National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Antietam National Battlefield Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NCRN/NRR—2011/413

ON THE COVER

Burnside Bridge in Antietam National Battlefield.
NPS NCRN I&M.

Antietam National Battlefield Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NCRN/NRR—2011/413

Jane Thomas, Tim Carruthers, Bill Dennison
Integration & Application Network
University of Maryland Center for Environmental Science
PO Box 775
Cambridge, MD 21613

Mark Lehman, Megan Nortrup, Patrick Campbell
National Capital Region Inventory & Monitoring
National Park Service
4598 MacArthur Blvd NW, Washington, DC 20007

Ed Wenschhof, Joe Calzarette, Debbie Cohen, Lindsay Donaldson, Andrew Landsman
Antietam National Battlefield
National Park Service
PO Box 158
Sharpsburg, MD 21782

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National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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

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

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

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the National Capital Region Network website (*http://science.nature.nps.gov/im/units/ncrn/index.cfm*) and the Natural Resource Publications Management website (*http://www.nature.nps.gov/publications/nrpm*) on the Internet.

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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. xiii) for more information.

The lands within Antietam National Battlefield are much as they were on the day of the battle and the park is charged with maintaining them in historical land use to preserve the view of the battle. The first step in framing this Natural Resource Condition Assessment was to define the key habitats within the park. Habitats 'managed for natural resource values' were the natural habitats (forests, wetlands and waterways, warm-season grasslands) and were assessed for ecological value, while habitats 'managed for agricultural values' (croplands and pastures) were assessed for being the most ecologically sustainable croplands and pastures possible.

Patches of forest within Antietam National Battlefield are well connected; however, forest interior area is small, providing moderate habitat potential for native fauna, including forest interior dwelling bird species. It is recommended to preserve this forest structure by limiting future fragmentation and minimizing stresses to forest areas. Very high deer populations are present within forest areas, resulting in limited regeneration capacity, as well as trampling, overgrazing, and reduction of habitat value for wildlife. It is recommended to implement deer reduction strategies. The abundant presence of exotic plant species displaces native species and reduces habitat value. Continued early detection of exotic species is recommended with subsequent active control measures. Assessment of exotic species cover would be better assessed with park-wide mapping as the current small number of plots is not ideal for assessing exotic species cover on a park scale.

Wetland and waterway habitats show no sign of acidification or low oxygen; however, high salinity and nutrients indicate degraded habitat value which is reflected in the regionally low diversity of benthos and fishes. The karst geology of Antietam and the surrounding landscape has implications for water quality of the streams within the park, affecting acid neutralizing capacity, temperature, and salinity of the waterways. It is recommended to identify and work with partners to reduce non-point source nutrient inputs from the watershed, as well as continue to implement (and begin to monitor) best management practices in agricultural lands. Additionally, efforts should continue to establish riparian buffers where appropriate, in consideration of cultural resources and historic vistas. Assessment of these habitats could be improved by inclusion of metrics indicative of groundwater condition, to better understand the effects of the karst geology of the area.

It is recommended to carry out baseline grassland plant inventories and optimize fire management to assist a transition to a greater proportion of native warm-season grasses. Warm-season grassland areas are currently not contiguous, limiting the habitat value to wildlife. It is recommended to remove tree lines and expand areas of native grasses where historically appropriate. Future assessments of natural resource condition would be improved by developing inventories and monitoring of bird, small mammal, and insect communities within native grassland habitats. Direct measures of the species and habitat diversity (i.e., range of successional stages) would also be beneficial in managing to maximize habitat value of warm-season grassland habitat.

The croplands and pastures within Antietam National Battlefield are susceptible to the high deer populations. It is recommended to implement deer population controls to ensure that these leased lands are viable. These land use areas are in high compliance with best management practice—it is recommended to organize and document compliance monitoring as well as to research new techniques of sustainable agriculture that would maintain historical land use while maintaining maximum resource condition in habitats managed for natural resource values within the park. Currently, assessment of implementation and effectiveness of Nutrient Management Plans and Soil & Water Conservation Plans have not been carried out. It is recom-

Habitats 'managed for natural resource values' were the natural habitats (forests, wetlands and waterways, warm-season grasslands) and were assessed for ecological value, while habitats 'managed for agricultural values' (croplands and pastures) were assessed for being the most ecologically sustainable croplands and pastures possible.

mended to monitor and enforce implementation as well as to investigate soil nutrients within these habitats to provide for better productivity and resource preservation. These additional data would improve future resource condition assessments for this habitat.

Pasture habitat within Antietam National Battlefield includes areas of cool-season grassland, which are currently managed as pasture with no immediate management goal to transition these areas to native warm-season grassland.

An additional framework—the National Capital Region Network Inventory and Monitoring 'vital signs' framework—was used to assess the current condition of park-wide natural resources for Antietam National Battlefield; therefore, key data gaps and research needs were summarized using that framework.

Air quality is poor within the park and while it is well monitored, the specific implications to the flora and fauna in the park are less well known. Gaining a better understanding of how reduced air quality is impacting wetland and grassland habitats in particular would help prioritize management efforts such as nutrient reductions in park lands, by showing what gains may be expected from these efforts.

Water quality has signs of degradation. Stream channels are highly variable in condition and a comprehensive assessment of stream physical habitat would allow for targeted management efforts and also allow for targeted engineering efforts to reduce water energy and erosion in the most susceptible areas. A detailed wetland delineation, including groundwater, would also provide a greater understanding of current features and potential threats to park resources. One of the key challenges to water quality is high nutrients—identification of sources would assist in assessing potential threats. Monitoring and enforcing implementation of Nutrient Management Plans would also help to identify nutrient sources within the park. Phosphates are consistently high throughout the region and as this nutrient often comes from non-point sources, challenges exist for identification and mitigation of these sources.

Some valuable biological communities occur within the park, with natural park habitats such as native warm-season grasslands becoming more significant as development continues throughout the region. Understanding the significance of these habitats to native grassland birds would require inventory and monitoring of these communities, including some specific studies on the potential impacts of traffic and vibrations to the success of these communities. The ecological community structure and succession of warm-season grassland communities themselves is poorly characterized in terms of habitat value to wildlife. Research into warm-season grassland communities would support the development of key indicators to monitor resource value of these habitats in the maintenance of a range of native biological communities. A better understanding of the dynamics of forest and grassland habitats in the presence of high deer populations and their ability to recover after deer reduction would assist in clarifying sustainable deer populations for future management.

Many of the faunal communities that constitute features of the park are migratory or have home ranges much greater than the park. For these reasons, assessing the connectivity and ownership of habitats and lands not just within but also outside of the park will allow a better understanding of the resilience of these communities and their susceptibility to change in the future. This is true for forest, grassland, and wetland and waterway habitats within the park. As a battlefield park, vegetating streamsides to reduce nutrient runoff from agricultural and pasture lands into waterways needs to be carried out in a way that maintains the cultural viewshed of the park. Studies to identify plant species that are small enough to maintain viewsheds but large enough to remove maximum nutrient content from surface and subsurface waters flowing from agricultural and pastoral lands would assist in improving compliance with best management practices for these habitats.

Antietam National Battlefield
Natural Resource Condition Assessment Resource Brief

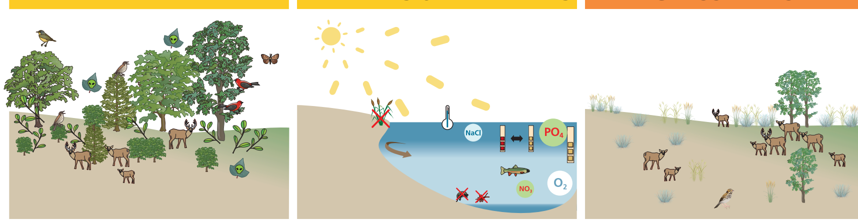
A relatively new approach to assessing and reporting on park resource conditions, Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national parks. Over the next several years, the National Park Service (NPS) plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Division.

Habitats in Antietam National Battlefield are in good condition overall. Habitats managed for natural resources are in fair condition. Forests were in fair condition, with high cover of exotic plants and large deer populations balanced by good bird diversity and continuous forest cover. Wetlands and waterways were also in fair condition, with good pH and buffering capacity but high nutrients and low stream biological diversity. Grasslands were in poor condition, due to large deer populations, low bird diversity, and patchy nature.

Habitats managed for agricultural values were in good condition overall. Croplands were in good condition, with good adoption of best management practices but also with large deer populations. Pastures were in very good condition with very good adoption of best management practices.

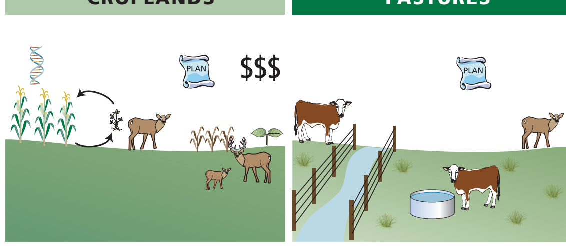
HABITAT-BASED NATURAL RESOURCE CONDITION ASSESSMENT OF ANTIETAM NATIONAL BATTLEFIELD

HABITATS MANAGED FOR NATURAL RESOURCES



FORESTS	WETLANDS & WATERWAYS	GRASSLANDS
Forest habitat has high cover of exotic plants, low % of impervious surface, and high diversity of forest-dwelling bird species. Deer populations are large and forest interior area is low but continuous, with few insect pests.	Wetlands are not acidic and have high buffering capacity, resulting in high dissolved oxygen and cool water temperature. Salinity, nitrate, and phosphate are high, fish diversity is low, and benthic invertebrates and physical habitat are very low.	Grassland habitat has very high deer populations and low bird diversity. Impervious surface cover is low but grasslands are patchy and have a small interior area.

HABITATS MANAGED FOR CULTURAL RESOURCES



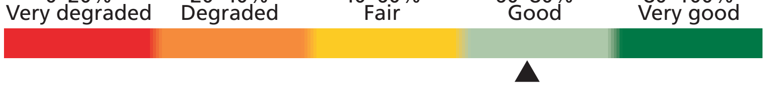
CROPLANDS	PASTURES
Croplands have high deer density, a high % of land undergoing crop rotation, conservation tillage, and cover crops, a fair % of land under integrated pest management and nutrient and soil & water conservation plans, and few crop yield concerns $$$.	Pasture has a low stocking rate, alternative water sources, fenced streams, active nutrient and soil and water conservation plans, but very high deer density.

The habitat-based natural resource condition assessment is area-weighted. Areas of each habitat are given below:

Forests: 149 ha
Wetlands & waterways: 18 ha
Warm-season grasslands: 23 ha
Croplands: 387 ha
Pastures: 131 ha

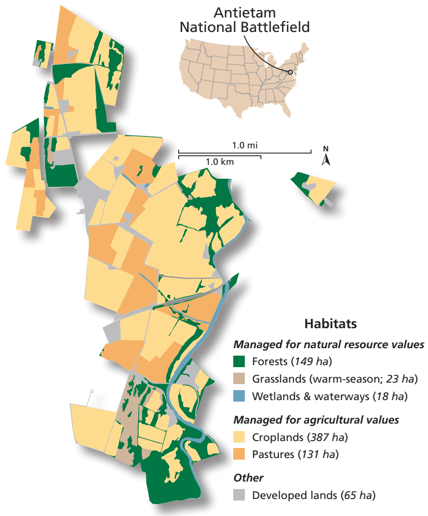
Percent attainment of desired habitat condition

0–20%	20–40%	40–60%	60–80%	80–100%
Very degraded	Degraded	Fair	Good	Very good



Habitat framework

Habitats within the park were defined as being either managed for natural resource values or managed for agricultural values. A habitat map was created and desired/degraded conditions were defined for each habitat. Metrics were then assigned to these habitat types, compared to established thresholds, leading to the condition assessment of each habitat.



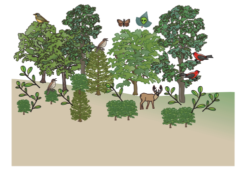
FORESTS

DEGRADED

Degraded forest has high cover of exotic plants, high % of impervious surface, and large deer populations. Native seedling regeneration and diversity of forest-dwelling bird species are low in patchy forest with high occurrence of insect pests.

Degraded	INDICATORS	Desired
high	Cover of exotic plants	low
high	Presence of insect pests	low
low	Native tree seedling regeneration	high
low	Forest dwelling bird diversity	high
high	Deer density	low
low	Forest connectivity	high
high	Impervious surface	low
high	Forest interior area	low

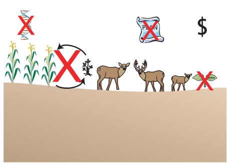
DESIRED



Desired forest has low cover of exotic plants, low % of impervious surface, and small deer populations. Native seedling regeneration and diversity of forest-dwelling bird species are high in contiguous forest with low occurrence of insect pests.

CROPLANDS

DEGRADED



Degraded croplands have high deer density and low % of land under best management practices: no crop rotation, no integrated pest management, no conservation tillage, no cover crops, absence of nutrient and soil & water conservation plans, and crop yield concerns $.

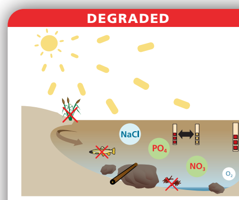
Degraded	INDICATORS	Desired
absent	Crop rotation	present
absent	Crop varieties for IPM	present
absent	Conservation tillage	present
absent	Cover crops	present
absent	Nutrient Management Plan	present
absent	Soil & Water Conservation Plan	present
present $	Crop yield concerns	absent $$$
high	Deer density	low

DESIRED

Desired croplands have low deer density and high % of land under best management practices: crop rotation, integrated pest management, conservation tillage, cover crops, existence of nutrient and soil & water conservation plans, and no crop yield concerns $$$.

WETLANDS & WATERWAYS

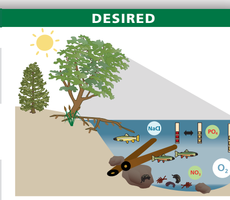
DEGRADED



Degraded wetlands have eroded streambanks with little sheltering debris and no shade, high nutrients and salinity, and acidic water with low buffering capacity, resulting in turbid water, low oxygen levels, and low populations of fish and benthic invertebrates.

Degraded	INDICATORS	Desired
low	pH	high
low	Dissolved oxygen	high
high	Water temperature	low
low	Acid neutralizing capacity	high
high	Salinity	low
high	Nitrate	low
high	Phosphate	low
low	Benthos	high
low	Fish	high
low	Physical habitat	high

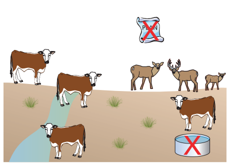
DESIRED



Desired wetlands have intact streambanks with shade and sheltering roots and debris, low nutrients and salinity, not acidic and with high buffering capacity, resulting in high oxygen, clear water, and high populations of fish and benthic invertebrates.

PASTURES

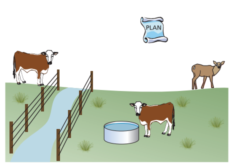
DEGRADED



Degraded pasture has a high stocking rate, no alternative water source, no fenced streams, no nutrient or soil & water conservation plan, and high deer density.

Degraded	INDICATORS	Desired
high	Stocking rate	low
stream	Water source	tank
absent	Fenced streams	present
absent	Nutrient Management Plan	present
absent	Soil & Water Conservation Plan	present
high	Deer density	low

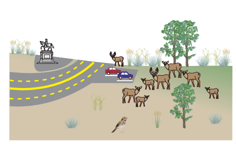
DESIRED



Desired pasture has a low stocking rate, alternative water sources, fenced streams, active nutrient and soil & water conservation plans and low deer density.

WARM-SEASON GRASSLANDS

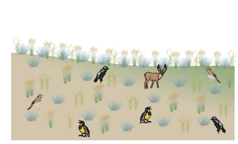
DEGRADED



Degraded grasslands have high deer populations and high % of impervious surface. Grassland bird diversity is low in grasslands that are patchy and small in area.

Degraded	INDICATORS	Desired
high	Deer density	low
high	Impervious surface	low
low	Grassland bird diversity	high
high	Grassland interior area	low
high	Contiguous grassland area	low

DESIRED



Desired grassland habitat has small deer populations and low % of impervious surface. Grassland bird diversity is high in grasslands that have a lot of interior area and are large in total size.

For more information, please visit the Park's Visitor Center or call 301-432-5124.

Antietam National Battlefield
National Park Service
www.nps.gov/anti

Developed in collaboration with:

National Capital Region Network Inventory & Monitoring Program
National Park Service

science.nature.nps.gov/im/units/nrcn/

Integration & Application Network (IAN)
University of Maryland Center for Environmental Science
www.ian.umces.edu

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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.

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. xiii) for more information.

1.1 NCRA 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] and
- follow national NRCA guidelines and standards for study design and reporting products.

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 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 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

NRCAs strive to provide *credible condition reporting for a subset of important park natural resources and indicators*

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.

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 an area-by-area basis: 1) by park ecosystem/habitat types or watersheds and 2) for other park areas as requested.

NRCA reporting products *provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:*

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)*
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values*

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.

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 a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA[9] Program information is posted at: *http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm*

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.
9. Acronyms are defined in Table B-3 in Appendix B.

Chapter 2: Park resource setting/ resource stewardship context

2.1 PARK RESOURCE SETTING

Antietam National Battlefield is a cultural resource park.

Antietam National Battlefield was established by Act of Congress on August 30, 1890 to commemorate the Battle of Antietam fought on September 17, 1862. The battle is considered by many historians to be one of the most crucial battles of the Civil War and the turning point against the Confederacy. The restriction of the Confederacy's northward movement by the Union forces at Antietam eventually enabled President Lincoln to issue the Emancipation Proclamation, injecting new moral values into the Union cause and subsequently altering the course of international politics. It was also at Antietam that more Americans died in battle than during any other single day in American military history (Snell and Brown 1982, NPS 1992).[10]

Congress originally placed the Antietam battlefield under the supervision of the Secretary of War. It was later transferred, along with 47 other historic areas, to the National Park Service on June 10, 1933.[11] Antietam and "Chickamauga and Chattanooga National Park or Military Park" were the first Civil War battlefields to be preserved by the War Department. However, both parks came to represent and illustrate two widely diverging methods of preserving battlefields. The Chickamauga method (used at Gettysburg, Shiloh, Kings Mountain, and other sites) involved acquiring much of the land of the battlefield for preservation, while the Antietam method (used at Appomattox, Fort Necessity, Kennesaw Mountain, and other sites) involved only as much land acquisition as was required for the building of roads and the erection of monuments and markers. The Antietam method was favored for its low cost and because it would not commit the United States to the perpetual care and maintenance of large areas (Snell and Brown 1982).

The legacy of the Antietam method of preserving battlefields is that of the 1,320 ha (3,263 acres) within the administrative/legislative boundary of the battlefield, 784 ha (1,937 acres) are owned in fee by the federal government (Figure 2.1) and managed by the National Park Service to maintain the historic setting and provide for visitor use, 205 ha (506 acres) are privately owned, and 332 ha (820 acres) are in private ownership with easements held by the federal government that restrict the levels and types of allowable development (ANTI 2009).

The battlefield is situated in a rural area of south Washington County, Maryland (Figure 2.2). A number of structures remain from the historic period, including the Miller, Mumma, Piper, Otto, and Sherrick farmhouses and the Pry house. Additionally, several structures and features added to the battlefield after the war are now considered historic in their own right, including Antietam National Cemetery where 4,776 Federal soldiers are buried, the road system established by the Army in the 1890s, the 103 monuments placed by states and individuals to commemorate those who fought at Antietam, and the observation tower overlooking Bloody Lane (Snell and Brown 1982).

10. Several historical details used in this report about Antietam National Battlefield have been excerpted from the excellent administrative history of Antietam written by Charles Snell and Sharon Brown in 1982.
11. President Franklin D. Roosevelt signed Executive Order 6166 which consolidated all National Parks and National Monuments, National Military Parks, the 11 National Cemeteries, National Memorials, and the National Capital Parks into a single National Park System.

Figure 2.1. GIS data layer[12] showing the administrative/legislative and fee boundaries of Antietam National Battlefield, which encompass 1,320 ha (3,263 acres) and 784 ha (1,937 acres), respectively.

Antietam National Cemetery sits on approximately 4.4 ha (11 acres) within the park. Established on March 23, 1865 by the state of Maryland, the cemetery's board of trustees turned their charge over to the Department of War in 1877, which oversaw the cemetery until it was turned over to the care of the National Park Service in 1933.

The scene at Antietam today is essentially as it was in 1862—a collection of farms and farmlands in a rural setting (NPS 1992). The park is divided by the two-lane Route 34 (Boonsboro Pike) which passes southwest through the park into neighboring Sharpsburg, Maryland and on towards the Potomac River. Northbound Sharpsburg Pike (Route 65) runs along the park's western edge, and through the park's West Woods. The climate of Washington County is of the humid–temperate, continental type.

Antietam consists primarily of broad, rolling valleys. Limestone underlying most of the park's forests and fields results in a karst topography of springs,

12. ANTI.

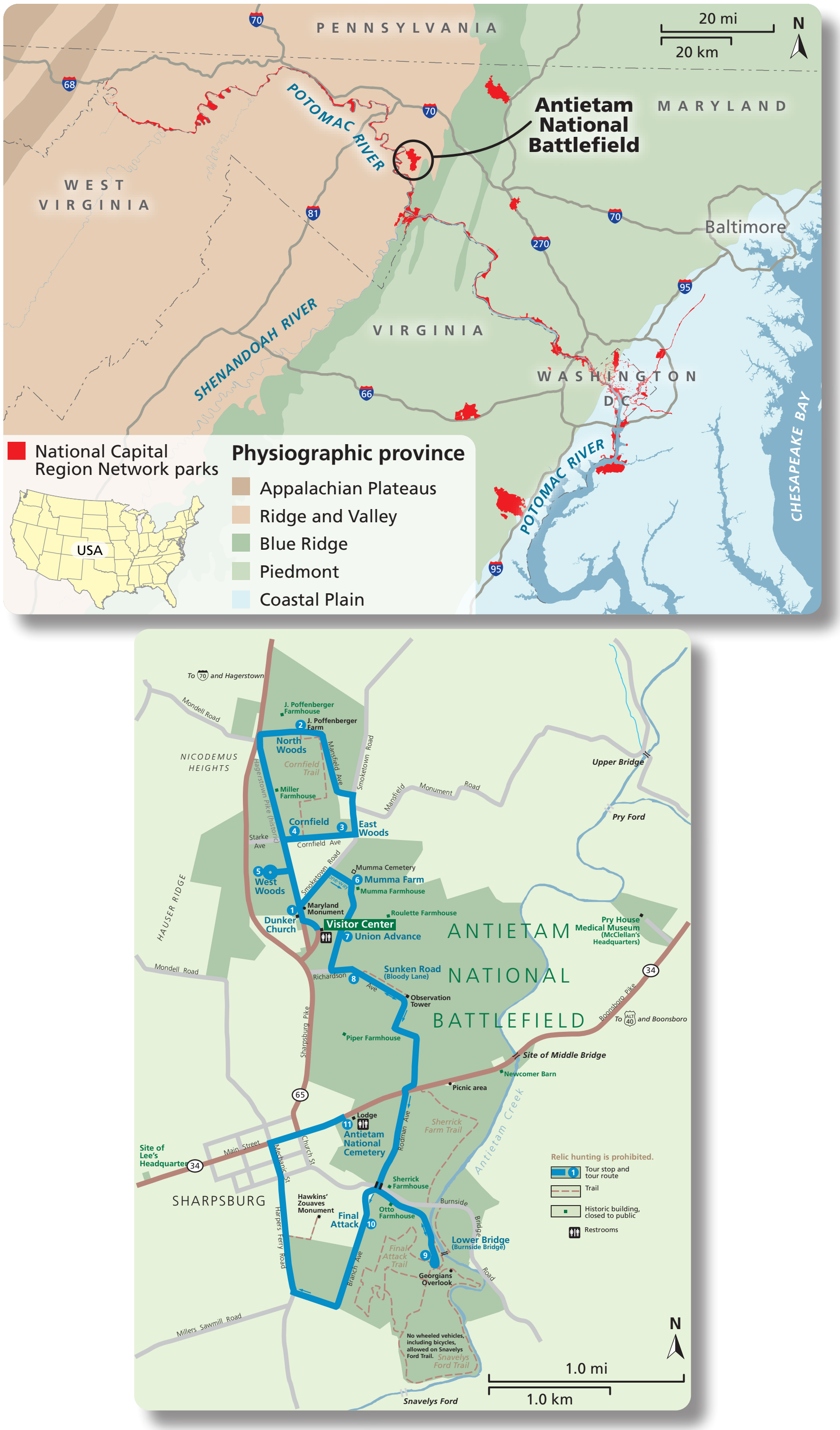


Figure 2.2. Location of Antietam National Battlefield in western Maryland.[13]

intermittent streams, and sinkholes. The soils of the battlefield are generally acidic, strongly leached, and highly or potentially highly erodible. Much of the battlefield has been used as farmland for well over a century.

At the time of the battle, corn was the primary crop, and orchards and family gardens were common. The park's farms are still actively cultivated, grazed, or planted in grass. A small number of grassland acres have been planted with native (warm-season)[14] grasses to improve its quality as wildlife habitat.

13. NPS.

Antietam Creek, a tributary of the Potomac River, runs along the east side of the park and is adjoined by a small floodplain forest. About 140 ha (345 acres) of the park on and around the battle sites were originally wooded, with oak (*Quercus* spp.), maple (*Acer* spp.), and sycamore (*Platanus occidentalis*) the primary species, along with hickories (*Carya* spp.) and walnut (*Juglans* spp.; NPS 1992, 2002). Currently, the largest forest and natural area in the park is Snavely Woods, one of the best-developed native oak/hickory forests on limestone remaining in Washington County, Maryland. The historically significant North, East, and West Woods—once mature woodlots—underwent significant clearing and cultivation following 1862. In keeping with the park's General Management Plan (NPS 1992), reforestation efforts for these woods began in 1995, to restore the visual integrity of the battlefield. The park's grasslands, woodlands, and waters are home to a variety of wildlife—birds, woodchucks (*Marmota monax*), and white-tailed deer (*Odocoileus virginianus*) are among the most common and conspicuous.

In summary, Antietam National Battlefield is one of the first battlefield parks to be established in the nation and used a land acquisition model that left significant areas of land in private ownership. The park today retains much of its Civil War-era character and is heavily agricultural. Karst topography influences the character of the soils, water, and vegetation. Many of the woodlands and grasslands that were cleared or cultivated since the battle in 1862 are undergoing or are slated for restoration. Visitation to Antietam has been increasing over the past decade, with nearly 353,000 visitors recorded in 2008 (NPS Public Use Statistics Office).[15]

2.1.1 Park resources

In the face of encroaching development and with its diverse landscape including forests, wetlands, waterways, and grasslands, the park represents a sanctuary for many plant and animal species. A wide range of mammals, birds, amphibians, reptiles, and threatened plant species make their home in the park.

Resource setting

Antietam National Battlefield covers 1,320 ha (3,263 acres) and is located in southern Washington County in western Maryland (Figure 2.2). Approximately 5 km (3 mi) of the 66-km (41-mi) Antietam Creek—a tributary of the Potomac River and ultimately Chesapeake Bay—run through the park. The park is located at the bottom of the 241 km^2 (93 mi^2) Antietam Creek watershed, which extends north into Pennsylvania (Figure 2.3).

Geology

The park is located entirely within the Ridge and Valley physiographic province, with the exception of some small outholdings in the east which are in the Blue Ridge physiographic province. The Ridge and Valley province is characterized by long, parallel ridges separated by valleys (Thorneberry–Ehrlich 2005). These valleys formed where resistant sandstone ridges border carbonate formations. The carbonate is more easily eroded, leaving valleys. Areas dominated by the carbonate formations (such as Antietam National Battlefield) exhibit karst topography—a term used to describe the features produced by dissolution of carbonate rocks, including fissures, sinkholes, underground streams, and caverns. The park itself is dotted with sinkholes and springs (Figure 2.4), although a comprehensive inventory of the karst features of the park has not yet been performed.

Antietam National Battlefield ranges from 90–160 m (300–520 ft) above sea level (Figure 2.5). The geology of the park played a significant role in the battles, marking strategic battle lines and last stands, and remains an important resource preservation consideration (Thorneberry–Ehrlich 2005). The primary bedrock underlying the park is the carbonate limestone (primarily Conococheague and Elkbrook limestone) typical of the valley regions of the Ridge and Valley physiographic province (Figure

14. Throughout this document, the term "warm-season" is used interchangeably with "native" when referring to grasses and grasslands. "Cool-season" is used interchangeably with "non-native" in the same contexts.
15. *http://www.nature.nps.gov/stats*

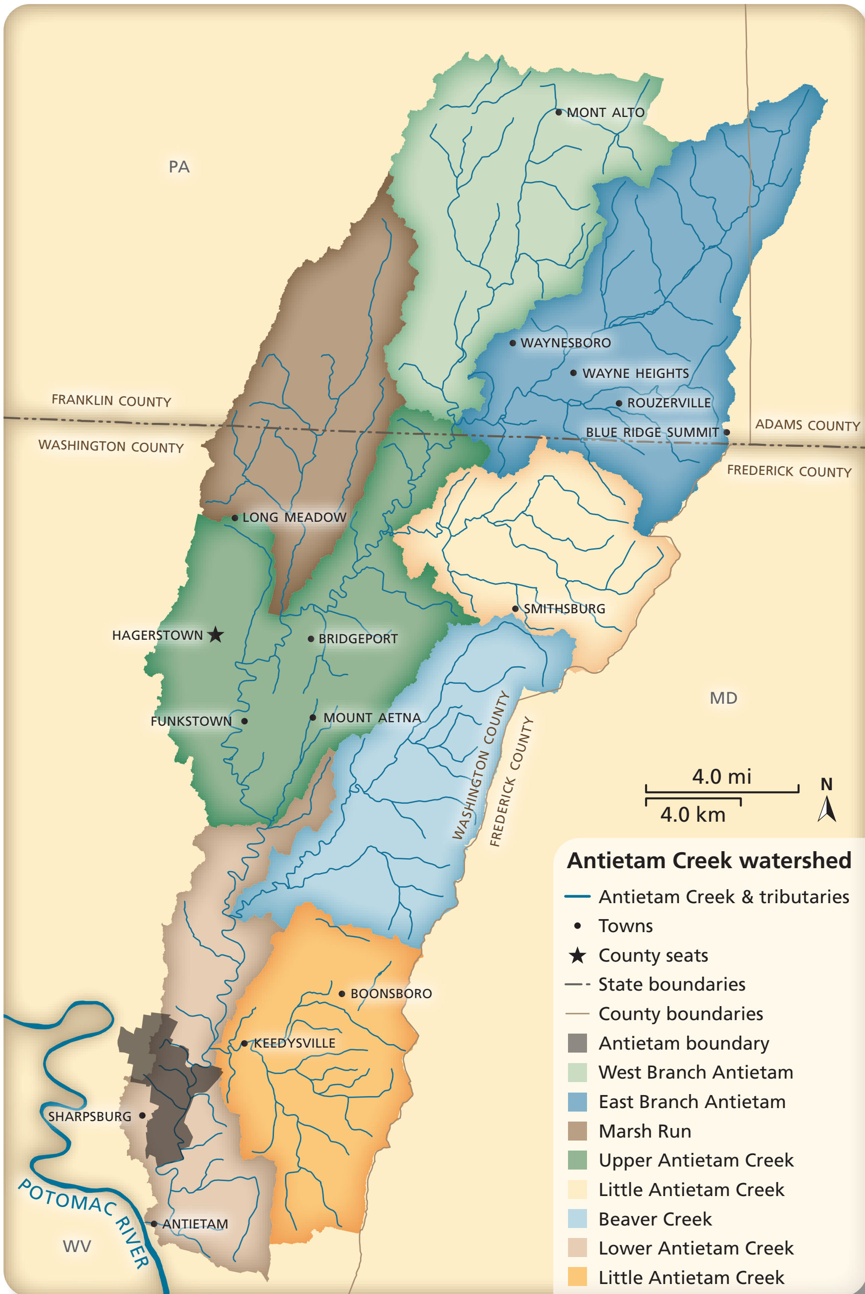


Figure 2.3. Antietam Creek and its watershed.[16]

2.6). This karst topography is susceptible to dissolution by both surface water and groundwater and this is accelerated by increasing air pollution in the eastern United States which increases the acidity of rainwater.

Due to the karst landscape, the groundwater discharge of the Antietam Creek basin is about 85% of the total discharge—higher than surrounding areas not underlain by folded and faulted carbonate rocks—resulting in large quantities of groundwater stored in the soil and substrate and very productive aquifers in the area (Thorneberry–Ehrlich 2005). This has resulted in limited surface expression of water and therefore the low density of perennial streams in the basin.

The soils of Antietam National Battlefield are primarily derived from the weathering of the limestone bedrock that underlies the park, resulting in well-drained loam and clay soils with patches of exposed bedrock throughout (Figure 2.7). Many of the flatter areas in the park are classified as prime farmland, a designation identifying land

16. USGS EDNA watersheds, ESRI, ANTI.

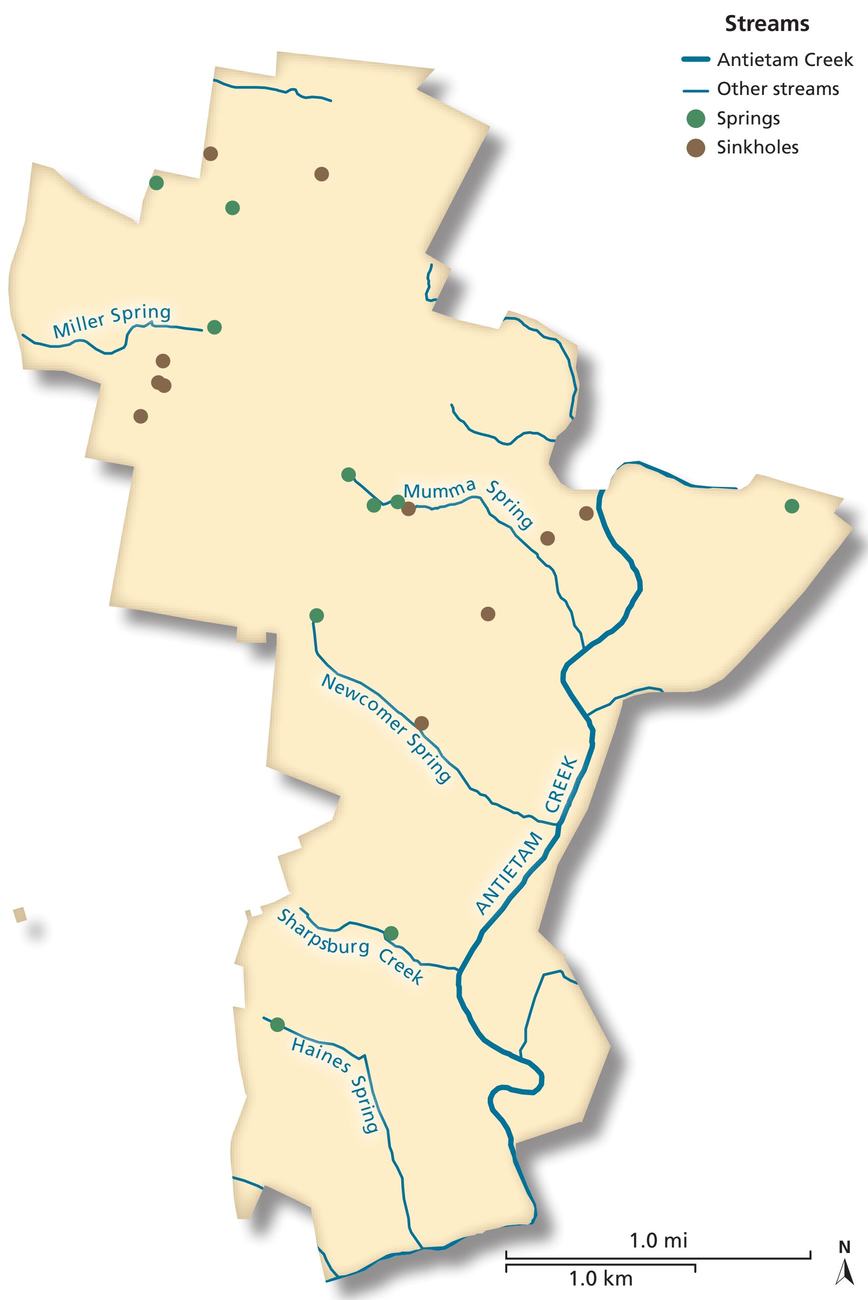


Figure 2.4. GIS data layer[17] depicting the stream network, springs, and sinkholes in Antietam National Battlefield.

that has a favorable combination of physical and chemical characteristics to promote greater production of crops, pasture, or hay.

Trails

There are several trails in the National Battlefield (Figure 2.8). The Antietam Remembered Trail is a short trail that loops to significant landmarks and monuments near the visitor center. The Bloody Lane Trail winds through the historic Mumma and Roulette Farms, following in the footsteps of Union soldiers as they advanced toward the Sunken Road. The West Woods Trail weaves through the historic woodlot where the Union Army launched numerous attacks. The Final Attack Trail is located where the Union soldiers launched their final advance to drive the Confederate Army from Maryland, only to be turned back by A.P. Hill's final Confederate counterattack. The Snavely Ford Trail follows Antietam Creek for much of its length. The Union Advance Trail crosses Burnside Bridge and makes a loop on the east side of Antietam Creek and explores the area where

17. ANTI.

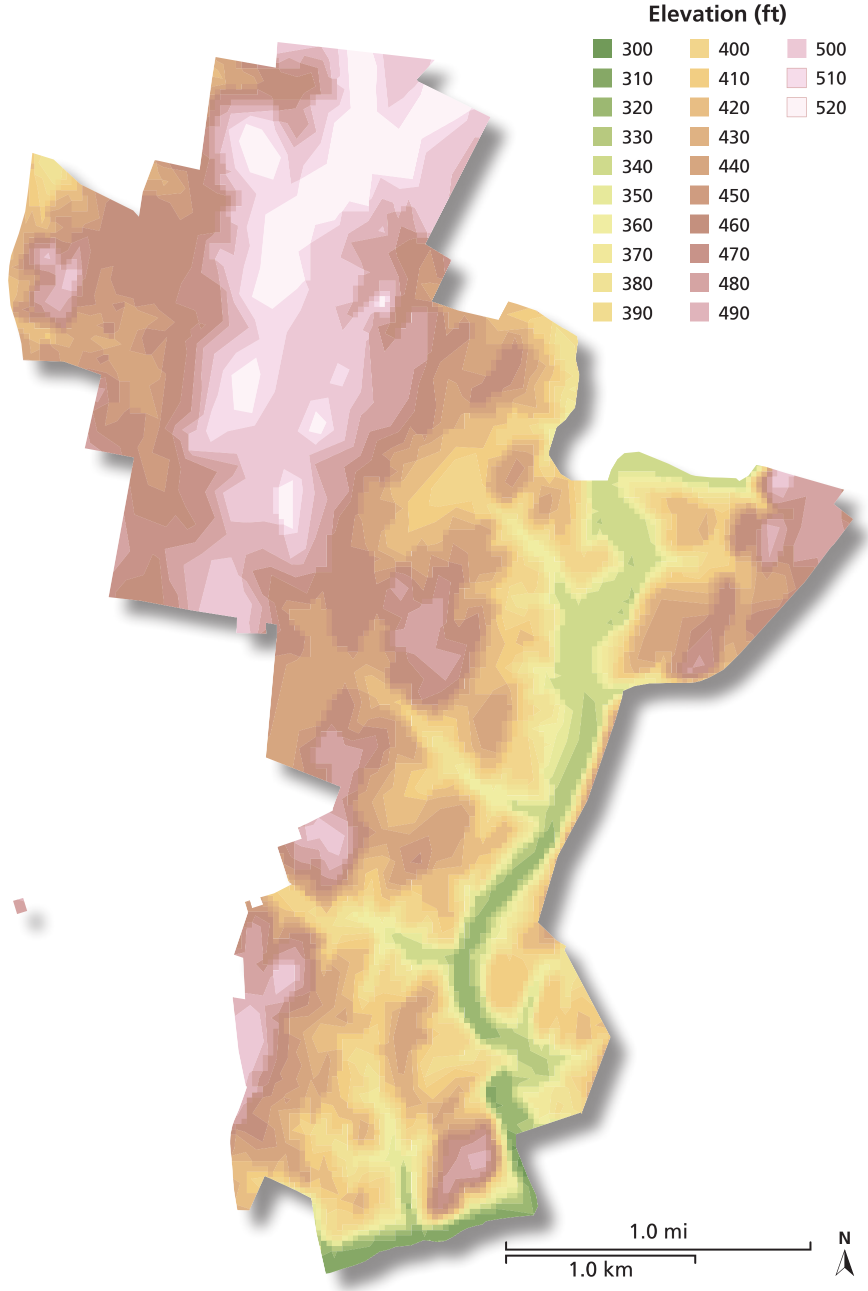


Figure 2.5. GIS data layer[18] of topographic elevation for Antietam National Battlefield.

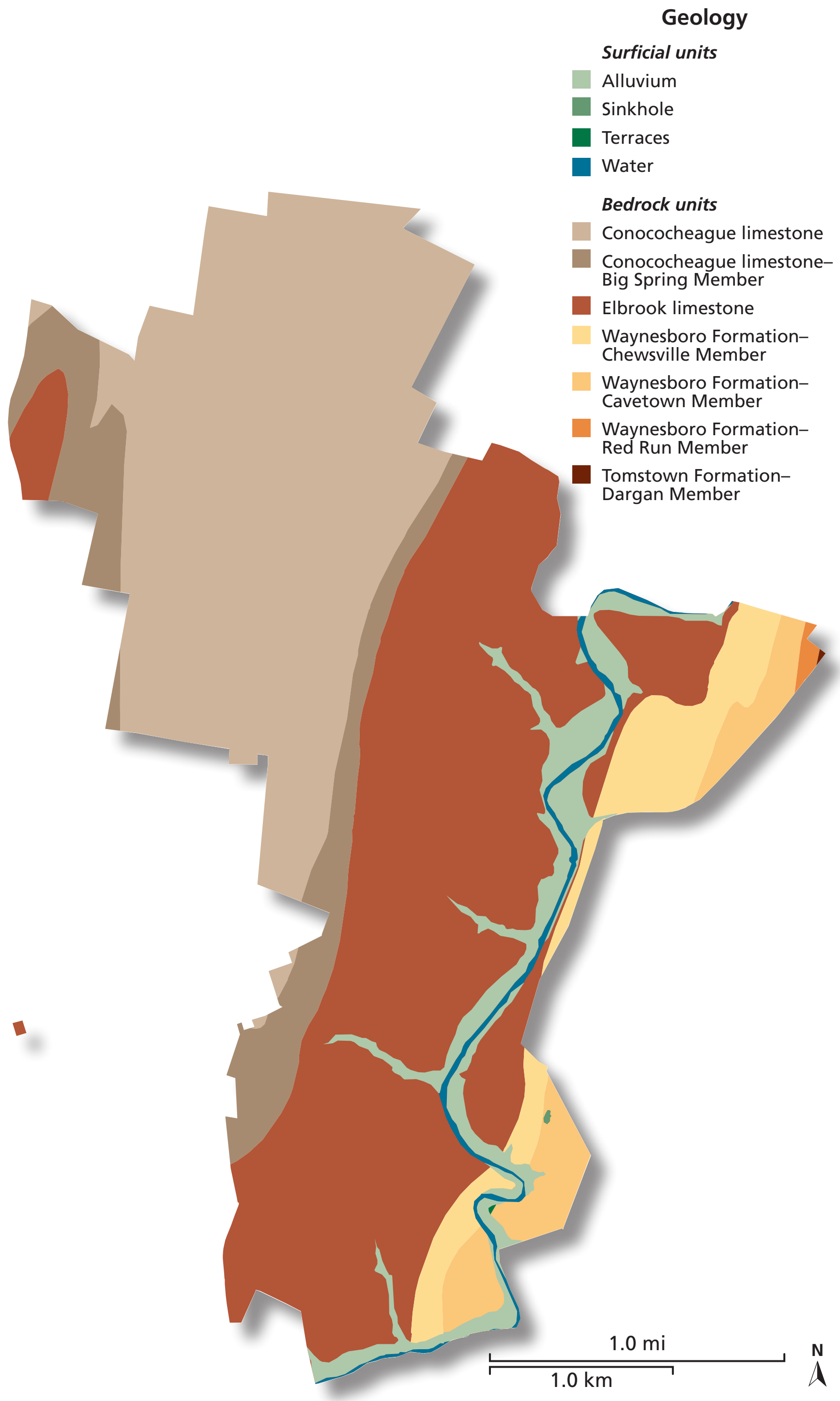
the Confederates defended the Burnside Bridge, then crosses over the creek to where the Union Ninth Corps made their advances to capture the bridge. The Cornfield Trail covers most of the area where the early morning action of battle took place. The Sherrick Farm Trail meanders through farm fields and woodlots typical of Antietam. The trail ends at the famous Burnside Bridge. The Three Farms Trail connects the north end trails to the south end trails by joining the Bloody Lane Trail in the north to the Sherrick Farm Trail in the south.

Forests

Forest and woodlands management at Antietam National Battlefield is guided by the General Management Plan (NPS 1992). This involves restoring and re-establishing the approximately 140 ha (345 acres) of woods that existed at the time of the battle in 1862, including re-establishing about 30 ha (75 acres) of the West Woods, 7.7 ha (19 acres) of the North Woods, 16 ha (39 acres) of the East Woods, and a number of smaller unnamed woods. Native mesic limestone forest species (primarily

18. National Elevation Database: Gesch et al 2002, Gesch 2007, ANTI.

Figure 2.6. GIS data layer[19] of surficial and bedrock geology in Antietam National Battlefield.



oak, maple, sycamore, hickories, and walnut) are selected for restoration and reforestation. Maryland has lost the majority of its mesic limestone forests and restoration will potentially provide habitat for a variety of rare plant species. All springs and streams in the park include a riparian buffer, connecting forest patches within the park (Figure 2.9).

