ABSTRACT


Data collection, inventorining, and monitoring have become important for a multitude of agencies in determining effective protection and management techniques in natural resource conservation and assessments. National Park managers across the country are frequently confronted with increasingly complex and challenging issues in natural resource assessment, management and monitoring. These issues require a broad understanding of the status and trends of each park's natural resources as a basis for making decisions, working with other agencies, and communicating with the public to protect park natural systems and native species. In this study, our objective was to create a GIS-based, user-friendly, and spatially-specific model from existing and readily available data that will be useful to NPS natural resource managers to create an effective assessment of natural resources at the individual park level. We completed an assessment of George Washington Birthplace National Monument (GEWA), a single park unit within the NPS system. We used established literature values, and a multiple criteria approach to determine relevant indicators at entire park, site specific sub-watershed levels that were indicative of park natural resources condition. Natural resources indicators were organized into three main categories: Landscape Condition, Biotic Condition and Chemical Condition. Model indicator results showed the majority of the GEWA condition assessments to be in an overall good condition. However, landscape condition status was found to vary by sub-watershed. Although data availability proved to be a major concern, we found our methods to be quite effective in establishing data
requirements necessary for comprehensive assessments, as well as establishing the required data collection formats that will allow for continued development of these assessment models.
A Natural Resource Condition Assessment of a Single Unit within the National Parks System: George Washington Birthplace National Monument

by
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DEDICATION

I would like to dedicate this work to my grandfather for introducing me to the outdoors and the “old way” of life. You are truly part of a dying breed and I am glad to have called you my “papaw”.
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1. LITERATURE REVIEW

1.1. Introduction

Today, data collection, inventorying, and monitoring are important in determining effective protection and management techniques in natural resource conservation and assessments. Each year, state and federal governments fund a number of monitoring programs to measure the status and trends of ecological and natural resources (Olsen et al. 1999). Although the desired outcome is the same, each program has a unique design and focus with different objectives (Olsen et al. 1999). Basic rules and principles continue to emerge for data collection and management; however, there are few realistic methods for comprehensive ecosystem management (Grumbine 1994). The implication is that managers and researchers must think in a more multifunctional direction.

National Park Service (NPS) managers across the country are confronted with increasingly complex and challenging issues. These issues require a broad understanding of the status and trends of each park's natural resources as a basis for making decisions, working with other agencies, and communicating with the public to protect park natural systems and native species.

1.2. Monitoring of the National Parks System: A Background

The NPS has created several programs in order to better improve management techniques through science. The Inventory and Monitoring (I&M) program was developed in 1992 to collect, organize, and make available natural resource data that can be transformed into information through analysis, synthesis and modeling (NPS 2007). The Vital Signs Monitoring Program (VSMP) was developed by the NPS in 2000 to provide the minimum
infrastructure needed to track the overall condition of natural resources in parks (Stevens et al. 2005). The Vital Signs Monitoring Program tracks the physical, chemical and biological elements and processes of the park ecosystems that represent the overall health or condition of the parks resources (Stevens et al. 2005). Both the I&M and Vital Signs Monitoring Programs are designed to improve resource planning, enhance parks for science, and enhance environmental stewardship of the parks. These programs remain active and are operated in conjunction with private consultants, universities and other state and federal agencies.

Currently, the NPS uses the Natural Resource Database Template (NRDT), a set of Microsoft Access relational database tables that parks and networks can use to develop applications for capturing natural resource inventory and monitoring data. The NRDT is a core database structure that can be modified and built upon by different parks and networks depending on the components of their inventory and monitoring program and the specific sampling protocols they use. Data from the I&M and VSMP are stored with MSAccess modules and/or R code.

Although the NPS has developed several programs to inventory and manage data on its park natural resources, there is still a lack of connection between the extensive amount of data collected and actual analyses or application of that data. Traditionally, the parks networks have only been involved in Natural Resource Condition Assessments (NRCA) in an advisory or data support capacity (Personal Communication, Adam Kozlowski 2010). The data collected by the NPS is intended for creating assessments and synthesis; however, much of it remains in archival fashion and is not easily restructured for analyses and modeling. The I&M program and other publically utilized data have faced challenges of
inconsistency in data collection and structure (Personal Communication, Adam Kozlowski 2010). These inconsistencies make developing models from data quite difficult. For example, if data on bat species is collected in or adjacent to a park over ten years without using the same protocol in each collection, the data may be rendered useless for analysis and synthesis. Most of the NPS long term monitoring projects are still very young (3-5 years of field data) and as such analysis tools have yet to be developed effectively. Because data and monitoring programs are so young, a very small fraction of the data used in early NRCA’s actually originates in the I&M databases (Personal Communication, Adam Kozlowski 2010).

1.3. Current Approaches to Natural Resource Condition Assessments

1.3.1 Traditional Data Sources

Current NRCA’s rely heavily on data mining and publically shared data. The amount of publically shared data seems to be increasing at an alarming rate worldwide (Hey and Trefethen 2003). Because of this, organizations like the National Science Foundation (NSF) have worked to develop different digital data frameworks to create coherent and organized publically available data (NSF, 2006). Data managers and scientists appear to be increasingly concerned by how to achieve more effective management and sharing of data in response to the overwhelming amount of data (Hey & Trefethen 2003). These publically shared data could potentially be a great resource for NRCA’s as well as other management programs. Publically shared data, however, can be said to exhibit the same problems faced by NPS collected data. When considering a natural resource condition assessment, it is very important that the data be easily accessed and utilized. Data are prone to becoming unusable
if they are not expertly managed (RIN 2008). Public data may be available in great amount but a lack of uniformity in behavior, policies and needs presents a constant problem for utilization of those data (RIN 2008). Therefore, data management practices must be applied long before any analysis is attempted. If the process of data sharing is to become more effective and useful, much more consideration needs to be given to making datasets usable by providing the information and possibly software tools necessary for others to re-use the data (Borgman 2007), as is the case with the NPS NRCA’s.

1.3.2. Current Limitations to NRCAs

It is generally time consuming, costly, and somewhat impossible to assess and monitor every system variable that contributes to the system as a whole (Nelson et al. 2003, Nelson et al. 2006) but what is still needed is a management strategy that incorporates a multitude of values rather than focusing on local impairments (Mangel et al. 1996). At present there is no rapid, affordable, or entirely comprehensive methodology for evaluating and rating natural resource conditions or ecosystem health. A solution to this can be a more novel approach to assess natural resources on a large geographic scale (Nelson et al. 2006). This can be accomplished by identifying a representative subset of species and ecosystem variables that are most likely to change in detectable ways in response to change in resource condition (Mangel et al. 1996). The NPS Vital Signs Program attempts to do this but there are limitations in spatial and temporal uniformity among parks. In the I&M program, data collected are variable from park to park (not all parks have the same ecological resources) and most projects are designed to return only basic status and trend data (Personal
Communication, Kozlowski 2010). Thus, what could be considered healthy in one park in terms of natural resources may not be important in another park.

The NPS also needs methods to determine criteria that may be the best indicator of natural resource condition on a broader scale as well as ways to interpret this. The Vital Signs Monitoring program develops factors that contribute to environmental change over a geographical area by establishing a set of indicators unique to each park (table 1.1). Multiple variables play a significant role in determining an area’s environmental health (Hershner et al. 2007). These variables change both spatially and temporally and cannot be applied to all systems, as is the case with each park within the National Parks System. The I&M and VSMP both address variables unique within parks but lack a methodology for assessing those variables. This need suggest that there should be a unique set of variables deemed vital to each park as well as threshold values associated with those indicators. The study and monitoring of environmental thresholds is of increasing relevance for park managers as the human population continues to put a strain on the world’s ecosystems (EI 2010). Many natural systems can withstand degradation up until a certain point at which impairment is likely to occur. In order for park managers to make proper management decisions, it is important to identify where such thresholds might exist and what the actual threshold values mean in terms of environmental condition (EI 2010). Assigning threshold values to currently developed indicators of park condition will help managers interpret results by providing a baseline for current park condition.

In recent decades, federal and state agencies, as well as volunteer organizations, have attempted to develop integrative approaches to efficiently monitor the health of our nation’s aquatic resources (Heiskary et al. 1994, Obrecht et al. 1998). Traditionally, chemical and
benthic macroinvertebrate monitoring have been the primary methods for assessment of these resources (Hilsenhoff 1982, US EPA 2002). Monitoring approaches have proven useful for reflecting local impairments to the sampled water bodies over short time periods (Hilsenhoff 1982). 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. Managing an ecosystem requires the management of the entire system by integration of resource use, biological condition and physical systems (Wood 1994). Thus, a comprehensive set of conditions needs to be valued (Knetsch 1990).

Threats from exotic species, water pollution, adjacent development, and other sources are management concerns for many U.S. National Parks. In 2003, Congress enacted an Appropriations Act which instructed and funded the NPS to assess environmental conditions in National Park units. The National Parks Service states that the main goal of any environmental or natural resource condition assessment is to provide accurate and timely information on natural and cultural resource conditions, as well as stewardship capacity, in our national parks (NPS 2001). Having been instructed by the US government to assess the environmental state of each park, the NPS needed a framework by which to do so.

1.4. The NPS and NRCAs

In 2004, the NPS Water Resources Division received funding to conduct natural resource/watershed condition assessments at national parks throughout the country. These landscape-scale assessments were intended to provide park planners and resource managers with detailed information for natural resource management and conservation. The assessments relied primarily on existing datasets consisting of biotic and abiotic natural
resource data available from a compilation of local, state, and federal agencies and organizations. Several state assessments were completed between 2004 and 2008.

A variety of assessments have been completed in the Northeast region of the NPS (Mahan 2004, Foley 2005, Mahan 2006, James-Pirri 2009, McElroy et al. 2009). These studies attempted to determine the current condition of natural resources at individual park units. In most cases, the assessment of current condition was based upon existing data, technical reports, and the published literature with no new data being collected. Natural resources that were evaluated in these assessments were land use dynamics, vegetation communities (including information on plant diseases), wetland resources, faunal communities, water resources, soils, air quality, soundscape, and visitor use. Current condition was primarily based on a comparison to historical data as a represented increase or decrease in condition from what was historically known.

From 2004 to 2006 a variety of natural resource condition assessments were completed in the northeast region of the NPS (Mahan 2004, Foley 2005, Mahan 2006). The initial purpose of each study was to assess natural resource conditions for individual parks within the NPS. Each study utilizes a wide variety of data and adequately characterizes natural resources at individual parks levels by providing current values associated with each resource. Although important in providing information on current status of natural resources in each park, these studies fail to attempt assessment or actual interpretation of results into recommendations for management. Level of impairment for each natural resource was based solely on professional opinion and not on a distinct set of values, or thresholds, by which to quantify levels of impairment. If levels of impairment are not clearly defined then substantial management issues may be difficult to address.
In 2009, McElroy et al. attempted to determine natural resource condition within Fire Island National Seashore (FIIS) of the NPS Northeast Coastal Barrier Network. The aim of their project was to compile a large-scale assessment of the natural resources associated with FIIS off the south shore of Long Island, New York. Their focus was to identify both the state of knowledge regarding individual resources and the degree to which they are affected by natural and anthropogenic factors (McElroy et al. 2009). The study uses a wide variety of datasets including data from the VSMP and I&M as well as other publically available data sources. Although the study adequately addresses natural resources of concern within FIIS, the majority of its findings are based on trend data or summary of current condition. They fail to determine a current status based on current thresholds and interpret results into management implications of important natural resources.

In 2009, James-Pirri attempted to determine natural resource condition within Minute Man National Historic Park (MIMA) of the NPS Northeast Region. The purpose of the study was to provide information on the current condition of natural resources at MIMA (James-Pirri 2009). The assessment of current condition was based upon existing data, technical reports, and the published literature; no new data were collected. This study built upon existing studies but also attempted to determine a current status based on existing literature and trends in each natural resource. The study utilized a scoring and rating system by which to categorize impairment levels within the park. Results were presented as both a summary of natural resources and current condition based on trends in natural resources. The study assessed indicators based on the VSMP vital signs identified for that park. The study also includes a metric of data reliability to be utilized in interpretation. Although the study was
adequate in attempting to determine the current status of natural resources in the park, the fact that indicators were based on specific aspects makes comparability across geographically similar parks quite difficult. Results for indicators were most often based on professional opinion and not a concrete set of indicator thresholds by which to scale impairment.

Although intended for essentially the same purpose, each study varied in scope, data availability, data assessment, model design, assessment results and management implications. Each study either characterized or summarized data or established trends based on past and present data. The problem still remained that there were no widely accepted definitions, approaches, or methods for conducting structured, replicable assessments of park resources. In other words, studies regarding current status determination were not being completed. A wide variety of methods were available depending on scale and data availability although the purpose was essentially the same (table. 1.2). The lack of uniformity among assessments can make comparative analysis across parks within the same geographic area quite difficult.

George Washington Birthplace National Monument (GEWA), a park in the NPS Northeast Coastal Barrier Network, is one park unit of interest for the NPS natural resource condition assessments. 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 (Blank et al. 2007). GEWA is part of the Northeast Coastal and Barrier Network of the NPS (figure 1.1). The park currently experiences a variety of management concerns including adjacent urbanization and a variety of water quality concerns (Blank et. Al 2007). 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 on the east and south, and private land on 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 (Blank et al. 2007). This area provides favorable habitats for birds, mammals, fish, reptiles, amphibians and invertebrates. Despite the small size of the national historic sites, the importance of inventorying these resources was made clear by parks superintendent John Donahue in 1995 when he stated the following in a memo to park staff:

“I also want to remind everyone that the natural and the cultural resources within our sites are woven together like the threads of a quilt. They cannot be separated without destroying the whole, nor can they be prioritized. The land and waters and wildlife of these sites deserve and will receive the same protection here as they do in Yellowstone National Park.”

1.5. Multiple Criteria Indices

Multiple criteria indices (MCIs) have recently evolved as a prominent tool for monitoring ecosystem health, previously they had more commonly used as indices of biotic integrity for stream health (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 a weighted system
and confidence factors derived from the most current and best available data. Restructured data derived from the original I&M datasets present the potential of being combined with multiple criteria to determine environmental conditions of each park. However, ecological indicators deemed most influential to environmental health must be defined.

One data rich and often utilized indicator of environmental health is land use and land use change (Pretto et al. 2009, Stevens et al. 2005). There is evidence that early civilizations may have caused mass extinctions and a considerable amount of environmental degradation (Steadman 1995, Hong et al. 1994). Thus, it is evident that environmental change has been occurring at the hands of humans for centuries. The development of various lands, whether through urbanization, deforestation, agriculturalization, or transportation has contributed to the progress of civilization (Cook 1976). The US census bureau stated an increase of nearly 26 million people from April 1, 2000 to July 1, 2009 (US Census 2009). It is also believed that as of 1998, nearly 75% of the US population lived in urban areas with over half of that percentage living in the suburban, newly developed areas (World Resources Institute 1998). The main concern of the National Parks Service has been that landowners adjacent to the park develop their properties in ways that might draw on the Park’s resources or otherwise interfere with historic viewsheds (John Karish 2009, Personal Communication). Park managers are also concerned with land loss along shorelines caused by erosion. With more and more of the human population leaving the city and moving into newly developed suburbia, an increasing threat of greater incidental impacts are to be expected in parks located in or adjacent to urbanizing areas.
Another concern is the agricultural development required to support a booming human population. At the turn of the century it was believed that agriculture had displaced one-third of temperate and tropical forests and one-quarter of natural grasslands worldwide with only marginal conversion back to natural land by abandonment (Mock 2000). It is these changes that can cause severe changes to the environment in and adjacent to the parks.

