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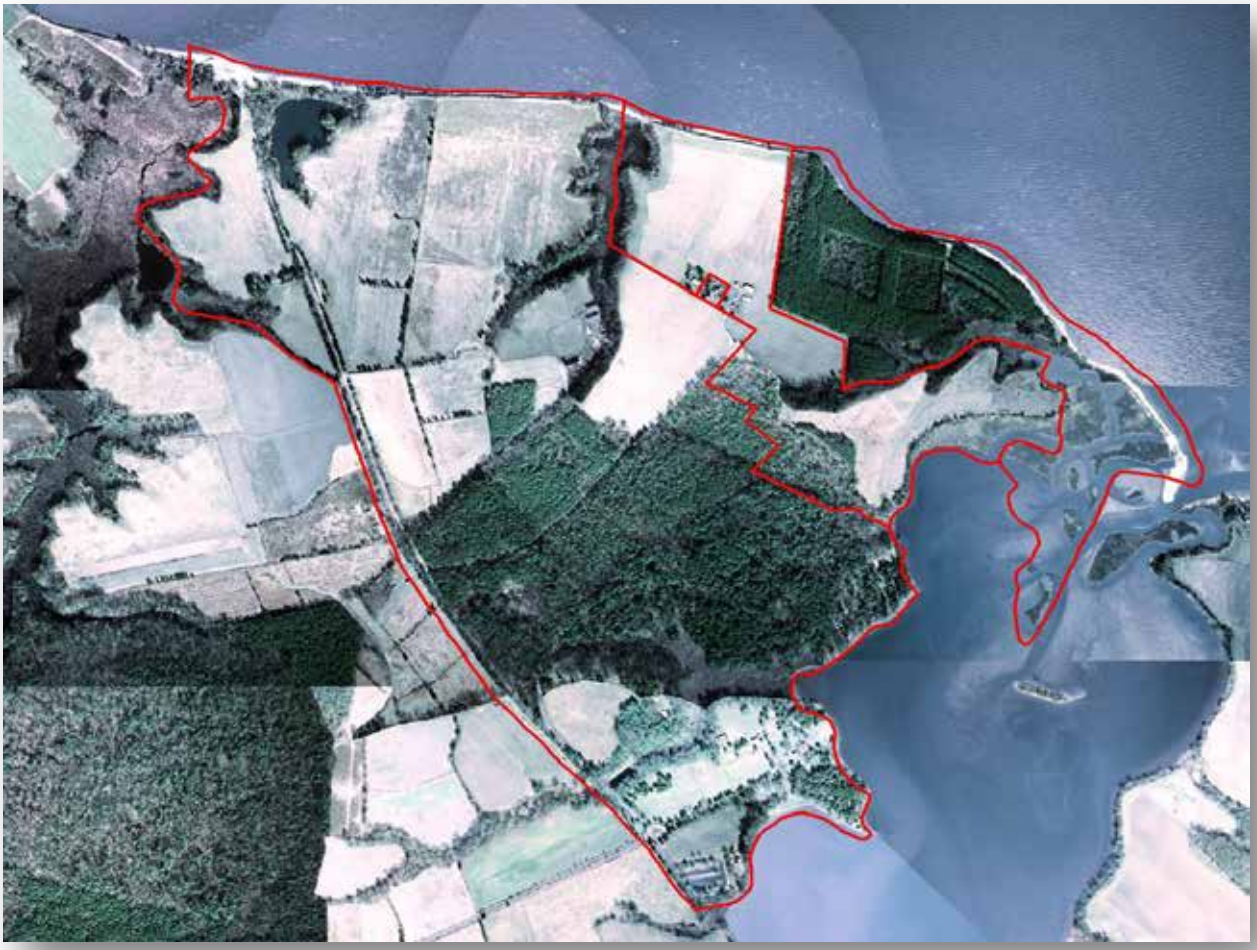
Natural Resource Stewardship and Science

Natural Resource Condition Assessments for George Washington Birthplace National Monument and Thomas Stone National Historic Site

Natural Resource Report NPS/NER/NRR—2012/576



ON THE COVER
Digital Orthophoto Quarter-Quadrangle (DOQQ) 2002 photo mosaic image of authorized boundary for George Washington Birthplace National Monument. Data courtesy of NPS George Washington Birthplace National Monument geodatabase.

Natural Resource Condition Assessments for George Washington Birthplace National Monument and Thomas Stone National Historic Site

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Executive Summary

The goal of this project was to develop a customized, GIS-based, natural resource condition assessment models for George Washington Birthplace National Monument (GEWA) and Thomas Stone National Historic Site (THST). This report explains the development of the natural resource condition assessment models, the spatial analysis approach, ecological criteria, and plans for continued development.

The assessment models for both parks focus on utilizing existing data, as well as the data relationship to sub-basins or catchment areas located entirely or partially within each park. The intent is to thoroughly examine the watersheds which drain within and across the boundaries of each park. Currently, the smallest watershed cataloguing units available from the U.S. Geological Survey (USGS) for both parks are 14-digit hydrologic unit codes (HUCs). However, finer sub-catchment scales would increase the potential for the parks to work with cooperators, decision-makers, and the local community on issues of mutual concern to protect within-park watershed resources. For the greatest utility to the park, natural resource condition assessments should help define the decision-making framework that affects the small watersheds within each park as this provides an environmentally manageable level in which the parks can be most effective in addressing resource stressors.

Data for GEWA and THST were compiled and organized into an ESRI enterprise geodatabase. The existing digital spatial data for GEWA were originally compiled as part of the synthesis of natural resource information for the park (Blank et.al. 2007). This database included spatial datasets developed for the National Park Service (NPS) Inventory and Monitoring Program's Northeast Coastal and Barrier Network, NPS Northeast Region geographic information system (GIS) files, data from the Conservation Fund's GEWA Community Profile, current demographic information, and datasets developed by the Chesapeake Bay Program (CBP). Existing digital spatial data for THST were compiled from the GEWA database, which includes several THST data layers, as well as data from the Northeast Coastal and Barrier Network website. Additional elevation and land use/land cover data for both parks were collected from the United States Geological Survey, as well as from additional local, state, federal, and private agencies.

The natural resource condition assessment models for GEWA and THST were designed to evaluate resource conditions based on data-supported landscape, biotic, and chemical/physical characteristics. The assessment models were additionally designed as an ESRI ArcGIS extension, with a user-friendly interface that provides the ability to handle new inputs and variations of parameters. Furthermore, the models were designed with the capacity to be applied to other parks or datasets if necessary.

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. xii) for more information.

Acknowledgments

This project would not have been possible without the help of personnel from George Washington Birthplace National Monument and Thomas Stone National Historic Site, as well as, the Northeast Coastal and Barrier Inventory and Monitoring Network of the National Park Service and various departments within North Carolina State. We would like to thank the following people for their contribution to this assessment effort:

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Prologue

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

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. xii) for more information.

Introduction

Project Overview

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety 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 reference conditions/values for comparison against current conditions[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.

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

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

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

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

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

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

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves 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 existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the 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. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

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 both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning and help parks to report on government accountability measures. In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) 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 draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

In recent decades, numerous federal and state agencies, as well as volunteer organizations, have developed integrative approaches to efficiently monitor the health of our nation's aquatic resources (Heiskary et al. 1994, Kerr et al. 1994, Obrecht et al. 1998). Traditionally, *in-situ* chemical and benthic macroinvertebrate monitoring have been the primary method of assessment for these resources (Hilsenhoff 1982, US EPA 1996). These methods have proven useful for reflecting local impairments to the sampled water bodies over short time periods. However, both methods may be limited in providing a "*whole-systems approach*" in the assessment of environmental conditions on a larger spatial and temporal scale. Multiple criteria indices have recently evolved as a prominent tool for monitoring ecosystem health, which build off of the stream health indices of biotic integrity (Zampella and Bunnell 1998, Karr and Chu 1997, Bozzetti and Schulz 2004). These indices use established ecological indicators to develop comprehensive estimations of environmental conditions. These estimations are based on weight vectors and confidence factors derived from current and best available data. However, to date, little work has been done to demonstrate the capacity of multiple criteria indices for natural resource condition assessments. Thus, the focus of this study was to develop a series of models that effectively use a multiple criteria approach to assess current natural resource conditions within George Washington Birthplace National Monument (GEWA) and Thomas Stone National Historic Site (THST).

The objectives of this project were three-fold:

1. Characterize the natural resources of GEWA and THST based on a literature review and existing data. This characterization emphasized bio-geographic and physical settings through the identification of "system level" ecological features, attributes, and functions—i.e., by watersheds, and/or habitats, and/or park management zones; regional and historic condition context; and unique and significant park resources and designations.
2. Identify existing and emerging stressors impacting park resources. The evaluation of existing and emerging threats in each park was based on the results of the natural resource condition assessments, established literature values, and professional judgment and expert opinion solicited from GEWA and THST staff, NC State University investigators, and others. Additionally, potential management concerns regarding currently impacted or likely "at-risk" resources, habitats, and/or watersheds, and recommended strategies to address threats and stressors within each park and in the larger contributing watersheds were identified.
3. Complete natural resource condition assessments for GEWA and THST. The natural resource condition assessment models were developed to work with a broad mix of ecological indicators. These indicators were analyzed to provide an index score or rating of current resource condition status for each park. As part of each assessment, the assumptions and logic for findings, level of confidence, critical data gaps, and recommend approaches to further refine and quantify reference/threshold conditions over time were identified.

Key features of the natural resource condition assessments for both parks centered on three development criteria: Geographic Scale, Model Development and Communication with Park Managers and Stakeholders.

Geographic Scale: Assessments for both GEWA and THST focused on sub-basins or catchment areas located either entirely or partially within each park where possible. The intent was to provide a level of detail that thoroughly accounted for existing drainage watersheds occurring within each park (e.g. Popes Creek, Bridges Creek, and other streams within each park). Currently the smallest watershed cataloguing units available from the U.S. Geological Survey (USGS) were 14-digit hydrologic units (HUC) for GEWA and 8-digit HUC for THST (Table 1 below). The available HUCs provided a geographic extent that was unsuitable for assessments at the level of each park. The 14-digit HUC (GEWA) and the 8-digit HUC (THST) served primarily as starting points for sub-catchment delineation. The need to focus the assessments on the smaller watershed areas has been highlighted in the currently ongoing General Management Plan planning process for GEWA (NPS, Northeast Region, Park Planning and Special Studies, Carol Cook, Community Planner, e-mail dated May 15, 2007). For example, Cook pointed out that these efforts have confirmed the importance of Popes Creek as a fundamental value to the park, as a site of research interest, and the key watershed in which the park is a stakeholder. At this scale, there remains the potential for the park to work with cooperators, decision-makers, and the local community on issues of mutual concern to protect within-park natural resources. For the greatest utility to the park, these assessments should help define the decision-making framework that affects the small watersheds within each park because this is the arena in which the parks can be most effective in addressing resource stressors.

Model Development: Although biologic indices based on a single taxonomic group have been used for some time, multiple criteria indices are a relatively younger tool. In theory, the process of developing a comprehensive natural resource condition assessment would begin with sampling specific environmental conditions or taxa. For the development of the GEWA and THST models, the assessments must rely on data that have already been collected. Since these data were not collected to fulfill the requirements of a particular model, it was necessary to customize model development based on the data that are available for each park. The goal was to maximize the usefulness of the existing data in the assessment models, relying heavily on the work of others, but customizing the models to the extent necessary to maximize the usefulness for park managers. These models were designed to be user-friendly in their ability to handle new inputs and variations of parameters. Additionally, these models were also designed to be easily applied to other parks or datasets should the input data be available.

The assessment models took advantage of the NPS comprehensive enterprise geodatabase developed for GEWA and THST. Additionally, these models integrated a natural resource assessment index for GEWA and THST that was developed from current literature and existing local, state, and federal data resources. This index was developed to evaluate the ecological function and integrity of the park, as well as examine potential threats to terrestrial and aquatic ecosystems.

Table 1. Summary table of additional model indicators useful for determining a more comprehensive natural resource condition assessment and emerging stressors for George Washington Birthplace National Monument and Thomas Stone National Historic Site. The threshold value designates the point at which the condition indicator signifies impairment. Due to a lack of suitable data available at the time of this assessment these indicators were not included in this assessment, but should be considered in future condition assessments.

Condition Indicator	Impairment Threshold Value	Geographic Relevance	Reliability Designation	Reference Citation
Landscape Condition Assessment				
Road Density	Weighted on type (highway, secondary, etc.)	Southeast U.S.	Fair	Chen and Roberts 2008
Population Dynamics	>37 individuals Per sq. mi.	Mid-Atlantic	High	Kepner et al. 1995
Biotic Condition Assessment				
At Risk Native Species	<13 (GEWA)	arbitrary	Poor	Hershner et al. 2007
Invasive Species	>30%	arbitrary	Poor	Hayes et al. 2005
Population Age Structure	varies	arbitrary	Poor	Shaffer 1981
Percent Diseased	varies	arbitrary	Poor	EPA 1990
Total Species (MAMMALS)	varies	arbitrary	Poor	Hayes et al. 2005
Total Species (REPTILES/AMPHIBIANS)	varies	arbitrary	Poor	Hayes et al. 2005
Total Species (FISH)	varies	arbitrary	Poor	EPA 1990
Total Species (BIRDS)	varies	arbitrary	Poor	Bradford et al. 2004
Total Species (ODONATES)	varies	arbitrary	Poor	AOI 1998
Species Abundance (MAMMALS)	varies	U.S.	Poor	Baker et al. 2003
Species Abundance (REPTILES/AMPHIBIANS)	varies	U.S.	Poor	Crother 2000
Species Abundance (FISH)	varies	U.S.	Poor	Matsen and Berge 2008
Species Abundance (BIRDS)	varies	U.S.	Poor	AOI 1998
Species Abundance (ODONATES)	varies	U.S.	Poor	DSA 1996
Chemical Condition Assessment				
Buffering Capacity	<20 mg/L	Mid-Atlantic	Fair	VA EPA 2007
Fecal Coliform	>100 colonies per 100 ml H2O	Mid-Atlantic	Fair	VA EPA 2007
Chlorophyll a (Freshwater Summer)	<12 mg/L	Mid-Atlantic	Good	VA EPA 2007
Chlorophyll a (Freshwater Spring)	<14 mg/L	Mid-Atlantic	Good	VA EPA 2007
Chlorophyll a (Oligohaline Summer)	<9.5 mg/L	Mid-Atlantic	Good	VA EPA 2007
Chlorophyll a (Oligohaline Spring)	<20.9 mg/L	Mid-Atlantic	Good	VA EPA 2007
Chlorophyll a (Mesohaline Summer)	<7.7 mg/L	Mid-Atlantic	Good	VA EPA 2007
Chlorophyll a (Mesohaline Spring)	<6.2 mg/L	Mid-Atlantic	Good	VA EPA 2007
Chlorophyll a (Saltwater Summer)	<4.5 mg/L	Mid-Atlantic	Good	VA EPA 2007
Chlorophyll a (Saltwater Spring)	<2.8 mg/L	Mid-Atlantic	Good	VA EPA 2007
Turbidity	<20%	Eastern U.S.	Fair	VA EPA 2007
Shellfish closures	varies	Mid-Atlantic	Good	Wefering et al.
Hydrology/Geomorphology Condition Assessment				
Sediment Transport	varies	arbitrary	Poor	unavailable
Natural Disturbance Condition Assessment				
Fire Regime				
Duration	TBD	site specific	Poor	unavailable
Extent	TBD	site specific	Poor	unavailable
Frequency	TBD	site specific	Poor	unavailable
Seasonality	TBD	site specific	Poor	unavailable

Condition Indicator	Impairment Threshold Value	Geographic Relevance	Reliability Designation	Reference Citation
Flood Regime				
Size	TBD	site specific	Poor	unavailable
Intensity	TBD	site specific	Poor	unavailable
Duration	TBD	site specific	Poor	unavailable
Ecological Processes Assessment				
Biodiversity (Index of Biotic Integrity)	<5.0	Mid-Atlantic	Fair	Maryland DNR

The assessment models were developed employing a user-friendly interface that provide the ability to handle new inputs and variations of parameters. To achieve this, the models included a customized user interface that allow the models to be run from a series of “drop down” menus to facilitate selecting or unselecting various parameters as well as updating data sets.

Involvement and expert opinion of park personnel and stakeholders was incorporated into the final selection of model indicators. The final selected indicators and each indicator’s associated value deemed for the literature served as a threshold for each of the model assessments. Indicator parameter values and ranges may be adjusted by park personnel to determine current natural resources conditions, data gaps, as well as explore a range of possible scenarios should existing conditions within or outside of the park change.

Study Areas

George Washington Birthplace National Monument

George Washington Birthplace National Monument (GEWA) is located on the Northern Neck of rural and tidal Virginia about 45 miles east of Fredericksburg on State Highway 3 and about 80 miles south of Washington, D.C. in Westmoreland County (Figure 1). The park is fairly flat and typical of the Middle Atlantic Coastal Plain. Park Service-owned and managed lands comprise about 551 acres bounded by the Potomac River on the north, Pope's Creek estuary in the east and south, and private land to the south and west. Land cover types include about 280 acres of open grasslands, 220 acres of forests, 25 acres of marshes and estuaries, 18 acres of memorial cultural landscapes, 5 acres of beaches and dune habitats, and 3 acres of developed lands. Birds, mammals, fish, reptiles, amphibians and invertebrates find favorable niches in several of these habitats. While inventories of the flora and fauna within the park have been conducted, a complete ecosystem health assessment, invaluable for planning purposes, has not been completed.

An overview of natural resource conditions, data sources, and management issues for GEWA is found in *George Washington Birthplace Natural Resource Synthesis*, prepared by Alan C. Ellsworth (2003), National Park Service (NPS) Northeast Regional Hydrologist. Ellsworth calls attention to the park's regional importance. He describes GEWA as a component of the Chesapeake Bay Program (CBP) and notes that "natural resources within GEWA have remained relatively pristine due to efforts focused on the preservation of the historical setting at this location and limited development along the park boundary. While GEWA is a small component of the CBP, it provides scientific and interpretive opportunities to exemplify proactive resource management practices."

The Northeast Regional Office of the NPS is currently working with the GEWA Park Superintendent and staff to develop a general management plan and environmental impact statement for the park. In order to meet NPS planning needs, North Carolina State University recently completed a synthesis of natural resource information for GEWA (Blank et al. 2007). This effort included compilation of an extensive catalog of georeferenced, digital data sets and imagery for the park and surrounding areas.

Thomas Stone National Historic Site

Thomas Stone National Historic Site (THST) is located across the Potomac River from GEWA and about 25 miles south of Washington D.C. in Charles County, Maryland (Figure 1). Park Service-owned and managed lands at the site comprise 328 acres primarily within the Hog Hole Run sub-catchment, which drains into Port Tobacco Creek. The park contains approximately 180 acres of forest, 110 acres of open fields, 5 acres of riparian habitat, and 2 acres of maintained lawns. While numerous observations of fauna and flora, especially beavers and avian species, have been recorded in the park, systematic inventories have not been conducted. The park shares many physiographic characteristics with GEWA and, like GEWA, is fairly typical of the Middle Atlantic Coastal Plain.

