria sagittalis	Present in Park	Unknown	Native					
Croton glandulosus var. *septentrionalis*	Present in Park	Unknown	Native					
Cryptotaenia canadensis	Present in Park	Unknown	Native					
Cuscuta compacta var. *compacta*	Present in Park	Unknown	Native					
Cuscuta gronovii var. *gronovii*	Present in Park	Unknown	Native					
Cuscuta pentagona var. *pentagona*	Present in Park	Unknown	Native					
Cynanchum laeve	Present in Park	Unknown	Native					
Cynodon dactylon	Present in Park	Unknown	Nonnative					
Cyperus compressus	Present in Park	Unknown	Native					
Cyperus echinatus	Present in Park	Unknown	Native					
Cyperus erythrorhizos	Present in Park	Unknown	Native					
Cyperus iria	Present in Park	Unknown	Nonnative					
Cyperus lancastriensis	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Cyperus lupulinus ssp. *lupulinus*	Present in Park	Unknown	Native					
Cyperus odoratus	Present in Park	Unknown	Native					
Cyperus polystachyos var. *texensis*	Present in Park	Unknown	Native					
Cyperus pseudovegetus	Present in Park	Unknown	Native					
Cyperus retrofractus	Present in Park	Unknown	Native					
Cyperus retrorsus	Present in Park	Unknown	Native					
Cyperus strigosus	Present in Park	Unknown	Native					
Cypripedium acaule	Present in Park	Unknown	Native					
Dactylis glomerata	Present in Park	Unknown	Nonnative					
Danthonia sericea	Present in Park	Unknown	Native					
Danthonia spicata	Present in Park	Unknown	Native					
Datura stramonium	Present in Park	Unknown	Nonnative					
Daucus carota	Present in Park	Unknown	Nonnative					
Decodon verticillatus	Present in Park	Unknown	Native					
Desmodium canescens	Probably Present	n/a	Native					
Desmodium ciliare	Probably Present	n/a	Native					
Desmodium glabellum	Probably Present	n/a	Native					
Desmodium laevigatum	Probably Present	n/a	Native					
Desmodium marilandicum	Probably Present	n/a	Native					
Desmodium nudiflorum	Present in Park	Unknown	Native					
Desmodium nuttallii	Probably Present	n/a	Native					
Desmodium obtusum	Present in Park	Unknown	Native					
Desmodium paniculatum	Present in Park	Unknown	Native					
Desmodium perplexum	Probably Present	n/a	Native					
Desmodium tenuifolium	Probably Present	n/a	Native					
Desmodium viridiflorum	Probably Present	n/a	Native					
Dianthus armeria	Present in Park	Unknown	Nonnative					
Dichanthelium boscii	Present in Park	Unknown	Native					
Dichanthelium clandestinum	Present in Park	Unknown	Native					
Dichanthelium commutatum	Present in Park	Unknown	Native					
Dichanthelium depauperatum	Present in Park	Unknown	Native					
Dichanthelium dichotomum	Present in Park	Unknown	Native					
Dichanthelium dichotomum var. *tenue*	Present in Park	Unknown	Native					
Dichanthelium laxiflorum	Present in Park	Unknown	Native					
Dichanthelium linearifolium	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Dichanthelium scoparium	Present in Park	Unknown	Native					
Digitaria sanguinalis	Present in Park	Unknown	Nonnative					
Diodia teres	Present in Park	Unknown	Native					
Diodia virginiana	Present in Park	Unknown	Native					
Dioscorea quaternata	Present in Park	Unknown	Native					
Dioscorea villosa	Present in Park	Unknown	Native					
Diospyros virginiana	Present in Park	Unknown	Native					
Draba verna	Probably Present	n/a	Nonnative					
Dryopteris marginalis	Probably Present	n/a	Native					
Duchesnea indica	Present in Park	Unknown	Nonnative					
Dulichium arundinaceum	Probably Present	n/a	Native					
Echinochloa crus-galli	Present in Park	Unknown	Nonnative					
Echinochloa walteri	Present in Park	Unknown	Native					
Eclipta prostrata	Present in Park	Unknown	Native					
Elaeagnus pungens	Present in Park	Unknown	Nonnative					
Elaeagnus umbellata	Present in Park	Unknown	Nonnative					
Eleocharis obtusa	Present in Park	Unknown	Native					
Elephantopus carolinianus	Probably Present	n/a	Native					
Elephantopus nudatus	Present in Park	Unknown	Native					
Elephantopus tomentosus	Present in Park	Unknown	Native					
Eleusine indica	Present in Park	Unknown	Nonnative					
Elymus hystrix	Present in Park	Unknown	Native					
Elymus riparius	Present in Park	Unknown	Native					
Elymus villosus	Present in Park	Unknown	Native					
Elymus virginicus	Present in Park	Unknown	Native					
Epifagus virginiana	Present in Park	Unknown	Native					
Epigaea repens	Present in Park	Unknown	Native					
Epilobium coloratum	Present in Park	Unknown	Native					
Eragrostis capillaris	Present in Park	Unknown	Native					
Eragrostis curvula	Present in Park	Unknown	Nonnative					
Eragrostis pilosa	Present in Park	Unknown	Nonnative					
Eragrostis spectabilis	Present in Park	Unknown	Native					
Erechtites hieraciifolia var. *hieraciifolia*	Present in Park	Unknown	Native					
Erigeron annuus	Present in Park	Unknown	Native					
Erigeron strigosus	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Erodium cicutarium	Probably Present	n/a	Native					
Erythronium americanum	Probably Present	n/a	Native					
Euonymus americana	Present in Park	Unknown	Native					
Eupatoriadelphus dubius	Probably Present	n/a	Native					
Eupatorium album var. *album*	Present in Park	Unknown	Native					
Eupatorium capillifolium	Present in Park	Unknown	Native					
Eupatorium fistulosum	Present in Park	Unknown	Native					
Eupatorium godfreyanum	Probably Present	n/a	Native					
Eupatorium hyssopifolium	Present in Park	Unknown	Native					
Eupatorium perfoliatum var. *perfoliatum*	Present in Park	Unknown	Native					
Eupatorium pilosum	Probably Present	n/a	Native					
Eupatorium purpureum var. *purpureum*	Present in Park	Unknown	Native					
Eupatorium rotundifolium	Present in Park	Unknown	Native					
Eupatorium serotinum	Present in Park	Unknown	Native					
Eupatorium sessilifolium	Probably Present	n/a	Native					
Euphorbia corollata	Present in Park	Unknown	Native					
Euphorbia spathulata	Present in Park	Unknown	Native					
Eurybia divaricata	Present in Park	Unknown	Native					
Euthamia caroliniana	Present in Park	Unknown	Native					
Euthamia graminifolia	Probably Present	n/a	Native					
Fagus grandifolia	Present in Park	Unknown	Native					
Festuca ovina	Present in Park	Unknown	Nonnative					
Festuca subverticillata	Present in Park	Unknown	Native					
Fimbristylis autumnalis	Present in Park	Unknown	Native					
Fragaria virginiana	Present in Park	Unknown	Native					
Fraxinus americana	Present in Park	Unknown	Native					
Fraxinus pennsylvanica	Present in Park	Unknown	Native					
Fraxinus profunda	Present in Park	Unknown	Native					
Galactia regularis	Present in Park	Unknown	Native					
Galactia volubilis	Present in Park	Unknown	Native					
Galium aparine	Present in Park	Unknown	Native					
Galium asprellum	Present in Park	Unknown	Native					
Galium circaezans	Present in Park	Unknown	Native					
Galium obtusum	Present in Park	Unknown	Native					
Galium pilosum	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Galium triflorum	Present in Park	Unknown	Native					
Gamochaeta purpurea	Present in Park	Unknown	Native					
Gaylussacia baccata	Present in Park	Unknown	Native					
Gaylussacia frondosa	Present in Park	Unknown	Native					
Gentiana saponaria	Probably Present	n/a	Native					
Geranium carolinianum	Present in Park	Unknown	Native					
Geranium molle	Present in Park	Unknown	Nonnative					
Geum canadense	Present in Park	Unknown	Native					
Glechoma hederacea	Present in Park	Unknown	Nonnative					
Gleditsia triacanthos	Present in Park	Unknown	Native					
Glyceria septentrionalis	Present in Park	Unknown	Native					
Glyceria striata	Present in Park	Unknown	Native					
Glycine max	Present in Park	Unknown	Nonnative					
Goodyera pubescens	Present in Park	Unknown	Native					
Gratiola neglecta	Present in Park	Unknown	Native					
Gratiola virginiana	Present in Park	Unknown	Native					
Gypsophila elegans	Present in Park	Unknown	Nonnative					
Hedera helix	Present in Park	Unknown	Nonnative					
Helianthemum canadense	Present in Park	Unknown	Native					
Hemerocallis fulva	Present in Park	Unknown	Nonnative					
Heteranthera reniformis	Present in Park	Unknown	Native					
Heuchera americana	Present in Park	Unknown	Native					
Hexastylis virginica	Present in Park	Unknown	Native					
Hibiscus moscheutos	Probably Present	n/a	Native					
Hibiscus syriacus	Probably Present	n/a	Nonnative					
Hieracium gronovii	Present in Park	Unknown	Native					
Hieracium venosum	Present in Park	Unknown	Native					
Holcus lanatus	Present in Park	Unknown	Nonnative					
Hordeum pusillum	Present in Park	Unknown	Native					
Hordeum vulgare	Present in Park	Unknown	Nonnative					
Houstonia caerulea	Present in Park	Unknown	Native					
Houstonia longifolia	Present in Park	Unknown	Native					
Houstonia purpurea	Present in Park	Unknown	Native					
Houstonia purpurea var. *purpurea*	Present in Park	Unknown	Native					
Huperzia lucidula	Probably Present	n/a	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Hydrangea arborescens	Probably Present	n/a	Native					
Hydrocotyle ranunculoides	Present in Park	Unknown	Native					
Hypericum canadense	Present in Park	Unknown	Native					
Hypericum crux-andreae	Probably Present	n/a	Native					
Hypericum gentianoides	Probably Present	n/a	Native					
Hypericum hypericoides	Present in Park	Unknown	Native					
Hypericum hypericoides ssp. *hypericoides*	Present in Park	Unknown	Native					
Hypericum hypericoides ssp. *multicaule*	Probably Present	n/a	Native					
Hypericum mutilum	Present in Park	Unknown	Native					
Hypericum perforatum	Present in Park	Unknown	Nonnative					
Hypericum punctatum	Present in Park	Unknown	Native					
Hypochaeris radicata	Present in Park	Unknown	Nonnative					
Hypoxis hirsuta	Present in Park	Unknown	Native					
Ilex ambigua	Probably Present	n/a	Native					
Ilex decidua	Present in Park	Unknown	Native					
Ilex glabra	Probably Present	n/a	Native					
Ilex opaca var. *opaca*	Present in Park	Unknown	Native					
Ilex verticillata	Present in Park	Unknown	Native					
Impatiens capensis	Present in Park	Unknown	Native					
Impatiens pallida	Probably Present	n/a	Native					
Ipomoea hederacea	Present in Park	Unknown	Nonnative					
Ipomoea lacunosa	Present in Park	Unknown	Native					
Ipomoea pandurata	Present in Park	Unknown	Native					
Ipomoea purpurea	Probably Present	n/a	Nonnative					
Iris germanica	Probably Present	n/a	Nonnative					
Iris virginica	Probably Present	n/a	Native					
Itea virginica	Present in Park	Unknown	Native					
Juglans nigra	Present in Park	Unknown	Native					
Juncus acuminatus	Present in Park	Unknown	Native					
Juncus articulatus	Probably Present	n/a	Native					
Juncus biflorus	Present in Park	Unknown	Native					
Juncus bufonius	Present in Park	Unknown	Native					
Juncus coriaceus	Present in Park	Unknown	Native					
Juncus effusus	Present in Park	Unknown	Native					
Juncus elliottii var. *elliottii*	Probably Present	n/a	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Juncus marginatus	Present in Park	Unknown	Native					
Juncus tenuis	Present in Park	Unknown	Native					
Juniperus virginiana var. *virginiana*	Present in Park	Unknown	Native					
Kalmia latifolia	Present in Park	Unknown	Native					
Krigia virginica	Present in Park	Unknown	Native					
Kummerowia stipulacea	Present in Park	Unknown	Nonnative					
Kummerowia striata	Present in Park	Unknown	Nonnative					
Kyllinga pumila	Present in Park	Unknown	Native					
Lactuca canadensis	Present in Park	Unknown	Native					
Lactuca serriola	Present in Park	Unknown	Nonnative					
Lagerstroemia indica	Present in Park	Unknown	Nonnative					
Lamium amplexicaule	Present in Park	Unknown	Nonnative					
Lamium purpureum	Present in Park	Unknown	Nonnative					
Laportea canadensis	Present in Park	Unknown	Native					
Lathyrus hirsutus	Probably Present	n/a	Nonnative					
Lathyrus latifolius	Present in Park	Unknown	Nonnative					
Lechea minor	Present in Park	Unknown	Native					
Lechea racemulosa	Present in Park	Unknown	Native					
Lechea tenuifolia	Present in Park	Unknown	Native					
Leersia oryzoides	Present in Park	Unknown	Native					
Leersia virginica	Present in Park	Unknown	Native					
Lepidium virginicum var. *virginicum*	Present in Park	Unknown	Native					
Lespedeza cuneata	Present in Park	Unknown	Nonnative					
Lespedeza hirta	Probably Present	n/a	Native					
Lespedeza intermedia	Present in Park	Unknown	Native					
Lespedeza procumbens	Present in Park	Unknown	Native					
Lespedeza repens	Present in Park	Unknown	Native					
Lespedeza stuevei	Probably Present	n/a	Native					
Lespedeza violacea	Present in Park	Unknown	Native					
Lespedeza virginica	Present in Park	Unknown	Native					
Leucanthemum vulgare	Present in Park	Unknown	Nonnative					
Leucothoe racemosa	Present in Park	Unknown	Native					
Liatris pilosa var. *pilosa*	Probably Present	n/a	Native					
Ligustrum sinense	Present in Park	Unknown	Nonnative					
Lilium superbum	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Linaria vulgaris	Probably Present	n/a	Nonnative					
Lindera benzoin	Present in Park	Unknown	Native					
Lindernia dubia	Present in Park	Unknown	Native					
Linum striatum	Probably Present	n/a	Native					
Linum usitatissimum	Present in Park	Unknown	Nonnative					
Liparis liliifolia	Probably Present	n/a	Native					
Liquidambar styraciflua	Present in Park	Unknown	Native					
Liriodendron tulipifera	Present in Park	Unknown	Native					
Lobelia cardinalis	Present in Park	Unknown	Native					
Lobelia inflata	Present in Park	Unknown	Native					
Lobelia nuttallii	Probably Present	n/a	Native					
Lobelia puberula	Probably Present	n/a	Native					
Lolium perenne	Present in Park	Unknown	Nonnative					
Lolium perenne ssp. *multiflorum*	Present in Park	Unknown	Nonnative					
Lolium temulentum	Present in Park	Unknown	Nonnative					
Lonicera japonica	Present in Park	Unknown	Nonnative					
Lonicera sempervirens	Probably Present	n/a	Native					
Ludwigia alternifolia	Present in Park	Unknown	Native					
Ludwigia decurrens	Present in Park	Unknown	Native					
Ludwigia palustris	Present in Park	Unknown	Native					
Lupinus perennis	Probably Present	n/a	Native					
Luzula echinata	Present in Park	Unknown	Native					
Luzula multiflora	Present in Park	Unknown	Native					
Lycopodium digitatum	Present in Park	Unknown	Native					
Lycopodium obscurum	Present in Park	Unknown	Native					
Lycopus americanus	Probably Present	n/a	Native					
Lycopus virginicus	Present in Park	Unknown	Native					
Lyonia ligustrina	Present in Park	Unknown	Native					
Lyonia mariana	Probably Present	n/a	Native					
Lysimachia nummularia	Present in Park	Unknown	Nonnative					
Lysimachia quadrifolia	Present in Park	Unknown	Native					
Lythrum salicaria	Present in Park	Unknown	Nonnative					
Magnolia grandiflora	Present in Park	Unknown	Nonnative					
Magnolia virginiana	Present in Park	Unknown	Native					
Maianthemum racemosum ssp. *racemosum*	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Malaxis unifolia	Probably Present	n/a	Native					
Malus pumila	Probably Present	n/a	Nonnative					
Matricaria discoidea	Present in Park	Unknown	Nonnative					
Medeola virginiana	Present in Park	Unknown	Native					
Melica mutica	Present in Park	Unknown	Native					
Melilotus officinalis	Present in Park	Unknown	Nonnative					
Menispermum canadense	Present in Park	Unknown	Native					
Microstegium vimineum	Present in Park	Unknown	Nonnative					
Mikania scandens	Present in Park	Unknown	Native					
Mimulus alatus	Probably Present	n/a	Native					
Mimulus ringens	Probably Present	n/a	Native					
Mitchella repens	Present in Park	Unknown	Native					
Mollugo verticillata	Present in Park	Unknown	Native					
Monotropa hypopithys	Present in Park	Unknown	Native					
Monotropa uniflora	Present in Park	Unknown	Native					
Morus alba	Present in Park	Unknown	Nonnative					
Morus rubra	Present in Park	Unknown	Native					
Muhlenbergia schreberi	Present in Park	Unknown	Native					
Murdannia keisak	Present in Park	Unknown	Nonnative					
Muscari neglectum	Present in Park	Unknown	Nonnative					
Myosotis discolor	Present in Park	Unknown	Nonnative					
Myrica cerifera	Present in Park	Unknown	Native					
Narcissus pseudonarcissus	Probably Present	n/a	Nonnative					
Nemophila aphylla	Probably Present	n/a	Native					
Nepeta cataria	Probably Present	n/a	Nonnative					
Nuphar lutea	Probably Present	n/a	Native					
Nuttallanthus canadensis	Present in Park	Unknown	Native					
Nyssa biflora	Present in Park	Unknown	Native					
Nyssa sylvatica	Present in Park	Unknown	Native					
Oenothera biennis	Present in Park	Unknown	Native					
Oenothera laciniata	Present in Park	Unknown	Native					
Oenothera parviflora	Present in Park	Unknown	Native					
Oldenlandia uniflora	Present in Park	Unknown	Native					
Onoclea sensibilis	Present in Park	Unknown	Native					
Ophioglossum vulgatum	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Opuntia humifusa	Probably Present	n/a	Native					
Ornithogalum umbellatum	Present in Park	Unknown	Nonnative					
Orontium aquaticum	Present in Park	Unknown	Native					
Osmorhiza longistylis	Present in Park	Unknown	Native					
Osmunda cinnamomea	Present in Park	Unknown	Native					
Osmunda cinnamomea var. *cinnamomea*	Present in Park	Unknown	Native					
Osmunda regalis var. *spectabilis*	Present in Park	Unknown	Native					
Ostrya virginiana	Present in Park	Unknown	Native					
Oxalis corniculata	Probably Present	n/a	Nonnative					
Oxalis dillenii	Present in Park	Unknown	Native					
Oxalis violacea	Present in Park	Unknown	Native					
Oxypolis rigidior	Present in Park	Unknown	Native					
Packera anonyma	Probably Present	n/a	Native					
Packera obovata	Present in Park	Unknown	Native					
Packera tomentosa	Present in Park	Unknown	Native					
Panicum anceps	Present in Park	Unknown	Native					
Panicum dichotomiflorum	Present in Park	Unknown	Native					
Panicum rigidulum var. *rigidulum*	Present in Park	Unknown	Native					
Panicum verrucosum	Present in Park	Unknown	Native					
Panicum virgatum	Present in Park	Unknown	Native					
Papaver rhoeas	Present in Park	Unknown	Nonnative					
Parthenium integrifolium	Probably Present	n/a	Native					
Parthenocissus quinquefolia	Present in Park	Unknown	Native					
Paspalum dilatatum	Present in Park	Unknown	Nonnative					
Paspalum floridanum	Present in Park	Unknown	Native					
Paspalum laeve	Present in Park	Unknown	Native					
Paspalum setaceum	Present in Park	Unknown	Native					
Passiflora incarnata	Present in Park	Unknown	Native					
Passiflora lutea	Present in Park	Unknown	Native					
Paulownia tomentosa	Present in Park	Unknown	Nonnative					
Peltandra virginica	Present in Park	Unknown	Native					
Penstemon canescens	Present in Park	Unknown	Native					
Penthorum sedoides	Present in Park	Unknown	Native					
Perilla frutescens	Present in Park	Unknown	Nonnative					
Phleum pratense	Present in Park	Unknown	Nonnative					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Phoradendron leucarpum	Probably Present	n/a	Native					
Photinia pyrifolia	Present in Park	Unknown	Native					
Phragmites australis	Present in Park	Unknown	Unknown					
Phryma leptostachya	Present in Park	Unknown	Native					
Phyllanthus caroliniensis	Present in Park	Unknown	Native					
Physalis angulata	Present in Park	Unknown	Nonnative					
Physalis heterophylla var. *heterophylla*	Probably Present	n/a	Native					
Physalis pubescens	Probably Present	n/a	Native					
Physalis virginiana var. *virginiana*	Present in Park	Unknown	Native					
Phytolacca americana	Present in Park	Unknown	Native					
Pilea pumila	Present in Park	Unknown	Native					
Pinus echinata	Present in Park	Unknown	Native					
Pinus taeda	Present in Park	Unknown	Native					
Pinus virginiana	Present in Park	Unknown	Native					
Piptochaetium avenaceum	Present in Park	Unknown	Native					
Pityopsis graminifolia	Probably Present	n/a	Native					
Plantago aristata	Present in Park	Unknown	Nonnative					
Plantago lanceolata	Present in Park	Unknown	Nonnative					
Plantago major	Probably Present	n/a	Nonnative					
Plantago rugelii	Present in Park	Unknown	Native					
Plantago virginica	Present in Park	Unknown	Native					
Platanthera ciliaris	Present in Park	Unknown	Native					
Platanthera clavellata	Present in Park	Unknown	Native					
Platanthera flava var. *flava*	Present in Park	Unknown	Native					
Platanthera lacera	Present in Park	Unknown	Native					
Platanus occidentalis	Present in Park	Unknown	Native					
Pluchea camphorata	Present in Park	Unknown	Native					
Poa annua	Present in Park	Unknown	Nonnative					
Poa autumnalis	Present in Park	Unknown	Native					
Poa compressa	Present in Park	Unknown	Nonnative					
Poa pratensis	Present in Park	Unknown	Nonnative					
Podophyllum peltatum	Present in Park	Unknown	Native					
Polygala mariana	Present in Park	Unknown	Native					
Polygonatum biflorum	Present in Park	Unknown	Native					
Polygonum amphibium var. *emersum*	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Polygonum arifolium	Present in Park	Unknown	Native					
Polygonum aviculare	Present in Park	Unknown	Nonnative					
Polygonum caespitosum var. *longisetum*	Present in Park	Unknown	Nonnative					
Polygonum convolvulus	Present in Park	Unknown	Nonnative					
Polygonum cuspidatum	Probably Present	n/a	Nonnative					
Polygonum pensylvanicum	Present in Park	Unknown	Native					
Polygonum persicaria	Present in Park	Unknown	Nonnative					
Polygonum punctatum	Present in Park	Unknown	Native					
Polygonum sagittatum	Present in Park	Unknown	Native					
Polygonum scandens	Present in Park	Unknown	Native					
Polygonum setaceum	Present in Park	Unknown	Native					
Polygonum virginianum	Present in Park	Unknown	Native					
Polypodium virginianum	Probably Present	n/a	Native					
Polypremum procumbens	Present in Park	Unknown	Native					
Polystichum acrostichoides	Present in Park	Unknown	Native					
Pontederia cordata	Present in Park	Unknown	Native					
Populus alba	Present in Park	Unknown	Nonnative					
Populus deltoides	Present in Park	Unknown	Native					
Populus grandidentata	Probably Present	n/a	Native					
Potamogeton epihydrus	Present in Park	Unknown	Native					
Potentilla canadensis	Present in Park	Unknown	Native					
Potentilla recta	Present in Park	Unknown	Nonnative					
Prenanthes altissima	Present in Park	Unknown	Native					
Prenanthes serpentaria	Present in Park	Unknown	Native					
Proserpinaca palustris	Probably Present	n/a	Native					
Prunella vulgaris	Present in Park	Unknown	Native					
Prunus domestica	Present in Park	Unknown	Nonnative					
Prunus persica	Probably Present	n/a	Nonnative					
Prunus serotina var. *serotina*	Present in Park	Unknown	Native					
Pseudognaphalium obtusifolium	Present in Park	Unknown	Native					
Pteridium aquilinum	Present in Park	Unknown	Native					
Pueraria montana var. *lobata*	Present in Park	Unknown	Nonnative					
Pycnanthemum tenuifolium	Present in Park	Unknown	Native					
Pyrrhopappus carolinianus	Probably Present	n/a	Native					
Pyrus communis	Probably Present	n/a	Nonnative					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Quercus alba	Present in Park	Unknown	Native					
Quercus coccinea	Present in Park	Unknown	Native					
Quercus falcata	Present in Park	Unknown	Native					
Quercus marilandica	Present in Park	Unknown	Native					
Quercus michauxii	Present in Park	Unknown	Native					
Quercus montana	Present in Park	Unknown	Native					
Quercus muehlenbergii	Present in Park	Unknown	Native					
Quercus nigra	Present in Park	Unknown	Native					
Quercus pagoda	Present in Park	Unknown	Native					
Quercus palustris	Present in Park	Unknown	Native					
Quercus phellos	Present in Park	Unknown	Native					
Quercus rubra	Present in Park	Unknown	Native					
Quercus stellata	Present in Park	Unknown	Native					
Quercus velutina	Present in Park	Unknown	Native					
Quercus X garlandensis	Present in Park	Unknown	Native					
Quercus X subintegra	Present in Park	Unknown	Native					
Ranunculus abortivus	Present in Park	Unknown	Native					
Ranunculus bulbosus	Present in Park	Unknown	Nonnative					
Ranunculus pusillus	Present in Park	Unknown	Native					
Ranunculus sardous	Probably Present	n/a	Nonnative					
Raphanus raphanistrum	Probably Present	n/a	Nonnative					
Rhexia mariana	Present in Park	Unknown	Native					
Rhexia virginica	Present in Park	Unknown	Native					
Rhododendron periclymenoides	Present in Park	Unknown	Native					
Rhododendron viscosum	Present in Park	Unknown	Native					
Rhus copallinum	Present in Park	Unknown	Native					
Rhus glabra	Present in Park	Unknown	Native					
Rhynchosia tomentosa	Present in Park	Unknown	Native					
Rhynchospora capitellata	Present in Park	Unknown	Native					
Rhynchospora gracilenta	Present in Park	Unknown	Native					
Rhynchospora inexpansa	Present in Park	Unknown	Native					
Rhynchospora microcephala	Present in Park	Unknown	Native					
Robinia pseudoacacia	Present in Park	Unknown	Native					
Rosa carolina var. *carolina*	Present in Park	Unknown	Native					
Rosa multiflora	Present in Park	Unknown	Nonnative					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Rosa palustris	Present in Park	Unknown	Native					
Rubus argutus	Present in Park	Unknown	Native					
Rubus flagellaris	Present in Park	Unknown	Native					
Rubus hispidus	Present in Park	Unknown	Native					
Rubus occidentalis	Present in Park	Unknown	Native					
Rudbeckia hirta	Probably Present	n/a	Native					
Ruellia caroliniensis	Probably Present	n/a	Native					
Rumex acetosella	Present in Park	Unknown	Nonnative					
Rumex conglomeratus	Probably Present	n/a	Nonnative					
Rumex crispus	Present in Park	Unknown	Nonnative					
Sabatia quadrangula	Present in Park	Unknown	Native					
Saccharum alopecuroidum	Present in Park	Unknown	Native					
Saccharum brevibarbe var. *contortum*	Present in Park	Unknown	Native					
Sagittaria latifolia	Present in Park	Unknown	Native					
Salix alba	Probably Present	n/a	Nonnative					
Salix humilis	Present in Park	Unknown	Native					
Salix nigra	Present in Park	Unknown	Native					
Salvia lyrata	Present in Park	Unknown	Native					
Sambucus nigra ssp. *canadensis*	Present in Park	Unknown	Native					
Sanicula canadensis	Present in Park	Unknown	Native					
Sassafras albidum	Present in Park	Unknown	Native					
Saururus cernuus	Present in Park	Unknown	Native					
Saxifraga virginiensis	Present in Park	Unknown	Native					
Schedonorus pratensis	Present in Park	Unknown	Nonnative					
Schizachyrium scoparium ssp. *scoparium*	Present in Park	Unknown	Native					
Scirpus atrovirens	Present in Park	Unknown	Native					
Scirpus cyperinus	Present in Park	Unknown	Native					
Scleranthus annuus	Present in Park	Unknown	Nonnative					
Scutellaria elliptica	Probably Present	n/a	Native					
Scutellaria integrifolia	Present in Park	Unknown	Native					
Scutellaria lateriflora	Present in Park	Unknown	Native					
Sedum ternatum	Present in Park	Unknown	Native					
Senna obtusifolia	Probably Present	n/a	Nonnative					
Sericocarpus asteroides	Present in Park	Unknown	Native					
Setaria faberi	Present in Park	Unknown	Nonnative					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Setaria italica	Present in Park	Unknown	Nonnative					
Setaria parviflora	Present in Park	Unknown	Native					
Setaria pumila ssp. *pumila*	Present in Park	Unknown	Nonnative					
Sida spinosa	Present in Park	Unknown	Nonnative					
Silene armeria	Present in Park	Unknown	Nonnative					
Silene caroliniana ssp. *pensylvanica*	Present in Park	Unknown	Native					
Silene latifolia ssp. *alba*	Probably Present	n/a	Nonnative					
Silphium compositum	Probably Present	n/a	Native					
Sisyrinchium angustifolium	Probably Present	n/a	Native					
Sisyrinchium mucronatum	Probably Present	n/a	Native					
Smilax bona-nox	Present in Park	Unknown	Native					
Smilax glauca	Present in Park	Unknown	Native					
Smilax herbacea	Present in Park	Unknown	Native					
Smilax laurifolia	Present in Park	Unknown	Native					
Smilax rotundifolia	Present in Park	Unknown	Native					
Smilax walteri	Present in Park	Unknown	Native					
Solanum carolinense	Present in Park	Unknown	Native					
Solidago altissima	Probably Present	n/a	Native					
Solidago bicolor	Probably Present	n/a	Native					
Solidago caesia	Probably Present	n/a	Native					
Solidago erecta	Present in Park	Unknown	Native					
Solidago gigantea	Probably Present	n/a	Native					
Solidago juncea	Probably Present	n/a	Native					
Solidago nemoralis var. *nemoralis*	Present in Park	Unknown	Native					
Solidago odora var. *odora*	Probably Present	n/a	Native					
Solidago pinetorum	Probably Present	n/a	Native					
Solidago rugosa	Present in Park	Unknown	Native					
Sonchus asper	Probably Present	n/a	Nonnative					
Sorghum halepense	Present in Park	Unknown	Nonnative					
Sparganium americanum	Present in Park	Unknown	Native					
Sphenopholis intermedia	Present in Park	Unknown	Native					
Sphenopholis obtusata	Present in Park	Unknown	Native					
Spiranthes lacera var. *gracilis*	Probably Present	n/a	Native					
Spirodela polyrrhiza	Probably Present	n/a	Native					
Sporobolus indicus var. *indicus*	Present in Park	Unknown	Native					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Stellaria media	Present in Park	Unknown	Native					
Stellaria pubera	Present in Park	Unknown	Native					
Strophostyles helvula	Present in Park	Unknown	Native					
Strophostyles umbellata	Present in Park	Unknown	Native					
Stylosanthes biflora	Present in Park	Unknown	Native					
Symphoricarpos orbiculatus	Probably Present	n/a	Native					
Symphyotrichum lanceolatum ssp. *lanceolatum*	Present in Park	Unknown	Native					
Symphyotrichum lateriflorum	Probably Present	n/a	Native					
Symphyotrichum patens	Present in Park	Unknown	Native					
Symphyotrichum pilosum	Present in Park	Unknown	Native					
Symplocarpus foetidus	Present in Park	Unknown	Native					
Symplocos tinctoria	Present in Park	Unknown	Native					
Taraxacum laevigatum	Probably Present	n/a	Nonnative					
Taraxacum officinale	Present in Park	Unknown	Nonnative					
Taxodium distichum	Present in Park	Unknown	Native					
Teesdalia nudicaulis	Present in Park	Unknown	Nonnative					
Tephrosia spicata	Present in Park	Unknown	Native					
Tephrosia virginiana	Probably Present	n/a	Native					
Thalictrum pubescens	Probably Present	n/a	Native					
Thelypteris noveboracensis	Present in Park	Unknown	Native					
Thelypteris palustris var. *pubescens*	Present in Park	Unknown	Native					
Thlaspi arvense	Probably Present	n/a	Nonnative					
Tipularia discolor	Present in Park	Unknown	Native					
Toxicodendron pubescens	Present in Park	Unknown	Native					
Toxicodendron radicans	Present in Park	Unknown	Native					
Toxicodendron vernix	Present in Park	Unknown	Native					
Trachelospermum difforme	Present in Park	Unknown	Native					
Tradescantia virginiana	Probably Present	n/a	Native					
Tragia urens	Present in Park	Unknown	Native					
Tragopogon pratensis	Probably Present	n/a	Nonnative					
Triadenum virginicum	Probably Present	n/a	Native					
Triadenum walteri	Probably Present	n/a	Native					
Trichostema dichotomum	Present in Park	Unknown	Native					
Tridens flavus	Present in Park	Unknown	Native					
Trifolium arvense	Present in Park	Unknown	Nonnative					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Trifolium aureum	Present in Park	Unknown	Nonnative					
Trifolium campestre	Probably Present	n/a	Nonnative					
Trifolium dubium	Present in Park	Unknown	Nonnative					
Trifolium pratense	Present in Park	Unknown	Nonnative					
Trifolium repens	Present in Park	Unknown	Nonnative					
Triodanis perfoliata	Probably Present	n/a	Native					
Tripsacum dactyloides	Probably Present	n/a	Native					
Triticum aestivum	Present in Park	Unknown	Nonnative					
Typha latifolia	Present in Park	Unknown	Native					
Ulmus alata	Present in Park	Unknown	Native					
Ulmus americana	Present in Park	Unknown	Native					
Ulmus rubra	Present in Park	Unknown	Native					
Utricularia gibba	Present in Park	Unknown	Native					
Uvularia perfoliata	Present in Park	Unknown	Native					
Uvularia sessilifolia	Present in Park	Unknown	Native					
Vaccinium corymbosum	Present in Park	Unknown	Native					
Vaccinium formosum	Present in Park	Unknown	Native					
Vaccinium fuscatum	Present in Park	Unknown	Native					
Vaccinium pallidum	Present in Park	Unknown	Native					
Vaccinium stamineum	Present in Park	Unknown	Native					
Vaccinium tenellum	Present in Park	Unknown	Native					
Valerianella locusta	Probably Present	n/a	Nonnative					
Valerianella radiata	Probably Present	n/a	Native					
Vallisneria americana	Present in Park	Unknown	Native					
Verbascum blattaria	Present in Park	Unknown	Nonnative					
Verbascum thapsus	Present in Park	Unknown	Nonnative					
Verbena urticifolia	Present in Park	Unknown	Native					
Verbesina alternifolia	Present in Park	Unknown	Native					
Verbesina occidentalis	Present in Park	Unknown	Native					
Vernonia noveboracensis	Present in Park	Unknown	Native					
Veronica agrestis	Probably Present	n/a	Nonnative					
Veronica arvensis	Present in Park	Unknown	Nonnative					
Veronica hederifolia	Probably Present	n/a	Nonnative					
Veronica officinalis	Present in Park	Unknown	Nonnative					
Veronica persica	Probably Present	n/a	Nonnative					