Wetlands and waterways

The U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) database has identified several types of wetlands within Antietam National Battlefield (Figure 2.9). These areas are mostly comprised of 'freshwater forested/shrub wetland' (i.e., floodplain and riparian areas along Antietam Creek and its tributaries) and the waterways them-

19. Thorneberry–Ehrlich 2005, ANTI.

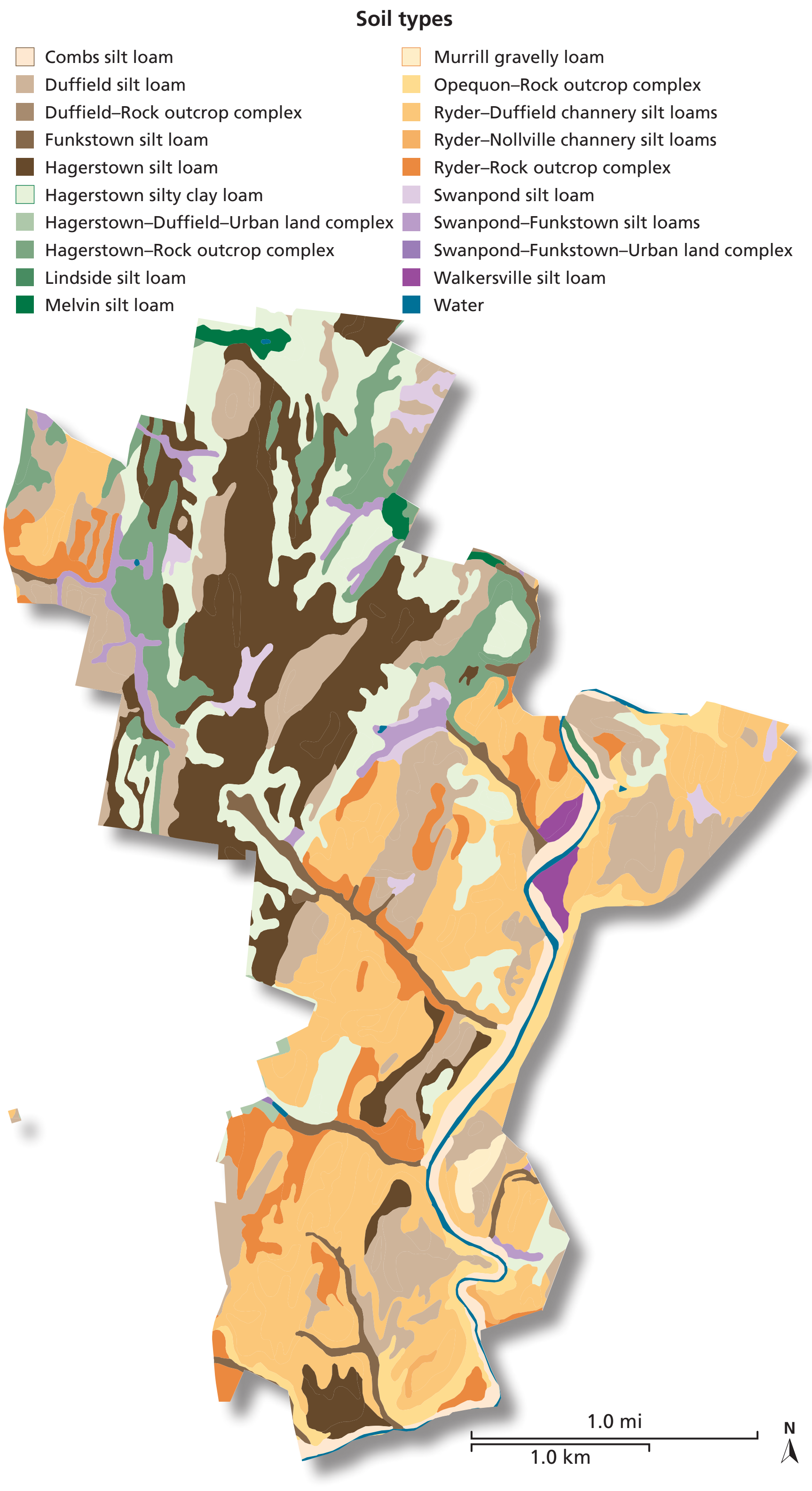
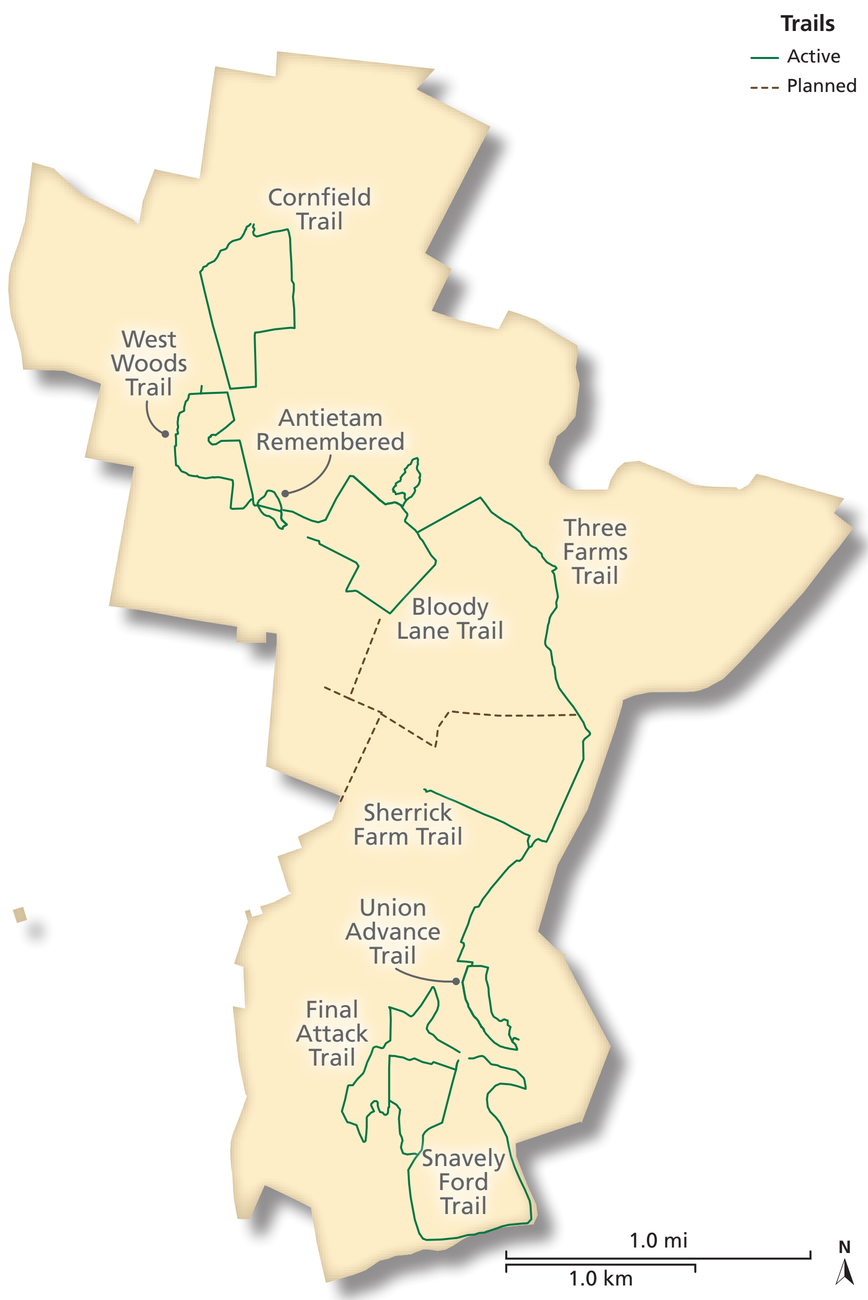


Figure 2.7. GIS data layer[20] of soil types found in Antietam National Battlefield.

selves—Antietam Creek, Mumma Spring, and Sharpsburg Creek—as well as small areas of freshwater emergent wetlands and freshwater ponds. All of the NWI-classified areas are considered 'wetlands' for legal and policy purposes. However, the floodplain and riparian areas were considered as 'forest' for the ecological and habitat purposes of this assessment (see Figure 3.1 and Section *3.5.2—Habitat framework* for detailed methodology).

20. SSURGO, ANTI.

Figure 2.8. GIS data layer[21] showing the trail system of Antietam National Battlefield.



Grasslands

Managed to maintain historic scenes and land use patterns that existed at the time of the battle, Antietam National Battlefield contains approximately 23 ha (58 acres) of managed warm-season grasslands, as well as 131 ha (323 acres) of cool-season grasslands (Figure 2.9). Warm-season grassland species are those that initiate growth in late spring and reach their peak during the warm summer months (Peterjohn 2006). These warm-season species are generally native to the Mid-Atlantic region, including such grasses as switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indian grass (*Sorghastrum nutans*). These bunch grasses provide habitat for birds and other animals by providing a complex three-dimensional structure with high species richness and varying extent of bare ground resulting from grazing, fires, and other disturbances. Cool-season grassland species start growing in early spring and flower from late spring through early summer. Storage in rhizomes controls

21. ANTI.

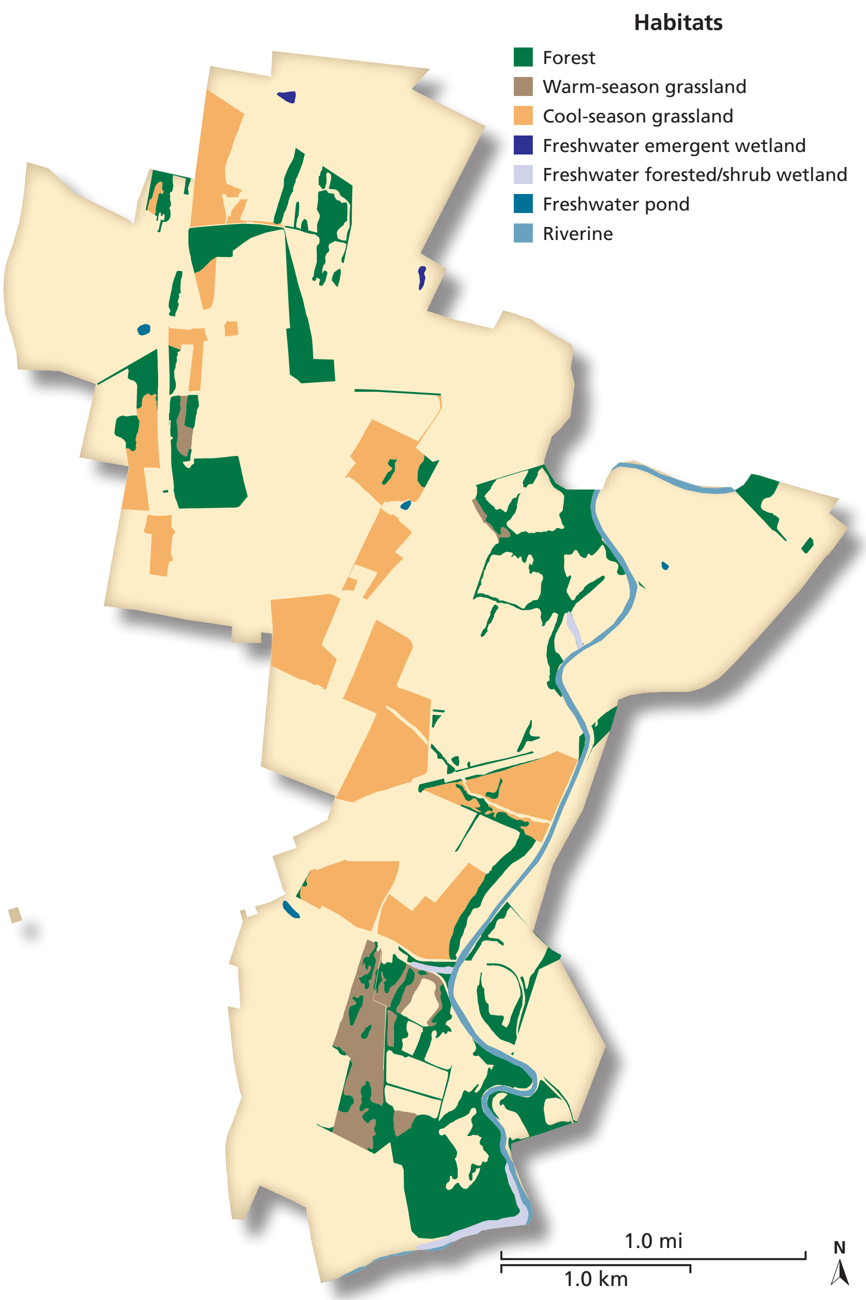


Figure 2.9. GIS data layer[22] showing general location and types of habitats in Antietam National Battlefield.

winter hardiness. Most cool-season grasses are non-native to the Mid-Atlantic region, including bluegrass (*Poa* spp.), brome (*Bromus* spp.), fescue (*Festuca* spp.), timothy (*Phleum pratense*), and orchard grass (*Dactylis glomerata*; Peterjohn 2006).

Agricultural lands

Agriculture is the most prominent land use within the park boundary and a variety of farming activities take place (NPS 1992). The farms range in size from 6.1 ha (15 acres) to nearly 80 ha (200 acres) and are a mix of federally owned lands leased to private farmers, privately owned farmed lands, and privately owned farmed lands with easements held by the federal government. Crops grown include wheat, soybeans, corn, barley, and timothy. At the time of the battle, Antietam National Battlefield contained approximately 14 ha (35 acres) of apple orchards, which are in the process of being restored using historic apple varieties. Some federal and private lands within the battlefield are also grazed by cattle, sheep, and goats.

22. National Wetlands Inventory, ANTI.

Rare, threatened, and endangered species

Antietam National Battlefield provides habitat for several plant species of concern, including some state-listed species. These are balsam fir (*Abies balsamea*), fringed brome (*Bromus ciliates*), cuckooflower (*Cardamine pratensis*), Hitchcock's sedge (*Carex hitchcockiana*), troublesome sedge (*Carex molesta*), burr-reed sedge (*Carex sparganioides*), vasevine/leatherflower (*Clematis viorna*), bulb bladderfern/bulblet fern (*Cystopteris bulbifera*), dwarf larkspur (*Delphinium tricorne*), shooting-star (*Dodecatheon meadia*), downy milk pea (*Galactia volubilis*), shining bedstraw (*Galium concinnum*), Kentucky coffee-tree (*Gymnocladus dioicus*), cow parsnip (*Heracleum maximum*), green violet (*Hybanthus concolor*), goldenseal (*Hydrastis canadensis*), butternut (*Juglans cinerea*), large twayblade/brown widelip orchid (*Liparis liliifolia*), Loesel's twayblade/yellow widelip orchid (*Liparis loeselii*), white bergamot/basal bee-balm (*Monarda clinopodia*), American ginseng (*Panax quinquefolius*), mudbank crowngrass/Walter's paspalum (*Paspalum dissectum*), Virginia ground-cherry (*Physalis virginiana*), Eastern prickly gooseberry (*Ribes cynosbati*), heartwing dock/Engelmann's dock (*Rumex hastatulus*), sandbar willow (*Salix exigua*), hoary skullcap/downy skullcap (*Scutellaria incana*), veined skullcap (*Scutellaria nervosa*), American mountain ash (*Sorbus americana*), Short's aster (*Symphyotrichum shortii*), arborvitae (*Thuja occidentalis*), and golden zizia/golden Alexanders (*Zizia aurea*).

In addition to these plants, there are several state-listed species of fish (checkered sculpin [*Cottus* sp. cf. *cognatus*], shield darter [*Percina peltata*]), birds (common raven [*Corvus corax*]), mollusks (cherrystone drop snail [*Hendersonia occulta*]) and insects (giant swallowtail [*Papilio cresphontes*]) present in the park.

2.1.2 Resource management issues overview

Antietam National Battlefield faces a number of resource management issues, many of which are related to the surrounding land use (NCRN 2006; Figure 2.10). Encroaching development reduces the habitat available for native flora and fauna. Between 1990 and 2000, population density in the vicinity of the park has continued to increase, particularly around Hagerstown (north of Antietam) and Frederick (east of the park; Figure 2.11). Not surprisingly, housing density also increased between 2000 and 2010, with increases occurring in all directions (Figure 2.12). Road density is also highest in these areas (Figure 2.13). High road density (>1.5 km km^{-2}) can impact turtle populations (Gibbs and Shriver 2002, Steen and Gibbs 2004). The area surrounding Antietam National Battlefield also has a low proportion of protected areas (Figure 2.14). Protection of 10–60% of suitable habitat is necessary to sustain long-term populations of area-sensitive and rare species (Andrén 1994, Environmental Law Institute 2003). Excessive numbers of white-tailed deer use the park as a refuge, resulting in overgrazing of native flora, particularly tree seedlings. Exotic and invasive plants out-compete native species, while insect and other pests cause damage to forest trees. On a regional scale, degraded air quality associated with vehicular traffic also affects aquatic habitats and sensitive species, and continued road development increases stormwater runoff of sediments and pollutants into the rivers.

Water

Due to the park's location at the bottom of the Antietam Creek watershed (Figure 2.3), it is susceptible to degradation of landscape and water quality that occurs outside the park and therefore beyond park management's control. The future quality of the creek and its tributaries are potentially impacted by agricultural inputs (manure and fertilizers, pesticides) from park and adjacent farmlands, upstream industrial and sewage discharge, and the increase of impervious surfaces and stormwater runoff in surrounding residential areas (Figure 2.15). Groundwater is also easily impacted because the park lies on a porous limestone bed (Thorneberry–Ehrlich 2005).

In 2002, a Total Maximum Daily Load (TMDL) was approved for Antietam

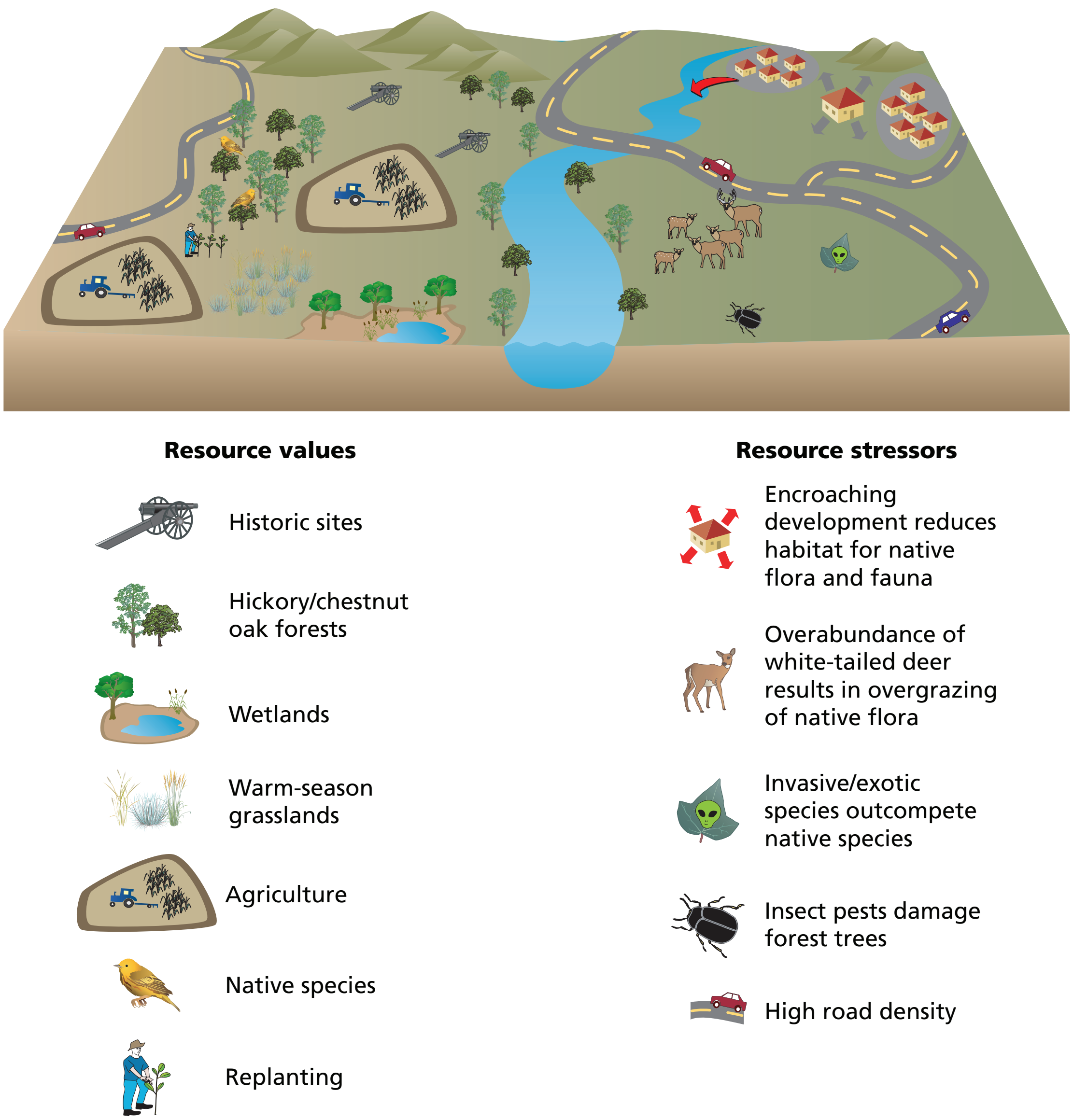


Figure 2.10. Conceptual diagram illustrating the major resource values and stressors in Antietam National Battlefield.

Creek for carbonaceous and nitrogenous biochemical oxygen demand (CBOD and NBOD, respectively) and in 2008, a TMDL was established for sediment (MDE 2002, 2009). These were based on low dissolved oxygen levels and high levels of sediments as identified in Maryland Department of the Environment's (MDE) 1996 and 1998 Section 303(d) lists of impaired waters. A TMDL is a pollution limit ideally set for every identified problem pollutant in each waterbody on the 303(d) list. The cap defines the maximum amount of each pollutant that the waterbody can theoretically receive and still meet water quality standards for all its designated uses—in the case of Antietam Creek in the vicinity of the park, it is designated as a Use IV-P waterbody (Recreational Trout Waters and Public Water Supply; MDE 2010).

The waters of Antietam Creek have also been identified by MDE as impaired by bacteria, nutrients, and impacts to biological communities. A TMDL for bacteria was submitted to the U.S. EPA to address that impairment, and the listing for nutrients and biological community impacts will be addressed separately at a future date (MDE 2009).

Grasslands

With grasslands and pasture lands making up a significant portion of Antietam National Battlefield's historic and current

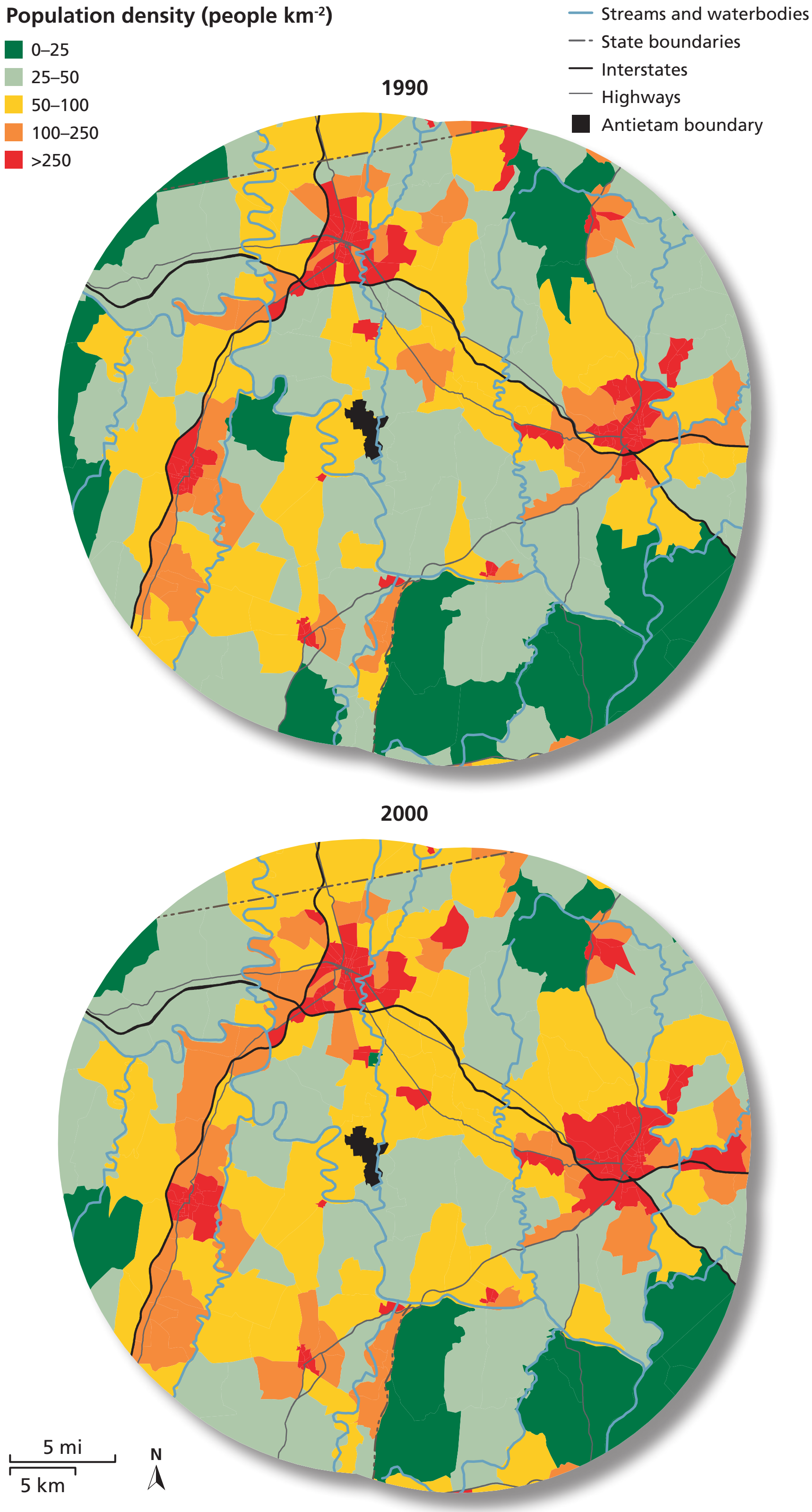


Figure 2.11. GIS data layer[23] showing population density surrounding the park in 1990 and 2000.

23. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

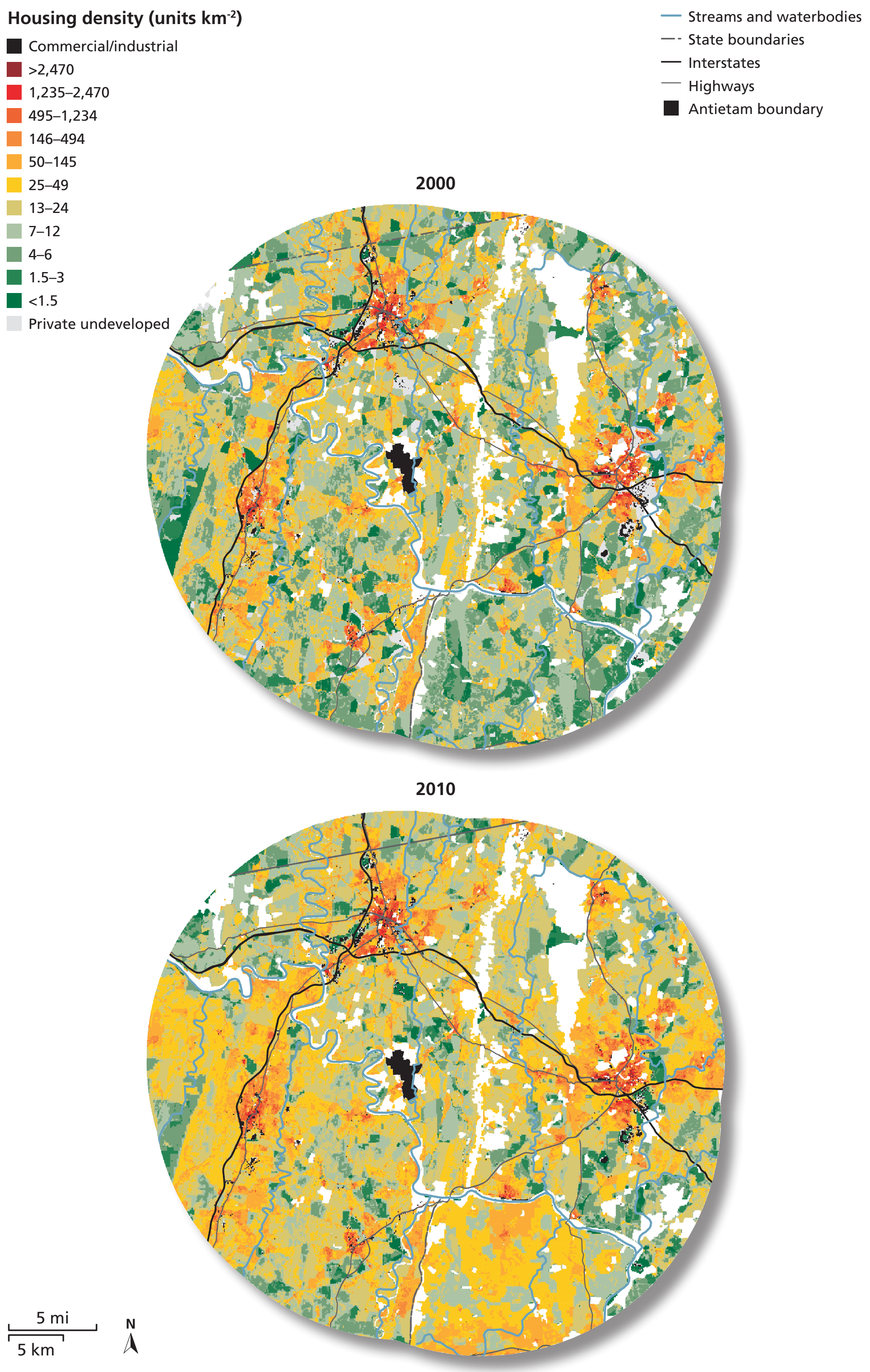


Figure 2.12. GIS data layer[24] showing population density surrounding the park in 1990 and 2000.

24. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

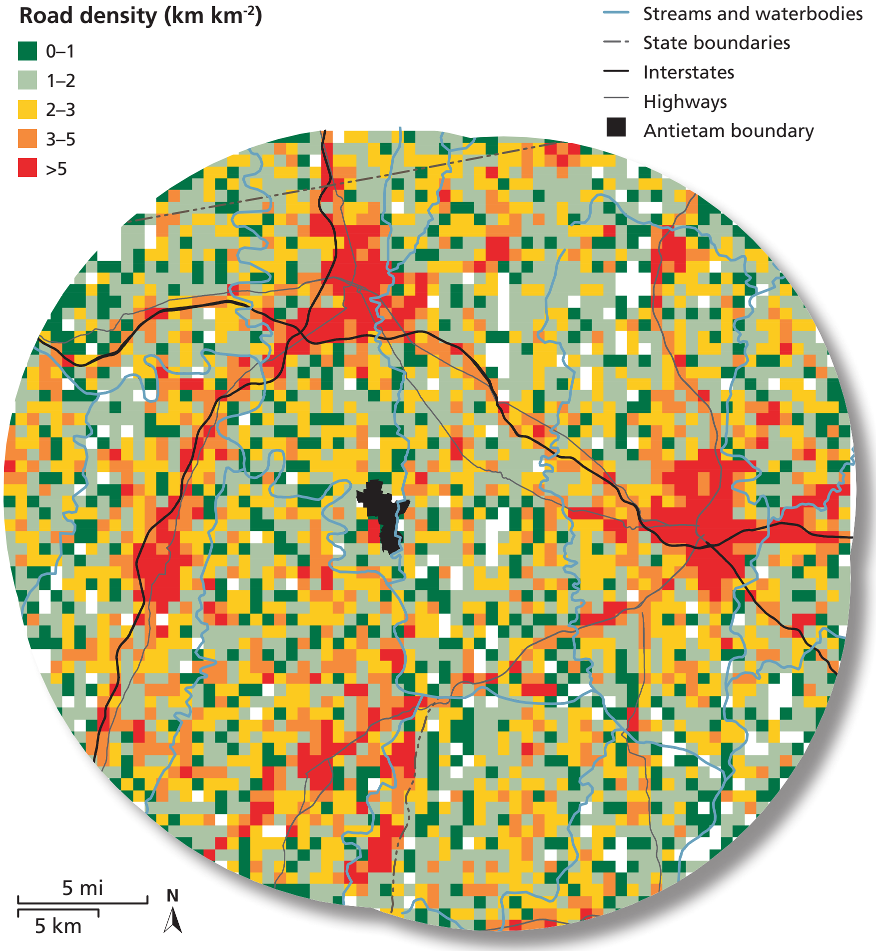


Figure 2.13. GIS data layer[25] showing road density surrounding the park in 2003.

viewsheds, management of grasslands is high on the list of Antietam's natural resource issues. Widespread declines have occurred in grassland bird communities of North America, with the primary cause in the eastern United States being afforestation (as land once cleared for agriculture reverts back to forest) that replaces early successional and old-field habitats preferred by these species (Askins 2000, Brennan and Kuvlesky 2005). Grasslands naturally change to early successional forest if left undisturbed, so active management is required to maintain grassland areas. Native warm-season grasslands were historically maintained by a combination of soil moisture levels and fire (Askins 1999), and current management options include mowing, grazing, and prescribed burns (Peterjohn 2006) and indeed, Antietam National Battlefield has prescribed fire plans in place for grasslands on the Otto Farm.

Forests

The mosaic of forest, grassland, and agricultural lands at Antietam National Battlefield is ideal habitat for white-tailed deer (*Odocoileus virginianus*). Deer populations in the Mid-Atlantic region exceed 40 deer km^{-2} (104 deer mi^{-2}) for rural and suburban national historical parks (Bates 2009). Research evidence suggests that overbrowsing by white-tailed deer can negatively affect forests by reducing growth and survival rates of native tree seedlings and saplings and preventing adult recruitment into tree populations (Russell et al. 2001). Excess herbivory may also cause irreversible shifts in successional stable-state forests by altering plant species compositions (Stromayer and Warren 1997, Augustine et al. 1998). Besides directly impacting vegetative communities, deer overbrowsing can contribute to declines in breeding bird abundances by decreasing the structural diversity and density in the forest understory (McShea and Rappole 1997).

25. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

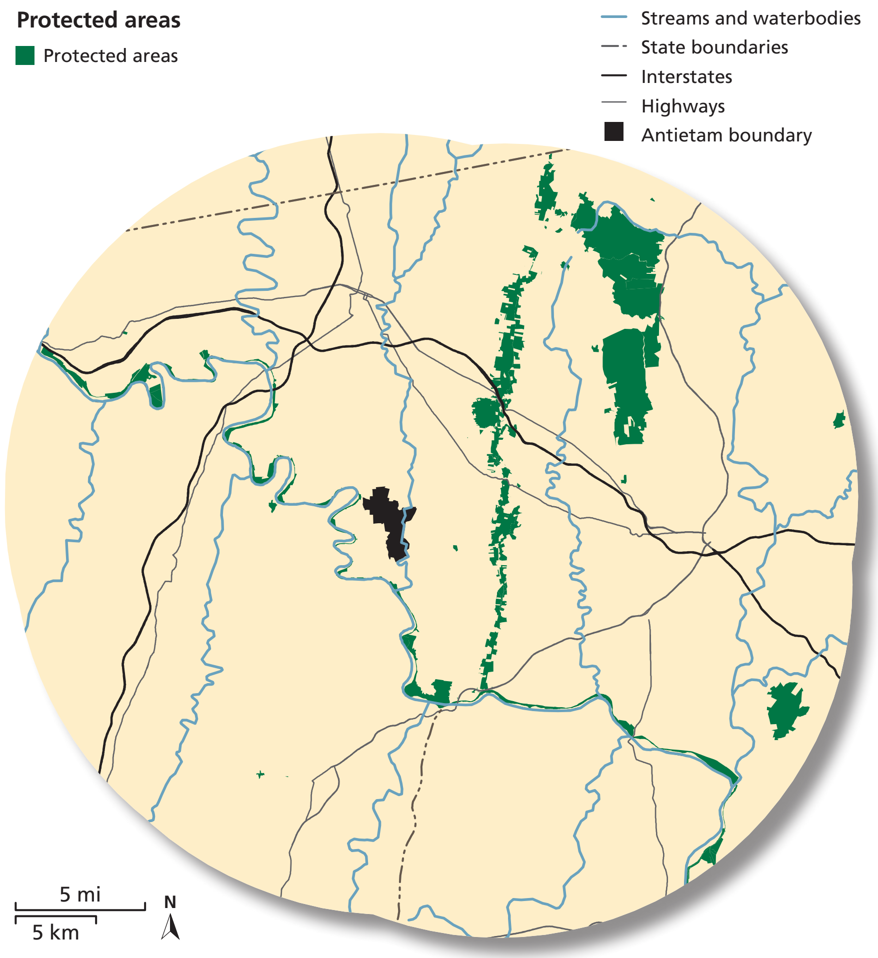


Figure 2.14. GIS data layer[26] showing protected areas surrounding the park in 2000.

Another forest resource issue is that of exotic and/or invasive plants. Invasive exotic plants may compete with native plants and therefore lead to a reduction in biodiversity of the native flora (Mack et al. 2000). A 2005 inventory of the vascular plants in Antietam National Battlefield showed that of the four most abundant species in the park, three were non-native (Engelhardt 2005). Those three species were multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), and garlic mustard (*Alliaria petiolata*).

Insect and fungal pathogens have emerged as major stressors to forests in the Mid-Atlantic region in recent decades. Pathogens of interest are the exotic gypsy moth (*Lymantria dispar*), the fungal agent *Discula destructiva* (dogwood anthracnose), the exotic hemlock woolly adelgid (*Adelges tsugae*), the fungal agent *Ophiostoma ulmi* (Dutch elm disease), and the exotic emerald ash borer (*Agrilus planipennis*, USDA 2009a,b, 2010a,b,c). However, emerald ash borer has not been found in Antietam National Battlefield at this time.

Agriculture

Deer populations in national historical parks in the Mid-Atlantic region have increased as a result of the forage provided by the agricultural landscapes within these parks (Hansen et al. 1997). Antietam National Battlefield is one of several historical parks that have entered into cooperative agricultural easements to maintain the landscape as it was during the historical period commemorated by the park. As such, overabundance of white-tailed deer is a significant resource issue in the park.

2.2 RESOURCE STEWARDSHIP CONTEXT

2.2.1 Park enabling legislation

Several laws and documents guide natural resource management for Antietam Nation-

26. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

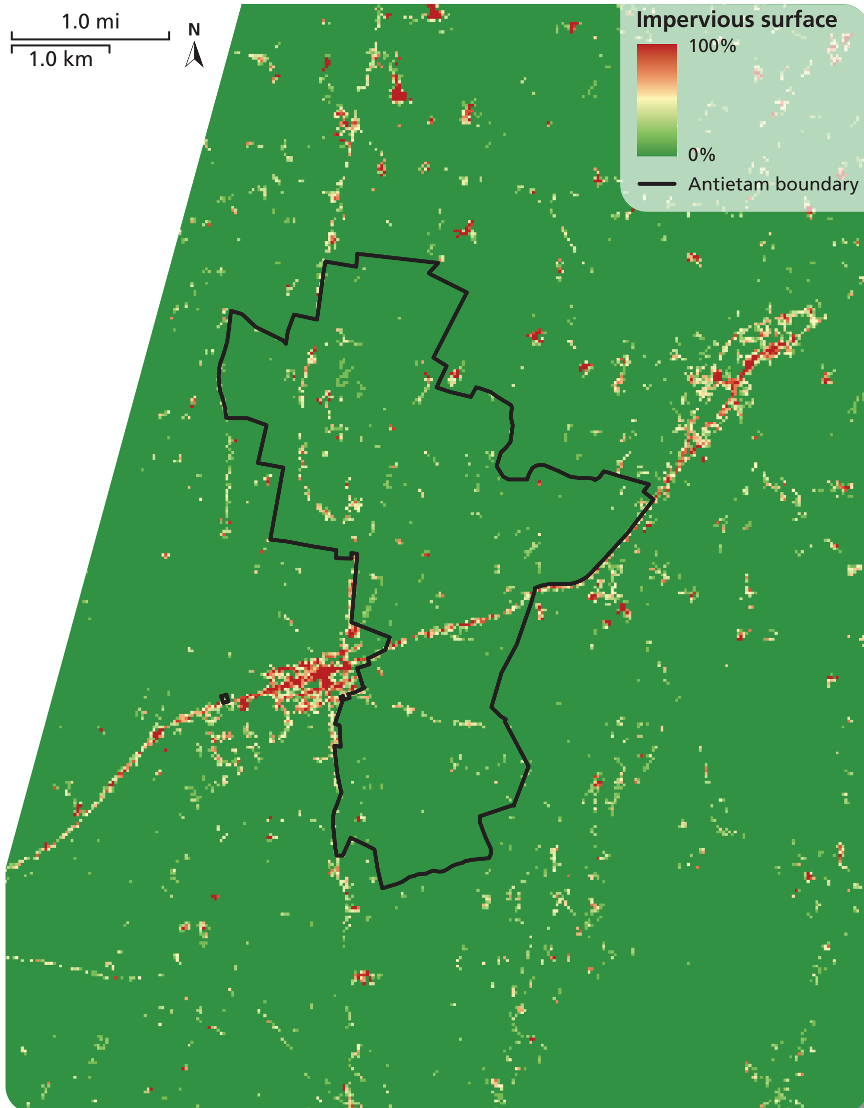


Figure 2.15. GIS data layer[27] showing percent impervious surface in and around Antietam National Battlefield in 2000.

al Battlefield—the National Park Service Organic Act of 1916 ("Organic Act," Ch. 1, 39 Stat 535), the park's federal and state founding legislation and follow-on legislation in 1960, the 1992 Antietam National Battlefield General Management Plan (GMP; NPS 1992), and the NPS Management Policies (U.S. Dept of Interior 2006).

The "Organic Act" that established the National Park Service (NPS) on August 25, 1916 provides the primary mandate NPS has for natural resource protection within all national parks. It states,

> *"the Service thus established shall promote and regulate the use of Federal areas known as national parks, monuments and reservations . . . by such means and measures as conform to the fundamental purpose of the said parks, monuments and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."*

Consequently, like all parks in the National Park system, one of Antietam National Battlefield's chief environmental mandates is to preserve the viewshed as well as the natural resources of the park. Any visitor activities associated with enjoyment can occur only to the extent that they do not impair the scenery and the natural resources for future generations.

27. RESAC Impervious Surface Area Time Series, ANTI.

Antietam's 1890 federal founding legislation allowed for the acquisition of lands "For the purpose of surveying, locating, and preserving the lines of battle . . . and for marking the same." A law in the state of Maryland, approved April 7, 1892, allowed federal land acquisition for these purposes and, "for the preservation of the grounds covered by said battlefields for historical or other purposes . . ."

According to Snell and Brown (1982), the U.S. Committee on Military Affairs (1891), in February 27, 1891 issued a report explaining the purpose of the 1890 federal law for Antietam, stating,

> *"The field on which the battle took place is practically unchanged from what it was on the day of the action, save the cutting down of some trees, and presents to-day, as it did in 1862, the most open field on which was fought any of the great battles of the rebellion—a field of which the eye in one sweep can take in all points. It is proposed to maintain the field in the same condition as to roads, fields, forests, and houses . . ."*

Federal legislation in 1960 (16 USC 430oo, April 22, 1960) restated and summarized previous legislation, stating that the Secretary of the Interior was authorized,

> *"to preserve, protect and improve the Antietam Battlefield . . .to assure the public a full and unimpeded view thereof, and to provide for the maintenance of the site . . . in, or its restoration to, substantially the condition in which it was at the time of the battle of Antietam."*

Thus, as a battlefield park, natural resource management at Antietam is set within a cultural and historic context. Section 5.3.5.2 (Cultural Landscapes) of NPS Management Policies (U.S. Dept of Interior 2006) clarifies the boundary between management for cultural and natural resources, stating that,

> *"The treatment of a cultural landscape will preserve significant physical attributes, biotic systems, and uses when those uses contribute to historical significance. Treatment decisions will be based on a cultural landscape's historical significance over time, existing conditions, and use. Treatment decisions will consider both the natural and built characteristics and features of a landscape, the dynamics inherent in natural processes and continued use, and the concerns of traditionally associated peoples."*

Antietam National Battlefield Park is therefore a park established to preserve and maintain a Civil War-era cultural landscape that is managed as much as possible to preserve physical attributes and biotic systems wherever historic considerations do not indicate otherwise. In this context, this natural resource condition assessment addresses natural habitats managed for natural resource values (forests, wetlands and waterways, warm-season grasslands), as well as habitats that are managed for agricultural values (croplands and pastures).

2.2.2 Resource stewardship planning

Antietam's 1992 General Management Plan (GMP; NPS 1992) analyzed and described three alternatives for future management and use of Antietam National Battlefield. They ranged from maintaining existing conditions to restoring most of the historic scene. Alternative B—1862 Scene Restoration—provided for restoration of the battlefield landscape to its approximate appearance on the eve of the battle of September 17, 1862. Restoration actions are in keeping with the 1960 legislative mandate "to provide for the maintenance of the site . . . in, or its restoration to, substantially the condition in which it was at the time of the battle" (Public Law 86-438).

Other actions under alternative B include simplifying the automobile tour route so that it focuses on the three main battle phases, incorporating new interpretive features and media to enhance visitor experiences, and cooperating with state, local, and private entities to ensure preservation of the rural/agricultural landscape inside and adjacent to the battlefield boundary. Restoration actions under alternative B call for the return of the landscape to a more historic appearance by re-establishing many of the farm fields, woods, orchards, fencelines, and historic trace roads that existed in 1862. These actions would have a beneficial effect on the natural environment by recovering a net total of 2.8 ha (7 acres) of prime and unique farmlands, re-establishing about 140 ha (345 acres) of limestone forest woodlands, increasing habitat diversity, decreasing automobile emissions in the park, and reducing erosion into Antietam Creek at Burnside Bridge.

2.2.3 Resource stewardship science

The 1992 Antietam National Battlefield GMP (NPS 1992), and the NPS Management Policies (U.S. Dept of Interior 2006) are the two primary documents that guide planning at the park, and are discussed in the previous two sections.

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Chapter 3: Study approach

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Antietam park staff, including Superintendent John Howard and natural resource staff Ed Wenschhof, Joe Calzarette, and Deb Cohen, initially met in April 2009, along with National Capital Region Network Inventory & Monitoring (NCRN I&M) staff Mark Lehman, Patrick Campbell, and Megan Nortrup, and University of Maryland Integration and Application Network staff Tim Carruthers and Jane Thomas. Topics discussed included which park boundaries to use in the assessment, identification of assessment metrics and data sources, habitat identification, and framework definition.

Additional conference calls were held in August and November 2009 to further progress the project. Also participating in these calls were natural resource staff from Monocacy National Battlefield and Manassas National Battlefield Park, to facilitate the concurrent natural resource assessments occurring at these three parks. Topics discussed during these calls included furthering the habitat identification and delineation and how to best assess the agricultural lands in the park, ultimately culminating in the creation of the 'habitats managed for natural resource values' and 'habitats managed for agricultural values' groupings.

A meeting was held at Monocacy National Battlefield in January 2010. Natural resource staff from Monocacy National Battlefield and Manassas National Battlefield Park were also present at this meeting. The purpose of this meeting was to draft the key findings and identify data gaps and management recommendations which are presented in Chapter 5.

3.1.1 Other NPS involvement

The NCRN I&M was the primary coordinator and leader for the production of this NRCA for Antietam National Battlefield. NCRN staff established a cooperative agreement with University of Maryland Center for Environmental Science Integration and Application Network (IAN) to work on this document, supplied the majority of the data used in the assessment, and provided knowledge of the larger context of the region's battlefield parks.

Antietam staff regularly monitor water quality.

Prior to the first meeting with park staff in April 2009, NCRN staff compiled an extensive collection of data and literature about the park, combining data gathered and analyzed by the NCRN with government reports, scientific literature, and park-generated data to provide a comprehensive picture of the available natural resource knowledge about the park. Following the April meeting, the NCRN produced map products for the assessment based on NCRN and other data, supplied introductory text on the park's background, and provided substantial editing and feedback during multiple stages in the document's production. NCRN staff also participated in several conference calls on topics including classification of agricultural lands and park boundaries.

In June 2010, following the completion of a working draft document, NCRN held a briefing with regional science staff from the Center for Urban Ecology to familiarize them with the status and content of the NRCAs for Antietam National Battlefield, Monocacy National Battlefield, and Manassas National Battlefield Park. NCRN staff contributed extensive comments on the initial draft report incorporating several suggestions made by Acting Regional Chief of Natural Resources, Dan Sealy. Comments were compiled and submitted by NCRN Science Communicator Megan Nortrup who also fielded follow-up questions from IAN staff.

3.2 REPORTING AREAS

3.2.1 Ecological reporting units

Two reporting frameworks were used in this assessment—the Inventory and Monitoring Vital Signs framework (Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics) and a habitat-based framework. For the habitat-based framework, the park fee boundary was used, which differs from the administrative/legislative boundary in that the fee boundary encompasses only the lands that are currently owned by NPS (Figure 2.1). NPS jurisdiction limitations generally prohibit the park from managing resources outside of the fee boundary, so the habitat assessment is limited to those lands. The administrative/legislative boundary equals 1,320 ha (3,263 acres), while the fee boundary is 784 ha (1,937 acres). Six predominant ecological habitat types were identified within Antietam National Battlefield, and these were divided into habitats managed for natural resource values (forests, wetlands and waterways, warm-season grasslands) and those managed for agricultural values (croplands, pastures, developed areas; Figure 3.1). Many ecological classification systems are based on vegetation communities (Anderson et al. 1998, Grossman et al. 1998) or land cover (Anderson et al. 1976). However, this habitat classification system was agreed upon in consultation with park staff and is at a sufficient level of classification to permit comparisons to other systems (i.e., formation class or Anderson level one) while also being coarse enough to contain sufficient monitoring data within each habitat to allow a meaningful assessment of resource condition. More detail on this methodology is presented in Section *3.5—Study methods*.

3.3 STUDY RESOURCES AND INDICATORS

3.3.1 Assessment frameworks used in this study

Introduction

For the assessment of resource conditions within Antietam National Battlefield, two synthetic frameworks were applied that addressed key structural and functional aspects of the ecosystem (U.S. EPA 2002). Recognizing the large amount of data included in this assessment from the NPS I&M, the first framework utilized was the ecological monitoring framework or 'vital signs' categorization developed by NPS I&M (Fancy et al. 2008). Fancy identified a key challenge of such large-scale monitoring programs as the development of information products which integrate and translate large amounts of complex scientific data into highly aggregated metrics for communication to policy-makers and non-scientists. Aggregated indices were developed and are presented within this document. More specific indices and raw data (Appendix A) are also presented to facilitate communication of key conclusions to scientists and field practitioners and to ensure that all approaches and calculations are explicit. The second framework (the habitat framework) calculates aggregated condition indices based upon the five main ecological habitats present within Antietam National Battlefield, divided into two broad groups—habitats managed for natural resource values (forests, wetlands and waterways, warm-season grasslands) and those managed for agricultural values (croplands, pastures). Developed areas, although defined as a separate habitat, were not assessed for natural resource condition.