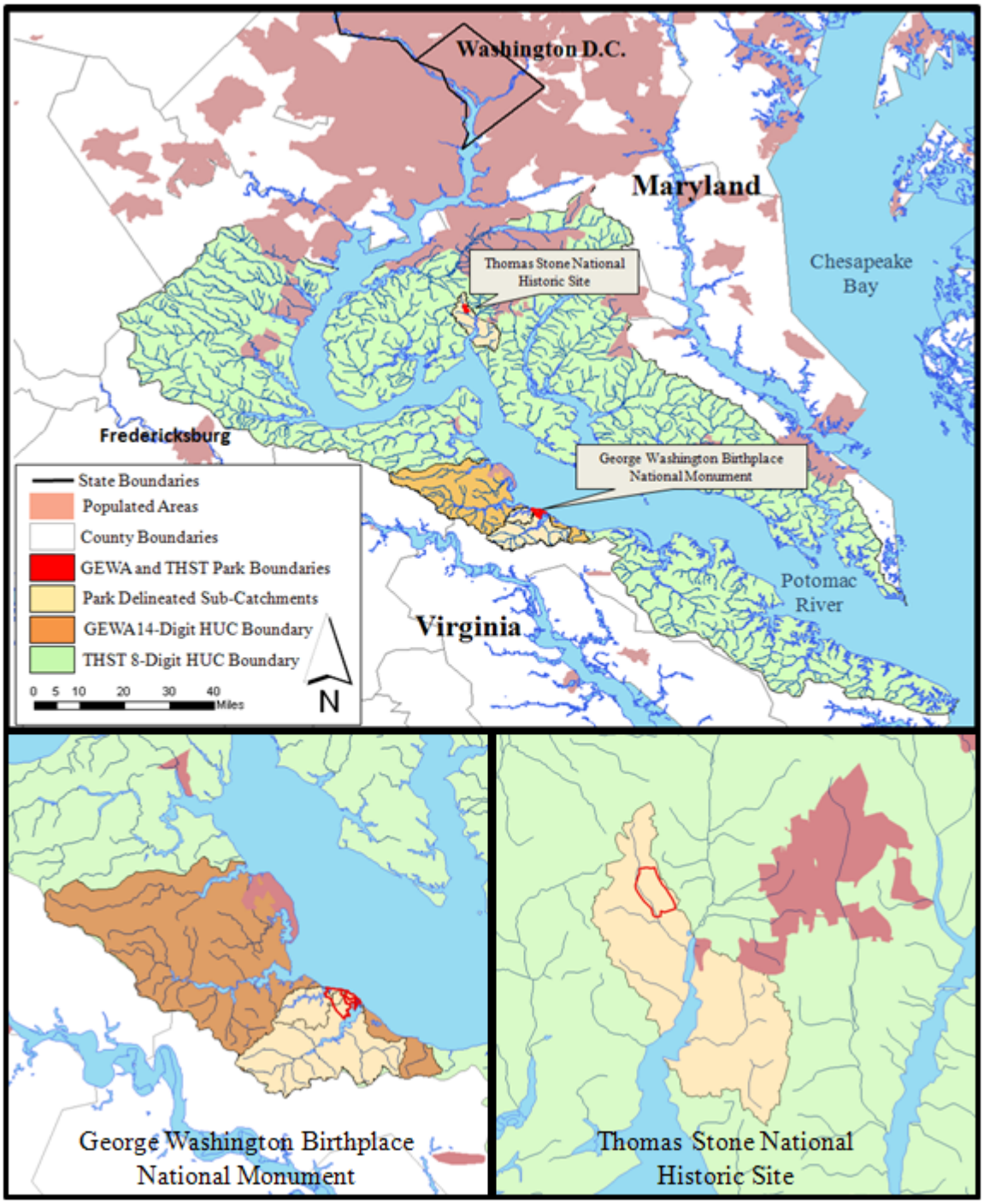

Figure 1. Location of George Washington Birthplace National Monument and Thomas Stone National Historic Site in relation to hydrologic features of the Lower Potomac watershed.

Methods

Ecological and Environmental Indicator Development

Digital spatial data for GEWA and THST, compiled from the synthesis of natural resource information for GEWA (Blank et al. 2007) and NPS data for THST, provided the existing data required for development of the natural resource condition assessments. These data included spatial datasets developed for the NPS Inventory and Monitoring Program, NPS Northeast Region geographic information system (GIS) files, data from the Conservation Fund's GEWA Community Profile, current demographic information, and datasets developed by the CBP.

This database includes the following data layers for GEWA and THST and surrounding areas:

- Current and historic aerial imagery
- Cultural resource data
- Park wetland mapping project data
- Biological inventory data
- Park vegetation
- Watershed delineations

Further attempts were made to enhance the existing datasets by incorporating data available from additional local, state, federal, and public agencies within the Chesapeake Bay/Potomac River region. All additional data incorporated into the GEWA and THST database were reviewed and edited for spatial integrity, topological correctness, and projection errors. The resultant databases were developed to form an enhanced GEWA and THST enterprise geodatabase that served as the baseline data source for all model assessments. The enhanced geodatabase was then reviewed to determine suitable data available for both study areas from which ecological/condition indicators could be determined. Values from the scientific literature and expert opinion were used to establish the model indicators, and each indicator's associated threshold value that was developed for the natural resource condition assessments.

The model indicators were separated into six categories: Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, Ecological Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes. However the latter three categories (Ecological Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes) were subsequently removed from the model development due to a lack of available data for each category.

Specific Indicators Considered but Discarded from this Assessment

Previous studies supported over 45 indicators with the potential for use within the assessment of natural resource condition at GEWA and THST. However, the lack of data necessary to adequately utilize these indicators led to their elimination from the GEWA and THST assessment models. Examples of these eliminated indicators and their attributes are listed in Table 1. Explanations of key indicators follow Table 1 and are grouped according to the relevant model assessment category (i.e. Landscape Condition, Biotic Condition, Chemical/Physical Condition, Hydrology/Geomorphology Condition, Natural Disturbance Condition, and Ecological Processes). Indicators listed in Table 1 represent data gaps that park staff and their inventory and monitoring network (Northeast Coastal and Barrier Network) should address in total or in part in order to improve the accuracy of future natural resource condition assessments.

Landscape Condition

Road Density

Density based on size of road. Threshold values would be based on type; i.e. primary, secondary, highway, interstate (Chen and Roberts 2008).

Population Densities

Total number of people located per square mile adjacent to the park. It is believed that if the population density is equal to or greater than 37 individuals per square mile that environmental integrity has the possibility of being threatened (Kepner et al. 1995).

Biotic Condition

At Risk Native Species

The number of at risk native species is of great importance to environmental integrity. At risk native species will be defined as those species listed as threatened or endangered on both the state and federal level. There are thirteen species listed to be endangered within Virginia and Maryland. Bald Eagles are the main species of concern on the federal level as well as two additional bird species which may need more research at the park levels. The threshold value established for THST and GEWA would be <13 species present, due to the fact that there are 13 known endangered species present in the park area and a decline in this number might suggests deteriorating conditions.

Invasive Species

Invasive Species are of great concern to parks nationwide. These species are out-competing many native species and therefore pushing these native species to extinction. Invasive species are normally defined as non native species that adversely affect the habitats they invade. These species cause negative economical, environmental or ecological affects. Not much work has been done to give a quantifiable affect by a certain number of invasive species. For the purpose of GEWA, the threshold that affects environmental integrity was defined as greater than 30 percent of known invasive species (statewide or coastal region) being present in a given area.

Population Age Structure

Age structure defines the number of individuals at a juvenile/non sexually mature age compared to adults/breeding age individuals. A healthy threshold for each group (fish, mammal, reptile, amphibian, bird and odonate) has not been established in the literature as it related to GEWA or THST. Many factors contribute to this difference in which a healthy mammal age structure may differ from a healthy fish species structure. A literature values and/or professional opinion are needed in order to include this indicator into the current models.

Diseased Organisms

Diseased individuals shall be defined as those individuals in a given species with a species and/or biotic condition threatening disease that may lead to the decline of that species or the overall biotic condition. Diseases range from species to species and much more research needs to be completed before this indicator can be included into the current models.

Chemical/Physical Condition

Buffering Capacity

Buffering capacity refers to the ability of water to keep pH levels from dramatically changing over time. If a body of water is unable to filter solids and keep the pH levels in check, biotic integrity of that waterbody becomes compromised. The VA EPA (2007) established values are for sustaining ecological function is that buffering capacity stay above 20 mg/L. If buffering capacity decreases, and alkalinity increases in a body of water, pH will drop accordingly. Optimal bio-physiological ranges for most organisms are found between a pH range of 6.0–9.0.

Fecal Coliform (colonies/100ml)

Fecal Coliform are non-sporulating bacteria and indicate the presence of sewage contamination of a waterway and the possible presence of other pathogenic organisms. The most common fecal coliform is E. Coli which indicated the presence of pathogens in feces. For the purpose of GEWA, thresholds were established for all fecal coliforms as well as for the presence of E. Coli by itself. Thresholds were also established on the single sample and geometric mean of bacteria present. For all fecal coliform geometric mean: 100 colonies per 100 ml of water single sample: greater than 150 colonies per 100 ml of water. For E. Coli alone geometric mean is greater than 70 colonies per 100 ml of water and single sample mean 150 colonies per 100 ml of water. Any sample taken above these values is reported to degrade environmental integrity (VA EPA 2007). The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be highly relevant given the fact that the values for the reported study was developed in the Mid-Potomac region.

Chlorophyll a

Chlorophyll is the green pigment found in most plants, algae and cyanobacteria. Chlorophyll a is mainly found in cyanobacteria and algae. This pigment allows algae to convert sunlight into organic compounds during photosynthesis. High amounts of chlorophyll a in water are a good indicator of nutrient pollution. When excess nutrients are present, fuel is provided for extreme algal growth. For the case of GEWA, chlorophyll a was used as an indicator of this excess nutrient concentration. Threshold values were established for all different types of water present in the GEWA watershed at peak times of the year for algal growth (spring and summer). For freshwater systems, environmental integrity is reported to be at risk when chlorophyll a reaches a concentration of 14 mg/liter in the spring and 12 mg/liter in the summer. In oligohaline waters this 20.9 mg/liter in spring and 9.5 mg/liter in summer. For mesohaline waters, 6.2 mg/liter in spring and 7.7 mg/liter in the summer. For saltwater systems, 2.8 mg/liter in spring and 4.5 mg/liter in the summer (VA EPA 2007). The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be highly relevant given the fact that the values for the reported study was developed in the middle Potomac region.

Turbidity

Turbidity is the cloudiness or haziness of the water caused by suspended sediment in the water column. Turbidity is a good indicator of water quality. It can be caused by many things from the growth of phytoplankton to disturbance caused by human construction. For the purpose of GEWA, turbidity is used to indicate water quality in the GEWA and THST watersheds.

Shellfish closures
Shellfish bed closures are an excellent indicator of bacteria present within any given waterbody. Land use changes for example can contribute to excessive bacterial loading and bed closure. Selected indicators using shellfish closures allows for an assessment of ecosystem impairments (Wefering et al. 2000). Shellfish closures over one year can be used to determine a portion of the chemical condition for both GEWA and THST.

Hydrology/Geomorphology Condition

Sediment Transport
Sediment transport describes the movement of solid particles along natural systems. This mainly pertains to how water and wind move particles within the watershed. This is very important to understand erosion and deposition, as well as the duration it takes for particles to move. Data in this field would prove very useful in preserving the landscape of both GEWA and Thomas Stone.

Natural Disturbance Condition

Fire Regime
Fire regime pertains to the event of natural or controlled burns to an ecosystem. Bunnell (1995) found that natural fire regimes were important in maintaining a diverse assemblage of vertebrate species in twelve different forest types in British Columbia. High intensity fires have also caused negative impacts to ecological communities. Therefore different components make a fire regime ideal or dangerous to an environmental community. These include duration, extent , frequency, and seasonality.

Flood Regime
A flood regime is very important to ecological communities. Floods carry sediment and nutrients to different habitats and can damage or positively influence species living in those waters. The main components of flood regime that determine whether a flood helps or hurts an ecosystem include flood size, intensity, and duration.

Ecological Processes

Biodiversity
Biodiversity is defined as the variation of life forms within a given ecosystem. Biodiversity is often used to measure the health of any given biologic system and its processes. Destruction of habitat, exotic species, hybridization and climate change all contribute to decreases biodiversity in a system. No clear threshold has been established for a diverse ecosystem but some knowledge of diversity can be gained by studying the components of biodiversity.

Specific Indicators Utilized in this Condition Assessment

The previous text highlighted various indicators identified by ourselves, park staff, and various peer reviewers as potentially useful for assessing the natural resource conditions at GEWA and THST, but were subsequently ruled out due to a lack of sufficient data. The following text and table (Table 2) highlight the specific indicators that were used to assess the condition of the natural resources of GEWA and THST. Reference or threshold values for these indicators were established for comparative calculations in producing model results. Where possible, the reference condition values were selected to represent geographically relevant values. Each reference value was converted to a base scale, ranging from 1–5 of overall condition.

Table 2. Model indicator threshold value for the landscape condition, biotic condition, and chemical condition assessment categories. The threshold value designates the point at which the condition indicator signifies impairment.

Condition Indicator	Impairment Threshold Value/Units	Specific Condition Threshold Value	Geographic Relevance	Reliability Designation	Reference Citation
Landscape Condition Assessment[a]					
Percent urban and agricultural cover	>50%	<16.7 Good 16.7–26 Good/Fair 26–32.5 Fair 32.5–43.4 Fair/Poor >43.4 Poor	Mid-Atlantic	High	Riitters et al. 1997, Jones et al. 1997
Percent watersheds with crops on >3% slope	>10%	<1.5 Good 1.5–4.2 Good/Fair 4.2–6.4 Fair 6.4–9.7 Fair/Poor >9.7 Poor	Mid-Atlantic	High	Hunsaker et al. 1992
Percent stream length with agricultural cover	>30%	<8.5 Good 8.5–14.6 Good/Fair 14.6–20.1 Fair 20.1–27.9 Fair/Poor >27.9 Poor	Mid-Atlantic	High	Jones et al. 1997, O'Neill et al. 1988, Riitters et al. 1997, Hunsaker et al. 1992
Percent forested	<50%	>82.4 Good 72.5–82.4 Good/Fair 63.8–72.5 Fair 48.4–68.3 Fair/Poor <48.4 – Poor	Northeastern United States	Fair	Welsch 1991, Mascutt et al. 1993
Percent forest fragmented	>20%	<7.8 Good 7.8–11.2 Good/Fair 11.2–13.8 Fair 13.8–21.4 Fair/Poor >21.4 Poor	Eastern United States	Good	Saunders et al. 2002, Heilmann et al. 2002, Zipperer 1991
Length of road per square km	>3.0 km	<1.3 Good 1.3–1.6 Good/Fair 1.6–1.9 Fair 1.9–3.0 Fair/Poor >3.0 Poor	Alabama – Southern U.S.	Fair	Chen and Roberts 2008
Percent stream length within 30m of road	>10%	<2.8 Good 2.8–4.6 Good/Fair 4.6–6.2 Fair 6.2–8.3 Fair/Poor >8.3 Poor	Eastern United States	Good	Heilman et al. 2002

Condition Indicator	Impairment Threshold Value/Units	Specific Condition Threshold Value	Geographic Relevance	Reliability Designation	Reference Citation
Impervious surface	>10%	<5 Good 5–10 Good/Fair 10–25 Fair 25–30 Fair/Poor >30 Poor	Eastern United States	Good	Arnold and Gibbons 1996, Lathrop et al. 2007
Biotic Condition Assessment[b]					
Species Presence (Bird)	<40%	>50 Good 50–40 Good/Fair 40–30 Fair 30–20 Fair/Poor <20 Poor	arbitrary	Poor	unavailable
Species Presence (Mammal)	<40%	>50 Good 50–40 Good/Fair 40–30 Fair 30–20 Fair/Poor <20 Poor	arbitrary	Poor	unavailable
Species Presence (Reptile/Amphibian)	< 40%	>50 Good 50–40 Good/Fair 40–30 Fair 30–20 Fair/Poor <20 Poor	arbitrary	Poor	unavailable
Species Presence (Fish)	< 40%	>50 Good 50–40 Good/Fair 40–30 Fair 30–20 Fair/Poor <20 Poor	arbitrary	Poor	unavailable
Species Presence (Odonate)	<40%	>50 Good 50–40 Good/Fair 40–30 Fair 30–20 Fair/Poor <20 Poor	arbitrary	Poor	unavailable

Condition Indicator	Impairment Threshold Value/Units	Specific Condition Threshold Value	Geographic Relevance	Reliability Designation	Reference Citation
Chemical Condition Assessment[c]					
pH	6.0–9.0	6.0–9.0 Good 6.0–5.5 or 9.0–9.5 Good/Fair 5.5–5.0 or 9.5–10.0 Fair 5.0–4.5 or 10.0–10.5 Fair/Poor >10.5 or <4.5 Poor	Mid-Atlantic	Fair	Dauer et al. 2000
Dissolved Oxygen	<6.0 mg/L	>6.0 Good 6.0–5.0 Good/Fair 5.0–4.0 Fair 4.0–3.0 Fair/Poor <3.0 Poor	Mid-Atlantic	Fair	VA EPA 2007
Temperature	15.5–21.2 C	15.50–21.20 Good 21.2–23.2 or 15.5–13.5 Good/Fair 23.2–25.2 or 13.5–10.5 Fair 25.2–27.2 or 10.5–8.5 Fair/Poor >27.20 or <8.5 Poor	Mid-Atlantic	Good	VA EPA 2007
Conductivity	<500 mg/L	>500 Good 500–400 Good–Fair 400–300 Fair 300–200 Fair–Poor <200 Poor	Mid-Atlantic	Fair	VA EPA 2007

[a]Landscape Condition: Data source: nlcd_2001, LiDar DEMS.
[b]Biological Condition: Data source: NPSpecies, VA GAP
[c]Chemical Condition: Data source: WQ table of FISH INVENTORY

Low-impact conditions, receiving a score of 5, served as a reference value from which model scores were compared. Conditions ranged from high impact (1 = Poor Condition) to low impact (5 = Good Condition). Intermediate scale values included Fair–Poor (2), Fair (3), Good–Fair (4). Table 2 presents the model indicators, threshold values adapted from the literature, and geographic relevance of each threshold value for the Landscape Condition, Biotic Condition, and Chemical Condition assessment categories. A more detailed description of the assessment categories and the indicators that comprise each category follows Table 2.

Description of the Landscape Condition Indicators

The following indicators were chosen in order to assess overall landscape condition within the GEWA and THST park boundaries (Table 2). The indicator results are based on sub-catchment delineations of the 14-digit and 8-digit USGS HUCs available for GEWA and THST, respectively.

Percent Urban and Agricultural Cover

The percent urban and agricultural cover indicator relates to the overall area of each delineated sub-catchment that contained urban and/or agricultural land. An area with greater urban and agricultural area can have adverse effects on the watershed it is within. A threshold value of greater than 50 percent has been reported to degrade environmental integrity and impact the functionality of the watershed (Riitters et al. 1997, Jones et al. 1997). The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be highly relevant (Reliability Designation = High) given the fact that the values for the reported studies were developed in the mid-Atlantic region of the United States.

Percent Watershed with Crops on greater than a 3% Slope

A sloped terrain increases the chances of runoff into nearby water systems. The environmental integrity of a watershed has been reported to be degraded when greater than 10 percent of a watershed's agricultural area meets this three percent slope boundary (Hunsaker et al. 1992). The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be highly relevant (Reliability Designation = High) given the fact that the values for the reported study was developed in the mid-Atlantic region of the United States.

Percent Stream length with Agricultural Cover

The proportion of stream length with agricultural cover has been reported to effect watershed condition after reaching a threshold value of greater than 30 percent (Jones et al. 1997, O'Neill et al. 1988, Riitters et al. 1997, Hunsaker et al. 1992). GEWA and THST streams were buffered on both sides to 30 meters and the proportion of agricultural use was computed from areas within the buffer area. The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be highly relevant (Reliability Designation = High) given the fact that the values for the reported studies were developed in a centralized area of the mid-Atlantic region of the United States.

Percent Forested

The proportion of the watershed that is forested has been reported to have an effect on overall watershed condition. Little is known of the overall forest habitat and health in GEWA and THST due to the fact that inventories have not yet been completed. Studies have reported that when an area within a watershed becomes deforested at more than 50 percent of the overall area,

environmental condition has been shown to deteriorate (Welsch 1991, Mascutt et al. 1993). GEWA and THST streams were buffered to within 30 meters and the forested was extracted for model assessments. Threshold values were applied from a study of riparian buffers in the northeastern United States. The geographic relevance of the threshold values in relation to GEWA and THST were assumed to be fairly reliable (Reliability Designation = Fair) given the fact that the values for the reported studies were developed in the northeastern region of the United States.

Percent Forest Fragmentation

Forest fragmentation is the process of larger patches of forest being broken up into smaller patches over time. Forest fragmentation has been reported to reduce biodiversity by making it more difficult for species to find food, and shelter and breed as well as reducing water quality (Riiters et al. 2002). Studies have shown that if a watershed has an overall forest fragmentation designation of greater than 20 percent, deteriorations in wildlife habitat and biodiversity have resulted (Saunders et al. 2002, Heilmann et al. 2002, Zipperer 1991). The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be relevant (Reliability Designation = Good) given the fact that the values for the reported studies were developed in the eastern region of the United States.

Length of Road per sq km

An ecosystem can be negatively affected when an area experiences disturbance from roadway construction and usage (Watts et al. 2007). A study in Alabama suggests that environmental integrity of a watershed is compromised if an area has a road density of more than 3.0 km^2 of roadway within its boundary (Chen and Roberts 2008). The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be fairly reliable (Reliability Designation = Fair) given the fact that the values for the reported study was developed in the Alabama region of the United States**.**

Percent Stream Length within 30 meters of road

Proximity to a stream is very important when considering road placement. The likelihood and extent of any impact on water quality depends not only on erosion or runoff, but also the connectivity between sediment sources and the receiving waters (Novotny and Chesters 1989). Environmental integrity has been reported to be reduced when road density comprises more than 10 percent of the area within 30 meters of a stream (Heilman et al. 2002). The geographic relevance of this threshold data in relation to GEWA and THST was assumed to be relevant (Reliability Designation = Good) given the fact that the values for the reported study were developed in the eastern region of the United States.