Scientific Name	Park Status	Abundance	Nativity	DCR-DNH rare species	Global Rank	State Rank	Federal Status	State Status
Veronica serpyllifolia	Present in Park	Unknown	Nonnative					
Viburnum acerifolium	Present in Park	Unknown	Native					
Viburnum dentatum	Present in Park	Unknown	Native					
Viburnum nudum	Present in Park	Unknown	Native					
Viburnum prunifolium	Present in Park	Unknown	Native					
Vicia angustifolia	Present in Park	Unknown	Nonnative					
Vicia grandiflora	Present in Park	Unknown	Nonnative					
Vicia hirsuta	Probably Present	n/a	Nonnative					
Vicia tetrasperma	Present in Park	Unknown	Nonnative					
Vinca minor	Present in Park	Unknown	Nonnative					
Viola bicolor	Present in Park	Unknown	Native					
Viola cucullata	Present in Park	Unknown	Native					
Viola pedata	Present in Park	Unknown	Native					
Viola sagittata	Present in Park	Unknown	Native					
Viola sagittata var. *sagittata*	Present in Park	Unknown	Native					
Viola sororia	Present in Park	Unknown	Native					
Viola X palmata	Probably Present	n/a	Native					
Viola X primulifolia	Present in Park	Unknown	Native					
Vitis aestivalis	Present in Park	Unknown	Native					
Vitis cinerea	Probably Present	n/a	Native					
Vitis labrusca	Probably Present	n/a	Native					
Vitis rotundifolia	Present in Park	Unknown	Native					
Vitis vulpina	Present in Park	Unknown	Native					
Vulpia myuros	Present in Park	Unknown	Nonnative					
Vulpia octoflora var. *octoflora*	Present in Park	Unknown	Native					
Woodwardia areolata	Present in Park	Unknown	Native					
Xanthium strumarium	Probably Present	n/a	Native					
Xanthorhiza simplicissima	Present in Park	Unknown	Native					
Yucca filamentosa	Present in Park	Unknown	Native					
Zizaniopsis miliacea	Present in Park	Unknown	Native					