It is also evident that development will proceed in this fashion with or without regulation as the population continues to increase (Casetti 2007). Traditionally, populations regulated resources on a day to day basis. This is no longer possible (Brouha 1994, Hodges 1995), and environmental impacts from population growth must be recognized as a critical conservation problem for park managers. There is no question that infinite growth is impossible in a finite system. The human population cannot continually expand without eventually overwhelming its base of natural resources (Mangel et al. 1996). Tilman et al. (1994) demonstrates that even moderate habitat destruction can lead to delayed but certain extinction of the dominant species in the remaining habitat. Quantifying habitat destruction whether through urbanization or agriculturalization should be a major emphasis in resource management plans (Mangel et al. 1996) for park managers. Therefore it is important to investigate landscape change and land use when considering an assessment of natural resources for each park.

Another important component and indicator of environmental change is the flora and fauna that inhabit an area. In order for an environmental assessment to be effective, it must contain information relative to nature’s laws: the physical laws and biological dynamics that comprise an ecosystem (Meffe 1993). Living resources have an evolutionary based history
that has proceeded to shape existing ecosystem structure and processes (Fowler and MacMahon 1982). Traditionally, studies have attempted to develop integrative approaches to efficiently monitor the health of our nation’s aquatic species from data collected (Heiskary et al. 1994, Obrecht et al. 1998). Fish and other aquatic communities are very sensitive to a variety of human interruptions and are very effective indicators of destructiveness (Ormerod 2003). It is also important, however, to monitor terrestrial wildlife as they are important to the ecological processes (Robinson and Bolen 1989, Stevens et al. 2005). Reptile species assemblages in an ecosystem can provide information about the environmental state of a system as well (Thompson et al. 2008). Indicator taxa, such as several bird and butterfly species and their population numbers, can give insight on biodiversity and environmental health (Larsen et al. 2009). The NPS has extensive datasets dedicated to the flora and fauna adjacent to and within each park system. Therefore, identifying the state of the living creatures within the parks is most certainly a vital component when addressing the condition of each park.

Once multiple indicators have been established, the positive or negative influence of each indicator should be determined by setting boundaries or thresholds for that indicator. Environmental assessments should always include predetermined responses to observe declines or other changes that signal responses to resource use and that allow for change that may come with new information (Mangel et al. 1996). Threshold models are increasingly important in determining the environmental consequences of anthropogenic activities and have a key role in setting management targets used by natural resource managers (Fairweather and Lester 2010). Thresholds should be established for biological systems that
would provide a baseline for a good environmental state (Mangel et al. 1996). For example, insect species can go from maintained to extremely harmful if the population growth and their natural enemies is not monitored using a threshold standard (Zhang and Swinton 2009). Using a threshold system of predetermined values reduce the complexity of analyzing processes within each park by using only those values most important to that park. Establishing thresholds will give park managers a way to assess the current health of the park as well as establish goals for future management practices.

Once indicators and thresholds have been selected, data must be managed to be easily incorporated into a model and presentations. Institutions often lack spatial and temporal definitions of their research that can be considered parallel with that of users, stakeholders, or the ecology of the resource (Kellert and Clark 1991). Many have attempted to give datasets spatial representation by utilizing a GIS or Spatial Database system. GIS models have been used most frequently in analyzing eco-hydrological processes through landscape analyses in water catchments (Aspinall and Pearson 2000). Other GIS based assessments are more specialized, with emphasis on watershed management, land use management or biotic species integrity (Aspinall and Pearson 2000, Bocco et al. 2001, Lunetta et al. 1997). GIS based modeling tools have been developed to create user friendly means of completing these types of assessments (Lunetta et al. 1997). These tools are designed to provide ease of use for resource managers who have little geospatial analysis training. Giving NPS data spatial representation in a GIS is the ideal way to present information to the public or those not familiar with the data.
In 2009, Borja reviewed studies on assessing ecological integrity in marine systems using multiple criteria indices. His goal was to determine a way to simplify current MCI’s that were deemed too complex and cumbersome. It was believed at the time that MCI’s had become too complex and included too much information. It was found that it is very important to develop MCI’s as critical tools for simplifying complex information to facilitate the incorporation of objective scientific data into management decision making. Many indices seem to add confusion since they cannot be utilized across all systems. Assessments become inconsistent across different regions because a base model (simplified model) may not be relevant from one water body to another. It must incorporate what is deemed important in that water body alone. Therefore if a simplified; base assessment is created, it must be flexible, accept multiple inputs, and allow for user edits if it is to be used on multiple systems. Usually, there is a need for consolidation of vast amounts of data for incorporation into a model. If data can be shared and simplified in NRCA approaches then managers can be provided with the simple answers they need to use NRCA information effectively and efficiently. There is a distinct need for a whole-systems approach that can be utilized by the multitude of managers across multiple systems.

Also in 2009, Roberto Llanso attempted to assess ecological integrity in the waters of the Chesapeake Bay. Using multiple biotic indices, Llanso proceeded to determine the quality of water in the bay and designate waters that may be impaired. He used combinations of key chemical stressors, such as dissolved oxygen, to couple with his benthic biological indicators. As with Borja’s study, the majority of Llanso’s data were collected directly as a result of his study and did not utilize other sources of widely available data. He found that
certain segments of the bay were “impaired” based on the biologically and chemically based MCI. Llanso established thresholds for impairment based on existing literature and applied them to his model. He found that dissolved oxygen and other chemical aspects played a large role in where the greatest degradation occurred. His designation of was often based, however, on insufficient data or data not spatially or temporally representative of the water body being accessed. His datasets contained a range of sample sizes and there was uncertainty in reference threshold values. Llanso’s study also lacked incorporation of watershed development or land use with that of the biotic and chemical aspects. This could suggest that large datasets, often not collected by the principal investigator, can become extremely useful when determining condition of such a large geographical scale. Data must represent the area of interest or be linked to the threshold of nearest relevance. If thresholds cannot be agreed upon, then MCI models should be designed to accept a variety of inputs based on the goals of management professionals.

In 2002, Rogers used several aspects of physical, chemical, and biological indices to assess impacts of contaminants and physical habitat alteration in urban streams. Rogers attempted to determine whether simple indices of chemical, physical and biological conditions could be used to separately estimate the influence of chemical and physical degradation on macroinvertebrate communities using multiple criteria. As with most studies, the data he used were solely collected for the purpose of his research. Rogers’s study took place in the Aberjona watershed located north of Boston Massachusetts, an area severely impacted by development for residential, commercial and industrial use. He found that the physical, biological and chemical factors all seem to play a role, however, investigating just
one is insufficient to determine overall environmental health of the system. Other than metals, Rogers’s study lacked a multitude of indicators for the chemical parameters and did not include human alterations to the landscape that may contribute to stream degradation. He did find, however, that comparative risk information can inform remediation and restoration efforts in these streams.

1.6. A New Approach to NRCAs

1.6.1 Summary of Objectives

The overall goal of this study was to provide a methodology for NPS natural resource managers to create an effective assessment of natural resources from existing data at the individual park level that could be applied to all other geographically relevant parks within the same system. Combining current NRCA development methodologies with a multiple criteria, approach, I developed a more comprehensive representation of natural resource condition within a single unit of the parks system. I believed that by using a more novel, whole-systems approach, I could develop an assessment that is both replicable and comparable across other geographically similar parks. The restructured data from the NPS I&M and VSMP, supplemented by publically shared data, presented the real potential of being combined with a multiple criteria approach to determine environmental condition of NPS park units.

Specifically, the goal of this project was to create a GIS based model that uses readily available data and a user-friendly interface to transform the data into a spatially represented assessment of park condition that can be utilized by park planners. Development of my model into a GIS is discussed in chapter 2.
1.6.2 General Approach to Methods

First, I characterized the natural resources of GEWA 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 identified 35 geographically relevant variables or indicators that are most likely to change in detectable ways in response to changes in resource condition. Indicators were split into six original indicator categories developed by Young and Sanzone (2002). These categories were Landscape Condition, Biotic Condition, Chemical and Physical Condition, Ecological Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes. A threshold value was identified for each indicator at which that particular indicator was considered to be “impaired” based on the literature. Each threshold value was then converted into a base scale of scores and ratings. Scores ranged from 1 to 5 and ratings from poor to good. A score of 1 received a rating of poor, a score of 2 received a rating of fair-poor, a score of 3 received a rating of fair, a score of 4 received a rating of good-fair and a score of 5 received a rating of good. Values at or above the designated threshold for each indicator were given a score of 5 and a rating of good. All indicator values below the designated threshold were represented as levels of impairment from a minimal impairment score of 4 (good-fair) to a maximum impairment score of 1 (poor).

Reliability designations were also established based on the geographic relevance of the literature used to derive each indicator threshold value. Reliability designations were given ratings of High, Medium or Low. Thresholds derived from studies conducted in the mid-Atlantic region were given reliability designations of High. Thresholds derived from
studies conducted within the eastern portion of the U.S. were given reliability designations of Medium and thresholds derived at any larger scale were given reliability designations of Low. The reliability designation was established for interpretation of NRCA results.

Next, I completed a natural resource condition assessment for GEWA. The natural resource condition assessment models were developed to work with a broad mix of ecological indicators, accept a variety of inputs for usability, and remain versatile for use on other parks deemed geographically similar. Indicators identified previously were analyzed to determine which could be supported by available data for GEWA. Of the original 35 indicators identified, data for GEWA only supported 13 indicators and 3 categories (figure 1.2). I converted all available data into coherent, easily processed, and spatially-referenced database for use incorporation into a GIS.

Finally, as part of each assessment, the assumptions and logic for findings, level of confidence, critical data gaps, and recommended approaches to further refine and quantify reference/threshold conditions over time were identified. See chapter 2 for a complete breakdown of methods.

1.6.3. Summary of Results

Eight landscape condition indicators were used based on available literature values, geographical relevance and data availability. Landscape condition, being the most data rich category, allowed for assessment at the watershed level i.e. within and adjacent to the park boundary. These landscape indicators included total percent of urban and agricultural cover, the percent of watershed with crops on a slope greater than three percent, percent stream length with agricultural cover, percent of total watershed that remained forested, percent of
watershed with fragmented forests, length of road per square kilometer of each watershed, percent of stream length within 30 meters of road, and the percent of impervious surface within the watershed.

Initial results in the Landscape Condition category suggested that percent agriculture and urban, percent forested and percent forest fragmentation all saw fair-poor (2) to poor (1) ratings. All other categories remained in good (5) condition making the overall landscape condition (overall LC) rating good-fair (4), however it was decided that each category should be investigated on a smaller sub-catchment scale in order to determine what areas contributed to these scores.

I found that overall model condition assessment scores were affected by contributions at the sub-catchment level. Three of the five sub-catchments contributed a poor rating (1) in terms of percent urban and agriculture with two contributing a good rating (5). Percent forested was affected by four of the five sub-catchments with four ratings of poor (1) and one rating of fair (3). Percent forest fragmentation was affected by three of the five sub-catchments with three ratings of poor (1), one rating of fair-poor (2) and one rating not applicable. All other categories exhibited an overall rating of Good (5) based on all five sub-catchment levels.

Data availability limited the development of the biotic condition assessment of GEWA to one indicator and to a scale of within the park boundary only. Although the literature had suggested multiple biotic indicators, the limited data available for each park would suggest using only the species presence/absence indicator. 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, species abundance was defined for several different groups. These include fish, mammals, reptiles, amphibians, birds and invertebrates. A threshold was arbitrarily developed for every group at less than 40 percent affecting biotic condition. Sufficient inventories for each group exist in the datasets relevant to GEWA, however no set threshold has been agreed upon by the scientific community. All categories exhibited a rating of Good (5) with the exception of invertebrates, which rated at Good-fair (4). The overall biologic condition (overall BC) was thus rated as Good (5).

The availability of data also limited the selection of chemical and physical characteristics indicators and results were based on water quality points collected throughout the park. Four indicators were selected after considering literature support, data availability and geographic relevance. These included pH, dissolved oxygen, temperature, and conductivity at selected water sample points within the parks boundary.

GEWA was rated in Good-fair (4) chemical condition overall (Overall CC) by both category and site. However, temperature was assigned a rating of fair-poor (2) by category with two sites receiving poor ratings (1), three sites receiving fair-poor ratings (2) and two sites receiving Good-fair ratings (4). Conductivity had two sites contributing a poor rating (1) and four sites contributing a Good rating (5) giving conductivity an overall rating of fair (3). Dissolved Oxygen contributed one poor site rating (1) in its category but rated Good-Fair (4) overall. See chapter 2 for a more complete description of results.
1.6.4. Discussion

Development of an NRCA using a multiple criteria based approach can be a very effective tool for determining universal, rapid overall assessment of natural resources conditions within an NPS park unit. Previous NRCAs have focused on one aspect of an areas condition (Olsen et al. 1999). Using a more whole-systems based approach and a multitude of vital indicators may give a more comprehensive estimation of natural resource condition.

In order to test how applicable my model is for making comparisons between geographically similar parks within the same network, I completed an NRCA using the same methodology for Thomas Stone National Historic Site (THST), another park within the Northeast Coastal Barrier Network. THST lies across the Potomac River from GEWA and shares many of the same management concerns.

THST exhibited similar landscape condition results with ratings ranging from fair-poor (2) to poor (1) in percent urban and agriculture, percent forested and percent forest fragmentation indicators. Unlike GEWA, THST received a fair-poor (2) rating for stream length within 30 meters of road. THST received an overall landscape condition (overall LC) rating of fair (3). THST was given an overall rating of fair (3) for biotic condition. THST received lower values than GEWA in terms of biotic condition due to lower scores in both the reptiles/amphibians and fish indicators. THST received a rating of good-fair (4) for chemical condition, similar to the results found in GEWA.
To test the performance of our indicators and thresholds, available indicators from existing condition assessments within the Northeastern Temperate Network (Minute Man National Historic Park and Acadia National Park) were compared to results generated for those parks based on the model developed in this study. Biotic condition was assessed for both Minute Man National Historic Park (MIMA) and Acadia National Park (ACAD) using the model developed in this study. Assessments were based on biotic indicator groups established in this study and the assessment was based on one available indicator: species presence or absence. Chemical condition comparisons were limited due to a lack of useable data in both MIMA and ACAD. pH and conductivity were both assessed using the model developed in this study for ACAD and interpretations from this studies model results were quite similar to those given in the initial report (Vaux et al. 2008). Comparisons utilizing the model developed in this study for both MIMA and ACAD are summarized in tables 1.3 and 1.4.

Comparisons between the model developed in this study and other NPS NRCA models were found to be quite difficult, as the majority of the complete NRCA studies take a very specific approach when determining indicators. Previous NPS NRCA studies (James-Pirri 2009, McElroy et al. 2009, Vaux et al. 2008) focused on specific indicators of park condition or vital signs set forth by the VSMP (table 1.1). This may be due to the fact that the focus of previous studies was not based on applicability across all parks within the network. The model described in this study provides a “whole-systems” approach to the VSMP methodology by expanding on the level 1 categories for indicator selection developed by the VSMP (table 1.1). Other NPS NRCA models (Mahan 2004, Foley 2005, Mahan 2006, James-Pirri 2009)
simply characterize or summarize park resources and determine trends among park resources based on historical data. The model in this study attempts to determine the current status of park resources based on literature supported thresholds. The model described in this study also attempts to interpret that status for management purposes (table 1.2). This could suggest that this model could become a baseline for assessment across parks within the same geographic system. With little adjustment, the model developed in this study could also be incorporated across a larger scale because of the broad reach of indicators developed. My 35 original indicators can be applied to other systems within the NPS as new, geographically relevant thresholds are decided upon for those systems. Thus, my model can be considered as a baseline for assessment and comparison across all parks within the NPS where data are readily available and thresholds have been defined.