Percent Impervious Surface

Impervious surfaces are mainly artificial structures of impenetrable materials such as asphalt, concrete, brick, and stone. These include roads, sidewalks, driveways and/or soil compacted by urban development. When impervious surfaces cover 10 percent or more of a given area, environmental quality can become degraded (Arnold and Gibbons 1996, Lathrop et al. 2007). The geographic relevance of the threshold data in relation to GEWA and THST was assumed to be relevant (Reliability Designation = Good) given the fact that the values for the reported studies were developed in the eastern region of the United States.

Description of the Biotic Condition Indicators

The following indicator was chosen for different species groups in order to classify overall biologic condition in the GEWA and THST watersheds and constituting sub-catchments (Table 1). Each was ranked based upon five intervals (good, good–fair, fair, fair–poor and poor respectively). The indicator was also given threshold values for each of the species groups on which to quantify the ranked values.

Species Presence/Absence

Species presence/absence is defined as the total number of species present compared to the total number of species predicted to occupy a given area. In the case of GEWA and THST, species abundance was defined for several different groups. These include fish, mammals, reptiles, amphibians, birds and odonates. A threshold was arbitrarily developed for every group at less than 40 percent affecting biotic condition. Sufficient inventories for each group exist in the GEWA and THST areas, however no set threshold has been agreed upon by the scientific community. Due to lack of a literature values to compare to the given threshold, a reliability designation of this indicator threshold was deemed poor (Reliability Designation = Poor).

Description of the Chemical Condition Indicators

The following indicators were chosen in order to classify overall chemical condition in the GEWA and THST sub-catchments (Table 1).

pH

pH is the measure of acidity of a given waterbody. The pH thresholds were established for freahwater, brackish water (mesohaline/oligohaline) and saltwater (polyhaline). Dauer (et al. 2000) determined pH values to be biologically tolerable to organisms when they occur within the following ranges; 6.0–9.0 for freshwater, 7.0–9.0 for brackish water, and 7.1–8.1 for saltwater. The reliability of these thresholds was deemed fair (Reliability Designation = Fair) due to the fact that pH fluctuations occur seasonally and can vary outside the bounds of 6.0–9.0 pH threshold and still be considered normal.

Dissolved Oxygen

Dissolved oxygen is a measure of the amount of gaseous oxygen (O^2) dissolved in the water. Dissolved oxygen is considered to deteriorate the chemical condition of the watershed when it reaches certain threshold levels (VA EPA 2007). In freshwater, the VA EPA (2007) has reported this value to be less than 6.0 mg/L. The dissolved oxygen threshold level is less than 5.5 mg/L for brackish water and less than 5.0 mg/L for saltwater (VA EPA 2007). For the purpose of this study 6.0 mg/L was used because differentiation between freshwater, brackish water, and saltwater was not possible. The reliability of this data was assumed to be fair (Reliability Designation = Fair) as dissolved oxygen levels fluctuate seasonally and with water depth and temperature. These fluctuations may occur intermittently or temporarily and require a longer-term trend analysis, as opposed to limited point samples.

Temperature

Water temperature in aquatic systems plays an important role in several biological processes. If temperature levels fluctuate between high and low values, biological processes can become impaired or cease to function all together. For GEWA and THST, the temperature range was based on normal temperature ranges for the eastern coast of the United States. These values were

directly taken from the VA EPA Virginia water quality standards (2007). It has been reported that sensitive biotic processes may be affected if temperatures fall outside the range of 15.5 to 21.2 degrees Celsius (VA EPA 2007). The reliability of this threshold was assumed to be good (Reliability Designation = Good).

Conductivity

Conductivity is defined as the measurement of the ability of an aqueous solution to carry an electrical current. It can determine mineralization as well as signify chemical and physical change in the natural water supply. For the purpose of GEWA and THST, a threshold value of 500 mg/L of dissolved solids was selected. It has been reported that below this threshold level, environmental integrity is reduced (VA EPA 2007). The reliability of this threshold was assumed to be fair (Reliability Designation = Fair) as conductivity may vary seasonally and with inputs such as rainfall.

Model Development

The GEWA and THST models were developed incorporating the each ecological indicator and associated threshold values detailed in Table 2. Initial model development required the available NPS datasets to be reformatted to provide consistent representation and adaption for model use (see Appendix A). The programming language Python was used to perform all geoprocessing operations on the reformatted datasets. This process is described in detail in Appendix B. Finally, a geographic user toolbar-style interface (the Resource Inventory and Site Condition assessment toolbar – "*RISC*") was created using Microsoft's VBA to implement all Python operations (see Appendix C). The RISC toolbar was designed to load as an extension of ESRI's ArcMAP. This design allows for a user friendly approach to implement all assessments.

Results

Assessment of Landscape Condition for GEWA and THST

The following procedures outline the processes for scoring each Landscape Condition indicator. The primary datasets used in the development of each Landscape Condition indicator included land use and land cover data, extracted from the 2001 USGS Multi-Resolution Land Characteristics Consortium's National Land Cover Dataset (NLCD), LiDAR-derived digital elevation models (LiDAR-DEMs), municipal and county parcel/land ownership data, transportation and road data, and the USGS National Hydrography Data. The 2001 NLCD dataset provides land cover and land use classifications based on modified Anderson Level II classification at 30 meters resolution. The value of using this dataset was that it provided a comprehensive land cover inventory, as well as standardized classifications of land use and land cover across the entire United States. This dataset also allows for subsequent land cover change analyses and spatial prediction models, incorporating future changes, to be based on similar datasets. Model results can also be updated as future NLCD datasets become available. Additionally, historical change detection, using an available 1992 NLCD dataset from the MRLC Consortium, could also be used to provide estimates of land cover stability occurring in within regions of both parks.

The following Figures 2A and 2B demonstrate the results of the land use and land cover extraction procedure for determining landscape condition criteria (GEWA). In the below figures (Figures 2A and 2B), the Landscape Condition assessment tool is used to identify all sub-catchments that either intersect or are entirely contained within the park boundary of GEWA.

Figures 3A and 3B demonstrate the results of the land use and land cover extraction procedure for determining landscape condition criteria. In the below (Figures 3A and 3B), the Landscape Condition assessment tool is used to identify all sub-catchments that either intersect or are entirely contained within the park boundary of THST.

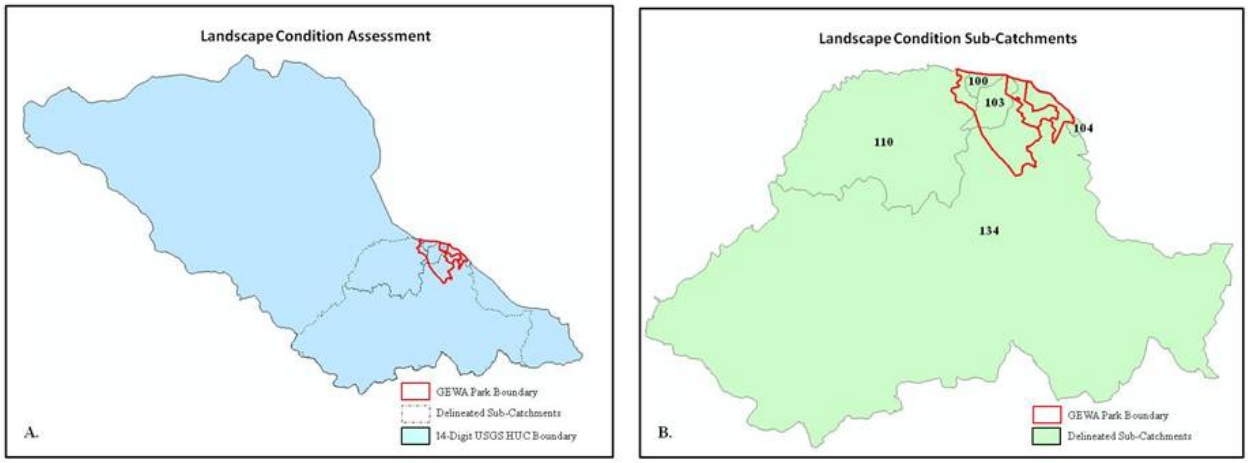

Figure 2. A. Identification of 14-digit USGS HUC boundary containing the George Washington Birthplace National Monument park boundary and the sub-catchment boundaries delineated using the Landscape Condition assessment tool. **B.** Five sub-catchments delineated from the 14-digit HUC containing the George Washington Birthplace National Monument park boundary. Each sub-catchment either intersects or is entirely contained within the park boundary.

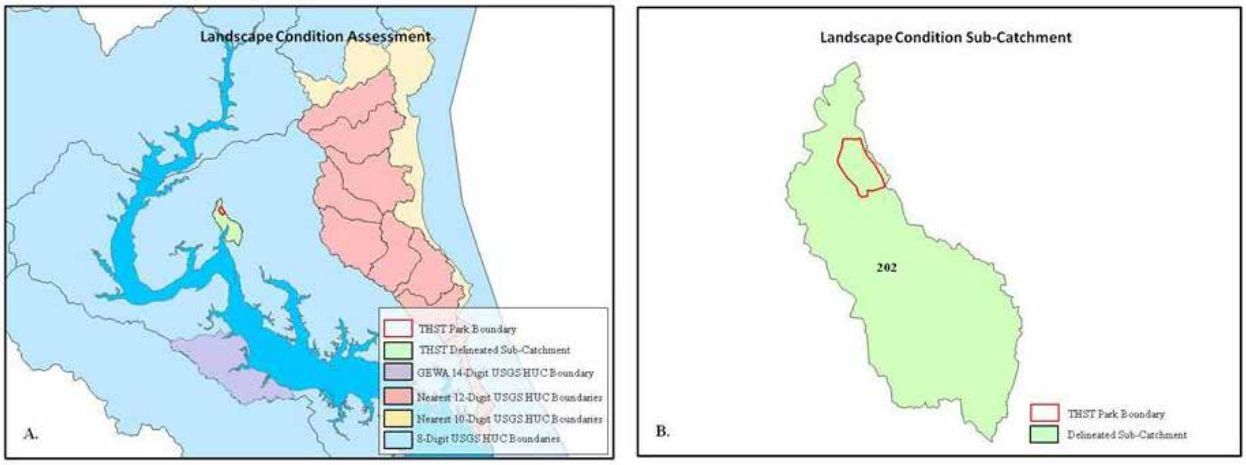

Figure 3. A. Identification of 8-digit USGS HUC boundary containing the Thomas Stone National Historic Site park boundary and the sub-catchment boundary delineated using the Landscape Condition assessment tool. **B.** Sub-catchment delineated from the 8-digit HUC containing the Thomas Stone National Historic Site park boundary. The delineated sub-catchment was contained entirely within the THST park boundary.

Following sub-catchments identification as seen in Figure 2B for GEWA and 3B for THST, subsequent analyses were performed based on the previously described landscape condition indicators (see Table 1). The following example demonstrates the implementation of the eight Landscape Condition model operations.

Percent Urban and Agricultural Cover

Sub-catchments identified by the "Basins" function on the RISC assessment toolbar that were found to either intersected the park or were found to be completely within the park boundary were extracted. The "Basins" operation used the original USGS 14-digit HUC, the USGS NHD, and high resolution LiDAR-DEMs to delineate drainage-scale sub-catchments surrounding or within the park boundary (Figures 2B and 3B). Using the urban and agriculture land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows (see Figures 4 and 5):

- <16.7 Percent Urban and Agriculture Land Cover = Good (score of 5)
- 16.7–26 Percent Urban and Agriculture Land Cover = Good–Fair (score of 4)
- 26–32.5 Percent Urban and Agriculture Land Cover = Fair (score of 3)
- 32.5–43.4 Percent Urban and Agriculture Land Cover = Fair–Poor (score of 2)
- >43.4 Percent Urban and Agriculture Land Cover = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 3 (GEWA) and Table 4 (THST) below.

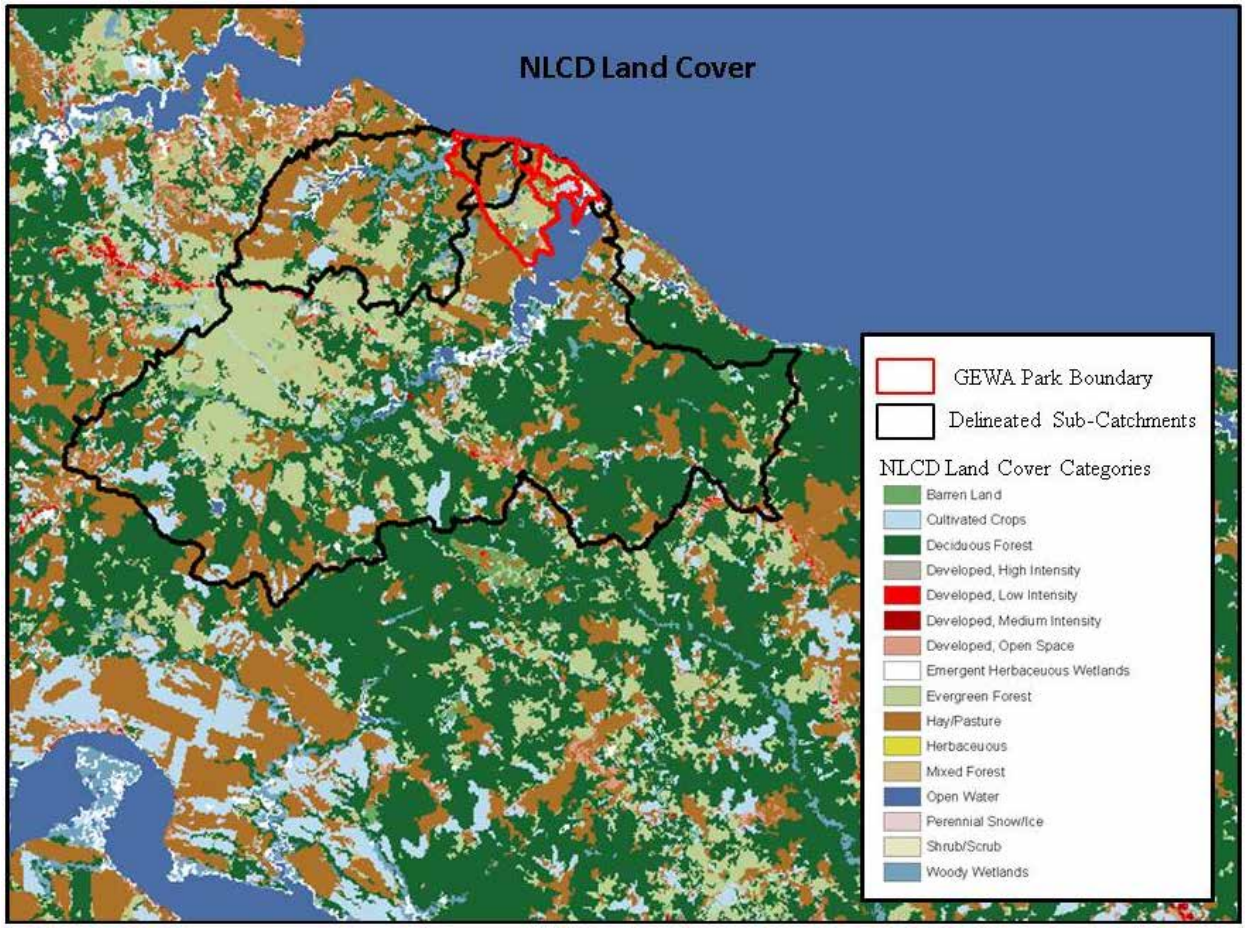

Figure 4. 2001 NCLD Land Cover data used for extraction of land cover types within and adjacent to the George Washington Birthplace National Monument park boundary (park boundary outlined in red).

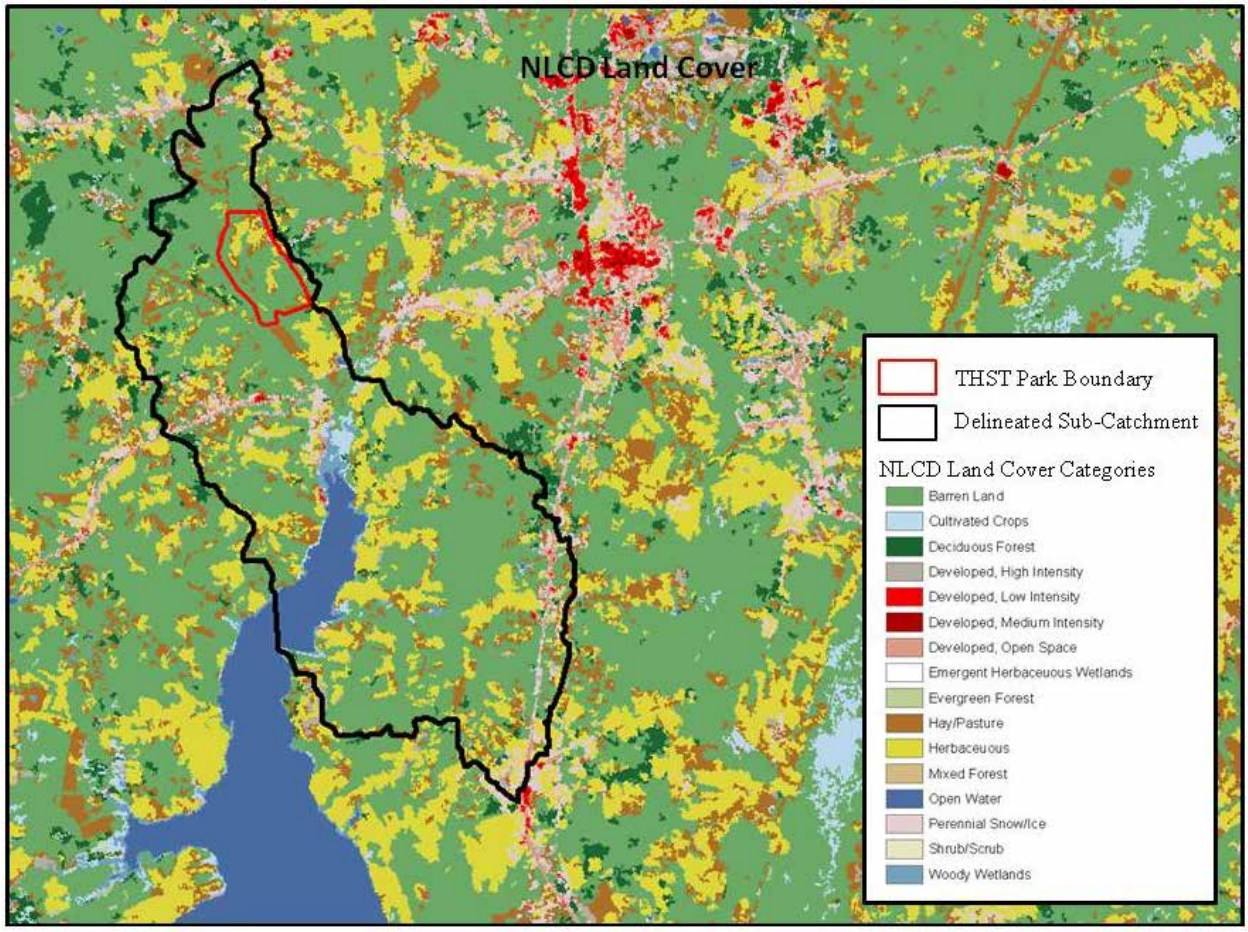

Figure 5. 2001 NCLD Land Cover data used for extraction of land cover types within and adjacent to the Thomas Stone National Historic Site park boundary (THST park boundary outlined in red).

Table 3. Percent urban and agricultural cover score and rating for George Washington Birthplace National Monument.

Percent Urban and Agricultural Cover	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	64	1	Poor
Sub-catchment ID 103	0.71	73	1	Poor
Sub-catchment ID 104	0.08	24	4	Good–Fair
Sub-catchment ID 110	8.59	49	1	Poor
Sub-catchment ID 134	45.19	26	4	Good–Fair
Overall	54.64	47	2.20	Fair–Poor

Table 4. Percent urban and agricultural cover score and rating for Thomas Stone National Historic SIte.