Appendix E. Wetland integrity methods for Richmond National Battlefield Park.

Landscape Connectivity

Datasets

1. Park vegetation map provided by the National Park Service (NPS) (Appendix F-1).
2. National Land Cover Database (NLCD) (Appendix F-2).
3. Environmental Concern Inc. 2002.
4. National Hydrography Dataset (NHD).

Methodology

1. Export park wetlands in polygon format.
2. Reclass the park vegetation map to NLCD classifications (Table F-1).
3. Classify unfragmented/natural land cover types (Table F-2).
4. Merge the vegetation map with the surrounding NLCD.
5. Identify wetland polygons in the NWI adjacent to park wetlands.
6. Dissolve wetlands into contiguous groups (i.e., wetland complexes) in a GIS.
7. Define riverine and non-riverine wetland complexes utilizing the NHD.
8. Buffer non-riverine wetlands by 500 meters.
9. Buffer riverine wetlands 500 meters upstream and downstream, along the NHD, to a width of 100 feet.
10. Run spatial analysis in a GIS to determine percentage of unfragmented (non-riverine) or natural (riverine) landscape within the buffers.

Classification

1. Park vegetation reclassified to NLCD codes (Table F-1).
2. Unfragmented/Natural land cover (Table F-2).
3. Wetlands are defined by the park vegetation map. If these wetlands intersect the park boundary we will incorporate NWI wetlands that are adjacent to, and contiguous with, the park wetlands.

Analysis

Grades will quantify the percentage of unfragmented/natural landscape within each buffer based on the grading index provided by the NPS.

Table E-1. National Park Service vegetation map crosswalk for NLCD classifications.

NLCD	Vegetation Map
11. Open Water	
12. Perennial Ice/Snow	
21. Developed, Open Space	Grazed Woodlot
22. Developed, Low Intensity	
23. Developed, Medium Intensity	Other Urban or Built-up Land
24. Developed, High Intensity	Transportation, Communications, and Utilities
31. Barren Land (Rock/Sand/Clay)	
41. Deciduous Forest	Dense Hardwood Regeneration, Oak - Hickory Forest, Piedmont / Low Elevation Mixed Oak / Heath Forest, Successional Black Walnut Forest, Successional Red-cedar Forest, Successional Tuliptree Forest, Successional Tree-of-Heaven Forest, Piedmont / Mountain Alluvial Forest, Inner Piedmont / Lower Blue Ridge Basic Mesic Forest, Mesic Mixed Hardwood Forest
42. Evergreen Forest	Successional Virginia Pine Forest, Virginia Pine Plantation, Loblolly Pine Plantation
43. Mixed Forest	
52. Shrub/Scrub	
71. Grassland/Herbaceous	
81. Pasture/Hay	Cultural Meadow
82. Cultivated Crops	
90. Woody Wetlands	
95. Emergent Herbaceous Wetlands	Beaver Wetland Complex, Northern Piedmont / Lower New England Basic Seepage Swamp, Upland Depression Swamp

Table E-2. Classification of natural systems.

Non-Anthropogenic	Anthropogenic Influence
11. Open Water	21. Developed, Open Space
12. Perennial Ice/Snow	22. Developed, Low Intensity
41. Deciduous Forest	23. Developed, Medium Intensity
42. Evergreen Forest	24. Developed, High Intensity
43. Mixed Forest	31. Barren Land (Rock/Sand/Clay)
52. Shrub/Scrub	81. Pasture/Hay
71. Grassland/Herbaceous	82. Cultivated Crops
90. Woody Wetlands	
95. Emergent Herbaceous Wetlands	

Buffer Index

<u>Datasets</u>

1. Land cover dataset created under “Landscape Connectivity.”
2. Wetland dataset created under “Landscape Connectivity.”
3. National Elevation Dataset (NED).

<u>Methodology</u>

1. Identify and classify vegetated, non-anthropogenic land cover.
2. In a GIS determine the percentage of the wetland perimeter adjacent to buffer.
3. In a GIS determine the average width of identified buffer, corrected for slope.

<u>Classification</u>

1. Natural land cover defined as defined under “Landscape Connectivity”
2. Slope correction
    a) We assume that the length of the buffer should increase as slope increases. The most simple relationship to use would be the length of the slope which increases with any increase in rise (over a constant run). Using trigonometry, we know that the length of the slope is the square root of the rise squared plus the run squared. The run is constant at the threshold value provided (i.e., 200 m, 100m, 50m, 10m) and the increase in rise results in a lengthening run determined by this formula.
    b) The critical assumption is that the increased length provides the same “protection” as the 200m buffer does on flat ground. Or, the higher the slope the longer the slope length needed to provide equivalent protection. For example, if 200 m on flat ground provides protection, then the slope length (i.e., buffer width) on a 40% slope would be 215.4m. A percent slope of 40% is derived from a run of 200 m and a rise of 80 m (200 * 0.4). The slope distance is determined by taking the square root of 200 squared plus 80 squared. In other words, on a slope of 40% the minimum buffer width required to provide the same protection as 200 m on flat ground would be 215.4 m.

<u>Analysis</u>

Grades will be assigned for both the percent of natural land cover and average corrected buffer width based on the grading index provided by the NPS.

Surrounding Land Use Index

<u>Datasets</u>

1. Park boundary polygon.
2. Land cover as defined above.
3. 1:250,000 Hydrologic units from the U.S. Geological Survey (USGS).

<u>Methodology</u>

1. Buffer park boundary to landscape area as delineated by the 8-digit Hydrologic Unit Code (HUC).
2. Rank land cover by human impact.
3. In a GIS run analysis of land cover within the watershed.

Classification

Land cover classifications ranked by anthropogenic impact (Table F-3).

Analysis

Land cover index for the buffer area summed for each pixel divided by the total number of pixels in the area. The maximum value = 1 and minimum – 0. Grades will be assigned based on the grading index provided by the NPS.

Table E-3. Land cover ranking.

NLCD/Vegetation Class	Ranking
24. Developed, High Intensity	1
23. Developed, Medium Intensity	0.9
22. Developed, Low Intensity	0.8
21. Developed, Open Space	0.7
82. Cultivated Crops	0.6
31. Barren Land (Rock/Sand/Clay)	0.5
81. Pasture/Hay	0.3
11. Open Water, 12. Perennial Ice/Snow, 41. Deciduous Forest, 42. Evergreen Forest, 43. Mixed Forest, 52. Shrub/Scrub, 71. Grassland/Herbaceous, 90. Woody Wetlands, 95. Emergent Herbaceous Wetlands	0

Appendix F-1: Vegetation types from the Richmond National Battlefield Park land cover map.

Local Name	NVCS Code
Beaver Wetland Complex	III.B.2.N.e
Cultural Meadow	V.A.5.N.c
Dense Hardwood Regeneration	Dense Hardwood Regeneration
Grazed Woodlot	Grazed Woodlot
Inner Piedmont / Lower Blue Ridge Basic Mesic Forest	I.B.2.N.a
Loblolly Pine Plantation	I.A.8.C.x
Mesic Mixed Hardwood Forest	I.B.2.N.a
Northern Piedmont / Lower New England Basic Seepage Swamp	I.B.2.N.g
Oak - Hickory Forest	I.B.2.N.a
Other Urban or Built-up Land	Other Urban or Built-up Land
Piedmont / Low Elevation Mixed Oak / Heath Forest	I.B.2.N.a
Piedmont / Mountain Alluvial Forest	I.B.2.N.d
Successional Black Walnut Forest	I.B.2.N.a
Successional Red-cedar Forest	I.A.8.N.c
Successional Tree-of-Heaven Forest	I.B.2.N.a
Successional Tuliptree Forest	I.B.2.N.a
Successional Virginia Pine Forest	I.A.8.N.b
Transportation, Communications, and Utilities	Transportation, Communications, and Utilities
Upland Depression Swamp	I.B.2.N.e
Virginia Pine Plantation	I.A.8.C.x

Appendix F-2. NLCD land cover codes and descriptions.

11. Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.

12. Perennial Ice/Snow - All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.

21. Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes

22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

23. Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

24. Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

31. Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

41. Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

52. Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

71. Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

95. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Appendix G. Description of abbreviations used in species tables.

NatureServe Ranks (NatureServe 2009):
Global Ranks:
G#G#: NatureServe Global Conservation Status Rank, Range Rank - A numeric range rank (e.g., G2G3) is used to indicate the rank of uncertainty in the status of a species or community. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4).

G1: Critically Imperiled
At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.

G2: Imperiled
At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

G3: Vulnerable
At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

G4: Apparently Secure
Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5: Secure
Common; widespread, and abundant.

State Ranks:
S#S#: NatureServe Subnational Conservation Status Rank - Range Rank-A numeric range rank (e.g., S2S3) is used to indicate the range of uncertainty about the status of the species or community. Ranges cannot skip more than one rank (e.g., SU should be used rather than S1S4).

S?: Unranked
State/Province conservation status not yet assessed.

S1: Critically Imperiled
Critically imperiled in the state or province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state or province.

S2: Imperiled
Imperiled in the state or province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state or province.

S3: Vulnerable
Vulnerable in the state or province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.

S4: Apparently Secure
Uncommon but not rare; some cause for long-term concern due to declines or other factors.

S5: Secure
Common, widespread, and abundant in the state or province.

VDGIF listings for endangered, threatened, or rare species (Virginia Department of Game and Inland Fisheries 2009):
SS=State Special Concern
FS=Federal Species of Concern

Species of Greatest Conservation Need:
I=VA Wildlife Action Plan - Tier I - Critical Conservation Need
II=VA Wildlife Action Plan - Tier II - Very High Conservation Need
III=VA Wildlife Action Plan - Tier III - High Conservation Need
IV=VA Wildlife Action Plan - Tier IV - Moderate Conservation Need

Appendix H. Fish species documented for Richmond National Battlefield Park. These species have been cross referenced to the VA Wildlife Action Plan (Virginia Department of Game and Inland Fisheries 2005) Species of Greatest Conservation Need; the VA listings for endangered, threatened, or rare species (VADGIF 2009); and NatureServe's global and state rankings. See reference or Appendix F for explanation of abbreviations.