Utility of thresholds

A natural resource condition assessment requires the establishment of criteria for defining ecological condition and the current assessment was based upon explicitly defined threshold values. Even though increasing scientific research has been focused upon defining ecological thresholds, uncertainty in definition as well as spatial and temporal variability has often led to disagreement

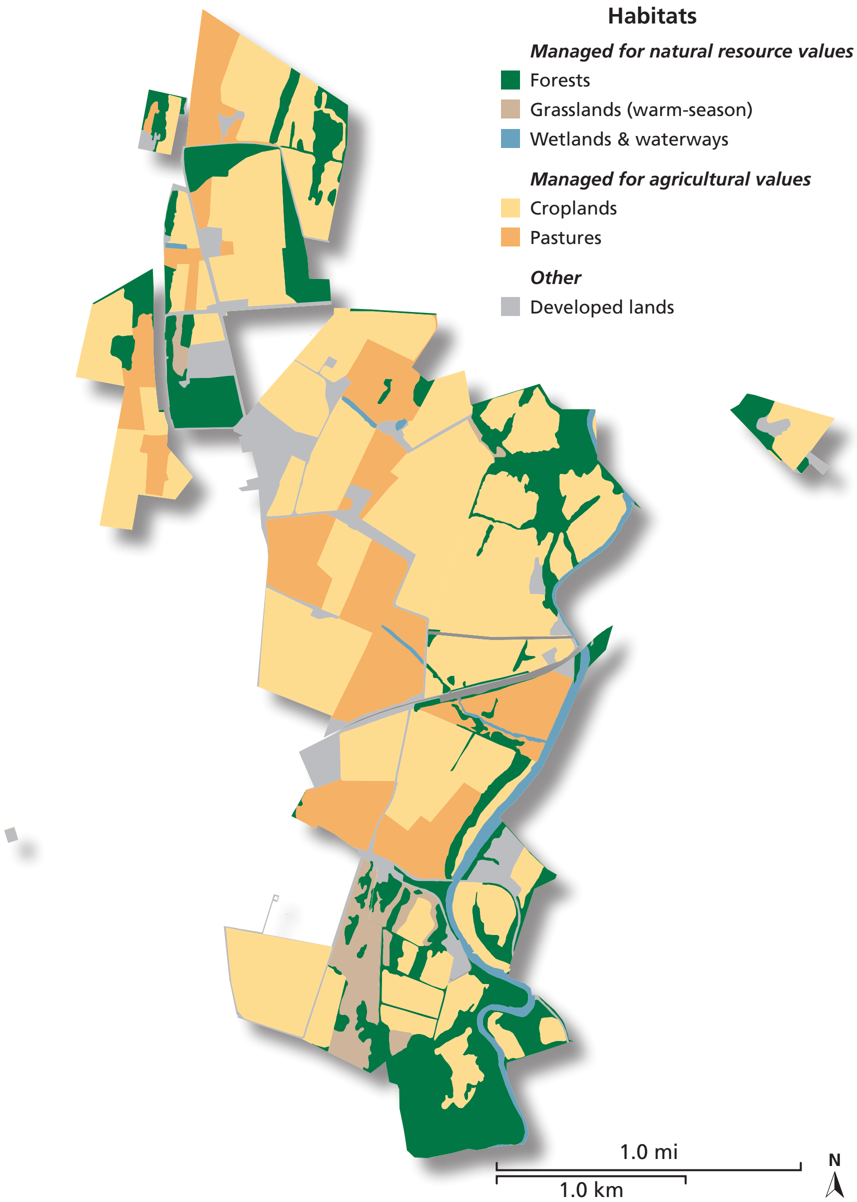


Figure 3.1. GIS data layer[28] of major habitat types in Antietam National Battlefield, as defined by aggregation of other GIS data layers.

on specific values (Groffman et al. 2006, Huggett 2005). Even with the definition of agreed-upon thresholds, there is still the question of how best to use these threshold values in a management context (Groffman et al. 2006). Recognizing these challenges, thresholds can still be effectively used to track ecosystem change and define achievable management goals (Biggs 2004). As long as threshold values are clearly defined and justified, they can be updated in the light of new research or management goals and can therefore provide an important focus for the discussion and implementation of ecosystem management (Jensen et al. 2000, Pantus and Dennison 2005).

Definition and types of thresholds

A threshold indicates a point or zone where current knowledge predicts a change in state or some aspects of ecosystem condition. More specifically, however, it represents an accepted value or range indicating that an ecosystem is moving away from a desired state and towards an undesirable ecosystem endpoint (Biggs 2004, Bennetts et al. 2007). Recognizing that many managed systems have multiple and broad-scale stressors, another perspective is to define a threshold as measuring the level of impairment that an environment can sustain before resulting in significant—and perhaps irre-

28. NCRN I&M, ANTI.

versible—damage (Hendricks and Little 2003). Three types of thresholds are used for different aspects of natural resources management and all can provide useful information for the assessment of natural resource condition. These thresholds are management, ecological, or regulatory and while in some cases they overlap (or are the same), these thresholds often provide different information as a result of being established for very different purposes (Figure 3.2; Bennetts et al. 2007).

Management thresholds are intended to instigate changes in management activity so as to maintain the natural resources of an ecosystem in a desired state. Therefore, these are likely to be the most conservative thresholds as it is necessary for management responses to occur before an ecological threshold is passed (Figure 3.2).

Ecological thresholds are based on best current scientific understanding and indicate a value where large changes in an ecosystem (and therefore natural resource values) are predicted (Figure 3.2). This definition includes the concept of 'critical loads,' as both ecological thresholds and critical loads estimate a metric value expected to be associated with change in the ecosystem. The difference is that an ecological threshold is based upon a response metric while a critical load relates to a known amount of some input to the system. Both ecological thresholds and critical loads are often determined by large modeling studies across multiple sites in varying ecosystem condition, e.g., the ecological threshold for Benthic Index of Biologic Integrity (Southerland et al. 2005) and critical loads for atmospheric nitrogen oxide and sulfur dioxide deposition (Dupont et al. 2005). If changes in an ecosystem begin and there is no early warning resulting in a management response (e.g., no management threshold) and the change continues past the ecological threshold (so that the ecosystem changes and natural resource values become impacted) then regulatory thresholds become relevant.

Regulatory thresholds are likely to be the least conservative threshold as they are frequently based on an aspect of the ecosystem posing a threat to human health (e.g., mercury concentration in fish; Meili et al. 2003), in which case the ecosystem may well have already undergone change to a degraded condition.

Process of threshold determination within ecological monitoring and habitat frameworks

Within this report, a range of management, ecological, and regulatory thresholds were used, although ecological thresholds were used preferentially. One helpful resource was the report by Hendricks and Little (2003) to the U.S. Environmental Protection Agency (U.S. EPA) specifically working towards the establishment of environmental thresholds for multiple metrics. U.S. EPA documentation also provided a basis for Air & Climate (National Ambient Air Quality Standards) and Water Resources (Freshwater Recreational Standards) thresholds, which were supplemented by scientific literature to clarify whether thresholds could be considered as ecologically relevant (rather than simply regulatory) (Tables 3.1, 3.2). Thresholds for Biological Integrity metrics were largely based on National Park Service (NPS) management thresholds and so the scientific literature was further investigated for experimental or correlative justification of these thresholds (Table 3.3). Finally, the thresholds established for Landscape Dynamics metrics were based on research studies, some of which are ongoing within the NCRN (Townsend et al. 2009; Table 3.4).

To conduct an assessment of the natural resource condition of the entire park, it was necessary to develop a framework incorporating all major land uses within the park to effectively assess lands managed for natural resource values as well as those managed for agricultural values (Figures 3.1, 3.3, 3.4). In Antietam National Battlefield, as in many battlefield parks, the enabling legislation focuses on maintaining a landscape similar to that on the day of the battle, which includes maintaining cropfields and pastures. Assessing these lands within a habitat context reflects that different land uses within the park create a mosaic and therefore the natural resource value of the forests, wetlands and waterways, and warm-season grasslands is, to some extent, dependent upon the adjacent agricultural lands. Furthermore, park management goals cover all lands within the park, suggesting that to best integrate a natural resource condition assessment into a relevant park management context, all lands need to be integrated into one assessment.

In the habitat assessment, a different approach was taken for the determination of metrics and thresholds within the two habitat categories (managed for natural resource values/managed for agricultural values). In habitats that are managed for natural resource values (forests, wetlands and waterways, warm-season grasslands), ecosystem or vital sign metrics were used as indicators of ecosystem function (Figure 3.3). For habitats managed for agricultural values (croplands and pastures), the percent of area compliant with Best Management Practices was used as an indicator of effectiveness at minimizing potential impacts of these lands on adjacent or downstream natural habitat areas (through sediment and nutrient inputs) (USDA 2007, Chesapeake Bay Program undated; Figure 3.4).

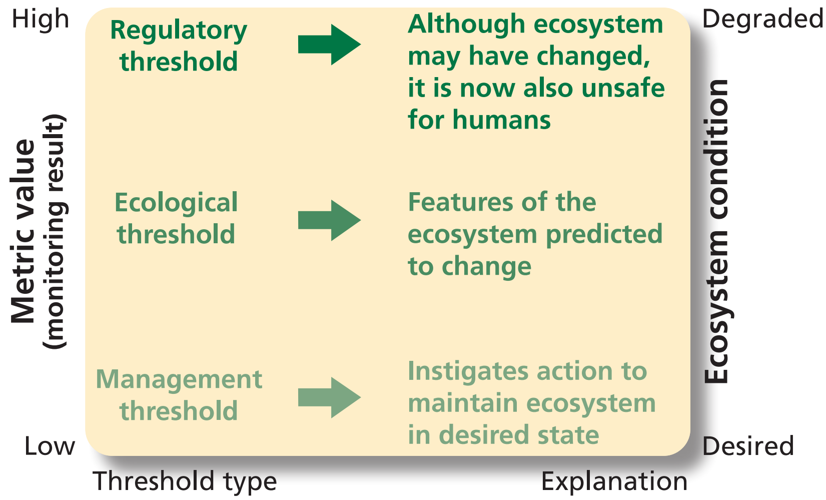


Figure 3.2. Conceptual relationship between ecosystem condition and the different types of thresholds. In all cases, it is presumed that the metric is well-studied with a reliable measurement protocol and well-understood responses (e.g., available large spatio-temporal data sets).

3.3.2 Candidate study resources and indicators

If time and resources for data gathering were unlimited, this assessment would include many more data sets and consider many additional components. The Inventory and Monitoring program in the National Capital Region provided a solid range of data types for this evaluation of natural resource conditions, but due to funding and technical constraints could not address the following possible components of the natural resources of Antietam: bird monitoring (grassland, wetland, forest, birds of prey,

Table 3.1. Thresholds for Air & Climate metrics.

Metric	Threshold	Justification	Threshold source
Ozone	0.06 ppm for the 3-yr average of 4th-highest daily maximum 8-hr average ozone concentration, averaged over five years.	The ozone threshold was based on human health but is also appropriate for plant health. Ozone was sampled on an hourly basis. An hourly value was calculated (mean of 4 hours before and after), recording the maximum 8-hr average value per day. For each year the 4th-highest daily value was recorded and then a 3-yr average was calculated.	NPS 2009
Wet nitrogen (N) deposition	1 kg N ha^{-1} yr^{-1} (annual total per site)	The nitrogen threshold was based on maintaining ecosystem structure and function. Annual wet deposition was used—NH_4 (ammonium) and NO_3 (nitrate) results were summed to obtain total wet nitrogen deposition.	NPS 2009
Wet sulfur (S) deposition	1 kg S ha^{-1} yr^{-1} (annual total per site)	The sulfur threshold was based on maintaining ecosystem structure and function.	NPS 2009
Visibility	2 dv (annual per site)	The visibility threshold was based upon how well and how far park visitors can see.	NPS 2009
Mercury (Hg) deposition	2 ng Hg L^{-1} (annual mean)	This modeled value corresponds to an inland fish tissue concentration of 0.5 mg methylmercury kg^{-1} wet weight.	Meili et al. 2003 Hammerschmidt and Fitzgerald 2006

Table 3.2. Thresholds for Water Resources metrics.

Metric	Threshold	Justification	Threshold source
pH	6.5 ≤ pH ≤ 8.5 (monthly instantaneous measurements)	Extreme pH values limit suitability of habitat for biota, e.g., salamander larvae abundance are reduced at extreme pH, by direct effects and reducing available food.	COMAR 2007b U.S. EPA freshwater recreation standards
Dissolved oxygen (DO)	≥ 5.0 mg DO L^{-1} (monthly instantaneous measurements)	Low concentrations of dissolved oxygen cause limitation and ultimately death of fish, benthic invertebrates and aquatic plants.	COMAR 2007b U.S. EPA freshwater recreation standards
Temperature	< 23.9°C (monthly instantaneous measurements)	Increased stream water temperature is unsuitable for many biota such as brook trout.	COMAR 2007b U.S. EPA freshwater recreation standards
Acid neutralizing capacity (ANC)	> 200 µeq L^{-1} (monthly instantaneous measurements)	Threshold based on U.S. EPA "sensitive to acidification" standard of 200 µeq L^{-1} (1 mg L^{-1} $CaCO_3$ = 20 µeq L^{-1}). Also justified by relationship to stream Benthic IBI.	Southerland et al. 2007
Salinity	< 0.25 (monthly instantaneous measurements)	Threshold based on U.S. EPA human drinking water standards of maximum 250 mg L^{-1} chloride ions (equivalent to a salinity of 0.25). Salinity was measured at each sample location for all sampling dates (2005–2006).	U.S. EPA 2009 EPA Standards for Drinking
Nitrate (NO_3)	< 2 mg NO_3 L^{-1} (monthly instantaneous measurements)	Nitrate threshold based on relationship to benthic invertebrate index.	Southerland et al. 2007
Phosphate (PO_4)	0.031 mg PO_4 L^{-1} (monthly instantaneous measurements)	Phosphate threshold based on U.S. EPA nutrient ecoregional criteria, to maintain baseline conditions with minimal impact from anthropogenic eutrophication.	U.S. EPA 2000 U.S. EPA nutrient criteria inland waters
Benthic index of biotic integrity (IBI)	Benthic IBI > 3 (one sample per site)	Threshold based on statewide assessment of benthic communities; resulting in the scale: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good).	Southerland et al. 2007 Norris and Sanders 2009
Physical habitat index (PHI)	PHI > 81 (one sample per site)	Threshold based on Maryland Biological Stream Survey data on the condition of MD streams: 0–50 (severely degraded), 51–65 (partially degraded), 66–80 (degraded), and 81–100 (minimally degraded).	Paul et al. 2003 Southerland et al. 2005

Table 3.3. Thresholds for Biological Integrity metrics.

Metric	Threshold	Justification	Threshold source
Cover of herbaceous species, woody vines, and target exotic trees and shrubs	< 5% cover. Measured as area of ground covered by herbs and vines, and percent of total basal area for shrubs and trees (one sample per site)	This threshold is more than a simple presence of these species, but an indication that they have the potential to increase in abundance, displacing native species.	This threshold is a guideline to commence active management of an area by removal of these species.
Presence of pest species	>1% of trees infested (one sample per site)	The emerald ash borer threshold is based upon any observed presence of this pest species being unacceptable. The gypsy moth threshold is based on documented forest response.	Montgomery 1990 Liebhold et al. 1994
Native tree seedling regeneration	35,000 seedlings ha^{-1} (one sample per site)	Based on natural densities of native tree seedlings in a healthy and self-sustaining forest. This threshold may vary depending on deer population.	McWilliams et al. 1995 Carter and Fredericksen 2007 Marquis et al. 1992
Fish index of biotic integrity (IBI)	Fish IBI > 3 (one sample per site)	Based on 1994–1997 data from a total of 1,098 sites. Sites were classified based on physical and chemical data and compared to a range of stream fish related metrics: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good).	Southerland et al. 2007
Presence of forest interior dwelling species (FIDS) of birds	> 4 sensitive FIDS or >1 highly sensitive FIDS (one park-wide assessment)	Threshold is based on bird sensitivity to forest fragmentation and disturbance both within and surrounding a forest patch, particularly during the breeding season. One highly sensitive species indicates high-quality FIDS habitat, > 6 highly sensitive species indicates exceptional quality habitat, and < 4 sensitive species indicates severe forest fragmentation and poor FIDS habitat.	MD DNR undated Jones et al. 2000
Grassland bird diversity	No threshold as such. Percentage of functional groups found in the park translates directly to the percent attainment.	Threshold is based on the percentage of four functional groups that is found in the park.	Peterjohn 2006
White-tailed deer density	Forest: < 8 deer km^{-2} Grassland: < 20 deer km^{-2} (one assessment per year)	The forest threshold for deer abundance is based on a 10-yr manipulative experiment. The grassland threshold is a guideline currently used for management of these areas.	Horsley et al. 2003

Table 3.4. Thresholds for Landscape Dynamics metrics.

Metric	Threshold	Justification	Threshold source
Impervious surface (within the park)	10% (one park-wide assessment)	Many ecosystem components such as wetlands, floral and faunal communities, and streambank structure show signs of impact above this impervious surface threshold. Recent studies on stream macro-invertebrates continue to show shifts to tolerant species and reductions in biodiversity at around this threshold. Overall, <10% is protected, 10–30% is impacted and >30% is degraded.	Arnold and Gibbons 1996 Lussier et al. 2008
Impervious surface (within the park + 5 times buffer area)	10% (one park-wide assessment)	As above	As above
Forest interior area	No threshold as such. Percentage of forest interior area in the park translates directly to the percent attainment.	Interior forest area is essential for the breeding success of many birds. The indicator is expressed as the number of acres of interior forest in the park divided by the number of potential acres of interior forest.	Temple 1986 MD DNR 2008
Forest connectivity index (Dcrit; within the park)	Dcrit < 360 m (one park-wide assessment)	Based on the distance that many small mammals and tree seeds can disperse, Dcrit is a measure of the distance where 75% of forest patches are connected (allowing dispersal).	Townsend et al. 2006, 2009 Bowman et al. 2002 He and Mladenoff 1999
Forest connectivity index (within the park + 5 times buffer area)	Dcrit < 360 m (one park-wide assessment)	As above	As above
Grassland interior area	No threshold as such. Percentage of grassland interior area in the park translates directly to the percent attainment.	Studies have shown that grassland bird nests located in grassland interior areas are more successful than those located near ecotone edges. The indicator is expressed as the number of acres of interior grassland in the park divided by the number of potential acres of interior grassland.	Burger et al. 1994
Contiguous grassland area	≥ 10 ha (one park-wide assessment)	Based on area needed to support grassland bird communities. Categories are as follows: 0–12 ac (very poor), 12–25 ac (poor), 25–50 ac (moderate), 50–100 ac (good), >100 ac (very good).	Peterjohn 2006

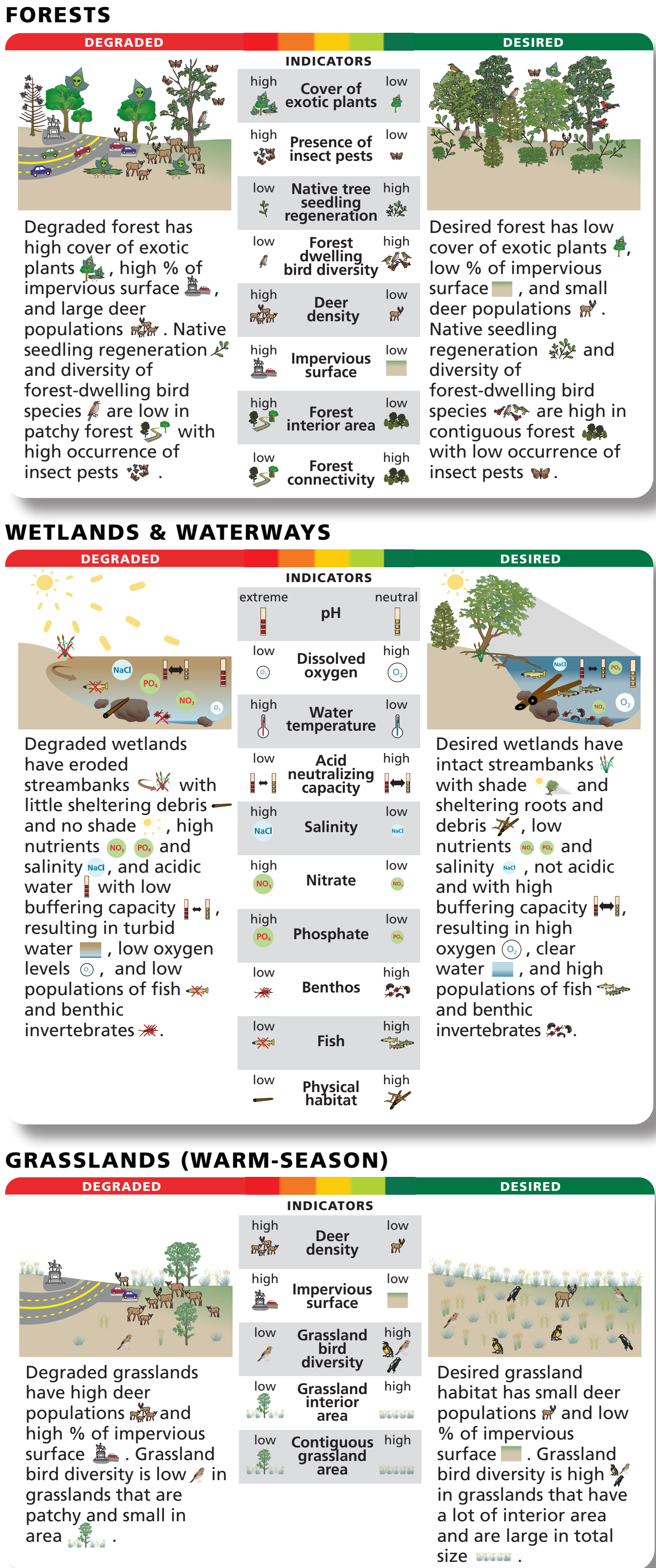
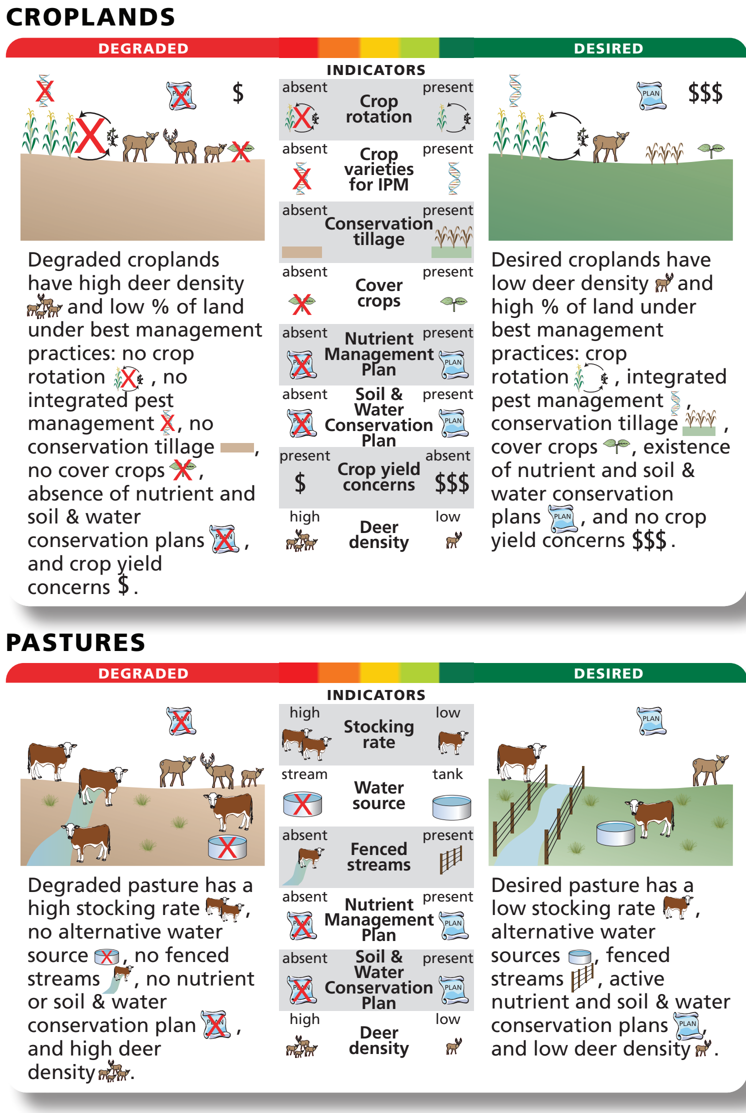


Figure 3.3. Conceptual framework for desired and degraded condition of habitats managed for natural resource values present within Antietam National Battlefield, indicating metrics to track status of condition.

Figure 3.4. Conceptual framework for desired and degraded condition of habitats managed for agricultural values present within Antietam National Battlefield, indicating metrics to track status of condition.



etc.), macrofungi, regular small mammal monitoring, grasses, groundwater levels, insects, toxics/drugs/hormones in water, plankton, and other components.

3.3.3 Priority study resources and indicators

Two frameworks were employed in this assessment: the ecological monitoring framework (based on Inventory & Monitoring Vital Signs) and the habitat framework (Figure 3.5). Measures of priority study resources and indicators are presented within these frameworks. More information on the ecological monitoring and habitat frameworks is presented in Section *3.5.1—Ecological monitoring framework* and Section *3.5.2—Habitat framework*.

3.4 FORMS OF REFERENCE CONDITIONS/REFERENCE VALUES USED IN THE STUDY

3.4.1 Air & Climate

Ozone—regulatory

Ground-level ozone is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for ozone (U.S. EPA 2004). In 1997, a human health ozone threshold was set by the National Ambient Air Quality Standards (NAAQS) at 0.08 ppm (U.S. EPA 2006), but has recently been revised and lowered to 0.075 ppm (NAAQS 2008), where the threshold concentration is the three-year average of the fourth-highest daily maximum eight-hour average ozone concentration measured at each monitoring station. In humans, and potentially other mammals, ozone can cause a number of health-related issues such as lung inflammation and reduced lung function, which can result in hospitalization. Concentrations of 0.12 ppm can be harmful with only short exposure during heavy exertion such as jogging, while similar symptoms can occur from prolonged exposure to concentrations of 0.08 ppm ozone (McKee et al. 1996). One study on 28 plant species, where plants were exposed for between three and six weeks, showed foliar impacts including premature defoliation in all species at ozone concentrations between 0.06 and 0.09 ppm (Kline et al. 2008).

To assess individual park condition, the NPS Air Resources Division has adopted a protocol of comparing the five-year mean (of the annual fourth-highest eight-hour rolling ozone concentration) against the established threshold (of 0.075 ppm; NPS 2009). A condition rating of Moderate ozone condition is defined as 0.061–0.075 ppm, and 80% of that threshold (≤0.06 ppm) is the upper limit for a condition rating of Good (NPS 2009). If the five-year mean is great than 0.076 ppm, ozone concentrations are considered to be of significant concern. Therefore, the 80% value (0.06 ppm) was used as the threshold in this assessment. The data assessed are presented in the NPS Air Quality Estimates 2003–2007 (NPS 2010). The result for the park was compared to the threshold. The park was given a rating of either 100% or 0% attainment .

Wet nitrogen and sulfur deposition—ecological

Deposition thresholds were based on maintaining ecosystem structure and function. Annual wet deposition (kg ha^{-1} y^{-1}) was used. Natural background deposition of nitrogen and sulfur in the eastern United States is approximately 0.5 kg ha^{-1} y^{-1} (0.4 lb $acre^{-1}$ y^{-1}; NPS 2005, 2009). Wet deposition makes up roughly half of this amount (~0.25 kg ha^{-1} y^{-1} [0.2 lb $acre^{-1}$ y^{-1}]; NPS 2009). Sensitive aquatic ecosystems as well as some organisms, such as lichens and freshwater diatom communities, can show deleterious effects of total nitrogen deposition at rates as low as 3.0–8.0 kg ha^{-1} y^{-1} (2.7–7.1 lb $acre^{-1}$ y^{-1}; wet deposition of 1.5–4.0 kg ha^{-1} y^{-1}[1.3–3.6 lb $acre^{-1}$ y^{-1}]; Fenn et al, 2003; Krupa 2002). The NPS Air Resources Division defines parks with less than 1 kg ha^{-1} y^{-1} (0.89 lb $acre^{-1}$ y^{-1}) wet deposition of N and S to be in good condition (NPS 2009), which was the threshold used in this assessment. The data assessed are presented in the NPS Air Quality Estimates 2003–2007 (NPS 2010). The result for the park was compared to the threshold. The park was given a rating of either 100% or 0% attainment .

Visibility condition—management

Regional haze regulations were developed by the U.S. EPA in 1999 to protect visual air quality in some 156 national parks and wilderness areas (U.S. EPA 2003). The metric for visibility is expressed in terms of a Haze Index, in deciview units (dv). This index is a measure of visibility calculated from light extinction, measured in inverse megameters (Mm^{-1}), with high values of the index being associated with poor visibility (U.S. EPA 2003). Natural visibility was estimated using the IMPROVE model (U.S. EPA 2003), based upon a series of regional characteristics, and this baseline subtracted from currently observed visibility values, using the mean value from all measurements in the 40–60th percentiles (group 50) (NPS 2009). The NPS Air Resources Division threshold of 2 dv, above which parks are considered to have a moderate or significant concern for visibility, was used in the current assessment (NPS 2009). The data assessed are presented in the NPS Air Quality Estimates 2003–2007 (NPS 2010). The result for the park was compared to the threshold. The park was given a rating of either 100% or 0% attainment .

Mercury deposition—regulatory

The threshold value of 2 ng Hg L^{-1} (2 ppt; annual mean) in rain, used in this assessment, is an indirect modeled estimate of rainfall concentrations that result in tissue concentrations within inland fish species of 0.5 mg methylmercury kg^{-1} (0.5 ppm) wet weight (Meili et al. 2003, Hammerschmidt and Fitzgerald 2006). The authors do concede that this value is for

Figure 3.5. Summary of the two frameworks used in this assessment, including metrics.

Ecological monitoring framework

Air & Climate
- Ozone (ppm)
- Wet nitrogen deposition (kg N ha^{-1} yr^{-1})
- Wet sulfate deposition (kg S ha^{-1} yr^{-1})
- Visibility condition (dv)
- Mercury deposition (ng Hg L^{-1})

Water Resources
- pH
- Dissolved oxygen (mg DO L^{-1})
- Water temperature (°C)
- Acid neutralizing capacity (µeq L^{-1})
- Salinity
- Nitrate (mg NO_3 L^{-1})
- Phosphate (mg PO_4 L^{-1})
- Benthic index of biological integrity
- Physical habitat index

Biological Integrity
- Exotic herbaceous species (% cover)
- Exotic tree/shrub density (% cover)
- Presence of forest pests (trees infested)
- Native seedling regeneration (seedlings ha^{-1})
- Fish index of biotic integrity
- Presence of forest interior dwelling bird species
- Grassland bird diversity
- Deer density (deer km^{-2})

Landscape Dynamics
- Impervious surface (% cover)
- Forest interior area
- Forest connectivity (m)
- Grassland interior area
- Contiguous grassland area

Habitat framework

—Habitats managed for natural resource values—

Forests
- Exotic herbaceous species (% cover)
- Exotic tree/shrub density (% cover)
- Presence of forest pest species (trees infested)
- Native seedling regeneration (seedlings ha^{-1})
- Presence of forest interior dwelling bird species
- Deer density (deer km^{-2})
- Impervious surface (% cover)
- Forest interior area
- Forest connectivity (m)

Wetlands & waterways
- pH
- Dissolved oxygen (mg DO L^{-1})
- Water temperature (°C)
- Acid neutralizing capacity (µeq L^{-1})
- Salinity
- Nitrate (mg NO_3 L^{-1})
- Phosphate (mg PO_4 L^{-1})
- Benthic index of biological integrity
- Fish index of biological integrity
- Physical habitat index

Warm-season grasslands
- Deer density (deer km^{-2})
- Impervious surface (% cover)
- Grassland bird diversity
- Grassland interior area (ha)
- Contiguous grassland area (ha)

—Habitats managed for agricultural values—

Croplands
- Crop rotation (yes/no)
- Crop varieties for IPM (yes/no)
- Conservation tillage (yes/no)
- Cover crops (yes/no)
- Nutrient Management Plan (yes/no)
- Soil & Water Conservation Plan (yes/no)
- Crop yield concerns (yes/no)
- Deer density (deer km^{-2})

Pastures
- Acceptable stocking rate (yes/no)
- Alternative water source (yes/no)
- Fenced streams (yes/no)
- Nutrient Management Plan (yes/no)
- Soil & Water Conservation Plan (yes/no)
- Deer density (deer km^{-2})

low organic soils, as highly humic soils are known to potentially store large amounts of mercury which can slowly leach into inland waters, in some cases contributing much more to mercury concentrations than current atmospheric deposition (Meili et al. 2003). Currently, the U.S. EPA also has a lower recommended fish tissue regulatory maximum threshold of 0.3 mg methylmercury kg^{-1} (0.3 ppm) wet weight, which would result in reducing the modeled atmospheric deposition threshold (U.S. EPA 2001). Human and mammalian regulatory thresholds are based on the effects of exposure. In vitro exposure can cause mental retardation, cerebral palsy, deafness, blindness, and dysarthria (speech disorder), and adult exposure can cause motor dysfunction and other neurological and mental impacts (U.S. EPA 2001). Avian species are particularly susceptible as mercury reduces reproductive potential (Wolfe et al. 1998). Measured atmospheric wet and dry mercury deposition trends from west to east across North America can also be measured in the common loon (*Gavia immer*) and throughout North America in mosquitoes (Evers et al. 1998, Hammerschmidt and Fitzgerald 2002). Mercury is also recognized to have a toxic effect on soil microflora, although no ecological depositional threshold is currently available (Meili et al. 2003). Mercury deposition data from 2004–2008 from the two sites closest to the park were obtained from the Maryland Deposition Network website (*http://nadp.sws.uiuc.edu/mdn*). The annual mean was calculated and compared to the threshold.

3.4.2 Water Resources

pH, dissolved oxygen, temperature—regulatory and ecological

The State of Maryland has classified its waterbodies on the basis of their designated uses. Minimum water quality critera have been established that will maintain these designated uses. Antietam Creek is designated as a Use IV-P waterbody (Recreational Trout Waters and Public Water Supply; COMAR 2007a, c). The thresholds for dissolved oxygen concentration, pH, and water temperature for this assessment were determined from these water quality criteria.

The acceptable range for pH is between 6.5 and 8.5 pH units (COMAR 2007b). The dissolved oxygen concentration is regulated to be equal to or greater than 5 mg DO L^{-1} (5 ppm) at all times, which is also a widely accepted ecological threshold to maintain aquatic life (COMAR 2007b). Water temperature is regulated to be less than 23.9°C (75.0°F; COMAR 2007b). All three measurements are taken monthly as instantaneous records. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Acid neutralizing capacity—ecological

The acid neutralizing capacity (ANC) threshold was developed by the Maryland Biological Stream Survey (MBSS) program after their first round of sampling (1995–1997). The MBSS data were used to detect stream degradation so as to identify streams in need of restoration and to identify ‘impaired waters’ candidates (Southerland et al. 2007). A total of 539 streams that received a fish or benthic index of biotic integrity (FIBI or BIBI) rating of poor (2) or very poor (1) were pooled and field observations and site-specific water chemistry data were used to determine stressors likely causing degradation. The resulting ANC threshold linked to degraded streams was values less than 200 μeq L^{-1}, which was used as the threshold in this assessment (Southerland et al. 2007, Norris and Sanders 2009; where 1 mg L^{-1} [1 ppm] $CaCO_3$ = 20 μeq L^{-1}). A less conservative threshold of 50 μeq L^{-1} has also been suggested by some authors (Hendricks and Little 2003, Schindler 1988). ANC is reported monthly as an instantaneous measure. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Salinity—regulatory

Salinity in drinking water is regulated by U.S. EPA under the National Secondary Drinking Water Standards (NSDWS) regulations. These regulations control contaminants in drinking water and are non-enforceable. The Secondary Maximum Contaminant Level (advisory only) for salinity is 250 mg L^{-1} (250 ppm; NSDWS 1997), which is equivalent to a salinity of 0.25. Therefore, the salinity threshold for this assessment was <0.25. Measurements were instantaneous and taken monthly. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Salinity was monitored by I&M at one site in Antietam, and at seven sites by Antietam National Battlefield staff. The data was taken as conductivity (ms cm^{-1}). This was converted to general salinity units using the methods of UNESCO (1983).

Nitrate—ecological

The nitrate concentration threshold was developed by the MBSS program after their first round of sampling as described for the ANC threshold. The MBSS determined that a nitrate concentration of 2 mg NO_3 L^{-1} (2 ppm) indicated stream degradation (Southerland et al. 2007, Norris and Sanders 2009). Instantaneous measurements were taken monthly. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "not detected," it was assigned a pass result because the detection limit for nitrate is lower than the assessment threshold (M. Norris, pers. comm.).

Phosphate—ecological

The phosphate threshold is based on the U.S. EPA Ecoregional Nutrient Criteria for total phosphorus. These criteria were developed to prevent eutrophication nationwide and are not regulatory (U.S. EPA 2000). The criteria are developed as baselines for specific geographic regions. Antietam National Battlefield is located in Ecoregion XI or the Central and Eastern Forested Uplands region (U.S. EPA 2000). The ecoregional reference condition value for total phosphorus is 0.010 mg P L^{-1} (10 ppb), which equates to a phosphate threshold of 0.031 mg PO_4 L^{-1} (31 ppb; U.S. EPA 2000). Measurements were taken monthly as instantaneous measurements. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "not detected," it was assigned a pass result because the detection limit for phosphate is lower than the assessment threshold (M. Norris, pers. comm.).

Benthic IBI—ecological

The aquatic macroinvertebrates threshold is based on the MBSS interpretation of the benthic index of biotic integrity (IBI). The IBI scores range from 1 to 5 and are calculated by comparing the site's benthic assemblage to the assemblage found at minimally impacted sites (Norris and Sanders 2009). An IBI score of 3 indicates that a site is considered to be comparable to (i.e., not significantly different from) reference sites. A score greater than 3 indicates that a site is in better condition than the reference sites. Any sites with IBIs less than 3 are in worse condition than reference sites (Southerland et al. 2007, Norris and Sanders 2009), and the entire scale is 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good; Southerland et al. 2007). Therefore, the threshold used in this assessment for aquatic macroinvertebrates was >3, which indicates that a site is in fair or good condition (Southerland et al. 2007). Reported data are for one IBI assessment per site. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Physical habitat index—ecological

For the physical habitat index (PHI), instream and near-stream habitat measures of first- through third-order streams were recorded between June and September at the same time as the fish were being sampled (Norris and Sanders 2009). This sampling period was chosen because the low flow conditions are typically limiting to the abundance of lotic (living in moving water) fish. Habitat assessments are determined based on data from numerous metrics such as stream width, riparian zone vegetation type and width, surrounding land use, extent of stream channelization, degree of stream erosion, and many more. Sites are given scores for each of the applicable categories and then those scores are adjusted to a percentile scale (Norris and Sanders 2009). The PHI threshold was developed by the MBSS program after initial sampling as described for the ANC threshold. The MBSS determined the scale for PHI values to be 0–50 (severely degraded), 51–65 (partially degraded), 66–80 (degraded), and 81–100 (minimally degraded), so the threshold used in this assessment was >81, indicating minimally degraded condition (Paul et al. 2002, Southerland et al. 2005). Data reported represent one sample per site. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

3.4.3 Biological Integrity

Percent cover of herbaceous species, woody vines, and target exotic trees and shrubs—management

Invasive exotic plants may compete with native plants and therefore lead to a reduction in biodiversity of the native flora (Mack et al. 2000). The threshold used for this assessment was that the abundance of these invasive exotic plants should not exceed 5% cover, measured as area of ground covered by herbs and vines, and percent of total basal area for shrubs and trees. Because 100% eradication is not a realistic goal, the threshold is intended to suggest more than just simple presence of these exotic species but that the observed abundance has the potential to establish and spread, i.e., 5% cover may be considered as the point where the exotic plants are becoming established rather than just present. The Organic Act that established the National Park Service in 1916, the U.S. Department of Interior NPS Management Policies (U.S. Dept of Interior 2006), and Antietam National Battlefield's General Management Plan all mandate the conservation of both natural and cultural resources (see Section *2.2.1—Park enabling legislation*). This threshold is a guide to commence active management of an area by removal of these species. Reported data was from permanent plots monitored annually and reported as the percent of plots that attained the threshold. The cover of exotic herbaceous species in a plot was calculated from the percent cover of the single exotic species with the greatest cover. The cover of exotic trees and shrubs in a plot was calculated as the percentage of total tree or shrub basal area. Tree saplings and seedlings were not included in this calculation. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Presence of pest species—management, ecological

The gypsy moth (*Lymantria dispar*) was accidentally introduced to North America in the late 1860s and has spread widely, resulting in an estimated 160,000 km^2 (62,500 mi^2) of forest defoliation during the 1980s alone (Liebhold et al. 1994, Montgomery 1990). The gypsy moth larvae feed on the foliage of hundreds of species of plants in North America, but its most common hosts are oak and aspen (*Populus* spp.) trees (USDA Forest Service 2009a). Hemlock woolly adelgid (*Adelges tsugae*) is another insect pest first reported in the eastern United States in 1951 near Richmond, Virginia (USDA Forest Service 2009b). This aphid-like insect is originally from Asia and feeds on Eastern hemlock trees (*Tsuga canadensis*), which are often damaged and killed within a few years of becoming infested. Due to the destructive nature and potential for forest damage from these pests, the threshold used was established as any observation of these pests (i.e., >1% of trees infested) being considered degraded. Reported data was from permanent plots monitored annually and reported as the percent of plots that attained the threshold. The percentage of trees infested was calculated by dividing the number of trees afflicted by pests in each plot by the total number of trees in each plot. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. Data reported for each plot were for hemlock woolly adelgid, gypsy moth, and "other insect damage."

Native tree seedling regeneration—ecological

The native tree seedling regeneration threshold used in this assessment of 35,000 seedlings ha^{-1} (14,000 seedlings $acre^{-1}$) is based upon seedling numbers in a mature, non-industrial private forestland in south-central Virginia (Carter and Fredericksen 2007). However, some estimates of required desirable native species regeneration to maintain a sustainable forest under different deer grazing scenarios are much higher—15 million tree seedlings per hectare (6,100,000 seedlings $acre^{-1}$; all desirable species) under very low, and as many as 21 million tree seedlings per hectare (8,500,000 seedlings $acre^{-1}$; all desirable species) under very high deer grazing pressure (Marquis et al. 1992). Reported data was from permanent plots monitored annually and reported as the percent of plots that attained the threshold. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Fish Index of Biotic Integrity—ecological

A threshold value of 3 was used as an ecological threshold indicating attainment of overall reference ecosystem condition. The fish index of biotic integrity (IBI) was proposed as a way of providing an informative measure of anthropogenic influence on fish communities and ecological integrity than measurements of physiochemical metrics alone (Karr 1981). The metric was then adapted and validated for streams of Maryland using a reference condition approach, based on 1994–1997 data from a total of 1,098 sites. Sites were classified based on physical and chemical data and compared to a range of stream fish-related metrics: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), and 4.0–5.0 (good), finding that 29% of stream sites sampled in Maryland were in poor or very poor condition (Southerland et al. 2007). The threshold used for this assessment was a fish IBI >3, indicating that a site is considered to be in fair or good condition (Southerland et al. 2007). Data used represent one sample per site. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Presence of forest interior dwelling species of birds—ecological

Presence of bird species can effectively provide a bio-indicator of subtle or unexpected changes in environmental condition (Koskimies 1989). Throughout Maryland, there was a documented 63% decline in individual birds of neotropical origin (including forest interior dwelling species [FIDS]) between 1980 and 1989 (Jones et al. 2000). This represented a continuation of documented declines at some sites between 1940 and 1980 (Terborgh 1992). The presence of FIDS is used as an indicator of high-quality forest interior habitat. Maryland Department of Natural Resources lists 39 FIDS that currently or historically nested in Maryland (MD DNR undated). Fifteen of those 39 species are either obligate riparian breeding species that are strongly associated with riparian forests during the breeding season, or for which riparian forests represent optimal breeding habitats for these species. For the purposes of this assessment, those 15 species were classified as 'highly area-sensitive' FIDS. Presence of at least four FIDS or at least one highly area-sensitive FIDS was assessed as high-quality forest interior habitat (Jones et al. 2000). Using this information, the ecological threshold was based on the presence of appropriate habitat for FIDS and defined as observation of at least four FIDS or at least one highly area-sensitive FIDS. In both cases, these birds ideally would have been observed in probable or confirmed breeding status (Jones et al. 2000); however, breeding status was not recorded for the available data within the park, which was collected at six sites for two years (Goodwin and Shriver 2009). These data were compared against the list of FIDS (MD DNR undated) and the number of FIDS was compared to the threshold. The park was given a rating of either 100% or 0% attainment.

Grassland bird diversity—ecological

Percent attainment for grassland birds is derived directly from the percentage of all four functional groups present. The four functional groups are defined as: disturbance-tolerant, preference for young grasslands, preference for mature grasslands, and "other" (rarely encountered in the Mid-Atlantic; Peterjohn 2006). The percent attainment is equivalent to the percentage of these four functional groups that were present in the park, based on the species observations from the 2007 and 2008 avian monitoring in the National Capital Region parks (Goodwin and Shriver 2009). Thus, the park was given a rating of 0%, 25%, 50%, 75%, or 100% attainment.

White-tailed deer density: forest—management, ecological; grassland—management

The forest threshold for white-tailed deer density (8.0 deer km^{-2} [21 deer mi^{-2}]) is a well-established ecological threshold (Horsley et al. 2003), and this threshold is also used as the management threshold (Horsley et al. 2003). Species richness and abundance of herbs and shrubs are consistently reduced as deer densities approach 8.0 km^{-2} (21 deer mi^{-2}), although shown in some studies to change at densities as low as 3.7 deer km^{-2} (9.6 deer mi^{-2}; Decalesta 1997). One large manipulation study in central Massachusetts found deer densities of 10–17 km^{-2} (26–44 deer mi^{-2}) inhibited the regeneration of understory species, while densities of 3–6 deer km^{-2} (8–16 deer mi^{-2}) supported a diverse and abundant forest understory (Healy 1997). There are multiple sensitive species of songbirds that cannot be found in areas where deer grazing has removed the understory vegetation needed for nesting, foraging and protection. Even though songbird species vary in how sensitive they are to increases in deer populations, these changes generally occur at deer densities greater than 8 deer km^{-2} (21 deer mi^{-2}; Decalesta 1997). In contrast, the grassland (or agricultural land) management threshold for deer abundance is less well-studied or justified and is used as a guiding management threshold, but is currently 20 deer km^{-2} (52 deer mi^{-2}). However, studies of national parks within the National Capital Region (Antietam and Monocacy National Battlefields and Cheseapeake and Ohio Canal National Historical Park) have shown that the current abundances of 45–54 deer km^{-2} (117–140 deer mi^{-2}) cause significant damage to the agricultural crops maintained as grassland habitat (Stewart et al. 2007). Data used represents biannual assessments at a park scale. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

3.4.4 Landscape Dynamics

Impervious surface—ecological

Many ecosystem components such as wetlands, floral and faunal communities, and streambank structure show signs of impact above 10% impervious surface, which is used as the threshold in this assessment (Arnold and Gibbons, 1996). Recent studies on stream macro-invertebrates continue to show shifts to more tolerant species and reductions in biodiversity at around this same threshold (Lussier et al. 2008). A study of nine metropolitan areas in the United States demonstrated measurable effects of impervious surface on stream invertebrate assemblages at impervious surface cover below 5% (Cuffney et al. 2010). Percent urban land is correlated to impervious surface and can provide a good approximation of watershed degradation due to increases of impervious surface. An impervious surface threshold of 10% was used in this assessment and data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.5). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Forest interior area

Interior forest area is essential for the breeding success of many birds. There are 31 species of birds that breed in the Ridge and Valley physiographic province of Maryland that require large blocks of mature interior forest (MD DNR undated). Interior forest was defined as mature forested land cover ≥100 m (330 ft) from non-forest land cover or from primary, secondary, or county roads (i.e., roads considered large enough to break the canopy; Temple 1986). The threshold attainment was expressed as the number of acres of interior forest in the park as a percentage of the total potential acres of interior forest within the park (if the total forest area was one large circular patch). The data used were a one-off, park-wide assessment.

Forest connectivity index—ecological

The connectivity of forest resources is an important control on species biodiversity (Franklin 1993). The critical dispersal threshold (Dcrit) is a measure of the distance at which 75% of forest patches are connected, therefore allowing landscape-level dispersal (Townsend et al. 2009). From 13 tree species, an effective dispersal distance of 65 ± 15 m (210 ± 50 ft; mean ± standard error) has been calculated, indicating on average a 95% probability of effective dispersal over that distance. The maximum dispersal distance for these same species was 997 ± 442 m (3,271 ± 1,450 ft), indicating almost zero probability (<0.1%) of a seed dispersing that distance (He and Mladenoff 1999). Other studies have shown similar dispersal ranges for small mammals (Bowman et al. 2002). For this assessment, Dcrit was calculated and compared to a threshold of <360 m (1,180 ft) based on the distance that many small mammals and tree seeds can disperse (He and Mladenoff 1999, Bowman et al. 2002).

Data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.6). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Grassland interior area

Studies have shown that grassland bird nests located in grassland interior areas are more successful than those located near ecotone edges (Burger et al. 1994). Interior grassland was defined as grassland ≥60 m (200 ft) from other land uses (Burger et al. 1994). The threshold attainment was expressed as the number of acres of interior grassland in the park as a percentage of the total potential acres of interior grassland within the park (if the total grassland area was one large circular patch). The data used were a one-off, park-wide assessment.

Contiguous grassland area

Peterjohn (2006) developed criteria to define area needed to support grassland bird communities. Contiguous grassland areas <5 ha (<12 acres) in size are generally avoided by grassland birds. Areas 5–10 ha (12–25 acres) are occupied by some species, areas 10–20 ha (25–50 acres) are consistently occupied by some species, and areas 40–100 ha (100–250 acres) can support entire grassland bird communities. Categories are as follows: 0–5 ha (very poor), 5–10 ha (poor), 10–20 ha (moderate), 20–40 ha (good), >40 ha (very good). This metric is based on the largest single contiguous patch of grassland within the park. The threshold used in this assessment was ≥10 ha, representing moderate to very good potential habitat. Data was a one-off, park-wide assessment. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

3.4.5 Agriculture

All metrics for cropland and pasture habitats were taken from Best Management Practices, defined by the U.S. Department of Agriculture's Natural Resources Conservation Service (2007) to be practices that ensure that no significant amount of pollution conveyed by runoff leaves the farm of enters a water body or groundwater (Table 3.5). Each metric was given a 100% or 0% attainment rating, based on whether or not it was in place/being implemented.

3.5 STUDY METHODS

3.5.1 Ecological monitoring framework

An ecological monitoring framework has been established by the National Park

Service (NPS) Inventory and Monitoring program (I&M; Fancy et al. 2008), based on multiple efforts, such as the U.S. EPA scientific advisory board assessment on reporting ecological condition (U.S. EPA 2002). The NPS ecological monitoring framework has six high-level data categories: Air & Climate; Geology & Soils; Water Resources; Biological Integrity; Human Use; and Landscape Dynamics (Fancy et al. 2008). In the assessment of natural resource condition of Antietam National Battlefield, data were available for four of these six data categories: Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics.