Percent Urban and Agricultural Cover	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	33	2	Fair–Poor

Percent Watershed with Crops on greater than a 3% Slope

Sub-catchments identified by the "Basins" function on the RISC assessment toolbar that were found to either intersected the park or were found to be completely within the park boundary were extracted. Using the evaluation and agriculture land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows:

- <1.5% Watershed with Crops on greater than a 3% Slope = Good (score of 5)
- 1.5–4.2% Watershed with Crops on greater than a 3% Slope = Good–Fair (score of 4)
- 4.2–6.4 % Watershed with Crops on greater than a 3% Slope = Fair (score of 3)
- 6.4–9.7% Watershed with Crops on greater than 3% Slope = Fair–Poor (score of 2)
- >9.7% Watershed with Crops on greater than 3% Slope = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 5 (GEWA) and Table 6 (THST) below.

Table 5. Percent of Watershed with crops on greater than a 3% slope score and rating for George Washington Birthplace National Monument.

Percent Watershed with Crops on greater than a 3% Slope	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	0	5	Good
Sub-catchment ID 103	0.71	0	5	Good
Sub-catchment ID 104	0.08	0	5	Good
Sub-catchment ID 110	8.59	0	5	Good
Sub-catchment ID 134	45.19	0	5	Good
Overall		0	5	Good

Table 6. Watershed with crops on greater than a 3% slope score and rating for THST.

Percent Watershed with Crops on greater than a 3% Slope	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	0	5	Good

Percent Stream length with Agricultural Cover

Sub-catchments identified by the "Basins" function on the RISC assessment toolbar that were found to either intersected the park or were found to be completely within the park boundary were extracted. Using the USGS National Hydrography Dataset (NHD) and agriculture land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows:

- <8.5 Percent Stream length with Agricultural Cover = Good(score of 5)
- 8.5–14.6 Percent Stream length with Agricultural Cover = Good–Fair (score of 4)
- 14.6–20.1 Percent Stream length with Agricultural Cover = Fair (score of 3)
- 20.1–27.9 Percent Stream length with Agricultural Cover = Fair–Poor (score of 2)
- >27.9 Percent Stream length with Agricultural Cover = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 7 (GEWA) and Table 8 (THST) below.

Table 7. Percent stream length with agricultural cover score and rating for George Washington Birthplace National Monument.

Percent Stream length with Agricultural Cover	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	0	5	Good
Sub-catchment ID 103	0.71	0	5	Good
Sub-catchment ID 104	0.08	0.90	5	Good
Sub-catchment ID 110	8.59	1.27	5	Good
Sub-catchment ID 134	45.19	0	5	Good
Overall		0.43	5	Good

Table 8. Percent stream length with agricultural cover score and rating for Thomas Stone National Historic Site.

Percent Stream length with Agricultural Cover	Area (km2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	6	5	Good

Percent Forested

Sub-catchments identified by the "Basins" function on the RISC assessment toolbar that were found to either intersected the park or were found to be completely within the park boundary were extracted. Using the 2001 NLCD land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows:

- >82.4 Percent Forested = Good (score of 5)
- 82.4–72.5 Percent Forested = Good–Fair (score of 4)
- 72.5–63.8 Percent Forested = Fair (score of 3)
- 63.8–48.4 Percent Forested = Fair–Poor (score of 2)
- <48.4 Percent Forested = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 9 (GEWA) and Table 10 (THST) below.

Table 9. Percent forested score and rating for George Washington Birthplace National Monument.

Percent Forested	Area (km2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	20.55	1	Poor
Sub-catchment ID 103	0.71	12.77	1	Poor
Sub-catchment ID 104	0.08	0	1	Poor
Sub-catchment ID 110	8.59	41.62	1	Poor
Sub-catchment ID 134	45.19	66.39	3	Fair
Overall		28.27	1.40	Poor

Table 10. Percent forested score and rating for Thomas Stone National Historic Site.

Percent Forested	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	58	2	Fair–Poor

Percent Forest Fragmentation

The forest fragmentation indicator was calculated using the 2001 NLCD raster dataset. For each watershed, the land use raster was reclassified into forested and non-forested classifications. Each cell in the raster was coded as a "1" if forested and a "0" if non-forested. A value was then calculated for each 3x3 cell block. This value equaled the sum of all 9 cells within the block. For example, should a block have had 4 forested cells, and 5 non-forested cells, its value would have been a 4. A count was then calculated as the number of times that each value (0–9) occurs within the watershed. Block fragmentation was then calculated as (1 - (value/9) * count). Watershed fragmentation was then calculated as (the sum of block fragmentation values / the total number of blocks) * 100. Using the 2001 NLCD land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows:

- <7.8 Percent Forest Fragmentation = Good (score of 5)
- 7.8–11.2 Percent Forest Fragmentation = Good–Fair (score of 4)
- 11.2–13.8 Percent Forest Fragmentation = Fair (score of 3)
- 13.8–21.4 Percent Forest Fragmentation = Fair–Poor (score of 2)
- >21.4 Percent Forest Fragmentation = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 11 (GEWA) and Table 12 (THST) below.

Table 11. Percent forest fragmentation score and rating for George Washington Birthplace National Monument.

Percent Forest Fragmentation	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	61.11	1	Poor
Sub-catchment ID 103	0.71	65.52	1	Poor
Sub-catchment ID 104	0.08	n/a	n/a	n/a
Sub-catchment ID 110	8.59	30.67	1	Poor
Sub-catchment ID 134	45.19	17.12	2	Fair–Poor
Overall		44	1.25	Poor

Table 12. Percent forest fragmentation score and rating for Thomas Stone National Historic Site.

Percent Forest Fragmentation	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	26	1	Poor

Length of Road per sq km

Sub-catchments identified by the "Basins" function on the RISC assessment toolbar that were found to either intersected the park or were found to be completely within the park boundary were extracted. Using the 2001 NLCD land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows:

- <1.3 km Length of Road per sq km = Good (score of 5)
- 1.3–1.6 km Length of Road per sq km = Good–Fair (score of 4)
- 1.6–1.9 km Length of Road per sq km = Fair (score of 3)
- 1.9–3.0 km Length of Road per sq km = Fair–Poor (score of 2)
- >3.0 km Length of Road per sq km = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 13 (GEWA) and Table 14 (THST) below.

Table 13. Length of road per square km (within and adjacent to park) score and rating for George Washington Birthplace National Monument.

Length of Road per sq km (within and adjacent to park)	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	0	5	Good
Sub-catchment ID 103	0.71	0	5	Good
Sub-catchment ID 104	0.08	0	5	Good
Sub-catchment ID 110	8.59	0	5	Good
Sub-catchment ID 134	45.19	0	5	Good
Overall		0	5	Good

Table 14. Length of road per square km (within and adjacent to park) score and rating for Thomas Stone National Historic Site.

Length of Road per sq km (within and adjacent to park)	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	0	5	Good

Percent Stream Length within 30 meters of road

Sub-catchments identified by the "Basins" function on the RISC assessment toolbar that were found to either intersected the park or were found to be completely within the park boundary were extracted. Using the USGS National Hydrography Dataset (NHD) and 2001 NLCD land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows:

- <2.8 Percent Stream Length w/in 30 meters of road = Good (score of 5)
- 2.8–4.6 Percent Stream Length w/in 30 meters of road = Good–Fair (score of 4)
- 4.6–6.2 Percent Stream Length w/in 30 meters of road = Fair (score of 3)
- 6.2–8.3 Percent Stream Length w/in 30 meters of road = Fair–Poor (score of 2)
- >8.3 Percent Stream Length w/in 30 meters of road = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 15 (GEWA) and Table 16 (THST) below.

Table 15. Percent stream length within 30 meters of roads score and rating for George Washington Birthplace National Monument.

Percent Stream Length w/in 30 meters of road	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	0	5	Good
Sub-catchment ID 103	0.71	0	5	Good
Sub-catchment ID 104	0.08	0	5	Good
Sub-catchment ID 110	8.59	1.54	5	Good
Sub-catchment ID 134	45.19	2.57	5	Good
Overall		0.82	5	Good

Table 16. Percent stream length within 30 meters of roads score and rating for Thomas Stone National Historic Site.

Percent Stream Length w/in 30 meters of road	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	8	2	Fair–Poor

Percent Impervious Surface

Sub-catchments identified by the "Basins" function on the RISC assessment toolbar that were found to either intersected the park or were found to be completely within the park boundary were extracted. Using the 2001 NLCD land cover data available within the GEWA-THST enterprise geodatabase, the Landscape Condition assessment tool was used to calculate an index score or rating for each sub-catchment by applying selected threshold/reference values as follows:

- <5 Percent Impervious Surface = Good (score of 5)
- 5–10 Percent Impervious Surface = Good–Fair (score of 4)
- 10–25 Percent Impervious Surface = Fair (score of 3)
- 25–30 Percent Impervious Surface = Fair–Poor (score of 2)
- >30 Percent Impervious Surface = Poor (score of 1)

An overall final score for the total was then calculated by averaging all sub-catchment areas and expressing the final score on a 1–5 scale. Results of this assessment are presented in Table 17 (GEWA) and Table 18 (THST) below.

Table 17. Percent impervious surface score and rating for George Washington Birthplace National Monument.

Percent Impervious Surface	Area (km2)	Value (%)	Score	Rating
Sub-catchment ID 100	0.13	0	5	Good
Sub-catchment ID 103	0.71	0.01	5	Good
Sub-catchment ID 104	0.08	1.14	5	Good
Sub-catchment ID 110	8.59	0.06	5	Good
Sub-catchment ID 134	45.19	0.16	5	Good
Overall		0.27	5	Good

Table 18. Percent impervious surface score and rating for Thomas Stone National Historic Site.

Percent Impervious Surface	Area (km^2)	Value (%)	Score	Rating
Sub-catchment ID 202	31.58	1	5	Good

Assessment of Biotic Condition for GEWA

Table 19 presents the result of the biotic condition assessment developed for GEWA. The percent value indicates the park species inventory (look-up table) comparison used to establish reference values. Percent values were calculated from reference values of historically known species within 10 miles of the GEWA and Thomas Stone park boundaries and park species inventories. Biologic condition was assessed for mammal, bird, reptile/amphibian, fish and invertebrate species. The results also included a proportion of species present, a numerical score converted from the percent values, and a rating based on the developed reference values.

Table 19. Summary and overall rating of Biotic Condition assessments for George Washington Birthplace National Monument.

Group	Proportion (Inventory/Expected)	Value (%)	Score	Rating
Mammals	24/46	52.17	5	Good
Birds	176/209	84.20	5	Good
Reptiles/Amphibians	47/65	72.31	5	Good
Fish	36/60	60.00	5	Good
Invertebrates	39/81	48.15	4	Good–Fair
Overall		63.366	4.8	Good

Figures 6–10 show the Biotic Condition assessment results for mammal species presence, bird species presence, reptile and amphibian species presence, fish species presence, and invertebrate species presence. Figure 11 shows an overall average score for biotic condition generated from averaging the individual assessments.

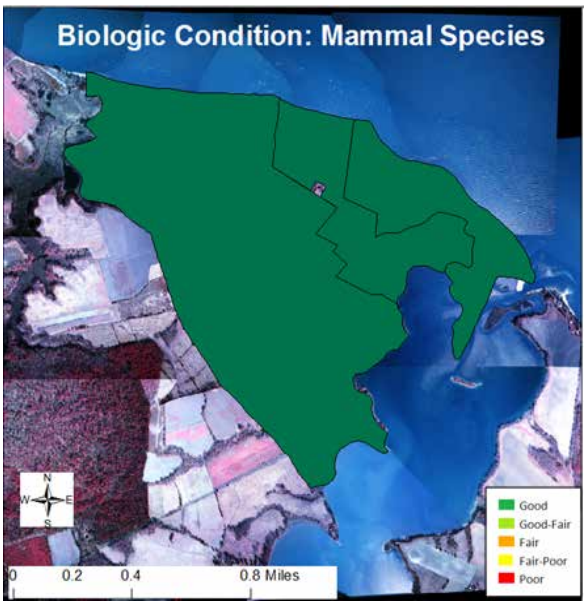

Figure 6. Biologic Condition model results: Mammal Species assessment (based on Table 2 threshold levels). Model Score: 5**;** Rating: Good.

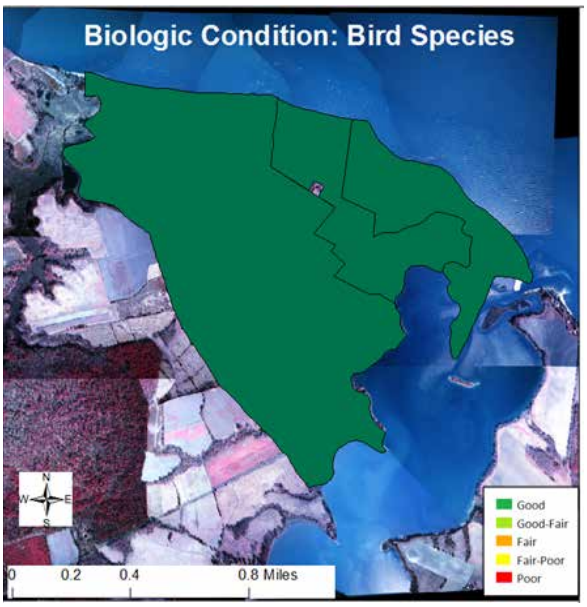

Figure 7. Biologic Condition model results: Bird Species assessment (based on Table 2 threshold levels). Model Score: 5; Rating: Good.

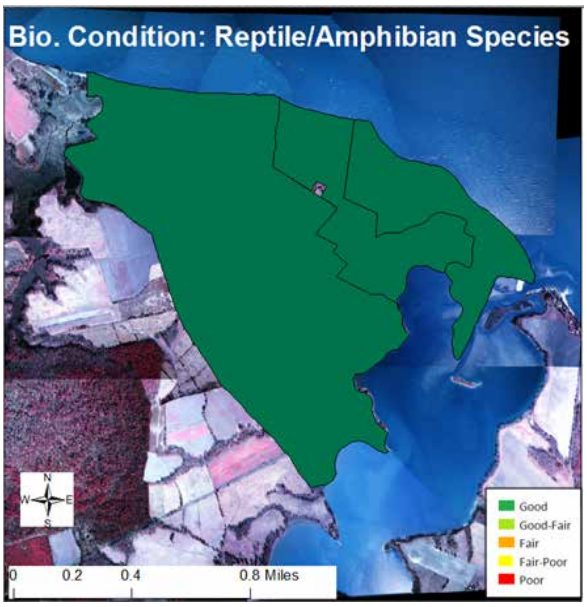

Figure 8. Biologic Condition model results: Reptile and Amphibian Species assessment (based on Table 2 threshold levels). Model Score: 5; Rating: Good.

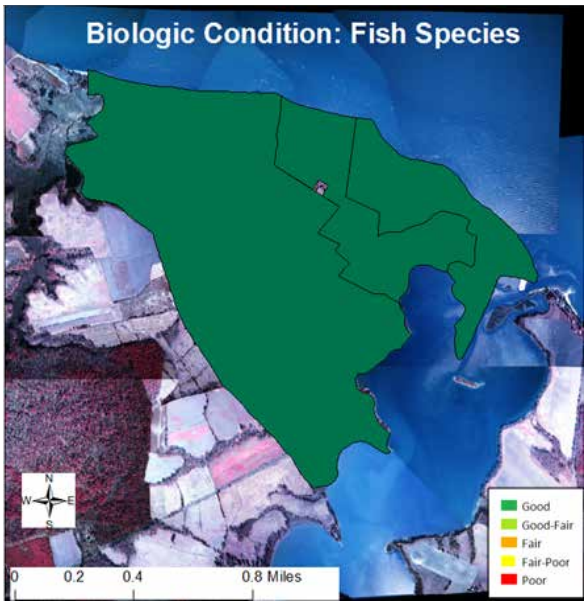

Figure 9. Biologic Condition model results: Fish Species assessment (based on Table 2 threshold levels). Model Score: 5; Rating: Good.

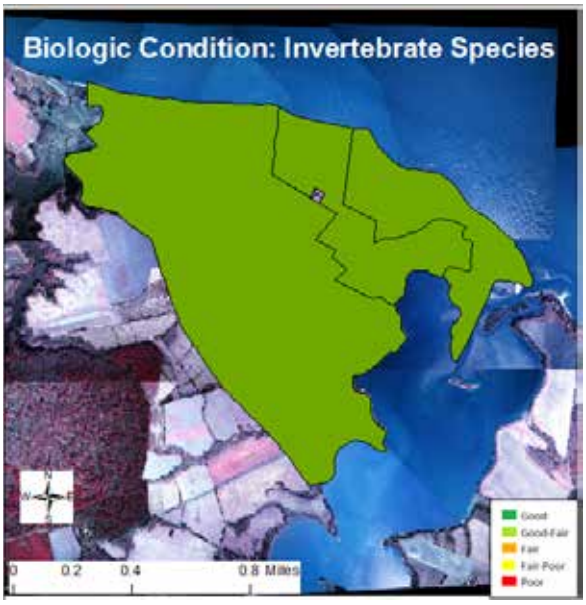

Figure 10. Biologic Condition model results: Invertebrate Species assessment (based on Table 2 threshold levels). Model Score: 4; Rating: Good–Fair.

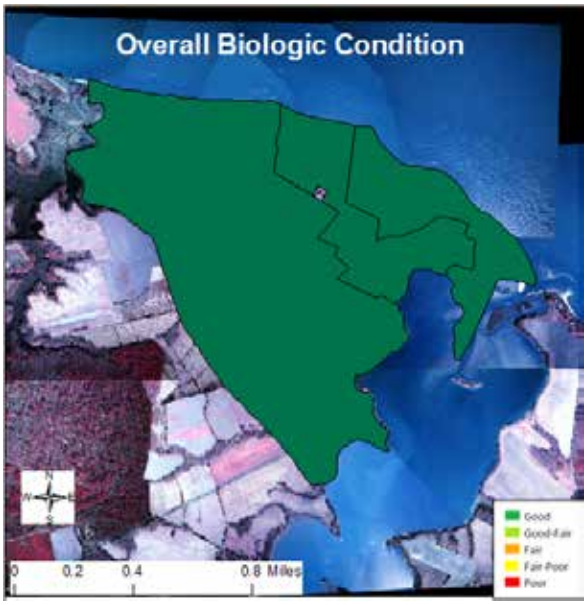

Figure 11. Overall Biologic Condition based on average scores across all species (based on Table 2 threshold levels). Model Score: 4.8; Rating: Good.

Assessment of Biotic Condition for THST

Table 20 presents the result of the biotic condition assessment developed for THST. The percent value indicates the park species inventory (look-up table) comparison used to establish reference values. Percent values were calculated from reference values of historically known species within 10 miles of the THST park boundary and park species inventories. Biologic condition was assessed for mammal, bird, reptile/amphibian, and fish species. Invertebrates inventory data for THST were not available. The results also included a proportion of species by number, a numerical score converted from the percent values, and a rating based on the developed reference values.

Table 20. Summary and overall rating of Biotic Condition assessments for Thomas Stone National Historic Site.

Group	Proportion (Inventory/Expected)	Value (%)	Score	Rating
Mammals	14/46	30.43	3	Fair
Birds	111/209	53.11	5	Good
Reptiles/Amphibians	19/65	29.23	2	Fair–Poor
Fish	16/54	29.63	2	Fair–Poor
Invertebrates	n/a	n/a	n/a	n/a
Overall		35.60	3	Fair

Figures 12–15 show the Biotic Condition assessment results for mammal species abundance, bird species abundance, reptile and amphibian species abundance, and fish species abundance. Figure 16 shows an overall average score for biotic condition generated from averaging the individual assessments.

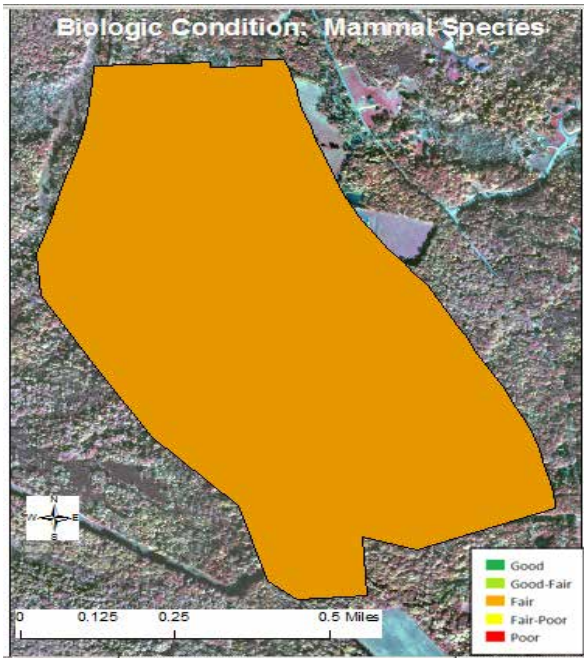

Figure 12. Biologic Condition model results: Mammal Species assessment (based on Table 2 threshold levels). Model Score: 3; Rating: Fair.