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	VA SGCN	Global Rank	State Rank	Federal Status	State Status
Acantharchus pomotis	mud sunfish	Present in Park	Common	Breeder	Native	Tier IV				
Ambloplites rupestris	rock bass	Present in Park	Uncommon	Breeder	Nonnative					
Ameiurus natalis	yellow bullhead	Present in Park	Common	Breeder	Native					
Anguilla rostrata	American eel	Present in Park	Common	Resident	Native	Tier IV	G4	S5		
Aphredoderus sayanus	pirate perch	Present in Park	Common	Breeder	Native					
Centrarchus macropterus	flier	Present in Park	Abundant	Breeder	Native					
Clinostomus funduloides	rosyside dace	Present in Park	Uncommon	Breeder	Native					
Dorosoma cepedianum	gizzard shad	Present in Park	Uncommon	Breeder	Native					
Enneacanthus gloriosus	bluespotted sunfish	Present in Park	Common	Breeder	Native					
Erimyzon oblongus	creek chubsucker	Present in Park	Common	Breeder	Native					
Esox niger	chain pickerel	Present in Park	Common	Breeder	Native					
Etheostoma fusiforme	swamp darter	Present in Park	Uncommon	Breeder	Native					
Etheostoma olmstedi	tessellated darter	Present in Park	Uncommon	Breeder	Native					
Gambusia holbrooki	mosquitofish	Present in Park	Abundant	Breeder	Native					
Lampetra aepyptera	least brook lamprey	Present in Park	Uncommon	Breeder	Native	Tier IV				
Lepomis auritus	redbreast sunfish	Present in Park	Common	Breeder	Native					
Lepomis cyanellus	green sunfish	Present in Park	Uncommon	Breeder	Native					
Lepomis gibbosus	pumpkinseed	Present in Park	Common	Breeder	Native					
Lepomis gulosus	warmouth	Present in Park	Common	Breeder	Native					
Lepomis macrochirus	bluegill	Present in Park	Abundant	Breeder	Nonnative					
Micropterus punctulatus	spotted bass	Present in Park	Uncommon	Breeder	Nonnative					
Micropterus salmoides	largemouth bass	Present in Park	Common	Breeder	Nonnative					
Nocomis leptocephalus	bluehead chub	Present in Park	Uncommon	Breeder	Native					
Notemigonus crysoleucas	golden shiner	Present in Park	Common	Breeder	Native					
Notropis chalybaeus	ironcolor shiner	Present in Park	Uncommon	Breeder	Native	Tier IV				
Noturus insignis	margined madtom	Present in Park	Uncommon	Breeder	Native					
Pomoxis annularis	white crappie	Present in Park	Uncommon	Breeder	Nonnative					
Pomoxis nigromaculatus	black crappie	Present in Park	Common	Breeder	Native					
Semotilus atromaculatus	creek chub	Present in Park	Uncommon	Breeder	Native					
Umbra pygmaea	eastern mudminnow	Present in Park	Abundant	Breeder	Native					

Appendix I. Amphibian species documented for Richmond National Battlefield Park.

These species have been cross referenced to the VA Wildlife Action Plan (VDGIF 2005) Species of Greatest Conservation Need; the VA listings for endangered, threatened, or rare species (VDGIF 2009); and NatureServe's global and state rankings (NatureServe 2009). See reference or Appendix F for an explanation of abbreviations.

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	VA SGCN	Global Rank	State Rank	Federal Status	State Status
Rana catesbeiana	American bullfrog	Present in Park	Abundant	Resident	Native					
Plethodon chlorobryonis	Atlantic Coast slimy salamander	Present in Park	Common	Resident	Native					
Hyla chrysoscelis	Cope's gray treefrog	Present in Park	Abundant	Resident	Native					
Bufo americanus americanus	eastern American toad	Present in Park	Common	Resident	Native					
Gastrophryne carolinensis	eastern narrowmouth toad	Present in Park	Common	Resident	Native					
Plethodon cinereus	eastern red-backed salamander	Present in Park	Abundant	Resident	Native					
Scaphiopus holbrookii	eastern spadefoot toad	Present in Park	Common	Resident	Native					
Bufo fowleri	Fowler's toad	Present in Park	Abundant	Resident	Native					
Hyla cinerea	green treefrog	Present in Park	Common	Resident	Native					
Ambystoma opacum	marbled salamander	Present in Park	Common	Resident	Native					
Acris crepitans crepitans	northern cricket frog	Present in Park	Common	Resident	Native					
Desmognathus fuscus fuscus	northern dusky salamander	Present in Park	Uncommon	Breeder	Native					
Rana clamitans melanota	northern green frog	Present in Park	Abundant	Resident	Native					
Pseudotriton ruber ruber	northern red salamander	Present in Park	Rare	Resident	Native					
Pseudacris crucifer crucifer	northern spring peeper	Present in Park	Abundant	Breeder	Native					
Rana palustris	pickerel frog	Present in Park	Common	Resident	Native					
Hyla femoralis	pine woods treefrog	Present in Park	Uncommon	Resident	Native					
Notophthalmus viridescens viridescens	red-spotted newt	Present in Park	Abundant	Breeder	Native					
Rana sphenocephala utricularia	southern leopard frog	Present in Park	Common	Resident	Native					
Eurycea cirrigera	southern two-lined salamander	Present in Park	Uncommon	Breeder	Native					
Ambystoma maculatum	spotted salamander	Present in Park	Common	Resident	Native					
Amphiuma means	two-toed amphiuma	Present in Park	Uncommon	Resident	Native					
Pseudacris feriarum feriarum	upland chorus frog	Present in Park	Common	Resident	Native					
Plethodon cylindraceus	white-spotted slimy salamander	Present in Park	Uncommon	Resident	Native					

Appendix J. Reptile species documented for Richmond National Battlefield Park.

These species have been cross referenced to the VA Wildlife Action Plan (VDGIF 2005) Species of Greatest Conservation Need; the VA listings for endangered, threatened, or rare species (VDGIF 2009); and NatureServe's global and state rankings (NatureServe 2009). See reference or Appendix Ffor an explanation of abbreviations.

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	VA SGCN	Global Rank	State Rank	Federal Status	State Status
Pseudemys rubriventris	American red-bellied turtle	Present in Park	Uncommon	Breeder	Native					
Elaphe obsoleta obsoleta	black ratsnake	Present in Park	Common	Breeder	Native					
Eumeces fasciatus	common five-lined skink	Present in Park	Common	Breeder	Native					
Sternotherus odoratus	common musk turtle (stinkpot)	Present in Park	Common	Breeder	Native					
Trachemys scripta scripta	common slider	Present in Park	Rare	Breeder	Unknown	Tier IV				
Nerodia sipedon sipedon	common watersnake	Present in Park	Common	Breeder	Native					
Agkistrodon contortrix mokasen	copperhead	Present in Park	Uncommon	Breeder	Native					
Terrapene carolina carolina	eastern box turtle	Present in Park	Abundant	Breeder	Native	Tier III	G5	S4		
Thamnophis sirtalis sirtalis	eastern garter snake	Present in Park	Unknown	Breeder	Native					
Heterodon platirhinos	eastern hog-nosed snake	Present in Park	Uncommon	Breeder	Native	Tier IV				
Lampropeltis getula getula	eastern kingsnake	Present in Park	Uncommon	Breeder	Native	Tier III				
Kinosternon subrubrum subrubrum	eastern mud turtle	Present in Park	Unknown	Breeder	Native					
Chrysemys picta picta	eastern painted turtle	Present in Park	Common	Breeder	Native					
Chelydra serpentina serpentina	eastern snapping turtle	Present in Park	Uncommon	Breeder	Native					
Carphophis amoenus amoenus	eastern worm snake	Present in Park	Abundant	Breeder	Native					
Scincella lateralis	little brown skink	Present in Park	Uncommon	Breeder	Native					
Lampropeltis triangulum triangulum	milk snake	Present in Park	Rare	Breeder	Native					
Coluber constrictor constrictor	northern black racer	Present in Park	Common	Breeder	Native					
Sceloporus undulatus hyacinthinus	northern fence lizard	Present in Park	Common	Breeder	Native					
Diadophis punctatus edwardsii	northern ring-necked snake	Present in Park	Common	Breeder	Native					
Storeria occipitomaculata occipitomaculata	red-bellied snake	Present in Park	Unknown	Breeder	Native					
Opheodrys aestivus	rough green snake	Present in Park	Unknown	Breeder	Native					
Eumeces inexpectatus	southeastern five-lined skink	Present in Park	Uncommon	Resident	Native					
Clemmys guttata	spotted turtle	Present in Park	Uncommon	Breeder	Native	Tier III				

Appendix K. Bird species documented for Richmond National Battlefield Park.

These species have been cross referenced to the VA Wildlife Action Plan (Virginia Department of Game and Inland Fisheries 2005) Species of Greatest Conservation Need; the VA listings for endangered, threatened, or rare species (VDGIF 2009); and NatureServe's global and state rankings (NatureServe 2009). See reference or Appendix F for an explanation of abbreviations. Bird species were also cross referenced to the Partners in Flight Priority Species (Partners in Flight 2005) and Audubon WatchList (National Audubon Society 2007).

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	SGCN	Priority Species	WatchList	Global Rank	State Rank	Fed. Status	State Status
Empidonax virescens	Acadian flycatcher	In Park	Abundant	Breeder	Native		Yes					
Anas rubripes	American black duck	In Park	Unknown	Unknown	Native	Tier II		Yes	G5	S4		
Corvus brachyrhynchos	American crow	In Park	Abundant	Breeder	Native							
Carduelis tristis	American goldfinch	In Park	Abundant	Breeder	Native							
Falco sparverius	American kestrel	In Park	Rare	Unknown	Native							
Setophaga ruticilla	American redstart	In Park	Common	Unknown	Native							
Turdus migratorius	American robin	In Park	Abundant	Breeder	Native							
Anas americana	American wigeon	In Park	Uncommon	Resident	Native							
Scolopax minor	American woodcock	In Park	Rare	Unknown	Native	Tier IV		Yes	G5	S5		
Haliaeetus leucocephalus	bald eagle	In Park	Rare	Unknown	Native	Tier II		Yes	G5	S2S3B,S3N	FS	ST
Icterus galbula	Baltimore oriole	In Park	Rare	Unknown	Native							
Riparia riparia	bank swallow	In Park	Rare	Unknown	Native							
Hirundo rustica	barn swallow	In Park	Common	Breeder	Native							
Strix varia	barred owl	In Park	Uncommon	Unknown	Native							
Dendroica castanea	bay-breasted warbler	In Park	Rare	Migratory	Native							
Ceryle alcyon	belted kingfisher	In Park	Rare	Breeder	Native							
Coragyps atratus	black vulture	In Park	Common	Unknown	Native							
Mniotilta varia	black-and-white warbler	In Park	Common	Breeder	Native	Tier IV			G5	S5		
Himantopus mexicanus	black-necked stilt	In Park	Rare	Unknown	Native							
Dendroica striata	blackpoll warbler	In Park	Common	Migratory	Native							
Dendroica caerulescens	black-throated blue warbler	In Park	Common	Migratory	Native							
Dendroica virens	black-throated green warbler	In Park	Uncommon	Unknown	Native							
Guiraca caerulea	blue grosbeak	In Park	Common	Breeder	Native							
Cyanocitta cristata	blue jay	In Park	Abundant	Breeder	Native							
Polioptila caerulea	blue-gray gnatcatcher	In Park	Abundant	Breeder	Native							
Vireo solitarius	blue-headed vireo	In Park	Unknown	Unknown	Native							
Anas discors	blue-winged teal	In Park	Uncommon	Unknown	Native							
Vermivora pinus	blue-winged warbler	In Park	Unknown	Unknown	Native							
Buteo platypterus	broad-winged hawk	In Park	Unknown	Unknown	Native							
Certhia americana	brown creeper	In Park	Uncommon	Resident	Native	Tier IV	Yes		G5	S3B,S5N		

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	SGCN	Priority Species	WatchList	Global Rank	State Rank	Fed. Status	State Status
Phalacrocorax auritus	brown pelican	In Park	Uncommon	Unknown	Native							
Toxostoma rufum	brown thrasher	In Park	Common	Breeder	Native	Tier IV			G5	S5		
Molothrus ater	brown-headed cowbird	In Park	Abundant	Breeder	Nonnative							
Bucephala albeola	bufflehead	In Park	Rare	Resident	Native							
Branta canadensis	Canada goose	In Park	Abundant	Breeder	Native							
Wilsonia canadensis	Canada warbler	In Park	Rare	Migratory	Native							
Dendroica tigrina	Cape May warbler	In Park	Uncommon	Migratory	Native							
Poecile carolinensis	Carolina chickadee	In Park	Abundant	Breeder	Native							
Thryothorus ludovicianus	Carolina wren	In Park	Abundant	Breeder	Native							
Sterna caspia	Caspian tern	In Park	Rare	Unknown	Native							
Bombycilla cedrorum	cedar waxwing	In Park	Common	Breeder	Native							
Dendroica pensylvanica	chestnut-sided warbler	In Park	Unknown	Unknown	Native							
Chaetura pelagica	chimney swift	In Park	Common	Breeder	Native	Tier IV	Yes		G5	S5		
Spizella passerina	chipping sparrow	In Park	Abundant	Breeder	Native							
Quiscalus quiscula	common grackle	In Park	Abundant	Breeder	Native							
Geothlypis trichas	common yellowthroat	In Park	Abundant	Breeder	Native							
Gallinago gallinago	common snipe	In Park	Unknown	Unknown	Native							
Accipiter cooperii	Cooper's hawk	In Park	Rare	Unknown	Native							
Junco hyemalis	dark-eyed junco	In Park	Abundant	Resident	Native							
Phalacrocorax auritus	double-crested cormorant	In Park	Unknown	Unknown	Native							
Picoides pubescens	downy woodpecker	In Park	Common	Breeder	Native							
Sialia sialis	eastern bluebird	In Park	Abundant	Breeder	Native							
Tyrannus tyrannus	eastern kingbird	In Park	Common	Breeder	Native	Tier IV			G5	S5		
Sturnella magna	eastern meadowlark	In Park	Common	Breeder	Native	Tier IV	Yes	Yes	G5	S5		
Sayornis phoebe	eastern phoebe	In Park	Common	Breeder	Native							
Pipilo erythrophthalmus	eastern towhee	In Park	Common	Breeder	Native	Tier IV	Yes		G5	S5		
Otus asio	eastern screech owl	In Park	Unknown	Unknown	Native							
Contopus virens	eastern wood-pewee	In Park	Abundant	Breeder	Native	Tier IV			G5	S5		
Sturnus vulgaris	European starling	In Park	Common	Breeder	Nonnative							
Spizella pusilla	field sparrow	In Park	Abundant	Unknown	Native	Tier IV	Yes	Yes	G5	S5		
Corvus ossifragus	fish crow	In Park	Uncommon	Unknown	Native							
Passerella iliaca	fox sparrow	In Park	Unknown	Unknown	Native							
Anas strepera	gadwall	In Park	Common	Unknown	Native							
Aquila chrysaetos	golden eagle	In Park	Rare	Migratory	Native							
Regulus satrapa	golden-crowned kinglet	In Park	Common	Resident	Native							
Ammodramus savannarum	grasshopper sparrow	In Park	Common	Breeder	Native	Tier IV	Yes	Yes	G5	S4		
Dumetella carolinensis	gray catbird	In Park	Common	Breeder	Native	Tier IV			G5	S5		
Catharus minimus	gray-cheeked thrush	In Park	Unknown	Unknown	Native							
Ardea herodias	great blue heron	In Park	Common	Unknown	Native							