Indicators developed for my model closely resemble the vital signs level 1 categories established by the NPS for parks within the Northeast Coastal Barrier Network in (table 1.1). The Landscape condition, Biotic condition and Chemical condition categories and their associated indicators can be related to the landscape, biologic integrity and water categories in level 1 of the NPS VSMP for the Northeast Coastal Barrier Network. Thus, my model is a good representation of natural resource condition for those categories where data was available. The data utilized for my study are also the same datasets utilized by the VSMP and can be found in the Natural Resource Information Portal (NRIP) of the NPS. These datasets support both the biologic and chemical conditions of my model and the VSMP based assessments. The only data not supported in the NRIP utilized for my study was data used to assess the Landscape condition indicators for which landscape measures have yet to be
established (Stevens et al. 2005). My model also provides threshold values by which to quantify results and interpret each of those categories; which had not currently been done in the VSMP and other associated NPS NRCAs (Mahan 2004, Foley 2005, Mahan 2006).

Results derived from the current models, however, are not a concrete representation of park condition, but are also to be considered an indicator of data gaps and a need for more data in certain categories. For example, a rating of poor (1) in any category may not represent actual condition for that category, but rather that this category is lacking sufficient data by which to make an assessment. An area may not be in poor biologic condition because several species are absent from an inventory list, but rather that there has been no inventory taken for that particular species. This makes the model useful as both an indicator of park condition in data rich categories, or as an indicator of data gaps for which managers should place more emphasis. Park officials can therefore focus inventoring efforts in categories with insufficient representation and make management decisions in data rich areas deemed to be in poor condition.

Reliability designations also may play a role in suggesting data gaps and a need for more information. For example, although the entirety of biotic categories rated from Good (5) to Good-fair (4), the reliability designation for this indicator is low. This suggests a need for better defined threshold values for each category. As better data becomes available, better thresholds can be established and therefore improve the utility of my model.

On the contrary, the reliability designation could suggest areas of severe concern where data amounts are adequate and threshold values are substantial. In the percent forest fragmentation, GEWA was rated poor (1) and the reliability designation for this indicator
was high. This could suggest to park managers that there should be concern in this category of their park unit. Park managers can then view the park at the sub-catchment level and determine how best to address the problem. In terms of GEWA, similar concern should be taken with landscape condition indicators; percent forested and percent urban and agriculture.

In conclusion, my model combines developed indicators from the VSMP, a multiple criteria approach, and a more novel methodology for assessment in order to provide park managers with a way to assess, but most importantly, interpret results to make adequate management decisions. Park managers can use NRCA category (landscape, biotic, and chemical) results, coupled with data availability and reliability designations to determine appropriate actions (table 1.5). If scores are low for a particular category, reliability designation and data availability should determine what actions should be taken. When scores are low and data availability is low, a manager should consider incorporation of inventorying and monitoring for that particular category. If scores are low, data availability is high, and reliability designation is low, then the implication is that threshold values should be investigated and management decisions be made accordingly. If indicator scores are low, data availability is high and reliability is high, then park managers should incorporate appropriate management techniques and run my model again as new data becomes available to see if model results have improved for the indicator in question.

I have provided park managers with the tools necessary to assess and interpret natural resource condition within an individual park unit as well as make comparisons across other geographically similar parks. My NRCA model combined the physical, biological and chemical aspects within and adjacent to the park to provide an overall indication of the
natural resources within that park. The NCRA allows park planners to investigate the current state of the park, prioritize management activities and also model changes that could occur in the future.
1.7. Literature Cited


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Rogers, C. 2002. "Use of physical, chemical, and biological indices to assess impacts of contaminants and physical habitat alteration in urban streams". Environmental toxicology and chemistry (0730-7268), 21 (6), pp. 1156.


Tucker, D.F. 2006. Presentation of Vital Sign Monitoring Program to NPS.


Table 1.1 Table of vital signs development for the Northeast Coastal and Barrier Island Network (NECBN) developed in Stevens et al. (2005). Indicators for GEWA highlighted in red. Current data status for vital sign is specified within the table.

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</table>

*+* High priority vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs (check mark indicates ones being developed by the Network).

*+* High priority vital signs that are monitored by a network, park, another NPS program, or by another Federal or state agency using existing funding. The network will collaborate with those other monitoring efforts.

*+* High priority vital signs for which monitoring will likely be done in the future, but which cannot currently be implemented because of limited staff and funding.

*+* Vital sign does not apply to park, or for which there are no foreseeable plans to conduct monitoring.

(Note: the shaded areas indicate those vital signs that the network is taking the lead on protocol development)
Table 1.2 Description of study types completed in NPS Natural Resources Condition Assessments developed in Stevens et al. (2005)

<table>
<thead>
<tr>
<th>Level of Analysis</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Data Summarization/Characterization</strong></td>
<td>Summarization is the calculation of basic statistics of interest from the monitoring data. It will encompass measured and derived variables specified in all monitoring protocols. Data summarization and characterization will form the basis of more comprehensive analyses, and for communicating results in both graphical and tabular formats.</td>
<td>The program lead for each monitoring protocol, working with the data management staff, will produce routine data summaries (See NCESN Data Management Plan Chapt 8). Parameters and procedures are specified in each protocol data analysis SOP.</td>
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| **Status Determination** | Analysis and interpretation of the ecological status (point in time) of a vital sign to address the following types of questions:  
- How do observed values for a vital sign compare with historical levels?  
- Do observed values exceed a regulatory standard, known or hypothesized ecological threshold? What is the level of confidence that the exceedance has actually occurred?  
- What is the spatial distribution (within park, network, ecoregion) of observed values for a given point in time? Do these patterns suggest directional relationships with other ecological factors?  
  Status determination will involve both expert interpretation of the basic statistics and statistical analysis to address these monitoring questions. Assumptions about the target population and the level of confidence in the estimates will be ascertained during the analysis. | The program lead for each monitoring protocol is the lead analyst for status determination, although the Network Coordinator, cooperators, partners, interns, or other network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts will support status determination. |
| **Trends Evaluation** | Evaluations of trends in vital signs will address:  
- Is there directional change in a vital sign over the period of measurement?  
- What is the rate of change (sudden vs. gradual), and how does this pattern compare with trends over broader spatial scales and known ecological relationships?  
- What is the level of confidence that an actual change (or lack thereof) has occurred?  
  Analysis of trends will employ parametric, nonparametric, or mixed models based on assumptions that can or cannot be reasonably made about the target population. Whose appropriate, exogenous variables (natural, random phenomena that may influence the response variable) will be accounted for in the analysis. | The program lead for each monitoring protocol is the lead analyst for trend evaluation, although the Network Coordinator, cooperators, partners, interns, or other network staff may conduct analyses and assist with interpreting results. Comparison with relevant long-term experimental results will aid interpretation. |
| **Synthesis and Modeling** | Examination of patterns across vital signs and ecological factors to gain broad insights on ecosystem processes and integrity. Analyses may include:  
- Qualitative and quantitative comparisons of vital signs with known or hypothesized relationships.  
- Data exploration and confirmation (e.g., correlation, ordination, classification, multiple regression, structural equation modeling).  
- Development of predictive models. Synthetic analysis has great potential to explain ecological relationships in the nonexperimental context of vital sign monitoring and will require close interaction with academic and agency researchers. | The Network Coordinator is the lead analyst for data synthesis and modeling, in collaboration with each project leader. Cooperators, partners, interns, or other network staff may conduct analyses and assist with interpreting results. Integration with researchers and experimental results is critical. |
Table 1.3. Comparison of results (interpretation) for Minute Man Historic Park utilizing MIMA data and NRCA model.

<table>
<thead>
<tr>
<th>Biotic Condition</th>
<th>MIMA Spec P/A</th>
<th>Value (%)</th>
<th>James-Pirri 2009</th>
<th>Hartis et al.</th>
<th>Threshold Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>39 of 110</td>
<td>35</td>
<td>Caution</td>
<td>Fair</td>
<td>Impaired</td>
</tr>
<tr>
<td>Rept/Amph</td>
<td>21 of 25</td>
<td>84</td>
<td>Caution</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Mammals</td>
<td>32 of 44</td>
<td>72</td>
<td>Unknown</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Fish</td>
<td>10 of 22</td>
<td>45</td>
<td>Sig. Concern</td>
<td>Good-Fair</td>
<td>Impaired</td>
</tr>
<tr>
<td>Invert.</td>
<td>No Data</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Table 1.4. Comparison of results (interpretation) for Acadia National Park utilizing ACAD data and NRCA model.

<table>
<thead>
<tr>
<th>Biotic Condition</th>
<th>ACAD Spec P/A</th>
<th>Value (%)</th>
<th>Vaux et al. 2008</th>
<th>Hartis et al.</th>
<th>Threshold Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>230 of 364</td>
<td>63</td>
<td>Unknown</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Rept/Amph</td>
<td>23 of 36</td>
<td>64</td>
<td>Unknown</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Mammals</td>
<td>43 of 51</td>
<td>84</td>
<td>Unknown</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Fish</td>
<td>38 of 69</td>
<td>55</td>
<td>Caution</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Invert.</td>
<td>No Data</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical Condition</th>
<th>ACAD (Park average)</th>
<th>Vaux et al.</th>
<th>Hartis et al.</th>
<th>Threshold Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Cond.</td>
<td>1000 Mg/L</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>
Table 1.5. Management implication based on model scores, rating, data availability and reliability designation

<table>
<thead>
<tr>
<th>Category/Indicator Condition Score</th>
<th>Data Availability</th>
<th>Reliability Designation</th>
<th>Management Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good (5)</td>
<td>High</td>
<td>High</td>
<td>No management action should be taken/ assess again after new data becomes available</td>
</tr>
<tr>
<td>Good (5)</td>
<td>High</td>
<td>Low</td>
<td>No management action should be taken/ assess again as better threshold becomes available</td>
</tr>
<tr>
<td>Good (5)</td>
<td>Low</td>
<td>High</td>
<td>No management action should be taken/ Increase I&amp;M</td>
</tr>
<tr>
<td>Good (5)</td>
<td>Low</td>
<td>Low</td>
<td>No management action should be taken/ Increase I&amp;M and assess as new thresholds become available</td>
</tr>
<tr>
<td>Good-Fair to Poor (4,3,2,1)</td>
<td>High</td>
<td>High</td>
<td>Management action required, urgency determined by level of impairment</td>
</tr>
<tr>
<td>Good-Fair to Poor (4,3,2,1)</td>
<td>High</td>
<td>Low</td>
<td>Management action required, urgency determined by level of impairment, develop adequate threshold</td>
</tr>
<tr>
<td>Good-Fair to Poor (4,3,2,1)</td>
<td>Low</td>
<td>High</td>
<td>Increase I&amp;M to improve data collection, re-run model and determine management strategy, urgency determined by level of impairment</td>
</tr>
<tr>
<td>Good-Fair to Poor (4,3,2,1)</td>
<td>Low</td>
<td>Low</td>
<td>Increase I&amp;M to improve data collection, develop adequate threshold, re-run model and determine management strategy, urgency determined by level of impairment</td>
</tr>
</tbody>
</table>
Figure 1.1. Location of NECBN within the NPS system.
Figure 1.2. Indicator use for GEWA compared to total indicators available.
2. Development of a Multiple Criteria-based Assessment for Identifying Natural Resource Conditions within the National Parks System

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Abstract. Data collection, inventorying, and monitoring have become important for a multitude of agencies, determining effective protection and management techniques in natural resource conservation and assessments. National Park Service (NPS) managers across the country are frequently confronted with increasingly complex and challenging issues in natural resource assessment, management and monitoring. These issues require a broad understanding of the status and trends of each park's natural resources as a basis for making decisions, working with other agencies, and communicating with the public to protect park natural systems and native species. In this study, our objective was to create a GIS-based, user-friendly, and spatially-specific model from existing and readily available data that will be useful to NPS natural resource managers as an effective assessment tool of natural resources at the individual park level. We completed an assessment of George Washington Birthplace National Monument (GEWA), a single park unit within the NPS system. We used established literature values and a multiple criteria approach to determine relevant indicators at entire park and site specific sub-watershed levels that were indicative of park natural resources condition. Natural resources indicators were organized into three main categories: Landscape Condition, Biotic Condition and Chemical Condition. Model indicator results showed the majority of the GEWA condition assessments to be in an overall good condition. Applicability of the model was tested by running the assessment on nearby Thomas Stone National Historic Site (THST). Landscape condition status was found to vary by sub-watershed. Although data availability proved to be a major concern, we found our methods to be quite effective in establishing data requirements necessary for comprehensive assessments, as well as establishing the required data collection formats that will allow for continued development and use of these assessment models.

Keywords: Multiple Criteria Indices, Geographic Information Systems, Natural Resource Condition Assessment, National Parks Service, Indicator
2.1. Introduction

Today, data collection, inventoring, and monitoring are important in determining effective protection and management techniques in natural resource conservation and assessments. Each year, state and federal governments fund a number of monitoring programs to measure the status and trends of ecological and natural resources on public lands (Olsen et al. 1999). Although the desired outcome is the same, each program has a unique design and focus with different objectives (Olsen et al. 1999). Basic rules and principles continue to emerge for data collection and management; however, there are few realistic methods for comprehensive ecosystem management in relation to the plethora of data available (Grumbine 1994). Current monitoring programs rely heavily on data mining and publically shared data. The amount of publically shared data has become increasingly available through data transfer and internet downloads (Hey and Trefethen 2003). Data managers and scientists must now contend with how to utilize not only historically-collected agency data, but also available public data that may provide a more comprehensive coverage for assessing local resources (Hey & Trefethen 2003). Available data, when collected at an appropriate scale and continuity, could potentially expand support of management programs and allow for effective management decisions.

The National Parks Service (NPS) manages approximately 84.4 million acres of federal and private land across the nation (Moffet and Carson 2006). Increasingly complex and challenging issues confronting National Park managers require a broad
understanding of the status and trends of each park's natural resources as a basis for making
decisions, working with other agencies, and communicating with the public to protect park
natural systems and native species.

Although the NPS has developed several programs to inventory and manage data on
its parks natural resources, there is still a lack of connection between the extensive amount of
data collected and actual analyses or application of those data. Traditionally, the National
Park Service networks have only been involved in the development of Natural Resource
Condition Assessments (NRCA’s) in an advisory and/or data support capacity (Personal
Comm. Kozlowski 2010). The data collected by the NPS is intended for creating
assessments and synthesis at the individual park level. However, the majority of the data
remains in multiple data formats or data archives and is not easily restructured for analyses
and modeling. Most of the NPS long term monitoring projects are still very young (3-5 years
of field data). Analysis tools have yet to be developed that effectively utilizes these data in
an updateable and on-going method to provide continued evaluations of natural resources
within each park (Personal Comm. Kozlowski 2010). Because data and monitoring programs
are so new, a very small fraction of the data used in early NRCA’s originates from NPS
databases (Personal Comm, Kozlowski 2010). As a direct result of this, vast amounts of
publically available data have the potential to supplement existing park data in current
NRCA’s.
In 2004, the NPS Water Resources Division received funding to conduct natural resource/watershed condition assessments at national parks throughout the country (Personal Comm. J. Kerish 2008). These landscape-scale assessments were intended to provide park planners and resource managers with detailed information for natural resource management and conservation. The assessments relied primarily on existing datasets consisting of biotic and abiotic natural resource data available from a compilation of local, state, and federal agencies and organizations (Personal Comm. J. Kerich 2008). Several state assessments were completed between 2004 and 2008, each varying in scope of study, data availability, data assessment and model design, assessment results and management implications. The challenge still remained that there were no widely accepted definitions, approaches, or methods for conducting structured, replicable assessments of park resources, and a wide variety of methods are available depending upon such things as the assessment purpose or use and scale (Personal Comm. J. Kerish 2008). The lack of uniformity among assessments suggests they would be of limited benefit to the NPS, on a continuing base, as the models failed to provide a ubiquitous approach that was easily repeatable and based on standardized datasets.