Data used

A total of 29 metrics across the four ecological monitoring framework categories were included from multiple data sources (Table 3.6), each with an established ecological, management, or regulatory threshold and based on a categorical scoring of threshold attainment (Table 3.7). While some metrics were measured at the park scale and therefore only have one value for the entire park (e.g., deer density and Landscape Dynamics metrics), there were up to eight sampling sites for Water Resources metrics within Antietam National Battlefield. Temporal intensity of measurement also varied between metrics, with only single assessments of Landscape Dynamics metrics, while Water Resources metrics were measured monthly during the available data range (Table 3.7). All data used in the assessment was collected between 2000 and 2008 (Table 3.7). Data used in the assessment was obtained from multiple sources, with the Air & Climate data coming from national air monitoring programs and the NPS Air Resources Division, Water Resources and Biological Integrity data from the NCRN I&M monitoring program and Antietam National Battlefield monitoring, and Landscape Dynamics data from a collaborative project between NCRN I&M and the University of Maryland Center for Environmental Science (Table 3.6).

Air & Climate results for ozone, wet nitrate and sulfur deposition, and visibility (2003–2007) were taken from interpolated results from an NPS (2009) report, while mercury deposition data (2004–2008) came from two nearby monitoring sites (Figure 3.6). A total of eight sites were monitored for water quality (pH, dissolved oxygen, temperature, salinity, nitrate, phosphate [all 2000–2008], and ANC [2005–2008]) in Antietam National Battlefield—one site monitored by NCRN I&M and seven sites monitored by park staff (Figure 3.7). Four sites were monitored during 2004–2006 by NCRN I&M for the Benthic Index of Biotic Integrity, Physical Habitat Index (both Water Resources metrics), and the Fish Index of Biotic Integrity (a Biological Integrity metric; Figure 3.8).

Forest data (exotic species cover and density, native tree seedling regeneration [both 2006–2007], and presence of pest species [2005–2007]) were collected at four sites, and a route for counting deer density was travelled each year from 2001–2008 (Figure 3.9). Data for the remaining two Biological Integrity metrics—presence of forest interior dwelling species of birds and grassland bird diversity—were obtained from an initial assessment in 2007–2008, currently presented in draft format (Goodwin and Shriver 2009).

Two Landscape Dynamics metrics (impervious surface [2000] and forest connectivity [2001]) were calculated at two scales: 1) within the park boundary, and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary. The purpose of this analysis was to assess land use immediately surrounding the park. The remaining Landscape Dynamics metrics (forest interior area, grassland interior area, contiguous grassland area, and cover of warm-season grassland) were calculated from land use data from 2008.

Due to the number of sampling sites (or spatial scale of measurement) and sampling frequency (monthly to annual), the amount of information used to characterize park resources (data density) varied from one (e.g., assessment of deer population in the park) to 780 measurements (nitrate) during the nine-year period (Table 3.7; Appendix A). These data were compared to thresh-

Table 3.5. Thresholds for Cropland and Pasture metrics.

Metric	Threshold	Justification	Threshold source
Crop rotation	In place (yes/no)	Crop rotation is an accepted Best Management Practice (BMP) for agriculture, to reduce erosion, maintain or improve soil organic matter, manage plant nutrient balance, and manage plant pests.	USDA 2007
Conservation tillage	In place (yes/no)	Conservation tillage is an accepted BMP for agriculture, to reduce erosion, reduce soil particulate emissions, improve soil organic matter, increase plant-available moisture, and reduce CO2 losses from the soil.	USDA 2007
Cover crops	In place (yes/no)	Cover crops are an accepted BMP for agriculture, to reduce erosion, capture and recycle excess nutrients in the soil, promote biological nitrogen fixation, reduce soil particulate emissions, improve soil organic matter, minimize soil compaction, increase biodiversity, suppress weeds, and manage soil moisture.	USDA 2007
Nutrient Management Plan	In place (yes/no)	A nutrient management plan (NMP) is a comprehensive plan that describes the optimum use of nutrients to minimize nutrient loss while maintaining yield. A NMP details the type, rate, timing, and placement of nutrients for each crop. Soil, plant tissue, manure and/or sludge tests are used to assure optimal application rates.	Chesapeake Bay Program undated
Soil & Water Conservation Plan	In place (yes/no)	Farm conservation plans are a combination of agronomic, management, and engineered practices that protect and improve soil productivity and water quality, and to prevent deterioration of natural resources on all or part of a farm. Plans may be prepared by staff working in conservation districts, natural resource conservation field offices or a certified private consultant. In all cases the plan must meet technical standards.	Chesapeake Bay Program undated
Crop yield concerns	Yes/no	Crop yield concerns indicate that a crop is not performing to its expected yield. In the context of this assessment, crop yield concerns are most often related to the overabundance of deer grazing.	
Stocking rate	1 animal/2 acres	A general guideline for the Mid-Atlantic region is one animal per acre. This has been conservatively modified by Antietam to be one animal per two acres of pasture.	Maryland Cooperative Extension undated
Alternative water sources	Yes/no	Providing alternative water sources for stock is an accepted BMP for pasturelands, to prevent access by stock to environmentally sensitive areas such as streams and other water sources	USDA 2007
Fenced streams	Yes/no	Fencing streams is an accepted BMP for pasturelands, to prevent access by stock to environmentally sensitive areas such as streams and other water sources	USDA 2007
Deer density (grassland)	< 20 deer km^{-2}	The forest threshold for deer abundance is based on a 10-yr manipulative experiment. The grassland threshold is a guideline currently used for management of these areas.	Horsley et al. 2003

Table 3.6. Sources of data used in Antietam National Battlefield resource condition assessment.

Metric	Agency	Reference/source
	Air & Climate	
Ozone	NPS	NPS 2009
Wet nitrogen deposition	NPS	NPS 2009
Wet sulfur deposition	NPS	NPS 2009
Visibility condition	NPS	NPS 2009
Hg deposition	MDN-NADP	*http://nadp.sws.uiuc.edu/mdn*
	Water Resources	
pH	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Dissolved oxygen	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Water temperature	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Acid neutralizing capacity	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Salinity	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Nitrate	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Phosphate	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010, ANTI
Benthic index biological integrity (BIBI)	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
Physical habitat index (PHI)	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
	Biological Integrity	
Cover of exotic herbaceous species	NCRN I&M	Schmit and Campbell 2007, 2008
Cover of exotic trees and shrubs	NCRN I&M	Schmit and Campbell 2007, 2008
Presence of forest pest species	NCRN I&M	Schmit and Campbell 2007, 2008
Native tree seedling regeneration	NCRN I&M	Schmit and Campbell 2007, 2008
Fish index biological integrity (FIBI)	NCRN I&M, MBSS	Norris and Sanders 2009
Presence of forest interior dwelling species (FIDS) of birds	NCRN I&M	Goodwin and Shriver 2009
Grassland bird diversity	NCRN I&M	Goodwin and Shriver 2009
Deer density	NCRN I&M	Bates 2007, ANTI
	Landscape Dynamics	
Impervious surface (within park)	UMCES, NCRN I&M	Townsend et al. 2006
Impervious surface (within park) + 5X buffer	UMCES, NCRN I&M	Townsend et al. 2006
Forest interior area	UMCES, NCRN I&M	NCRN I&M
Forest connectivity (Dcrit; within park)	UMCES, NCRN I&M	Townsend et al. 2006
Forest connectivity (within park) + 5X buffer	UMCES, NCRN I&M	Townsend et al. 2006
Grassland interior area	UMCES, NCRN I&M	NCRN I&M
Contiguous grassland area	UMCES, NCRN I&M	NCRN I&M

Table 3.7. Summary of data used in Antietam National Battlefield resource condition assessment.

Metric	Threshold	Sites	Samples	Period
Air & Climate				
Ozone	< 0.06 ppm	Park	1	2003–2007
Wet nitrogen (N) deposition	< 1 kg N ha^{-1} yr^{-1}	Park	1	2003–2007
Wet sulfur (S) deposition	< 1 kg S ha^{-1} yr^{-1}	Park	1	2003–2007
Visibility condition	< 2 dv	Park	1	2003–2007
Mercury (Hg) deposition	< 2 ng Hg L^{-1}	2	396	2004–2008
Water Resources				
pH	6.5 ≥ pH ≥ 8.5	8	767	2000–2008
Dissolved oxygen (DO)	≥ 5.0 mg DO L^{-1}	8	751	2000–2008
Water temperature	≤ 23.9°C	8	768	2000–2008
Acid neutralizing capacity	≥ 200 µeq L^{-1}	1	38	2005–2008
Salinity	< 0.25	8	424	2000–2008
Nitrate (NO_3)	< 2 mg NO_3 L^{-1}	8	780	2000–2008
Phosphate (PO_4)	< 0.031 mg PO_4 L^{-1}	8	765	2000–2008
Benthic index biological integrity (BIBI)	> 3	3	4	2004–2006
Physical habitat index (PHI)	> 81	3	4	2004–2006
Biological Integrity				
Cover of exotic herbaceous species	< 5% (of area)	4	4	2006–2007
Cover of exotic trees and shrubs	< 5% (of total basal area)	4	6	2006–2007
Presence of forest pest species	< 1% of trees infested	4	4	2005–2007
Native tree seedling regeneration	> 35,000 seedlings ha^{-1}	4	4	2006–2007
Fish index biological integrity (FIBI)	> 3	3	4	2004–2006
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	6	14	2007–2008
Grassland bird diversity	% functional groups found translates directly to % attainment	6	1	2007–2008
Deer density	< 8 deer km^{-2} (forest) < 20 deer km^{-2} (grassland)	Park	15	2001–2008
Landscape Dynamics				
Impervious surface (within park)	10%	Park	1	2000
Impervious surface (within park) + 5X buffer	10%	Park	1	2000
Forest interior area	% of total forest area translates to % attainment	Park	1	2008
Forest connectivity (Dcrit; within park)	< 360 m	Park	1	2001
Forest connectivity (within park) + 5X buffer	< 360 m	Park	1	2001
Grassland interior area	% of total grassland area translates to % attainment	Park	1	2008
Contiguous grassland area	≥ 10 ha	Park	1	2008

Figure 3.6. Map of sampling stations PA00/ARE128 and MD99/BEL116[29] used for measuring mercury concentrations near Antietam National Battlefield.

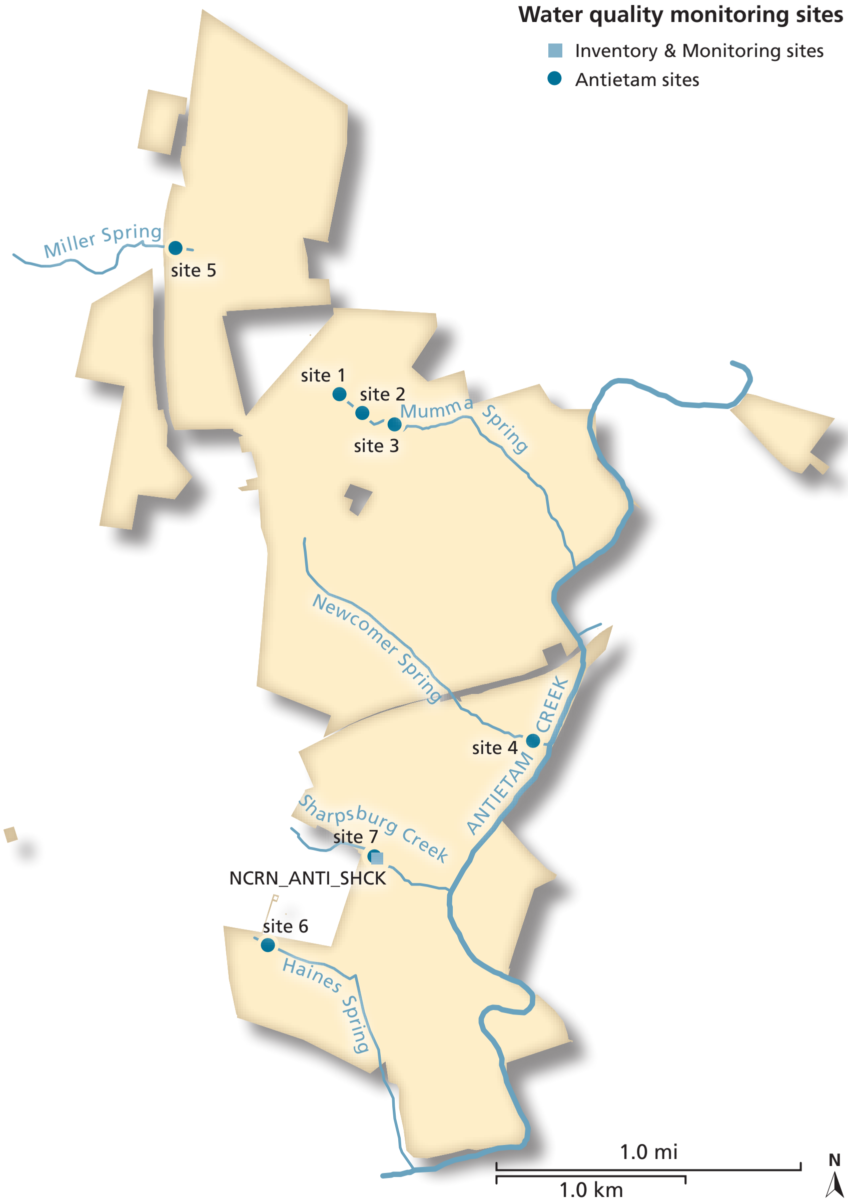
old values (Tables 3.1, 3.2, 3.3, 3.4), as a percentage of measurements attaining the threshold value for each metric, where a value of 100% indicated that all sites and times met the threshold to maintain natural resources, and a value of 0% indicated that no sites at any sampling time met the threshold value. For all four categories (Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics), an un-weighted mean was calculated for all metrics within that category to produce a category percentage attainment for all four categories of available data in Antietam National Battlefield. An assessment was made of the whole park by calculating an un-weighted mean of the four category percentage attainment values. For determination of status of metrics, vital sign categories, and the whole park assessment, percentage attainment scores were categorized on a scale from very good to very degraded (Table 3.8).

3.5.2 Habitat framework

The habitat list defined by the International Union for the Conservation of Nature (IUCN) was chosen as the basis from which park-specific habitats were determined (IUCN 2007). The IUCN habitat classification includes 16 habitat types at the highest level, which are further divided into sub-habitats (Table 3.9). A total of six general habitat types were identified for Antietam National Battlefield and these were further defined as

29. National Atmospheric Deposition Program: *http://nadp.sws.uiuc.edu;* Mercury Deposition Network: *http://nadp.sws.uiuc.edu/mdn*

Figure 3.7. Stream sampling locations[30] used for long-term water quality monitoring at Antietam National Battlefield.



being either managed for natural resource values (forests, wetlands and waterways, warm-season grasslands) or managed for agricultural values (croplands, pastures, and developed lands) (Figures 3.1, 3.3, 3.4).

A habitat map was created for the park by starting with the draft Inventory & Monitoring (I&M) vegetation map which is based on color infrared aerial photography captured in March and April of 2004. Next, a table was created to crosswalk the I&M vegetation map classes to the IUCN vegetation classes. This vegetation layer was then unioned with the National Wetlands Inventory in an effort to capture small wetland areas not represented on the vegetation map and a park-provided agricultural lease layer which contained the most current information on the usage of leased areas. This resulted in a new vector layer that could be symbolized to highlight polygons where these three layers were in disagreement. These disagreements were resolved through consultation with the park natural resource staff and site visits where required. Lastly, where the park natural resource staff had more current or detailed information for an area—for example, grassland maintenance regimes, or current restoration projects—this information was integrated into the final habitat map.

30. Norris et al. 2007, ANTI.

Figure 3.8. Stream sampling locations[31] monitored for BIBI, FIBI, and PHI.

To provide a basis for condition assessment for each habitat, the desired versus degraded extremes were conceptually described (Figures 3.3, 3.4) based on a series of 32 metrics which can be used to track the relative condition of the habitat between these two states. Metrics were assigned to these habitat types based on being of a relevant spatial scale, responsive to change, and with an established threshold, such that an explicit measurement of condition was calculated relative to the conceptual range of a desired through to degraded state.

Much of the data set was a subset of that used for the ecological monitoring framework, so the the threshold justifications are presented in Tables 3.1, 3.2, 3.3, 3.4, and 3.5 and the sources of all data are presented in Table 3.6. Justification for the inclusion of metrics as relevant to a particular habitat assessment is provided below.

Calculating habitat scores

For each individual metric, the percent attainment of the threshold value was calculated as described for ecological monitoring categories. The attainment of threshold condition for each of the habitat types present within Antietam National Battlefield was calculated as an un-weighted mean of the attainment scores for the

31. NCRN I&M, ANTI.

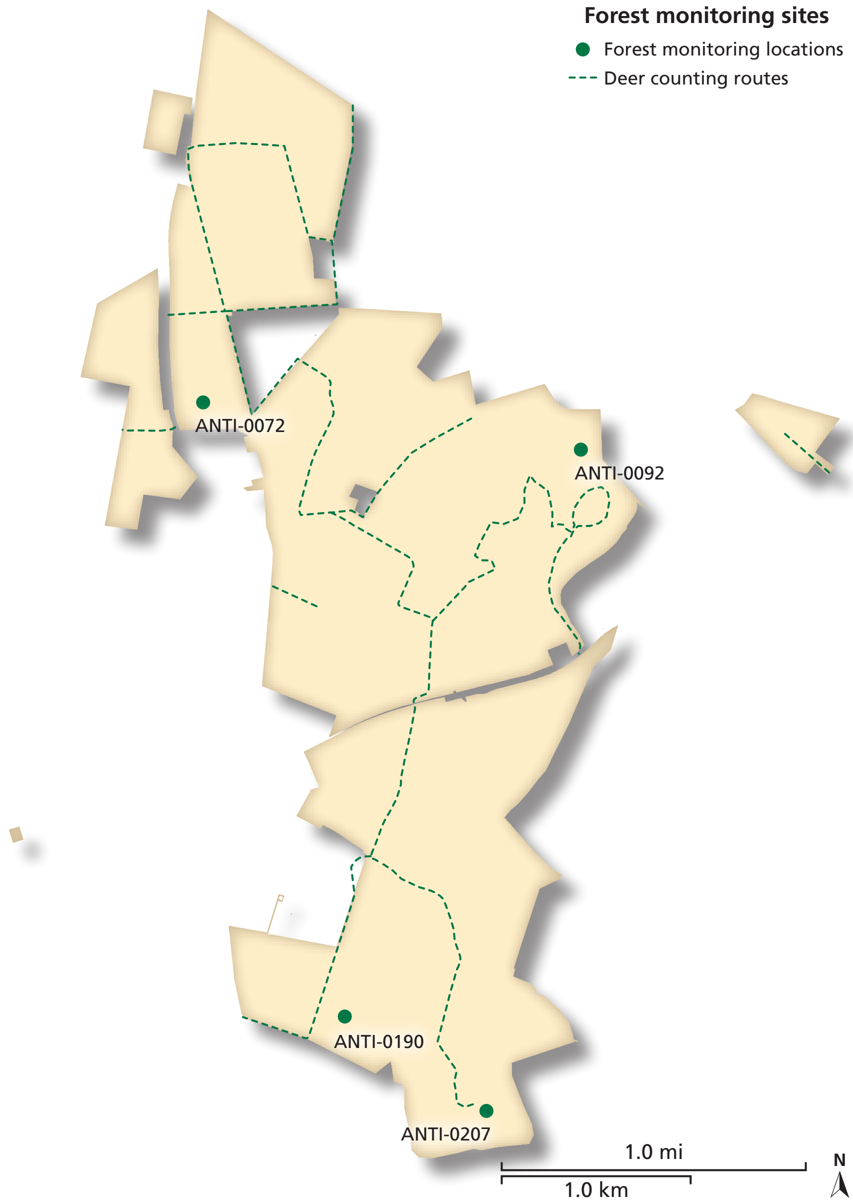


Figure 3.9. Forest monitoring sites and deer counting routes[32] in Antietam National Battlefield.

metrics used to assess the condition of that particular habitat (Tables 3.10, 3.11). Calculation of the park condition status was calculated as an area-weighted mean, based upon the relative area of each habitat type within the park (Table 3.12). For determination of status of metrics, habitats, and the whole park assessment, percentage attainment scores were categorized on a scale from very good to very degraded (Table 3.8).

Of the 773 ha (1,910 acres)[33] within the fee boundary of Antietam National Battlefield used in this assessment, 190 ha (470 acres) were designated as habitats that are managed for natural resource values (forests: 149 ha [368 acres]; wetlands and waterways: 18 ha [44 acres]; and warm-season grasslands: 23 ha [58 acres]; Table 3.12). 518 ha (1,280 acres) were designated as habitats that are managed for agricultural values (croplands: 387 ha [957 acres]; and pastures: 131 ha [323 acres], bringing the total area assessed to 708 ha (1,750 acres). The remaining 65 ha (160 acres) were classified as developed lands and were not assessed.

32. NCRN I&M, ANTI.
33. Note: this area differs from the official fee area of 1,937 acres due to irreconcilable mapping resolution issues.

Table 3.8. Categorical ranking of threshold attainment categories.

Measured attainment of thresholds	Natural resource condition
80–100%	Very good
60–<80%	Good
40–<60%	Fair
20–<40%	Degraded
0–<20%	Very degraded

Table 3.9. Summary of IUCN major habitat classifications.

	IUCN general habitat description	# sub-habitats
1	Forest	9
2	Savanna	2
3	Shrubland	8
4	Grassland	7
5	Wetland (inland)	18
6	Rocky areas (inland cliffs and mountain peaks)	0
7	Caves and non aquatic subterranean	2
8	Desert	3
9	Marine neritic (submerged nearshore, oceanic islands)	10
10	Marine oceanic	4
11	Marine deep benthic	6
12	Marine intertidal	7
13	Marine coastal/supratidal	5
14	Artificial terrestrial	6
15	Artificial aquatic	13
16	Other	

Table 3.10. Summary of data used in Antietam National Battlefield habitat-based condition assessment of habitats managed for natural resource values.

Metric	Threshold	Sites	Samples	Period
Forests				
Cover of exotic herbaceous species	< 5% (of area)	4	4	2006–2007
Cover of exotic trees and shrubs	< 5% (of total basal area)	4	6	2006–2007
Presence of forest pest species	< 1% of trees infested	4	4	2005–2007
Native tree seedling regeneration	> 35,000 seedlings ha^{-1}	4	4	2006–2007
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	6	14	2007–2008
Deer density (forest)	< 8 deer km^{-2} (forest)	Park	15	2001–2008
Impervious surface (within park)	10%	Park	1	2000
Forest interior area	% of total forest area translates to % attainment	Park	1	2008
Forest connectivity (Dcrit; within park)	< 360 m	Park	1	2001
Wetlands & waterways				
pH	6.5 ≥ pH ≥ 8.5	8	767	2000–2008
Dissolved oxygen (DO)	≥ 5.0 mg DO L^{-1}	8	751	2000–2008
Water temperature	≤ 23.9ºC	8	768	2000–2008
Acid neutralizing capacity	≥ 200 µeq L^{-1}	1	38	2005–2008
Salinity	< 0.25	8	424	2000–2008
Nitrate (NO_3)	< 2 mg NO_3 L^{-1}	8	780	2000–2008
Phosphate (PO_4)	< 0.031 mg PO_4 L^{-1}	8	765	2000–2008
Benthic index biological integrity (BIBI)	> 3	3	4	2004–2006
Fish index biological integrity (FIBI)	> 3	3	4	2004–2006
Physical habitat index (PHI)	> 81	3	4	2004–2006
Grasslands (warm-season)				
Deer density (grassland)	< 20 deer km^{-2} (grassland)	Park	15	2001–2008
Impervious surface (within park)	10%	Park	1	2000
Grassland bird diversity	% functional groups found translates directly to % attainment	6	1	2007–2008
Grassland interior area	% of total grassland area translates to % attainment	Park	1	2008
Contiguous grassland area	≥ 10 ha	Park	1	2008

Table 3.11. Summary of data used in Antietam National Battlefield habitat-based condition assessment of habitats managed for agricultural values.

Metric	Threshold	Sites	Samples	Period
Croplands				
Crop rotation	In place (yes/no)	Park	1	2010
Crop varieties for IPM	In place (yes/no)	Park	1	2010
Conservation tillage	In place (yes/no)	Park	1	2010
Cover crops	In place (yes/no)	Park	1	2010
Nutrient Management Plan	In place (yes/no)	Park	1	2010
Soil & Water Conservation Plan	In place (yes/no)	Park	1	2010
Crop yield concerns	Yes/no	Park	1	2010
Deer density (grassland)	< 20 deer km^{-2}	Park	8	2001–2008
Pastures				
Stocking rate	1 animal / 2 acres	Park	1	2010
Protected water sources	Yes/no	Park	1	2010
Fenced streams	Yes/no	Park	1	2010
Nutrient Management Plan	In place (yes/no)	Park	1	2010
Soil & Water Conservation Plan	In place (yes/no)	Park	1	2010
Deer density (grassland)	< 20 deer km^{-2}	Park	8	2001–2008

Table 3.12. Area of each habitat type assessed in Antietam National Battlefield. Developed lands make up another 65 ha (160 acres) but were not assessed.

Habitat	Area (ha)	Area (acres)	% of area assessed
Habitats managed for natural resource values			
Forests	149	368	21%
Wetlands and waterways	18	44	3%
Warm-season grasslands	23	58	3%
Total	***190***	***470***	***27%***

Habitat	Area (ha)	Area (acres)	% of area assessed
Habitats managed for agricultural values			
Croplands	387	957	55%
Pastures	131	323	18%
Total	***518***	***1,280***	***73%***

TOTAL AREA ASSESSED	**708 ha (1,750 acres)**

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Chapter 4: Natural resource conditions

4.1 REGIONAL/LANDSCAPE CONTEXT

As detailed in Section *2.1.2—Resource management issues overview*, Antietam National Battlefield faces a number of resource management issues, many of which are related to the surrounding land use (NCRN 2006; Figure 2.10). These issues include encroaching development, increasing population density (Figure 2.11) and housing density (Figure 2.12), high road density (Figure 2.13), low proportion of protected areas (Figure 2.14), excessive numbers of white-tailed deer, and exotic and invasive plants.

On a regional scale, atmospheric deposition of nitrate (Figure 4.1) and mercury (Figures 4.2, 4.3) are persistent problems. As in the case of upstream pollution in park waters, this suite of atmospheric stressors acts to potentially degrade the resources in Antietam National Battlefield, yet stressor abatement outside the park poses significant challenges.

4.2 CONDITION SUMMARIES BY REPORTING AREAS

4.2.1 Habitat framework

Using the habitat framework to synthesize 22 metrics measuring the condition of forest, wetland and waterway, and warm-season grassland habitats, these 'managed for natural resource values' habitats were assessed to be in fair condition (53% attainment of threshold condition; Table 4.1). Synthesizing 12 metrics measuring the condition of cropland and pasture habitats, these 'managed for agricultural values' habitats were assessed as being in good condition (69% attainment of threshold condition; Table 4.2). Pasture was in very good condition, croplands were assessed as good, forests and wetlands and waterways were in fair condition, and warm-season grasslands were assessed as poor. Overall, the habitats of Antietam National Battlefield were assessed as being in good condition, with 69% attainment of threshold condition (Table 4.3). These results are synthesized in Figure 4.4.

The Sherrick Farm trail.

Forests

Forest habitat within Antietam National Battlefield was assessed as being in fair condition, attaining desired condition in 57% of the 50 measurements across all nine metrics, collected between 2000 and 2008 (Tables 3.10, 4.1). Presence of forest pest species, forest interior dwelling bird species, percent impervious surface (Figure 4.5), and forest connectivity (Figure 4.6) within the park all scored as very good (100% attainment), as did exotic tree/shrub density (83% attainment). Cover of exotic herbaceous species scored as degraded (25% attainment) and the remaining metrics (forest interior area [Figure 4.7], native tree seedling regeneration, and deer density) were very degraded, with 4%, 0%, and 0% attainment of desired condition, respectively.

Wetlands and waterways

Wetlands and waterways habitat within Antietam National Battlefield was assessed as being in fair condition, attaining desired condition in 43% of 4,305 measurements across all 10 metrics, collected between 2004 and 2008 (Tables 3.10, 4.1). Water temperature (100% attainment; Figure 4.8), acid neutralizing capacity (100% attainment; Figure 4.9), dissolved oxygen (91% attainment; Figure 4.10), and pH (86%;

Figure 4.1. Total wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) (kg ha^{-1}) for the continental United States in 2009.[34]

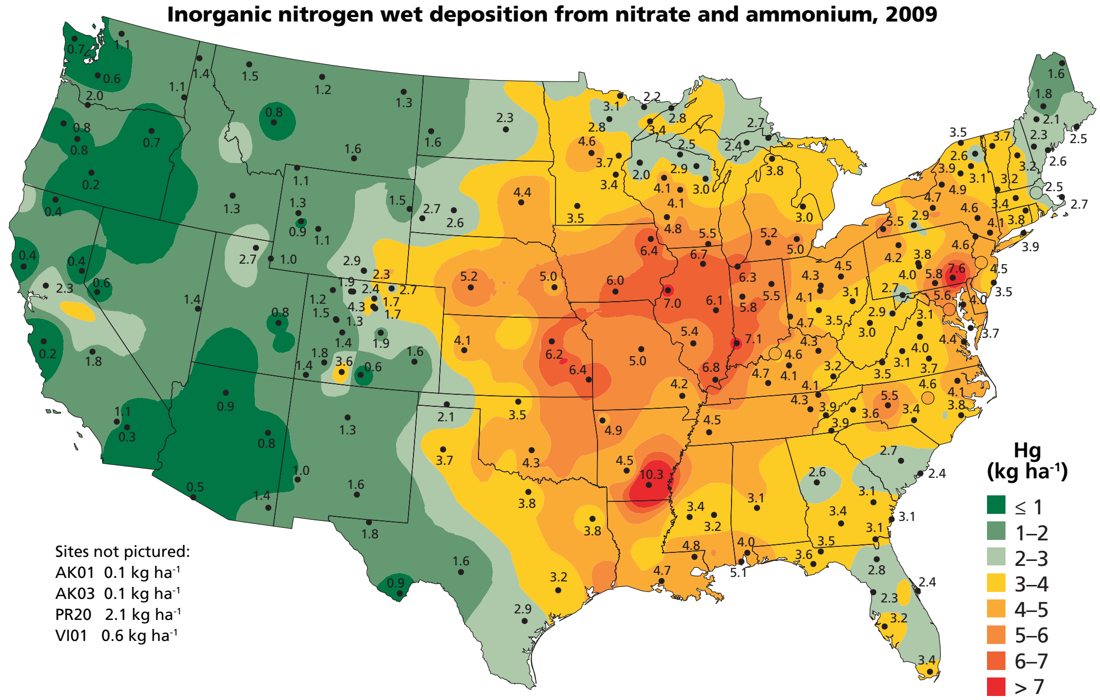
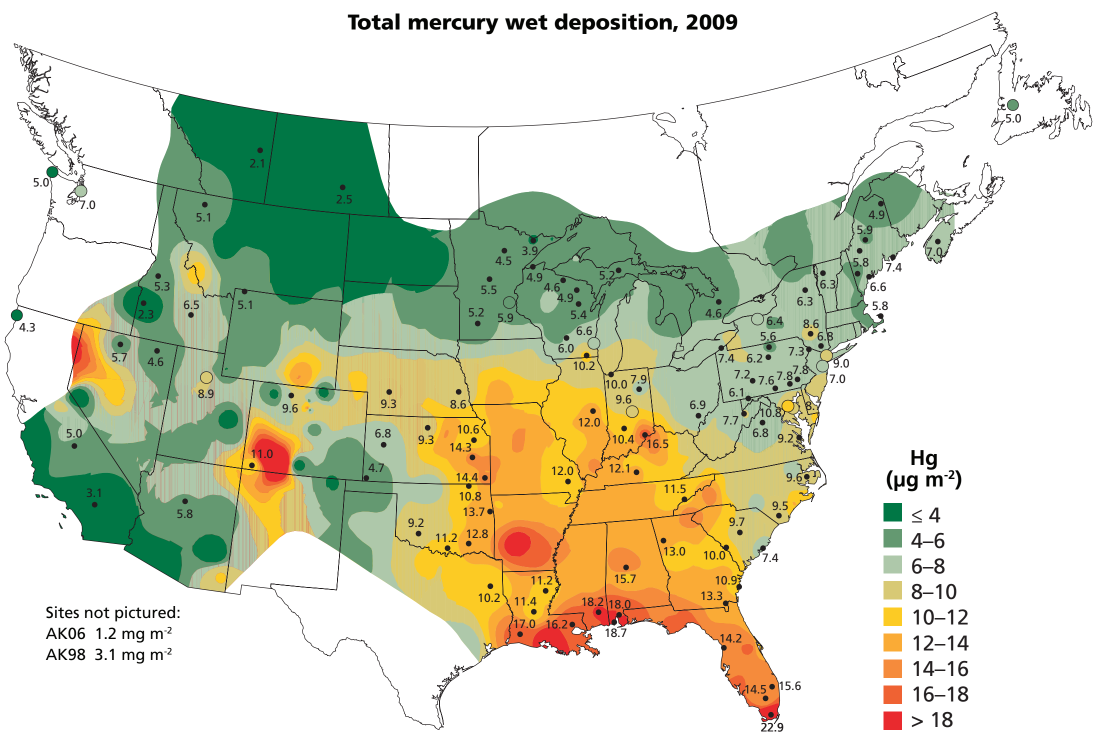


Figure 4.2. Total wet mercury (Hg) deposition (µg m^{-2}) for the continental United States in 2009.[35]



34. National Atmospheric Deposition Program/National Trends Network *http://nadp.sws.uiuc.edu*
35. National Atmospheric Deposition Program/Mercury Deposition Network *http://nadp.sws.uiuc.edu*

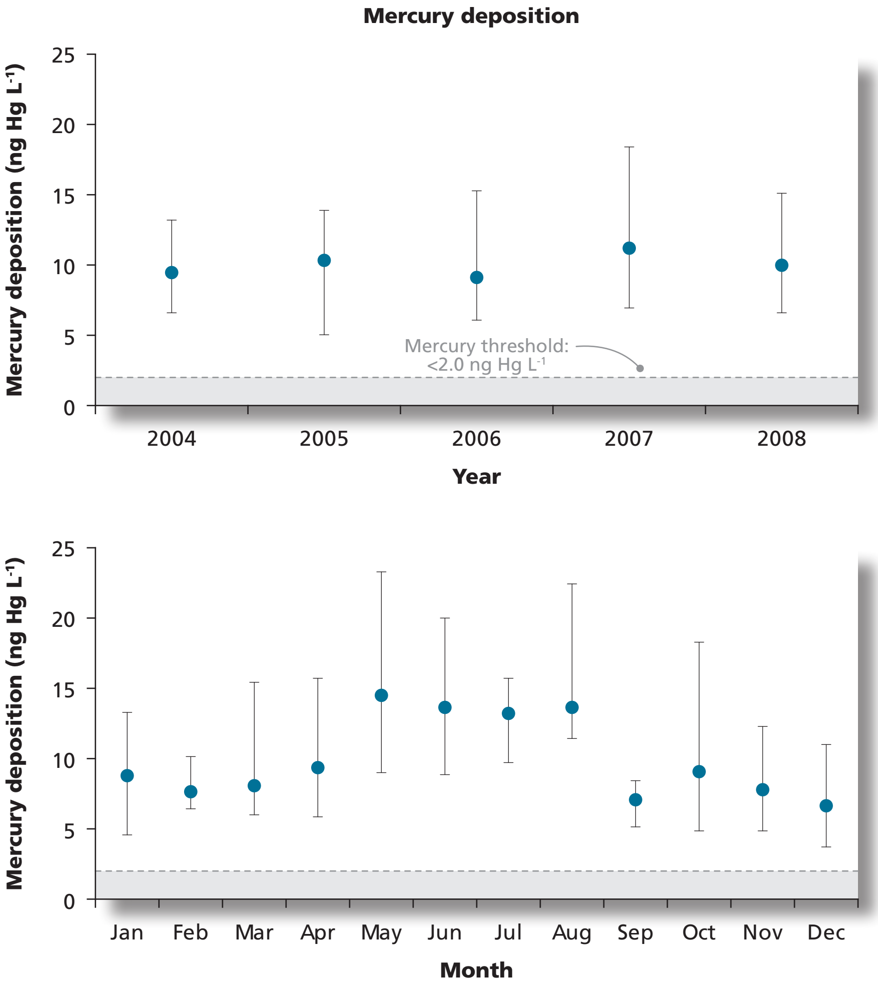


Figure 4.3. Mean monthly mercury deposition (ng Hg L^{-1}) from 2004 to 2007 at sites PA00 and MD99 (see Figure 3.6).[36] Acceptable range (Hg ≤ 2 ng L^{-1}) is shown in gray.

36. Mercury Deposition Network, *http://nadp.sws.uiuc.edu/mdn*

Table 4.1. Summary of habitat-based resource condition assessment of Antietam National Battlefield for habitats that are managed for natural resource values. Park score is area-weighted average, based on the area of each habitat (see Table 3.12).

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Forests				
Cover of exotic herbaceous species	16.5%	25	57	53
Cover of exotic trees and shrubs	2.7%	83		
Presence of forest pest species	0%	100		
Native tree seedling regeneration	4,375 seedlings ha^{-1}	0		
Presence of forest interior dwelling species (FIDS) of birds	2 highly sensitive 5 sensitive	100		
Deer density (forest)	37.3 deer km^{-2}	0		
Impervious surface (within park)	1.07%	100		
Forest interior area	3%	4		
Forest connectivity (Dcrit; within park)	350 m	100		
Wetlands & waterways				
pH	7.5	-86	43	
Dissolved oxygen (DO)	8.6 mg DO L^{-1}	91		
Water temperature	13.6 °C	100		
Acid neutralizing capacity	4,445 µeq L^{-1}	100		
Salinity	0.3	8		
Nitrate (NO_3)	5.3 mg NO_3 L^{-1}	11		
Phosphate (PO_4)	0.298 mg PO_4 L^{-1}	3		
Benthic index biological integrity (BIBI)	1.9	0		
Fish index biological integrity (FIBI)	2.8	33		
Physical habitat index (PHI)	60.6	0		
Grasslands (warm-season)				
Deer density	37.3 deer km^{-2}	0	36	
Impervious surface (within park)	1.07%	100		
Grassland bird diversity	25%	25		
Grassland interior area	3%	5		
Contiguous grassland area	15.8 ha	50		

Table 4.2. Summary of habitat-based resource condition assessment of Antietam National Battlefield for habitats that are managed for agricultural values. Park score is area-weighted average, based on the area of each habitat (see Table 3.12).

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Croplands				
Crop rotation		82	65	69
Crop varieties for IPM		54		
Conservation tillage		91		
Cover crops		100		
Nutrient Management Plan		99		
Soil & Water Conservation Plan		73		
Crop yield concerns		18		
Deer density	37.3 deer km^{-2}	0		
Pastures				
Stocking rate		100	81	
Water source		100		
Fenced streams		100		
Nutrient Management Plan		100		
Soil & Water Conservation Plan		86		
Deer density (grassland)	37.3 deer km^{-2}	0		

Table 4.3. Area-weighted results of habitat-based resource condition assessment of Antietam National Battlefield.

Habitat	Area (ha)	Score (%)	Area-weighted score (%)
Forests	149	57	65
Wetlands and waterways	18	43	
Warm-season grasslands	23	36	
Croplands	387	65	
Pastures	131	81	

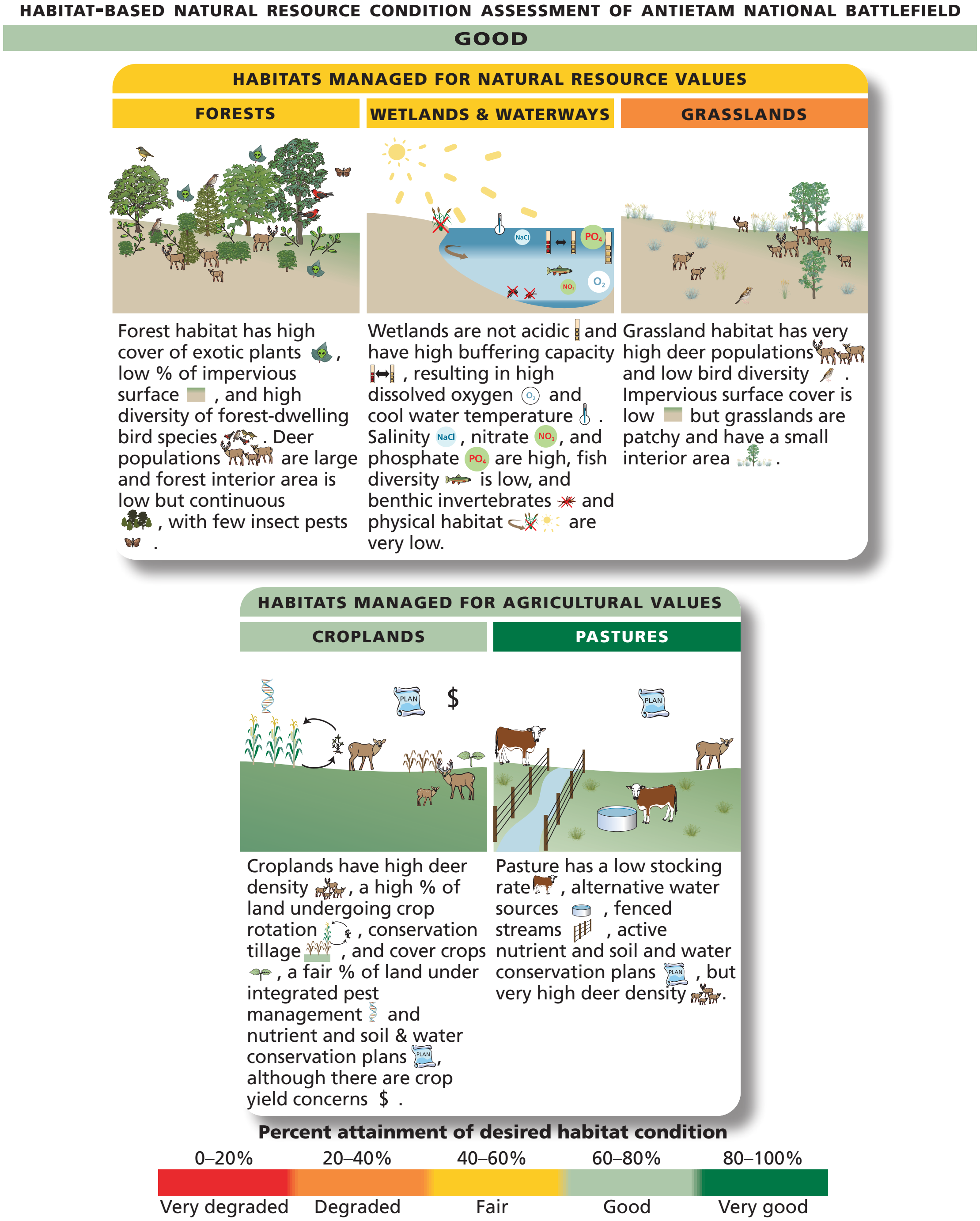


Figure 4.4. Summary results of habitat-based resource condition assessment of Antietam National Battlefield.

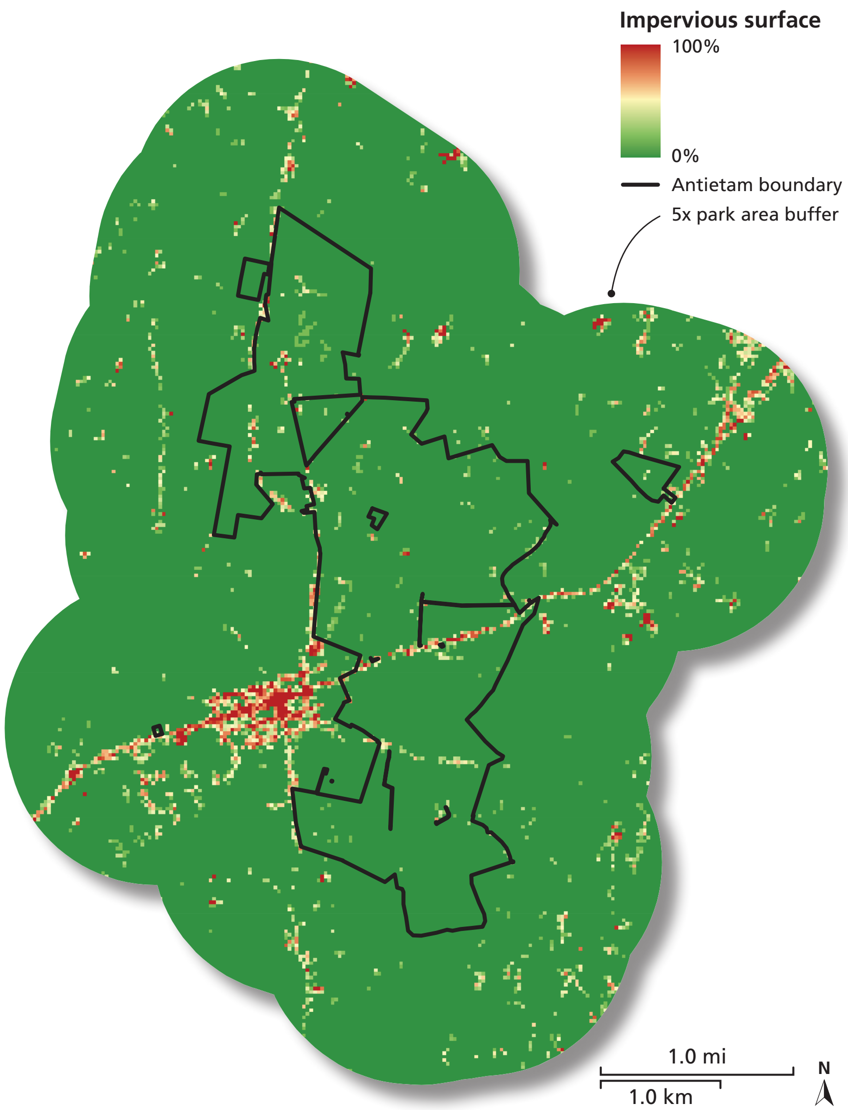


Figure 4.5. GIS data layer showing percent impervious surface in 2000 within and around Antietam National Battlefield.[37] The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

37. NCRN I&M.

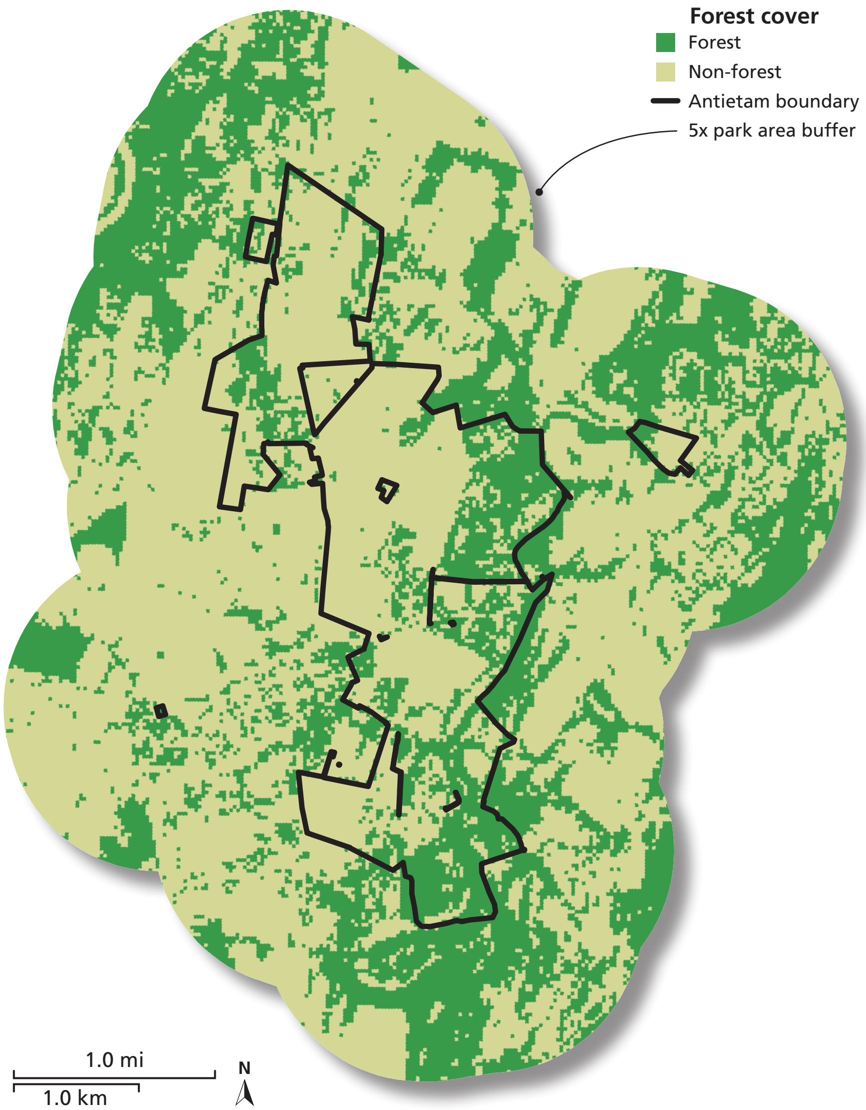


Figure 4.6. Extent of forest and non-forest landcover (Landsat 30-m) within and around Antietam National Battlefield in 2000.[38] The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

38. Townsend et al. 2006.

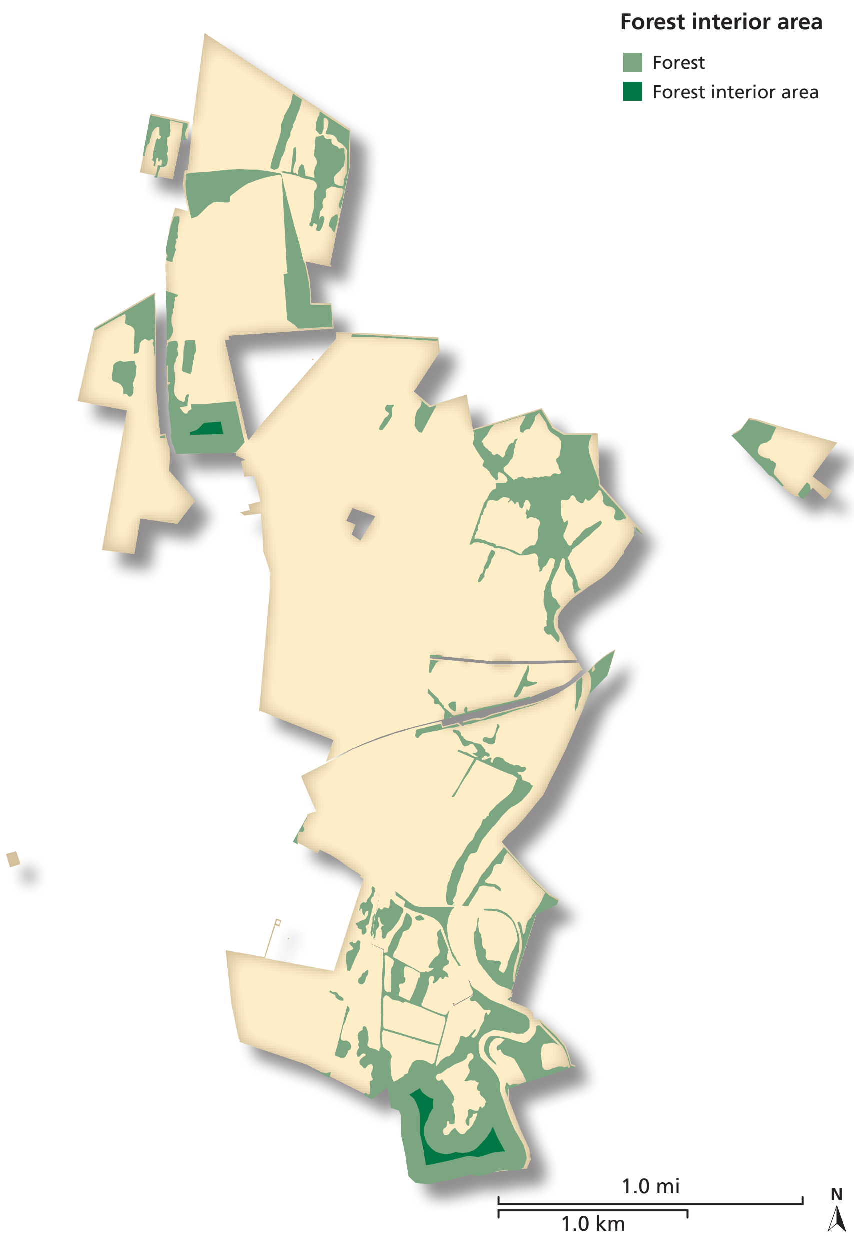
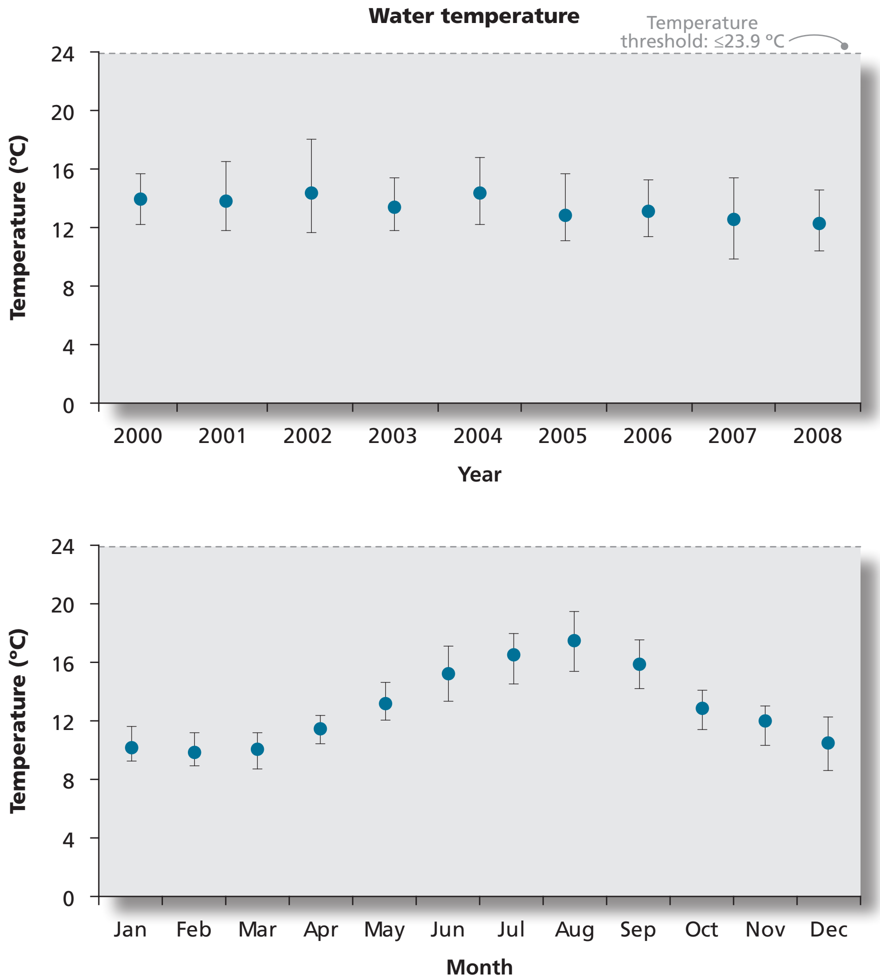


Figure 4.7. Forest area and forest interior area in Antietam National Battlefield.[39] Forest interior area is defined as forested land cover ≥ 100 m from non-forest land cover or from primary, secondary, or county roads.