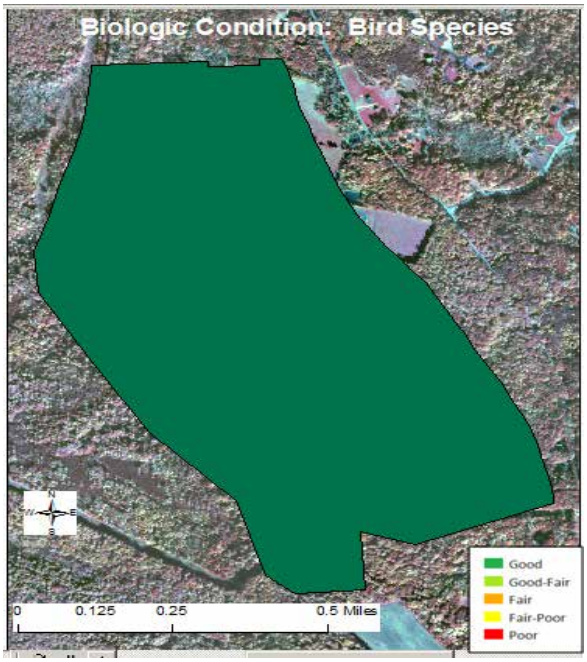

Figure 13. Biologic Condition model results: Bird Species assessment (based on Table 2 threshold levels). Model Score: 5; Rating: Good.

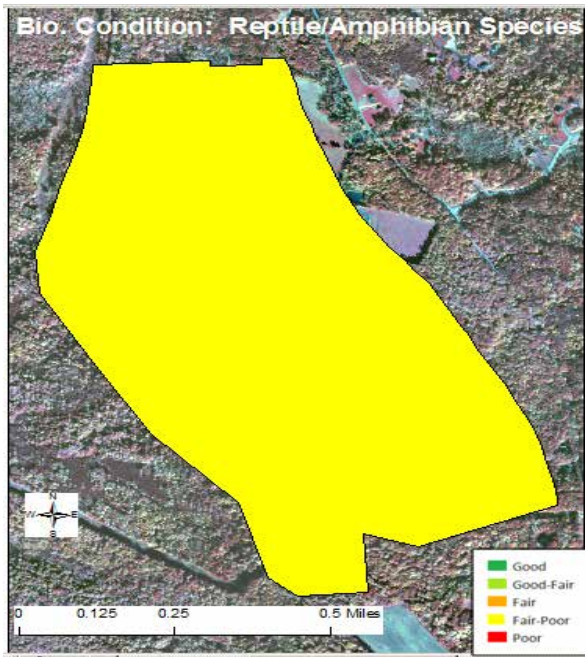

Figure 14. Biologic Condition model results: Reptile and Amphibian Species assessment (based on Table 2 threshold levels). Model Score: 2; Rating: Fair–Poor.

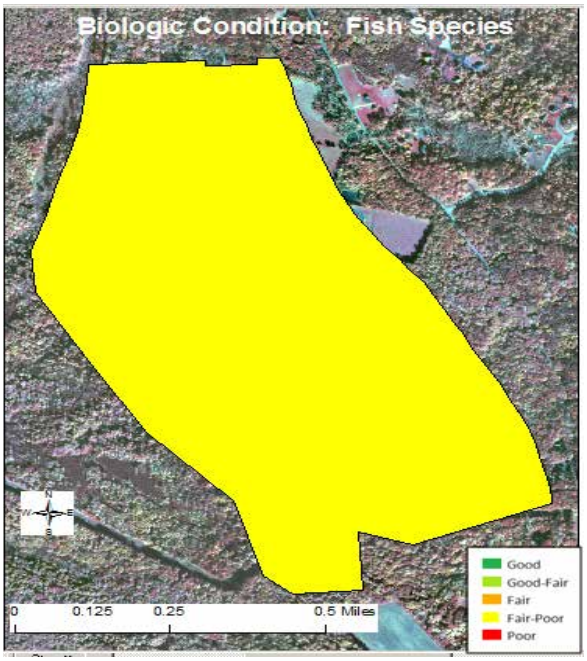

Figure 15. Biologic Condition model results: Fish Species assessment (based on Table 2 threshold levels). Model Score: 2; Rating: Fair–Poor.

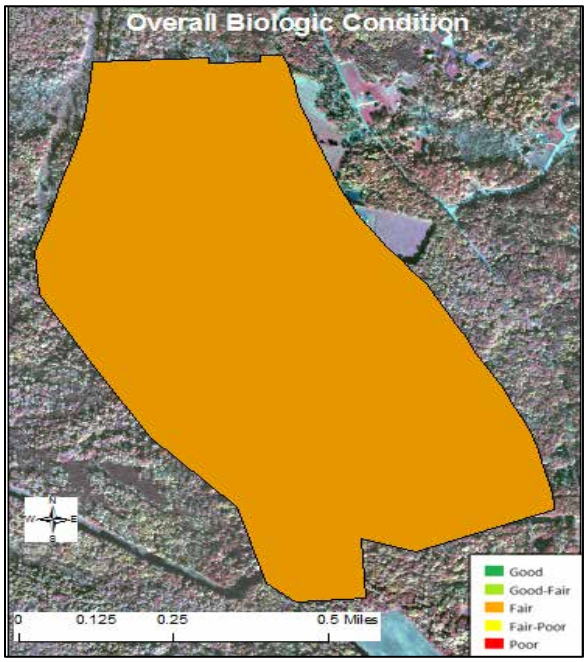

Figure 16. Overall Biologic Condition based on average scores across all species (based on Table 2 threshold levels). Model Score: 3; Rating: Fair.

Assessment of Chemical Condition and Physical Characteristics for GEWA

The chemical assessment for GEWA was derived from seven sample sites, as seen in Figure 17 below. The sample sites represent the following site locations within the NPS GEWA database collected on the date 2004-08-25. The scores are based on one point in time and are therefore not very accurate representations of overall levels for each parameter. However, the data can be compared to future data taken during the same time frame.

Table 21 presents the results of the chemical condition assessment developed for GEWA. The model results of each indicator (pH, dissolved oxygen, temperature, conductivity) were scored between 1 and 5 and ranked between Poor and Good. Overall chemical and physical characteristic scores and ranks were calculated by averaging the values for each site (see Figures 18–21 for individual chemical condition indicator assessments). Note: Values were based on a single point in time and do not represent an overall average of the indicator. They are based on one point in time from which data was collected.

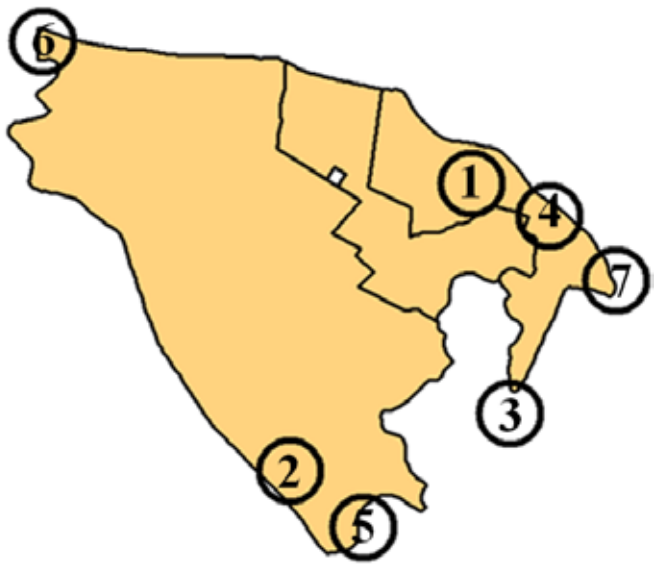

Figure 17. Location of the seven sample sites within the George Washington Birthplace National Monument park boundary. These sample sites were used for calculating the chemical condition and physical characteristic assessments.

Table 21. Summary and overall rating of chemical and physical characteristic assessments for George Washington Birthplace National Monument.

	Indicator									
Site ID	pH Score	pH Rating	DO Score	DO Rating	Temp Score	Temp Rating	Conductivity Score	Conductivity Rating	Overall Score	Overall Rating
1	5	Good	5	Good	1	Poor	1	Poor	3	Fair
2	5	Good	2	Fair–Poor	2	Fair–Poor	1	Poor	2.5	Fair
3	5	Good	5	Good	2	Fair–Poor	5	Good	4.25	Good–Fair
4	5	Good	2	Fair–Poor	2	Fair–Poor	5	Good	3.5	Good–Fair
5	5	Good	5	Good	1	Poor	5	Good	4	Good–Fair
6	5	Good	1	Poor	4	Good–Fair	2	Fair–Poor	3	Fair
7	5	Good	5	Good	4	Good–Fair	5	Good	4.75	Good

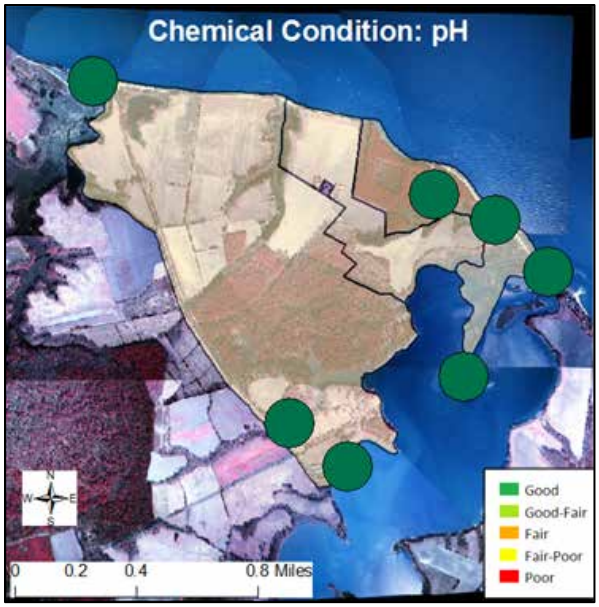

Figure 18. Chemical Condition: pH values and threshold rating at inventory points throughout the park based on samples collected August 2004.

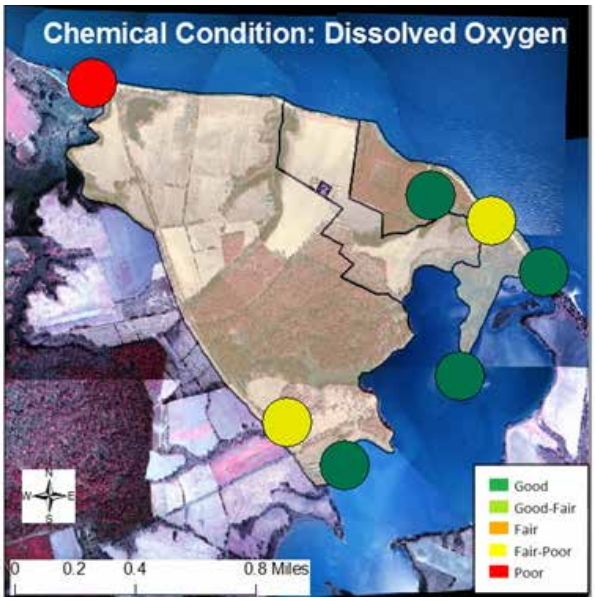

Figure 19. Chemical Condition: Dissolved Oxygen levels and threshold ratings at inventory points throughout the park based on samples collected August 2004.

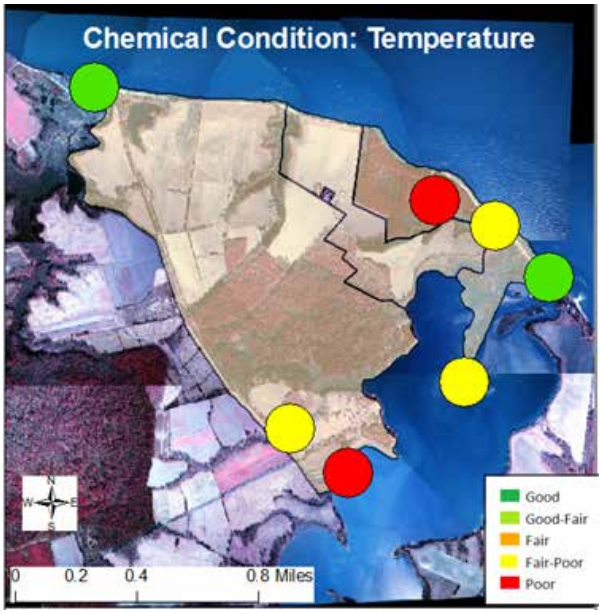

Figure 20. Chemical Condition: Temperature ranges collected at inventory points throughout the park. Samples were collected August 2004. Threshold ratings based on biotic health ranges between 15.5^{o} and 21.2^{o} Celsius.

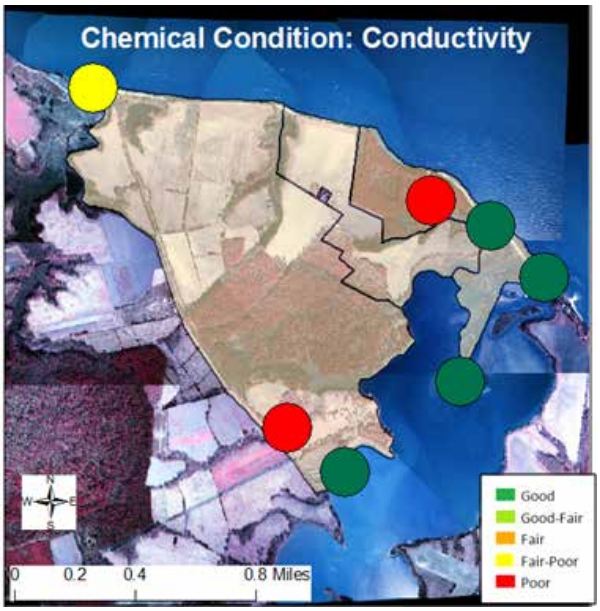

Figure 21. Chemical Condition: Conductivity levels and threshold ratings collected at inventory points throughout the park based on samples collected August 2004.

The overall chemical/physical condition for GEWA was derived as an average of all chemical/physical parameters and their respective scores (Figure 22).

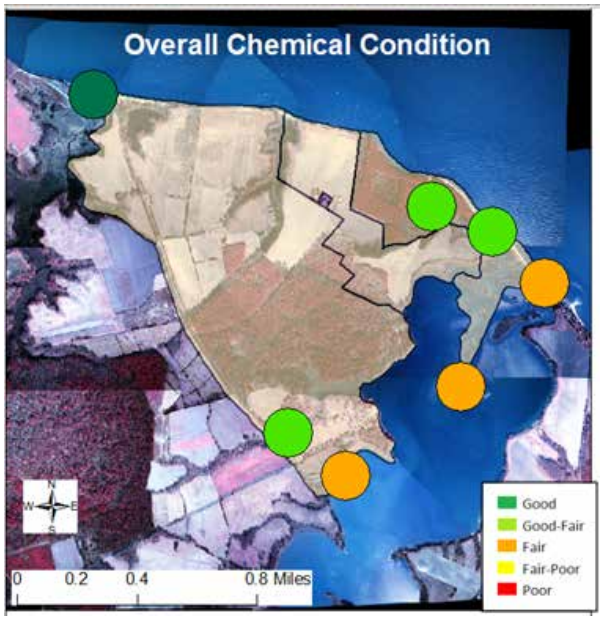

Figure 22. Overall Chemical Condition based on an average of the four indicators (pH, dissolved oxygen, temperature, and conductivity) at each sampling point based on samples collected August 2004.

Assessment of Chemical Condition and Physical Characteristics for THST

The Chemical aspects of THST were separated into two sample sites (Figure 23). The sample sites represent the following site locations within the NPS THST database collected on the date 2003-07-10. Note: Values were based on a single point in time and do not represent an overall average of the indicator. They are based on one point in time from which data was collected.

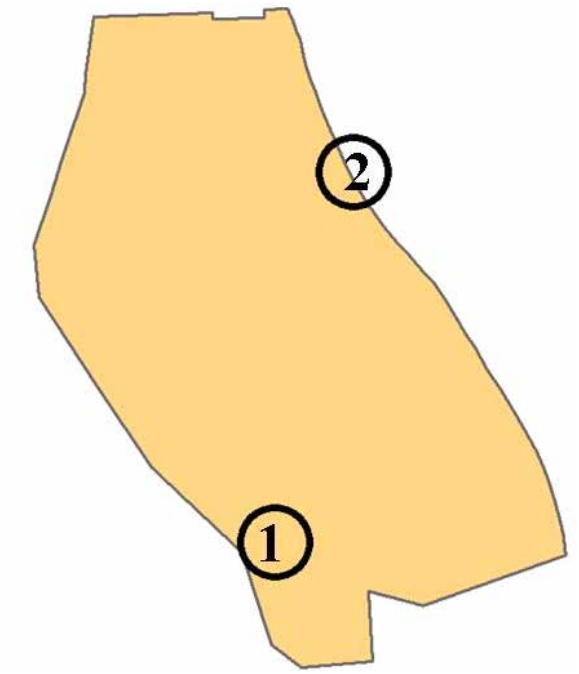

Figure 23. Location of the two sample sites within the THST park boundary. These sample sites were used for calculating the chemical condition and physical characteristic assessments.

Results of the chemical condition assessment developed for THST are presented in Table 22. The model results of each indicator (pH, dissolved oxygen, temperature, conductivity) were scored between 1 and 5 and ranked between Fair and Good, respectively (see Figures 24–27 for individual chemical condition indicator assessments). Overall chemical and physical characteristic scores and ranks were calculated by averaging the values for each site.

Table 22. Summary and overall rating of Chemical and Physical Characteristic assessments for Thomas Stone National Historic SiteTHST.

	INDICATOR									
Site ID	pH Score	pH Rating	DO Score	DO Rating	Temp Score	Temp Rating	Conductivity Score	Conductivity Rating	Overall Score	Overall Rating
1	5	Good	5	Good	4	Good–Fair	1	Poor	3.75	Good–Fair
2	5	Good	4	Good–Fair	5	Good	1	Poor	3.75	Good–Fair

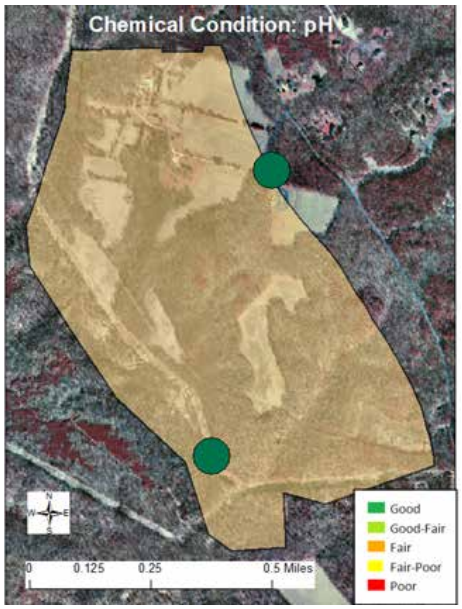

Figure 24. Chemical Condition: pH values and threshold rating at inventory points throughout the park based on samples collected July 2003.

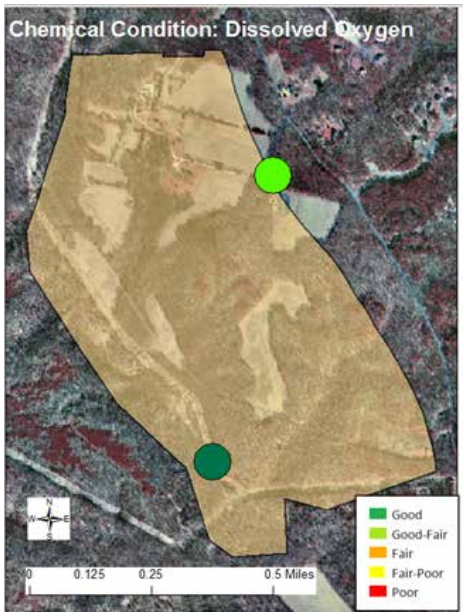

Figure 25. Chemical Condition: Dissolved Oxygen levels and threshold ratings at inventory points throughout the park based on samples collected July 2003.