The construction of a universal model for the assessment of ecosystem status can be quite a challenge. It is generally time consuming, costly, and impossible to assess and monitor every environmental variable that contributes to the system as a whole (Nelson et al. 2003, Nelson et al. 2006). However, a model that incorporates a multitude of values, typically on a larger geographic scale, rather than focusing on local impairments provides a way of developing a quick referencing system that can establish baseline conditions (Mangel
et al. 1996, Nelson et al. 2006). This can be accomplished by identifying a representative subset of species and ecosystem variables that are most likely to change in detectable ways in response to change in resource condition (Mangel et al. 1996).

Multiple criteria indices (MCIs) have recently evolved as a prominent tool for monitoring ecosystem health that has commonly been used as indices of biotic integrity for stream health (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 based on a numerical score. These estimations are usually based on an additive or weighted system and confidence factors derived from the most current and best available data (Rogers 2002).

This study provides a methodology for NPS natural resource managers to create an effective assessment of natural resources from existing data at the individual park level. Specifically, the goal of this study was to create a GIS-based model that used readily available data to develop a spatially-specific assessment of park condition that will be useful to park planners within the GEWA park unit. The development of this NRCA was intended to provide park planners with tools to investigate the current ecological state of the park, prioritize management activities, assess data and inventory needs, and model changes that could occur in the future.
2.2. Materials and Methods

2.2.1. Study Area

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 (Blank et al. 2007).

2.2.2. General Approach

We characterized the natural resources of GEWA based on a literature review and existing data. This characterization emphasized bio-geographic and physical settings relevant to the park. Available inventoring and monitoring data from NPS archives were converted into a spatially-referenced database for use in a GIS. Possible geographically-relevant indicators of park condition were identified from established literature, as well as from professional knowledge of park researchers, for use in scoring.
or rating our natural resource condition assessment model for GEWA. The natural resource condition assessment model was designed to work with a broad mix of ecological indicators, accept a variety of inputs for usability, and remain versatile for use on other park systems. This NRCA combined the physical, biological and chemical aspects within and adjacent to the park to provide an overall indication of the natural resources within the park.

2.2.3. Database Development

Digitally archived data, compiled from the synthesis of natural resource information (Blank et al. 2007) and additional NPS data required for this study were used 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 Chesapeake Bay Program.

Existing NPS data were combined with data available from additional local, state, federal, and public agencies within the Chesapeake Bay/Potomac River region. All data were reviewed to determine completeness and suitability for development of ecological/condition indicators within GEWA and adjacent regions.

For data to be applicable to future model development, the NPS and publically available data were combined into a spatially compliant database. This conversion required tabular inventory data to be connected (georeferenced) to spatial reference sample point locations throughout the GEWA study site. Within the database, each point was associated with data from one or several attributes or external tables, establishing a one-to-one or one-to-many
attribute relationship between linked attributes. The Microsoft Access software package (Microsoft Office (Office 12.0 Access 2007) was used to link related tables and extract usable data. The data were originally collected in various formats and levels of organization. Assessment data was then transformed along with geographic coordinates, into tables and saved in a format compatible with ESRI’s ArcGIS software (ESRI, version 9.3 2008). This process allowed for interoperability of all data within the database.

All data connected using Microsoft Access’ query design functionality were then available as spatial attribute tables. This process was completed for all biotic and chemical indicators as these data were initially collected in incompatible data structures. Additionally, this process allowed fields to be systematically sorted and analyzed, with each possessing the potential to geographically represent several data observations.

When extremely large datasets, or geodatabases were used, many problems with communication between each software type and scripting language were experienced. For example, when extensive geodatabases with linked tables were used, instances of replicated data and incompatible data types were experienced and communication errors between software packages were commonplace. Relationships between linked tables were used to create simplified databases. Input of simplified database tables into the NRCA eliminated problems with communication between software packages and led to fewer problems with replicated data. A simple database or .dbf extension format was used for easy incorporation of data into the NRCA.
2.2.4. Metric Development

Values from scientific literature and expert opinion were used to establish model indicators (table 2.1), and associated threshold values were developed for each indicator (table 2.2). 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. Threshold values were then established for each indicator and used for comparative calculations. Where possible, reference condition values were selected to represent values relevant to the study area and for threshold selection. Indicators without geographically relevant reference values were subsequently removed since inclusion of these values would not be relevant to the assessment. For example, many indicators were suggested by the literature for inclusion into the assessment but lacked any measured value for the specific study area. Each reference value was converted to a base scale, ranging from 1-5 of overall condition. Low impact conditions, that received a score of 5 (i.e. Good Condition), served as a reference value to which model scores were compared. A score of 1 represented a high impact or Poor Condition. Intermediate scale values included Fair-Poor (2), Fair (3), Good-Fair (4). Table 1 presents the model indicators, threshold values adapted from the literature, and geographic relevance of each threshold value for the Landscape Condition, Biotic Condition, Chemical and Physical Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes assessment categories. The NRCA used the original USGS 14-digit HUC, the USGS NHD, and high resolution LiDAR-DEMs to delineate sub-catchments surrounding or within the park boundary that were used for assessing categories affected by processes within the
watersheds (Figure 3). Land use/Land cover data were used to extract land cover types within and adjacent to the park (Figure 4). Other categories were assessed by data collected at specific points. Only indicators that could be supported by the data were used for assessment of GEWA.

2.2.5. Model Development

Developing a spatially-specific model required communication between several software packages including Microsoft Access, Python (PythonWin, Python 2.5.2 2008), Microsoft’s Visual Basic for Applications (Microsoft, Visual Basic 6.0 2008), and ESRI’s ArcMAP, as well as the scripting languages associated with each package. Python, a dynamic object-oriented scripting language used for software customization, was used as the primary scripting language to transfer data from a Microsoft database table format to an ArcMAP interface. Python programming language incorporates spatial analysis and geoprocessing functionality that is recognized by ESRI’s ArcGIS software package and provides the ability to incorporate commands or arguments into script format for repeatability and further customization.

Python scripts were incorporated into ArcMAP with the use of Microsoft’s Visual Basic for Applications (VBA), a software package that enables developers to create user defined functions and automate processes in ArcGIS. VBA was used to develop a customized interface toolbar to provide a user-friendly method of accessing available data for assessment of each ecological indicator category based on derived indicators and threshold values.
2.3. Results

2.3.1. Database Results

Data obtained from NPS data archives, public data, literature values, and expert opinion were converted into a spatially-referenced database for use in a GIS. The development of this database standardized data that was obtained in multiple data formats, external data tables, and varying levels of completeness. This Process also made the resulting database available for metric and model development.

2.3.2. Metric Results

The NRCA was initially comprised of six categories (table 1), however 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. A review of existing literature and data mining allowed 13 of the original 35 indicators to be used for development of the GEWA assessment (8 Landscape Condition, 1 Biotic Condition, and 4 Chemical Condition). Score divisions were decided upon based on suggested literature division and professional opinion (table 2.1). A reliability designation was also included to suggest reliability of the thresholds utilized in this study. The reliability designation is based on geographic relevance of the threshold value source. The indicators, along with threshold values, score divisions and reliability designations are summarized in table 2.
2.3.2.1. Metrics Results for Landscape Condition

Eight landscape condition indicators were used based on available literature values, geographical relevance and data availability. These landscape indicators are; total percent of urban and agricultural cover, the percent of watershed with crops on a slope greater than three percent, percent stream length with agricultural cover, percent of total watershed that remained forested, percent of watershed with fragmented forests, length of road per square kilometer of each watershed, percent of stream length within 30 meters of road, and the percent of impervious surface within the watershed (table 2.2.).

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 reportedly degrades environmental integrity and impact the functionality of the watershed (Riitters et al. 1997, Jones et al. 1997). The geographic relevance of this threshold data to GEWA was assumed to be highly relevant (Reliability Designation = High) because values were developed in the mid-Atlantic region of the United States.

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 to GEWA was assumed to be highly relevant (Reliability Designation = High) because the values were developed in the mid-Atlantic region of the United States.
The proportion of stream length with agricultural cover has been reported to affect watershed condition after reaching a threshold value greater than 30 percent (Jones et al. 1997, O’Neill et al. 1998, Riitters et al. 1997, Hunsaker et al. 1992). GEWA 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 to GEWA was assumed to be highly relevant (Reliability Designation = High) because values were developed in a centralized area of the mid-Atlantic region of the United States.

Little is known of the overall forest habitat and health in GEWA due to the fact that inventories have not yet been completed, but the proportion of the watershed that is forested has been reported to have an effect on overall watershed condition. Studies have reported that when 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 streams and forested areas were 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 were found to be fairly reliable (Reliability Designation = Medium) because the values were developed in the northeastern region of the United States.

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, shelter and to breed as well as reducing water quality (Riitters 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 to GEWA was found to be highly relevant (Reliability Designation = High) because values were developed in the eastern region of the United States.

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/km² of roadway (Chen and Roberts 2008). The geographic relevance of this threshold to GEWA was found to be fairly reliable (Reliability Designation = Medium) because the values were developed in the south-eastern region of the United States.

Proximity to a stream is very important when considering road placement. The likelihood and extent of any impact on water quality depend not only on erosion or runoff, but also on 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 to GEWA was found to be highly relevant (Reliability Designation = High) because the values were developed in the eastern region of the United States.

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 to GEWA was found to be highly relevant (Reliability Designation = High) because the values were developed in the eastern region of the United States.

2.3.2.2. Metrics Results for Biotic Condition

Data availability limited development of the biotic condition assessment of GEWA to one indicator. Although the literature suggested multiple biotic indicators, the limited data available for each park permitted use of only the species presence/absence indicator.

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 GEWA, species presence/absence was defined for fish, mammals, reptiles, amphibians, birds and invertebrates. For each group, a threshold value of 40% was chosen as an indicator of biotic condition. Sufficient inventories for each group exist in the datasets, however no specific threshold has been agreed upon by the scientific community. Since there is a lack of literature values for comparison, the reliability designation of this indicator threshold was poor (Reliability Designation = Low).

2.3.2.3. Metric Results for Chemical Condition

Data availability limited the selection of chemical and physical characteristics indicators. After considering literature, data availability and geographic relevance four indicators were selected. These were pH, dissolved oxygen, temperature, and conductivity all measured at selected water sample points within the parks boundary (Figure 2.6).
The pH thresholds were established for freshwater, 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 fair (Reliability Designation = Medium) because pH fluctuations occur seasonally and values can vary outside the bounds of 6.0 – 9.0 pH threshold and still be considered normal.

Dissolved oxygen is considered to deteriorate the chemical condition of the watershed when it reaches certain threshold levels (EPA 2007). In freshwater, the 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 (EPA 2007). For this study, 6.0 mg/L was used because differentiation between freshwater, brackish water, and saltwater was not possible. The reliability designation of this threshold was fair (Reliability Designation = Medium) since dissolved oxygen levels fluctuate seasonally and with water depth and temperature. These fluctuations may occur intermittently or temporarily and require a long-term trend analysis.

Water temperature in aquatic systems plays an important role in several biological processes. If temperature levels fluctuate, biological processes can become impaired or cease to function all together. In GEWA, the temperature range was based on normal temperature ranges for the eastern coast of the United States. These values were taken directly from the 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 (EPA 2007). The reliability of this threshold was good (Reliability Designation = High).

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

2.3.3. Model Results

2.3.3.1. Assessment of Landscape Condition

Initial assessment in the Landscape Condition category suggested that percent agriculture and urban, percent forested, and percent forest fragmentation all had fair-poor (2) to poor (1) ratings. All other categories were in good (5) condition making the overall landscape condition (overall LC) rating good-fair (4). However it was decided that each category should be investigated on a smaller sub-catchment scale in order to determine if there were areas that contributed to low scores. The eight Landscape condition were reassessed based on all sub-catchment watersheds that either intersect or are entirely within the park boundary (table 2.2) and results were assigned based on each sub-catchment.
The Landscape condition assessment of the NRCA model assigned index scores and ratings, by sub-catchment, for the eight remaining landscape condition indicators based on the selected threshold/reference values for each (table 2.2). An overall final score for each indicator was calculated by averaging all sub-catchment areas and expressing the final score on a 1-5 scale (table 2.3).

We found that model condition assessment scores were affected by contributions at the sub-catchment level. Three of the five sub-catchments each had a poor rating (1) for percent urban and agriculture and two had a good rating (5). Overall percent forested was affected by four of the five sub-catchments with four ratings of poor (1) and one rating of fair (3). Percent forest fragmentation was affected by three of the five sub-catchments with three ratings of poor (1), one with a rating of fair-poor (2) and one with no rating. All other categories exhibited an overall rating of Good (5) based on all five sub-catchment levels.

2.3.3.2. Assessment of Biotic Condition

Table 2.4 presents the results of the biotic condition assessment developed for GEWA. The percent value indicates the park species inventory 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 from park species inventories. 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. All categories had a rating of Good (5) with the exception of invertebrates, that rated at Good-fair (4). The overall biologic condition (overall BC) was thus rated as Good (5). A map output of biologic condition was also created (figure 2.5).
2.3.3.3. Assessment of Chemical Condition

Table 2.5 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 (figure 6) and by each category. A map output of chemical condition rating by indicator is created for each indicator in the model (see figure 2.6).

GEWA was rated in Good-fair (4) chemical condition overall (Overall CC) by both category and site. However, temperature was rated fair-poor (2) by category with two sites receiving poor ratings (1), three sites receiving fair-poor ratings (2) and two sites receiving Good-fair ratings (4). Conductivity had two sites with a poor rating (1) and four sites with a Good rating (5) giving conductivity an overall rating of fair (3). Dissolved Oxygen had one poor site rating (1) in its category but rated Good-Fair (4) overall. Site specific and category specific results can be found in table 2.5.

2.4. Discussion

A GIS-based natural resource condition assessment can be created using a wide variety of data if certain considerations are taken into account. Initial data structure, data gaps, and interpretation all pose potential problems but when considered beforehand, can result in a useful management and planning tool. When data are stored and managed properly, they can easily be incorporated into a model, especially if that model is capable of
accepting a variety of inputs. Our study showed that using simplified sub-sets of extensive datasets linked by common attributes, had the most potential for geoprocessing when a variety of different software packages are required for analysis, especially when this software has to communicate seamlessly from one scripting language to another. Using these smaller subsets tended to reduce data redundancies and other potential errors. The VBA-developed custom-GIS interface allowed users to input simple data tables into ArcMAP and process each based on model values with less than three button clicks. The combination of these software packages creates a user-friendly and versatile NRCA that allowed for complex assessment of each park with little formal training in computer science. Thus, Park managers can complete traditionally complex and time consuming assessments with ease.

Our study showed using multiple criteria indices also allowed the development of a very effective tool for determining a universal, rapid overall assessment of natural resource conditions within GEWA. Previous NRCAs have traditionally focused on one aspect of an area’s condition (Olsen et al. 1999). These assessments are quite frequently administered independently of other assessments in the same general area, therefore the results of each assessment may not contribute to an overall knowledge of the area of concern. When multiple indicators are used, a more comprehensive estimation of environmental integrity can be decided upon, and appropriate management decisions can be applied (Borja 2009, Llanso 2009, Rogers 2002).

To determine the applicability of our model to other parks within the U.S. National Parks System, we completed an assessment of Thomas Stone National Historic Site (THST) using our NRCA model. The THST park is comprised of 328 acres and is located across the
Potomac River from GEWA (see figure 1) and about 25 miles south of Washington D.C. in Charles County, Maryland. The park shares many physiographic characteristics with GEWA and, like GEWA, is fairly typical of the Middle Atlantic Coastal Plain with approximately 180 acres of forest, 110 acres of open fields, 5 acres of riparian habitat, and 2 acres of maintained lawns. Numerous observations of fauna and flora, especially beavers and avian species, have been recorded in the park but systematic inventories have not been conducted.

We completed an assessment of THST using three categories (Landscape, Biologic, and Chemical) and their associated indicators. The results for THST, like GEWA, were based on available data and performed similarly to the model developed with GEWA (See tables 2.6, 2.7, and 2.8).