39. NCRN I&M, ANTI.

Figure 4.8. Median, 1st quartile, and 3rd quartile water temperature (°C) from 2000 to 2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.[40] Acceptable range (temp. ≤ 23.9°C) is shown in gray.



40. Norris et al. 2007, ANTI.

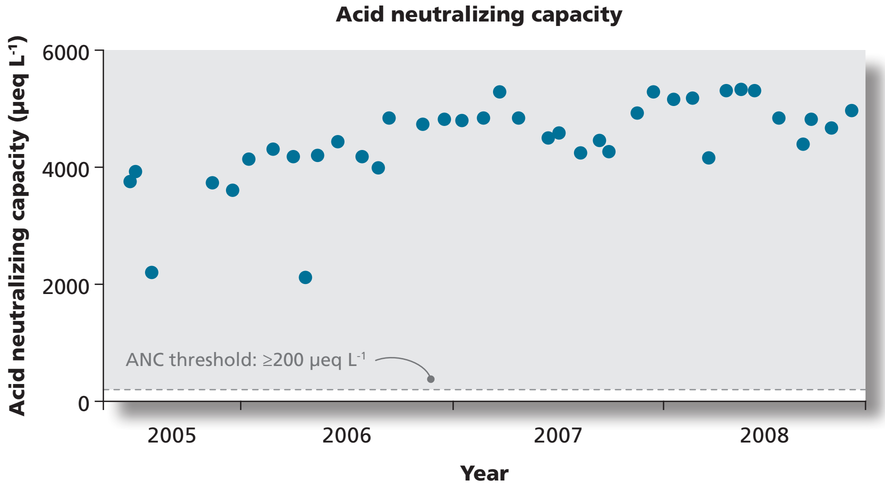


Figure 4.9. Acid neutralizing capacity (ANC; µeq L^{-1}) from 2005 to 2008 for one stream sampling location (NCRN_ANTI_SHCK; see Figure 3.7) in Antietam National Battlefield.[41] Acceptable range (ANC ≥ 200 µeq L^{-1}) is shown in gray.

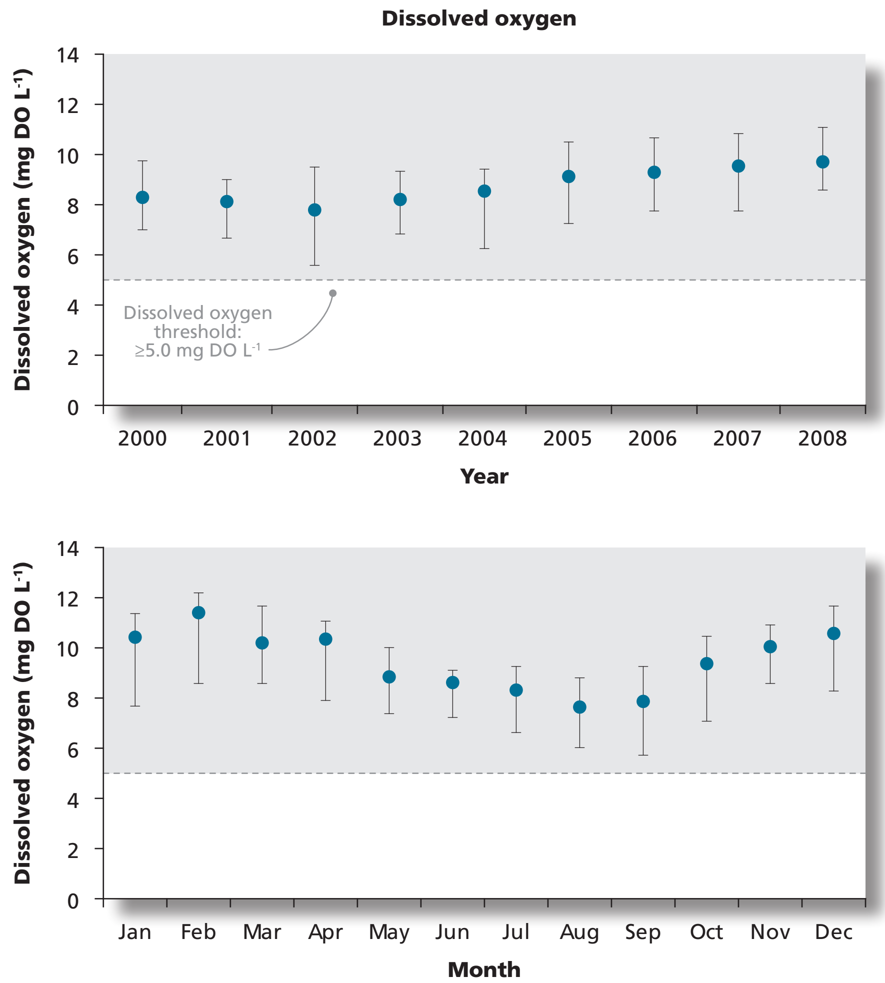
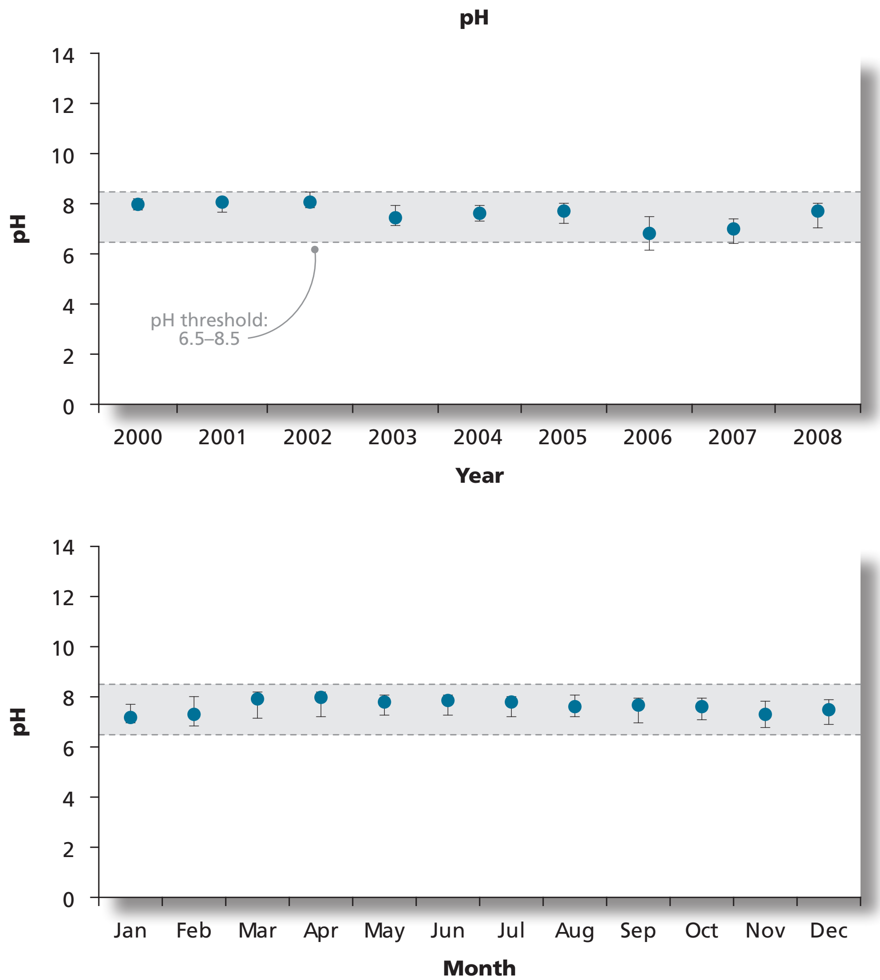


Figure 4.10. Median, 1st quartile, and 3rd quartile dissolved oxygen concentration (mg DO L^{-1}) from 2000 to 2008 for eight stream sampling locations in Antietam National Battlefield (see Figure 3.7).[42] Acceptable range (DO ≥ 5.0 mg L^{-1}) is shown in gray.

41. Norris et al. 2007.
42. Norris et al. 2007, ANTI.

Figure 4.11. Median, 1st quartile, and 3rd quartile pH values from 2000 to 2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.[43] Acceptable ranges (6.5 ≤ pH ≤ 8.5) are shown in gray.



43. Norris et al. 2007, ANTI.

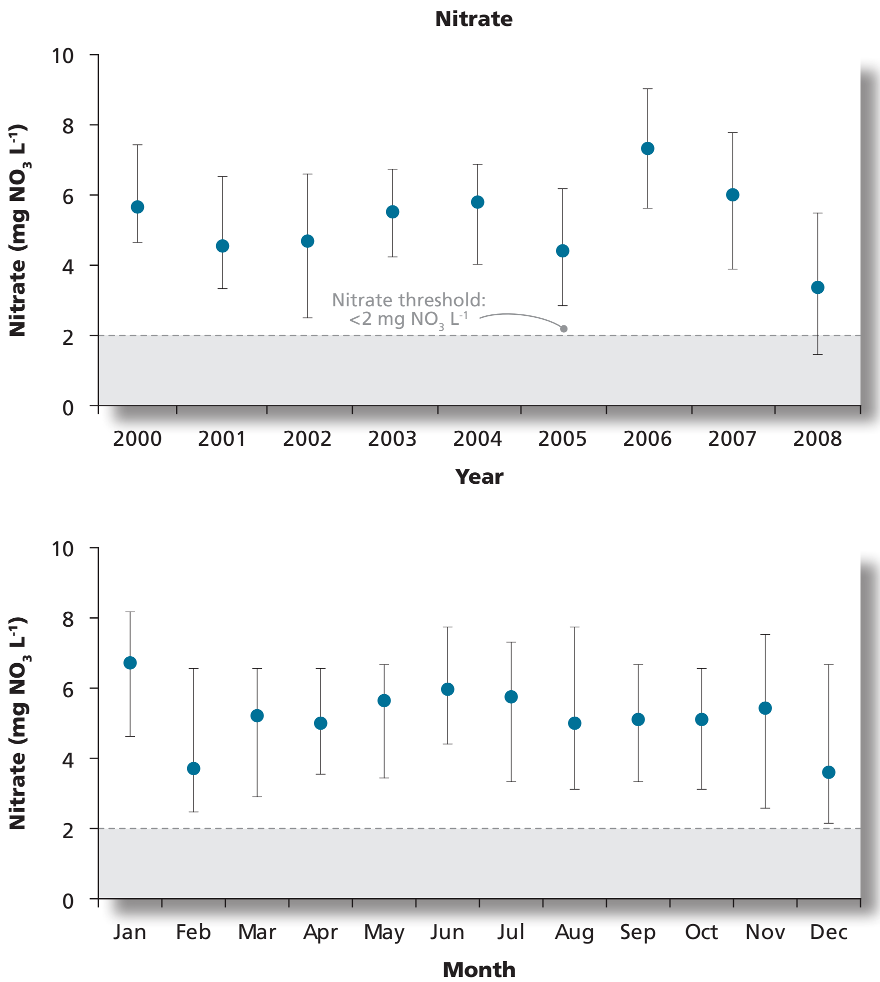


Figure 4.12. Median, 1st quartile, and 3rd quartile nitrate concentration (mg NO_3 L^{-1}) from 2000–2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.[44] Acceptable range (NO_3 ≤ 2.0 mg L^{-1}) is shown in gray.

44. Norris et al. 2007, ANTI.

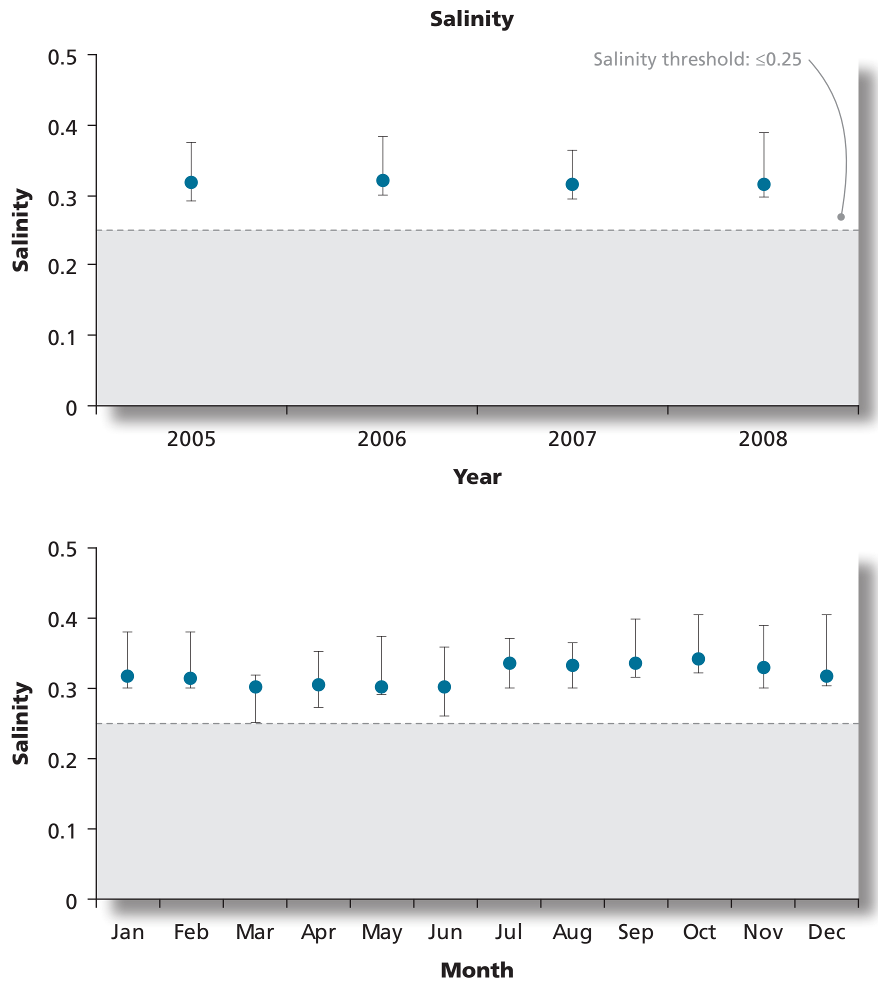


Figure 4.13. Median, 1st quartile, and 3rd quartile monthly salinity concentration from 2005–2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.[45] Acceptable range (salinity ≤ 0.25) is shown in gray.

Figure 4.11) were in very good (desired) condition. Stream fish were in degraded condition (33% attainment). The remaining metrics—nitrate (11% attainment; Figure 4.12), salinity (8% attainment; Figure 4.13), phosphate (3% attainment; Figure 4.14), Physical Habitat Index (0% attainment), and the Benthic Index of Biotic Integrity (0% attainment) were in very degraded condition.

Grasslands (warm-season)

Warm-season grasslands in Antietam National Battlefield were assessed as being in degraded condition overall, attaining desired condition in 36% of 19 measurements across five metrics, collected between 2000 and 2008 (Tables 3.10, 4.1). Impervious surface cover within the park was well below the desired threshold of 10% (Figure 4.5). Contiguous grassland area was assessed as fair (50% attainment) while grassland bird diversity was degraded (25% attainment). Grassland interior area (5% attainment; Figure 4.15) and deer density (0% attainment) were very degraded.

Croplands

Cropland in Antietam National Battlefield was assessed as being in good condition, with 65% attainment of desired condition across eight metrics (Tables 3.11, 4.2). Best management practices (BMPs) are widely implemented on agricultural lands within the park, with cover crops (100% attainment), Nutrient Management Plans (99% attainment), conservation tillage (91% attainment), and crop rotation (82% attainment) were all assessed as being in very good condition. Existence of Soil and Water Conservation Plans was in good condition (73% attainment), use of crop varieties for integrated pest management was fair (54% attainment), while crop yield concerns (18% attainment) and deer density (0% attainment) were in very degraded condition.

45. Norris et al. 2007, ANTI.

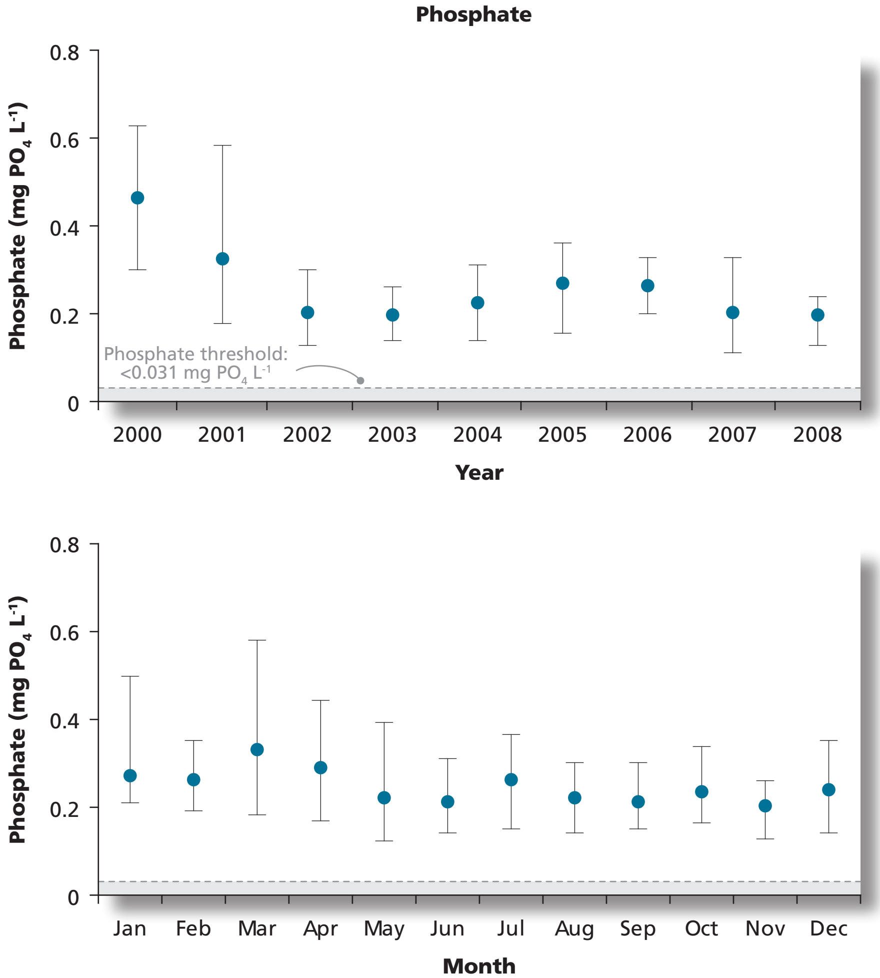


Figure 4.14. Median, 1st quartile, and 3rd quartile phosphate concentrations (mg PO_4 L^{-1}) from 2000 to 2008 for eight stream sampling locations (see Figure 3.7) for Antietam National Battlefield.[46] Acceptable range (PO_4 < 0.031 mg L^{-1}) is also shown in gray.

46. Norris et al. 2007, ANTI.

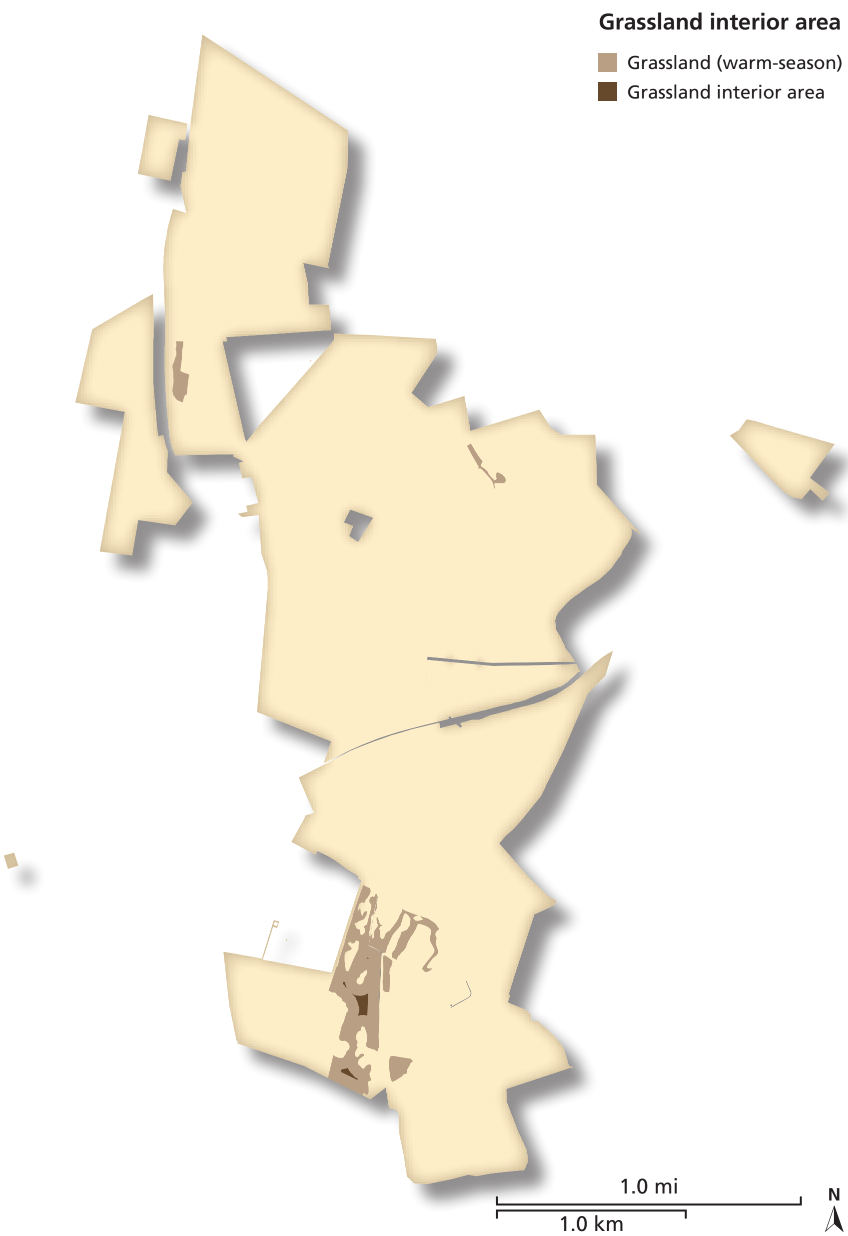


Figure 4.15. Grassland area and grassland interior area in Antietam National Battlefield.[47] Grassland interior area is defined as grassland ≥60 m from other land uses.

Pastures

Pasture lands in Antietam National Battlefield was assessed as being in very good condition, with 81% attainment of desired condition across six metrics (Tables 3.11, 4.2). BMPs are widely implemented on pastured lands in the park, with animal stocking rate (100% attainment), alternative water sources (100% attainment), fenced streams (100% attainment), Nutrient Management Plans (100% attainment), and Soil and Water Conservation Plans (86% attainment) all in very good condition. Deer density was in very degraded condition, with 0% attainment of desired condition.

4.3 PARK-WIDE CONDITIONS

4.3.1 Ecological monitoring framework

Using an ecological monitoring framework to synthesize 29 metrics measuring the condition of Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics, natural resources within Antietam National Battlefield were assessed to be in a degraded condition (39% attainment of threshold condition; Tables 3.7, 4.4). Air & Climate were in a very degraded condition, while Landscape Dynamics were in good condition and Water Resources and Bio-

47. NCRN I&M, ANTI.

logical Integrity were assessed as being in fair condition.

Air & Climate

Using the interpolated results from NPS Air Resources Division and mercury monitoring data, Air & Climate in Antietam National Battlefield were measured to be in a very degraded condition (0% attainment of threshold condition; Table 4.4). Ozone concentration and wet nitrogen and sulfur deposition were within an order of magnitude of the threshold; however, visibility and mercury deposition were all an order of magnitude higher than threshold concentrations (Figure 4.3, Table 3.7).

Water Resources

Water Resources within Antietam National Battlefield were assessed as being in fair condition, attaining desired condition in 44% of the 4,301 measurements across all nine metrics, collected between 2000 and 2008 (Tables 3.7, 4.4). Water temperature (100% attainment; Figure 4.8), acid neutralizing capacity (100% attainment; Figure 4.9), dissolved oxygen (91% attainment; Figure 4.10), and pH (86% attainment; Figure 4.11) were all in very good condition, with high attainment of desired conditions. In contrast, several metrics were in very degraded condition—nitrate (11% attainment; Figure 4.12), salinity (8% attainment; Figure 4.13), phosphate (3% attainment; Figure 4.14), Physical Habitat Index (0% attainment), and the Benthic Index of Biotic Integrity (0% attainment) were all very degraded.

Biological Integrity

Biological Integrity within Antietam National Battlefield attained desired threshold condition in 46% of 52 measures over eight metrics, resulting in an assessment of degraded condition (Tables 3.7, 4.4). Exotic tree and shrub density and presence of forest pest species were low (83% and 100% attainment of threshold, respectively), and presence of forest interior bird species was high (100%), resulting in very good condition for those three metrics. Fish communities (33% attainment), cover of exotic herbaceous species, and grassland bird diversity (both 25% attainment) were all degraded. Native tree seedling regeneration was very low (0% attainment) and deer density was extremely high (0% attainment), with 37 deer km^{-2} (96 deer mi^{-2}) compared to the threshold of 8 deer km^{-2} (21 deer mi^{-2}; forest) and 20 deer km^{-2} (52 deer mi^{-2}; grassland), resulting in a very degraded assessment for these two metrics.

Landscape Dynamics

Landscape Dynamics were assessed both within and just surrounding Antietam National Battlefield, and overall were in good condition, attaining desired threshold condition in 66% of seven measurements over the seven metrics (Tables 3.7, 4.4). Percentage of impervious surface both within and surrounding the park was acceptably low and well below the threshold of 10% impervious cover (Figure 4.5). The forest that is present is well connected and so attained desired condition for forest connectivity (Figure 4.6); however, the proportion of forest interior area was very low (4% of potential forest interior area; Figure 4.7), as was grassland interior area (5% of potential grassland interior area; Figure 4.15).

4.4 LITERATURE CITED (CHAPTER 4)

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Table 4.4. Summary resource condition assessment for Antietam National Battlefield by metric categories.

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Air & Climate				39
Ozone	0.078 ppm	0	0	
Wet nitrogen deposition	4.6 kg N ha^{-1} yr^{-1}	0		
Wet sulfur deposition	5.8 kg S ha^{-1} yr^{-1}	0		
Visibility	13.75 dv	0		
Hg deposition	13.1 ng Hg L^{-1}	0		
Water Resources				
pH	7.5	86	44	
Dissolved oxygen (DO)	8.6 mg DO L^{-1}	91		
Water temperature	13.6 °C	100		
Acid neutralizing capacity	4,445 µeq L^{-1}	100		
Salinity	0.3	8		
Nitrate (NO_3)	5.3 mg NO_3 L^{-1}	11		
Phosphate (PO_4)	0.298 mg PO_4 L^{-1}	3		
Benthic index biological integrity (BIBI)	1.9	0		
Physical habitat index (PHI)	60.6	0		
Biological Integrity				
Cover of exotic herbaceous species	16.5%	25	46	
Cover of exotic trees and shrubs	2.7%	83		
Presence of forest pest species	0%	100		
Native tree seedling regeneration	4,375 seedlings ha^{-1}	0		
Fish index biological integrity (FIBI)	2.8	33		
Presence of forest interior dwelling species (FIDS) of birds	2 highly sensitive 5 sensitive	100		
Grassland bird diversity	25%	25		
Deer density (forest)	37.3 deer km^{-2}	0		
Deer density (grassland)	37.3 deer km^{-2}			
Landscape Dynamics				
Impervious surface (within park)	1.07%	100	66	
Impervious surface (within park) + 5X buffer	1.07%	100		
Forest interior area	3%	4		
Forest connectivity (Dcrit; within park)	350 m	100		
Forest connectivity (within park) + 5X buffer	130 m	100		
Grassland interior area	3%	5		
Contiguous grassland area	15.8 ha	50		

Chapter 5: Discussion

5.1 ASSESSING NATURAL RESOURCE CONDITION IN A BATTLEFIELD PARK

Enabling legislation for many parks was established for reasons other than to specifically protect the ecological benefits of natural areas within the park. Therefore a landscape may be maintained for a particular historic view or to maintain other cultural features of significance, raising the question of how to assess the natural resource condition of these landscapes. The lands within the park are much as they were on the day of the battle and the park is charged with maintaining them in historical land use to preserve the view of the battle. The crop and pasture lands are commercially viable farming lands managed using agricultural leases, which are interspersed with natural wetland and waterway, forest, and warm-season grassland areas. The first step in framing this Natural Resource Condition Assessment was to define the key habitats within the park, considering ecology as well as how these different areas are managed and what data may be available to assess habitats. To address this challenge and in recognition of the vastly different land management goals for different habitats within the park, it was decided to conceptually divide habitats into two groups. Firstly, those 'managed for natural resource values' being the natural habitats (forests, wetlands and waterways, warm-season grasslands) whose ecological value was assessed using vital sign metrics from the National Park Service (NPS) Inventory & Monitoring (I&M) Program in the National Capital Region Network (NCRN), and secondly those 'managed for agricultural values' (croplands and pastures) were assessed for being the most ecologically sustainable croplands and pastures possible.

An assessment framework must allow for change (e.g., improvement) and metrics must be measurable and show variation, so it was deemed ultimately unhelpful to assess working landscapes as 'degraded' natural habitats. This approach works at recognizing the park's management goals by synthesizing an assessment of whether these cultural or working lands are in their best condition for that landscape. In this way, it was possible to assess all lands within the park, recognizing management goals and cultural resource values but providing an integrated framework that supports an assessment of the natural resource value of the whole park.

Prescribed burning in Antietam National Battlefield.

5.2 KEY FINDINGS AND MANAGEMENT IMPLICATIONS

To synthesize multiple diverse data sets, a habitat framework was used to assess current condition of natural resources for Antietam National Battlefield (Chapters 3, 4), therefore key findings and management implications are summarized using the same framework (Tables 5.1, 5.2, 5.3, 5.4, 5.5).

5.2.1 Forests

Patches of forest within Antietam National Battlefield are well connected; however, forest interior area is small, providing moderate habitat potential for native fauna including forest interior dwelling bird species (FIDS; Table 5.1). It is recommended to preserve this forest structure by limiting future fragmentation (such as roads, trails, and structures) of these forest patches, as

Table 5.1. Key findings, management implications, and recommended next steps for forest habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Forests		
• Deer overpopulation reducing forest regeneration capacity	• Increased herbivory reducing desired plant and bird species • More road collisions	• Implement deer population control measures
• Presence of exotic plants	• Displacement of native species, reducing biodiversity	• Early detection • Exotic control measures (spraying and mechanical) • Prioritize control strategies
• Well-connected forest but with small patch sizes	• Acts as a refuge for forest interior dwelling species of birds, amphibians	• Minimize stressors • Minimize fragmentation (roads, structures, trails) • Maintain size, especially of larger patches

Table 5.2. Key findings, management implications, and recommended next steps for wetland and waterway habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Wetlands and waterways		
• Antietam Creek and tributaries have degraded water quality (nitrate, phosphate, salinity)	• Affects stream flora and fauna • Reduces quality of visitor experience	• Reduce non-point source nutrient inputs from watershed (partnership with agencies) • Continue riparian buffer establishment (woody or herbaceous, depending upon cultural resources/viewshed present)
• Stream benthos (IBI) very poor	• Reduced biodiversity • Reduced support of higher trophic levels	• Revise thresholds to be relevant for karst streams • Improve water quality

Table 5.3. Key findings, management implications, and recommended next steps for warm-season grassland habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Grasslands (warm-season)		
• General lack of comprehensive data for grasslands	• Difficulties in assessing the health of grasslands	• Implement grassland monitoring, particularly diversity, invasive species, birds, mammals, and insects • Carry out a baseline grassland plant inventory
• Grassland areas are not contiguous and are limited in interior area	• Decreases habitat value for avian fauna and mammals (by increasing potential predation)	• Remove tree lines where historically appropriate • Expand area of native grasses

Table 5.4. Key findings, management implications, and recommended next steps for cropland habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Croplands		
• Deer overpopulation	• Reduced productivity and viability of cropland	• Implement deer population control measures
• Croplands are in high compliance with best management practice	• Suggests that croplands are being managed sustainably	• Organize and document compliance monitoring • Research new techniques in sustainable agriculture
• Nutrient management plan is in place but implementation and effectiveness not documented	• While compliant with regulations, nutrient impacts on surrounding habitats managed for natural resource values are unknown	• Park-wide agricultural best management practice effectiveness survey • Monitor and enforce Nutrient Management Plans and required soil testing.

Table 5.5. Key findings, management implications, and recommended next steps for pasture habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Pastures		
• Deer overpopulation	• Degrading value of pasture, impacting surrounding habitats	• Implement deer population control measures
• Nutrient management plan is in place but implementation and effectiveness not documented	• While compliant with regulations, nutrient impacts on surrounding habitats managed for natural resource values are unknown	• Park-wide agricultural best management practices effectiveness survey • Comprehensive soil nutrient assessment and monitoring

well as minimizing stresses (such as invasive species) on these forest areas. Very high deer populations are present within these forest areas resulting in limited regeneration capacity of these forests, as well as trampling, overgrazing, and reduction of habitat value for wildlife. It is recommended to implement deer reduction strategies to attain a population closer to the sustainable 8 deer km^{-2} (21 deer mi^{-2}), down from the current population over 37 deer km^{-2} (96 deer mi^{-2}). The abundant presence of exotic herbaceous and woody species displaces native species and reduces habitat value. Continued early detection of exotic species is recommended with subsequent active control measures (spraying and physical removal). Assessment of exotic species cover would be better assessed with park-wide mapping as the current small number of plots is not ideal for assessing exotic species cover on a park scale.

5.2.2 Wetlands and waterways

Wetland and waterway habitats show no sign of acidification or low oxygen; however, high salinity and nutrients indicate degraded wetland and waterway habitat value, which is reflected in the regionally low benthic index of biotic integrity and fish diversity (Table 5.2).

The karst geology of Antietam and the surrounding landscape has implications for water quality of the streams within the park. The acid neutralizing capacity (ANC) of streams in Antietam National Battlefield was higher (better buffering capacity) than streams in the nearby Monocacy National

Battlefield and Manassas National Battlefield park, due to the dissolution of the limestone and dolomite bedrock underlying the park by surface and groundwater (White 1993, Norris and Pieper 2010). This high ANC resulted in a stable and near-neutral pH in the park's streams.

The temperature of Antietam's streams showed a smaller range with less seasonal fluctuation than streams in Monocacy National Battlefield and Manassas National Battlefield Park. This is due to the relatively large influence of groundwater on karst systems—in Antietam, the groundwater discharge of the basin is about 85% of the total (Thorneberry–Ehrlich 2005).

The high salinity observed in Antietam is likely also a result of the karst landscape surrounding the park. Water passing through karst systems contains high levels of dissolved materials due to the dissolution of the bedrock. As salinity measures dissolved salts, karst streams are likely to return high salinity readings (Norris and Pieper 2010). These high levels of dissolved material may also impact the benthic invertebrate communities, which were very degraded in Antietam. This dissolved material can clog the gills of these animals, limiting their survival and reproduction (R. Hilderbrand, pers. comm.).

It is recommended to identify and work with partners to reduce non-point source nutrient inputs from the watershed as well as continue to implement best management practices in agricultural lands. Additionally, efforts should continue to establish riparian buffers (ideally to 50 m [160 ft]; Mayer et al. 2006) where appropriate, in consideration of cultural resources and historic vistas (using shrubs and grasses instead of trees may be appropriate in these cases). Assessment of these habitats could be improved by inclusion of metrics indicative of groundwater condition, due to the karst geology of the area—the carbonate rocks in karst landscapes are particularly susceptible to dissolution from both surface water and groundwater (Thorneberry-Ehrlich 2005). This results in high connectivity between groundwater and surface expression in streams and surface water.

5.2.3 Grasslands (warm-season)

It is recommended to carry out baseline grassland plant inventories and optimize fire management to assist a transition to a greater abundance of native warm-season grasses, monitoring the effectiveness of different burning cycles (Table 5.3). Warm-season grassland areas are currently not contiguous, limiting the habitat value to birds, mammals, and insects. It is recommended to remove tree lines and expand areas of native grasses where historically appropriate and to develop inventories and monitor these key faunal communities. Future assessments of natural resource condition would be improved by inclusion of measures of monitoring of bird, small mammal, and insect communities within native grassland habitats. Direct measures of the species and habitat diversity (i.e., range of successional stages) would also be beneficial in managing to maximize habitat value of warm-season grassland habitat.

5.2.4 Croplands

The croplands within Antietam National Battlefield are susceptible to the very high deer populations (Table 5.4), which are the primary cause of the crop yield concerns. It is recommended to implement deer population controls to ensure that these leased croplands are viable. These land use areas are in high compliance with best management practice—it is recommended to organize and document compliance monitoring as well as to research new techniques of sustainable agriculture that would maintain historical land use while maintaining maximum resource condition in habitats managed for natural resource values within the park. Currently, assessment of implementation and effectiveness of Nutrient Management Plans and Soil & Water Conservation Plans have not been carried out. It is recommended to monitor and enforce implementation as well as to investigate soil nutrients within these habitats to provide for better productivity and resource preservation. These additional data would improve future resource condition assessments for this habitat.

5.2.5 Pastures

The pastures within Antietam National Battlefield are susceptible to the very high deer populations (Table 5.5). It is recommended to implement deer population controls to ensure that these leased lands are viable. Pasture habitat within Antietam National Battlefield includes areas of cool-season grassland, which are currently managed as pasture with no immediate management goal to transition these areas to native warm-season grassland. Warm-season grassland supports greater habitat value for grassland birds, native grass species, small mammals, and insect pollinators, so transitioning these grassland habitats would maximize the natural resource value of these areas. Currently, assessment of implementation and effectiveness of Nutrient Management Plans as well as Soil and Water Conservation Plans have not been carried out. It is recommended to monitor implementation as well as to investigate soil nutrients within these habitats to provide for better productivity and resource preservation. These additional data would improve future resource condition assessments for this habitat.

5.3 DATA GAPS AND SUBSEQUENT RESEARCH NEEDS

The NPS NCRN I&M 'vital signs' framework was used to assess the current condition of park-wide natural resources for Antietam National Battlefield (Chapters 3, 4), therefore key data gaps and research needs were summarized using the same framework (Tables 5.6, 5.7, 5.8, 5.9).

5.3.1 Air & Climate

Air quality is poor within the park and while it is well monitored, the specific implications to the flora and fauna in the park are less well known (Table 5.6). Gaining a better understanding of how reduced air quality is impacting wetland and grassland habitats (particularly) would help prioritize management efforts such as nutrient reductions in park lands, by showing what gains may be expected from these efforts.

5.3.2 Water Resources

Water quality has signs of degradation, and is essential to the preservation of biotic integrity within all major habitats in the park (Table 5.7). Stream channels are highly variable in condition and a comprehensive assessment of stream physical habitat would allow for targeted management efforts and also allow for targeted engineering efforts to reduce water energy and erosion in the most susceptible areas. A detailed wetland delineation, including groundwater, would also provide a greater understanding of current features and potential threats to park resources. One of the key challenges to water quality is high nutrients—identification of nutrient sources, both within the park and throughout the watershed, would assist in assessing potential threats, and working with watershed parters and agencies would ultimately be highly beneficial to address broader water quality concerns within the park. Monitoring and enforcing implementation of Nutrient Management Plans would also help to identify nutrient sources within the park. Phosphates are consistently high throughout the region and as this nutrient often comes from non-point sources, challenges exist for identification and mitigation of these sources.

5.3.3 Biological Integrity

Some valuable biological communities occur within the park, with the natural park habitats such as native warm-season grasslands becoming more significant as development continues throughout the region (Table 5.8). Understanding the significance of these habitats to native grassland birds would require inventory and monitoring of these communities, including some specific studies on the potential impacts of traffic and vibrations to the success of these communities. The ecological community structure and succession of warm-season grassland communities themselves is poorly characterized in terms of habitat value to birds, small mammals, and insect pollinators. Research into warm-season grassland communities would support the development of key indicators to monitor resource value of these habitats in the maintenance of a range of native biological communities. Very high deer populations

Table 5.6. Data gaps, justification, and research needs for Air & Climate in Antietam National Battlefield.

Data gaps	Justification	Research needs
Air & Climate		
• Ecological thresholds (for atmospheric effects on water and grasslands—deposition of nitrogen, sulfur, and mercury)	• Ecosystem impacts from deposition and human influence (acid rain and fertilization) unknown	• Investigating habitat-specific effects • Deposition impacts to wetlands and grasslands • Prevailing wind patterns within the park
• Park-scale air quality data	• Need to implement park-specific management actions	• Using transport and deposition models • Calibrating with roadside data within the park

Table 5.7. Data gaps, justification, and research needs for Water Resources in Antietam National Battlefield.

Data gaps	Justification	Research needs
Water Resources		
• Stream channel morphology, and changes due to erosion	• Biodiversity relies on maintenance of stable wetland morphology	• Research engineering solutions to reduce water energy and erosion
• Water quality, including groundwater	• Degraded water quality reduces habitat value of wetlands for native flora and fauna	• Identify nutrient sources, especially phosphate, as this nutrient is consistently high throughout the region and sources are non-point
• Detailed wetland delineation	• In this pervious karst landscape, all habitats are connected by water flows	• Fine-scale mapping including surface and sub-surface flows • 'Groundwatershed' maps of flow throughout park
• Nutrient and salt sources are poorly defined both within and outside the park	• Need to know where to prioritize management actions	• Tracers, models and budgets needed (inside and outside the park) • Identify inputs (point and diffuse)
• Comprehensive assessment of stream physical habitat condition	• High spatial variability of condition	• Mapping and assessing streambank condition
• Watershed condition	• Strong connectivity in water resources within the park to external stressors throughout the watershed	• Work with watershed partners and agencies to assess watershed and stream condition

Table 5.8. Data gaps, justification, and research needs for Biological Integrity in Antietam National Battlefield.

Data gaps	Justification	Research needs
Biological Integrity		
• Bird community thresholds and management goals	• The park contains increasingly rare habitat for neotropical and grassland birds	• Inventory and monitor types of birds, particularly grassland birds, within the park
• Acoustic and vibration monitoring	• Traffic vibrations and noise can impact bird populations	• Monitor noise and vibrations and assess impacts to bird communities
• Understanding grazing impacts on multiple habitats (grassland, cropland, pasture)	• Intense herbivory impacts habitat structure and function	• Impacts of different deer densities on different habitats, including establishing deer density thresholds
• Importance of maintaining late successional warm-season grasslands	• Grassland diversity can enhance diversity of birds, mammals and insect pollinators	• Actively monitor effects of different grassland management actions, including burn strategy
• Small mammal dynamics and populations in grasslands	• Park contains increasingly rare grassland habitat important to declining populations of mammals dependent on early successional habitats	• Inventory and monitor small mammals specific to grasslands
• Grassland insect and pollinator populations and roles	• Park contains increasingly rare grassland habitat	• Inventory and monitor insects, particularly those that are important food sources for grassland birds
• Sustainability of raptor populations and affects on grassland birds	• Park contains increasingly rare grassland habitat	• Inventory and monitor raptors that prey on neotropical and grassland birds • Establish baseline for sound levels and types of sounds within park

Table 5.9. Data gaps, justification, and research needs for Landscape Dynamics in Antietam National Battlefield.

Data gaps	Justification	Research needs
Landscape Dynamics		
• Implications of external land use changes on park resources	• Connectivity of ecological processes from park to watershed	• Landscape analysis at multiple scales
• Wetland corridor function	• Needed for migration and movement of fauna	• Assessment of current and potential use by fauna
• Cultural requirements for tree heights	• Vegetating streamsides needs to be carried out in a way that maintains cultural viewscapes	• Assess maximum acceptable plant height and species

in the park have contributed to very low native tree seedling regeneration, although the seedling regeneration data did not take reforestation activities into account. A better understanding of the dynamics of these forest habitats in the presence of high deer populations and their ability to recover after deer reduction would assist in clarifying sustainable deer populations for future management.