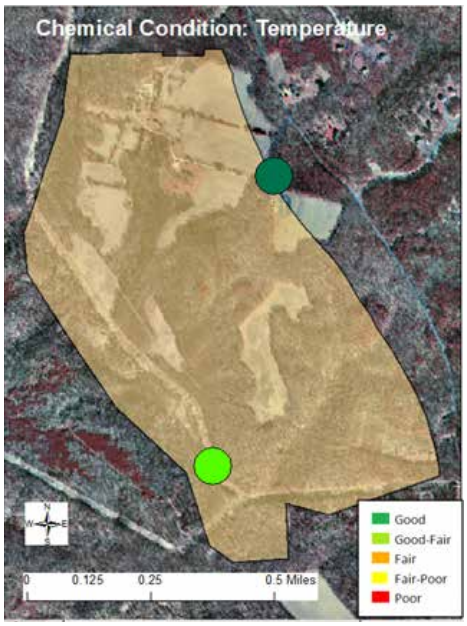

Figure 26. Chemical Condition: Temperature ranges collected at inventory points throughout the park. Samples were collected July 2003. Threshold ratings based on biotic health ranges between 15.5^{o} and 21.2^{o} Celsius.

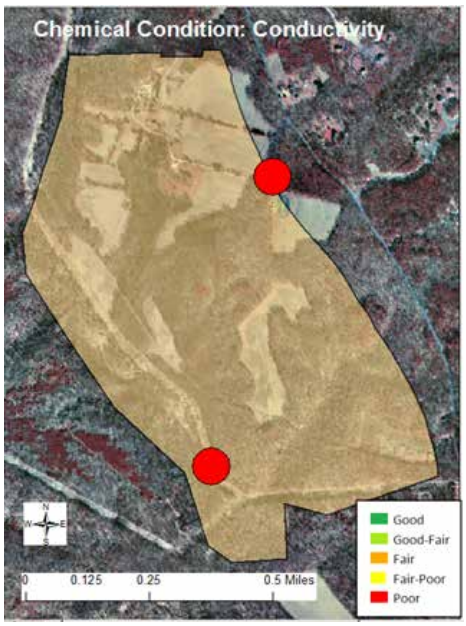

Figure 27. Chemical Condition: Conductivity levels and threshold ratings collected at inventory points throughout the park based on samples collected July 2003.

Overall Chemical /Physical Condition for THST

The overall chemical/physical condition was derived as an average of all chemical/physical parameters (pH, Dissolved Oxygen, Temperature, and Conductivity) at each sampling point and their respective scores (Figure 28).

In addition to the chemical indicators included in the GEWA and THST assessment models, several chemical parameters impacting both parks have been established by the National Parks Air Quality Monitoring Program (NPAQMP). Along with these established values, a threshold scale was established for future incorporation in the GEWA and THST assessment models. Table 23 represents all values not currently included in the GEWA and THST assessment models that were established in the NPAQMP.

Table 23 provides useful background information for GEWA and THST park staff to incorporate regional air quality information into their future Resource Stewardship Strategies. The air quality indicators and their associated threshold criteria can also be used in the short term once park specific data become available from NPAQMP to develop park specific resource briefs that can inform park staff and the general public regarding the current air quality condition within GEWA and THST in much the same way as the condition assessments for Cape Cod National Seashore (CACO) and Assateague Island National Seashore (ASIS).

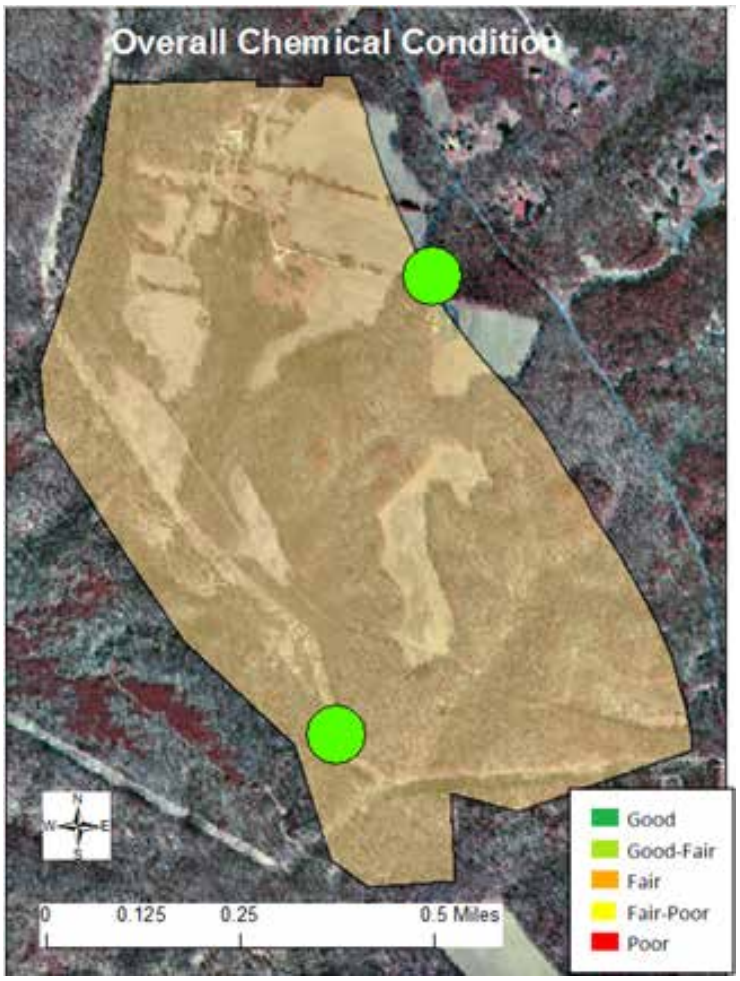

Figure 28. Overall Chemical Condition based on an average of the four indicators (pH, Dissolved Oxygen, Temperature, and Conductivity) at each sampling point. All samples were collected July 2003.

Given the location of both GEWA and THST it's unlikely that either park is subject to severe acidic deposition exposure, however, their relative proximity to Washington D.C. makes these areas potentially subject to visibility, particulate matter (PM), and ozone impacts. Thus it's our recommendation that at a minimum, the park staff assess the PM 2.5, Visibility, and ozone indicators within GEWA and THST, and incorporate those results into future park planning and management activities.

Table 23. NPS Air Quality Monitoring Program: Air Quality Parameters.

Indicator	Units	Good	Good–Fair	Fair	Fair–Poor	Poor	GEWA Condition	GEWA Score	GEWA Rating	THST Condition	THST Score	THST Rating
Ozone (5 yr Avg.)	ppb	<25	25–40	40–50	50–65	>65	30–35	4	Good–Fair	30–35	4	Good–Fair
Nitrate Concentration	mg/L	<0.60	0.60–1.05	1.05–1.20	1.20–1.80	>1.80	0.90–1.05	4	Good–Fair	1.05–1.20	3	Fair
Sulfate Concentration	mg/L	<0.50	0.50–1.25	1.25–1.75	1.75–2.50	>2.50	1.50–1.75	3	Fair	1.05–1.20	4	Good–Fair
Ammonium Concentration	mg/L	<0.10	0.10–0.25	0.25–0.40	0.40–0.55	>0.55	0.25–0.30	3	Fair	0.25–0.30	3	Fair
Sodium Concentration	mg/L	<0.05	0.05–0.20	0.20–0.30	0.30–0.45	>0.45	0.15–0.20	4	Good–Fair	0.15–0.20	4	Good–Fair
Magnesium Concentration	mg/L	<0.015	0.015–0.030	0.030–0.040	0.040–0.055	>0.055	0.020–0.025	4	Good–Fair	0.020–0.025	4	Good–Fair
Potassium Concentration	mg/L	<0.01	0.01–0.04	0.04–0.06	0.06–0.09	>0.09	0.02–0.03	4	Good–Fair	0.02–0.03	4	Good–Fair
Chlorine Concentration	mg/L	<0.10	0.10–0.25	0.25–0.35	0.35–0.50	>0.50	0.30–0.35	3	Fair	0.30–0.35	3	Fair
Calcium Concentration	mg/L	<0.10	0.10–0.25	0.25–0.30	0.30–0.40	>0.40	<0.10	5	Good	0.10–0.15	4	Good–Fair
Sulfate (WD)	kg/ha	<3.0	3.0–12.0	12.0–18.0	18.0–27.0	>27.0	15.0–18.0	3	Fair	18–21	2	Fair–Poor
Nitrate (WD)	kg/ha	<4.0	4.0–10.0	10.0–14.0	14.0–20.0	>20.0	12.0–14.0	3	Fair	12.0–14.0	3	Fair
Ammonium (WD)	kg/ha	<0.50	0.5–2.0	2.0–3.0	3.0–4.5	>4.5	2.5–3.0	3	Fair	2.5–3.0	3	Fair
Sodium (WD)	kg/ha	<0.50	0.5–2.0	2.0–3.0	3.0–4.5	<4.5	2.5–3.0	3	Fair	2.0–2.5	3	Fair
Magnesium (WD)	kg/ha	<0.15	0.15–0.30	0.30–0.40	0.40–0.55	>0.55	0.35–0.40	3	Fair	0.30–0.35	3	Fair
Potassium (WD)	kg/ha	<0.1	0.10–0.40	0.40–0.60	0.60–0.90	>0.90	0.30–0.40	4	Good–Fair	0.30–0.40	4	Good–Fair
Chlorine (WD)	kg/ha	<0.5	0.5–2.0	2.0–3.0	3.0–4.5	>4.5	>4.5	1	Poor	4.0–4.5	2	Fair–Poor
Calcium (WD)	kg/ha	<1.0	1.0–1.5	1.5–2.0	2.0–2.5	>2.50	<1.0	5	Good	1.0–1.25	4	Good–Fair
PM 2.5	Mi/m^3	5.3–6.8	6.8–11.7	11.7–14.8	14.8–19.6	19.6–21.1	13.3–14.8	3	Fair	13.3–14.8	3	Fair
Visibility (20% on clear days)	Mm–1	<8	8.0–17.0	17–25	25–34	>34	>34	1	Poor	>34	1	Poor
Visibility (20% on hazy days)	Mm–1	<40	40–92	92–127	127–179	>179	>179	1	Poor	161–178	2	Fair–Poor

*WD = Wet Deposition

Discussion

Data availability was the largest limitation in development of these GIS based models utilized to assess the natural resource condition of GEWA and THST. Generally speaking sufficient landscape data existed for both parks to allow a reasonably confident condition assessment to be performed for both parks. However, as evidenced by the proposed indicators in Table 1 and the actual indicators utilized in Table 2, significant data gaps exist for the biological and water quality (e.g. chemical) portions of this assessment. Thus, the strength of this assessment for GEWA and THST beyond the landscape scale is limited. Park staff at GEWA and THST are encouraged to discuss these limitations with their regional support scientists at the Northeast Coastal and Barrier I & M Network, NPS air resources division (air quality), and any other regional hydrologists, aquatic ecologists, or support scientists that can lend expertise or financial support to address the data needs at these two parks.

GEWA Natural Resource Condition

Overall the landscape condition assessment portion of this analysis indicates that for many of the GEWA indicators the park is in Good condition (see Table 24). The exceptions to this assessment reside within the forest indicators (e.g. % forested and % fragmented forest) and the urban to agricultural cover indicator. A reliable biological condition at this park was difficult to derive based on a lack of rigorous data for any given species or group of species, however, from what data were available we estimate that the overall condition for many of the target groups was good. We recommend that the park collect additional data regarding species abundances, richness, and diversity over time to obtain a more specific and accurate picture of biologic condition at GEWA. Water quality condition, termed simply chemical condition ranged from good to poor depending on which analyte was assessed. Our assessment of the water quality data must be taken with caution as they only represent one discrete point in time. The park is strongly encouraged to begin a long-term water quality sampling program that at a minimum captures water quality data on a monthly basis as parameters such as DO, pH, temperature, and conductivity can vary strongly with season and waterway discharge.

THST Natural Resource Condition

The landscape condition assessment for THST was comparable to GEWA with scores ranging from good to poor depending on the indicator assessed (see Table 25). THST was similar to GEWA in that the park exhibited a high degree of forest fragmentation and low percentage of total forest cover within the park. There was also a higher incidence of stream reaches within 30 m of a road at THST causing this metric to score in the fair–poor range. The overall biologic condition at THST was rated as fair with indicators scores in the fair–poor range for fish and reptiles/amphibians, though our confidence in these scores is low based on a lack of time series abundance, diversity, and richness data for any particular species or group of species at THST at the time of this assessment. Water quality chemistry data was another research/monitoring area of the park that needs significant improvement. All of the parameters with the exception of conductivity scored in the “good” range, though admittantly our confidence in this portion of the assessment is low based on only having one sample in time to work with. Thus, the same recommendations for addressing the data biological and chemistry needs at GEWA apply here as well.

Table 24. Summary of condition assessment scores for the park (GEWA).

Indicator	Impairment Threshold Value	Current Condition	Confidence in Assessment
Percent urban and agricultural cover	>50%	Fair–Poor	High
Percent watersheds with crops on >3% slope	>10%	Good	High
Percent stream length with agricultural cover	>30%	Good	High
Percent Forested	<50%	Poor	High
Percent Forest Fragmented	>20%	Poor	High
Length of road per square km	>3.0 km	Good	High
Percent stream length within 30 m of road	>10%	Good	High
Impervious surface	>10%	Good	High
Species Presence (Bird)	<40%	Good	Low
Species Presence (Mammal)	<40%	Good	Low
Species Presence (Reptile/Amphibian)	<40%	Good	Low
Species Presence (Fish)	<40%	Good	Low
Species Presence (Odonate)	<40%	Good–Fair	Low
pH*	6.0–9.0	Good	Low
Dissolved Oxygen*	<6.0 mg/L	Fair	Low
Temperature*	15.5–21.2 ^{0}C	Fair–Poor	Low
Conductivity*	<500 mg/L	Fair	Low

*Water quality current condition scores were derived from an average of the analyte scores (e.g. pH) over the range of sample sites (n=7) in the parks to derive a parkwide condition. The overall scores for water quality shown in Tables 21 (GEWA) and 22 (THST) represent an average of the individual pH, DO, Temperature, and Conductivity scores for the individual sample points to derive an overall score for the individual sample sites.

Table 25. Summary of condition assessment scores for the park (THST).

Indicator	Impairment Threshold Value	Current Condition	Confidence in Assessment
Percent urban and agricultural cover	>50%	Fair–Poor	High
Percent watersheds with crops on >3% slope	>10%	Good	High
Percent stream length with agricultural cover	>30%	Good	High
Percent Forested	<50%	Fair–Poor	High
Percent Forest Fragmented	>20%	Poor	High
Length of road per square km	>3.0 km	Good	High
Percent stream length within 30m of road	>10%	Fair–Poor	High
Impervious surface	>10%	Good	High
Species Presence (Bird)	<40%	Good	Low
Species Presence (Mammal)	<40%	Fair	Low
Species Presence (Reptile/Amphibian)	<40%	Fair–Poor	Low
Species Presence (Fish)	<40%	Fair–Poor	Low
Species Presence (Odonate)	<40%	NA	Low
pH*	6.0–9.0	Good	Low
Dissolved Oxygen*	<6.0 mg/L	Good	Low
Temperature*	15.5–21.2 ^{0}C	Good	Low
Conductivity*	<500 mg/L	Poor	Low

*Water quality current condition scores were derived from an average of the analyte scores (e.g. pH) over the range of sample sites (n=2) in the parks to derive a parkwide condition. The overall scores for water quality shown in Tables 21 (GEWA) and 22 (THST) represent an average of the individual pH, DO, Temperature, and Conductivity scores for the individual sample points to derive an overall score for the individual sample sites.

As additional data becomes available new indicators (such as those shown in Table 1) can be added into the model. The current model and associated databases establish a baseline for continued data collection in and around the park boundaries. Data collected in the table or feature class formats that are used by the models will allow future data collections to be incorporated by park staff. The current model serves as a data analysis tool that is useful for assessing data gaps within the park databases. Additionally, model results are useful for park managers to assess the current quality of available park data, as well as prioritize management efforts based on indicator assessment results.

The incorporation of long term biological, vegetation, air resource, and water quality data that is currently underway at both GEWA and THST, but was not available at the time of this assessment will be vital in tracking long term trends for target indicators at these two parks. GEWA and THST park staff are encouraged to utilize the information contained within this report to assist in developing the long term resource stewardship strategies for their respective parks.

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Appendix A. Python Programming Language developed for Landscape Condition Assessment.

Assessment Code: *LandscapeCondition.py*

```
#Description: Calls various functions to calculate indicator values for landscape condition
#
#Arguments: sys.argv[1] = Workspace
#          sys.argv[2] = Land Use Directory
#          sys.argv[3] = Park Basins
#          sys.argv[4] = Watershed Raster
#          sys.argv[5] = Streams
#          sys.argv[6] = Roads
#          sys.argv[7] = Impervious surface raster directory
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 03 February 2009
#

import sys, string, os, arcgisscripting, LC_AgUrb, LC_CropSlope, LC_StreamAg, LC_Forest, LC_ForFrag,
LC_RoadDens, LC_StreamRoad, LC_Impervious

reload(LC_AgUrb)
reload(LC_CropSlope)
reload(LC_StreamAg)
reload(LC_Forest)
reload(LC_ForFrag)
reload(LC_RoadDens)
reload(LC_StreamRoad)
reload(LC_Impervious)

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

work = sys.argv[1]
LU_dir = sys.argv[2]
Park_Basins = sys.argv[3]
WS_Raster = sys.argv[4]
```

```
streams = sys.argv[5]
roads = sys.argv[6]
Impervious = sys.argv[7]

gp.Workspace = work
DB_work = gp.Workspace
PGDB = DB_work + "/WCA.mdb"

#Set Spatial Reference
sr =
"PROJCS['NAD_1983_UTM_Zone_18N',GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1
983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.017453292
5199433]],PROJECTION['Transverse_Mercator'],PARAMETER['False_Easting',500000.0],PARAMETER['False_
Northing',0.0],PARAMETER['Central_Meridian',-
75.0],PARAMETER['Scale_Factor',0.9996],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]"

# Process: Create scores Feature Dataset...
try:
    basins_s = gp.CreateFeatureDataset_management(PGDB, "scores", sr)
    print "Successfully Created 'scores' feature dataset"
except:
    print "Error in 'Create scores Feature Dataset'"

scores = PGDB + "/scores"

#Copy ParkBasins to scores feature dataset
Basins = Park_Basins
try:
    # Process: Copy ParkBasins to data_layers dataset, FeatureClass To FeatureClass...
    gp.FeatureClassToFeatureClass_conversion(Basins, scores, "LC_score", "")
    print "Successfully Created 'LC_score' Layer"

except:
    # If an error occurred while running a tool print the messages
    print "Error importing Park Basins polygon to scores feature dataset. " + gp.GetMessages()

#Run script functions for indicators
print "Begin LC_1 Function"
LC_AgUrb.LC_1 (work,LU_dir,Park_Basins)
print "LC_1 Function Complete"
print "Begin LC_2 Function"
LC_CropSlope.LC_2 (work,LU_dir,WS_Raster)
print "LC_2 Function Complete"
print "Begin LC_3 Function"
LC_StreamAg.LC_3 (work,LU_dir,streams)
print "LC_3 Function Complete"
print "Begin LC_4 Function"
LC_Forest.LC_4 (work,LU_dir)
print "LC_4 Function Complete"
print "Begin LC_5 Function"
LC_ForFrag.LC_5 (work,LU_dir)
print "LC_5 Function Complete"
print "Begin LC_6 Function"
LC_RoadDens.LC_6 (work,roads)
print "LC_6 Function Complete"
print "Begin LC_7 Function"
```

```
LC_StreamRoad.LC_7 (work,roads,streams)
print "LC_7 Function Complete"
print "Begin LC_8 Function"
LC_Impervious.LC_8 (work, Impervious)
print "LC_8 Function Complete"


answer = raw_input("Landscape Condition Assessment Complete. Click 'Enter' to exit")
```