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	SGCN	Priority Species	WatchList	Global Rank	State Rank	Fed. Status	State Status
Myiarchus crinitus	great crested flycatcher	In Park	Abundant	Breeder	Native							
Ardea alba	great egret	In Park	Rare	Unknown	Native							
Bubo virginianus	great horned owl	In Park	Rare	Unknown	Native							
Tringa melanoleuca	greater yellowlegs	In Park	Uncommon	Unknown	Native							
Butorides virescens	green heron	In Park	Uncommon	Unknown	Native	Tier IV			G5	S5		
Anas crecca	green-winged teal	In Park	Common	Resident	Native							
Picoides villosus	hairy woodpecker	In Park	Common	Breeder	Native							
Larus argentatus	herring gull	In Park	Unknown	Unknown	Native							
Catharus guttatus	hermit thrush	In Park	Uncommon	Resident	Native							
Lophodytes cucullatus	hooded merganser	In Park	Common	Resident	Native							
Wilsonia citrina	hooded warbler	In Park	Common	Breeder	Native							
Eremophila alpestris	horned lark	In Park	Unknown	Unknown	Native							
Carpodacus mexicanus	house finch	In Park	Common	Breeder	Nonnative							
Troglodytes aedon	house wren	In Park	Rare	Unknown	Native							
Passerina cyanea	indigo bunting	In Park	Abundant	Breeder	Native							
Oporornis formosus	Kentucky warbler	In Park	Common	Breeder	Native	Tier IV	Yes		G5	S5		
Charadrius vociferus	killdeer	In Park	Uncommon	Breeder	Native							
Larus atricilla	laughing gull	In Park	Rare	Unknown	Native							
Calidris minutilla	least sandpiper	In Park	Common	Migratory	Native							
Tringa flavipes	lesser yellowlegs	In Park	Unknown	Unknown	Native							
Seiurus motacilla	Louisiana waterthrush	In Park	Common	Breeder	Native	Tier IV	Yes		G5	S5		
Dendroica magnolia	magnolia warbler	In Park	Uncommon	Unknown	Native							
Anas platyrhynchos	mallard	In Park	Common	Unknown	Native							
Zenaida macroura	mourning dove	In Park	Abundant	Breeder	Native							
Colinus virginianus	northern bobwhite	In Park	Common	Breeder	Native	Tier IV	Yes	Yes	G5	S5		
Cardinalis cardinalis	northern cardinal	In Park	Abundant	Breeder	Native							
Colaptes auratus	northern flicker	In Park	Common	Breeder	Native							
Circus cyaneus	northern harrier	In Park	Rare	Resident	Native	Tier III			G5	S1S2B,S3N		
Mimus polyglottos	northern mockingbird	In Park	Common	Breeder	Native							
Parula americana	northern parula	In Park	Common	Breeder	Native	Tier IV	Yes		G5	S5		
Anas acuta	northern pintail	In Park	Unknown	Unknown	Native							
Stelgidopteryx serripennis	northern rough-winged swallow	In Park	Uncommon	Unknown	Native	Tier IV			G5	S5		
Aegolius acadicus	northern saw-whet owl	In Park	Rare	Resident	Native	Tier II						
Seiurus noveboracensis	northern waterthrush	In Park	Uncommon	Migratory	Native							
Icterus spurius	orchard oriole	In Park	Common	Breeder	Native							
Pandion haliaetus	osprey	In Park	Rare	Unknown	Native							
Seiurus aurocapillus	ovenbird	In Park	Abundant	Breeder	Native	Tier IV			G5	S5		
Dendroica palmarum	palm warbler	In Park	Rare	Migratory	Native							
Podilymbus podiceps	pied-billed grebe	In Park	Rare	Unknown	Native							

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	SGCN	Priority Species	WatchList	Global Rank	State Rank	Fed. Status	State Status
Dryocopus pileatus	pileated woodpecker	In Park	Common	Breeder	Native							
Dendroica pinus	pine warbler	In Park	Abundant	Breeder	Native							
Dendroica discolor	prairie warbler	In Park	Common	Breeder	Native	Tier IV			G5	S5		
Protonotaria citrea	prothonotary warbler	In Park	Uncommon	Breeder	Native	Tier IV			G5	S4		
Progne subis	purple martin	In Park	Uncommon	Unknown	Native							
Melanerpes carolinus	red-bellied woodpecker	In Park	Abundant	Breeder	Native							
Vireo olivaceus	red-eyed vireo	In Park	Abundant	Breeder	Native							
Melanerpes erythrocephalus	red-headed woodpecker	In Park	Common	Breeder	Native							
Buteo lineatus	red-shouldered hawk	In Park	Common	Breeder	Native							
Buteo jamaicensis	red-tailed hawk	In Park	Common	Breeder	Native							
Agelaius phoeniceus	red-winged blackbird	In Park	Abundant	Breeder	Native							
Larus delawarensis	ring-billed gull	In Park	Unknown	Unknown	Native							
Aythya collaris	ring-necked duck	In Park	Abundant	Resident	Native							
Pheucticus ludovicianus	rose-breasted grosbeak	In Park	Rare	Migratory	Native							
Regulus calendula	ruby-crowned kinglet	In Park	Common	Resident	Native							
Archilochus colubris	ruby-throated hummingbird	In Park	Common	Breeder	Native							
Euphagus carolinus	rusty blackbird	In Park	Rare	Resident	Native							
Passerculus sandwichensis	savannah sparrow	In Park	Common	Resident	Native							
Piranga olivacea	scarlet tanager	In Park	Common	Breeder	Native	Tier IV	Yes		G5	S5B		
Accipiter striatus	sharp-shinned hawk	In Park	Rare	Resident	Native							
Tringa solitaria	solitary sandpiper	In Park	Common	Migratory	Native							
Melospiza melodia	song sparrow	In Park	Abundant	Breeder	Native							
Actitis macularia	spotted sandpiper	In Park	Rare	Unknown	Native							
Piranga rubra	summer tanager	In Park	Abundant	Breeder	Native							
Catharus ustulatus	Swainson's thrush	In Park	Unknown	Unknown	Native							
Melospiza georgiana	swamp sparrow	In Park	Common	Resident	Native							
Vermivora peregrina	Tennessee warbler	In Park	Rare	Migratory	Native							
Tachycineta bicolor	tree swallow	In Park	Uncommon	Unknown	Native							
Baeolophus bicolor	tufted titmouse	In Park	Abundant	Breeder	Native							
Cathartes aura	turkey vulture	In Park	Abundant	Unknown	Native							
Catharus fuscescens	veery	In Park	Rare	Migratory	Native							
Sitta carolinensis	white-breasted nuthatch	In Park	Abundant	Breeder	Native							
Vireo griseus	white-eyed vireo	In Park	Abundant	Breeder	Native							
Zonotrichia albicollis	white-throated sparrow	In Park	Abundant	Resident	Native							
Meleagris gallopavo	wild turkey	In Park	Common	Breeder	Native							
Troglodytes troglodytes	winter wren	In Park	Unknown	Resident	Native							
Aix sponsa	wood duck	In Park	Common	Breeder	Native							
Hylocichla mustelina	wood thrush	In Park	Abundant	Breeder	Native	Tier IV	Yes	Yes	G5	S5		
Helmitheros vermivorus	worm-eating warbler	In Park	Rare	Unknown	Native	Tier IV	Yes		G5	S4		

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	SGCN	Priority Species	WatchList	Global Rank	State Rank	Fed. Status	State Status
Dendroica petechia	yellow warbler	In Park	Uncommon	Breeder	Native	Tier IV			G5	S5		
Sphyrapicus varius	yellow-bellied sapsucker	In Park	Unknown	Unknown	Native							
Coccyzus americanus	yellow-billed cuckoo	In Park	Common	Breeder	Native	Tier IV			G5	S5B		
Icteria virens	yellow-breasted chat	In Park	Common	Breeder	Native	Tier IV	Yes		G5	S5		
Dendroica coronata	yellow-rumped warbler	In Park	Abundant	Resident	Native							
Vireo flavifrons	yellow-throated vireo	In Park	Common	Breeder	Native	Tier IV			G5	S4		
Dendroica dominica	yellow-throated warbler	In Park	Common	Breeder	Native							

Appendix L. Mammal species documented for Richmond National Battlefield Park.

These species have been cross referenced to the VA Wildlife Action Plan (VDGIF 2005) Species of Greatest Conservation Need; the VA listings for endangered, threatened, or rare species (VDGIF 2009); and NatureServe's global and state rankings (NatureServe 2009). See reference or Appendix F for an explanation of abbreviations.

Scientific Name	Common Name	Park Status	Abundance	Residency	Nativity	VA SGCN	Global Rank	State Rank	Federal Status	State Status
Castor canadensis	American beaver	Present in Park	Uncommon	Breeder	Native					
Mustela vison	American mink	Present in Park	Rare	Unknown	Native					
Felis silvestris	domestic cat	Present in Park	Uncommon	Unknown	Nonnative					
Tamias striatus	eastern chipmunk	Present in Park	Common	Breeder	Native					
Sylvilagus floridanus	eastern cottontail	Present in Park	Uncommon	Breeder	Native					
Sciurus carolinensis	eastern gray squirrel	Present in Park	Uncommon	Breeder	Native					
Reithrodontomys humulis	eastern harvest mouse	Present in Park	Uncommon	Breeder	Native					
Scalopus aquaticus	eastern mole	Present in Park	Uncommon	Breeder	Native					
Urocyon cinereoargenteus	gray fox	Present in Park	Uncommon	Breeder	Native					
Mus musculus	house mouse	Present in Park	Common	Breeder	Nonnative					
Oryzomys palustris	marsh rice rat	Present in Park	Uncommon	Breeder	Native					
Microtus pennsylvanicus	meadow vole	Present in Park	Uncommon	Breeder	Native					
Blarina brevicauda	northern short-tailed shrew	Present in Park	Uncommon	Breeder	Native					
Procyon lotor	raccoon	Present in Park	Common	Breeder	Native					
Vulpes vulpes	red fox	Present in Park	Rare	Unknown	Nonnative					
Lontra canadensis	river otter	Present in Park	Rare	Unknown	Native					
Glaucomys volans	southern flying squirrel	Present in Park	Common	Breeder	Native					
Mephitis mephitis	striped skunk	Present in Park	Uncommon	Breeder	Native					
Didelphis virginiana	Virginia opossum	Present in Park	Uncommon	Breeder	Native					
Peromyscus leucopus	white-footed mouse	Present in Park	Abundant	Breeder	Native					
Odocoileus virginianus	white-tailed deer	Present in Park	Abundant	Breeder	Native					
Marmota monax	woodchuck	Present in Park	Uncommon	Breeder	Native					
Microtus pinetorum	woodland vole	Present in Park	Common	Breeder	Native					

Appendix M. SSURGO definition of 'erosion hazard (off-road, off-trail).'

The ratings in this interpretation indicate the hazard of soil loss from off-road and off-trail areas after disturbance activities that expose the soil surface. The ratings are based on slope and soil erosion factor K. The soil loss is caused by sheet or rill erosion in off-road or off-trail areas where 50 to 75 percent of the surface has been exposed by logging, grazing, mining, or other kinds of disturbance.

The ratings are both verbal and numerical. The hazard is described as "slight," "moderate," "severe," or "very severe." A rating of "slight" indicates that erosion is unlikely under ordinary climatic conditions; "moderate" indicates that some erosion is likely and that erosion-control measures may be needed; "severe" indicates that erosion is very likely and that erosion-control measures, including revegetation of bare areas, are advised; and "very severe" indicates that significant erosion is expected, loss of soil productivity and off-site damage are likely, and erosion-control measures are costly and generally impractical.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the specified aspect of forestland management (1.00) and the point at which the soil feature is not a limitation (0.00).

Rating Options

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value to represent the map unit as a whole.

A map unit is typically composed of one or more "components." A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. The components in the map unit name represent the major soils within a map unit delineation. Minor components make up the balance of the map unit. Great differences in soil properties can occur between map unit components and within short distances. Minor components may be very different from the major components. Such differences could significantly affect use and management of the map unit. Minor components may or may not be documented in the database. The results of aggregation do not reflect the presence or absence of limitations of the components which are not listed in the database. An on-site investigation is required to identify the location of individual map unit components.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be generated. Aggregation must be done because, on any soil map, map units are delineated but components are not. The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie.

The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Tie-break Rule: Higher
The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Appendix N. SSURGO definition of 'Flooding Frequency.'

Flooding is the temporary inundation of an area caused by overflowing streams, by runoff from adjacent slopes, or by tides. Water standing for short periods after rainfall or snowmelt is not considered flooding, and water standing in swamps and marshes is considered ponding rather than flooding.

Frequency is expressed as none, very rare, rare, occasional, frequent, and very frequent.

"None" means that flooding is not probable. The chance of flooding is nearly 0 percent in any year. Flooding occurs less than once in 500 years.

"Very rare" means that flooding is very unlikely but possible under extremely unusual weather conditions. The chance of flooding is less than 1 percent in any year.

"Rare" means that flooding is unlikely but possible under unusual weather conditions. The chance of flooding is 1 to 5 percent in any year.

"Occasional" means that flooding occurs infrequently under normal weather conditions. The chance of flooding is 5 to 50 percent in any year.

"Frequent" means that flooding is likely to occur often under normal weather conditions. The chance of flooding is more than 50 percent in any year but is less than 50 percent in all months in any year.

"Very frequent" means that flooding is likely to occur very often under normal weather conditions. The chance of flooding is more than 50 percent in all months of any year.

Appendix O. Climate data.

The threat of changing climate is real, and much research points to the high likelihood of broad ecological impacts as a result. How these changes will impact specific park resources is yet unknown, but they are likely to be comprehensive. That is not to say that those changes will be catastrophic. While specific biota or processes will be impacted, climate change may not result in extinctions or degradations.

There is much interest in documenting the trends in climate over time due to increasing temperatures and changing weather patterns across the globe (Blaustein et al. 2001, Walther et al. 2002, Corn 2005). Such changes have the potential to impact natural resources by shifting dominant vegetation communities, impacting animal species at the frontiers of their range, and impacting fundamental ecosystem processes. Invasive species, such as the hemlock woolly adelgid (*Adelges tsugae*), may be aided by warmer winter temperatures and spread further throughout the eastern coast (Paradis et al. 2007).

The Earth's climate has warmed by approximately 0.6°C (1.08°F) over the past 100 years. The main period of warming has occurred since 1976, and is greater than at any other time during the last 1,000 years (Walther et al. 2002). Average temperatures for January rose more than 5°F in the continental U.S. over the past 40 years (National Audubon Society 2009). Monitoring programs are important to track changes in species composition and abundance over time.

Analysis of four decades of data from the Audubon's Christmas Bird Count indicates a northward shift of birds seen in North America during the first weeks of winter. Movement occurred among 58% of the observed species (177 of 305) with an average northward movement of 35 miles, and 60 species moving in excess of 100 miles north (National Audubon Society 2009). Climate change can have the largest impact on the survival of many long-distance migratory birds. Birds are removed from food sources and cannot predict changes to their breeding or overwintering grounds. Some species are therefore unable to advance their arrival date in spring breeding grounds to coincide with leaf-out and the changing availability of different prey sources such as insects.

Climate data

We included some basic analysis on the climate of the landscape around Richmond NBP. Our analysis includes several weather events examined over the long term (~60 years). We attempted to narrow the suite of factors down to those metrics where data were available and long-term trends were established. These include temperature, precipitation, available moisture and phenology through growing degree days.

We used data provided by the Southeast Regional Climate Center (SERCC) to assess climate change for Richmond NBP. The SERCC is a regional climate center headquartered at the University of North Carolina at Chapel Hill and is directed and overseen by the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) and National Environmental Satellite, Data and Information Service (NESDIS). The Richmond airport is one of the locations with available long-term climate information summaries provided through the SERCC Historical Climate Summaries product. This product allows access to annual, monthly, and daily climate information, including mean temperature (The Southeast Regional Climate Center 2009). It is important to note that we are simply reporting the available data; this analysis is not statistically significant given gaps in data availability and wide variations in the data.

Temperature

We used the monthly average temperature data to examine annual temperature trends as well as seasonally for winter (December – February), spring (March – May), summer (June – August), and fall (September – November) seasons. The range of dates for which data were available was 1949 to 2009 however, due to incomplete data for 2009, this assessment utilizes data from 1949 to 2008. In some years data is incomplete or unavailable for certain months. In assessing seasonal trends, those years with one or more months of incomplete data are omitted from our analysis.

The mean annual temperature for Richmond, Virginia has increased approximately 0.27° F per decade (mean = 58.17° F) from 1949 to 2008 based on data available. This observed increasing trend was similar for all four seasons.