The data used for the assessment of forest interior dwelling species of birds and grassland birds (Goodwin and Shriver 2009) was focused on forested sites within the park. Therefore, grassland bird species were likely under-represented.

5.3.4 Landscape Dynamics

Many of the faunal communities that constitute features of the park are migratory or have home ranges much greater than the park. For these reasons, assessing the connectivity and ownership of habitats and lands not just within but also outside of the park will allow a better understanding of the resilience of these communities and their susceptibility to change in the future (Table 5.9). This is true for forest, grassland, and wetland and waterway habitats within the park. As a battlefield park, vegetating streamsides to reduce nutrient runoff from agricultural and pasture lands into waterways needs to be carried out in a way that maintains the cultural viewshed of the park. Studies to identify plant species that are small enough to maintain viewsheds but large enough to remove maximum nutrient content from surface and subsurface waters flowing from agricultural and pastoral lands would assist in improving compliance with best management practices for these habitats.

5.4 LITERATURE CITED (CHAPTER 5)

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Appendix A: Raw data used in Antietam National Battlefield Natural Resource Condition Assessment

Table A-1. Annual mean mercury wet deposition (ng Hg L^{-1}). Values that fail threshold (>2.0 ng Hg L^{-1}) are in bold.

Year	Count	Mean
2004	65	**11.01**
2005	81	**11.97**
2006	82	**12.84**
2007	86	**15.28**
2008	82	**13.55**
Overall	396	13.09
Std error		0.58

Table A-2. Water quality data. Values that do not meet the thresholds are in bold. Site locations are shown in Figure 3.7 and thresholds are shown in Table 3.2.

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
I&M data								
NCRN_ANTI_SHCK	5/23/2005	8.09	10.50	13.30			**4.6**	
NCRN_ANTI_SHCK	6/2/2005	8.14	10.85	14.75	3740		**4.9**	
NCRN_ANTI_SHCK	6/30/2005	8.13	9.97	16.77	3920		**5.0**	
NCRN_ANTI_SHCK	10/11/2005	8.18	9.81	14.60	2200		**9.3**	
NCRN_ANTI_SHCK	11/17/2005	8.27	8.60	10.20	3720		**9.3**	
NCRN_ANTI_SHCK	12/14/2005	8.03	5.81	7.50	3592	**0.3**	**5.4**	
NCRN_ANTI_SHCK	1/26/2006	7.83	11.55	10.40	4120	**0.3**	**11.7**	
NCRN_ANTI_SHCK	2/28/2006	8.25	8.56	10.85	4300	**0.3**	**9.9**	
NCRN_ANTI_SHCK	3/23/2006	8.36	9.00	11.50	4180	**0.3**	**9.8**	
NCRN_ANTI_SHCK	4/12/2006	8.32	**3.53**	14.30	2100	**0.3**	**14.3**	
NCRN_ANTI_SHCK	5/18/2006	8.26	**1.98**	13.30	4200	**0.3**	**8.8**	
NCRN_ANTI_SHCK	6/28/2006	8.11	8.98	16.00	4420	**0.3**	**9.0**	
NCRN_ANTI_SHCK	7/26/2006	8.26	9.33	16.60	4180	**0.3**	**10.6**	
NCRN_ANTI_SHCK	8/14/2006	7.67	8.46	17.90	3980	**0.3**	**10.2**	
NCRN_ANTI_SHCK	10/12/2006	8.22	9.32	14.30	4820	0.2	**10.3**	
NCRN_ANTI_SHCK	11/17/2006	8.26	9.27	13.05	4720	**0.3**	**10.9**	
NCRN_ANTI_SHCK	12/18/2006	8.27	8.30	13.05	4800	**0.3**	**2.1**	
NCRN_ANTI_SHCK	1/25/2007	7.38	9.90	10.10	4780	**0.3**	1.6	**1.070**
NCRN_ANTI_SHCK	2/22/2007	8.41	9.41	11.60	4820	**0.3**	**2.4**	**0.370**
NCRN_ANTI_SHCK	3/27/2007	8.30	8.98	13.10	5280	**0.3**	**5.5**	**0.150**
NCRN_ANTI_SHCK	5/16/2007	8.2	8.72	15.80	4820	**0.3**	**6.0**	**0.060**
NCRN_ANTI_SHCK	6/5/2007	8.24	7.83	15.30	4500	**0.3**	**4.4**	**0.360**
NCRN_ANTI_SHCK	7/11/2007	8	10.34	15.60	4580	**0.3**	**7.8**	**0.180**
NCRN_ANTI_SHCK	8/13/2007	8.15	8.27	17.90	4240	**0.3**	**3.9**	**0.310**
NCRN_ANTI_SHCK	8/30/2007	8.23	7.77	17.30	4440	**0.3**	**5.0**	**0.230**
NCRN_ANTI_SHCK	10/17/2007	8.24	8.66	14.40	4260	**0.3**	**5.3**	**0.220**
NCRN_ANTI_SHCK	11/14/2007	8.41	8.84	13.10	4920	**0.3**	**7.9**	**0.210**
NCRN_ANTI_SHCK	12/19/2007	8.41	10.23	9.50	5280	**0.3**	**9.3**	**0.330**
NCRN_ANTI_SHCK	1/22/2008		9.45	7.40	5140	**0.3**	**8.9**	**0.230**
NCRN_ANTI_SHCK	2/19/2008	8.1	10.69	10.30	5180	**0.3**	**8.0**	**0.300**
NCRN_ANTI_SHCK	3/20/2008	8.24	8.65	10.70	4140	**0.3**	**9.3**	**0.290**
NCRN_ANTI_SHCK	4/14/2008	8.29	11.61	12.95	5300	**0.3**	**8.3**	**0.220**
NCRN_ANTI_SHCK	5/7/2008	8.27	12.09	15.55	5320	**0.3**	**8.3**	**0.200**
NCRN_ANTI_SHCK	6/18/2008	8.07	9.91	14.82	5300	**0.3**	**7.9**	**0.170**
NCRN_ANTI_SHCK	7/30/2008	8.02	9.57	15.55	4824	**0.3**	**6.2**	**0.270**
NCRN_ANTI_SHCK	8/13/2008	7.53	9.55	14.80	4380	**0.3**	**8.0**	**0.170**
NCRN_ANTI_SHCK	9/18/2008	7.96	9.47	14.40	4800	**0.3**	**6.7**	**0.190**
NCRN_ANTI_SHCK	10/22/2008	8.21	10.44	10.80	4660	**0.3**	**6.3**	**0.230**
NCRN_ANTI_SHCK	11/19/2008	8.28	11.79	7.50	4960	**0.3**	**6.3**	**0.240**

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
ANTI data								
Site 1	3/24/2000	7.93	9.3	13.3			8.5	0.690
Site 1	4/27/2000	8.11	8.7	11.2			6.0	0.270
Site 1	5/17/2000	7.98	8.2	12.1			6.0	0.200
Site 1	5/31/2000	8.12	8.2	11.2			4.2	0.450
Site 1	6/9/2000	7.98	7.4	12.2			8.5	0.220
Site 1	6/22/2000	7.8	7.1	12.1			10.3	0.800
Site 1	7/11/2000	7.01	7.1	11.8			10.0	0.940
Site 1	7/25/2000	7.82	8.1	12.5			8.0	0.670
Site 1	8/16/2000	7.87	6.6	12.9			9.0	0.300
Site 1	9/21/2000	7.84	6.1	16			9.0	0.340
Site 1	10/20/2000	7.75	6.9	12.4			6.6	0.250
Site 1	3/15/2001	8.35		7.9			5.6	0.630
Site 1	4/19/2001	7.73	7.8	11			3.5	0.520
Site 1	5/8/2001	7.68	8	11.7			4.4	0.650
Site 1	5/23/2001	7.5	6.8	12			7.7	0.270
Site 1	6/14/2001	7.6	**4.6**	16.63			3.9	0.150
Site 1	6/29/2001	7.6	6.3	13			7.6	0.330
Site 1	7/11/2001	7.5	6.7	13			7.2	0.270
Site 1	7/24/2001	7.5	5.8	13.2			6.9	0.110
Site 1	8/15/2001	7.42	7.3	13.7			10.2	1.440
Site 1	9/19/2001	7.45	5.67	13.7			5.9	0.150
Site 1	10/12/2001	7.5	6.08	13.2			7.8	0.180
Site 1	3/14/2002	8.11	**4.88**	10			6.1	0.430
Site 1	4/5/2002	7.7	6	9			3.8	0.450
Site 1	4/23/2002	8.45	5.65	10.4			2.8	0.260
Site 1	5/8/2002	7.7	**4.04**	13			7.7	0.200
Site 1	5/29/2002	7.66	5.05	12.9			6.6	0.270
Site 1	6/12/2002	7.66	6.08	14			7.7	0.160
Site 1	6/26/2002	7.63	7.05	13.8			7.0	0.110
Site 1	7/12/2002	7.83	5.96	13.5			6.4	0.160
Site 1	7/24/2002	7.68	5.33	14			4.7	0.120
Site 1	8/14/2002	7.71	**4.42**	14.4			9.6	0.260
Site 1	9/11/2002	7.62	**3.64**	14.2			9.2	0.340
Site 1	10/21/2002	7.22	5.45	13.3			6.3	0.090
Site 1	3/17/2003	7.2	5.71	12.1			7.8	0.170
Site 1	4/7/2003	7.21	5.91	11.3			6.8	0.140
Site 1	4/23/2003	7.19	5.1	11.5			6.2	0.300
Site 1	5/8/2003	6.98	5.23	12.2			7.7	0.270
Site 1	5/20/2003	7.07	5.43	12.5			8.1	0.260
Site 1	6/10/2003	6.92	6.80	12.9			5.2	0.140
Site 1	6/24/2003	6.99	7.00	12.8			9.0	0.200
Site 1	7/7/2003	7.11	7.20	12.8			8.4	0.140
Site 1	7/21/2003	7.19	**4.18**	12.9			7.4	0.090
Site 1	8/4/2003	7.32	6.82	13.1			4.8	0.080

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
ANTI data								
Site 1	8/18/2003	7.35	**4.29**	13			5.2	0.130
Site 1	9/22/2003	7.06	**4.61**	12.9			5.1	0.170
Site 1	10/16/2003	7.2	**4.4**	13.3			4.4	0.090
Site 1	3/17/2004	7.03	6.05	10.55			5.9	0.690
Site 1	4/6/2004	7.28	6.35	11.67			4.0	0.580
Site 1	4/21/2004	7.15	6.1	11.67			5.8	0.290
Site 1	5/11/2004	7.32	5.77	12.22			6.5	0.280
Site 1	5/26/2004	7.33	6.55	12.78			7.3	0.120
Site 1	6/9/2004	7.24	6.21	12.78			7.5	0.220
Site 1	6/25/2004	7.27	7.97	12.78			5.3	0.210
Site 1	7/14/2004	7.4		13.6			5.0	0.120
Site 1	7/28/2004	7.3		12.6			9.0	0.260
Site 1	8/16/2004	7.53	7.11	14.1			7.6	0.210
Site 1	8/31/2004	7	5.52	14			8.8	0.110
Site 1	9/27/2004	6.85	5.64	13.9			6.7	0.130
Site 1	10/21/2004	7.08	6.23	12.5			7.1	0.360
Site 1	2/8/2005	7.09	8.32	11.63		**0.309**	**7.2**	**0.350**
Site 1	2/23/2005	7.26	6.59	11.66		**0.312**	**4.5**	**0.330**
Site 1	3/7/2005	7.19	7.49	11.59		**0.311**	**5.7**	**0.270**
Site 1	3/25/2005	7.21	6.57	11.27		**0.266**	**5.6**	0.160
Site 1	4/15/2005	7.05	7.07	11.86		0.241	**6.4**	**0.680**
Site 1	4/28/2005	7.30	7.85	12.83		0.238	**7.5**	**0.340**
Site 1	5/12/2005	7.35	7.76	12.75		**0.285**	**3.2**	**0.470**
Site 1	5/27/2005	7.26	7.99	12.43		**0.290**	**5.8**	**0.060**
Site 1	6/10/2005	7.45	7.17	12.52		**0.292**	**7.7**	0.380
Site 1	6/24/2005	7.28	6.91	12.67		**0.297**	**8.5**	**0.060**
Site 1	7/13/2005	7.27	6.87	12.73		**0.332**	**7.9**	**0.110**
Site 1	7/26/2005	7.11	6.12	12.84		**0.336**	**6.9**	**0.310**
Site 1	8/12/2005	7.28	6.40	12.96		**0.343**	**8.8**	**0.100**
Site 1	8/30/2005	7.20	5.78	13.16		**0.350**	**8.0**	0.030
Site 1	9/14/2005	7.38	5.73	13.12		**0.332**	**7.5**	**0.090**
Site 1	9/30/2005	7.4	6.16	12.69		**0.335**	**3.3**	**0.250**
Site 1	10/19/2005	7.24	8.2	13.05		**0.325**	**3.9**	**0.340**
Site 1	11/3/2005	7.19	7.94	13.05		**0.322**	**5.6**	**0.160**
Site 1	11/14/2005	6.86	7.27	12.96		**0.325**	**8.3**	0.170
Site 1	11/30/2005	7.08	7.25	12.75		**0.315**	**7.3**	**0.130**
Site 1	12/21/2005	**5.81**	11.63	7.98		**0.320**	**8.3**	**1.090**
Site 1	12/28/2005	7.1	6.78	12.24		**0.317**	**7.1**	**0.260**
Site 1	1/20/2006	7.12	6.71	12.2		**0.308**	**13.7**	**0.290**
Site 1	1/30/2006	7.16	7.49	12.28		**0.307**	**8.9**	0.270
Site 1	2/24/2006	7.3	7.62	11.86		**0.307**	**7.6**	**0.190**
Site 1	3/27/2006	6.82	8.18	12.04		**0.307**	**9.1**	**0.290**
Site 1	4/26/2006	6.9	6.98	12.34		**0.314**	**6.6**	**0.260**
Site 1	5/30/2006	**5.44**	7.17	12.63		**0.319**	1.2	**0.220**

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
ANTI data								
Site 1	6/29/2006	**5.22**	9.67	13.09		**0.311**	**9.2**	0.320
Site 1	7/29/2006	**4.95**	8.59	12.71		**0.319**	**11.1**	**0.190**
Site 1	8/28/2006	**5.47**	6.98	12.91		**0.329**	**10.2**	**0.240**
Site 1	9/27/2006	**5.18**	6.83	13		**0.339**	**9.8**	**0.330**
Site 1	10/30/2006	**5.74**	7.69	12.88		**0.340**	**13.7**	**0.360**
Site 1	11/28/2006	6.74	7.7	12.99		**0.330**	**10.8**	0.170
Site 1	1/9/2007	7.05	7.36	12.4		**0.323**	**6.5**	**0.480**
Site 1	1/30/2007	7.01	7.23	12.18		**0.321**	**2.1**	**2.100**
Site 1	3/6/2007	7.08	7.88	11.67		**0.315**	**6.8**	**0.170**
Site 1	3/20/2007					0.008	**10.3**	**0.050**
Site 1	4/24/2007	**6.08**	7.75	12.34		**0.298**	**14.4**	**0.120**
Site 1	5/24/2007	**5.67**	7.37	12.65		**0.298**	**9.8**	**0.240**
Site 1	6/22/2007					0.008	**12.6**	**0.230**
Site 1	7/24/2007	**5.26**	7.11	13		**0.314**	**10.4**	0.150
Site 1	8/28/2007	**5.24**	6.46	13.15		**0.326**	**11.4**	**0.200**
Site 1	9/27/2007	**5.3**	5.25	13.32		**0.332**	**11.3**	**0.250**
Site 1	10/31/2007	**6.46**	5.76	12.23		**0.344**	**7.0**	**0.080**
Site 1	11/29/2007	**5.63**	**4.71**	11.98		**0.347**	**3.9**	**0.140**
Site 1	12/21/2007	6.88	12.16	8.18		**0.305**	**10.9**	0.080
Site 1	2/5/2008	6.86	8.61	12.2		**0.326**	**3.7**	**0.230**
Site 1	2/28/2008	6.98	7.78	11.92		**0.325**	**3.0**	**0.390**
Site 1	4/7/2008	7.25	8.18	12.19		**0.305**	**6.7**	**0.060**
Site 1	4/30/2008	6.74	7.65	12.45		**0.301**	**5.5**	**0.320**
Site 1	5/23/2008	7	7.38	12.6		**0.294**	**8.1**	0.130
Site 1	6/20/2008	6.74	7.14	12.66		**0.284**	**6.8**	**0.130**
Site 1	7/22/2008	8.04	9.41	17.35		**0.304**	0.3	0.010
Site 1	8/22/2008	**6.47**	8.18	13.46		**0.311**	**3.1**	**0.210**
Site 1	9/29/2008	7.05	7.41	13.85		**0.323**	**3.4**	**0.150**
Site 1	10/30/2008	7.2	8.50	12.16		**0.327**	1.8	0.180
Site 1	11/25/2008	7.41	8.97	11.14		**0.330**	1.3	**0.210**
Site 1	12/15/2008	6.93	8.99	12.65		**0.326**	**2.4**	**0.170**
Site 2	3/24/2000	8.34	11	13.3			5.0	0.630
Site 2	4/27/2000	**8.6**	11.6	10			2.5	0.630
Site 2	5/17/2000	**8.68**	10.5	12.7			5.3	0.470
Site 2	5/31/2000	**8.82**	10.6	13.2			2.6	0.160
Site 2	6/9/2000	**8.68**	10.9	14.3			6.5	0.200
Site 2	6/22/2000	**8.54**	8	15.7			5.2	0.750
Site 2	7/11/2000	7.88	8.7	13.8			7.0	0.600
Site 2	7/25/2000	8.1	10.1	15.2			10.5	0.600
Site 2	8/16/2000	8.17	8.7	15			8.6	0.570
Site 2	9/21/2000	8.05	9.5	13.2			5.6	0.180
Site 2	10/20/2000	8.28	10.2	12.8			2.9	0.760
Site 2	3/15/2001	8.4	11.5	7.4			2.5	1.140
Site 2	4/19/2001	8.4	11.4	6.8			7.1	0.580

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 2	5/8/2001	8.49	16	11.4			4.1	1.070
Site 2	5/23/2001	8.28	9.7	13.8			0.9	**0.630**
Site 2	6/14/2001	8.16	8.8	16.5			3.5	0.140
Site 2	6/29/2001	8.1	8.6	17.5			5.2	0.460
Site 2	7/11/2001	8.39	8.82	16			7.3	0.460
Site 2	7/24/2001	8.4	8.19	18			2.9	0.300
Site 2	8/15/2001	8.22	8.08	18.7			3.3	1.530
Site 2	9/19/2001	8.2	7.86	17			3.5	0.250
Site 2	10/12/2001	8.24	8.6	12			5.6	0.370
Site 2	4/5/2002	6.95	13.2	6.9			2.5	0.610
Site 2	4/23/2002	**9.13**	11.7	9.7			1.1	**0.360**
Site 2	5/8/2002	**8.56**	20	7.61			4.1	0.340
Site 2	5/29/2002	**8.51**	8.81	17.7			0.1	**0.250**
Site 2	6/12/2002	8.43	8.84	16.8			6.8	0.320
Site 2	6/26/2002	8.38	8.97	18.1			7.7	0.140
Site 2	7/12/2002	**8.7**	9.3	16.1			2.3	0.460
Site 2	7/24/2002	8.15	8.28	19.8			1.0	**0.240**
Site 2	8/14/2002	8.47	6.11	**25.5**			4.6	0.780
Site 2	9/11/2002							0.110
Site 2	10/21/2002	7.77	10.43	12			4.0	0.260
Site 2	3/17/2003	8.06	9.12	11.12			5.4	0.650
Site 2	4/8/2003	8.08	10.48	8.7			3.7	0.190
Site 2	4/23/2003	8.09	8.39	10.9			3.5	0.150
Site 2	5/8/2003	7.84	8.11	13.7			2.0	0.270
Site 2	5/20/2003	7.72	8.92	10.7			6.4	0.100
Site 2	6/10/2003	7.41	8.70	14.1			5.3	0.300
Site 2	6/24/2003	7.62	9.30	15.2			5.8	0.300
Site 2	7/7/2003	7.87	8.80	16.9			6.5	0.260
Site 2	7/21/2003	7.95	9.39	16.6			6.3	0.250
Site 2	8/4/2003	8.02	9.26	16.2			6.8	0.300
Site 2	8/18/2003	7.97	9.15	17.2			4.4	0.210
Site 2	9/22/2003	7.57	9.14	16.5			4.7	0.190
Site 2	10/16/2003	7.83	10.03	13.8			5.1	0.190
Site 2	3/17/2004	7.9	10.9	7.78			2.5	0.450
Site 2	4/6/2004	8.15	11.09	10			9.8	0.330
Site 2	4/21/2004	7.97	10.1	12.22			6.6	0.310
Site 2	5/11/2004	7.99	9.57	14.44			6.7	0.130
Site 2	5/26/2004	7.96	8.47	15.56			5.9	0.010
Site 2	6/9/2004	7.84	8.28	17.22			5.4	0.090
Site 2	6/25/2004	7.97	8.77	15.56			6.5	0.220
Site 2	7/14/2004	8.1		17			6.3	0.140
Site 2	7/28/2004	7.88		16.1			3.8	0.260
Site 2	8/16/2004	8	9.33	17.9			5.8	0.170
Site 2	8/31/2004	7.39	6.49	20.9			3.0	0.190

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 2	9/27/2004	7.66	8.83	16.8			5.1	0.200
Site 2	10/21/2004	7.72	8.54	13			3.6	0.440
Site 2	2/8/2005	8.08	14.63	8.91		**0.309**	**5.8**	0.010
Site 2	2/23/2005	7.72	11.41	7.79		**0.315**	**3.5**	0.220
Site 2	3/7/2005	8.15	12.02	8.31		**0.315**	**2.7**	**0.410**
Site 2	3/25/2005	6.98	11.21	8.83		**0.255**	**3.0**	**0.170**
Site 2	4/15/2005	7.94	11.19	10.98		0.244	**3.9**	**0.800**
Site 2	4/28/2005	8.16	10.29	13.16		0.248	**4.5**	**0.630**
Site 2	5/12/2005	7.45	10.20	11.96		**0.295**	1.3	0.640
Site 2	5/27/2005	8.16	10.30	14.64		**0.295**	**3.4**	**0.283**
Site 2	6/10/2005	8.07	9.05	17.28		**0.299**	**4.6**	**0.060**
Site 2	6/24/2005	8.09	8.80	17.11		**0.302**	**5.4**	**0.680**
Site 2	7/13/2005	8.03	8.43	19.19		**0.341**	**4.1**	**0.320**
Site 2	7/26/2005	8.05	8.15	20.05		**0.342**	**4.0**	0.270
Site 2	8/12/2005	8.04	8.46	20.09		**0.348**	**6.1**	**0.220**
Site 2	8/30/2005	8.01	8.38	19.68		**0.354**	**2.7**	**0.280**
Site 2	9/14/2005	8.16	8.75	17.97		**0.332**	**7.2**	**0.300**
Site 2	9/30/2005	8.14	10.2	13.57		**0.335**	0.5	**0.260**
Site 2	10/19/2005	7.7	10.42	12.91		**0.324**	1.8	0.180
Site 2	11/3/2005	7.26	10.55	11.7		**0.316**	**5.7**	**0.038**
Site 2	11/14/2005	7.67	9.72	12.37		**0.327**	**5.1**	**0.230**
Site 2	11/30/2005	7.61	9.9	11.7		**0.286**	**4.6**	**0.330**
Site 2	12/21/2005	7.11	7.19	12.26		**0.321**	**2.9**	**0.180**
Site 2	12/28/2005	7.86	10.63	9.06		**0.317**	**6.7**	0.360
Site 2	1/20/2006	7.56	10.57	9.46		0.205	0.8	**0.240**
Site 2	1/30/2006	8.06	11.09	10.16		**0.306**	**8.6**	**0.240**
Site 2	2/24/2006	**5.79**	12.58	6.33		**0.289**	**7.8**	**0.260**
Site 2	3/27/2006	**6.35**	12.11	9.17		**0.306**	**8.6**	**0.330**
Site 2	4/26/2006	6.75	10.64	11.24		**0.313**	**5.6**	0.370
Site 2	5/30/2006	6.84	9.15	16.42		**0.320**	**2.0**	**0.230**
Site 2	6/29/2006	**5.93**	8.93	16.95		**0.303**	**8.5**	**0.310**
Site 2	7/29/2006	**6.19**	9.28	18.63		**0.322**	**10.9**	**0.290**
Site 2	8/28/2006	**6.39**	8.85	19.15		**0.334**	**8.0**	**0.210**
Site 2	9/27/2006	6.59	9.94	14.36		**0.340**	**7.7**	0.310
Site 2	10/30/2006	**6.16**	9.68	13.01		**0.327**	**9.5**	**0.340**
Site 2	11/28/2006	6.77	10.96	12.28		**0.322**	**7.8**	**0.200**
Site 2	1/9/2007	7.31	11.37	9.06		**0.315**	**5.4**	**0.660**
Site 2	1/30/2007	7.74	12.2	6.12		**0.321**	**7.4**	**0.200**
Site 2	3/6/2007	7.58	13.03	5.37		**0.315**	**7.2**	0.820
Site 2	3/20/2007					0.008	**6.3**	**0.230**
Site 2	4/24/2007	6.88	10.38	13.66		**0.303**	**8.2**	**0.160**
Site 2	5/24/2007	6.65	9.94	13.97		0.302	7.2	0.190
Site 2	6/22/2007					0.008	**8.6**	**0.160**
Site 2	7/24/2007	6.82	9.24	17.24		**0.314**	**8.1**	**0.260**

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 2	8/28/2007	**6.46**	8.82	18.5		**0.327**	**9.1**	**0.070**
Site 2	9/27/2007	6.74	7.97	18.44		**0.327**	**3.7**	**0.210**
Site 2	10/31/2007	6.5	10.71	10.28		**0.339**	**4.7**	0.010
Site 2	11/29/2007	**5.98**	10.48	7.37		**0.339**	**3.7**	**0.100**
Site 2	12/21/2007	7.6	11.71	9.54		**0.315**	**4.4**	**0.110**
Site 2	2/5/2008	**6.49**	12.3	10.09		**0.314**	**3.2**	**0.130**
Site 2	2/28/2008	7.76	11.97	6.91		**0.320**	**3.6**	**0.230**
Site 2	4/7/2008	7.7	11.14	10.2		**0.306**	**6.0**	0.160
Site 2	4/30/2008	7.21	10.39	11.48		**0.303**	**4.1**	**0.250**
Site 2	5/23/2008	7.64	10.13	13.01		**0.297**	**6.1**	**0.060**
Site 2	6/20/2008	8.16	9.13	17.22		**0.297**	0.3	**0.180**
Site 2	7/22/2008	7.09	8.29	12.64		**0.294**	**4.0**	**0.180**
Site 2	8/22/2008	8.14	9.55	16.51		**0.282**		0.210
Site 2	9/29/2008	8.21	9.2	17.45		**0.324**	1.6	**0.210**
Site 2	10/30/2008	7.19	11.07	7.71		**0.332**	0.0	**0.120**
Site 2	11/25/2008	7.97	12.74	5.12		**0.332**	0.3	**0.440**
Site 2	12/15/2008	7.54	10.33	11.84		**0.312**	1.6	**0.200**
Site 3	3/24/2000	8.4	11.2	14			4.3	0.540
Site 3	4/27/2000	**8.55**	11	9			3.1	0.500
Site 3	5/17/2000	8.46	9.9	14			6.5	0.380
Site 3	5/31/2000	8.38	9.3	13.9			3.4	0.280
Site 3	6/9/2000	8.34	10.2	13.9			6.5	0.740
Site 3	6/22/2000	8.25	8	16			5.6	0.740
Site 3	7/11/2000	7.93	7.8	17.5			5.1	1.450
Site 3	7/25/2000	7.9	8.8	18.7			9.3	0.350
Site 3	8/16/2000	7.94	8.3	17.4			5.8	0.140
Site 3	9/21/2000	8.05	9	13.6			6.8	0.160
Site 3	10/20/2000	8.29	9.8	11.4			6.1	0.440
Site 3	3/15/2001	8.3	-	6.9			4.3	1.030
Site 3	4/19/2001	8.28	-	10.8			2.9	0.320
Site 3	5/8/2001	8.2	9.8	12			3.4	0.430
Site 3	5/23/2001	8.03	8.5	14.7			5.9	0.540
Site 3	6/14/2001	8	8.2	17.4			4.6	0.300
Site 3	6/29/2001	8	8.6	17.5			3.1	0.240
Site 3	7/11/2001	8.07	8.12	17.3			5.5	0.290
Site 3	7/24/2001	**8.9**	7.6	18			3.4	0.160
Site 3	8/15/2001	8.07	7.4	19.6			2.7	0.370
Site 3	9/19/2001	8.17	8.01	18.8			4.1	0.320
Site 3	4/5/2002	**8.57**	15.47	7.7			1.5	**0.500**
Site 3	4/23/2002	**8.75**	12.33	10.5			3.3	0.310
Site 3	5/8/2002	8.42	8.43	18.3			**6.5**	0.030
Site 3	5/29/2002	8.22	9.35	14.8			4.4	0.180
Site 3	6/12/2002	8.16	8.55	16.8			8.3	0.020
Site 3	6/26/2002	8.07	8.22	18.1			8.7	0.210

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 3	7/12/2002	8.28	8	17.9			3.3	0.220
Site 3	7/24/2002	7.96	7.34	19.2			1.9	**0.300**
Site 3	8/14/2002	8.18	6.39	**24**			2.4	0.260
Site 3	9/11/2002	0		0			6.2	0.320
Site 3	10/21/2002	7.82	9.04	12.7			6.9	0.200
Site 3	3/17/2003	8.06	10	11.1			6.6	0.150
Site 3	4/8/2003	8.36	10.58	8.4			6.2	0.150
Site 3	4/23/2003	8.19	7.9	12.6			4.7	1.370
Site 3	5/8/2003	7.9	8.16	14.4			1.1	0.150
Site 3	5/20/2003	7.77	8.91	13.1			6.4	0.110
Site 3	6/10/2003	7.56	9.50	14.4			7.0	0.230
Site 3	6/24/2003	7.77	9.70	15.7			5.6	0.230
Site 3	7/7/2003	7.96	9.60	17.8			5.4	0.250
Site 3	7/21/2003	8	6.85	22.1			3.9	0.290
Site 3	8/4/2003	8.15	8.11	19			4.2	0.250
Site 3	8/18/2003	8.05	9.06	18.4			3.1	0.110
Site 3	9/22/2003	7.77	9.55	17.3			4.2	0.250
Site 3	10/16/2003	7.98	14.5	10.37			7.3	0.380
Site 3	3/17/2004	8.28	11	7.22			1.0	0.760
Site 3	4/9/2004	8.22	10.94	11.67			5.7	0.380
Site 3	4/21/2004	8.18	10.24	12.22			9.1	0.300
Site 3	5/11/2004	8.19	9.35	15.56			6.7	0.170
Site 3	5/26/2004	8.09	8.75	17.22			5.6	0.180
Site 3	6/9/2004	8.01	8.43	17.22			6.0	0.180
Site 3	6/25/2004	8.08	8.58	17.78			5.6	0.220
Site 3	7/14/2004	8.08		18.9			6.2	0.270
Site 3	7/28/2004	7.91		18.6			7.4	0.290
Site 3	8/16/2004	8.08	11.44	16.9			5.4	0.240
Site 3	8/31/2004	7.92	8.67	20.3			3.7	0.310
Site 3	9/27/2004	7.76	9.3	17			**6.0**	0.010
Site 3	10/21/2004	7.77	9.3	12.7			4.0	0.590
Site 3	2/8/2005	8.37	14.97	9.08		**0.301**	**6.6**	**0.320**
Site 3	2/23/2005	7.7	11.94	6.5		**0.309**	**2.1**	**0.190**
Site 3	3/7/2005	8.13	12.39	7.72		**0.302**	**2.4**	0.260
Site 3	3/25/2005	7.9	11.93	8.57		0.247	**3.1**	**0.090**
Site 3	4/15/2005	8.17	10.68	13.05		0.236	**6.7**	**0.710**
Site 3	4/28/2005	8.27	10.52	14.14		0.238	**5.0**	**0.170**
Site 3	5/12/2005	8.09	10.38	11.85		**0.290**	**2.5**	**0.480**
Site 3	5/27/2005	8.04	10.21	15.05		0.167	1.5	0.077
Site 3	6/10/2005	7.99	8.64	18.33		**0.299**	**3.6**	**0.240**
Site 3	6/24/2005	8.01	8.77	19.78		**0.304**	**3.2**	**0.410**
Site 3	7/13/2005	8.06	8.56	21.24		**0.339**	**2.4**	**0.330**
Site 3	7/26/2005	8.07	8.36	21.60		**0.342**	1.6	**0.210**
Site 3	8/12/2005	7.93	7.20	23.51		**0.350**	**3.0**	0.370

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
ANTI data								
Site 3	8/30/2005	8.08	7.90	21.03		**0.351**	**3.4**	**0.260**
Site 3	9/14/2005	8.25	8.78	19.90		**0.330**	**5.6**	**0.110**
Site 3	9/30/2005	8.2	9.37	19.75		**0.337**	**3.3**	**0.640**
Site 3	10/19/2005	8.14	11.04	10.96		**0.439**	**2.5**	**0.100**
Site 3	11/3/2005	8.04	10.69	12.45		**0.307**	**11.4**	0.090
Site 3	11/14/2005	7.98	10.13	12.89		**0.321**	**5.1**	**0.090**
Site 3	11/30/2005	7.69	10.04	11.94		**0.281**	**3.2**	**0.230**
Site 3	12/21/2005	7.69	12.93	6.3		**0.312**	1.0	**0.470**
Site 3	12/28/2005	8.06	11.59	8.63		**0.307**	**7.1**	**0.190**
Site 3	1/20/2006	7.55	10.16	9.54		**0.297**	**12.8**	0.320
Site 3	1/30/2006	8.1	11.31	10.29		**0.298**	**7.1**	**0.180**
Site 3	2/24/2006	7.62	12.62	6.5		**0.291**	**5.7**	**0.370**
Site 3	3/27/2006	**6.1**	12.65	10.66		**0.276**	**6.3**	**0.350**
Site 3	4/26/2006	7.93	10.58	12.21		**0.308**	**4.3**	**0.190**
Site 3	5/30/2006	**6.1**	8.05	18.9		**0.322**	**7.7**	0.480
Site 3	6/29/2006	**5.7**	9.16	17.19		**0.298**	**9.9**	**0.200**
Site 3	7/29/2006	6.81	8.91	21.01		**0.319**	**6.9**	**0.280**
Site 3	8/28/2006	6.87	8.26	21.6		**0.327**	**7.9**	**0.320**
Site 3	9/27/2006	**6.22**	7.39	16.74		**0.346**	**6.5**	**1.230**
Site 3	10/30/2006	**6.46**	9.62	13.77		**0.321**	**8.7**	0.280
Site 3	11/28/2006	7.68	11.02	12.34		**0.315**	**8.1**	**0.250**
Site 3	1/9/2007	7.73	11.77	9.25		**0.310**	**5.9**	**0.510**
Site 3	1/30/2007	7	13.46	4.92		**0.317**	**15.4**	**0.230**
Site 3	3/6/2007	7.13	13.04	6.5		**0.294**	**6.5**	**0.480**
Site 3	3/20/2007					0.008	**7.0**	**0.160**
Site 3	4/24/2007	6.95	10.48	14.17		**0.292**	**9.6**	**0.150**
Site 3	5/24/2007	6.92	9.47	16.65		**0.297**	**6.4**	**0.150**
Site 3	6/22/2007					0.008	**4.2**	0.150
Site 3	7/24/2007	7.4	8.95	20.9		**0.305**	**8.6**	**0.520**
Site 3	8/28/2007	7.24	9.05	20.34		**0.330**	**8.2**	**0.040**
Site 3	9/27/2007	6.78	7.8	20.95		**0.312**	**5.7**	**0.810**
Site 3	10/31/2007	7.88	9.78	15.94		**0.342**	**6.0**	**0.480**
Site 3	11/29/2007	6.75	10.53	10.56		**0.345**	**3.7**	0.160
Site 3	12/21/2007	6.88	12.16	8.18		**0.305**	**5.7**	**0.210**
Site 3	2/5/2008	7.2	12.73	9.1		**0.286**	**5.0**	**0.100**
Site 3	2/28/2008	6.93	12.72	6.37		**0.310**	**6.8**	**0.200**
Site 3	4/7/2008	7.92	11.79	9.71		**0.297**	**2.8**	**0.170**
Site 3	4/30/2008	7.98	10.74	11.86		**0.287**	**5.4**	0.410
Site 3	5/23/2008	7.99	9.76	14.2		**0.284**	**5.9**	0.010
Site 3	6/20/2008	8.12	9.08	18.49		**0.294**	**4.5**	**0.080**
Site 3	7/22/2008	8.1	9.27	20.18		**0.300**	**2.8**	**0.270**
Site 3	8/22/2008	8.16	9.65	17.97		**0.311**	**3.8**	**0.210**
Site 3	9/29/2008	7.86	6.45	18.63		**0.327**	1.3	0.270
Site 3	10/30/2008	8.02	11.29	8.73		**0.332**	**2.2**	**0.210**

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 3	11/25/2008	8.14	12.99	6.45		**0.327**	0.8	**0.260**
Site 3	12/25/2008	7.57	10.54	11.91		**0.304**	0.3	**0.240**
Site 4	3/24/2000	8.35	9.1	11.2			4.4	0.570
Site 4	4/27/2000	7.9	8.5	11.4			4.8	0.450
Site 4	5/17/2000	7.59	9.4	14			7.7	0.380
Site 4	5/31/2000	7.84	8.3	13.4			3.5	0.220
Site 4	6/9/2000	7.9	8.2	14.2			5.5	0.300
Site 4	6/22/2000	7.78	7	14.2			7.7	0.510
Site 4	7/11/2000	7.86	8.4	17.3			7.4	0.570
Site 4	7/25/2000	7.44	8.4	15.6			6.7	0.690
Site 4	8/16/2000	7.37	5.8	17			7.9	0.230
Site 4	9/21/2000	7.58	6.7	15.5			7.5	0.300
Site 4	10/20/2000	7.9	7.9	14.9			5.1	0.550
Site 4	3/15/2001	8.34	11.5	8.4			1.1	0.950
Site 4	4/19/2001	8.17	10.3	14.5			4.3	0.500
Site 4	5/8/2001	8.4	10.4	12.7			2.8	0.320
Site 4	5/23/2001	8.38	14.8	14.9			2.0	0.410
Site 4	6/14/2001	8.17	9	19.3			3.3	0.200
Site 4	6/29/2001	8.2	8.9	15.9			3.2	0.180
Site 4	7/11/2001	8.35	8.80	15.1			2.6	0.170
Site 4	7/24/2001	8.25	8.73	18			1.4	**0.120**
Site 4	8/15/2001	8.15	8.76	18.8			1.9	**0.320**
Site 4	9/19/2001	8.35	9.8	14.9			1.7	**0.180**
Site 4	10/12/2001	8.32	9.65	10.7			2.9	0.180
Site 4	3/14/2002	8.27	14.85	9.3			2.8	1.310
Site 4	4/5/2002	8.45	15	9.3			1.3	**0.080**
Site 4	4/23/2002	**8.96**	13.05	11.7			2.1	0.150
Site 4	5/8/2002	**8.93**	10.1	15.4			3.5	0.100
Site 4	5/29/2002	**8.92**	7.67	20.1			4.6	0.090
Site 4	6/12/2002	**8.89**	9.36	16.4			2.0	0.080
Site 4	6/26/2002	**8.86**	7.32	22.3			2.2	0.170
Site 4	7/12/2002	**9.02**	9.85	15.2			1.8	**0.160**
Site 4	7/24/2002	8.23	7.88	20.8			1.2	**0.060**
Site 4	8/14/2002	**8.77**	6.89	21.8			0.7	0.270
Site 4	9/11/2002	**8.76**	5.84	21.7			0.3	**0.130**
Site 4	10/21/2002	8.05	10.12	11.6			2.5	0.450
Site 4	3/17/2003	7.97	10.33	14.7			2.9	0.110
Site 4	4/8/2003	8.27	9.47	10.5			2.3	0.490
Site 4	4/23/2003	7.93	8.88	11.1			4.8	0.170
Site 4	5/8/2003	7.91	8.33	13.2			2.7	0.450
Site 4	5/20/2003	7.74	8.86	12.8			3.1	0.390
Site 4	6/10/2003	7.5	10.10	14.8			3.3	0.050
Site 4	6/24/2003	7.74	10.10	15.4			2.9	0.130
Site 4	7/7/2003	7.71	9.70	14.3			3.0	0.100

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
ANTI data								
Site 4	7/21/2003	8.02	9.34	16			2.1	0.140
Site 4	8/4/2003	8.15	9.59	15.9			0.8	**0.120**
Site 4	8/18/2003	8.14	9.64	15.6			0.3	**0.100**
Site 4	9/22/2003	7.75	9.95	14.2			3.1	0.090
Site 4	10/16/2003	7.74	10.34	11.3			2.6	0.390
Site 4	3/17/2004	8.12	10.61	9.44			2.0	0.360
Site 4	4/6/2004	8.3	10.42	14.4			2.3	0.300
Site 4	4/21/2004	7.97	10.38	12.78			5.4	0.150
Site 4	5/11/2004	8.03	9.41	14.44			2.5	0.180
Site 4	5/26/2004	7.77	8.88	14.44			3.5	0.090
Site 4	6/9/2004	7.83	9.19	13.33			4.2	0.320
Site 4	6/25/2004	7.87	8.84	14.44			2.8	0.190
Site 4	7/14/2004	8.07		15.4			1.9	**0.140**
Site 4	7/28/2004	7.99		16.3			1.8	**0.510**
Site 4	8/16/2004	8.16	13.04	16.5			1.5	0.230
Site 4	8/31/2004	7.92	8.46	19			0.6	**0.430**
Site 4	9/27/2004	7.82	9.64	16.8			1.2	**0.210**
Site 4	10/21/2004	7.95	8.94	12.1			3.2	0.240
Site 4	2/8/2005	8.1	13.9	11.28		**0.369**	**2.7**	**0.340**
Site 4	2/23/2005	8.06	11.31	8.55		**0.325**	1.0	0.140
Site 4	3/7/2005	8.13	11.77	9.77		**0.388**	1.5	**0.140**
Site 4	3/25/2005	7.91	10.79	10.49		**0.327**	1.6	**0.090**
Site 4	4/15/2005	**11.32**	8.01	13.84		**0.310**	**3.2**	**0.500**
Site 4	4/28/2005	8.08	10.01	15.16		**0.308**	**2.4**	**0.330**
Site 4	5/12/2005	8.09	10.54	12.02		**0.365**	0.7	0.360
Site 4	5/27/2005	8.10	10.77	14.31		**0.374**	1.0	0.010
Site 4	6/10/2005	8.10	9.48	17.27		**0.376**	**2.1**	0.010
Site 4	6/24/2005	8.13	9.69	17.04		**0.373**	1.3	**0.270**
Site 4	7/13/2005	8.08	9.41	17.78		**0.437**	**2.0**	**0.430**
Site 4	7/26/2005	8.00	9.07	16.67		**0.426**	**3.4**	0.370
Site 4	8/12/2005	8.06	9.20	17.98		**0.427**	1.6	**0.100**
Site 4	8/30/2005	8.13	9.23	18.86		**0.422**	1.8	**0.070**
Site 4	9/14/2005	8.03	9.23	15.66		**0.400**	**8.0**	**0.220**
Site 4	9/30/2005	7.98	11.16	10.67		**0.399**	**2.0**	**0.410**
Site 4	10/19/2005	8.14	11.04	10.96		**0.439**	**2.5**	0.100
Site 4	11/3/2005	7.74	11.18	9.94		**0.416**	**9.5**	**0.330**
Site 4	11/14/2005	7.92	10.87	11.33		**0.411**	**2.1**	**0.170**
Site 4	11/30/2005	7.21	10.31	11.24		**0.402**	**3.0**	**0.330**
Site 4	12/21/2005	8.1	12.7	6.73		**0.389**	1.7	**1.170**
Site 4	12/28/2005	**6.46**	11.43	7.55		**0.404**	**4.3**	0.340
Site 4	1/30/2006	8.08	11.62	9.82		**0.384**	**3.1**	**0.200**
Site 4	2/24/2006	8.22	12.15	9.07		**0.374**	**3.0**	**0.230**
Site 4	3/27/2006	**5.95**	14.16	7.28		**0.364**	**2.9**	**0.330**
Site 4	4/26/2006	6.77	11.29	13.67		**0.386**	**3.6**	**0.190**

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 4	5/30/2006	**6.46**	9.53	17.96		**0.393**	1.9	0.190
Site 4	6/29/2006	6.52	9.22	14.27		**0.386**	**4.4**	**0.440**
Site 4	7/29/2006	**6.22**	9.62	17.13		**0.392**	**2.7**	**0.180**
Site 4	8/28/2006	6.65	8.53	19.05		**0.389**	**2.7**	**0.320**
Site 4	9/27/2006	**6.47**	9.58	14.17		**0.412**	**2.1**	**0.260**
Site 4	10/30/2006	**6.22**	10.96	10.16		**0.412**	**5.5**	0.160
Site 4	11/28/2006	7.54	10.9	12.42		**0.398**	**7.8**	**0.200**
Site 4	1/9/2007	6.65	11.3	8.99		**0.383**	**5.0**	**0.540**
Site 4	1/30/2007	6.85	12.51	5.09		**0.380**	**8.2**	**0.350**
Site 4	3/6/2007	7.14	11.92	9.72		**0.389**	1.1	**0.430**
Site 4	3/20/2007					0.008	**3.5**	**0.220**
Site 4	4/24/2007	7.08	10.59	15.3		**0.377**	**3.7**	**0.210**
Site 4	5/24/2007	6.88	9.78	13.84		**0.378**	**3.7**	**0.080**
Site 4	6/22/2007					0.008	**3.1**	0.200
Site 4	7/24/2007	6.95	8.83	17.72		**0.366**	**3.0**	**0.160**
Site 4	8/28/2007	7.01	7.42	18.37		**0.429**	**2.2**	**0.120**
Site 4	9/27/2007	7.53	5.91	19.11		**0.463**		0.150
Site 4	10/31/2007	**6.17**	10.69	7.79		**0.345**	1.5	**0.150**
Site 4	11/29/2007	**6.25**	11.78	6.67		**0.438**	1.1	0.330
Site 4	12/21/2007	7.63	12.37	8.84		**0.452**	**2.6**	**0.060**
Site 4	2/5/2008	6.53	11.71	8.8		**0.436**	1.6	**0.130**
Site 4	2/28/2008	7.75	11.77	7.22		**0.417**	**2.0**	**0.260**
Site 4	4/7/2008	8.17	11.48	10.86		**0.396**	0.9	**0.160**
Site 4	4/30/2008	8.01	12.75	12.66		**0.398**	1.5	0.320
Site 4	5/23/2008	7.96	9.98	14.65		**0.387**	**3.2**	**0.090**
Site 4	6/20/2008	8	9.56	16.39		**0.386**	**3.0**	**0.060**
Site 4	7/22/2008	7.97	8.64	18.57		**0.411**	0.8	**0.160**
Site 4	8/22/2008	7.91	9.71	15.3		**0.254**	0.2	**0.200**
Site 4	9/29/2008	7.94	8.84	17.44		**0.417**	**2.1**	0.540
Site 4	10/30/2008	7.71	11.04	7.22		**0.418**	0.5	**0.130**
Site 4	11/25/2008	8.01	13.27	4.76		**0.427**	0.0	**0.070**
Site 4	12/15/2008	7.72	10.86	10.46		**0.439**	1.1	**0.240**
Site 5	3/24/2000	7.9	11.1	11.2			5.2	1.200
Site 5	4/27/2000	8.29	12.1	12			7.4	0.570
Site 5	5/17/2000	7.93	8.9	18.2			8.2	0.710
Site 5	5/31/2000	7.96	7	15.7			5.6	0.520
Site 5	6/9/2000	8.07	8.2	17.7			3.4	0.310
Site 5	6/22/2000	7.96	7.3	16.1			7.1	1.190
Site 5	7/11/2000	7.5	**4.6**	17.7			4.9	0.430
Site 5	7/25/2000	7.7	10.9	18.8			8.4	0.960
Site 5	8/16/2000	7.57	7.9	20			4.6	0.580
Site 5	9/21/2000	7.64	7.2	15.9			5.7	0.380
Site 5	10/20/2000	7.75	11.4	19.2			4.5	0.170
Site 5	3/15/2001	7.94	12.4	6.2			4.2	0.480