THST exhibited similar landscape condition results with ratings ranging from fair-poor (2) to poor (1) in percent urban and agriculture, percent forested and percent forest fragmentation indicators. Unlike GEWA, THST received a fair-poor (2) rating for stream length within 30 meters of road. THST received an overall landscape condition (overall LC) rating of fair (3) and was given an overall rating of fair (3) for biotic condition. THST received lower values than GEWA for biotic condition with lower scores in both the reptiles/amphibians and fish indicators. THST received a rating of good-fair (4) for chemical condition, similar to the results found in GEWA.

Results derived from the current models, are not a definitive representation of park condition, but can be an indicator of data gaps. For example, a rating of poor (1) in any category may not represent the actual condition for that category, but may indicate that this category is lacking sufficient data to make an assessment. An area may not be in poor
biologic condition because of the absence of species, but rather that there has been no inventory taken for that particular species. This makes the model useful as both an indicator of park condition in data rich categories and as an indicator of data gaps that managers should place more emphasis on. Park officials can focus inventorying efforts in categories with insufficient representation and make management decisions in data rich areas deemed to be in poor condition.

Reliability designations may play a role in suggesting data gaps and a need for more information. For example, although all of the biotic categories rated from Good (5) to Good-fair (4), the reliability designation for this indicator is low. Data availability was considered to be high for biotic condition. This suggests a need for better defined threshold values for each category. As better data becomes available, better thresholds can be established and therefore improve the utility of our model.

The reliability designation can also suggest areas of severe concern where data amounts are adequate and threshold values are substantial. In the percent forest fragmentation, GEWA was rated poor (1) and the reliability designation for this indicator was high. Park managers can then view the park at the sub-catchment level and determine how best to address the problem. In terms of GEWA, similar concern should be taken with landscape condition indicators; percent forested and percent urban and agriculture.

Data availability was the largest limitation in development of these models. The chemical assessment for GEWA was derived from the multiple sample sites. Unfortunately, the scores are based on one point in time and are not accurate representations of overall
levels for each parameter. However, the data can be compared to future data taken during the same time frame.

Previous studies support over 35 indicators (table 1) that could be used for the assessment of natural resource conditions. However, the lack of data led to the elimination of over 22 of originally proposed indicators and attributes from the GEWA assessment models. All 35 indicators were considered for the current GEWA models but were removed due to a lack of data. More data would provide a more comprehensive assessment of park natural resources and improve modeling scenarios. As additional data become available new indicators can be added into the model and these indicators can be easily included in future assessments of other parks. The 35 indicators included in this study should provide a framework for future assessments on other park systems.

There were also issues with data compatibility and data structure that made incorporating certain datasets into the model difficult. For example, species data should be in a standardized format that would allow easier incorporation into our model. It is very important that data be easily accessed and utilized for efficient use in a model with little manipulation. When data must be manipulated to be fit into a model, human error can be introduced. Uniformity in behavior, policies and needs must be considered before any data are incorporated into an NRCA (RIN 2008). Data are may become unusable if they are not expertly managed, so careful data management practices and inventory protocol should be followed before any assessment is attempted (RIN 2008).
2.5. Conclusions

Our objective was to use existing data to develop a model that assessed current natural resource conditions within the U.S. NPS GEWA Historical Site. We found the landscape condition of the park to be most threatened by forest fragmentation. The integrity of the park’s landscape condition was affected by having a low percentage of the park forested and a large amount of agriculture and urbanization occurring within and around the park. We found the biotic condition of the park to be in overall good condition with only minor concern for invertebrates. Chemical condition of GEWA is in good to fair condition based on the results of our study.

The databases developed for this study establish a baseline for continued data collection in and around the park boundaries. Data stored in formats used in our NRCA will allow future data to be incorporated by park managers. If a common data format or template is used across all parks, then utilization will become much easier and more efficient. 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, and to prioritize management efforts. The user-friendly interface associated with the model will allow managers with little programming experience to assess data relevant to the park. The ability to change threshold values within the model makes the model useful in prediction and goal planning by park managers. The model can therefore be used not only as an assessment of current trends but also as a planning tool for reaching condition goals within the park.
In response to the overwhelming amount of data today, data managers and scientists appear to be increasingly concerned by how to achieve more effective management and sharing of data (Hey & Trefethen 2003). In our study, publically shared data have proven to be a great resource when developing NRCA’s, and show potential for incorporation into other management programs. Public data may be available in great amount but data management practices must be applied long before any analysis is attempted (RIN 2008). If the process of data sharing is to become more effective and useful, much more consideration needs to be given to making datasets usable by providing the information and possibly software tools necessary for others to re-use the data (Borgman 2007), as is the case with the NPS NRCA’s.
2.6. Literature Cited


Lathrop et al. 2007. Consequences of land use change in the New York–New Jersey Highlands, USA: Landscape indicators of forest and watershed integrity. Landscape and Urban Planning. 79(2), pp. 150-159

Mangel et al. 1996. Principles for the Conservation of Wild Living Resources. Author(s): Source: Ecological Applications. 6(2), pp. 338-362


Rogers et al. 2002. Use of physical, chemical and biological indices to assess impacts of contaminants and physical habitat alteration in urban streams. Env. Tox. And Chem. 21(6), pp. 1156-1167


<table>
<thead>
<tr>
<th>LANDSCAPE CONDITION ASSESSMENT</th>
<th>Impairment</th>
<th>Geographic Relevance</th>
<th>Reliability Designation</th>
<th>Reference Citation</th>
</tr>
</thead>
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<tr>
<td>Percent urban and agricultural cover</td>
<td>&gt; 50%</td>
<td>Mid-Atlantic</td>
<td>High</td>
<td>Riitters et al. 1997, Jones et al. 1997</td>
</tr>
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<td>Percent watersheds with crops on &gt;3% slope</td>
<td>&gt; 10%</td>
<td>Mid-Atlantic</td>
<td>High</td>
<td>Hunsaker et al. 1992</td>
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<td>Percent forested</td>
<td>&lt; 50%</td>
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<td>Medium</td>
<td>Welsch 1991, Mascutt et al. 1993</td>
</tr>
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<td>Length of road per square km</td>
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<td>Alabama – Southern U.S.</td>
<td>Medium</td>
<td>Chen and Roberts 2008</td>
</tr>
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<td>High</td>
<td>Heilman et al. 2002</td>
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<td>Impervious surface</td>
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<td>Arnold and Gibbons 1996, Lathrop et al. 2007</td>
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<td>Road Density</td>
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<td>Kepner et al. 1995</td>
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<th>Reliability Designation</th>
<th>Reference Citation</th>
</tr>
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<td>Species Presence (BIRD)</td>
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<td>Low</td>
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<tr>
<td>Species Presence (MAMMAL)</td>
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<td>Low</td>
</tr>
<tr>
<td>Species Presence (REPTILE/AMPHIBIAN)</td>
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<tr>
<td>Species Presence (FISH)</td>
<td>&lt; 40%</td>
<td>arbitrary</td>
<td>Low</td>
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<tr>
<td>Species Presence (ODONATE)</td>
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<td>Low</td>
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<td>At Risk Native Species</td>
<td>&lt; 13 (GEWA)</td>
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<td>Invasive Species</td>
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<td>Percent Diseased</td>
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<td>arbitrary</td>
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<th>Geographic Relevance</th>
<th>Reliability Designation</th>
<th>Reference Citation</th>
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<td>Medium</td>
<td>Dauer et al. 2000</td>
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<td>Dissolved Oxygen</td>
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<td>Mid-Atlantic</td>
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<td>Temperature</td>
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<td>High</td>
<td>EPA 2007</td>
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<td>Conductivity</td>
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<td>Medium</td>
<td>EPA 2007</td>
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<td>Mid-Atlantic</td>
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<td>Nitrite as Nitrogen (NO2)</td>
<td>&gt; 90 mg/L</td>
<td>Mid-Atlantic</td>
<td>Medium</td>
<td>EPA 2007</td>
</tr>
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<td>Buffering Capacity</td>
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<td>Medium</td>
<td>EPA 2007</td>
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<td>Iron (Fe)</td>
<td>&gt; 1.0 mg/L</td>
<td>Mid-Atlantic</td>
<td>Medium</td>
<td>EPA 2007</td>
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<tr>
<td>Fecal Coliform</td>
<td>&gt; 100 colonies per 100 ml H2O</td>
<td>Mid-Atlantic</td>
<td>Medium</td>
<td>EPA 2007</td>
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<tr>
<td>Chlorophyll a (Freshwater Summer)</td>
<td>&lt; 12 mg/L</td>
<td>Mid-Atlantic</td>
<td>High</td>
<td>EPA 2007</td>
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<tr>
<td>Chlorophyll a (Freshwater Spring)</td>
<td>&lt; 14 mg/L</td>
<td>Mid-Atlantic</td>
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<td>Chlorophyll a (Oligohaline Summer)</td>
<td>&lt; 9.5 mg/L</td>
<td>Mid-Atlantic</td>
<td>High</td>
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Table 2.1. (Continued)

<table>
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<th>Value</th>
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<th>Source</th>
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<td>Chlorophyll a (Oligohaline Spring)</td>
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<td>Chlorophyll a (Mesohaline Summer)</td>
<td>&lt; 7.7 mg/L</td>
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<td>Chlorophyll a (Mesohaline Spring)</td>
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<td>Chlorophyll a (Saltwater Summer)</td>
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<td>Turbidity (Saltwater Spring)</td>
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**HYDROLOGY/GEOMORPHOLOGY CONDITION ASSESSMENT**

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<th>Value</th>
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<td>Sediment Transport</td>
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**NATURAL DISTURBANCE CONDITION ASSESSMENT**

<table>
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<th>Value</th>
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<tr>
<td>Duration</td>
<td>TBD</td>
<td>site specific</td>
<td>Low</td>
<td>unavailable</td>
</tr>
<tr>
<td>Extent</td>
<td>TBD</td>
<td>site specific</td>
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<td>unavailable</td>
</tr>
<tr>
<td>Frequency</td>
<td>TBD</td>
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<td>Seasonality</td>
<td>TBD</td>
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<td>Size</td>
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<td>Intensity</td>
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**ECOLOGICAL PROCESSES ASSESSMENT**

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<td>&lt; 5.0</td>
<td>Mid-Atlantic</td>
<td>Medium</td>
<td>Maryland DNR</td>
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Table 2.2. List off all indicators with data used for assessment. This includes the units and respective threshold values.

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<thead>
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<th>Indicator</th>
<th>Data</th>
<th>Units</th>
<th>Good</th>
<th>Good-Fair</th>
<th>Fair</th>
<th>Fair-Poor</th>
<th>Poor</th>
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<td>% Urban and Agriculture Cover</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>%</td>
<td>&lt; 16.7</td>
<td>16.7-26</td>
<td>26-32.5</td>
<td>32.5-43.4</td>
<td>&gt; 43.4</td>
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<td>% Watershed w Crops on &gt; 3% Slope</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>%</td>
<td>&lt; 1.5</td>
<td>1.5-4.2</td>
<td>4.2-6.4</td>
<td>6.4-9.7</td>
<td>&gt; 9.7</td>
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<tr>
<td>% Stream Length w Agricultural Cover</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>%</td>
<td>&lt; 8.5</td>
<td>8.5-14.6</td>
<td>14.6-20.1</td>
<td>20.1-27.9</td>
<td>&gt; 27.9</td>
</tr>
<tr>
<td>% Forested</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>%</td>
<td>&gt; 82.4</td>
<td>72.5-82.4</td>
<td>63.8-72.5</td>
<td>48.4-68.3</td>
<td>&lt; 48.4</td>
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<tr>
<td>% Forest Fragmentation</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>%</td>
<td>&lt; 7.8</td>
<td>7.8-11.2</td>
<td>11.2-13.8</td>
<td>13.8-21.4</td>
<td>&gt; 21.4</td>
</tr>
<tr>
<td>Length of Road per sq km</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>kilometers</td>
<td>&lt; 1.3</td>
<td>1.3-1.6</td>
<td>1.6-1.9</td>
<td>1.9-3.0</td>
<td>&gt; 3.0</td>
</tr>
<tr>
<td>% Stream Length w/in 30 m of Road</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>%</td>
<td>&lt; 2.8</td>
<td>2.8-4.6</td>
<td>4.6-6.2</td>
<td>6.2-8.3</td>
<td>&gt; 8.3</td>
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<tr>
<td>% Impervious Surface</td>
<td>nlcd_2001, LiDar DEMS</td>
<td>%</td>
<td>&lt; 5</td>
<td>5.0-10.0</td>
<td>10.0-25.0</td>
<td>25.0-30.0</td>
<td>&gt; 30</td>
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<td>Mammal Species</td>
<td>NPSpecies, VA GAP</td>
<td>%</td>
<td>&gt; 50</td>
<td>40-30</td>
<td>30-20</td>
<td>20-10</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Fish Species</td>
<td>NPSpecies, VA GAP</td>
<td>%</td>
<td>&gt; 50</td>
<td>40-30</td>
<td>30-20</td>
<td>20-10</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Bird Species</td>
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<td>%</td>
<td>&gt; 50</td>
<td>40-30</td>
<td>30-20</td>
<td>20-10</td>
<td>&lt; 10</td>
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<td>Reptile/Amphibian Species</td>
<td>NPSpecies, VA GAP</td>
<td>%</td>
<td>&gt; 50</td>
<td>40-30</td>
<td>30-20</td>
<td>20-10</td>
<td>&lt; 10</td>
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<td>Invert Species</td>
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<td>40-30</td>
<td>30-20</td>
<td>20-10</td>
<td>&lt; 10</td>
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<td>pH</td>
<td>WQ table of FISH INV</td>
<td>pH Scale</td>
<td>6.0-9.0</td>
<td>6.0-5.5, 9.0-9.5</td>
<td>5.5-5.0, 9.5-10.0</td>
<td>5.0-4.5, 10.0-10.5</td>
<td>&gt; 10.5, &lt; 4.5</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>WQ table of FISH INV</td>
<td>mg/L</td>
<td>&gt; 6.0</td>
<td>6.0-5.0</td>
<td>5.0-4.0</td>
<td>4.0-3.0</td>
<td>&lt; 3.0</td>
</tr>
<tr>
<td>Temperature</td>
<td>WQ table of FISH INV</td>
<td>Degrees C</td>
<td>15.50-21.20</td>
<td>21.2-23.2, 15.5-13.5</td>
<td>23.2-25.2, 13.5-10.5</td>
<td>25.2-27.2, 10.5-8.5</td>
<td>&gt;27.20, &lt; 8.5</td>
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<td>Conductivity</td>
<td>WQ table of FISH INV</td>
<td>mg/L</td>
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<td>500-400</td>
<td>400-300</td>
<td>300-200</td>
<td>&lt; 200</td>
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Table 2.3. Summary of Landscape Condition Results for GEWA.