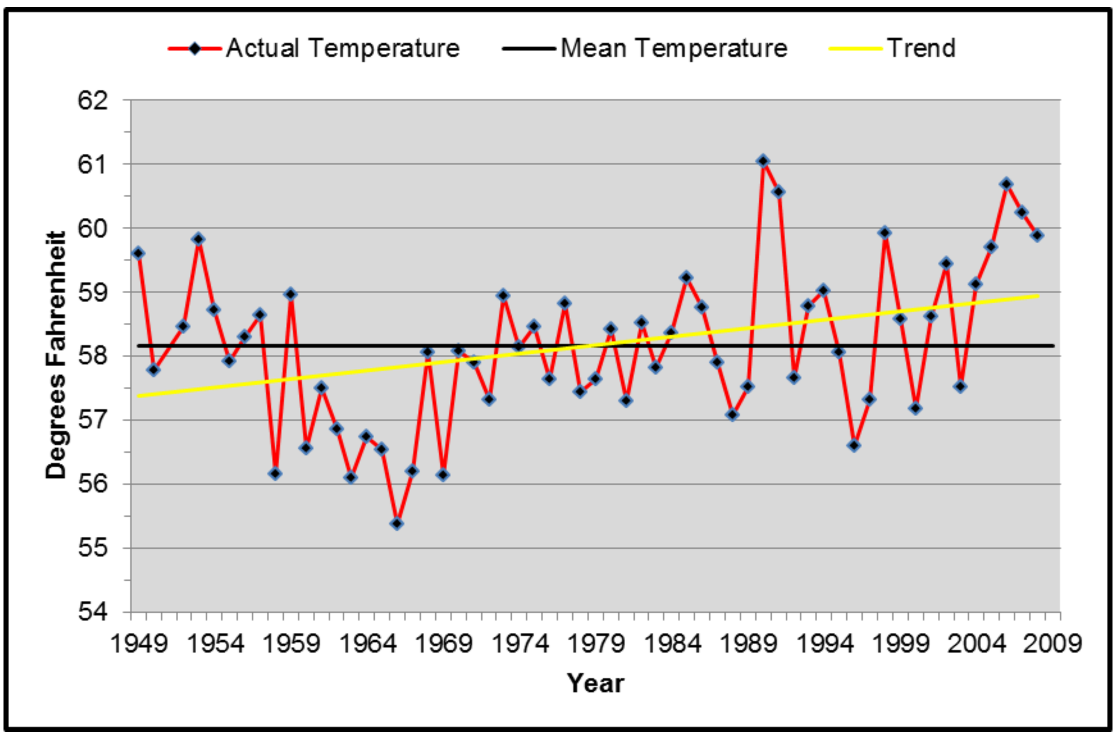

Figure O-1. Mean annual temperature for Richmond, VA from 1949 to 2008. The mean annual temperature is 58.17° F. There is an increasing trend of 0.27° F per decade (1951 was omitted due to insufficient data).

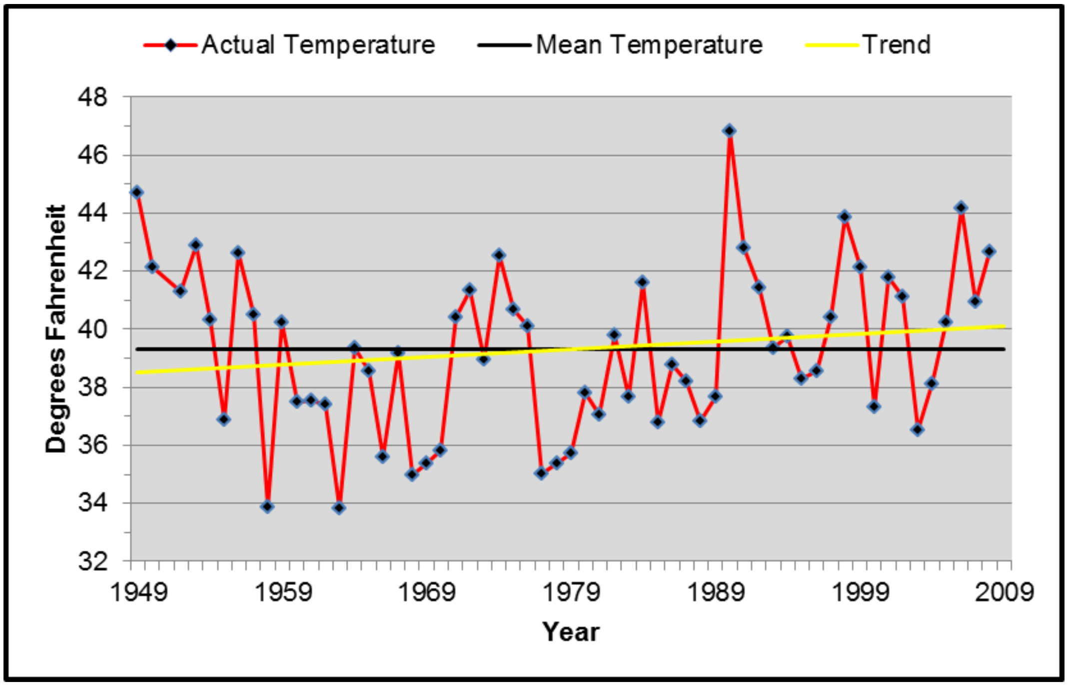

Figure O-2. Winter mean temperature for Richmond, VA from 1949 to 2008. The mean temperature is 39.3 °F with an increasing trend of 0.27° F per decade (1951 was omitted due to insufficient data).

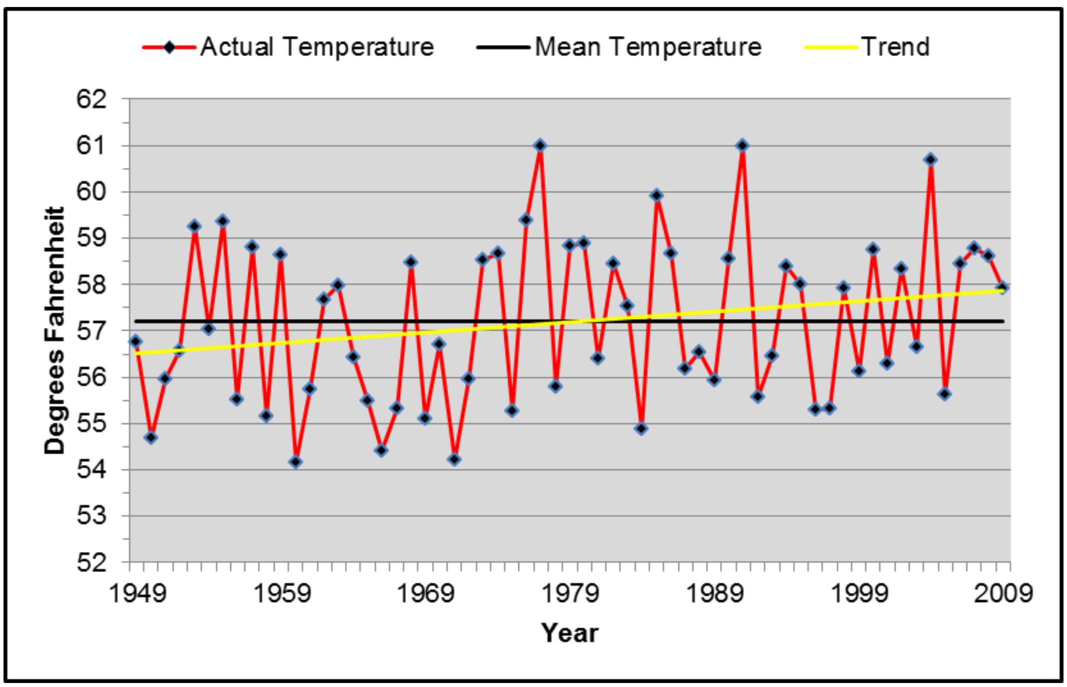

Figure O-3. Spring mean temperature for Richmond, VA from 1962 to 2009. The mean temperature is 57.2° F with an increasing trend of 0.23° F per decade.

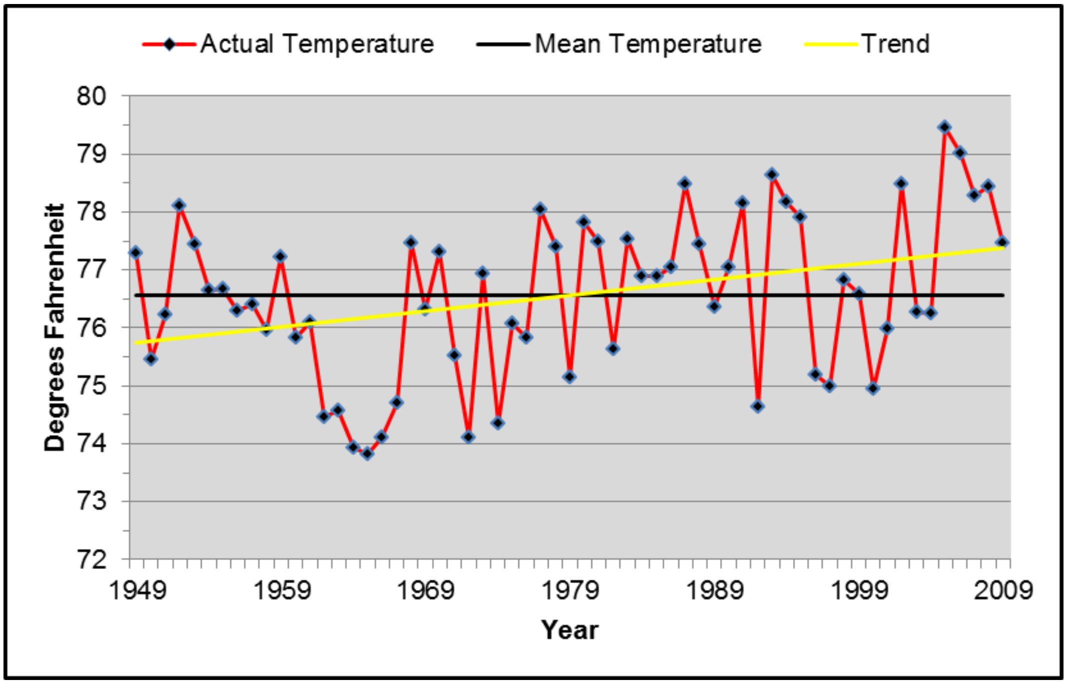

Figure O-4. Summer mean temperature for Richmond, VA from 1949 to 2008. The mean temperature is 76.6° F with an increasing trend of 0.27° F per decade.

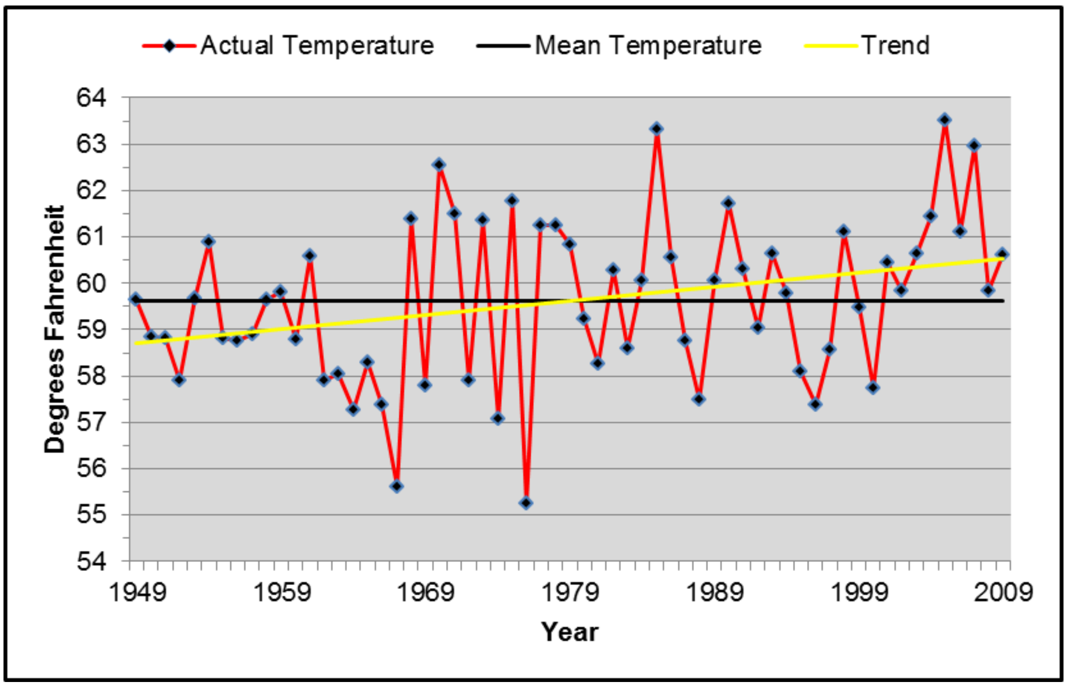

Figure O-5. Fall mean temperature for Richmond, VA from 1949 to 2008. The mean temperature is 59.6° F with an increasing trend of 0.30° F per decade.

Precipitation and snowfall

Annual values were compiled for precipitation using data collected at the Richmond airport from 1949 to 2008. Data is incomplete or unavailable for a few months in some years. In assessing seasonal trends, those years with one or more months of incomplete data are not considered and are omitted from our analysis. Rainfall is fairly evenly distributed throughout the year in Richmond, but the month averaging the most rainfall over the last 60 years is July with an average of 5.0 inches a year. The driest month on average is February with 3.0 inches per year. The annual precipitation at Richmond has an average of 43.72 and an increasing trend of approximately 0.18 inches per decade.

The average annual snowfall at Richmond is 13.1 inches and has an decreasing trend of 0.19 inches per decade.

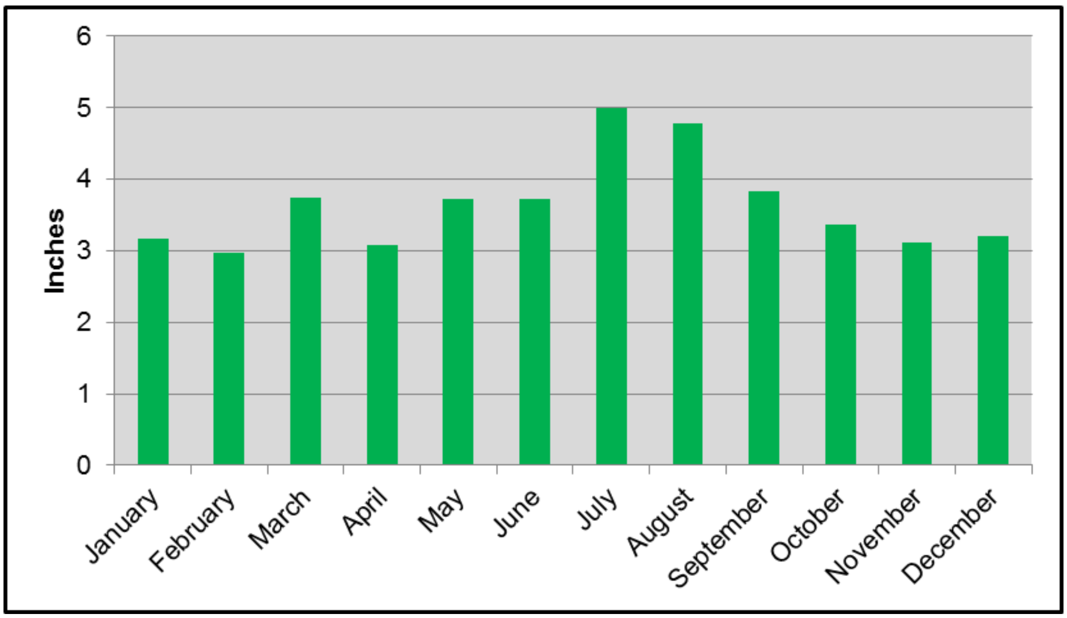

Figure O-6. Monthly precipitation averages from 1949 to 2008. July had the highest amount of rain on average with 5.0 inches, and February was the driest month with 3.0 inches.

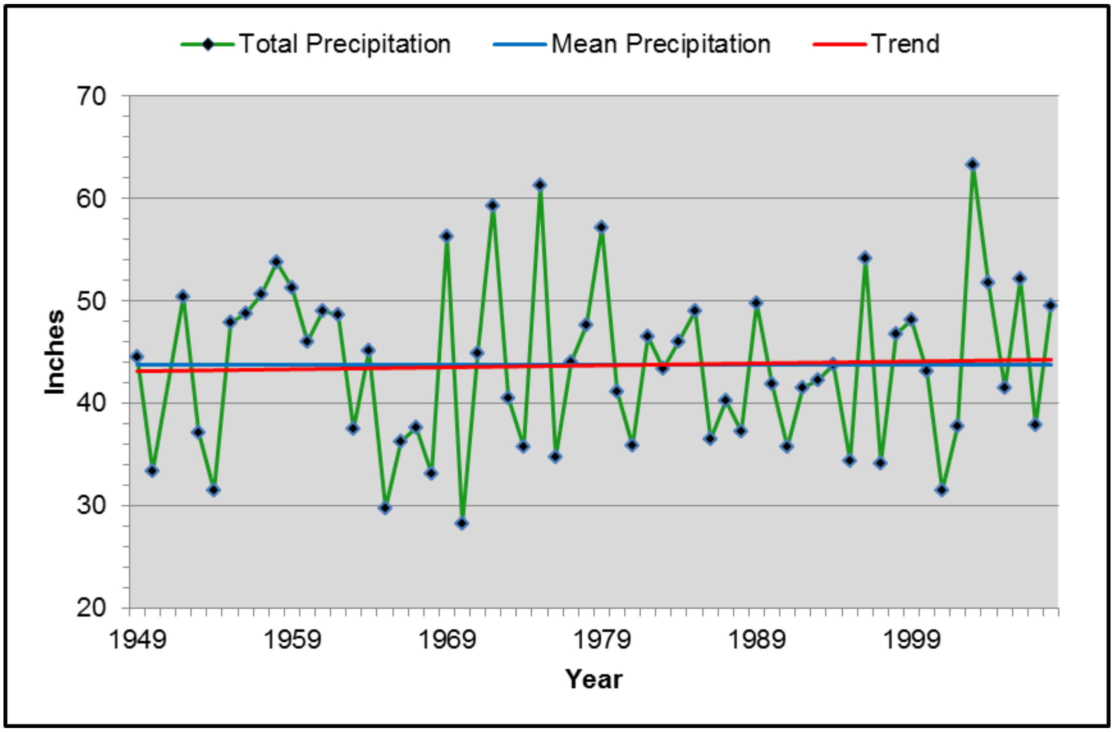

Figure O-7. Annual precipitation for Richmond, VA from 1949 to 2008. The mean annual precipitation is 43.72 inches with an increasing trend of 0.18 inches per decade. Year 1951 was omitted due to insufficient data.