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
ANTI data								
Site 5	4/19/2001	7.95	11.2	11.5			7.7	0.790
Site 5	5/8/2001	7.9	7.2	10.5			4.1	0.500
Site 5	5/23/2001	7.85	6.8	11.8			5.9	0.670
Site 5	6/14/2001	7.8	9.8	15.2			13.2	1.810
Site 5	6/29/2001	7.46	7.83	16.3			8.6	0.320
Site 5	7/11/2001	7.85	6.5	15.4			6.4	0.410
Site 5	8/15/2001	7.6	**4.77**	19.4			4.8	0.280
Site 5	9/19/2001	7.88	7.11	17.7			3.6	0.170
Site 5	10/12/2001	8.15	7.66	14			5.5	0.240
Site 5	4/5/2002	8.25	13.68	8.7			6.3	0.360
Site 5	4/23/2002	**8.69**	12.12	12.2			2.1	0.170
Site 5	5/8/2002	7.97	9.27	16.2			1.4	**0.250**
Site 5	5/29/2002	7.75	10.19	14.8			3.2	0.500
Site 5	6/12/2002	7.85	7.88	18.8			6.2	0.220
Site 5	6/26/2002	7.68	8.89	18.8			11.0	0.140
Site 5	7/12/2002	8.38	10	18			5.3	0.380
Site 5	7/24/2002	7.77	7.4	20.4			9.9	0.200
Site 5	8/14/2002	7.92	5.98	22.7			9.2	0.150
Site 5	9/11/2002	8.22	7.27	20			8.9	0.080
Site 5	10/21/2002	6.86	9.08	16			4.8	0.290
Site 5	3/17/2003	7.18	8.62	10.1			6.6	0.210
Site 5	4/8/2003	7.52	8.51	10.1			7.8	0.270
Site 5	4/23/2003	7.37	7.63	11			5.1	0.210
Site 5	5/8/2003	7.13	8.48	13.1			10.0	0.190
Site 5	5/20/2003	6.94	7.82	12.1			8.7	0.200
Site 5	6/10/2003	7.19	6.6	13.2			6.9	0.460
Site 5	6/24/2003	7.12	7.50	13.6			9.0	0.220
Site 5	7/7/2003	7.02	7.80	14.8			9.6	0.060
Site 5	7/21/2003	7.17	8.58	16.8			9.0	0.220
Site 5	8/4/2003	7.33	7.49	17.8			5.9	0.240
Site 5	8/18/2003	7.06	7.97	17.2			7.8	0.220
Site 5	9/22/2003	6.9	7.44	16.6			7.7	0.160
Site 5	10/16/2003	7.14	7.35	17.6			6.6	0.100
Site 5	3/17/2004	7.96	10.2	10.55			4.9	0.590
Site 5	4/6/2004	7.34	12	12.22			2.5	0.590
Site 5	4/21/2004	7.37	10	11.67			8.5	0.140
Site 5	5/11/2004	7.31	8.45	11.67			7.7	0.280
Site 5	5/26/2004	7.28	7.68	13.33			**8.1**	0.020
Site 5	6/9/2004	7.18	7.87	13.33			5.1	0.260
Site 5	6/25/2004	7.14	7.45	14.44			7.2	0.110
Site 5	7/14/2004	7.34		19.1			7.8	0.200
Site 5	7/28/2004	7.39		18.4			7.0	0.260
Site 5	8/16/2004	7.54	6.56	20.2			6.4	0.240
Site 5	8/31/2004	7.33	5.53	21.9			5.6	0.340

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 5	9/27/2004	7.12	9.24	18.3			4.6	0.100
Site 5	10/21/2004	6.95	7.18	15.8			5.3	0.310
Site 5	2/8/2005	7.28	12.53	10.31		**0.419**	**6.5**	**0.210**
Site 5	2/23/2005	6.57	9.93	9.28		**0.411**	**3.7**	**0.390**
Site 5	3/7/2005	6.89	9.26	9.7		**0.413**	**3.9**	**0.130**
Site 5	3/25/2005	6.97	9.2	10.53		**0.315**	**5.2**	0.330
Site 5	4/15/2005	**5.54**	9.08	10.72		**0.308**	**4.8**	**0.310**
Site 5	4/28/2005	**6.28**	10.84	12.40		**0.315**	**6.2**	**0.290**
Site 5	5/12/2005	6.66	10.19	11.95		**0.381**	**3.7**	**0.420**
Site 5	5/27/2005	7.44	10.68	13.29		**0.379**	1.8	**0.290**
Site 5	6/10/2005	6.98	8.81	16.56		**0.395**	**4.7**	0.050
Site 5	6/24/2005	7.60	8.40	18.23		**0.394**	**5.4**	**0.240**
Site 5	7/13/2005	7.02	8.83	16.67		**0.453**	**5.7**	**0.270**
Site 5	7/26/2005	7.25	7.94	18.46		**0.448**	**3.8**	**0.610**
Site 5	8/12/2005	7.31	7.61	20.77		**0.464**	**4.2**	**0.120**
Site 5	8/30/2005	7.52	7.27	21.50		**0.460**	**3.5**	0.390
Site 5	9/14/2005	7.82	7.37	20.21		**0.426**	**3.1**	**0.370**
Site 5	9/30/2005	8	8.29	16.64		**0.401**	1.0	0.030
Site 5	10/19/2005	7.48	9.5	15.95		**0.449**	**2.7**	**0.250**
Site 5	11/3/2005	6.94	9.12	15.41		**0.437**	**5.7**	**0.100**
Site 5	11/14/2005	7.57	10.67	15.04		**0.436**	**4.1**	0.270
Site 5	11/30/2005	**5.6**	9.06	11.68		**0.383**	0.0	**1.540**
Site 5	12/21/2005	**6.07**	10.1	11.64		**0.431**	0.4	**1.300**
Site 5	12/28/2005	7.1	7.59	11.76		**0.262**	**7.3**	**0.260**
Site 5	1/20/2006	7.07	11.29	11.77		**0.384**	**8.1**	**0.450**
Site 5	1/20/2006	**6.35**	8.25	9.2		**0.389**	**4.2**	0.250
Site 5	1/30/2006	7.23	9.81	11.55		**0.393**	**8.0**	**0.150**
Site 5	2/24/2006	**6.27**	10.72	9.51		**0.400**	**10.1**	**0.160**
Site 5	3/27/2006	**6.3**	12.73	10.21		**0.399**	**7.8**	
Site 5	4/26/2006	**5.97**	10.74	11.35		**0.413**	**6.3**	**0.430**
Site 5	5/30/2006	6.52	9.1	16.21		**0.418**	**8.4**	0.070
Site 5	6/29/2006	**5.76**	8.17	15.36		**0.384**	**9.0**	**0.260**
Site 5	7/29/2006	**5.49**	9.66	18.9		**0.413**	**6.4**	**0.600**
Site 5	8/28/2006	**6.31**	7.38	20.39		**0.415**	**9.7**	**0.370**
Site 5	9/27/2006	**5.61**	8.92	16.83		**0.432**	**4.9**	**0.160**
Site 5	10/30/2006	7.03	8.85	15.69		**0.419**	**9.9**	0.300
Site 5	11/28/2006	**6.34**	9.11	14.18		**0.401**	**6.2**	**0.120**
Site 5	1/9/2007	6.92	7.86	12.47		**0.407**	**5.5**	**0.700**
Site 5	1/30/2007	**5.92**	9.73	9.68		**0.410**	**5.1**	**0.500**
Site 5	3/6/2007	**6.28**	10.1	9.53		**0.376**	**2.3**	**0.270**
Site 5	3/20/2007					0.008	**8.5**	**0.190**
Site 5	4/24/2007	**5.74**	8.85	11.36		**0.386**	**10.0**	**0.190**
Site 5	5/24/2007	**6.06**	10	13.42		**0.402**	**11.9**	**0.050**
Site 5	6/22/2007					0.008	**9.6**	0.420

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 5	7/24/2007	**6.42**	**4.92**	20.27		**0.405**	**7.6**	**2.150**
Site 5	8/28/2007	**5.84**	8.34	19.38		**0.459**	**8.3**	**0.730**
Site 5	9/27/2007	7.51	12.01	23.77		**0.425**	**9.8**	**0.200**
Site 5	10/31/2007	**6.07**	9.67	15.62		**0.463**	**7.3**	**0.260**
Site 5	11/29/2007	**6.39**	10.29	12.09		**0.458**	**4.2**	0.350
Site 5	12/21/2007	**6.04**	9.47	12.93		**0.424**	**2.9**	**0.080**
Site 5	2/5/2008	6.84	10.09	11.13		**0.425**	1.2	**0.370**
Site 5	2/28/2008	**6.08**	9.93	9.98		**0.445**	**4.0**	**0l.17**
Site 5	4/7/2008	**5.49**	10.03	10.55		**0.408**	**5.1**	**0.100**
Site 5	4/30/2008	6.64	9.34	11.87		**0.388**	**5.9**	0.210
Site 5	5/23/2008	6.7	9.29	12.89		**0.383**	**5.4**	0.030
Site 5	6/20/2008	7.28	9.15	19.34		**0.404**	1.1	**0.180**
Site 5	7/22/2008	**6.09**	7.9	17.04		**0.418**	**2.7**	**0.070**
Site 5	8/22/2008	7.3	6.51	21.36		**0.422**	**7.5**	**0.200**
Site 5	9/29/2008	7.59	8.04	19.62		**0.447**	1.2	0.090
Site 5	10/30/2008	**5.84**	10.76	11.39		**0.417**	**2.0**	**0.220**
Site 5	11/25/2008	**6.39**	9.69	9.07		**0.410**	1.0	**0.220**
Site 5	12/15/2008	6.82	9.53	13.02		**0.413**	1.5	**0.410**
Site 6	3/24/2000	**9.8**	9.8	12			5.1	0.340
Site 6	4/27/2000	8.15	8.1	10.1			2.5	0.280
Site 6	5/17/2000	7.85	5.8	11.7			3.7	0.200
Site 6	5/31/2000	7.84	**4.8**	12.2			4.6	0.640
Site 6	6/9/2000	7.88	**3.4**	13.1			4.2	0.420
Site 6	6/22/2000	7.78	5	14.2			3.3	0.500
Site 6	7/11/2000	7.67	**3.3**	14.6			5.2	0.870
Site 6	7/25/2000	7.77	5.2	15.6			6.5	0.520
Site 6	8/16/2000	7.57	**2.6**	16.4			4.9	0.300
Site 6	9/21/2000	7.62	5.7	15.6			5.3	0.230
Site 6	10/20/2000	7.69	**3.3**	13.7			5.1	0.330
Site 6	3/15/2001	7.57	7.2	8.7			8.2	0.770
Site 6	4/19/2001	7.65	8.2	10.2			6.4	0.630
Site 6	5/8/2001	7.68	5.4	10.8			5.4	0.360
Site 6	5/23/2001	7.68	10.2	11.9			7.6	0.600
Site 6	6/14/2001	7.78	5.8	13.4			9.7	0.140
Site 6	6/29/2001	7.6	**4.7**	13.8			7.1	0.100
Site 6	7/11/2001	7.4	**2.5**	13.6			7.2	0.240
Site 6	7/24/2001	7.6	**0.95**	14.4			4.2	0.170
Site 6	8/15/2001	7.61	**1.16**	15.4			5.6	1.970
Site 6	9/19/2001	7.57	**1.25**	14			5.0	0.130
Site 6	10/12/2001	7.66	**2.11**	11.8			5.2	0.170
Site 6	3/14/2002	7.88	**3.21**	6.9			2.8	0.210
Site 6	4/5/2002	8.02	**3.25**	7.7			2.6	0.240
Site 6	4/23/2002	8.13	**4.33**	9.8			3.6	0.130
Site 6	5/8/2002	7.86	5.8	11.1			6.4	0.150

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
ANTI data								
Site 6	5/29/2002	8.03	**4.31**	12.2			7.2	0.170
Site 6	6/12/2002	7.83	14.46	13.8			9.3	0.090
Site 6	6/26/2002	7.92	**3.33**	14.3			6.7	0.140
Site 6	7/12/2002	8.04	**3.02**	14.3			5.2	0.090
Site 6	7/24/2002	7.88	**1.43**	16			5.4	0.170
Site 6	8/14/2002	7.86	**2.06**	16.4			5.4	0.020
Site 6	9/11/2002	8.06	**0.58**	15			5.9	0.210
Site 6	10/21/2002	7.26	6.3	14.2			6.0	0.100
Site 6	3/17/2003	7.26	7.99	13.3			5.0	0.510
Site 6	4/8/2003	7.36	6.8	9.9			4.3	0.200
Site 6	4/23/2003	7.18	6.36	10.4			4.3	0.300
Site 6	5/8/2003	7.12	5.5	11.2			5.6	0.200
Site 6	5/20/2003	7.08	7.63	11.2			6.1	0.140
Site 6	6/10/2003	6.87	7.90	11.7			5.8	0.230
Site 6	6/24/2003	6.94	7.50	12.6			5.6	0.190
Site 6	7/7/2003	7.1	**4.80**	13.4			6.2	0.180
Site 6	7/21/2003	7.22	**3.5**	14.1			8.0	0.080
Site 6	8/4/2003	7.28	**3.23**	14.5			6.3	0.170
Site 6	8/18/2003	7.24	**3.2**	14.9			4.3	0.170
Site 6	9/22/2003	6.92	**3.52**	15.2			4.3	0.120
Site 6	10/16/2003	7.2	**4.31**	14.3			5.8	0.290
Site 6	3/17/2004	7.36	6.05	8.89			4.4	0.380
Site 6	4/6/2004	7.29	8.1	10			6.9	0.510
Site 6	4/21/2004	7.37	7.87	11.11			10.0	0.200
Site 6	5/11/2004	7.45	5.78	11.11			5.8	0.060
Site 6	5/26/2004	7.33	**4.8**	12.22			6.9	0.090
Site 6	6/9/2004	7.29	5.50	12.78			8.6	0.170
Site 6	6/25/2004	7.29	**4.70**	12.22			7.7	0.170
Site 6	7/14/2004	7.19		14.9			4.3	0.140
Site 6	7/28/2004	7.21		15.5			6.2	0.120
Site 6	8/16/2004	7.5	**3.3**	16.4			5.9	0.140
Site 6	8/31/2004	7.02	**1.86**	17.4			4.8	0.140
Site 6	9/27/2004	6.87	**0.62**	16.4			**6.8**	0.000
Site 6	10/21/2004	7.02	**2.7**	13			4.8	0.390
Site 6	2/8/2005	**6.48**		9.88		**0.264**	**6.5**	**0.670**
Site 6	2/23/2005	7.2	5.37	9.31		**0.276**	**9.2**	0.350
Site 6	3/7/2005	7.3	6.74	9.44		**0.268**	**5.6**	**0.220**
Site 6	3/25/2005	7.17	8.52	10.17		0.210	**5.5**	**0.180**
Site 6	4/15/2005	7.12	8.25	10.57		0.209	**6.7**	**0.490**
Site 6	4/28/2005	7.29	6.75	11.77		0.217	**5.3**	**0.440**
Site 6	5/12/2005	7.45	6.15	11.23		**0.259**	**3.6**	0.560
Site 6	5/27/2005	7.28	**4.84**	11.31		**0.263**	**5.2**	0.020
Site 6	6/10/2005	7.38	**2.78**	12.62		**0.263**	**4.7**	**0.190**
Site 6	6/24/2005	7.26	**2.45**	13.32		**0.268**	**7.4**	**0.270**

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 6	7/13/2005	7.36	**2.33**	15.61		**0.295**	**4.0**	**0.150**
Site 6	7/26/2005	7.18	**1.68**	15.74		**0.297**	**3.3**	0.270
Site 6	8/12/2005	7.26	**2.34**	15.73		**0.304**	**4.5**	**0.240**
Site 6	8/30/2005	7.31	**3.51**	16.50		**0.303**	**5.5**	**0.280**
Site 6	9/14/2005	6.97	**3.40**	15.43		**0.287**	**4.0**	**0.200**
Site 6	9/30/2005	7.74	**4.86**	13.15		**0.286**	**3.4**	**0.350**
Site 6	10/19/2005	7.5	6.57	14.22		**0.276**	**7.0**	0.170
Site 6	11/3/2005	7.18	6.42	13.2		**0.273**	**11.0**	**0.160**
Site 6	11/14/2005	7.15	**4.76**	13.27		**0.274**	**7.0**	**0.290**
Site 6	11/30/2005	6.94	8.6	13.29		0.237	**5.4**	**0.050**
Site 6	12/21/2005	7.14	6.64	11.35		**0.277**	**12.3**	**0.090**
Site 6	12/28/2005	8.09	10.78	8.68		**0.406**	**2.8**	0.620
Site 6	1/20/2006	6.99	7.13	11.6		**0.253**	**6.8**	**0.200**
Site 6	1/30/2006	**5.86**	7.02	11.48		**0.259**	**7.4**	**0.140**
Site 6	2/24/2006	7.27	6.82	10.24		**0.262**	**2.5**	**0.410**
Site 6	3/27/2006	6.76	6.48	9		**0.271**	**7.1**	**0.410**
Site 6	4/26/2006	**5.63**	6.63	10.59		**0.279**	**6.0**	0.320
Site 6	5/30/2006	**5.21**	**4.03**	11.87		**0.277**	**7.2**	**0.400**
Site 6	6/29/2006	**5.72**	9.04	12.75		0.239	**8.1**	**0.190**
Site 6	7/29/2006	**4.9**	**4.07**	14.55		**0.264**	**6.4**	**0.360**
Site 6	8/28/2006	**5.1**	**3.43**	15.14		**0.275**	**2.8**	**0.190**
Site 6	9/27/2006	**4.96**	**3.8**	14.45		**0.282**	**5.9**	0.260
Site 6	10/30/2006	6.86	6.61	14.05		**0.270**	**7.6**	**0.250**
Site 6	11/28/2006	7.16	6.05	13.43		**0.267**	**6.0**	**0.310**
Site 6	1/9/2007	6.99	7.58	12.19		**0.256**	**6.9**	**0.210**
Site 6	1/30/2007	6.98	6.05	9.47		**0.275**	0.1	**0.160**
Site 6	3/6/2007	7.06	8.69	9.94		**0.269**	**3.9**	0.670
Site 6	3/20/2007					0.008	**2.2**	**0.040**
Site 6	4/24/2007	**5.65**	7.55	10.77		**0.270**	**7.2**	0.020
Site 6	5/24/2007	**5.84**	**3.45**	11.69		0.270	6.3	0.100
Site 6	6/22/2007					0.008	**6.6**	**0.100**
Site 6	7/24/2007	**5.72**	**2.83**	13.91		**0.282**	**6.1**	**0.140**
Site 6	8/28/2007	**5.52**	**1.47**	15.23		**0.288**	**5.7**	**0.200**
Site 6	9/27/2007					0.008		
Site 6	10/31/2007	6.56	5.09	13.37		**0.309**	**4.4**	**0.080**
Site 6	11/29/2007	**5.94**	5.96	11.8		**0.300**	**5.8**	**0.090**
Site 6	12/21/2007	6.93	7.57	12.8		**0.280**	**6.2**	**0.070**
Site 6	2/5/2008	6.73	9.16	11.51		**0.267**	4.9	0.120
Site 6	2/28/2008	6.75	7.44	9.96		**0.276**	**2.4**	**0.300**
Site 6	4/7/2008	7.25	7.65	10.75		**0.271**	**4.3**	0.010
Site 6	4/30/2008	7.14	10.5	11.42		0.247	**5.0**	**0.160**
Site 6	5/23/2008	7.09	7.46	11.79		**0.250**	**7.0**	**0.270**
Site 6	6/20/2008	7.24	6.57	12.48		**0.251**	**7.3**	0.010
Site 6	7/22/2008	7.04	5.9	13.27		**0.258**	**4.8**	0.030

Site	Date	pH	DO	Temp	ANC	Sal	NO_3	PO_4
				ANTI data				
Site 6	8/22/2008	7.13	**3.97**	13.75		**0.266**	**3.7**	**0.130**
Site 6	9/29/2008	7.03	**3.47**	14.39		**0.276**	**5.7**	**0.190**
Site 6	10/30/2008	7.24	**3.78**	10.69		**0.288**	1.4	**0.140**
Site 6	11/25/2008	7.29	5.07	9.58		**0.293**	0.4	**0.230**
Site 6	12/15/2008	6.92	7.8	12.82		**0.269**	**5.5**	**0.190**
Site 7	1/30/2006	7.38	11.11	11.24		**0.378**	**6.3**	**0.240**
Site 7	2/24/2006	8.3	12.04	9.61		**0.369**	1.9	**0.260**
Site 7	3/27/2006	8.24	12.28	11.34		**0.347**	**6.4**	**0.190**
Site 7	4/26/2006	7.35	10.82	13.72		**0.366**	4.7	0.330
Site 7	5/30/2006	6.67	10.08	17.68		**0.354**	**6.4**	**0.180**
Site 7	6/29/2006	**6.41**	10	14.96		**0.401**	**6.8**	**0.320**
Site 7	7/29/2006	**6.17**	10.31	16.39		**0.361**	**5.7**	**0.440**
Site 7	8/28/2006	**6.21**	10.38	16.22		**0.284**	**2.3**	**0.450**
Site 7	9/27/2006	6.88	10.24	14.65		**0.258**	5.7	0.310
Site 7	10/30/2006	7.43	10.62	12.72		**0.378**	**3.4**	**0.370**
Site 7	11/28/2006	7.72	11.15	13		**0.386**	**6.9**	**0.130**
Site 7	1/9/2007	7.87	11.04	11.43		**0.334**	**4.5**	**0.620**
Site 7	1/30/2007	7.88	11.53	8.9		**0.358**	1.3	**0.470**
Site 7	3/6/2007	7.93	11.46	11.02		**0.387**	5.3	0.310
Site 7	3/20/2007					0.008	**5.8**	**0.090**
Site 7	4/24/2007	6.95	11.03	14.13		**0.366**	**6.5**	**0.050**
Site 7	5/24/2007	7.06	10.3	14.16		**0.357**	**4.6**	**0.410**
Site 7	6/22/2007					0.008	**6.7**	**0.090**
Site 7	7/24/2007	6.9	10.15	17.06		**0.334**	**6.4**	**0.040**
Site 7	8/28/2007	6.7	9.78	16.62		**0.364**	**6.5**	**0.110**
Site 7	9/27/2007	6.73	8.95	17.56		0.220	**6.9**	**0.280**
Site 7	10/31/2007	7.11	11.37	11.33		**0.384**	4.6	0.120
Site 7	11/29/2007	6.69	11.1	10.49		**0.339**	1.6	0.020
Site 7	12/21/2007	7.48	12.2	9.7		**0.409**	**3.6**	**0.110**
Site 7	2/5/2008	7.55	11.38	10.36		**0.404**	1.1	**0.430**
Site 7	2/28/2008	8	11.62	9.01		**0.402**	**2.4**	**0.150**
Site 7	4/7/2008	8.24	11.12	11.89		**0.299**	4.9	0.120
Site 7	4/30/2008	8.01	12.46	12.83		**0.389**	**5.0**	**0.190**
Site 7	5/23/2008	7.88	10.37	13.85		**0.373**	**4.7**	**0.200**
Site 7	6/20/2008	8.01	10.44	15.23		**0.355**	**4.1**	**0.080**
Site 7	7/22/2008	8.01	10.11	16.49		**0.351**	0.9	**0.500**
Site 7	8/22/2008	8.1	9.07	16.26		**0.346**	1.6	**0.210**
Site 7	9/29/2008	7.87	10.50	14.57		**0.358**	0.4	**0.240**
Site 7	10/30/2008	8.1	10.58	11.5		**0.358**	**4.1**	**0.170**
Site 7	11/25/2008	8.25	11.99	9.22		**0.361**	0.8	**0.190**
Site 7	12/15/2008	7.95	11.25	11.73		**0.400**	**2.8**	**0.290**
Mean		7.51	8.62	13.57	4445	0.32	5.31	0.298
Std error		0.03	0.09	0.13	117.74	0.003	0.1	0.01

Table A-3. Benthic Index of Biotic Integrity. Values that do not meet the threshold (<3.0) are in bold. Site locations are shown in Figure 3.8.

Site name	BIBI
NCRW-120-N-2004	**2.25**
ANTI-101-N-2006	**2.50**
ANTM-101-N-2004	**1.50**
ANTM-112-N-2004	**1.50**
Mean	1.94
Std error	0.26

Table A-4. Physical Habitat Index. Values that do not meet the threshold (<81) are in bold. Site locations are shown in Figure 3.8.

Site name	PHI
NCRW-120-N-2004	**63.00**
ANTI-101-N-2006	**57.17**
ANTM-101-N-2004	**72.35**
ANTM-112-N-2004	**49.91**
Mean	60.61
Std error	4.74

Table A-5. Percent cover of exotic herbaceous plants. Values that do not meet the threshold (>5%) are in bold. Site locations are shown in Figure 3.9.

Site	Year	Mean cover (%)
ANTI-0072	2006	1.3
ANTI-0092	2007	**27.8**
ANTI-0190	2007	**31.5**
ANTI-0207	2007	**5.4**
Mean		16.5
Std error		7.7

Table A-6. Percent cover of exotic shrubs and trees. Values that do not meet the threshold (>5%) are in bold. Site locations are shown in Figure 3.9.

Site	Year	Invasive basal area	Total basal area	% invasive by basal area
		Shrubs		
ANTI-0072	2006	0	0	
ANTI-0092	2007	0	355.5	0.00
ANTI-0190	2007	0	0	
ANTI-0207	2007	0	247.9	0.00
		Trees		
ANTI-0072	2006	0	243.5	0.00
ANTI-0092	2007	0	19742.4	0.00
ANTI-0190	2007	3510.3	21336.0	**16.45**
ANTI-0207	2007	0	27549.7	0.00
Mean				2.74
Std error				2.74

Table A-7. Presence of forest pest species. Values that do not meet the threshold (>1%) are in bold. Site locations are shown in Figure 3.9.

Site	Year	Mean cover (%)
ANTI-0072	2006	0.00
ANTI-0092	2007	0.00
ANTI-0190	2007	0.00
ANTI-0207	2007	0.00
Mean		0.00

Table A-8. Native seedling regeneration (seedlings ha^{-1}). Values that do not meet the threshold (35,000 seedlings ha^{-1}) are in bold. Site locations are shown in Figure 3.9.

Site	Year	All seedlings	Native seedlings
ANTI-0072	2006	5833	**5833**
ANTI-0092	2007	1666	**1666**
ANTI-0190	2007	7500	**7500**
ANTI-0207	2007	2500	**2500**
Mean			4375
Std error			1377

Table A-9. Fish Index of Biotic Integrity. Values that do not meet the threshold (<3.0) are in bold. Site locations are shown in Figure 3.8.

Site	Date	Fish IBI
NCRW-120-N-2004	2004	4.67
ANTI-101-N-2006	2006	4.67
ANTM-101-N-2004	2004	**1.00**
ANTM-112-N-2004	2004	**1.00**
Mean		2.84
Std error		1.06

Table A-10. Presence of forest interior dwelling species of birds. Values that do not meet the threshold (>1 highly sensitive species; >4 sensitive species) are in bold. ✓ indicates presence; — indicates absence.

Species	Common name	2007	2008	
Highly sensitive				
Dendroica caerulescens	Black-throated blue warbler	✓	—	
Dryocopus pileatus	Pileated woodpecker	—	✓	
Empidonax virescens	Acadian flycatcher	✓	✓	
Number of species		2	2	
Mean				2.00
Std error				0.00
Sensitive				
Dendroica magnola	Magnolia warbler	✓	—	
Hylocichla mustelina	Wood thrush	✓	✓	
Picoides villosus	Hairy woodpecker	—	✓	
Piranga olivacea	Scarlet tanager	✓	—	
Seiurus aurocapillus	Ovenbird	✓	—	
Vireo olivaceus	Red-eyed vireo	✓	✓	
Vireo flavifrons	Yellow-throated vireo	—	✓	
Wilsonia citrina	Hooded warbler	✓	—	
Number of species		6	4	
Mean				5.00
Std error				1.00

Table A-11. Presence and functional diversity of grassland birds.

Species	Common name	Functional group			
		1	2	3	4
Ammodramus savannarum	Grasshopper sparrow		✓		

Functional group 1: Disturbance-tolerant species
Functional group 2: Prefers young grasslands
Functional group 3: Prefers mature grasslands
Functional group 4: Other (rarely encountered)

Table A-12. Deer density (deer km^{-2}). Values that exceed the threshold (forest: 8 deer km^{-2}; grassland: 20 deer km^{-2}) are in bold. Deer-counting routes are shown in Figure 3.9.

Year	Deer density (deer km^{-2})	95% confidence interval	95% confidence interval
2001 (fall)	**29.76**	24.14	36.69
2002 (spring)	**23.18**	20.22	26.57
2002 (fall)	**33.91**	31.18	36.87
2003 (spring)	**25.61**	18.05	36.33
2003 (fall)	**47.50**	38.10	59.22
2004 (spring)	**40.94**	27.94	60.00
2004 (fall)	**49.29**	44.93	54.07
2005 (spring)	**28.74**	17.81	46.37
2005 (fall)	**35.14**	34.37	59.28
2006 (spring)	**32.77**	26.27	40.87
2006 (fall)	**43.66**	27.43	69.50
2007 (spring)	**41.84**	28.26	61.95
2007 (fall)	**38.82**	20.52	73.43
2008 (spring)	**34.43**	28.01	42.33
2008 (fall)	**53.21**	41.00	69.06
Mean	37.25		
Std error	2.28		

Table A-13. List of plant species recorded in Antietam National Battlefield.

Scientific name	Common name/s	Status
	Vascular plants	
Abies balsamea	balsam fir	Native
Abies concolor	balsam fir, colorado fir, concolor fir, silver fir, white balsam, white fir	Non-Native
Abies nordmanniana	Caucasian fir, Nordmann fir	Non-Native
Abutilon theophrasti	butterprint, buttonweed, Indian mallow, velvetleaf, velvetleaf (or butter-print), velvetleaf Indian mallow	Non-Native
Acalypha gracilens	slender copperleaf, slender threeseed mercury	Native
Acalypha rhomboidea	Virginia threeseed mercury	Native
Acer negundo	ashleaf maple, box elder, boxelder, boxelder maple, california boxelder, manitoba maple, western boxelder	Native
Acer nigrum	black maple, black sugar maple, hard maple, rock maple, sugar maple	Native
Acer palmatum dissectum		Non-Native
Acer platanoides	Norway maple	Non-Native
Acer pseudoplatanus	sycamore, sycamore maple	Non-Native
Acer rubrum	red maple	Native
Acer saccharinum	silver maple	Native
Acer saccharum	sugar maple	Native
Achillea millefolium	bloodwort, carpenter's weed, common yarrow, hierba de las cortaduras, milfoil, plumajillo, western yarrow, yarrow (common)	Native
Achillea millefolium ssp. lanulosa		Native
Adiantum pedatum	maidenfern, maidenhair, maidenhair fern, northern maidenhair	Native
Aesculus hippocastanum	horse chestnut	Non-Native
Agastache nepetoides	catnip giant hyssop, yellow giant hyssop, yellow gianthyssop	Native
Ageratina altissima var. altissima	white snakeroot	Native
Agrimonia gryposepala	agrimony, tall hairy agrimony, tall hairy grooveburr	Native
Agrimonia pubescens	groovebur, roadside agrimony, soft agrimony, soft groovebur	Native
Agrimonia rostellata	beaked agrimony, woodland groovebur	Native
Agropyron repens	couchgrass, dog grass, quackgrass	Non-Native
Agrostis stolonifera	carpet bentgrass, creeping bent, creeping bentgrass, redtop, redtop bent, seaside bentgrass, spreading bent	Native
Agrostis stolonifera var. palustris		Native
Ailanthus altissima	ailanthus, copal tree, tree of heaven, tree-of-heaven	Non-Native
Alliaria officinalis		Non-Native
Alliaria petiolata	garlic mustard, garlic-mustard	Non-Native
Allium canadense	Canada garlic, meadow garlic, meadow onion, wild onion	Native
Allium cernuum	nodding onion	Native
Allium tricoccum	ramp, small white leek, wild leek	Native
Allium vineale	wild garlic	Non-Native
Alopecurus geniculatus	marsh meadow-foxtail, water foxtail	Non-Native
Amaranthus blitoides	mat amaranth, prostrate amaranth, prostrate pigweed	Native
Amaranthus hybridus	green pigweed, slim amaranth, smooth amaranth, smooth pigweed	Non-Native
Ambrosia artemisiifolia	annual ragweed, common ragweed, low ragweed, ragweed, Roman wormwood, short ragweed, small ragweed	Native
Ambrosia trifida	blood ragweed, giant ragweed, great ragweed, horseweed, perennial ragweed (great), tall ragweed	Native

Scientific name	Common name/s	Status
Vascular plants		
Ampelopsis brevipedunculata	Amur peppervine, creeper, porcelainberry, wild grape	Non-Native
Amphicarpaea bracteata	American hogpeanut, hog-peanut	Native
Anagallis arvense var. arvense		Non-Native
Anagallis arvensis	pimpernel, scarlet pimpernel	Non-Native
Andropogon gerardii	big bluestem, bluejoint, turkeyfoot	Native
Andropogon scoparius		Native
Andropogon virginicus	Broomsedge bluestem	Native
Anemone virginiana	tall thimbleweed, Virginia anemone	Native
Anemonella thalictroides		Native
Antennaria neglecta	field pussytoes	Native
Antennaria plantaginifolia	plantainleaf pussytoes, woman's tobacco	Native
Anthemis arvensis	corn chamomile, mayweed, scentless chamomile	Non-Native
Anthemis cotula	chamomile, dog fennel, dogfennel, mayweed, mayweed chamomile, mayweed dogfennel, stinking chamomile, stinkweed	Non-Native
Anthoxanthum odoratum	sweet vernalgrass	Non-Native
Aplectrum hyemale	Adam and Eve, puttyroot	Native
Apocynum cannabinum	common dogbane, dogbane, hemp dogbane, Indian hemp, Indian-hemp, Indianhemp, prairie dogbane	Native
Aquilegia canadensis	American columbine, Colorado columbine, red columbine	Native
Arabis laevigata	smooth rock-cress, smooth rockcress	Native
Arabis lyrata	lyrate rockcress	Native
Aralia nudicaulis	Wild sarsaparilla	Native
Arctium minus	bardane, beggar's button, burdock, common burdock, lesser burdock, lesser burrdock, small burdock, smaller burdock, wild burdock, wild rhubarb	Non-Native
Arisaema triphyllum	Indian jack in the pulpit, Jack in the pulpit, Jack-in-the-pulpit	Native
Aristolochia serpentaria	Virginia dutchmanspipe, Virginia snakeroot	Native
Arnoglossum atriplicifolium	pale Indian plaintain	Native
Artemisia biennis	biennial sagewort, biennial wormwood	Non-Native
Artemisia vulgaris	common wormwood, mugwort	Non-Native
Asarum canadense	Canadian wild ginger, Canadian wildginger	Native
Asclepias quadrifolia	fourleaf milkweed	Native
Asclepias syriaca	broadleaf milkweed, common milkweed	Native
Asclepias tuberosa	butterfly milkweed, butterflyweed	Native
Asimina triloba	pawpaw	Native
Asparagus officinalis	asparagus, garden asparagus, garden-asparagus	Non-Native
Asplenium platyneuron	ebony spleenwort	Native
Asplenium rhizophyllum	walking fern	Native
Asplenium trichomanes	maidenhair spleenwort	Native
Aster cordifolius	common blue wood aster	Native
Aster divaricatus		Native
Aster lateriflorus	calico aster	Native
Aster shortii	Short's aster	Native
Aster simplex		Native
Athyrium filix-femina	common ladyfern, lady fern, ladyfern, subarctic lady fern	Native

Scientific name	Common name/s	Status
Vascular plants		
Barbarea verna	early yellowrocket	Non-Native
Barbarea vulgaris	garden yellow rocket, garden yellow-rocket, garden yellowrocket, winter cress, yellow rocket	Non-Native
Berberis thunbergii	Japanese barberry	Non-Native
Berteroa incana	hoary alyssum, hoary false alyssum, hoary false madwort	Non-Native
Betula alleghaniensis	yellow birch	Native
Betula nigra	river birch	Native
Betula pendula	European white birch	Non-Native
Betula pendula laciniata		Non-Native
Bidens bipinnata	Spanish needles, spanish-needles	Native
Bidens connata	purple-stem beggarticks, purplestem beggarticks	Native
Bidens frondosa	bur marigold, devil's beggartick, devil's beggarticks, devil's bootjack, devil's-pitchfork, devils beggartick, pitchfork weed, sticktight, sticktights, tickseed sunflower	Native
Boehmeria cylindrica	small-spike false nettle, smallspike false nettle, smallspike falsenettle	Native
Botrychium biternatum	sparselobe grapefern	Native
Botrychium dissectum	cut-leaf grape fern, cutleaf grapefern	Native
Botrychium dissectum var. obliquum		Native
Botrychium multifidum	broadleaf grapefern, leathery grape fern, leathery grapefern	Native
Botrychium virginianum	rattlesnake fern	Native
Brassica nigra	black mustard, shortpod mustard	Non-Native
Bromus ciliatus	fringed brome	Native
Bromus commutatus	hairy brome, hairy chess, meadow brome	Non-Native
Bromus inermis	awnless brome, smooth brome	Non-Native
Bromus pubescens	hairy wood brome grass, hairy woodland brome	Native
Bromus sterilis	barren bromegrass, poverty brome, sterile brome	Non-Native
Bromus tectorum	cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats	Non-Native
Buglossoides arvensis	corn gromwell, corn-gromwell, field gromwell	Non-Native
Buxus sempervirens	common box	Non-Native
Calystegia sepium ssp. sepium	hedge false bindweed	Non-Native
Campanula americana		Native
Campanulastrum americanum	American bellflower	Native
Campsis radicans	common trumpetcreeper, cow-itch, trumpet creeper	Native
Capsella bursa-pastoris	shepardspurse, shepherd's purse, shepherd's-purse, shepherdspurse	Non-Native
Capsella rubella		Non-Native
Cardamine angustata	slender toothwort	Native
Cardamine concatenata	cutleaf toothwort	Native
Cardamine parviflora	sand bittercress, smallflowered bittercress	Native
Cardamine pratensis	cuckoo flower	Native
Carduus acanthoides	plumeless thistle, spiny plumeless thistle, spiny plumeless-thistle	Non-Native
Carduus nutans	chardon penche, musk thistle, nodding plumeless thistle, nodding plumeless-thistle, nodding thistle, plumeless thistle	Non-Native
Carex aggregata	glomerate sedge	Native

Scientific name	Common name/s	Status
Vascular plants		
Carex albicans	whitetinge sedge	Native
Carex amphibola	amphibious sedge, eastern narrowleaf sedge	Native
Carex blanda	bland sedge, eastern woodland sedge, woodland sedge	Native
Carex cephalophora	oval-leaf sedge, oval-leaved sedge, ovalleaf sedge	Native
Carex communis	fibrousroot sedge	Native
Carex complanata var. hirsuta		Native
Carex conjuncta	soft fox sedge	Native
Carex digitalis	slender wood sedge, slender woodland sedge	Native
Carex flaccosperma	thinfruit sedge	Native
Carex glaucodea	blue sedge	Native
Carex grisea		Native
Carex hirsutella	fuzzy wuzzy sedge, hirsute sedge	Native
Carex hitchcockiana	Hitchcock's sedge, hitchcock's sedge	Native
Carex jamesii	James' sedge	Native
Carex laxiflora	broad looseflower sedge	Native
Carex molesta	troublesome sedge	Native
Carex muehlenbergii	Muhlenberg's sedge, muhlenberg's sedge	Native
Carex normalis	greater straw sedge	Native
Carex oligocarpa	eastern few-fruit sedge, richwoods sedge	Native
Carex pensylvanica	Penn sedge, Pennsylvania sedge	Native
Carex platyphylla	broad-leaved sedge, broadleaf sedge	Native
Carex radiata	eastern star sedge	Native
Carex retroflexa	reflexed sedge	Native
Carex rosea	rosy sedge	Native
Carex sparganioides	burr reed sedge	Native
Carex spicata	prickly sedge	Non-Native
Carex stipata	owlfruit sedge, sawbeak sedge, stalk-grain sedge	Native
Carex swanii	swan sedge, Swan's sedge	Native
Carex tribuloides	blunt broom sedge	Native
Carex umbellata	parasol sedge	Native
Carex willdenowii	Willdenow's sedge	Native
Carpinus caroliniana	American hornbeam, american hornbean	Native
Carya alba	mockernut hickory	Native
Carya cordiformis	bitternut hickory	Native
Carya glabra	pignut hickory	Native
Carya ovata	carya ovata australis, shag-bark hickory, shagbark hickory	Native
Castanea dentata	American chestnut	Native
Catalpa speciosa	northern catalpa	Native
Caulophyllum thalictroides	blue cohosh	Native
Celastrus orbiculatus	Asian bittersweet, Asiatic bittersweet, oriental bittersweet	Non-Native
Celastrus scandens	American bittersweet, staffvine, waxwork	Native
Celtis occidentalis	common hackberry, hackberry, western hackberry	Native
Centaurea cyanus	bachelor's button, cornflower, garden cornflower	Non-Native
Cerastium arvense	starry chickweed, field chickweed	Native

Scientific name	Common name/s	Status
Vascular plants		
Cerastium fontanum ssp. vulgare	big chickweed, common mouse-ear chickweed	Non-Native
Cerastium viscosum		Non-Native
Cerastium vulgatum	big chickweed, mouseear chickweed	Non-Native
Cercis canadensis	eastern redbud, Redbud	Native
Chaerophyllum procumbens	spreading chervil	Native
Chamaesyce nutans	eyebane, nodding spurge, spotted sandmat, spotted spurge	Native
Cheilanthes lanosa	hairy lipfern	Native
Chelidonium majus	celandine	Non-Native
Chenopodium album	common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot	Non-Native
Chenopodium ambrosioides	Mexican tea, Mexican-tea	Non-Native
Chimaphila maculata	striped prince's pine, striped prince's-pine	Native
Chondrilla juncea	hogbite, rush skeletonweed, skeletonweed	Non-Native
Chrysanthemum leucanthemum	ox-eye daisy, oxeye daisy	Non-Native
Cichorium intybus	blue sailors, chicory, coffeeweed, Common chicory, succory	Non-Native
Cicuta maculata	common water hemlock, poison parsnip, spotted cowbane, spotted parsley, spotted water hemlock, spotted water-hemlock, spotted waterhemlock, water hemlock	Native
Cimicifuga racemosa	black bugbane	Native
Circaea canadensis		Non-Native
Circaea lutetiana ssp. canadensis	broad-leaf enchanter's-nightshade, broadleaf enchanter's nightshade	Native
Circaea quadrisulcata		Native
Cirsium arvense	Californian thistle, Canada thistle, Canadian thistle, creeping thistle, field thistle	Non-Native
Cirsium vulgare	bull thistle, common thistle, spear thistle	Non-Native
Claytonia virginica	narrow-leaved spring beauty, Spring beauty, Virginia springbeauty	Native
Clematis viorna	vasevine	Native
Clematis virginiana	devil's darning needles, devil's-darning-needles, virgin's bower, Virginia bower	Native
Clinopodium vulgare	wild basil	Native
Collinsonia canadensis	richweed	Native
Commelina communis	Asiatic dayflower, common dayflower	Non-Native
Conium maculatum	cigue maculee, cigue tachetee, deadly hemlock, poison hemlock, poison parsley, poison-hemlock	Non-Native
Conoclinium coelestinum	blue mistflower	Native
Conopholis americana	American squawroot, squaw-root	Native
Convolvulus arvensis	creeping jenny, European bindweed, field bindweed, morningglory, perennial morningglory, smallflowered morning glory	Non-Native
Convolvulus sepium	hedge false bindweed	Native
Convolvulus sepium var. repens		Native
Conyza canadensis	Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail	Native
Cornus alternifolia	alternate-leaf dogwood, alternateleaf dogwood	Native
Cornus amomum	silky dogwood	Native
Cornus florida	flowering dogwood	Native
Coronilla varia	crownvetch, purple crown-vetch, purple crownvetch, Varia crownvetch	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Corydalis flavula	pale corydalis, yellow fumewort	Native
Corylus americana	hazelnut, American hazelnut	Native
Cryptotaenia canadensis	Canadian honewort, honewort	Native
Cuscuta gronovii	scaldweed	Native
Cynodon dactylon	Bermudagrass, chiendent pied-de-poule, common bermudagrass, devil-grass, grama-seda, manienie, motie molulu	Non-Native
Cynoglossum officinale	common houndstongue, gypsy-flower, gypsyflower, hound's tongue, houndstongue	Non-Native
Cyperus echinatus	globe flatsedge	Native
Cyperus esculentus	chufa, chufa flatsedge, yellow nutgrass, yellow nutsedge	Native
Cyperus strigosus	stawcolored flatsedge, strawcolor flatsedge, strawcolor nutgrass, straw-colored flatsedge, strawcolored nutgrass	Native
Cystopteris bulbifera	bulb bladderfern, bulblet bladderfern	Native
Cystopteris fragilis	brittle bladder fern, brittle bladderfern, fragile fern	Native
Cystopteris protrusa	lowland bladderfern	Native
Dactylis glomerata	cocksfoot, orchard grass, orchardgrass	Non-Native
Danthonia spicata	poverty danthonia, poverty oatgrass, poverty wild oat grass	Native
Datura stramonium	Jamestown weed, jimsonweed, mad apple, moonflower, stinkwort, thorn apple	Non-Native
Datura stramonium var. stramonium	jimsonweed	Non-Native
Daucus carota	bird's nest, Queen Anne's lace, wild carrot	Non-Native
Delphinium tricorne	dwarf larkspur, rock larkspur	Native
Dentaria heterophylla		Native
Dentaria laciniata		Native
Desmodium canescens	hoary tickclover, hoary ticktrefoil	Native
Desmodium paniculatum	narrow-leaf tick-trefoil, panicled tickclover, panicledleaf ticktrefoil	Native
Desmodium perplexum	perplexed ticktrefoil	Native
Dianthus armeria	Deptford pink, Deptford's pink	Non-Native
Dicentra canadensis	squirrel corn	Native
Dicentra cucullaria	dutchman's breeches, Dutchman's-breeches, Dutchmans breeches, dutchmans britches	Native
Dichanthelium boscii	Bosc's panicgrass	Native
Dichanthelium scabriusculum	woolly rosette grass	Native
Dichanthelium villosissimum var. villosissimum	white-hair rosette grass, whitehair rosette grass	Native
Digitaria filiformis	slender crabgrass	Native
Dioscorea quaternata	fourleaf yam	Native
Dioscorea villosa	wild yam	Native
Diospyros virginiana	common persimmon, eastern persimmon, Persimmon	Native
Dipsacus fullonum ssp. sylvestris	common teasel, Fuller's teasel, teasel	Non-Native
Dodecatheon meadia	common shooting star, pride of Ohio	Native
Draba verna	spring draba, spring Whitlowgrass	Non-Native
Dryopteris carthusiana	spinulose wood fern, spinulose woodfern	Native
Dryopteris marginalis	marginal woodfern, woodfern	Native
Duchesnea indica	India mockstrawberry, Indian strawberry	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Echinochloa muricata	rough barnyard grass, rough barnyardgrass	Non-Native
Echinochloa muricata var. muricata	rough barnyardgrass	Native
Echium vulgare	blueweed, common echium, common vipersbugloss	Non-Native
Eclipta alba		Native
Elaeagnus multiflora	cherry silverberry	Non-Native
Elaeagnus umbellata	autumn olive, oleaster	Non-Native
Eleusine indica	crowsfoot grass, goose grass, goosegrass, Indian goose grass, Indian goosegrass, manienie ali'I, silver crabgrass, wiregrass	Non-Native
Elymus hystrix	eastern bottle-brush grass, eastern bottlebrush grass	Native
Elymus repens	quackgrass	Non-Native
Elymus riparius	river wild-rye, riverbank wildrye	Native
Elymus villosus	hairy wild rye, hairy wildrye, slender wild-rye	Native
Elymus virginicus	Virginia wild rye, Virginia wildrye	Native
Epifagus virginiana	beechdrops	Native
Epilobium coloratum	purple-leaf willowherb, purpleleaf willowherb, willowweed	Native
Equisetum arvense	field horsetail, scouring rush, western horsetail	Native
Equisetum hyemale	horsetail, scouring horsetail, scouringrush, scouringrush horsetail, tall scouring-rush, western scouringrush	Native
Eragrostis spectabilis	petticoat-climber, purple lovegrass	Native
Erigenia bulbosa	harbinger of spring	Native
Erigeron annuus	annual fleabane, eastern daisy fleabane	Native
Erigeron philadelphicus	Philadelphia daisy, Philadelphia fleabane	Native
Erigeron pulchellus	poor robin fleabane, robin's plantain	Native
Erigeron strigosus	Daisy Fleabane, prairie fleabane, rough fleabane	Native
Erodium cicutarium	alfilaree, alfilaria, California filaree, cutleaf filaree, filaree, red-stem stork's-bill, redstem, redstem filaree, redstem stork's bill, stork's bill, storksbill	Non-Native
Erythronium albidum	small white fawnlily, white fawnlily	Native
Erythronium americanum	dogtooth violet	Native
Euonymus alata	burning bush, winged burning bush, winged euonymus	Non-Native
Euonymus americana	strawberry bush, strawberrybush	Native
Euonymus americanus		Native
Euonymus atropurpurea	eastern wahoo, wahoo	Native
Eupatorium coelestinum	blue mistflower	Native
Eupatorium dubium	coastalplain joepyeweed	Native
Eupatorium fistulosum	Joe Pye weed, trumpetweed	Native
Eupatorium purpureum	sweetscented joepyeweed	Native
Eupatorium rugosum	richweed, snakeroot, white snakeroot	Native
Euphorbia corollata	flowering spurge, floweringspurge euphorbia	Native
Euphorbia dentata	toothed euphorbia, toothed spurge, toothedleaf poinsettia	Native
Euphorbia esula	leafy spurge, spurge, wolf's milk, wolf's-milk	Non-Native
Euphorbia supina		Native
Fagus grandifolia	American beech	Native
Festuca pratensis		Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Festuca rubra	ravine fescue, red fescue	Native
Festuca subverticillata	nodding fescue	Native
Floerkea proserpinacoides	false mermaid-weed, false mermaidweed, falsemermaid	Native
Fraxinus americana	white ash	Native
Fraxinus americana var. biltmoreana		Native
Fraxinus pennsylvanica	green ash	Native
Galactia regularis	eastern milkpea	Native
Galactia volubilis	downy milkpea	Native
Galearis spectabilis	showy orchid, showy orchis	Native
Galinsoga ciliata	shaggy soldier	Non-Native
Galinsoga parviflora	gallant soldier, gallant-soldier, gallantsoldier, littleflower quickweed	Non-Native
Galinsoga quadriradiata	fringed quickweed, hairy galinsoga, shaggy soldier, shaggy-soldier	Non-Native
Galium aparine	bedstraw, catchweed bedstraw, cleavers, cleaverwort, goose grass, scarthgrass, sticky-willy, stickywilly, white hedge	Native
Galium asprellum	rough bedstraw	Native
Galium circaezans	licorice bedstraw, wild licorice, woods bedstraw	Native
Galium concinnum	shining bedstraw	Native
Galium lanceolatum	lanceleaf wild licorice	Native
Galium parisiense	wall bedstraw	Non-Native
Galium triflorum	fragrant bedstraw, sweet bedstraw, sweetscented bedstraw	Native
Geranium bicknellii	Bicknell's cranesbill, northern crane's-bill	Native
Geranium columbinum	longstalk cranesbill	Non-Native
Geranium maculatum	spotted crane's-bill, spotted geranium, wild crane's-bill	Native
Geranium molle	awnless geranium, dovefoot geranium	Non-Native
Geranium pusillum	small geranium, small-flower crane's-bill	Non-Native
Geum canadense	white avens	Native
Glechoma hederacea	creeping charlie, gill-over-the-ground, ground ivy, groundivy, haymaids	Non-Native
Gleditsia triacanthos	common honeylocust, Honey locust, honey-locust, honeylocust, honey-locusts	Native
Gleditsia triacanthus inermis		Native
Glyceria fluitans	water mannagrass	Non-Native
Glyceria striata	fowl manna grass, fowl mannagrass	Native
Gnaphalium obtusifolium var. obtusifolium	rabbit tobacco	Native
Gymnocladus dioicus	Kentucky coffeetree, Kentucy coffeetree	Native
Hackelia virginiana	beggar's-lice, beggarslice, sticktight, virginia stickseed	Native
Hamamelis virginiana	American witchhazel, witch-hazel, witchhazel	Native
Hedera helix	English ivy	Non-Native
Hemerocallis fulva	orange day lily, orange daylily, tawny daylily	Non-Native
Hepatica americana		Native
Hepatica nobilis var. acuta	sharplobe hepatica	Native
Hepatica nobilis var. obtusa	roundlobe hepatica	Native
Heracleum maximum	common cowparsnip, cow parsnip, cowparsnip	Native