<table>
<thead>
<tr>
<th>Percent Urban and Agricultural Cover</th>
<th>Area (km²)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
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<tbody>
<tr>
<td>Sub-catchment ID 100</td>
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<td>73</td>
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<tr>
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<td>49</td>
<td>1</td>
<td>Poor</td>
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<tr>
<td>Sub-catchment ID 134</td>
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<td>4</td>
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</tr>
<tr>
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<td>47</td>
<td>2</td>
<td>Fair-Poor</td>
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<table>
<thead>
<tr>
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<th>Area (km²)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
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<td>5</td>
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<tr>
<td>Sub-catchment ID 104</td>
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<td>0</td>
<td>5</td>
<td>Good</td>
</tr>
<tr>
<td>Sub-catchment ID 110</td>
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<td>0</td>
<td>5</td>
<td>Good</td>
</tr>
<tr>
<td>Sub-catchment ID 134</td>
<td>45.19</td>
<td>0</td>
<td>5</td>
<td>Good</td>
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<tr>
<td>Overall</td>
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<td>0</td>
<td>5</td>
<td>Good</td>
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<table>
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<th>Percent Stream length with Agricultural Cover</th>
<th>Area (km²)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>Sub-catchment ID 110</td>
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<td>1.27</td>
<td>5</td>
<td>Good</td>
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<tr>
<td>Overall</td>
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<td>0.43</td>
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<table>
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<th>Percent Forested</th>
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<td>Sub-catchment ID 104</td>
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<td>66.39</td>
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<tr>
<td>Overall</td>
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<td>28.27</td>
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<td>Poor</td>
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<table>
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<th>Percent Forest Fragmentation</th>
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<th>Score</th>
<th>Rating</th>
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<td>Sub-catchment ID 103</td>
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<td>1</td>
<td>Poor</td>
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Table 2.3. (Continued)

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</table>

| Overall | 54.64 | 44 | 1 | Poor |

<table>
<thead>
<tr>
<th>Length of Road per sq km (within and adjacent to park)</th>
<th>Area (km²)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-catchment ID 100</td>
<td>0.13</td>
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<td>Good</td>
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<tr>
<td>Sub-catchment ID 103</td>
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<td>0</td>
<td>5</td>
<td>Good</td>
</tr>
<tr>
<td>Sub-catchment ID 104</td>
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<td>0</td>
<td>5</td>
<td>Good</td>
</tr>
<tr>
<td>Sub-catchment ID 110</td>
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<td>1.54</td>
<td>5</td>
<td>Good</td>
</tr>
<tr>
<td>Sub-catchment ID 134</td>
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<td>2.57</td>
<td>5</td>
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</table>

| Overall | 54.64 | 0.82 | 5 | Good |

<table>
<thead>
<tr>
<th>Percent Stream Length w/in 30 meters of road</th>
<th>Area (km²)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-catchment ID 100</td>
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<td>Sub-catchment ID 104</td>
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<td>Good</td>
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<td>1.54</td>
<td>5</td>
<td>Good</td>
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<tr>
<td>Sub-catchment ID 134</td>
<td>45.19</td>
<td>2.57</td>
<td>5</td>
<td>Good</td>
</tr>
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</table>

| Overall | 54.64 | 0.82 | 5 | Good |

<table>
<thead>
<tr>
<th>Percent Impervious Surface</th>
<th>Area (km²)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
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| Overall | 54.64 | 0.27 | 5 | Good |

| Overall LC | 54.64 | | 4 | Good-Fair |
Table 2.4. Summary of Biotic Condition Results for GEWA.

<table>
<thead>
<tr>
<th>Group</th>
<th>Proportion (Inventory/Expected)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammals</td>
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</tr>
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<td>Birds</td>
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<td>84.20</td>
<td>5</td>
<td>Good</td>
</tr>
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<td>Reptiles/Amphibians</td>
<td>47/65</td>
<td>72.31</td>
<td>5</td>
<td>Good</td>
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<tr>
<td>Fish</td>
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<td>60.00</td>
<td>5</td>
<td>Good</td>
</tr>
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<td>Invertebrates</td>
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<td>Good-Fair</td>
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Table 2.5. Summary of Chemical Condition Results for GEWA.

<table>
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<th>Site ID</th>
<th>pH Score</th>
<th>pH Rating</th>
<th>DO Score</th>
<th>DO Rating</th>
<th>Temp Score</th>
<th>Temp Rating</th>
<th>Cond. Score</th>
<th>Cond. Rating</th>
<th>Overall Score</th>
<th>Overall CC (Site)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Good</td>
<td>1</td>
<td>Poor</td>
<td>1</td>
<td>Poor</td>
<td>3</td>
<td>Fair</td>
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<tr>
<td>2</td>
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<td>2</td>
<td>Fair-Poor</td>
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<td>Fair-Poor</td>
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<td>Poor</td>
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<td>Fair</td>
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<td>Good</td>
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<td>Fair-Poor</td>
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<td>Good</td>
<td>4</td>
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<td>Good</td>
<td>2</td>
<td>Fair-Poor</td>
<td>2</td>
<td>Fair-Poor</td>
<td>5</td>
<td>Good</td>
<td>4</td>
<td>Good-Fair</td>
</tr>
<tr>
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<td>Good</td>
<td>5</td>
<td>Good</td>
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<td>Poor</td>
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<td>Good</td>
<td>4</td>
<td>Good-Fair</td>
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<tr>
<td>Overall CC (Category)</td>
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<td>Fair-Poor</td>
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<td>Fair</td>
<td>4</td>
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Table 2.6. Summary of Landscape condition results for THST.

<table>
<thead>
<tr>
<th>Percent Urban and Agricultural Cover</th>
<th>Area (km(^2))</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
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<td>33</td>
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<table>
<thead>
<tr>
<th>Percent Watershed with Crops on greater than a 3% Slope</th>
<th>Area (km(^2))</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
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<tr>
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</table>

<table>
<thead>
<tr>
<th>Percent Stream length with Agricultural Cover</th>
<th>Area (km(^2))</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
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</thead>
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<tr>
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</table>

<table>
<thead>
<tr>
<th>Percent Forested</th>
<th>Area (km(^2))</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
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<td>Sub-catchment ID 202</td>
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<td>Fair-Poor</td>
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</table>

<table>
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<th>Percent Forest Fragmentation</th>
<th>Area (km(^2))</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
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<td>Sub-catchment ID 202</td>
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<table>
<thead>
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<th>Length of Road per sq km (within and adjacent to park)</th>
<th>Area (km(^2))</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-catchment ID 202</td>
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<td>5</td>
<td>Good</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Percent Stream Length w/in 30 meters of road</th>
<th>Area (km(^2))</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
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<th>Percent Impervious Surface</th>
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<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
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<table>
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<th>Score</th>
<th>Rating</th>
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Table 2.7. Summary of Biotic Condition Results for THST.

<table>
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<th>Group</th>
<th>Proportion (Inventory/Expected)</th>
<th>Value (%)</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammals</td>
<td>14/46</td>
<td>30.43</td>
<td>3</td>
<td>Fair</td>
</tr>
<tr>
<td>Birds</td>
<td>111/209</td>
<td>53.11</td>
<td>5</td>
<td>Good</td>
</tr>
<tr>
<td>Reptiles/Amphibians</td>
<td>19/65</td>
<td>29.23</td>
<td>2</td>
<td>Fair-Poor</td>
</tr>
<tr>
<td>Fish</td>
<td>16/54</td>
<td>29.63</td>
<td>2</td>
<td>Fair-Poor</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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Table 2.8. Summary of Chemical Condition Results for THST.

<table>
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<th>Site ID</th>
<th>pH Score</th>
<th>pH Rate</th>
<th>DO Score</th>
<th>DO Rate</th>
<th>Temp Score</th>
<th>Temp Rating</th>
<th>Cond. Score</th>
<th>Cond. Rating</th>
<th>Overall Score</th>
<th>Overall CC (Site)</th>
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<td>Good</td>
<td>4</td>
<td>Good-Fair</td>
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<td>Poor</td>
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<td>Good-Fair</td>
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<tr>
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<td>5</td>
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<td>Poor</td>
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<td>Good-Fair</td>
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<tr>
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<td>5</td>
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<td>5</td>
<td>Good</td>
<td>1</td>
<td>Poor</td>
<td>4</td>
<td>Good-Fair</td>
</tr>
</tbody>
</table>


Figure 2.1. Geographic locations of GEWA and THST including park boundaries, watershed boundaries and state boundaries.
Figure 2.2. Flow chart of General Approach to Methods
Figure 2.3. Five sub-catchments delineated from the 14-digit HUC containing the GEWA park boundary
Figure 2.4. 2001 NLCD Land Cover data used for extraction of land cover types within and adjacent to the GEWA park boundary.
Figure 2.5. Map output of biotic condition for Mammal species within the GEWA park boundary.
Figure 2.6. Map output of Chemical Condition for Conductivity within the GEWA park boundary.
3. Conclusion

3.1. Overview

The research described previously presents the methodology for development of an effective assessment of natural resources in the National Parks System. Specifically, the goal of this study was to create a GIS-based model that uses easily assessable data to develop a spatially-specific assessment of an individual park’s natural resources condition that is useful to park planners within the GEWA park unit of the National Parks System. The totality of the work is presented in the two previous chapters. The first chapter provides a background of data collection in natural resources, a history of NPS techniques and strategies to utilize said data, multiple criteria indices, and the need for a more improved assessment of natural resource condition among parks. The second chapter describes the methodology behind creation of a natural resource condition assessment for George Washington Birthplace National Monument.

3.2. Summary of Chapters

3.2.1. Literature Review and Introduction

Chapter 1 describes historical approaches to data management and the need for a more comprehensive approach to analysis of this data. Although the NPS collects extensive amounts of data, there is still a lack of connection between collection and actual analysis or application. The NPS has traditionally taken an advisory role in NRCA development. Current NRCA’s rely primarily on data mining and publically shared data. Clarification of NRCA criteria and indicators has often been a difficult task, as areas of interest often differ on temporal and spatial scale. Although the NPS has developed
several programs to address variables that are important to each individual park, a unique set of variables deemed vital to each park that can be adjusted at the investigators discretion (see table 1.5). This chapter expands on the idea of using NPS data, supplemented with vast amounts of state, federal and public data, to create a natural resource condition assessment for individual units in the National Parks System. The NRCA was developed as a GIS based model that uses readily available data, multiple indicator criteria and a user-friendly interface to transform data into a spatially represented assessment of park condition available for utilization by park planners.

3.2.2. Manuscript: Development of a multiple criteria-based assessment for identifying natural resource conditions within the National Parks System

This chapter describes the process of development of a natural condition assessment for a single park unit located in the Northeast region of the National Parks System; George Washington Birthplace National Monument (GEWA). We determined that the compilation of available data supported three main categories on which to base the assessment. These were Landscape condition, Biologic condition and the Chemical and Physical characteristics of the contributing watersheds and sub-watersheds. Using a multiple criteria approach, the three main categories were then sub-divided into 13 indicators of environmental health. Where possible, reference values were established for each indicator and converted to a base scale, ranging from 1-5, to determine overall
condition at each indicator. Our assessment suggests that GEWA be rated good-fair (4) in overall Landscape Condition, however some sub-watershed units exhibited poorer scores than others and were addressed at the sub-watershed level. Our assessment determined that GEWA be rated Good (5) in overall biologic condition. GEWA was rated Good-fair (4) for Overall Chemical Condition, however some site-specific readings ranked much lower and have been recommended to be investigated on a site-specific basis.

The main constraint found when developing and completing the NRCA for GEWA was a lack of available data and literature values for indicator thresholds. Data management should be of utmost importance when considering an NRCA for any unit of the NPS. If data are not adequately and uniformly collected, managed, and interpreted then an NRCA may be rendered useless. Our assessment attempts to address not only the natural resource condition of a park unit, but also to identify areas of concern in the form of data gaps, problems with initial data structure and interpretation. Park officials can therefore focus on inventoring efforts in categories with insufficient data and make management decisions in data rich areas ranked in poor condition.

To determine applicability of our model to other geographically relevant parks within the U.S. National Parks System, we completed an assessment of Thomas Stone National Historic Site (THST) using the same assessment, categories, indicators and thresholds. THST shares many of the same physiographic characteristics with GEWA.
and is a fairly typical representation of another park unit within the NPS Northeast region. THST exhibited similar ratings and scores to that of GEWA.

3.3. Recommendations for Future Work

The research described within this work presents the framework for developing a natural resource condition assessment of a single park unit within the NPS system using a variety of available data sources. There are many opportunities to improve upon this assessment model as well as to extend this model to other park units within the NPS.

- Continued data collection at GEWA and THST are necessary to ensure the effectiveness of the NRCA. As additional data are collected within and adjacent to the parks boundaries, the NRCA should be applied to determine if values are affected based on the new data, especially in previously data poor categories. Data should also be collected in a more uniform manner which could potentially reduce redundancies, geoprocessing errors and false rating values. A template by which data is collected would ensure ease of use in the NRCA and simplify data compilation for geoprocessing. Additional data might also help facilitate the inclusion of previously omitted categories and indicators that weren’t included in the initial model due to a lack of data. Utilization of the NRCA model on other geographically relevant park units should also be completed to test model effectiveness.
• Updates to model threshold values should occur as new data is collected and as scientific knowledge of each threshold improves. Determination of the threshold values lies with the resource manager, and is therefore easily changed in the GIS interface for each indicator. Increased input from natural resource professionals will assist in refinements to both the threshold values themselves and the rating and scoring system currently in use. Validity of the assessment can only increase as the values of respective thresholds are decided upon.

• The utilization of geoprocessing within the model can further be improved upon by including other categories and indicators previously omitted into the toolbar developed. A more robust toolbar could assist in future use of the model on other park units. Improvements in software packages used will also make geoprocessing faster and more efficient, reducing waiting time for results and potential errors.

• Correlations between indicators can potentially be developed and interdependence among indicators can help remove unnecessary indicators and provide a weighted value to those indicators deemed most important. As interactions between indicators and categories are further understood, model improvements can be made.
The work previously presented in this thesis presents the framework for future NRCAs within the NPS. Park managers now have the tools necessary to quantify natural resource condition within their respective park units and can therefore make management decisions accordingly. The development of a GIS interface provides park managers with a user-friendly and time saving tool to determine the potential condition of each individual park. The opportunity exists for continued collaboration between North Carolina State University and the NPS as outlined in the recommendations above. By working in conjunction with the NCSU, NPS can continue to enhance assessments and improve monitoring and assessment of the Nation’s parks and its natural resources.
Appendix 1. Spatial Database Adaptation

In addition to existing database material, much work was done to convert this data into a spatially compliant database. This conversion required tabular inventory data to be connected to spatial reference points. It was necessary to associate each point based on established one-to-one and one-to-many relationships. The relationships between tables were established with the use of a common field within each table. Appendix Figure 1 shows established table relationships based on interlinking fields. These tables were joined together by using a Microsoft Access’ query design functionality to combine related tables and extract usable data (Appendix Figure 2). The data for assessment was then transferred along with geographic coordinates to a new table (Appendix Figure 3) and saved in a format compatible with ESRI’s ArcGIS software.

Appendix Figure 1.1. Linkages between database tables (birdobserv.shp).
Appendix Figure 1.2. Microsoft Access query design (*birdobserv.shp*).

Appendix Figure 1.3. Extracted table from query design in Figures 1 and 2.

All data connected using Microsoft Access’ query design functionality were then available as a spatial attribute table (Appendix Figure 4). This process was completed for all biotic and chemical indicators. Additionally, this process allowed fields to be sorted and analyzed. Each geographical point may represent several observations. The example below demonstrates query design functionality that relates one point that may contain hundreds of entries (Appendix Figure 4).
Appendix Figure 1.4. Tabular data linked in Microsoft query design functionality to relate feature class attributes.
Appendix 2. Python Code Development

Python, dynamic object-oriented programming language used for software development, was chosen as the primary scripting language. This programming language incorporates spatial analysis and geoprocessing functionality that is recognized by EASRI’s ArcGIS software package by providing the ability to incorporate commands or arguments into a script for repeatability and further customization.

For example, the python script `bird_sort.py` (Appendix Figure 5) compares the number of species identified during inventory sampling to the total number of bird species historically known to be present in and around the park areas (Virginia GAP). Using the python code, the model interface was developed to allow for parameters modifications by providing the flexibility to select a workspace directory, the table from which to compare the park inventories, and specify evaluation fields within the comparison tables and spatial feature class. As parameter arguments are processed through the script, a model’s results are created in Python’s “Interactive Window” (Appendix Figure 6). The model results of assessment of bird species within a park (`bird_sort.py`) produces a text file of all the arguments computed during processing, as well as the proportion of bird species collected, and the indicator score based on the designated threshold values.

Appendix Figure 2.1. Python script `bird_sort.py` compares the number of species collected during inventory sampling to the total number of bird species historically known to be present in and around the park (Virginia GAP data).
Appendix Figure 2.2. Output of *bird_sort.py* in Python’s Interactive Window.