Assessment Code: *LC_AgUrb.py*

```
#Description: Calculates indicator values for Landscape Condition's % Urban and Ag cover per watershed
#
#Arguments: Workspace
#          Land Use Directory
#          Basins
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 17 January 2009


# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

def LC_1 (work,LU_dir,Park_Basins):

    gp.Workspace = work
    DB_work = gp.Workspace
    PGDB = DB_work + "/WCA.mdb"

    #Add new fields to LC_score
    LC_score = PGDB + "/scores/LC_score"

    try:
        gp.addfield(LC_score,"LC1_score","LONG",'50','50')
    except:
```

```
    #If an error occurred while adding field
    print "Error creating 'LC1_score' field"

try:
    gp.addfield(LC_score,"LC1_value","LONG",'50','50')
except:
    #If an error occurred while adding field
    print "Error creating 'LC1_value' field"

#Add total and Perc fields to each landuse raster
gp.Workspace = LU_dir
rasters = gp.listrasters("*","All")
raster = rasters.next()

while raster:
    rows = gp.searchcursor(raster)
    row = rows.next()
    total = 0
    while row:
        row_int = int(row.COUNT)
        total = total + row_int
        row = rows.next()
        sum = total
    del row
    del rows
    #print "Total Area = " + str(sum) + "Cells."
    try:
        gp.addfield(raster,"TOTAL","FLOAT","")
        print gp.getmessages()
    except:
        print "Error adding 'TOTAL' field to LULC raster "
    try:
        gp.CalculateField_management (raster,"TOTAL",sum)#,"PYTHON")
    except:
        print "Error calculating 'TOTAL' field"
        print gp.getmessages()
    try:
        print "About to add perc field"
        gp.addfield(raster,"PERC","LONG",'50','50')
    except:
        #If an error occurred while adding field
        print "Error creating 'Perc' field"
    try:
        print "Going to calculate field PERC with VB"
        gp.CalculateField_management(raster,"PERC","[COUNT] / [TOTAL] * 100","VB")
    except:
        print "Error calculating 'PERC' field"
    raster = rasters.Next()

#Calculate score, and add to LC_score feature data class
files = os.listdir(LU_dir)
rows = gp.UpdateCursor(LC_score)
row = rows.Next()
while row:
    ws1 = str(row.GRIDCODE)
    ws = ws1[:-2]
```

```
        lc = str(row.LC1_score)
        for file in files:
            if file == (ws + ".img"):
                TRows = gp.searchCursor(file)
                Trow = TRows.next()
                agurb = 0
                while Trow:
                    row_val = int(Trow.VALUE)
                    row_perc = float(Trow.PERC)
                    if row_val == 21 or row_val == 22 or row_val == 23 or row_val == 24 or row_val == 81 or row_val
== 82:
                        agurb = agurb + row_perc
                    Trow = TRows.next()
                agurb_sum = agurb

                #set score variable
                if agurb_sum <= 16.7:
                    ls = 5
                elif agurb_sum >16.7 and agurb_sum <= 26:
                    ls = 4
                elif agurb_sum >26 and agurb_sum <= 32.5:
                    ls = 3
                elif agurb_sum >32.5 and agurb_sum <= 43.4:
                    ls = 2
                elif agurb_sum >43.4:
                    ls = 1

        row.LC1_score = ls
        row.LC1_value = agurb_sum
        rows.UpdateRow(row)
        row = rows.next()

    #answer = raw_input("Percent Urban and Agriculture Cover Indicator Complete. Click 'Enter' to exit")
    print "Percent Urban and Agriculture Cover Indicator Complete"
```

Assessment Code: *LC_CropSlope.py*

```
#Description: Calculates indicator values for Landscape Condition's % crops on slopes > 3% per watershed
#
#Arguments: Workspace
#          Land Use Directory
#          LC_score
#          watershed raster
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 17 February 2009
#
#_____________________________________________________________________________________


# Import system modules
import sys, string, os, arcgisscripting
```

```
# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")

def LC_2 (work,LU_dir,WS_Raster):

    gp.Workspace = work
    DB_work = gp.Workspace
    PGDB = DB_work + "/WCA.mdb"
    LC_score = PGDB + "/scores/LC_score"

    #Convert ws_ras to a slope raster
    #variables
    ws_slope = PGDB + "/ws_slope"
    measure = "DEGREE"

    #Process: Calculate slope
    try:
        gp.Slope_sa(WS_Raster, ws_slope, measure)
    except:
        print "Error in creating slope raster"

    #Convert ws_slope to integer raster
    #variables
    ws_int = PGDB + "/ws_int"

    #Process: Convert to integer raster
    try:
        gp.Int_3d(ws_slope, ws_int)
    except:
        print "Error in creating integer raster"

    #Use map algebra to set all cells with slope less than 4 to 'null', and all else to 1
    #variables
    setnull = "setnull (" + ws_int + " < 4, 1)"
    ws_null = PGDB + "/ws_null"
```

```
#Process: Calculate setnull raster
try:
    gp.SingleOutputMapAlgebra_sa(setnull, ws_null, ws_int)
except:
    print "Error in creating setnull raster"

#Convert setnull raster to polygon
#variables
slope = PGDB + "/data_layers/slope"
field = "Value"

#Process: Produce slope null polygon
try:
    gp.RasterToPolygon_conversion(ws_null, slope, '', field)
except:
    print "Error converting setnull raster to polygon"


#Extract by mask each watershed land use by slope polygon

gp.Workspace = LU_dir
rasters = gp.listrasters("*", "All")
raster = rasters.next()
slope_dir = os.makedirs(workspace + "/basins_results/slope")

while raster:
    rows = gp.searchcursor(raster)
    row = rows.next()
    while row:
        row_val = int(row.TOTAL)
        row = rows.next()
        total = row_val
    print total
    del row
    del rows
    ws = os.path.basename(raster)
    slope_lu = workspace + "/basins_results/slope/" + ws[:-4] + "_slope.img"

    try:
        gp.ExtractByMask_sa(raster, slope, slope_lu)
    except:
        print "Error extracting by mask ws: " + raster
    try:
        gp.addfield(slope_lu,"TOTAL","FLOAT","","")
    except:
        print "Error adding 'TOTAL' field to slope raster "
    try:
        gp.CalculateField_management (slope_lu,"TOTAL",total)#,"PYTHON")
    except:
        print "Error calculating 'TOTAL' field"
    try:
        gp.addfield(slope_lu,"PERC","LONG",'50','50')
    except:
        #If an error occurred while adding field
        print "Error creating 'Perc' field"
    try:
```

```
        gp.CalculateField_management(slope_lu,"PERC","[COUNT] / [TOTAL] * 100","VB")
    except:
        print "Error calculating 'PERC' field"

    raster = rasters.Next()

#Calculate score
try:
    gp.addfield(LC_score, "LC2_score", "LONG",'50','50')
except:
    print "Error in adding 'LC2_score' field"
try:
    gp.addfield(LC_score, "LC2_value", "LONG",'50','50')
except:
    print "Error in adding 'LC2_value' field"


rows = gp.UpdateCursor(LC_score)
row = rows.Next()
while row:
    ws1 = str(row.GRIDCODE)
    ws = ws1[:-2]
    lc = str(row.LC2_score)
    sloperas_dir = work + "/basins_results/slope"
    gp.workspace = sloperas_dir
    rasters = gp.listrasters("*","All")
    raster = rasters.next()
    while raster:
        if raster == (ws + "_slope.img"):
            print raster
            TRows = gp.searchCursor(raster)
            Trow = TRows.next()
            while Trow:
                row_val = int(Trow.VALUE)
                print row_val
                row_perc = float(Trow.PERC)
                if row_val == 82:
                    cropslope = row_perc
                else:
                    cropslope = 0
                Trow = TRows.next()
            cropslope_sum = cropslope

            #set score variable
            if cropslope_sum <= 1.5:
                ls = 5
            elif cropslope_sum > 1.5 and cropslope_sum <= 4.2:
                ls = 4
            elif cropslope_sum > 4.2 and cropslope_sum <= 6.4:
                ls = 3
            elif cropslope_sum > 6.4 and cropslope_sum <= 9.7:
                ls = 2
            elif cropslope_sum > 9.7:
                ls = 1
            else:
                ls = 5
```

```
        raster = rasters.Next()
    row.LC2_score = ls
    row.LC2_value = cropslope_sum
    rows.UpdateRow(row)
    row = rows.next()

  #answer = raw_input("Percent Urban and Agriculture Cover Indicator Complete. Click 'Enter' to exit")
```

Assessment Code: *LC_Forest.py*

```
#Description: Calculates indicator values for Landscape Condition's % Forested cover per watershed
#
#Arguments: workspace
#          Landuse_dir
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 23 February 2009
#
#_____________________________________________________________________________________


# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")


def LC_4 (work,LU_dir):

  gp.Workspace = work
  DB_work = gp.Workspace
  PGDB = DB_work + "/WCA.mdb"
  LC_score = PGDB + "/scores/LC_score"

  #Add new fields to LC_score
  try:
    gp.addfield(LC_score,"LC4_score","LONG",'50','50')
  except:
```

```
    #If an error occurred while adding field
    print "Error creating 'LC4_score' field"
try:
    gp.addfield(LC_score,"LC4_value","LONG",'50','50')
except:
    #If an error occurred while adding field
    print "Error creating 'LC4_value' field"


#Calculate % Forested score for each watershed
rows = gp.UpdateCursor(LC_score)
row = rows.Next()

while row:
    ws1 = str(row.GRIDCODE)
    #print "ws1 = " + str(ws1)
    ws = ws1[:-2]
    #print "ws = " + str(ws)
    lc = str(row.LC4_score)
    gp.workspace = LU_dir
    rasters = gp.listrasters("*","All")
    raster = rasters.next()
    while raster:
        #print "raster = " + str(raster)
        if raster == (ws + ".img"):
            print "raster match = " + str(raster)
            TRows = gp.searchCursor(raster)
            Trow = TRows.next()
            for_perc = 0
            while Trow:
                row_val = int(Trow.VALUE)
                #print row_val
                row_perc = float(Trow.PERC)
                if row_val == 41 or row_val == 42 or row_val == 43:
                    for_perc = for_perc + row_perc
                Trow = TRows.next()
            forest = for_perc
            print "forest = " + str(forest)

            #set score variable
            if forest <= 48.4:
                ls = 1
            elif forest > 48.4 and forest <= 63.8:
                ls = 2
            elif forest > 63.8 and forest <= 72.5:
                ls = 3
            elif forest > 72.5 and forest <= 82.4:
                ls = 4
            elif forest > 82.4:
                ls = 5
            else:
                ls = 1
            print "ls = " + str(ls)

        raster = rasters.Next()
    row.LC4_score = ls
```

```
        row.LC4_value = forest
        rows.UpdateRow(row)
        row = rows.next()

    #answer = raw_input("Forest Cover Indicator Complete. Click 'Enter' to exit")
```

Assessment Code: *LC_ForFrag.py*

```
#Description: Calculates indicator values for Landscape Condition's % Fragmented Forest cover per watershed
#
#Arguments: Workspace
#          Landuse_dir
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 23 February 2009
#
#_____________________________________________________________________________________

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

workspace = sys.argv[1]
Landuse_dir = sys.argv[2]
LC_score = sys.argv[3]

def LC_5 (work,LU_dir):

    gp.Workspace = work
    DB_work = gp.Workspace
    PGDB = DB_work + "/WCA.mdb"
    LC_score = PGDB + "/scores/LC_score"

    #Add new fields to LC_score
    try:
        gp.addfield(LC_score,"LC5_score","LONG",'50','50')
```

```
except:
    #If an error occurred while adding field
    print "Error creating 'LC5_score' field"
try:
    gp.addfield(LC_score,"LC5_value","LONG",'50','50')
except:
    #If an error occurred while adding field
    print "Error creating 'LC5_value' field"

#Forest Frag Process
rows = gp.UpdateCursor(LC_score)
row = rows.Next()

while row:
    ws1 = str(row.GRIDCODE)
    ws = ws1[:-2]
    lc = str(row.LC5_score)

    gp.workspace = LU_dir
    rasters = gp.listrasters("*","All")
    raster = rasters.next()

    while raster:
        if raster == (ws + ".img"):
            #remap = "11 39 0;40 49 1;50 99 0"
            reclass = LU_dir + "/reclass" + ws
            try:
                gp.Reclassify_sa(raster, "VALUE", "11 39 0;40 49 1;50 99 0", reclass, "NODATA")
            except:
                print "Error reclassifying LULC raster" + gp.getmessage()
            block = LU_dir + "/block" + ws
            try:
                gp.BlockStatistics_sa(reclass, block, "Rectangle 3 3 Cell", "SUM", "NODATA")
            except:
                print "Error calculating Block Statistics"  + gp.getmessage()
            try:
                gp.addfield(block,"FRAG","FLOAT",",")
            except:
                print "Error adding 'FRAG' field"
            try:
                gp.CalculateField_management(block,"FRAG","(1 - ([VALUE] / 9)) * [COUNT]","VB")
            except:
                print "Error calculating 'FRAG' field"

            Trows = gp.searchcursor(block)
            Trow = Trows.next()
            countsum = 0.0001
            fragsum = 0
            while Trow:
                value = int(Trow.VALUE)
                count = int(Trow.COUNT)
                frag = int(Trow.FRAG)

                if value != 0:
                    countsum = countsum + count
                    fragsum = fragsum + frag
```

```
            Trow = Trows.next()
            Counts = countsum
            Frags = fragsum
        del Trow
        del Trows
        wsfrag = (Frags / Counts) * 100

        #set score variable
        if wsfrag > 0 and wsfrag <= 7.8:
            ls = 5
        elif wsfrag > 7.8 and wsfrag <= 11.2:
            ls = 4
        elif wsfrag > 11.2 and wsfrag <= 13.8:
            ls = 3
        elif wsfrag > 13.8 and wsfrag <= 21.4:
            ls = 2
        elif wsfrag > 21.4:
            ls = 1
        else:
            ls = 999
    raster = rasters.next()
  row.LC5_score = ls
  row.LC5_value = wsfrag
  rows.UpdateRow(row)
  row = rows.next()


#answer = raw_input("Forest Fragmentation Indicator Complete. Click 'Enter' to exit")
```

Assessment Code: *LC_Impervious.py*

```
#
#Description: Calculates indicator values for Landscape Condition's % Impervious cover per watershed
#
#Arguments: Workspace
#          Imperv_dir
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 23 February 2009
#
#_____________________________________________________________________________________


# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
```

```
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")


def LC_8 (work, Impervious):

    gp.Workspace = work
    DB_work = gp.Workspace
    PGDB = DB_work + "/WCA.mdb"
    LC_score = PGDB + "/scores/LC_score"

    #Add new fields to LC_score
    try:
        gp.addfield(LC_score,"LC8_score","LONG",'50','50')
    except:
        #If an error occurred while adding field
        print "Error creating 'LC8_score' field"
    try:
        gp.addfield(LC_score,"LC8_value","LONG",'50','50')
    except:
        #If an error occurred while adding field
        print "Error creating 'LC8_value' field"

    #Add Potential, Actual, and Impervious fields to each impervious raster
    rows = gp.UpdateCursor(LC_score)
    row = rows.Next()

    while row:
        ws1 = str(row.GRIDCODE)
        ws = ws1[:-2]
        lc = str(row.LC8_score)

        gp.workspace = Impervious
        rasters = gp.listrasters("*","All")
        raster = rasters.next()

        while raster:
            if raster == (ws + ".img"):
                print "raster match = " + str(raster)
                try:
                    gp.addfield(raster,"POTENTIAL","FLOAT",",")
                except:
                    print "Error adding 'Potential' field to impervious raster "
                try:
                    gp.addfield(raster,"ACTUAL","FLOAT",",")
                except:
```

```
        print "Error adding 'Actual' field to impervious raster "
    try:
        gp.addfield(raster,"IMPERVIOUS","FLOAT",",")
    except:
        print "Error adding 'Impervious' field to impervious raster "

    Trows = gp.searchcursor(raster)
    Trow = Trows.next()
    pot = 0
    act = 0
    while Trow:
        count = int(Trow.COUNT)
        count1 = int(Trow.COUNT) * 100
        value = int(Trow.VALUE)
        val = count * value

        pot = pot + count1
        act = act + val
        Trow = Trows.next()
        potential = pot
        actual = act

    del Trow
    del Trows
    imperv = (actual / potential) * 100
    try:
        gp.CalculateField_management(raster,"Potential",potential)#,"PYTHON")
    except:
        print "Error calculating 'Potential' field"
    try:
        gp.CalculateField_management(raster,"Actual",actual)#,"PYTHON")
    except:
        print "Error calculating 'Actual' field"
    try:
        gp.CalculateField_management(raster,"Impervious","[Actual] / [Potential] * 100","VB")
    except:
        print "Error calculating 'Potential' field"
    impervi = imperv

    #set score variable
    if impervi <= 5:
        ls = 5
    elif impervi > 5 and impervi <= 10:
        ls = 4
    elif impervi > 10 and impervi <= 25:
        ls = 3
    elif impervi > 25 and impervi <= 30:
        ls = 2
    elif impervi > 30:
        ls = 1
    else:
        ls = 1

    raster = rasters.next()
row.LC8_score = ls
row.LC8_value = impervi
```

```
        rows.UpdateRow(row)
        row = rows.next()


    #answer = raw_input("Impervious Cover Indicator Complete. Click 'Enter' to exit")
```

Assessment Code: *LC_RoadDens.py*

```
#Description: Calculates indicator values for Landscape Condition's Road Density per watershed
#
#Arguments: Workspace
#          Roads
#          Length (field in roads shapefile)
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 23 February 2009
#
#Notes: Length Argument is not currently operational. Roads shapefile must have a length field named
"Shape_Length"
#_____________________________________________________________________________________

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


def LC_6 (work,roads):
    gp.Workspace = work
    DB_work = gp.Workspace
    PGDB = DB_work + "/WCA.mdb"
    LC_score = PGDB + "/scores/LC_score"
```

```
#Add LC6_score field
try:
    gp.addfield(LC_score, "LC6_score", "LONG",'50','50')
except:
    print "Error in adding 'LC6_score' field"
try:
    gp.addfield(LC_score, "LC6_value", "LONG",'50','50')
except:
    print "Error in adding 'LC6_value' field"


#Identity tool
roads_idt = PGDB + "/data_layers/roads_idt"

#Process Identity
try:
    gp.identity_analysis(roads,LC_score,roads_idt)
except:
    print "Error processing 'Identity' tool"

#Calculate Road Density per watershed
#Rlength = "Rrow." + length
rows = gp.UpdateCursor(LC_score)
row = rows.Next()

while row:
    ws1 = str(row.GRIDCODE)
    lc = str(row.LC6_score)
    area = abs(row.Shape_Area)
    #len_field = "Rrow." + length
    Rrows = gp.searchcursor(roads_idt)
    Rrow = Rrows.Next()
    Rdens = 0
    while Rrow:
        Rgrid = str(Rrow.GRIDCODE)
        Rlgth = abs(Rrow.Shape_Length)
        if Rgrid == ws1:
            print Rgrid
            Rdens = Rdens + Rlgth
        Rrow = Rrows.Next()
    tot_length = Rdens
    print "tot_length = " + str(tot_length)
    density = tot_length / area

    #set score variable
    if density <= 1.3:
        ls = 5
    elif density > 1.3 and density <= 1.6:
        ls = 4
    elif density > 1.6 and density <= 1.9:
        ls = 3
    elif density > 1.9 and density <= 3.0:
        ls = 2
    elif density > 3.0:
        ls = 1
    else:
```

```
        ls = 5

    row.LC6_score = ls
    row.LC6_value = density
    rows.UpdateRow(row)
    row = rows.Next()



  #answer = raw_input("Road Density Indicator Complete. Click 'Enter' to exit")
```