Scientific name	Common name/s	Status
	Vascular plants	
Hesperis matronalis	dame rocket, dame's rocket, dames rocket, dames violet, mother-of-the-evening	Non-Native
Heuchera americana	alumroot, American alumroot	Native
Hibiscus syriacus	althea, rose of Sharon, rose-of-sharon, shrub althea, shrub-althea	Non-Native
Hieracium caespitosum	meadow hawkweed, yellow hawkweed	Non-Native
Hieracium venosum	rattlesnakeweed	Native
Hosta ventricosa	blue plantain lily	Non-Native
Houstonia caerulea	azure bluet	Native
Houstonia purpurea	purple bluets, Venus' pride	Native
Humulus japonicus	Japanese hop	Non-Native
Hybanthus concolor	eastern greenviolet, nodding violet	Native
Hydrangea arborescens	smooth hydrangea, wild hydrangea	Native
Hydrastis canadensis	goldenseal	Native
Hydrophyllum canadense	blunt-leaf waterleaf, bluntleaf waterleaf	Native
Hydrophyllum virginianum	Shawnee salad, Shawnee-salad	Native
Hypericum mutilum	dwarf St. Johnswort	Native
Hypericum perforatum	common St Johnswort, common St. John's wort, common St. Johnswort, Klamath weed, Klamathweed, St. John's wort, St. Johnswort	Non-Native
Hypericum punctatum	spotted St. Johnswort	Native
Hystrix patula		Native
Ilex crenata	Japanese holly	Non-Native
Ilex opaca	American holly	Native
Impatiens capensis	jewelweed, spotted touch-me-not	Native
Impatiens pallida	pale snapweed, pale touch-me-not	Native
Ipomoea hederacea		Non-Native
Ipomoea pandurata	bigroot morningglory, bigroot morninglory, man of the earth, man-of-the-earth	Native
Jeffersonia diphylla	twinleaf	Native
Juglans cinerea	butternut	Native
Juglans nigra	black walnut	Native
Juncus compressus	roundfruit rush	Native
Juncus tenuis	field rush, path rush, poverty rush, slender rush, slender yard rush, wire-grass	Native
Juniperus horizontalis plumosa		Non-Native
Juniperus virginiana	eastern red-cedar, eastern redcedar, red cedar juniper	Native
Justicia americana	American water-willow, common water-willow, spike justica	Native
Lactuca biennis	tall blue lettuce, wild blue lettuce	Native
Lactuca canadensis	Canada lettuce, Florida blue lettuce, wild lettuce	Native
Lactuca floridana	Florida lettuce, woodland lettuce	Native
Lactuca scariola		Non-Native
Lactuca serriola	China lettuce, prickly lettuce, wild lettuce	Non-Native
Lamium album	white deadnettle	Non-Native
Lamium amplexicaule	common henbit, giraffehead, henbit, henbit deadnettle	Non-Native
Lamium maculatum	spotted henbit	Non-Native
Lamium purpureum	purple deadnettle, red deadnettle	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Laportea canadensis	Canada lettuce, Canada woodnettle, Canadian wood-nettle, Canadian woodnettle	Native
Larix decidua	European larch	Non-Native
Lechea intermedia	largepod pinweed	Native
Leersia oryzoides	rice cut grass, rice cutgrass	Native
Leersia virginica	white grass, whitegrass	Native
Lemna minor	common duckweed, least duckweed, lesser duckweed	Native
Leonurus cardiaca	common motherwort, motherwort	Non-Native
Lepidium campestre	cream-anther field pepperwort, field pepperweed	Non-Native
Lepidium virginicum	peppergrass, poorman pepperweed, poorman's pepper, poorman's-pepperwort, Virginia pepperweed, Virginian peppercress	Native
Leucanthemum vulgare	ox-eye daisy, oxeye daisy, oxeye-daisy, oxeyedaisy	Non-Native
Ligustrum vulgare	European privet, wild privet	Non-Native
Linaria vulgaris	butter and eggs, butterandeggs, flaxweed, greater butter-and-eggs, Jacob's ladder, ramsted, wild snapdragon, yellow toadflax	Non-Native
Lindera benzoin	northern spicebush, spicebush	Native
Lindernia dubia	moistbank pimpernel, shortstalk lindernia, yellow-seed false pimpernel, yellowseed false pimpernel	Native
Liparis liliifolia	brown widelip orchid	Native
Liparis loeselii	yellow wide-lip orchid, yellow widelip orchid	Native
Lippia lanceolata		Native
Liquidambar styraciflua	sweetgum	Native
Liriodendron tulipifera	tulip poplar, tuliptree, yellow poplar, yellow-poplar	Native
Lobelia cardinalis	cardinal flower	Native
Lobelia inflata	Indian tobacco, Indian-tobacco	Native
Lobelia puberula	downy lobelia	Native
Lobelia siphilitica	great blue lobelia	Native
Lolium arundinaceum	Lolium arundinaceum, tall fescue	Non-Native
Lolium perenne ssp. perenne	perennial rye grass, perennial ryegrass	Non-Native
Lonicera japonica	Chinese honeysuckle, Japanese honeysuckle	Non-Native
Lonicera maackii	Amur honeysuckle, Amur honeysuckle bush	Non-Native
Lonicera morrowii	Morrow's honeysuckle	Non-Native
Lonicera tatarica	bush honeysuckle, Tartarian honeysuckle, Tatarian honeysuckle	Non-Native
Ludwigia alternifolia	bushy seedbox, seedbox	Native
Ludwigia palustris	marsh primrose-willow, marsh seedbox	Native
Luzula echinata	hedgehog woodrush	Native
Lychnis alba	white cockle	Native
Lycopsis arvensis		Non-Native
Lycopus americanus	American bugleweed, American water horehound, American waterhorehound, cut-leaf water-horehound, water horehound, waterhorehound	Native
Lycopus virginicus	Virginia bugleweed, virginia bugleweed, Virginia water horehound	Native
Lysimachia ciliata	fringed loosestrife, fringed yellow-loosestrife	Native
Lysimachia nummularia	creeping jenny, moneywort	Non-Native
Maclura pomifera	bois d'arc, osage orange, osage-orange, osageorange	Native

Scientific name	Common name/s	Status
Vascular plants		
Maianthemum racemosum ssp. racemosum	false Solomon's-seal, feather Solomons seal, feathery false lily of the vally, feathery false Solomon's-seal	Native
Malus floribunda	Japanese flowering crabapple	Non-Native
Matricaria discoidea	disc mayweed, pineapple weed, pineappleweed	Non-Native
Melilotus officinalis	yellow sweet-clover, yellow sweetclover	Non-Native
Melissa officinalis	common balm	Non-Native
Menispermum canadense	Canadian moonseed, common moonseed	Native
Mentha arvensis	field mint, wild mint	Native
Mentha spicata	bush mint (spearmint), spearmint	Native
Mertensia virginica	Virginia bluebells	Native
Microstegium vimineum	Japanese stiltgrass, Nepalese browntop	Non-Native
Mikania scandens	climbing hempvine, climbing hempweed	Native
Mimulus alatus	sharpwing monkeyflower	Native
Mirabilis nyctaginea	heart-leaf four-o'clock, heart-leaved four o'clock, heartleaf four o'clock, heartleaf four-o'clock, prairie four o clock, wild four-o'clock	Native
Mitchella repens	partridgeberry	Native
Mitella diphylla	twoleaf miterwort	Native
Monarda clinopodia	white bergamot	Native
Monarda fistulosa	mintleaf beebalm, Oswego-tea, wild bergamot, wildbergamot beebalm, wildbergamot horsemint	Native
Monotropa uniflora	Indian pipe	Native
Morus alba	mulberry, white mulberry	Non-Native
Morus rubra	red mulberry	Native
Muhlenbergia frondosa	wire-stem muhly, wirestem muhly	Native
Muhlenbergia schreberi	nimblewill, nimblewill muhly	Native
Muhlenbergia sobolifera	rock muhly	Native
Muhlenbergia tenuiflora	slender muhly	Native
Muscari botryoides	common grape hyacinth	Non-Native
Myrica pensylvanica	northern bayberry	Native
Narcissus pseudonarcissus	common daffodil, daffodil	Non-Native
Nasturtium officinale	no common name (local name: watercress)	Non-Native
Nepeta cataria	catmint, catnip, catwort, field balm	Non-Native
Nyssa sylvatica	black gum, black tupelo, blackgum	Native
Oenothera biennis	common evening primrose, common evening-primrose, common eveningprimrose, evening primrose (common), hoary eveningprimrose, king's-cureall	Native
Onoclea sensibilis	sensitive fern	Native
Ophioglossum vulgatum	Southern adder's-tongue, southern adderstongue	Native
Ornithogalum nutans	drooping star of Bethlehem	Non-Native
Ornithogalum umbellatum	Pyrenees Star of Bethlehem, sleepydick, Star-of-Bethlehem	Non-Native
Orobanche uniflora	naked broom-rape, naked broomrape, oneflowered broomrape	Native
Osmorhiza claytonii	Clayton's sweetroot, hairy sweet-cicely	Native
Osmorhiza longistylis	aniseroot, longstyle sweetroot	Native
Osmunda cinnamomea	cinnamon fern	Native
Ostrya virginiana	eastern hophornbeam, hophornbeam	Native

Scientific name	Common name/s	Status
Vascular plants		
Oxalis corniculata	‘ihi, creeping oxalis, creeping woods, creeping woodsorrel, oxalis, yellow oxalis, yellow wood sorrel	Native
Oxalis europaea		Native
Oxalis stricta	common yellow oxalis, erect woodsorrel, sheep sorrel, sourgrass, toad sorrel, upright yellow wood-sorrel, upright yellow woodsorrel, yellow woodsorrel	Native
Oxalis violacea	purple woodsorrel, violet wood-sorrel, violet woodsorrel	Native
Panax quinquefolius	American ginseng, american ginseng	Native
Panicum boscii		Native
Panicum capillare	annual witchgrass, common panic grass, common witchgrass, panicgrass, ticklegrass, tumble panic, tumbleweed grass, witches hair, witchgrass	Native
Panicum dichotomiflorum	fall panic, fall panicgrass, fall panicum, western witchgrass	Native
Panicum villosissimum		Native
Parietaria pensylvanica	Pennsylvania pellitory	Native
Paronychia canadensis	smooth forked nailwort	Native
Parthenocissus quinquefolia	American ivy, fiveleaved ivy, Virginia creeper, woodbine	Native
Paspalum ciliatifolium		Native
Paspalum dissectum	mudbank crowngrass	Native
Paspalum laeve	field paspalum	Native
Paspalum setaceum	fringeleaf paspalum, sand paspalum, slender crown grass, thin paspalum	Native
Paulownia tomentosa	princess tree, princesstree, royal paulownia	Non-Native
Pellaea atropurpurea	purple cliffbrake, purple-stem cliff-brake, purple-stem cliffbrake	Native
Perilla frutescens	beefsteak, beefsteak mint, beefsteakplant, Purple mint	Non-Native
Phacelia dubia	smallflower phacelia	Native
Phalaris arundinacea	reed canary grass, reed canarygrass	Native
Phleum pratense	common timothy, timothy	Non-Native
Phlox divaricata	wild blue phlox	Native
Phragmites australis	common reed	Native
Phryma leptostachya	American lopseed, lopseed	Native
Physalis heterophylla	clammy ground-cherry, clammy groundcherry	Native
Physalis heterophylla var. hetero-phylla	clammy groundcherry	Native
Physalis longifolia var. subglabrata	longleaf groundcherry	Native
Physalis virginiana	ground cherry (Virginia), lanceleaf groundcherry, Virginia ground-cherry, Virginia groundcherry	Native
Phytolacca americana	American pokeweed, common pokeweed, inkberry, pigeonberry, poke, pokeberry, pokeweed	Native
Picea abies	Norway spruce	Non-Native
Pilea pumila	Canada clearweed, Canadian clearweed	Native
Pinus resinosa	norway pine, red pine	Non-Native
Pinus rigida	pitch pine	Native
Pinus strobus	easter white pine, eastern white pine, northern white pine, soft pine, weymouth pine, white pine	Native
Pinus virginiana	jersey pine, scrub pine, Virginia pine	Native
Plantago aristata	bottlebrush Indianwheat, largebracted plantain	Native

Scientific name	Common name/s	Status
	Vascular plants	
Plantago lanceolata	buckhorn plantain, English plantain, lanceleaf Indianwheat, lanceleaf plantain, narrowleaf plantain, ribgrass, ribwort	Non-Native
Plantago major	broadleaf plantain, buckhorn plantain, common plantain, great plantain, rippleseed plantain	Native
Plantago rugelii	black-seed plantain, blackseed plantain, Rugel's plantain	Native
Platanus occidentalis	American sycamore, sycamore	Native
Poa annua	annual blue grass, annual bluegrass, walkgrass	Non-Native
Poa pratensis	Kentucky bluegrass	Non-Native
Poa sylvestris	woodland bluegrass	Native
Poa trivialis	rough bluegrass	Non-Native
Podophyllum peltatum	may apple, mayapple	Native
Polygonatum biflorum	king Solomon's seal, King Solomon's-seal, smooth Solomon's seal, Solomon's seal	Native
Polygonum aviculare	prostrate knotweed, yard knotweed	Non-Native
Polygonum caespitosum	bristled knotweed, bunchy knotweed, oriental ladysthumb	Non-Native
Polygonum cespitosum	oriental ladysthumb	Native
Polygonum convolvulus	black bindweed, black-bindweed, climbing buckwheat, climbing knotweed, cornbind, dullseed cornbind, pink smartweed, wild buckwheat	Non-Native
Polygonum hydropiper	annual smartweed, marshpepper knotweed, mild water-pepper	Non-Native
Polygonum hydropiperoides	swamp smartweed	Native
Polygonum lapathifolium	curltop ladysthumb, curlytop knotweed, curlytop smartweed, dock-leaf smartweed, nodding smartweed, pale smartweed, smartweed	Native
Polygonum pensylvanicum	Pennsylvania knotweed, Pennsylvania smartweed, pinkweed, pinweed	Native
Polygonum persicaria	lady's-thumb, ladysthumb, ladysthumb smartweed, smartweed, spotted knotweed, spotted ladysthumb, spotted smartweed	Non-Native
Polygonum virginianum	jumpseed, Virginia smartweed	Native
Polymnia canadensis	rayless leafcup, whiteflower leafcup	Native
Polymnia uvedalia		Native
Polypodium virginianum	rock polypody	Native
Polystichum acrostichoides	Christmas fern	Native
Populus deltoides	common cottonwood, cottonwood, eastern cottonwood, plains cottonwood	Native
Portulaca oleracea	akulikuli-kula, common purslane, duckweed, garden purslane, little hogweed, little-hogweed, purslane, pursley, pusley, wild portulaca	Native
Potentilla canadensis	dwarf cinquefoil	Native
Potentilla intermedia	downy cinquefoil	Non-Native
Potentilla recta	roughfruit cinquefoil, sulfur (or erect) cinquefoil, sulfur cinquefoil, sulphur cinquefoil	Non-Native
Potentilla simplex	common cinquefoil, oldfield cinquefoil, oldfield fivefingers, spreading cinquefoil	Native
Prenanthes trifoliolata	gall of the earth	Native
Prunella vulgaris	common selfheal, heal all, healall, selfheal	Native
Prunus avium	sweet cherry	Non-Native
Prunus cerasus	sour cherry	Non-Native
Prunus pensylvanica	fire cherry, pin cherry	Native
Prunus serotina	black cherry, black chokecherry	Native
Prunus serrulata	Japanese flowering cherry	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Prunus virginiana	chokecherry, chokecherry (common), common chokecherry, Virginia chokecherry	Native
Pseudotsuga menziesii var. menziesii	coast douglas fir, Douglas-fir	Non-Native
Pseudotsuga taxifolia	no common name (local name: Douglas fir)	Non-Native
Pteridium aquilinum	bracken, bracken fern, brackenfern, northern bracken fern, western brackenfern	Native
Pyracantha coccinea	scarlet firethorn	Non-Native
Pyrola americana	American wintergreen	Native
Pyrola rotundifolia		Native
Pyrus comunis	common pear	Non-Native
Quercus alba	white oak	Native
Quercus bicolor	swamp white oak	Native
Quercus coccinea	scarlet oak	Native
Quercus michauxii	swamp chestnut oak	Native
Quercus muehlenbergii	chinkapin oak	Native
Quercus palustris	pin oak	Native
Quercus prinus	chestnut oak	Native
Quercus rubra	northern red oak	Native
Quercus stellata	post oak	Native
Quercus velutina	black oak	Native
Ranunculus abortivus	early woodbuttercup, kidney-leaf buttercup, littleleaf buttercup, small-flower buttercup, smallflower crowfoot	Native
Ranunculus acris	meadow buttercup, tall buttercup	Non-Native
Ranunculus bulbosus	blister flower, bulbous buttercup, bulbous crowfoot, gowan, St. Anthony's turnip, yellow weed	Non-Native
Ranunculus hispidus	bristly buttercup	Native
Ranunculus recurvatus	blisterwort, littleleaf buttercup	Native
Ranunculus sardous	hairy buttercup	Non-Native
Ranunculus sceleratus	celeryleaf buttercup, cursed buttercup	Native
Rhododendron carolinianum	Carolina azalea	Non-Native
Rhus aromatica	fragrant sumac	Native
Rhus glabra	smooth sumac	Native
Rhus hirta	staghorn sumac	Native
Rhus typhina	staghorn sumac	Native
Ribes cynosbati	eastern prickly gooseberry, pasture currant	Native
Robinia pseudoacacia	black locust, false acacia, yellow locust	Native
Rosa carolina	Carolina rose	Native
Rosa multiflora	multiflora rose	Non-Native
Rubus allegheniensis	Allegheny blackberry	Native
Rubus occidentalis	black raspberry	Native
Rubus pensilvanicus	Pennsylvania blackberry	Native
Rubus phoenicolasius	Japanese wineberry, wine raspberry, wineberry	Non-Native
Rudbeckia hirta	blackeyed Susan, blackeyedsusan	Native
Rudbeckia laciniata	cutleaf coneflower, green-head coneflower	Native

Scientific name	Common name/s	Status
Vascular plants		
Ruellia caroliniensis	Carolina wild petunia	Native
Rumex acetosella	common sheep sorrel, field sorrel, red (or sheep) sorrel, red sorrel, sheep sorrel	Non-Native
Rumex crispus	Curley dock, curly dock, narrowleaf dock, sour dock, yellow dock	Non-Native
Rumex hastatulus	heartwing dock, heartwing sorrel	Native
Rumex obtusifolius	bitter dock, bluntleaf dock	Non-Native
Rumex pulcher	fiddle dock	Non-Native
Rumex verticillatus	swamp dock	Native
Salix exigua	sandbar willow	Native
Salix nigra	black willow	Native
Salvia lyrata	lyreleaf sage	Native
Sambucus nigra ssp. canadensis	blue elder, common elderberry, elder, elderberry, Mexican elderberry	Native
Sanguinaria canadensis	bloodroot	Native
Sanicula canadensis	Canada sanicle, Canadian blacksnakeroot	Native
Sanicula odorata	cluster sanicle, clustered blacksnakeroot	Native
Saponaria officinalis	bouncing bet, bouncing-bett, bouncingbet, bouncingbet soapweed, soapwort, sweet Betty	Non-Native
Sassafras albidum	sassafras	Native
Satureja vulgaris		Native
Saxifraga virginiensis	early saxifrage	Native
Scrophularia marilandica	carpenter's square, maryland figwort	Native
Scutellaria incana	hoary skullcap	Native
Scutellaria incana var. incana	hoary skullcap	Native
Scutellaria lateriflora	blue skullcap, mad dog skullcap	Native
Scutellaria nervosa	veiny skullcap	Native
Sedum ternatum	woodland stonecrop	Native
Senecio aureus	golden ragwort	Native
Setaria faberi	Chinese foxtail, Chinese millet, giant bristlegrass, giant foxtail, Japanese bristlegrass, nodding foxtail, tall green bristlegrass	Non-Native
Setaria geniculata	marsh bristlegrass	Native
Setaria glauca	pearl millet, pigeongrass, wild millet, yellow bristlegrass, yellow foxtail	Non-Native
Setaria pumila	cattail grass, yellow bristle grass, yellow bristlegrass	Non-Native
Setaria viridis	bottle grass, green bristle grass, green bristlegrass, green foxtail, pigeon-grass, wild millet	Non-Native
Sicyos angulatus	blueeyedgrass, bur cucumber, burcucumber, oneseed burr cucumber, wall bur cucumber	Native
Sida spinosa	prickly fanpetals, prickly sida	Native
Silene cucubalus		Non-Native
Silene odora		Native
Silene stellata	whorled catchfly, widowsfrill	Native
Silene vulgaris	bladder campion, bladder silene, cowbell, maiden's tears, maiden's-tears, maidenstears, rattleweed	Non-Native
Sisymbrium altissimum	Jim Hill mustard, tall hedge-mustard, tall mustard, tall tumblemustard, tumble mustard, tumblemustard, tumbleweed mustard	Non-Native
Sisymbrium officinale	hairypod hedgemustard, hedge mustard, hedge tumblemustard, hedge-mustard, hedgemustard, hedgeweed, wild mustard	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Sisyrinchium angustifolium	blue eyegrass, blue-eyed grass, common blue eyedgrass, common blue-eyedgrass, narrowleaf blue-eyed grass	Native
Smallanthus uvedalius	hairy leafcup	Native
Smilacina racemosa		Native
Smilax herbacea	herbaceous greenbriar, smooth carrionflower	Native
Smilax hispida	no common name (local name: bristly greenbrier)	Native
Smilax rotundifolia	bullbriar, common catbriar, common greenbrier, greenbrier, horsebriar, roundleaf greenbriar, roundleaf greenbrier	Native
Solanum carolinense	apple of Sodom, bull nettle, Carolina horsenettle, devil's tomato, horsenettle, sand briar	Native
Solanum dulcamara	bitter nightshade, bittersweet nightshade, blue nightshade, climbing nightshade, European bittersweet, fellenwort, woody nightshade	Non-Native
Solanum nigrum	black nightshade, deadly nightshade, garden nightshade	Non-Native
Solidago bicolor	white goldenrod	Native
Solidago caesia	wreath goldenrod	Native
Solidago canadensis	Canada goldenrod, Canadian goldenrod, common goldenrod	Native
Solidago canadensis var. canadensis	Canada goldenrod, Canadian goldenrod	Native
Solidago canadensis var. hargeri	Canadian goldenrod, Harger's goldenrod	Native
Solidago canadensis var. scabra	Canada goldenrod, Canadian goldenrod	Native
Solidago flexicaulis	zigzag goldenrod	Native
Solidago juncea	early goldenrod	Native
Solidago nemoralis	dyersweed goldenrod, gray goldenrod	Native
Solidago odora	anisescented goldenrod, fragrant goldenrod	Native
Solidago ulmifolia	elmleaf goldenrod	Native
Sonchus asper	perennial sowthistle, prickly sowthistle, spiny sowthistle, spiny-leaf sowthistle	Non-Native
Sorbus americana	American mountain ash	Native
Sorghastrum nutans	Indiangrass, yellow indian-grass	Native
Sorghum halepense	aleppo milletgrass, herbe de Cuba, Johnson grass, Johnsongrass, sorgho d'Alep, sorgo de alepo, zacate Johnson	Non-Native
Sphenopholis nitida	shiny wedgescale	Native
Sphenopholis obtusata	prairie wedgegrass, prairie wedgescale	Native
Spiranthes cernua	nodding ladies'-tresses, nodding ladiestresses, white nodding ladies'-tresses	Native
Spiranthes lacera var. lacera	northern slender ladies'-tresses	Native
Staphylea trifolia	American bladdernut, american bladdernut	Native
Stellaria aquatica		Non-Native
Stellaria graminea	grass-leaf starwort, grassleaved stichwort, grasslike starwort, grassy starwort, lesser starwort, little starwort	Non-Native
Stellaria media	chickweed, common chickweed, nodding chickweed	Non-Native
Stellaria pubera	star chickweed	Native
Stuckenia pectinatus	sago pondweed	Native
Stylophorum diphyllum	celandine poppy	Native
Symphoricarpos orbiculatus	coralberry, coralberry (buck brush), Indiancurrant coralberry	Native
Symphyotrichum cordifolium	common blue wood aster	Native

Scientific name	Common name/s	Status
Vascular plants		
Symphyotrichum divaricatum	southern annual saltmarsh aster	Native
Symphyotrichum ericoides var. ericoides	white heath aster	Native
Symphyotrichum shortii	Short's aster	Native
Synosma suaveolens		Native
Tanacetum vulgare	common tansy, garden tansy, tansy	Non-Native
Taraxacum officinale	blowball, common dandelion, dandelion, faceclock	Non-Native
Taxodium distichum	bald cypress, baldcypress	Native
Teucrium canadense	American germander, Canada germander, Candad germander, germander, hairy germander, wood sage	Native
Thalictrum dioicum	early meadow-rue	Native
Thalictrum polygamum		Native
Thalictrum thalictroides	rue anemone	Native
Thlaspi arvense	fanweed, field pennycress, Frenchweed, pennycress, stinkweed	Non-Native
Thuja occidentalis	arborvitae, eastern white cedar, northern white cedar, northern white-cedar, swamp cedar	Non-Native
Tilia americana	American basswood	Native
Tovara virginiana		Native
Toxicodendron radicans	eastern poison ivy, poison ivy, poisonivy	Native
Tragopogon dubius	common salsify, goat's beard, goatsbeard, meadow goat's-beard, salsifis majeur, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify	Non-Native
Tragopogon pratensis	Jack-go-to-bed-at-noon, meadow salsify	Non-Native
Tridens flavus	Purpletop, purpletop tridens	Native
Trifolium arvense	hairy clover, hare's foot clover, oldfield clover, rabbit-foot clover, rabbit-foot clover, stone clover	Non-Native
Trifolium aureum	golden clover	Non-Native
Trifolium campestre	Field (Big-hop) clover, field clover, large hop clover, lesser hop clover, low hop clover	Non-Native
Trifolium dubium	hop clover, smallhop clover, suckling clover	Non-Native
Trifolium hybridum	alsike clover	Non-Native
Trifolium pratense	red clover	Non-Native
Trifolium repens	Dutch clover, ladino clover, white clover	Non-Native
Trillium sessile	toadshade	Native
Triticum aestivum	common wheat, wheat	Non-Native
Tsuga canadensis	canada hemlock, eastern hemlock, hemlock spruce	Native
Typha latifolia	broadleaf cattail, cattail, cattail (common), common cattail	Native
Ulmus americana	American elm	Native
Ulmus rubra	slippery elm	Native
Urtica dioica	California nettle, slender nettle, stinging nettle, tall nettle	Non-Native
Uvularia perfoliata	perfoliate bellwort	Native
Uvularia puberula	mountain bellwort	Native
Valerianella locusta	Lewiston cornsalad	Native
Verbascum blattaria	moth mullein, white moth mullein	Non-Native
Verbascum thapsus	big taper, common mullein, flannel mullein, flannel plant, great mullein, mullein, velvet dock, velvet plant, woolly mullein	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Verbena urticifolia	white verbena, white vervain	Native
Verbesina alternifolia	wingstem	Native
Vernonia noveboracensis	New York ironweed	Native
Veronica agrestis	field speedwell, green field speedwell	Non-Native
Veronica anagallis-aquatica	blue water speedwell, water speedwell	Native
Veronica hederifolia	ivyleaf speedwell	Non-Native
Veronica officinalis	common gypsyweed	Native
Veronica peregrina	neckweed, purslane speedwell	Native
Veronica persica	bird-eye speedwell, birdeye speedwell, birdseye speedwell, Persian speedwell, winter speedwell	Non-Native
Veronica serpyllifolia	thyme-leaf speedwell, thymeleaf speedwell	Non-Native
Viburnum acerifolium	mapleleaf viburnum	Native
Viburnum prunifolium	blackhaw	Native
Vinca minor	common periwinkle, lesser periwinkle, myrtle	Non-Native
Viola bicolor	field pansy	Native
Viola blanda	sweet white violet	Native
Viola palmata	early blue violet, trilobed violet	Native
Viola papilionacea	common blue violet, hooded blue violet, meadow violet	Native
Viola pensylvanica		Native
Viola pubescens	downy yellow violet	Native
Viola sororia	common blue violet, hooded blue violet	Native
Viola striata	striped cream violet	Native
Viola triloba		Native
Vitis aestivalis	summer grape	Native
Vitis labrusca	fox grape	Native
Vitis riparia	river-bank grape, riverbank grape	Native
Vitis rotundifolia	muscadine, muscadine grape	Native
Vitis vulpina	fox grape, frost grape, wild grape	Native
Woodsia obtusa	blunt-lobe woodsia, bluntlobe cliff fern	Native
Xanthium strumarium	cocklebur, cockleburr, common cocklebur, rough cocklebur, rough cockleburr	Native
Zea mays	corn	Non-Native
Zizia aurea	golden alexanders, golden zizia	Native

Table A-14. List of fish species recorded in Antietam National Battlefield.

Scientific name	Common name/s	Status
Fish		
Ambloplites rupestris	rock bass	Non-Native
Ameiurus natalis	yellow bullhead	Native
Ameiurus nebulosus	brown bullhead	Native
Anguilla rostrata	American eel	Native
Campostoma anomalum	central stoneroller	Native
Catostomus commersoni	white sucker	Native
Clinostomus funduloides	rosyside dace	Native
Cottus caeruleomentum	Blue Ridge sculpin	Native
Cottus girardi	Potomac sculpin	Native
Cottus sp. cf. cognatus	checkered sculpin	
Cyprinella analostana	satinfin shiner	Native
Cyprinella spiloptera	spotfin shiner	Native
Cyprinus carpio	common carp, European carp	Non-Native
Etheostoma blennioides	greenside darter	Non-Native
Etheostoma caeruleum	rainbow darter	Native
Etheostoma flabellare	fantail darter	Native
Etheostoma olmstedi	tessellated darter	Native
Exoglossum maxillingua		Native
Hypentelium nigricans	northern hogsucker	Native
Lepomis auritus	redbreast sunfish	Native
Lepomis cyanellus	green sunfish	Non-Native
Lepomis gibbosus		Native
Lepomis macrochirus	bluegill	Non-Native
Luxilus cornutus	common shiner	Native
Margariscus margarita	pearl dace	Native
Micropterus dolomieu	smallmouth bass	Non-Native
Micropterus salmoides	largemouth bass	Non-Native
Moxostoma erythrurum	golden redhorse	Non-Native
Moxostoma macrolepidotum	shorthead redhorse	Native
Nocomis micropogon	river chub	Native
Notropis hudsonius	spottail shiner	Native
Notropis rubellus	rosyface shiner	Native
Oncorhynchus mykiss	rainbow trout	Non-Native
Perca flavescens	yellow perch	Native
Percina peltata	shield darter	Native
Pimephales notatus	bluntnose minnow	Non-Native
Rhinichthys atratulus	blacknose dace, eastern blacknose dace	Native
Rhinichthys cataractae	longnose dace	Native
Salmo trutta	brown trout	Non-Native
Salvelinus fontinalis	brook trout, charr, salter	Native
Semotilus atromaculatus	creek chub	Native
Semotilus corporalis	fallfish	Native

Table A-15. List of amphibian species recorded in Antietam National Battlefield.

Scientific name	Common name/s	Status
Amphibians		
Anaxyrus americanus americanus	eastern American toad	Native
Desmognathus fuscus fuscus	northern dusky salamander	Native
Eurycea bislineata	northern two-lined salamander, two-lined salamander	Native
Eurycea longicauda longicauda	longtail salamander, long-tailed salamander	Native
Plethodon cinereus	eastern red-backed salamander, redback salamander, red-backed salamander	Native
Plethodon glutinosus	northern slimy salamander, slimy salamander	Native
Pseudacris crucifer crucifer	northern spring peeper	Native
Rana catesbeiana	American bullfrog, bullfrog	Non-Native
Rana clamitans melanota	green frog, northern green frog	Native
Rana palustris	pickerel frog	Native
Rana sylvatica	wood frog	Native

Table A-16. List of reptile species recorded in Antietam National Battlefield.

Scientific name	Common name/s	Status
Reptiles		
Agkistrodon contortrix mokasen	northern copperhead	Native
Chelydra serpentina serpentina	common snapping turtle	Native
Chrysemys picta picta	eastern painted turtle	Native
Clemmys insculpta	ornate box turtle, wood turtle	Native
Diadophis punctatus edwardsii	northern ringneck snake	Native
Elaphe obsoleta obsoleta	black rat snake	Native
Lampropeltis triangulum triangulum	eastern milk snake	Native
Nerodia sipedon sipedon	northern water snake	Native
Pseudemys rubriventris	redbelly turtle	Native
Regina septemvittata	queen snake, queensnake	Native
Terrapene carolina carolina	eastern box turtle	Native
Thamnophis sirtalis sirtalis	eastern garter snake	Native

Table A-17. List of bird species recorded in Antietam National Battlefield.

Scientific name	Common name/s	Status
	Birds	
Accipiter cooperii	Cooper's hawk	Native
Accipiter gentilis	northern goshawk	Native
Accipiter striatus	sharp-shinned hawk	Native
Agelaius phoeniceus	red-winged blackbird	Native
Aix sponsa	wood duck	Native
Ammodramus savannarum	grasshopper sparrow	Native
Anas discors	blue-winged teal	Native
Anas platyrhynchos	mallard	Native
Anas rubripes	American black duck	Native
Anthus rubescens	American pipit	Native
Archilochus colubris	ruby-throated hummingbird	Native
Ardea alba	great egret	Native
Ardea herodias	great blue heron	Native
Asio otus	long-eared owl	NA
Aythya americana	redhead	NA
Bartramia longicauda	upland sandpiper	Native
Bombycilla cedrorum	cedar waxwing	Native
Bonasa umbellus		Native
Branta canadensis	Canada goose	Native
Bubo virginianus	great horned owl	Native
Buteo jamaicensis	red-tailed hawk	Native
Buteo lagopus		NA
Buteo lineatus	red-shouldered hawk	Native
Buteo platypterus	broad-winged hawk	Native
Butorides virescens	green heron	Native
Cardinalis cardinalis	northern cardinal	Native
Carduelis flammea	common redpoll	NA
Carduelis pinus	pine siskin	NA
Carduelis tristis	American Goldfinch	Native
Carpodacus mexicanus	House Finch	Non-Native
Carpodacus purpureus	Purple Finch	Native
Cathartes aura	Turkey Vulture	Native
Catharus fuscescens	Veery	Native
Catharus guttatus	hermit thrush	Native
Catharus ustulatus	Swainson's thrush	NA
Certhia americana	brown creeper	Native
Ceryle alcyon	Belted Kingfisher	Native
Chaetura pelagica	Chimney Swift	Native
Charadrius vociferus	killdeer	Native
Chordeiles minor	Common Nighthawk	Native
Circus cyaneus	Northern Harrier	Native
Coccothraustes vespertinus	Evening Grosbeak	NA
Coccyzus americanus	Yellow-billed Cuckoo	Native

Scientific name	Common name/s	Status
	Birds	
Coccyzus erythropthalmus	Black-billed Cuckoo	Native
Colaptes auratus	Northern Flicker	Native
Colinus virginianus	Northern Bobwhite	Native
Columba livia	Rock Dove	Non-Native
Contopus virens	Eastern Wood Pewee, Eastern Wood-Pewee	Native
Coragyps atratus	Black Vulture	Native
Corvus brachyrhynchos	American Crow	Native
Corvus corax	Common Raven, Northern Raven	Native
Corvus ossifragus	Fish Crow	Native
Cyanocitta cristata	Blue Jay	Native
Dendroica caerulescens	Black-throated Blue Warbler	NA
Dendroica cerulea	Cerulean Warbler	NA
Dendroica coronata	Yellow-rumped Warbler	Native
Dendroica discolor	Prairie Warbler	Native
Dendroica dominica	Yellow-throated Warbler	NA
Dendroica fusca	Blackburnian Warbler	Native
Dendroica magnolia	Magnolia Warbler	Native
Dendroica palmarum	Palm Warbler	Native
Dendroica pensylvanica	Chestnut-sided Warbler	NA
Dendroica petechia	American Yellow Warbler, Yellow Warbler	Native
Dendroica pinus	Pine Warbler	Native
Dendroica striata	Blackpoll Warbler	Native
Dendroica tigrina	Cape May Warbler	NA
Dendroica virens	Black-throated Green Warbler	Native
Dolichonyx oryzivorus	Bobolink	Native
Dryocopus pileatus	Pileated Woodpecker	Native
Dumetella carolinensis	Gray Catbird, Grey Catbird	Native
Empidonax minimus	Least Flycatcher	NA
Empidonax traillii	Willow Flycatcher	NA
Empidonax virescens	Acadian Flycatcher	Native
Eremophila alpestris	Horned Lark	Native
Euphagus carolinus	Rusty Blackbird	NA
Falco sparverius	American Kestrel	Native
Gallinago gallinago	common snipe	NA
Geothlypis trichas	Common Yellowthroat	Native
Guiraca caerulea	blue grosbeak	Native
Haliaeetus leucocephalus	Bald Eagle	Native
Helmitheros vermivorus	Worm-eating Warbler	NA
Hirundo rustica	Barn Swallow	Native
Hylocichla mustelina	Wood Thrush	Native
Icteria virens	Yellow-breasted Chat	Native
Icterus galbula	Baltimore oriole	Native
Icterus spurius	Orchard Oriole	Native
Junco hyemalis	Dark-eyed Junco	Native

Scientific name	Common name/s	Status
	Birds	
Lanius ludovicianus	Loggerhead Shrike	Native
Larus argentatus	Herring Gull	NA
Larus delawarensis	Ring-billed Gull	Native
Lophodytes cucullatus	Hooded Merganser	Native
Megaceryle alcyon	Belted kingfinsher	Native
Melanerpes carolinus	Red-bellied Woodpecker	Native
Melanerpes erythrocephalus	Red-headed Woodpecker	Native
Meleagris gallopavo	Wild Turkey	Native
Melospiza melodia	Song Sparrow	Native
Mergus merganser	Common Merganser	Native
Mimus polyglottos	Northern Mockingbird	Unknown
Mniotilta varia	Black-and-white Warbler	NA
Molothrus ater	Brown-headed Cowbird	Native
Myiarchus crinitus	Great Crested Flycatcher	Native
Oporornis formosus	Kentucky Warbler	Native
Otus asio	Eastern Screech-Owl	Native
Pandion haliaetus	Osprey	Native
Parula americana	Northern Parula	Native
Parus atricapillus	Black-capped Chickadee	NA
Parus bicolor	Tufted Titmouse	Native
Parus carolinensis	Carolina Chickadee	Native
Passer domesticus	House Sparrow	Non-Native
Passerculus sandwichensis	Savannah Sparrow	Native
Passerella iliaca	Fox Sparrow	Native
Passerina cyanea	Indigo Bunting	Native
Petrochelidon pyrrhonota	American Cliff Swallow, Cliff Swallow	NA
Phasianus colchicus	Common Pheasant, ring-necked pheasant	NA
Pheucticus ludovicianus	Rose-breasted Grosbeak	Native
Picoides pubescens	Downy Woodpecker	Native
Picoides villosus	hairy woodpecker	Native
Pipilo erythrophthalmus	Eastern Towhee, Rufous-sided Towhee	Native
Piranga olivacea	Scarlet Tanager	Native
Piranga rubra	Summer Tanager	NA
Podilymbus podiceps	Pied-billed Grebe	Native
Poecile carolinensis	Carolina chickadee	
Polioptila caerulea	blue-gray gnatcatcher, Blue-grey Gnatcatcher	Native
Pooecetes gramineus	Vesper Sparrow	Native
Progne subis	Purple Martin	Native
Protonotaria citrea	Prothonotary Warbler	Native
Quiscalus quiscula	Common Grackle	Native
Regulus calendula	Ruby-crowned Kinglet	Native
Regulus satrapa	Golden-crowned Kinglet	Native
Riparia riparia	Bank Swallow, Sand Martin	NA
Sayornis phoebe	Eastern Phoebe	Native

Scientific name	Common name/s	Status
	Birds	
Seiurus aurocapillus	Ovenbird	NA
Seiurus motacilla	Louisiana Waterthrush	Native
Seiurus noveboracensis	Northern Waterthrush	NA
Setophaga ruticilla	American Redstart	Native
Sialia sialis	Eastern Bluebird	Native
Sitta canadensis	Red-breasted Nuthatch	NA
Sitta carolinensis	White-breasted Nuthatch	Native
Sphyrapicus varius	Yellow-bellied Sapsucker	Native
Spizella arborea	American Tree Sparrow	Native
Spizella passerina	Chipping Sparrow	Native
Spizella pusilla	Field Sparrow	Native
Stelgidopteryx serripennis	Northern rough-winged swallow	Native
Strix varia	Barred Owl	Native
Sturnella magna	Eastern Meadowlark	Native
Sturnus vulgaris	European Starling	Non-Native
Tachycineta bicolor	Tree Swallow	Native
Thryothorus ludovicianus	Carolina Wren	Native
Toxostoma rufum	Brown Thrasher	Native
Tringa melanoleuca	Greater Yellowlegs	Native
Tringa solitaria	Solitary Sandpiper	Native
Troglodytes aedon	House Wren	Native
Troglodytes troglodytes	Winter Wren	Native
Turdus migratorius	American Robin	Native
Tyrannus forficatus	Scissor-tailed Flycatcher	NA
Tyrannus tyrannus	Eastern Kingbird	Native
Tyto alba	Barn Owl, Common Barn-Owl	Native
Vermivora chrysoptera	Golden-winged Warbler	NA
Vermivora peregrina	Tennessee Warbler	NA
Vermivora pinus	Blue-winged Warbler	NA
Vermivora ruficapilla	Nashville Warbler	NA
Vireo flavifrons	Yellow-throated Vireo	NA
Vireo gilvus	Warbling Vireo	Native
Vireo griseus	White-eyed Vireo	Native
Vireo olivaceus	red-eyed vireo	Native
Vireo solitarius	Blueheaded vireo	Native
Wilsonia canadensis	Canada Warbler	Native
Wilsonia citrina	Hooded Warbler	Native
Zenaida macroura	Mourning Dove	Native
Zonotrichia albicollis	White-throated Sparrow	Native
Zonotrichia leucophrys	White-crowned Sparrow	Native

Table A-18. List of mammal species recorded in Antietam National Battlefield.

Scientific name	Common name/s	Status
	Mammals	
Blarina brevicauda	mole shrew, northern short-tailed shrew, short-tailed shrew	Native
Canis latrans	coyote	
Castor canadensis	american beaver, beaver	Native
Cryptotis parva	bee shrew, least shrew, little short-tailed shrew	Native
Didelphis virginiana	Virginia opossum	Native
Eptesicus fuscus	big brown bat	Native
Glaucomys volans	southern flying squirrel	Native
Lasiurus borealis	eastern red bat, red bat	Native
Lasiurus cinereus	hoary bat	Native
Lutra canadensis	River otter	
Marmota monax	woodchuck	Native
Mephitis mephitis	striped skunk	Native
Microtus pennsylvanicus	meadow vole	Native
Mus musculus	house mouse	Native
Mustela vison	American Mink, mink	Native
Myotis keenii	Keen's myotis	Native
Myotis lucifugus	little brown bat, little brown myotis	Native
Ochrotomys nuttalli	golden mouse	Non-Native
Odocoileus virginianus	white-tailed deer	Native
Ondatra zibethicus	muskbeaver, muskrat	Native
Peromyscus leucopus	white-footed mouse	Native
Peromyscus maniculatus	deer mouse	Native
Pipistrellus subflavus	eastern pipistrelle	Native
Procyon lotor	common raccoon, northern raccoon, Raccoon	Native
Rattus norvegicus	Norway rat	Native
Reithrodontomys humulis	eastern harvest mouse	Native
Scalopus aquaticus	Eastern Mole, topos	Native
Sciurus carolinensis	eastern gray squirrel, gray squirrel	Native
Sciurus niger	Eastern fox squirrel	
Sorex cinereus	Cinereus Shrew, common shrew, masked shrew	Native
Sylvilagus floridanus	Eastern Cottontail	Native
Tamias striatus	eastern chipmunk	Native
Tamiasciurus hudsonicus	red squirrel	Native
Urocyon cinereoargenteus	common gray fox, Gray Fox	Native
Vulpes vulpes	Red Fox	Native
Zapus hudsonius	meadow jumping mouse	Native

Appendix B: Information used in Antietam National Battlefield Natural Resource Condition Assessment

Table B-1. I&M reports used in the natural resource condition assessment.

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1991. In: R.H. Bruleigh Jr. Woodchuck impacts on cultural and biological resources at Antietam National Battlefield and Cemetery.

1992. Ground-water spring discharge: Maryland, Washington County. In: James, R.W. and M.J. Smigaj. Water resources data: Maryland and Delaware, water year 1992: volume 2 ground-water data. United States Geological Survey, Towson, MD.

1992. Potomac River basin: 01619500 Antietam Creek near Sharpsburg, MD. In: James, R.W., R.H. Simmons, and B.F. Strain. Water resources data: Maryland and Delaware, water year 1992: Volume 1 surface water data. United States Geological Survey, Towson, MD.

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Table B-3. List of acronyms used in this document.

Acronym	Description
ANC	Acid neutralizing capacity
ANTI	Antietam National Battlefield (NPS—NCRN)
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
CATO	Catoctin Mountain Park (NPS—NCRN)
CBOD	Carbonaceous biochemical oxygen demand
CHOH	Chesapeake & Ohio Canal National Historical Park (NPS—NCRN)
COMAR	Code of Maryland Regulations
DC	District of Columbia
DO	Dissolved oxygen
FIBI	Fish Index of Biotic Integrity
FIDS	Forest Interior Dwelling Species of birds
GIS	Geographic Information Systems
GMP	General Management Plan
GWMP	George Washington Memorial Parkway (NPS—NCRN)
HAFE	Harpers Ferry National Historical Park (NPS—NCRN)
I&M	Inventory & Monitoring Program (NPS)
IAN	Integration & Application Network (UMCES)
IBI	Index of Biotic Integrity
IMPROVE	Interagency Monitoring of Protected Visual Environments
IPM	Integrated Pest Management
IUCN	International Union for Conservation of Nature
MANA	Manassas National Battlefield Park (NPS—NCRN)
MBSS	Maryland Biological Stream Survey
MD DNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDN	Mercury Deposition Network
MONO	Monocacy National Battlefield (NPS—NCRN)
NAAQS	National Ambient Air Quality Standards
NACE	National Capital Parks—East (NPS—NCRN)
NADP	National Atmospheric Deposition Program
NBOD	Nitrogenous biochemical oxygen demand
NPS	National Park Service
NCRN	National Capital Region Network
NRCA	Natural Resource Condition Assessment
NSDWS	National Secondary Drinking Water Standards
NWI	National Wetlands Inventory
PHI	Physical Habitat Index
PRWI	Prince William Forest Park (NPS—NCRN)
RESAC	Regional Earth Science Applications Center
ROCR	Rock Creek Park (NPS—NCRN)
RSS	Resource Stewardship Strategy
TMDL	Total Maximum Daily Load
UMCES	University of Maryland Center for Environmental Science

UNESCO	United Nations Educational, Scientific, and Cultural Organization
U.S. EPA	U.S. Environmental Protection Agency
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WOTR	Wolf Trap National Park for the Performing Arts (NPS—NCRN)

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Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

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