Another example of python scripting in the GEWA natural resource assessment is demonstrated for the pH chemical assessment. In this assessment, the *PH.py* python code provides the pH for all water inventory stations in the park (Appendix Figure 7). The script accepts three arguments; workspace, usable feature class, and field from which to sort. The script is designed to sort through all usable records in the database based on the specific field, in this case pH (Appendix Figure 8). It then compares all values to preset thresholds and assigns those values a score. These data are easily converted into maps and tabular data.
Appendix Figure 2.3. The *PH.py* python script provides the pH values for all water inventory stations in the park.

Appendix Figure 2.4. Output of *PH.py* in Python’s Interactive Window.
Appendix 3. Toolbar Development: Connecting Microsoft Visual Basic and Python

The natural resource assessment model tools have been designed to be implemented through a customized, user-friendly software extension tool that is compatible with ESRI’s ArcGIS platform. This extension tool is accessed through the custom Resource Inventory and Site Condition (RISC) assessment toolbar (Appendix Figure 9). The toolbar consists of three control buttons, each of which opens a dialog window that allows the user to select inputs for a particular model function. This toolbar was designed to promote more automation in the process (fewer necessary user-defined inputs) and enhance usability (more options for LU/LC formats, raster or polygon). The toolbar itself was created using Microsoft Visual Basic (VBA) programming language. The job of the toolbar is to import and execute analysis functions written in the Python programming language. Both VBA and Python communicate seamlessly with ESRI’s ArcMap.

Appendix Figure 3.1. Custom ArcGIS Resource Inventory and Site Condition (RISC) assessment toolbar. This toolbar operates as a toolbar extension in ESRI’s ArcMap software platform.

The “Assessment” function of the RISC toolbar presents a series of assessment model functions. The “Assessment” command button opens a new dialog window containing six additional control buttons (Appendix Figure 10). Each control button opens a subsequent dialog window where the user can enter inputs for the assessment of each ecological category: Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, Ecological Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes. Unfortunately, due to the limitation of the existing data within the GEWA and THST geodatabase, the latter three categories (Ecological Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes) were not available for model development. The following is an overview of the Landscape Condition, Biotic Condition, and Chemical and Physical Characteristic assessment tools:
Appendix Figure 3.2. The "Assessment" button on the RISC toolbar opens a dialog window from which each of the individual resource indicator assessments are initiated.

Landscape Condition Tool: The landscape condition tool allows for multiple user input and is opened directly from the RISC toolbar (Appendix Figure 9). The user can select workspace, land use directory, individual park catchment, watershed raster, streams and roads layers, as well as the impervious surface directory for either park from a scrollable list. As seen in appendix figure 11, the first option in the Landscape Condition dialogue box is the “Workspace” option. This option allows a user to define a working directory to complete all geoprocessing and store outputs. The second option is the “Land Use Directory” box. This option allows the user to navigate to the directory where the geodatabase that will be used in the subsequent assessments is located. The next option is the “Park Basins” input box. This box allows the user to select the park basin on which to run the natural resource assessment. Inputs for the watershed raster, streams layer, and roads layer can all be defined in the next three boxes. These boxes accept the input on which to run the streams, roads, and the generated watershed scripts. Lastly is the “Impervious Surface” directory box. This option allows the user to browse to the location on which to run the impervious surface script. Once the Landscape Condition dialogue box accepts all user inputs the “Run Landscape Condition” button processes all scripts associated with the assessment (see appendix). This action generates an overall landscape condition score and rating. Additionally, the overall values are stored in a separate file for convenient exportability and report generation.
Appendix Figure 3.3. Landscape Condition assessment input window.

**Biotic Condition Tool:** The Biologic Condition dialogue box is opened directly from the RISC toolbars “Assessment” button (Appendix Figure 9). As with the landscape condition tool, the first option with the biologic condition dialogue box allows the definition of a workspace and watershed raster. The Biotic Condition dialogue box also allows the user to input all feature classes and database tables from which to assess biological conditions. Each option asks for a look-up table (i.e. comparison table) that assessment results may be based on. This operation generates several scripts from the python programming language which compares all database tables with unique values related to the given group of interest. This operation also generates inputs relating to each group type (i.e. mammals, fish, reptiles/amphibians, odonates, bird species, etc.). For example, the assessment of birds generates a script (*bird_sort.py*) to compare the NPS inventory with the total number of bird species that are known to be historically present within the GEWA park system. The next option requests a feature class or inventory database table. This selection should represent inventory data that the user would like to compare to the look-up table. Next to each of the above selections are field inputs. These inputs should represent the database field heading of each table on which the model will generate comparisons.
Appendix Figure 3.4. Biologic Condition Tool.

The Biotic Condition tool was also equipped to handle changes in the threshold values for each species embedded in their respective python scripts (Appendix Figure 13). These values are assigned during indicator selection and are used to determine what score will be given for each group in the biotic condition design. This option additionally provides the flexibility to make adjustments so that predictions could be made if population levels were to shift dramatically over time. The threshold values command may be used to adjust threshold values between 0.00 and 1.00 (0% and 100%, respectively). The “Run Biotic Condition” command processes all scripts associated with the biotic condition assessment (see appendix). This action generates an overall biotic condition score and rating. Additionally, the overall values are stored in a separate file for convenient exportability and report generation.
Appendix Figure 3.5. Biologic Condition accepts user input for threshold values for investigative purposes.

**Chemical and Physical Characteristics Tool:** The Chemical and Physical Characteristics dialogue box is opened directly from the RISC toolbars “Assessment” button (Appendix Figure 9). As with the Landscape Condition and Biotic Condition tools, this assessment tool designates a workspace from the browse function (Appendix Figure 14). The “Shapefile/Table” function allows the user to navigate to feature classes or database tables that contains the physical and chemical parameters to be assessed. For example, in the GEWA chemical condition assessment, there were four indicators available. These include pH, dissolved oxygen, temperature, and conductivity.
Appendix Figure 3.6. Chemical/Physical Condition Tool. The user may change threshold values for investigative purposes.

As with the Biotic condition, the chemical/physical condition has the capability for the user to change threshold values for each measurement. As seen in Appendix figure 14 above, each chemical indicator field has a threshold value command button. The “Threshold Value” command opens a dialogue box in which indicator threshold ranges can be adjusted for any query (Appendix Figure 15). The threshold value adjustment dialog window allows the user to modify threshold ranges based on suitable reference or literature values. The “Run Chemical Condition” command processes all scripts associated with the biotic condition assessment (see appendix). This action generates an overall chemical condition score and rating. Additionally, the overall values are stored in a separate file for convenient exportability and report generation.
Overall Condition: Scores generated from the Landscape, Biotic, and Chemical condition assessments are generated independently (as previously described), or may be subsequently combined to develop an overall index of park health and areas of concern. The ability to change thresholds also makes this tool useful for natural resource planning, as well as for predicting future management needs.
Appendix 4. Python Programming Language developed for Condition Assessment.

Assessment Code: *LandscapeCondition.py*

```python
# 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
#
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_1983',SPHEROID['GRS_1980',6378137.0,298.25722101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],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

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

# 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")
for raster in rasters:
    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 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

# 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

```
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

# 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

# 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
#

# 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 = count1 * 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)
#
# 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:
        gpaddField(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
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:

# 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")

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

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

# 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 = Arrows.next()
sum = total
del Arow
del Arrows
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

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

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_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],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")
Assessment Code: BiologicalCondition.py

#Description: Calls various functions to calculate indicator values for Biotic condition
#
#Arguments: sys.argv[1] = Workspace
#           sys.argv[3] = Fish
#           sys.argv[4] = Birds
#           sys.argv[5] = Reptiles and Amphibians
#           sys.argv[6] = Odonates
#

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

#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWA.shp
#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
Assessment Code: fish_sort.py

#Description: Calculates indicator values for Biological Condition's fish species proportion per watershed
#
#sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
#sys.argv[2] = fishspec.dbf
#sys.argv[3] = FIELDS
#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
# sys.argv[1] = C:/Users/bmhartzis/Desktop/GEWA/GEWAshp
# sys.argv[2] = herpspec.dbf
# sys.argv[3] = FIELDS
# 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
#
#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
#
# sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWAshp
# sys.argv[2] = odspec.dbf
# sys.argv[3] = FIELDS
# 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

**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
#

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
# sys.argv[1] = C:/Users/bmhartis/Desktop/GEWA/GEWA.shp
# 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 = row.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
#
#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
#
#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
#
# 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]
inputbl = 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.CCl_score = ls
    rows.UpdateRow(row)
    row = rows.next()
Appendix 5. Tutorial for proper use of “RISC” toolbar

Overview

The goal of this project was to develop a customized, GIS-based, natural resource condition assessment model. This tutorial explains the development of the natural resource condition assessment model and a step based approach to using the model.

The natural resource condition assessments model focuses on maximizing the usefulness of the existing data in assessment models, and providing a custom GIS-based model to evaluate resource conditions based on the current data. The assessment models have been designed as an ESRI ArcGIS extension, with a user-friendly interface that provides the ability to handle new inputs and variations of parameters. Additionally, the models were designed with the intention they could be applied to a multitude of datasets.

Indicators were selected and incorporated into the model. Each indicator was 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 due to a lack of available data for each category.

Landscape Condition: The below indicators were chosen in order to classify overall landscape condition within the GEWA and THST watershed and constituting sub-basins. Each indicator was ranked based upon five intervals (good, good-fair, fair, fair-poor, and poor respectively). Indicators were also given threshold values on which to base the ranked values. These thresholds were derived from known literature values. The indicators are as follows:

**Landscape Condition:** The following indicator was chosen in order to classify overall Landscape condition. Each were ranked based upon five intervals (good, good-fair, fair, fair-poor, and poor respectively). The indicator was also given threshold values on which to base the ranked values. These thresholds were derived from known literature values. The following landscape condition indicators were used for the assessment:

**Percent Urban and Agricultural Cover:** Percent urban and agricultural cover relates to the overall area of the watershed containing urban and/or agricultural cover. 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).

**Percent Watershed with Crops on greater than a 3% Slope:** The proportion of watershed with crops on a slope greater than three percent relates directly to agricultural
areas having a cropland set on a slope greater than three percent. If an area has cropland on sloped terrain, chances of runoff into a nearby water system are much higher. 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).

**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. 1998, Riitters et al. 1997, Hunsaker et al. 1992). For the purposes of GEWA and THST, streams were buffered to 30 meters and the proportion of agricultural use was taken from areas within the buffer area.

**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 forest condition in GEWA and THST due to the fact that inventories have not yet been completed. This raises some questions about forest habitat and overall health. When an area within a watershed becomes deforested at less than 50 percent of the overall area, environmental condition is estimated to deteriorate (Welsch 1991, Mascutt et al. 1993). In the case of GEWA and THST, streams were buffered to within 30 meters and the proportion of that area determined to be forested was used. Threshold values were taken on a study of riparian buffers in the northeastern 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, shelter and breed as well as reducing water quality (Riitters et al. 2002). In the case of GEWA and THST, if the watershed has an overall forest fragmentation of greater than 20 percent, some of the above instances may be occurring (Saunders et al. 2002, Heilmann et al. 2002, Zipperer 1991).

**Length of Road per sq km (within and adjacent to park):** This indicator relates directly to road density within the GEWA and THST park systems. 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 is reported to be compromised if an area has more than 3.0 km of roadway within its boundary (Chen and Roberts 2008).

**Percent Stream Length w/in 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 the 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 compromised when road density comprises more than 10 percent of the area within 30 meters of a stream (Heilman et al. 2002).

**Percent Impervious Surface:** Impervious surfaces are mainly artificial structures that are covered by impenetrable materials such as asphalt, concrete, brick, and stone. These include but are not limited to roads, sidewalks, driveways and/or soil compacted by urban development. When impervious surfaces encompass 10 percent or more of a given area, environmental quality can become degraded (Arnold and Gibbons 1996, Lathrop et al. 2007).

**Biotic Condition:** The following indicator was chosen in order to classify overall Biologic condition. Each were ranked based upon five intervals (good, good-fair, fair, fair-poor and poor respectively). The indicator was also given threshold values on which to base the ranked values. These thresholds were derived from known literature values. The following biotic condition indicator was used for the assessment:

**Species Abundance:** Species abundance is defined as the total number of species present compared to the total number of species known to occupy a given area. In the case of GEWA, species abundance was defined for several different groups. These include but are not limited to fish, mammals, reptiles, amphibians, birds and odonates. A threshold was arbitrarily developed for every group at less than 40 percent affecting biotic condition.

**Chemical Condition:** The below indicators were chosen in order to classify overall Chemical condition. Each were ranked based upon five intervals (good, good-fair, fair, fair-poor and poor respectively). Indicators were also given threshold values on which to base the ranked values. These thresholds were derived from known literature values. The indicators are as follows:

**pH:** pH is the measure of acidity or basicity of a given waterbody. For the purpose of GEWA, pH thresholds were established for all three types of water present in the GEWA park area. These include freshwater, brackish water (mesohaline/oligohaline) and saltwater (polyhaline). pH values are considered good when they are ; 6.0-9.0 in freshwater, 7.0-9.0 in brackish water and 7.1-8.1 for saltwater (Dauer et al. 2000).

**Dissolved Oxygen:** Dissolved oxygen measures the amount of gaseous oxygen (O2) dissolved in water. Dissolved oxygen measurements were also taken in the three types of water (i.e. saline, brackish, fresh) found in the GEWA park system. Dissolved oxygen is considered to deteriorate the chemical condition of the watershed when it reaches certain threshold levels (EPA 2007). In freshwater, the EPA (2007) has reported this value to be less than 6.0 mg/L. The dissolved oxygen level is less than 5.5 mg/L for brackish and less than 5.0 mg/L for saltwater (EPA 2007). For the purpose of this study 6.0 mg/L was used because differentiation between water types was poor.
Temperature: Temperature in aquatic systems plays an important role in several biological processes. If temperature levels fluctuate between high and low values, these biological processes can become impaired or cease to function at all. For GEWA and THST, temperature boundaries were based on normal temperature ranges for the eastern coast of the United States. These values were directly taken from the EPA Virginia water quality standards (2007). It is reported that sensitive biotic processes may be affected if temperature ranges fall above or below 15.5 to 21.2 degrees Celsius.

Conductivity: Conductivity is defined as the measurement of the ability of an aqueous solution to carry and electrical current. It can determine mineralization as well as signify 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 compromised (EPA 2007).

<table>
<thead>
<tr>
<th><strong>LANDSCAPE CONDITION ASSESSMENT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condition Indicator</strong></td>
</tr>
<tr>
<td>Percent urban and agricultural cover</td>
</tr>
<tr>
<td>Watersheds with crops on &gt;3% slope</td>
</tr>
<tr>
<td>Percent stream length with agricultural cover</td>
</tr>
<tr>
<td>Percent forested</td>
</tr>
<tr>
<td>Percent forest fragmented</td>
</tr>
<tr>
<td>Length of road per square km</td>
</tr>
<tr>
<td>Percent stream length within 30m of road</td>
</tr>
<tr>
<td>Impervious surface</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>BIOTIC CONDITION ASSESSMENT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condition Indicator</strong></td>
</tr>
<tr>
<td>Species Presence (BIRD)</td>
</tr>
<tr>
<td>Species Presence (MAMMAL)</td>
</tr>
<tr>
<td>Species Presence (REPTILE/AMPHIBIAN)</td>
</tr>
<tr>
<td>Species Presence (FISH)</td>
</tr>
<tr>
<td>Species Presence (ODONATE)</td>
</tr>
</tbody>
</table>
**CHEMICAL CONDITION ASSESSMENT**

<table>
<thead>
<tr>
<th>Condition Indicator</th>
<th>Current Impairment Threshold Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.0-9.0</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>&lt; 6.0 mg/L</td>
</tr>
<tr>
<td>Temperature</td>
<td>15.5-21.2 C</td>
</tr>
<tr>
<td>Conductivity</td>
<td>&lt; 500 mg/L</td>
</tr>
</tbody>
</table>

**“RISC” toolbar**

The natural resource assessment model tools have been designed to be implemented through a customized, user-friendly extension that is compatible with ESRI’s ArcGIS software platform. This extension is accessed through a custom Resource Inventory and Site Condition (RISC) assessment toolbar (Figure 1). The RISC toolbar can be added directly to ESRI’s ArcMap. The toolbar consists of three control buttons, each of which opens a dialog where the user can select inputs for a particular model function. This toolbar was designed to promote more automation in the process (fewer necessary user-defined inputs) and enhance usability (more options for LU/LC formats, raster or polygon). The toolbar itself was created using Microsoft Visual Basic (VBA) programming language. The job of the toolbar is to call and run analysis functions written in the Python programming language. Both VBA and Python communicate seamlessly with ESRI’s ArcMap.
Appendix Figure 5.1. Custom ArcGIS Resource Inventory and Site Condition (RISC) assessment toolbar. This toolbar operates as an employable toolbar extension in ESRI’s ArcMap software platform.