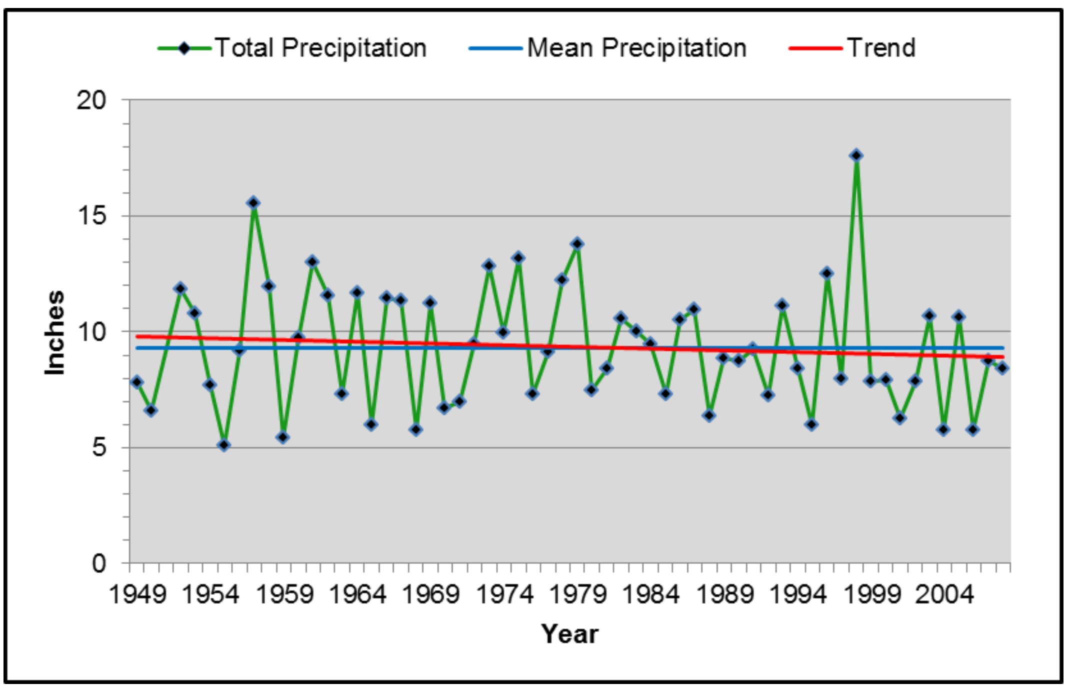

Figure O-8. Winter precipitation for Richmond, VA from 1949 to 2008. The mean precipitation is 9.30 inches with a decreasing trend of 0.16 inches per decade. Year 1951 was omitted due to insufficient data.

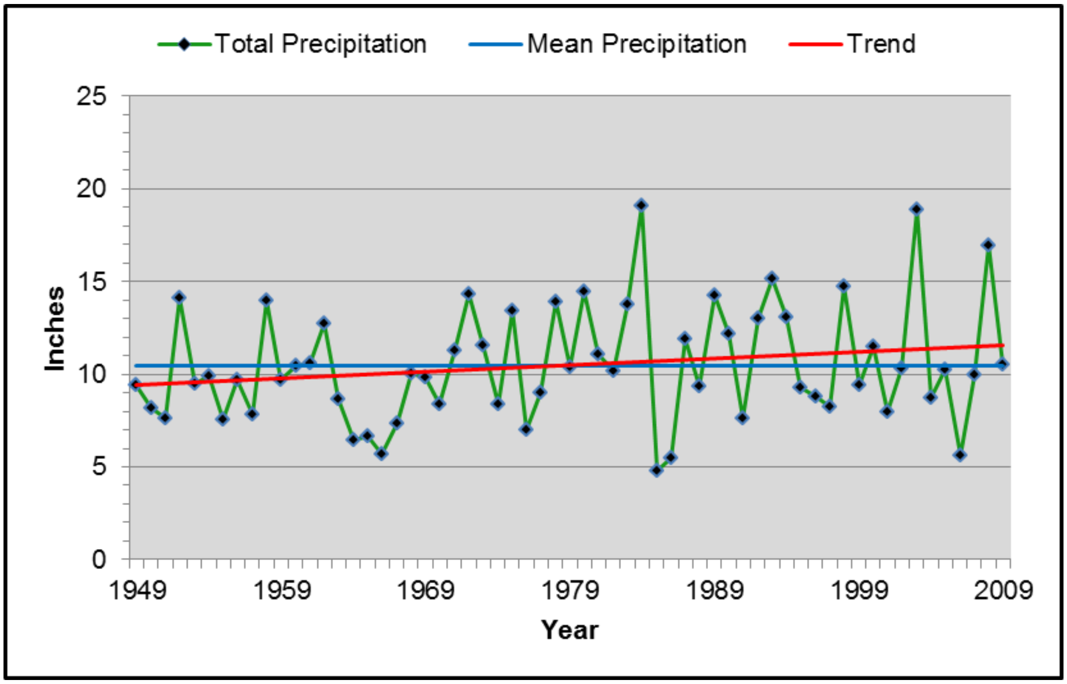

Figure O-9. Spring precipitation for Richmond, VA from 1949 to 2008. The mean precipitation is 10.49 inches with an increasing trend of 0.37 inches per decade.

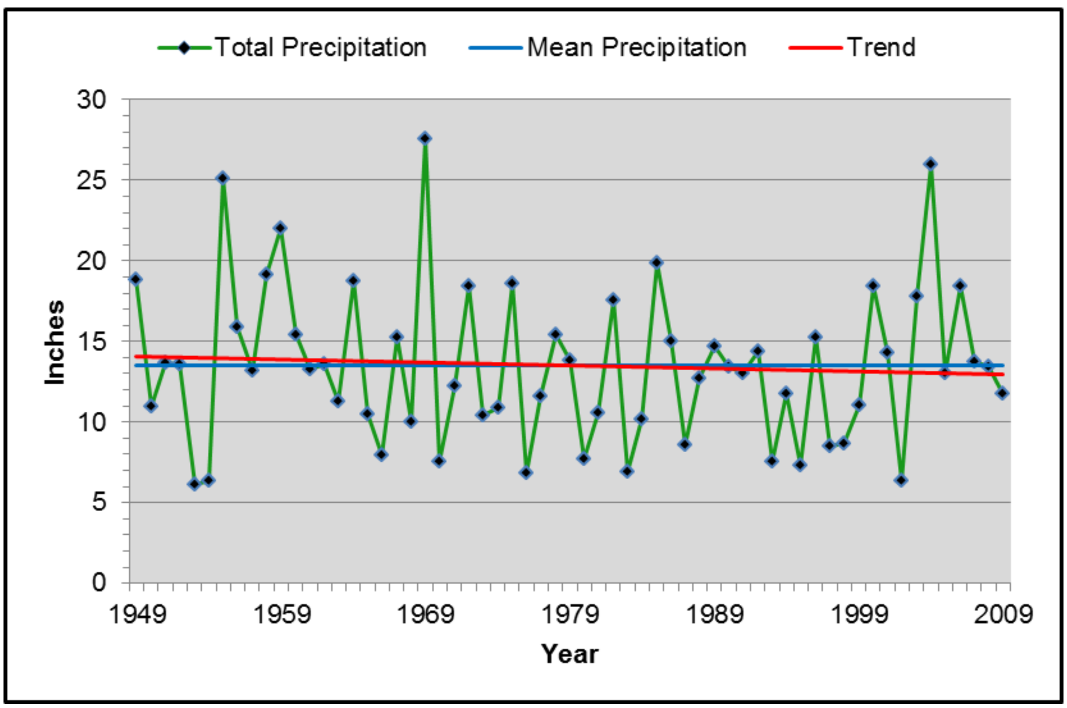

Figure O-10. Summer precipitation for Richmond, VA from 1949 to 2008. The mean precipitation is 13.48 inches with a decreasing trend of 0.19 inches per decade.

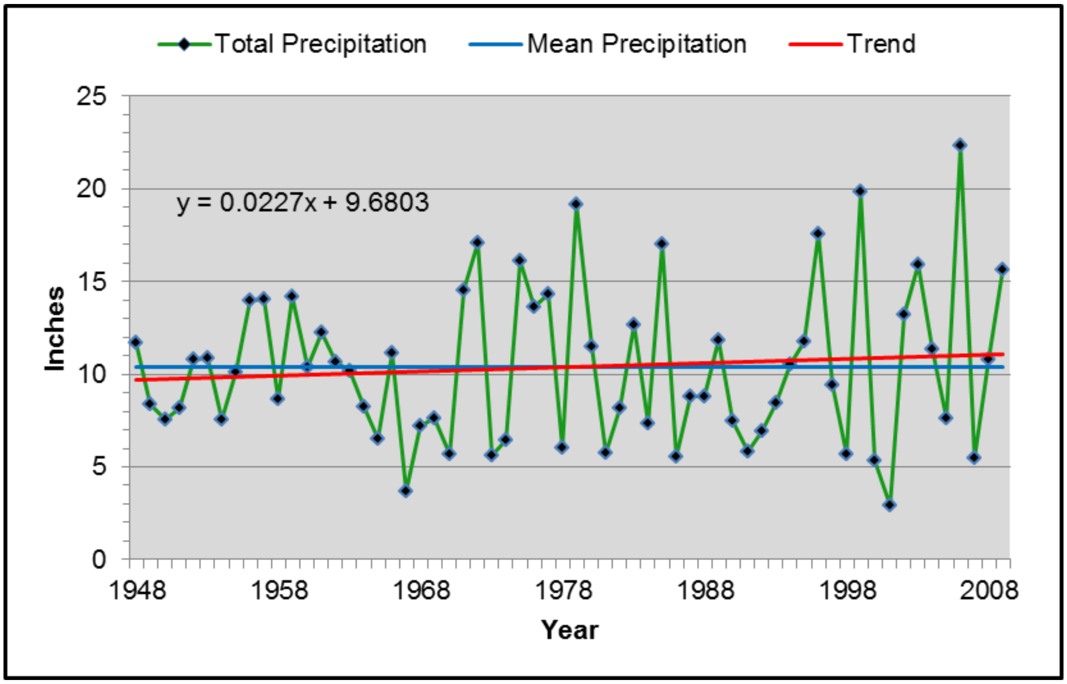

Figure O-11. Fall precipitation for Richmond, VA from 1949 to 2008. The mean precipitation is 10.40 inches with an increasing trend of 0.23 inches per decade.

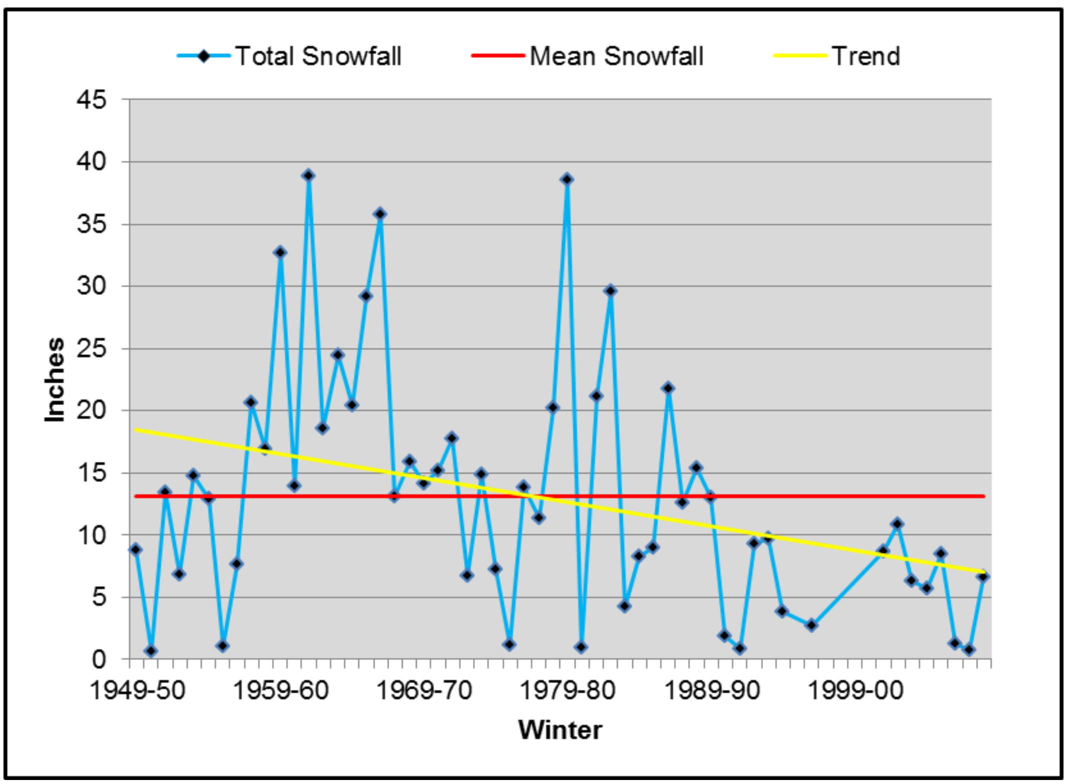

Figure O-12. Annual snowfall for Richmond, VA from 1949 to 2008. The mean annual snowfall is 13.11 inches with a decreasing trend of 1.94 inches per decade. Five winters were omitted due to insufficient data (1995-96, 1997-98, 1998-99, 1999-2000, and 2001-02)

Phenology (Growing Degree Days)

Patterns of seasonal variation in temperature and precipitation impact biological processes of all local biota. These cycles may alter the timing of many different behaviors like migration, flowering, and the birth of young. The study of such cycles and seasonal timing is termed "phenology" and changes in these annual cycles can provide information regarding important issues like the length of the growing season.

The best metric available for recording the passage of phenological time is "growing degree days." Growing degree days can be thought of as a measure of heat accumulation throughout a growing season. They can vary depending on the reference temperature corresponding to the species or process of interest. Therefore the reference temperature is often set to 40°F because at this temperature plants can photosynthesize, and it can be used as an indicator of the growing season. GDDs cannot be equated to calendar days, they are their own unit of measure. In this case, GDDs accumulate anytime the average temperature is more than 40 °F. We calculated the approximate number of growing degree days per month for Richmond NBP day total with the simple formula:

$GDD = (T_m - 40)\ D_m$

Where GDD = Growing degree days
T_m = monthly mean temperature
D_m = number of days in month
The number of growing degrees days for each month were summed to determine the approximate number of growing degree days per year. These values were plotted against time (year) to illustrate the long-term trends in the numbers of growing degree days at Richmond NBP.

We observed an increasing trend in the annual number of growing degree days which may indicate an increase in the growing season through time. To better illustrate this, we elected to examine the same data in terms of phenology. Much research has been completed equating phenological events to growing degree days (McMaster and Wilhelm 1997, University of Massachusetts Extension 2008, Virginia Tech FORSITE 2008). We attempted to put this in the context of a calendar year by selecting an arbitrary GDD target value (1200 GDD) and estimating the date at which that number of growing degree days was achieved. This would be analogous to estimating the specific date a phenologic event was to occur (e.g., the blooming of dogwood trees).