Assessment Code: *LC_StreamAg.py*

```
#Description: Calculates indicator values for Landscape Condition's % Stream length with Agricultural cover per
watershed
#
#Arguments: workspace
#          Landuse_dir
#          streams
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 23 February 2009
#
#_____________________________________________________________________________________________


# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")


def LC_3 (work,LU_dir,streams):

    gp.Workspace = work
    DB_work = gp.Workspace
    PGDB = DB_work + "/WCA.mdb"
```

```
LC_score = PGDB + "/scores/LC_score"

#Add new fields to LC_score
try:
   gp.addfield(LC_score,"LC3_score","LONG",'50','50')
except:
   #If an error occurred while adding field
   print "Error creating 'LC3_score' field"
try:
   gp.addfield(LC_score,"LC3_value","LONG",'50','50')
except:
   #If an error occurred while adding field
   print "Error creating 'LC3_value' field"

#clip streams to HUC
HUC = PGDB + "\\hydrology\\huc14"
HUC_streams = PGDB + "/hydrology/huc_streams"

try:
   gp.Clip_analysis(streams, HUC, HUC_streams)
except:
   print "Error clipping streams to HUC"

#Buffer streams
buf_out = PGDB + "/hydrology/streams_buf"
buf_dist = "30 meters"

try:
  gp.Buffer_analysis(HUC_streams, buf_out, buf_dist, "FULL", "ROUND", "NONE", "")
except:
   print "Error buffering streams"

#Calculate % Forested score for each watershed
rows = gp.UpdateCursor(LC_score)
row = rows.Next()

while row:
   ws1 = str(row.GRIDCODE)
   ws = ws1[:-2]
   lc = str(row.LC3_score)
   gp.workspace = LU_dir
   rasters = gp.listrasters("*","All")
   raster = rasters.next()
   while raster:
      if raster == (ws + ".img"):
         ws_streams = LU_dir + "/" + ws + "_streams.img"
         try:
            gp.ExtractByMask_sa(raster,buf_out,ws_streams)
         except:
            print "Error extracting by mask watershed: " + ws
         Arows = gp.searchcursor(ws_streams)
         Arow = Arows.next()
         total = 0
         while Arow:
            row_int = int(Arow.COUNT)
            total = total + row_int
```

```
        Arow = Arows.next()
        sum = total
    del Arow
    del Arows
    try:
        gp.addfield(ws_streams,"TOTAL","FLOAT",",")
    except:
        print "Error adding 'TOTAL' field to ws_streams raster "
    try:
        gp.CalculateField_management (ws_streams,"TOTAL",sum)#,"PYTHON")
    except:
        print "Error calculating 'TOTAL' field"
    try:
        gp.addfield(ws_streams,"PERC","LONG",'50','50')
    except:
        #If an error occurred while adding field
        print "Error creating 'Perc' field"
    try:
        gp.CalculateField_management(ws_streams,"PERC","[COUNT] / [TOTAL] * 100","VB")
    except:
        print "Error calculating 'PERC' field"

    TRows = gp.searchCursor(ws_streams)
    Trow = TRows.next()
    Ag_perc = 0
    while Trow:
        row_val = int(Trow.VALUE)
        row_perc = float(Trow.PERC)
        if row_val == 82:
            Ag_perc = Ag_perc + row_perc
        #else:
            #Ag_perc = 0
        Trow = TRows.next()
    Ag = Ag_perc

    #set score variable
    if Ag <= 8.5:
        ls = 5
    elif Ag > 8.5 and Ag <= 14.6:
        ls = 4
    elif Ag > 14.6 and Ag <= 20.1:
        ls = 3
    elif Ag > 20.1 and Ag <= 27.9:
        ls = 2
    elif Ag > 27.9:
        ls = 1
    else:
        ls = 5
    print "ls = " + str(ls)

  raster = rasters.Next()
row.LC3_score = ls
row.LC3_value = Ag
rows.UpdateRow(row)
row = rows.next()
```

```
    #answer = raw_input("Stream Length with Agriculture Cover Indicator Complete. Click 'Enter' to exit")
```

Assessment Code: *LC_StreamRoad.py*

```
#Description: Calculates indicator values for Landscape Condition's Road Density per watershed
#
#Arguments: workspace
#          roads
#          streams
#
#Requirements: ArcGIS 9.2
#
#Author: Ernie Hain, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written: 23 February 2009
#
#_____________________________________________________________________________________________

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


def LC_7 (work,roads,streams):
    gp.Workspace = work
    DB_work = gp.Workspace
    PGDB = DB_work + "/WCA.mdb"
    LC_score = PGDB + "/scores/LC_score"

    #Add temp feature dataset
    #Set Spatial Reference
    sr =
"PROJCS['NAD_1983_UTM_Zone_18N',GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1
```

```
983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.017453292
5199433]],PROJECTION['Transverse_Mercator'],PARAMETER['False_Easting',500000.0],PARAMETER['False_
Northing',0.0],PARAMETER['Central_Meridian',-
75.0],PARAMETER['Scale_Factor',0.9996],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]"

    # Process: Create temp Feature Dataset...
    try:
        gp.CreateFeatureDataset_management(PGDB, "Temp", sr)
    except:
        print "Error in 'Create temp Feature Dataset'"

    temp = PGDB + "/Temp"

    #Add LC7_score field
    try:
        gp.addfield(LC_score, "LC7_score", "LONG",'50','50')
    except:
        print "Error in adding 'LC7_score' field"
    #Add LC7_value field
    try:
        gp.addfield(LC_score, "LC7_value", "Long", '50','50')
    except:
        print "Error in adding 'LC7_value' field"

    #Calculate % Stream w/in 30 m of a road for each watershed
    rows = gp.UpdateCursor(LC_score)
    row = rows.Next()

    while row:
        ws1 = str(row.GRIDCODE)
        ws = ws1[:-2]
        lc = str(row.LC7_score)
        ws_ind = temp + "/ws_" + ws
        exp = "[GRIDCODE] = " + ws1
        ws_stream = temp + "/stream_" + ws
        ws_road = temp + "/road_" + ws
        ws_roadbuf = temp + "/roadbuf_" + ws
        bufstream = temp + "/bufstream_" + ws
        try:
            gp.select_analysis(LC_score, ws_ind, exp)
        except:
            print "Error selecting ws: " + ws
        try:
            gp.Clip_analysis(streams, ws_ind, ws_stream)
        except:
            print "Error clipping streams for ws: " + ws
        Srows = gp.searchCursor(ws_stream)
        Srow = Srows.Next()
        total = 0
        while Srow:
            len = float(Srow.Shape_Length)
            total = total + len
            Srow = Srows.next()
        total_len = total
        del Srow
        del Srows
```

```
    try:
      gp.Clip_analysis(roads, ws_ind, ws_road)
    except:
       print "Error clipping roads for ws: " + ws
    try:
       gp.Buffer_analysis(ws_road, ws_roadbuf, "30 meters",)
    except:
       print "Error creating buffer for roads in ws: " + ws
    try:
       gp.Clip_analysis(ws_stream, ws_roadbuf, bufstream)
    except:
       print "Error clipping streams to roads buffer in ws: " + ws
    Brows = gp.searchCursor(bufstream)
    Brow = Brows.Next()
    st_total = 0
    while Brow:
       st_len = float(Brow.Shape_Length)
       st_total = st_total + st_len
       Brow = Brows.Next()
    stream_rd = st_total
    del Brow
    del Brows
    value = stream_rd / total_len * 100

    #set score variable
    if value <= 2.8:
       ls = 5
    elif value > 2.8 and value <= 4.6:
       ls = 4
    elif value > 4.6 and value <= 6.2:
       ls = 3
    elif value > 6.2 and value <= 8.3:
       ls = 2
    elif value > 8.3:
       ls = 1
    else:
       ls = 5
    row.LC7_score = ls
    row.LC7_value = value
    rows.UpdateRow(row)
    row = rows.next()


try:
    gp.Delete_management(temp, "")
except:
    print "Error deleting 'Temp' feature dataset"



#answer = raw_input("Percent Stream Length within 30 m of a Road Indicator Complete. Click 'Enter' to exit")
```

Appendix B. Python Programming Language developed for Biologic Condition Assessment.

Assessment Code: *BiologicalCondition.py*

```
#Description: Calls various functions to calculate indicator values for Biotic condition
#
#Arguments: sys.argv[1] = Workspace
#          sys.argv[2] = Mammals
#          sys.argv[3] = Fish
#          sys.argv[4] = Birds
#          sys.argv[5] = Reptiles and Amphibians
#          sys.argv[6] = Odonates
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written: 25 May 2009
#
#_____________________________________________________________________________________________


import sys, string, os, arcgisscripting,

reload ()

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

work = sys.argv[1]
Mammal = sys.argv[2]
Fish = sys.argv[3]
Birds = sys.argv[4]
RepAmph = sys.argv[5]
Odonates = sys.argv[6]


print work + Mammal + Fish + Birds + RepAmph + Odonates
```

```
answer = raw_input("Biological Condition Assessment Complete. Click 'Enter' to exit")
```

Assessment Code: *bird_sort.py*

```
#Description: Calculates indicator values for Biological Condition's Bird species proportion per watershed
#
#Arguments: SmallMammal
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = birdspec.dbf
#sys.argv[3] = FIELD5
#sys.argv[4] = birdobserv.shp
#sys.argv[5] = Scientific
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")



import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

work = sys.argv[1]
```

```
Bird1 = sys.argv[2]
Bird2 = sys.argv[3]
Birdinv1 = sys.argv[4]
Birdinv2 = sys.argv[5]

gp.workspace = work

# Open a searchcursor
#
rows = gp.searchcursor(work + "/" + Bird1,"","",Bird2)
rows.Reset()
row = rows.Next()
allspec=[]
count=[]
while row:
    if row.getvalue(Bird2) not in allspec:
        allspec.append(row.getvalue(Bird2))


    row = rows.next()

rows = gp.searchcursor(work + "/" + Birdinv1,"","",Birdinv2)
rows.Reset()
row = rows.Next()
invspec=[]
while row:
    if row.getvalue(Birdinv2) not in invspec:
        invspec.append(row.getvalue(Birdinv2))

    row = rows.next()



for species in allspec:
    if species in invspec:
        count.append(species)

pop= ((float(len(species)))/(len(allspec)))
print pop


if pop >= .50:
    ls = 5
elif pop < .50  and pop >= .40:
    ls = 4
elif pop <.40 and pop >= .30:
    ls = 3
elif pop < .30 and pop >= .20:
    ls = 2
elif pop < .20:
    ls = 1

print ls
```

Assessment Code: *fish_sort.py*

```
#Description: Calculates indicator values for Biological Condition's fish species proportion per watershed
#
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = fishspec.dbf
#sys.argv[3] = FIELD5
#sys.argv[4] = allfish.shp
#sys.argv[5] = LATINNAME
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

work = sys.argv[1]
Fish1 = sys.argv[2]
Fish2 = sys.argv[3]
Fishinv1 = sys.argv[4]
Fishinv2 = sys.argv[5]

gp.workspace = work
```

```
# Open a searchcursor
#
rows = gp.searchcursor(work + "/" + Fish1,"","",Fish2)
rows.Reset()
row = rows.Next()
allspec=[]
count=[]
while row:
    if row.getvalue(Fish2) not in allspec:
        allspec.append(row.getvalue(Fish2))


    row = rows.next()

rows = gp.searchcursor(work + "/" + Fishinv1,"","",Fishinv2)
rows.Reset()
row = rows.Next()
invspec=[]
while row:
    if row.getvalue(Fishinv2) not in invspec:
        invspec.append(row.getvalue(Fishinv2))

    row = rows.next()



for species in allspec:
    if species in invspec:
        count.append(species)

pop= ((float(len(species)))/(len(allspec)))
print pop


if pop >= .50:
    ls = 5
elif pop < .50  and pop >= .40:
    ls = 4
elif pop <.40 and pop >= .30:
    ls = 3
elif pop < .30 and pop >= .20:
    ls = 2
elif pop < .20:
    ls = 1

print ls
```

Assessment Code: *herp_sort.py*

```
#Description: Calculates indicator values for Biological Condition's amphibian and reptile species proportion per
watershed
#
```

```
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = herpspec.dbf
#sys.argv[3] = FIELD5
#sys.argv[4] = herp_w_names.shp
#sys.argv[5] = Scientific
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

work = sys.argv[1]
Herp1 = sys.argv[2]
Herp2 = sys.argv[3]
Herpinv1 = sys.argv[4]
Herpinv2 = sys.argv[5]

gp.workspace = work
```

```
# Open a searchcursor
#
rows = gp.searchcursor(work + "/" + Herp1,"","",Herp2)
rows.Reset()
row = rows.Next()
allspec=[]
count=[]
while row:
    if row.getvalue(Herp2) not in allspec:
        allspec.append(row.getvalue(Herp2))


    row = rows.next()

rows = gp.searchcursor(work + "/" + Herpinv1,"","",Herpinv2)
rows.Reset()
row = rows.Next()
invspec=[]
while row:
    if row.getvalue(Herpinv2) not in invspec:
        invspec.append(row.getvalue(Herpinv2))

    row = rows.next()



for species in allspec:
    if species in invspec:
        count.append(species)

pop= ((float(len(species)))/(len(allspec)))
print pop


if pop >= .50:
    ls = 5
elif pop < .50  and pop >= .40:
    ls = 4
elif pop <.40 and pop >= .30:
    ls = 3
elif pop < .30 and pop >= .20:
    ls = 2
elif pop < .20:
    ls = 1

print ls
```

Assessment Code: *mammal_sort.py*

```
#Description: Calculates indicator values for Biological Condition's collected mammal species proportion per
watershed
#
#
#
#Requirements: ArcGIS 9.3
```

```
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = mamspec.dbf
#sys.argv[3] = FIELD5
#sys.argv[4] = allmammals.shp
#sys.argv[5] = Scientific
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

work = sys.argv[1]
Mammal1 = sys.argv[2]
Mammal2 = sys.argv[3]
Mammalinv1 = sys.argv[4]
Mammalinv2 = sys.argv[5]

gp.workspace = work



# Open a searchcursor
#
rows = gp.searchcursor(work + "/" + Mammal1,"","",Mammal2)
```

```
rows.Reset()
row = rows.Next()
allspec=[]
count=[]
while row:
    if row.getvalue(Mammal2) not in allspec:
        allspec.append(row.getvalue(Mammal2))


    row = rows.next()

rows = gp.searchcursor(work + "/" + Mammalinv1,"","",Mammalinv2)
rows.Reset()
row = rows.Next()
invspec=[]
while row:
    if row.getvalue(Mammalinv2) not in invspec:
        invspec.append(row.getvalue(Mammalinv2))

    row = rows.next()



for species in allspec:
    if species in invspec:
        count.append(species)

pop= ((float(len(species)))/(len(allspec)))
print pop


if pop >= .50:
    ls = 5
elif pop < .50  and pop >= .40:
    ls = 4
elif pop <.40 and pop >= .30:
    ls = 3
elif pop < .30 and pop >= .20:
    ls = 2
elif pop < .20:
    ls = 1

print ls
```

Assessment Code: *OD_sort.py*

```
#Description: Calculates indicator values for Biological Condition's odonate species proportion per watershed
#
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: fhernst@ncsu.edu
#
#Date Written:  25 May 2009
```

```
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = odspec.dbf
#sys.argv[3] = FIELD5
#sys.argv[4] = ODOOBS.shp
#sys.argv[5] = SPECIES
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

work = sys.argv[1]
Odonate1 = sys.argv[2]
Odonate2 = sys.argv[3]
Odonateinv1 = sys.argv[4]
Odonateinv2 = sys.argv[5]

gp.workspace = work


# Open a searchcursor

#
rows = gp.searchcursor(work + "/" + Odonate1,"","",Odonate2)
rows.Reset()
row = rows.Next()
allspec=[]
count=[]
```

```
while row:
    if row.getvalue(Odonate2) not in allspec:
        allspec.append(row.getvalue(Odonate2))

    row = rows.next()

rows = gp.searchcursor(work + "/" + Odonateinv1,"","",Odonateinv2)
rows.Reset()
row = rows.Next()
invspec=[]
while row:
    if row.getvalue(Odonateinv2) not in invspec:
        invspec.append(row.getvalue(Odonateinv2))

    row = rows.next()

for species in allspec:
    if species in invspec:
        count.append(species)

pop= ((float(len(species)))/(len(allspec)))
print pop

if pop >= .50:
    ls = 5
elif pop < .50  and pop >= .40:
    ls = 4
elif pop <.40 and pop >= .30:
    ls = 3
elif pop < .30 and pop >= .20:
    ls = 2
elif pop < .20:
    ls = 1

print ls
```

Appendix C. Python Programming Language used to Develop Chemical Condition Assessment.

Assessment Code: *ChemicalCondition.py*

```
#Description: Calls various functions to calculate indicator values for Chemical condition
#
#Arguments: sys.argv[1] = Workspace
#          sys.argv[2] = pH
#          sys.argv[3] = DO
#          sys.argv[4] = conductivity
#          sys.argv[5] = Temperature
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written: 25 May 2009
#
#_____________________________________________________________________________________


import sys, string, os, arcgisscripting,

reload ()

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")

work = sys.argv[1]
pH = sys.argv[2]
DO = sys.argv[3]
conductivity = sys.argv[4]
Temperature = sys.argv[5]



print work + pH + DO + conductivity + Temperature
```

```
answer = raw_input("Chemical Condition Assessment Complete. Click 'Enter' to exit")
```

Assessment Code: *PH.py*

```
#Description: Calculates indicator values for chemical Condition's pH per watershed
#
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = waterchem.shp
#sys.argv[3] = PH
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

workspace = sys.argv[1]
inputtbl = sys.argv[2]
fld = sys.argv[3]
```

```
gp.workspace = workspace



# Open a searchcursor
#   Input: C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#
rows = gp.searchcursor(workspace + "/" + inputtbl,"","",fld)
rows.Reset()
row = rows.Next()

while row:
   if row.getvalue(fld):
      print row.getvalue(fld)

   row = rows.next()



while row:
   if score >= 6.0 and score >=9.0:
      ls = 5
   elif score > 9.0 and score <= 9.5 and score <6.0 and score >= 5.5:
      ls = 4
   elif score > 9.5 and score <= 10.0 and score < 5.5 and score >= 5.0:
      ls = 3
   elif score > 10.0 and score <= 10.5 and score < 5.5 and score >= 5.0:
      ls = 2
   elif score >10.5 and score < 4.5:
      ls = 1
   print ls
   row= rows.next
```

Assessment Code: *DO.py*

```
#Description: Calculates indicator values for chemical Condition's Dissolved Oxygen per watershed
#
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = waterchem.shp
#sys.argv[3] = DO
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")
```

```
# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

workspace = sys.argv[1]
inputtbl = sys.argv[2]
fld = sys.argv[3]


gp.workspace = workspace



# Open a searchcursor
#   Input: C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#
rows = gp.searchcursor(workspace + "/" + inputtbl,"","",fld)
rows.Reset()
row = rows.Next()

while row:
    if row.getvalue(fld):
        print row.getvalue(fld)
    row = rows.next()
row_val = row.getvalue(fld)
while row:
    if row_val >= 6.0:
        ls = 5
    elif row_val < 6.0 and row_val >= 5.0:
        ls = 4
    elif row_val < 5.0 and row_val >= 4.0:
        ls = 3
    elif row_val < 4.0 and row_val >= 3.0:
        ls = 2
    elif row_val < 3.0 and row_val > 2.0:
```

```
    ls = 1

    row.CC1_score = ls
    rows.UpdateRow(row)
    row = rows.next()
```

Assessment Code: *Temperature.py*

```
#Description: Calculates indicator values for chemical Condition's temperature per watershed
#
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = waterchem.shp
#sys.argv[3] = TEMP
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

workspace = sys.argv[1]
```

```
inputtbl = sys.argv[2]
fld = sys.argv[3]


gp.workspace = workspace



# Open a searchcursor
#   Input: C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#
rows = gp.searchcursor(workspace + "/" + inputtbl,"","",fld)
rows.Reset()
row = rows.Next()

while row:
   if row.getvalue(fld):
      print row.getvalue(fld)
   row = rows.next()
   row_val = row.getvalue(fld)
while row:

   if row_val >= 15.5 and row_val >=21.2:
      ls = 5
   elif row_val > 13.5 and row_val < 15.5 and row_val < 23.2 and row_val > 21.2:
      ls = 4
   elif row_val > 10.5 and row_val < 13.5 and row_val < 25.2 and row_val > 23.2:
      ls = 3
   elif row_val > 8.5 and row_val < 10.5 and row_val < 27.2 and row_val > 25.2:
      ls = 2
   elif row_val >27.2 and row_val < 8.5:
      ls = 1

      row.CC1_score = ls
      rows.UpdateRow(row)
      row = rows.next()
```

Assessment Code: *Conductivity.py*

```
#Description: Calculates indicator values for chemical Condition's conductivity per watershed
#
#
#
#Requirements: ArcGIS 9.3
#
#Author: Brett Hartis, Center for Earth Observation, North Carolina State University. email: bmhartis@ncsu.edu
#
#Date Written:  25 May 2009
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = waterchem.shp
#sys.argv[3] = COND
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
```

```
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Check out ArcGIS 3D Analyst extension license
gp.CheckOutExtension("3d")

#set script to overwrite existing data:
gp.overwriteoutput = 1

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/3D Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion Tools.tbx")


import sys

# Print the arguments
for index, arg in enumerate(sys.argv):
    print 'Argument', str(index) + ':', arg
import arcgisscripting
gp = arcgisscripting.create(9.3)

workspace = sys.argv[1]
inputtbl = sys.argv[2]
fld = sys.argv[3]


gp.workspace = workspace



# Open a searchcursor
#   Input: C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#
rows = gp.searchcursor(workspace + "/" + inputtbl,"","",fld)
rows.Reset()
row = rows.Next()

while row:
    if row.getvalue(fld):
        print row.getvalue(fld)
    row = rows.next()

while row:

    if row_val >= 500:
        ls = 5
    elif row_val >=400 and row_val < 500:
```

```
    ls = 4
elif row_val >= 300 and row_val <400:
    ls = 3
elif row_val >= 200 and row_val < 300:
    ls = 2
elif row_val < 200 :
    ls = 1

    row.CC1_score = ls
    rows.UpdateRow(row)
    row = rows.next()
```

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National Park Service
U.S. Department of the Interior

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