“Assessment” function
The “Assessment” function of the RISC toolbar presents a series of assessment model functions. The “Assessment” command button opens a new dialog window containing six additional control buttons (see figure 2). Each control button opens a subsequent dialog window where the user can enter inputs for the assessment of each ecological category: Landscape Condition, Biotic Condition, and Chemical and Physical Characteristics, Ecological Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes. Unfortunately, due to the limitation of existing data, the latter three categories (Ecological Processes, Hydrology and Geomorphology, and Natural Disturbance Regimes) were unavailable for model development. The following is an overview of the Landscape Condition, Biotic Condition, and Chemical and Physical Characteristic assessment tools:
Appendix Figure 5.2. The "Assessment" button on the RISC toolbar opens a dialog window from which each of the individual resource indicator assessments are initiated.

Landscape Condition Tool:
Overview
Landscape condition tool allows for multiple user input and is opened directly from the RISC toolbar (Figure 1). The user can select workspace, land use directory, individual park basin, watershed raster, streams and roads layers as well as the impervious surface directory for the park all from a scroll down list. As seen in figure 3, the first option in the Landscape Condition dialogue box is the “Workspace” option. This option allows a user to define a working directory to complete all geoprocessing and store outputs. The second option is the “Land Use Directory” box. This option allows the user to navigate to the directory where the geodatabase is located for that will be used in the subsequent assessments. Next option is the “Park Basins” input box. This box allows the user to select the park basin on which to run the natural resource assessment. Inputs for the watershed raster, streams layer, and roads layer can all be defined in the next three boxes. These boxes accept the input on which to run the streams, roads and the generated watershed scripts. Lastly is the “Impervious Surface” directory box. This option allows the user to
browse to the location on which to run the impervious surface script. Once the Landscape Condition dialogue box accepts all user inputs the “Run Landscape Condition” button processes all scripts associated with the assessment (see appendix). This action generates an overall landscape condition score and rating. Additionally, the overall values are stored in a separate file for convenient exportability and report generation.

Appendix Figure 5.3. Landscape Condition Tool

Example 1: Demonstrate the Landscape Condition Tool: George Washington Birthplace

**Step 1:** Insert all inputs into the Landscape Condition Tool userform.

Define the Workspace

Workspace: `C: Final_Tools\Assessment\LandscapeCondition\test_data`

Define Land use Directory
Land use Directory:
*Final_Tools\Assessment\LandscapeCondition\test_data\basins_results\lulc*

Define Park Basins Layer
   Park Basins:
*Final_Tools\Assessment\LandscapeCondition\test_data\WCA.mdb\basins\basins_park*

Define Watershed Raster
   Watershed Raster:
*Final_Tools\Assessment\LandscapeCondition\test_data\WCA.mdb\ws_ras*

Define Streams Layer
   Streams:
*Final_Tools\Assessment\LandscapeCondition\test_data\WCA.mdb\hydrology\GEWA_streams*

Define Roads Layer
   Roads:
*Final_Tools\Assessment\LandscapeCondition\test_data\WCA.mdb\data_layers\GMP_roads*

Define Impervious Surface Directory
   Impervious Surface Directory:
*Final_Tools\Assessment\LandscapeCondition\test_data\basins_results\impervious*

As geoprocessing begins, information about what processes are taking place is displayed in the ArcMap DOS window. Files are read based on several imbedded python scripts and scores are assigned to each individual indicator. The scores then print and are placed in an excel file for readability. They can also be found in the personal geodatabase “WCA.mdb” along with other tables and calculations made during the Landscape Condition Assessment. They are represented as follows in shapefile LC_Score also created during geoprocessing:

- LC_1 = % Urban and Agricultural Land
- LC_2 = % Watershed with Crops on slope greater than 3%
- LC_3 = % Stream Length with Agricultural Cover
- LC_4 = % Forested
- LC_5 = % Forest Fragmentation
- LC_6 = Length of Road per square mile
- LC_7 = % Stream Length within 30 m of road
- LC_8 = % Impervious
Values are represented in attribute table form as well

Biotic Condition Tool
Overview:
The Biotic Condition Assessment assess biotic integrity of the study area based on the presence or absence of a species from that area. The assessment is based on five species categories: Mammal Species, Fish Species, Bird Species, Reptile/Amphibian Species and Invertebrate species. An assessment is made for each species category by comparing an inventory table to a list of historically known species from the Virginia GAP analysis project. A proportion is derived from the comparison and The Biologic Condition dialogue box is opened directly from the RISC toolbars “Assessment” button (Figure 4).
Appendix Figure 5.4. Biotic Condition Tool

As with the landscape condition tool, the first option with the biologic condition dialogue box allows the definition of a workspace but the watershed raster is not included. This is due mainly to the fact that watershed specific species list are unavailable. The Biotic Condition dialogue box also allows the user to input all feature classes and database tables from which to assess biological conditions. Each option asks for a look-up table (i.e. comparison table—figure 5) that assessment results may be based on. This operation generates several scripts from the python programming language which compares all database tables with unique values related to the given group of interest. This operation also generates inputs relating to each group type (i.e. mammals, fish, reptiles/amphibians, invertebrates, bird species, etc.). For example, the assessment of fish generates a script (*fish_sort.py*) to compare the NPS inventory with the total number of fish species that are known to be historically present within any park system.
Appendix Figure 5.5. “fishspec.dbf” is the lookup table for all fish species historically known in the GEWA park. “Field 5” is the corresponding search field to compare to the inventory database table.

The next option requests a feature class or inventory database table (Figure 6). This selection should represent inventory data that that the user would like to compare to the look-up table. The default provides for a “.dbf” designation for the dBASE lookup tables and a “.shp” designation for the shapefiles on which to base the biologic comparison (See figure 4). Feature classes can also be accepted as dBASE or “.dbf” as the model runs table comparisons as well. As of now, only string values will be accepted as user input. The browse functionality is currently unavailable and one must know the respective inventory data and comparison table on which to run the model. Next to each of the above selections are field inputs. These inputs should represent the database fields heading of each table on which the model will generate comparisons.
Appendix Figure 5.6. “allfish.shp” contains the fish inventory database tables for GEWA. The Field “LATINNAME” is the field on which the model bases its comparison to the above “fishspec.dbf”.

Example 2: Demonstrate Biologic Tool: George Washington Birthplace

Step 1: Open Biologic Condition Tool from the “assessment” section of the “RISC” toolbar and insert inputs in appropriate text boxes.

Define the Workspace:

Workspace: \GEWA\GEWAsmp

Define Compiled Mammal Comparison Table and Field on which to do the comparison:

Mammal look-up table: manspec.dbf
LU Field: FIELDS5

Define the Mammal inventory database table and Field on which to do comparison:

Inventory Shp: allmammals.shp
LU Field: Scientific

Define Compiled Fish Comparison Table and Field on which to do the comparison:

Fish look-up table: fishspec.dbf
LU Field: FIELDS5

Define the Fish inventory database table and Field on which to do comparison:

Inventory Shp: allfish.shp
LU Field: LATINNAME

Define Compiled Bird Comparison Table and Field on which to do the comparison:

Bird look-up table: birdspec.dbf
LU Field: FIELDS5

Define the Bird inventory database table and Field on which to do comparison:

Inventory Shp: birdobserv.shp
LU Field: Scientific

Define Compiled Reptile/Amphibian Comparison Table and Field on which to do the comparison:

Reptile/Amphibian look-up table: herpspec.dbf
LU Field: FIELDS5

Define the Reptile/Amphibian inventory database table and Field on which to do comparison:

Inventory Shp: herp_w_names.shp
LU Field: Scientific
Define Compiled invertebrate Comparison Table and Field on which to do the comparison:

Invertebrate look-up table: *odspec.dbf*  
LU Field: *FIELDS5*

Define the invertebrate inventory database table and Field on which to do comparison:

Inventory Shp: *ODOOBS.shp*  
LU Field: *SPECIES*

All of the above relate either to a dBASE lookup table or a set of inventory data with spatial reference (Figure 7 and Figure 8).

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Appendix Figure 5.7. All inventory shp inputs have a corresponding shapefile and table.
Appendix Figure 5.8. All lookup table inputs have a corresponding lookup table for each species.

Step 2. Click “Run Biologic Condition”
The first process that takes place is called from a hidden python script called “Biologic_Condition.py”. This script creates a new personal geodatabase called “BC.mdb” in the selected workspace “GEWA\GEWAsnp” (Figure 9).
Appendix Figure 5.9. New PGDB is created and placed within the workspace.

Within this database is an empty table labeled “Biotic Condition” (Figure 10). It contains five fields labeled “OBJECTID”, “Category”, “Value”, “Score” and “Rating”. The “OBJECTID” assigns a number to each entry and cannot be edited. “Category” will describe the assessment being run, i.e. “Mammal Species” or “Bird Species”. “Value” is the proportion derived from the comparison of the look-up table and inventory data for each category. “Score” is the score (1-5) given to that category based on its value. “Rating” is the designation related to the categories score. Ratings are “Good”, “Good-Fair”, “Fair”, “Fair-Poor” and “Poor” based upon the scores 5,4,3,2 and 1 in that order.
Appendix Figure 5.10. Within the new PGDB “BC.mdb” resides the table “Biotic_Condition”

*Note: When running multiple assessments, “BC.mdb” should be considered a temporary name. As new assessments are run, “BC.mdb” should be renamed. (i.e. “GEWABC.mdb”). If renaming of BC.mdb is not completed, the model will fail when trying to create another PGDB named “BC.mdb”

After completion of the empty table in only a few seconds, the model continues to the next task: Assessment of each category. The output found in the ArcMap DOS window (Figure 11) allows the user to see what processes the model is undergoing as well as providing the user with what it is reading from the VBA userform. It shows all arguments being passed into each script (arguments that were entered by the user in step 1.) It also completes the comparison of tables and prints the Value, Score, and Rating of that category. This process occurs for all five categories. As each completes, the user need only hit enter to proceed to the next as prompted by the ArcMap DOS window.
Appendix Figure 5.11. ArcMap DOS window providing both input parameters and output values for mammal comparison.

For the example problem, the first output should read as above. It also includes an associated txt file of results that can be found in the same folder as the map document you are processing. In the case it is found in /Maps folder. This output is that of the mammal species comparison being executed by the script “mammal_sort.py” from behind the scenes (Argument 0 in Figure 11).
The other outputs from the Biotic Condition should read as follows:
Fish Species (Figure 12)

Appendix Figure 5.12. ArcMap DOS window providing both input parameters and output values for Fish comparison and associated text file.
Bird Species (Figure 13)

Appendix Figure 5.13. ArcMap DOS window providing both input parameters and output values for Bird comparison and associated text file.
Appendix Figure 5.14. ArcMap DOS window providing both input parameters and output values for Reptile/Amphibian comparison and associated text file.
Appendix Figure 5.15. ArcMap DOS window providing both input parameters and output values for Invertebrate comparison and associated text file.

The Biotic Condition is now complete and the table “Biotic_Condition” in the “BC.mdb” created earlier can now be populated with values from the text files.

**Chemical and Physical Characteristics Tool**

**Overview**

The Chemical and Physical Characteristics dialogue box (Figure 16) is opened directly from the RISC toolbars “Assessment” button.
As with the Landscape Condition and Biotic Condition tools, this assessment tool designates a workspace from the browse function seen above. The “Shapefile/Table” function allows the user to navigate to feature classes or database tables that contain the physical and chemical parameters to be assessed. For example, in the GEWA chemical condition assessment, there were four indicators available. These include pH, dissolved oxygen, temperature, and conductivity (Figure 17). Each indicator is related to its own individual script as well as threshold values. Threshold values are viewed by clicking on the “threshold values” button on the chemical/physical characteristics tool (Figure 18). It was originally intended that threshold values can be changed from the C/P characteristics userform but more testing is needed to ensure this function. For now, threshold values are imbedded in each indicators individual python code.
Appendix Figure 5.17. Chemical/Physical Characteristics tool and its parameters.
Appendix Figure 5.18. Threshold button for PH indicator

The “Run Chemical Condition” command processes all scripts associated with the chemical/physical condition assessment. This action generates an overall chemical condition score and rating for each site within GEWA. Additionally, the values are stored in a separate file for convenient exportability and report generation.

*Example 3: Demonstrate Chemical/Physical Condition Assessment: Thomas Stone
Note: Before running the C/P condition tool make a copy of input tables/shapefiles as they will be changed from their original format.

**Step 1:** Open Chemical/Physical Characteristics Condition Tool from the “assessment” section of the “RISC” toolbar and insert inputs in appropriate text boxes.
Define Workspace:
   Workspace: \GEWA\GEWAshp
Define Shapefile/Table on which to Complete the Assessment:
   Shapefile/Table: waterchemTHST.shp

Define the PH field to sort through:
   PH: $PH$
Define the Dissolved Oxygen field to sort through:
   Dissolved Oxygen: \textit{DO}
Define the Temperature field to sort through:
   Temperature: \textit{TEMP}
Define the Conductivity field to sort through:
   Conductivity: \textit{COND}
The above relate directly to fields located in the attribute table of the shapefile specified in “Shapefile/Table” input (Figure 19).

Appendix Figure 5.19. WaterchemTHST.shp and its associated table are sorted through by the C/P Condition assessment.

\textbf{Step 2:} Click “Run Chemical/Physical Characteristics Condition” Tool
The pH assessment begins first scrolling through each record of measurement and assigning each a score and a rating, just as in the Biologic assessment. However, this time the values are added to the shapefiles attribute table, not a personal geodatabase. This makes for easy mapping and interpretation of the data in ArcMap. A script behind
the scenes adds a field called “PHScore” and “PHrate” to the shapefiles attribute table (Figure 20).

Appendix Figure 5.20. waterchemTHST.shp now has fields “PHScore” and “PHrate” that is populated during geoprocessing of C/P condition.

As all the arguments pass into the python script for pH (PH.py), a DOS window appears and prints out all of the values for each measurement as well as the assigned scores and ratings (Figure 21).

Appendix Figure 5.21. ArcMap DOS window for pH analysis.

This process occurs for each of the other three indicators (Dissolved Oxygen, Temperature, and Conductivity). Fields are added to the shapefile, waterchemTHST.shp
(figure 22), and DOS windows print out arguments, values, scores and ratings for each measurement taken.

Appendix Figure 5.22. Added fields are shown in the attribute table for waterchemTHST.shp

Appendix Figure 5.23. DOS Print-out for Dissolved Oxygen Analysis.
Appendix Figure 5.24. DOS print-out for Temperature analysis.
Appendix Figure 5.25. DOS print-out for Conductivity Analysis

**Overall Condition**

Scores generated from the Landscape, Biotic, and Chemical condition assessment are generated independently (as previously described), or may be subsequently combined to develop an overall index of natural park health and areas of concern.