Since our source data is a monthly mean daily temperature, we calculated the total monthly accumulated GDD by multiplying the mean daily temperature by the number of days in the month. We then set a reference number of GDDs at 1200 to approximate a springtime phenological event. Historically, this value was achieved during the month of May. We used the total GDD accumulated for the year through June 30th (sum of January, February, March, April, May, and June), then calculated the difference from 1200.

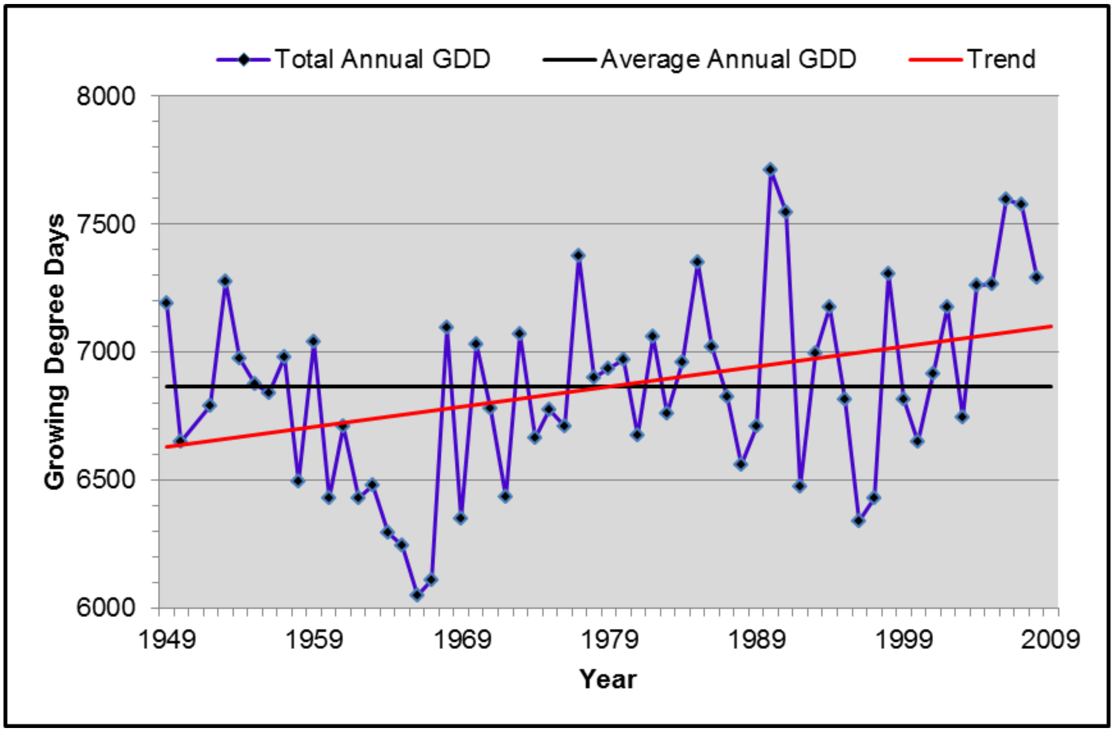

Figure O-13. The total annual growing degree days for Richmond, VA from 1949 to 2008. The long-term average annual growing degree days (GDDs) is 6864. The trend line indicates an increasing amount of GDDs, approximately 78 per decade (R2=0.13). This figure omits 1 year due to incomplete data (1951).

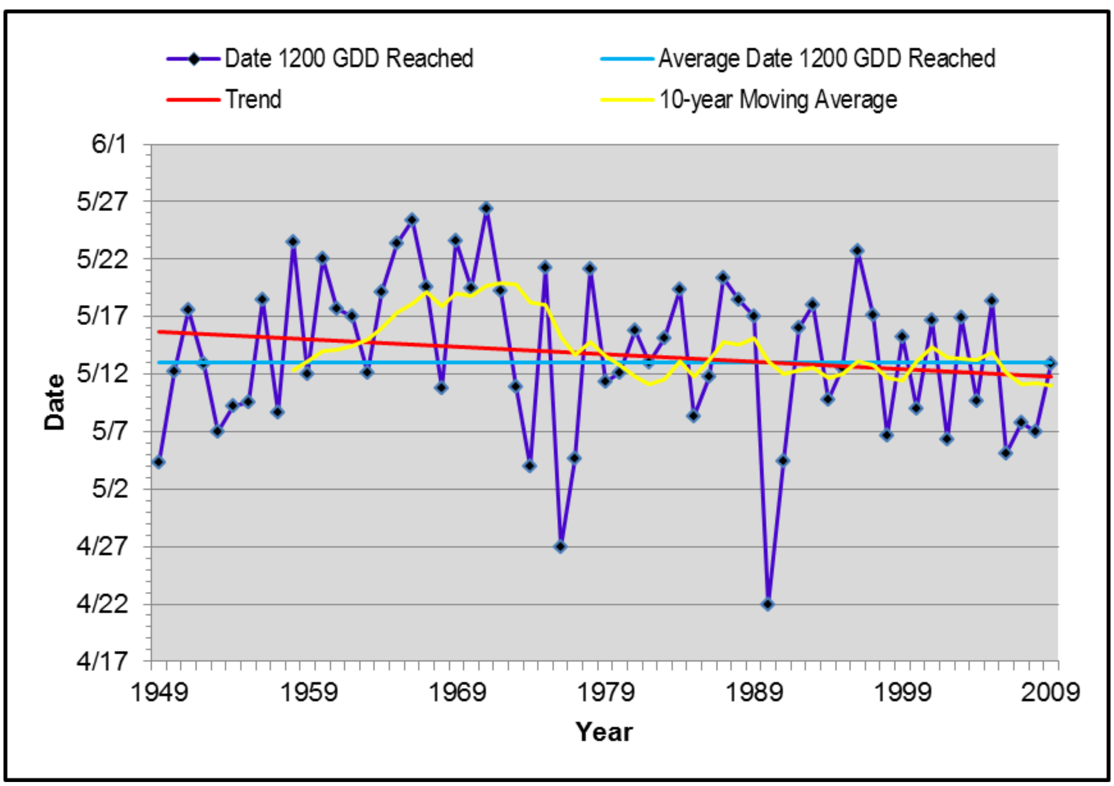

Figure O-14. The approximate date when 1200 GDD has been reached in Richmond, VA during years 1949 – 2008. The mean annual date is 5/13. The decreasing trend indicates that this date is arriving earlier each year (0.6 days per decade).

We estimated the number of days required to achieve the 1200 GDD by calculating the slope of the line for the appropriate month. If the difference was positive, we estimated the exact date where 1200 was achieved by determining the slope of the line between the total GDD for May and the total for June. If negative, the same procedure was used between April and May. This permitted us to use the most accurate daily rate in our estimation. Using this process we determined the calendar date that 1200 GDD was achieved for each year in the dataset and plotted it over time.

The decreasing trend suggests the growing season of Richmond is lengthening over time since the date 1200 GDD is reached is arriving earlier. However, the annual variation for this factor is high, making the correlation for this trend very weak (R^2 = 0.03).

Climate Summary

Using these local data, climate does not appear to be a major threat or stressor although there is a slight increasing trend of temperatures. This could be accounted for simply by natural variation in the past fifty years, or it could be in fact a result of global warming. As of now there is no way to be sure, however climate data and others should be monitored and trends analyzed periodically to examine changes and future trends. An emphasis should be placed on consistency, ensuring data is collected every year using the same techniques. It would be advisable for the park to maintain basic phenological information. This could be used along with data gathered throughout the region to quantify the changing phenology over a reasonably short time frame. The park can easily identify specific events (e.g., the appearance of the first bloom) that can be monitored and recorded annually as part of other ongoing activities.

Appendix P. Air quality standards and explanations.

Air Quality Context – National Standards

The Clean Air Act established both primary and secondary National Ambient Air Quality Standards (NAAQS) for six criteria pollutants. The primary standards are established to protect public health; the secondary standards are set to protect public welfare, including natural resources. Currently, the secondary standards are set to the same limits as the primary standards. However, the NPS along with other entities have documented that specific park Air Quality Related Values (AQRV) can be adversely affected at levels well below the NAAQS, or by pollutants for which no NAAQS exist. This suggests that the current NAAQS are not protective of ecosystems, and consequently the U.S. Environmental Protection Agency (EPA) is considering revising the secondary standards for ozone and nitrogen and sulfur oxides (U.S. Environmental Protection Agency 2008a). For this reason, the NPS recommends AQRV target values that are below the NAAQS established to protect human health.

The EPA requires monitoring of six pollutants considered harmful to human health that can also negatively affect the environment. The six “criteria” pollutants are listed and described below (U.S. Environmental Protection Agency 2008c). The first two are considered problematic in hundreds of counties across the U.S., and the last four are of concern only in a handful of locations at most. Currently, Richmond NBP is not designated as nonattainment area for any criteria pollutant listed below.

Ozone (O_3)

Ozone high in the atmosphere protects us from ultraviolet (UV) radiation, but ozone at ground-level can negatively affect plant populations and can cause respiratory irritation when humans or animals breathe it. Ozone is formed when other pollutants, primarily nitrogen oxides and volatile organic compounds, react in the atmosphere in the presence of sunlight, usually during the warm summer months. Ozone causes considerable damage to vegetation throughout the world, including agricultural crops and native plants in natural ecosystems. Ozone is not directly emitted; rather it is formed from reactions involving volatile organic compounds and nitrogen oxides in the presence of sunlight. The reference value for acceptable ozone is set by the National Ambient Air Quality standards (NAAQS) at 0.075ppm for the 3-year average of 4th highest daily maximum 8-hour average (U.S. Environmental Protection Agency 2008b).

Vegetation sensitivity to ozone is also taken into consideration when conducting air quality assessments in national parks. A 2004 vegetation risk assessment identified 18 plant species present at Richmond NBP that are sensitive to ozone (National Park Service 2004). This risk assessment indicated that the risk of injury to plants is moderate at Richmond NBP due to occasionally elevated levels of ozone exposure coupled with soil moisture values which fail to significantly inhibit the uptake of ozone. The 2004 report also identifies 11 bioindicator species that can be monitored at Richmond NBP to indicate increased ozone injury to vegetation. The ARD uses the vegetation risk evaluation to modify the average ozone concentration air quality condition status when assigning parks a final ozone status rating. If a park is evaluated as a high risk of plant injury, the ARD would assign that park the next more severe ozone condition status (i.e., reclassify “moderate” to “significant concern”).

Atmospheric deposition

In 2004, the National Park Service conducted an assessment entitled Air Quality Inventory and Monitoring Considerations for the Mid-Atlantic Network (National Park Service 2004). They reported on atmospheric deposition of compounds that can affect acidity, nutrient balances, and wildlife in surface waters; air toxics; surface water chemistry in the context of acidification due to atmospheric deposition; fine particulate matter and ozone; and ozone-sensitive plant species. The report concluded that Richmond NBP had adequate coverage of wet and dry deposition monitors within 56 miles of the park, in Green Bay, VA. The park was rated with a moderate risk for foliar ozone injury, and long-term monitoring of bioindicator species such as tree-of-heaven, spreading dogbane, common milkweed, redbud, white ash, yellow-poplar, American sycamore, black cherry, American elder, crownbeard, and northern fox grape were recommended. Long-term monitoring of contaminant levels in aquatic life and terrestrial vertebrates were also recommended.

Particulate matter (PM) is subdivided into two categories by size:

Fine particulate matter ($PM_{2.5}$)

Fine particles can be inhaled deeply into the lungs and can cause respiratory irritation and, over the long term, are associated with elevated levels of cardiovascular disease and mortality. Particles also obscure visibility and affect global climate. Fine particles are generated by combustion; major sources include industry and motor vehicles. Such particles can also be formed in the atmosphere through reactions involving gases. The reference value for acceptable $PM_{2.5}$ is set by the National Ambient Air Quality standards (NAAQS) at 35 µg/m^3 for a 24-hour average (U.S. Environmental Protection Agency 2008b).

Coarse particulate matter (PM_{10}) consists of particles smaller than 10 micrometers. They may cause respiratory irritation. Coarse particles stem from grinding and other mechanical processes and include wind-blown dust. The reference value for acceptable PM_{10} is set by the National Ambient Air Quality standards (NAAQS) at 150 µg/m^3 for a 24-hour average (U.S. Environmental Protection Agency 2008b).

Sulfur dioxide (SO_2) originates mostly from coal combustion and causes respiratory irritation. It also contributes to acid rain and particle formation. The reference value for acceptable SO_2 is set by the National Ambient Air Quality standards (NAAQS) at 0.033ppm for the annual arithmetic mean (U.S. Environmental Protection Agency 2008b).

Carbon monoxide (CO) is a colorless, odorless gas that is formed during incomplete combustion of fuels. Its major sources include vehicles and fires. Exposure to high levels of carbon monoxide can cause dizziness, headaches, confusion, blurred vision, and ultimately coma and death. The reference value for acceptable CO is set by the National Ambient Air Quality standards (NAAQS) at 9 ppm for the annual arithmetic mean (U.S. Environmental Protection Agency 2008b).

Lead (Pb) is a metal found in particles and can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system. In children, it has been found to lower IQ. Lead originates mainly from the processing of metals in industry.

Nitrogen dioxide (NO_2) is a brownish gas that is generated during high-temperature combustion. It is a member of a family of chemicals called nitrogen oxides, or NO_x. Major sources of NO_x include coal-fired power plants, industrial boilers, and motor vehicles. Like ozone, it causes respiratory irritation. It is also important because it can react to form ozone and particles, contribute to acid rain, deposit into water bodies and upset the nutrient balance, and degrade visibility. The reference value for acceptable NO_2 is set by the National Ambient Air Quality standards (NAAQS) at 0.053ppm for an 8-hour average, not to be exceeded more than once per year (U.S. Environmental Protection Agency 2008b).

The National Ambient Air Quality Standards (NAAQS) are public health-based levels not to be exceeded for each pollutant (U.S. Environmental Protection Agency 2008b). Air quality is summarized for the public in terms of the Air Quality Index (AQI Table E-1), a scale that runs from 0 to 500, where any number over 100 is considered to be unhealthy (AirNow 2008). Based on measurements or predicted levels of pollutants, an AQI is calculated for each of the criteria pollutants, and the highest value is reported to the public. The breakpoints and calculations used for the AQI are shown in Table E-2 (U.S. Environmental Protection Agency 1999). These public-health-based measures and reference values give us a good starting point in which to discuss air quality. Several of the NAAQS reference values can be further refined to 80% of their current level for a more appropriate natural resource-based target.

Table P-1. The Air Quality Index (AQI) is a cross-agency U.S. Government venture whose purpose is to explain air quality health implications to the public.

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 – 50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51 – 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 – 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 – 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 – 300	Health alert: everyone may experience more serious health effects.
Hazardous	> 300	Health warnings of emergency conditions. The entire population is more likely to be affected.

Table P-2. Breakpoint values of the AQI (U.S. Environmental Protection Agency 1999, 2008c).

Category	Value	O_3 (ppm), 8/hr	CO (ppm), 8/hr	SO_2 (ppm), 24/hr	$PM_{2.5}$, (μg/m^3)	PM_{10}, (μg/m^3)	NO_2
Good	0-50	0.000–0.059	0.0–4.4	0.000–0.034	0.0–15.4	0–54	([1])
Moderate	51-100	0.060–0.075	4.5–9.4	0.035–0.144	15.5–40.4	55–154	([1])
Unhealthy for Sensitive Groups	101-150	0.076–0.095	9.5–12.4	0.145–0.224	40.5–65.4	155–254	([1])
Unhealthy	151-200	0.096–0.115	12.5–15.4	0.225–0.304	[3] 65.5–150.4	255–354	([1])
Very Unhealthy	201-300	0.116–0.374	15.5–30.4	0.305–0.604	[3] 150.5–250.4	355–424	0.65–1.24
	301-400	([2])	30.5–40.4	0.605–0.804	[3] 250.5–350.4	425–504	1.25–1.64
Hazardous	401-500	([2])	40.5–50.4	0.805–1.004	[4] 350.5–500.4	505–604	1.65–2.04

[1] NO_2 has no short-term NAAQS and can generate an AQI only above an AQI value of 200.
[2] 8-hour O_3 values do not define higher AQI values ([2] 301). AQI values of 301 or higher are calculated with 1-hour O_3 concentrations.
[3] If a different SHL for $PM_{2.5}$ is promulgated, these numbers will change accordingly.

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